CGMS

CGMS-43 ESA-WP-01
Draft, 27 April 2015

Prepared by ESA
Agenda Item: D
Discussed in Plenary

STATUS OF THE CURRENT AND FUTURE ESA EARTH OBSERVATION MISSIONS AND PROGRAMMES

CGMS is informed of the status of the current European Space Agency Earth Observation missions. Two of them, MSG and MetOp are in co-operation with EUMETSAT. The Gravity field and steady-state Ocean Circulation Explorer, GOCE, the first Explorer satellite launched on 17 March 2009, ended its mission in November 2013, exceeding its predicted lifetime. The SMOS satellite was launched on 2 November 2009. All reprocessed Level 1 and 2 data are available from the ESA Cal/Val portal since mid-March 2012. The CryoSat-2 satellite was launched on 8 April 2010. Release of systematic CryoSat products (Level 1b and 2) to scientific community is going on. The Proba-V small satellite was launched on 7 May 2013. Its coarse resolution imager continues the data acquisition of the Vegetation payload on-board SPOT-4 and 5. The Swarm satellites were launched on 22 November 2013. About 4,000 data user projects worldwide use data from the ESA EO missions and this number is increasing further. The total volume of ESA EO mission data exceeds 100 Terabytes per year, available to users free of charge.

CGMS is further informed of the status of the future European Space Agency Earth Observation missions. Two of them, MTG and Post EPS (now EPS SG) are in co-operation with EUMETSAT. The Living Planet Programme has three lines of implementation: Earth Explorer satellites, Earth Watch satellites plus services and applications demonstration. Progress in the preparation of the forthcoming Explorer missions ADM-Aeolus, EarthCARE and BIOMASS is described.

Copernicus represents the major new initiative of European efforts in Earth Observation. The start of the Copernicus pre-operational services took place in 2008, with the provision of the relevant data. The first Copernicus dedicated satellite ("Sentinel-1A") was launched on 3 April 2014, other Sentinels will follow in 2015 onwards. Sentinel missions are developed in partnership with the European Union.

CGMS is also informed of the status of the Earth Watch Programme Element, Global Monitoring of Essential Climate Variables (also known as the 'ESA Climate Change Initiative' or CCI). The CCI Programme has continued to progress well. The thirteen existing project teams have made significant progress on algorithm development and on specifying a future operational system. The Programme achieved its phase 1 objectives end-2013 and continues in Phase 2 starting since early 2014.

Status of the Current and Future ESA Earth Observation Missions and Programmes

1 INTRODUCTION

This paper provides information on the status of the current and future European Space Agency Earth Observation missions. ESA's Living Planet Programme comprises a science and research element, which includes the Earth Explorer missions, and an Earth Watch element, which is designed to facilitate the delivery of Earth observation data for use in operational services. Earth Watch includes the well-established meteorological missions with the European Organisation for the Exploitation of Meteorological Satellites (Eumetsat). These missions (MSG, MTG, MetOp and EPS-SG) are not dealt with in this report.

Current in-flight missions include three R&D satellites from the Earth Explorer series, and two small satellites of the Proba series. The status of future Earth Explorer and Earth Watch missions is presented, as well as the progress in the development of the ESA Climate Change Initiative (CCI).

Although the past ESA ERS-1, ERS-2, Envisat and GOCE missions are no longer operating, thousands of users still access the large ESA on-line archives to get products generated from their respective instrument complements.

2 CURRENT ESA SATELLITE SYSTEMS

Satellites	Equator Crossing Time Altitude	Launch date	Access to data or products	Instruments	Status, applications and other information
PROBA-1	7:30 (D) 615 km	22/10/2001	Earthnet on line	CHRIS, SREM	The orbit is drifting from the original 10:30 desc. ECT.
SMOS (with CNES and CDTI)	06:00 (A) 755 km	2/11/2009	SMOS data centres	MIRAS (Microwave Imaging Radiometer using Aperture Synthesis), GPS, STA	L-band radiometer for salinity & soil moisture observation
PROBA-2	06:00 (A) 730 km	2/11/2009	Earthnet on line	SWAP, LYRA, TPMU, DSLP	2nd flight unit of the PROBA programme. Main mission: space weather
CryoSat-2	717 km (92° incl.)	8/04/2010	Earthnet on line	SIRAL (SAR Interferometric Radar Altimeter), DORIS, LRR	Polar ice monitoring
PROBA-V	10:30 (D)	5/07/2013	Earthnet on line	VEGETATION-P	2nd flight unit of the PROBA programme. Main mission: vegetation monitoring
Swarm A & C (with CNES and CSA)	87.35°	22/11/2013	Earthnet on line	ACC, SM, EFI (SWARM), GPS (ESA), LRR (DLR), STR (SWARM), VFM	Earth magnetic field
Swarm B	87.75°	22/11/2013	Earthnet on line		
Sentinel-1A (with EC)	06/00 (D)	03/04/2014	Copernicus Space component data access	SAR-C	Radar imagery

2.1 Status of current Earth Explorer satellites

Three ESA Earth Explorer missions are currently in operation, namely SMOS (launched in 2009), CryoSat-2 (launched in 2010) and Swarm (launched in 2013). All three missions, as well as GOCE, have provided outstanding results of interest to the meteorological and climate research communities at large.

