The METEOSAT Second Generation imager: definition and challenges

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ABSTRACT

METEOSAT Second Generation (MSG) will be a spin-stabilised spacecraft embarking a new type of imaging instrument, called Spinning Enhanced Visible and InfraRed Imager (SEVIRI), to be in orbit after 1998, for twelve years of operation. The definition process of this instrument is recalled, in order to highlight why the SEVIRI will really be a challenging instrument. After a brief description of SEVIRI potential in the domain of meteorological products extraction, the EUMETSAT image simulation programme will be presented.

1. WIND FIELD AS KEY METEOROLOGICAL PARAMETER

1.1. NEED FOR WIND FIELDS

One of the primary objectives for numerical weather forecasting in the next decade is to improve the knowledge of the initial state of the atmosphere. Questions are then addressed to the observing systems, in order to get the best possible data, in terms of geographical and temporal coverages and of measurement accuracy.

The first priority parameter is **the three-dimensional wind field**. At the present time, a global and timely coverage of such wind data is far from being achieved, especially over the oceans, the southern hemisphere and the intertropical areas.

As the forecast techniques are continuously improving, there is a clear **need for direct measurement of the wind field on a global basis.** Taking account of the information given by the scientific presentations made during this workshop, we will try to describe the future trends in space-based wind measurement, with particular attention to the successor of the operational METEOSAT satellites, to be in orbit at the turn of the century.

1.2. KNOWLEDGE OF THE WIND FIELD

The three-dimensional wind fields is sampled at ground-based radiosonde stations under WMO coordinated procedures. This is usually considered as the baseline reference for any other wind measurement technique. The global repartition of these data is very irregular - mainly the continents of the northern hemisphere - and as the measurement accuracy improvement has reached some limits, other techniques are needed.

Amongst the new techniques, the most accurate appears the air-borne device operated under the WMO **ASDAR** programme.

This is really an "in-situ" technique, covering the air traffic areas, but most effort is put on remote sensing of the wind, either from ground or space.

The **wind profilers**, providing detailed 3-D wind fields, are developing very rapidly. But they only provide local information, for supporting activities like air-traffic control. For large scale weather forecasting, the are expected to replace the rawinsonde measurement, with the same problem of geographical coverage.

It is also possible to mention some experiments made with **over-the horizon radars**, using the diffraction of meter radio-waves on the sea surface. One radar allows to derive the wind speed at sea-level. Two radars enable to compute the wind direction. This can help the synoptic survey of some oceanic areas. No defined plans to implement operationally such devices are known.

The second set of techniques addresses space-based instrumentation. Space-borne instruments are reasonably felt as the basis for providing continuous global sets of wind data. But, apart of the CMWs of the geostationary satellites, no other technique is operational.

The **wind scatterometer** of SEASAT (1978) has demonstrated the potential of millimeter-wave diffraction technique for deriving the wind field at sea level. The scatterometer working on ERS-1 since July 1991 will allow to make a pre-operational demonstration of such an instrument. But, as it addresses the wind at sea level, the primary benefit will be to oceanography and marine meteorology rather than numerical weather forecasting.

Great hopes are put on satellite-borne **wind lidars**, which are felt as the only way to extract the three-dimensional wind field from space. But the technical challenges of such instruments are so high that no operational application is foreseen before - at least - two decades. Demonstration instruments (LAWS, ALADIN) are under definition, to be demonstrated on polar platforms after the year 2000.

It is also possible to derive wind information over the sea using the backscattered information from altimeters or microwave sounders, but they can only be considered as anecdotal from the operational point of view. The cloud motion measurement appears really as the only reliable technique for providing wind data on a global scale.

1.3. ROLE OF GEOSTATIONARY SATELLITES

The operational system of five geostationary satellites appears as the only able to provide "quasi 3-D" global wind data on an operational basis during, at least the next two decades. This is a challenge for satellite operators.

The present system, relying on broad-band channels imageries, has been defined in the late sixties and set operational in the seventies. Although great efforts have been made, it is felt reaching limits, for what concerns the quality of wind provided by operators. This has been noted many times as, that the CMWs add no information to the model analysis, except in data sparse areas... but, new information coming from ECMWF demonstrate now the opposite, what is very satisfactory for satellites operators. Listing a summary of the results of nearly 15 years of operational CMW extraction it sounds as follows:

* It provides a nearly global set of wind data, with particular focus on the inter-tropical areas, allowing to fill gaps in the traditional rawinsonde network. Only the polar regions are not covered, but polar orbiting imager might help to fill the gap.

* As relying on clouds as tracers of atmospheric motion, the data set is limited to cloudy areas.

