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Support to Operational Hydrology and Water Management

Hydro-SAF Future Developments on Convective Rainfall

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EUMETRAIN CONVECTION WEEK 2015

8-12 June 2015

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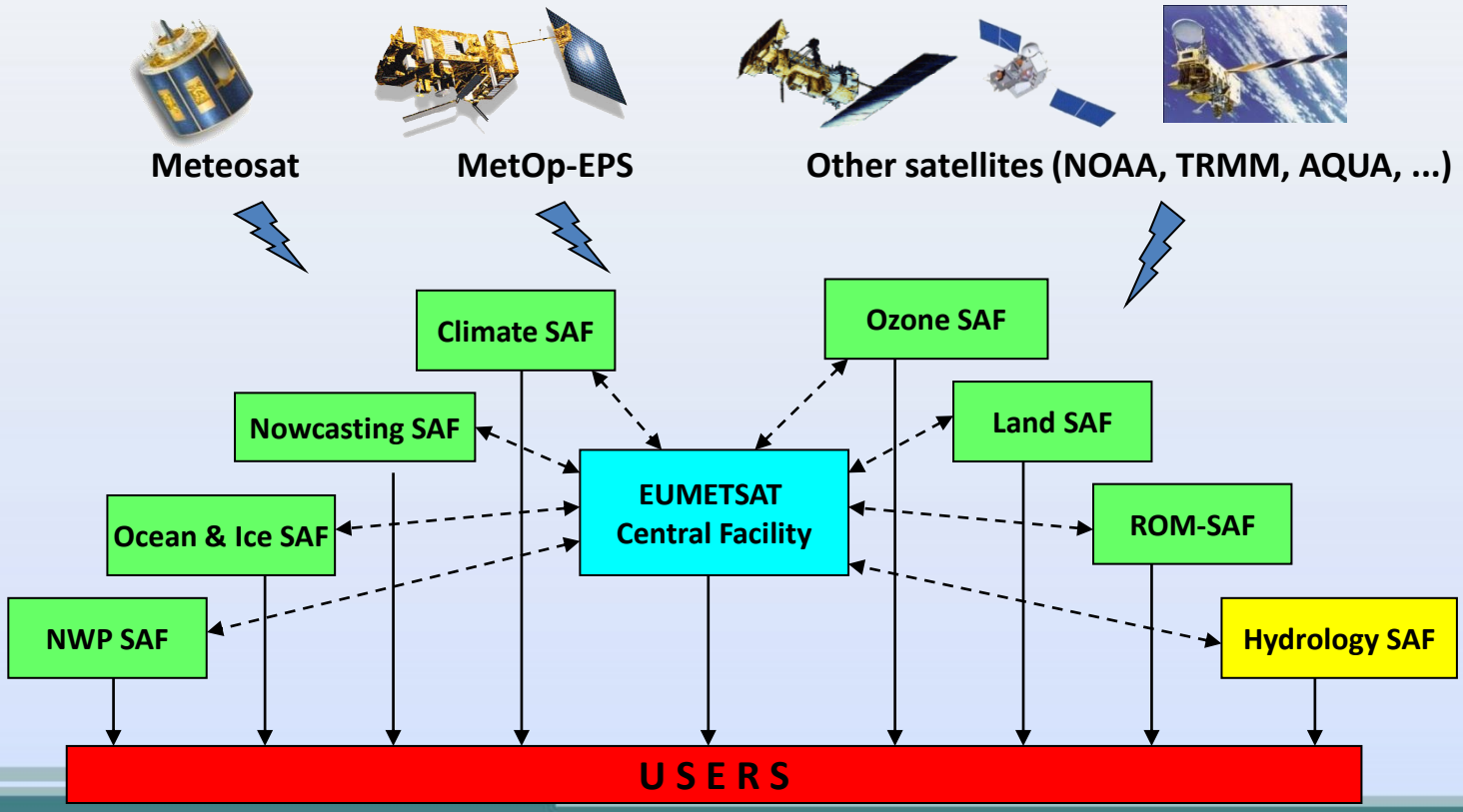
H-SAF overview

The "EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF)" was established by the EUMETSAT Council on 3 July 2005, and kicked-off on 16 September 2005, as part of the EUMETSAT SAF Network.



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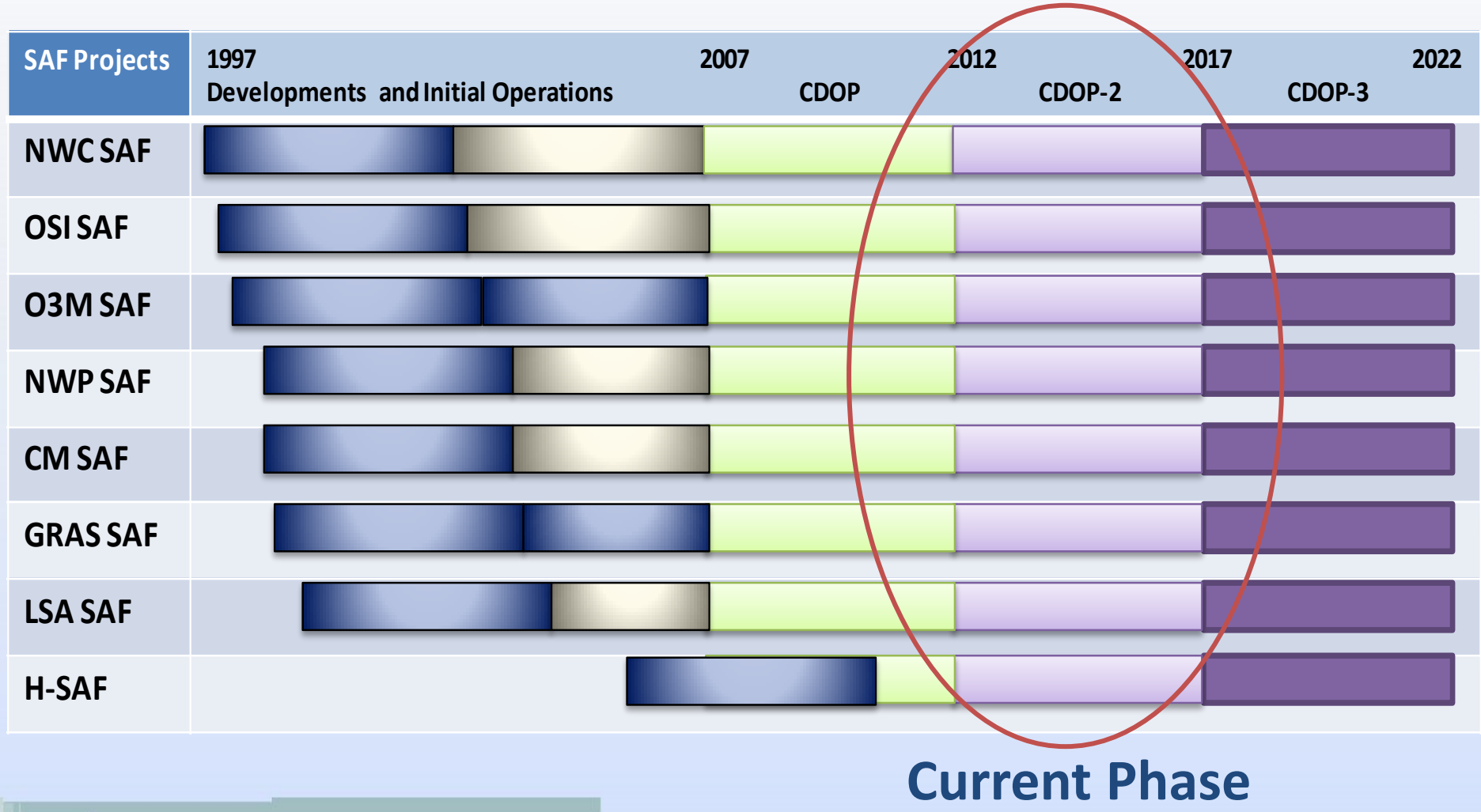
The Context: The SAF Schedule



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H-SAF objectives

- to provide satellite-derived products from existing and future satellites with sufficient time and space resolution to satisfy the needs of operational hydrology; 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; the activity includes:
  - ✓ downscaling/upscaling modelling from observed/retrieved fields to basin level;
  - ✓ fusion of satellite-derived measurements with data from radar and rain gauge networks;
  - ✓ assimilation of satellite-derived products in hydrological models;
  - ✓ assessment of the impact of the new satellite-derived products on hydrological applications.

Why from Space?

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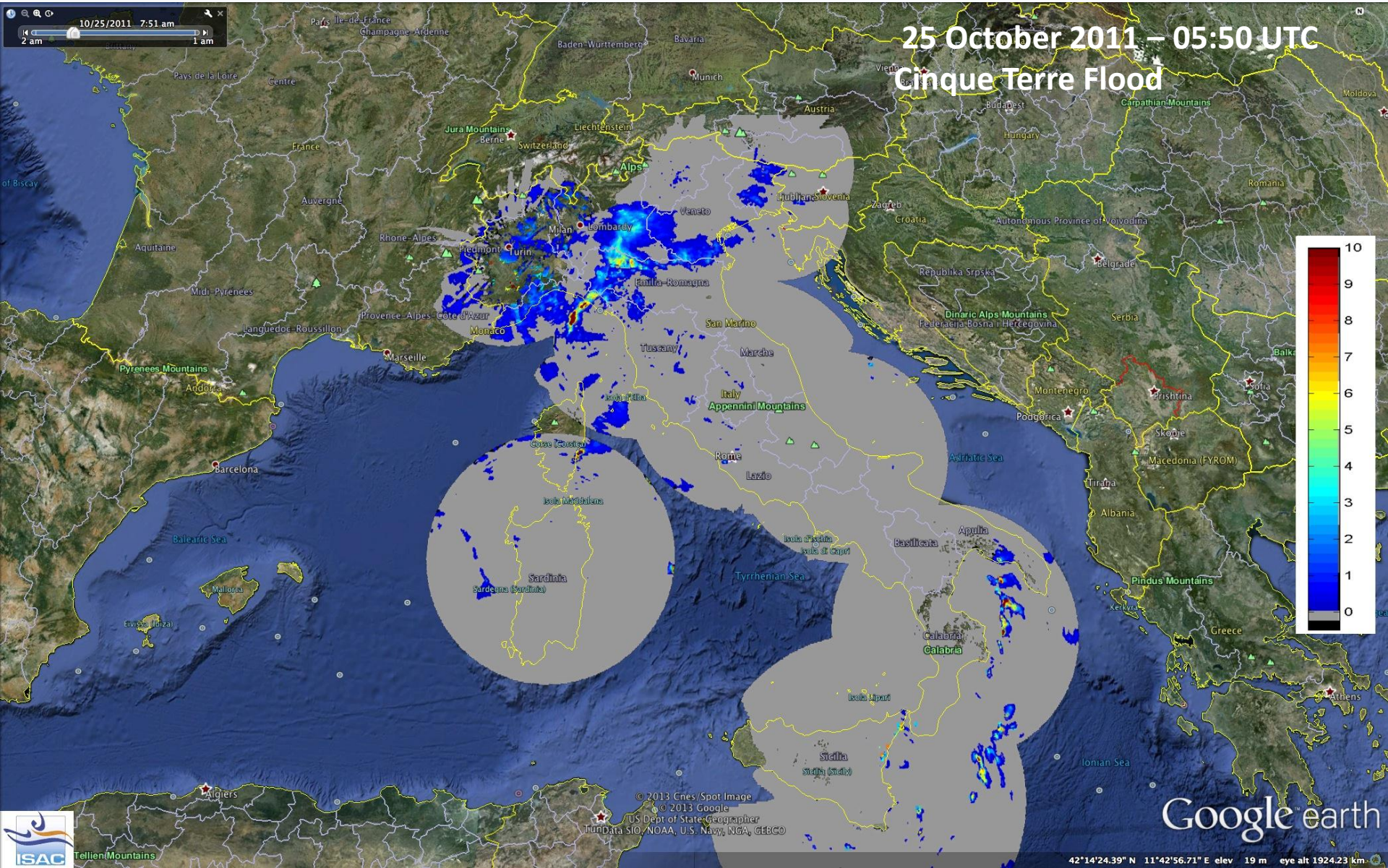
Heavy Precipitation Events Monitoring: Italian Radar Network Mosaic (DPC)



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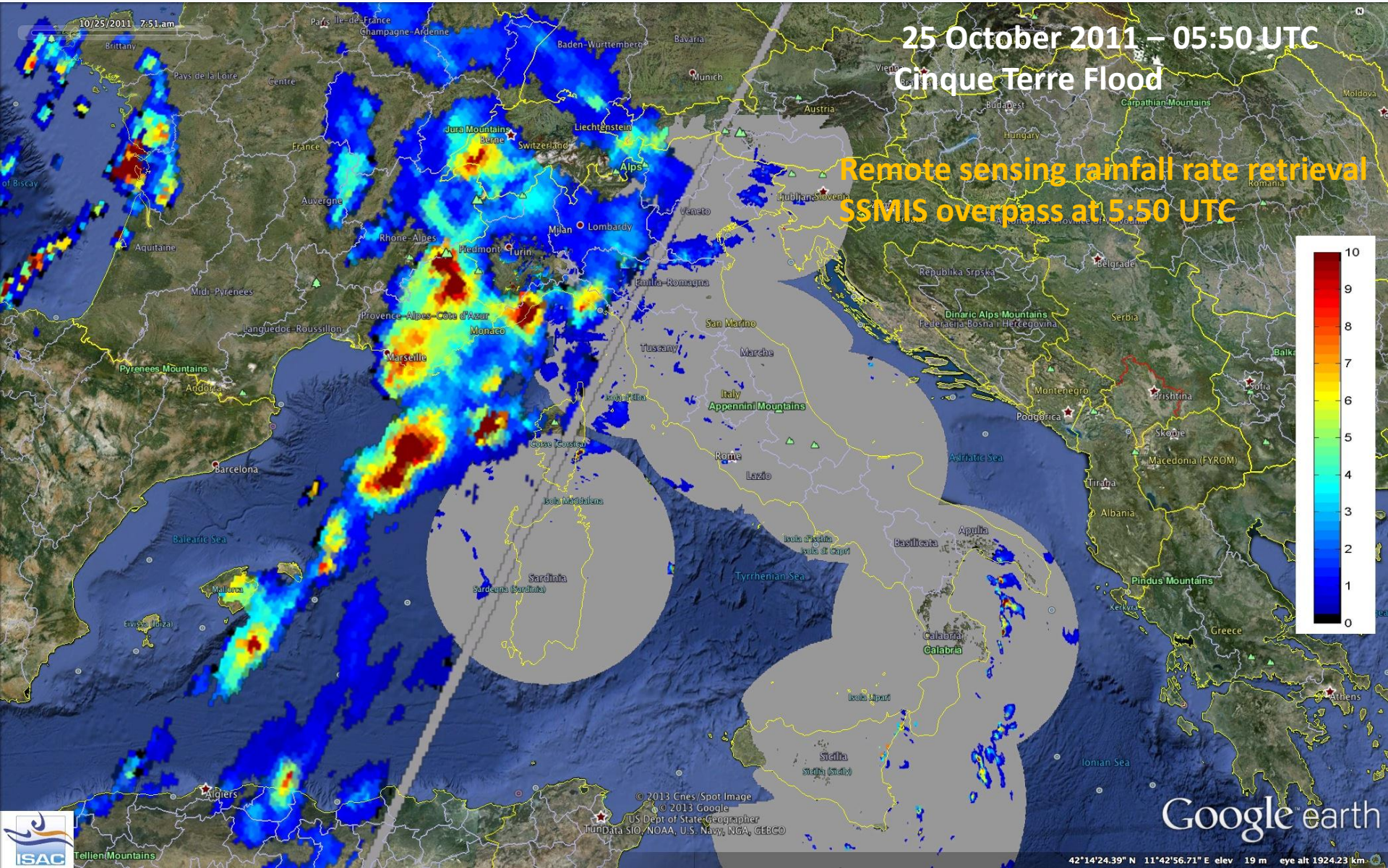

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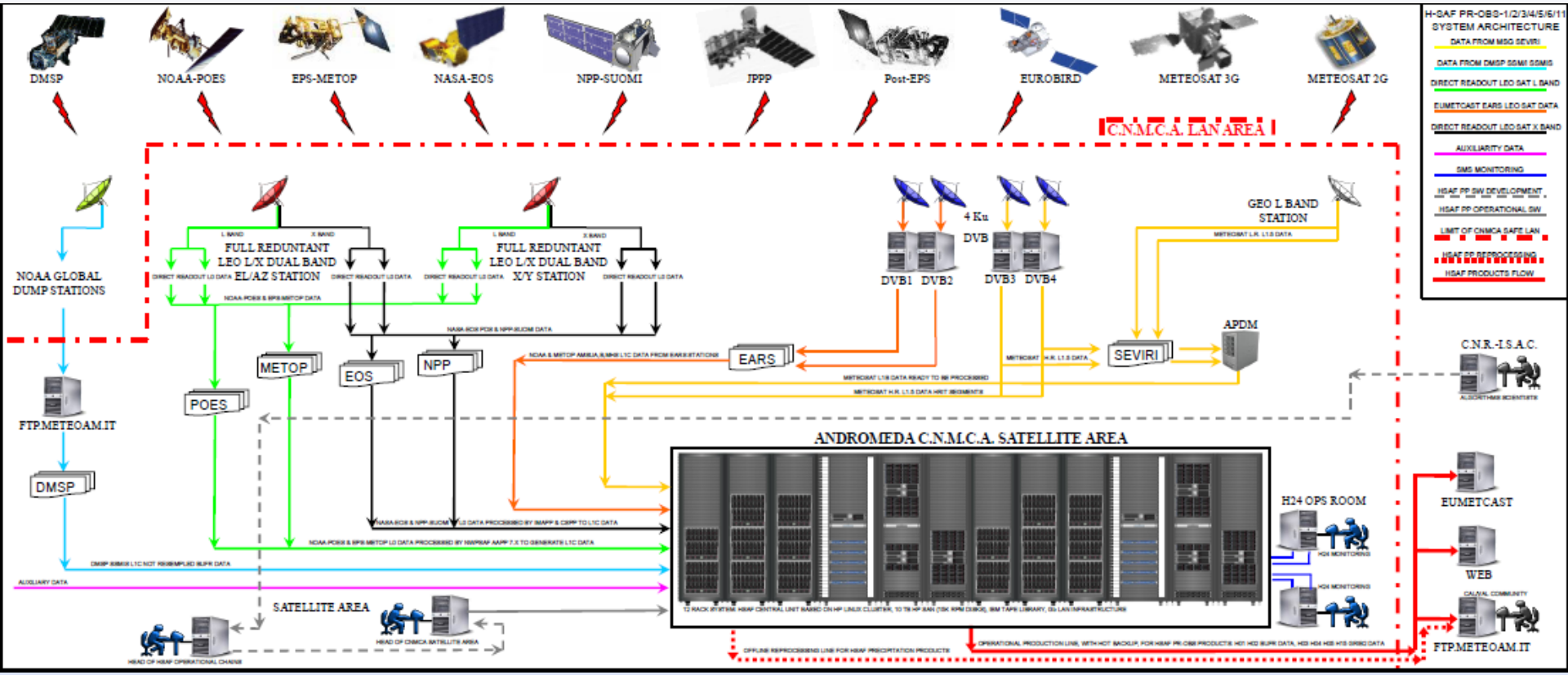
Generation Chain Architecture



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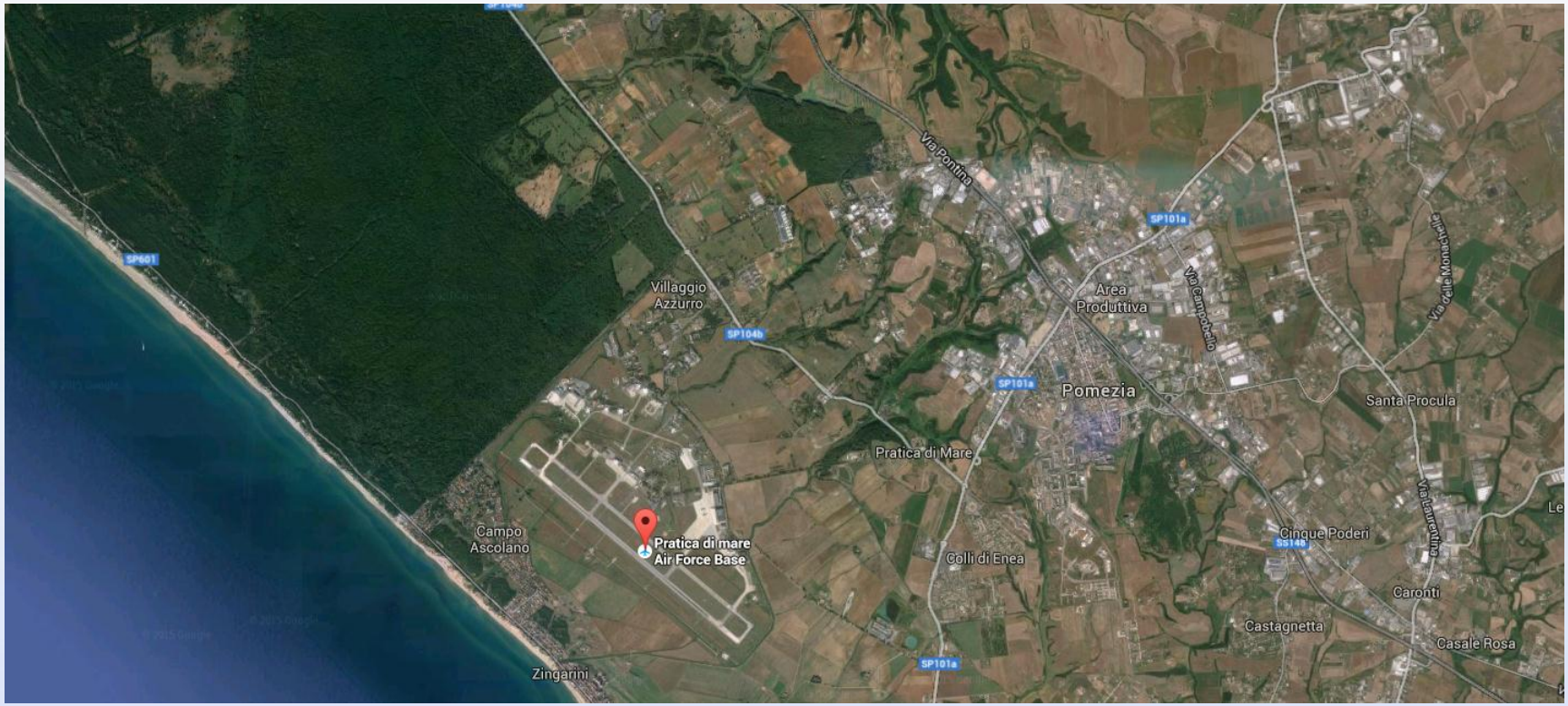
C.N.M.C.A. – ITALIAN AIR FORCE



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C.N.M.C.A. – ITALIAN AIR FORCE

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H-SAF Products

Precipitation Products

H01 PR-OBS-1	Precipitation rate at ground by MW conical scanners	Operational
H02A PR-OBS-2A	Precipitation rate at ground by MW cross-track scanners	Operational
H03A PR-OBS-3A	Precipitation rate at ground by GEO/IR supported by LEO/MW	Operational
H04A PR-OBS-4A	Precipitation rate at ground by LEO/MW supported by GEO/IR	Operational
H05A PR-OBS-5A	Accumulated precipitation at ground by blended MW and IR	Operational
H15A PR-OBS-6A	Blended SEVIRI Convection area/LEO MW Convective Precipitation	Pre-operational

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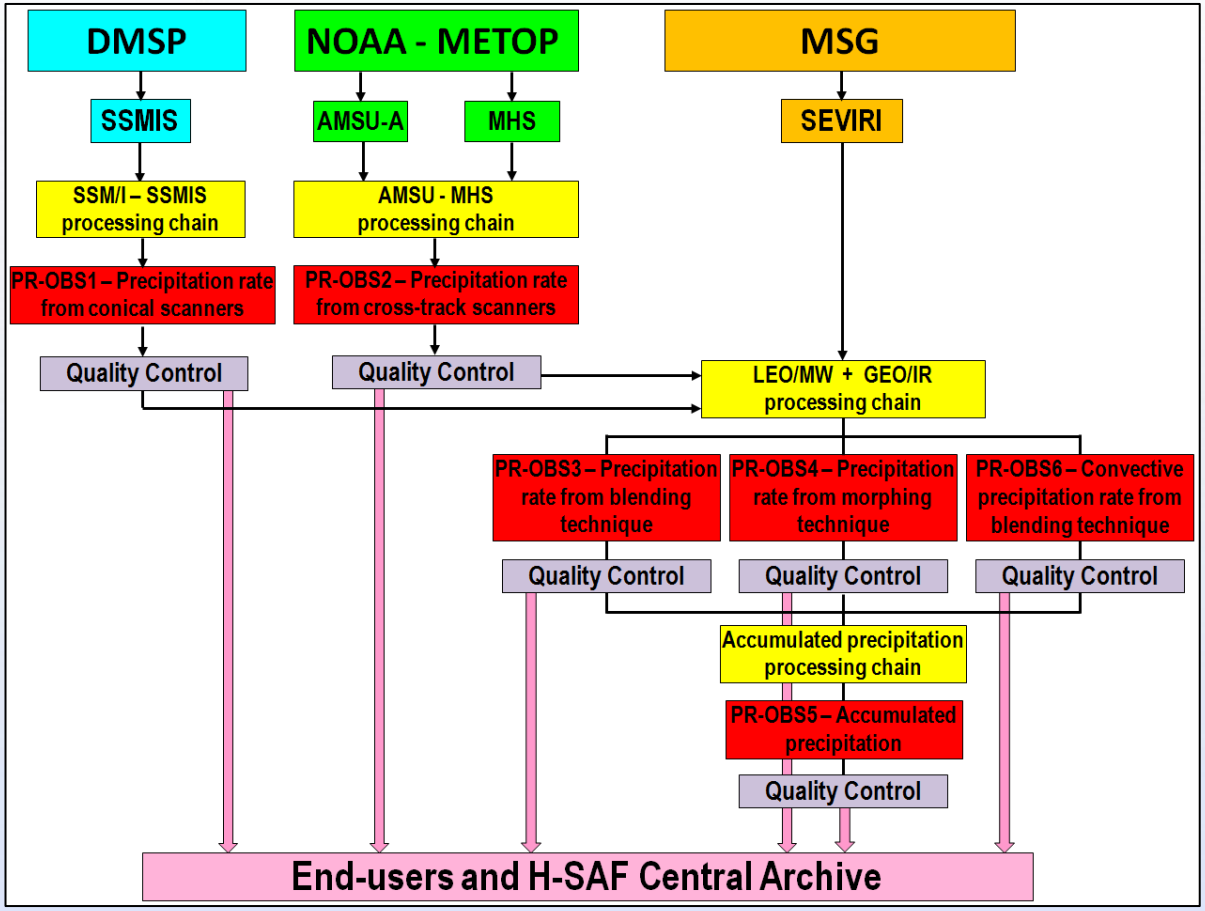
Microwave vs. Infrared

- Direct signal of precipitation is only observed by microwave.
- Optical wavelengths in the visible spectral range “sees” cloud thickness and *particle size*. Infrared wavelengths “sees” cloud top. Bot are correlated with rain but the rain cannot be directly measured.
- Radar allows to derive direct information about precipitation (but much more expensive and have their own problems as well).

