LATEST DEVELOPMENTS OF NEFODINA SOFTWARE IN THE FRAMEWORK OF HYDROLOGICAL SAF PROJECT

Davide Melfi[1] , Francesco Zauli[1] , Daniele Biron[1], Massimiliano Sist[1], Luigi De Leonibus[2]
(1) Centro Nazionale di Meteorologia e Climatologia Aeronautica , (2) USAM Ufficio Generale Spazio Aereo e Meteorologia

Abstract

Since the Continuous Development and Operations Phase (CDOP) the catalogue of HSAF project presents the PR-OBS06 product (Blended SEVIRI Convection area/LEO MW Convective Precipitation), a product dedicated to convective precipitation.
The 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.
Core of the algorithm of this retrieval software is NEFODINA, a tool of Italian Meteorological Service deputed to monitor strong convective clouds and individuate their characteristics. The paper shows the latest developments of NEFODINA software and their impact on the PR-OBS06 retrieval. This product is foreseen "in operation" for the second half of 2014 and during this actual phase (CDOP-2: 2012-2017) the product will be enlarged to Full Disk area and a dedicated WP will be structured to finalize the upgrade; some examples are already presented.

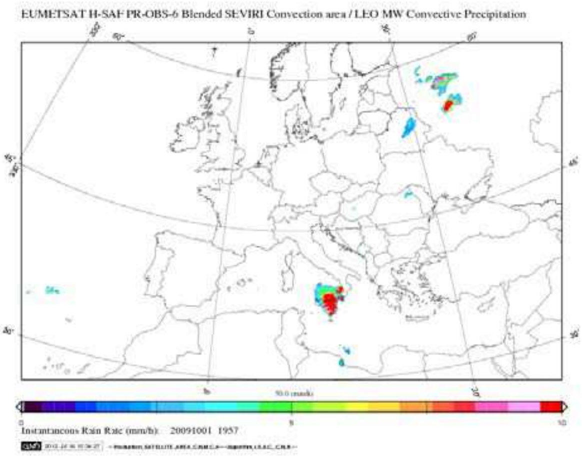


Figure 1: 1st October 2009 **- PR-OBS6 output**

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:
    - o precipitation (liquid, solid, rate, accumulated);
    - o soil moisture (at large-scale, at local-scale, at surface, in the roots region);
    - o 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:

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

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 µm 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 µm. 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.

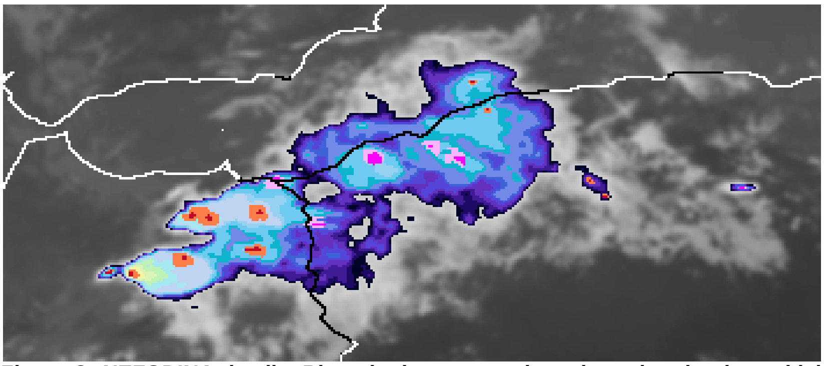
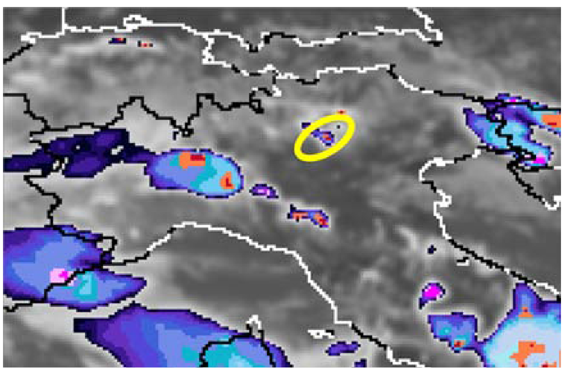


Figure 2: **NEFODINA detail - Blue shades are used to show the cloud to which we are interested. Dark blue is used for lowest cloud and light blue/yellow for highest clouds. With red shades are indicated the cloud top of the detected convective cell evaluated in growing phase With pink shades are indicated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

a) 

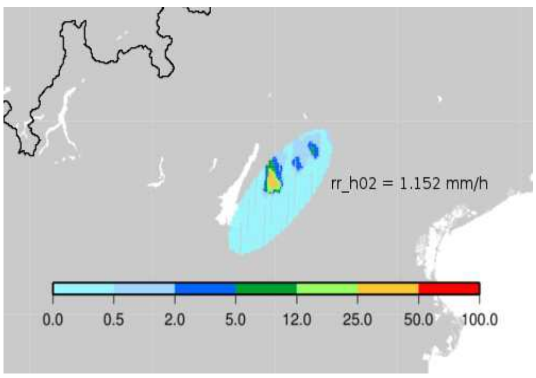
b) 

Figure 3a: **Convective cell's area detected by NEFODINA.**
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 Microvawe 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.