* The quality of the data appears clearly as **limited by the uncertainty of the height assignment** of the top of the clouds to be tracked and also to the possibility of tracking accurately cloudy features.

* Another limiting factor is **the quality of the tracer** used, and it is absolutely not sure that some clouds are the best atmospheric drifters. Some attempts with constitutive elements of the atmosphere (WV, Ozone) have opened some perspective.

Providing wind data with a quality able to fulfil satisfy meteorological users is a real challenge for the next generation of geostationary satellites. The GOES/I-M series, in the USA, GOMS, in the USSR and METEOSAT Second Generation (MSG) in Europe will embark new instrumentation with a great potential for wind extraction. This instrumentation will help solving the problems listed above.

2. MSG

2.1. GENERAL

METEOSAT Second Generation appears as the primary programme of EUMETSAT for the next decade, as it is the follow-on and upgrade of the METEOSAT Operational Programme. As defined by EUMETSAT Council, its missions will be:

Basic multispectral imagery, with better spectral, spatial and temporal resolution than the existing METEOSAT satellites, basically in support to nowcasting and short-range weather forecasting

High resolution imagery, by observing the Earth in the same visible band as METEOSAT, with a spatial resolution similar to the AVHRR instrument, in support to mesoscale phenomena monitoring over Europe

Air Mass Analysis, by using some H_2O and CO_2 absorption channels, whose usefulness for nowcasting has been demonstrated by VAS experience

Meteorological Product Extraction (winds, surface temperatures,...) as upgraded with the improved capacity of the imager.

Support to Climate and Environment monitoring, as well as to Earth resources management

Continuity of METEOSAT data collection and dissemination missions.

In order to cut development risks and costs of its future geostationary system, the EUMETSAT Council has decided to rely on a well proven concept of spin-stabilised platform, in order to put the effort on the instrumentation. The MSG satellites embark an imaging instrument, the Spinning Enhanced Visible and Infra Red Imager (SEVIRI), which will be described below. MSG will also be able to disseminate images and products with a greater efficiency than the present METEOSAT.

The launch of the first flight model is foreseen for 1999. Three other satellites will follow, in order to ensure twelve years of operations. The programme is now under definition, in cooperation with ESA, for a development starting in 1994.

Basically, the MSG imager will allow a "three-dimensional" view of the Atmosphere from the geostationary orbit. This objective is coherent with this of NOAA, developing the GOES-I series, which will embark an imager and an independent sounder, on a three-axis stabilised platform.

2.2. THE IMAGING RADIOMETER

The Spinning Enhanced Visible and Infra Red Imager of MSG will be a challenging instrument in geostationary orbit, for supporting the missions listed above. The baseline concept (table 1) can be considered as the combination of three instruments in one single imager

MSG SEVIRI			GOES I Imager	EPS VIRSR
Bands	Name	Limits (μm)	Limits (μm)	Limits (μm)
VIS	HRVis	0.5 - 0.9	0.55-0.75	
&	VIS0.6	0.60-0.67		0.60-0.62
	VIS0.8	0.77-0.89		0.86-0.88
NIR	IR1.6	1.56-1.70		1.58-1.64
Window	IR3.7	3.50-4.00	3.8-4.0	3.62-3.83
	IR8.7	8.5-8.9		8.4-8.7
	IR10.8	10.3-11.3	10.3-11.3	10.3-11.3
	IR12.0	11.5-12.5	11.5-12.5	11.5-12.5
Water vapour	IR6.2	5.7-6.7	6.5-7.0	6.5 (IRTS)
	IR7.3	7.1-7.6		7.3 (IRTS)
Ozone	IR9.7	9.69-9.82		9.7 (IRTS)
Carbon	IR4.5	4.47-4.57		4.52 (IRTS)
dioxide	IR13.4	13.2-13.6		13.3 (IRTS)
	IR14.0	13.8-14.2		13.9 (IRTS)

Table 1: Coherence of MSG imager with the GOES-I imager, VIRSR and IRTS[1]

VIRSR[2], with a slight different definition of the channels, adapted to the particular situation of the satellite, with a coarser spatial resolution (3km at nadir) put providing data with a repeat cycle of 15mn.

An air mass monitor with six channels, two in the water vapour absorption band, as a continuation of MOP, three in the carbon dioxide band, coming from VAS and one in the ozone absorption band (9.7 μm), operating with the same spatio-temporal resolution as the imaging channels.

A High Resolution VISible imager (HRVIS), with a sampling distance equivalent to the polar orbiting VIRSR (1km at nadir), providing images with the 15mn basic repeat cycle.

The main characteristic, of SEVIRI will be to allow the simultaneous operation of all channels with the same sampling characteristics. It will provide the users with high accuracy images and products (winds, surface temperatures,...) but also with new type of information on atmospheric stability. The efficiency of the system will also be improved by the possibility of merging information from the GEO and LEO orbit.