Current Precipitation Products

Mugnai et al., 2013, NHESS

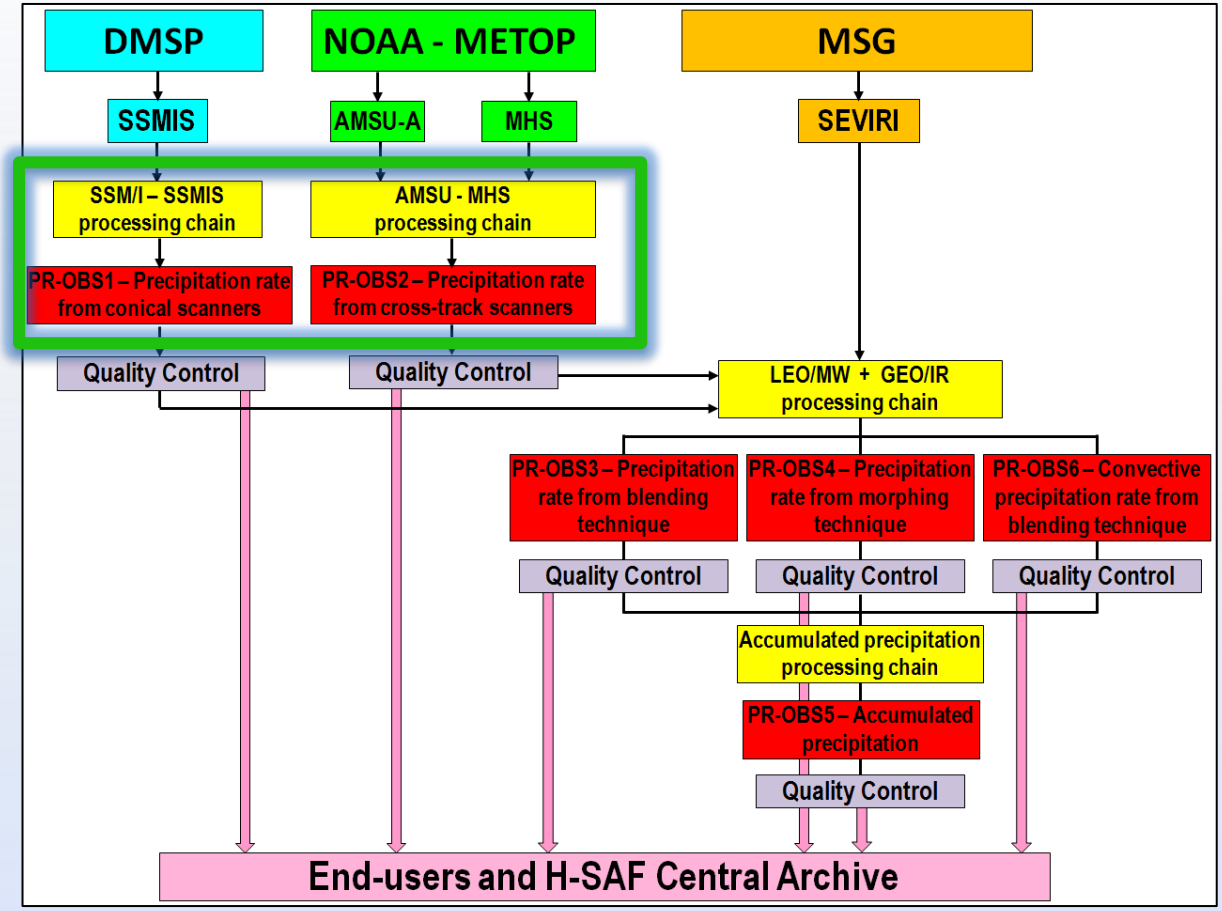


Current H-SAF precipitation product generation chain

All precipitation products are generated routinely at the CNMCA, Italy
[CNMCA also manages the Data service for all H-SAF products].

Current Precipitation Products

Mugnai et al., 2013, NHESS



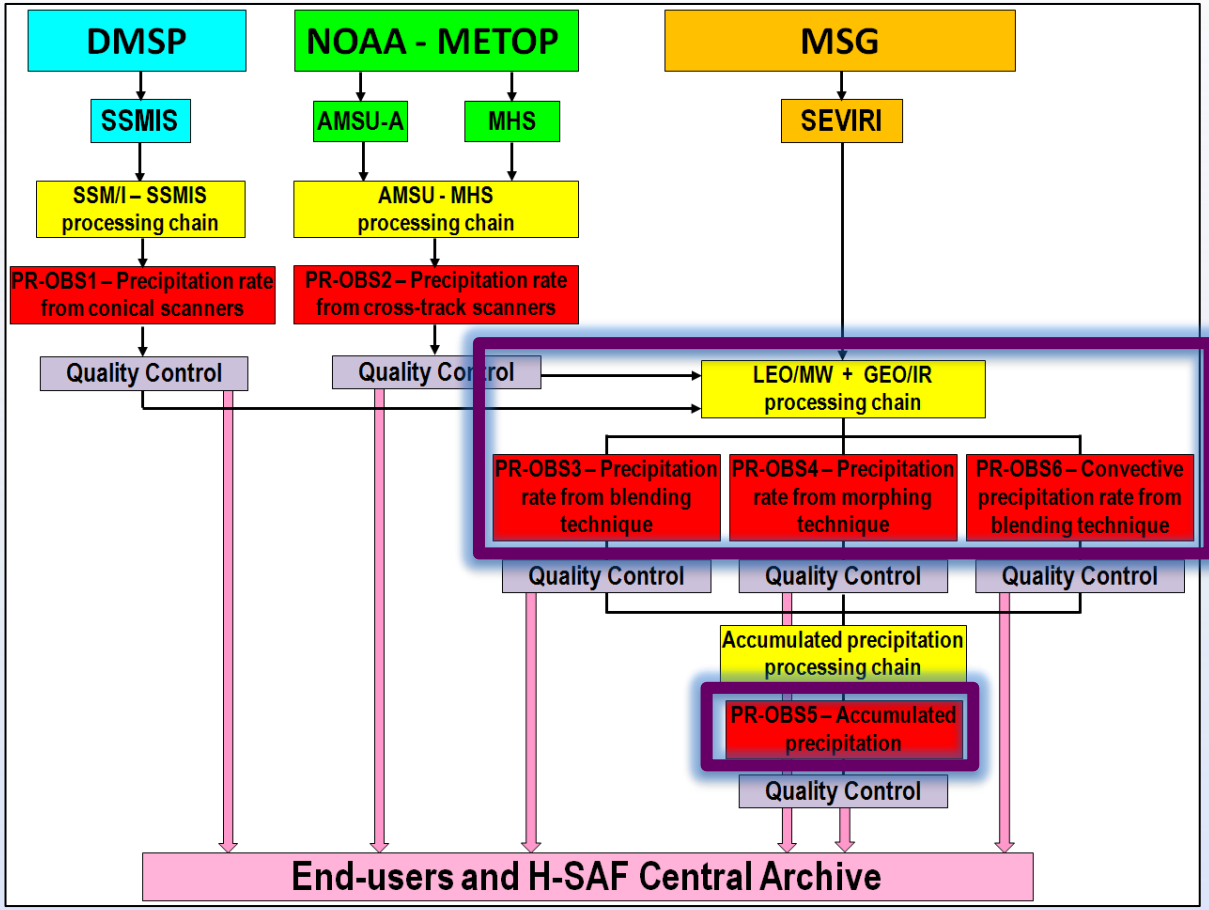
Current H-SAF precipitation product generation chain

All precipitation products are generated routinely at the CNMCA, Italy
[CNMCA also manages the Data service for all H-SAF products].

The H-SAF precipitation products based on PMW algorithms for cross-track and conical scanning radiometers are currently operational. They are developed by the SatMet group at ISAC/CNR-Rome

Current Precipitation Products

Mugnai et al., 2013, NHESS



Current H-SAF precipitation product generation chain

All precipitation products are generated routinely at the CNMCA, Italy [CNMCA also manages the Data service for all H-SAF products].

The use of IR/MW blending/morphing techniques for monitoring of precipitation at high temporal and spatial resolution is subject to **accuracy, consistency,** and ***high temporal sampling*** of retrievals from PMW observations.

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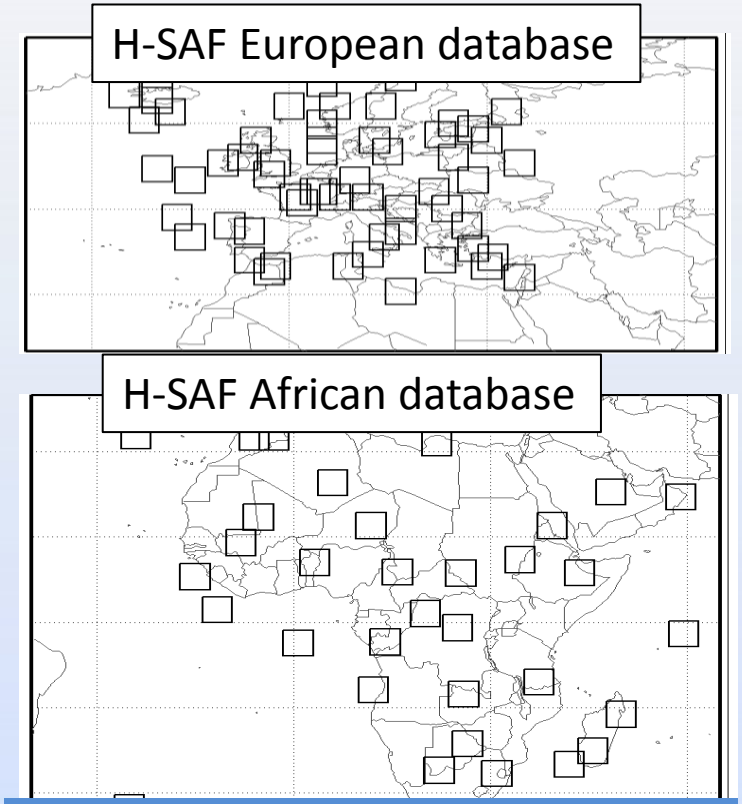
Microwave Products

H01 and H02 common features
The H01 and H02 algorithms are based on the same physical foundation

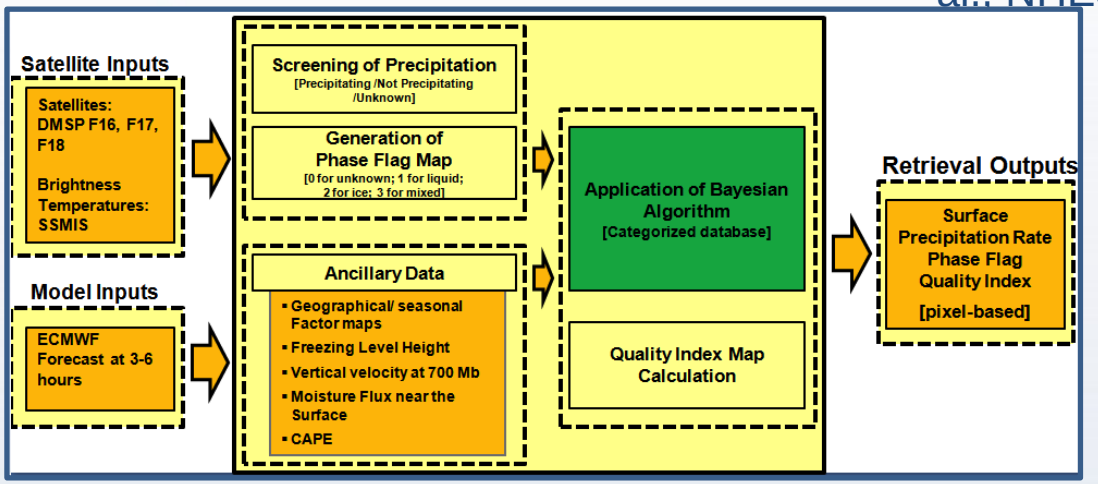
- Both algorithms use a **common database** made up of millions of microphysical-meteorological profiles derived from high resolution simulations (three nested grids; third grid at 2.5 km resolution) over the regions of interest (H-SAF area, Africa, Southern Atlantic) produced by a cloud resolving model (UW-NMS);
- A radiative transfer model is used to calculate brightness temperatures (TBs).



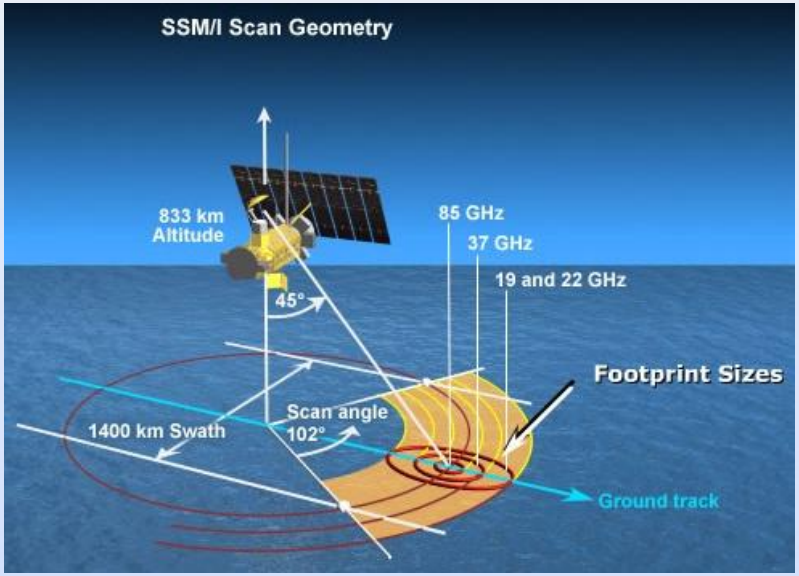
94 simulations (60 for European Db and 34 for African DB)

H01: Cloud Dynamics and Radiation Database (CDRD) Bayesian Algorithm for conical scanners

(Sanò et al., TGRS, 2013, Casella et al., TGRS, 2013; Smith et al., Mugnai et al., NHESS, 2013)



- Use of MW conical scanners (Tb) (DMSP-SSMIS);
- Physically-based Bayesian technique;
- *A synthetic a-priori* database built from cloud model generated microphysical profiles coupled to RTE model;
- Use of dynamical-thermodynamical-hydrological (DTH) model-derived variables to reduce *ambiguity* problem of retrieval solution; DTH variables from ECMWF forecast/analysis are used as additional input;
- Precipitation phase and Quality index evaluation.
- Proc. Time: < 2 min (H-SAF area), Hor. Res.: ≅15 km



H01: Cloud Dynamics and Radiation Database (CDRD) Bayesian Algorithm for conical scanners

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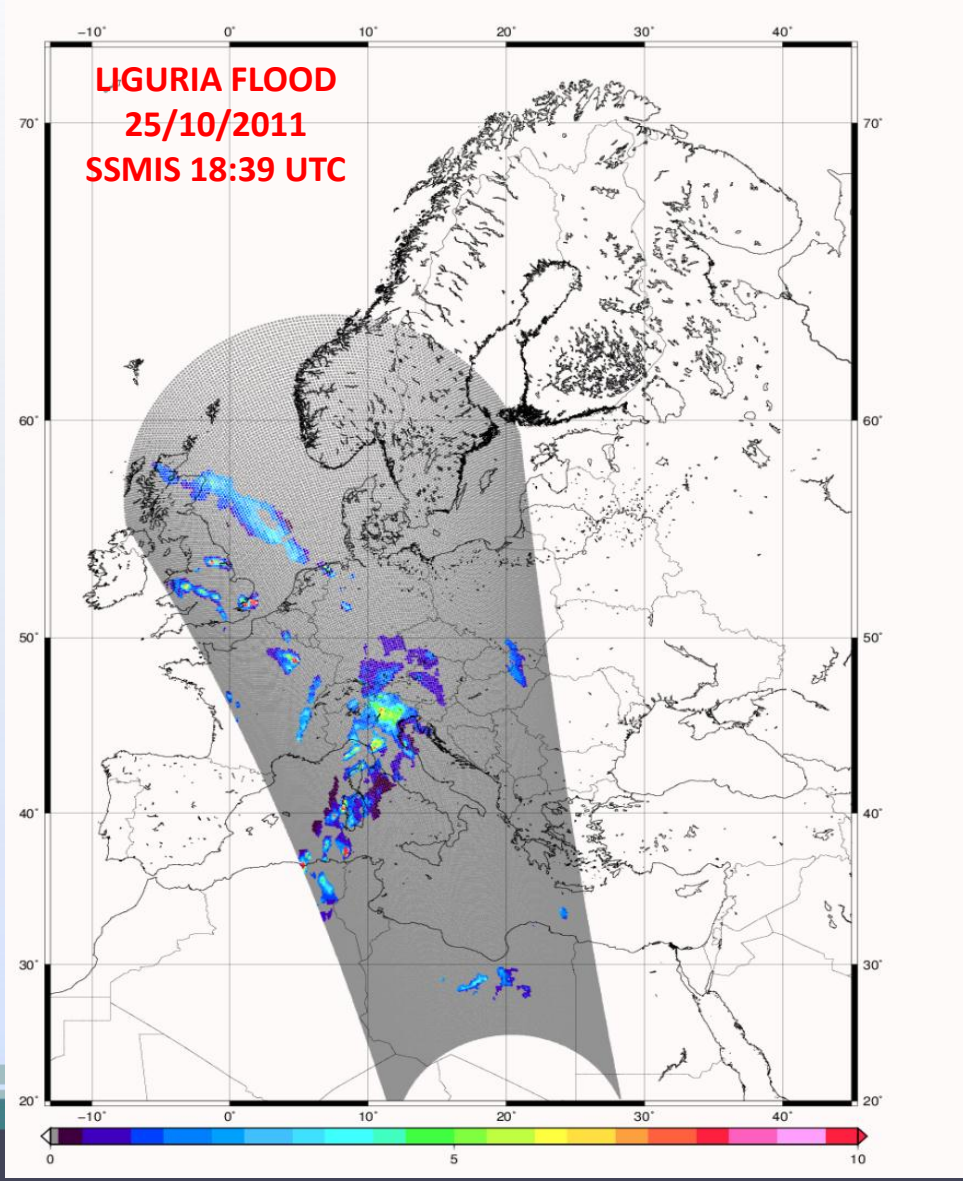


PR-OBS1 / H01

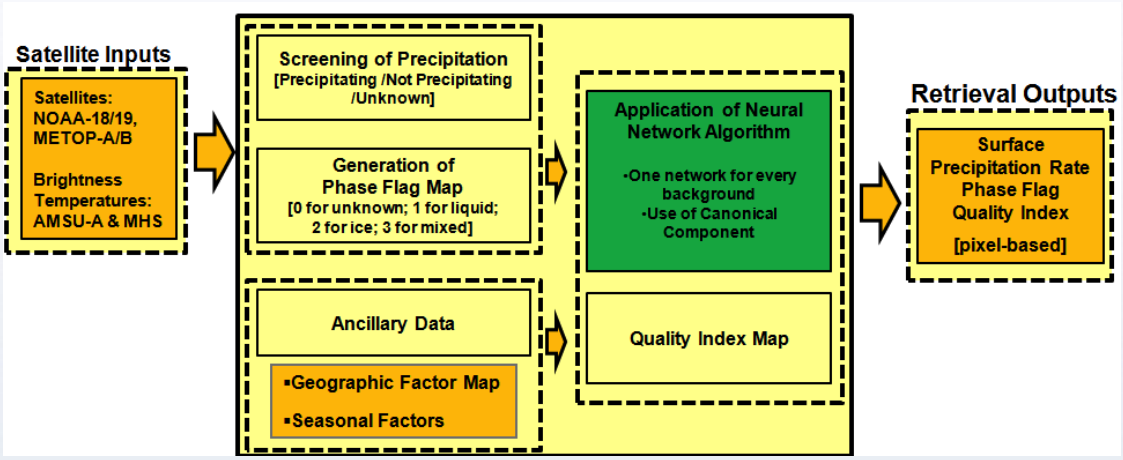
- Measurements of brightness temperature (TB) are made by radiometers on Low Earth Orbit (LEO) satellites of the Defence Meteorological Satellites Program (DMPS). Microwave Imager Sounder (SSMIS) radiometers include additional window and sounding channels that can provide more information on the atmospheric structure.

- The vertical structure necessary for the retrieval is input through the use of a database of radiative cloud/precipitation models previously built by means of simulations carried out over real events.

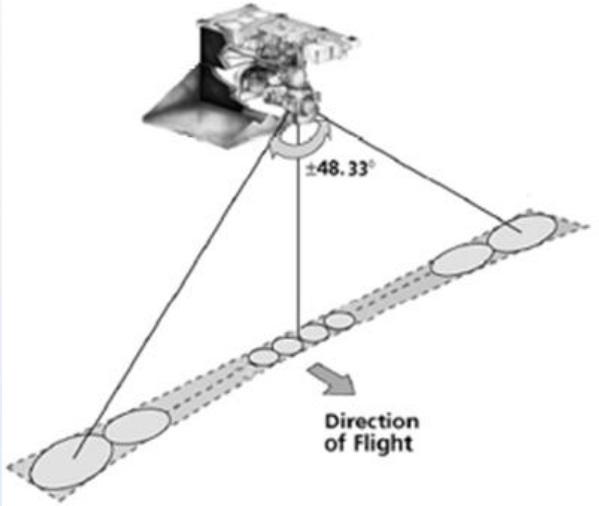
- Precipitation rates are estimated by means of Bayesian technique using the passive microwave measurements (brightness temperatures) and a probabilistic (Bayesian) analysis of a Cloud Radiation Database (CRD). The accuracy of the product depends on the representativeness of the database.

H02: PMW Neural-net Precipitation Retrieval (PNPR) Algorithm for cross-track scanners

(Mugnai et al., NHESS, 2013b, Sanò et al., AMTD, 2014)



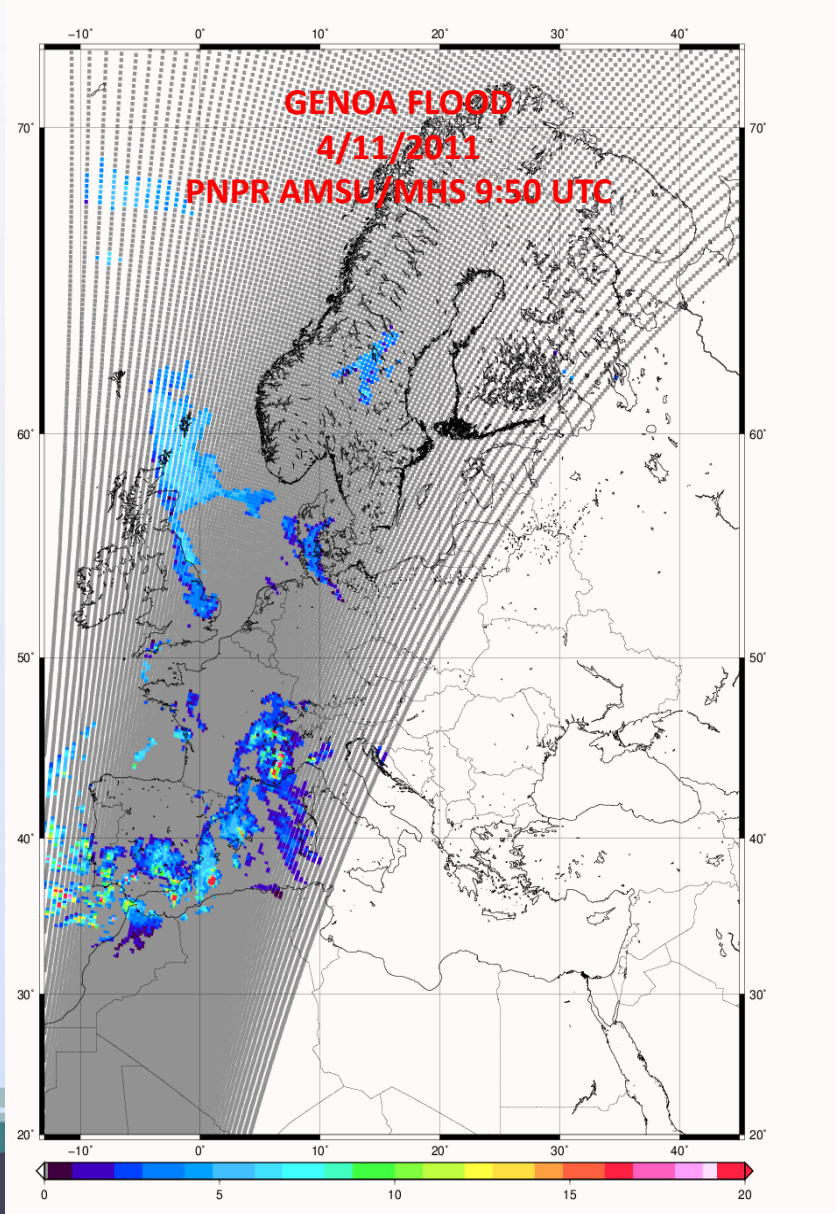
AMSU-A scan geometry



- Use of MW cross-track scanners (Tb) (NOAA and MetOp);
- Training database built from same cloud resolving simulations as CDRD;
- New optimal Artificial Neural Network (ANN) algorithm, one ANN for all surface backgrounds;
- The Full Disk Algorithm uses two ANNs (ANN-A for European Area, ANN-B for African Area) trained by the two Databases.
- Correction of MetOp-A channel [AMSU-A Channel 7 (54 GHz)] using a specific ANN.
- Input: AMSU-A/MHS channels, additional channel derived variables;
- Geographycal inputs (i.e., latitude, season, topography) used as additional input;
- Precipitation phase and Quality index evaluation
- Proc. Time: < 30 sec (H-SAF area), Hor. Res.: ≅16-50 km

H02: PMW Neural-net Precipitation Retrieval (PNPR) Algorithm for cross-track scanners

(Mugnai et al., NHESS, 2013b, Sanò et al., AMTD, 2014)



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PR-OBS2 / H02

- Surface precipitation rate are generated from MW sounders taken by cross-track scanners on operational satellites in sun-synchronous orbits.

- In absorption bands exploited for temperature sounding (the 54 GHz band of **AMSU-A**) or for water vapour sounding (the 183 GHz band of **AMSU-B** and **MHS**) the effect of surface emissivity is minimised. Precipitation that, *per sé*, represents a "disturb" for these instruments that are designed for all-weather temperature/humidity sounding, is retrieved by exploiting the differential effect of liquid drops or ice particles at different frequencies associated to weighting functions peaking in different atmospheric layers.