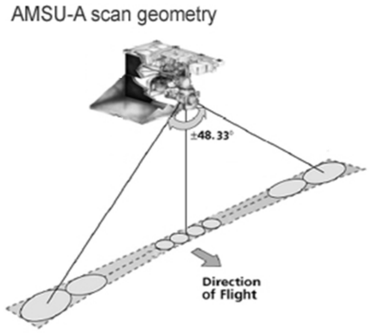


Figure 4: **AMSU-A dimension of the IFOVs**

6. LATEST DEVELOPMENTS

Trusted by the good performance of the algorithm (a case study was presented last year during the EUMETSAT conference in Sopot) we foresee that it will become "in operation" for the second half of 2014.
Another implementation is foreseen during this actual phase (CDOP-2: 2012-2017): the product will be enlarged to Full Disk area and a dedicated WP will be structured to finalize the upgrade.
Since now we are working to optimize the code of NEFODINA software to realize the run over the full disk in a reasonable time. We already performed this result using a simultaneous run of NEFODINA over four different area (Figure 5).

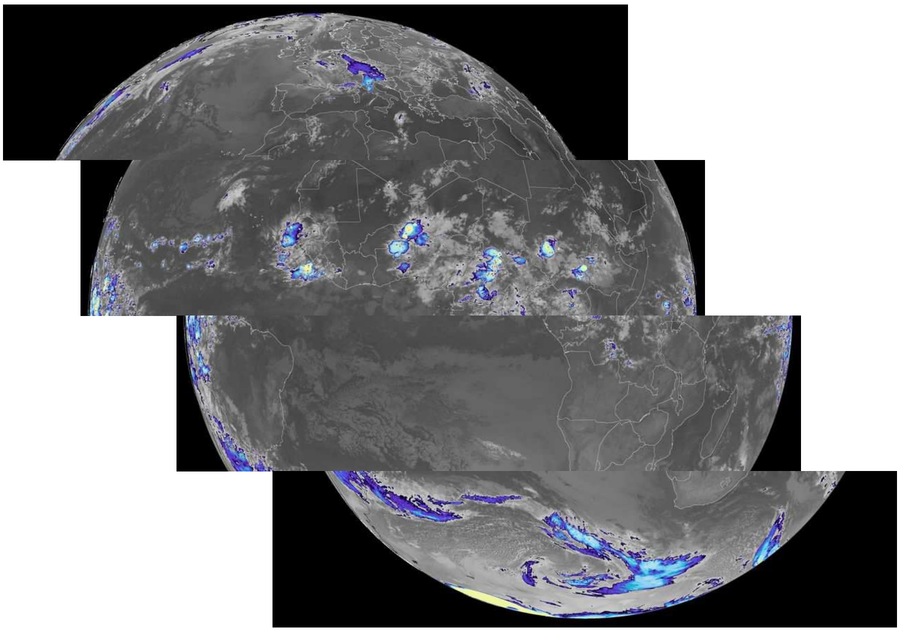


Figure 5: **simultaneous runs of NEFODINA over four different area to cover the full disk**

This is possible thanks to the high geographical scalability of the software demonstrating by the fact that since this year the area of Brazil, South Africa and Europe are present on the website ***nefodina.meteoam.it***

A parallel development is conducted by a collaboration between Centro Nazionale di Meteorologia e Climatologia Aeronautica (CNMCA) and University of Tor Vergata.
Another software, CELLTRACK (Figure 6 and Figure 7), about the detection of severe thunderstorm

and convective cells is developed. Based on a completely different approach from NEFODINA, using more SEVIRI channels and a trained Neural Network, we believe that it could be a complementary tool in the convective precipitation retrieval.