2.1.1 GOCE

In orbit from March 2009 to November 2013, the Gravity field and steady-state Ocean Explorer (GOCE) measured the Earth's gravity field with unprecedented detail to advance our understanding of ocean circulation, sea-level change and Earth-interior processes.

2.1.1.1 Status of spacecraft

GOCE successfully completed its last measurement cycle at an altitude of 223.88 km on 19 October 2013. The satellite re-entered into the Earth atmosphere on 11 November 2013. No damage or casualties due to debris have been reported. The GOCE spacecraft was indeed working very well until just minutes before re-entry.

2.1.1.2 Performance and results

All Level 1 and Level 2 data up to 1st October 2013, which marks the last instrument calibration activity, have been processed and released to the user community. The 5th generation GOCE gravity field solutions based on the so-called Time-wise (TIM) and Direct (DIR) methodologies, have been processed and verified by the GOCE High-level Processing Facility team, and are now made available to the public by ESA. This was a major mission milestone, after the release of the previous 4th generation gravity solutions on 20 March 2013. While the 4th generation spanned 27 months-worth of effective data volume, the 5th generation solutions span the complete mission lifetime, including the low orbit data up to the re-entry of the satellite in November 2013.

The 5th International GOCE User Workshop was held on 25-28 November 2014 at UNESCO in Paris. A year after the satellite re-entered the atmosphere, scientists using data from the GOCE satellite have made a breakthrough in our understanding of ocean currents. While the mission is well known for its gravity measurements, the second mission objective as an ‘ocean circulation explorer’ has reached a milestone. Using GOCE data, scientists have produced the most accurate model of ocean current speeds to date by subtracting the GOCE geoid from the mean sea-surface height measured over a 20-year period by satellites including ESA’s veteran Envisat. The result shows the mean dynamic topography of the ocean surface from which ocean currents and their speeds were calculated and validated using *in situ* buoys. This GOCE-based model stands as more accurate than any other model based on space data to date.

2.1.2 SMOS

Launched on 2 November 2009, SMOS is the second Earth Explorer Opportunity mission to be developed as part of ESA's Living Planet Programme. SMOS carries a novel microwave sensor to capture images of brightness temperature, from which information on soil moisture and ocean salinity is derived. The data acquired from the SMOS mission will lead to better weather and extreme-event forecasting, and contribute to seasonal-climate forecasting.

2.1.2.1 Status of spacecraft

The platform is operated under CNES responsibility. No major anomalies or failures have been identified since launch, and the same applies for the interfaces to the payload. The remaining amount of propellant is sufficient to maintain spacecraft operations for another 120 years! The cumulative data lost since 1 May 2010 hence amounts to 0.083% and the degraded data amounts to 0.953%, with an exceptional overall mission performance of 98.965%.

After the successful SMOS Mission Extension Review, ESA's Member States and the French space agency CNES, which is responsible for operating the satellite platform, have decided to extend the SMOS mission into 2017.

2.1.2.2 Performance and results

In general, the RFI situation, in particular over Europe, continues to improve, except over Japan urban areas. To reduce the RFI contamination, continuous monitoring and interaction with national authorities will continue. The flagging of RFI contamination in the SMOS data products will be improved through investigating additional techniques.

SMOS Cal/Val activities continued with ground-based L-Band observations at DOME C, Concordia station supporting verification of the SMOS instrument stability and calibration and grand-band L-band radiometers deployed at various locations for long-term validation of SMOS soil moisture involving the Finnish Meteorological Institute (FMI), the University of Valencia (UVEG) and the Laboratoire d'Hydrologie (LHTE) in Grenoble, France. Also airborne campaigns were held in 2014 in Canada and Svalbard.

The NRT light data product is regularly distributed by ESA to the WMO's Global Telecommunication System (GTS) network, with the UK Met Office injecting the data into the system, as well as to EUMETSAT's EUMETCast system. This direct link into the data collection points for operational agencies will increase the uptake of SMOS data in this community.

ECMWF has been instrumental in monitoring SMOS brightness temperatures since launch. A new contract was placed with ECMWF covering the period from 9/2014 to 12/2015 to further exploit the potential of SMOS observations for NWP applications. The first progress meeting was held on 18 December 2014.

The 2nd SMOS reprocessing campaign is presently on-going and will generate, with a state-of-the-art algorithm baseline, a complete and homogeneous set of Level 1 and 2 data products for the entire mission duration. The overall 2nd SMOS mission reprocessing plan is now the following: release of the entire level 1 mission archive and deployment of the new algorithm baseline (level 1 and level 2) in the ground segment by end of April 2015; release of the entire level 2 mission archive by end of 2015.