- Since the relationship between precipitation and satellite brightness temperatures is nonlinear and imperfectly known, the **rain rate retrievals value** here employ neural networks trained with tested physical models.

AMSU – MHS Neural Network Algorithm

The CDRD approach would be too time-consuming for cross-track scanning radiometers.

The estimates for surface precipitation rates and hydrometeor water-paths were trained using a mesoscale numerical weather prediction (NWP) model (**MM5**), a two-stream radiative transfer model (**TBSCAT**), and electromagnetic models for ice hydrometeors (**F(λ)**).

The MM5 model has been initialized with *National Center for Atmospheric Research* for **122 representative storms** and their corresponding brightness temperatures simulated at AMSU frequencies.

Only storms with simulated morphologies that match simultaneous AMSU observations near 183±7 GHz were used. The global nature of these storms used for training addresses the principal weakness in statistical methods trained with radar or other non-global data.

The validity of these simulated storms is supported by their general agreement with histograms of concurrent AMSU observations

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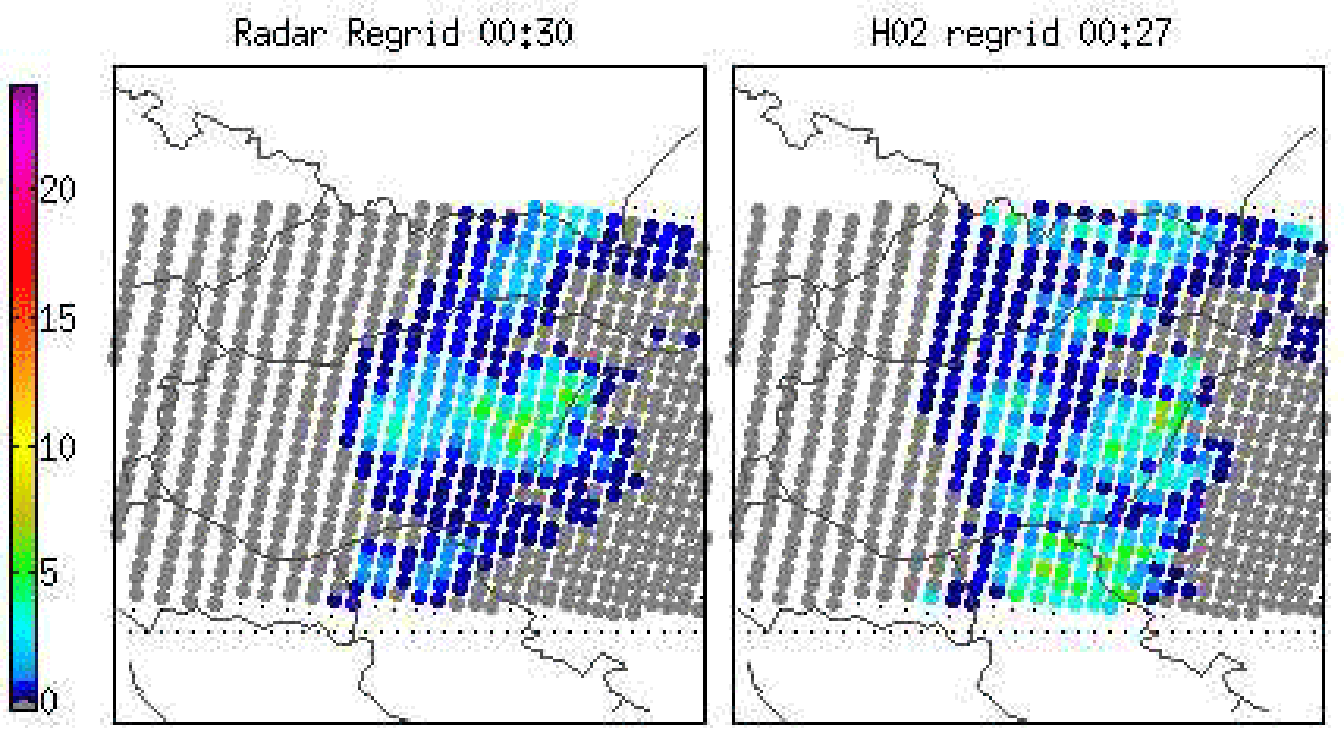
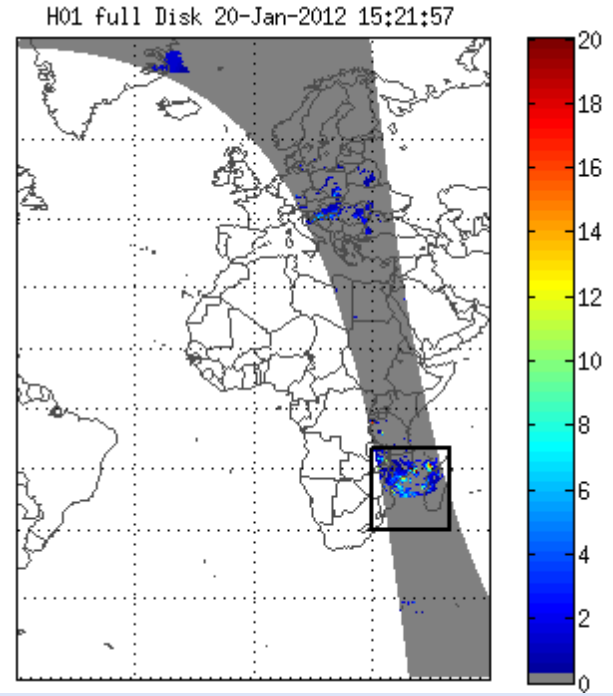
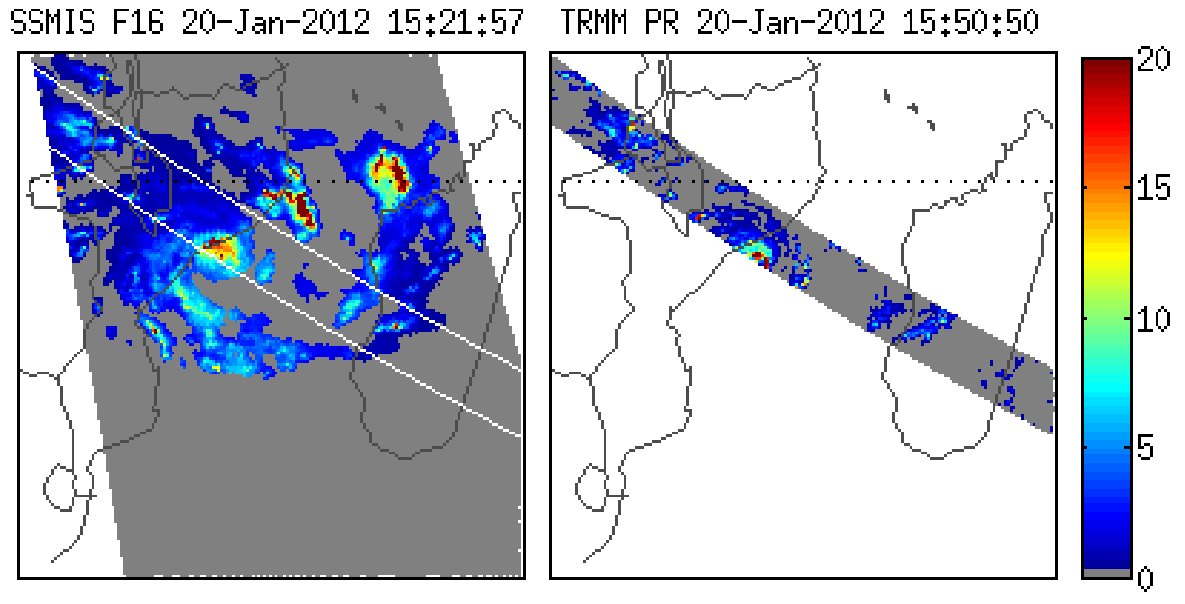
Consistency between retrievals from cross-track and conical scanning radiometers

Hungary July 07, 2011



CASE STUDY: Tropical Cyclone FUNSO
Algorithm: H01 (CDRD)





Tropical cyclone Funso formed in the Mozambique channel off the coast of Mozambique on 19 January 2012. Storms and floods from Funso have killed at least 22 people and forced tens of thousands from their homes in Mozambique.

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Multi-Platform Products

PR-OBS3 / H03

MW-IR Blended Technique “Rapid Update” (RU)

The RU allows to compute **instantaneous rain intensities at the ground at the geostationary time-space scale** (Turk et al. 2000, Torricella et al. 2007).

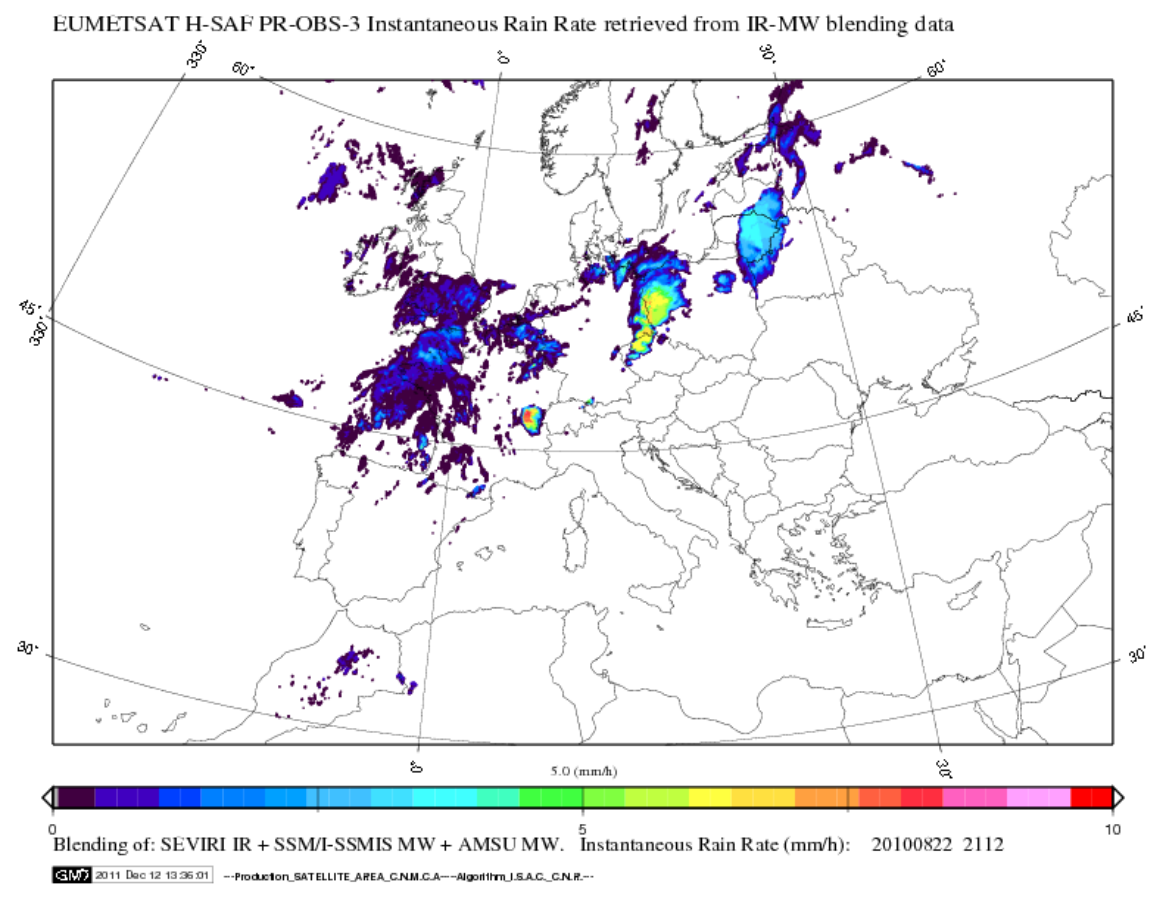
It is based on a **blended MW-IR technique that correlates, by means of the *statistical probability matching*, brightness temperatures measured by the IR geostationary sensors and PMW-estimated precipitation rates at the ground.**

Main inputs to the RU procedure

- geolocated IR brightness temperatures at **10.8 μm from the MSG-SEVIRI**;
- rain intensities from PMW data and algorithms.

PR-OBS3 / H03

MW-IR Blended Technique “Rapid Update” (RU)



PR-OBS3 / H03

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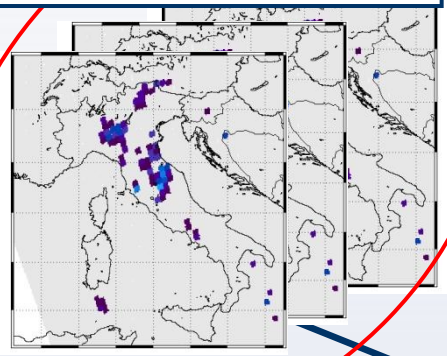
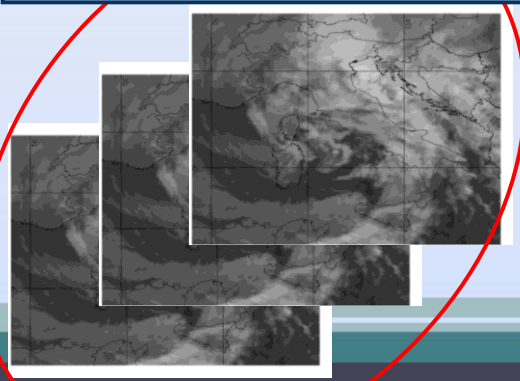
How the RU algorithm works

Rain intensity maps from PMW data



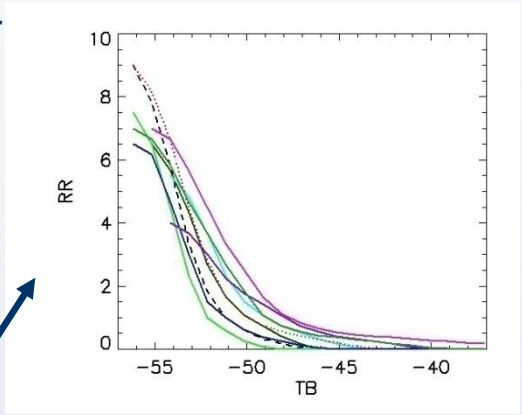
AT TIME t…

MSG- SEVIRI IR brightness temperatures at 10.8 μm



Extract space and time coincident locations from IR and MW data for each grid box

The process is restarted for each IR slot in the study period



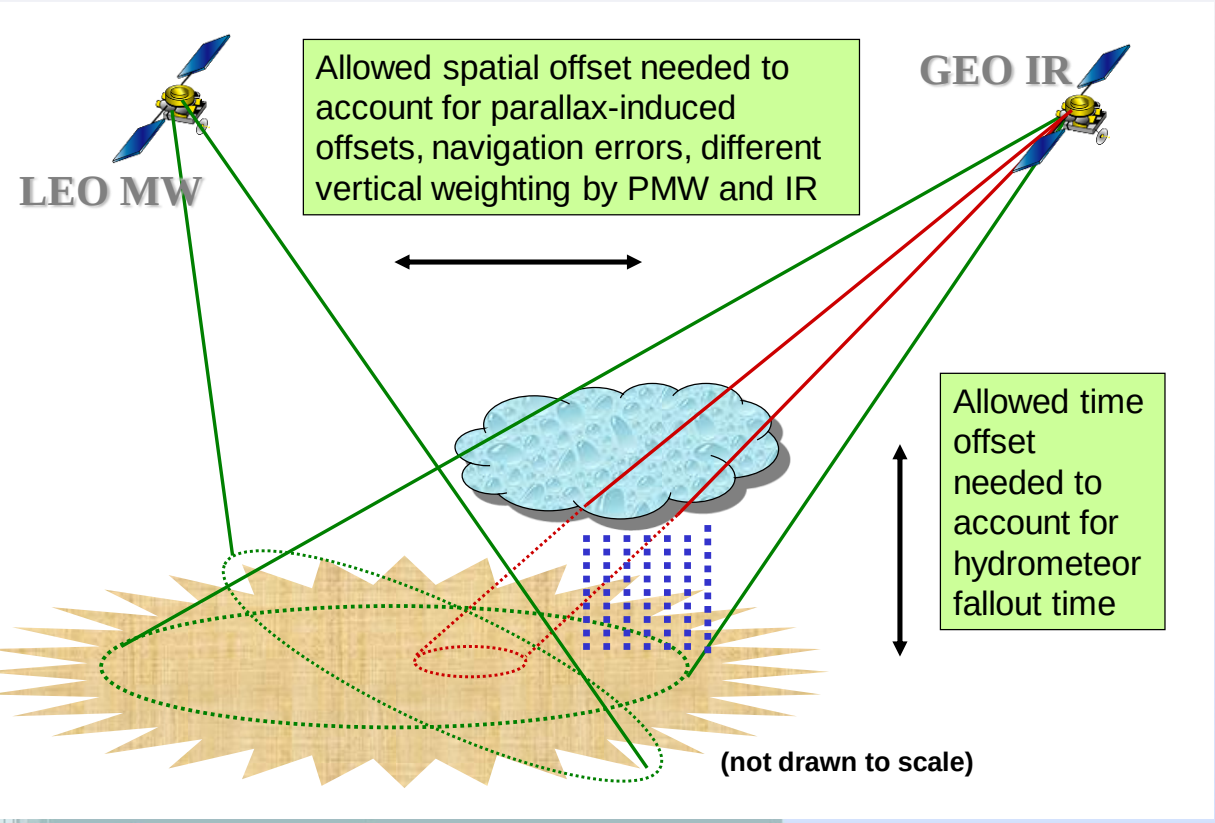
Create dynamical geolocated statistical relationships RR-T_b

Assign RR at every IR pixel

Produce instantaneous rain intensity maps at the geostationary time/space resolution

PR-OBS3 / H03

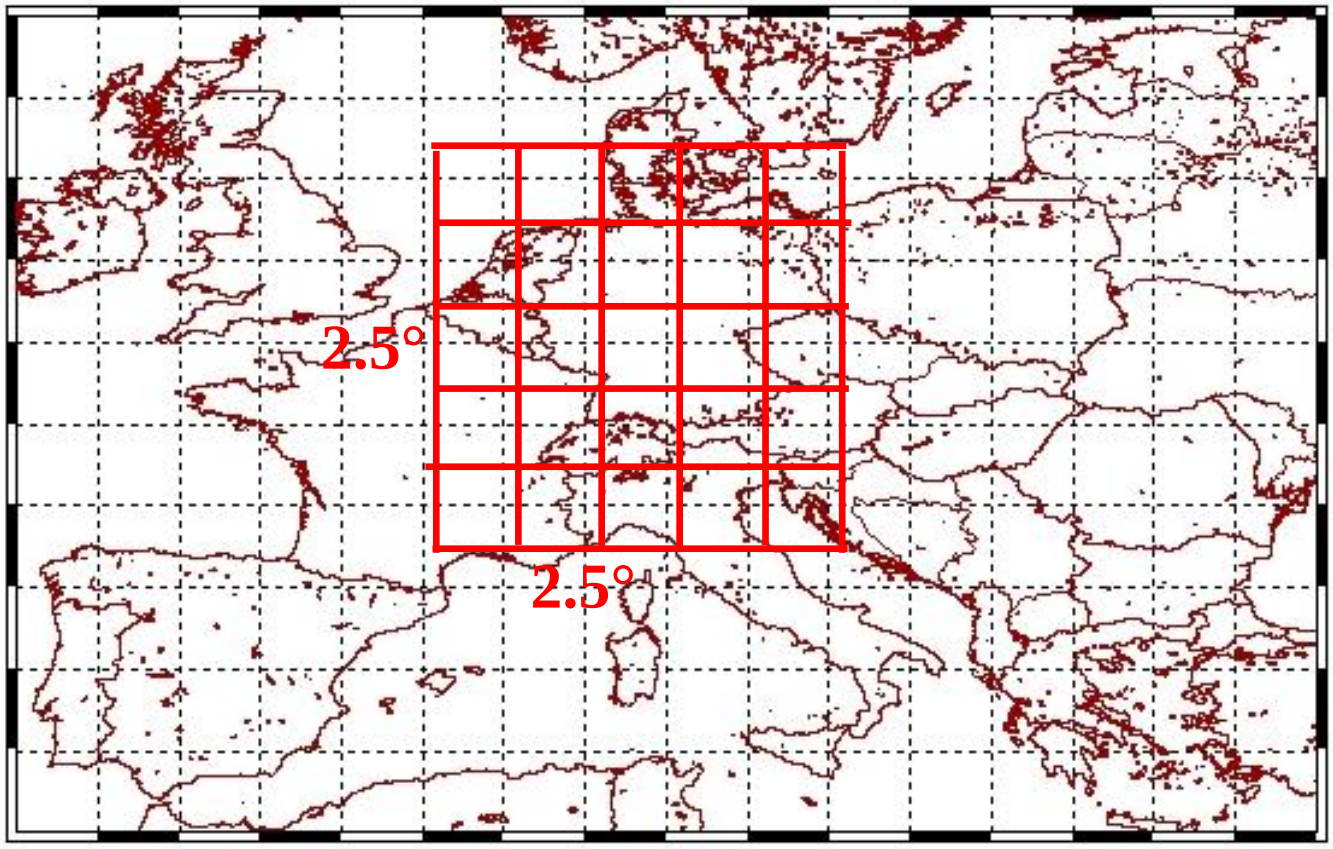
Collocating PMW and IR observations



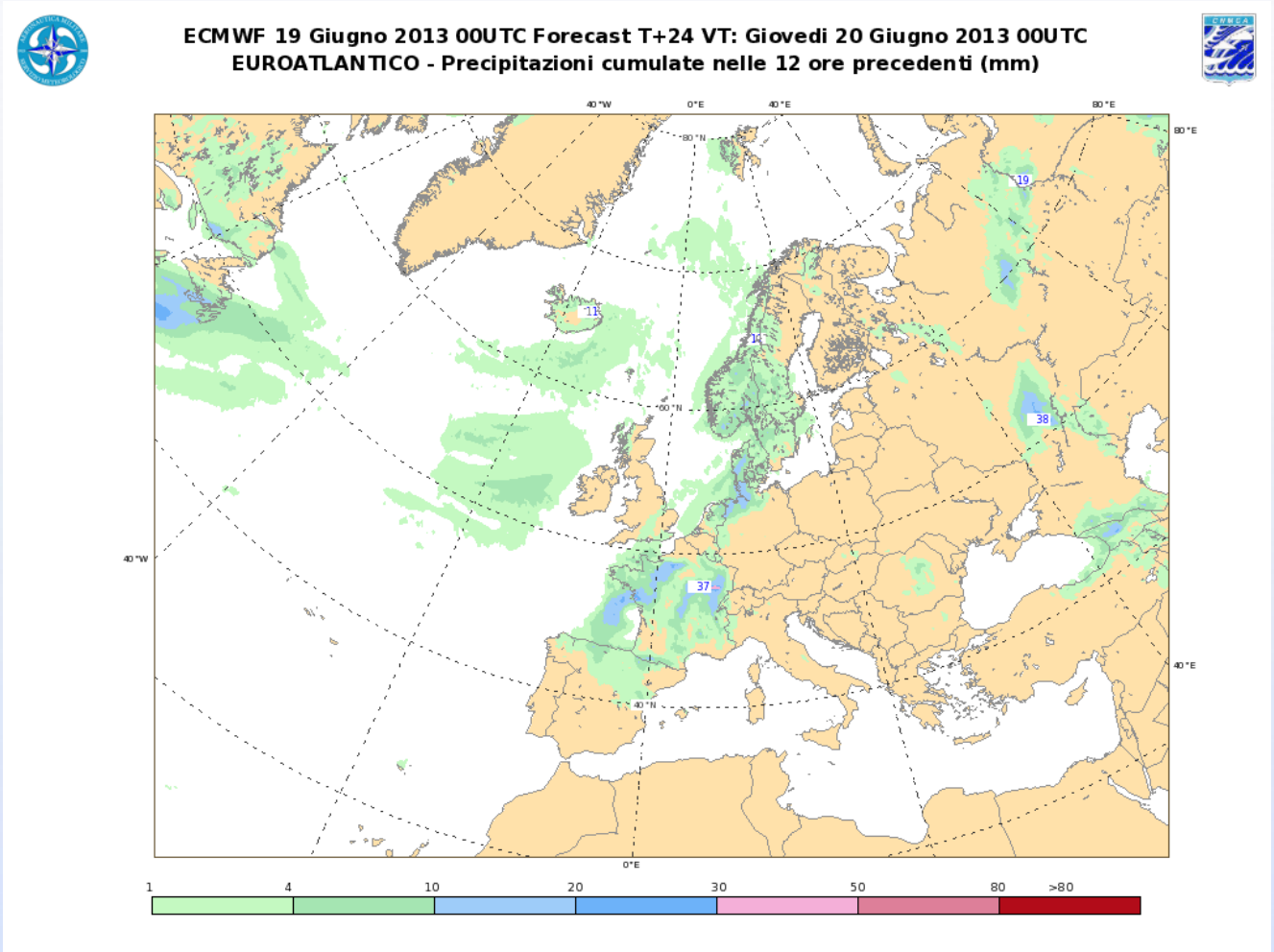
The PR-OBS3 algorithm is based on a collection of time and space overlapping SEVIRI IR images and Low Earth Orbit (LEO) MW radiometers. As a new MW swath is available, the MW-derived pixels are paired with the time and space coincident geostationary (GEO) TB at 10.8 mm.

PR-OBS3 / H03

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 is built.



