H SAF
Support to Operational Hydrology and Water Management

Eumetrain event week *December 1-5, 2014*
Droughts, Floods and Landslides
Session 7: Satellite Precipitation Products and Applications

Precipitation Products from the Hydrology SAF: Part 1: current status and future developments

Giulia Panegrossi
Institute of Atmospheric Sciences and Climate
ISAC-CNR, Rome
Italy
g.panegrossi@isac.cnr.it

H SAF
Support to Operational Hydrology and Water Management

H-SAF Precipitation Products:

Development team

ISAC/CNR

V. Levizzani, S. Dietrich

D. Casella, E. Cattani, S. Laviola, G. Panegrossi, P. Sanò

Passive Microwave Precipitation Products

Combined IR-MW products – Cloud classification - Snowfall

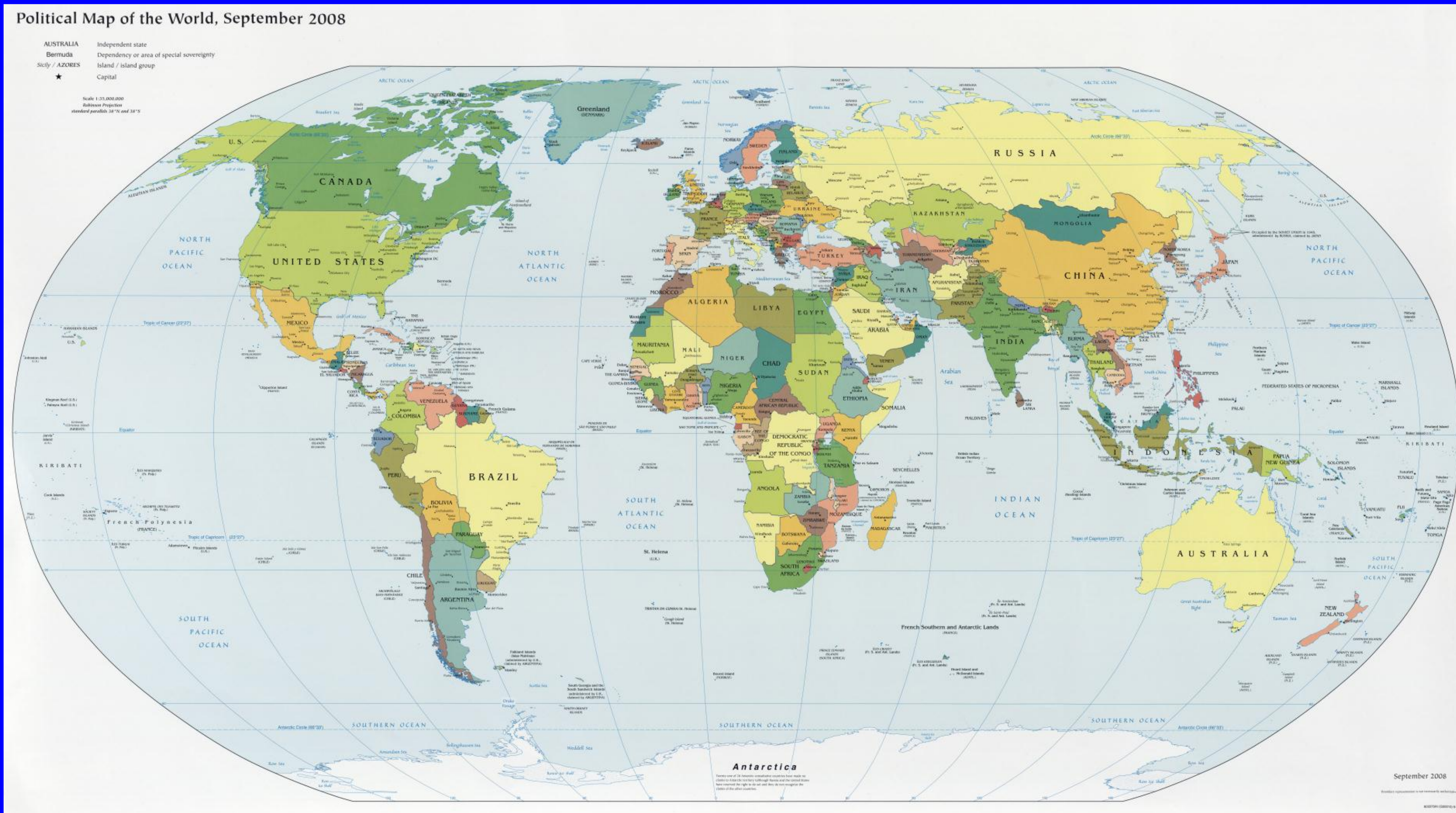
ITAF MET Service

D. Biron, L. De Leonibus, D. Melfi, A. Vocino, F. Zauli,

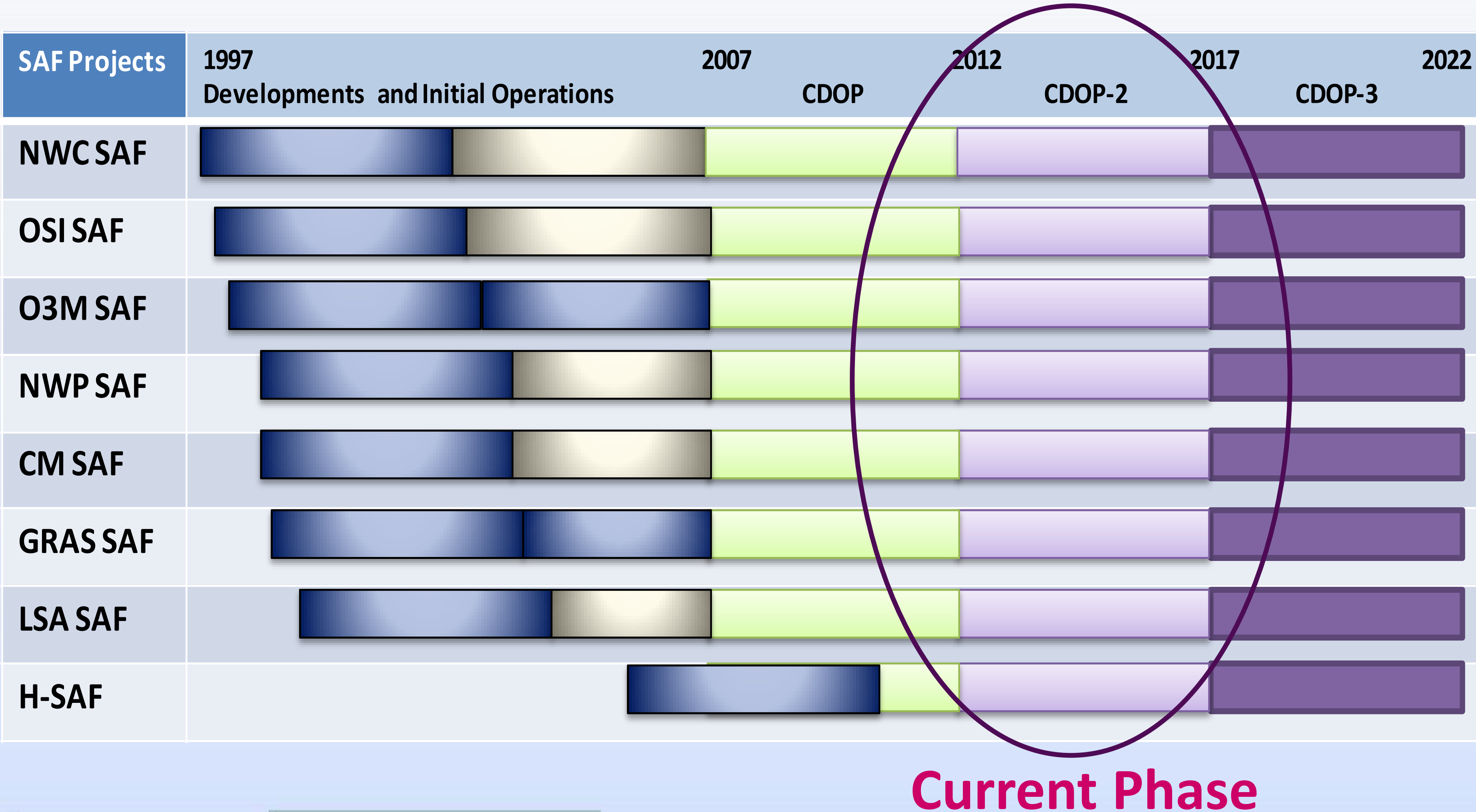
Massimiliano Sist, Michele De Rosa, Matteo Picchiani (Geo-K s.r.l)

Convective Precipitation – MTG LI- Cumulated Precipitation

Where are you from?



