THE IMPACT OF NEFODINA CONVECTIVE CLOUDS IDENTIFICATION IN THE RAIN RATE RETRIEVAL OF H-SAF

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Abstract

The impact of Nefodina software and its capabilities to recognize convective objects and their characteristics in rain rate estimation in EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF) project is presented.

The PR-OBS6 (Blended SEVIRI Convection area/LEO MW Convective Precipitation – Figure 1), a product dedicated to convective precipitation, is in HSAF project since the Continuous Development and Operations Phase (CDOP). The mentioned algorithm is based on the rapid updating technique: an instantaneous precipitation map is generated by IR images from operational geostationary satellites and "calibrated" by precipitation measurements from MW images in sun-synchronous orbits. The use of NEFODINA convective clouds identification inside the operative chain of PR-OBS6 improved the performance of the product. A case study is also presented to show the comparison between the convective rain rate retrieval by PR-OBS6 with other HSAF precipitation products and RELASE software (Rainfall Estimation from Lightning And SEviri data).

Figure 1: 1st October 2009 - PR-OBS6 output

1. THE EUMETSAT HYDROLOGICAL SATELLITE APPLICATION FACILITY (H-SAF)

The “EUMETSAT Satellite Application Facility on support to Operational Hydrology and Water Management” (H-SAF) was established by the EUMETSAT Council on July 3, 2005 and started activity at the official date of September 1, 2005 as part of the EUMETSAT SAF Network.

The H-SAF objectives are:

- to provide new satellite-derived products from existing and future satellites with sufficient time and space resolution to satisfy the needs of operational hydrology, by mean of the following identified products:
  - precipitation (liquid, solid, rate, accumulated);
  - soil moisture (at large-scale, at local-scale, at surface, in the roots region);
  - snow parameters (detection, cover, melting conditions, water equivalent);
- to perform independent validation of the usefulness of the new products for fighting against floods, landslides, avalanches, and evaluating water resources.
2. PRECIPITATION RETRIEVAL

Precipitation is the most important variable in the hydrological budget of the Earth. So the better understanding of the spatial and temporal distribution of precipitation is fundamental for any hydrologic and climatic applications and meteorological satellites provide a unique opportunity for monitoring the precipitation for regions where ground measurement is limited and consistent with the accuracy required by hydrologists.

The following table presents the list of the precipitation products in HSAF catalogue:

<table>
<thead>
<tr>
<th>Product acronym</th>
<th>Product name</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR-OBS1</td>
<td>Precipitation rate at ground from MW conically scanning radiometers (SSM/I, SSMIS) on LEO satellites</td>
</tr>
<tr>
<td>PR-OBS2</td>
<td>Precipitation rate at ground by MW cross-track scanning radiometers (AMSU-MHS) on LEO satellites</td>
</tr>
<tr>
<td>PR-OBS3</td>
<td>Precipitation rate at ground by GEO/IR supported by LEO/MW (Rapid Update)</td>
</tr>
<tr>
<td>PR-OBS4</td>
<td>Precipitation rate at ground by LEO/MW supported by GEO/IR (CMORPH)</td>
</tr>
<tr>
<td>PR-OBS5</td>
<td>Accumulated precipitation at ground by blended MW+IR</td>
</tr>
<tr>
<td>PR-ASS1</td>
<td>Instantaneous and accumulated precipitation at ground computed by a NWP model</td>
</tr>
<tr>
<td>PR-OBS6</td>
<td>Blended SEVIRI Convection area/ LEO MW Convective Precipitation</td>
</tr>
</tbody>
</table>

Table 1: Precipitation products in HSAF catalogue.

As shown by the Table 1, the precipitation is retrieved from Microwave instruments (more information about are remanded to the ATB-Documents in references), on account of their ability to "see" through cloud tops and detect directly the presence of actual precipitation particles within and below the clouds, but the most common approach is to combine geostationary and low orbital satellite data with several techniques to provide global precipitation estimation merging the high-quality, sparsely sampled data from polar-orbital satellites characterized by the more physically direct detection with continuously sampled data from geostationary satellites.

3. PR-OBS6 ALGORITHM

PR-OBS6 is a multisensory algorithm based on the rapid-update technique (RU), that was originally developed at the Naval Research Laboratory (Turk and Miller, 2005). RU is a blended passive microwave (MW) – infrared (IR) technique for the retrieval of instantaneous precipitation intensities in real-time by combining IR MSG-SEVIRI brightness temperatures (TB) at 10.8 $\mu$m with rain rates from MW measurements (PR-OBS1 and PR-OBS2).

The RU algorithm is based on a collection of time and space overlapping SEVIRI IR images and Low Earth Orbit (LEO) MW radiometers. As a new MW swath is available, the MW-derived pixels are paired with the time and space coincident geostationary (GEO) TB at 10.8 $\mu$m. Coincident data are subsequently located in a geographical latitude-longitude grid (2.5° x 2.5°), and for each grid box the histogram of the IR TBs and that of the corresponding MW rain rates are built. Then geolocated IR TBs vs MW rain rates relationships are produced by combining the TB histograms and those of MW rain rates by means of a probabilistic histogram matching technique and used in the assignment of a precipitation intensity value at each GEO pixel. As soon as a grid box is refreshed with new data, the corresponding relationship is updated using updated IR TB and MW rain rate histograms. Relationships older than 24 hours with respect to the acquisition time of the IR TB are considered not reliable until a refresh of the relationship is done.