Case study: 19 June 2013 Germany



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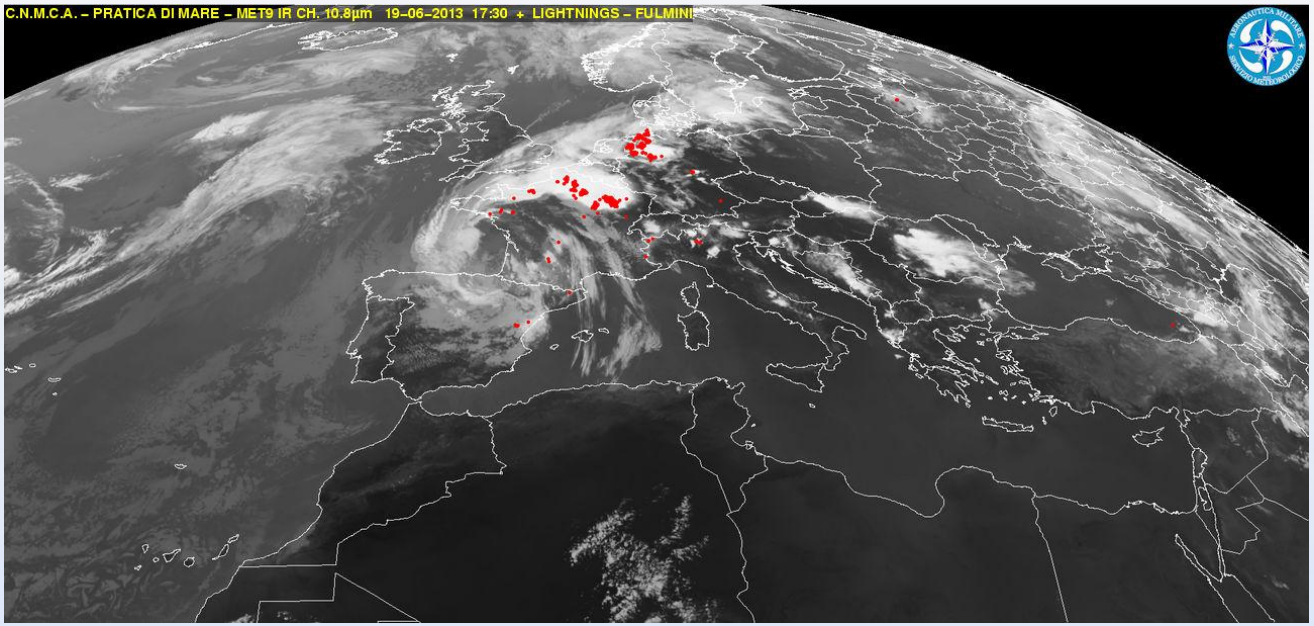

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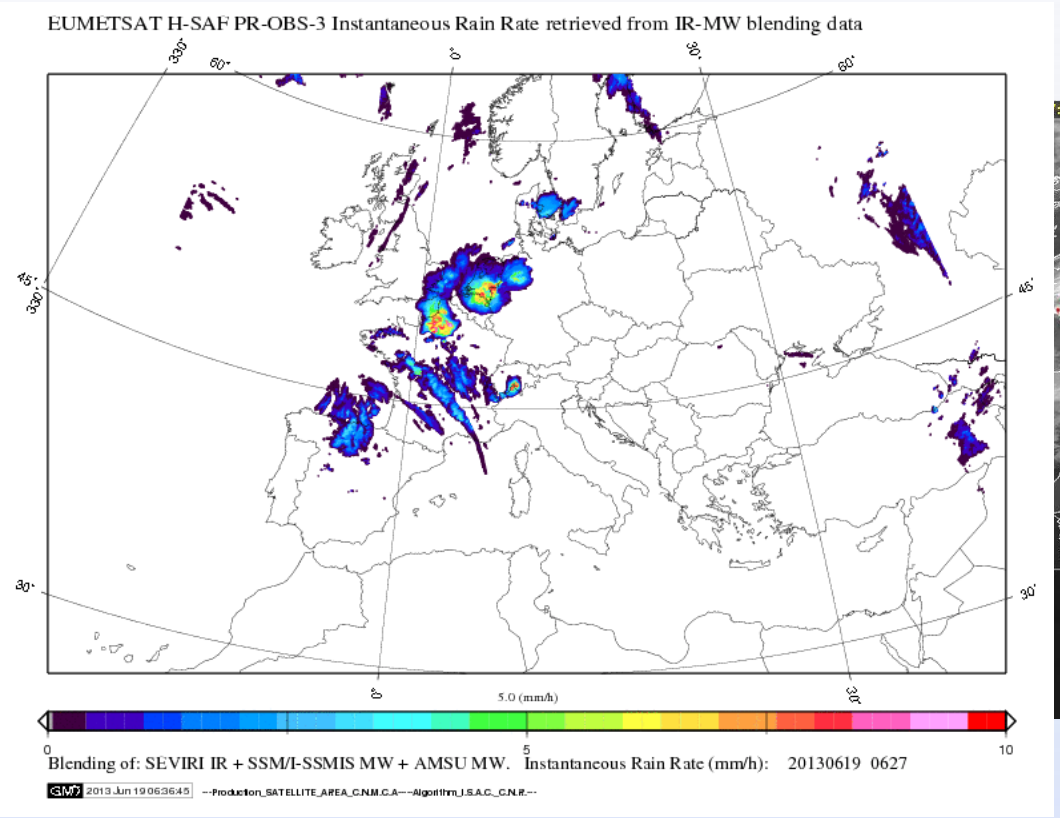
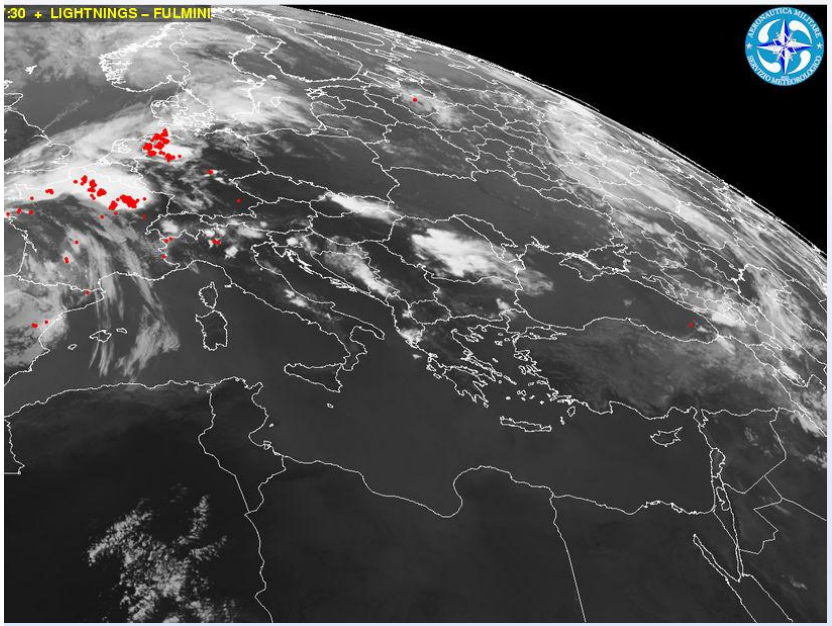
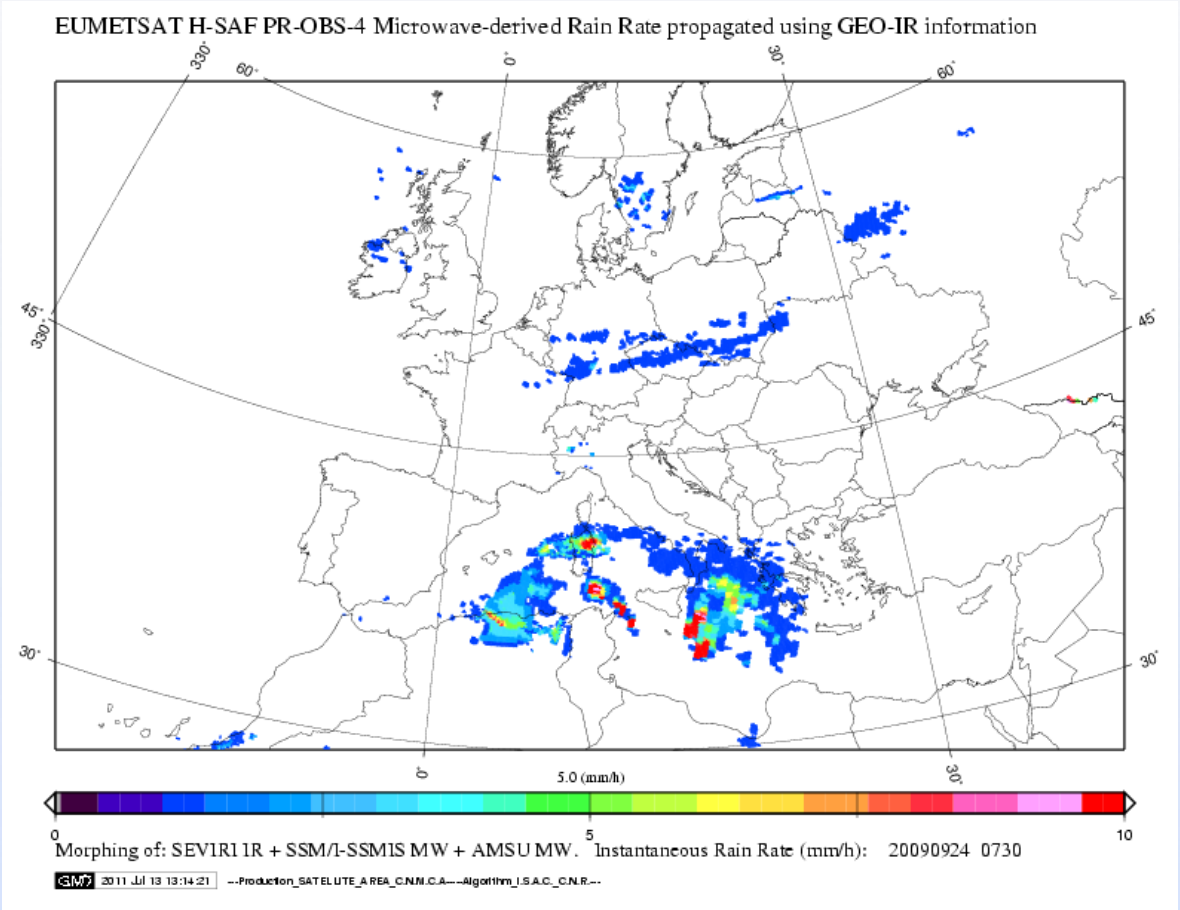




PR-OBS4 / H04

Multi-platform algorithm: MORPHING Technique



Propagation vector matrices are produced by computing spatial lag correlations over successive images of GEO/IR and then used to propagate the MW-derived precipitation estimates in time and space when updated MW data are unavailable
(OFFLINE PRODUCT)

PR-OBS4 / H04

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AMSU+SSMI rain rates [mmh^{-1}]

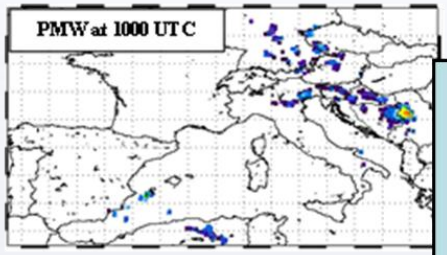
CMORPH Method

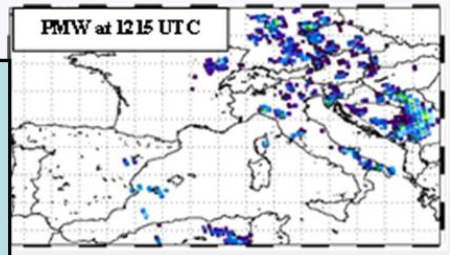
Three Steps

1 – Rain advection in forward

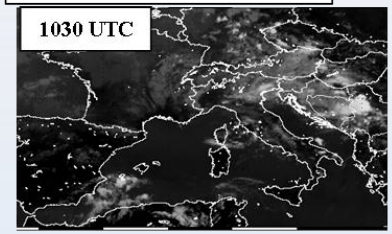
2 – Rain advection in backward

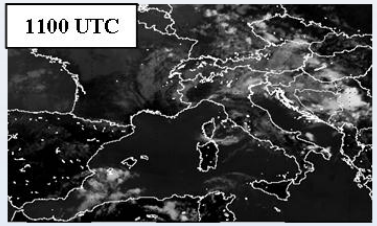
3 – Rain morphing

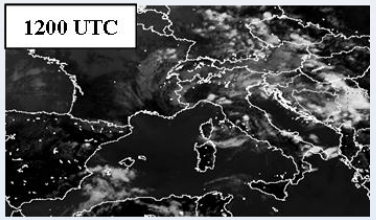


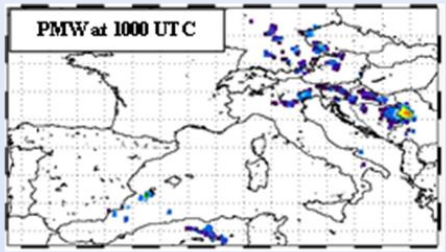


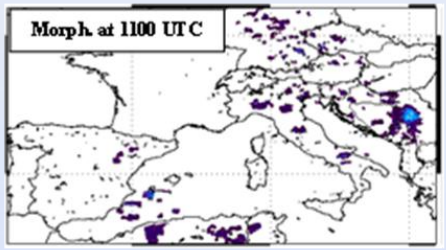
MSG-SEVIRI IR-10.8 μm

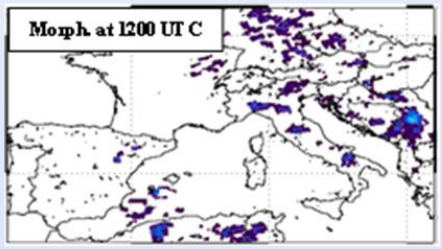


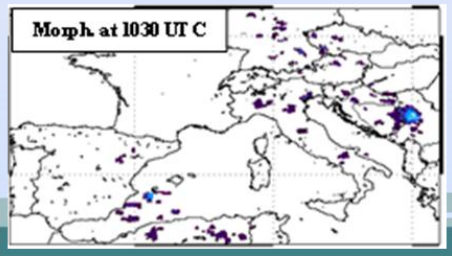


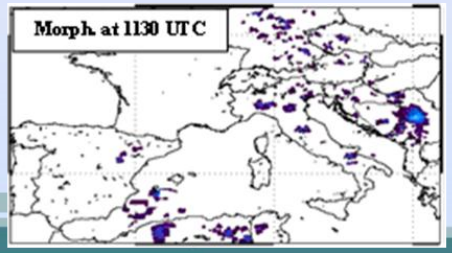


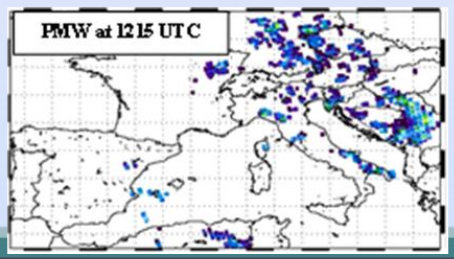












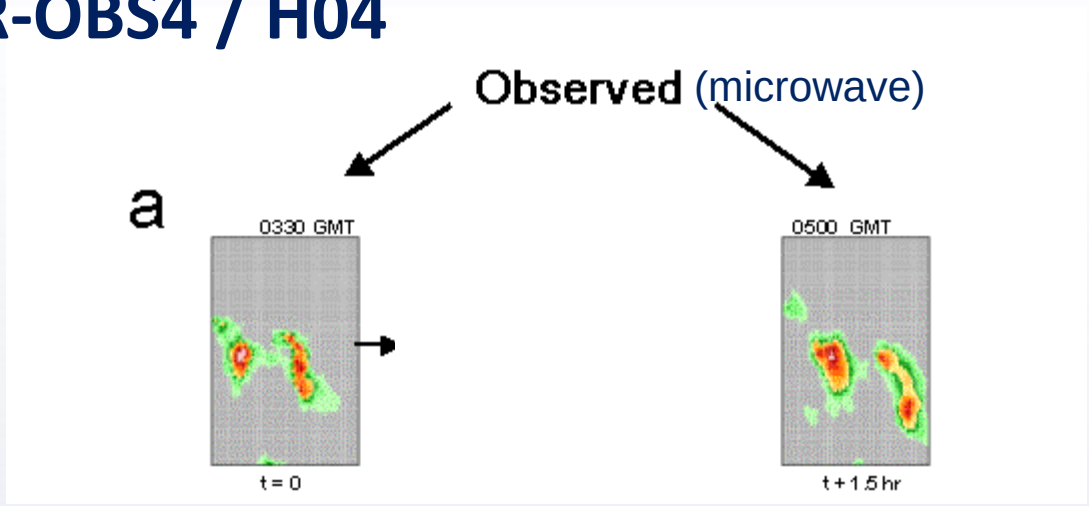
PR-OBS4 / H04

H SAF
Support to Operational Hydrology and Water Management

LEO + GEO Satellite Merging

TRANSPORT METHOD

CMORPH



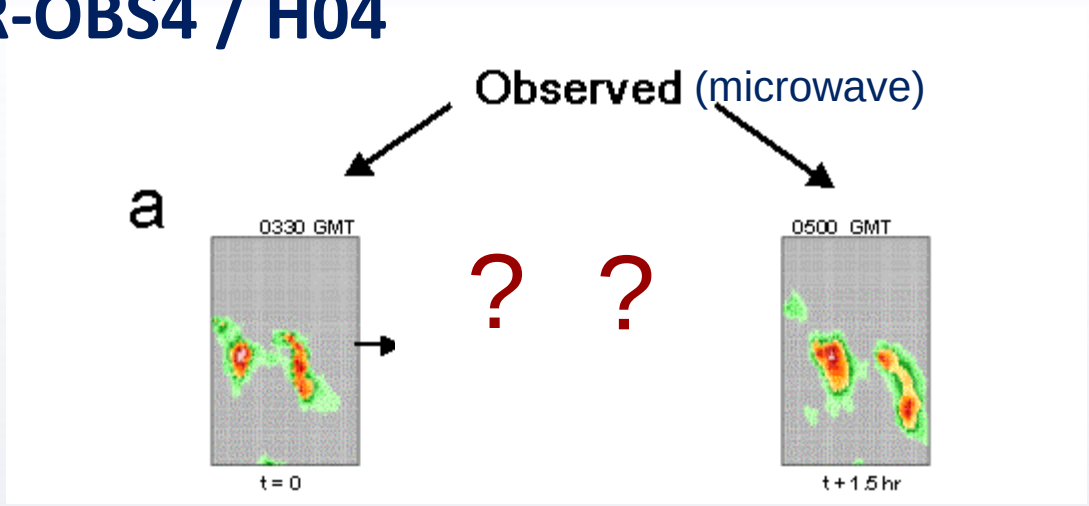
PR-OBS4 / H04

H SAF
Support to Operational Hydrology and Water Management

LEO + GEO Satellite Merging

TRANSPORT METHOD

CMORPH



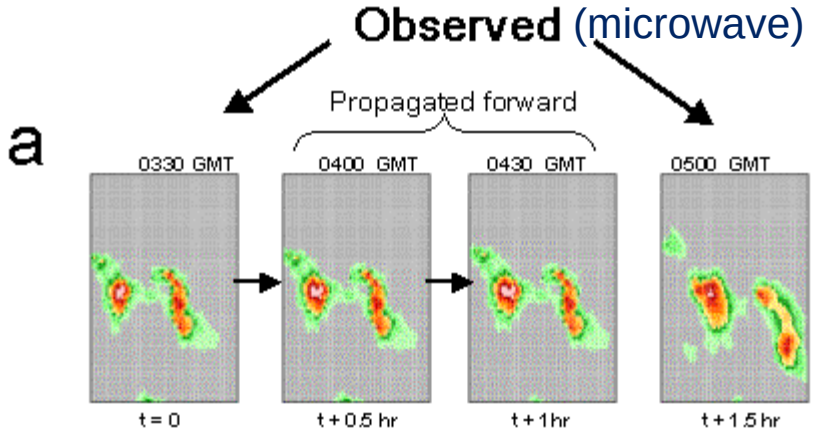
PR-OBS4 / H04

H SAF
Support to Operational Hydrology and Water Management

LEO + GEO Satellite Merging

TRANSPORT METHOD

CMORPH



PR-OBS4 / H04

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Support to Operational Hydrology and Water Management

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TRANSPORT METHOD

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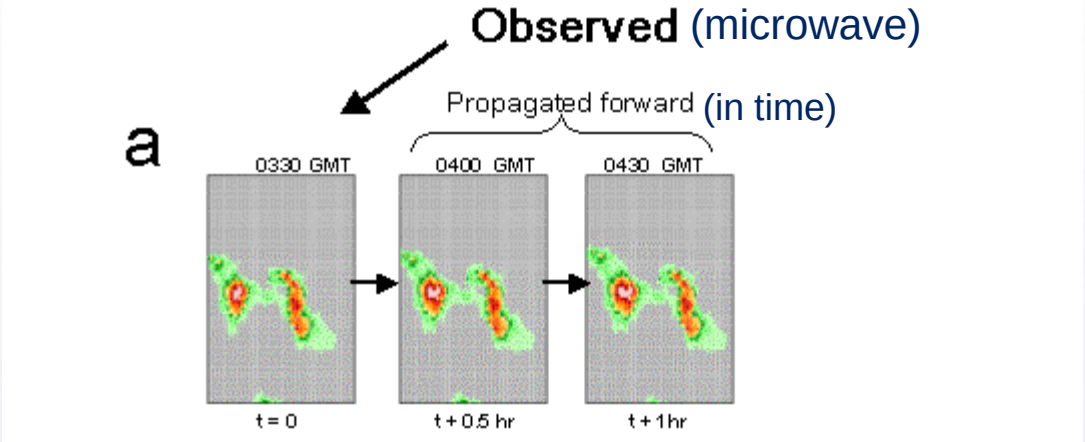