The Context: The SAF Schedule



H-SAF : Satellite Application Facility on Support to Operational Hydrology and Water Management

Objectives:

- *Provide operational high quality level 2/3 products and develop new 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);

- *Perform independent validation of the usefulness of the new products for civil protection purposes (i.e., fighting against floods, landslides, avalanches), and for evaluating water resources;*
  - *Quality monitoring:* 12 countries involved: Austria, Belgium, Bulgaria, ECMWF, Finland, France, Germany, Hungary, Italy, Poland, Slovakia, Turkey; coordinated by **DPC (Italy)**
  - *Hydrovalidation:* 8 countries involved : Poland, Belgium, Bulgaria, Finland, Germany, Italy, Slovakia, Turkey; 21 test sites provided; coordinated by **IMGW (Poland)**

H SAF
Support to Operational Hydrology and Water Management

Composition of the H-SAF Consortium

Country	Units in the Country (responsible unit in bold)	Role in the Project
Austria	- **Zentral Anstalt für Meteorologie und Geodynamik** - Technische Univ. Wien, Inst. Photogrammetrie & Fernerkundung	**Leader for soil moisture**
Belgium	- **Institut Royal Météorologique**	
Bulgaria	- **National Institute of Meteorology and Hydrology**	
ECMWF	- **European Centre for Medium-range Weather Forecasts**	**Contributor for "core" soil moisture**
Finland	- **Finnish Meteorological Institute** - Helsinki Technical University, Laboratory of Space Technology - Finnish Environment Institute	**Leader for snow parameters**
France	- **Météo-France** - CNRS Centre d'Etudes Spatiales de la BIOsphere - CNRS Centre d'études des Environnem. Terrestres et Planétaires	
Germany	- **Bundesanstalt für Gewässerkunde**	
Hungary	- **Hungarian Meteorological Service**	
Italy	- **Italian Meteorological Service** - Department for Civil Protection - CNR Institute of Atmospheric Sciences and Climate - Ferrara University, Department of Physics - CIMA Research Foundation - University of Rome "La Sapienza", Dept. of Electrical Engineering	**Host + Leader for precipitation+ Leader for product quality monitoring (validation)**
Poland	- **Institute of Meteorology and Water Management**	**Leader for Hydrovalidation**
Slovakia	- **Slovenský Hydrometeorologický Ústav**	
Turkey	- **Turkish State Meteorological Service** - Middle East Technical University, Civil Engineering Department - Istanbul Technical University, Meteorological Department - Anadolu University	**Contributor for "core" snow parameters**

Questions addressed in this Lectures

Part 1:

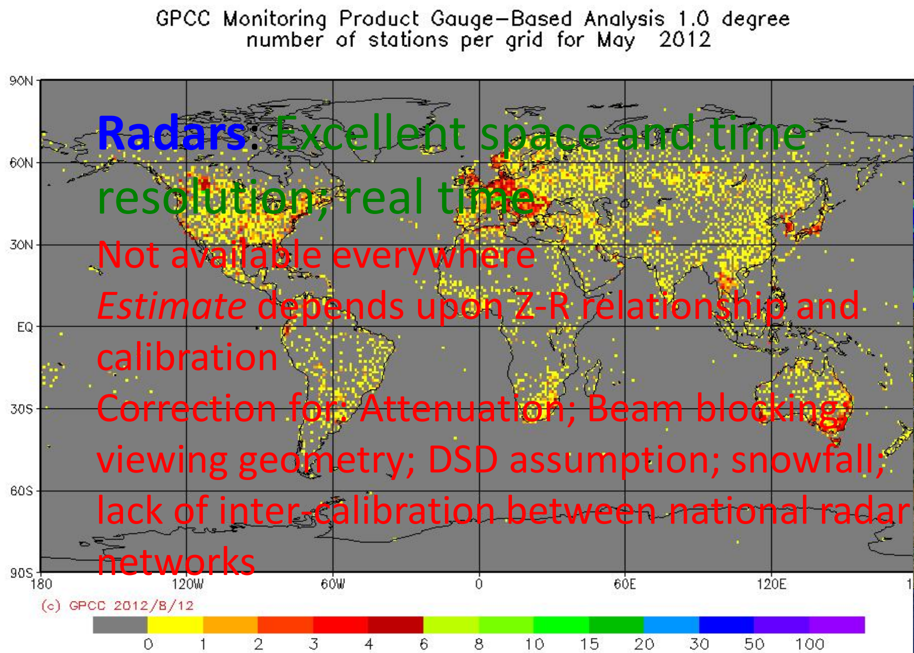
How can we retrieve precipitation from space?

What are the H-SAF precipitation products?

Part 2:

Can H-SAF products be used for extreme event monitoring?

Why from Space?

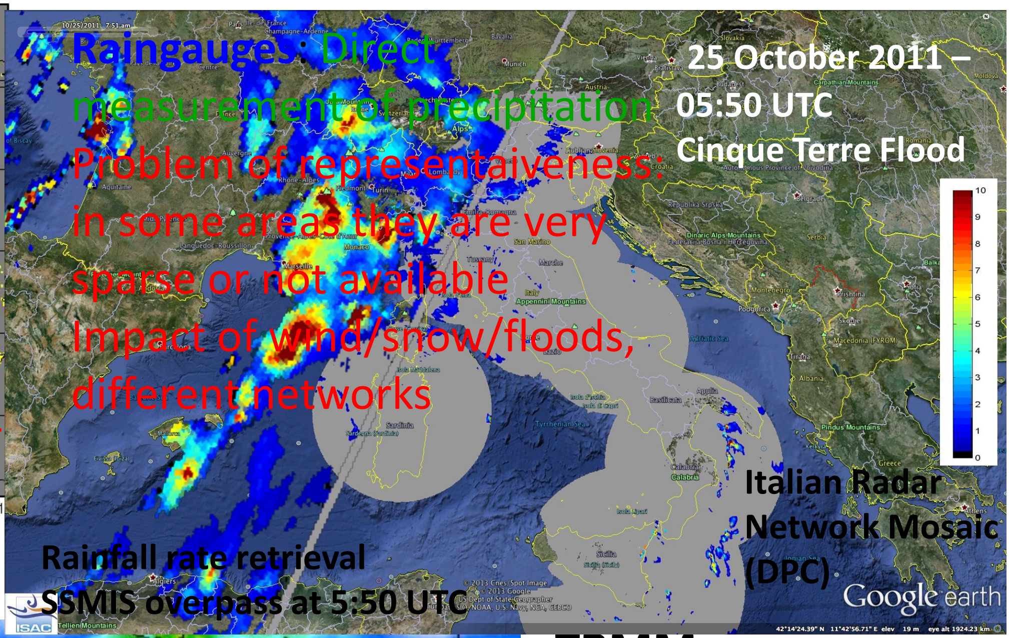


Radars: Excellent space and time resolution, real time

Not available everywhere

Estimate depends upon Z-R relationship and calibration

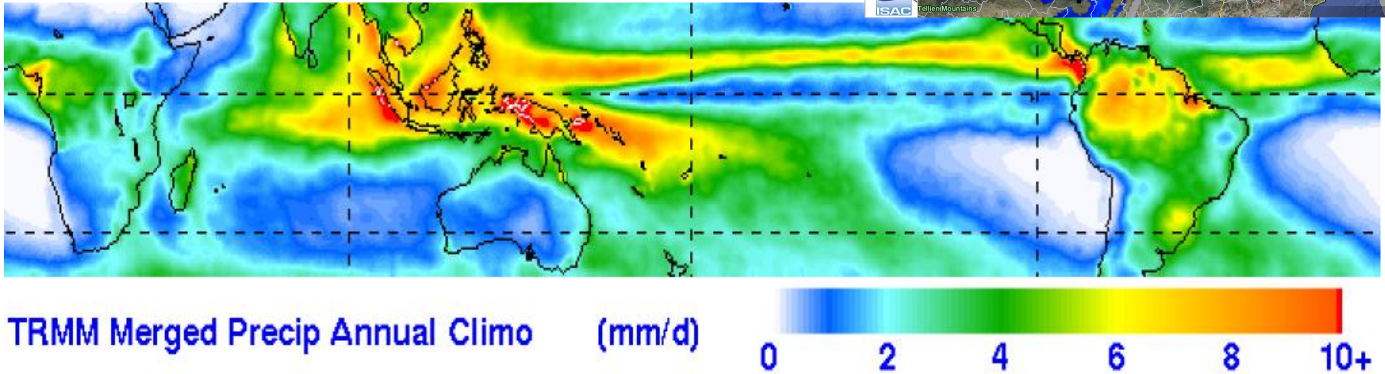
Correction for: Attenuation; Beam blocking; viewing geometry; DSD assumption; snowfall; lack of inter-calibration between national radar networks



Raingauges: Direct measurement of precipitation

Problem of representaiveness: in some areas they are very sparse or not available

Impact of wind/snow/floods, different networks



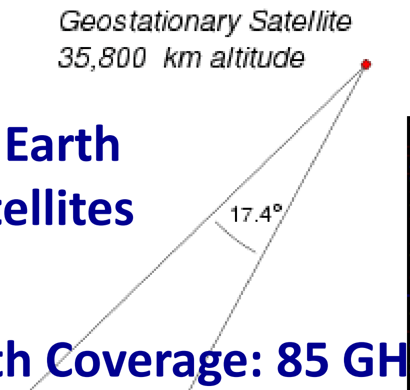
TRMM Rainfall Global/Regional Climatology 1998-2000

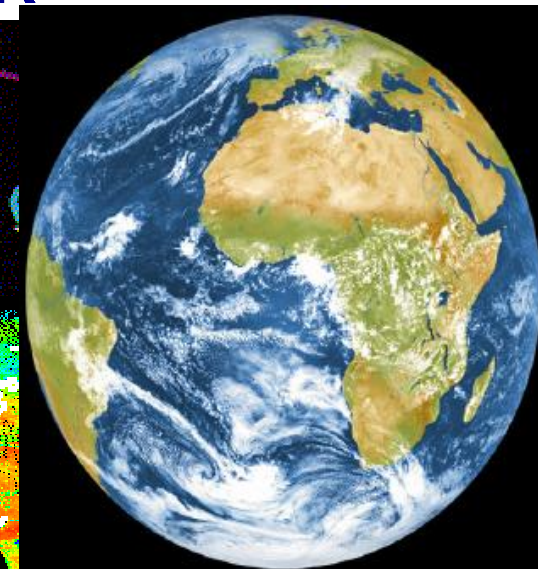
Credit: NASA

Remote Sensing of precipitation:
Global
Provides precipitation at different temporal/spatial scales but…
is a based on a very complex retrieval process