SMOS has now gathered more than five years of soil moisture and ocean surface salinity data, the longest continuous record from space. 18 TB of SMOS data are distributed every year, of which around 13 TB are used by scientists and around 5 TB for near-real time applications by operational users.

A large dedicated international meeting "The Ocean Salinity Science and Salinity Remote Sensing Workshop[1]" was held on 26-28 November 2014 at the UK Met Office. Scientists emphasized the importance of SMOS salinity data to determine and monitor for the first time from space an ensemble of key ocean processes for climate and biochemistry. This includes, for example, the detailed salinity structure of tropical instability waves along the equator and the salt exchanged across major oceanic current fronts through energetic ocean rings. Occurrences of large-scale salinity anomalies in the Pacific and Indian oceans related to El Niño, La Niña and the Indian Ocean climate were also well-evidenced in the five year-long data. In addition, the dispersal of freshwater into the ocean from the major large tropical rivers, namely the Amazon, Orinoco and Congo Rivers, their impact on tropical cyclone intensification and the oceanic imprints of the intense rainfall in the Trade Wind convergence zones can now be regularly monitored to better understand the variability of the oceanic part of the global water cycle.

A land-oriented workshop, "Understanding the Carbon and Water Cycles using SMOS Data and Models2", was held on 13-14 November 2014 at CESBIO, Toulouse, France. A summary is published on the workshop web site. The five-year soil moisture data set shows how seasonal changes are more pronounced at higher latitudes, but monsoon dynamics in the Indian subcontinent are also clearly visible. The 'Sahel transition' region in Africa is well depicted and seasonal flooding in regions such as La Plata in Argentina and the Orinoco Basin in Venezuela can also be seen. The 2nd SMOS science conference is planned for 25-29 May 2015, together with a SMOS training course led by the CESBIO team for 18-22 May, at ESAC, Spain.

2.1.3 CryoSat-2

ESA's Earth Explorer CryoSat-2 mission, launched on 8 April 2010, is dedicated to the precise monitoring of the changes in the thickness of marine ice floating in the polar oceans and variations in the thickness of the vast ice sheets that overlie Greenland and Antarctica.

[1] See http://www.oceansalinityscience2014.org

[2] See www.smos4waterandcarbon.info

2.1.3.1 Status of spacecraft and mission

The overall performance of the CryoSat-2 mission during the past year was satisfactory.

2.1.3.2 Performance and results

During the reporting period, the end-to-end mission performance, namely the overall mission data return, taking into consideration the planned (1.5%) and the unplanned unavailability (0.0%) of the space and ground segment, was 98.5%. Since the start of the operational phase, the overall mission science data availability return has been 97.9%, well above the design performance of 94%.

The activities related to the release of the next ice product baseline (i.e. Baseline C) have been progressing. The final acceptance review of the ground processors was successfully completed in October 2014. The final release of Baseline C, planned for the fourth quarter of 2014 was postponed to April 2015 in order to synchronize with the release of the new orbit products provided by CNES. This decision will improve further the overall data quality and save up operational costs. The new Baseline-C comprises a dozen of important improvements with respect to Baseline-B. The Baseline-C products are now ready to be released to the scientific community.

Activities related to the 2nd reprocessing campaign of ice products (4Q 2014 - 3Q 2015) proceeded according to plan. During the reporting period, new SAR acquisitions over dedicated land areas in Antarctica were executed for three weeks in order to support the development of the ground processing algorithms of the Copernicus Sentinel-3 mission. This activity was carried out in collaboration with CNES.

Cal/Val campaigns in Antarctica have taken place in late 2014-early 2015 and a new campaign is planned during the austral summer of 2015-2016. The 2014 CryoSat-2 Validation Experiment (CryoVEx 2014) and NASA large-scale airborne field campaign IceBridge in the Arctic have been carried out and their results are under interpretation.

Using special data processing provided by the UK's Centre for Polar Observation and Modelling (CPOM), CryoSat measurements can now be delivered within two days of acquisition through a website[3] launched in mid-April 2015. The rapid data processing is important for managing and planning activities affected by Arctic sea ice, such as shipping, tourism, Arctic exploration and search and rescue.

The first map of Arctic ice thickness was released in June 2011. Since then, important new results have been obtained with CryoSat-2:

- New global marine gravity model from CryoSat-2 and Jason-1: CryoSat data was used to create a new gravity map, exposing thousands of previously unchartered 'seamounts', ridges and deep ocean structures. This new picture of the least explored part of the ocean offers fresh clues about how continents form and break

[3] http://www.cpom.ucl.ac.uk/csopr/index.html

up. Measurements can be used to create global marine gravity models and, from them, maps of the seafloor.