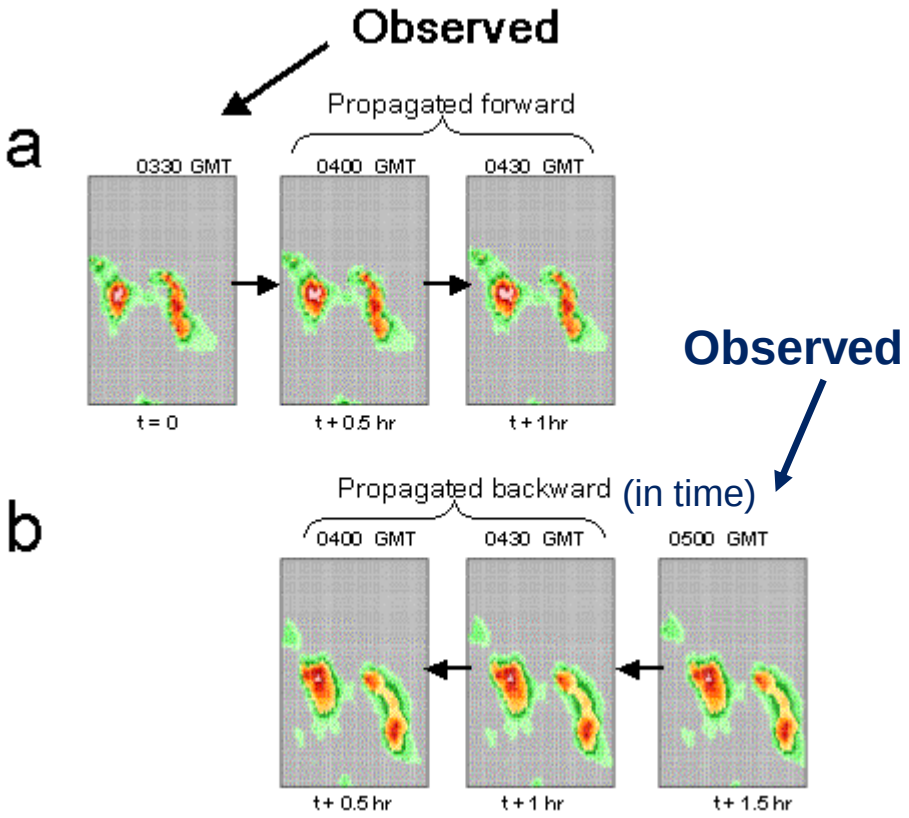
PR-OBS4 / H04

H SAF
Support to Operational Hydrology and Water Management

LEO + GEO Satellite Merging

TRANSPORT METHOD

CMORPH



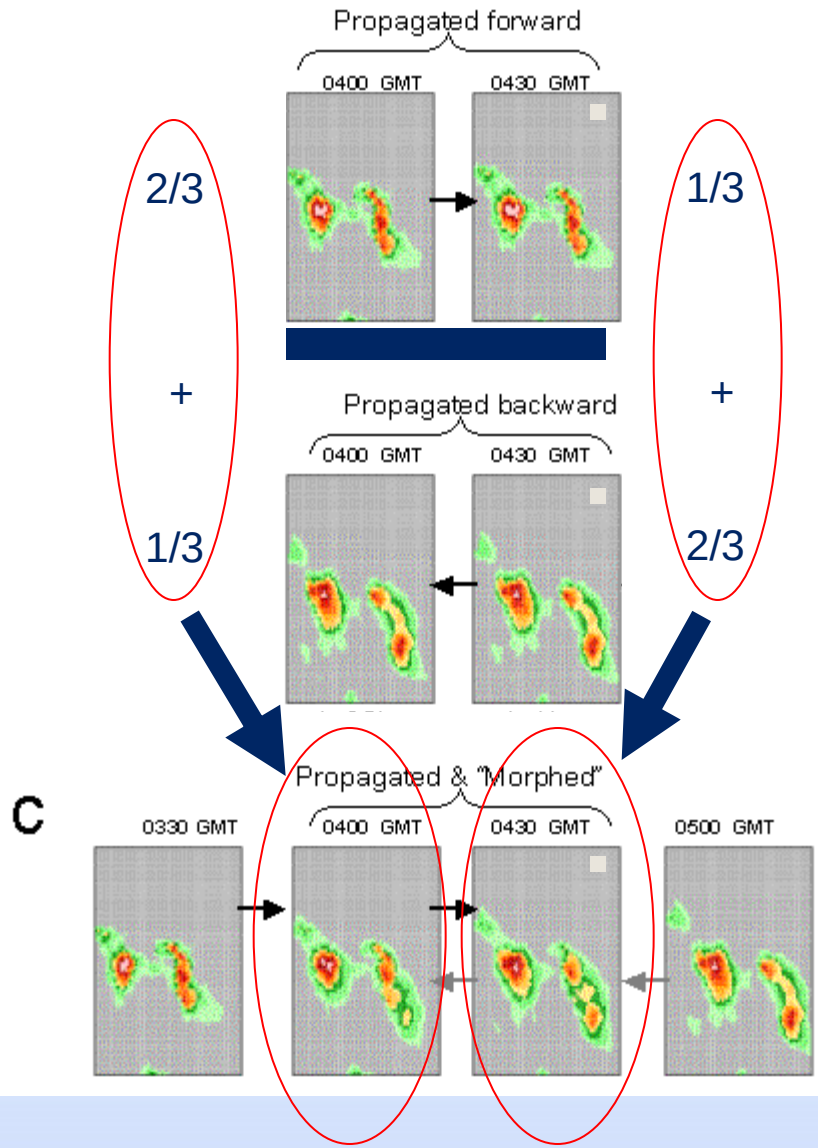
PR-OBS4 / H04

H SAF
Support to Operational Hydrology and Water Management

LEO + GEO Satellite Merging

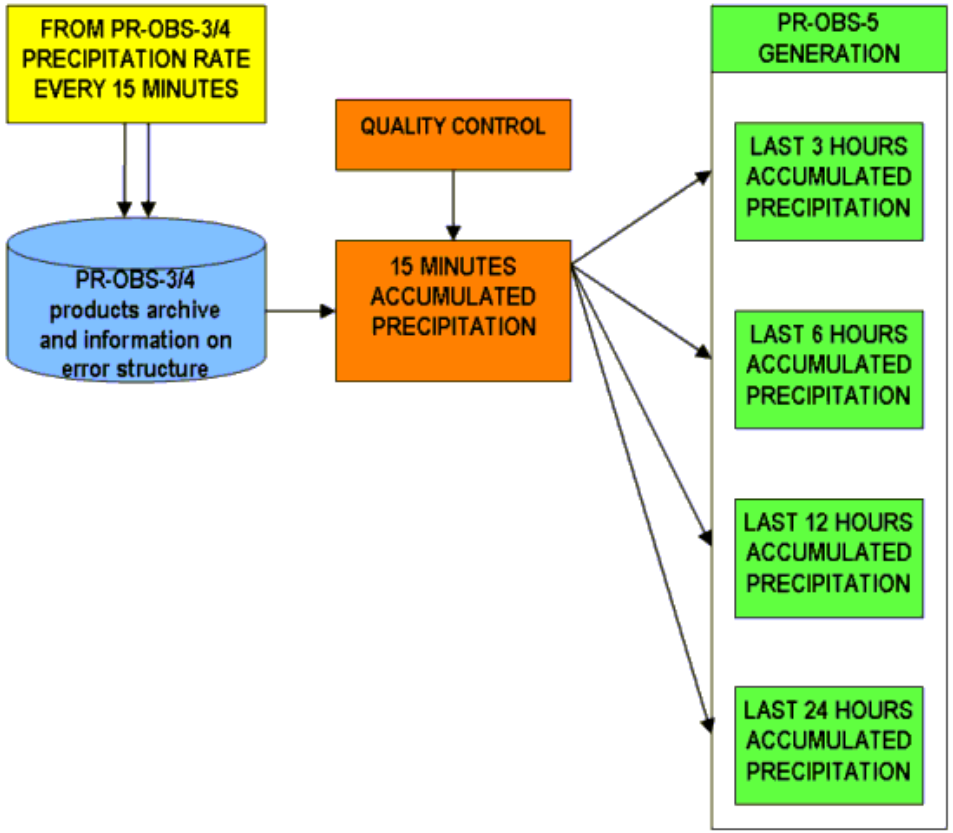
TRANSPORT METHOD

CMORPH



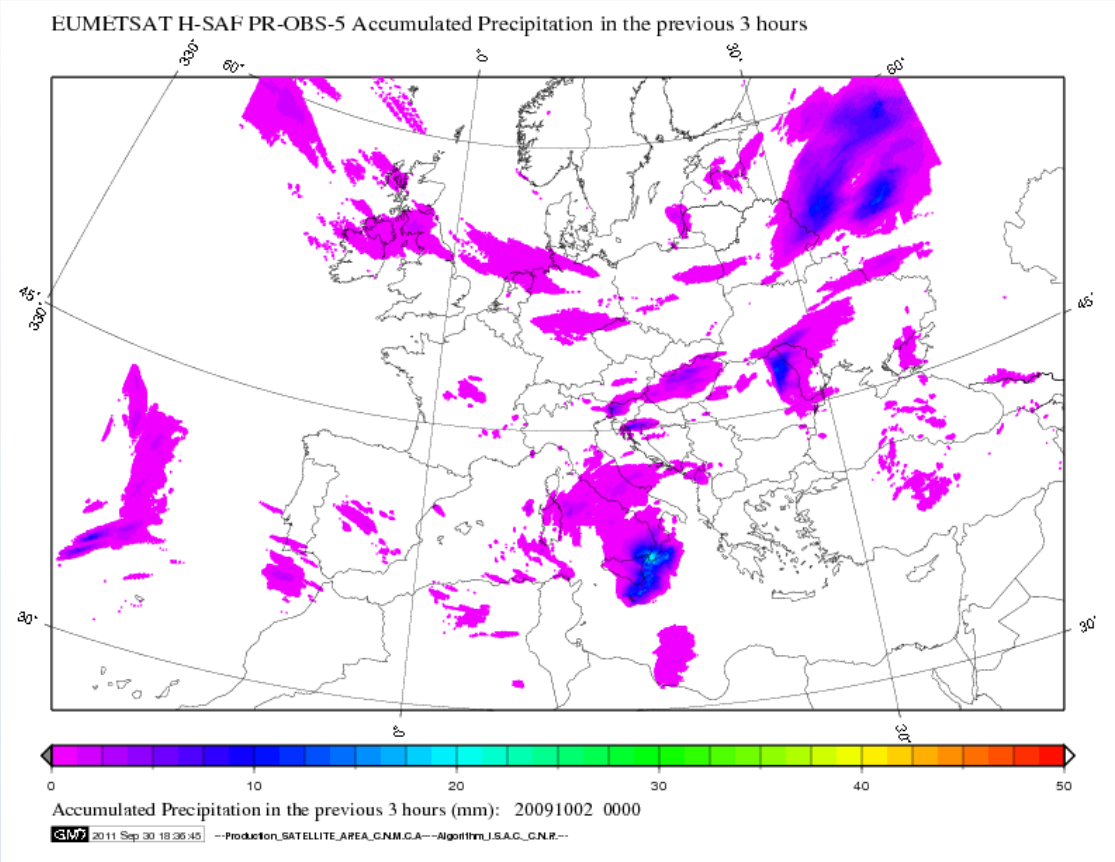
PR-OBS5 / H05

Accumulated Precipitation



- In the **current version (v1.2)**, the product is derived by a simple time integration of product PR-OBS-3 (96 samples/day at 15-min intervals) over 3, 6, 12 and 24 hours. The alternative accumulated precipitation product derived by use of PR-OBS-4 (i.e. “Morphing”) is still not operational.
- Climatological thresholds are applied on the final products to avoid some outliers **(quality control)**.

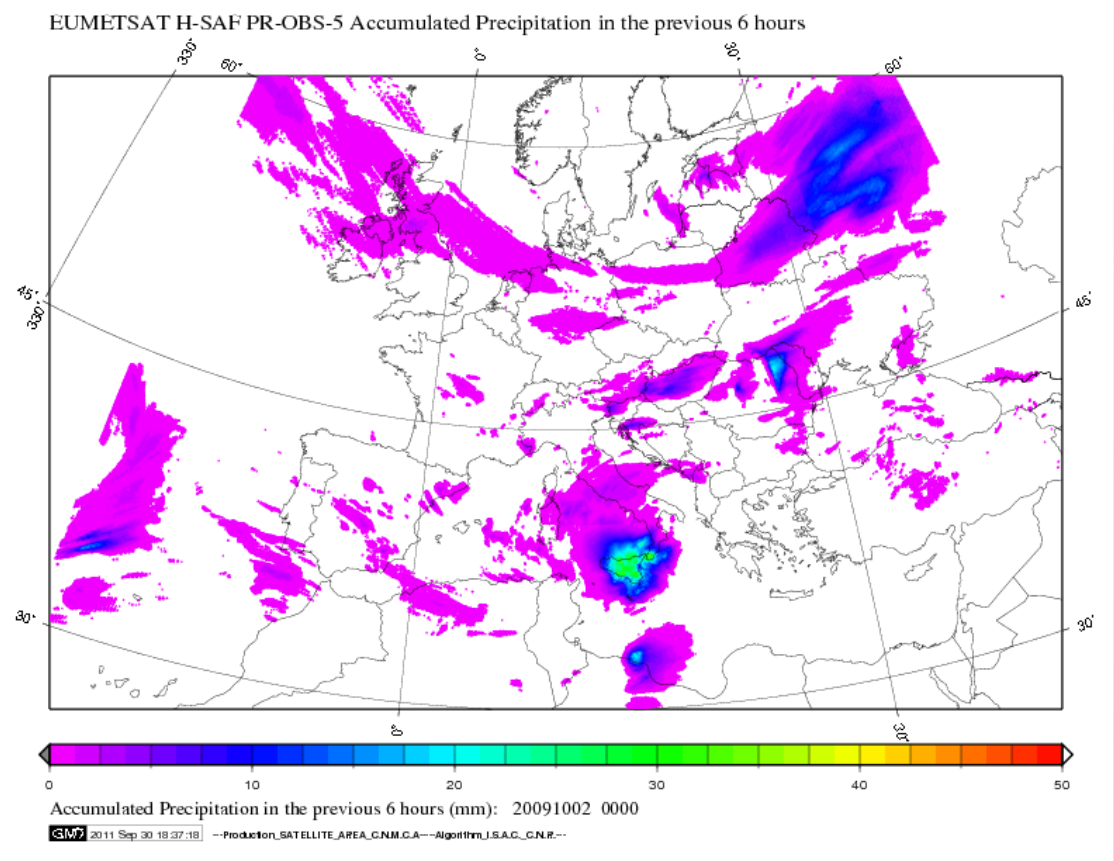
H-SAF Operational Products: examples



PR-OBS5 / H05

Accumulated Precipitation

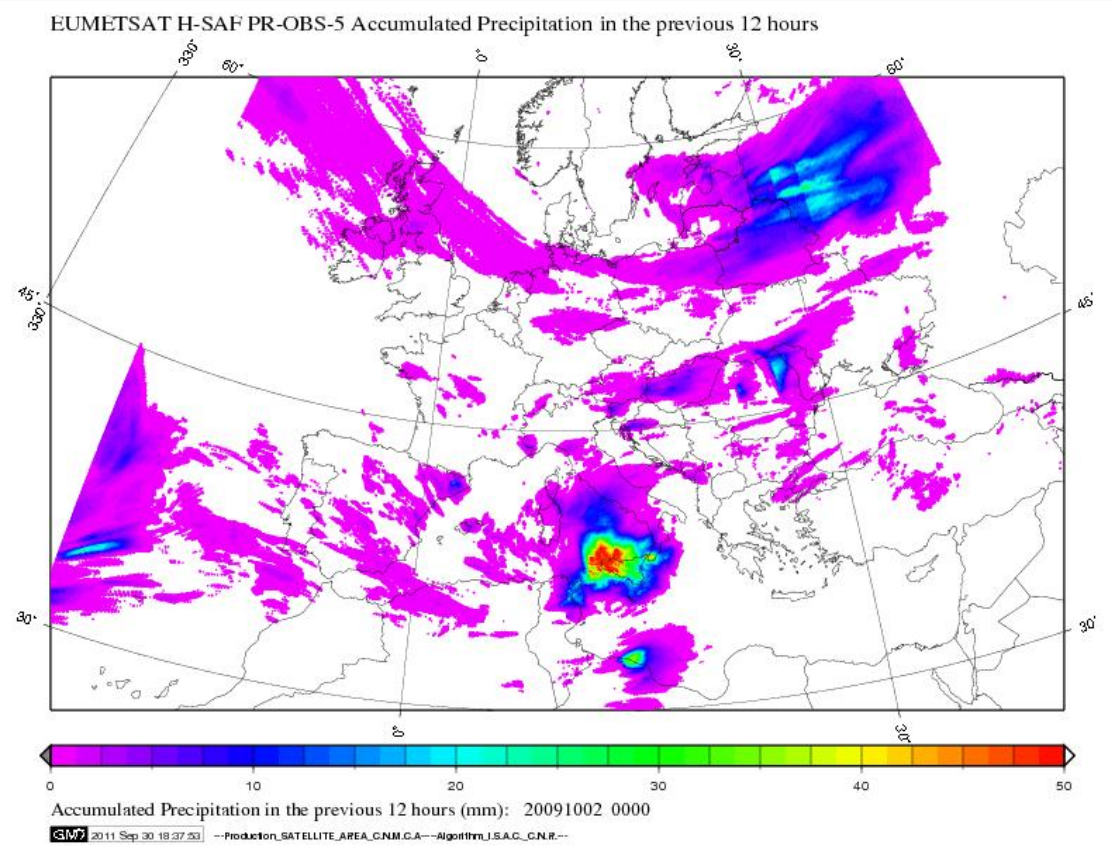
H-SAF Operational Products: examples



PR-OBS5 / H05

Accumulated Precipitation

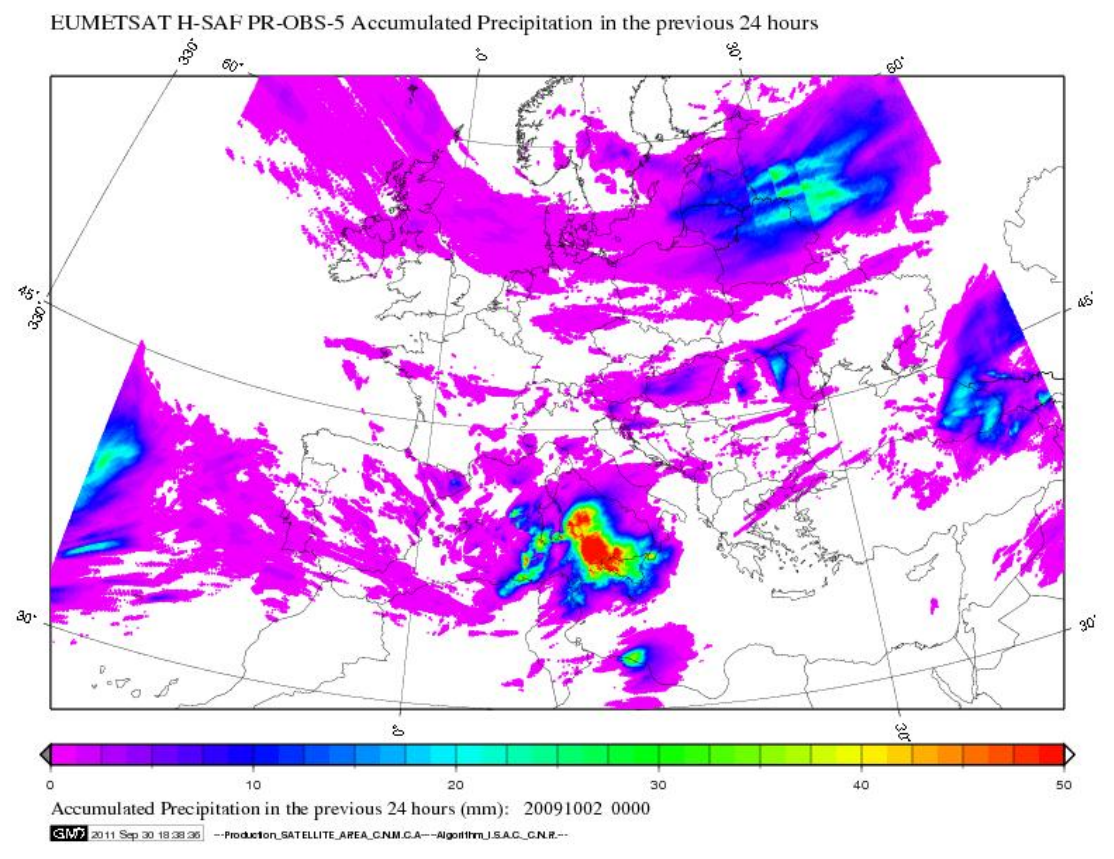
H-SAF Operational Products: examples



PR-OBS5 / H05

Accumulated Precipitation

H-SAF Operational Products: examples



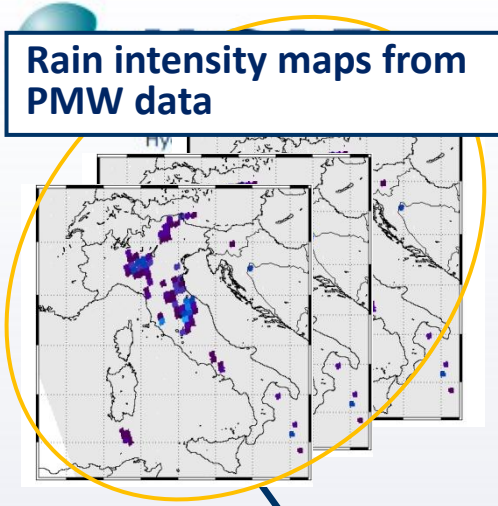
PR-OBS5 / H05

Accumulated Precipitation

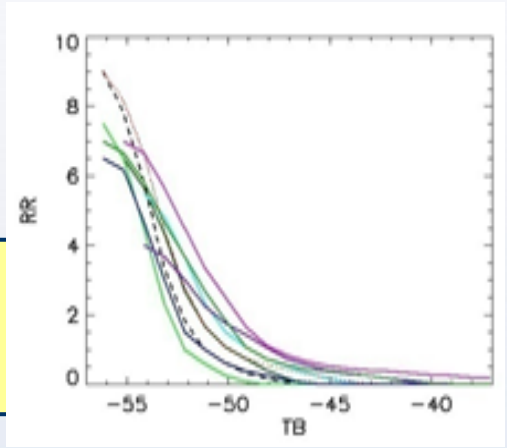
H15 Algorithm

BLENDING Technique + NEFODINA

Rain intensity maps from PMW data



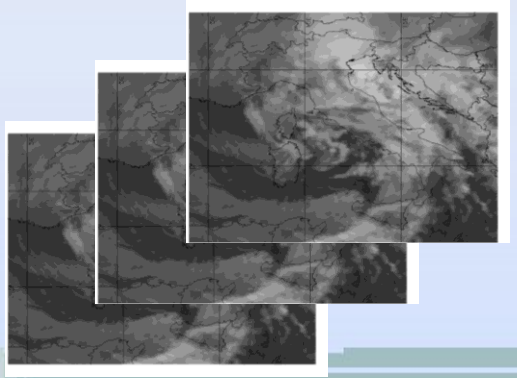
The process is restarted for each IR slot



Extract space and time coincident locations from IR and MW data

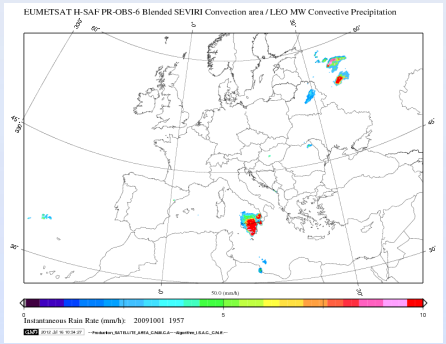
Create dynamical geolocated statistical relationships RR-T_b

MSG- SEVIRI IR brightness temperatures at 10.8 µm



Assign RR at every IR pixel

Produce instantaneous rain intensity maps at the geostationary time/space resolution



H15 Algorithm

BLENDING Technique + NEFODINA

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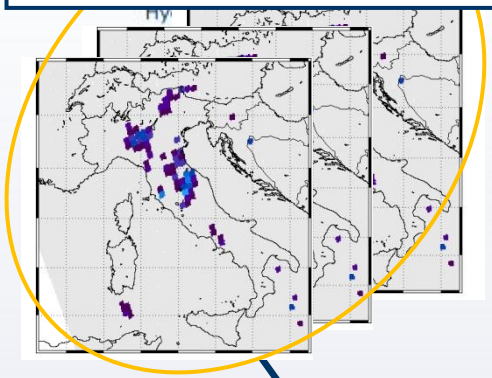
Rain intensity maps from PMW data



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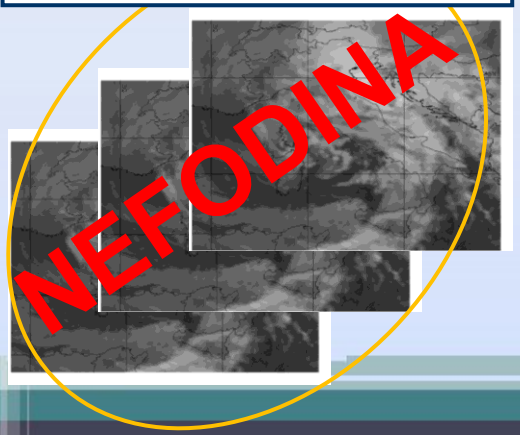

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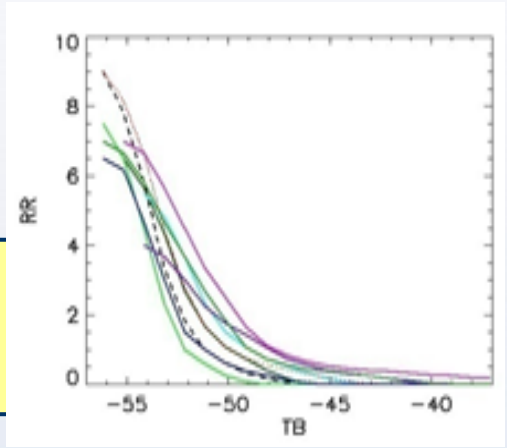

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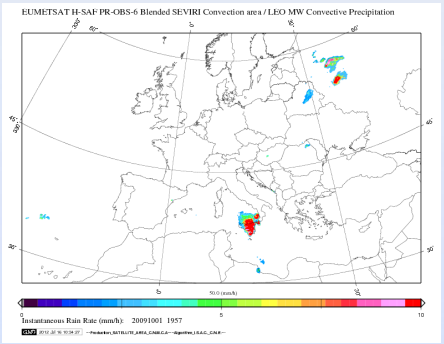
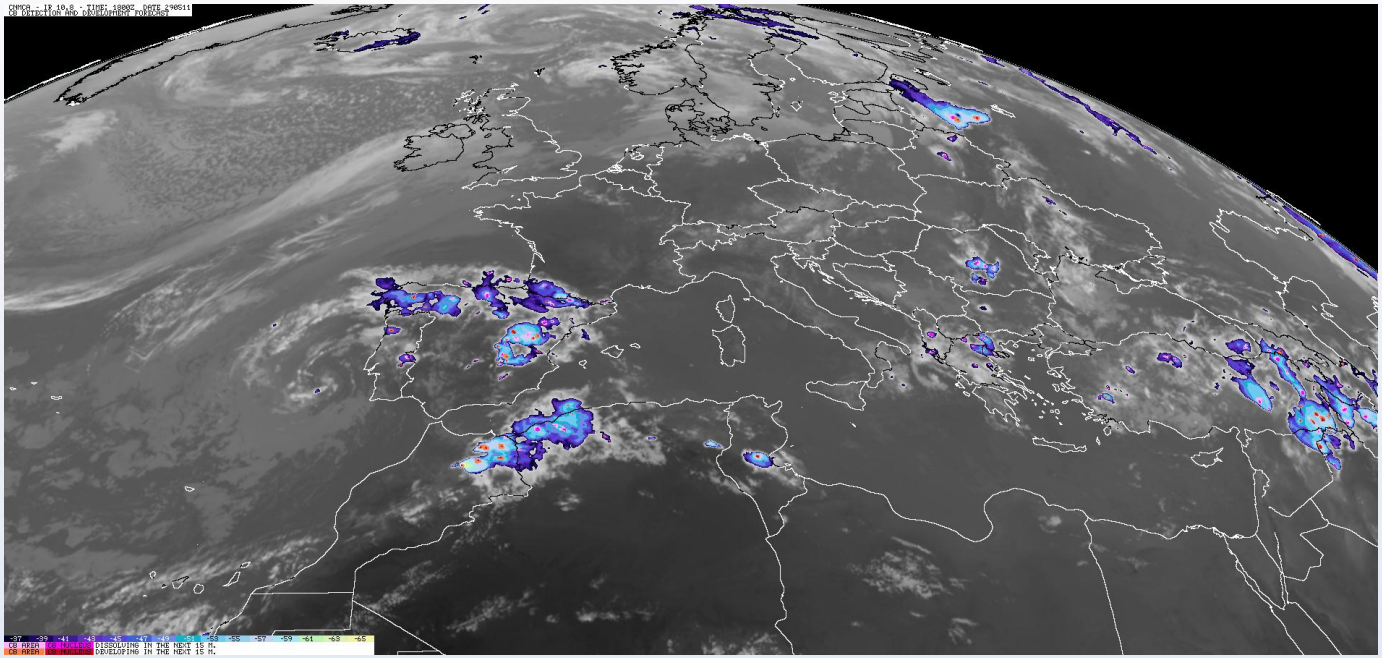
NEFODINA

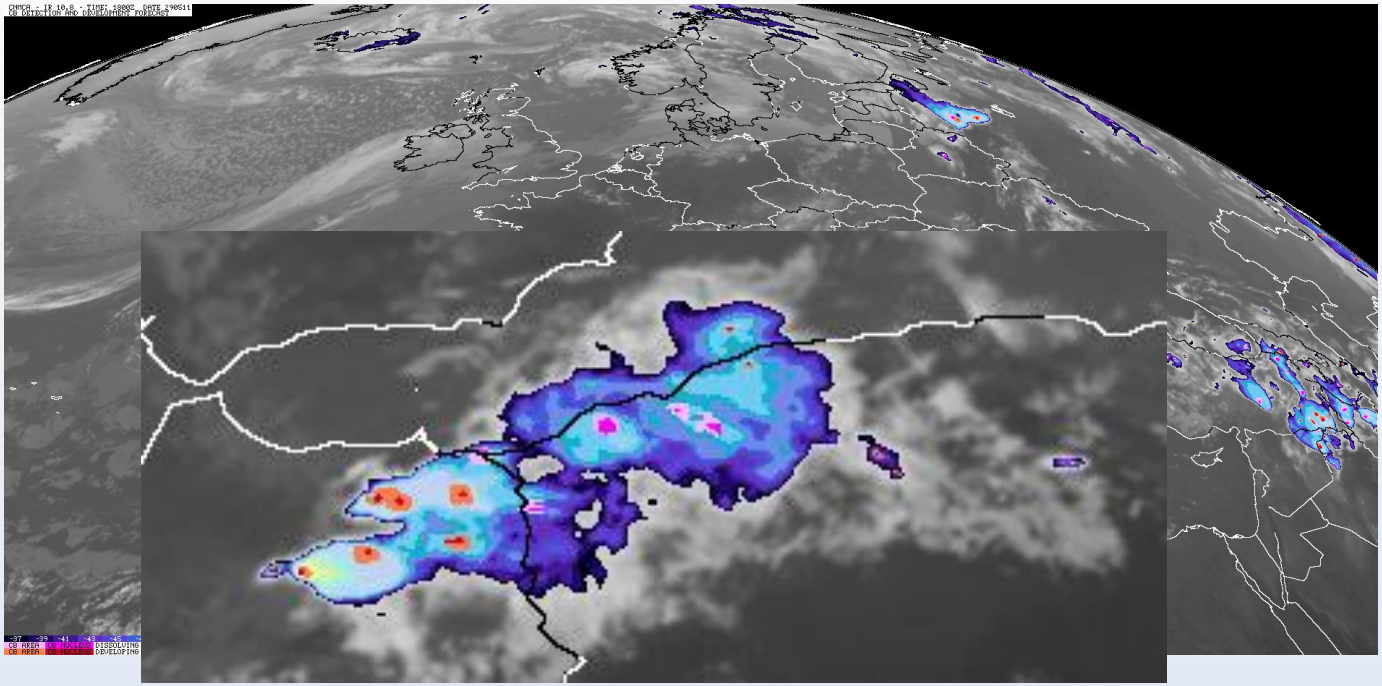


NEFODINA software



http://nefodina.meteoam.it

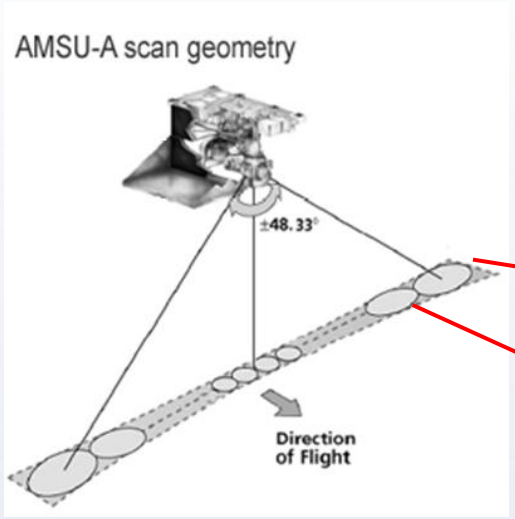
NEFODINA software

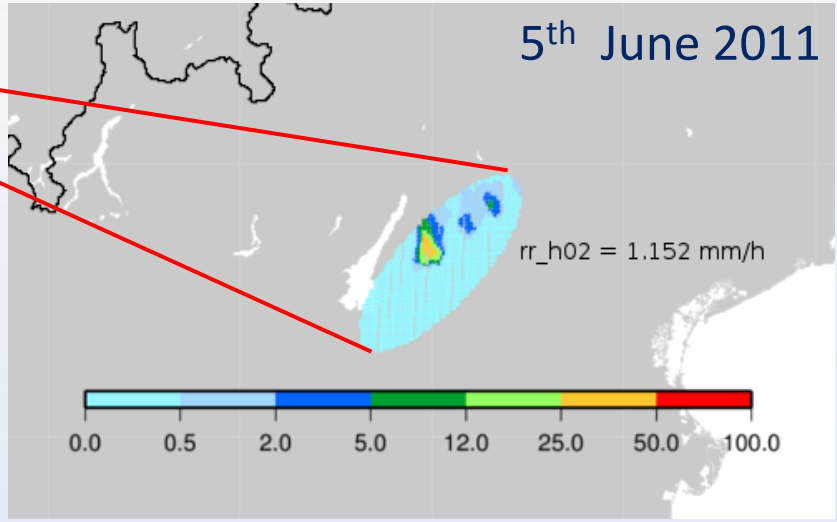


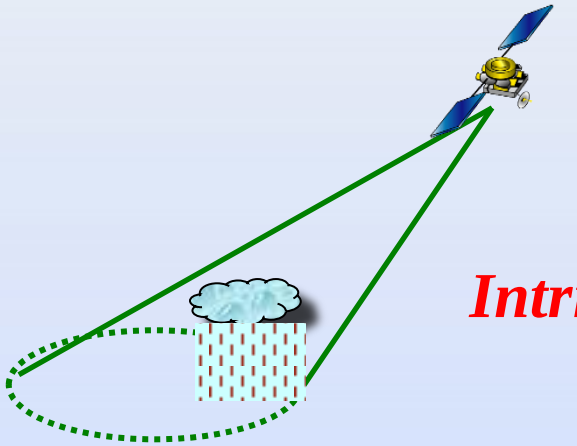
- With red shades are indicated the cloud top of the detected convective cell in growing phase
- With pink shades are indicated the cloud top of the detected convective cell in decreasing phase.

