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EVOLUTION OF THE SPACE-BASED GOS: GAP ANALYSIS

At the last three CGMS Sessions, WMO delivered a report on the status of the space-based component of GOS. The report consisted of a wide overview of satellite programmes and short sections on the analysis of compliance of the system with WMO requirements. This report is now being converted into a WMO database and will continue to be updated on a nearly-continuous basis. Also, a section on the potential performance of typical instruments in terms of data quality will be added. This year's updated report will be distributed as soon as the conversion to the database is completed.

The present document (WMO-WP-05) contains an Annex "Gap Analysis" that is based on collected material and could be used to identify priorities for future plans. It was prepared by Dr Bizzarro Bizzarri as consultant for the WMO Space Programme.

With reference to a typology of 29 instruments/missions, the Gap Analysis records for each instrument/mission:

- The definition of "nominal" instrument characteristics;
- The addressed geophysical parameters;
- The assumed/suggested observing strategy;
- The current and planned programmes until year 2020;
- Comments on the situation as projected beyond 2020;
- Recommendations.

A synoptic table of geophysical parameters (127) versus instrument/mission types (29) is provided in Appendix 1 to the Annex.

For each of the 157 instruments mentioned in the main text, a descriptive table is provided in Appendix 2 to the Annex. For most programmes, the analysis is based on the status as of September 2006, i.e. the information contained in the yearly report on the status of GOS presented at CGMS-34. However, follow-on developments that affected the scenario have been taken into account to the best of the author's knowledge.

CGMS Members are invited to use this Gap Analysis as a reference for further discussions on the evolution of the GOS and global planning of future missions.

EVOLUTION OF THE SPACE-BASED GOS: GAP ANALYSIS

1 BACKGROUND - PREVIOUS REPORTS

Since CGMS-32 (Sochi, 17-20 May 2004) WMO has been submitting every year a report on the "Status of the space-based component of the Global Observing System (GOS)". Updates were issued for CGMS-33 (Tokyo, 1-4 November 2005) and CGMS-34 (Shanghai, 2-7 November 2006). The initial issue was limited to meteorological satellites (programmes and instruments description), the second included R&D satellite programmes and descriptions of a few of their instruments, the third extended the list of instrument descriptions.

The document has not been re-edited, since very little has changed since the last issue. The content of the report is being converted to a database at WMO and will be updated on a nearly-continuous basis. The next issue will be distributed after CGMS-35 and will incorporate the information collected at CGMS-35. It is recalled that the report contained:

- Description of geostationary meteorological satellites programmes: Meteosat, GOES, GMS/MTSAT, GOMS/Elektro, FY-2/FY-4, INSAT, Kalpana and COMS;
- Description of operational sunsynchronous meteorological satellite programmes: NOAA/POES, DMSP, NPOESS, EPS/MetOp, Meteor and FY-1/FY-3;
- Description of R&D programmes of GOS interest: ESA (Earth Watch programme, ERS 1/2 and Envisat, Earth Explorer programme and GMES), NASA (Nimbus, SeaSat, ERBS, UARS, SeaSat, Landsat, EOS, ESSP, TRMM, GPM, radio-occultation missions), JAXA programmes, CNES programmes, ISRO programmes, Roscosmos programmes;
- As Annex 1, the list of frequencies utilised by operational meteorological satellites for data transmission to the ground;
- As Annex 2, definitions of spectral bands and acronyms;
- As Annex 3, instruments descriptive tables for both operational and R&D satellites.

It is planned to add to this a new section on the potential performance of typical instruments in terms of data quality.

2 GAP ANALYSIS

A "Gap Analysis" is provided in the Annex. Each of the previous reports included a short analysis of the current and short-term future situation in GEO and LEO, limited to meteorological satellites and a few missions (imagery and sounding in LEO and GEO, MW imagery in LEO). The Gap Analysis extends the time consideration to year 2020, and considers nearly all relevant types of instruments/missions. For each of them (29) the following is considered:

- The definition of "nominal" instrument characteristics;
- The addressed geophysical parameters;
- The assumed/suggested observing strategy;
- The current and planned programmes until year 2020;
- Comments on the situation as projected in the post 2020 timeframe;
- Recommendations.

A synoptic table of geophysical parameters (127) versus instrument/mission types (29) is provided in Appendix 1 to the Annex.

Appendix 2 to the Annex provides a descriptive table for each of the 157 instruments mentioned in the main text. The nominal level of update is, for most programmes, September 2006, i.e. what was contained in the yearly report on the status of GOS presented at CGMS-34. However, follow-on developments that affected the scenario have been taken into account to the best of our knowledge.

3 UTILIZATION OF THE GAP ANALYSIS

The Gap Analysis has been designed to help identifying priorities for future plans. It will play a role for developing a new vision and corresponding Implementation Plan to be submitted to the fourteenth session of the Commission for Basic Systems (CBS) in 2008.

A first draft of the Gap analysis was presented at:

- The second Workshop on the Re-design and Optimization of the Space-based Global Observing System (Geneva 21-22 June 2007).

Thereafter it was provided as input to:

- The 3rd session of the Expert Group on the Evolution of the Global Observing System (ET-EGOS) (Geneva 9-13 July 2007), and
- The third sessions of the Expert Team on Satellite Systems (ET-SAT) and Expert Team on Satellite Utilization and Products (ET-SUP) (Geneva 3-7 September 2007).

Only minor updating has been applied since then.

4 CONCLUSIONS

CGMS Members are invited to consider the Gap Analysis as a reference document for further discussions on the evolution of the GOS and on global planning of future missions.

ANNEX

GAP ANALYSIS

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Explanations

This Gap analysis is intended to collect information as “factual” as possible, to provide the rationale for orienting the development of the satellite-based component of GOS.

Missions/instruments are selected on the basis of established heritage, consolidated plans or, at least, demonstrated or being demonstrated concepts.

For each mission/instrument, generic characteristics are defined, so as to encompass most of what is currently considered desirable and feasible (not necessarily affordable) for the post-2020 timeframe.

A list of geophysical parameters that could be potentially retrieved from the mission/instrument of specified reference characteristics is provided. The achievable data quality will be evaluated in a dedicated study to be performed for WMO by the end of 2008.

For each mission/instrument, an observing strategy is recommended, as follows:

- For missions/instruments in GEO the observing strategy is simply the most recent one adopted by WMO (6 regularly-spaced stationarity longitudes, plus adequate contingency). The perspective situation for post-2020 shows that this strategy can be implemented.
- For the missions/instruments in LEO presumably to be flown on the backbone operational meteorological satellite system, the WMO requirement is “*4 satellites in optimally spaced orbital planes*”. When the system was implemented by two NOAA satellites, the orbital planes were around 7:30 and 13:30 LST (at the equatorial crossing node). Moving to four satellites, the other two should have been added around 10:30 and 16:30 LST. However, when EUMETSAT entered the scenario, they selected 9:30 LST as optimal for Europe, whereas 13:30 LST was optimal for the USA (these two orbits serve East-Atlantic and East-Pacific respectively around 12 UTC, optimal for merging with conventional observations at the main synoptic hours). With the advent of four-dimensional assimilation these motivations are no longer valid, but at that time they fixed the scenario, presumably still for a long time to come. With 9:30 and 13:30 as baseline, the optimal third orbital plane becomes 5:30 that also coincides with the peak of activity of meteorological services in the early morning. This situation based on three orbital planes 4-hour dephased is difficult to be shifted to a four orbital planes 3-hour dephased. It is preferable to stay with the three orbital planes configuration and provide for contingency in each orbital plane.

- For a number of missions in LEO, global coverage at 4-hour intervals is not requested. Depending on the type of observation and the need for synergies, the strategy indicates:
  - in which of the orbital planes of the backbone system the mission should be flown;
  - whether the mission can be flown in other orbits, independent of the backbone system.
- There are cases when the observing strategy indicates the need for dedicated constellations.

The gap analysis follows. It is differentiated by orbital planes and by class of the instrument as compared with the characteristics of the reference mission/instrument. The main features of each instrument are recorded, and the instrument class as compared with the reference instrument is indicated by a coded colour.

A list of comments follows, differentiated by orbital planes. The comments focus on the expected situation in year 2020 and compare with the stated observing strategy. Contingency aspects in each orbital plane are considered.

Finally, a number of recommendations are proposed. It is noted that these recommendations directly derive from the “factual” information collected in the document, and involve as little as possible subjective elements such as priorities, affordability and sustainability. Therefore, this set of recommendations only constitutes a background on which final recommendations should be worked out by the relevant bodies.

1. MULTI-PURPOSE VIS/IR IMAGERY FROM LEO

This mission is implemented by medium-resolution multi-channel radiometers operating in the VIS and IR parts of the spectrum. Generic characteristics of the instruments are listed as follows.

Generic characteristics of multi-purpose VIS/IR imagers in LEO (years 2020's)						
Spectral range	**Bandwidths**	**No. of channels**	**Typical SNR or NEΔT**	**Resolution**	**Swath**	**Scanning**
~ 0.4 to ~14 μm	0.02-1.0 μm	5-40	50 @ 1 % albedo, 0.1 K @ 300 K	0.3-1.0 km	> 2800 km	cross-track

Addressed products are as follows.

Geophysical parameters addressed by the multi-purpose VIS/IR imagery mission in LEO		
Cloud imagery	Total aerosol optical depth	Snow cover
Cloud cover	Total aerosol type	Snow surface temperature
Cloud type	Short-wave cloud reflectance	Snow albedo
Cloud optical depth	Downwelling SW irradiance at Earth's surface	Frozen soil and permafrost
Cloud top height	Earth's surface albedo	Leaf Area Index (LAI)
Cloud top temperature	Surface emissivity in TIR window channels	Normalised Difference Vegetation Index (NDVI)
Cloud drop effective radius at cloud top	Sea surface temperature	Photosynthetically Active Radiation (PAR)
Cloud ice effective radius at cloud top	Sea-ice surface temperature	Fractional Absorbed PAR (FAPAR)
Water vapour imagery	Sea-ice cover	Fire temperature
Water vapour total column	Land surface temperature	Fire fractional cover
Precipitation at surface (index)	Surface soil moisture (index)	Fire radiative power

The recommended observing strategy is:

- three orbital planes (early morning: 5:30 ± 2 h; mid-morning: 9:30 ± 2 h; early afternoon: 13:30 ± 2 h);
- one fully compliant instrument in each plane, and one backup, as similar as possible.

The evolution of current and planned Multi-purpose VIS/IR imagers in LEO is shown below.

Instrument class	**≤ 10 channels**	**Channels not optimal**	**High quality**	**Quality exceeding requirements**

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
VIIRS	NPOESS 2&4	05:30										X	X	X	X	X	X
MVISR	FY-1D	08:20	X														
AVHRR/3	MetOp 1-3	09:30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
VIRR+MERSI	FY-3 A/C/E/G	10:00	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
AVHRR/3	NOAA-17	10:20	X	X	X												
MSU-MR	Meteor-M 1&2	10:20	X	X	X	X	X	X									
MODIS	EOS-Terra	10:30	X	X													
MODIS	EOS-Aqua	13:30	X	X	X												
VIIRS	NPP	13:30			X	X	X	X	X	X							
VIIRS	NPOESS 1&3	13:30							X	X	X	X	X	X	X	X	X
AVHRR/3	NOAA 18	13:40	X	X	X	X											
AVHRR/3	NOAA-19	14:00			X	X	X	X	X	X							
VIRR+MERSI	FY-3 B/D/F	14:00			X	X	X	X	X	X	X	X	X	X	X	X	X
VIRS	TRMM	35°	X	X	X												

Comparative characteristics of multi-purpose VIS/IR imagers in LEO						
Feature	**NPOESS VIIRS**	**NOAA & MetOp AVHHR**	**FY-1D MVISR**	**FY-3 VIRR+MERSI**	**Meteor-M MSU-MR**	**Terra & Aqua MODIS**
No. of SW channels (0.4-2.4 μm)	15	3	7	26	3	20
No. of LW channels (3.5-15 μm)	7	3	3	4	3	16
Typical SW bandwidths	20-60 nm	100 nm	50-100 nm	20-50 nm	200 nm	10-30 nm
Typical LW bandwidths	0.2-1.0 μm	0.4-1.0 μm	0.4-1.0 μm	0.4-1.0 μm	0.6-1.0 μm	0.1-0.5 μm
Swath	3000 km	2900 km	2800	2800 km	3000 km	2330 km
IFOV	0.4 and 0.8 km	1.1 km	1.1 km	0.25 and 1.0 km	1.0 km	0.25, 0.5 and 1.0 km

Comments (with focus on the post-2020 range):

- In the early morning time slot, there will be no coverage until 2016 (NPOESS-2). The instrument thereafter available, VIIRS, provides high quality data. There will be no backup.
- In the mid-morning time slot, the MetOp AVHRR does not meet post-2020 quality requirements. The FY-3 instrument complex (VIRR + MERSI) apparently meets but, going to details, the IR channels are defective (same as AVHRR on VIRR, none on MERSI): it would be a good backup. However, a high-quality VIS/IR imager is not yet committed.
- In the early afternoon time slot, the post-2020 requirements will be met by VIIRS on NPOESS. VIRR + MERSI on FY-3 would be a good backup.

Recommendations:

- In the early morning: to add a redundant VIS/IR imager, possibly of the class of VIIRS, or at least of the class of VIRR + MERSI.
- In the mid-morning time: to provide a high-quality VIS/IR imager, presumably on the follow-on of MetOp/EPS. The FY-3 instrument complex (VIRR + MERSI) should possibly be upgraded to VIIRS level to provide full redundancy.
- In the early afternoon: to possibly upgrade VIRR + MERSI to VIIRS level to provide full redundancy.

2. MULTI-PURPOSE VIS/IR IMAGERY FROM GEO

This mission is implemented by medium-resolution multi-channel radiometers operating in the VIS and IR parts of the spectrum. Generic characteristics of the instruments are listed as follows.

Generic characteristics of multi-purpose VIS/IR imagers in GEO (years 2020's)					
Spectral range	**Bandwidths**	**No. of channels**	**Typical SNR or NEΔT**	**Resolution**	**Observing cycle**
~ 0.4 to ~14 μm	0.03-1.0 μm	5-20	30 @ 1 % albedo, 0.1 K @ 300 K	0.5-2.0 km	< 15 min (full disk), less for limited areas

Addressed products are as follows (same as from LEO, with possibly some lower quality, but much more frequently; plus winds from cloud and water vapour tracking).

Geophysical parameters addressed by the multi-purpose VIS/IR imagery mission in GEO		
Cloud imagery (and derived wind)	Total aerosol optical depth	Snow cover
Cloud cover	Total aerosol type	Snow surface temperature
Cloud type	Short-wave cloud reflectance	Snow albedo
Cloud optical depth	Downwelling SW irradiance at Earth's surface	Frozen soil and permafrost
Cloud top height	Earth's surface albedo	Leaf Area Index (LAI)
Cloud top temperature	Surface emissivity in TIR window channels	Normalised Difference Vegetation Index (NDVI)
Cloud drop effective radius at cloud top	Sea surface temperature	Photosynthetically Active Radiation (PAR)
Cloud ice effective radius at cloud top	Sea-ice surface temperature	Fractional Absorbed PAR (FAPAR)
Water vapour imagery (and derived wind)	Sea-ice cover	Fire temperature
Water vapour total column	Land surface temperature	Fire fractional cover
Precipitation at surface (index)	Surface soil moisture (index)	Fire radiative power

The recommended observing strategy is:

- six sectors, 60 degrees wide along the equator (centres: 0°, 60°E, 120°E, 180°E, 120°W, 60°W);
- at least one "SEVIRI-like" instrument in each sector, and one backup, as similar as possible.

The evolution of current and planned Multi-purpose VIS/IR imagers in GEO is shown below.

Instrument class	**< 5 channels**	**GOES IMAGER-like**	**State-of-art**	**Advanced generation**

Instrument	Satellite	Long.	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
SEVIRI	Meteosat 8-11	0°	X	X	X	X	X	X	X	X	X	X	X	X	X		
FCI	Meteosat 12→	0°										X	X	X	X	X	X
MSU-GS	Elektro-L 2	14.5°E				X	X	X	X	X	X	X	X				
MVIRI	Meteosat-7	57°E	X	X													
VHRR	Kalpana-1	74°E	X	X	X	X											
MSU-GS	Elektro-L 1 & 3	76°E	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
IMAGER	INSAT-3D	83°E	X	X	X	X	X	X	X	X							
S-VISSR	FY-2 D & F	86.5°E	X	X	X	X	X	X	X	X	X	X					
MCSI (TBD)	FY-4 O/A→	86.5°E						X	X	X	X	X	X	X	X	X	X
VHRR + CCD	INSAT-3A	93.5°E	X	X	X	X	X	X									
S-VISSR	FY-2 E & G	123°E			X	X	X	X	X	X	X	X	X	X			
MCSI (TBD)	FY-4 O/B→	123°E										X	X	X	X	X	X
MI	COMS-1	128°E		X	X	X	X	X	X	X	X						
Imager TBD	COMS-2	128°E								X	X	X	X	X	X	X	X
JAMI/IMAGER	MTSAT 1R & 2	140°E	X	X	X	X	X	X	X	X	X						
Imager TBD	MTSAT-FO→	140°E								X	X	X	X	X	X	X	X
		180°E															
IMAGER	GOES-11/13/15	135°W	X	X	X	X	X	X	X	X	X						
ABI	GOES-17	135°W									X	X	X	X	X	X	X
IMAGER	GOES-12/14	75°W	X	X	X	X	X	X	X	X							
ABI	GOES-16 (R)	75°W								X	X	X	X	X	X	X	X
IMAGER	GOES-10	60°W	X	X	X												

Comparative characteristics of multi-purpose VIS/IR imagers in GEO												
Feature	Meteosat MVIRI	Meteosat SEVIRI	Meteosat FCI	GOES IMAGER	GOES ABI	Elektro-L MSU-GS	INSAT-3A VHRR+CCD	INSAT-3D IMAGER	Kalpana VHRR	FY-2 S-VISSR	COMS MI	MTSAT JAMI
Channels	3	12	16	5	16	10	3 + 3	6	3	5	5	5
Cycle	30 min	15 min	2.5 & 10 min	30 min	15 min	15 min	180 min	30 min	180 min	30 min	30 min	30 min
IFOV VIS	2.5 km	1 & 3 km	0.5 & 1 km	1 km	0.5 & 1 km	1 km	1 & 2 km	1 km	2 km	1.25 km	1 km	1 km
IFOV IR	5.0 km	3 km	1 & 2 km	4 km	2 km	4 km	8 km	4 & 8 km	8 km	5 km	4 km	4 km

Comments (with focus on the post-2020 range):

- Sector 30°W-30°E: the Meteosat 3rd Generation FCI will meet post-2020 requirements, and backed by hot standby.
- Sector 30-90°E: the FY-4 O imager is being designed to meet post-2020 requirements. The Elektro-L MSU-GS is already at SEVIRI level, and could be upgraded to meet post-2020 requirements.
- Sector 90-150°E: the FY-4 O imager is being designed to meet post-2020 requirements. MTSAT-FO has been announced to be upgraded to ABI/FCI level to meet post-2020 requirements. The imager being defined for COMS-2 could be upgraded to SEVIRI level.
- Sector 150°E-150°W: nothing is planned.
- Sector 90-150°W: the GOES ABI (following GOES-R) meets post-2020 requirements. It is backed by a standby GOES satellite at 105°W also backing GOES-E.
- Sector 30-90°W: the GOES-R ABI meets post-2020 requirements. It is backed by a standby GOES satellite at 105°W also backing GOES-W.

Recommendations:

- The total gap in the Sector 180° ± 30° (Central Pacific Ocean) should be filled, at least to the extent necessary to provide winds by tracking cloud and water vapour patches. An imager of the current GOES/IMAGER class, and another for redundancy, could be sufficient for this purpose (this could be achieved by means of spare satellites of the previous generation).
- In Sector 90-150°E, COMS-2, currently being defined in respect of the VIS/IR imagery mission, should consider aiming at FCI/ABI level rather then to SEVIRI since, at the time of their expected launch (2014), the state-of-art of imagery from GEO will be fixed by the GOES-R ABI and the Meteosat 3rd Generation FCI, and also FY-4 O and MTSAT-FO will have an advanced imager.

3. IR TEMPERATURE/HUMIDITY SOUNDING FROM LEO

This mission is implemented by medium spectral resolution spectrometers or radiometers operating in the IR part of the spectrum. Generic characteristics of the instruments are listed as follows.

Generic characteristics of IR temperature/humidity sounders in LEO (years 2020's)						
Spectral range	**Spectral resolution**	**No. of channels**	**Typical NEΔT**	**Resolution**	**Swath**	**Scanning**
3.6 to 16 μm	0.25-0.5 cm^{-1}	4000-8000	0.2 K @ 280 K	4-12 km	> 2200 km	cross-track

Addressed products are as follows.

Geophysical parameters addressed by the IR temperature/humidity sounding mission in LEO			
Air temperature profile	Cloud cover profile	Sea surface temperature	NO_2 total column
Water vapour profile	Cloud top height	Land surface temperature	CH_4 total column
Water vapour total column	Cloud top temperature	O_3 profile	CO_2 total column
Height of the tropopause	Downwelling LW irradiance at Earth's surface	O_3 total column	CO total column
Height of the top of the PBL	Surface emissivity in TIR window channels	HNO_3 total column	SO_2 total column

The recommended observing strategy is:

- three orbital planes (early morning: 5:30 ± 2 h; mid-morning: 9:30 ± 2 h; early afternoon: 13:30 ± 2 h);
- one fully compliant instrument in each plane, and one backup, as similar as possible.

The evolution of current and planned IR sounders in LEO is shown below.

Instrument class	**IR radiometer**	**IR spectrometer**

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
CrIS	NPOESS 2&4	05:30										(X)	(X)	(X)	(X)	(X)	(X)
IASI	MetOp 1-3	09:30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
IRAS	FY-3 A/C/E/G	10:00	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HIRS	NOAA-17	10:20	X	X	X												
IRFS-2	Meteor-M2	10:20		X	X	X	X	X									
AIRS	EOS-Aqua	13:30	X	X	X												
CrIS	NPP	13:30			X	X	X	X	X	X							
CrIS	NPOESS 1&3	13:30							X	X	X	X	X	X	X	X	X
HIRS	NOAA 18	13:40	X	X	X	X											
HIRS	NOAA-19	14:00			X	X	X	X	X	X							
IRAS	FY-3 B/D/F	14:00			X	X	X	X	X	X	X	X	X	X	X	X	X

Comparative characteristics of IR temperature/humidity sounders in LEO						
Feature	**NPOESS CrIS**	**NOAA HIRS**	**MetOp IASI**	**FY-3 IRAS**	**Meteor-M IRFS**	**EOS-Aqua AIRS**
No. of channels	1300	20	8461	26	4000	2378
Spectral resolution	0.625-2.5 cm^{-1}	10-20 cm^{-1}	0.25 cm^{-1}	10-20 cm^{-1}	0.5 cm^{-1}	0.5-2.0 cm^{-1}
Swath	2230 km	2200 km	2230 km	2250 km	2500 km	1650 km
IFOV	14 km	10 or 18 km	12 km	17 km	35 km	13.5 km

Comments (with focus on the post-2020 range):

- In the early morning time slot, there will be no coverage until 2016 (NPOESS-2). The instrument thereafter available, CrIS, would provide high quality data: but currently in not in the baseline. Also, no backup is currently foreseen.
- In the mid-morning time slot, an instrument such as the MetOp IASI would meet the post-2020 quality requirements, but is not yet committed. The FY-3 instrument, IRAS, would provide partial backup.
- In the early afternoon time slot, the post-2020 requirements will be met by CrIS on NPOESS. IRAS on FY-3 would be a partial backup.

Recommendations:

- In the early morning: to baseline CrIS on NPOESS-2, and possibly add a backup sounder on another platform.
- In the mid-morning time: to continue with a high-quality sounding interferometer on the follow-on of MetOp/EPS. The FY-3 instrument, IRAS, should possibly be upgraded to IASI level to provide full redundancy.
- In the early afternoon: to possibly upgrade IRAS to CrIS level to provide full redundancy.

4. IR TEMPERATURE/HUMIDITY SOUNDING FROM GEO

This mission is implemented by medium spectral resolution spectrometers or radiometers operating in the IR part of the spectrum. Generic characteristics of the instruments are listed as follows.

Generic characteristics of IR temperature/humidity sounders in GEO (years 2020's)					
Spectral range	**Spectral resolution**	**No. of channels**	**Typical NEΔT**	**Resolution**	**Observing cycle**
3.6 to 16 μm	0.25-0.5 cm^{-1}	4000-8000	0.2 K @ 280 K	4-8 km	< 30 min (full disk), less for limited areas

Addressed products are as follows (same as from LEO, with possibly somewhat lower quality, but much more frequently; plus wind profile from water vapour tracking).

Geophysical parameters addressed by the IR temperature/humidity sounding mission in GEO			
Air temperature profile	Cloud cover profile	Sea surface temperature	NO_2 total column
Water vapour profile (and derived wind profile)	Cloud top height	Land surface temperature	CH_4 total column
Water vapour total column	Cloud top temperature	O_3 profile	CO_2 total column
Height of the tropopause	Downwelling LW irradiance at Earth's surface	O_3 total column	CO total column
Height of the top of the PBL	Surface emissivity in TIR window channels	HNO_3 total column	SO_2 total column

The recommended observing strategy is:

- six sectors, 60 degrees wide along the equator (centres: 0°, 60°E, 120°E, 180°E, 120°W, 60°W)
- at least one hyperspectral instrument in each sector, and one backup, as similar as possible.

The evolution of current and planned IR sounders in GEO is shown below.

Instrument class	**Radiometer**	**Spectrometer**

Instrument	Satellite	Long.	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
IRS	Meteosat 12→	0°										X	X	X	X	X	X
SOUNDER	INSAT-3D	83°E	X	X	X	X	X	X	X	X							
IIS TBD	FY-4 O/A→	86.5°E						X	X	X	X	X	X	X	X	X	X
IIS TBD	FY-4 O/B→	123°E										X	X	X	X	X	X
Sounder TBD	MTSAT-FO→	140°E											(X)	(X)	(X)	(X)	(X)
		180°E															
SOUNDER	GOES-11/13/15	135°W	X	X	X	X	X	X	X	X	X						
HES	GOES-17	135°W									(X)	(X)	(X)	(X)	(X)	(X)	(X)
SOUNDER	GOES-12/14	75°W	X	X	X	X	X	X	X	X							
HES	GOES-16 (R)	75°W								(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
SOUNDER	GOES-10	60°W	X	X	X												

Comparative characteristics of IR temperature/humidity sounders in GEO				
Feature	**Meteosat 3rd Generation IRS**	**GOES up to 15 SOUNDER**	**GOES-R HES**	**INSAT-3D SOUNDER**
Range	4.6-14.3 μm	3.74-14.71 μm + 0.7 μm	3.68-15.4 μm	3.74-14.71 μm + 0.7 μm
Channels	1736	18 (IR) + 1 (VIS)	1508	18 (IR) + 1 (VIS)
Spectral resolution	0.625 cm^{-1}	13 to 100 cm^{-1}	0.5 to 2.5 cm^{-1}	13 to 100 cm^{-1}
Cycle (full disk)	30 min	8 h	60 min	8 h
IFOV IR	4 km	8 km	2-20 km	10 km

Comments (with focus on the post-2020 range):

- Sector 30°W-30°E: the Meteosat 3rd Generation IRS will meet post-2020 requirements. In this specific moment it is not sure that the IRS payload will have a backup in hot standby.
- Sector 30-90°E: the FY-4 O sounder is being designed to meet post-2020 requirements. The backup policy for FY-4 O satellites is to have two satellites, one at 86.5°E, and one at 123° E.
- Sector 90-150°E: the FY-4 O imager is being designed to meet post-2020 requirements. The backup is at 86.5°E. MTSAT-FO also is announced to be compliant with post-2020 requirements. However the sounder has not yet been confirmed.
- Sector 150°E-150°W: nothing is planned.

- Sector 90-150°W: the GOES HES (following GOES-R) would meet post-2020 requirements. It would be backed by a standby GOES satellite at 105°W also backing GOES-E. However, HES on GOES-R is currently not baselined.
- Sector 30-90°W: the GOES HES (following GOES-R) would meet post-2020 requirements. It would be backed by a standby GOES satellite at 105°W also backing GOES-W. However, HES on GOES-R is currently not baselined.

Recommendations:

- The most important problem is the confirmation of HES on GOES-R and follow-on. Without that, three consecutive Sectors, 150°E-150°W + 90-150°W + 30-90°W, i.e. half of the total coverage from GEO, would have no sounder, that implies not only missing temperature/humidity profiles (that in some way are provided by LEO satellites), but also wind profile that is derived from frequent humidity profiling.
- Assuming that HES on GOES is finally confirmed, the problem of Sector 150°E-150-W should be addressed.
- In Sector 30°W-30°E, the hot-standby policy of Meteosat should be extended to the IRS mission.

5. MW TEMPERATURE/HUMIDITY SOUNDING FROM LEO

This mission is implemented by MW radiometers supporting the IR sounder for nearly-all-weather conditions. Generic characteristics of the instruments are listed as follows.

Generic characteristics of MW temperature/humidity sounders in LEO (years 2020's)

Spectral range	Spectral resolution	No. of channels	Typical NEΔT	Resolution	Swath	Scanning
23 to 200 GHz	10-4000 MHz	~ 30	0.2 to 1.0 K	10-50 km	> 2200 km	cross-track

Addressed products are as follows.

Geophysical parameters addressed by the MW temperature/humidity sounding mission in LEO

Air temperature profile (nearly-all-weather)	Downwelling LW irradiance at Earth's surface	Cloud liquid water total column
Water vapour profile (nearly-all-weather)	Freezing level height in clouds	Cloud ice total column
Water vapour total column (nearly-all-weather)	Melting layer depth in clouds	Precipitation rate at surface

The recommended observing strategy is:

- three orbital planes (early morning: 5:30 ± 2 h; mid-morning: 9:30 ± 2 h; early afternoon: 13:30 ± 2 h);
- one fully compliant instrument in each plane, and one backup, as similar as possible.

The evolution of current and planned MW sounders in LEO is shown below.

Instrument class	Water vapour only	MSU-like	AMSU-like, but conical scanning	AMSU-like

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
ATMS	NPOESS 2&4	05:30										(X)	(X)	(X)	(X)	(X)	(X)
AMSU-A+MHS	MetOp 1-3	09:30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
MWTS+MWHS	FY-3 A/C/E/G	10:00	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
AMSU-A+AMSU-B	NOAA-17	10:20	X	X	X												
MTVZA	Meteor-M 1&2	10:20	X	X	X	X	X	X									
AMSU-A+HSB	EOS-Aqua	13:30	X	X	X												
ATMS	NPP	13:30			X	X	X	X	X	X							
ATMS	NPOESS 1&3	13:30							X	X	X	X	X	X	X	X	X
AMSU-A+MHS	NOAA 18	13:40	X	X	X	X											
AMSU-A+MHS	NOAA-19	14:00			X	X	X	X	X	X							
MWTS+MWHS	FY-3 B/D/F	14:00			X	X	X	X	X	X	X	X	X	X	X	X	X
SAPHIR	Megha-Tropiques	20°				X	X	X	X	X							

Comparative characteristics of MW temperature/humidity sounders in LEO

Feature	NPOESS ATMS	NOAA & MetOp AMSU-A + AMSU-B or MHS	FY-3 MWTS+MWHS	Meteor-M MTVZA	EOS-Aqua AMSU-A + HSB
No. of channels	22	15 + 5	4 + 5	29	15 + 5
Bandwidths	3 to 5000 MHz	3 to 6000 MHz	180 to 2000 MHz	3 to 2500 MHz	3 to 6000 MHz
Swath	2300 km	2200 km	2250 km	2200 km	1650 km
IFOV	32 and 16 km	48 and 16 km	70 and 15 km	17 to 60 km	40 and 13 km

Comments (with focus on the post-2020 range):

- In the early morning time slot, there will be no coverage until 2016 (NPOESS-2). The instrument thereafter available, ATMS, would provide high quality data, but currently is not in the baseline. Also, no backup is currently foreseen.
- In the mid-morning time slot, instruments such as the MetOp AMSU-A + MHS would meet the post-2020 quality requirements, but are not yet committed. Of the FY-3 instruments, MWTS is similar to the old MSU of TOVS, MWHS is state-of-art: they would provide partial backup.
- In the early afternoon time slot, the post-2020 requirements will be met by ATMS on NPOESS. The FY-3 MWTS and MWHS would provide partial backup.

Recommendations:

- In the early morning: to baseline ATMS on NPOESS-2, and possibly add another sounder on another platform to provide redundancy.
- In the mid-morning time: to continue with a high-quality MW sounding package on the follow-on of MetOp/EPS. On FY-3, the MWTS unit should possibly be upgraded to AMSU-A level to provide full redundancy.
- In the early afternoon: to possibly upgrade the MWTS unit to AMSU-A level to provide full redundancy.

6. MW TEMPERATURE/HUMIDITY SOUNDING FROM GEO

This mission could be implemented by sounding/imaging radiometers operating in the millimetre and submillimetre range of the spectrum, so as to enable using antennas of practicable sizes. Generic characteristics of the instruments are listed as follows.

Generic characteristics of millimetre-submillimetre wave imaging sounders in GEO (years 2020's)					
Spectral range	**Bandwidths**	**No. of channels**	**Typical NEΔT**	**Resolution**	**Observing cycle**
50 to 450 GHz	50 to 4000 MHz	~ 40	0.1 to 0.6 K	10-50 km	1 h (full disk) to 15 min for areas 1/10 of disk

Addressed products are as follows (same as from LEO, with possibly somewhat lower quality, but much more frequently).

Geophysical parameters addressed by the millimetre-submillimetre wave imaging/sounding mission in GEO		
Air temperature profile (nearly-all-weather)	Downwelling LW irradiance at Earth's surface	Cloud liquid water total column
Water vapour profile (nearly-all-weather)	Freezing level height in clouds	Cloud ice total column
Water vapour total column (nearly-all-weather)	Melting layer depth in clouds	Precipitation rate at surface

The recommended observing strategy is:

- six sectors, 60 degrees wide along the equator (centres: 0°, 60°E, 120°E, 180°E, 120°W, 60°W);
- at least one instrument in each sector, either viewing the full disk or addressing selected areas.

Currently there is only one plan being considered for millimetre-submillimetre sounders in GEO.

Instrument class	**To meet post-2020 requirements**

Instrument	Satellite	Long.	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
		0°															
		60°E															
GEO-MW TBD	FY-4 M/A→	123.5°E									(X)	(X)	(X)	(X)	(X)	(X)	(X)
		180°E															
		120°W															
		60°W															

Comments (with focus on the post-2020 range):

- Although WMO recommended the introduction of millimetre-submillimetre sounding from GEO, especially for frequent precipitation observation, only China is considering an appropriate mission.
- Other project exists (GEM, GOMAS, GeoSTAR), only at conceptual stage.

Recommendations:

- To implement a demonstration mission in the context of the International Geostationary Laboratory initiative (IGeoLab). According to the current situation, the initiative should be led by China.
- To perform the demonstration mission moving the satellite across the various Sectors, or at least across the Sectors covering Countries participating to the IGeoLab initiative for GEO-Microwave.
- The Countries cooperating with China to implement the demonstration mission should contribute by providing system elements (including support to the ground segment), airborne campaigns, and support to scientific studies.

7. CONICAL-SCANNING MW IMAGERY (intermediate frequencies)

This mission is implemented by MW radiometers that need to exploit multi-polarisation for one or another reason (conical scanning provides constant zenith angle). It is a multi-purpose mission, with particular emphasis on precipitation. Generic characteristics of the instruments are listed as follows.

Generic characteristics of MW conical scanning imagers in LEO (years 2020's)						
Spectral range	**Spectral resolution**	**No. of frequencies**	**Typical NEΔT**	**Resolution**	**Swath**	**Scanning**
6.5 to 190 GHz	100-4000 MHz	4 to 20	0.3 to 1.0 K	5-50 km	> 1400 km	conical

Addressed products are as follows.

Geophysical parameters addressed by the conical scanning MW imagery mission in LEO		
Precipitation rate at surface	Sea surface temperature (nearly-all-weather)	Surface soil moisture
Cloud liquid water total column	Sea-ice surface temperature	Snow cover
Cloud ice total column	Sea-ice cover	Snow water equivalent
Precipitable water (over the sea)	Sea-ice type	Snow surface temperature
Horizontal wind over sea surface	Land surface temperature (nearly-all-weather)	Snow status (wet/dry)

The recommended observing strategy is:

- three orbital planes (early morning: 5:30 ± 2 h; mid-morning: 9:30 ± 2 h; early afternoon: 13:30 ± 2 h);
- one fully compliant instrument in each plane, and one backup, as similar as possible;
- additional satellites in low-inclination non-sunsynchronous orbits.

The evolution of current and planned MW conical scanners in LEO is shown below. It is noted that, pending the re-definition of the NPOESS CMIS (now "MIS"), the old CMIS specifications are still used.

Instrument class	**SSM/I-class**	**SSMIS-class**	**CMIS-class**	**High spatial resolution**

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
SSMIS	**DMSP 17/19/20**	**05:30**	X	X	X	X	X	X	X	X	X	X	X				
CMIS	**NPOESS 2&4**	**05:30**										X	X	X	X	X	X
SSM/I	**DMSP-F13**	**06:30**	X														
SSMIS	**DMSP-16**	**08:10**	X	X	X												
MWRI	**FY-3 A/C/E/G**	**10:00**	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MTVZA	**Meteor-M 1&2**	**10:20**	X	X	X	X	X	X									
AMSR-E	**EOS-Aqua**	**13:30**	X	X	X												
AMSR-2	**GCOM-W 1 (2, 3)**	**13:30**				X	X	X	X	X	(X)	(X)	(X)	(X)	(X)	(X)	(X)
CMIS	**NPOESS 3**	**13:30**														X	X
MWRI	**FY-3 B/D/F**	**14:00**			X	X	X	X	X	X	X	X	X	X	X	X	X
TMI	**TRMM**	**35°**	X	X	X												
GMI	**GPM "core"**	**65°**						X	X	X	X	X	X				
MADRAS	**Megha-Tropiques**	**20°**				X	X	X	X	X							

Comparative characteristics of conical scanning MW imagers in LEO									
Feature	**DMSP SSM/I**	**DMSP SSMIS**	**NPOESS CMIS**	**FY-3 MWRI**	**Meteor-M MTVZA**	**Aqua/GCOM AMSR E/2**	**TRMM TMI**	**GPM core GMI**	**Meg-Trop MADRAS**
Frequencies	4	21	63	6	21	6	5	7	5
Channels	7	24	77	12	29	12	9	13	9
Range	19-86 GHz	19-183 GHz	6.6-183 GHz	10.6-150 GHz	10.6-183 GHz	6.9-89 GHz	10.6-86 GHz	10.6-183 GHz	19-157 GHz
Swath	1400 km	1700 km	1700 km	1400 km	2200 km	1450 km	760 km	850 km	1740 km
IFOV (90 GHz)	13 km	13 km	4 km	10 km	17 km	5 km	6 km	6 km	8 km

Comments (with focus on the post-2020 range):

- In the early morning time slot, the instrument meeting post-2020 requirements will be available in 2016 (CMIS on NPOESS). No other satellite to serve as redundancy is currently planned.
- In the mid-morning time slot, no instrument is planned that meets post-2020 requirements. Only partial fulfilment from MWRI on FY-3 (SSM/I-class).
- In the early afternoon time slot, the post-2020 requirements will be met by CMIS on NPOESS from 2020 onwards. MWRI on FY-3 would be a partial backup. GCOM-W 2 and 3 are not yet committed.
- Flights in non-sunsynchronous orbits are not committed for long-term continuation, not in low-inclination orbit, nor at the relatively high inclination orbit of the GPM “core”.

Recommendations:

- In the early morning: to add another MW conical scanner on another platform to provide redundancy.
- In the mid-morning: to provide a CMIS-class MW conical scanner. On FY-3, to upgrade MWRI to provide full redundancy.
- In the early afternoon: to pursue long-term continuation of AMSR-2 on GCOM-W so as to have full redundancy with NPOESS CMIS/MIS.
- In non-sunsynchronous orbit: at least the GPM “core” mission should be provided with long-term continuity (its MW imager is associated to a dual-frequency radar to “calibrate” the full GPM mission).

8. LOW-FREQUENCY MW IMAGERY

This mission is implemented by MW radiometers addressing applications that require low frequencies, thus large antennas. Generic characteristics of the instruments are listed as follows.

Generic characteristics of low-frequency MW conical scanning imagers in LEO (years 2020's)						
Spectral range	**Spectral resolution**	**No. of frequencies**	**Typical NEΔT**	**Resolution**	**Swath**	**Scanning**
1.4 to 37 GHz	30-2000 MHz	1 to 5	0.3 to 1.0 K	5-50 km	> 1000 km	conical

Addressed products are as follows.

Geophysical parameters addressed by the low-frequency MW imagery mission in LEO		
Sea surface salinity	Sea surface temperature	Polar ice cover
Surface soil moisture	Land surface temperature	Polar ice type
Soil moisture in the roots region	Horizontal wind over sea surface	Sea-ice surface temperature

The recommended observing strategy is:

- each main parameter to be observed by at least one satellite, generally of R&D nature.

The evolution of current and planned low-frequency MW imagers in LEO is shown below.

Instrument objective	**Soil moisture in the roots region and ocean salinity**	**Sea surface wind including direction, and temperature**	**Sea surface temperature, surface soil moisture**

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
Aquarius	SAC-D	06:00			X	X	X	X									
MIRAS	SMOS	06:00		X	X	X											
WindSat	Coriolis	06:00	X	X	X												
MSMR	OceanSat 1	12:00	X	X													

Comparative characteristics of low-frequency MW imagers in LEO				
Feature	**SAC-D Aquarius**	**SMOS MIRAS**	**Coriolis WindSat**	**OceanSat MSMR**
Frequencies	1.4 GHz passive radiometer, 1.3 GHz radar scatterometer	1.4 GHz	5	4
Channels	up to 6 (full pol)	up to 6 (full pol)	22 (full pol in 3 channels)	8
Range	-	-	6.6-37 GHz	6.6-21 GHz
Scanning	3 parallel beams along track	synthetic aperture	conical	conical
Swath	390 km	1000 km	1000 km	1360 km
IFOV	100 km	50 km	25 km @ 19 GHz, 70 km @ 6.6 GHz	40 km @ 18 GHz, 110 @ 6.6 GHz

Comments (with focus on the post-2020 range):

- Currently, there is no plan for continuing systems such as Aquarius and MIRAS beyond the R&D stage.
- WindSat was a risk-reduction mission for CMIS on NPOESS. With the re-structuring of CMIS it seems that the polarimetric capability (for winds) will be retained, whereas the lowest frequency (for sea-surface temperature and surface soil moisture), if retained, will be associated to resolution lower than previously expected.