- Arctic sea ice volume in 2014: CryoSat has delivered the 2014 map of autumn sea-ice thickness in the Arctic, revealing a small decrease in ice volume. In a new phase for ESA's ice mission, the measurements can now also be used to help vessels navigate through the north coastal waters of Alaska, for example. Measurements made during October and November 2014 show that the volume of Arctic sea ice now stands at about 10,200 km^3 – a small drop compared to last year's 10,900 km^3. The volume is the second-highest since measurements began in 2010, and the five-year average is relatively stable. This, however, does not necessarily indicate a turn in the long-term downward trend.
- Joint use of CryoSat and Sentinel-1A data has allowed the detection of a rapid ice loss in the Austfonna ice cap in the Svalbard archipelago.

There was a dedicated CryoSat session at the AGU fall meeting in San Francisco, 15-19 December 2014. Around 50 papers (oral and posters) presented results using CryoSat data. The latest CryoSat results were presented in several sessions (i.e. Climate, Ocean, Cryosphere) at the last EGU meeting in Vienna, 13-16 April 2015. The 4th CryoSat International User Workshop is planned to be held in the 2nd week of February 2016 in UK.

2.1.4 SWARM

Swarm is the fourth Earth Explorer Opportunity Mission of ESA's Earth Observation Envelope Programme. This constellation of three satellites is designed to measure the magnetic signals that stem from Earth's core, mantle, crust, oceans, ionosphere and magnetosphere.

2.1.4.1 Status of spacecrafts

The three Swarm satellites were successfully launched on 22 November 2013 into their circular polar target orbit at 490 Km altitude. Two satellites are now flying at an altitude of about 460 km and an inclination of 87.35°. They orbit almost side by side, about 150 km apart as they pass over the equator. The third satellite is flying in a higher orbit of 530 km and at a different inclination of 87.75°, slightly closer to the pole. All platforms and instruments are fully functional apart from the Absolute Scalar Magnetometer (ASM) on Swarm-C, after the loss of the two on-board instruments.

2.1.4.2 Performance and results

A Swarm Initial magnetic Field Model (SIFM) has been developed. This model confirms that Swarm indeed provides (by far) the best-ever measurements of the Earth's magnetic field. At the present (high) altitude, the data set from the mission is already outperforming previous missions. Despite the current set of problems, Swarm mission is well under way to set new standards in all its scientific domains. A special issue of Geophysical Research Letters on initial results is under preparation. Around 20 papers were submitted and are currently in the peer review process.

2.2 Status of current Earth Watch satellites

2.2.1 Proba-V

Launched on 7 May 2013, Proba-V is tasked with a full-scale mission: to map land cover and vegetation growth across the entire planet every two days. Proba-V is flying a lighter but fully functional redesign of the 'Vegetation' imaging instruments previously flown aboard France's full-sized Spot-4 and Spot-5 satellites, which have been observing Earth since 1998. The Spot Vegetation dataset had close to 10 000 registered users around the globe and has contributed to hundreds of scientific papers over 15 years. But with further Spot satellites lacking the capacity to carry Vegetation instruments, Proba-V has been designed to meet the future needs of this group. Proba-V's Vegetation instrument boasts improved spatial resolution from its Spot predecessors: 350 m resolution compared to 1 km for Spot Vegetation, with 100 m resolution available within its central field of view.

Proba-V will provide data to the instrument's worldwide user community of scientists and service providers. Uses of Proba-V Vegetation data include day-by-day tracking of extreme weather, alerting authorities to crop failures, monitoring inland water resources and tracing the steady spread of deserts and deforestation.

2.2.1.1 Status of spacecraft

The Proba-V mission has been running nominally since it was declared operational. All the key parameters on-board have been well within their design margins. No platform and payload degradations have been detected. The Vegetation Instrument acquisition and calibration requests have been performed nominally.

2.2.1.2 Performance and results

ESA is coordinating with the Participating States on the implementation of the programme element. Proba-V is the first of its kind within the Earth Watch Programme, and grants Programme Participants the specific right to derive and use high-level products and exploiting them in a national programme.

The kilometric Earth Watch products are distributed in accordance with the approved data policy[4]. Any user can register under the standard ESA fast registration procedure for free and open access[5]. The reprocessing of the Proba-V archive with an updated software has been finalised. During the reporting period 50 new users were registered for Proba-V. In total, 352 registered users have ordered Proba-V data by end of March 2015. Data exploitation of Proba-V will be addressed at the upcoming 'Sentinel-3 for Science' workshop[6], planned for June 2015. A dedicated Proba-V workshop is planned for January 2016.

[4] ESA/PB-EO(2013)31

[5] https://earth.esa.int/web/guest/pi-community/apply-for-data/fast-registration

[6] Information on this event is available at seom.esa.int/S3forScience2015/

2.2.2 Sentinel-1

The Sentinel-1 mission is a polar-orbiting satellite system for the continuation of Synthetic Aperture Radar (SAR) operational applications. Sentinel-1 is a C-band imaging radar mission to provide an all-weather day-and-night supply of imagery for GMES user services. The SAR will operate in two main modes: Interferometric Wide Swath and Wave. The first has a swath width of 250 km and a ground resolution of 5×20 m.

