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EURAINSAT: EUROPEAN SATELLITE RAINFALL ANALYSIS AND MONITORING AT THE GEOSTATIONARY SCALE

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1. INTRODUCTION

The latest generation sensors on board the Geostationary Operational Environmental Satellites (GOES) (Menzel and Purdom, 1994) and the upcoming METEOSAT Second Generation (MSG) (see Fig. 1) Spinning Enhanced Visible and Infrared Imager (SEVIRI) (Schmetz et al., 1998) significantly enhance the ability of sensing cloud microstructure and precipitation forming processes (Levizzani et al., 2000) from a geostationary platform. A potential exists for improved instantaneous rainfall measurements from space by combining infrared (IR) and visible (VIS) observations with passive microwave (MW) measurements.

IR and VIS satellite rainfall estimates have long since been available and suffered from the difficulty in associating cloud top features to precipitation at ground level. They were used for climate purposes or combined with radar measurements for nowcasting (e.g. recent examples by Amorati et al., 2000; Porcù et al., 1999; Vicente et al., 1998).

Physically-based passive MW methods were developed mainly using data from the Special Sensor Microwave/Imager (SSM/I) and are based on several different physical principles (see for example Smith et al., 1998; Wilheit et al., 1994). Limitations of MW algorithms include the relatively large footprint and the low earth orbits not suitable for most of the operational strategies.

Combined MW and IR algorithms using SSM/I radiometric data were first oriented to monthly averages over wide areas (e.g. Adler et al., 1993) or to global products as it is for the Global Precipitation Climatology Project (GPCP) (Huffman et al., 2001), although the need for instantaneous combined estimations was recognized already some time ago (e.g. Levizzani et al., 1996). Several methods exist (Sorooshian et al., 2000; Todd et al., 2001; Turk et al., 1999) that make use of IR and MW at various degrees of complexity and targeting different rainfall regimes. Some of these are running operationally, granting that their validation requires additional work in the years to come. In particular, global rapid-update estimates with near real-time adjustment of the thermal IR co-localized with MW-based rainrates are operationally very promising (Turk et al., 1999).

The algorithms for the Tropical Rainfall Measuring Mission (TRMM) Precipitation radar (PR) require a special mention given the novelty and potential of the active instruments for future missions: an example is the TRMM algorithm 2A-25 (Iguchi et al., 2000). Combined MW and rain radar algorithms are relatively new and were developed for the TRMM Microwave Imager (TMI) and the PR (e.g. TRMM algorithm 2B-31, Haddad et al., 1997).

Finally, rainfall and humidity assimilation, and microphysical parameterizations for Local Area Models (LAM) and General Circulation Models (GCM) open up the road to very effective operational meteorological applications that incorporate the verification of model output (Turk et al., 1997).

2. EURAINSAT: THE PROJECT

EURAINSAT is a project partially funded by the European Commission with the aim of developing new satellite rainfall estimation methods at the geostationary scale for an operational use in short and

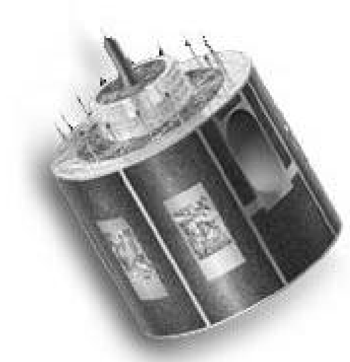

FIG. 1. Artist impression of the Meteosat Second Generation spacecraft (courtesy of EUMETSAT).

[?] *Corresponding author address*: V. Levizzani, ISAO-CNR, via Gobetti 101, I-40129 Bologna, Italy; e-mail: v.levizzani@isao.bo.cnr.it very short range weather monitoring and forecasting. It will exploit the new channels in the VIS, near IR and IR of the MSG SEVIRI that will be launched in middle 2002. The project started in January 2001 and will last until December 2003.

The consortium has two objectives in mind: 1) contribute to improving the knowledge of clouds and precipitation formation processes using meteorological satellite sensors, and 2) make available new precipitation products for weather analysis and forecasting. SEVIRI will in fact provide better multispectral measurements for the identification of the physical processes of cloud formation and evolution. The 15 min image repetition time is also more compatible with the time responses of cloud systems.

The following key geographic areas and major meteorological events were adopted:

- Flood-producing episodes (e.g. Northwestern and Southern Italy);
- Several cases involving the presence/absence of ice, polluted air masses and maritime conditions;
- Influence of orography, e.g. the Alps during the Mesoscale Alpine Programme (MAP) Special Observing Period (SOP) (Bougeault et al., 2001);
- Sustained light rain and "insignificant" rain cases (very difficult to detect from satellite) in UK and Northern Europe;
- Tropical and sub-tropical cases over Africa, where the Niger catchment was selected given the relatively regular ground raingage network;
- A climatological window over Europe (30-60 N, 15 W-20 E).