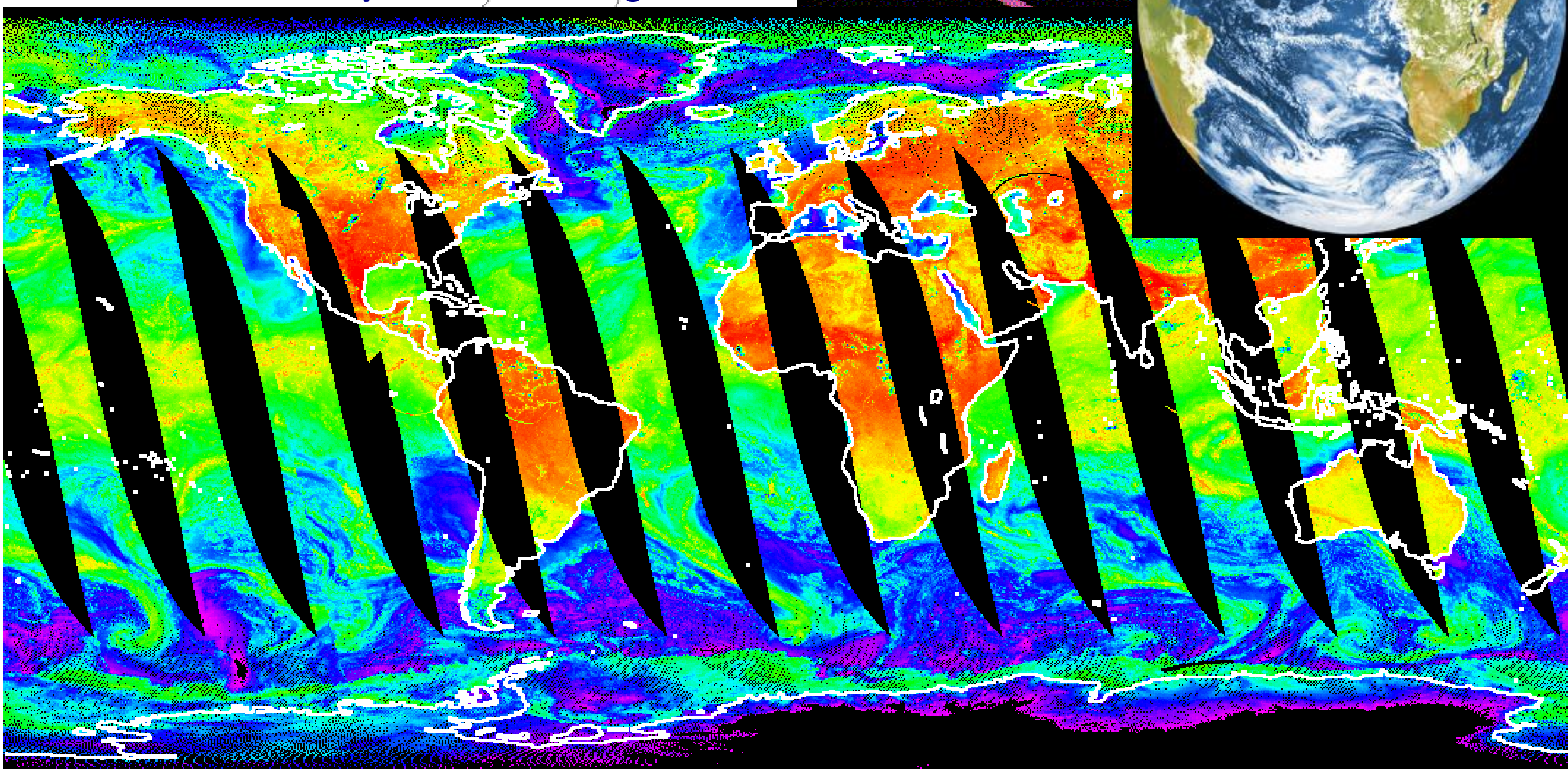
Geosynchronous Earth Orbit (GEO) VIS/IR

Two Main Orbits for Earth Orbiting Weather Satellites





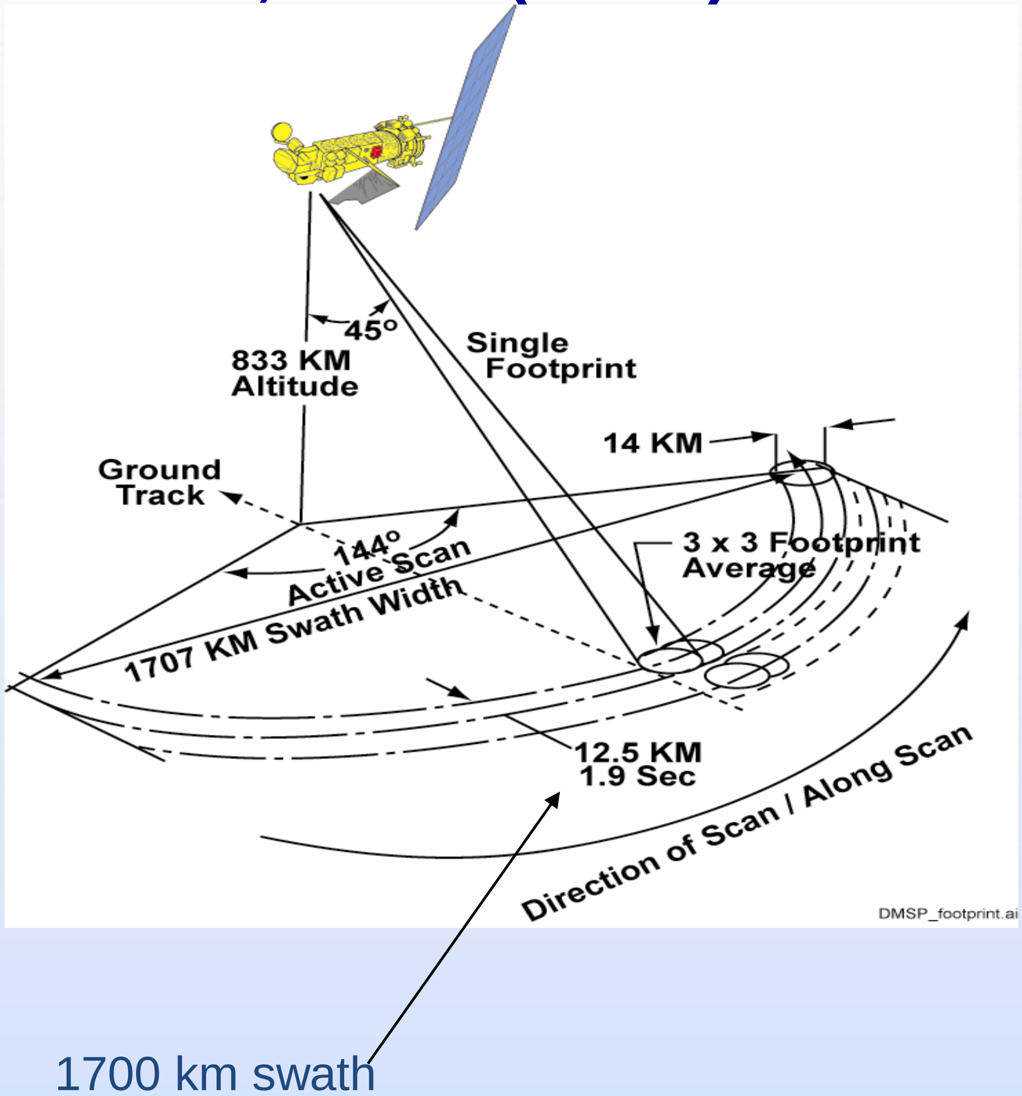
DMSP SSMIS Daily Earth Coverage: 85 GHz H



Conical scanning radiometers

i.e., SSMIS (SSM-I)

- On Board DMSP F-16, F17, F18, F19 Spacecraft
- Launched October 2003
- 24 Channels (19-183 GHz)
- Added 150 and 183 GHz channel capabilities for high latitude precipitation and snowfall
- IFOV size with channel frequency (max ≅13 km)
- Sampling Freq. 12.5 km



H SAF
Support to Operational Hydrology and Water Management

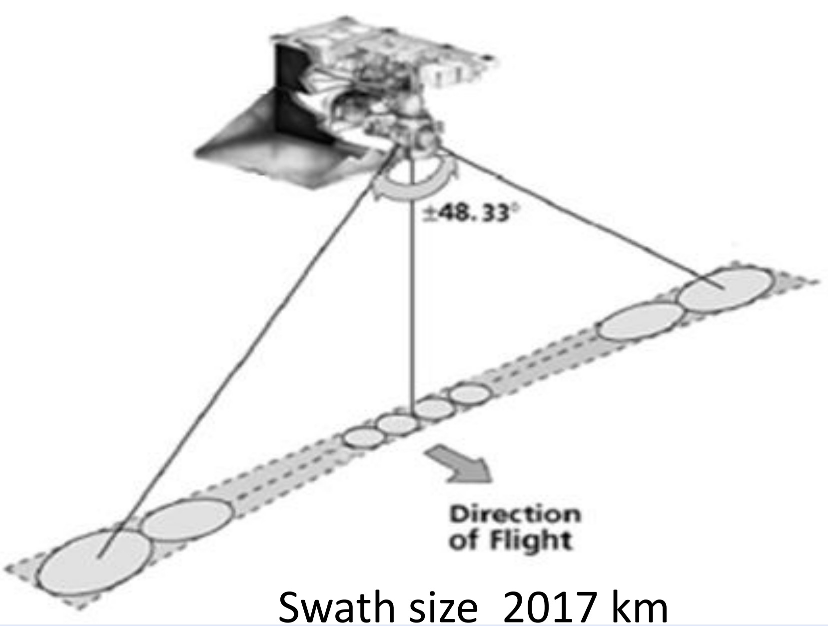
Cross-track scanning radiometers

i.e, AMSU-A/MHS

Currently on board NOAA 18-19 and MetOp A-B

AMSU-A (817/833 km)		MHS (817/833 km)
Channel Frequency (GHz)		Channel Frequency (GHz)
1	23.8	89
2	31.4	157
3	50.3	183.311±1
4	52.8	183.311±3
5	53.596±0.115	183.311±7
6	54.4	
7	54.94	
8	55.5	
9	57.29	
10	57.29±0.217	
11	57.29±0.3222±0.048	
12	57.29±0.3222±0.022	
13	57.29±0.3222±0.01	
14	57.29±0.3222±0.0045	
15	89	