The first Sentinel-1A satellite was successfully launched on 3 April 2014. It was successfully commissioned in September 2014. The Sentinel-1A operational qualification phase is proceeding according to plan. The end of this phase is planned for May 2015. The overall operations mission performance has been nominal during the reporting period. The opening of the Sentinel-1 product dissemination to all users took place on 3 October 2014. Data can be accessed online at https://sentinel.esa.int. As of 19 February 2015, a total of 5,284 users had self-registered. Since the opening of the regular data flow on 3 October, 47,000 products had been made available for download and 316,104 products downloaded by users, representing approximately 430 TB of data.

Sentinel-1A will be followed by the second satellite within two years. The Sentinel-1B Flight Acceptance Readiness is planned for December 2015. The 3-month Launch Period has been formally agreed with Arianespace, the Sentinel-1B launcher services provider, as 1 March to 31 May 2016.

3 FUTURE ESA SATELLITE SYSTEMS

3.1 Future Earth Explorer missions

The Earth Explorers are research missions designed to address key scientific challenges identified by the science community while demonstrating breakthrough technology in observing techniques. Involving the science community right from the beginning in the definition of new missions and a peer-reviewed selection process ensures that a resulting mission is developed efficiently and provides the exact data required by the user.

3.1.1 EarthCARE

EarthCARE – the largest and most complex Earth Explorer mission to date – is being developed as a joint venture between ESA and the Japan Aerospace Exploration Agency, JAXA. EarthCARE will advance our understanding of the role that clouds and aerosols play in reflecting incident solar radiation back into space and trapping infrared radiation emitted from Earth's surface. By acquiring vertical profiles of clouds and aerosols, as well as the radiances at the top of the atmosphere, EarthCARE aims to address these issues. The mission will employ high-performance lidar and radar technology that has never been flown in space before.

The main EarthCARE risk remains associated with the development of the ATLID and its challenging transmitter, due to the technologies involved and the complexity of this instrument. The EarthCARE critical path is driven by the progress achieved on

the ATLID transmitter. The first transmitter Test Readiness Review is now planned in June 2015.

The EarthCARE International Science Workshop took place on 17-19 September 2014 at the National Museum of Emerging Science and Innovation in Tokyo. About 150 scientists participated in the event. The workshop demonstrated overall a good state of scientific preparation. It was suggested that more collocated airborne radar/lidar and in-situ measurements should be acquired in order to further reduce uncertainties in cloud retrieval algorithms. The proposed aerosol classification should also be further validated. Considering that ECMWF has made significant progress in the preparations of EarthCARE radar and lidar cloud profile assimilation, the mission should also be further considered in the domain of (severe) weather forecasting.

Current plans call for an EarthCARE Acceptance Review in May 2018. The mission has a design lifetime of three years, including a six-months commissioning phase.

3.1.2 ADM-AEOLUS

The ADM (Atmospheric Dynamics Mission)-Aeolus satellite will carry a single, but complex, instrument that will probe the atmosphere to profile the world's winds. Reliable and timely wind profiles are urgently needed by meteorologists to improve weather forecasts. In the long term, they will also contribute to climate research. Aeolus will carry a pioneering instrument called ALADIN that uses laser light scattering and the Doppler Effect to gather data on wind.

Developing the laser transmitter has been a very long and difficult undertaking – forging new technologies in many areas such as optics, opto-electronics, precision mechanics and thermo-mechanical design. The first flight laser transmitter qualification campaign was successfully integrated into the ALADIN instrument. The Optical Bench optics have been confirmed flight worthy after successful completion of a series of tests with the first flight laser transmitter and dedicated laboratory sample tests.

The 2nd laser transmitter build has undergone re-acceptance campaign and leak rate stability verification. A severe degradation of performance has emerged during these reacceptance activities. The critical path of the schedule is solely driven by the delivery of the second flight laser transmitter.

The uncertainties related to this delivery have not allowed consolidating the overall schedule. A realistic case scenario leads to Aladin delivery in December 2015. Discussions are on-going with Airbus to enable a launch readiness within 2016.

The Aeolus Science and Cal/Val Workshop was held in ESA-ESRIN February 10-13 2015 with about 85 participants confirming very high interest in the expected Aeolus products and their usefulness for numerical weather forecasts and climate research.. The program contained a broad selection of science and Cal/Val related talks in addition to talks on the instrument, ground segment, products and user tools.