Recommendations:

- The re-designed CMIS (i.e. MIS) should retain at least the full polarimetric channels for sea surface winds, and the 10 GHz frequency for surface soil moisture; and possibly the 6.6 GHz frequency for sea-surface temperature, avoiding that the reduction exercise brings to a marginal resolution.
- Long-term continuity should be arranged for a mission exploiting the 1.4 GHz frequency for ocean salinity and soil moisture in the roots regions. Alternative solutions enabling association of frequencies up to 5 GHz should be studied, to extend the capability to sea-surface temperature.

9. RADIO OCCULTATION SOUNDING

This mission is implemented by receivers of signals from navigation systems (GPS, GLONASS, Galileo) embarked on LEO satellites, during the occultation phase. Generic characteristics of the instruments are listed as follows.

Generic characteristics of radio-occultation sounders (years 2020's)				
Frequencies	**No. of channels**	**Effective resolution**	**Observing cycle**	**Scanning**
1160 to 1600 MHz	~ 16	~ 300 km	1000-1500 occultations/day/satellite	Occultation of GNSS signals

Addressed products are as follows.

Geophysical parameters addressed by the radio occultation sounding mission in LEO		
Air temperature profile	Height of the tropopause	Electron density profile
Water vapour profile	Height of the top of the PBL	Geoid's undulations
Air pressure profile	Total Electron Content (TEC)	Gravity anomalies

The recommended observing strategy is:

- to have available as many satellites as necessary to achieve at least one sample in each 300 x 300 km^2 cell of the Earth surface every 6 hours;
- this implies at least 24 satellites in several distinct orbital planes, not necessarily sun-synchronous.

The evolution of current and planned radio-occultation sounders in LEO is shown below.

Instrument class	**Fore- & aft-**	**Constellation, fore- & aft-**	**Only aft- (setting occultations)**

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
ROSA	SAC-D	06:00			X	X	X	X									
GRAS	MetOp	09:30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Radiomet	Meteor-M-2	10:20		X	X	X	X	X									
ROSA	OceanSat-2	12:00		X	X	X	X	X	X								
IGOS	COSMIC (6 sats)	71°	X	X	X	X	X										
BlackJack	CHAMP	87°	X	X	X												
BlackJack	GRACE	89°	X	X	X	X	X										

Comparative characteristics of radio-occultation sounders in LEO							
Feature	**MetOp GRAS**	**CHAMP BlackJack**	**GRACE BlackJack**	**COSMIC (6 sats) IGOS ≈ BlackJack**	**SAC-D ROSA**	**OceanSat-2 ROSA**	**Meteor-M-2 Radiomet**
Viewing geometry	fore- & aft-	only aft-	only aft-	fore- & aft-	fore- & aft-	fore- & aft-	fore- & aft-
No. of soundings	500 / day	250 / day	250 / day	3000 / day	500 / day	500 / day	500 / day

Comments (with focus on the post-2020 range):

- The only programme extending to 2020 is MetOp. GRAS provides only 500 soundings/day, not meeting the post-2020 requirements.
- To implement the required constellation of 24 satellites, each one with one radio-occultation receiver additional to the other instruments, is practically impossible. The COSMIC constellation of 6 dedicated micro-satellites constitutes the optimal approach.

Recommendation:

- The provide continuity to the demonstrative COSMIC mission, and extend the concept aiming at 3 or 4 constellations of micro-satellites for a total number of about 24 satellites, to provide global 300 km sampling every 6 hours; or, as a minimum, 12 satellites to provide global 300 km sampling every 12 hours.

10. EARTH RADIATION BUDGET FROM LEO

This mission is implemented by broad-band radiometry of the total radiation from Earth-Atmosphere to Space, and of its short-wave component (reflected solar radiation). Provision of additional information from key narrow-band channels, and on multi-directional viewing (to retrieve irradiance) is necessary. The incoming solar radiation (by cavity radiometer) also must be observed.

Generic characteristics of the Earth radiation budget mission in LEO (years 2020's)					
Spectral range	**No. of channels**	**Accuracy**	**Resolution**	**Swath**	**Scanning**
0.2 μm to 300 μm	2 broad-band plus 1-2 narrow-band	NEΔR = 0.5 W·m^{-2}·sr^{-1}	20 km	2800 km	cross-track + multi-view
0.2 μm to 10 μm	1 (active cavity)	Absolute: 0.2 W·m^{-2}	-	-	sun-pointing

Addressed products are as follows.

Geophysical parameters addressed by the Earth radiation budget mission in LEO		
Outgoing short-wave irradiance at TOA	Outgoing long-wave irradiance at TOA	Downwelling solar irradiance at TOA

The recommended observing strategy is:

- to cover the diurnal cycle by observing at least at 3-hour intervals, that implies four LEO satellites;
- alternatively (better), to exploit synergy with GEO and reduce LEO to one satellite as a "calibrator".

The evolution of current and planned Earth radiation radiometers in LEO is shown below.

Instrument class	**Cavity radiometers**	**≥ 3 channels**	**Multi-viewing capability**	**< 3 channels**

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
TSIS	NPOESS 2/4	05:30										(X)	(X)	(X)	(X)	(X)	(X)
ERM	FY-3 A/C/E/G	10:00	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CERES	EOS-Terra	10:30	X	X													
ACRIM III	ACRIMSat	10:30	X	X	X	(X)	(X)	(X)									
CERES	EOS-Aqua	13:30	X	X	X												
TIM	Glory	13:30			X	X	X	X	X								
ERBS	NPOESS 1/3	13:30							X	X	X	X	X	X	X	(X)	(X)
ERM	FY-3 B/D/F	14:00			X	X	X	X	X	X	X	X	X	X	X	X	X
ScaRaB	Megha-Tropiques	20°				X	X	X	X	X							
CERES	TRMM	35°	failed														
TIM	SORCE	40°	X	X													

Comparative characteristics of Earth radiation budget radiometers (TIM, TSIS, ACRIM-III not included)				
Features	**EOS Terra & Aqua CERES**	**NPOESS-1 ERBS**	**FY-3 ERM** (includes Total Solar Irradiance)	**Megha-Tropiques ScaRaB**
Total energy channel	0.3 - 100 μm	0.3 - 100 μm	0.2 - 50 μm	0.2 - 50 μm
Short-wave channel	0.3 - 5.0 μm	0.3 - 5.0 μm	0.2 - 3.8 μm	0.2 - 4.0 μm
Narrow-band channels	8 - 12 μm	8 - 12 μm		0.55 - 0.65 μm 10.5 - 12.5 μm
No. of channels	3	3	2	4
Swath	3000 km	3000 km	2200 km	3200 km
IFOV	10 km (cross-track scanning), 20 km (bi-axial scanning)	10 km (cross-track scanning), 20 km (bi-axial scanning)	28 km (scanning unit), 2200 km (non-scanning unit)	40 km

Comments (with focus on the 2020 range):

- In the early morning time slot: nothing current and nothing planned for ERB. There is a plan for solar irradiance (TSIS on NPOESS 2/4), but currently not in the baseline. No backup.
- In the mid-morning time slot, ERM on FY-3 provides coverage but does not meet post-2020 requirements. No backup.
- In the early afternoon time slot, the post-2020 requirements are met by ERBS on NPOESS. However, current plan is only for NPOESS-1, i.e. till 2019. ERM on FY-3 provides backup.

Recommendations:

- The need for capturing the diurnal cycle, due to strong dependence of ERB on the cloud evolution, requires sampling at least every 3 hours, better 1 hour. The mission should therefore be structured so as to exploit synergy with GEO satellites.
- Assuming that an ERB payload is embarked on a sufficient number of GEO satellites, the effort in LEO could be limited to one advanced payload (e.g., ERBS on NPOESS-3 to provide continuity to NPOESS-1) plus some limited-performance payload (e.g. ERM on two FY-3 platforms) for completing coverage of high latitudes and as backup.
- The Total Solar Irradiance monitoring mission must have a follow-on. The plan for TSIS on NPOESS 1 and 3 should be confirmed. ERM has a built-in total solar irradiance monitor.

11. EARTH RADIATION BUDGET FROM GEO

This mission is implemented by broad-band radiometry of the total radiation from Earth-Atmosphere to Space, and of its short-wave component (reflected solar radiation).

Generic characteristics of the Earth radiation budget mission in GEO (years 2020's)				
Spectral range	**No. of channels**	**Accuracy (NEΔR)**	**Resolution**	**Observing cycle**
0.2 μm to 300 μm	2 broad-band (total + SW)	0.5 $W \cdot m^{-2} \cdot sr^{-1}$	40 km	< 30 min (full disk)

Addressed products are as follows (nearly the same as from LEO, with possibly somewhat lower quality, but much more frequently).

Geophysical parameters addressed by the Earth radiation budget mission in GEO	
Outgoing short-wave irradiance at TOA	Outgoing long-wave irradiance at TOA

The recommended observing strategy is:

- to include a broad-band radiometer on a number of operational GEO satellites such as to realise about 60° spacing around the equator;
- to exploit synergy with LEO using the instrument(s) in LEO (capable of multi-viewing and including solar irradiance measurement) for "calibration" so as to simplify the instrument in GEO to the maximum possible extent (two broadband channels only, since a multi-channel narrow-band imager will anyway be co-flying as primary payload of the same GEO satellite).

The evolution of current and planned Earth radiation radiometers in GEO is shown below.

Instrument class	**To meet post-2020 requirements**

Instrument	Satellite	Long.	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
GERB	Meteosat 8 to 11	0°	X	X	X	X	X	X	X	X	X	X	X	X	X		
		60°E															
		120°E															
		180°E															
		120°W															
		60°W															

Characteristics of the GERB radiometer	
Features	**GERB (Meteosat 8 to 11)**
Total energy channel	0.3 2- 30 μm
Short-wave channel	0.32 - 4.0 μm
No. of channels	2
Coverage/cycle	Full disk every 15 min
IFOV	42 km s.s.p.

Comment (with focus on the post-2020 range):

- No plan exists to fly ERB missions in GEO. This also holds for Meteosat Third Generation.

Recommendation:

- To re-design a composite Earth radiation mission based on GEO satellite to monitor the diurnal cycle (specifically due to clouds) and on one or more LEO satellites equipped for multi-viewing/multi-spectral observation and solar irradiance monitoring.

12. WIND SCATTEROMETRY

This mission is implemented by radar scatterometers that provide backscatter coefficient observations under a number of viewing angles.

Generic characteristics of the wind scatterometry mission in LEO (years 2020's)				
Frequency	**Swath**	**Look angles**	**Resolution**	**Scanning**
C-band (preferred) or Ku-band	700 - 1500 km	3 - 4	20 - 50 km	pushbroom (preferred) or conical

Addressed products are as follows.

Geophysical parameters addressed by the wind scatterometry mission in LEO				
Horizontal vector wind over sea surface	Surface soil moisture	Leaf Area Index (LAI)	Snow water equivalent	Sea-ice type

The recommended observing strategy is:

- to implement a composite system of satellites equipped with radar scatterometers and MW radiometers of the Coriolis/WindSat or NPOESS/CMIS type (i.e. with a few full-polarimetric channels); and to exploit other passive MW radiometers (speed only) so that the complex provides global coverage of sea-surface winds every 3 hours (accounting for limited swath);
- three orbital planes (early morning: 5:30 ± 2 h; mid-morning: 9:30 ± 2 h; early afternoon: 13:30 ± 2 h);
- one instrument (either radar or polarimetric MW) in each plan, and one backup;
- however, in the complex of radars + passive MW instruments, at least two should be radars.

The evolution of current and planned scatterometers in LEO is shown below. For convenience, the polarimetric passive MW radiometers (Coriolis/WindSat and NPOESS/CMIS) also are indicated.

Instrument class	**Swath < 700 km**	**Swath > 700 km, Ku-band**	**Swath > 700 km, C-band**	**Polarimetric passive MW**

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
CMIS	NPOESS 2&4	05:30										X	X	X	X	X	X
SeaWinds	QuikSCAT	06:00	X	X													
WindSat	Coriolis	06:00	X	X	X												
ASCAT	MetOp	09:30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
AMI-SCAT	ERS-2	10:30	X	X	X												
SCAT	OceanSat-2	12:00		X	X	X	X	X	X								
CMIS	NPOESS 3	13:30														X	X
SeaWinds	GCOM-W 2, 3	13:30								(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)

Comparative characteristics of wind scatterometers			
Feature	**SeaWinds (QuikSCAT and possibly GCOM-W 2,3) and SCAT (OceanSat-2)**	**ASCAT (MetOp)**	**AMI-SCAT (ERS-2)**
Frequency	13.4 GHz	5.3 GHz	5.3 GHz
Swath	1800 km	1100 km	500 km
Look angles	4	3	3
IFOV	50 km (conical scanning), or 25 km (sampling 12.5 km	25 km (sampling 12.5 km)	50 km (sampling 25 km)

Comments (with focus on the 2020 range):

- In the early morning time slot: covered by polarimetric passive MW (NPOESS/CMIS). No backup.
- In the mid-morning time slot: could be covered by an ASCAT-like instrument on post-EPS. No backup.
- In the early afternoon time slot: the planned GCOM-W 2 and 3 (not yet committed) would provide measurements by radar, NPOESS/CMIS by polarimetric passive MW. SCAT on OceanSat-2 is currently not committed for long-term continuity.
- There is information (in the literature, not official) on a Chinese plan for a SeaWinds-like scatterometer to be embarked on HY-2 (HaiYang-2) sometimes around 2010. Orbital LST seems to be 06/18.

Recommendations:

- An ASCAT-like instrument should continue to be flown on post-EPS.
- The plan for GCOM-W 2 and 3, with SeaWinds, should be confirmed, and/or the Indian OceanSat-2 with SCAT should be extended to a long-term programme, aiming at having at least one radar scatterometer in the early afternoon orbit.
- Backup in the early morning and mid morning could be provided by non-polarimetric passive MW radiometers (only wind speed), equipped with frequencies such as 19 GHz (e.g., satellites of the GPM constellation). These would also contribute to implement more frequent global coverage.
- If the HY-2 programme materialises, the best orbit should be in the early morning, complementary to MetOp/ASCAT in mid-morning and GCOM-W in early afternoon.

13. RADAR ALTIMETRY

This mission is implemented by essentially nadir-pointing radar that measures the distance between the satellite and the reflecting sea surface. It can also be used on land and ice. It is possible to implement SAR capability to more accurately detect ice border and topography. To be associated with co-aligned passive MW radiometers for water vapour correction.

Generic characteristics of the altimetry mission in LEO (years 2020's)			
	Frequency	**Resolution**	**Scanning**
Altimeter	Two within the range 1.55 to 35.5 GHz	20 to 30 km along track	none
MW radiometer	23 GHz plus nearby window(s) (19 and/or 34 GHz)	20 to 30 km along track	none

Addressed products are as follows.

Geophysical parameters addressed by the altimetry mission in LEO				
Ocean topography	Significant wave height	Ice sheet topography	Sea ice thickness	Total Electron Content (TEC)

The recommended observing strategy is:

- two satellites (for more frequent coverage and redundancy) in high non-sunsynchronous orbit for large-scale and long-term application;
- two satellites (for more frequent coverage and redundancy) in low sunsynchronous orbit, with SAR capability, for sea ice and regional purposes.

The evolution of current and planned altimeters and associated MW radiometers in LEO is shown below.

Instrument class	**Two frequencies, no SAR**	**Single frequency, SAR**	**SAR capability**	**Single frequency, no SAR**

Instrument	**Satellite**	**LST**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**→**
SRAL + MWR	**Sentinel-3/1**	**10:00**						X	X	X	X	X	X	X			
SRAL + MWR	**Sentinel-3/2**	**10:00**								X	X	X	X	X	X	X	
RA-2 + MWR	**Envisat**	**10:00**	X	X	X	X											
RA + MWR	**ERS-2**	**10:30**	X	X	X												
Poseidon-2 + JMR	**Jason-1**	**66°**	X	X	X												
Poseidon-3 + AMR	**Jason-2**	**66°**		X	X	X	X	X	X	X	X						
SIRAL	**CryoSat-2**	**92°**			X	X	X	X									

Comparative characteristics of radar altimeters and associated MW radiometers							
Feature	**ERS-2 RA**	**Envisat RA-2**	**Poseidon 2 & 3 (Jason 1 & 2)**	**CryoSat-2 SIRAL**	**Sentinel-3 SRAL**	**ERS-2, Envisat & Sentinel-3: MWR**	**Jason 1 & 2 JMA = AMR**
Frequency	13.8 GHz	3.2 & 13.8 GHz	5.3 & 13.58 GHz	13.56 GHz	5.3 & 13.58 GHz	23.8 and 36.5 GHz (+18.7 GHz on S-3)	18.7, 23.8 and 34 GHz
Repeat cycle	35 days	35 days	10 days	30 days	27 days	27 or 35 days	10 days
IFOV	20 km	20 km	30 km	15 km (SAR. 250 m)	20 km (SAR: 300 m)	20 km	25 km

Comments (with focus on the 2020 range):

- In low (sunsynchronous) orbit the requirements are not met even if Sentinel-3 is developed and continued after the first two demonstration flight units, still based on two satellites in orbit at the same time; in fact, the orbits of the two satellites are close to each other.
- In the high (non-sunsynchronous) orbit, post-EPS requirements are met if continuity is provided to the Ocean Surface Topography Mission (OSTM).
- There is information (in the literature! not official) on a Chinese plan for an altimeter to be embarked on HY-2 (HaiYang-2) sometimes around 2010. Orbital LST seems to be 06/18.

Recommendations:

- To provide continuity to the Sentinel-3 programme keeping the feature of having two satellites in orbit at each time.
- To provide continuity to the Jason programme ensuring that the launches schedule overlap to the extent of having two satellites in orbit at each time.
- If the HY-2 programme materialises, the orbit should be well separated from the one of Sentinel-3 (ideally: LST 16:00, but 18:00 would be acceptable).

14. OCEAN COLOUR IMAGERY FROM LEO

This mission is implemented by VIS/NIR imagers specifically designed to work on low-level signals (because of low reflectivity of ocean) and narrow bandwidth channels to address specific water features.

Generic characteristics of the ocean colour mission in LEO (years 2020's)						
Spectral range	**Bandwidths**	**No. of SW channels**	**Typical SNR**	**Resolution**	**Swath**	**Scanning**
400 to 900 nm	4 to 10 nm	8-15	1000	300-1000 m	1400-2800 km	cross-track

Addressed products are as follows.

Geophysical parameters addressed by the ocean colour mission in LEO		
Chlorophyll concentration	Colour Dissolved Organic Matter (CDOM)	Leaf Area Index (LAI)
Diffuse attenuation coefficient (DAC)	Photosynthetically Active Radiation (PAR)	Normalised Difference Vegetation Index (NDVI)
Suspended sediments concentration	Fractional Absorbed PAR (FAPAR)	Oil spills

The recommended observing strategy is:

- two satellites: one in mid-morning, one in early afternoon, to increase probability of cloud-free conditions; each one with backup, even if by instruments not optimal.

The evolution of current and planned ocean colour monitors in LEO is shown below.

Instrument class	**Channels with $\lambda < 1\ \mu m$: > 10 most bandwidths ~ 10 nm**	**Channels with $\lambda < 1\ \mu m$: > 10 some bandwidths < 10 nm**	**Channels with $\lambda < 1\ \mu m$: < 10 all bandwidths > 10 nm**

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
VIIRS	NPOESS 2&4	05:30										X	X	X	X	X	X
MERIS	Envisat	10:00	X	X	X	X											
OLCI	Sentinel-3/1	10:00						X	X	X	X	X	X	X			
OLCI	Sentinel-3/2	10:00								X	X	X	X	X	X	X	
MERSI	FY-3 A/C/E/G	10:00	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SGLI	GCOM-C 1 (2,3)	10:30					X	X	X	X	X	(X)	(X)	(X)	(X)	(X)	(X)
MODIS	EOS-Terra	10:30	X	X													
SeaWiFS	SeaStar	12:00	X	X	X												
OCM	OceanSat 1, 2	12:00	X	X	X	X	X	X	X								
MODIS	EOS-Aqua	13:30	X	X	X												
VIIRS	NPP	13:30			X	X	X	X	X	X							
VIIRS	NPOESS 1&3	13:30							X	X	X	X	X	X	X	X	X
MERSI	FY-3 B/D/F	14:00			X	X	X	X	X	X	X	X	X	X	X	X	X

Comparative characteristics of ocean colour monitoring radiometers in LEO								
Feature	**OceanSat OCM**	**SeaStar SeaWiFS**	**Terra/Aqua MODIS**	**Envisat MERIS**	**Sentinel-3 OLCI ≈ MERIS-2**	**FY-3 MERSI**	**NPOESS VIIRS**	**GCOM-C SGLI**
Channels $\lambda < 1\ \mu m$	8	8	12	15	15	12	7	13
Bandwidths	20-40 nm	20-40 nm	10-50 nm	4-20 nm	4-20 nm	20 nm	15-40 nm	8-20 nm
Swath	1420 km	2800 km	2230	1150 km	1270 km	2900 km	3000 km	1000 km
IFOV	300 m	1.1 km	1.0 km	300 m	200-500 m	1.0 km	800 m	250-1000 m

Comments (with focus on the 2020 range):

- In the mid-morning Sentinel-3 (with OLCI), if continued, and GCOM-C 2 and 3 (with SGLI), if approved, would cover the requirement for high-quality measurements, also with backup.
- In the early afternoon NPOESS/VIIRS and FY-3/MERSI will provide a basic service, also redundant. However, none of the two meet post-2020 requirements.

Recommendation:

- To provide long-term continuity of Sentinel-3.
- To approve GCOM-C 2/3 but improve the effectiveness of SGLI by placing it in an afternoon orbit (ideal: LST = 14:00). Or upgrade MERSI on FY-3 (by narrowing the channel bandwidths).

15. OCEAN COLOUR IMAGERY FROM GEO

This mission is implemented by VIS/NIR imagers specifically designed to work on low-level signals (because of low reflectivity of ocean) and narrow bandwidth channels to address specific water features.

Generic characteristics of the ocean colour mission in GEO (years 2020's)					
Spectral range	**Bandwidths**	**No. of SW channels**	**Typical SNR**	**Resolution**	**Observing cycle**
400 to 900 nm	10 to 40 nm	8-15	1000	200-500 m	60 min (area of 2500 x 2500 km^2)

Addressed products are as follows (the same as from LEO, with possibly somewhat lower quality, but much more frequently).

Geophysical parameters addressed by the ocean colour mission in GEO		
Chlorophyll concentration	Colour Dissolved Organic Matter (CDOM)	Leaf Area Index (LAI)
Diffuse attenuation coefficient (DAC)	Photosynthetically Active Radiation (PAR)	Normalised Difference Vegetation Index (NDVI)
Suspended sediments concentration	Fractional Absorbed PAR (FAPAR)	Oil spills

The recommended observing strategy is:

- no need for international coordination, except among countries in the same field of view: in fact, it is a mission for local purposes (on coastal waters).

The evolution of current and planned ocean colour monitors in GEO is shown below.

Instrument class	**To meet post-2020 requirements**

Instrument	Satellite	Long.	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
		0°															
		60°E															
GOCI	COMS-1 & 2	128°E		X	X	X	X	X	X	X	X	X	X	X	X	X	X
		180°E															
HES	GOES-17	135°W									(X)	(X)	(X)	(X)	(X)	(X)	(X)
HES	GOES-16 (R)	75°W								(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)

Comparative characteristics of ocean colour monitoring radiometers in GEO		
Feature	**COMS (GOCI)**	**GOES-R (HES)**
Channels λ < 1 μm	8	14
Bandwidths	10-40 nm	20-40 nm
Cycle	60 min for sectors of 2500 x 2500 km^2 (or equivalent)	60 min for sectors of 2500 x 2500 km^2 (or equivalent)
IFOV	500 m	150-300 m

Comments (with focus on the 2020 range):

- The only consolidated plan for ocean colour monitoring from GEO is for GOCI on COMS.
- The plan for ocean colour from GOES-R / HES is no longer in the baseline. HES itself is not confirmed.

Recommendation:

- None: ocean colour from GEO is considered of local interest.

16. IMAGERY WITH SPECIAL VIEWING GEOMETRY

This mission is implemented by VIS/IR imagers specifically designed for viewing under different angles for one or another purpose (accurate atmospheric correction, anisotropy effects, best geometry to exploit multi-polarisation, need for reconstructing irradiances from observed radiances, etc.).

Generic characteristics of imagers with special viewing geometry in LEO (years 2020's)

	Spectral range	Bandwidths	No. of channels	Accuracy	Full-pol channels	Viewing angles	Resolution	Swath	Scanning
Sea-surface temperature	3.5 to 12.5 μm	0.3 to 1.0 μm	IR: 3	NEΔT = 0.05 @ 280 K	-	2-	.0.5-1.0 km	500-1000 km	conical
Aerosol, cirrus clouds	SW: 340-2200 nm LW: 3.5-25 μm	SW: 6 to 40 nm LW: 0.4-2.0 μm	SW: 10 LW: 10	SNR: 200 @ 10 % ρ NEΔT = 0.1 @ 300 K	4 to 6 (in SW)	2 to 10	1 to 5 km	1400-2500 km	conical or pushbroom
Bi-directional reflectance	400 to 900 nm	20 to 40 nm	4-10	SNR = 300 @ 10 % ρ	-	10	0.3 to 5 km	500-2500 km	mixed

Addressed products are as follows.

Geophysical parameters addressed by special viewing instruments in LEO

Sea-surface temperature (IR)	Aerosol optical depth profile (short wave)	SW Earth's surface bi-directional reflectance
Land-surface temperature (IR)	Total aerosol optical depth (short-wave)	Earth's surface albedo
Cloud optical depth (short-wave)	Aerosol effective radius profile	Photosynthetically Active Radiation (PAR)
Cloud drop effective radius at cloud top	Total aerosol effective radius	Fractional Absorbed PAR (FAPAR)
Cloud ice effective radius at cloud top	Aerosol type profile	Snow albedo
Short-wave cloud reflectance	Downwelling SW irradiance at Earth's surface	Oil spill cover

The recommended observing strategy is:

- at least one instruments for accurate sea-surface temperature (backup is the VIS/IR imagery mission on the backbone satellites of GOS, i.e. those in the 05:30, 09:30 and 13:30 LST orbits);
- at least one instrument specifically designed for multi-angle/multi-spectral/multi-polarisation observation for aerosol, cirrus clouds and bidirectional reflectances (partial backup is the VIS/IR imagery mission on the backbone satellites of GOS, i.e. those in the 05:30, 09:30 and 13:30 LST orbits).

The evolution of current and planned special viewing instruments is shown below.

Instrument class	For aerosol	For BRDF	For aerosol and BRDF	For temperature

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
SLSTR	Sentinel-3/1	10:00						X	X	X	X	X	X	X			
SLSTR	Sentinel-3/2	10:00								X	X	X	X	X	X	X	
AATSR	Envisat	10:00	X	X	X	X											
ATSR-2	ERS-2	10:30	X	X	X												
MISR	EOS-Terra	10:30	X	X													
POLDER	PARASOL	13:30	X	X													
APS	NPOESS 1/3	13:30							(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
APS	Glory	13:30			X	X	X	X	X								

Comparative characteristics of special viewing instruments in LEO

	ERS-2 and Envisat ATSR-2 = AATSR	Sentinel-3 SLSTR	EOS-Terra MISR	PARASOL POLDER	NPOESS, Glory APS
Channels	4 VIS/NIR/SWIR, 3 MWIR/TIR	6 VIS/NIR/SWIR, 3 MWIR/TIR	4 channels, VIS/NIR	9 channels, VIS/NIR	11 channels, VIS/NIR/SWIR
Polarisations	-	-	none	3, for 3 channels	4, for all channels
Viewing angles	2	2	9	Several	Several within ± 60° along-track
Swath	500 km	Dual view: 750 km ; single view: 1675 km	360 km	2200 km	N/A (non-scanning)
IFOV at s.s.p.	1 km	VIS/NIR/SWIR: 500 m, MWIR/TIR 1.0 km	Selectable: 275 m or 550 m or 1100 m	6 km	10 km

Comments (with focus on the 2020 range):

- Accurate sea-surface temperature for climate: the post-2020 requirement will be met if continuity is provided to Sentinel-3, which embarks the follow-on of the ATSR series operating since 1991.
- Aerosol and cirrus clouds: no provision is currently foreseen to provide continuity to POLDER and extend its capabilities. The operational VIS/IR imagers being designed for post-2020 provide more information than what is available from the current instruments, but are far from meeting the required accuracy because of lack of information on multi-polarisation and multi-directionality.
- Bidirectional Reflectance Distribution Function (BRDF): nothing is planned beyond POLDER and MISR.

Recommendations:

- To provide long-term continuity to the Sentinel-3 mission, that would enable to continue the ATSR series of extremely accurate measurements of the sea-surface temperature for the purpose of climate monitoring.
- To focus the problem of the lack of planning for accurate observation of aerosol and cirrus clouds, that strongly affect atmospheric radiation processes.
- To associate the problem of aerosol and cirrus clouds that require multi-polarisation and multi-viewing observations in addition to multi-spectral, to that one of re-designing the Earth radiation budget mission.

17. LIGHTNING IMAGERY FROM LEO

This mission is implemented by special cameras observing the earth all-time and recording rate and intensity of flashes in a given area (the IFOV). Generic characteristics of the instruments are listed as follows.

Generic characteristics of lightning imagers in LEO (years 2020's)						
Spectral range	**Bandwidth**	**Detection efficiency (DE)**	**False alarm rate (FAR)**	**Resolution**	**Swath**	**Scanning**
777.4 nm	1.2 nm	90 % for 7 $\mu J \cdot m^{-2} \cdot sr^{-1}$, 40 % for 4 $\mu J \cdot m^{-2} \cdot sr^{-1}$	1 s^{-1} for 50 % cloud cover with clouds albedo 80 %	5 km	600 km	pushbroom

Addressed products are as follows.

Geophysical parameters addressed by a lightning mission in LEO		
Convective precipitation (proxy)	NO_x generation (proxy)	Earth electric field

The recommended observing strategy is:

- since from LEO it is not possible to have enough frequent observation, the synergy with GEO should be exploited. One payload in LEO (two for redundancy) should be operated, both for extending the observation at high latitudes, and for "calibrating" the GEO system.

The evolution of current and planned lightning imagers in LEO is shown below.

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
LIS	TRMM	35°	X	X	X												

Comments (with focus on the post-2020 range):

- There is no plan for continuing a lightning mission in LEO.
- Consideration is being given to embarking a lightning imager on the "core" satellite of the GPM constellation.

Recommendation:

- To consider the continuation of a lightning mission in LEO in the framework of the GPM (and a possible GPM follow-on), in synergy with a number of lightning imagers flown on the GEO satellite system.

18. LIGHTNING IMAGERY FROM GEO

This mission is implemented by special cameras observing the earth all-time and recording rate and intensity of flashes in a given area (the IFOV). Generic characteristics of the instruments are listed as follows.

Generic characteristics of lightning imagers in GEO (years 2020's)					
Spectral range	**Bandwidth**	**Detection efficiency (DE)**	**False alarm rate (FAR)**	**Resolution**	**Observing cycle**
777.4 nm	1.2 nm	90 % for 7 $\mu J \cdot m^{-2} \cdot sr^{-1}$, 40 % for 4 $\mu J \cdot m^{-2} \cdot sr^{-1}$	1 s^{-1} for 50 % cloud cover with clouds albedo 80 %	5-10 km	All time (~ 1 ms)

Addressed products are as follows (the same as from LEO, with possibly somewhat lower quality, but much more frequently).

Geophysical parameters addressed by a lightning mission in GEO		
Convective precipitation (proxy)	NO_x generation (proxy)	Earth electric field

The recommended observing strategy is:

- six sectors, 60 degrees wide along the equator (centres: 0°, 60°E, 120°E, 180°E, 120°W, 60°W);
- at least one instrument in each sector, and one backup, as similar as possible.

The evolution of current and planned lightning imagers in GEO is shown below.

Instrument	Satellite	Long.	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
LI	Meteosat 12→	0°										X	X	X	X	X	X
LM (TBD)	FY-4 O/A→	86.5°E						X	X	X	X	X	X	X	X	X	X
LM (TBD)	FY-4 O/B→	123°E										X	X	X	X	X	X
		180°E															
GLM	GOES-17	135°W									X	X	X	X	X	X	X
GLM	GOES-16 (R)	75°W								X	X	X	X	X	X	X	X

Comments (with focus on the post-2020 range):

- Sector 30°W-30°E: the Meteosat 3rd Generation LI will meet post-2020 requirements. The Meteosat system has backup in hot standby.
- Sector 30-90°E: the FY-4 O LM is being designed to meet post-2020 requirements. The backup policy for FY-4 O satellites is to have two satellites, one at 86.5°E, and one at 123° E.
- Sector 90-150°E: the FY-4 O LM is being designed to meet post-2020 requirements. The backup is at 86.5°E.
- Sector 150°E-150°W: nothing is planned.
- Sector 90-150°W: the GOES GLM (following GOES-R) would meet post-2020 requirements. It would be backed by a standby GOES satellite at 105°W also backing GOES-E.
- Sector 30-90°W: the GOES GLM (following GOES-R) would meet post-2020 requirements. It would be backed by a standby GOES satellite at 105°W also backing GOES-W.

Recommendation:

- The problem of Sector 150°E-150°W should be addressed.

19. CLOUD AND PRECIPITATION RADAR

This mission is implemented by radar of different characteristics depending on the type of addressed cloud: non-precipitating, with light-moderate precipitation, with heavy precipitation. Generic characteristics of the instruments are listed as follows.

Generic characteristics of radar for cloud and precipitation in LEO (years 2020's)					
	Frequency	**Sensitivity**	**Resolution**	**Swath**	**Scanning**
Heavy precipitation	~ 14 GHz	< 18 dBZ @ 0.5 mm/h at ground	< 5 km (horiz.), 200-500 m (vert.)	200-300 km	pushbroom
Light-moderate precipitation	~ 35 GHz	< 12 dBZ @ 0.2 mm/h at ground	< 5 km (horiz), 200-500 m (vert.)	up to 200 km desirable, nadir-only acceptable	pushbroom
Non precipitating cloud	~ 94 GHz	< -36 dBZ for total-column	1-5 km (horiz), 200-500 m (vert.)	up to 50 km desirable, nadir-only acceptable	pushbroom

Addressed products are as follows.

Geophysical parameters addressed by cloud and precipitation radar in LEO		
Precipitation profile(liquid and solid)	Cloud liquid water profile (< 100 μm)	Cloud ice total column
Precipitation rate at surface (liquid or solid)	Cloud liquid water total column (< 100 μm)	Cloud ice effective radius profile
Freezing level height in clouds	Cloud drop effective radius profile	Cloud top height
Melting layer depth in clouds	Cloud ice profile	Cloud base height

The recommended observing strategy is:

- to exploit the synergy with passive MW radiometers so as to limit the number of radar-equipped satellites to what is needed for having at least one radar of each type in orbit.
- since, in this concept, the radar is used to "calibrate" passive MW radiometers, the orbit should be non-sunsynchronous so as to intercept all sunsynchronous orbits of the GPM constellation.

The evolution of current and planned cloud and precipitation radar in LEO is shown below.

Instrument class	**Single frequency, nadir-only**	**Dual frequency, imaging**	**Single frequency, imaging**

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
CPR (94 GHz)	Earth-CARE	10:30							X	X	X						
CPR (94 GHz)	CloudSat	13:30	X	X													
PR (14 GHz)	TRMM	35°	X	X	X												
DPR (14 & 35 GHz)	GPM "core"	65°						X	X	X	X	X	X				

Comparative characteristics of cloud and precipitation radar in LEO					
Feature	**PR (TRMM)**	**DPR (GPM "core")**		**CPR (CloudSat)**	**CPR (Earth-CARE)**
Frequency	13.8 GHz	13.6 GHz	35.55 GHz	94.05 GHz	94.05 GHz, Doppler capability
Swath	215 km	245 km	120 km	N/A	N/A
Vertical resolution	250 m	250 m	250 m	500 m	400 m
IFOV	4.3 km	5.0 km	5.0 km	2 km	1 km

Comment (with focus on the 2020 range):

- No plan for any atmospheric radar after 2017.

Recommendations:

- To provide long-term continuity to the "core" satellite of the GPM constellation.
- For the 35 GHz component, non-scanning instruments additional to the scanning one on "core" GPM should be provided on some other satellite concurring to the GPM constellation, provided that the sensitivity is enhanced for the purpose of measuring light rain and rainfall in high latitudes.
- For the 94 GHz component, some follow-on of Earth-CARE and CloudSat should be provided. Sensitivity is a priority requirement in respect of swath.

20. LIDAR-BASED MISSIONS (for wind, for cloud/aerosol, for water vapour, for altimetry)

These missions are implemented by lidar of different characteristics depending on the type of addressed parameter: wind, cloud, aerosol, water vapour, ice topography. Generic characteristics of the instruments are listed as follows.

Generic characteristics of lidar for various observations from LEO (years 2020's)				
	Wavelength(s)	**No. of channels**	**Resolution**	**Scanning**
Doppler wind lidar	355 nm	2 (Mie & Rayleigh)	~ 50 km	none (oblique)
Differential absorption lidar (DIAL)	940 nm (H_2O), 1.6 µm (CO_2) ... plus nearby windows	2 - 3	~ 50 km	none (nadir)
Aerosol profiling lidar	1 or 2, 355 nm or 532 & 1064 nm	3 (Mie co- & cross-polar, Rayleigh co-polar)	~ 10 km	none (nadir)
Lidar altimeter	2, e.g. 532 & 1064 nm	2	~ 100 m	none (nadir)

Addressed products are as follows.

Geophysical parameters addressed by lidar in LEO			
Wind profile (horizontal vector)	Height of the tropopause	Aerosol optical depth profile	Aerosol type profile
Water vapour profile	Cloud top height	Total aerosol optical depth	Total aerosol type
Carbon dioxide profile	Cloud optical depth	Aerosol effective radius profile	PSC occurrence profile
Height of the top of the PBL	Cloud particle effective radius	Total aerosol effective radius	Sea ice thickness (from altimeter)

The recommended observing strategy is:

- operational status to be pursued only for Doppler wind lidar, assuming satisfactory demonstration with ADM-Aeolus. At least one satellite to be provided, possibly two to improve coverage and reliability;
- the other missions could stay, for the moment, in the R&D environment.

The evolution of current and planned lidar-based missions in LEO is shown below.

Instrument class	Single wavelength	Two wavelengths	Doppler capability	Altimeter

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
ALADIN	ADM-Aeolus	06:00		X	X	X	X										
ATLID	Earth-CARE	10:30							X	X	X						
CALIOP	Calipso	13:30	X	X	X												
GLAS	ICESat	94°	X	X													

Comparative characteristics of lidars in LEO				
Feature	**ALADIN (ADM-Aeolus)**	**ATLID (Eart-CARE)**	**CALIOP (Calipso)**	**GLAS (ICESat)**
Wavelength(s)	355 nm, High-Spectral Resolution Laser	355 nm, High-Spectral Resolution Laser	532 & 1064 nm	532 & 1064 nm
FOV and sampling	50 km every 200 km	30 m every 100 m	70 m every 333 m	66 m every 170 m
Vertical resolution	250 m to 2 km	100 m	30 m	10 cm surface, 200 m cloud top
Viewing geometry	side-looking	2° ahead along-track	nadir	nadir

Comments (with focus on the 2020 range):

- No DIAL is currently operating or planned. A proposal for CO_2 (A-SCOPE) is being assessed.
- No follow-on mission is currently planned for ADM-Aeolus, pending demonstration.
- In general, no lidar-based mission is planned for the 2020 timeframe.

Recommendations:

- To focus efforts towards providing operational follow-on to ADM-Aeolus after successful mission demonstration. This implies possible re-design of the mission in such a way as to improve effectiveness (specifically, observing cycle) and affordability.
- Also, to strengthen the observing capability of ADM-Aelous follow-on in respect of aerosol observation.
- As for lidar altimetry, to re-design a comprehensive mission in the overall context of the radar-based altimetry missions, including CryoSat.

21. CROSS-NADIR SHORT-WAVE SPECTROMETRY (FOR CHEMISTRY) FROM LEO

This mission is implemented by UV/VIS/NIR/SWIR spectrometers designed for use in atmospheric chemistry. Generic characteristics of the instruments are listed as follows.

Generic characteristics of short-wave cross-nadir spectrometers in LEO (years 2020's)

Spectral range	Spectral resolution	No. of channels	Typical SNR	Resolution	Swath	Scanning
270 to 2400 nm	0.05 to 0.8 nm	8000-16000	1000	5-20 km	2800 km	cross-track

Addressed products are as follows.

Geophysical parameters addressed by short-wave cross-nadir spectrometers in LEO

Aerosol optical depth profile	O_3 profile	BrO profile	H_2O profile	CO_2 profile	CO total column	SO_2 total column
Total aerosol optical depth	O_3 total column	NO_2 profile	CH_4 profile	CO_2 total column	N_2O profile	CH_2O profile
Surface spectral reflectance	ClO profile	NO_2 total column	CH_4 total column	CO profile	SO_2 profile	CH_2O total column

The recommended observing strategy is:

- at least two instruments on sunsynchronous satellites with LST in mid-morning and early afternoon.

The evolution of current and planned SW cross-nadir spectrometers in LEO is shown below.