AMSU-A scan geometry

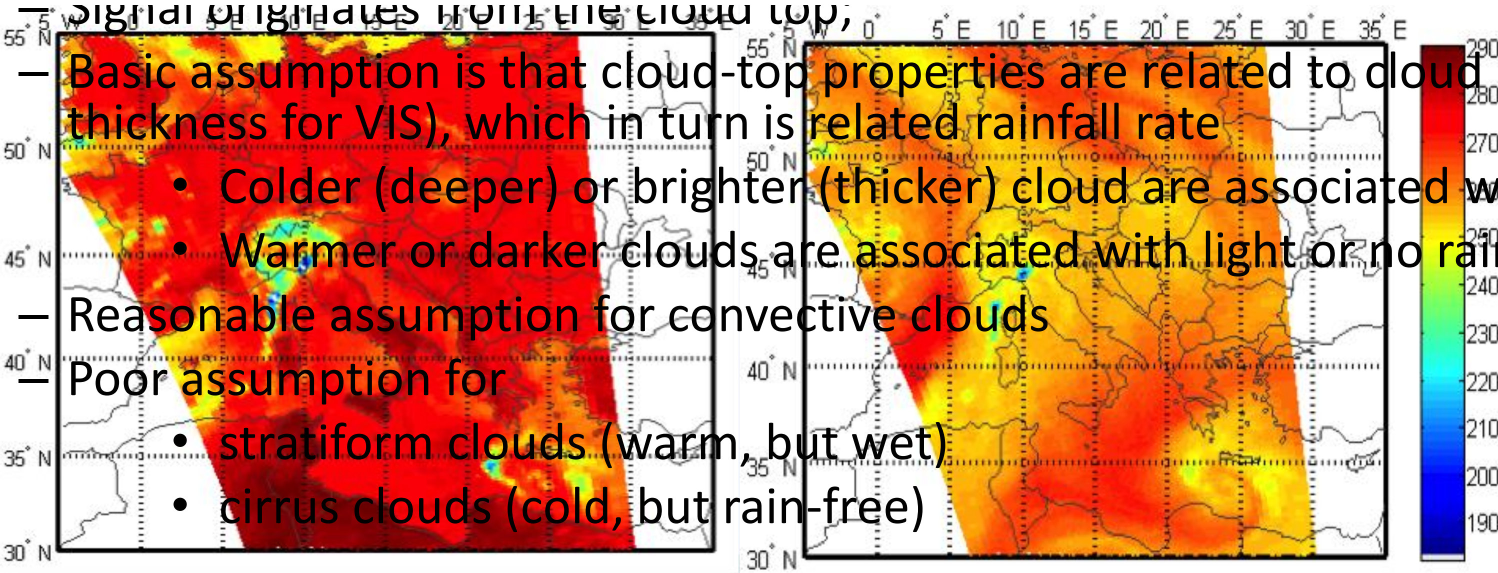


Swath size 2017 km

IFOV: 48 km (AMSU-A) or 16 km (MHS) at nadir
Sampling Freq. 16 km

VIS/IR vs. PMW observations

MW radiation can penetrate the cloud, which means that depending on the frequency, type of cloud, and microphysical structure, the signal reaching the radiometer originates from different parts within the cloud, and depending on the background surface and environmental conditions the signal can be related to surface precipitation.



– Signal originates from the cloud top;
– Basic assumption is that cloud-top properties are related to cloud height (or thickness for VIS), which in turn is related rainfall rate
  - Colder (deeper) or brighter (thicker) cloud are associated with heavier rain
  - Warmer or darker clouds are associated with light or no rain
– Reasonable assumption for convective clouds
– Poor assumption for
  - stratiform clouds (warm, but wet)
  - cirrus clouds (cold, but rain-free)

October 25, 2011, 11:44 UTC MHS (NOAA 19) TB (K) at 150 GHz (left) and TB (K) at 183.31±3 GHz WV band (right). **LEO satellites: low spatial resolution and temporal sampling**

PMW Remote Sensing of precipitating clouds

1. Combination of absorption and scattering effects:
   - Complex Index of Refraction (Real part: Scattering, Imaginary part: Absorption) (depending on Composition of hydrometeors: liquid, ice, and mixed)
   - Particle Sizes: Mie Size Parameter $x = 2\pi r / \lambda$
   - Shape (hydrometers are not spheres!)
2. Spatial distribution (3-D!!!) of the hydrometeors within the cloud;
3. Background surface properties (i.e., emissivity, skin temperature, roughness, salinity, SST)
4. Large footprints: beam filling effect

H SAF
Support to Operational Hydrology and Water Management

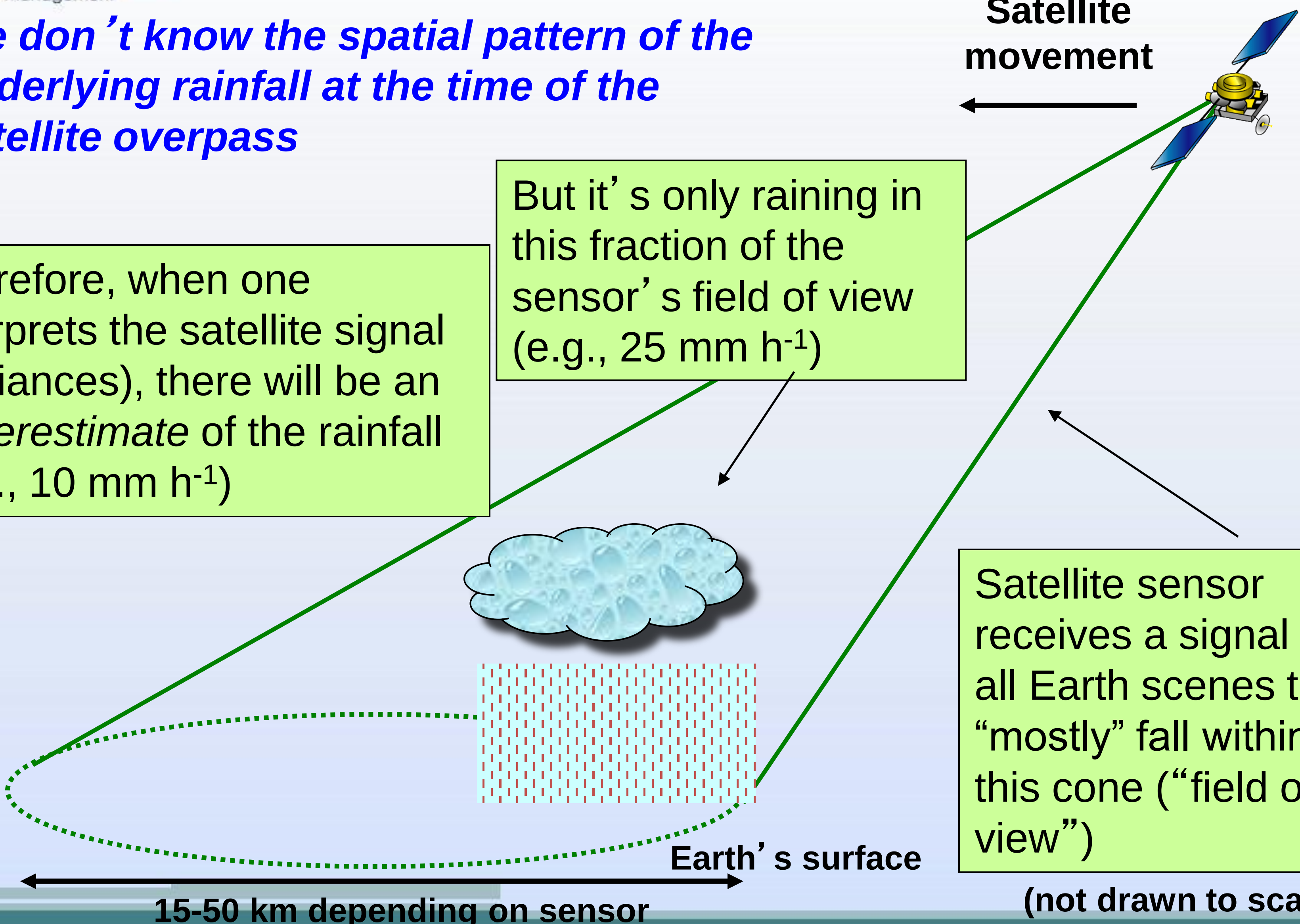
The Satellite "Beamfilling"

We don't know the spatial pattern of the underlying rainfall at the time of the satellite overpass

But it's only raining in this fraction of the sensor's field of view (e.g., 25 mm h^{-1})

Therefore, when one interprets the satellite signal (radiances), there will be an *underestimate* of the rainfall (e.g., 10 mm h^{-1})

Satellite sensor receives a signal for all Earth scenes that "mostly" fall within this cone ("field of view")