The Satellite "Beam filling" Problem

Comparison between precipitation retrieval by microwave sensor on polar satellite (AMSU) and radar.

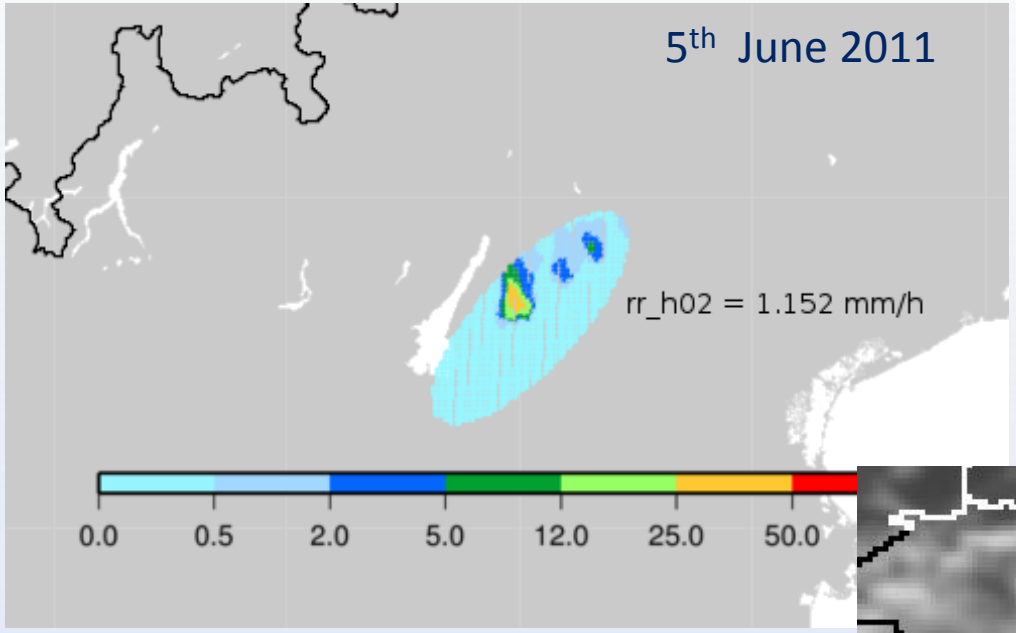




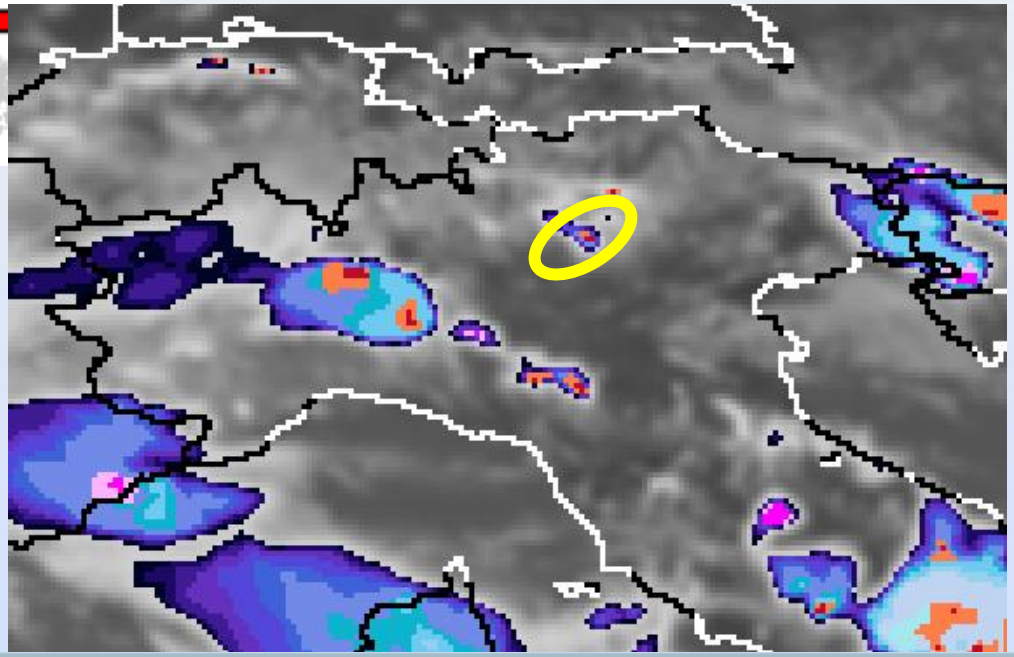


Intrinsic Underestimation

NEFODINA software

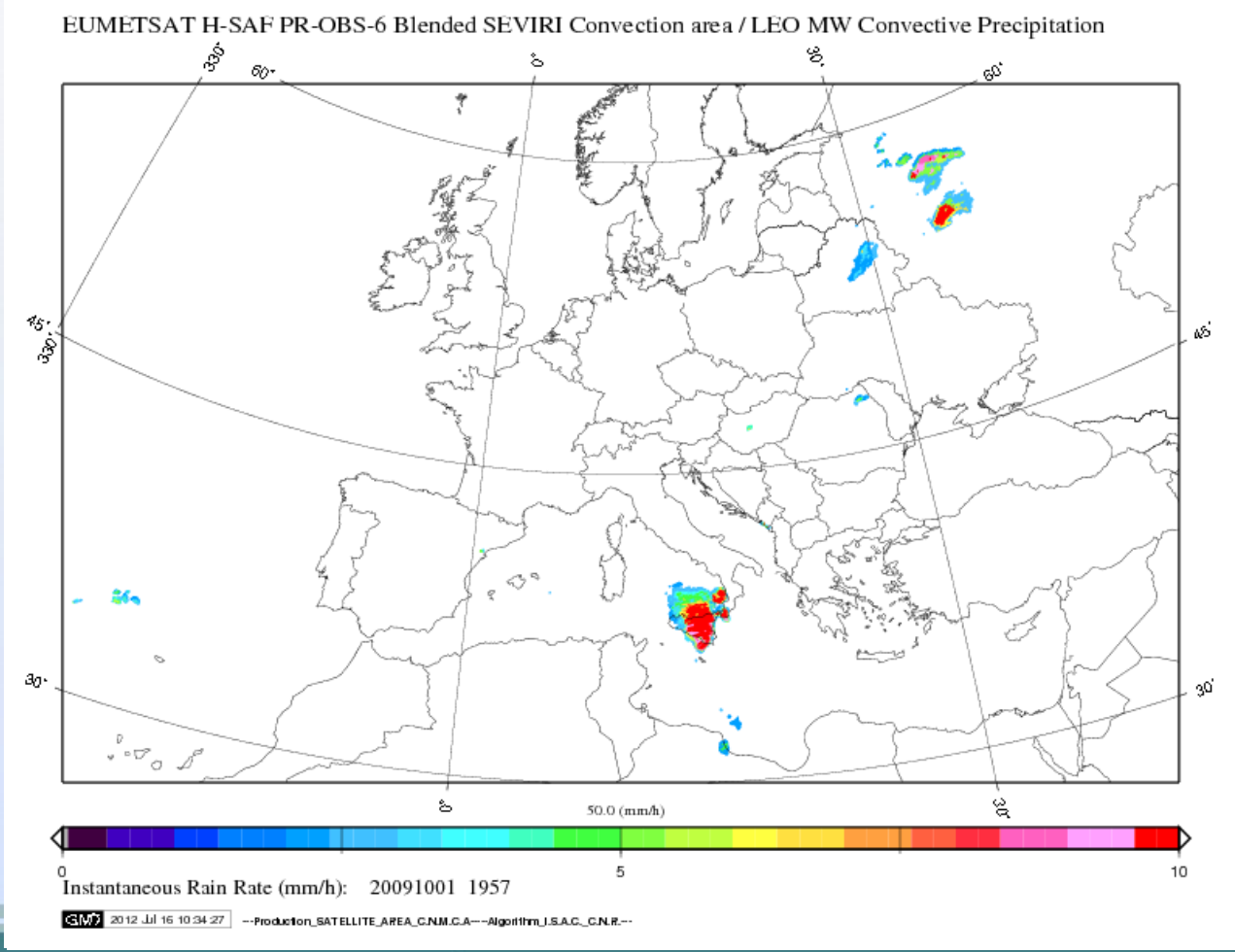


Rain redistribution based on convective cell's area



H SAF
Support to Operational Hydrology and Water Management

PR-OBS6 / H15



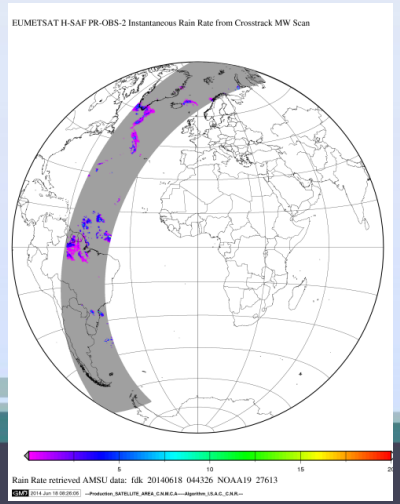
HSAF Processing-time

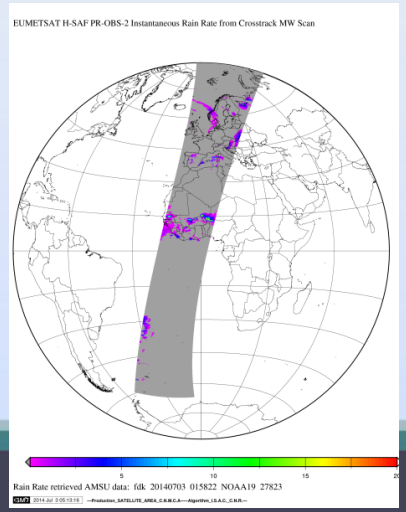
Products	ONLINE	OFFLINE	OUTPUT format ftp://ftp.meteoam.it/utilities/
PR-OBS01	3 min (input – 2,5 h delay)	1 month /1 week + Recovery from archive	BUFR
PR-OBS02	30 sec (input – 5 min delay)		
PR-OBS03	1 min	1 month /1 week + Recovery from archive	GRIB2
PR-OBS04	2 min		
PR-OBS05	3 min		
PR-OBS06	5 min		

In development Products

Enlargement to Full DisK

H02B PR-OBS-2B	Precipitation rate at ground by MW cross-track scanners	Algorithms to be assessed by end 2014 Expected Operations in 2016
H03B PR-OBS-3B	Precipitation rate at ground by GEO/IR supported by LEO/MW	
H04B PR-OBS-4B	Precipitation rate at ground by LEO/MW supported by GEO/IR	
H05B PR-OBS-5B	Accumulated precipitation at ground by blended MW and IR	
H15B PR-OBS-6B	Convective Precipitation rate at ground by GEO/IR supported by LEO/MW	





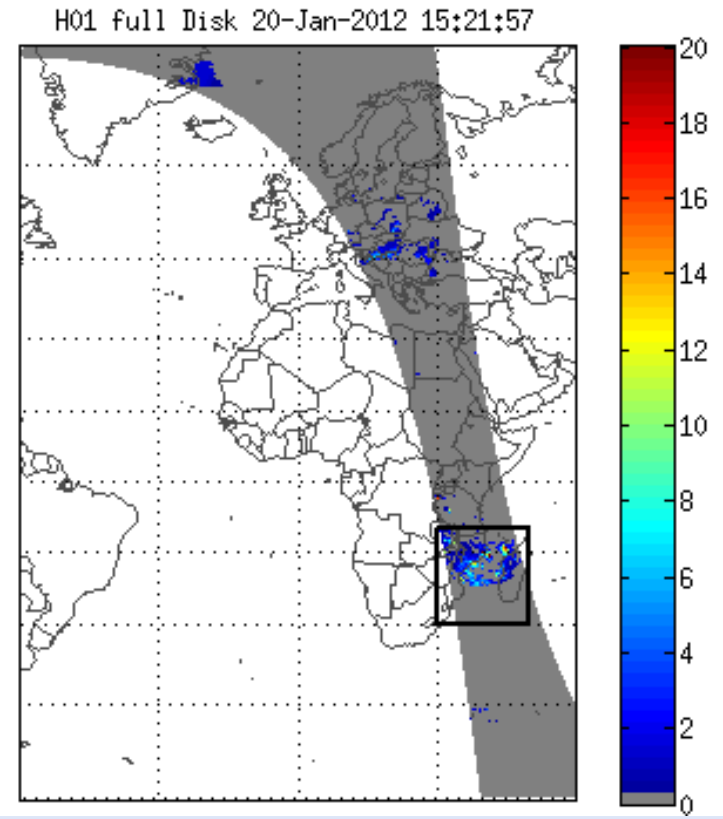
H15 developments

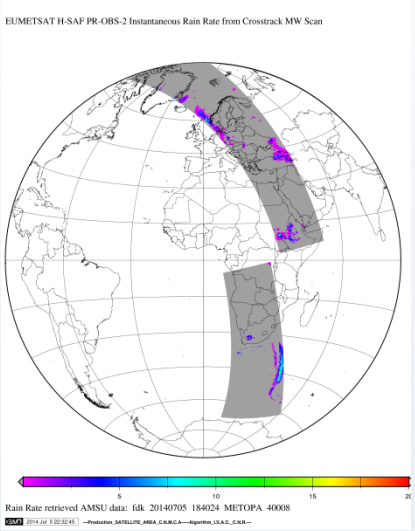
- Software
- Algorithm
- Inputs
- Convection Mask

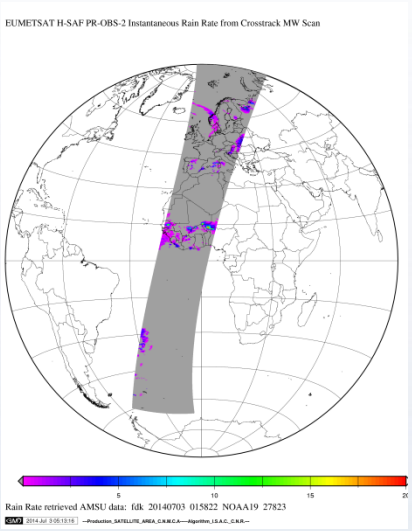
H15 developments

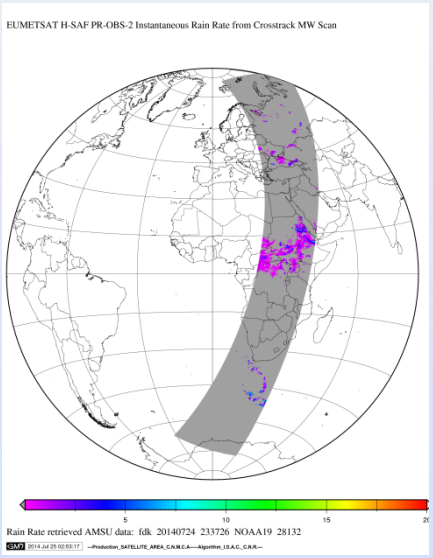
- Software → Full Disk
- Algorithm
- Inputs
- Convection Mask

H15 – Full disk









H SAF
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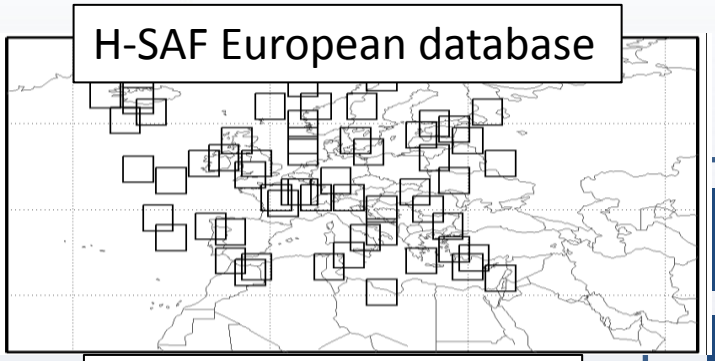
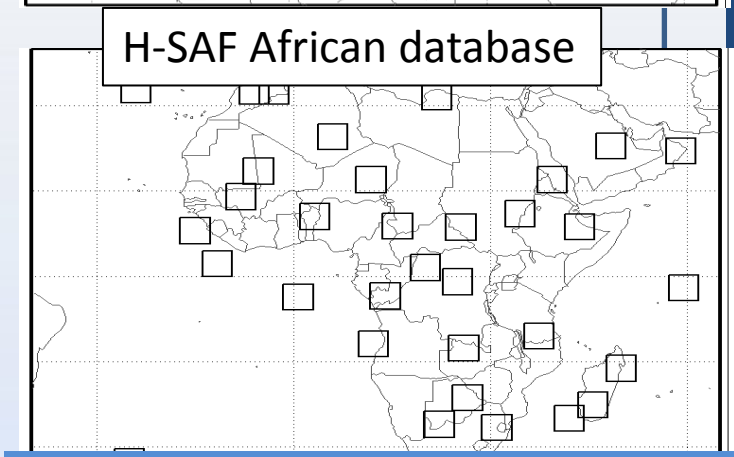
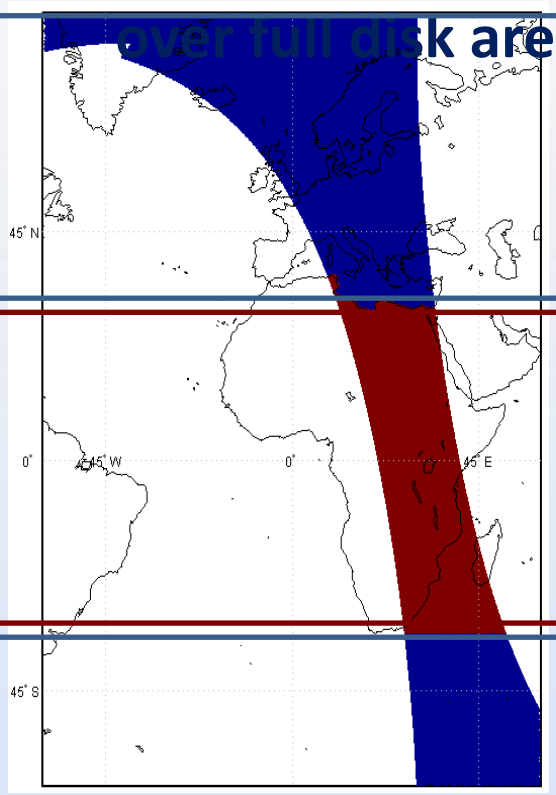
H01 & H02 : Algorithms and Databases Optimization over full disk area





94 simulations (60 for European Db and 34 for African DB)



H01

H02A ANN-A

European Database

H01

H02B ANN-B

African Databas e

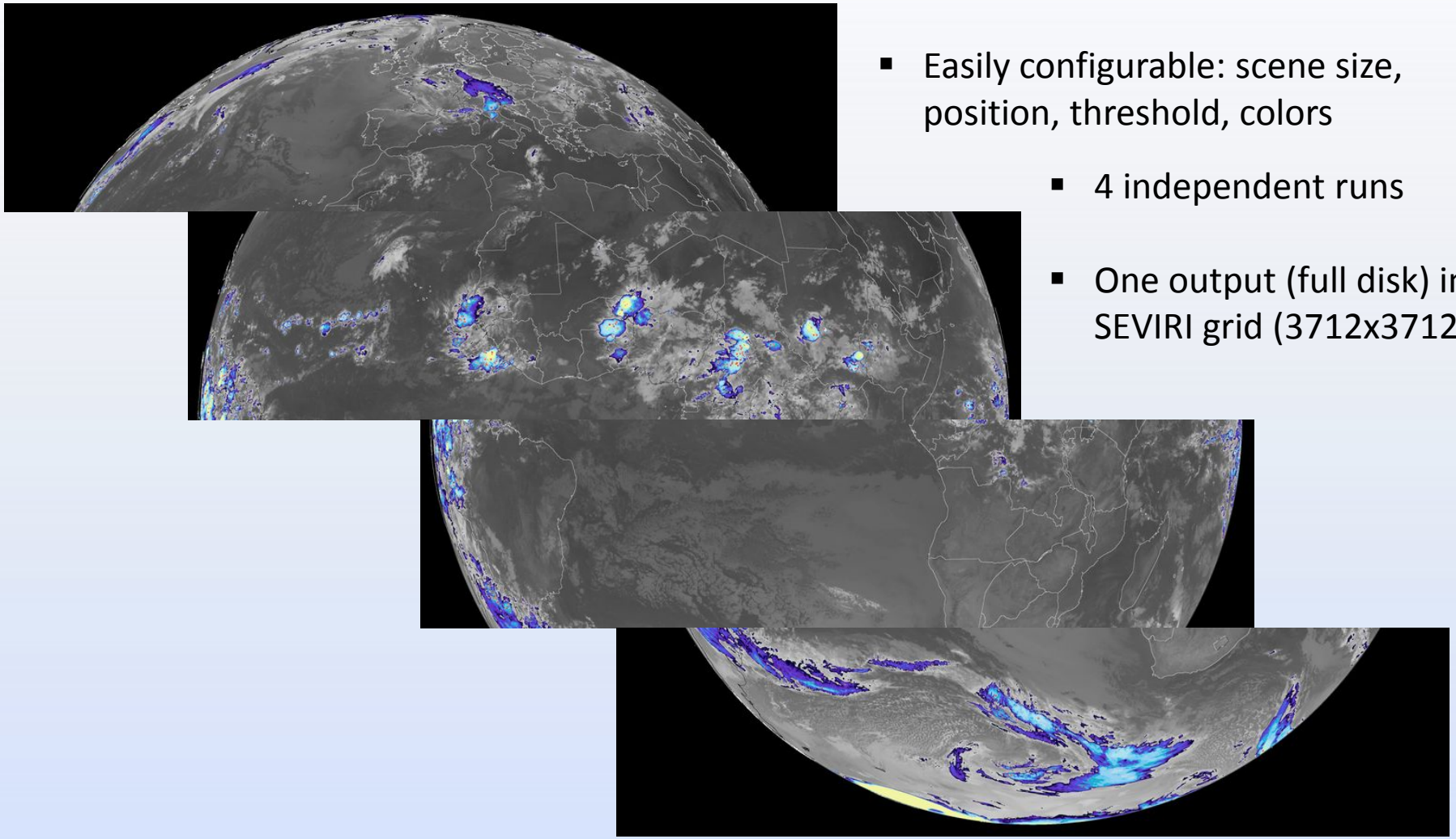
H01

H02A ANN-A

European Database

H SAF
Support to Operational Hydrology and Water Management

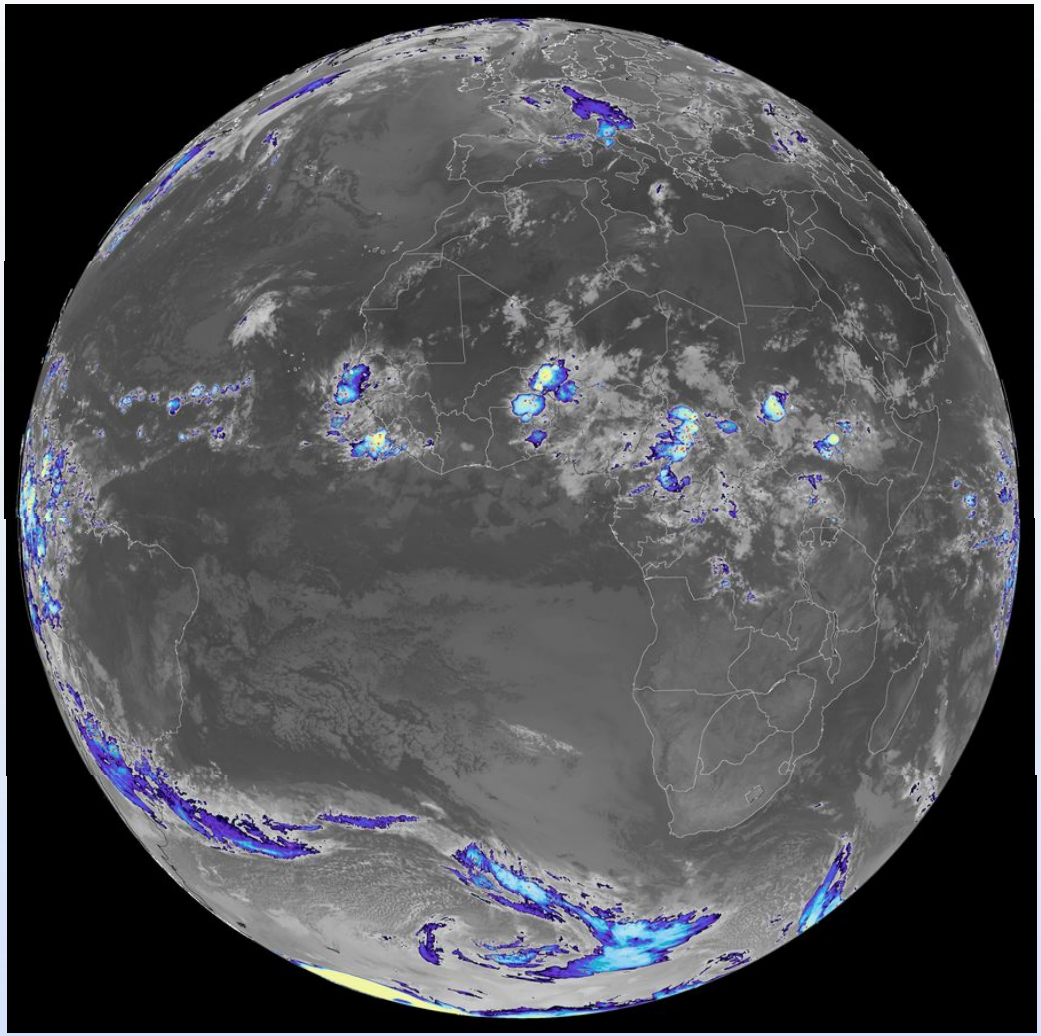
H15 – Full disk



- High geographic scalability
- Easily configurable: scene size, position, threshold, colors
  - 4 independent runs
- One output (full disk) in SEVIRI grid (3712x3712)