Instrument class	UV only, non-scanning	Limited to UV	Limited to UV/VIS	Close to post-2020 req.	Focus on few species

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
GOME-2	MetOp 1-3	09:30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
TBD	Sentinel-5	09:30														(X)	(X)
TOU/SBUS	FY-3 A/C/E/G	10:00	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SCIAMACHY	Envisat	10:00	X	X	X	X											
SBUV/2	NOAA-17	10:20	X	X	X												
MOPITT	EOS-Terra	10:30	X	X													
GOME	ERS-2	10:30	X	X	X												
TANSO-FTS	GOSAT	13:00		X	X	X	X	X	X								
OCO	OCO	13:15		X	X	X											
OMPS-nadir	NPP	13:30			X	X	X	X	X	X							
OMPS-nadir	NPOESS 1&3	13:30							X	X	X	X	X	X	X	X	X
OMI	EOS-Aura	13:45	X	X	X	X	X										
SBUV/2	NOAA 18	13:40	X	X	X	X											
SBUV/2	NOAA-19	14:00			X	X	X	X	X	X							
TOU/SBUS	FY-3 B/D/F	14:00			X	X	X	X	X	X	X	X	X	X	X	X	X

Comparative characteristics of short-wave cross-nadir spectrometers in LEO

Feature	ERS-2 GOME	MetOp GOME-2	FY-3 TOU/SBUS	NOAA SBUV/2	EOS-Terra MOPITT	Envisat SCIAMACHY	OCO	GOSAT TANSO-FTS	EOS-Aura OMI	NPOESS OMPS
Range	240-790 nm	240-790 nm	250-360 nm	250-340 nm	2200-4700 nm	240-2380 nm	760-2080 nm	750-2100 nm	270-500 nm	250-380 nm
$\lambda/\Delta\lambda$	~ 1500	~ 1500	~ 280	~ 300	~ 300	~ 1500	~ 20000	~ 25000	~ 700	~ 300
Swath	120-960 km	960-1920 km	3000 km	none	640 km	1000 km	10 km	790 km	2600 km	2800 km
IFOV s.s.p.	40 x 40 km^2, 40 x 320 km^2	40 x 40 km^2, 40 x 80 km^2	50 km (TOU), 200 km (SBUS)	170 km	22 km	16 x 32 km^2	1.29 x 2.25 km^2	10.5 km	13 x 24 km^2, 36 x 48 km^2	50 km, 250 km

Comments (with focus on the 2020 range):

- The only instrument approaching post-2020 requirements is SCIAMACHY on Envisat, not available in the 2020 timeframe. A "Sentinel-5" mission is being considered by ESA to provide continuity.
- The only instruments currently planned for the 2020 timeframe, both in the mid-morning and early afternoon orbits, are TOU/SBUS on FY-3 and OMPS on NPOESS, both limited to UV and nearly exclusively addressing ozone.

Recommendations:

- To materialise the Sentinel-5 programme and make provision for its long-term continuity.
- To continue flying at least a couple of instruments limited to UV for more frequent observation of O_3.

22. CROSS-NADIR SHORT-WAVE SPECTROMETRY (FOR CHEMISTRY) FROM GEO

This mission is implemented by UV/VIS/NIR spectrometers designed for use in atmospheric chemistry. Generic characteristics of the instruments are listed as follows.

Generic characteristics of short-wave cross-nadir spectrometers in GEO (years 2020's)					
Spectral range	**Spectral resolution**	**No. of channels**	**Typical SNR**	**Resolution**	**Observing cycle**
290 to 800 nm	0.05 to 1 nm	3000-5000	500-2000	5-10 km	30-60 min (for areas 5000 x 3000 km^2)

Addressed products are as follows (nearly the same as from LEO, with possibly somewhat lower quality, but much more frequently).

Geophysical parameters addressed by short-wave cross-nadir spectrometers in GEO					
Aerosol optical depth profile	Surface spectral reflectance	O_3 profile	NO_2 profile	SO_2 profile	CH_2O profile
Total aerosol optical depth	BrO profile	O_3 total column	NO_2 total column	SO_2 total column	CH_2O total column

The recommended observing strategy is:

- no need for international coordination, except among countries in the same field of view: in fact, it is a mission for local/regional purposes.

The evolution of current and planned SW cross-nadir spectrometers in GEO is shown below.

Instrument	Satellite	Long.	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
TBD	Sentinel-4	0°										(X)	(X)	(X)	(X)	(X)	(X)

Comment (with focus on the 2020 range):

- The only plan currently being pursued for UV/VIS spectroscopy from GEO is the ESA "Sentinel-5", not yet fully defined and approved.

Recommendation:

- To materialise the Sentinel-4 programme and make provision for its long-term continuity.

23. CROSS-NADIR IR SPECTROMETRY (FOR CHEMISTRY) FROM LEO

This mission is implemented by IR spectrometers designed for use in atmospheric chemistry. Generic characteristics of the instruments are listed as follows.

Generic characteristics of very-high-spectral-resolution IR cross-nadir spectrometers in LEO (years 2020's)						
Spectral range	**Spectral resolution**	**No. of channels**	**Typical NEΔT**	**Resolution**	**Swath**	**Scanning**
3.3 to 16 μm	0.05-0.1 cm^{-1}	10000-20000	0.1 K @ 280 K	5-20 km	2800 km	cross-track

Addressed products are as follows.

Geophysical parameters addressed by very-high-spectral-resolution IR cross-nadir spectrometers in LEO					
Air temperature profile	O_3 profile	NO_2 profile	CO_2 profile	N_2O profile	N_2O_5 profile
H_2O profile	O_3 total column	NO_2 total column	CO_2 total column	N_2O total column	SF_6 profile
H_2O total column	HNO_3 profile	CH_4 profile	CO profile	SO_2 profile	C_2H_6 profile
PAN profile	HNO_3 total column	CH_4 total column	CO total column	SO_2 total column	C_2H_2 profile

The recommended observing strategy is:

- considering that there will be operational IR spectrometer sounders for the basic temperature/humidity sounding mission, it will be sufficient to have one additional high-spectral-resolution sounder for atmospheric chemistry.

The evolution of current and planned IR cross-nadir spectrometers in LEO is shown below.

Instrument class	**Total columns possible**	**Closest to post-2020 req.**	**Marginal spectral resolution**

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
CrIS	NPOESS 2&4	05:30										(X)	(X)	(X)	(X)	(X)	(X)
IASI	MetOp 1-3	09:30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
IRFS-2	Meteor-M2	10:20		X	X	X	X	X									
TANSO	GOSAT	13:00		X	X	X	X	X	X								
AIRS	EOS-Aqua	13:30	X	X	X												
CrIS	NPP	13:30			X	X	X	X	X	X							
CrIS	NPOESS 1&3	13:30							X	X	X	X	X	X	X	X	X
TES-nadir	EOS-Aura	13:45	X	X	X	X	X										

Comparative characteristics of IR cross-nadir spectrometers in LEO							
Feature	**NPOESS CrIS**	**MetOp IASI**	**Meteor-M2 IRFS-2**	**GOSAT TANSO-FTS**	**GOSAT TANSO-CAI**	**EOS-Aqua AIRS**	**EOS-Aura TES-nadir**
Range	3.92-15.40 μm	3.62-15.50 μm	5-15 μm	0.76-14.3 μm	0.38-1.6 μm	3.74-15.40 μm	3.28-15.38 μm
Spectral resolution	0.625 to 2.5 cm^{-1}	0.25 cm^{-1}	0.5 cm^{-1}	0.2 cm^{-1}	4 channels	0.5 to 2.0 cm^{-1}	0.06 cm^{-1}
Swath	2200 km	2130 km	1000 or 2500 km	790 km	1000 km	1650 km	885 km
IFOV s.s.p.	14 km	12 km	35 km	10.5 km	0.5-1.5 km	13.5 km	0.53 x 5.3 km^2

Comments (with focus on the 2020 range):

- The only instrument approaching post-2020 requirements would be TES on EOS-Aura, not available in the 2020 timeframe.
- The only instrument currently considered for the 2020 timeframe is CrIS on NPOESS, with marginal spectral resolution for chemistry, and not baselined in the early morning.
- As IASI follow-on, consideration is given to an option for improved spectral resolution to cover atmospheric chemistry requirements. On Sentinel-4 the Thermal IR range is not currently considered.

Recommendation:

- To provide a follow-on to the EOS-Aura TES. To be noted that, without a very-high spectral resolution IR sounder, species such as HNO_3. SF_6, N_2O_5, PAN, C_2H_6 and C_2H_2 could not be observed.

24. CROSS-NADIR IR SPECTROMETRY (FOR CHEMISTRY) FROM GEO

This mission is implemented by IR spectrometers designed for use in atmospheric chemistry. Generic characteristics of the instruments are listed as follows.

Generic characteristics of very-high-spectral resolution IR sounders in GEO (years 2020's)					
Spectral range	**Spectral resolution**	**No. of channels**	**Typical NEΔT**	**Resolution**	**Observing cycle**
3.6 to 15 μm	0.1-0.2 cm^{-1}	5000-10000	0.1 K @ 280 K	5-10 km	30-60 min (for areas 5000 x 3000 km^2)

Addressed products are as follows (nearly the same as from LEO, with possibly somewhat lower quality, but much more frequently).

Geophysical parameters addressed by very-high-spectral resolution IR sounders in GEO				
Air temperature profile	O_3 profile	NO_2 profile	CO_2 profile	N_2O profile
H_2O profile	O_3 total column	NO_2 total column	CO_2 total column	N_2O total column
H_2O total column	HNO_3 profile	CH_4 profile	CO profile	SO_2 profile
PAN profile	HNO_3 total column	CH_4 total column	CO total column	SO_2 total column

The recommended observing strategy is:

- no need for international coordination, except among countries in the same field of view: in fact, it is a mission for local/regional purposes.

The evolution of current and planned IR cross-nadir spectrometers in GEO is shown below.

Instrument class	**Marginal spectral resolution**

Instrument	Satellite	Long.	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
IRS	Meteosat 12→	0°										X	X	X	X	X	X
Sounder TBD	FY-4 O/A→	86.5°E						X	X	X	X	X	X	X	X	X	X
Sounder TBD	FY-4 O/B→	123°E										X	X	X	X	X	X
Sounder TBD	MTSAT-FO→	140°E											(X)	(X)	(X)	(X)	(X)
		180°E															
HES	GOES-17	135°W									(X)	(X)	(X)	(X)	(X)	(X)	(X)
HES	GOES-16 ®	75°W								(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)

Comparative characteristics of very-high-spectral-resolution IR sounders in GEO		
Feature	**Meteosat 3rd Generation IRS**	**GOES-R HES**
Range	4.6-14.3 μm	3.68-15.4 μm
Channels	1736	1508
Spectral resolution	0.625 cm^{-1}	0.5 to 2.5 cm^{-1}
Cycle (full disk)	30 min	60 min
IFOV IR	4 km	2-20 km

Comments (with focus on the 2020 range):

- No planned IR spectrometer sounder for GEO has enough high spectral resolution to meet post-2020 requirements from atmospheric chemistry.
- With the spectral resolution of currently planned IR sounders only total columns of few species will be observable.

Recommendation:

- If a requirement exists for frequent profiles of, e.g., HNO_3, or if certain species need frequent observation in nigh time, the need for high-spectral-resolution IR sounding from GEO should be re-assessed.

25. LIMB-SOUNDING SHORT-WAVE SPECTROMETRY

This mission is implemented by UV/VIS/NIR/SWIR spectrometers designed for use in atmospheric chemistry. Generic characteristics of the instruments are listed as follows.

Generic characteristics of short-wave limb-sounding spectrometers in LEO (years 2020's)					
Spectral range	**Spectral resolution**	**No. of channels**	**Typical SNR**	**Resolution**	**Scanning**
270 to 2400 nm	0.05 to 0.8 nm	8000-16000	1000	2 km (vertical)	limb

Addressed products are as follows.

Geophysical parameters addressed by short-wave limb-sounding spectrometers in LEO			
Air temperature profile	O_3 profile	NO_2 profile	CO_2 profile
Water vapour profile	ClO profile	H_2O profile	N_2O profile
Aerosol optical depth profile	BrO profile	CH_4 profile	PSC occurrence profile

The recommended observing strategy is:

- at least one instrument on a sunsynchronous satellite should be provided, to provide the necessary high vertical resolution in the stratosphere and above;
- at least the spectral range needed for ozone (UV/VIS) should be covered.

The evolution of current and planned SW limb-sounding spectrometers in LEO is shown below.

Instrument class	**Limited to UV/VIS/NIR**	**Closest to post-2020 req.**	**Occultation**

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
SCIAMACHY	Envisat	10:00	X	X	X	X											
GOMOS	Envisat	10:00	X	X	X	X											
POAM-3	SPOT-4	10:30	X	X													
OMPS-limb	NPP	13:30			X	X	X	X	X	X							
OMPS-limb	NPOESS 1&3	13:30							(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)

Comparative characteristics of short-wave limb-sounding spectrometers in LEO				
Feature	**Envisat SCIAMACHY-limb**	**Envisat GOMOS (occultation of stars)**	**SPOT-4 POAM-3 (occultation of sun)**	**NPOESS OMPS-limb**
Range	240-2380 nm	248-956 nm	350-1024 nm	290-1000 nm
Resolving power $\lambda/\Delta\lambda$	~ 1500	~ 500	9 channels	~ 200
Vertical resolution	3 km, range 10-100 km	1.7 km, range 20-100 km	0.6 km, range 10-60 km	1 km, range 10-60 km
Horizontal coverage	swath:1000 km	~ 500 occultations/day	few 10's occultations/day	swath: 750 km

Comments (with focus on the 2020 range):

- The only instrument approaching post-2020 requirements is SCIAMACHY on Envisat, not available in the 2020 timeframe. The "Sentinel-5" mission being considered by ESA is not currently including a SW limb-sounding component.
- The only instrument planned for the 2020 timeframe was OMPS on NPOESS, limited to UV/VIS and nearly exclusively addressing ozone. However, the limb-sounding component, now recovered for NPP, is no longer in the baseline for NPOESS.

Recommendations:

- To revise the situation of certain important trace species (e.g., ClO and BrO) that, in the stratosphere, in the absence of a SW limb sounder, could only be observed in the Sub-mm range for which, however, there is no plan currently being pursued (only proposals such as "PREMIER").
- To confirm at least an ozone limb-sounder (e.g., OMPS on NPOESS).

26. LIMB-SOUNDING INFRARED SPECTROMETRY

This mission is implemented by very-high-spectral-resolution sounders operated in limb mode, designed for use in atmospheric chemistry. Generic characteristics of the instruments are listed as follows.

Generic characteristics of limb-sounding IR spectrometers in LEO (years 2020's)

Spectral range	Spectral resolution	No. of channels	Typical NEΔT	Resolution	Scanning
3.3 to 16 μm	0.1 cm^{-1}	~ 20000	0.1 K @ 200 K	2 km (vertical)	limb

Addressed products are as follows.

Geophysical parameters addressed by limb-sounding IR spectrometers in LEO

Air temperature profile	HNO_3 profile	H_2O profile	CO_2 profile	SF_6 profile
O_3 profile	NO_2 profile	CH_4 profile	N_2O profile	PSC occurrence profile

The recommended observing strategy is:

- at least one instrument on a sunsynchronous satellite should be provided, to provide the necessary high vertical resolution in the stratosphere and above.

The evolution of current and planned IR limb-sounding spectrometers in LEO is shown below.

Instrument class	Closest to post-2020 req.	Spectroradiometer

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
MIPAS	Envisat	10:00	X	X	X	X											
HIRDLS	EOS-Aura	10:00	X	X	X	X	X										
TES-limb	EOS-Aura	13:45	X	X	X	X	X										

Comparative characteristics of limb-sounding IR spectrometers in LEO

Feature	MIPAS (Envisat)	HIRDLS (EOS-Aura)	TES-limb (EOS-Aura)
Range	4.15-14.6 μm	6.12-17.76 μm	3.28-15.38 μm
Spectral resolution	0.035 cm^{-1}	21 channels	0.015 cm^{-1}
Vertical resolution	3 km, range 5-150 km	1 km, range 10-100 km	2.3 km, range 0-37 km
Horizontal coverage	two views (fore- and side)	2000-3000 km	none

Comments (with focus on the 2020 range):

- Both the Envisat MIPAS and the EOS-Aura TES approach post-2020 requirements, but none will be available in the 2020 timeframe. The "Sentinel-5" mission being considered by ESA is not currently including an IR limb-sounding component (or a SW limb sounder).
- Without limb sounders the vertical resolution required in the stratosphere and above cannot be achieved in any way.

Recommendation:

- To revise the situation of certain important trace species (e.g., HNO_3) that, in the stratosphere, in the absence of an IR limb sounder, could only be observed in the Sub-mm range for which, however, there is no plan currently being pursued (only proposals such as "PREMIER").

27. LIMB-SOUNDING SUBMILLIMETRE SPECTROMETRY

This mission is implemented by limb sounders exploiting millimetre-submillimetre wavelengths, designed for use in atmospheric chemistry. Generic characteristics of the instruments are listed as follows.

Generic characteristics of limb-sounding mm-submm spectrometers in LEO (years 2020's)					
Spectral range	**Spectral resolution**	**No. of bands / channels**	**Typical NEΔT**	**Resolution**	**Scanning**
100 to 3000 GHz	5-50 MHz	5-10 bands, 500-2000 channels	0.1 K @ 200 K	2 km (vertical)	limb

Addressed products are as follows.

Geophysical parameters addressed by limb-sounding mm-submm spectrometers in LEO				
Air temperature profile	O_3 profile	BrO profile	HCl profile	N_2O profile
H_2O profile	ClO profile	HNO_3 profile	H_2O profile	HDO profile

The recommended observing strategy is:

- at least one instrument on a sunsynchronous satellite should be provided, to provide the necessary high vertical resolution in the stratosphere and above.

The evolution of current and planned mm-submm limb-sounding spectrometers in LEO is shown below.

Instrument class	**Close to post-2020**

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
MLS	EOS-Aura	10:00	X	X	X	X	X										

Comparative characteristics of limb-sounding mm-submm spectrometers in LEO	
Feature	**MLS (EOS-Aura)**
Bands and channels	Five bands: 118, 190, 240, 640 and 2500 GHz; for a total of ~ 1000 channels
Spectral resolution	10 MHz
Vertical resolution	1.5 km, range 5-120 km

Comments (with focus on the 2020 range):

- The EOS-Aura MLS approaches post-2020 requirements, but will not be available in the 2020 timeframe. The "Sentinel-5" mission being considered by ESA is not currently including an mm-submm limb-sounding component (nor SW and IR limb sounders).
- Without limb sounders the vertical resolution required in the stratosphere and above cannot be achieved in any way.
- Mm-submm and IR limb sounding are only at the stage of proposal ("PREMIER" in the ESA Earth Explorer missions), currently being assessed.

Recommendation:

- To revise the situation of certain important trace species (e.g., HCl and HDO) that can only be observed in the mm-submm range; but also of ClO and BrO, that are best observed in mm-submm.

28. HIGH-RESOLUTION SHORT-WAVE IMAGERY FOR LAND OBSERVATION

This mission is implemented by imagers exploiting a variety of trade-offs between geometric resolution and swath, often offering the flexibility of in-flight selection of the area to be observed. Generic characteristics of the instruments are listed as follows.

Generic characteristics of high-resolution short-wave imagers in LEO (years 2020's)					
Spectral range	**Spectral resolution**	**No. of channels**	**Typical SNR**	**Resolution**	**Scanning**
0.5 to 1.6 nm	20 nm	5 to 10	50 @ 0.5 % albedo	< 1 to > 10 m	pushbroom

Addressed products are as follows.

Geophysical parameters addressed by high-resolution short-wave imagers in LEO			
Soil type	Photosynthetically Active Radiation (PAR)	Leaf Area Index (LAI)	Glacier cover
Vegetation type	Fractional Absorbed PAR (FAPAR)	Fire fractional cover	Snow cover
Fraction of vegetated land	Normalised Difference Vegetation Index (NDVI)	Sea-ice cover	Oil spill cover

The recommended observing strategy is:

- to rely on programmes managed by R&D space agencies, since there are many, and are run with a fair degree of continuity;
- to complement, when necessary, with data from programmes run by private companies, that generally cover resolution ranges of the order of 1 m or less.

The evolution of current and planned high-resolution short-wave imagers in LEO is extremely variegated. Only programmes managed by CGMS-member space agencies are recorded below. This implies that resolutions of the order of 1 m or less, that are managed by private companies, are not included. Two instruments have been fit, that actually are not only short-wave (ASTER) or do not have high resolution (Vegetation); the reason is that in this text there isn't another category where they fit better.

Instrument class	**IFOV > 10 m pointing many channels**	**IFOV > 10 m pointing many channels including TIR**	**IFOV > 10 m narrow swath hyperspectral**	**IFOV > 10 m large swath many channels**	**IFOV > 10 m large swath few channels**	**IFOV < 10 m pointing few channels**	**IFOV < 10 m not pointing few channels**	**IFOV ~ 1 km wide swath few channels**

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
MSS, TM	Landsat-5	10:00	X	X													
ETM+	Landsat-7	10:00	X	X	X												
OLI	LDCM	10:00				X	X	X	X	X	X	X	X	X	X	X	
ALI, LAC	NMP EO-1	10:15	X	X													
Hyperion	NMP EO-1	10:15	X	X													
KMSS	Meteor-M 1/2	10:20	X	X	X	X	X	X									
ASTER	EOS-Terra	10:30	X	X	X												
HRV	SPOT-2	10:30	X														
HRVIR	SPOT-4	10:30	X	X													
HRG, HRS	SPOT-5	10:30	X	X	X												
Vegetation	SPOT 4 & 5	10:30	X	X	X												
HiRI	Pléiades 1/2	10:30			X	X	X	X	X	X	X	X					
MSI	Sentinel-2 1/2	10:30						X	X	X	X	X	X	X	X	X	
AVNIR-2, PRISM	ALOS	10:30	X	X	X	X	X										
PAN, MS	Monitor-E	10:30	X	X	X												
PAN-A, PAN-F	CartoSat 1	10:30	X	X	X	X											
PAN	CartoSat 2	10:30	X	X	X	X	X	X									
LISS-3, LISS-4	ResourceSat 1/2	10:30	X	X	X	X	X	X	X	X	X						
AWiFS	ResourceSat 1/2	10:30	X	X	X	X	X	X	X	X	X						
Geoton	Resurs-DK	70°	X	X	X	X											

Comment (with focus on the 2020 range):

- Apparently there isn't and there will not be a problem of data availability.

Recommendation:

- To ensure that data access is friendly and costs and delivery time are minimal.

29. SYNTHETIC APERTURE RADAR

This mission is implemented by side-looking radar associated to special signal analysis that enables achieving very-high resolution imagery. The technology implies very restrictive conditions that require exploiting a variety of trade-offs between frequency, geometric resolution, swath and polarisation. Frequency is the parameter that mostly characterises the measurement objectives. Modern SAR's offer large flexibility of in-flight alternating the operating mode: but not the frequency, which therefore is used here for the top-level instrument classification. Generic characteristics of the instruments are listed as follows.

Generic characteristics of SAR imagers in LEO (years 2020's)

Type	Frequency	Resolution	Swath	Polarisations	Scanning
L-band	~ 1.4 GHz	10-30 m associated to narrow swath; ~ 1 km associated to large swath	50-100 km associated to high resolution; ~ 400 km associated to coarse resolution	HH or VV, or alternating: VV/HH, HH/HV, VV/VH	pushbroom
C-band	~ 5.4 GHz				
X-band	~ 9.5 GHz				

Addressed products, mostly conditioned by the adopted frequency, are as follows.

Geophysical parameters addressed by SAR imagers in LEO (depending on frequency)

Soil moisture at surface	Fraction of vegetated land	Ocean ice sheet topography	Wave - Directional energy frequency spectrum
Soil moisture at surface (index)	Glacier cover	Sea-ice cover	Wave - Dominant direction
Soil moisture in the roots region	Vegetation type	Sea-ice cover (all-weather)	Wave - Dominant period
Snow status (wet/dry)	Soil type	Sea-ice thickness	Wave - Significant height
Snow water equivalent	Fire fractional cover	Sea-ice type	Oil spill cover

The recommended observing strategy is:

- to rely on programmes managed by R&D space agencies, since there are many, and are run with a fair degree of continuity.

The evolution of current and planned SAR's in LEO is shown below. The German X-band SAR-Lupe constellation of 5 satellites (first already in orbit) is not listed since military-classified. The Italian X-band COSMO-SkyMed is included because dual-use (military and civilian).

Instrument class	C-band, non-multiparameter	X-band, non-multiparameter	L-band, multiparameter	C-band, multiparameter	X-band, multiparameter

Instrument	Satellite	LST	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	→
SAR	RadarSat-1/2	06:00	X	X	X	X	X	X	X	X							
SAR-2000	COSMO-SkyMed 1/4	06:00	X	X	X	X	X	X	X	X	X						
SAR-L	SAOCOM 1/2	06:00		X	X	X	X	X	X	X	X						
SAR-C	GMES 1/2	06:00					X	X	X	X	X	X	X	X			
Severjanin	Meteor 1/2	10:20	X	X	X	X	X	X									
AMI-SAR	ERS-2	10:30	X	X	X												
AMI-Wave	ERS-2	10:30	X	X	X												
ASAR	Envisat	10:30	X	X	X	X											
ASAR-Wave	Envisat	10:30	X	X	X	X											
PALSAR	ALOS	10:30	X	X	X	X	X										

Comments (with focus on the 2020 range):

- Continuing availability of C-band SAR, still the most popular, seems to be secured, especially if long-term continuity is provided to GMES-1 (former *Sentinel-1*).
- L-band SAR, the most useful for hydrology, seems to have attracted sufficient interest (see the Japanese ALOS/PALSAR and the Argentinean SAOCom). It is hoped that it could have long-term continuity.
- X-band SAR, the most useful for recognition, is likely to be continued in the long-term, also thanks to the dual interest (civilian and military).

Recommendation:

- To ensure that data access is friendly and costs and delivery time are minimal.

APPENDIX 1 TO THE ANNEX

Correspondence table of geophysical parameters v/s remote sensing techniques

The attached table (two sheets) records in matrix form the relevance of the various instruments types (the 29 ones defined in this document) to the various geophysical parameters (127 have been identified in this document). The information content is the same as what can be found in the second table of each instrument/mission Section (“Geophysical parameters addressed by ………”).

Geophysical parameters and possible remote sensing techniques (sheet 1 of 2)

Geophysical parameter \ Instrument type	01. Multi-purpose VIS/IR imagery from LEO	02. Multi-purpose VIS/IR imagery from GEO	03. IR temperature/humidity sounding from LEO	04. IR temperature/humidity sounding from GEO	05. MW temperature/humidity sounding from LEO	06. MW temperature/humidity sounding from GEO	07. Conical-scanning MW imagery (mid-frequencies)	08. Low-frequency MW imagery	09. Radio occultation sounding	10. Earth radiation budget from LEO	11. Earth radiation budget from GEO	12. Wind scatterometry	13. Radar altimetry	14. Ocean colour imagery from LEO	15. Ocean colour imagery from GEO	16. Imagery with special viewing geometry	17. Lightning imagery from LEO	18. Lightning imagery from GEO	19. Cloud and precipitation radar	20. Lidar-based missions (Doppler, backscatter, DIAL, ALT)	21. Cross-nadir short-wave spectrometry from LEO	22. Cross-nadir short-wave spectrometry from GEO	23. Cross-nadir IR spectrometry from LEO	24. Cross-nadir IR spectrometry from GEO	25. Limb-sounding short-wave spectrometry	26. Limb-sounding IR spectrometry	27. Limb-sounding Sub-millimetre wave spectrometry	28. High-resolution SW imagery for land observation	29. Synthetic Aperture Radar
Temperature profile			X	X																			X	X	X	X	X		
Temperature profile (nearly-all-weather)					X	X			X																				
Water vapour (profile)			X	X																X			X	X			X		
Water vapour (profile) (nearly-all-weather)					X	X			X																				
Water vapour (total column)	X	X	X	X																	X	X	X	X					
Water vapour (total column) (nearly-all-weather)					X	X	X																						
Wind at level of tracer (cloud, water vapour patch)		X																											
Wind over sea surface							X	X				X																	
Wind profile				X																X									
Height of the top of the PBL			X	X					X											X									
Height of the tropopause			X	X					X											X									
Pressure profile									X																				
Water vapour imagery	X	X																											
Cloud imagery	X	X																											
Cloud top height	X	X	X	X															X	X	X	X							
Cloud top temperature	X	X	X	X																									
Cloud type	X	X														X													
Cloud cover (profile)																			X										
Cloud cover (total column)	X	X	X	X																									
Cloud base height																			X										
Cloud optical depth	X	X														X				X									
Cloud liquid water (< 100 μm) (profile)																			X										
Cloud liquid water (< 100 μm) (total column)					X	X	X												X										
Cloud drop effective radius (profile)																			X										
Cloud drop effective radius (top of cloud)	X	X														X			X	X									
Cloud ice (profile)																			X										
Cloud ice (total column)					X	X	X												X										
Cloud ice effective radius (profile)																			X										
Cloud ice effective radius (top of cloud)	X	X														X			X	X									
Freezing level height					X	X													X										
Melting layer depth					X	X													X										
Precipitation accumulated at surface (index)	X	X																											
Precipitation profile (liquid and solid)																			X										
Precipitation rate at surface (liquid or solid)					X	X	X												X										
Lightning detection																	X	X											
Aerosol optical depth (profile)																X				X	X	X							
Aerosol optical depth (total column)	X	X														X				X	X	X							
Aerosol effective radius (profile)																X				X	X	X							
Aerosol effective radius (total column)																X				X	X	X							
Aerosol type (profile)																X				X	X	X							
Aerosol type (total column)	X	X														X				X	X	X							
Downwelling solar irradiance at TOA										X																			
Outgoing spectral radiance at TOA			X	X																	X	X	X	X					
Outgoing long-wave irradiance at TOA										X	X																		
Outgoing short-wave irradiance at TOA										X	X																		
Short-wave cloud reflectance	X	X														X													
Downwelling LW irradiance at Earth's surface			X	X	X	X																							
Downwelling SW irradiance at Earth's surface	X	X														X													
Earth's surface albedo	X	X														X													
Photosynthetically Active Radiation (PAR)	X	X														X												X	
Fractional Absorbed PAR (FAPAR)	X	X														X												X	
SW Earth's surface bi-directional reflectance																X													
Ocean topography													X																
Ocean ice sheet topography													X																X
Chlorophyll concentration														X	X														
Colour Dissolved Organic Matter (CDOM)														X	X														
Diffuse Attenuation Coefficient (DAC)														X	X														
Suspended sediments concentration														X	X														
Oil spill cover														X	X	X												X	X
Wave directional energy frequency spectrum																													X
Dominant wave direction																													X
Dominant wave period																													X
Significant wave height													X																X

Geophysical parameters and possible remote sensing techniques (sheet 2 of 2)

Geophysical parameter \ Instrument type	01. Multi-purpose VIS/IR imagery from LEO	02. Multi-purpose VIS/IR imagery from GEO	03. IR temperature/humidity sounding from LEO	04. IR temperature/humidity sounding from GEO	05. MW temperature/humidity sounding from LEO	06. MW temperature/humidity sounding from GEO	07. Conical-scanning MW imagery (mid-frequencies)	08. Low-frequency MW imagery	09. Radio occultation sounding	10. Earth radiation budget from LEO	11. Earth radiation budget from GEO	12. Wind scatterometry	13. Radar altimetry	14. Ocean colour imagery from LEO	15. Ocean colour imagery from GEO	16. Imagery with special viewing geometry	17. Lightning imagery from LEO	18. Lightning imagery from GEO	19. Cloud and precipitation radar	20. Lidar-based missions (Doppler, backscatter, DIAL, ALT)	21. Cross-nadir short-wave spectrometry from LEO	22. Cross-nadir short-wave spectrometry from GEO	23. Cross-nadir IR spectrometry from LEO	24. Cross-nadir IR spectrometry from GEO	25. Limb-sounding short-wave spectrometry	26. Limb-sounding IR spectrometry	27. Limb-sounding Sub-millimetre wave spectrometry	28. High-resolution SW imagery for land observation	29. Synthetic Aperture Radar
Sea surface salinity								X																					
Sea surface temperature	X	X	X	X												X													
Sea surface temperature (all-weather)							X	X																					
Sea-ice cover	X	X																										X	X
Sea-ice cover (all-weather)							X	X																					X
Sea-ice surface temperature	X	X																											
Sea-ice surface temperature (all-weather)							X	X																					
Sea-ice thickness													X							X									X
Sea-ice type							X	X				X																	X
Land surface temperature	X	X	X	X												X													
Land surface temperature (all-weather)							X	X																					
Fire fractional cover	X	X																										X	X
Fire radiative power	X	X																											
Fire temperature	X	X																											
Frozen soil and permafrost	X	X																											
Fraction of vegetated land																												X	X
Vegetation type																												X	X
Leaf Area Index (LAI)	X	X										X																X	
Normalised Difference Vegetation Index (NDVI)	X	X																										X	
Soil emissivity in TIR window channels	X	X	X	X																									
Soil moisture at surface							X	X				X																	X
Soil moisture at surface (index)	X	X																											X
Soil moisture in the roots region								X																					X
Glacier cover																												X	X
Soil type																												X	X
Snow albedo	X	X														X													
Snow cover	X	X																										X	
Snow cover (all-weather)							X																						
Snow status (wet/dry)							X																						X
Snow surface temperature	X	X																											
Snow surface temperature (all-weather)							X																						
Snow water equivalent							X					X																	X
Solid Earth – Geoid's undulations									X																				
Solid Earth - Gravity anomalies									X																				
Space Weather - Electron density profile									X																				
Space Weather - Total Electron Content (TEC)									X				X																
Greenhouse & chemically active gas: O_3 profile			X	X																	X	X	X	X	X	X	X		
Greenhouse & chemically active gas: O_3 total column			X	X																	X	X	X	X					
Chemically active species: BrO profile																					X	X			X		X		
Chemically active species: C_2H_2 profile																							X	X					
Chemically active species: C_2H_6 profile																							X	X					
Chemically active species: CH_2O profile																					X	X							
Chemically active species: CH_2O total column																					X	X							
Chemically active species: ClO profile																					X	X			X		X		
Chemically active species: HCl profile																											X		
Chemically active species: HDO profile																											X		
Chemically active species: HNO_3 profile																							X	X		X	X		
Chemically active species: HNO_3 total column			X	X																			X	X					
Chemically active species: N_2O_5 profile																							X	X					
Chemically active species: NO_2 profile																					X	X	X	X	X	X			
Chemically active species: NO_2 total column			X	X																	X	X	X	X					
Chemically active species: PAN profile																							X	X					
Chemically active species: PSC occurrence profile																				X	X	X			X	X			
Chemically active species: SF_6 profile																								X		X			
Chemically active species: SO_2 profile																					X	X	X	X					
Chemically active species: SO_2 total column			X	X																	X	X	X	X					
Greenhouse gas: CH_4 profile																					X	X	X	X	X	X			
Greenhouse gas: CH_4 total column			X	X																	X	X	X	X					
Greenhouse gas: CO profile																					X	X	X	X					
Greenhouse gas: CO total column			X	X																	X	X	X	X					
Greenhouse gas: CO_2 profile																				X	X	X	X	X	X	X			
Greenhouse gas: CO_2 total column			X	X																	X	X	X	X					
Greenhouse gas: H_2O profile																				X	X	X	X	X	X	X	X		
Greenhouse gas: N_2O profile																					X	X	X	X	X	X	X		

APPENDIX 2 TO THE ANNEX

SATELLITES AND INSTRUMENTS

This Appendix 2 contains the following information on satellites and instruments:

List of satellites mentioned in the main text, including information on:
- launch date (actual or expected)
- expected end of service
- orbital height (for LEO)
- Local Solar Time (LST) for sunsynchronous orbits, at the ascending (a) or descending (d) equatorial node; or orbital inclination for non-sunsynchronous orbits; or longitude of stationariness for GEO
- status of the satellite at the reference date of September 2006
- reference to the instruments mentioned in the main text, carried by the satellite.

List of instruments mentioned in the main text, including information on:
- development of the acronym
- satellites hosting the instrument (including those no longer operational)
- period of utilisation (including previous years if the instrument is the continuation of a series).

Instrument tables, including information on:
- satellites hosting the instrument (also if no longer active)
- status of development of the instrument and utilisation period
- addressed mission
- instrument type
- scanning technique
- time for global coverage (observing cycle)
- geometric resolution
- resources required to the platform (mass, power, data rate) (if the information is available)
- channels characteristics: spectral range, spectral resolution (or bandwidths), radiometric accuracy, polarisation, geometric resolution if changing with channel.

Areas of missing information are highlighted in “yellow”.