During the Development Phase of the HSAF program (2005-2010) the detection capability technique has been evaluated with a large validation activities. In detail a preliminary screening between convective and stratus clouds has been demonstrated a positive impact in the setting-up of TB/rain relation.
The preliminary screening to identify the convective areas is performed with NEFODINA (Puca, De Leonibus, Zauli, Rosci and Biron, 2005) a software of CNMCA that allows the automatic detection and classification of convective cloud systems and the monitoring of their lifecycles.

4. NEFODINA SOFTWARE

The NEFODINA (DYNAmic NEFOanalisyS) product has been developed by Italian Air Force Met Service (IAFMS) to estimate thunderstorms’ presence and intensity using only geostationary satellite data. More precisely using a multichannel approach (infrared window at 10.8µm and water vapor absorption bands (at 6.2µm and 7.3 µm) are used), it provides information on Convective Objects (COs) inside cloudy systems (from mesoscale system down to single cell thunderstorm). It is an important now-casting application used by the forecasters to diagnose the convective activity, evaluate its severity and its potential development.

NEFODINA produces images that identify detected cells, their development (developing/dissolving phase) and their movement (Figure 2). These output images are associated to ASCII files which contain quantitative information of the IR1, WV1 and WV2 channels BTs along with CO shape, slope index (spatial BT gradient), CO area and CO mean and minimum BTs.

![Figure 2: NEFODINA detail](image)

Figure 2: NEFODINA detail - Blue shades are used to show the cloud to which we are interested. Dark blue is used for lowest cloud and light blue/yellow for highest clouds. With red shades are indicated the cloud top of the detected convective cell evaluated in growing phase. With pink shades are indicated the cloud top of the detected convective cell evaluated in decreasing phase. The dark red and dark pink colors are used to indicate the most intensive convective regions.

5. THE USE OF NEFODINA

As already said above, NEFODINA is used as “convection mask”, but it is not the only use of NEFODINA in PR-OBS6 elaboration. In addition to this “passive” role, NEFODINA participates to the convective precipitation retrieval redistributing the initial estimation, made by PR-OBS1 and PR-OBS2, on the base of convective cell’s areas calculated by the software (Figure 3a).

![Figure 3a: Convective cell’s area detected by NEFODINA](image)

Figure 3a: Convective cell’s area detected by NEFODINA.

![Figure 3b: Intrinsic Underestimation](image)

Figure 3b: Intrinsic Underestimation - Comparison between precipitation retrieval by microwave sensor on polar satellite (AMSU) and radar.
This because, that in spite of its ability to see through the clouds, the Microwave instruments share the precipitation on all the area covered by the IFOV (Figure 3b) that in the edge of the swath is very large (Figure 4).
This could not be a problem for stratiform precipitation but is mandatory to take a different approach for convective precipitation.

Figure 4: AMSU-A dimension of the IFOVs

6. CASE STUDY

The Case study is the 1st of October 2009. The area of interest in the NE of Sicily island (Giampilieri area). Here the Department of Civil Protection (DPC) measured 190/200 mm in less than 6 hours. Heavy rain can turn into disasters and catastrophes when affecting areas deforested and inhabited. And this is the case. The mud flows evolved along the slope of the hills near the coastline, have reached speeds of several tens of kilometers per hour and large volumes (estimated at between 60.000 and 80.000 cubic meters) and each cubic meter of mud weighed not less than two tons because the mud has incorporated the vegetation, dry stone walls and boulders of the substrate acquiring a considerable destructive power evidenced by the effects on this area (Figures 5 and 6)

Figure 5-6: effects of the landslide on the area of Giampilieri

The event, very well localized, was linked to a cell that preceded a mesoscale cluster larger and organized.
As highlighted by the figure below (Figure 7), the accumulated precipitation made using the PR-OBS3 ( multisensory algorithm based on the rapid-update technique (RU) but without distinction between convective and stratiform clouds) product is completely underestimated, whereas accumulated precipitation made using the PR-OBS6 reflects the reality.
7. OUTLOOKS

The position of convective precipitation is almost entirely seen by means of lightning rate and locations.

Resuming an old idea of Tapie-Smith (1998) to estimate the rain rate with the amount of lightning, we created a rainfall retrieval technique, Rainfall Estimation from Lightning And Seviri data (RELASE), that uses geostationary satellite Infrared (IR) observations and lightning information retrieved from LAMPINET (lightning network of the Italian Air Force Meteorological Service)

So a quantitative relationship for rainfall estimation using lightning and Seviri data has been developed using a bivariate linear regression for the cluster’s rain volume:

\[ RR = (b_0 + b_1 S/N + b_2 T) N \]

where \( S \) is the number of strokes and \( N \) the number of pixels.

The figure below (Figure 9) shows how much similar are the estimation of the accumulated precipitation made using RELASE outputs and the radar measurement.
The RELASE software has been tested on 873 lightning's clusters and the results are:

POD = 0.48  FAR = 0.34  CSI = 0.30

In Figure 10 the Giampilieri case study event with the rain rate estimated with RELASE sw.

The good scores of RELASE software suggest a possible use as product in HSAF project to improve rainfall estimation of MW and IR techniques.

Obviously, the usefulness of the software is limited to the spatial coverage of the lightening network unless the RELASE coefficient have been calculated for several networks (LAMPINET, ATDNet); this limitation will be solved by the Lightening Imager on MTG. The coefficients were being already calculated by synthetic data.
8. REFERENCES


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