3.1.3 BIOMASS

The Biomass mission has been selected in May 2013 as the 7th Earth Explorer mission of its Living Planet programme. The satellite will be designed to provide, for the first time from space, P-band radar measurements that are optimised to determine the amount of biomass and carbon stored in the world's forests with greater accuracy than ever before. This information, which is poorly known in the tropics, is essential to our understanding of the role of forests in Earth's carbon cycle and in climate change. These objectives will be achieved by measuring biomass and forest height at a resolution of 200 m and forest disturbances at a resolution of 50 m.

Reliable knowledge of tropical forest biomass also underpins the implementation of the UN Reducing Emissions from Deforestation and forest Degradation (REDD+) initiative – an international effort to reduce carbon emissions from deforestation and land degradation in developing countries.

In addition, the measurements made by Biomass offer the opportunity to map the elevation of Earth's terrain under dense vegetation, yielding information on subsurface geology and allowing the estimation of glacier and ice-sheet velocities, critical to our understanding of ice-sheet mass loss in a warming Earth. Biomass also has the potential to evolve into an operational system, providing long-term monitoring of forests – one of Earth's most important natural resources. The launch of the mission is foreseen for 2020.

Two industrial consortia led by Astrium-Ltd. and OHB respectively have started their work on the Phase B1. The Phase B1 studies have been conducted according to schedule. The completion of all technology development activities is expected in Q2/2015.

The re-assessment of the mission validity taking account of newly discovered ground based military radars has been completed. The Earth Science Advisory Committee recommended to ESA to continue with the full implementation of the Biomass mission without delay. On 18 February 2015 the ESA Program Board on Earth Observation approved the continuation of the full mission implementation.

The 1st Biomass Science workshop was held on 27-30 January 2015 at ESRIN in Frascati, Italy. The workshop objectives were to gather and foster the future Biomass scientific community, engage the international forest network community, the UN-FCCC REDD community and the international carbon modelling community, present the Biomass Mission status at the end of Phase-B1 and anticipated Biomass products, and provide a forum for international exchange on P-band SAR applications with an emphasis on biomass. More than 200 experts participated in the workshop with a strong involvement of the end user communities.

3.2 Future Earth Watch missions

In addition to meteorological satellites, the GMES (Global Monitoring for Environment and Security) Sentinel missions, which form part of the GMES Space Component, will collect robust, long-term climate-relevant datasets. Also ESA has initiated studies

on a Jason-CS mission aimed at continuing high-precision altimetry observations of the ocean beyond the current Jason-1, -2 and 3 series.

3.2.1 Sentinel-2

The pair of Sentinel-2 satellites will routinely deliver high-resolution optical images globally, providing enhanced continuity of SPOT- and Landsat-type data. Sentinel-2 will carry an optical payload with visible, near infrared and shortwave infrared sensors comprising 13 spectral bands: 4 bands at 10 m, 6 bands at 20 m and 3 bands at 60 m spatial resolution (the latter is dedicated to atmospheric corrections and cloud screening), with a swath width of 290 km.

The Sentinel-2A Satellite environmental qualification tests and functional test program have successfully been completed. The Ground System Acceptance Review Board took place on 20 March 2015.

The Sentinel-2A launch by VEGA (VV05) is scheduled on 11 June 2015 at 22:51:44 local Kourou time (12 June at 3:51:44, Western European time; 01:51:44 UTC). The Satellite and its Ground Support Equipment will be shipped to Cayenne in French Guiana by air cargo from Munich, Germany, on 20 April 2015.

The Sentinel-2B satellite is being developed in parallel, for a launch with Rockot in the second half of 2016.

3.2.2 Sentinel-3

The Sentinel-3 mission's main objective is to measure sea-surface topography, sea- and land-surface temperature and ocean- and land-surface colour with high-accuracy and reliability in support of ocean forecasting systems, and for environmental and climate monitoring. Sentinel-3 builds directly on a proven heritage pioneered by ERS-2 and Envisat. Its innovative instrument package includes:

- A Sea and Land Surface Temperature Radiometer (SLSTR), based on Envisat's Advanced Along Track Scanning Radiometer (AATSR), to determine global sea-surface temperatures to an accuracy of better than 0.3 K.
- An Ocean and Land Colour Instrument (OLCI) based on heritage from Envisat's Medium Resolution Imaging Spectrometer (MERIS). With 21 bands, compared to 15 on MERIS, a design optimised to minimise sun-glint and a resolution of 300 m over all surfaces, OLCI marks a new generation of measurements over the ocean and land. The swath of OCLI and nadir SLSTR fully overlap.
- A dual-frequency (Ku and C band) advanced Synthetic Aperture Radar Altimeter (SRAL) based on CryoSat heritage and providing measurements at a resolution of ~300 m in SAR mode along track. SRAL is supported by a microwave radiometer for atmospheric correction and a DORIS receiver for orbit positioning.