H SAF
Support to Operational Hydrology and Water Management

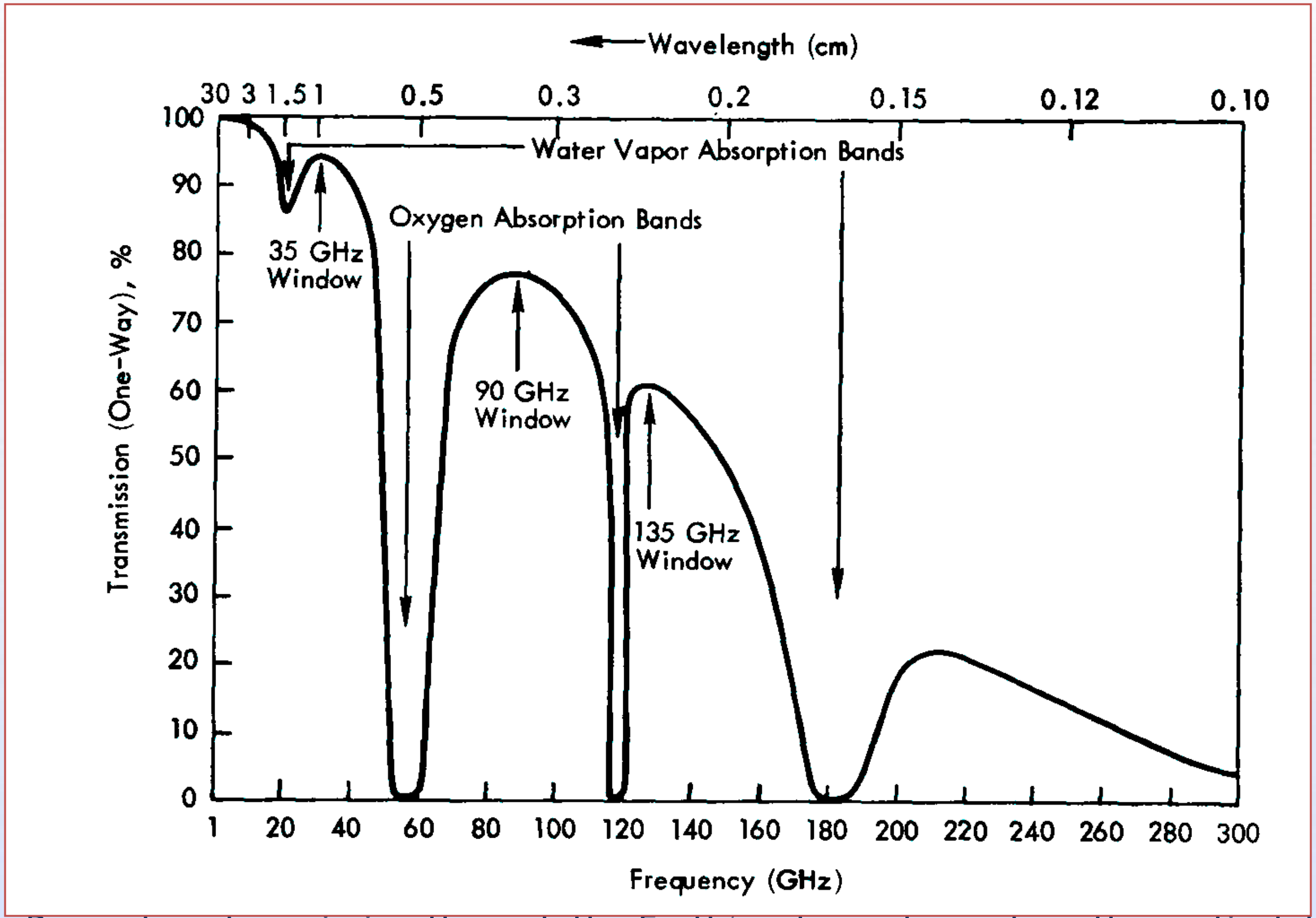
PMW Remote Sensing of precipitating clouds

1. Combination of absorption and scattering effects:
   - Complex Index of Refraction (Real part: Scattering, Imaginary part: Absorption) (depending on Composition of hydrometeors: liquid, ice, and mixed)
   - Particle Sizes: Mie Size Parameter $x = 2\pi r / \lambda$
   - Shape (hydrometers are not spheres!)
2. Spatial distribution (3-D!!!) of the hydrometeors within the cloud;
3. Background surface properties (i.e., emissivity, skin temperature, roughness, salinity, SST)
4. Large footprints: beam filling effect

All these factors determine what portions of the clouds the radiometer can sense at each wavelength and how/if it can be related to precipitation

Precipitation retrieval: a very complex problem

Passive MW Radiometry



Percentage trasmission through the Earth's atmosphere along the vertical direction, under clear-sky conditions. *[Adapted from Ulaby et al, 1981*]

- Microwave region for precipitation: 10-200 GHz (10-0.15 cm)
- **Uses the same principles as thermal emission remote sensing**
- Multi-frequency/multi-polarization sensing
- **Weak energy source so need large IFOV and wide bands (LEO)**

PMW (LEO) Precipitation Retrieval
Simplified Basic Theory

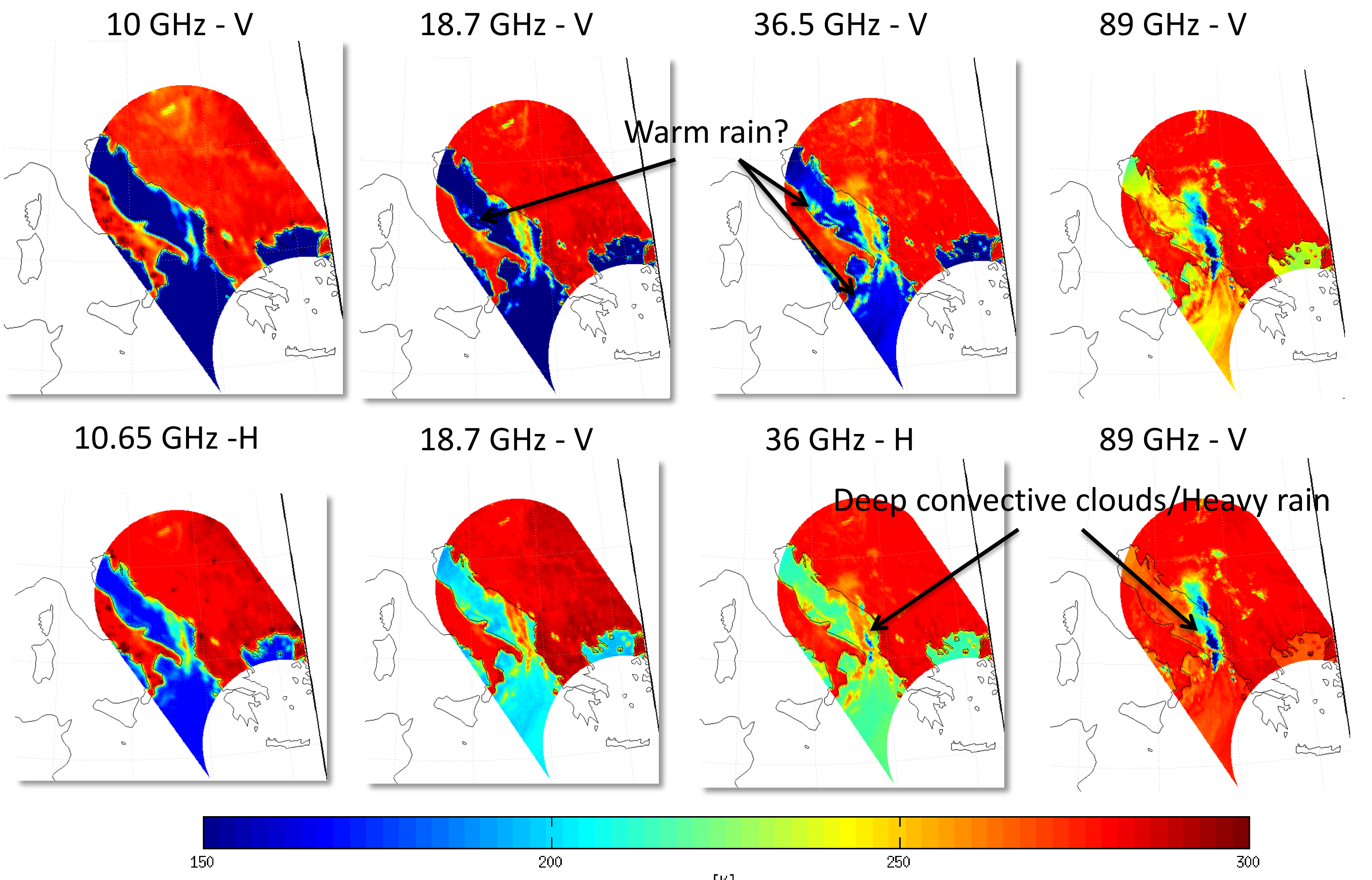
Emission: rain water in clouds emits radiation, at lower frequencies it can be seen against a radiatively cold background (i.e. oceans).

- **At Lower frequencies** liquid precipitation dominates radiative transfer by absorption and emission processes due to the relatively large imaginary part of the index of refraction of liquid water (Atmospheric ice has almost no noticeable absorption due to its very small imaginary index of refraction).
- **Strength**: Sensitive to clouds with little or no ice
- **Weakness**: must know terrestrial radiances without cloud beforehand; generally applicable over oceans but not land

Scattering: ice in clouds scatters (warm) terrestrial radiation downward, producing cold areas in imagery.