The basic preoccupation has been to propose a **coherent system**, enabling the user community to take full advantage of both polar orbiting and geostationary satellites, embarking similar payloads. There is consistently a great potential for improving existing applications and developing new ones. Exploring all possibilities provided by such a

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1/ Infra-Red Temperature Sounder to be flown on poplar platforms (ex. HIRS-3)

2/ Visible & Infra-Red Scanning radiometer, to be flown an the polar platforms after 1998-2000 (ex AVHRR-)

system will then be the challenge for the users during the coming years. EUMETSAT and other operators are aware of this, and need close cooperation with the user community, to refine the system and provide it with a comprehensive service.

3. PRELIMINARY DEVELOPMENTS

3.1. PROBLEMS TO BE STUDIED

The METEOSAT, GOES, GMS and INSAT imageries and the VAS experience can be used to describe some potential uses for the SEVIRI instrument, on the basis of requirements coming from current practice of operational meteorologists and scientists. However, it is clear that these uses will not be the only ones. Other uses may appear after the SEVIRI will be in orbit, because the synergistic use of AVHRR and VAS data from a single instrument has not been possible so far.

Wind extraction from MSG images has been determined as the driver in requirements concerning the future meteorological extraction facility. It is obvious from the existing experience and from the new potential of the instrument.. The main problems to be addressed in parallel to the definition phases of the satellite programs may be listed as follows.

Improve the height assignment of CMW using the new channels of the SEVIRI, mainly the split-window WV and the CO_2 absorption band, and other techniques like stereoscopy.

Develop **new cloud discrimination techniques**, for tracking only the best wind drifters.

Review and study the potential of the new channels for **determining new type of features to be tracked** as tracers, in order to provide a real global coverage. This address mainly the ozone and WV channels, but also raise the question of indirect wind computation through the "sounding" data provided by SEVIRI.

Study the dynamics of clouds as wind drifters (relation between wind and cloud motion, according to cloud types)

Study the potential of the 15mn repeat cycle and the 3km sampling distance for the use of wind fields in support to Nowcasting.

This list is not exhaustive. As MSG has to provide the operational follow-on of the existing METEOSATs, the products and their extraction algorithms have to be defined in parallel to the development of the SEVIRI itself.

3.2. IMAGE SIMULATOR

This has to be done as soon as possible, without waiting for the instrument being in orbit. For this reason, EUMETSAT has initiated a programme of image simulation.

The SEVIRI simulator shall allow the production of synthetic images of the earth scene within each channel from the list given in table 1. The synthetic images shall reproduce the noise characteristics and sampling strategy of the imager, in space (geometric resolution) and time (repeat cycle), in order to show to SEVIRI developers and potential users, what atmospheric information the MSG system might provide. This shall allow to meet the following objectives:

> **Demonstration** of the SEVIRI performances to general user community, government authorities, etc...
>
> **Production of demonstration image data sets** allowing operational agencies and research teams to evaluate their use in deriving old and new meteorological, climatological, or environmental products.
>
> **Development of data extraction algorithms** in support of the CMWs mission
>
> **Simulation of the data flows** during the design, development and commissioning phases of the MSG ground segment.

The use of simulated data for the preparation of ground applications of future satellite instruments has been demonstrated by other satellite programmes. For example, the earth observation satellite programme SPOT in France, used synthetic images to define the work to be done with the future satellite data. A simulator of the GOES-I/M imager has been developed, with different objectives.

As SEVIRI is a new instrument concept, reference to existing products is not sufficient for defining its uses. The new potential applications have to be demonstrated as soon as possible. This is the goal of the SEVIRI simulator.

4. CONCLUSION

Starting with the GOES-I/M series, and continuing with MSG, the second generation of geostationary meteorological satellites represent a great improvement compared to existing system, by combining imaging and sounding. Their ability to look into the three dimensional atmosphere might allow the production of a wind field "more three dimensional" as now. This is the real challenge for the next decade.

References

[1] *ECMWF/EUMETSAT workshop on the use of satellite data in operational numerical weather forecasting* - ECMWF, 9 to 12 may 1989 - 2 Vol.

[2] *4th AVHRR data users's meeting* - Rothenburg, FRG, 5 to 8 September 1989 - EUM/P06

[3] *Workshop on the use of satellite data in nowcasting and very short range forecasting* - Te Meteorological Office College, Reading, UK, 16 to 20 July 1990 - EUM/P07

[4] *8th METEOSAT scientific users' meeting* - Norrköping, Sweden, 28 to 30 August 1990 - EUM/P08