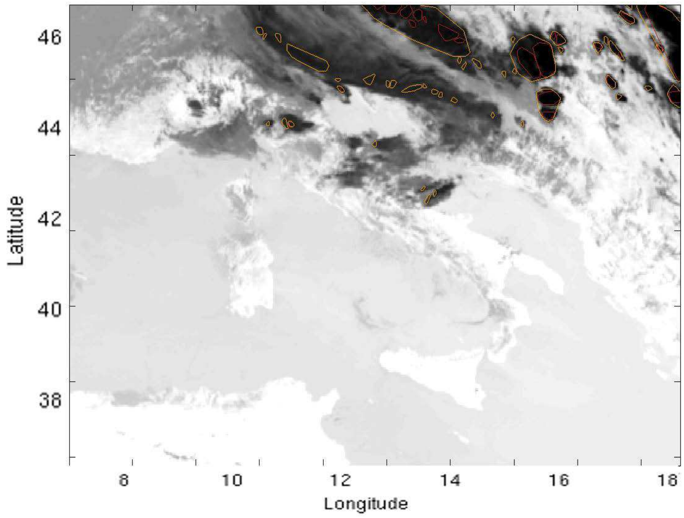


Figure 6: **24 June 2013 12:45UTC — CELLTRACK example**

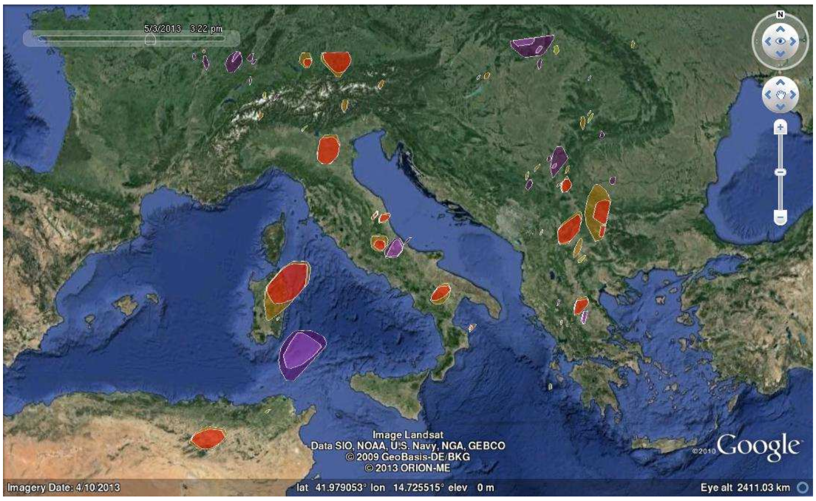


Figure 7: **03 May 2013 15:15 UTC — CELLTRACK KML output example**

7. REFERENCES

Mugnai A., Dietrich S., Levizzani V., (2011) Precipitation Products from the Hydrology SAF, EUM/STG-SWG/30/11/DOC/07

Tapia, A., Smith, J. A., and Dixon, M, (1998) Estimation of convective rainfall from lightning observations, Journal of Applied Meteorology, **37**, 11, pp 1497-1509

CNR-ISAC Italy, (2010), Algorithm Theoretical Basic Document for “PR-OBS1 Precipitation rate at ground by MW conical scanners” .

CNR-ISAC Italy, (2010), Algorithm Theoretical Basic Document for “PR-OBS2 Precipitation rate at ground by MW cross-track scanners

CNR-ISAC Italy, (2010), Algorithm Theoretical Definition Document for “PR-OBS3 Precipitation rate at ground by GEO/IR supported by LEO/MW". Available online at: http://hsaf.meteoam.it/documents/ATDD/ATDD-03.pdf

CNR-ISAC Italy, (2010), Algorithm Theoretical Basic Document for "PR-OBS4 Precipitation rate at ground by LEO/MW supported by GEO/IR".

Zauli F., Biron D., Vocino A., Melfi D. and Sist M., *"The impact of NEFODINA convective clouds identification in the rain rate retrieval of H-Saf"*, EUMETSAT Meteorological Satellite Conference 2012 - Sopot (Poland), 3-7 September 2012

De Leonibus L., Zauli F., Biron D., Vocino A., Melfi D., Facciorusso L., Cheloni A., Palella D., Torrisi L. and Marcucci F., *"EUMETSAT Hydrological SAF Precipitation Suite at C.N.M.C.A."*, EUMETSAT Meteorological Satellite Conference 2012 - Sopot (Poland), 3-7 September 2012

Zauli F., Biron D., Melfi D. and Sist M., *"First operational results of RELASE (Rainfall Estimation from Lightning And SEviri data) software at CNMCA*", European Conferences on Severe Storms 2011 - Palma de Mallorca (Balearic Islands, Spain), 3-7 October 2011

Zauli F., Biron D., Melfi D. and Sist M., *"Possible uses of lightning data for rainfall estimation by multi-sensor and cross-platforms approach"*, EUMETSAT Meteorological Satellite Conference 2011 - Oslo (Norway), 5-9 September 2011

De Leonibus L., Zauli F., Biron D., Melfi D., Labate D. and Laquale P., *"Simulation of Meteosat Third Generation – lightning imager through tropical rainfall measuring mission – Lightning imaging sensor data",* SPIE 2008, San Diego, California, USA, 12-14 August 2008

Puca S., De Leonibus L., Zauli F., Rosci P., Biron D., "*Improvements on numerical "object" detection and nowcasting of convective cell with the use of SEVIRI data (IR and WV channels) and neural techniques"*, The World Weather Research Programme's symposium on nowcasting and very short range forecasting, Tolouse – France, 5-9 Sept. 2005

Kolios S., Feidas B. *"An automated nowcasting system of mesoscale convective systems for the Mediterranean basin using Meteosat imagery. Part I: System description"*, Meteorological Applications, 20 Issue 3, pp. 287-295