- **At Higher frequencies** scattering at both liquid and solid hydrometeors increases dramatically; at frequencies above the absorption band around 60 GHz scattering by ice particles dominate the interaction.
- **Strength**: can be applied to high-frequency channels where surface effects are not detected: works over both land and ocean
- **Weakness**: precipitation at the surface is not directly sensed; retrieval relies on relationship between upper portion (ice) and lower portion (liquid) of clouds; poor at detecting precipitation clouds with little or no ice (e.g. warm rain, orographic clouds, light rain over land)

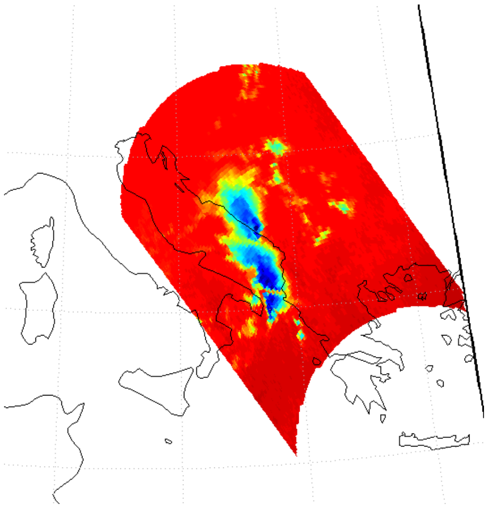
Example of multichannel PMW observations



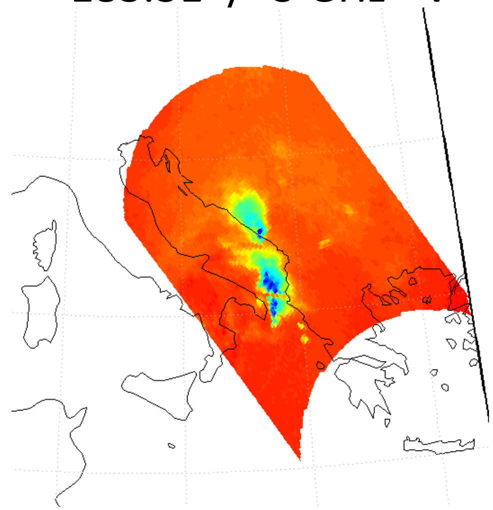
NASA/JAXA Global Precipitation Mission (GPM) Microwave Imager (GMI) – September 1, 2014 – 20:20 UTC

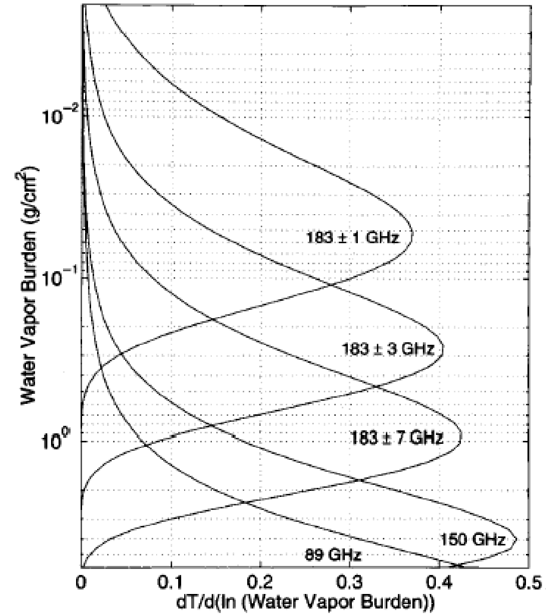
Example of multichannel PMW observations
High frequency channels

165.5 GHz - V

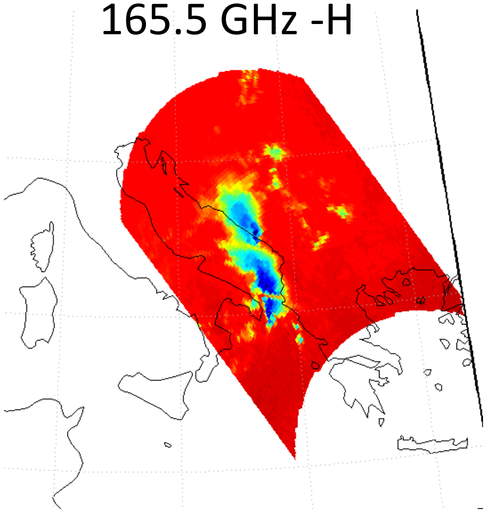


183.31+/- 3 GHz - V

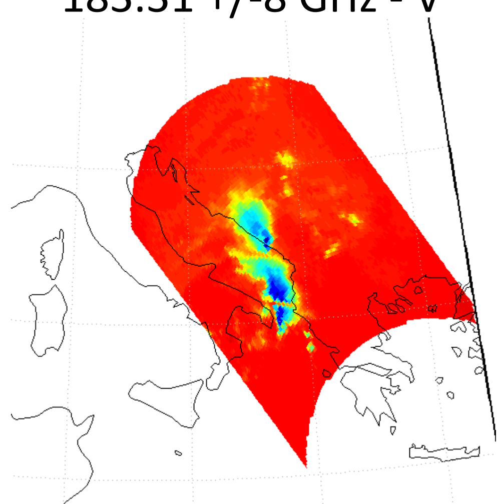




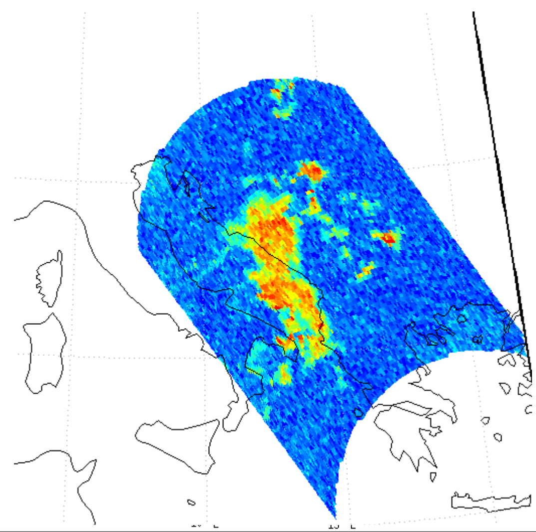
165.5 GHz -H

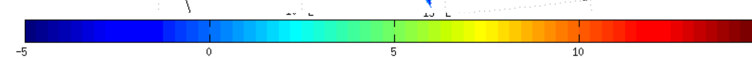


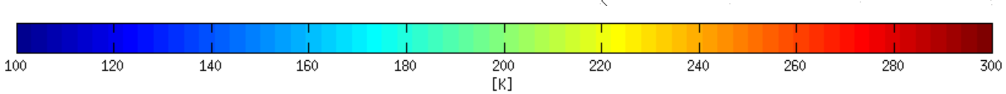
183.31 +/-8 GHz - V



165.5 GHz – V-H







NASA/JAXA Global Precipitation Mission (GPM) Microwave Imager (GMI) – September 1, 2014 – 20:20 UTC

H-SAF precipitation products
Two basic principles:

1/2 Exploitation of PMW radiometers (conically and cross-track scanning) offering the most complete set of satellite based observations to retrieve surface precipitation due to the ability of MW radiation to penetrate precipitating clouds and interact with its liquid and iced hydrometeors

Higher confidence in:

- Identification of different types of precipitation (deep convective, convective, stratiform)
- Retrieve convective precipitation due to the correlation between the upper portion of the cloud (high density ice) and rainfall;
- Stratiform and warm rain over ocean
- Stratiform rain over land in specific environmental conditions (contrast between surface and cloud)

Less confidence in:

- Oropgraphic precipitation (with warm-topped clouds);
- Light precipitation at high latitudes (low moisture and temperature conditions)
- Snowfall and/or with presence of snow/ice at the ground
- Warm rain over land (no confidence);

H-SAF precipitation products
Two basic principles:

2/2 Combination of LEO MW estimates and GEO IR observations for precipitation monitoring and hydrological applications to benefit from physical robustness of MW and space/time resolution of IR. In remote areas (high latitudes, polar regions) only LEO MW observations can be used.

Physical Robustness:

– Microwave radiances are sensitive to cloud microphysical structure and it is related to rainfall (in most cases)
– IR/VIS data reflect cloud-top conditions only and thus are more weakly related to actual rainfall rates over a wider range of conditions than MW radiances.

Space/Time Resolution

– IR/VIS data are available at 4 km/1km resolution (MSG) on geostationary platforms, allowing looks in many locations every 15 minutes
– MW instruments are presently restricted to polar-orbiting platforms, limiting views to 2 per day per satellite at most latitudes—more suitable for larger scales in time and space. Need to use constellation of satellites

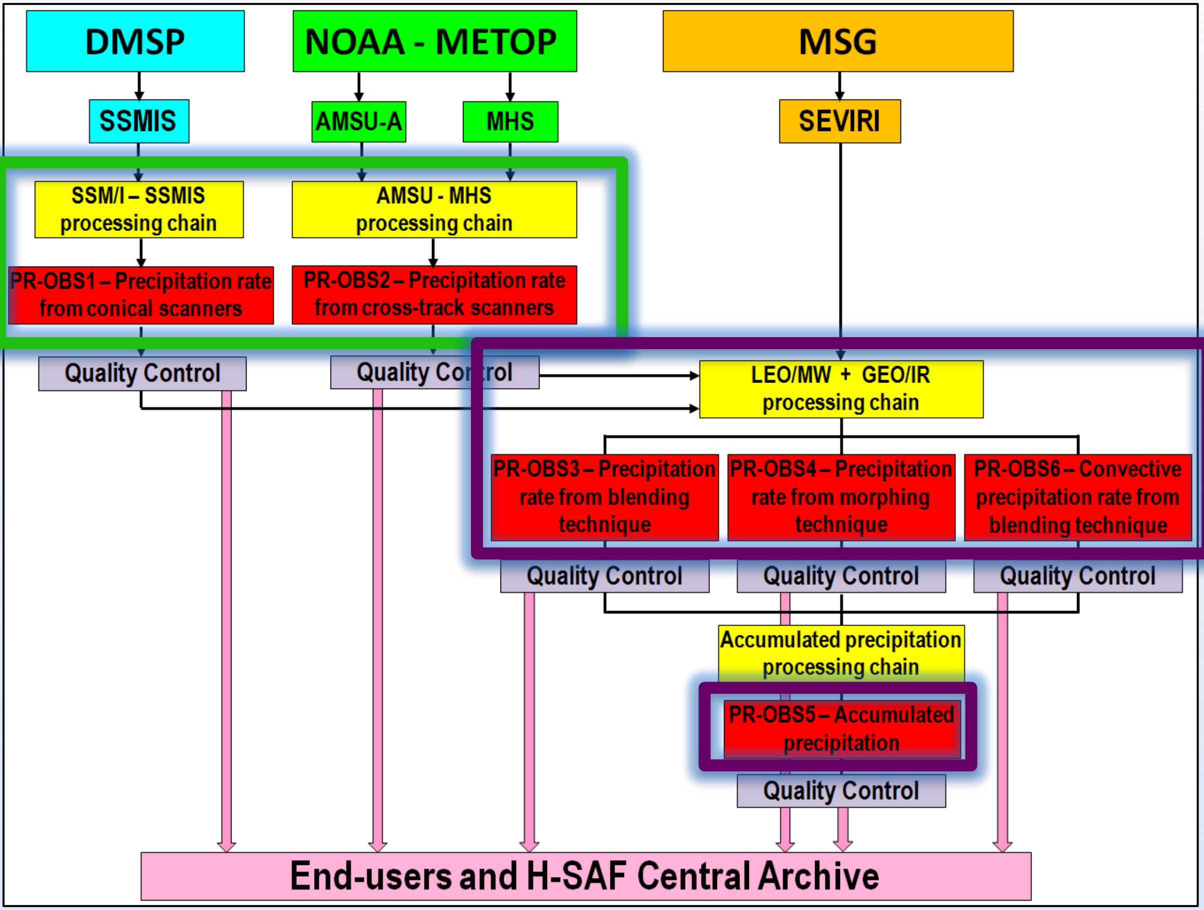
H SAF
Support to Operational Hydrology and Water Management