List of satellites mentioned in the gap analysis text ***(sheet 1 of 3)***						
Satellite	**Launch**	**End of service**	**Height**	**LST/incl.**	**Status**	**Instruments mentioned in the text**
ACRIMSat	20 Dec 1999	expected ≥ 2011	703 km	10:50 d	Operational	ACRIM-III
ADM-Aeolus	Sep-2008	expected ≥ 2011	400 km	06.00 d	Being built	ALADIN
ALOS	24 Jan 2006	expected ≥ 2010	692 km	10:30 d	Operational	PRISM, AVNIR-2, PALSAR
CALIPSO	28 Apr 2006	expected ≥ 2009	705 km	13:30 a	Operational	CALIOP
CartoSat-1	5 May 2005	expected ≥ 2010	618 km	10:30 d	Operational	PAN-A, PAN-F
CartoSat-2	10 Jan 2007	expected ≥ 2012	635 km	10:30 d	Operational	PAN
CHAMP	15 Jul 2000	expected ≥ 2009	450 km	87°	Operational	BlackJack
CloudSat	28 Apr 2006	expected ≥ 2008	705 km	13:30 a	Operational	CPR
COMS-1	2008	expected ≥ 2015	GEO, 128°E	or 116°E	Being built	MI, GOCI
COMS-2	2014	expected ≥ 2021	GEO, 128°E	or 116°E	Being defined	IMAGER TBD, GOCI
Coriolis	6 Jan 2003	expected ≥ 2009	830 km	06:00 d	Operational	WindSat
COSMIC (6 satellites)	14 Apr 2006	expected ≥ 2011	800 km	71°	Operational	IGOS
COSMO-SkyMed-1	8 Jun 2007	expected ≥ 2012	619 km	06:00 d	Just launched	SAR-2000
COSMO-SkyMed-2	end-2007	expected ≥ 2013	619 km	06:00 d	Close to launch	SAR-2000
COSMO-SkyMed-3	mid-2008	expected ≥ 2014	619 km	06:00 d	Built	SAR-2000
COSMO-SkyMed-4	early-2009	expected ≥ 2015	619 km	06:00 d	Being built	SAR-2000
CryoSat-2	Mar-2009	expected ≥ 2012	717 km	92°	Being built	SIRAL
DMSP-F15	24 Mar 1995	expected ≥ 2007	850 km	06.30 d	Operational	SSM/I
DMSP-S16	18 Oct 2003	expected ≥ 2008	833 km	08.10 d	Operational	SSMIS
DMSP-S17	2007	expected ≥ 2012	833 km	05.30 d	Close to launch	SSMIS
DMSP-S18	2008	expected ≥ 2013	833 km	08.00 d	Being built	SSMIS
DMSP-S19	2010	expected ≥ 2015	833 km	05.30 d	Planned	SSMIS
DMSP-S20	2012	expected ≥ 2017	833 km	05.30 d	Planned	SSMIS
Earth-CARE	Dec-2012	expected ≥ 2015	450 km	10.30 d	Planned	ATLID, CPR
Elektro-L-1	2007	expected ≥ 2014	GEO,	76°E	Close to launch	MSU-GS
Elektro-L-2	2010	expected ≥ 2017	GEO, 76°E	or 14.5°E	Planned	MSU-GS
Elektro-L-3	2015	expected ≥ 2022	GEO, 76°E	or 14.5°E	Planned	MSU-GS
Envisat	1 Mar 2002	expected ≥ 2010	800 km	10.00	Operational	ASAR, RA-2, AATSR, MWR, MERIS, MIPAS, GOMOS, SCIAMACHY
EOS-Aqua	4 May 2002	expected ≥ 2009	705 km	13:30 a	Operational	MODIS, CERES, AIRS, AMSU-A, HSB, AMSR-E
EOS-Aura	15 Jul 2004	expected ≥ 2011	705 km	13:45 a	Operational	HIRDLS, MLS, OMI, TES
EOS-Terra	18 Dec 1999	expected ≥ 2008	705 km	10:30 d	Operational	ASTER, MODIS, CERES, MISR, MOPITT
ERS-2	21 Apr 1995	expected ≥ 2009	785 km	10.30	Operational	AMI-SAR, AMI-SCAT, RA, ATSR-2, MWR, GOME
FY-1D	15 May 2002	expected ≥ 2007	866 km	8.20 d	Operational	MVISR
FY-2D	8 Dec 2006	expected ≥ 2011	GEO,	86.5°E	Operational	S-VISSR
FY-2E	2009	expected ≥ 2014	GEO,	123°E	Planned	S-VISSR
FY-2F	2011	expected ≥ 2016	GEO,	86.5°E	Planned	S-VISSR
FY-2G	2013	expected ≥ 2018	GEO,	123°E	Planned	S-VISSR
FY-3A	2007	expected ≥ 2010	836 km	10.00 d	Being built	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, ERM
FY-3B	2009	expected ≥ 2013	836 km	14.00 a	Planned	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, ERM
FY-3C	2012	expected ≥ 2015	836 km	10.00 d	Planned	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, ERM
FY-3D	2014	expected ≥ 2017	836 km	14.00 a	Planned	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, ERM
FY-3E	2016	expected ≥ 2019	836 km	10.00 d	Planned	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, ERM

List of satellites mentioned in the gap analysis text (sheet 2 of 3)						
Satellite	**Launch**	**End of service**	**Height**	**LST/incl.**	**Status**	**Instruments mentioned in the text**
FY-3F	2018	expected ≥ 2021	836 km	14.00 a	Planned	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, ERM
FY-3G	2020	expected ≥ 2023	836 km	10.00 d	Planned	VIRR, MERSI, MWRI, IRAS, MWTS, MWHS, TOU/SBUS, ERM
FY-4 O/A	2012	expected ≥ 2017	GEO, 105°E	or 86.5°E	Being defined	IIR, LM, MCSI
FY-4 O/B	2015	expected ≥ 2020	GEO,	105°E	Being defined	IIR, LM, MCSI
FY-4 O/C	2015	expected ≥ 2020	GEO,	86.5°E	Being defined	IIR, LM, MCSI
FY-4 O/D	2019	expected ≥ 2024	GEO,	105°E	Being defined	IIR, LM, MCSI
FY-4 O/E	2019	expected ≥ 2024	GEO,	86.5°E	Being defined	IIR, LM, MCSI
FY-4 M/A	2015	expected ≥ 2020	GEO,	123.5°E	Being defined	GEO-MW
FY-4 M/B	2018	expected ≥ 2023	GEO,	123.5°E	Being defined	GEO-MW
FY-4 M/C	2022	expected ≥ 2027	GEO,	123.5°E	Being defined	GEO-MW
GCOM-C-1	2011	expected ≥ 2016	798 km	10:30 d	Planned	SGLI
GCOM-C-2	2015	expected ≥ 2020	798 km	10:30 d	Proposed	SGLI
GCOM-C-3	2019	expected ≥ 2024	798 km	10:30 d	Proposed	SGLI
GCOM-W-1	2010	expected ≥ 2015	700 km	13:30 a	Planned	AMSR-2
GCOM-W-2	2014	expected ≥ 2019	700 km	13:30 a	Proposed	AMSR-2, SeaWinds
GCOM-W-3	2018	expected ≥ 2023	700 km	13:30 a	Proposed	AMSR-2, SeaWinds
Glory	2009	expected ≥ 2015	705 km	13:30 a	Planned	APS, TIM
GMES-1	2011	expected ≥ 2017	700 km	06:00 d	Planned	SAR-C
GMES-2	2012	expected ≥ 2017	700 km	06:00 d	Planned	SAR-C
GOES-10	25 Apr 1997	expected ≥ 2009	GEO,	60°W	Operational	IMAGER, SOUNDER
GOES-11	3 May 2000	expected ≥ 2009	GEO,	135°W	Operational	IMAGER, SOUNDER
GOES-12	23 Jul 2001	expected ≥ 2009	GEO,	75°W	Operational	IMAGER, SOUNDER
GOES-13	24 May 2006	expected ≥ 2011	GEO,	105°W	Standby	IMAGER, SOUNDER
GOES-14	Apr 2008	expected ≥ 2015	GEO,	TBD	Being built	IMAGER, SOUNDER
GOES-15	Apr 2009	expected ≥ 2016	GEO,	TBD	Planned	IMAGER, SOUNDER
GOES-16 (R)	2014	expected ≥ 2021	GEO,	TBD	Being defined	ABI, HES (to be confirmed), GML
GOES-17	2014	expected ≥ 2021	GEO,	TBD	Being defined	ABI, HES (to be confirmed), GML
GOSAT	Aug 2008	expected ≥ 2013	666 km	13:00 d	Planned	TANSO-FTS, TANSO-CAI
GPM "core"	2012	expected ≥ 2017	407 km	65°	Planned	DPR, GMI
GRACE	17 Mar 2002	expected ≥ 2011	400 km	89°	Operational	BlackJack
ICESat	12 Jan 2003	expected ≥ 2007	600 km	94°	Operational	GLAS
INSAT-3A	10 Apr 2003	expected ≥ 2012	GEO,	93.5°E	Operational	VHRR, CCD
INSAT-3D	2007	expected ≥ 2014	GEO,	83°E	Close to launch	IMAGER, SOUNDER
JASON-1	7 Dec 2001	expected ≥ 2008	1336 km	66°	Operational	Poseidon-2, JMR
JASON-2	2008	expected ≥ 2015	1334 km	66°	Planned	Poseidon-3, AMR
Kalpana-1	12 Sep 2002	expected ≥ 2010	GEO,	74°E	Operational	VHRR
LDCM	~ 2010	N/A	TBD	TBD	Being studied	OLI
Landsat-5	1 Mar 1984	expected ≥ 2008	705 km	10:00	Operational (partially)	MSS, TM
Landsat-7	15 Apr 1999	expected ≥ 2009	705 km	10:00	Operational	ETM+
Megha-Tropiques	end-2009	expected ≥ 2014	867 km	20°	Planned	MADRAS, SAPHIR, ScaRaB
Meteor-M-1	2007	expected ≥ 2011	830 km	10:20 a	Close to launch	MSU-MR, KMSS, MTVZA, Severjanin
Meteor-M-2	2008	expected ≥ 2012	830 km	10:20 a	Planned	MSU-MR, KMSS, IRFS-2, MTVZA, Radiomet, Severjanin
Meteosat-7	3 Sep 1997	expected ≥ 2008	GEO,	57.5°E	Operational	MVIRI
Meteosat-8 (MSG)	28 Aug 2002	expected ≥ 2009	GEO,	3.6°W	Hot standby	SEVIRI, GERB
Meteosat-9	22 Dec 2005	expected ≥ 2013	GEO,	0°	Operational	SEVIRI, GERB
Meteosat-10	2011	expected ≥ 2018	GEO,	TBD	In storage	SEVIRI, GERB
Meteosat-11	2013	expected ≥ 2019	GEO,	TBD	Being built	SEVIRI, GERB
Meteosat-12 (MTG)	2015	expected ≥ 2020	GEO,	TBD	Being defined	Being defined (FCI, IRS, LI)

List of satellites mentioned in the gap analysis text (sheet 3 of 3)						
Satellite	**Launch**	**End of service**	**Height**	**LST/incl.**	**Status**	**Instruments mentioned in the text**
MetOp-1	19 Oct 2006	expected ≥ 2010	834 km	09.30 d	Operational	AVHRR/3, HIRS/4, AMSU-A, MHS, IASI, GOME-2, GRAS, ASCAT
MetOp-2	Oct 2010	expected ≥ 2015	834 km	09.30 d	In storage	AVHRR/3, HIRS/4, AMSU-A, MHS, IASI, GOME-2, GRAS, ASCAT
MetOp-3	Apr 2015	expected ≥ 2020	834 km	09.30 d	Being built	AVHRR/3, AMSU-A, MHS, IASI, GOME-2, GRAS, ASCAT
Monitor-E	26 Aug 2005	expected ≥ 2008	540 km	10:30 a	Operational	PAN, MS
MTSAT-1R	26 Feb 2005	expected ≥ 2010	GEO,	140°E	Operational	JAMI
MTSAT-2	18 Feb 2006	expected ≥ 2015	GEO,	145°E	Standby	IMAGER
MTSAT-FO	2014	expected ≥ 2021	GEO,	140°E	Being defined	IMAGER TBD, SOUNDER TBD
NMP EO-1	21 Nov 2000	expected ≥ 2007	705 km	10:15 d	Operational	ALI, LAC, Hyperion
NOAA-15	13 May 1998	expected ≥ 2007	807 km	05.30 d	Backup	AVHRR/3, HIRS/3, AMSU-A, AMSU-B
NOAA-16	21 Sep 2000	expected ≥ 2007	849 km	15.30 a	Backup	AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SBUV/2
NOAA-17	24 Jun 2002	expected ≥ 2009	810 km	10.20 d	Operational	AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SBUV/2
NOAA-18	20 May 2005	expected ≥ 2010	854 km	13.40 a	Operational	AVHRR/3, HIRS/4, AMSU-A, MHS, SBUV/2
NOAA-19	2009	expected ≥ 2014	840 km	14.00 a	Being built	AVHRR/3, HIRS/4, AMSU-A, MHS, SBUV/2
NPOESS-1	2013	expected ≥ 2018	833 km	13.30 a	Planned	VIIRS, CrIS, ATMS, OMPS-nadir, ERBS (OMPS-limb, APS in stanby list)
NPOESS-2	2016	expected ≥ 2021	833 km	5.30 d	Planned	VIIRS, CMIS (CrIS, ATMS, TSIS in standby list)
NPOESS-3	2020	expected ≥ 2025	833 km	13.30 a	Planned	VIIRS, CrIS, ATMS, CMIS, OMPS-nadir (ERBS, OMPS-limb, APS in standby list)
NPOESS-4	2022	expected ≥ 2027	833 km	5.30 d	Planned	VIIRS, CMIS (CrIS, ATMS, TSIS in standby list)
NPP	2009	expected ≥ 2014	833 km	13.30 a	Being built	VIIRS, CrIS, ATMS, OMPS
OceanSat-1	26 May 1999	expected ≥ 2007	720 km	12:00	Operational	OCM, MSMR
OceanSat-2	2008	expected ≥ 2013	720 km	12:00	Planned	OCM. SCAT, ROSA
OCO	2008	expected ≥ 2010	705 km	13:15 a	Being built	OCO
PARASOL	18 Dec 2004	expected ≥ 2008	705 km	13:30 a	Operational	POLDER
Pléiades-1	end-2008	expected ≥ 2013	694 km	10:15 d	Being built	HiRI
Pléiades-2	early 2010	expected ≥ 2015	694 km	10:15 d	Planned	HiRI
QuikSCAT	19 Jun 1999	expected ≥ 2008	803 km	06:00 d	Operational	SeaWinds
RadarSat-1	4 Nov 1995	expected ≥ 2008	798 km	06:00 d	Operational	SAR
RadarSat-2	2007	expected ≥ 2014	798 km	06:00 d	Close to launch	SAR
ResourceSat-1	17 Oct 2003	expected ≥ 2009	817 km	10:30	Operational	LISS-3, LISS-4, AWiFS
ResourceSat-2	2009	expected ≥ 2014	817 km	10:30	Planned	LISS-3, LISS-4, AWiFS
Resurs-DK	15 Jun 2006	expected ≥ 2009	350 km	70°	Operational	Geoton
SAC-D	2009	expected ≥ 2012	657 km	06:00 d	Being built	Aquarius, ROSA
SAOCom-1	2008	expected ≥ 2014	629 km	06:00 d	Being built	SAR-L
SAOCom-2	2009	expected ≥ 2015	629 km	06:00 d	Being built	SAR-L
SeaStar	1 Aug 1997	expected ≥ 2009	705 km	12:00 d	Operational	SeaWiFS
Sentinel-2/1	2012	expected ≥ 2019	800 km	10:30 d	Planned	MSI
Sentinel-2/2	2013	expected ≥ 2020	800 km	10:30 d	Planned	MSI
Sentinel-3/1	2012	expected ≥ 2018	815 km	10.00 d	Planned	SRAL, OLCI, SLSTR
Sentinel-3/2	2014	expected ≥ 2020	815 km	10.00 d	Planned	SRAL, OLCI, SLSTR
Sentinel-4	2016	expected ≥ 2023	GEO,	0°	Being defined	TBD (for chemistry)
Sentinel-5	2020	expected ≥ 2025	834 km	09.30 d	Being defined	TBD (for chemistry)
SMOS	Sep-2007	expected ≥ 2010	763 km	06.00 d	Close to launch	MIRAS
SORCE	25 Jan 2003	expected ≥ 2009	645 km	40°	Operational	TIM
SPOT-2	22 Jan 1990	expected ≥ 2007	822 km	10:30 d	Partly operational	HRV
SPOT-4	24 Mar 1998	expected ≥ 2008	822 km	10:30 d	Operational	HRVIR, Vegetation, POAM-3
SPOT-5	4 May 2002	expected ≥ 2009	822 km	10:30 d	Operational	HRG, HRS, Vegetation
TRMM	27 Nov 1997	expected ≥ 2009	402 km	35°	Operational	PR, TMI, CERES, VIRS, LIS

List of instruments mentioned in the gap analysis text (sheet 1 of 3)			
Acronym	**Full name**	**Satellites**	**Utilisation**
AATSR	Advanced Along-Track Scanning Radiometer (= ATSR-2)	ERS-1/2, Envisat	1991-2010
ABI	Advanced Baseline Imager	GOES-R and follow-on	2014 →
ACRIM-III	Active Cavity Radiometer Irradiance Monitoring - III	SMM, UARS, ACRIMSat	1980-2012
AIRS	Atmospheric Infra-Red Sounder	EOS-Aqua	2002-2009
ALADIN	Atmospheric Laser Doppler Instrument	ADM-Aeolus	2008-2011
ALI	Advanced Land Imager	NMP-EO-1	2000-2008
AMI-SAR	Active Microwave Instrument - SAR mode	ERS-1/2	1991-2009
AMI-SCAT	Active Microwave Instrument - Scat mode	ERS-1/2	1991-2009
AMR	Advanced Microwave Radiometer	Jason-2	2008-2015
AMSR-2	Advanced Microwave Scanning Radiometer - 2	GCOM-W 1/2/3	2010-2023
AMSR-E	Advanced Microwave Scanning Radiometer for EOS	EOS-Aqua	2002-2009
AMSU-A	Advanced Microwave Sounding Unit - A	NOAA 15 to 19 MetOp 1 to 3 EOS-Aqua	1998-2014 2006-2020 2002-2009
AMSU-B	Advanced Microwave Sounding Unit - B	NOAA-15/16/17	1998-2009
APS	Aerosol Polarimetry Sensor	Glory, NPOESS 1 & 3	2009-2025
Aquarius	Aquarius	SAC-D	2009-2012
ASAR	Advanced Synthetic Aperture Radar – SAR mode	Envisat	2002-2010
ASCAT	Advanced Scatterometer	MetOp 1 to 3	2006-2020
ASTER	Advanced Spaceborne Thermal Emission and Reflection radiometer	EOS-Terra	1999-2009
ATLID	Atmospheric Lidar	Earth-CARE	2013-2015
ATMS	Advanced Technology Microwave Sounder	NPP, NPOESS 1 to 4	2009-2027
AVHRR/3	Advanced Very High Resolution Radiometer	TIROS-N, NOAA 6 to 19 MetOp 1 to 3	1978-2014 2006-2020
AVNIR 1/2	Advanced Visible and Near-Infrared Radiometer 1 and 2	ADEOS-1 ALOS	1996-1997 2006-2010
AWiFS	Advanced Wide Field Sensor	ResourceSat-1/2	2003-2014
BlackJack	BlackJack	CHAMP, GRACE	2000-2011
CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarisation	CALIPSO	2006-2009
CCD	Charge Coupled Device Camera	INSAT-2E, INSAT-3A	1999-2012
CERES	Clouds and the Earth's Radiant Energy System	TRMM, Terra, Aqua	1997-2009
CMIS	Conical-scanning Microwave Imager/Sounder	NPOESS 2 to 4	2016-2027
CPR	Cloud Profiling Radar	CloudSat	2006-2008
CPR	Cloud Profiling Radar	Earth-CARE	2013-2015
CrIS	Cross-track Infrared Sounder	NPP, NPOESS 1 to 4	2009-2027
DPR	Dual-frequency Precipitation Radar	GPM-core	2012-2017
ERBS	Earth Radiation Budget Sensor	NPOESS-1/3	2013-2025
ERM	Earth Radiation Measurement	FY-3 A to G	2007-2023
ETM+	Enhanced Thematic Mapper +	Landsat-7	1999-2009
FCI	Flexible Combined Imager	Meteosat Third Generation	2015 →
GEO-MW	Microwave Sounder in Geostationary Orbit	FY-4 M A/B and follow-on	2015 →
Geoton	Panchromatic and multispectral radiometer	Resurs-DK	2006-2009
GERB	Geostationary Earth Radiation Budget	Meteosat 8 to 11 (MSG)	2002-2019
GLAS	Geoscience Laser Altimeter System	ICESat	2003-2008
GLM	Geostationary Lightning Mapper	GOES-R and follow-on	2014 →
GMI	GPM Microwave Imager	GPM-core	2012-2017
GOCI	Geostationary Ocean Color Imager	COMS-1/2	2008-2021
GOME	Global Ozone Monitoring Experiment	ERS-2	1995-2009
GOME-2	Global Ozone Monitoring Experiment - 2	MetOp 1 to 3	2006-2020
GOMOS	Global Ozone Monitoring by Occultation of Stars	Envisat	2002-2010
GRAS	GNSS Receiver for Atmospheric Sounding	MetOp 1 to 3	2006-2020
HES	Hyperspectral Environmental Suite	GOES-R and follow-on	2014 →
HIRDLS	High-Resolution Dynamics Limb Sounder	EOS-Aura	2004-2010
HiRI	High-Resolution Imager	Pléiades-1/2	2008-2015
HIRS-3/4	High-resolution Infra Red Sounder	TIROS-N, NOAA 6 to 19 Metop-1/2	1978-2014 2006-2015

List of instruments mentioned in the gap analysis text (sheet 2 of 3)			
Acronym	**Full name**	**Satellites**	**Utilisation**
HRG	Haute Résolution Géométrique	SPOT-5	2002-2009
HRS	Haute Résolution Stéréoscopique	SPOT-5	2002-2009
HRV	Haute Résolution dans le Visible	SPOT-1/2/3	1986-2007
HRVIR	Haute Résolution dans le Visible et l'Infra-Rouge	SPOT-4	1998-2008
HSB	Humidity Sounder for Brazil	EOS-Aqua	2002-2009
Hyperion	Hyperion	NMP EO-1	2000-2008
IASI	Infrared Atmospheric Sounding Interferometer	MetOp 1 to 3	2006-2020
IGOS	Integrated GPS Occultation Receiver	COSMIC (6 satellites)	2006-2011
IIS	Interferometric Infrared Sounder	FY-4 O A/B and follow-on	2012 →
IMAGER	GOES Imager INSAT Imager MTSAT Imager	GOES 8 to 15 INSAT-3D MTSAT-2	1994-2015 2007-2014 2010-2015
IMAGER TBD	COMS Imager MTSAT-FO Imager	COMS-2 MTSAT-FO	2014-2021 2014 →
IRAS	Infra Red Atmospheric Sounder	FY-3 A to G	2007-2023
IRFS-2	IR Sounding Spectrometer	Meteor-M-2	2008-2012
IRS	Infra Red Sounder	Meteosat Third Generation	2015 →
JAMI	Japanese Advanced Meteorological Imager	MTSAT-1R	2005-2010
JMR	Jason Microwave Radiometer	Jason-1	2001-2008
KMSS	High-resolution VIS/IR Radiometer	Meteor-M 1/2	2007-2012
LAC	LEISA (Linear Etalon Imaging Spectrometer Array) Atmospheric Corrector	NMP EO-1	2000-2008
LI	Lightning Imager	Meteosat Third Generation	2015 →
LIS	Lightning Imaging Sensor	TRMM	1997-2009
LISS-3	Linear Imaging Self-Scanning Sensor - 3	IRS-1C/1D, ResourceSat-1/2	1995-2014
LISS-4	Linear Imaging Self-Scanning Sensor - 4	ResourceSat 1/2	2003-2014
LM	Lightning Mapper	FY-4 O A/B and follow-on	2012 →
MADRAS	Microwave Analysis & Detection of Rain & Atmospheric Structures	Megha-Tropiques	2009-2014
MCSI	Multiple Channel Scanning Imager	FY-4 O A/B and follow-on	2012 →
MERIS	Medium Resolution Imaging Spectrometer	Envisat	2002-2010
MERSI	Medium Resolution Spectral Imager	FY-3 A to G	2007-2023
MHS	Microwave Humidity Sounding	NOAA-18/19 MetOp 1 to 3	2005-2014 2006-2020
MI	Meteorological Imager	COMS-1	2008-2015
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding	Envisat	2002-2010
MIRAS	Microwave Imaging Radiometer using Aperture Synthesis	SMOS	2007-2010
MISR	Multi-angle Imaging Spectro-Radiometer	EOS-Terra	1999-2008
MLS	Microwave Limb Sounder	UARS, EOS-Aura	1991-2011
MODIS	Moderate-resolution Imaging Spectro-radiometer	EOS Terra/Aqua	1999-2009
MOPITT	Measurement Of Pollution In The Troposphere	EOS Terra	1999-2008
MSI	Multi-Spectral Imager	Sentinel-2	2012-2020
MSMR	Multi-frequency Scanning Microwave Radiometer	OceanSat-1	1999-2008
MSS	Multi-Spectral Scanner	Landsat 1 to 5	1972-2008
MSU-GS	Elektro-GOMS Imager	Elektro-L and follow-on	2007 →
MSU-MR	VIS/IR Imaging Radiometer	Meteor-M 1/2	2007-2012
MTVZA	Imaging/Sounding Microwave Radiometer	Meteor-M 1/2	2007-2012
MVIRI	Meteosat Visible Infra-Red Imager	Meteosat 1 to 7	1977-2008
MVISR	Multichannel Visible Infrared Scanning Radiometer	FY-1 A to D	1988-2007
MWHS	Micro-Wave Humidity Sounder	FY-3 A to G	2007-2023
MWR	Micro-Wave Radiometer	ERS-1/2, Envisat	1991-2010
MWR	Micro-Wave Radiometer	Sentinel-3	2012-2020
MWRI	Micro-Wave Radiation Imager	FY-3 A to G	2007-2023
MWTS	Micro-Wave Temperature Sounder	FY-3 A to G	2007-2023
OCM	Ocean Color Monitor	OceanSat-1/2	1999-2013
OCO	Orbiting Carbon Observatory	OCO	2008-2010
OLCI	Ocean and Land Colour Imager	Sentinel-3	2012-2020

List of instruments mentioned in the gap analysis text (sheet 3 of 3)			
Acronym	**Full name**	**Satellites**	**Utilisation**
OLI	Operational Land Imager	LDCM	2010 →
OMI	Ozone Monitoring Instrument	EOS Aura	2004-2011
OMPS	Ozone Mapping and Profiler Suite	NPP, NPOESS 1 & 3	2009-2025
PALSAR	Phased-Array L-band Synthetic Aperture Radar	ALOS	2006-2010
PAN	Panchromatic Camera	CartoSat-2	2007-2012
PAN + MS	Panchromatic + Multispectral Radiometers	Monitor-E	2005-2008
PAN-A, PAN-F	Panchromatic Cameras	CartoSat-1	2005-2010
POAM	Polar Ozone and Aerosol Measurement	SPOT-3/4	1993-2008
POLDER	Polarization and Directionality of the Earth's Reflectances	PARASOL	2004-2008
Poseidon 2/3	Poseidon 2/3	JASON 1/2	2001-2015
PR	Precipitation Radar	TRMM	1997-2009
PRISM	Panchromatic Remote-sensing Instrument for Stereo Mapping	ALOS	2006-2010
RA, RA-2	Radar Altimeter	ERS-1/2, Envisat	1991-2010
Radiomet	Radio-occultation sounder	Meteor-M 1/2	2007-2012
ROSA	Radio Occultation Sounder of the Atmosphere	OceanSat-2, SAC-D	2008-2013
SAPHIR	Sondeur Atmospherique du Profil d'Humidite Intertropicale par Radiometrie	Megha-Tropiques	2009-2014
SAR	Synthetic Aperture Radar (C-band)	RadarSat 1/2	1995-2014
SAR-2000	Synthetic Aperture Radar 2000 (X-band)	COSMO-SkyMed	2007-2015
SAR-C	Synthetic Aperture Radar (C-band)	GMES-1 A/B	2011-2018
SAR-L	Synthetic Aperture Radar (L-band)	SAOCom 1/2	2008-2015
SBUV/2	Solar Backscatter Ultraviolet / 2	NOAA 9 to 19 except 12/15	1984-2014
ScaRaB	Scanner for Radiation Budget	Megha-Tropiques	2009-2014
SCAT	Scatterometer	OceanSat-2	2008-2013
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Cartography	Envisat	2002-2010
SeaWiFS	Sea-viewing Wide Field-of-view Sensor	SeaStar	1997-2009
SeaWinds	SeaWinds	QuickSCAT GCOM-W 2/3	1999-2008 2014-2023
Severjanin	X-band Synthetic Aperture Radar	Meteor-M 1/2	2007-2012
SEVIRI	Spinning Enhanced Visible Infra-Red Imager	Meteosat 8 to 11 (MSG)	2002-2019
SGLI	Second-generation Global Imager	GCOM-C 1/2/3	2011-2024
SIRAL	SAR Interferometer Radar Altimeter	CryoSat-2	2009-2012
SLSTR	Sea and Land Surface Temperature Radiometer	Sentinel-3	2012-2020
SOUNDER	GOES Sounder INSAT Sounder	GOES 8 to 15 INSAT-3D	1994-2015 2007-2014
SOUNDER TBD	MTSAT-FO Sounder	MTSAT-FO	2017 →
SRAL	SAR Radar Altimeter	Sentinel-3	2012-2020
SSM/I	Special Sensor Microwave – Imager	DMSP F-8/10/11/13/14/15	1987-2007
SSMIS	Special Sensor Microwave – Imager/Sounder	DMSP F 16 to 20	2003-2017
S-VISSR	Stretched Visible-Infrared Spin Scan Radiometer	FY-2 A to G	1997-2018
TANSO-CAI	Thermal And Near infrared Sensor for carbon Observations - Cloud and Aerosol Imager	GOSAT	2008-2013
TANSO-FTS	Thermal And Near infrared Sensor for carbon Observations - Fourier Transform Spectrometer	GOSAT	2008-2013
TES	Tropospheric Emission Spectrometer	EOS-Aura	2004-2011
TIM	Total Irradiance Monitoring	SORCE, Glory	2003-2013
TM	Thematic Mapper	Landsat-4/5	1982-2008
TMI	TRMM Microwave Imager	TRMM	1997-2009
TOU/SBUS	Total Ozone Unit & Solar Backscatter Ultraviolet Sounder	FY-3 A to G	2007-2023
TSIS	Total Solar Irradiance Sensor	NPOESS 2 & 4	2016-2027
Végétation	Végétation	SPOT-4/5	1998-2009
VHRR (in GEO)	Very High Resolution Radiometer	INSAT-1A to 3A, Kalpana-1	1982-2012
VIIRS	Visible/Infrared Imager Radiometer Suite	NPP, NPOESS 1 to 4	2009-2027
VIRR	Visible and Infra Red Radiometer	FY-3 A to G	2007-2023
VIRS	Visible and Infra Red Scanner	TRMM	1997-2009
WindSat	WindSat	Coriolis	2003-2009

INSTRUMENT TABLES

AATSR	Advanced Along-Track Scanning Radiometer (same as ATSR-2)
Satellites	**ERS-1 (ATSR), ERS-2 (ATSR-2) and Envisat (AATSR)**
Status (Sept 2006)	**Operational** – Utilised in the period 1991 to ~ 2010
Mission	Multi-purpose VIS/IR imagery, with emphasis on very accurate sea surface temperature for climate
Instrument type	7-channel VIS/IR radiometer with dual view for accurate atmospheric corrections (4 channels on ERS-1)
Scanning technique	Conical oblique (cross-nadir and 47° fore); 2000 pixel of 1 km s.s.p.; swath 500 km; scan rate 400 rpm
Coverage/cycle	Global coverage in 3 days (IR) or 6 days (VIS)
Resolution (s.s.p.)	1 km IFOV
Resources	Mass: 101 kg - Power: 100 W - Data rate: 625 kbps

Central wavelength	Bandwidth	Radiometric accuracy (NEΔT or SNR)
550 nm (not on ERS-1 ATSR)	20 nm	20 @ 0.5 % albedo
659 nm (not on ERS-1 ATSR)	20 nm	20 @ 0.5 % albedo
865 nm (not on ERS-1 ATSR)	20 nm	20 @ 0.5 % albedo
1610 nm	300 nm	20 @ 0.5 % albedo
3.70 μm	3.55-3.85 μm	0.08 K @ 270 K
10.85 μm	10.35-11.35 μm	0.05 K @ 270 K
12.00 μm	11.50-12.50 μm	0.05 K @ 270 K

ABI	Advanced Baseline Imager
Satellites	**GOES-R (to become GOES-16) and follow-on**
Status (Sept 2006)	**Being defined** – To be utilised from 2014 onward
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	16-channel VIS/IR radiometer
Coverage/cycle	Full disk every 15 min, 3000x5000 km^2 ("CONUS", Continental U.S.) in 5 min, 1000x1000 km^2 in 30 s
Resolution (s.s.p.)	0.5 km at 0.64 μm, 1.0 km at 0.47, 0.86 and 1.61 μm, 2 km in the remaining 12 channels
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Bandwidth	Radiometric accuracy (NEΔT or SNR)
470 nm	40 nm	300 @ 100 % albedo
640 nm	100 nm	300 @ 100 % albedo
860 nm	40 nm	300 @ 100 % albedo
1380 nm	30 nm	300 @ 100 % albedo
1610 nm	60 nm	300 @ 100 % albedo
2260 nm	50 nm	300 @ 100 % albedo
3.90 μm	0.20 μm	0.1 K @ 300 K
6.15 μm	0.90 μm	0.1 K @ 300 K
7.00 μm	0.40 μm	0.1 K @ 300 K
7.40 μm	0.20 μm	0.1 K @ 300 K
8.50 μm	0.40 μm	0.1 K @ 300 K
9.70 μm	0.20 μm	0.1 K @ 300 K
10.3 μm	0.50 μm	0.1 K @ 300 K
11.2 μm	0.80 μm	0.1 K @ 300 K
12.3 μm	1.00 μm	0.1 K @ 300 K
13.3 μm	0.60 μm	0.3 K @ 300 K

ACRIM-III	Active Cavity Radiometer Irradiance Monitoring - III
Satellites	**SMM (ACRIM-I), UARS (ACRIM-2), ACRIMSat (ACRIM-III)**
Status (Sept 2006)	**Operational** – Utilised from 1980 until ~ 2012
Mission	Total solar irradiance monitoring
Instrument type	Assemblage of 3 active cavity radiometers for total irradiance. Range: 0.15 – 5.0 μm
Scanning technique	Sun pointing during orbital movement, data sampled every 2 min
Coverage/cycle	One measurement after integration on all data taken during the diurnal orbit arc; thus 100 min
Resolution (s.s.p.)	N/A (sun pointing)
Resources	Mass: 13 kg - Power: 10 W - Data rate: 600 bps

AIRS	Atmospheric Infra-Red Sounder
Satellite	**EOS-Aqua**
Status (Sept 2006)	**Operational** – Utilised in the period 2002 to ~ 2009
Mission	Temperature/humidity sounding, ozone profile and total-column green-house gases
Instrument type	Grating spectrometer, 2378 channels, resolving power $\lambda/\Delta\lambda$ = 1200, 4 supporting channels in VIS/NIR
Scanning technique	Cross-track: 90 samples scanned, swath 1650 km - Along-track: one 13.5-km line every 2.67 s
Coverage/cycle	Global coverage once/day
Resolution (s.s.p.)	13.5 km IFOV for the spectrometer; 2.3 km IFOV for VIS/NIR channels
Resources	Mass: 177 kg - Power: 220 W - Data rate: 1.27 Mbps

Spectral range (μm)	Spectral range (cm^{-1})	Spectral resolution	Accuracy (NEΔT or SNR)
3.74 - 4.61 μm	2170 - 2674 cm^{-1}	~ 2.0 cm^{-1}	0.14 K @ 280 K
6.20 - 8.22 μm	1216 - 1613 cm^{-1}	~ 1.0 cm^{-1}	0.20 K @ 280 K
8.80 - 15.4 μm	650 - 1136 cm^{-1}	~ 0.5 cm^{-1}	0.35 K @ 280 K
0.41-0.44 μm	not relevant	30 nm	> 100 @ 40 % albedo
0.58-0.68 μm	not relevant	100 nm	> 100 @ 40 % albedo
0.71-0.92 μm	not relevant	210 nm	> 100 @ 40 % albedo
0.49-0.94 μm	not relevant	N/A (broadband)	> 100 @ 40 % albedo

ALADIN	Atmospheric Laser Doppler Instrument
Satellite	**ADM-Aeolus**
Status (Sept 2006)	**Being developed** – To be utilised in the period 2008 to ~ 2011
Mission	Wind profile in clear-air. Also aerosol profile, cloud top height
Instrument type	Single-wavelength lidar (355 nm) with Doppler capability, side-looking (35° off-nadir). High Spectral Resolution Laser (HSRL) to discriminate aerosol types
Scanning technique	No scanning. Pulse echoes averaged over 50 km FOV. FOV sampled at 200 km intervals
Coverage/cycle	Global coverage in 16 d for cells of 100 km side
Resolution	Horizontal: 50 km FOV sampled at 200 km intervals. Vertical: 250 m to 2 km with increasing height
Resources	Mass: 500 kg - Power: 840 W - Data rate: 11 kbps

ALI	Advanced Land Imager
Satellite	**NMP EO-1**
Status (Sept 2006)	**Technological demonstration running** – To be utilised in the period 2000-2007
Mission	Advanced technology for land and vegetation observation
Instrument type	VIS/NIR radiometer, 9 VIS/NIR narrow-band channels, one panchromatic (PAN)
Scanning technique	Pushbroom; 1230 pixel/line (9 narrow-band channels), 3700 pixel/line (PAN); swath 37 km [reduced configuration for demonstration purpose - there should be 5 such arrays, to cover a 185 km swath]
Coverage/cycle	Global coverage in 80 days, in daylight [for full configuration it would be 16 days]
Resolution (s.s.p.)	30 m (9 narrow-band channels), 10 m (PAN)
Resources	Mass: 106 kg - Power: 100 W - Data rate: 300 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
443 nm	433 - 453 nm	……… @ ….. % albedo
482 nm	450 - 515 nm	……… @ ….. % albedo
565 nm	525 - 605 nm	……… @ ….. % albedo
660 nm	630 - 690 nm	……… @ ….. % albedo
790 nm	775 - 805 nm	……… @ ….. % albedo
867 nm	845 - 890 nm	……… @ ….. % albedo
1250 nm	1200 - 1300 nm	……… @ ….. % albedo
1650 nm	1550 - 1750 nm	……… @ ….. % albedo
2215 nm	2080 - 2350 nm	……… @ ….. % albedo
Panchromatic	480 - 690 nm	……… @ ….. % albedo

AMI-SAR	Active Microwave Instrument - SAR mode
Satellites	**ERS-1 and ERS-2**
Status (Sept 2006)	**Operational** – Utilised in the period 1991 to ~ 2008
Mission	High-resolution all-weather multi-purpose imager for ocean, land and ice; wave spectra
Instrument type	C-band SAR, frequency 5.3 GHz, polarisation VV
Scanning technique	Side-looking, 23° off-nadir, swath 100 km. Wave spectra are achieved by processing 5 x 5 km² 30-m resolution SAR imagettes within the SAR swath, 350 km off-track, sampling at 200 or 300 km intervals. The AMI wave mode can be operated at the same time as the AMI-Scat mode
Coverage/cycle	Imagery: global coverage in 9 months average, depending on operation mode (duty cycle 12 %). Wave spectra: global coverage in 1.5 months (duty cycle 70 %)
Resolution	Imagery: 30 m. Wave spectra: 5 km
Resources	Mass: 325.8 kg - Power: 4800 W (peak) - Data rate: 105 Mbps (imagery), 370 kbps (wave mode)

AMI-Scat	Active Microwave Instrument - Scat mode
Satellites	**ERS-1 and ERS-2**
Status (Sept 2006)	**Operational** – Utilised in the period 1991 to ~ 2009
Mission	Sea surface wind vector. Also large-scale soil moisture
Instrument type	C-band radar scatterometer (5.3 GHz), 3 side looking antennas
Scanning technique	One 500-km swaths starting from 200 km off-track. 3 looks each pixel (45, 90 and 135° azimuth)
Coverage/cycle	Global coverage in 3 days average, depending on operation mode (alternative to AMI-SAR, thus duty cycle about 80 %)
Resolution	Best quality: 50 km; sampling: 25 km
Resources	Mass: 325.8 kg (AMI) - Power: 4800 W (peak) - Data rate: 500 kbps

AMR	JASON Microwave Radiometer
Satellite	**Jason-2**
Status (Sept 2006)	**Being built** – To be utilised in the period 2008 to ~ 2015
Mission	Water vapour correction for the Poseidon-3 radar altimeter
Instrument type	3-frequency MW radiometer, 18.7, 23.8 and 34 GHz
Scanning technique	Nadir-only viewing, associated to the Poseidon-3 radar altimeter
Coverage/cycle	Global coverage in 1 month for 30 km average spacing, or in 10 days for 100 km average spacing
Resolution (s.s.p.)	25 km
Resources	Mass: 27 kg - Power: 31 W - Data rate: 100 bps

AMSR-2	**Advanced Microwave Scanning Radiometer - 2**
Satellites	**GCOM-W 1, 2 and 3**
Status (mid-2006)	**Planned** – To be utilised in the period: 2010 to ~ 2023
Mission	Multi-purpose MW imager
Instrument type	MW radiometer with 6 frequencies / 12 channels
Scanning technique	Conical: 55° zenith angle; swath: 1450 km - Scan rate: 40 scan/min = 10 km/scan
Coverage/cycle	Global coverage once/day
Resolution	Changing with frequency, consistent with an antenna diameter of 2 m
Resources	Mass: 320 kg - Power: 400 W - Data rate: 130 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy (NEΔT)	IFOV	Pixel
6.925	350	V, H	0.3 K	35 x 62 km	10 x 10 km
10.65	100	V, H	0.6 K	24 x 42 km	10 x 10 km
18.7	200	V, H	0.6 K	14 x 22 km	10 x 10 km
23.8	400	V, H	0.6 K	15 x 26 km	10 x 10 km
36.5	1000	V, H	0.6 K	7 x 12 km	10 x 10 km
89.0	3000	V, H	1.1 K	3 x 5 km	5 x 5 km

AMSR-E	**Advanced Microwave Scanning Radiometer for EOS**
Satellites	**EOS-Aqua**
Status (mid-2006)	**Operational** - Utilisation period: 2002 to ~ 2009
Mission	Multi-purpose MW imager
Instrument type	MW radiometer with 6 frequencies / 12 channels
Scanning technique	Conical: 55° zenith angle; swath: 1450 km - Scan rate: 40 scan/min = 10 km/scan
Coverage/cycle	Global coverage once/day
Resolution	Changing with frequency, consistent with an antenna diameter of 1.6 m
Resources	Mass: 314 kg - Power: 350 W - Data rate: 87.4 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy (NEΔT)	IFOV	Pixel
6.925	350	V, H	0.3 K	43 x 75 km	10 x 10 km
10.65	100	V, H	0.6 K	29 x 51 km	10 x 10 km
18.7	200	V, H	0.6 K	16 x 27 km	10 x 10 km
23.8	400	V, H	0.6 K	14 x 21 km	10 x 10 km
36.5	1000	V, H	0.6 K	9 x 14 km	10 x 10 km
89.0	3000	V, H	1.1 K	4 x 6 km	5 x 5 km

AMSU-A	**Advanced Microwave Sounder Unit - A**
Satellites	**NOAA 15 to 19 - MetOp 1 to 3 - EOS-Aqua**
Status (Sept 2006)	**Operational** – Utilisation period: 1998 to ~ 2014 on NOAA, 2006 to ~ 2020 on MetOp, 2002 to ~ 2009 on EOS-Aqua
Mission	Temperature sounding in nearly-all-weather conditions
Instrument type	15-channel MW radiometer
Scanning technique	Cross-track: 30 steps of 48 km s.s.p., swath 2250 km - Along-track: one 48-km line every 8 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	48 km IFOV
Resources	Mass: 104 kg - Power: 99 W - Data rate: 3.2 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisation	Radiometric accuracy (NE∆T)
23.800	270	V	0.30 K
31.400	180	V	0.30 K
50.300	180	V	0.40 K
52.800	400	V	0.25 K
53.596 ± 0.115	170	H	0.25 K
54.400	400	H	0.25 K
54.940	400	V	0.25 K
55.500	330	H	0.25 K
f_0 = 57.290344	330	H	0.25 K
f_0 ± 0.217	78	H	0.40 K
f_0 ± 0.3222 ± 0.048	36	H	0.40 K
f_0 ± 0.3222 ± 0.022	16	H	0.60 K
f_0 ± 0.3222 ± 0.010	8	H	0.80 K
f_0 ± 0.3222 ± 0.0045	3	H	1.20 K
89.000	6000	V	0.50 K

AMSU-B	Advanced Microwave Sounder Unit - B
Satellites	**NOAA 15 to 17**
Status (Sept 2006)	**Operational** – Utilisation period: 1998 to ~ 2009
Mission	Humidity sounding in nearly-all-weather conditions. Also precipitation
Instrument type	5-channel MW radiometer
Scanning technique	Cross-track: 90 steps of 16 km s.s.p., swath 2250 km - Along-track: one 16-km line every 8/3 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	16 km IFOV
Resources	Mass: 50 kg - Power: 90 W - Data rate: 60 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisation	Radiometric accuracy (NE∆T)
89.0	1000	V	0.37 K
150.0	1000	V	0.84 K
183.31 ± 7.0	2000	V	0.60 K
183.31 ± 3.0	1000	V	0.70 K
183.31 ± 1.0	500	V	1.06 K

APS	Aerosol Polarimetry Sensor
Satellites	**Glory, NPOESS 1 and 3**
Status (Sept 2006)	**Being built** for Glory; currently not baselined for NPOESS - To be utilised in the period 2009 to ~ 2013 on Glory, ~ 2025 if also on NPOESS 1/3
Mission	Aerosol optical thickness, size distribution and shape
Instrument type	9-channel VIS/NIR/SWIR polarimeter with multi-angle capability
Scanning technique	Along-track viewing only, fore- and aft- ± 60° (250 steps of 8 mrad), one full measurement every 8.8.km
Coverage/cycle	30000 measurements/day at 8.8 km intervals – Global coverage (25 km average spacing) in 30 days
Resolution s.s.p.	5.6 IFOV
Resources	Mass: 58 kg - Power: 45 W - Data rate: 160 kbps

Central wavelength	Bandwidth	Polarisations	Radiometric accuracy (SNR)
412 nm	20 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
445 nm	18 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
488 nm	20 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
555 nm	20 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
672 nm	20 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
746 nm	15 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
865 nm	39 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
1240 nm	20 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
1378 nm	15 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
1610 nm	60 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo
2250 nm	50 nm	0, 45, 90 and 135 degrees	.... @ .... % albedo

Aquarius	Aquarius
Satellite	**SAC-D**
Status (Sept 2006)	**Planned** – To be utilised in the period: 2009 to ~ 2012
Mission	Ocean salinity, soil moisture
Instrument type	Co-aligned MW radiometer at 1.413 GHz + scatterometer at 1.26 GHz, both polarimetric
Scanning technique	Pushbroom. Three parallel cross-track beams: 76 km x 94 km, 84 km x 120 km, 96 km x 156 km implementing a swath of 390 km
Coverage/cycle	Global coverage in 4 days (soil moisture). Average over one month for accurate salinity measurements
Resolution	100 km average in the 390 km swath
Resources	Mass: 247 kg - Power: 291 W - Data rate: 5 kbps