The project has gathered together a substantial part of the satellite rainfall community and in this sense has already reached an important milestone. This is particularly true considering that the team actively participates into the development of scenarios and concept for the future Global Precipitation Measurement (GPM) Mission. More information on EURAINSAT and its findings can be gained at the web site *http://www.isao.bo.cnr.it/~eurainsat/*.

3. MULTISPECTRAL MICROPHYSICAL CHARACTERIZATION OF CLOUD PROCESSES

A method was developed by Rosenfeld and Lensky (1998) to infer precipitation-forming processes in clouds based on multispectral satellite data. The method was originally based on the Advanced High Resolution Radiometer (AVHRR) imagery on polar orbiting satellites (Lensky and Rosenfeld, 1997). The forthcoming MSG SEVIRI is expected to enhance the capabilities of extracting cloud physical properties (Watts et al., 1998) more relevant for cloud genesis and evolution and not anymore limited by the insufficient number of passages. The effective radius (r_e) of the particles and the cloud optical thickness are extracted and used for radiative transfer calculations that define the cloud type and improve its characterization. Precipitation forming processes are inferred using also data from the AVHRR, The TRMM VIS and IR Sensor (VIRS) and the Moderate-resolution Imaging Spectroradiometer (MODIS) on board NASA's Terra spacecraft.

Microphysically "maritime" clouds grow in very clean air with small cloud condensation nuclei (CCN) and droplet concentrations, which produce very efficient coalescence and warm rain processes. "Continental" clouds normally grow, on the contrary, in polluted air having large CCN and droplet concentrations, i.e. the coalescence is relatively inefficient. The better knowledge of cloud microstructure and precipitation forming processes will facilitate the development of a new generation of improved passive MW rainfall algorithms. The importance of the cloud characterization method has recently been demonstrated by observing the effects of forest fire (Rosenfeld, 1999), urban pollution (Rosenfeld, 2000) and desert dust aerosols (Rosenfeld et al., 2001) in inhibiting precipitation formation processes.

4. RAINFALL ESTIMATION METHODS

4.1 MW Methods

Many methods have been proposed for detecting rainfall from MW satellite sensors. Simple methods using polarization-corrected brightness temperatures (e.g. Kidd, 1998) have been proposed together with more physical approaches that rely upon microphysical characterization by

- stratifying clouds into different microphysical types and examining how much of the variability in the bias of MW rainfall estimation is explained by the microphysical characterization;
- developing a library of passive MW signatures from different cloud types, and
- using a microphysical cloud classification for improving cloud radiative transfer modeling based on statistical multivariate generators of cloud genera.

The scheme of Mugnai et al. (1993) and Smith et al. (1992) is a good example of such methods, especially in the very complex environment of severe storm microphysics. Cloud modeling and MW radiative transfer has been recently applied to stratiform rainfall by Bauer et al. (2000). Panegrossi et al. (1998) have shown the importance of testing the physical initialization and the consistency between model and measurement manifolds.

4.2 Combined Multispectral and MW Methods

Cloud microphysical information, when combined with MW measurements, can lead to improvements in satellite-based rainfall measurements, especially from clouds in the extra tropics and over land (e.g. Bauer et al., 1998). EURAINSAT concentrates on exploiting SEVIRI data in the VIS, near IR and water vapor (WV) for cloud characterization and screening within a rapid cycle of rainfall estimation based on SSM/I, TMI and geostationary IR data. Data from MODIS serve the purpose of simulating data from MSG SEVIRI during the pre-launch phase. Moreover, the project shares in the cloud-related work from the MODIS team (King et al. 1997).

Two are the main research lines:

- Develop new MSG-MW rainfall algorithms incorporating the observed cloud microstructure and precipitation forming processes. State of the art cloud (Khain et al., 2000) and radiative transfer modeling will be instrumental to detailed cloud and rainfall type discrimination.
- Introduce such methods into rapid update rainfall cycles for near real time rainfall estimations over oceans and land with the widest possible area coverage. Mid-latitude Europe, the Mediterranean basin, North Africa, the Middle East and equatorial and tropical African regions are the main targets for operational and climatological applications. Applications to the Mediterranean have been reported by Meneguzzo et al. (1998).

5. APPLICATIONS

Applications embrace, among others, water availability, global change studies, nowcasting, hydrogeological disaster management, agriculture and famine reduction, and monitoring of remote areas.

Data assimilation procedures that improve cloud and humidity characterization in current analysis schemes for LAMs are at hand. Most important are the sensitivity to the orography and the modeling of moist processes (Buzzi et al., 1998). Cloud parameterization using information from multispectral methods is foreseen as a main goal. Extensive rainfall model output verification is another important task that can only be possible using satellite data with enhanced physical content such as those provided by the SEVIRI-MW proposed scheme.

MW signatures of precipitation, as given by a space-borne multi-frequency radiometer, have been shown to be the base for estimating the path attenuation in K-band satellite communications (Marzano et al., 2000) and opening the door to potential rainfall fade mitigation approaches.

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