H SAF
Support to Operational Hydrology and Water Management

H15 – Full disk



- High geographic scalability
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- 4 independent runs
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H SAF
Support to Operational Hydrology and Water Management

H15 developments

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H15 developments

- Software
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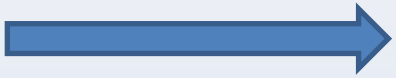
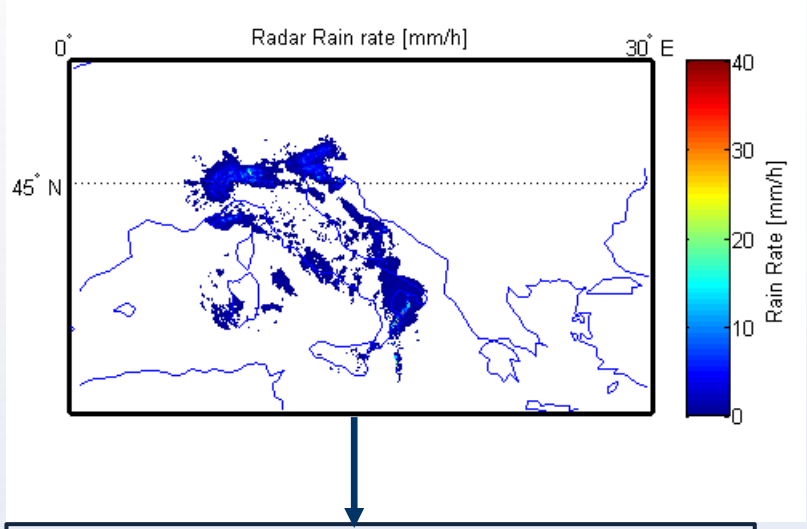
- Convection Mask



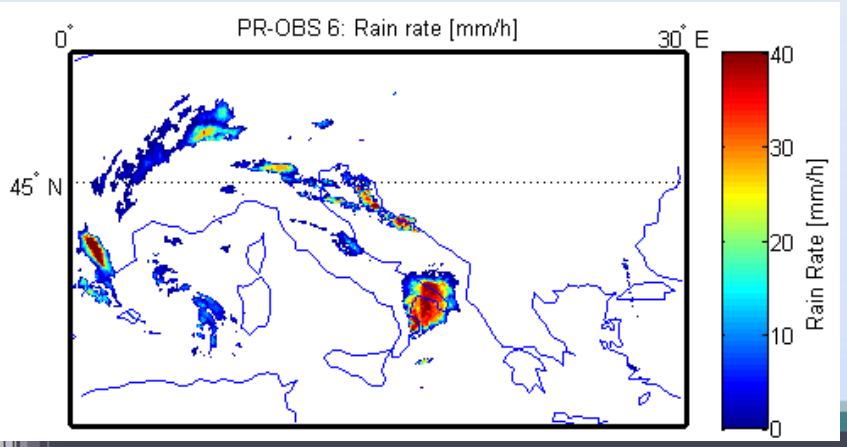
Calibration Campaign

Tor Vergata University

H15 calibration



Cost function based on Rain Rate: F=RMSE(Radar;H15*)



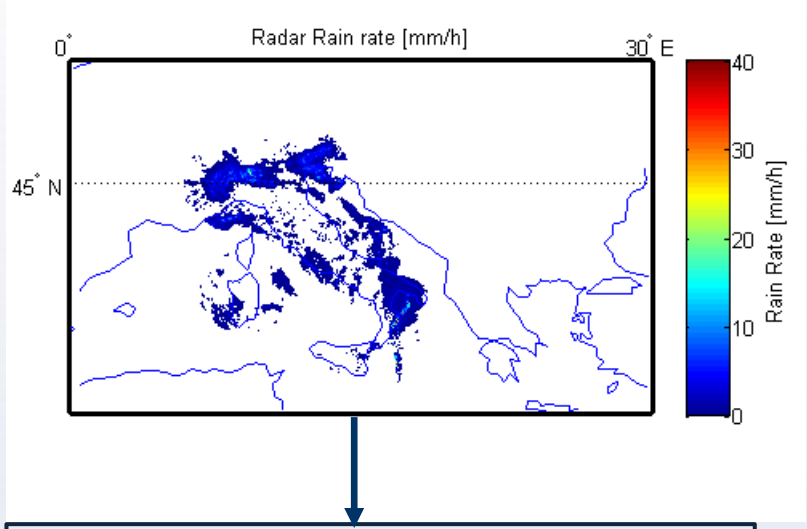
Simulated Annealing Approach

- ***Regularization algorithm to find a functional***
- ***Minimization is based on cost functions F considering rain rates [R.R.] (radar)***
- ***Different F definitions have been tested***

Training Set	Validation Set(*)	Test Set
2013-05-03	*2013-12*	*2013-11-19*
2013-06-24	*2013-01*	
2013-06-25	*2013-02*	
2013-11-18		
2013-11-19		

(*) full month considered

H15 calibration



Cost function based on Rain Rate:
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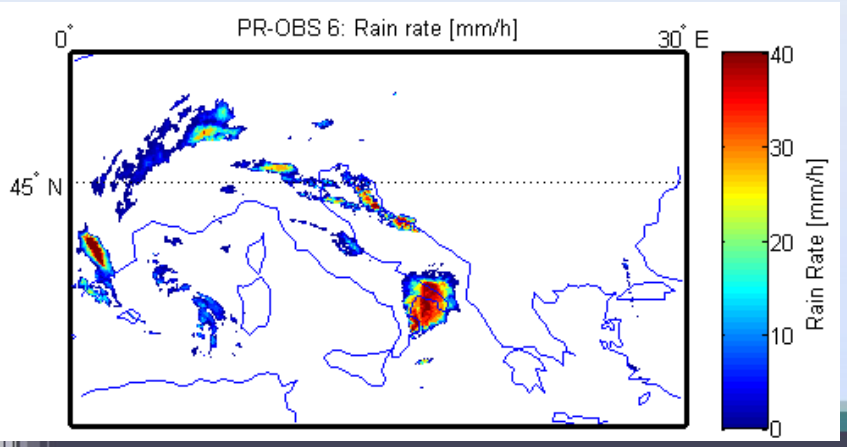
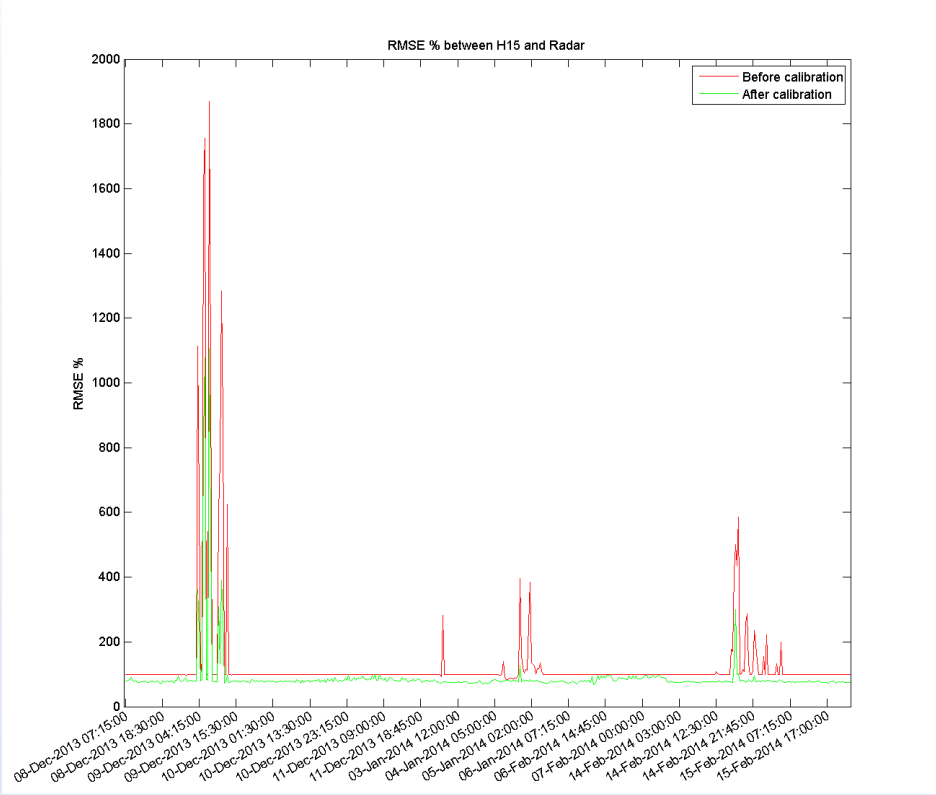


Best performance with exponential correction

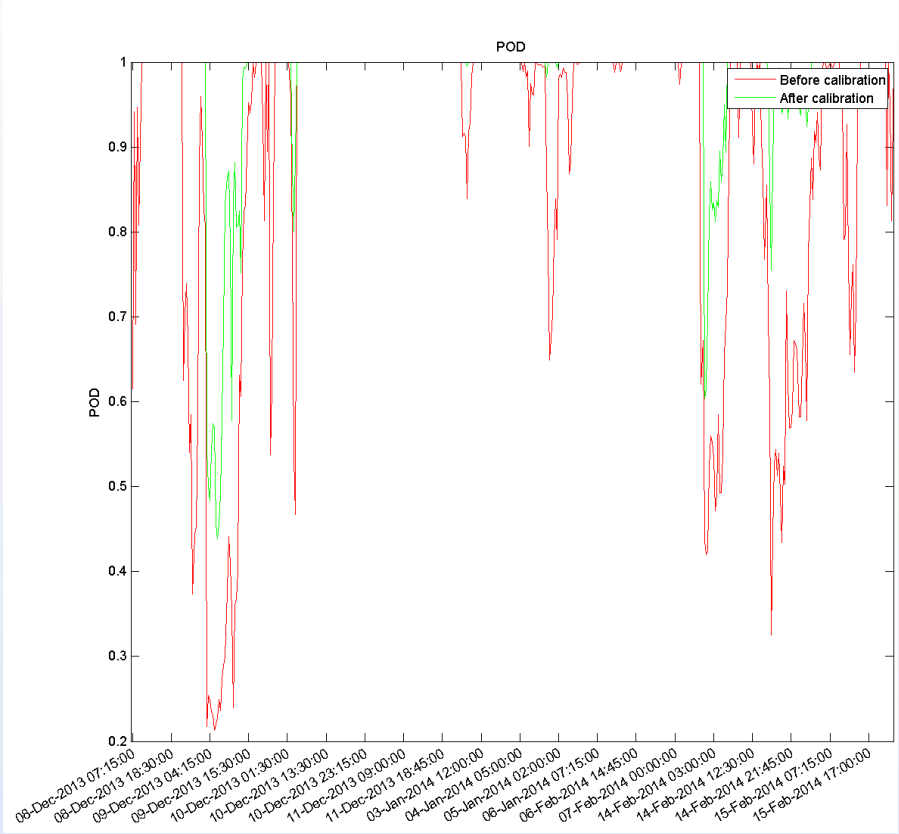
$$H15^{*}=e^{(H15 \cdot m + q)}$$

Statistical evaluation on validation set



$$RMSE\,\% = \sqrt{\frac{1}{N}\sum_{k=1}^{N}\frac{(sat_k - true_k)^2}{true_k^2}} \cdot 100$$

Range: 0 to ∞. Perfect score: 0



$$POD = \frac{hits}{hits + misses} - \frac{hits}{observed\ yes}$$

Range: 0 to 1. Perfect score: 1
hit: event observed from satellite and also observed from ground.
miss: event not observed from satellite but observed from ground.
Observed yes: total of correctly observed event from satellite.

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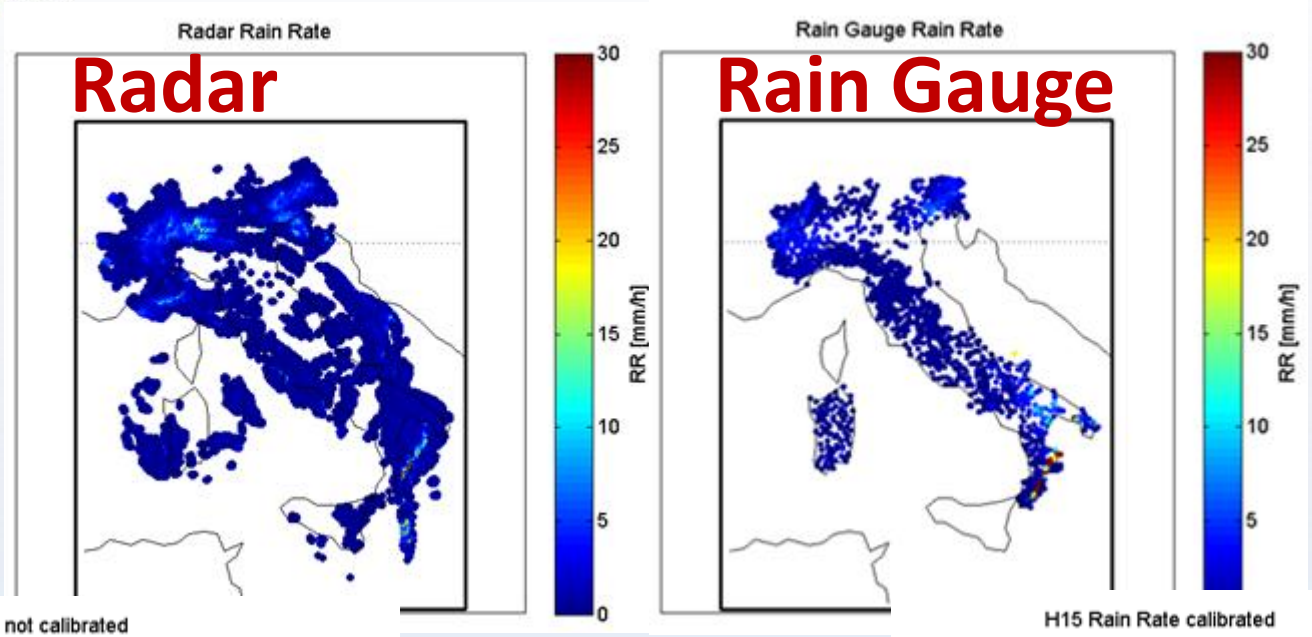
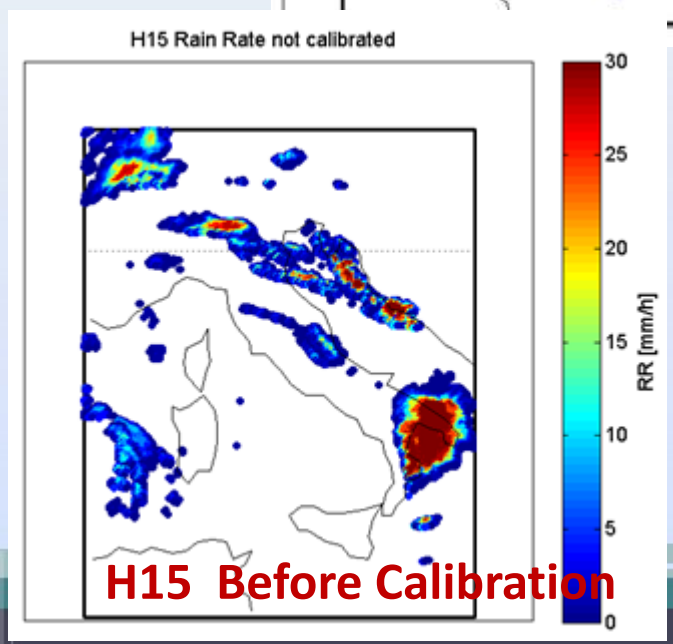
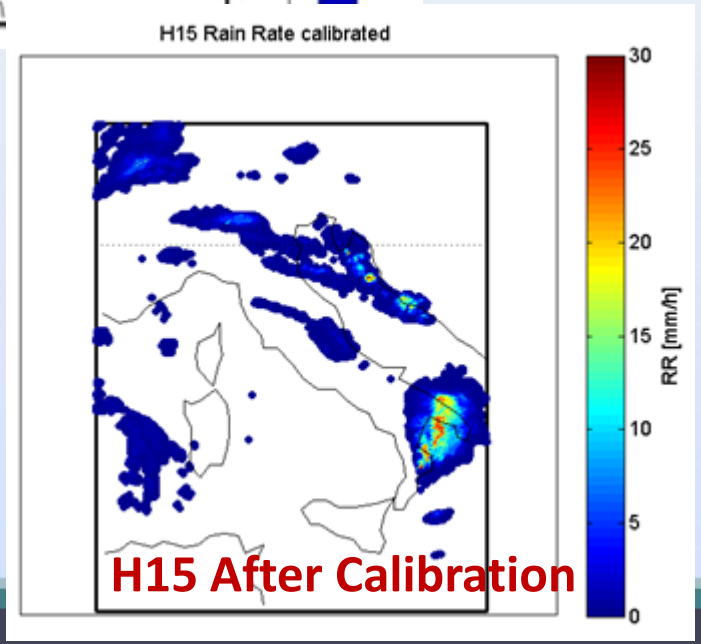
Test Date: 19-11-2013 07:27







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H15 developments

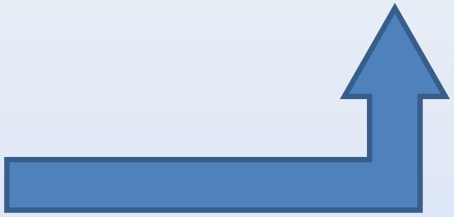
- Software
- Algorithm
- Inputs
- Convection Mask

H15 developments

The reliability of these products strongly depends on three factors:

1) accuracy of the PMW precipitation retrievals;
2) temporal frequency of PMW observations
3) consistency among the precipitation estimates obtained from the different PMW sensors.

- Inputs



- Convection Mask

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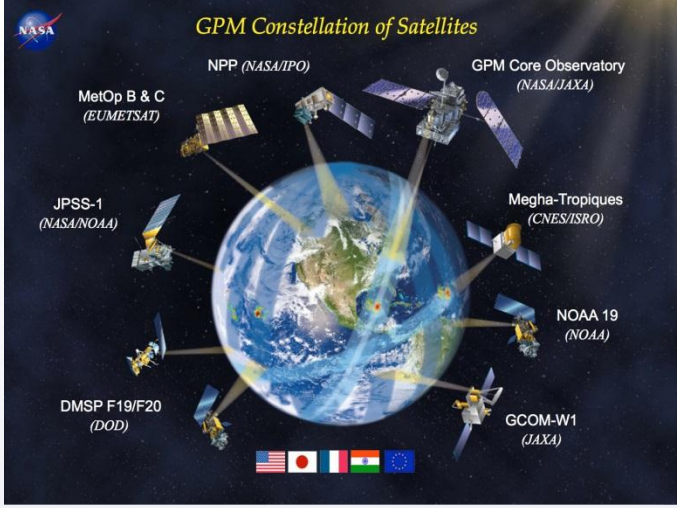
New inputs



Suomi NPP ATMS - We propose to develop a new **H18** product for the cross-scanning radiometer Advance Technology Microwave Sounder (ATMS) on board the NASA/NOAA Suomi NPP satellite. The product will be based on the Neural Network approach used for H02B product.

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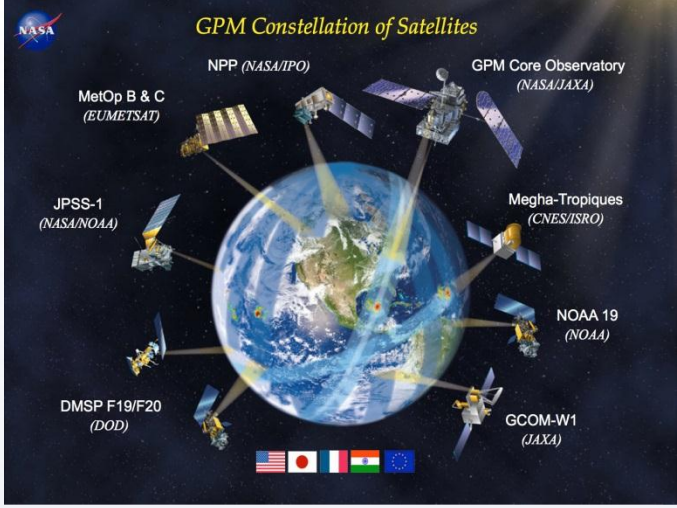
New inputs



G-COMW1 AMSR-2 - We propose to develop a new **H17** product for the conical scanning radiometer AMSR-2. The algorithm will be based on the Bayesian technique (PR-OBS-1) and on the use of the Cloud Dynamical Radiation Database (CDRD) used for H01, but adapted to the AMSR-2 radiometer characteristics (i.e., channel frequencies and polarization, viewing geometry, horizontal resolution, etc.). The product delivery is subject to the availability of AMSR-2 data in near-real time via Eumetcast.

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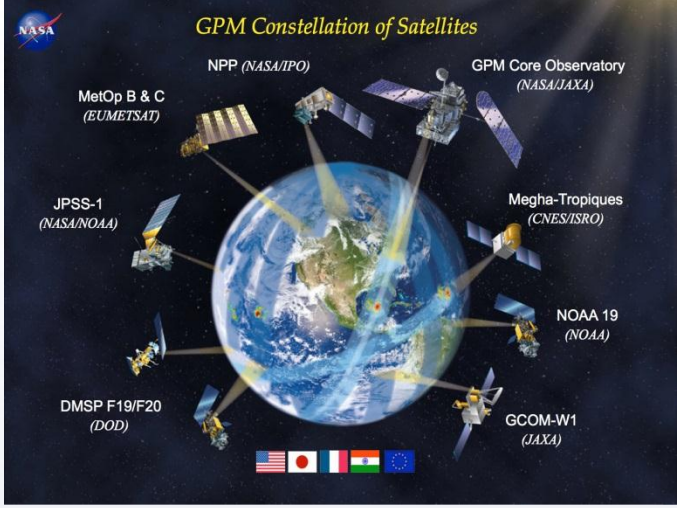
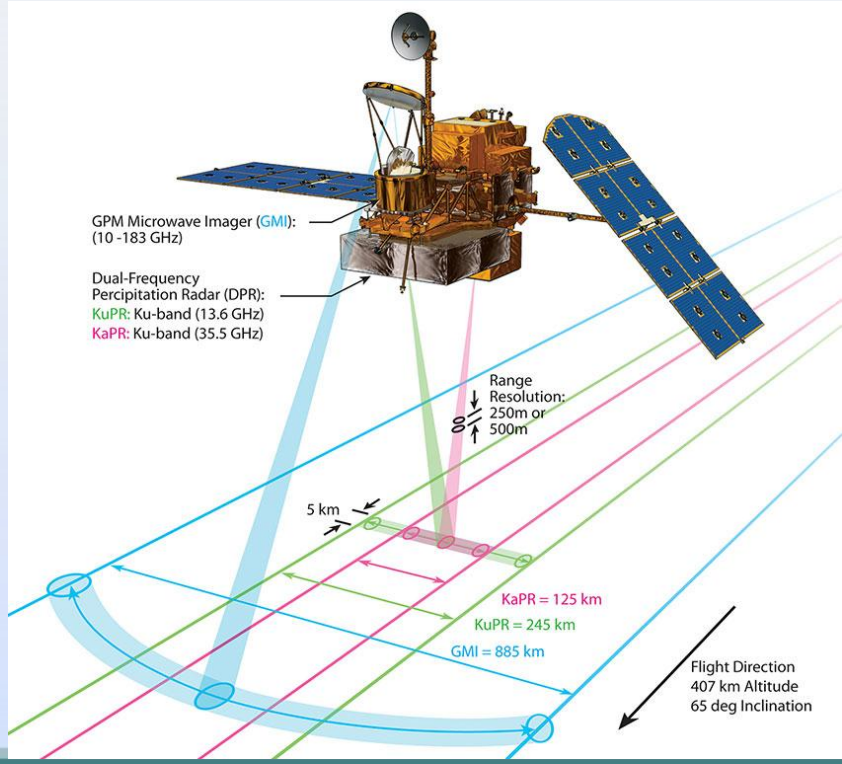
New inputs



GMI - Two products (H19 and H20) had been already planned in the CDOP-2 proposal for the **GPM Microwave Imager**. However, due to the delay of the launch date (February 27, 2014) we propose a redefinition of the two products:

- ✓ H19: product for the MSG full disk area based on the a Neural Network approach and on the use of a cloud-radiation model database (as in H01), with the additional input provided by the DPR;
- ✓ H20: global product based on a Neural Network approach (as in H02), and on the use of an observational datasets built from DPR retrievals and GMI brightness temperatures coincidences.