Current Precipitation Products

Identifier	Product Description	Algorithm	Resp. Inst.	Status
H01 PR-OBS-1	Precipitation rate at ground by MW conical scanners	Bayesian CDRD	ISAC-CNR Rome	Operational
H02 PR-OBS-2	Precipitation rate at ground by MW cross-track scanners	Neural Network	ISAC-CNR Rome	Operational
H03 PR-OBS-3	Precipitation rate at ground by GEO/IR supported by LEO/MW	Blending	ISAC-CNR Bologna	Pre-operational
H04 PR-OBS-4	Precipitation rate at ground by LEO/MW supported by GEO/IR	Morphing	ISAC-CNR Bologna	Pre-operational
H05 PR-OBS-5	Accumulated precipitation at ground by blended MW and IR	Time integration	CNMCA	Pre-operational
H15 PR-OBS-6	Blended SEVIRI Convection area / LEO MW precipitation -	Blending + NEFODINA	CNMCA	In development

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.

Why is consistency important?

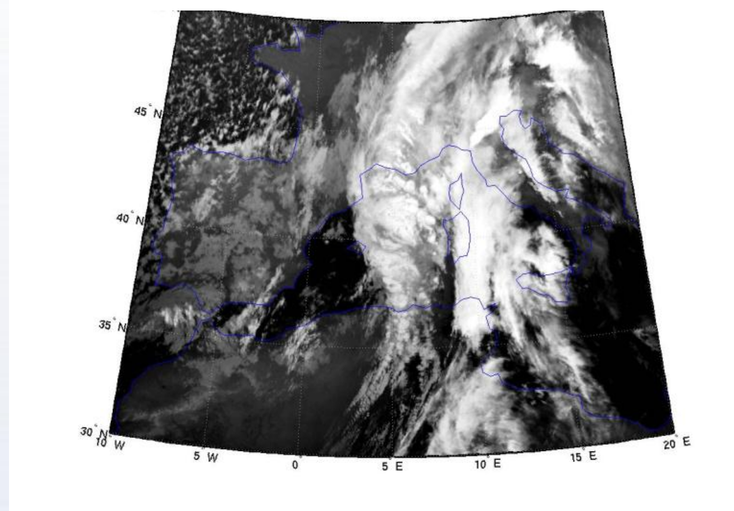
Southern Tuscany (Grosseto area) Devastating Flood on 11-12 November 2012

Very intense and persistent storm;

Max Acc. Precip exceeding:

- 177 mm/3 hr
- 270 mm /12 hr
- 400 mm / 72 hr

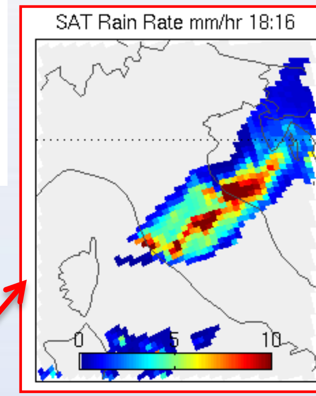
SEVIRI IR Ch09 (10.8 µm)



RR from Conical-scanning

2012 Nov 11:
- H01 F-17 05:16
- H01 F-16 05:25
- H01 F-18 07:26
- H01 F-17 16:15
- H01 F-16 17:51
- H01 F-18 18:27

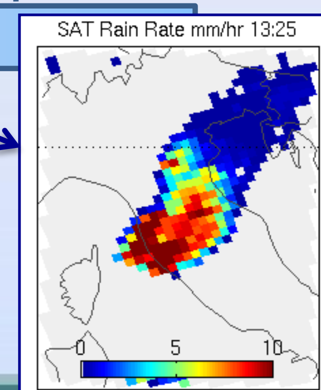
2012 Nov 12:
- H01 F-17 05:12
- H01 F-18 07:14
- H01 F-17 16:04
- H01 F-16 16:42
- H01 F-18 18:16



RR from Cross-track scanning

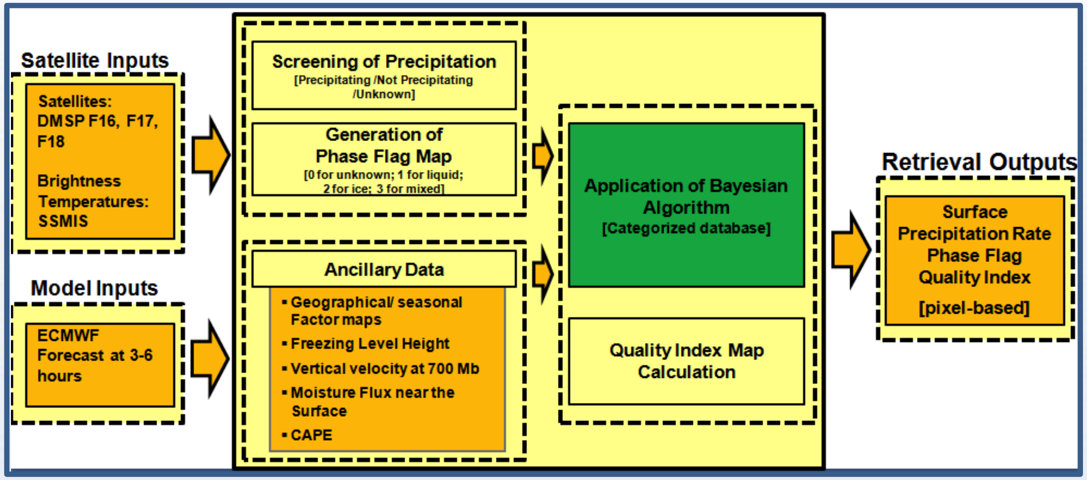
2012 Nov 11:
- H02 N19 01:26
- H02 N18 02:09
- H02 MetOp 09:34
- H02 N19 12:53
- H02 N18 13:56
- H02 MetOp 19:26

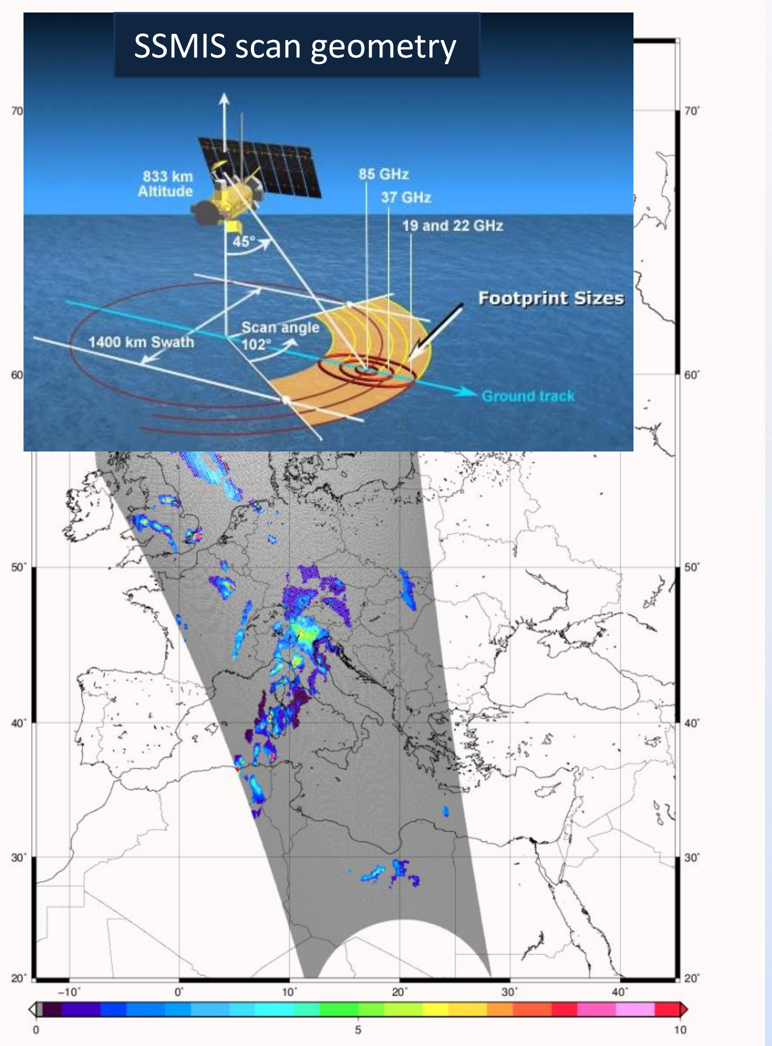
2012 Nov 12:
- H02 N19 01:15
- H02 N18 01:58
- H02 MetOp 09:23
- H02 N19 12:42
- H02 N18 13:25