ASAR	Advanced Synthetic Aperture Radar - SAR mode
Satellite	**Envisat**
Status (Sept 2006)	**Operational** – Utilised in the period 2002 to ~ 2010
Mission	High-resolution all-weather multi-purpose imager for ocean, land and ice
Instrument type	C-band SAR, frequency 5.331 GHz, multi-polarisation and variable pointing/resolution
Scanning technique	Side-looking, 15-45° off-nadir, swath 100 to 405 km, depending on operation mode – See table
Coverage/cycle	Global coverage in 5 day for the 'global monitoring' mode (if used for 70 % of the time); in longer periods for other operation modes, up to 3 months
Resolution	30 m to 1 km, depending on operation mode – See table
Resources	Mass: 832 kg - Power: 1400 W - Data rate: 100 Mbps

Operation mode	Resolution	Swath	Polarisation
Stripmap	30 m	100 km selectable within a range of 485 km	HH or VV
ScanSAR alternating pol	30 m	100 km selectable within a range of 485 km	VV/HH, HH/HV, VV/VH
ScanSAR wide swath	150 m	405 km	HH or VV
ScanSAR wide swath	150 m	405 km	HH or VV
ScanSAR global monitoring	1 km	405 km	HH or VV
Wave	30 m	5 x 5 km^2 imagettes sampled at 100 km intervals	HH or VV

ASCAT	Advanced Scatterometer
Satellites	**MetOp 1 to 3**
Status (Sept 2006)	**Being commissioned** - To be utilised in the period: 2006 to ~ 2020
Mission	Sea surface wind vector. Also large-scale soil moisture
Instrument type	C-band radar scatterometer (5.255 GHz), side looking both left and right. 3 antennas on each side
Scanning technique	Two 550-km swaths separated by a 700-km gap along-track. 3 looks each pixel (45, 90 and 135° azimuth)
Coverage/cycle	Global coverage in 1.5 days
Resolution	Best quality: 50 km – standard quality: 25 km – basic sampling: 12.5 km
Resources	Mass: 260 kg - Power: 215 W - Data rate: 42 kbps

ASTER	Advanced Spaceborne Thermal Emission and Reflection radiometer
Satellite	**EOS-Terra**
Status (Sept 2006)	**Operational** – Utilised in the period 1999 to ~ 2007
Mission	Land and vegetation observation
Instrument type	14-channel radiometer in three sub-systems, VIS/NIR (3 channels), SWIR (6 channels), TIR (5 channels)
Scanning technique	VNIR and SWIR pushbroom; 4000 pixel/line (VNIR), 2000 pixel/line (SWIR); TIR whiskbroom (670 pixel/line; swath 60 km s.s.p.; cross-track pointing capability within a range of ± 318 km (VNIR) or ± 116 km (SWIR and TIR); along-track stereoscopic viewing in one NIR channel (0.81 μm)
Coverage/cycle	By exploiting strategic pointing, any place within 16 days, or within 5 days limited to VNIR in daylight
Resolution (s.s.p.)	15 m (VNIR), 30 m (SWIR), 90 m (TIR)
Resources	Mass: 421 kg - Power: 463 W - Data rate: 8.3 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR or NEΔT)
0.56 μm	0.52 - 0.60 μm	…... @ ….. % albedo
0.66 μm	0.63 - 0.69 μm	…... @ ….. % albedo
0.81 μm	0.76 - 0.86 μm	…... @ ….. % albedo
1.65 μm	1.60 - 1.70 μm	…... @ ….. % albedo
2.165 μm	2.145 - 2.185 μm	…... @ ….. % albedo
2.205 μm	2.185 - 2.225 μm	…... @ ….. % albedo
2.260 μm	2.235 - 2.285 μm	…... @ ….. % albedo
2.330 μm	2.295 - 2.365 μm	…... @ ….. % albedo
2.395 μm	2.360 - 2.430 μm	…... @ ….. % albedo
8.30 μm	8.125 - 8.475 μm	…... K @ ….. K
8.65 μm	8.475 - 8.825 μm	…... K @ ….. K
9.10 μm	8.925 - 9.275 μm	…... K @ ….. K
10.60 μm	10.25 - 10.95 μm	…... K @ ….. K
11.30 μm	10.95 - 11.65 μm	…... K @ ….. K

ATLID	Atmospheric Lidar
Satellite	**Earth-CARE**
Status (Sept 2006)	**Being developed** – To be utilised in the period 2013 to ~ 2015
Mission	Aerosol profile, cloud top height
Instrument type	Single-wavelength lidar (355 nm), High Spectral Resolution Laser (HSRL) to discriminate Mie and Rayleigh scattering components, thus improve aerosol type classification
Scanning technique	Near-nadir viewing 2° ahead along-track, sampling at 100 m intervals along track, near continuous profiling
Coverage/cycle	Global coverage in 16 d for cells of 100 km side
Resolution	Horizontal: 30 m IFOV sampled at 100 m intervals along track. Vertical: 100 m
Resources	Mass: 230 kg - Power: 310 W - Data rate: 822 kbps

ATMS	Advanced Technology Microwave Sounder
Satellites	**NPP, NPOESS 1/3 and possibly 2/4**
Status (Sept 2006)	**Being built** – To be utilised in the period 2009 to ~ 2025 (2027 if also on NPOESS 2/4)
Mission	Temperature and humidity sounding in nearly-all-weather conditions. Also precipitation
Instrument type	22-channel MW radiometer
Scanning technique	Cross-track: 96 steps of 16 km s.s.p., swath 2200 km - Along-track: one 16-km line every 8/3 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	16 km for channels 165-183 GHz, 32 km for channels 50-90 GHz, 75 km for channels 23-32 GHz
Resources	Mass: 75.4 kg - Power: 93 W - Data rate: 20 kbps

Central frequency (GHz)	Bandwidth (MHz)	Quasi-polarisation	Radiometric accuracy (NEΔT)
23.800	270	QV	0.90 K
31.400	180	QV	0.90 K
50.300	180	QH	1.20 K
51.760	400	QH	0.75 K
52.800	400	QH	0.75 K
53.596 ± 0.115	170	QH	0.75 K
54.400	400	QH	0.75 K
54.940	400	QH	0.75 K
55.500	330	QH	0.75 K
f_0 = 57.290344	330	QH	0.75 K
f_0 ± 0.217	78	QH	1.20 K
f_0 ± 0.3222 ± 0.048	36	QH	1.20 K
f_0 ± 0.3222 ± 0.022	16	QH	1.50 K
f_0 ± 0.3222 ± 0.010	8	QH	2.40 K
f_0 ± 0.3222 ± 0.0045	3	QH	3.60 K
89.5	5000	QV	0.50 K
165.5	3000	QH	0.60 K
183.31 ± 7.0	2000	QH	0.80 K
183.31 ± 4.5	2000	QH	0.80 K
183.31 ± 3.0	1000	QH	0.80 K
183.31 ± 1.8	1000	QH	0.80 K
183.31 ± 1.0	500	QH	0.90 K

AVHRR/3	**Advanced Very High Resolution Radiometer / 3**
Satellites	**TIROS-N, NOAA 6 to 19 - MetOp 1 to 3**
Status (Sept 2006)	**Operational** – Utilisation period: 1978 to ~ 2014 on NOAA, 2006 to ~ 2020 on MetOp
Mission	Multi-purpose VIS/IR imagery
Instrument type	6-channel VIS/IR radiometer (channel 1.6 and 3.7 alternative)
Scanning technique	Cross-track: 2048 pixel of 800 m s.s.p., swath 2900 km - Along-track: six 1.1-km lines/s
Coverage/cycle	Global coverage twice/day (IR) or once/day (VIS)
Resolution (s.s.p.)	1.1 km IFOV
Resources	Mass: 33 kg - Power: 27 W - Data rate: 621.3 kbps

Central wavelength	Spectral interval	Radiometric accuracy (NEΔT or SNR)
0.630 μm	0.58 - 0.68 μm	9 @ 0.5 % albedo
0.862 μm	0.725 - 1.00 μm	9 @ 0.5 % albedo
1.61 μm	1.58 - 1.64 μm	20 @ 0.5 % albedo
3.74 μm	3.55 - 3.93 μm	0.12 K @ 300 K
10.80 μm	10.3 - 11.3 μm	0.12 K @ 300 K
12.00 μm	11.5 - 12.5 μm	0.12 K @ 300 K

AVNIR 1/2	**Advanced Visible and Near-Infrared Radiometer - 2**
Satellites	**ALOS and ADEOS-1 (AVNIR)**
Status (Sept 2006)	**Operational on ALOS** – To be utilised in the period 2006 to ~ 2010 (AVNIR: 2002-2003)
Mission	Vegetation observation
Instrument type	4-channel VIS/NIR radiometer (AVNIR: 5 channels)
Scanning technique	Bushbroom, 7000 pixel/line, swath 70 km s.s.p., possible to be pointed cross-track within a swath of 1400 km
Coverage/cycle	Global coverage in 46 days, in daylight. With strategic pointing, one place can be observed every 2 days.
Resolution (s.s.p.)	10 m IFOV
Resources	Mass: … kg - Power: … W - Data rate: 160 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
0.46 μm	0.42 - 0.50 μm	200 @ 25 % albedo
0.56 μm	0.52 – 0.60 μm	200 @ 29 % albedo
0.65 μm	0.61 – 0.69 μm	200 @ 41 % albedo
0.825 μm	0.76 – 0.89 μm	200 @ 59 % albedo
0.60 μm (AVNIR)	0.52 – 0.69 μm	100 @ 100 % albedo or 5 @ 3.3 % albedo

AWiFS	Advanced Wide Field Sensor
Satellite	**IRS-P6 (ResourceSat-1) and ResourceSat-2**
Status (Sept 2006)	**Operational** - Utilisation period: 2003 to ~ 2014
Mission	Land and vegetation observation
Instrument type	Two parallel radiometers, 4 VIS/NIR/SWIR channels
Scanning technique	Bushbroom, 12000 pixel/line, swath 740 km (with two instruments)
Coverage/cycle	Global coverage in 5 days, in daylight
Resolution (s.s.p.)	56 m IFOV
Resources	Mass: 103.6 kg - Power: 114 W - Data rate: 52.5 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
0.555 μm	0.52 – 0.59 μm	…… @ ….. % albedo
0.650 μm	0.62 – 0.68 μm	…… @ ….. % albedo
0.815 μm	0.77 – 0.86 μm	…… @ ….. % albedo
1.625 μm	1.55 – 1.70 μm	…… @ ….. % albedo

BlackJack	BlackJack
Satellites	**CHAMP, Microlab-1 (GPS/MET), SAC-C (GOLPE), GRACE**
Status (Sept 2006)	**Operational** – Utilised in the period 1995 to ~ 2011
Mission	Temperature/humidity sounding with highest vertical resolution, space weather
Instrument type	GPS receiver measuring the phase delay due to refraction during occultation between GPS and LEO
Scanning technique	Limb scanning from 830 km to close-to-surface by time sampling – Azimuth: 90° sectors fore- and aft-
Coverage/cycle	About 500 soundings/day – Average spacing 1000 km – Global coverage (300 km spacing) in 10 days
Resolution	About 300 km horizontal, 0.5 km vertical
Resources	Mass: … kg - Power: … W - Data rate: 17 kbps

CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarisation
Satellite	**CALIPSO**
Status (Sept 2006)	**Operational** – Utilised in the period 2006 to ~ 2009
Mission	Aerosol profile, cloud top height
Instrument type	Two-wavelengths lidar (532 and 1064 nm), measurements at two orthogonal polarisations
Scanning technique	Nadir-only viewing, sampling at 330 m intervals along track, near continuous profiling
Coverage/cycle	Global coverage in 16 d (orbit repeat cycle) for cells of 100 km side
Resolution	Horizontal: 70 m IFOV sampled at 333 m intervals along track. Vertical: 30 m
Resources	Mass: 156 kg - Power: 124 W - Data rate: 332 kbps

CCD	Charge-Coupled Device Camera
Satellites	**INSAT-2E and INSAT-3A**
Status (Sept 2006)	**Operational** – Utilisation period: 1999 to ~ 2012
Mission	Cloud imagery
Instrument type	3-channel VIS camera
Coverage/cycle	10° x 10° every 3 hours. More frequently on demand. Daylight operation only
Resolution (s.s.p.)	1.0 km
Resources	Mass: 55 kg - Power: 50 W - Data rate: … kbps

Central wavelength	Spectral interval	Radiometric Accuracy (SNR)
0.71 μm	0.63 - 0.79 μm	417 @ 100 % albedo
0.81 μm	0.77 - 0.86 μm	336 @ 100 % albedo
1.62 μm	1.55 - 1.70 μm	342 @ 100 % albedo

CERES	Clouds and the Earth's Radiant Energy System
Satellites	**TRMM, EOS-Terra and EOS-Aqua**
Status (Sept 2006)	**Operational** – Utilised in the period 1997 to ~ 2009
Mission	Earth radiation budget
Instrument type	Two broad-band and one narrow-band channel radiometer
Scanning technique	Cross-track: 80 steps of 20 km s.s.p., swath 3000 km - Along-track: one 20-km line every 3 s
Coverage/cycle	Global coverage twice/day (IR and total radiance) or once/day (short-wave)
Resolution (s.s.p.)	20 km
Resources	Mass: 100 kg - Power: 103 W - Data rate: 20 kbps

Channel	Spectral interval	Noise Equivalent Radiance	Absolute accuracy	SNR
Narrow-band	8 - 12 μm	.... $Wm^{-2}sr^{-1}$	.... $Wm^{-2}sr^{-1}$	....
Short-wave	0.3 - 5.0 μm	.... $Wm^{-2}sr^{-1}$	.... $Wm^{-2}sr^{-1}$	....
Total radiance	0.3 - 100 μm	.... $Wm^{-2}sr^{-1}$	.... $Wm^{-2}sr^{-1}$	....

CMIS	Conical-scanning Microwave Imager/Sounder
Satellites	**NPOESS 2 to 4**
Status (Sept 2006)	**Design being reconsidered in view of descoping** – Utilisation period: 2016 to ~ 2027
Mission	Multi-purpose MW imager with temperature/humidity sounding channels for improved precipitation
Instrument type	63-frequency, 77-channel MW radiometer
Scanning technique	Conical: 53.6- 58.1° zenith angle, swath 1700 km – Scan rate: 31.6 scan/min = 12.5 km/scan
Coverage/cycle	Global coverage once/day
Resolution (constant)	Changing with frequency, consistent with antenna diameters of 2.2 m (6-90 GHz) and 0.7 m (> 90GHz)
Resources	Mass: 257 kg - Power: 291 W - Data rate: 280 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisations (*)	Accuracy (NEΔT)	IFOV	Pixel
6.625	350	V, H	.... K	34 x 56 km	40 x 12.5 km
10.65	100	V, H, R, L	.... K	21 x 35 km	20 x 12.5 km
18.7	200	V, H, P, M, L, R	.... K	12 x 20 km	10 x 12.5 km
23.8	400	V, H	.... K	9.5 x 17 km	10 x 12.5 km
36.5	1000	V, H, P, M	.... K	6.2 x 10 km	5 x 12.5 km
50.3	134	V	.... K	4.5 x 7.5 km	5 x 12.5 km
52.240	1280	V	.... K	4.5 x 7.5 km	5 x 12.5 km
53.570	960	V	.... K	4.5 x 7.5 km	5 x 12.5 km
54.380	440	V	.... K	4.5 x 7.5 km	5 x 12.5 km
54.905	350	V	.... K	4.5 x 7.5 km	5 x 12.5 km
55.490	340	V	.... K	4.5 x 7.5 km	5 x 12.5 km
56.660	300	V	.... K	4.5 x 7.5 km	5 x 12.5 km
59.380	280	V	.... K	4.5 x 7.5 km	5 x 12.5 km
59.940	440	V	.... K	4.5 x 7.5 km	5 x 12.5 km
60.3712	57.6	L	.... K	4.5 x 7.5 km	5 x 12.5 km
60.4080	16	L	.... K	4.5 x 7.5 km	5 x 12.5 km
60.4202	8.4	L	.... K	4.5 x 7.5 km	5 x 12.5 km
60.5088	44.8	L	.... K	4.5 x 7.5 km	5 x 12.5 km
60.43476 (**)	20 (40 FFT channels)	H	.... K	4.5 x 7.5 km	5 x 12.5 km
89.0	4000	V, H	.... K	2.5 x 4.2	2.5 x 6.25 km
166 ± 0.7875	1425	V	.... K	15 x 25	10 x 12.5 km
183.31 ± 7.70	4500	V	.... K	15 x 25	10 x 12.5 km
183.31 ± 3.10	3500	V	.... K	15 x 25	10 x 12.5 km
183.31 ± 0.7125	1275	V	.... K	15 x 25	10 x 12.5 km

(*) Polarisations: H = horizontal, V = vertical, P = + 45°, M = - 45°, L = left-hand circular, R = right-hand circular
(**) 20 MHz band centred on 60.43476 GHz (7+ line of O_2) split in 40 channels by Fast Fourier Transform (FFT)

CPR	Cloud Profiling Radar
Satellite	**CloudSat**
Status (Sept 2006)	**Operational** – Utilised in the period 2006 to ~ 2008
Mission	Vertical profile of cloud water (liquid and ice)
Instrument type	Radar, frequency 94.05 GHz,
Scanning technique	None. Along-track sampling at 2 km intervals
Coverage/cycle	Global coverage in 16 days for cells of 100 km side
Resolution	Horizontal: 1.4 km (cross-track) x 3.5 km (along-track); vertical 500 m
Resources	Mass: 230 kg - Power: 270 W - Data rate: 15 kbps

CPR	Cloud Profiling Radar
Satellite	**Earth-CARE**
Status (Sept 2006)	**Planned** – To be utilised in the period 2013 to ~ 2015
Mission	Vertical profile of cloud water (liquid and ice), vertical velocity
Instrument type	Radar, frequency 94.05 GHz, Doppler capability
Scanning technique	None. Along-track sampling at 1 km intervals
Coverage/cycle	Global coverage in 16 days for cells of 100 km side
Resolution	Horizontal: 0.65 km (cross-track) x 1 km (along-track); vertical 400 m
Resources	Mass: … kg - Power: … W - Data rate: … kbps

CrIS	Cross-track Infrared Sounder
Satellites	**NPP, NPOESS 1/3 and possibly 2/4**
Status (Sept 2006)	**Being built** – To be utilised in the period 2009 to ~ 2025 (2027 if also on NPOESS 2/4)
Mission	Temperature/humidity sounding, ozone profile and total-column green-house gases
Instrument type	IR spectrometer/interferometer (1300 channels)
Scanning technique	Cross-track: 32 steps of 48 km s.s.p., swath 2200 km - Along-track: one 48-km line every 8 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	3 x 3 14 km IFOV covering a 48 x 48 km² cell (average sampling distance: 16 km)
Resources	Mass: 87 kg - Power: 91 W - Data rate: 1.44 Mbps

Spectral range (μm)	Spectral range (cm^{-1})	Spectral resolution (unapodised)	Radiometric accuracy (NEΔT)
9.13 - 15.40 μm	650 - 1095 cm^{-1}	0.625 cm^{-1}	……… K @ …… K
5.71 - 8.26 μm	1210 - 1750 cm^{-1}	1.25 cm^{-1}	……… K @ …… K
3.92 – 4.64 μm	2155 - 2550 cm^{-1}	2.5 cm^{-1}	……… K @ …… K

DPR	Dual-frequency Precipitation Radar
Satellite	**GPM-core**
Status (Sept 2006)	**Planned** – To be utilised in the period 2012 to ~ 2017
Mission	Vertical profile of precipitation
Instrument type	Dual-frequency imaging radar, frequencies 13.6 GHz and 35.55 GHz
Scanning technique	Electronic scanning, planar array of 148 elements, swath 245 km at 13.6 GHz, 120 km at 35.55 GHz
Coverage/cycle	Nearly-global in 5 days, high-latitudes (> 65°) not covered
Resolution (s.s.p.)	Horizontal 5.0 km, vertical 250 m (blind to the lowest ~ 150 m)
Resources	Mass: 780 kg - Power: 710 W - Data rate: 190 kbps

ERBS	Earth Radiation Budget Sensor
Satellites	**NPOESS 1 and possibly 3**
Status (Sept 2006)	**Recurring model of CERES** – To be utilised in the period 2013 to ~ 2018 (possibly to ~ 2025)
Mission	Earth radiation budget
Instrument type	Two broad-band and one narrow-band channel radiometer
Scanning technique	Cross-track: 80 steps of 20 km s.s.p., swath 3000 km - Along-track: one 20-km line every 3 s
Coverage/cycle	Global coverage twice/day (IR and total radiance) or once/day (short-wave)
Resolution (s.s.p.)	20 km
Resources	Mass: … kg - Power: … W - Data rate: … kbps

Channel	Spectral interval	Noise Equivalent Radiance	Absolute accuracy	SNR
Narrow-band	8 - 12 μm	0.3 $Wm^{-2}sr^{-1}$	.... $Wm^{-2}sr^{-1}$	....
Short-wave	0.3 - 5.0 μm	0.8 $Wm^{-2}sr^{-1}$	.... $Wm^{-2}sr^{-1}$	....
Total radiance	0.3 - 100 μm	0.6 $Wm^{-2}sr^{-1}$	.... $Wm^{-2}sr^{-1}$	....

ERM	Earth Radiation Measurement
Satellites	**FY-3 A to G**
Status (Sept 2006)	**Close to launch** – To be utilised in the period 2007 to ~ 2023
Mission	Earth radiation budget and Total solar irradiance
Instrument type	Two broad-band channels radiometer. Two units, one scanning, one non-scanning. In addition, 3 cavity radiometers for total solar irradiance
Scanning technique	Scanner: swath 2200 km; cross-track scanning,151 steps of 28 km s.s.p. every 4 s; non-scanning: 120 degrees viewing angle, 8 samples every 4 s. Total solar irradiance: sun-pointing
Coverage/cycle	Global coverage twice/day (total radiance) or once/day (short-wave)
Resolution (s.s.p.)	Scanner: 28 km - Non-scanner: N/A - Total solar irradiance: N/A
Resources	Mass: … kg - Power: … W - Data rate: … kbps

Channel	Spectral interval	Noise Equivalent Radiance	Absolute accuracy	SNR
Short-wave (outgoing)	0.2 – 3.8 μm	0.4 $W\,m^{-2}\,sr^{-1}$	1.5 $W\,m^{-2}\,sr^{-1}$	900
Total radiance (outgoing)	0.2 - 50 μm	0.4 $W\,m^{-2}\,sr^{-1}$	1.1 $W\,m^{-2}\,sr^{-1}$	1250
Total solar irradiance (incoming)	0.2 - 50 μm	0.2 $W\,m^{-2}$	0.5 %	?

ETM+	Enhanced Thematic Mapper +
Satellite	**Landsat-7**
Status (Sept 2005)	**Operational** – Utilised in the period 1999 to ~ 2006
Mission	Land and vegetation observation
Instrument type	VIS/NIR radiometer, 6 VIS/NIR narrow-band channels, one panchromatic (PAN), one in TIR
Scanning technique	Wiskbroom; 6000 pixel/line (narrow-band), 12000 pixel/line (PAN), 3000 pixel/line (TIR); swath 185 km
Coverage/cycle	Global coverage in 16 days, in daylight.
Resolution (s.s.p.)	30 m (6 narrow-band channels), 15 m (PAN), 60 m (TIR)
Resources	Mass: 441 kg - Power: 590 W - Data rate: 150 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
0.48 μm	0.45 - 0.52 μm	32 @ ….. % albedo
0.56 μm	0.53 - 0.61 μm	35 @ ….. % albedo
0.66 μm	0.63 - 0.69 μm	26 @ ….. % albedo
0.83 μm	0.78 - 0.90 μm	32 @ ….. % albedo
1.65 μm	1.55 - 1.75 μm	25 @ ….. % albedo
2.20 μm	2.09 - 2.35 μm	17 @ ….. % albedo
Panchromatic	0.50 - 0.90 μm	15 @ ….. % albedo
11.45 μm	10.4 - 12.5 μm	0.5 K @ 300 K

FCI	Flexible Combined Imager
Satellites	**Meteosat-12 and follow-on (Meteosat Third Generation)**
Status (Sept 2006)	**Being defined** - To be utilised from 2015 onward
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	16-channel VIS/IR radiometer
Coverage/cycle	Full disk in 10 min and 2.5 min over Europe; or alternating modes
Resolution (s.s.p.)	Sampling distance (pixel) of 0.5, 1.0 or 2.0 km (see table). IFOV ~ 1.2 times the sampling distance
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Channel no.	Central wavelength	Bandwidth	Radiometric accuracy (SNR or NEΔT)	Pixel
1	444 nm	60 nm	25 @ 1 % albedo	1.0 km
2	510 nm	50 nm	25 @ 1 % albedo	1.0 km
3	645 nm	80 nm	30 @ 1 % albedo	0.5 km
4	860 nm	70 nm	30 @ 1 % albedo	1.0 km
5	960 nm	60 nm	12 @ 1 % albedo	1.0 km
6	1375 nm	30 nm	40 @ 1 % albedo	1.0 km
7	1610 nm	60 nm	30 @ 1 % albedo	1.0 km
8	2260 nm	50 nm	25 @ 1 % albedo	0.5 km
9	3.80 μm	0.40 μm	0.1 K @ 300 K	1.0 km
10	6.30 μm	0.40 μm	0.3 K @ 250 K	2.0 km
11	7.35 μm	0.50 μm	0.3 K @ 250 K	2.0 km
12	8.70 μm	0.30 μm	0.1 K @ 300 K	2.0 km
13	9.66 μm	0.30 μm	0.3 K @ 250 K	2.0 km
14	10.50 μm	0.70 μm	0.1 K @ 300 K	1.0 km
15	12.30 μm	0.50 μm	0.1 K @ 300 K	2.0 km
16	13.30 μm	0.60 μm	0.2 K @ 270 K	2.0 km

GEO-MW	Microwave Sounder in Geostationary Orbit
Satellites	**FY-4 M A/B and follow-on**
Status (Sept 2007)	**Being defined** - To be utilised from 2015 onward
Mission	Precipitation, temperature/humidity sounding, cloud liquid and ice water
Instrument type	TBD
Coverage/cycle	
Resolution (s.s.p.)	
Resources	Mass: … kg - Power: … W - Data rate: … kbps

Band central frequency	No. channels in band	Average bandwidth	Radiometric accuracy	Resolution
TBD				

Geoton	Panchromatic and multispectral radiometer
Satellite	**Resurs-DK**
Status (Sept 2006)	**Operational** – Utilisation period: 2006 to ~ 2009
Mission	Land and vegetation observation
Instrument type	3-channel VIS/NIR radiometer (multispectral), 1 channel in panchromatic mode (0.58-0.8 μm)
Scanning technique	Bushbroom, 12000 pixel/line; swath 30 km addressable within an area of regard of 450 km
Coverage/cycle	Global coverage in 80 days, in daylight; locally more frequent by strategic pointing
Resolution (s.s.p.)	2-3 m in multi-spectral mode, 1 m in panchromatic mode
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
0.55 μm	0.5 – 0.6 μm	…… @ ….. % albedo
0.65 μm	0.6 – 0.7 μm	…… @ ….. % albedo
0.75 μm	0.7 – 0.8 μm	…… @ ….. % albedo

GERB	**Geostationary Earth Radiation Budget**
Satellites	**Meteosat 8 to 11 (Meteosat Second Generation)**
Status (Sept 2006)	**Operational** – Utilisation period: 2002 to ~ 2019
Mission	Earth radiation budget
Instrument type	Two broad-band channels radiometer
Coverage/cycle	Full disk every 5 min. Integration over three cycles (15 min) to comply with accuracy requirements
Resolution (s.s.p.)	42 km
Resources	Mass: 25 kg - Power: 35 W - Data rate: 50.6 kbps

Channel	Spectral interval	Noise Equivalent Radiance	Absolute accuracy	SNR
Short-wave	0.32 - 4.0 μm	0.8 $Wm^{-2}sr^{-1}$	2.4 $Wm^{-2}sr^{-1}$	1250
Total radiance	0.32 - 30 μm	0.15 $Wm^{-2}sr^{-1}$	0.4 $Wm^{-2}sr^{-1}$	400

GLAS	**Geoscience Laser Altimeter System**
Satellite	**ICESat**
Status (Sept 2006)	**Operational** – Utilised in the period 2003 to ~ 2008
Mission	Polar ice sheet thickness and topography. Also cloud top height and aerosol
Instrument type	Two-wavelengths lidar (532 and 1064 nm)
Scanning technique	Nadir-only viewing, sampling at 170 m intervals along track, near continuous profiling
Coverage/cycle	Global coverage in 183 d (orbit repeat cycle) leaving cross-track 2.5 km gaps at 80° latitude, 15 km at equator
Resolution	Horizontal: 66 m IFOV sampled at 170 m intervals along track. Vertical: 10 cm surface, 200 m cloud top
Resources	Mass: 298 kg - Power: 300 W - Data rate: 450 bps

GLM	**Geostationary Lightning Mapper**
Satellites	**GOES-R and follow-on**
Status (Sept 2006)	**Proposed** – To be utilised from 2014 onward
Mission	Proxy for convective precipitation, proxy for NO_x generation, study of Earth electric field
Instrument type	CCD camera operating at 777.4 nm (O_2) to count flashes and measure their intensity
Coverage/cycle	Large fraction of the disk continuously observed (time resolution 2 ms)
Resolution (s.s.p.)	8 km
Resources	Mass: … kg - Power: … W - Data rate: … kbps

GMI	**GPM Microwave Imager**
Satellite	**GPM-core**
Status (Sept 2006)	**Planned** – To be utilised in the period 2012 to ~ 2017
Mission	Multi-purpose MW imager, with emphasis on precipitation
Instrument type	MW radiometer with 7 frequencies / 13 channels
Scanning technique	Conical: 53° zenith angle; useful swath: 850 km - Scan rate: 32 scan/min = 12.8 km/scan
Coverage/cycle	Global coverage in 2 days; high latitudes (> 70°) not covered
Resolution	Changing with frequency, consistent with an antenna diameter of 1.2 m
Resources	Mass: 80 kg - Power: 90 W - Data rate: 25 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy (NEΔT)	IFOV	Pixel
10.65	100	V, H	0.6 K	19.4 x 32.2 km	12.8 x 25.6 km
18.7	200	V, H	0.7 K	11.2 x 18.3 km	6.4 x 12.8 km
23.8	200	V	0.9 K	9.2 x 15.0 km	6.4 x 12.8 km
36.5	1000	V, H	0.4 K	8.6 x 14.4 km	6.4 x 12.8 km
89.0	6000	V, H	0.7 K	4.4 x 7.2 km	3.2 x 6.4 km
165.5	3000	V, H	1.5 K	4.4 x 7.2 km	3.2 x 6.4 km
183.31	3500	V	1.5 K	4.4 x 7.2 km	3.2 x 6.4 km
183.31	4500	V	1.5 K	4.4 x 7.2 km	3.2 x 6.4 km

GOCI	Geostationary Ocean Color Imager
Satellites	**COMS 1 and 2**
Status (Sept 2006)	**Being designed** – To be utilised in the period 2008 to ~ 2021
Mission	Ocean colour and aerosol
Instrument type	8-channel VIS/NIR radiometer
Scanning technique	Pushbroom, 6000 pixel/line (3700 useful), swath 1420 km
Coverage/cycle	Area of 2500 km x 2500 km, hourly in daylight
Resolution (s.s.p.)	500 m IFOV
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Bandwidth	**Radiometric accuracy** (SNR @ specified NE∆L)
412 nm	20 nm	1000 @ 0.100 W m^{-2} sr^{-1} μ^{-1}
443 nm	20 nm	1090 @ 0.086 W m^{-2} sr^{-1} μ^{-1}
490 nm	20 nm	1170 @ 0.067 W m^{-2} sr^{-1} μ^{-1}
555 nm	20 nm	1070 @ 0.056 W m^{-2} sr^{-1} μ^{-1}
660 nm	20 nm	1010 @ 0.032 W m^{-2} sr^{-1} μ^{-1}
680nm	10 nm	870 @ 0.031 W m^{-2} sr^{-1} μ^{-1}
745 nm	20 nm	860 @ 0.020 W m^{-2} sr^{-1} μ^{-1}
865 nm	40 nm	750 @ 0.016 W m^{-2} sr^{-1} μ^{-1}

GOME	Global Ozone Monitoring Experiment
Satellite	**ERS-2**
Status (Sept 2006)	**Operational** – Utilised in the period 1995 to ~ 2009
Mission	Ozone profile and total-column or gross profile of other species. Tracked species: BrO, ClO, H_2O, HCHO, NO, NO_2, NO_3, O_2, O_3, O_4, OClO, SO_2 and aerosol
Instrument type	UV/VIS grating spectrometer, four bands, 4096 channels, with 3 polarisation channels
Scanning technique	Cross-track: 3 steps of 40 km or 320 km ssp, swath 120 or 960 km - Along-track: one 40-km line every 6 s
Coverage/cycle	Global coverage every 24 days with high resolution or 3 days with low resolution. Daylight only
Resolution (s.s.p.)	40 x 40 km^2 associated to 120 km swath or 40 x 320 km^2 associated to 960 km swath
Resources	Mass: 50 kg - Power: 50 W - Data rate: 40 kbps

Spectral range	Number of channels	Spectral resolution	SNR at specified input radiance
240 - 295 nm	1024	0.22 nm	.... @ .... W m^{-2} sr^{-1} nm^{-1}
290 - 405 nm	1024	0.24 nm	.... @ .... W m^{-2} sr^{-1} nm^{-1}
400 - 605 nm	1024	0.40 nm	.... @ .... W m^{-2} sr^{-1} nm^{-1}
590 - 790 nm	1024	0.40 nm	.... @ .... W m^{-2} sr^{-1} nm^{-1}
290 - 790 nm	3	292-402 nm, 402-597 nm, 597-790 nm	.... @ .... W m^{-2} sr^{-1} nm^{-1}

GOME-2	Global Ozone Monitoring Experiment - 2
Satellites	**MetOp 1 to 3**
Status (Sept 2006)	**Being commissioned** - To be utilised in the period 2006 to ~ 2020
Mission	Ozone profile and total-column or gross profile of other species. Tracked species: BrO, ClO, H_2O, HCHO, NO, NO_2, NO_3, O_2, O_3, O_4, OClO, SO_2 and aerosol
Instrument type	UV/VIS grating spectrometer, four bands, 4096 channels, with 200 polarisation channels
Scanning technique	Cross-track: 24 steps of 40 km or 80 km ssp, swath 960 or 1920 km - Along-track: one 40-km line every 6 s
Coverage/cycle	Global coverage every 3 days with high resolution or 1.5 days with low resolution. Daylight only
Resolution (s.s.p.)	40 x 40 km^2 associated to 960 km swath or 40 x 80 km^2 associated to 1920 km swath
Resources	Mass: 73 kg - Power: 42 W - Data rate: 400 kbps

Spectral range	Number of channels	Spectral resolution	SNR at specified input radiance
240 - 315 nm	1024	0.24 - 0.29 nm	7-177 @ 50 % albedo and 60° Solar Zenith Angle
311 - 403 nm	1024	0.26 - 0.28 nm	372-3000 @ 50 % albedo and 60° SZA
401 - 600 nm	1024	0.44 - 0.53 nm	4000 @ 50 % albedo and 60° SZA
590 - 790 nm	1024	0.44 - 0.53 nm	2000-4000 @ 50 % albedo and 60° SZA
312 - 790 nm	200	2.8 nm at 312 nm to 40 nm at 790 nm	100 for λ< 400 nm, 1000 for 400 nm < λ < 790 nm

GOMOS	Global Ozone Monitoring by Occultation of Stars
Satellite	**Envisat**
Status (Sept 2006)	**Operational** – Utilised in the period 2002 to ~ 2010
Mission	Profiles of ozone and other species. Tracked species: O_3, H_2O, NO_2, NO_3, OClO, BrO, ClO and aerosol
Instrument type	UV/VIS/NIR grating spectrometer, three bands, ~ 1000 channels, two broadband channels for scintillations
Scanning technique	Limb sounding during occultation of 25-40 stars/orbit, i.e. average 500 occultations/day
Coverage/cycle	One global coverage/day with one measurement every 1000 x 1000 km^2 cell in average
Resolution	Vertical: 1.7 km, in the altitude range 20-100 km. Horizontal effective resolution: ~ 300 km (limb geometry)
Resources	Mass: 163 kg - Power: 146 W - Data rate: 222 kbps

Spectral range	Number of channels	Spectral resolution	SNR at specified input radiance
248 - 693 nm	~ 500	0.89 nm	12 @ ……………
750 - 776 nm	~ 200	0.12 nm	6 @ …………
915 - 956 nm	~ 300	0.12 nm	3 @ …………
466 - 705 nm	2	466-582 nm, 644-705 nm	15 @ ………….