Future perspective:

Higher temporal sampling

- Full exploitation of *all* overpasses of present and future satellites carrying cross-track and conically scanning PMW radiometers, which has now reached its optimal configuration with the NASA/JAXA GPM (number of satellites, GPM core satellite)

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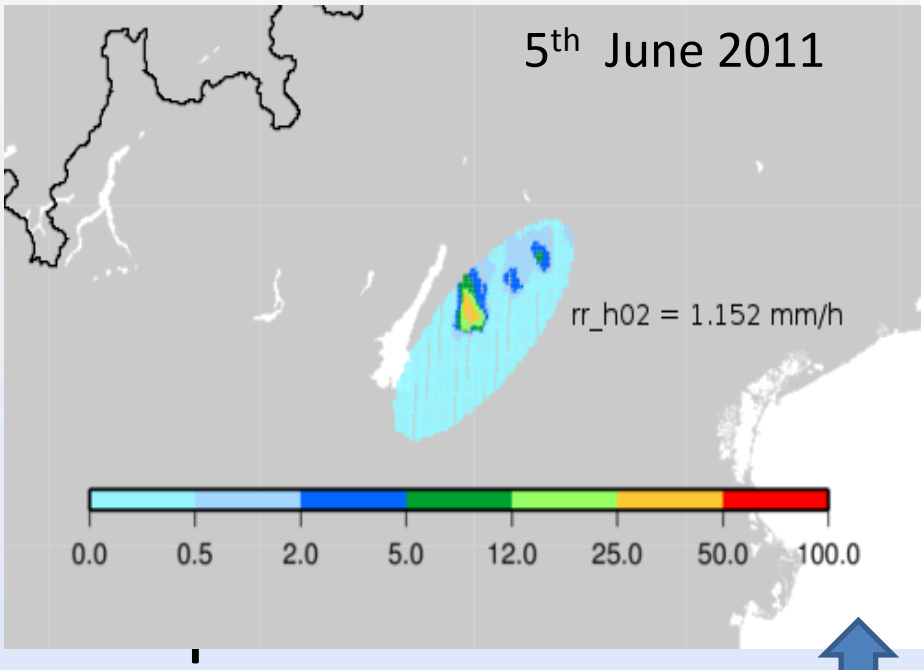
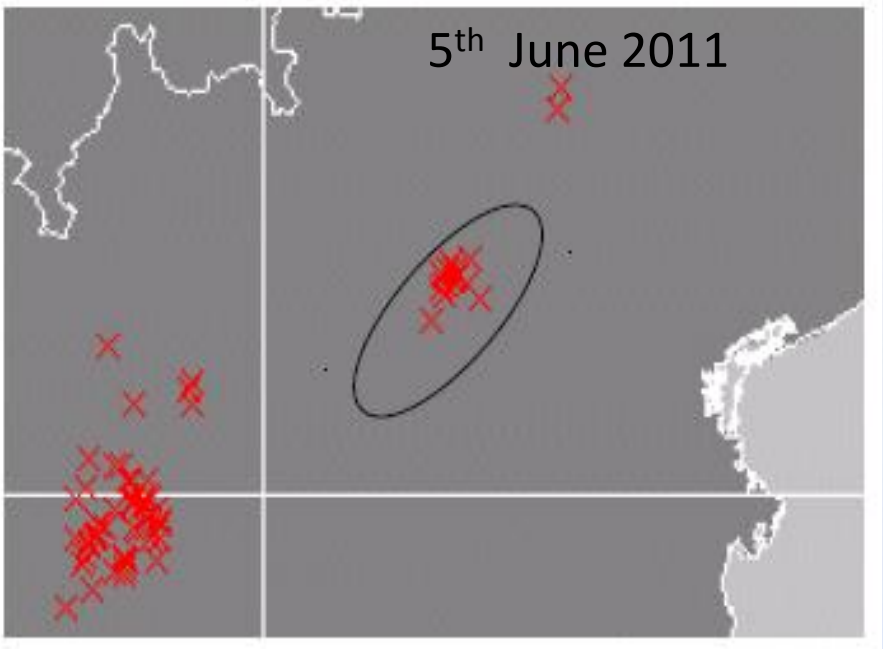
H15 developments

- Software
- Algorithm
- Inputs
- Convection Mask

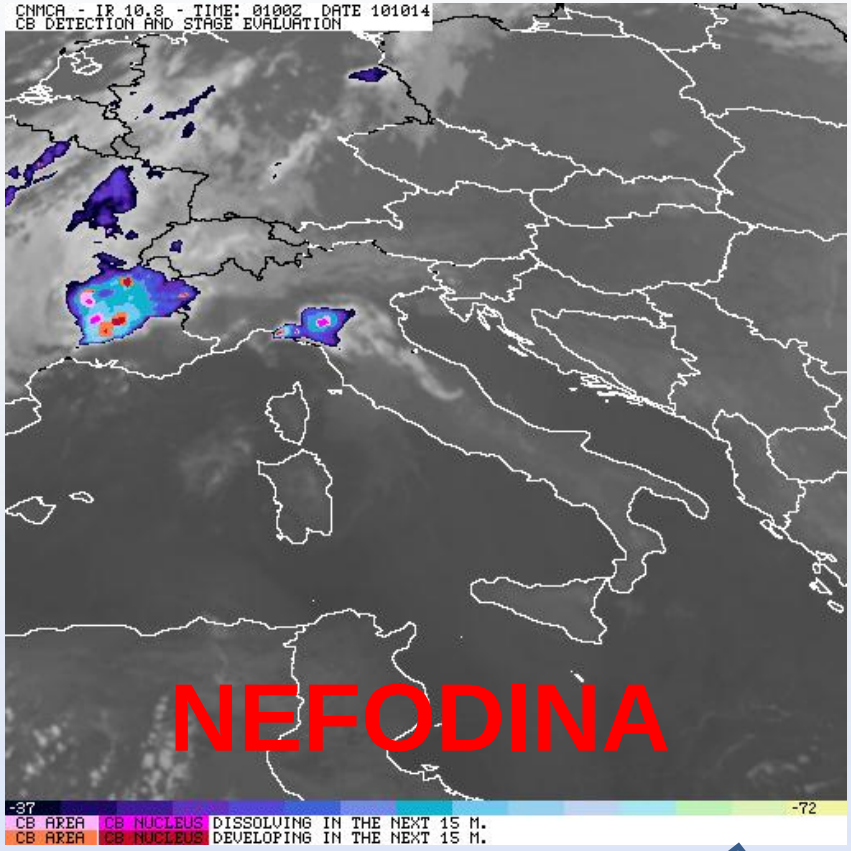
H15 developments

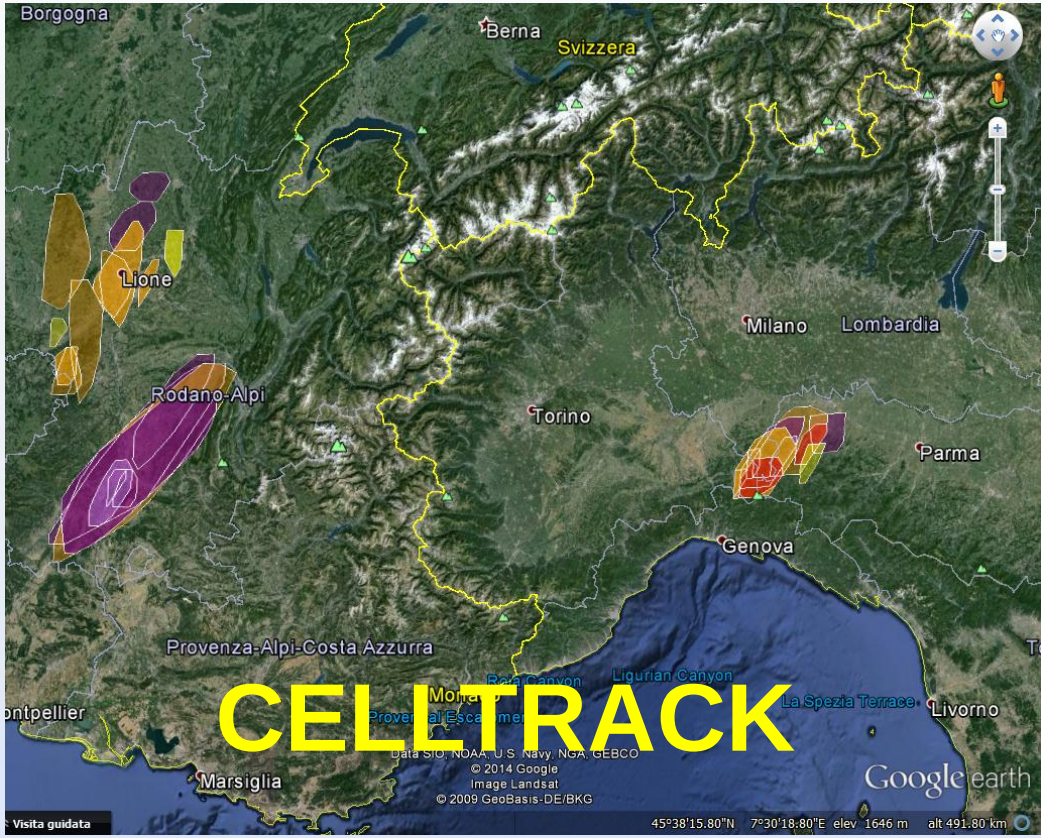




- Convection Mask

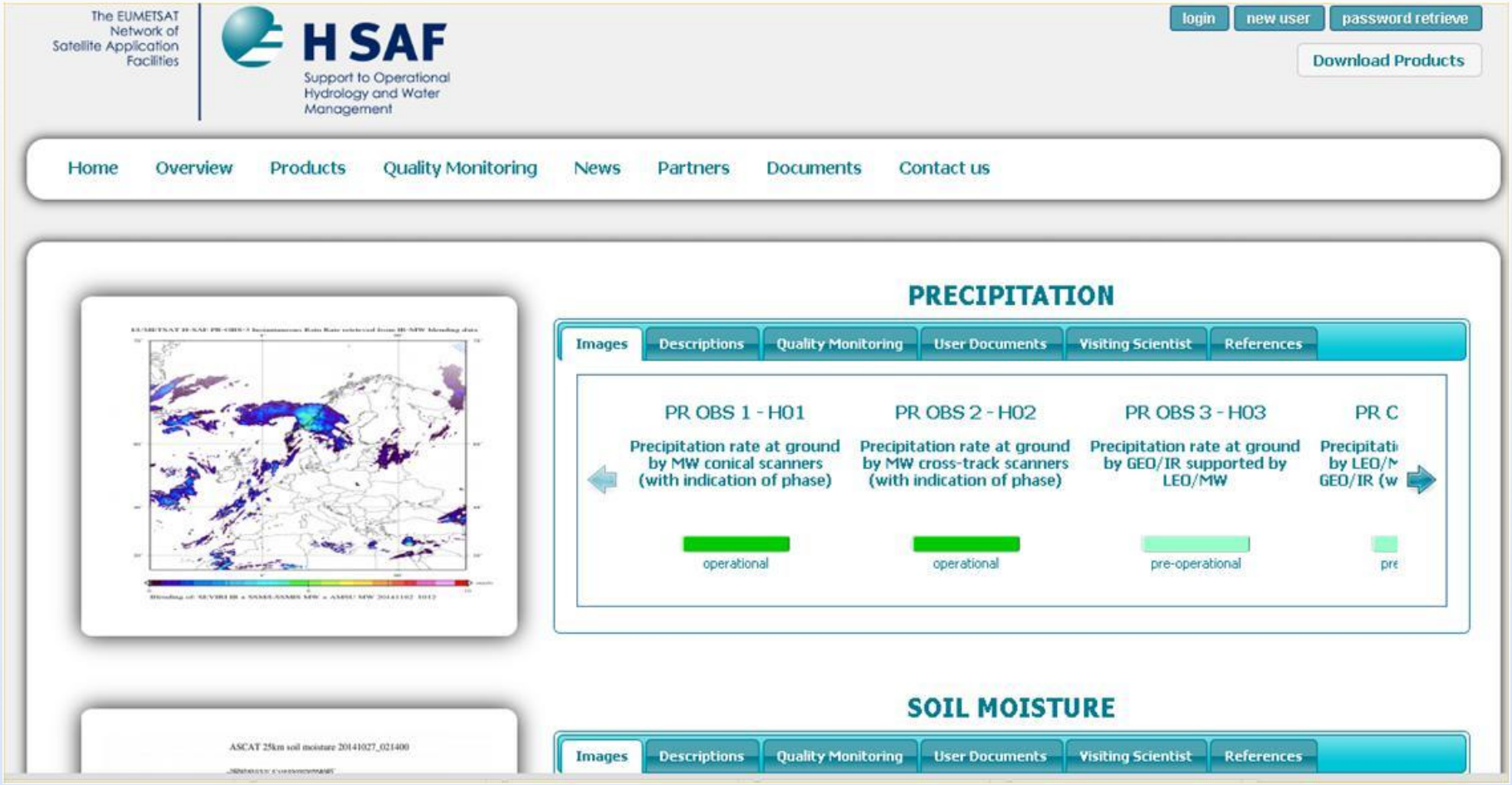
Convection Mask





NEFODINA_2.0

User Services – Website



hsaf.meteoam.it

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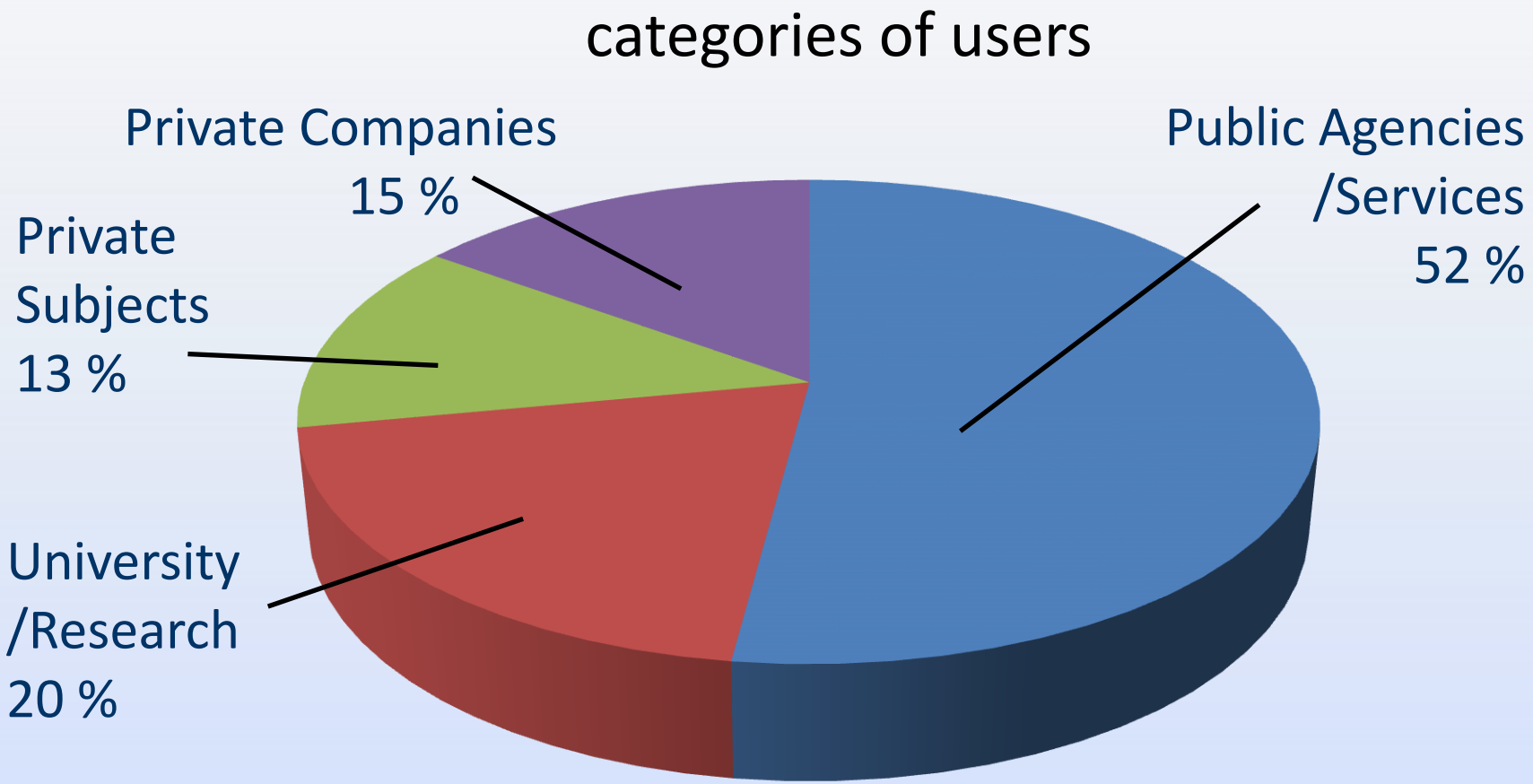
Achievements and status of the Programme

Establishment of user community

Trend in user registration:

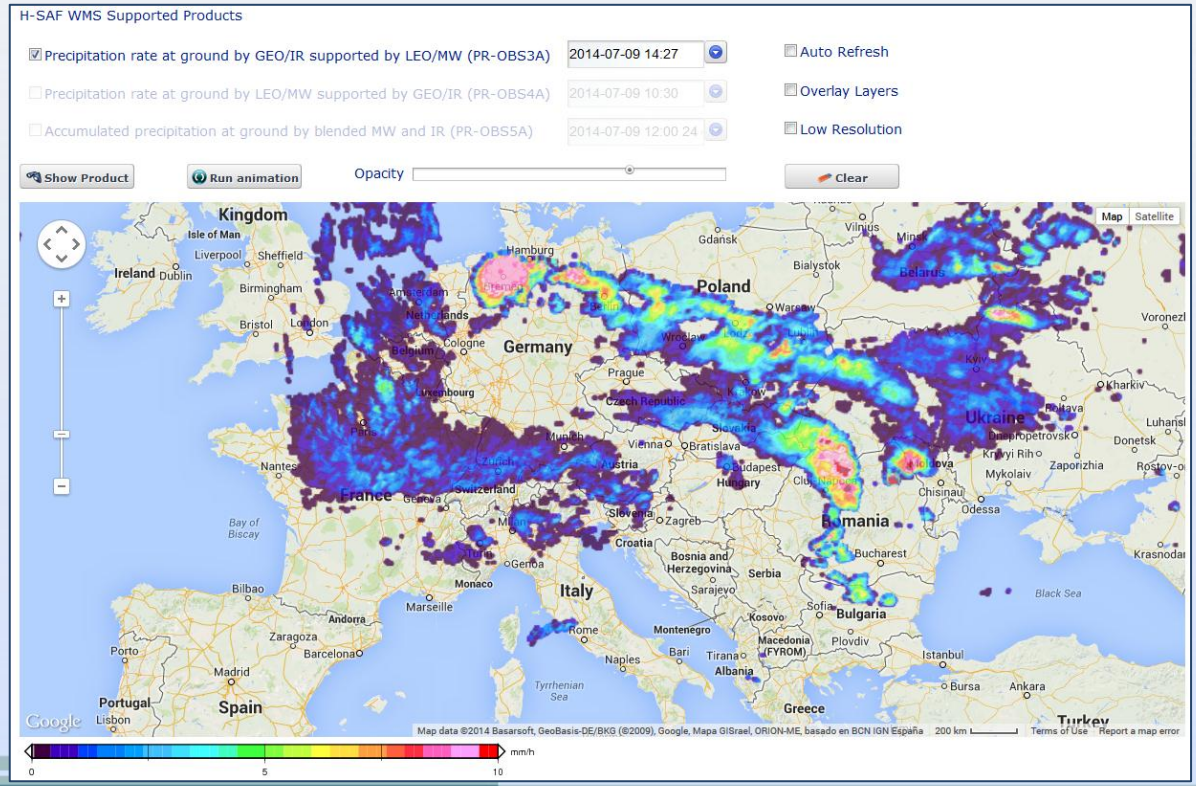
Achievements and status of the Programme

Establishment of user community



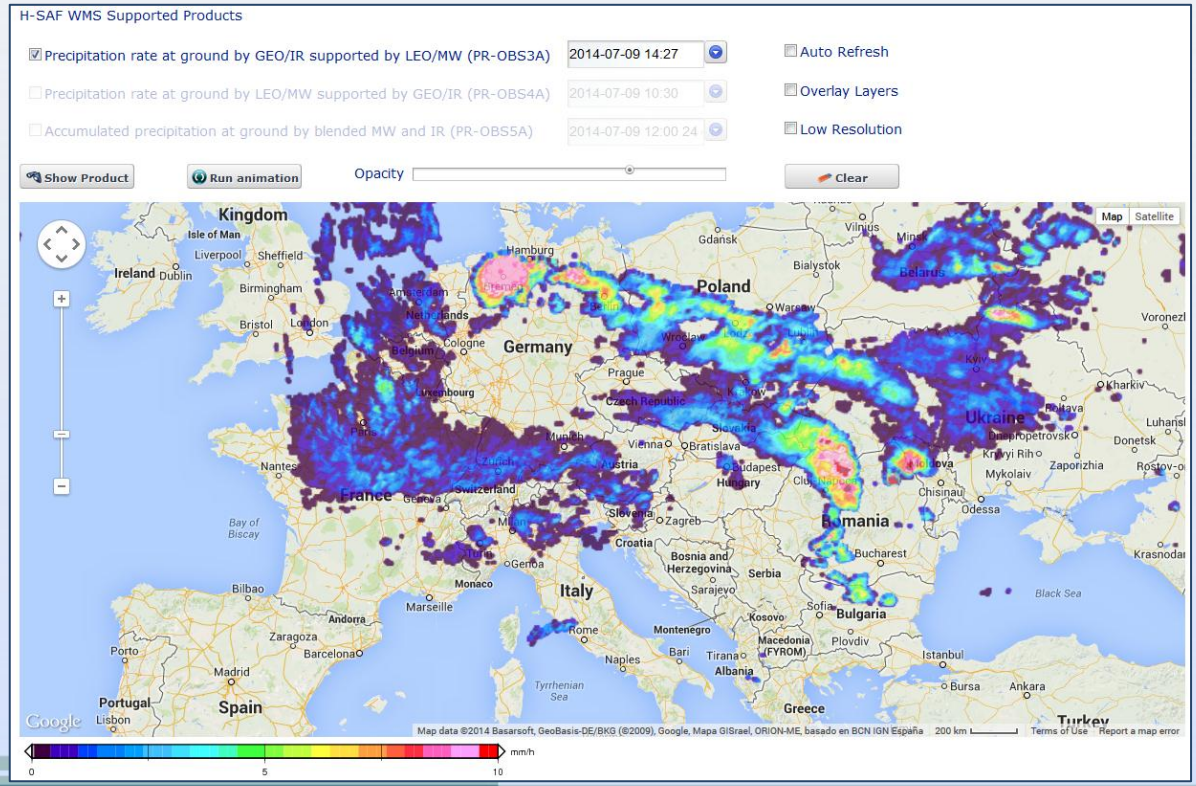
User Services – Map Tool

The **Map Tool** is a web application that provides an easy to use tool - you only need a web browser and a good internet connection - to display a set of precipitation products (H03, H04 and H05) on a **georeferenced map**.



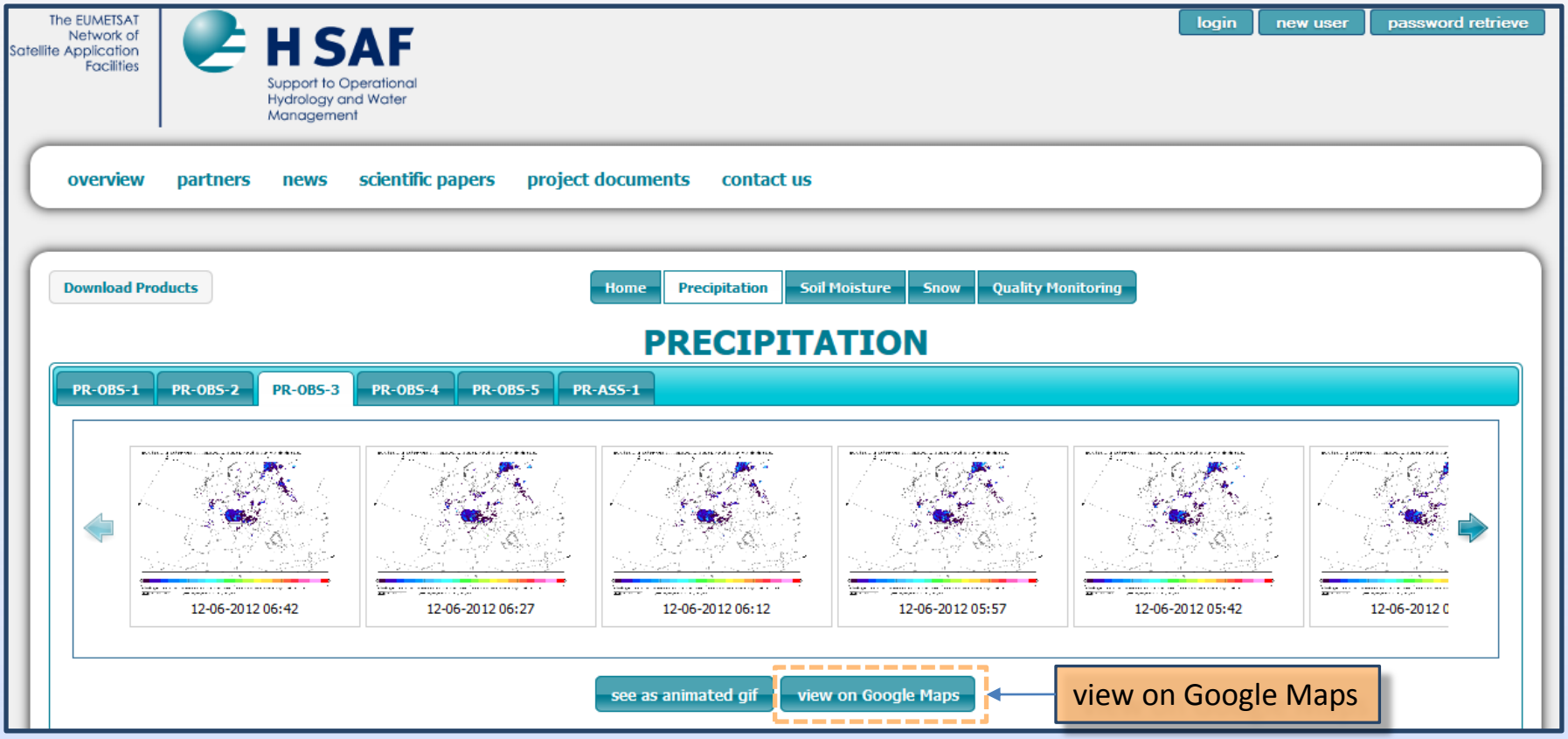
User Services – Map Tool

The **MAP Tool** is also an operational tool that allows users to monitor the current status of rainfall on the ground (H03, H04) or the status of the accumulated precipitation (H05), updating automatically the map with the last H-SAF product available.



User Services – Map Tool

The **MAP Tool** can be reached from the official website of HSAF hsaf.meteoam.it after registration.



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Thanks to …

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5 - GEO-K s.r.l.
6 - Telespazio

… and you for your attention!