The Sentinel-3A and 3B satellites' platform and instruments are currently undergoing integration and tests. ESA is formalising with Eurockot the definition of the final launch slot, compatible with a Sentinel-3A launch by October 2015. The Sentinel-3B schedule remains driven by the refurbishment of the SLSTR PFM model after dismounting from the Sentinel-3A Satellite. The latest estimate is that 14 months will be

required for this activity, which would lead to a launch readiness at the end of the first quarter 2017.

The Sentinel-3 Mission was presented at the Danish Meteorological Institute (DMI) on 17 March, highlighting its importance in terms of sea ice monitoring.

3.2.3 Sentinels-4/-5

The Sentinel-4 and Sentinel-5 missions are dedicated to monitoring the composition of the atmosphere for GMES Atmosphere Services. Both missions will be carried on meteorological satellites operated by Eumetsat. The Sentinel-4 and -5 missions will provide information on atmospheric variables in support of European policies. Services will include the monitoring of air quality, stratospheric ozone and solar radiation, and climate monitoring.

3.2.3.1 Sentinel-4

To be carried on the geostationary Meteosat Third Generation satellites, the Sentinel-4 mission comprises an Ultraviolet Visible Near-infrared (UVN) spectrometer and data from Eumetsat's thermal InfraRed Sounder (IRS), both embarked on the MTG-Sounder (MTG-S) satellite. After the MTG-S satellite is in orbit, the Sentinel-4 mission also includes data from Eumetsat's Flexible Combined Imager (FCI) embarked on the MTG-Imager (MTG-I) satellite. The Flight Readiness Review of the first MTG-S1 satellite is expected to take place in Q1 2021. The recurrent Flight Model 2 will be embarked on board the second MTG-S satellite (MTG-S2) whose Flight Acceptance Review is presently planned in Q1 2029.

An abstract titled: “The Sentinel-4 Mission and its Atmospheric Composition Products” has been submitted to the ATMOS 2015 conference in Heraklion, Greece planned in June 2015 and to the EUMETSAT Meteorological Satellite Conference in Toulouse planned in September 2015.

3.2.3.2 Sentinel-5

To be carried on the polar-orbiting MetOp Second Generation satellite, the Sentinel-5 mission comprises an Ultraviolet Visible Near-infrared Shortwave (UVNS) spectrometer and data from Eumetsat's IRS, the Visible Infrared Imager (VII) and the Multi-viewing Multi-channel Multi-polarization Imager (3MI). The first MetOp Second Generation satellite is expected to be launched in 2020.

Following the successful completion of the System Requirements Review in December 2014, the Sentinel-5 Preliminary Design Review (PDR) is now planned for the May-July time frame.

An abstract ‘Copernicus Sentinel-5: Long-Term Global Monitoring of Atmospheric Composition’ has been submitted to the ATMOS 2015 conference taking place in Heraklion, Greece in June 2015.

3.2.3.3 Sentinel-5P

In addition, a Sentinel-5 Precursor mission is being developed as a gap-filler, within the 2016-2023 timeframe, between the end-of-life of the current atmospheric chemistry mission (OMI on EOS/Aura) and the operational availability of Sentinel-5. As a joint initiative between ESA and the Netherlands, the mission will comprise a satellite and a UVNS instrument called TROPOMI.

Calibration of the Earth port of the TROPOMI payload has just been completed at Centre Spatial de Liège (CSL). The critical path for the programme is the remaining TROPOMI Sun port calibration. A Sentinel-5 Precursor Launch Period of 12 April 2016 to 11 July 2016 on Rockot has formally been notified to the Launcher Authority.

3.2.4 Sentinel-6 (Jason-CS)

The Jason-CS satellites will form the space component of the Jason Continuity of Service mission, within the Copernicus Space Component Segment 3. Jason-CS will extend high-accuracy ocean topography measurements well into the 2020s, thanks to the participation of all partners (EUMETSAT, ESA, CNES, NOAA and NASA/JPL).

The Poseidon-4 altimeter will employ digital architecture and the simultaneous measurement in the advanced SAR mode as well as in the conventional pulse-width limited mode. The Advanced Microwave Radiometer, Climate Quality (AMR-C) will be an enhanced version of JPL's instrument used on Jason-2 and Jason-3. A major programmatic decision has been the abandonment of the High Resolution Microwave Radiometer (HRMR) studies.

The GNSS receiver optimised for Precise Orbit Determination will be an instrument derived from the Sentinel-3b GNSS receiver, while Radio Occultation (RO) capability will be satisfied by a NASA-provided GNSS-RO. Additionally a DORIS Receiver and a NASA-provided Laser Retro-Reflector Array will be embarked.

The industrial contract for the procurement of the Sentinel-6/Jason-CS A satellite has been signed by ESA and Airbus DS. A The Copernicus Procurement Board accepted the Sentinel-6/Jason-CS contract proposal for the combined procurement of the recurrent B model.

The EUMETSAT Jason-CS Programme proposal is open for subscription by Member States in preparation of a resolution at the June 2015 EUMETSAT Council. This shall secure the EUMETSAT funding share for both the A and B Sentinel-6/Jason-CS satellites procurement, as required to proceed with phase C1.