GRAS	GNSS Receiver for Atmospheric Sounding
Satellites	**MetOp 1 to 3**
Status (Sept 2006)	**Being commissioned** - To be utilised in the period 2006 to ~ 2020
Mission	Temperature/humidity sounding with highest vertical resolution, space weather
Instrument type	GPS receiver measuring the phase delay due to refraction during occultation between GPS and LEO
Scanning technique	Limb scanning from 830 km to close-to-surface by time sampling – Azimuth: 90° sectors fore- and aft-
Coverage/cycle	About 500 soundings/day – Average spacing 1000 km – Global coverage (300 km spacing) in 10 days
Resolution	About 300 km horizontal, 0.5 km vertical
Resources	Mass: 30 kg - Power: 30 W - Data rate: 27 kbps

HES	Hyperspectral Environmental Suite
Satellites	**GOES-R (to become GOES-16) and follow-on**
Status (Sept 2006)	**Currently not baselined. Plan being revisited** - In case, to be utilised from 2014 onward
Mission	Temperature/humidity sounding and wind profile derivation by tracking water vapour features
Instrument type	IR spectrometer (+ one VIS channel) for sounding, 14-19 channel radiometer for coastal waters
Coverage/cycle	Full disk in maximum 60 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	2-10 km for sounding (0.5-1.0 km for the VIS channel), 0.15-2.0 km for coastal waters
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Spectral range (µm)	**Spectral range (cm^{-1})**	**Spectral resolution** (goal and threshold)	**Accuracy** (variation in the range)
15.0 - 15.4 µm	650 - 665 cm^{-1}	0.5 - 0.625 cm^{-1}	0.30 - 1.00 K @ 250 K
13.9 - 15.0 µm	665 - 720 cm^{-1}	0.5 - 0.625 cm^{-1}	0.17 - 0.30 K @ 250 K
13.0 - 13.9 µm	720 - 770 cm^{-1}	0.5 - 0.625 cm^{-1}	0.15 - 0.17 K @ 250 K
9.84 - 13.0 µm	770 - 1016 cm^{-1}	0.5 - 0.625 cm^{-1}	0.15 - 0.20 K @ 250 K
9.56 - 9.84 µm	1016 - 1046 cm^{-1}	0.5 - 0.625 cm^{-1}	0.15 - 0.20 K @ 250 K
8.33 – 9.56 µm	1046 - 1200 cm^{-1}	0.5 - 0.625 cm^{-1}	0.20 - 0.90 K @ 250 K
5.75 - 8.26 µm **or**	1210 - 1740 cm^{-1} **or**	0.625 - 1.25 cm^{-1}	0.13 - 0.24 K @ 250 K
4.65 - 6.06 µm	1650 - 2150 cm^{-1}	0.625 - 1.25 cm^{-1}	0.60 - 1.60 K @ 250 K
4.44 - 4.65 µm	2150 - 2250 cm^{-1}	2.5 cm^{-1}	1.5 - 2.0 K @ 250 K
3.68 - 4.44 µm (goal)	2250 - 2720 cm^{-1}	2.5 cm^{-1}	0.4 - 3.0 K @ 250 K
0.52 - 0.70 µm	N/A	0.18 µm	300 @ 100 % albedo

			Central wavelength	**Bandwidth**	**SNR at specified input radiance**
Channel designed for coastal water monitoring	Baseline channels for ocean colour Resolution 150 - 300 m		0.412 µm	0.02 µm	300 (threshold) to 600 (goal)
			0.443 µm	0.02 µm	300 (threshold) to 600 (goal)
			0.477 µm	0.02 µm	300 (threshold) to 600 (goal)
			0.490 µm	0.02 µm	300 (threshold) to 600 (goal)
			0.510 µm	0.02 µm	300 (threshold) to 600 (goal)
			0.530 µm	0.02 µm	300 (threshold) to 600 (goal)
			0.550 µm	0.02 µm	300 (threshold) to 600 (goal)
			0.645 µm	0.02 µm	300 (threshold) to 600 (goal)
			0.667 µm	0.02 µm	300 (threshold) to 600 (goal)
			0.678 µm	0.02 µm	300 (threshold) to 600 (goal)
			0.750 µm	0.02 µm	300 (threshold) to 600 (goal)
			0.763 µm	0.02 µm	300 (threshold) to 600 (goal)
			0.865 µm	0.04 µm	300 (threshold) to 600 (goal)
			0.905 µm	0.02 µm	300 (threshold) to 600 (goal)
	Goal channels	Cloud detection Resolution 0.9 - 1.2 km	1.38 µm	0.03 µm	300 (threshold) to 600 (goal)
			1.61 µm	0.06 µm	300 (threshold) to 600 (goal)
			2.26 µm	0.05 µm	300 (threshold) to 600 (goal)
		Sea surface temperature Resolution 1.0 - 2.0 km	11.2 µm	0.8 µm	NEΔT = 0.1 K @ 250 K
			12.3 µm	1.0 µm	NEΔT = 0.1 K @ 250 K

HIRDLS	**High-Resolution Dynamics Limb Sounder**
Satellite	**EOS-Aura**
Status (Sept 2006)	**Operational** – Utilised in the period 2004 to ~ 2011
Mission	Chemistry of the high atmosphere. Tracked species: CFC-11, CFC-12, CH_4, $ClONO_2$, H_2O, HNO_3, N_2O, N_2O_5, NO_2, O_3, temperature and aerosol
Instrument type	21-channel filter radiometer; range 6.12-17.76 µm
Scanning technique	Limb scanning, 6 azimuth angles, swath 2000-3000 km
Coverage/cycle	Global coverage every 12 hours for cells of 500 km side
Resolution	Vertical: 1 km, in the altitude range 10-100 km. Horizontal effective resolution: ~ 300 km (limb geometry)
Resources	Mass: 220 kg - Power: 220 W - Data rate: 65 kbps

HiRI	High Resolution Imager
Satellites	**Pléiades 1 and 2**
Status (Sept 2006)	**Under development** - To be utilised in the period 2008 to ~ 2015
Mission	Land and vegetation observation. Digital Elevation Model (DEM)
Instrument type	Two parallel radiometers, 5 VNIR channels, 4 multi-spectral (MS), one panchromatic (PAN)
Scanning technique	Bushbroom, 7500 pixel/line (MS), 30000 pixel/line (PAN), swath 20 km s.s.p.; cross-track and along-track pointing capability by up to ± 30° off-nadir. By combining cross- and along- track capabilities, composite images of 120 km x 120 km may be built. Stereoscopic capability in-orbit and between successive orbits
Coverage/cycle	Global coverage in 26 days, in daylight. With strategic pointing, one place can be observed every 2 days.
Resolution (s.s.p.)	2.8 m (MS), 0.7 m (PAN)
Resources	Mass: 200 kg - Power: 400 W - Data rate: 465 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
0.49 μm	0.45 – 0.53 μm	...... @ ..... % albedo
0.55 μm	0.52 – 0.58 μm	...... @ ..... % albedo
0.66 μm	0.62 – 0.70 μm	...... @ ..... % albedo
0.83 μm	0.78 – 0.89 μm	...... @ ..... % albedo
0.69 μm (PAN)	0.48 – 0.90 μm	...... @ ..... % albedo

HIRS 3/4	High-resolution Infra Red Sounder 3 / 4
Satellites	**TIROS-N, NOAA 6 to 17, NOAA 18 and 19** (HIRS/4) - **MetOp 1 and 2** (HIRS/4)
Status (Sept 2006)	**Operational** – Utilisation period: 1978 to ~ 2014 on NOAA, 2006 to ~ 2015 on MetOp
Mission	Temperature/humidity sounding
Instrument type	20-channel IR radiometer (including one VIS)
Scanning technique	Cross-track: 56 steps of 26 km s.s.p., swath 2200 km - Along-track: one line each 42 km every 6.4 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	18 km for HIRS/3, 10 km IFOV for HIRS/4
Resources	Mass: 35 kg - Power: 24 W - Data rate: 2.88 kbps

Wavelength	Wave number	Bandwidth	Radiometric accuracy (NEΔN or SNR)	Radiometric accuracy (NEΔT or SNR)
14.95 μm	669 cm^{-1}	3 cm^{-1}	3.00 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
14.71 μm	680 cm^{-1}	10 cm^{-1}	0.67 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
14.49 μm	690 cm^{-1}	12 cm^{-1}	0.50 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
14.22 μm	703 cm^{-1}	16 cm^{-1}	0.31 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
13.97 μm	716 cm^{-1}	16 cm^{-1}	0.21 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
13.64 μm	733 cm^{-1}	16 cm^{-1}	0.24 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
13.35 μm	749 cm^{-1}	16 cm^{-1}	0.20 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
12.47 μm	802 cm^{-1}	16 cm^{-1}	0.15 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
11.11 μm	900 cm^{-1}	35 cm^{-1}	0.10 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
9.71 μm	1030 cm^{-1}	25 cm^{-1}	0.15 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
7.33 μm	1364 cm^{-1}	40 cm^{-1}	0.20 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
6.52 μm	1534 cm^{-1}	55 cm^{-1}	0.20 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
4.57 μm	2188 cm^{-1}	23 cm^{-1}	0.006 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
4.52 μm	2210 cm^{-1}	23 cm^{-1}	0.003 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
4.47 μm	2237 cm^{-1}	23 cm^{-1}	0.004 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
4.45 μm	2247 cm^{-1}	23 cm^{-1}	0.004 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
4.13 μm	2420 cm^{-1}	28 cm^{-1}	0.002 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
4.00 μm	2500 cm^{-1}	35 cm^{-1}	0.002 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
3.76 μm	2660 cm^{-1}	100 cm^{-1}	0.001 $mW \cdot m^{-2} \cdot sr^{-1} \cdot cm$	..... K @ ..... K
0.69 μm	N/A	0.05 μm	0.10 % albedo	.... @ .... % albedo

HRG	**Haute Résolution Géométrique**
Satellite	**SPOT-5**
Status (Sept 2006)	**Operational** – Utilisation period: 2002 to ~ 2009
Mission	Land and vegetation observation. Digital Elevation Model (DEM)
Instrument type	Two parallel radiometers, 5 VIS/NIR/SWIR channels, 4 multi-spectral (MS), one panchromatic (PAN)
Scanning technique	Bushbroom, 6000 pixel/line (MS), 12000 pixel/line (PAN), swath 60 km ssp (117 km with two instruments), cross-track pointing capability within a range of ± 450 km. Stereoscopic capability between successive orbits
Coverage/cycle	Global coverage in 26 days, in daylight. With strategic pointing, one place can be observed every 3 days.
Resolution (s.s.p.)	10 m (the three VNIR channels), 20 m (the SWIR channel), 5 m (PAN) with *super-mode* at 2.5 m
Resources	Mass: 356 kg - Power: 344 W - Data rate: … Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
0.545 μm	0.49 – 0.61 μm	…... @ ….. % albedo
0.645 μm	0.61 – 0.68 μm	…... @ ….. % albedo
0.835 μm	0.78 – 0.89 μm	…... @ ….. % albedo
1.645 μm	1.58 – 1.75 μm	…... @ ….. % albedo
0.59 μm (PAN) (2 shifted channels)	0.49 – 0.69 μm	…... @ ….. % albedo

HRS	**Haute Résolution Stéréoscopique**
Satellite	**SPOT-5**
Status (Sept 2006)	**Operational** – Utilisation period: 2002 to ~ 2009
Mission	Digital Elevation Model (DEM) by in-orbit stereoscopy
Instrument type	Single VIS channel (0.51-0.73 μm), SNR ….. @ ….. % albedo
Scanning technique	Bushbroom, 12000 pixel/line, swath 120 km ssp, along-track fore- and aft- pointing by ± 20°
Coverage/cycle	Global coverage in 26 days, in daylight
Resolution (s.s.p.)	10 m IFOV cross-track, 5 m sampling along-track
Resources	Mass: 90 kg - Power: 128 W - Data rate: … Mbps

HRV	**Haute Résolution dans le Visible**
Satellites	**SPOT-1, SPOT-2, SPOT-3**
Status (Sept 2006)	**Operational** (on SPOT-2) - Utilisation period: 1986 to ~ 2007
Mission	Land and vegetation observation. Digital Elevation Model (DEM)
Instrument type	Two parallel radiometers, 4 VIS/NIR channels, three multi-spectral (MS), one panchromatic (PAN)
Scanning technique	Bushbroom, 3000 pixel/line (MS), 6000 pixel/line (PAN), swath 60 km ssp (117 km with two instruments), cross-track pointing capability within a range of ± 450 km. Stereoscopic capability between successive orbits
Coverage/cycle	Global coverage in 26 days, in daylight. With strategic pointing, one place can be observed every 3 days.
Resolution (s.s.p.)	20 m (MS), 10 (PAN)
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
0.545 μm	0.50 – 0.59 μm	…... @ ….. % albedo
0.645 μm	0.61 – 0.68 μm	…... @ ….. % albedo
0.84 μm	0.79 – 0.89 μm	…... @ ….. % albedo
0.62 μm (PAN)	0.51 – 0.73 μm	…... @ ….. % albedo

HRVIR	Haute Résolution dans le Visible et l'Infra-Rouge
Satellite	**SPOT-4**
Status (Sept 2006)	**Operational** - Utilisation period: 1998 to ~ 2008
Mission	Land and vegetation observation. Digital Elevation Model (DEM)
Instrument type	Two parallel radiometers, 4 VIS/NIR/SWIR multi-spectral (MS) channels, one also panchromatic (PAN)
Scanning technique	Bushbroom, 3000 pixel/line (MS), 6000 pixel/line (PAN), swath 60 km ssp (117 km with two instruments), cross-track pointing capability within a range of ± 450 km. Stereoscopic capability between successive orbits
Coverage/cycle	Global coverage in 26 days, in daylight. With strategic pointing, one place can be observed every 3 days.
Resolution (s.s.p.)	20 m (MS), 10 (PAN)
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
0.545 μm	0.50 – 0.59 μm	…... @ ….. % albedo
0.645 μm (MS)	0.61 – 0.68 μm	…... @ ….. % albedo
0.645 μm (PAN)	0.61 – 0.68 μm	…... @ ….. % albedo
0.84 μm	0.79 – 0.89 μm	…... @ ….. % albedo
1.64 μm	1.58 – 1.75 μm	…... @ ….. % albedo

HSB	Humidity Sounder for Brazil
Satellite	**EOS-Aqua**
Status (Sept 2006)	**No longer operational** – To be utilised in the period 2002 to ~ 2009 – Actually failed in 2003.
Mission	Humidity sounding in almost all-weather conditions. Also precipitation rate
Instrument type	5-channel MW radiometer
Scanning technique	Cross-track: 90 steps of 13.5 km ssp, swath 1650 km - Along-track: one 13.5-km line every 8/3 s
Coverage/cycle	Near-global coverage once/day
Resolution (s.s.p.)	13.5 km IFOV
Resources	Mass: 51 kg - Power: 80 W - Data rate: 4.2 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisation	Radiometric accuracy (NEΔT)
150.0	1000	V	1.0 K
183.31 ± 7.0	2000	V	1.0 K
183.31 ± 3.0	1000	V	1.0 K
183.31 ± 1.0	500	V	1.0 K

Hyperion	Hyperion
Satellite	**NMP EO-1**
Status (Sept 2006)	**Technological demonstration running** – To be utilised in the period 2000-2008
Mission	Advanced technology for land and vegetation observation
Instrument type	VIS/NIR/SWIR grating spectrometer with 220 channels, in two groups covering the ranges 0.4-1.0 μm and 0.9-2.5 μm respectively; channels bandwidths 10 nm
Scanning technique	Pushbroom; 250 pixel/line; swath 7.5 km
Coverage/cycle	Global coverage in 1 year, in daylight.
Resolution (s.s.p.)	30 m IFOV
Resources	Mass: 49 kg - Power: 51 W - Data rate: … Mbps

IASI	**Infrared Atmospheric Sounding Interferometer**
Satellites	**MetOp 1 to 3**
Status (Sept 2006)	**Being commissioned** - To be utilised in the period 2006 to ~ 2020
Mission	Temperature/humidity sounding, ozone profile and total-column green-house gases
Instrument type	IR spectrometer/interferometer (8461 channels) with one embedded IR imaging channel
Scanning technique	Cross-track: 30 steps of 48 km ssp, swath 2130 km - Along-track: one 48-km line every 8 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	4 x 12-km IFOV close to the centre of a 48 x 48 km^2 cell (average sampling distance: 24 km)
Resources	Mass: 236 kg - Power: 210 W - Data rate: 1.5 Mbps (after onboard processing)

Spectral range (μm)	**Spectral range (cm^{-1})**	**Spectral resolution** (unapodised)	**Accuracy** (for 0.25 cm^{-1} channels) **(NEΔT)**
8.26 - 15.50 μm	645 - 1210 cm^{-1}	0.25 cm^{-1}	0.2-0.3 K @ 280 K
5.00 - 8.26 μm	1210 - 2000 cm^{-1}	0.25 cm^{-1}	0.2-0.5 K @ 280 K
3.62 - 5.00 μm	2000 - 2760 cm^{-1}	0.25 cm^{-1}	0.5-2.0 K @ 280 K
10.3-12.5 μm	N/A	N/A	0.8 K @ 280 K

IGOS	**Integrated GPS Occultation Receiver**
Satellites	**COSMIC constellation (6 satellites)**
Status (Sept 2006)	**Operational** – Utilised in the period 2006 to ~ 2011
Mission	Temperature/humidity sounding with highest vertical resolution, space weather
Instrument type	GPS receiver measuring the phase delay due to refraction during occultation between GPS and LEO
Scanning technique	Limb scanning from 830 km to close-to-surface by time sampling – Azimuth: 90° sectors fore- and aft-
Coverage/cycle	About 500 soundings/day – Average spacing 1000 km – Global coverage (300 km spacing) in 10 days
Resolution	About 300 km horizontal, 0.5 km vertical
Resources	Mass: … kg - Power: … W - Data rate: 17 kbps

IIS	**Interferometric Infrared Sounder**
Satellites	**FY-4 O A/B and follow-on**
Status (Sept 2006)	**Being defined** - To be utilised from 2012 onward
Mission	Temperature/humidity sounding and wind profile derivation by tracking water vapour features
Instrument type	IR spectrometer/interferometer with large detector arrays for simultaneous sounding of more pixels
Coverage/cycle	Full disk in 60 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	Prototype flight 8.0 km, follow-on 4.0 km
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Spectral range (cm^{-1})	**Spectral range (μm)**	**Spectral resolution**	**Radiometric accuracy (NEΔR)**
685 - 1130 cm^{-1}	14.6 - 8.85 μm	0.8 cm^{-1} (later: 0.3 cm^{-1})	0.4 mW·m^{-2}·sr^{-1}·cm^{-1} (later: 0.2 mW·m^{-2}·sr^{-1}·cm^{-1}
1650 - 2250 cm^{-1}	6.06 - 4.44 μm	0.2 cm^{-1} (later: 0.6 cm^{-1})	0.1 mW·m^{-2}·sr^{-1}·cm^{-1} (later: 0.06 mW·m^{-2}·sr^{-1}·cm^{-1})

IMAGER	**GOES Imager**
Satellites	**GOES 8 to 15**
Status (Sept 2006)	**Operational** – Utilisation period: 1994 to ~ 2015
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	5-channel VIS/IR radiometer
Coverage/cycle	Full disk every 30 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	4.0 km for IR channels; 1.0 km for the VIS channel
Resources	Mass: … kg - Power: … W - Data rate: 2.62 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (NEΔT or SNR)
0.65 μm	0.55 - 0.75 μm	.... @ ... % albedo
3.90 μm	3.80 - 4.00 μm	0.11 K @ 300 K
6.55 μm	5.80 - 7.30 μm	0.14 K @ 300 K
10.70 μm	10.2 - 11.2 μm	0.09 K @ 300 K
13.35 μm	13.0 - 13.7 μm	...... K @ 300 K

IMAGER	INSAT Imager
Satellites	INSAT-3D
Status (Sept 2006)	**Being built** – To be utilised in the period 2007 to ~ 2014
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	6-channel VIS/IR radiometer
Coverage/cycle	Full disk every 30 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	4.0 km for IR window channels; 1.0 km for VIS/SWIR channels; 8.0 km for water-vapour channel
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Spectral interval	Radiometric accuracy (NEΔT or SNR)
0.65 μm	0.52 - 0.72 μm	150 @ 1 % albedo
1.625 μm	1.55 - 1.70 μm	150 @ 1 % albedo
3.90 μm	3.80 - 4.00 μm	1.4 K @ 300 K
6.8 μm	6.50 - 7.10 μm	1.0 K @ 230 K
10.8 μm	10.2 - 11.2 μm	0.35 K @ 300 K
12.0 μm	11.5 - 12.5 μm	0.35 K @ 300 K

IMAGER	MTSAT Imager
Satellites	MTSAT- 2
Status (Sept 2006)	**Standby** (Operational utilisation period: 2010 to 2015)
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	5-channel VIS/IR radiometer
Coverage/cycle	Full disk scanned in ≤ 27.6 min every 60 min. Half disk scanned in ≤ 14.4 min every 60 min.
Resolution (s.s.p.)	4.0 km for IR channels; 1.0 km for the VIS channel
Resources	Mass: 142.5 kg - Power: 193 W (normal operations, in sunlight) - Data rate: 2.62 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (NEΔT or SNR)
0.675 μm	0.55 - 0.80 μm	6.5 @ 2.5 % albedo
3.75 μm	3.50 - 4.00 μm	0.09 K @ 300 K
6.75 μm	6.50 - 7.00 μm	0.12 K @ 300 K
10.8 μm	10.3 - 11.3 μm	0.11 K @ 300 K
12.0 μm	11.5 - 12.5 μm	0.20 K @ 300 K

IMAGER TBD	COMS Imager
Satellites	COMS-2
Status (Sept 2006)	**Being defined** (Operational utilisation period: 2014 to 2021)
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	TBD
Coverage/cycle	TBD
Resolution (s.s.p.)	TBD
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Spectral interval	Radiometric accuracy (NEΔT or SNR)
TBD	TBD	TBD

IMAGER TBD	**MTSAT-FO Imager**
Satellites	**MTSAT-3 and follow-on**
Status (Sept 2006)	**Being defined** (Operational utilisation period: 2014 to 2030)
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	Channels to be added to current imager: finally to be similar to MTG/FCI and GOES-R/ABI
Coverage/cycle	Full disk in 10 min
Resolution (s.s.p.)	0.5 km VIS channels, 2 km IR channels
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	**Spectral interval**	**Radiometric accuracy (NEΔT or SNR)**
TBD	TBD	TBD

IRAS	**Infra Red Atmospheric Sounder**
Satellites	**FY-3 A to G**
Status (Sept 2006)	**Close to launch** – To be utilised in the period 2007 to ~ 2023
Mission	Temperature/humidity sounding
Instrument type	26-channel IR radiometer (including 6 in short-wave)
Scanning technique	Cross-track: 56 steps of 26 km ssp, swath 2250 km - Along-track: one line each 42 km every 6.4 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	17 km IFOV
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Wavelength	**Wave number**	**Bandwidth**	**Radiometric accuracy (NEΔT or NEΔρ)**
14.95 μm	669 cm^{-1}	3 cm^{-1}	2.50 K @ 290 K
14.71 μm	680 cm^{-1}	10 cm^{-1}	0.50 K @ 290 K
14.49 μm	690 cm^{-1}	12 cm^{-1}	0.37 K @ 290 K
14.22 μm	703 cm^{-1}	16 cm^{-1}	0.22 K @ 290 K
13.97 μm	716 cm^{-1}	16 cm^{-1}	0.20 K @ 290 K
13.64 μm	733 cm^{-1}	16 cm^{-1}	0.22 K @ 290 K
13.35 μm	749 cm^{-1}	16 cm^{-1}	0.18 K @ 290 K
12.47 μm	802 cm^{-1}	30 cm^{-1}	0.12 K @ 290 K
11.11 μm	900 cm^{-1}	35 cm^{-1}	0.10 K @ 290 K
9.71 μm	1030 cm^{-1}	25 cm^{-1}	0.14 K @ 290 K
7.43 μm	1345 cm^{-1}	50 cm^{-1}	0.27 K @ 290 K
7.33 μm	1365 cm^{-1}	40 cm^{-1}	0.37 K @ 290 K
6.52 μm	1533 cm^{-1}	55 cm^{-1}	0.53 K @ 290 K
4.57 μm	2188 cm^{-1}	23 cm^{-1}	0.10 K @ 290 K
4.52 μm	2210 cm^{-1}	23 cm^{-1}	0.05 K @ 290 K
4.47 μm	2235 cm^{-1}	23 cm^{-1}	0.08 K @ 290 K
4.45 μm	2245 cm^{-1}	23 cm^{-1}	0.08 K @ 290 K
4.19 μm	2388 cm^{-1}	25 cm^{-1}	0.06 K @ 290 K
3.98 μm	2515 cm^{-1}	35 cm^{-1}	0.10 K @ 290 K
3.76 μm	2660 cm^{-1}	100 cm^{-1}	0.11 K @ 290 K
1.64 μm	6098 cm^{-1}	450 cm^{-1}	0.1 %
1.24 μm	8065 cm^{-1}	650 cm^{-1}	0.1 %
0.94 μm	10638 cm^{-1}	200 cm^{-1}	0.1 %
0.94 μm	10638 cm^{-1}	550 cm^{-1}	0.1 %
0.885 μm	11299 cm^{-1}	385 cm^{-1}	0.1 %
0.69 μm	14500 cm^{-1}	1000 cm^{-1}	0.1 %

IRFS-2	**Infrared Sounding Spectrometer**
Satellites	**Meteor-M-2**
Status (Sept 2006)	**Being built** – To be utilised in the period 2008 to ~ 2012
Mission	Temperature/humidity sounding, ozone profile and total-column green-house gases
Instrument type	IR spectrometer/interferometer, 4000 channels
Scanning technique	Cross-track: 30 steps to cover a swath of 1000 km if contiguous, up to 2500 km with gaps
Coverage/cycle	Near-global coverage twice/day (with gaps) or once/day (continuous)
Resolution (s.s.p.)	35 km IFOV
Resources	Mass: … kg - Power: … W - Data rate: 600 kbps

Spectral range (μm)	**Spectral range (cm^{-1})**	**Spectral resolution** (unapodised)	**Radiometric accuracy (NEΔT)**
5 – 15 μm	667 – 2000 cm^{-1}	0.5 cm^{-1}	0.5 K @ 300 K

IRS	**Infra-Red Sounder**
Satellites	**Meteosat-12 and follow-on (Meteosat Third Generation)**
Status (Sept 2006)	**Being defined** - To be utilised from 2015 onward
Mission	Temperature/humidity sounding and wind profile derivation by tracking water vapour features
Instrument type	IR spectrometer/interferometer with large detector arrays for simultaneous sounding of more pixels
Coverage/cycle	Full disk in 30 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	4.0 km
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Spectral range (cm^{-1})	**Spectral range (μm)**	**Spectral resolution**	**Radiometric accuracy (NEΔT)**
700 - 1210 cm^{-1}	14.3 - 8.26 μm	0.625 cm^{-1}	0.2-0.5 K @ 280 K
1600 - 2175 cm^{-1}	6.25 – 4.6 μm	0.625 cm^{-1}	0.2-0.8 K @ 280 K

JAMI	**Japanese Advanced Meteorological Imager**
Satellites	**MTSAT- 1R**
Status (Sept 2006)	**Operational** (Utilisation period: 2005 to 2010)
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	5-channel VIS/IR radiometer
Coverage/cycle	Full disk every 30 min. Half disk every 15 min.
Resolution (s.s.p.)	4.0 km for IR channels; 1.0 km for the VIS channel
Resources	Mass: 166.3 kg - Power: 152 W - Data rate: 2.7 Mbps

Central wavelength	**Spectral interval**	**Radiometric accuracy (NEΔT or SNR)**
0.725 μm	0.55 - 0.90 μm	6.5 @ 2.5 % albedo
3.75 μm	3.50 - 4.00 μm	0.18 K @ 300 K
6.75 μm	6.50 - 7.00 μm	0.18 K @ 300 K
10.8 μm	10.3 - 11.3 μm	0.15 K @ 300 K
12.0 μm	11.5 - 12.5 μm	0.18 K @ 300 K

JMR	**JASON Microwave Radiometer**
Satellite	**Jason-1**
Status (Sept 2006)	**Operational** – Utilised in the period 2001 to ~ 2008
Mission	Water vapour correction for the Poseidon-2 radar altimeter
Instrument type	3-frequency MW radiometer, 18.7, 23.8 and 34 GHz
Scanning technique	Nadir-only viewing, associated to the Poseidon-2 radar altimeter
Coverage/cycle	Global coverage in 1 month for 30 km average spacing, or in 10 days for 100 km average spacing
Resolution (s.s.p.)	25 km
Resources	Mass: 27 kg - Power: 31 W - Data rate: 100 bps

KMSS	High-resolution VIS/IR Radiometer
Satellites	**Meteor-M-1/2**
Status (Sept 2006)	**Being built** – To be utilised in the period 2007 to ~ 2012
Mission	High-resolution imagery
Instrument type	6-channel VIS/NIR radiometer implemented by 3 cameras, two side-to-side and one overlapping
Scanning technique	Cross-track: 8000 CCD/line; swath 960 km
Coverage/cycle	Global coverage in 3 days
Resolution (s.s.p.)	60 - 120 m IFOV (see table)
Resources	Mass: 8.1 kg - Power: 20.4 W - Data rate: 60 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)	Resolution
0.41 μm	0.37 - 0.45 μm	200 @ 100 % albedo	120 m
0.48 μm	0.45 - 0.51 μm	200 @ 100 % albedo	120 m
0.635 μm	0.58 - 0.69 μm	200 @ 100 % albedo	120 m
0.555 μm	0.535 - 0.575 μm	200 @ 100 % albedo	60 m
0.655 μm	0.63 - 0.68 μm	200 @ 100 % albedo	60 m
0.830 μm	0.76 - 0.90 μm	200 @ 100 % albedo	60 m

LAC	**LEISA** (Linear Etalon Imaging Spectrometer Array) **Atmospheric Corrector**
Satellite	**NMP EO-1**
Status (Sept 2006)	**Technological demonstration running** – To be utilised in the period 2000-2008
Mission	Advanced technology for land and vegetation observation – To correct ALI data for atmospheric effects
Instrument type	NIR filter-wedge spectrometer with 256 channels covering the ranges 0.93-1.58 μm with spectral resolution ranging from 2 to 6 nm. In addition, a 1.38 μm channel enables cirrus detection
Scanning technique	Pushbroom; 768 pixel/line; swath 185 km
Coverage/cycle	Global coverage in 16 days, in daylight.
Resolution (s.s.p.)	250 m IFOV
Resources	Mass: 10.5 kg - Power: 35 W - Data rate: 95 Mbps

LI	Lightning Imager
Satellites	**Meteosat-12 and follow-on (Meteosat Third Generation)**
Status (Sept 2006)	**Being defined** - To be utilised from 2015 onward
Mission	Proxy for convective precipitation, proxy for NO_x generation, study of Earth electric field
Instrument type	CCD camera operating at 777.4 nm (O_2) to count flashes and measure their intensity
Coverage/cycle	Full disk continuously observed (time resolution ~1 ms)
Resolution (s.s.p.)	10 km
Resources	Mass: … kg - Power: … W - Data rate: … kbps

LIS	Lightning Imaging Sensor
Satellite	**TRMM**
Status (Sept 2006)	**Operational** – Utilised in the period 1997 to ~ 2009
Mission	Proxy for convective precipitation, proxy for NO_x generation, study of Earth electric field
Instrument type	CCD camera operating at 777.4 nm (O_2) to count flashes and measure their intensity
Scanning technique	Pushbroom, matrix array of 128 x 128 detectors, swath 600 km; each earth location observed continuously (every 2 ms) for about 90 s
Coverage/cycle	Intertropical coverage 1 to 2 times/day depending on latitude (best coverage at 15°N and 15°S)
Resolution (s.s.p.)	4 km
Resources	Mass: 21 kg - Power: 33 W - Data rate: 6 kbps

LISS-3	Linear Imaging Self-Scanning Sensor - 3
Satellites	**IRS-1C, IRS-1D, IRS-P6 (ResourceSat-1) and ResourceSat-2**
Status (Sept 2006)	**Operational** - Utilisation period: 1995 to ~ 2014
Mission	Land and vegetation observation
Instrument type	Two parallel radiometers, 4 VIS/NIR/SWIR channels
Scanning technique	Bushbroom, 6000 pixel/line (SWIR 2100 pixel/line on IRS-1C/1D), swath 140 km (with two instruments)
Coverage/cycle	Global coverage in 24 days, in daylight
Resolution (s.s.p.)	IRS-1C/1D: 23.5 m (three VNIR channels), 70 m (SWIR channel), ResourceSat-1/2: 23.5 m in all channels.
Resources	Mass: 106.1 kg - Power: 70 W - Data rate: 52.5 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
0.555 μm	0.52 – 0.59 μm	…... @ ….. % albedo
0.650 μm	0.62 – 0.68 μm	…... @ ….. % albedo
0.815 μm	0.77 – 0.86 μm	…... @ ….. % albedo
1.625 μm	1.55 – 1.70 μm	…... @ ….. % albedo

LISS-4	Linear Imaging Self-Scanning Sensor - 4
Satellite	**IRS-P6 (ResourceSat-1) and ResourceSat-2**
Status (Sept 2006)	**Operational** – Utilisation period: 2003 to ~ 2014
Mission	Land and vegetation observation
Instrument type	3-channel VIS/NIR radiometer, one camera each channel
Scanning technique	Bushbroom, 4096 pixel/line per camera; swath 23.9 km if the 3 cameras are used each for 1 different channel (thus multi-spectral), or 70 km if all cameras are used for viewing parallel strips in the same channel (thus panchromatic). Cross-track pointing capability ± 26° for stereoscopy in between orbits
Coverage/cycle	Global coverage in 24 days, in daylight. 5 days for a target area by using cross-track pointing
Resolution (s.s.p.)	5.8 m IFOV
Resources	Mass: 169.5 kg - Power: 216 W - Data rate: 105 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
0.555 μm	0.52 – 0.59 μm	…... @ ….. % albedo
0.650 μm	0.62 – 0.68 μm	…... @ ….. % albedo
0.815 μm	0.77 – 0.86 μm	…... @ ….. % albedo

LM	Lightning MAPPER
Satellites	**FY-4 O A/B and follow-on**
Status (Sept 2006)	**Being defined** - To be utilised from 2014 onward
Mission	Proxy for convective precipitation, proxy for NO_x generation, study of Earth electric field
Instrument type	CCD camera operating at 777.4 nm (O_2) to count flashes and measure their intensity
Coverage/cycle	Full disk continuously observed (time resolution ~1 ms)
Resolution (s.s.p.)	10 km
Resources	Mass: … kg - Power: … W - Data rate: … kbps

MADRAS	Microwave Analysis & Detection of Rain & Atmospheric Structures
Satellite	**Megha-Tropiques**
Status (Sept 2006)	**Planned** - To be utilised in the period 2009 to ~ 2014
Mission	Contribution to the Global Precipitation Measurement mission (GPM)
Instrument type	MW radiometer with 5 frequencies / 9 channels
Scanning technique	Conical: 56° zenith angle; swath: 1740 km - Scan rate: 24.6 scan/min = 16 km/scan
Coverage/cycle	Intertropical coverage 2 to 5 times/day depending on latitude (best coverage at 15°N and 15°S)
Resolution	IFOV ranging from 7 km at 157 GHz to 50 km at 18.7 GHz
Resources	Mass: … kg - Power: … W - Data rate: … kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Radiometric accuracy (NEΔT)	IFOV	Pixel
18.7	180	V, H	1.0 K	40 x 60 km	40 x 40 km
23.8	360	V	0.86 K	40 x 60 km	40 x 40 km
36.5	900	V, H	0.72 K	40 x 60 km	40 x 40 km
89.0	1100	V, H	1.23 K	11 x 16 km	10 x 10 km
157.0	1100	V, H	3.3 K	6 x 9 km	6 x 6 km

MCSI	**Multiple Channel Scanning Imager**
Satellites	**FY-4 O A/B and follow-on**
Status (Sept 2006)	**Being defined** (Operational utilisation period: 2014 to 2030)
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	12-channel VIS/IR radiometer
Coverage/cycle	Full disk every 30 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	From 1 to 4 km (see table)
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Spectral interval	Radiometric accuracy (NEΔT or SNR)	Resolution @ s.s.p.
0.65 (m	0.55 - 0.75 (m	200 @ 100 % albedo	1 km
0.825 (m	0.75 - 0.90 (m	200 @ 100 % albedo	1 km
1.375 (m	1.36 - 1.39 (m	200 @ 100 % albedo	2 km
1.61 (m	1.58 - 1.64 (m	200 @ 100 % albedo	2 km
2.25 (m	2.1 - 2.35 (m	200 @ 100 % albedo	2 km
3.75 (m	3.5 - 4.0 (m	0.3 K @ 300 K	4 km
6.25 (m	5.8 - 6.7 (m	0.3 K @ 260 K	4 km
7.1 µm	6.9 - 7.3 µm	0.3 K @ 260 K	4 km
8.5 µm	8.0 - 9.0 µm	0.2 K @ 300 K	4 km
10.7 µm	10.3 - 11.1 µm	0.2 K @ 300 K	4 km
11.0 µm	11.5 - 12.5 µm	0.2 K @ 300 K	4 km
13.5 µm	13.2 - 13.8 (m	0.5 K @ 300 K	4 km

MERIS	**Medium Resolution Imaging Spectrometer**
Satellite	**Envisat**
Status (Sept 2006)	**Operational** – Utilised in the period 2002 to ~ 2010
Mission	Ocean colour, vegetation, aerosol, cloud properties
Instrument type	15-channel VIS/NIR spectro-radiometer, channel positions and bandwidths selectable
Scanning technique	Bushbroom, 3700 pixel/line (split in 5 parallel optical systems), total swath 1150 km
Coverage/cycle	Global coverage in 3 days, in daylight
Resolution (s.s.p.)	Basic IFOV 300 m, reduced resolution for global data recording: 1200 km
Resources	Mass: 200 kg - Power: 175 W - Data rate: 24 Mbps

Central wavelength	Bandwidth	**Radiometric accuracy** (SNR @ specified input radiance)
412.5 nm	10 nm	.... @ ....
442.5 nm	10 nm	.... @ ....
490 nm	10 nm	.... @ ....
510 nm	10 nm	.... @ ....
560 nm	10 nm	.... @ ....
620 nm	10 nm	.... @ ....
665 nm	10 nm	.... @ ....
681.25 nm	7.5 nm	.... @ ....
708.75 nm	10 nm	.... @ ....
753.75 nm	7.5 nm	.... @ ....
760.625 nm	3.75 nm	.... @ ....
778.75 nm	15 nm	.... @ ....
865 nm	20 nm	.... @ ....
885 nm	10 nm	.... @ ....
900 nm	10 nm	.... @ ....

MERSI	**Medium Resolution Spectral Imager**
Satellites	**FY-3 A to G**
Status (Sept 2006)	**Close to launch** – To be utilised in the period: 2007 to ~ 2023
Mission	Vegetation indexes and ocean colour
Instrument type	20-channel radiometer, 19 narrow-bandwidth in VIR/NIR/SWIR and one broadband in the Thermal IR
Scanning technique	Cross-track: 2048 (8192) pixels of 1 km(250 m) ssp, swath 2900 km - Along-track: ten 10-km lines every 1.5 s
Coverage/cycle	Global coverage in 1 day (in daylight)
Resolution (s.s.p.)	250 m for broad-band channels, 1.0 km for narrow-band channels
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Channel set	Central wavelength	Spectral range or Bandwidth	Radiometric accuracy (NEΔT or NE$\Delta\rho$)
Broad-band channels with 250 m resolution, mostly for clouds, vegetation and surface temperature	0.470 μm	0.445 - 0.495 μm	0.45 %
	0.550 μm	0.525 - 0.575 μm	0.4 %
	0.650 μm	0.625 - 0.675 μm	0.3 %
	0.865 μm	0.840 - 0.890 μm	0.3 %
	11.250 μm	10.0 - 12.5 μm	0.3 K @ 300 K
Narrow-band channels with 1000 m resolution, for ocean colour, vegetation, aerosol	412 nm	20 nm	0.1 %
	443 nm	20 nm	0.1 %
	490 nm	20 nm	0.05 %
	520 nm	20 nm	0.05 %
	565 nm	20 nm	0.05 %
	650 nm	20 nm	0.05 %
	685 nm	20 nm	0.05 %
	765 nm	20 nm	0.05 %
	865 nm	20 nm	0.05 %
	905 nm	20 nm	0.10 %
	940 nm	20 nm	0.10 %
	980 nm	20 nm	0.10 %
	1030 nm	20 nm	0.10 %
	1640 nm	50 nm	0.05 %
	2130 nm	50 nm	0.05 %

MHS	**Microwave Humidity Sounder Unit**
Satellites	**NOAA 18 to 19 - MetOp 1 to 3**
Status (Sept 2006)	**Operational** - Utilisation period: 2005 to ~ 2014 on NOAA, 2006 to ~ 2020 on MetOp
Mission	Humidity sounding in almost all-weather conditions. Also precipitation rate
Instrument type	5-channel MW radiometer
Scanning technique	Cross-track: 90 steps of 16 km s.s.p., swath 2180 km - Along-track: one 16-km line every 8/3 s
Coverage/cycle	Near-global coverage twice/day
Resolution (s.s.p.)	16 km IFOV
Resources	Mass: 63 kg - Power: 93 W - Data rate: 3.9 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisation	Radiometric accuracy (NEΔT)
89.0	2800	V	0.22 K
157.0	2800	V	0.38 K
183.31 ± 3.0	2000	H	0.42 K
183.31 ± 1.0	1000	H	0.57 K
190.311	2000	V	0.45 K

MI	**Meteorological Imager**
Satellites	**COMS-1**
Status (Sept 2006)	**Being designed** – To be utilised in the period 2008 to ~ 2015
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	5-channel VIS/IR radiometer
Coverage/cycle	Full disk in 27 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	1 km IFOV in 1 VIS channel, 4 km IFOV in 4 IR channels
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	**Spectral interval**	**Radiometric accuracy (NEΔT or SNR)**
0.675 μm	0.55 - 0.8 μm	10 @ 5 % albedo, 170 @ 100 % albedo
3.75 μm	3.50 - 4.0 μm	0.10 K @ 300 K
6.75 μm	6.5 - 7.0 μm	0.12 K @ 300 K
10.8 μm	10.3 - 11.3 μm	0.12 K @ 300 K
12 μm	11.5 - 12.5 μm	0.20 K @ 300 K

MIPAS	**Michelson Interferometer for Passive Atmospheric Sounding**
Satellite	**Envisat**
Status (Sept 2006)	**Operational** – Utilised in the period 2002 to ~ 2010
Mission	Chemistry of the high atmosphere. Tracked species: O_3, NO, NO_2, HNO_3, HNO_4, N_2O_5, $ClONO_2$, COF_2, HOCl, CH_4, H_2O, N_2O, CFC's (F11, F12, F22, CCl_4, CF_4), CO, OCS, C_2H_2, C_2H_6, SF_6 and aerosol
Instrument type	Michelson interferometer; range 685-2410 cm^{-1} (4.15-14.6 μm); spectral resolution 0.035 cm^{-1} unapodised; 60000 channels/spectrum; NESR: 50 $nW \cdot cm^{-2} \cdot sr^{-1} \cdot cm$ @ 685 cm^{-1}, 4.2 $nW \cdot cm^{-2} \cdot sr^{-1} \cdot cm$ @ 2410 cm^{-1}
Scanning technique	Limb scanning, fore- and side. 75 s for one vertical scan; 80 scans/orbit, 1145 profiles/day
Coverage/cycle	Global coverage every 3 days for one measurement in every 300 x 300 km^2 cell
Resolution	Vertical: 3 km, in the altitude range 5-150 km. Horizontal effective resolution: ~ 300 km (limb geometry)
Resources	Mass: 320 kg - Power: 210 W - Data rate: 8 Mbps

MIRAS	**Microwave Imaging Radiometer using Aperture Synthesis**
Satellite	**SMOS**
Status (Sept 2006)	**Close to launch** – To be utilised in the period: 2008 to ~ 2010
Mission	Ocean salinity, soil moisture
Instrument type	MW radiometer at 1.413 GHz with synthetic-aperture antenna. Several polarimetric modes.
Scanning technique	Pushbroom. Correlation interferometry is implemented among receiver arrays deployed on the three arms of an "Y" shaped antenna. A swath of 1000 km is implemented
Coverage/cycle	Global coverage in 3 days (soil moisture). Average over more weeks is needed depending on the desired accuracy for salinity measurements
Resolution	50 km basic, to be degraded depending on the desired accuracy for salinity measurements
Resources	Mass: 369 kg - Power: 375 W - Data rate: … kbps

MISR	**Multi-angle Imaging Spectro-Radiometer**
Satellite	**EOS-Terra**
Status (Sept 2006)	**Operational** – Utilised in the period 1999 to ~ 2008
Mission	Bidirectional Reflectance Distribution Function (BRDF), vegetation, aerosol
Instrument type	Assembly of 9 cameras, each one with 4 spectral VIS/NIR channels, each camera with different pointing
Scanning technique	Pushbroom; cross-track: 1500 pixels each camera, swath 360 km; along track: nine viewing angles: nadir, ± 26.1°, ± 45.6°, ± 60.0° and ± 70.5°
Coverage/cycle	Near-global coverage in one week, in daylight.
Resolution (s.s.p.)	Selectable: 275 m or 550 m or 1100 m
Resources	Mass: 148 kg - Power: 131 W - Data rate: 3.3 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
446 nm	.... - ..... nm	.... @ ..... % albedo
558 nm	.... - ..... nm	.... @ ..... % albedo
672 nm	.... - ..... nm	.... @ ..... % albedo
866 nm	.... - ..... nm	.... @ ..... % albedo

MLS	**Microwave Limb Sounder**
Satellite	**EOS-Aura**
Status (Sept 2006)	**Operational** – Utilised in the period 2004 to ~ 2011
Mission	Chemistry of the high atmosphere. Tracked species: BrO, ClO, CO, H_2O, HCl, HCN, HNO_3, HO_2, HOCl, N_2O, O_3, OH, SO_2, temperature and pressure
Instrument type	5-band / 36 sub-bands / 1000 channels millimetre-submillimetre heterodyne radiometer at frequencies 118 GHz (9 bands), 190 GHz (6 bands), 240 GHz (7 bands), 640 GHz (9 bands) and 2500 GHz (5 bands)
Scanning technique	Limb scanning
Coverage/cycle	Global coverage every 3 d for cells of 300 km side
Resolution	Vertical: 1.5 km, in the altitude range 5-120 km. Horizontal effective resolution: ~ 300 km (limb geometry)
Resources	Mass: 490 kg - Power: 550 W - Data rate: 100 kbps

MODIS	**Moderate-resolution Imaging Spectro-radiometer**
Satellites	**EOS-Terra and EOS-Aqua**
Status (Sept 2006)	**Operational** – Utilised in the period 1999 to ~ 2009
Mission	Multi-purpose VIS/IR imagery
Instrument type	36-channel VIS/IR spectro-radiometer
Scanning technique	Swath 2230 km. Whiskbroom scanning: a strip of 19.7 km width along-track is cross-track scanned every 2.956 s. The strip includes 16 parallel lines sampled by 2048 pixel of 1000 m s.s.p., or 32 parallel lines sampled by 4096 pixel of 500 m s.s.p., or 64 parallel lines sampled by 8192 pixel of 250 m s.s.p.
Coverage/cycle	Global coverage nearly twice/day (long-wave channels) or once/day (short-wave channels)
Resolution (s.s.p.)	IFOV: 0.25 km (two channels), 0.5 km (5 channels), 1.0 km (29 channels)
Resources	Mass: 250 kg - Power: 225 W - Data rate: 6.2 Mbps

Central wavelength	Bandwidth	Radiometric accuracy (SNR or NE∆T) at specified NESR	IFOV at s.s.p.
645 nm	50 nm	128 @ 21.8 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	250 m
858 nm	35 nm	201 @ 24.7 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	250 m
469 nm	20 nm	243 @ 35.3 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	500 m
555 nm	20 nm	228 @ 29.0 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	500 m
1240 nm	20 nm	74 @ 5.4 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	500 m
1640 nm	24 nm	275 @ 7.3 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	500 m
2130 nm	50 nm	110 @ 1.0 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	500 m
412 nm	15 nm	880 @ 44.9 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
443 nm	10 nm	838 @ 41.9 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
488 nm	10 nm	802 @ 32.1 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
531 nm	10 nm	754 @ 27.9 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
551 nm	10 nm	750 @ 21.0 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
667 nm	10 nm	910 @ 9.5 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
678 nm	10 nm	1087 @ 8.7 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
748 nm	10 nm	586 @ 10.2 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
870 nm	15 nm	516 @ 6.2 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
905 nm	30 nm	167 @ 10.0 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
936 nm	10 nm	57 @ 3.6 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
940 nm	50 nm	250 @ 15.0 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
1375 nm	30 nm	150 @ 6.0 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
3.750 µm	0.180 µm	0.05 K @ 0.45 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
3.959 µm	0.060 µm	2.00 K @ 2.38 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
3.959 µm	0.060 µm	0.07 K @ 0.67 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
4.050 µm	0.060 µm	0.07 K @ 0.79 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
4.515 µm	0.165 µm	0.25 K @ 0.17 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
4.515 µm	0.067 µm	0.25 K @ 0.59 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
6.715 µm	0.360 µm	0.25 K @ 1.16 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
7.325 µm	0.300 µm	0.25 K @ 2.18 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
8.550 µm	0.300 µm	0.25 K @ 9.58 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
9.730 µm	0.300 µm	0.25 K @ 3.69 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
11.030 µm	0.500 µm	0.05 K @ 9.55 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
12.020 µm	0.500 µm	0.05 K @ 8.94 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
13.335 µm	0.300 µm	0.25 K @ 4.52 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
13.635 µm	0.300 µm	0.25 K @ 3.76 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
13.935 µm	0.300 µm	0.25 K @ 3.11 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
14.235 µm	0.300 µm	0.35 K @ 2.08 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m

MOPITT	**Measurement Of Pollution In The Troposphere**
Satellites	**EOS-Terra**
Status (Sept 2006)	**Operational** – Utilised in the period 1999 to ~ 2008
Mission	Atmospheric chemistry. Tracked species: CO (profile) and CH_4 (total column)
Instrument type	Gas correlation spectrometer; 3 bands, 8 channels. For CO: 4.62 µm (four channels) and 2.33 µm (two channels); for CH_4: 2.26 µm (two channels)
Scanning technique	Cross-track, 29 steps for a total swath of 640 km
Coverage/cycle	Global coverage in 5 days, in daylight
Resolution (s.s.p.)	22 km IFOV
Resources	Mass: 182 kg - Power: 243 W - Data rate: 25 kbps

MSI	**Multi-Spectral Imager**
Satellite	**Sentinel-2 1 and 2**
Status (Sept 2006)	**Being defined** – To be utilised in the period 2012 to ~ 2020
Mission	Land observation, vegetation, territory management and hazards mitigation
Instrument type	12-channel VIS/NIR/SWIR spectro-radiometer
Scanning technique	Pushbroom, swath ≥ 200 km nominally close to nadir, pointable off-track for emergencies
Coverage/cycle	Global coverage in 2 weeks, in daylight. More frequent possible for emergencies
Resolution (s.s.p.)	IFOV: 10 to 60 m. depending on channel (see table)
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	**Bandwidth**	**Radiometric accuracy** (SNR @ specified input radiance)	**IFOV at s.s.p.**
443 nm	20 nm	129 @ 129.11 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	60 m
490 nm	65 nm	154@ 128.00 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	10 m
560 nm	35 nm	168.4 @ 128.00 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	10 m
665 nm	30 nm	142.1 @ 108.00 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	10 m
705 nm	15 nm	117 @ 74.60 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	20 m
740 nm	15 nm	89 @ 68.23 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	20 m
775 nm	20 nm	105 @ 66.70 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	20 m
842 nm	115 nm	174.6 @ 103.00 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	10 m
865 nm	20 nm	72 @ 52.39 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	20 m
940 nm	20 nm	114 @ 8.77 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	60 m
1375 nm	20 nm	50 @ 6.00 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	60 m
1610 nm	90 nm	100 @ 4.00 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	20 m
2190 nm	180 nm	100 @ 1.70 $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	20 m

MSMR	**Multi-frequency Scanning Microwave Radiometer**
Satellite	**IRS-P4 (OceanSat-1)**
Status (Sept 2006)	**Operational** – Utilisation period: 1999 to ~ 2008
Mission	Sea-surface temperature, wind on sea-surface, total-column water vapour over the sea
Instrument type	MW radiometer with 4 frequencies / 8 channels
Scanning technique	Conical: 55° zenith angle; swath: 1360 km - Scan rate: 11.16 scan/min = 36 km/scan
Coverage/cycle	Global coverage once/day
Resolution	Changing with frequency, consistent with an antenna diameter of 80 cm
Resources	Mass: … kg - Power: … W - Data rate: … kbps

Central frequency	**Bandwidth**	**Polarisations**	**Radiometric accuracy (NEΔT)**	**IFOV**	**Pixel**
6.6 GHz	350 MHz	V, H	< 1.0 K	68 x 105 km	50 x 36 km
10.65 GHz	100 MHz	V, H	< 1.0 K	43 x 66 km	50 x 36 km
18.0 GHz	200 MHz	V, H	< 1.0 K	26 x 40 km	25 x 36 km
21.0 GHz	400 MHz	V, H	< 1.0 K	22 x 34 km	25 x 36 km

MSS	**Multi-Spectral Scanner**
Satellite	**Landsat 1 to 5**
Status (Sept 2006)	**Operational** – Utilised in the period 1972 to ~ 2008
Mission	Land and vegetation observation
Instrument type	VIS/NIR radiometer, 6 short-wave channels, one in TIR
Scanning technique	Wiskbroom; 2300 pixel/line; swath 185 km
Coverage/cycle	Global coverage in 16 days, in daylight.
Resolution (s.s.p.)	80 m IFOV
Resources	Mass: 64 kg - Power: 50 W - Data rate: 15 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
0.55 μm	0.50 - 0.60 μm	…….. @ ….. % albedo
0.65 μm	0.60 - 0.70 μm	…….. @ ….. % albedo
0.75 μm	0.70 - 0.80 μm	…….. @ ….. % albedo
0.95 μm	0.80 - 1.10 μm	…….. @ ….. % albedo

MSU-GS	Elektro-GOMS Imager
Satellites	**Elektro-L and follow on**
Status (Sept 2006)	**Being built** -To be utilised from 2007 onward
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	10-channel VIS/IR radiometer
Coverage/cycle	Full disk every 15-30 min.
Resolution (s.s.p.)	4.0 km for the IR channels, 1.0 km for the VNIR channels
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR or NEΔT)
0.57 μm	0.50 - 0.65 μm	200 @ 100 % albedo
0.72 μm	0.65 - 0.80 μm	200 @ 100 % albedo
0.86 μm	0.80 - 0.90 μm	200 @ 100 % albedo
3.75 μm	3.50 - 4.00 μm	0.35 K @ 300 K
6.35 μm	5.70 - 7.00 μm	0.4 K @ 300 K
8.00 μm	7.50 - 8.50 μm	0.1 K @ 300 K
8.70 μm	8.20 - 9.20 μm	0.15 K @ 300 K
9.70 μm	9.20 - 10.2 μm	0.15 K @ 300 K
10.7 μm	10.2 - 11.2 μm	0.15 K @ 300 K
11.7 μm	11.2 - 12.5 μm	0.25 K @ 300 K

MSU-MR	VIS/IR Imaging Radiometer
Satellites	**Meteor-M-1/2**
Status (Sept 2006)	**Being built** – To be utilised in the period 2007 to ~ 2012
Mission	Multi-purpose VIS/IR imagery
Instrument type	6-channel VIS/IR radiometer
Scanning technique	Cross-track: 1540 pixels in line, swath 2800 km - Along-track: six 1-km lines/s
Coverage/cycle	Global coverage twice/day (IR) or once/day (VIS)
Resolution (s.s.p.)	1.0 km IFOV
Resources	Mass: 70 kg - Power: … W - Data rate: 660 kbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR or NEΔT)
0.60 μm	0.50 - 0.70 μm	1000 @ 80 % albedo
0.95 μm	0.80 - 1.10 μm	1000 @ 80 % albedo
1.70 μm	1.60 - 1.80 μm	1000 @ 80 % albedo
3.80 μm	3.50 – 4.10 μm	0.5 K @ 300 K
11.00 μm	10.5 - 11.5 μm	0.15 K @ 300 K
12.00 μm	11.5 - 12.5 μm	0.15 K @ 300 K

MTVZA	Imaging/Sounding Microwave Radiometer
Satellites	**Meteor-M-1/2**
Status (Sept 2006)	**Being built** – To be utilised in the period 2007 to ~ 2012
Mission	Multi-purpose MW imager with temperature/humidity sounding channels for improved precipitation
Instrument type	21-frequency / 29-channel MW radiometer
Scanning technique	Conical: 53.3° zenith angle, swath 1500 km – Scan rate: 24.9 scan/min = 15.8 km/scan
Coverage/cycle	Near-global coverage twice/day
Resolution	From 10 km at 183 GHz to 200 km at 10.6 GHz; consistent with an antenna diameter of 65 cm
Resources	Mass: 80 kg - Power: 80 W - Data rate: 35 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy (NEΔT)	IFOV	Pixel
10.6	100	V, H	0.5 K	89x198 km	32x32 km
18.7	200	V, H	0.4 K	52x160 km	32x32 km
23.8	400	V, H	0.3 K	42x94 km	32x32 km
31.5	400	V, H	0.3 K	35x76 km	32x32 km
36.7	400	V, H	0.3 K	30x67 km	32x32 km
42.0	400	V, H	0.4 K	26x60 km	32x32 km
48.0	400	V, H	0.4 K	24x43 km	32x32 km
52.80	400	V	0.4 K	21x48 km	48x48 km
53.30	400	V	0.4 K	21x48 km	48x48 km
53.80	400	V	0.4 K	21x48 km	48x48 km
54.64	400	V	0.4 K	21x48 km	48x48 km
55.63	400	V	0.4 K	21x48 km	48x48 km
57.290344±0.3222±0.1	50	H	0.4 K	21x48 km	48x48 km
57.290344±0.3222±0.05	20	H	0.7 K	21x48 km	48x48 km
57.290344±0.3222±0.025	10	H	0.9 K	21x48 km	48x48 km
57.290344±0.3222±0.01	5	H	1.3 K	21x48 km	48x48 km
57.290344±0.3222±0.005	3	H	1.7 K	21x48 km	48x48 km
91.655	2500	V, H	0.6 K	14x30 km	16x16 km
183.31 ± 7.0	1500	V	0.5 K	9x21 km	32x32 km
183.31 ± 3.0	1000	V	0.6 K	9x21 km	32x32 km
183.31 ± 1.0	500	V	0.8 K	9x21 km	32x32 km

MVIRI	Meteosat Visible Infra-Red Imager
Satellites	**Meteosat 1 to 7**
Status (Sept 2006)	**Operational** - Utilisation period: 1977 to ~ 2008
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	3-channel VIS/IR radiometer
Coverage/cycle	Full disk every 30 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	IFOV: 5.0 km for IR channels, 2.5 km for the VIS channel
Resources	Mass: 65 kg - Power: 17 W - Data rate: 333 kbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR or NEΔT)
0.70 μm	0.50 - 0.90 μm	3 @ 1 % albedo
6.40 μm	5.70 - 7.10 μm	1.0 K @ 250 K
11.5 μm	10.5 - 12.5 μm	0.5 K @ 300 K

MVISR	Multichannel Visible Infrared Scanning Radiometer
Satellites	**FY-1 A to D**
Status (Sept 2006)	**Operational** – Utilisation period: 1988 to ~ 2007
Mission	Multi-purpose VIS/IR imagery with emphasis on vegetation and ocean colour
Instrument type	10-channel VIS/IR radiometer
Scanning technique	Cross-track: 2048 pixel of 800 m s.s.p., swath 2800 km - Along-track: six 1.1-km lines/s
Coverage/cycle	Global coverage twice/day (IR) or once/day (VIS)
Resolution (s.s.p.)	1.1 km
Resources	Mass: 55 kg - Power: 45 W - Data rate: 1.23 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR or NEΔT)
0.455 μm	0.43 - 0.48 μm	3.0 @ 0.5 % albedo
0.505 μm	0.48 - 0.53 μm	3.0 @ 0.5 % albedo
0.555 μm	0.53 - 0.58 μm	3.0 @ 0.5 % albedo
0.630 μm	0.58 - 0.68 μm	3.0 @ 0.5 % albedo
0.865 μm	0.84 - 0.89 μm	3.0 @ 0.5 % albedo
0.932 μm	0.90 - 0.965 μm	3.0 @ 0.5 % albedo
1.600 μm	1.55 - 1.64 μm	3.0 @ 0.5 % albedo
3.740 μm	3.55 - 3.93 μm	0.40 K @ 300 K
10.80 μm	10.3 - 11.3 μm	0.22 K @ 300 K
12.00 μm	11.5 - 12.5 μm	0.22 K @ 300 K

MWHS	Micro-Wave Humidity Sounder
Satellites	**FY-3 A to G**
Status (Sept 2006)	**Close to be launched** – To be utilised in the period: 2007 to ~ 2023
Mission	Humidity sounding in nearly-all-weather conditions
Instrument type	4-frequency / 5-channel MW radiometer
Scanning technique	Cross-track: 98 steps of 16 km s.s.p., swath 2700 km - Along-track: one 15-km line every 2.667 s
Coverage/cycle	Global coverage twice/day
Resolution (s.s.p.)	15 km IFOV
Resources	Mass: 44 kg - Power: 60 W - Data rate: 7.5 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy (NEΔT)
150	1000	V, H	0.9 K
183.31 ± 7.0	2000	V	0.9 K
183.31 ± 3.0	1000	V	0.9 K
183.31 ± 1.0	500	V	1.1 K

MWR	Micro-Wave Radiometer
Satellites	**ERS-1, ERS-2 and Envisat**
Status (Sept 2006)	**Operational** – Utilised in the period 1991 to ~ 2010
Mission	Water vapour correction for the radar altimeter (RA on ERS-1/2, RA-2 on Envisat)
Instrument type	2-frequency MW radiometer, 23.8 and 36.5 GHz
Scanning technique	Nadir-only viewing, associated to the supported radar altimeter
Coverage/cycle	Global coverage in 1 month for 30 km average spacing, or in 10 days for 100 km average spacing
Resolution (s.s.p.)	20 km
Resources	Mass: 25 kg - Power: 23 W - Data rate: 16.7 kbps

MWR	Micro-Wave Radiometer
Satellites	**Sentinel-3 1 & 2**
Status (Sept 2006)	**Being defined** – To be utilised in the period 2012 to ~ 2020
Mission	Water vapour correction for the radar altimeter (SRAL)
Instrument type	3-channel MW radiometer: 18.7, 23.8 and 36.5 GHz
Scanning technique	Nadir-only viewing, associated to the supported radar altimeter
Coverage/cycle	Global coverage in 1 month for 30 km average spacing, or in 10 days for 100 km average spacing
Resolution (s.s.p.)	20 km
Resources	Mass: … kg - Power: … W - Data rate: … kbps

MWRI	**Micro-Wave Radiation Imager**
Satellites	**FY-3 A to G**
Status (Sept 2006)	**Close to be launched** – To be utilised in the period 2007 to ~ 2023
Mission	Multi-purpose MW imager
Instrument type	6-frequency, 12-channel MW radiometer
Scanning technique	Conical: 53.1° zenith angle, swath 1400 km – Scan rate: 35.3 scan/min = 10 km/scan
Coverage/cycle	Global coverage once/day
Resolution (constant)	Changing with frequency, consistent with an antenna diameter of 90 cm
Resources	Mass: … kg - Power: … W - Data rate: … kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy (NEΔT)	IFOV	Pixel
10.65	180	V, H	0.5 K	51 x 85 km	70 x 70 km
18.7	200	V, H	0.5 K	30 x 50 km	40 x 40 km
23.8	400	V, H	0.8 K	27 x 45 km	30 x 30 km
36.5	900	V, H	0.5 K	18 x 30 km	25 x 25 km
89	4600	V, H	1.0 K	9 x 15 km	12 x 12 km
150	3000	V, H	1.3 K	7.5 x 12 km	10 x 10 km

MWTS	**Micro-Wave Temperature Sounder**
Satellites	**FY-3 A to G**
Status (Sept 2006)	**Close to be launched** – To be utilised in the period 2007 to ~ 2023
Mission	Temperature sounding in nearly-all-weather conditions
Instrument type	4-frequency, 4-channel MW radiometer
Scanning technique	Cross-track: 15 steps of 62 km s.s.p., swath 2250 km - Along-track: one line of 118 km every 16 s
Coverage/cycle	Global coverage once/day
Resolution (s.s.p.)	62 km IFOV
Resources	Mass: … kg - Power: … W - Data rate: … kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisation	Accuracy
50.30	180	V	0.5 K
53.596 ± 0.115	340	H	0.4 K
54.94	400	V	0.4 K
57.290	330	H	0.4 K

OCM	**Ocean Color Monitor**
Satellite	**IRS-P4 (OceanSat-1) and OceanSat-2**
Status (Sept 2006)	**Operational** – Utilisation period: 1999 to ~ 2013
Mission	Ocean colour and aerosol
Instrument type	8-channel VIS/NIR radiometer
Scanning technique	Pushbroom, 6000 pixel/line (3700 useful), swath 1420 km
Coverage/cycle	Global coverage in 2 days, in daylight
Resolution (s.s.p.)	360 m x 236 m IFOV
Resources	Mass: 78 kg - Power: 134 W - Data rate: 20.8 Mbps

Central wavelength	Bandwidth	**Radiometric accuracy** (SNR @ specified NESR)
412 nm	20 nm	1300 @ 0.26 W m^{-2} sr^{-1} μ^{-1}
442 nm	20 nm	1300 @ 0.23 W m^{-2} sr^{-1} μ^{-1}
489 nm	20 nm	1300 @ 0.17 W m^{-2} sr^{-1} μ^{-1}
512 nm	20 nm	1500 @ 0.17 W m^{-2} sr^{-1} μ^{-1}
557 nm	20 nm	1500 @ 0.15 W m^{-2} sr^{-1} μ^{-1}
670 nm	20 nm	1800 @ 0.10 W m^{-2} sr^{-1} μ^{-1}
768 nm	40 nm	1800 @ 0.05 W m^{-2} sr^{-1} μ^{-1}
867 nm	40 nm	2000 @ 0.08 W m^{-2} sr^{-1} μ^{-1}

OCO	Orbiting Carbon Observatory
Satellite	**EOS-Aura**
Status (Sept 2006)	**Being built** – To be utilised in the period 2008 to ~ 2010
Mission	CO_2 profile.
Instrument type	3 NIR/SWIR grating spectrometer, 3 bands, 0.76 µm (O_2), 1.61 and 2.06 µm (CO_2) - 3000 channels total
Scanning technique	Pushbroom, cross-track swath 10 km, 160 pixels/line binned to 10 super-pixels/line. Three pointing modes: nadir, towards sun glint and towards a specific target
Coverage/cycle	Global coverage in one month for cells of 100 km side, in daylight
Resolution (s.s.p.)	1.29 km (cross-track), 2.25 km (along-track
Resources	Mass: 150 kg - Power: 165 W - Data rate: 1 Mbps

Spectral range	Number of channels	Spectral resolution	SNR at specified input radiance (NESR)
758 - 772 nm	1024	0.04 nm	…….. @ ……… $mW \cdot m^{-2} \cdot nm^{-1} \cdot sr^{-1}$
1594 - 1619 nm	1024	0.08 nm	…….. @ ……… $mW \cdot m^{-2} \cdot nm^{-1} \cdot sr^{-1}$
2042 - 2082 nm	1024	0.10 nm	…….. @ ……… $mW \cdot m^{-2} \cdot nm^{-1} \cdot sr^{-1}$

OLCI	Ocean and Land Colour Imager
Satellite	**Sentinel-3 1 & 2**
Status (Sept 2006)	**Planned** – To be utilised in the period 2012 to ~ 2020
Mission	Ocean colour, vegetation, aerosol, cloud properties
Instrument type	16-channel VIS/NIR spectro-radiometer, channel positions and bandwidths selectable
Scanning technique	Pushbroom, 5 side-to-side telescopes, total swath 1270 km. Off-nadir view to avoid sun glint
Coverage/cycle	Global coverage in 2 days, in daylight
Resolution (s.s.p.)	250 to 500 m
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Bandwidth	**Radiometric accuracy** (SNR @ expected input radiance)
413 nm	10 nm	2006
443 nm	10 nm	2087
490 nm	10 nm	1683
510 nm	10 nm	1629
560 nm	10 nm	1481
620 nm	10 nm	1131
665 nm	10 nm	1022
681 nm	7.5 nm	829
709 nm	10 nm	956
754 nm	7.5 nm	673
761 nm	3.75 nm	407
779 nm	15 nm	810
865 nm	20 nm	688
885 nm	10 nm	417
900 nm	10 nm	312
1020 nm	40 nm	TBD

OLI	**Operational Land Imager** (current assumption: similar to ALI)
Satellites	**LDCM**
Status (Sept 2006)	**Planned** – To be utilised in the period 2010 onwards
Mission	Land and vegetation observation
Instrument type	VIS/NIR radiometer, 9 VIS/NIR narrow-band channels, one panchromatic (PAN)
Scanning technique	Pushbroom; 6000 pixel/line (9 narrow-band channels), 18000 pixel/line (PAN); swath 185 km
Coverage/cycle	Global coverage in 16 days, in daylight.
Resolution (s.s.p.)	30 m (9 narrow-band channels), 10 m (PAN)
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
443 nm	433 - 453 nm	.... @ ..... % albedo
482 nm	450 - 515 nm	.... @ ..... % albedo
565 nm	525 - 605 nm	.... @ ..... % albedo
660 nm	630 - 690 nm	.... @ ..... % albedo
790 nm	775 - 805 nm	.... @ ..... % albedo
867 nm	845 - 890 nm	.... @ ..... % albedo
1250 nm	1200 - 1300 nm	.... @ ..... % albedo
1650 nm	1550 - 1750 nm	.... @ ..... % albedo
2215 nm	2080 - 2350 nm	.... @ ..... % albedo
Panchromatic	480 - 690 nm	.... @ ..... % albedo

OMI	**Ozone Monitoring Instrument**
Satellite	**EOS-Aura**
Status (Sept 2006)	**Operational** – Utilised in the period 2004 to ~ 2011
Mission	Ozone profile and total-column or gross profile of other species. Tracked species: BrO, NO_2, O_3, OClO, SO_2 and aerosol
Instrument type	UV/VIS grating imaging spectrometer, three bands, 1560 channels total
Scanning technique	Pushbroom, cross-track swath 2600 km – Zoom mode available, with swath 725 km
Coverage/cycle	Global coverage every day, in daylight
Resolution (s.s.p.)	13 x 24 km^2 associated to 2600 km swath, reduced to 36 x 48 km^2 for profiles. 13 x 12 km^2 in zoom mode
Resources	Mass: 65 kg - Power: 66 W - Data rate: 800 kbps

Spectral range	Number of channels	Spectral resolution	SNR at specified input radiance (NESR)
270 - 314 nm	390	0.42 nm	.... @ .... $mW \cdot m^{-2} \cdot nm^{-1} \cdot sr^{-1}$
306 - 380 nm	390	0.45 nm	.... @ .... $mW \cdot m^{-2} \cdot nm^{-1} \cdot sr^{-1}$
350 - 500 nm	780	0.63 nm	.... @ .... $mW \cdot m^{-2} \cdot nm^{-1} \cdot sr^{-1}$

OMPS	**Ozone Mapping and Profiler Suite**
Satellites	**NPP, NPOESS 1 and 3**
Status (Sept 2006)	**Being built.** Limb component currently not baselined on NPOESS – Utilisation period: 2009 to ~ 2025
Mission	Ozone profile and total-column or gross profile of other species. Tracked species: BrO, HCHO, NO_2, O_3, OClO, SO_2
Instrument type	Three UV/VIS/NIR grating spectrometers for mapping, nadir profiling and limb sounding respectively
Scanning technique	Mapper: cross-track swath 2800 km, along-track one 50-km line in 7.6 s. Nadir profiler: one along-track sounding every 38 s (250 km). Limb sounder: 1-km vertical steps between 10 and 60 km; three adjacent 250-km views, fore- and sides, for a 750 km swath
Coverage/cycle	Global coverage: mapper once/day, nadir profiler in 6 days, limb sounder in 4 days. Daylight only
Resolution (s.s.p.)	Mapper: 50 km. Nadir profiler: 250 km. Limb sounder: about 300 km
Resources	Mass: 56.2 kg - Power: 54 W - Data rate: 180 kbps

Subsystem	Spectral range	Spectral resolution	SNR at specified input radiance
Cross-track mapper for total ozone	300 - 380 nm	1 nm	1000
Nadir-viewing ozone profiler	250 - 310 nm	1 nm	35 (at 250 nm) to 400 (at 310 nm)
Limb scanning	290 - 1000 nm	1.5 to 40 nm	320 (at 290 nm) to 1200 (at 600 nm)

PALSAR	**Phased-Array L-band Synthetic Aperture Radar**
Satellite	**ALOS**
Status (Sept 2006)	**Operational** – To be utilised in the period 2006 to ~ 2010
Mission	High-resolution all-weather soil moisture and ocean surface features observation
Instrument type	L-band SAR, frequency 1.27 GHz, multi-polarisation and variable pointing/resolution
Scanning technique	Side-looking, 10-51° off-nadir, swath 40 to 350 km, depending on operation mode – See table
Coverage/cycle	Global coverage in minimum 2 weeks, depending on operation mode (duty cycle 17.5 min/orbit)
Resolution	7 to 100 m, depending on operation mode – See table
Resources	Mass: … kg - Power: … W - Data rate: 240 Mbps

Operation mode	Resolution	Swath	Polarisation	Incidence angle
Highest resolution	7-44 m	40-70 km	HH or VV	8-60°
High resolution	14-89 m	40-70 km	HH/HV or VV/VH	8-60°
ScanSAR	100 m	250-350 km	HH or VV	18-43°
Polarimetry	24-89 m	30 km	HH/HV + VV/VH	8-30°

PAN	**Panchromatic Camera**
Satellite	**CartoSat-2**
Status (June 2007)	**Operational** – Utilisation period: 2007 to ~ 2012
Mission	Very-high resolution land imagery
Instrument type	Single VNIR channel (0.50-0.85 µm), SNR = ... @ ..... % albedo
Scanning technique	Pushbroom, 12288 pixel/line, swath 9.6 km
Coverage/cycle	Global coverage in 1 year, in daylight
Resolution (s.s.p.)	< 1 m IFOV
Resources	Mass: 120 kg - Power: 60 W - Data rate: 336 Mbps

PAN + MS	**Panchromatic + Multispectral Radiometers** (also known as PSA + RDSA)
Satellite	**Monitor-E**
Status (Sept 2006)	**Operational** – Utilisation period: 2005 to ~ 2008
Mission	Land and vegetation monitoring, Digital Elevation Model (DEM) by in-orbit stereoscopy
Instrument type	Two VIS/NIR radiometers, one panchromatic, one multi-channel
Scanning technique	Pushbroom. PAN: 12000 pixel/line, swath 90 km addressable within an area of regard of 780 km. MS: MS: 8000 pixel/line; swath 160 km addressable within an area of regard of 890 km. Fore- and aft- pointing capability for stereoscopy (by satellite tilting)
Coverage/cycle	Global coverage in 26 days (PAN) or 14 days (MS), in daylight; locally more frequent by strategic pointing
Resolution (s.s.p.)	IFOV: 8 m (PAN), 20 m (MS)
Resources	Mass: 420 kg - Power: 450 W - Data rate: 123 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)	Resolution @ s.s.p.
0.565 µm	0.54 - 0.59 µm	...... @ ..... % albedo	20 m
0.660 µm	0.63 - 0.68 µm	...... @ ..... % albedo	20 m
0.845 µm	0.79 - 0.90 µm	...... @ ..... % albedo	20 m
0.68 µm (PAN)	0.51 - 0.85 µm	...... @ ..... % albedo	8 m

PAN-A, PAN-F	**Panchromatic Cameras**
Satellite	**IRS-P5 (CartoSat-1)**
Status (Sept 2006)	**Operational** – Utilisation period: 2005 to ~ 2010
Mission	Digital Elevation Model (DEM) by in-orbit stereoscopy
Instrument type	Single VNIR channel (0.50-0.85 µm), SNR = 345 @ 55 $mW \cdot cm^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$
Scanning technique	Pushbroom, 12000 pixel/line, swath 30 km; PAN-A aft- view 10°, PAN-F fore- view 26°
Coverage/cycle	Global coverage in 126 days, in daylight
Resolution (s.s.p.)	2.5 m IFOV
Resources	Mass: ... kg - Power: ... W - Data rate: 340 Mbps

POAM	**Polar Ozone and Aerosol Measurement**
Satellites	**SPOT-3** (POAM-2), **SPOT-4** (POAM-3)
Status (Sept 2006)	**Operational** (on SPOT-4) - Utilisation period: 1993 to ~ 2008
Mission	Atmospheric chemistry in high troposphere and stratosphere. Species: H_2O, NO_2, O_2, O_3 and aerosol
Instrument type	9-channel photometer operating in the range 350-1024 nm (POAM-3) or 350-1064 nm (POAM-2)
Scanning technique	Limb scanning in solar occultation; vertical range 10-60 km
Coverage/cycle	N/A (few tens of events/day limited to latitudes above ~ 60°)
Resolution	300 km (horizontal), 0.6 km (vertical)
Resources	Mass: 24.9 kg - Power: ... W - Data rate: ... kbps

POLDER	Polarization and Directionality of the Earth's Reflectances
Satellites	**PARASOL, ADEOS-1, ADEOS-2**
Status (Sept 2006)	**Operational** (on PARASOL) - Utilisation period: 2004 to ~ 2008 (ADEOS-1: 1996-97; ADEOS-2: 2002-03)
Mission	Aerosol, ocean colour, vegetation, Bidirectional Reflectance Distribution Function (BRDF)
Instrument type	9-wavelength radiometer with 3 polarisations at 4 wavelengths (3 in ADEOS) - total: 17 channels
Scanning technique	242 x 274 CCD arrays, 2200 km swath, each earth's spot viewed from more directions as satellite moves
Coverage/cycle	Near-global coverage every day in daylight.
Resolution (s.s.p.)	6 km IFOV (PARASOL), 6.5 km IFOV (ADEOS)
Resources	Mass: 32 kg - Power: 50 W - Data rate: 883 kbps

Central wavelength	Bandwidth	Polarisations	Radiometric accuracy (SNR)
444.5 nm	20 nm	three	…... @ ….. % albedo
444.9 nm	20 nm	none	…... @ ….. % albedo
492.2 nm	20 nm	three	…... @ ….. % albedo
564.5 nm	20 nm	none	…... @ ….. % albedo
670.2 nm	20 nm	three	…... @ ….. % albedo
763.3 nm	10 nm	none	…... @ ….. % albedo
763.1 nm	40 nm	none	…... @ ….. % albedo
860.8 nm	40 nm	three	…... @ ….. % albedo
907.3 nm	20 nm	none	…... @ ….. % albedo

Poseidon 2/3	Poseidon 2/3
Satellites	**Jason-1** (Poseidon -2) and **Jason-2** (Poseidon-3)
Status (Sept 2006)	**Operational** – Utilised in the period 2001 to ~ 2015
Mission	Ocean topography, significant wave height, wind speed
Instrument type	Two-frequency (5.3 and 13.58 GHz) radar altimeter
Scanning technique	Nadir-only viewing, sampling at 30 km intervals along track
Coverage/cycle	Global coverage in 1 month for 30 km average spacing, or in 10 days for 100 km average spacing
Resolution	30 km IFOV
Resources	Mass: 70 kg - Power: 78 W - Data rate: 22.5 kbps

PR	Precipitation Radar
Satellite	**TRMM**
Status (Sept 2006)	**Operational** – Utilised in the period 1997 to ~ 2009
Mission	Vertical profile of precipitation
Instrument type	Imaging radar, frequency 13.8 GHz,
Scanning technique	Electronic scanning, planar array of 128 elements, swath 215 km
Coverage/cycle	Intertropical coverage 1 to 2 times/day depending on latitude (best coverage at 15°N and 15°S)
Resolution (s.s.p.)	Horizontal 4.3 km, vertical 250 m (blind to the lowest ~ 150 m)
Resources	Mass: 465 kg - Power: 250 W - Data rate: 93.2 kbps

PRISM	Panchromatic Remote-sensing Instrument for Stereo Mapping
Satellite	**ALOS**
Status (Sept 2006)	**Operational** – To be utilised in the period 2006 to ~ 2010
Mission	Digital Elevation Model (DEM) by stereoscopy
Instrument type	Single-channel (0.52-0.77 μm) radiometer with three views, fore-, nadir and aft- (± 24° and nadir)
Scanning technique	Push-broom, nadir image 28000 pixel/line / 70 km swath, fore- and aft- 14000 pixel/line / 35 km swath
Coverage/cycle	Global coverage in 46 days for nadir imagery, 96 days for stereoscopy
Resolution (s.s.p.)	2.5 m IFOV for the nadir image
Resources	Mass: … kg - Power: … W - Data rate: 960 Mbps

RA, RA-2	**Radar Altimeter**
Satellites	**ERS-1, ERS-2 and Envisat**
Status (Sept 2006)	**Operational** – Utilised in the period 1991 to ~ 2010
Mission	Ocean topography, significant wave height, wind speed on sea surface
Instrument type	Radar altimeter: RA-2 two-frequencies (3.2 and 13.6 GHz), ERS-1/2 RA single frequency (13.8 GHz)
Scanning technique	Nadir-only viewing, continuous sampling along track
Coverage/cycle	Global coverage in 1 month for 30 km average spacing, or in 10 days for 100 km average spacing
Resolution	20 km IFOV
Resources	Mass: 110 kg - Power: 161 W - Data rate: 100 kbps

Radiomet	**Radio-occultation sounder**
Satellites	**Meteor-M-2**
Status (Sept 2006)	**Being built** – Utilisation period: 2008 to ~ 2012
Mission	Temperature/humidity sounding with highest vertical resolution, space weather
Instrument type	GPS receiver measuring the phase delay due to refraction during occultation between GPS and LEO
Scanning technique	Limb scanning from 830 km to close-to-surface by time sampling – Azimuth 90° fore- and aft-
Coverage/cycle	About 500 soundings/day – Average spacing 1000 km – Global coverage (300 km spacing) in 10 days
Resolution	300 km (horizontal), 0.5-1.0 km (vertical)
Resources	Mass: … kg - Power: … W - Data rate: … bps

ROSA	**Radio Occultation Sounder of the Atmosphere**
Satellites	**OceanSat-2 and SAC-D**
Status (Sept 2006)	**Being built** - To be utilised in the period 2008 to ~ 2013
Mission	Temperature/humidity sounding with highest vertical resolution, space weather
Instrument type	GPS receiver measuring the phase delay due to refraction during occultation between GPS and LEO
Scanning technique	Limb scanning from 700 km to close-to-surface by time sampling – Azimuth: 90° sectors fore- and aft-
Coverage/cycle	About 500 soundings/day – Average spacing 1000 km – Global coverage (300 km spacing) in 10 days
Resolution	About 300 km horizontal, 0.5 km vertical
Resources	Mass: 17 kg - Power: 38 W - Data rate: … kbps

SAPHIR	**Sondeur Atmospherique du Profil d'Humidite Intertropicale par Radiometrie**
Satellite	**Megha-Tropiques**
Status (Sept 2006)	**Planned** - To be utilised in the period 2009 to ~ 2014
Mission	Humidity sounding in nearly-all-weather conditions. Also precipitation
Instrument type	6-channel MW radiometer
Scanning technique	Cross-track: 127 steps of 10 km s.s.p., swath 1700 km - Along-track: one 10-km lines every 1.6 s
Coverage/cycle	Intertropical coverage 2 to 5 times/day depending on latitude (best coverage at 15°N and 15°S)
Resolution (s.s.p.)	10 km IFOV
Resources	Mass: … kg - Power: … W - Data rate: … kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisation	Radiometric accuracy (NEΔT)
183.31 ± 0.2	200	V	2.35 K
183.31 ± 1.1	350	V	1.45 K
183.31 ± 2.8	500	V	1.36 K
183.31 ± 4.2	700	V	1.38 K
183.31 ± 6.8	1200	V	1.03 K
183.31 ± 11	2000	V	1.10 K

SAR	**Advanced Synthetic Aperture Radar (C-band)**
Satellite	**RadarSat 1/2**
Status (Sept 2006)	**Operational** – Utilised in the period 1995 to ~ 2014
Mission	High-resolution all-weather multi-purpose imager for ocean, land and ice
Instrument type	C-band SAR, frequency 5.405 GHz, multi-polarisation and variable pointing/resolution
Scanning technique	Side-looking, possible both to left- and right- end, (alternatively) 20-49° off-nadir, swath 25 to 500 km, depending on operation mode – See table
Coverage/cycle	Global coverage in 4 days for the 'ScanSAR wide' mode (if used 50 % of the time); in longer periods for other operation modes, up to 6 months
Resolution	3 to 100 m, depending on operation mode – See table
Resources	Mass: 705 kg - Power: 1650 W - Data rate: 105 Mbps

Operation mode	Resolution	Swath	Polarisation
Standard	25 x 28 m²	100 km selectable in the range 250-750 km	HH/HV or VV/VH
Fine	10 x 9 m²	50 km selectable in the range 525-750 km	HH/HV or VV/VH
ScanSAR wide	100 x 100 m²	500 km in the range 250-750	HH/HV or VV/VH
ScanSAR narrow	50 x 50 m²	300 km selectable in the range 300-720 km	HH/HV or VV/VH
Polarimetric standard	25 x 28 m²	25 km selectable in the range 250-600 km	VV/HH, HH/HV, VV/VH
Polarimetric fine	11 x 9 m²	25 km selectable in the range 400-600 km	VV/HH, HH/HV, VV/VH
Multi-look fine	11 x 9 m²	50 km selectable in the range 400-750 km	HH or VV
Ultra-fine	3 x 3 m²	20 km selectable in the range 400-550 km	HH or VV

SAR-2000	**Advanced Synthetic Aperture Radar - 2000 (X-band)**
Satellite	**COSMO-SkyMed 1 to 4**
Status (Sept 2006)	**Just launched** – To be utilised in the period 2007 to ~ 2014
Mission	High-resolution all-weather multi-purpose imager for ocean, land and ice
Instrument type	X-band SAR, frequency ~ 9.5 GHz, multi-polarisation and variable swath/resolution
Scanning technique	Side-looking, possible both to left- and right- end, (alternatively) 20-50° off-nadir, swath 30 to 200 km, depending on operation mode – See table
Coverage/cycle	Global coverage in 2 weeks for the 'huge swath' mode (if used 50 % of the time); in longer periods for other operation modes, up to 3 months. The constellation of four COSMO-SkyMed enables to address any selected target every 12 hours, for emergencies
Resolution	1 to 100 m, depending on operation mode – See table
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Operation mode	Resolution	Swath	Polarisation
Spotlight	1 m	frames of size 10 x 10 km²	HH or VV or HV or VH
Stripmap	3-15 m	40 km	HH or VV or HV or VH
ScanSAR wide swath	30 m	100 km	HH or VV or HV or VH
ScanSAR huge swath	100 m	200 km	HH or VV or HV or VH
Stripmap ping-pong	15 m	30 km	HH/HV + VV/VH

SAR-C	**Advanced Synthetic Aperture Radar (C-band)**
Satellite	**GMES 1 A/B (previous name: Sentinel 1)**
Status (Sept 2006)	**Being developed** – To be utilised in the period 2011 to ~ 2018
Mission	High-resolution all-weather multi-purpose imager for ocean, land and ice
Instrument type	C-band SAR, frequency 5.405 GHz, multi-polarisation and variable swath/resolution
Scanning technique	Side-looking, 15-45° off-nadir, swath 80 to 400 km, depending on operation mode – See table
Coverage/cycle	Global coverage in 5 day for the 'Extra-wide swath' mode (duty cycle 70 %); in longer periods for other operation modes (duty cycle 30 %), up to 3 months
Resolution	4 m to 80 m, depending on operation mode – See table
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Operation mode	Resolution	Swath	Polarisation
Stripmap (SM)	4 x 5 m^2	80 km	VV + VH or HH + HV
ScanSAR - Interferometric wide-swath (IW)	5 x 20 m^2	240 km	VV + VH or HH + HV
ScanSAR - Extra-wide swath (EW)	25 x 80 m^2	400 km	VV + VH or HH + HV
Wave (WV)	20 x 5 m^2	20 x 20 km^2 every 100 km	HH or VV

SAR-L	**Advanced Synthetic Aperture Radar (L-band)**
Satellite	**SAOCOM 1/2**
Status (Sept 2006)	**Being developed** – To be utilised in the period 2008 to ~ 2015
Mission	High-resolution all-weather multi-purpose imager for ocean, land (specifically soil moisture) and ice
Instrument type	L-band SAR, frequency 1.275 GHz, multi-polarisation and variable pointing/resolution
Scanning technique	Side-looking, 15-50° off-nadir, swath 30 to 320 km, depending on operation mode – See table
Coverage/cycle	Global coverage in 1 week for the 'wide-swath' mode (if used 50 % of the time); in longer periods for other operation modes, up to 3 months
Resolution	10 to 100 m, depending on operation mode – See table
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Operation mode	Resolution	Swath	Polarisation
High resolution A	10 m	60 km selectable within a range of 320 km	HH or VV
High resolution B	10 m	30 km selectable within a range of 320 km	VV/HH, HH/HV, VV/VH
Medium resolution	20 m	60 km selectable within a range of 320 km	HH or VV
ScanSAR wide swath	100 m	320 km	HH or VV
ScanSAR narrow swath	50 m	120 km selectable within a range of 320 km	HH or VV

SBUV/2	**Solar Backscatter Ultraviolet / 2**
Satellites	**NOAA 9 to 19 except 12 and 15**
Status (Sept 2006)	**Operational** – Utilisation period: 1984 to ~ 2014
Mission	Vertical profile of ozone and other species. Solar irradiance
Instrument type	UV spectro-radiometer. Either 12 discrete 1-nm bandwidth channels selectable in the interval 252 to 340 nm, or continuous sweep from 160 to 340 nm.
Scanning technique	Nadir view only
Coverage/cycle	About 1650 measurements/day. Global coverage (170 km spacing) in 10 days, in daylight
Resolution	170 km
Resources	Mass: … kg - Power: … W - Data rate: … bps

ScaRaB	**Scanner for Radiation Budget**
Satellites	**Megha-Tropiques** (also Meteor-3-7 and Resurs-O1-4)
Status (Sept 2006)	**Planned** - To be utilised in the period 2009 to ~ 2014 (1994-95 on Meteor-3-7, in 1998-99 on Resurs-O1-4)
Mission	Earth radiation budget at Top Of Atmosphere (TOA)
Instrument type	4-channel radiometer, two broad-band, two narrow-band
Scanning technique	Cross-track: 51 pixel/scan, swath 3200 km - Along-track: 1 scan / 6 s
Coverage/cycle	Intertropical coverage 2 to 6 times/day depending on latitude (best coverage at 15°N and 15°S)
Resolution (s.s.p.)	40 km IFOV
Resources	Mass: … kg - Power: … W - Data rate: … kbps

Channel	Spectral interval	Noise Equivalent Radiance	Absolute accuracy	SNR
Short-wave	0.2 - 4.0 μm	< 0.5 W m^{-2} sr^{-1}	1 to 2 %	850
Total radiance	0.2 - 50 μm	< 0.5 W m^{-2} sr^{-1}	1 to 2 %	1000
VIS	0.55 – 0.65 μm	< 1.0 W m^{-2} sr^{-1}	1 to 2 %	120
TIR	10.5-12.5 μm	<0.5 W m^{-2} sr^{-1}	1 to 2 %	60

SCAT	**Scatterometer**
Satellites	**OceanSat-2**
Status (mid-2006)	**Close to launch** – To be utilised in the period 2008-2013
Mission	Sea surface wind vector
Instrument type	Ku-band radar scatterometer (13.52 GHz)
Scanning technique	Conical scanning, two beams, to provide four views of each spot from different angles; swath > 1400 km
Coverage/cycle	Global coverage every day
Resolution	50 km
Resources	Mass: … kg - Power: … W - Data rate: … kbps

SCIAMACHY	**Scanning Imaging Absorption Spectrometer for Atmospheric Cartography**
Satellite	**Envisat**
Status (Sept 2006)	**Operational** – Utilised in the period 2002 to ~ 2010
Mission	Atmospheric chemistry. Tracked species: O_3, O_2, O_4, NO, NO_2, NO_3, N_2O, CO, CO_2, CH_4, H_2O, BrO, ClO, OClO, HCHO, SO_2 and aerosol
Instrument type	UV/VIS/NIR/SWIR grating spectrometer, eight bands, 8192 channels, with 7 polarisation channels
Scanning technique	Cross-track: 16-km cross-track x 32-km along-track, for a swath of 1000 km - One scan line in 4.5 s Limb mode: in addition to vertical scanning, ± 500 km horizontal scanning across track is provided Solar and lunar occultation: in this mode the instrument is self-calibrating (DOAS principle) The three modes are alternative to each other
Coverage/cycle	Cross-track mode: if used full time, it would provide global coverage every 3 days (in daylight) Limb mode: if used full time, it would provide global coverage every 3 days (in daylight) Solar and lunar occultation: N/A
Resolution	Cross-track mode: 16 x 32 km^2 s.s.p. Limb mode: 3 km, in the altitude range 10-100 km, horizontal effective resolution: ~ 300 km (limb geometry) Solar and lunar occultation: 1 km, in the altitude range 10-100 km, horizontal effective resolution: ~ 300 km
Resources	Mass: 198 kg - Power: 122 W - Data rate: 400 kbps

Spectral range	**Number of channels**	**Spectral resolution**	**SNR at specified input radiance**
240-314 nm	1024	0.24 nm	.... @ ....
309-405 nm	1024	0.26 nm	.... @ ....
394-620 nm	1024	0.44 nm	.... @ ....
604-805 nm	1024	0.48 nm	.... @ ....
785-1050 nm	1024	0.54 nm	.... @ ....
1000-1750 nm	1024	1.48 nm	.... @ ....
1940-2040 nm	1024	0.22 nm	.... @ ....
2265-2380 nm	1024	0.26 nm	.... @ ....
310-2380 nm	7	67 to 137 nm, depending on channel	.... @ ....