The role of NOAA in Jason-CS is being redefined, following the shift of responsibility between NOAA and NASA for post-Jason 3 altimetry missions. In keeping with the NASA FY-16 budget request included in the Presidential request submitted to Congress approval, NASA will take the central role among the US partners for the development of Sentinel-6/Jason-CS US instruments and launch services procurement.

The next Ocean Surface Topography Science Team (OSTST) gathering will be held in Q3 2015.

3.3 The ESA Climate Change Initiative (CCI)

3.3.1 Background

Combined satellite and *in situ* data archives can be used to produce data products for climate monitoring, modelling and prediction. To this end, the ESA Climate Change Initiative (CCI) was launched in 2009. The CCI has been created to address the GCOS Essential Climate Variable (ECV) requirements for satellite datasets and derived products. Its principal objective is "*to realize the full potential of the long-term global Earth Observation archives that ESA together with its Member states have established over the last thirty years, as a significant and timely contribution to the ECV databases required by the UNFCCC*". The CCI focuses on the exploitation of data records primarily, but not exclusively, from past ESA satellite missions, for the benefit of climate monitoring and climate research. It complements existing efforts in Europe (e.g. led by EUMETSAT through the CM SAF) and internationally which focus on datasets characterizing meteorological aspects of the climate system.

3.3.2 CCI Phase 1

A competitive tender for proposals to generate climate-quality products addressing a first set of ECVs was released by ESA in the last quarter of 2009. As part of CCI phase 1, between August and December 2010, ten ECV_cci projects were launched. The ECV_cci teams are consortia of between six and 15 European partner institutions, including academia, government agencies and system engineering companies.

In addition to the ten ECV_cci teams, a CCI Climate Modelling User Group (CMUG) consisting of major European climate modelling centres has been set up. At all stages of the program, its task is to provide a climate modelling perspective on the CCI, and to test datasets generated in the CCI within their models. CMUG also aims to provide an interface between the CCI and the international climate modelling community. The existence of CMUG emphasizes the important role of climate modelling as a primary user of CCI output. Finally, a CCI project on sea ice was launched in January 2012, together with two other projects dedicated to ice sheets and soil moisture, though funded under a different scheme.

All CCI projects have reached the end of Phase 1 of the programme and generated ECV data products. The CMUG project Phase 1 was also completed by its deadline at the end of March 2014. In 2014 the *Ice_Sheets_cci* was split into two parallel contractual activities, covering respectively the Greenland and the Antarctic Ice Sheets.

The ECV products for nearly all the projects are available publically, via the project websites, accessible from the main CCI website: http://www.esa-cci.org.

3.3.3 CCI Phase 2

The last project to complete Phase 1 was the Ice_Sheets_cci at the end of March 2015. The kick-off meeting for Phase 2 of its two parts were held at the end of April, so that all currently active projects now have started Phase 2, but the Fire_cci project, for which a RFQ is soon to be released.

A number of programme-wide activities are planned for Phase 2, one of which – the CCI Visualisation Tool – has already begun. The CCI is producing a Visualisation Tool as a communication aid, to showcase the ECV data products from the programme. Animations have been put together for the key variable from each project where data is currently available. These help demonstrate to both a scientific and lay audience the global nature of the products, the temporal coverage achieved and can highlight climate phenomena or events in the data, such as El Niño years.

As the ECV products mature, the focus of project teams has expanded from the specifications of the data sets to looking at how the data can be used, both across the CCI programme and in broader climate and environmental research questions.

For example, a new cross-cutting activity has emerged from a CCI meeting held at the International Space Science Institute from 2-5 February 2015. Representatives from seven of the CCI projects came to a meeting organised by Sea Level science leader, Dr Anny Cazenave, on 'An Integrative Study of the Sea Level Budget'. A proposal has been put forward to ESA for a new project on the 'CCI Global Water Cycle'. This would use CCI products to give a systematic assessment of global water cycle sources and sinks and produce the first synoptic assessment and first systematic closure of the global sea level budget. This information will also improve understanding of the drivers of sea level rise.

The CCI project teams continue to make scientific publications in high impact scientific journals. These report progress on the retrieval algorithms resulting from the round robin exercise, as well as new results related to climate process and trends, based on analysis of the ECV data sets being generated in CCI. A special issue on the round robin processes performed by the CCI teams during Phase 1 has been accepted in the journal *Remote Sensing of Environment*.

The projects have also had time to promote their data sets more widely within their research communities. This means that some products have been downloaded extensively, for example, *Ocean_Colour_cci* products have had 400,000 file downloads and *Sea_Level_cci* have had 50 users request access to their products, which has led to more than 10,000 downloads. There are variations between the projects depending on the product maturity, competition from other products, size of the research community, and how international it is but all are seeing an increase in users of their data.