SeaWiFS	**Sea-viewing Wide Field-of-view Sensor**
Satellite	**SeaStar (now called OrbView-2)**
Status (Sept 2006)	**Operational** – Utilised in the period 1997 to ~ 2009
Mission	Ocean colour (chlorophyll, suspended sediments, yellow matter, ...) and aerosol
Instrument type	8-channel VIS/NIR radiometer
Scanning technique	Cross-track: 2048 pixel of 800 m s.s.p., swath 2800 km - Along-track: six 1.1-km lines/s - Possibility to tilt the instrument to see aft- or fore- along track by 20 degrees to avoid sunglint
Coverage/cycle	Global coverage every day, in daylight
Resolution (s.s.p.)	1.1 IFOV
Resources	Mass: 45 kg - Power: … W - Data rate: 2 Mbps

Central wavelength	Bandwidth	Radiometric accuracy (SNR at specified input radiance)
412 nm	20 nm	499 @ 9.10 mW/cm^2
443 nm	20 nm	674 @ 8.41 mW/cm^2
490 nm	20 nm	667 @ 6.56 mW/cm^2
510 nm	20 nm	640 @ 5.64 mW/cm^2
555 nm	20 nm	596 @ 4.57 mW/cm^2
670 nm	20 nm	442 @ 2.46 mW/cm^2
765 nm	40 nm	455 @ 1.61 mW/cm^2
865 nm	40 nm	467 @ 1.09 mW/cm^2

SeaWinds	SeaWinds
Satellites	**QuikSCAT, ADEOS-2, GCOM-W 2/3**
Status (mid-2006)	**Operational** (on QuikSCAT) - Utilisation period: 1999 to ~ 2008. If GCOM 2/3 approved, 2014 to ~ 2023
Mission	Sea surface wind vector
Instrument type	Ku-band radar scatterometer (13.4 GHz)
Scanning technique	Conical scanning, two beams, to provide four views of each spot from different angles; swath 1800 km
Coverage/cycle	Global coverage every day
Resolution	Best quality: 50 km – standard quality: 25 km – basic sampling: 12.5 km
Resources	Mass: 200 kg - Power: 220 W - Data rate: 40 kbps

Severjanin	Onboard Radar Complex
Satellites	**Meteor-M 1 and 2**
Status (Sept 2006)	**Being built** – Utilisation period: 2007 to ~ 2012
Mission	High-resolution all-weather land observation
Instrument type	X-band SAR, frequency 9.623 GHz
Scanning technique	Side-looking 25-48°, swath 600 km
Coverage/cycle	Global coverage in 1 month (duty cycle 10-20 %)
Resolution	Two modes: 400-500 m or 700-1000 m
Resources	Mass: … kg - Power: … W - Data rate: 10 Mbps

SEVIRI	Spinning Enhanced Visible Infra-Red Imager
Satellites	**Meteosat 8 to 11 (Meteosat Second Generation)**
Status (Sept 2006)	**Operational** - Utilisation period: 2002 to ~ 2019
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	12-channel VIS/IR radiometer (11 narrow-bandwidth, 1 high-resolution broad-bandwidth VIS)
Coverage/cycle	Full disk every 15 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	4.8 km IFOV, 3 km sampling for narrow channels; 1.4 km IFOV, 1 km sampling for broad VIS channel
Resources	Mass: 260 kg - Power: 150 W - Data rate: 3.26 Mbps

Central wavelength	**Spectral interval** (99 % encircled energy)	Radiometric accuracy (SNR or NE∆T)
N/A (broad bandwidth channel)	0.6 – 0.9 μm	4.3 @ 1 % albedo
0.635 μm	0.56 – 0.71 μm	10.1 @ 1 % albedo
0.81 μm	0.74 – 0.88 μm	7.28 @ 1 % albedo
1.64 μm	1.50 – 1.78 μm	3 @ 1 % albedo
3.92 μm	3.48 – 4.36 μm	0.35 K @ 300 K
6.25 μm	5.35 – 7.15 μm	0.75 K @ 250 K
7.35 μm	6.85 – 7.85 μm	0.75 K @ 250 K
8.70 μm	8.30 – 9.10 μm	0.28 K @ 300 K
9.66 μm	9.38 – 9.94 μm	1.50 K @ 255 K
10.8 μm	9.80 - 11.8 μm	0.25 K @ 300 K
12.0 μm	11.0 - 13.0 μm	0.37 K @ 300 K
13.4 μm	12.4 - 14.4 μm	1.80 K @ 270 K

SGLI	Second-generation Global Imager
Satellites	**GCOM-C (3 satellites)**
Status (Sept 2006)	**Being designed** – To be utilised in the period: 2011 to ~ 2024
Mission	Ocean colour, vegetation indexes, aerosol
Instrument type	19-channel radiometer, 17 narrow-bandwidth in VIR/NIR/SWIR and two broadband in the Thermal IR. Two channels with three polarisations, with along-track tilting capability of ± 45°
Scanning technique	VNIR: pushbroom; SWIR/TIR: whiskbroom Swath 1100 km Cross-track: 3 CCD of 2000 pixels each of 250 m s.s.p. (non polarimetric channels) and 1 CCD of 1000 pixels of 1 km s.s.p. (polarimetric channels)
Coverage/cycle	Global coverage in 3 days (in daylight)
Resolution (s.s.p.)	250 m to 1.0 km (see below)
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Bandwidth	Radiometric accuracy (SNR or NEΔT) at specified NESR	IFOV at s.s.p.
380 nm	10 nm	….. @ 60 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	250 m
412 nm	10 nm	….. @ 75 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	250 m
443 nm	10 nm	….. @ 64 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	250 m
490 nm	10 nm	….. @ 53 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	250 m
530 nm	20 nm	….. @ 41 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	250 m
565 nm	20 nm	….. @ 33 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	250 m
670 nm	10 nm	….. @ 23 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	250 m
670 nm	20 nm	….. @ 25 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	250 m
763 nm	8 nm	….. @ 40 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
865 nm	20 nm	…. @ 8 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	250 m
865 nm	20 nm	….. @ 30 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	250 m
670 nm 3 pol	20 nm	….. @ 25 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
865 nm 3 pol	20 nm	….. @ 30 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
1050 nm	20 nm	….. @ 57 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
1380 nm	20 nm	…. @ 8 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
1640 nm	200 nm	…. @ 3 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	250 m
2210 nm	50 nm	……. @ 1.9 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	1000 m
10.8 μm	0.7 μm	…. K @ 300 K	500 m
12.0 μm	0.7 μm	…. K @ 300 K	500 m

SIRAL	SAR Interferometer Radar Altimeter
Satellite	**CryoSat-2**
Status (Sept 2006)	**Being built** – To be utilised in the period 2009 to ~ 2012
Mission	Ice topography, ocean topography, significant wave height, wind speed on sea surface
Instrument type	Single frequency radar altimeter (13.56 GHz), with SAR capability along-track for high spatial resolution, and two cross-track aligned antennas implementing SAR interferometry to capture elevation changes
Scanning technique	No scanning. Several operating modes possible, depending on the target area
Coverage/cycle	Global coverage on high latitudes in 1 month
Resolution	15 km IFOV. When used in SAR mode, the along-track resolution is 250 m
Resources	Mass: 70 kg - Power: 149 W - Data rate: 60 kbps, 12 Mbps (SAR), 24 Mbps (SAR interferometry)

SLSTR	Sea and Land Surface Temperature Radiometer
Satellites	**Sentinel-3 1 & 2**
Status (Sept 2006)	**Planned** – To be utilised in the period 2012 to ~ 2020
Mission	Multi-purpose VIS/IR imagery, with emphasis on very accurate surface temperature for climate
Instrument type	9-channel VIS/IR radiometer with dual viewing directions for accurate atmospheric corrections
Scanning technique	Conical oblique, with cross-nadir swath of 1675 km, fore-viewing swath of 750 km
Coverage/cycle	From 24 h (IR channels in cross-nadir swath, to 4 days (SW channels in dual viewing)
Resolution (s.s.p.)	IFOV: 0.5 km for short-wave channels, 1.0 km for thermal IR
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Bandwidth	Radiometric accuracy (NEΔT or SNR)
0.555 μm	20 nm	20 @ 0.5 % albedo
0.659 μm	20 nm	20 @ 0.5 % albedo
0.865 μm	20 nm	20 @ 0.5 % albedo
1.375 μm	15 nm	20 @ 0.5 % albedo
1.61 μm	60 nm	20 @ 0.5 % albedo
2.25 μm	50 nm	20 @ 0.5 % albedo
3.74 μm	380 nm	0.08 K @ 270 K
10.85 μm	900 nm	0.05 K @ 270 K
12.0 μm	1000 nm	0.05 K @ 270 K

SOUNDER	**GOES Sounder**
Satellites	**GOES 8 to 15**
Status (Sept 2006)	**Operational** – Utilisation period: 1994 to ~ 2015
Mission	Temperature/humidity sounding
Instrument type	19-channel IR radiometer (including one VIS)
Coverage/cycle	Full disk in 8 h, 3000x3000 km² in 42 min, 1000x1000 km² in 5 min
Resolution (s.s.p.)	8.0 km
Resources	Mass: … kg - Power: … W - Data rate: 40 kbps

Wavelength	Wave number	Bandwidth	Radiometric accuracy (SNR or NEΔT)
14.71 μm	680 cm^{-1}	13 cm^{-1}	1.24 K @ 290 K
14.37 μm	696 cm^{-1}	13 cm^{-1}	0.79 K @ 290 K
14.06 μm	711 cm^{-1}	13 cm^{-1}	0.68 K @ 290 K
13.64 μm	733 cm^{-1}	16 cm^{-1}	0.55 K @ 290 K
13.37 μm	748 cm^{-1}	16 cm^{-1}	0.49 K @ 290 K
12.66 μm	790 cm^{-1}	30 cm^{-1}	0.23 K @ 290 K
12.02 μm	832 cm^{-1}	50 cm^{-1}	0.14 K @ 290 K
11.03 μm	907 cm^{-1}	50 cm^{-1}	0.10 K @ 290 K
9.71 μm	1030 cm^{-1}	25 cm^{-1}	0.12 K @ 290 K
7.43 μm	1345 cm^{-1}	55 cm^{-1}	0.06 K @ 290 K
7.02 μm	1425 cm^{-1}	80 cm^{-1}	0.06 K @ 290 K
6.51 μm	1535 cm^{-1}	60 cm^{-1}	0.15 K @ 290 K
4.57 μm	2188 cm^{-1}	23 cm^{-1}	0.20 K @ 290 K
4.52 μm	2210 cm^{-1}	23 cm^{-1}	0.17 K @ 290 K
4.45 μm	2248 cm^{-1}	23 cm^{-1}	0.20 K @ 290 K
4.13 μm	2420 cm^{-1}	40 cm^{-1}	0.14 K @ 290 K
3.98 μm	2513 cm^{-1}	40 cm^{-1}	0.22 K @ 290 K
3.74 μm	2671 cm^{-1}	100 cm^{-1}	0.14 K @ 290 K
0.70 μm	N/A	0.05 μm	……. @ …. % albedo

SOUNDER	**INSAT Sounder**
Satellites	**INSAT-3D**
Status (Sept 2006)	**Being built** – To be utilised in the period 2007 to ~ 2014
Mission	Temperature/humidity sounding
Instrument type	19-channel IR radiometer (including one VIS)
Coverage/cycle	6000 km x 6000 km in 3 h. Smaller areas in correspondingly shorter time intervals
Resolution (s.s.p.)	10.0 km
Resources	Mass: … kg - Power: … W - Data rate: … kbps

Wavelength	Wave number	Bandwidth	Radiometric accuracy (SNR or NEΔT)
14.71 μm	680 cm^{-1}	13 cm^{-1}	1.50 K @ 320 K
14.37 μm	696 cm^{-1}	13 cm^{-1}	1.00 K @ 320 K
14.06 μm	711 cm^{-1}	13 cm^{-1}	0.50 K @ 320 K
13.96 μm	716 cm^{-1}	16 cm^{-1}	0.50 K @ 320 K
13.37 μm	748 cm^{-1}	16 cm^{-1}	0.50 K @ 320 K
12.66 μm	790 cm^{-1}	30 cm^{-1}	0.30 K @ 320 K
12.02 μm	832 cm^{-1}	50 cm^{-1}	0.15 K @ 320 K
11.03 μm	907 cm^{-1}	50 cm^{-1}	0.15 K @ 320 K
9.71 μm	1030 cm^{-1}	25 cm^{-1}	0.20 K @ 320 K
7.43 μm	1345 cm^{-1}	55 cm^{-1}	0.20 K @ 320 K
7.02 μm	1425 cm^{-1}	80 cm^{-1}	0.20 K @ 320 K
6.51 μm	1535 cm^{-1}	60 cm^{-1}	0.20 K @ 320 K
4.57 μm	2188 cm^{-1}	23 cm^{-1}	0.15 K @ 320 K
4.52 μm	2210 cm^{-1}	23 cm^{-1}	0.15 K @ 320 K
4.45 μm	2248 cm^{-1}	23 cm^{-1}	0.15 K @ 320 K
4.13 μm	2420 cm^{-1}	40 cm^{-1}	0.15 K @ 320 K
3.98 μm	2513 cm^{-1}	40 cm^{-1}	0.15 K @ 320 K
3.74 μm	2671 cm^{-1}	100 cm^{-1}	0.15 K @ 320 K
0.695 μm	N/A	0.05 μm	1000 @ 100 % albedo

SOUNDER TBD	**MTSAT-FO Infra-Red Sounder**
Satellites	**MTSAT-3 and follow-on**
Status (Sept 2006)	**Being defined** - To be utilised from 2017 onward
Mission	Temperature/humidity sounding and wind profile derivation by tracking water vapour features
Instrument type	TBD - User requirement imply using a spectrometer. Feasibility not yet confirmed
Coverage/cycle	Full disk in 60 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	TBD
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Spectral range (cm^{-1})	Spectral range (μm)	Spectral resolution	Radiometric accuracy (NEΔT)
700 - 1210 cm^{-1}	14.3 - 8.26 μm	0.625 cm^{-1}	0.2-0.5 K @ 280 K
1600 - 2175 cm^{-1}	6.25 – 4.6 μm	0.625 cm^{-1}	0.2-0.8 K @ 280 K

SRAL	**SAR Radar Altimeter**
Satellites	**Sentinel-3 1 & 2**
Status (Sept 2006)	**Planned** – To be utilised in the period 2012 to ~ 2020
Mission	Ocean and ice topography, significant wave height, wind speed on sea surface
Instrument type	Dual-frequency radar altimeter (5.3 and 13.58 GHz); SAR capability along-track for high spatial resolution
Scanning technique	No scanning. SAR mode possible to be activated, depending on the target area
Coverage/cycle	Global coverage in 1 month for 30 km average spacing, or in 10 days for 100 km average spacing
Resolution	20 km IFOV. When used in SAR mode, the along-track resolution is 300 m
Resources	Mass: … kg - Power: … W - Data rate: … kbps, … Mbps (SAR)

SSM/I	**Special Sensor Microwave - IMAGER**
Satellites	**DMSP F 8, 10, 11, 13, 14 and 15**
Status (Sept 2006)	**Operational** – Utilisation period: 1987 to ~ 2007
Mission	Multi-purpose MW imager
Instrument type	4-frequency, 7-channel MW radiometer
Scanning technique	Conical: 53.1° zenith angle, swath 1400 km – Scan rate: 31.9 scan/min = 12.5 km/scan
Coverage/cycle	Global coverage once/day
Resolution (constant)	Changing with frequency, consistent with an antenna diameter of 61 x 66 cm
Resources	Mass: 48.5 kg - Power: 45 W - Data rate: … kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy (NEΔT)	IFOV	Pixel
19.35	400	V, H	0.43 K	45 x 68 km	25.0 x 12.5 km
22.235	400	V	0.73 K	40 x 60 km	25.0 x 12.5 km
37.0	1500	V, H	0.38 K	24 x 36 km	25.0 x 12.5 km
85.5	3000	V, H	0.71 K	11 x 16 km	12.5 x 12.5 km

SSMIS	Special Sensor Microwave – Imager/Sounder
Satellites	DMSP F 16 and DMSP S 17 to 20
Status (Sept 2006)	**Operational** – Utilisation period: 2003 to ~ 2017
Mission	Multi-purpose MW imager with temperature/humidity sounding channels for improved precipitation
Instrument type	21-frequency, 24-channel MW radiometer
Scanning technique	Conical: 53.1° zenith angle, swath 1700 km – Scan rate: 31.9 scan/min = 12.5 km/scan
Coverage/cycle	Global coverage once/day
Resolution (constant)	Changing with frequency, consistent with an antenna diameter of 61 x 66 cm
Resources	Mass: 96 kg - Power: 135 W - Data rate: 14.2 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy (NEΔT)	IFOV	Pixel
19.35	400	V, H	0.7 K	45 x 68 km	25.0 x 12.5 km
22.235	400	V	0.7 K	40 x 60 km	25.0 x 12.5 km
37.0	1500	V, H	0.5 K	24 x 36 km	25.0 x 12.5 km
50.3	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
52.8	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
53.596	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
54.4	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
55.5	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
57.29	350	-	0.5 K	18 x 27 km	37.5 x 12.5 km
59.4	250	-	0.6 K	18 x 27 km	37.5 x 12.5 km
60.792668 ± 0.357892 ± 0.050	120	V + H	0.7 K	18 x 27 km	37.5 x 12.5 km
60.792668 ± 0.357892 ± 0.016	32	V + H	0.6 K	18 x 27 km	75.0 x 12.5 km
60.792668 ± 0.357892 ± 0.006	12	V + H	1.0 K	18 x 27 km	75.0 x 12.5 km
60.792668 ± 0.357892 ± 0.002	6	V + H	1.8 K	18 x 27 km	75.0 x 12.5 km
60.792668 ± 0.357892	3	V + H	2.4 K	18 x 27 km	75.0 x 12.5 km
63.283248 ± 0.285271	3	V + H	2.4 K	18 x 27 km	75.0 x 12.5 km
91.655	3000	V, H	0.9 K	10 x 15 km	12.5 x 12.5 km
150	1500	H	0.9 K	.... x .... km	37.5 x 12.5 km
183.31 ± 6.6	1500	H	1.2 K	.... x .... km	37.5 x 12.5 km
183.31 ± 3.0	1000	H	1.0 K	.... x .... km	37.5 x 12.5 km
183.31 ± 1.0	500	H	1.2 K	.... x .... km	37.5 x 12.5 km

S-VISSR	Stretched Visible and Infrared Spin Scan Radiometer
Satellites	FY-2 A to G
Status (Sept 2006)	**Operational** – Utilisation period: 1997 to ~ 2018
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	5-channel VIS/IR radiometer
Coverage/cycle	Full disk every 30 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	5.0 km for IR channels; 1.25 km for the VIS channel
Resources	Mass: ... kg - Power: ... W - Data rate: ... Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR or NEΔT)
0.77 μm	0.55 - 0.99 μm	1.5 @ 0.5 % albedo
3.75 μm	3.50 - 4.00 μm	0.4 K @ 300 K
6.95 μm	6.30 - 7.60 μm	0.5 K @ 300 K
10.8 μm	10.3 - 11.3 μm	0.3 K @ 300 K
12.0 μm	11.5 - 12.5 μm	0.3 K @ 300 K

TANSO-CAI	Thermal And Near infrared Sensor for carbon Observations - Cloud and Aerosol Imager
Satellite	**GOSAT**
Status (Sept 2006)	Under development – To be utilised in the period 2008 to ~ 2013
Mission	Cloud and aerosol observation
Instrument type	4-channel UV/ VIS/NIR/SWIR radiometer
Scanning technique	Push-broom, 2000 pixel/line (three VNIR channels), 500 pixels/line (SWIR channel); 1000 km swath
Coverage/cycle	Global coverage in 3 days
Resolution (s.s.p.)	0.5 km IFOV in VNIR, 1.5 km in SWIR
Resources	Mass: 40 kg - Power: 100 W - Data rate: ... Mbps

Central wavelength	Bandwidth	Radiometric accuracy (SNR)
380 nm	20 nm	200 @ 15 % albedo
674 nm	20 nm	200 @ 11 % albedo
870 nm	20 nm	200 @ 11 % albedo
1600 nm	90 nm	200 @ 10 % albedo

TANSO-FTS	Thermal And Near infrared Sensor for carbon Observations - Fourier Transform Spectrometer
Satellite	**GOSAT**
Status (Sept 2006)	Under development – To be utilised in the period 2008 to ~ 2013
Mission	Measurements of CO_2, CH_4 and other species
Instrument type	4–band SWIR/TIR interferometer
Scanning technique	Cross-track mechanical pointing, swath 790 km
Coverage/cycle	Global coverage in 3 days
Resolution (s.s.p.)	10.5 km IFOV
Resources	Mass: 250 kg - Power: 310 W - Data rate: ... Mbps

Spectral range (μm)	Spectral range (cm^{-1})	**Spectral resolution** (unapodised)	Radiometric accuracy (NEΔT or SNR)
14.28 - 5.55 μm	700 - 1800 cm^{-1}	0.2 cm^{-1}	..... K @ 280 K
1.92 – 2.08 μm	4800 - 5200 cm^{-1}	0.2 cm^{-1}	300 @ 30 % albedo
1.56 – 1.72 μm	5800 - 6400 cm^{-1}	0.2 cm^{-1}	300 @ 30 % albedo
0.757 – 0.775 μm	12900 - 13200 cm^{-1}	0.5 cm^{-1}	300 @ 30 % albedo

TES	Tropospheric Emission Spectrometer
Satellite	**EOS-Aura**
Status (Sept 2006)	**Operational** – Utilised in the period 2004 to ~ 2011
Mission	Atmospheric chemistry. Tracked species: CFC-11, CFC12, CH_4, CO, CO_2, H_2O, HCl, HDO, HNO_3, N_2, N_2O, NH_3, NO, NO_2, O_3, OCS, SO_2 and aerosol
Instrument type	IR imaging interferometer, four bands, 40540 channels (cross-track mode) or 162162 channels (limb mode)
Scanning technique	Cross-track mode: array of 16 detectors of 0.53 x 0.53 km^2 IFOV s.s.p. moving in 10 steps to cover a FOV of 5.3 x 8.5 km^2 that can be pointed everywhere within a cone of 45° aperture or a swath of 885 km. Limb mode: each detector subtends a 2.3 km IFOV at the lowest altitude (surface); the 16 detectors simultaneously observe a range of altitudes of 37 km; the 10 transverse steps cover 23 km (horizontal). The two modes are alternative to each other.
Coverage/cycle	Cross-track mode: if used full time and exploiting strategic pointing, in 16 days (the orbital repeat cycle) a global coverage could be obtained for cells of ~ 80-km side. Limb mode: if used full time, it would provide global coverage every 3 days (for cells of 300-km side).
Resolution	Cross-track mode: 0.53 x 0.53 km^2 s.s.p. Limb mode: 2.3 km in the altitude range 0-37 km; horizontal effective resolution: ~ 300 km (limb geometry)
Resources	Mass: 385 kg - Power: 334 W - Data rate: 4.5 Mbps

Spectral range (μm)	Spectral range (cm^{-1})	Spectral resolution (unapodised)	Accuracy (NEΔT)
11.11 - 15.38 μm	650 - 900 cm^{-1}	0.059 cm^{-1} (nadir view), 0.015 cm^{-1} (limb mode)	……… K @ 280 K
8.70 - 12.20 μm	820 - 1150 cm^{-1}	0.059 cm^{-1} (nadir view), 0.015 cm^{-1} (limb mode)	……… K @ 280 K
5.13 - 9.09 μm	1100 - 1950 cm^{-1}	0.059 cm^{-1} (nadir view), 0.015 cm^{-1} (limb mode)	……… K @ 280 K
3.28 - 5.26 μm	1900 - 3050 cm^{-1}	0.059 cm^{-1} (nadir view), 0.015 cm^{-1} (limb mode)	……… K @ 280 K

TIM	Total Irradiance Monitoring
Satellites	**SORCE and Glory**
Status (Sept 2006)	**Operational** (on SORCE); to be launched (on Glory) – Utilised from 2003 until ~ 2012
Mission	Total solar irradiance monitoring
Instrument type	Assemblage of 4 active cavity radiometers. Range: 0.2-10 μm.
Scanning technique	Sun pointing during orbital movement, data sampled every 2 min
Coverage/cycle	One measurement after integration on all data taken during the diurnal orbit arc; thus 100 min
Resolution (s.s.p.)	N/A (sun pointing)
Resources	Mass: 7.9 kg - Power: 14 W - Data rate: 539 bps

TM	Thematic Mapper
Satellites	**Landsat 4 and 5**
Status (Sept 2006)	**Operational** – Utilised in the period 1982 to ~ 2008
Mission	Land and vegetation observation
Instrument type	VIS/NIR radiometer, 6 short-wave channels, one in TIR
Scanning technique	Wiskbroom; 6000 pixel/line (6 short-wave channels), 1500 pixel/line (TIR); swath 185 km
Coverage/cycle	Global coverage in 16 days, in daylight.
Resolution (s.s.p.)	30 m (6 short-wave channels), 120 m (TIR)
Resources	Mass: 258 kg - Power: 332 W - Data rate: 85 Mbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
0.48 μm	0.45 - 0.52 μm	60 @ ….. % albedo
0.56 μm	0.52 - 0.60 μm	60 @ ….. % albedo
0.66 μm	0.63 - 0.69 μm	46 @ ….. % albedo
0.83 μm	0.76 - 0.90 μm	46 @ ….. % albedo
1.65 μm	1.55 - 1.75 μm	36 @ ….. % albedo
2.20 μm	2.08 - 2.35 μm	28 @ ….. % albedo
11.45 μm	10.4 - 12.5 μm	0.5 K @ 300 K

TMI	TRMM Microwave Imager
Satellite	**TRMM**
Status (Sept 2006)	**Operational** – To be utilised in the period 1997 to ~ 2009
Mission	Multi-purpose MW imager, with emphasis on precipitation
Instrument type	MW radiometer with 5 frequencies / 9 channels
Scanning technique	Conical: 53° zenith angle; useful swath: 760 km - Scan rate: 32 scan/min = 12.8 km/scan
Coverage/cycle	Intertropical coverage 1 to 2 times/day depending on latitude (best coverage at 15°N and 15°S)
Resolution	Changing with frequency, consistent with an antenna diameter of 61 x 66 cm
Resources	Mass: 65 kg - Power: 50 W - Data rate: 8.8 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy (NEΔT)	IFOV	Pixel
10.65	100	V, H	0.6 K	37 x 63 km	24 x 25.6 km
19.35	500	V, H	0.7 K	18 x 30 km	12 x 12.8 km
21.3	200	V	0.9 K	18 x 23 km	12 x 12.8 km
37.0	2000	V, H	0.4 K	9 x 16 km	6 x 12.8 km
85.5	3000	V, H	0.7 K	5 x 7 km	3 x 6.4 km

TOU/SBUS	Total Ozone Unit and Solar Backscatter Ultraviolet Sounder
Satellites	**FY-3 A to G**
Status (Sept 2006)	**Close to launch** – Utilisation period: 2007 to ~ 2023
Mission	Ozone total column and vertical profile
Instrument type	Two UV spectro-radiometers. TOU with 6 channels of 1.2 nm bandwidth in the range 308-360 nm, SBUS with 12 discrete channels of 1.15 nm bandwidth in the range 252-340 nm
Scanning technique	TOU cross-track scanning, swath 3000 km, SBUS nadir view only
Coverage/cycle	TOU: global coverage once/day. SBUS: global coverage (200 km spacing) in 7 days. Daylight
Resolution	50 km for total ozone from TOU, 200 km for ozone profile from SBUS
Resources	Mass: … kg - Power: … W - Data rate: … kbps

TSIS	Total Solar Irradiance Sensor
Satellites	**NPOESS 2 & 4**
Status (Sept 2006)	**Not in current baseline** - If remanifested, to be utilised from 2016 until ~ 2027
Mission	Total solar irradiance monitoring, and also spectral solar irradiance in UV/VIS/NIR/SWIR
Instrument type	Assemblage of 4 active cavity radiometers for total irradiance (TIM, range 0.2-10 μm), plus a prism spectrometer for spectral irradiance (SIM, range 0.2-2.0 μm, spectral resolution from 0.25 to 33 nm)
Scanning technique	Sun pointing during orbital movement, data sampled every 2 min
Coverage/cycle	One measurement after integration on all data taken during the diurnal orbit arc; thus 100 min
Resolution (s.s.p.)	N/A (sun pointing)
Resources	TIM: mass 7.9 kg, power 14 W, data rate 539 bps – SIM: mass 22 kg, power 25.3 W, data rate …... kbps

Végétation	Végétation
Satellites	**SPOT-4, SPOT-5**
Status (Sept 2006)	**Operational** - Utilisation period: 1998 to ~ 2009
Mission	Vegetation observation
Instrument type	4-channel VIS/NIR/SWIR radiometer
Scanning technique	Bushbroom, 1728 pixel/line, swath 2200 km
Coverage/cycle	Near-global coverage in one day
Resolution (s.s.p.)	1.15 km IFOV
Resources	Mass: 152 kg - Power: 200 W - Data rate: 510 kbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR)
0.450 μm	0.43 – 0.47 μm	…... @ ….. % albedo
0.645 μm	0.61 – 0.68 μm	…... @ ….. % albedo
0.835 μm	0.78 – 0.89 μm	…... @ ….. % albedo
1.645 μm	1.58 – 1.75 μm	…... @ ….. % albedo

VHRR (in GEO)	Very High Resolution Radiometer
Satellites	**INSAT-1 A/B/C/D, INSAT-2 A/B/D/E, INSAT-3A, Kalpana**
Status (Sept 2006)	**Operational** – Utilisation period: 1982 to ~ 2012
Mission	Multi-purpose VIS/IR imagery and wind derivation by tracking clouds and water vapour features
Instrument type	3-channel VIS/IR radiometer
Coverage/cycle	Full disk every 3 hours, more frequently on demand. Half-hourly triplets around 00 and 12 UT for winds
Resolution (s.s.p.)	8.0 km for IR channels; 2 km for the VIS channel
Resources	Mass: … kg - Power: … W - Data rate: … kbps

Central wavelength	Spectral interval	Radiometric accuracy (SNR or NEΔT)
0.65 μm	0.55 - 0.75 μm	> 6 @ 2.5 % albedo
6.40 μm	5.70 - 7.10 μm	0.50 K @ 300 K
11.5 μm	10.5 - 12.5 μm	0.25 K @ 300 K

VIIRS	**Visible/Infrared Imager Radiometer Suite**
Satellites	**NPP, NPOESS 1 to 4**
Status (Sept 2006)	**Being built** – Utilisation period: 2009 to ~ 2027
Mission	Multi-purpose VIS/IR imagery, including ocean colour
Instrument type	22-channel VIS/IR radiometer, including a day/night 0.7 μm channel
Scanning technique	Cross-track: 16 parallel lines sampled by 2048 pixel of 800 m s.s.p. and 32 parallel lines sampled by 4096 pixel of 400 m s.s.p.; swath 3000 km. Along-track: one 11.9-km strip of 16 or 32 lines in 1.786 s.
Coverage/cycle	Global coverage twice/day (IR) or once/day (VIS)
Resolution (s.s.p.)	400 m for five AVHRR-like channels and the VIS day/night channel, 800 m for all other channels
Resources	Mass: 252 kg - Power: 186 W - Data rate: 5.9 Mbps

Channel set and resolution	**Central wavelength**	**Bandwidth or spectral interval**	**Radiometric accuracy (SNR or NEΔT)**	
			High or single gain	Low gain
High-quality radiometric channels, resolution 800 m	412 nm	20 nm	352 @ 45 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	316 @ 155 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$
	445 nm	18 nm	380 @ 40 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	409 @ 146 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$
	488 nm	20 nm	416 @ 32 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	414 @ 123 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$
	555 nm	20 nm	362 @ 21 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	315 @ 90 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$
	672 nm	20 nm	242 @ 10 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	360 @ 68 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$
	746 nm	15 nm	199 @ 9.6 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	
	865 nm	39 nm	215 @ 6.4 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	340 @ 33.4 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$
	1240 nm	20 nm	101 @ 5.4 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	
	1378 nm	15 nm	83 @ 6.0 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	
	1610 nm	60 nm	342 @ 7.3 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	
	2250 nm	50 nm	10 @ 0.12 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	
	3.70 μm	0.18 μm	0.40 K @ 270 K	
	4.05 μm	0.155 μm	0.11 K @ 300 K	0.42 K @ 380 K
	8.55 μm	0.30 μm	0.09 K @ 270 K	
	10.763 μm	1.00 μm	0.07 K @ 300 K	
	12.013 μm	0.95 μm	0.07 K @ 300 K	
Day/night band, resolution 800 m	0.7 μm	0.5 - 0.9 μm	5 @ 6.70 E-5	
High-resolution imaging channels, resolution 400 m	0.64 μm	0.60 - 0.68 μm	119 @ 22 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	
	0.865 μm	0.845 - 0.884 μm	150 @ 25 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	
	1.61 μm	1.58 - 1.64 μm	6 @ 7.3 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$	
	3.74 μm	3.55 - 3.93 μm	2.50 K @ 270 K	
	11.45 μm	10.5 - 12.4 μm	1.50 K @ 210 K	

VIRR	**Visible and Infra Red Radiometer**
Satellites	**FY-3 A to G**
Status (Sept 2006)	**Close to launch** – Utilisation period: 2007 to ~ 2023
Mission	Multi-purpose VIS/IR imagery with emphasis on vegetation and ocean colour
Instrument type	10-channel VIS/IR radiometer
Scanning technique	Cross-track: 2048 pixel of 800 m s.s.p., swath 2800 km - Along-track: six 1.1-km lines/s
Coverage/cycle	Global coverage twice/day (IR) or once/day (VIS)
Resolution (s.s.p.)	1.1 km IFOV
Resources	Mass: … kg - Power: … W - Data rate: … Mbps

Central wavelength	Spectral interval	Radiometric accuracy (NEΔρ or NEΔT)
0.455 μm	0.43 - 0.48 μm	0.05 %
0.505 μm	0.48 - 0.53 μm	0.05 %
0.555 μm	0.53 - 0.58 μm	0.05 %
0.630 μm	0.58 - 0.68 μm	0.10 %
0.865 μm	0.84 – 0.89 μm	0.10 %
1.360 μm	1.325 - 1.395 μm	0.19 %
1.600 μm	1.55 - 1.64 μm	0.15 %
3.740 μm	3.55 - 3.93 μm	0.3 K @ 300 K
10.80 μm	10.3 - 11.3 μm	0.2 K @ 300 K
12.00 μm	11.5 - 12.5 μm	0.2 K @ 300 K

VIRS	**Visible and Infra-Red Scanner**
Satellites	**TRMM**
Status (Sept 2006)	**Operational** – To be utilised in the period 1997 to ~ 2009
Mission	Multi-purpose VIS/IR imagery
Instrument type	5-channel VIS/IR radiometer
Scanning technique	Cross-track: 256 pixel of 1.6 km s.s.p., swath 720 km - Along-track: 240 lines/min, 1.7 km/scan
Coverage/cycle	Intertropical coverage 1 to 2 times/day depending on latitude (best coverage at 15°N and 15°S)
Resolution (s.s.p.)	2.0 km IFOV
Resources	Mass: 34.5 kg - Power: 40 W - Data rate: 50 kbps

Central wavelength	Spectral interval	Radiometric accuracy (NEΔT or SNR)
0.630 μm	0.58 - 0.68 μm	9 @ 0.5 % albedo
1.61 μm	1.58 - 1.64 μm	20 @ 0.5 % albedo
3.74 μm	3.55 - 3.93 μm	0.12 K @ 300 K
10.80 μm	10.3 - 11.3 μm	0.12 K @ 300 K
12.00 μm	11.5 - 12.5 μm	0.12 K @ 300 K

WindSat	**WindSat**
Satellite	**Coriolis**
Status (Sept 2006)	**Operational** – Utilised in the period 2003 to ~ 2009
Mission	Demonstration of sea surface wind vector observation by polarimetric passive radiometry. Also sea-surface temperature, precipitation, ice, snow and soil moisture index
Instrument type	5-frequency, 22-channel MW radiometer; three channels with full polarimetric capability
Scanning technique	Conical: 50-55° zenith angle, swath 1000 km – Scan rate: 31.6 scan/min = 12.5 km/scan
Coverage/cycle	Global in 1.5 days
Resolution (constant)	Changing with frequency, consistent with antenna diameters of 1.83 m
Resources	Mass: 341 kg - Power: 350 W - Data rate: 35 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy (NEΔT)	IFOV	Pixel
6.8	125	V, H	.... K	40 x 60 km	40 x 50 km
10.7	300	V, H, P, M, L, R	.... K	25 x 38 km	20 x 25 km
18.7	750	V, H, P, M, L, R	.... K	16 x 27 km	10 x 25 km
23.8	500	V, H	.... K	12 x 20 km	10 x 12.5 km
37.0	2000	V, H, P, M, L, R	.... K	8 x 13 km	5 x 12.5 km

(*) Polarisations: H = horizontal, V = vertical, P = + 45°, M = - 45°, L = left-hand circular, R = right-hand circular