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)

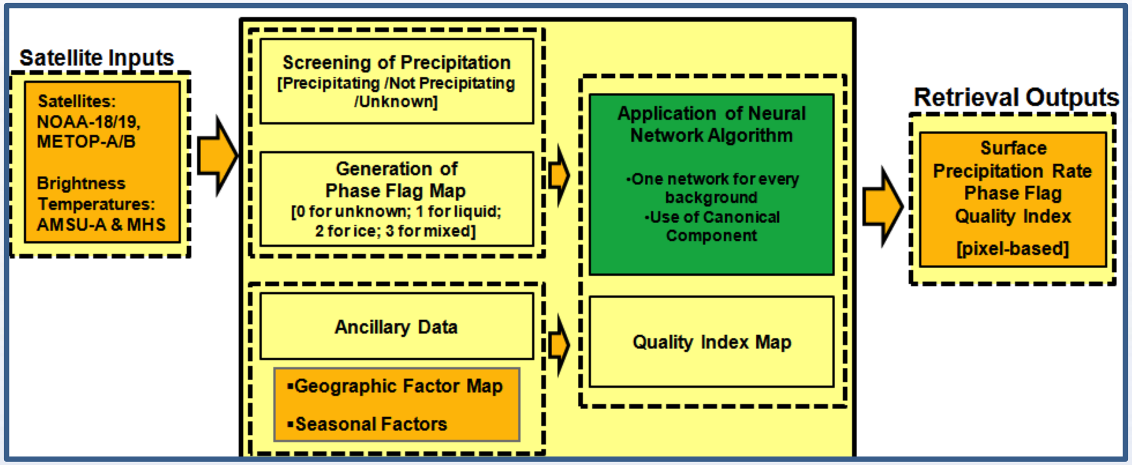




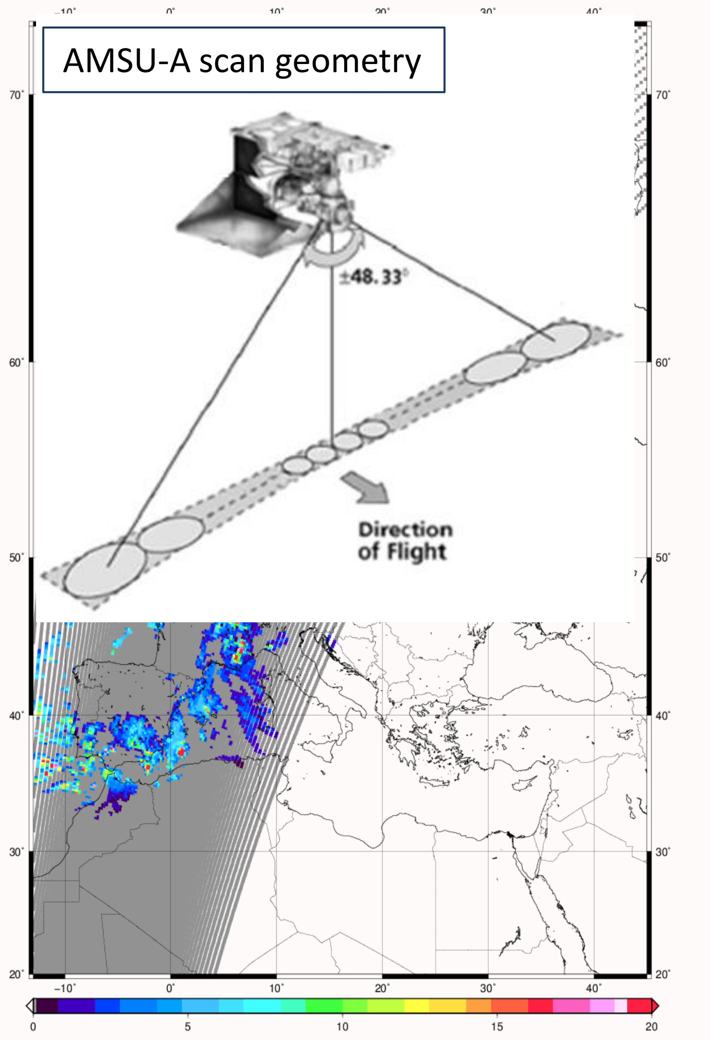
- Use of MW conical scanners (Tb) (DMSP-SSMIS);
- Physically-based Bayesian technique;
- *A synthetic a-priori* database built from cloud model generated microphysical profiles coupled to RTE model;
- Use of dynamical-thermodynamical-hydrological (DTH) model-derived variables to reduce *ambiguity* problem of retrieval solution; DTH variables from ECMWF forecast/analysis are used as additional input;
- The Full Disk Algorithm uses two Databases (H-SAF area and Africa/Southern Atlantic).
- Precipitation phase and Quality index evaluation.
- Proc. Time: < 2 min (H-SAF area), Hor. Res.: ≅15 km
- Timeliness: 2.5 h (due to delay in availability of DMSP data)

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

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



- 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
- Timeliness: 30 minutes



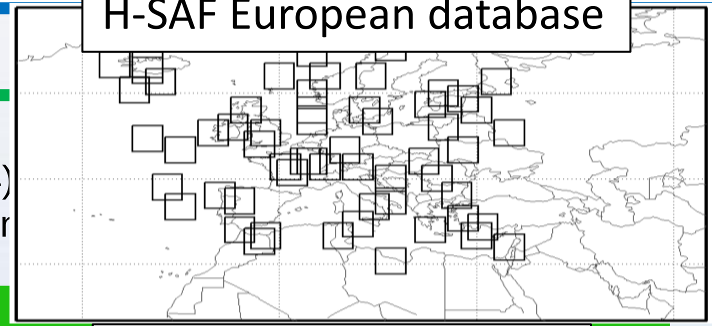
H01 and H02 common features

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

H SAF Support to Operational Hydrology and Water Management

- 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)...

H-SAF European database



- Screening procedure (based on Chen and Staelin, 2003);
- New screening procedure for arid surfaces (Casella et al. 2014)
- Phase flag determination procedure (Grody et al. (2000), Roser (2009).
- Quality index determination procedure.

Based on:

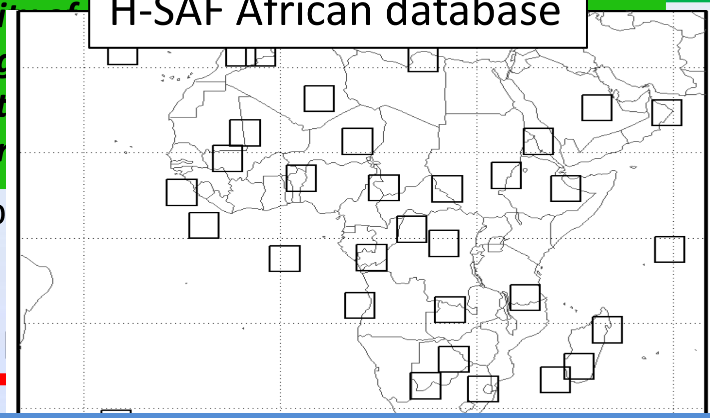
Quality of

Backg

Event

Interr

H-SAF African database



Main differences between H01 and H02:

- Retrieval technique;
- Radiometer characteristics (i.e. scan geometry, spatial resolutio
  - Product spatial resolution:
    - H01: ≅15 km (SSMIS 89 GHz channel resolution);
    - H02: from 16 x 16 km^2 / circular at nadir to 26 x 52

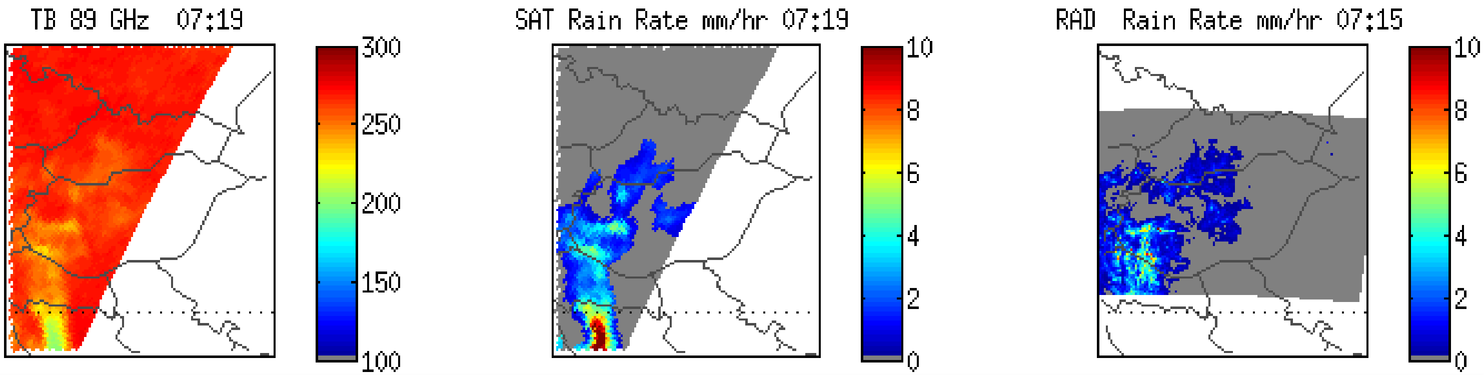
94 simulations (60 for European Db and 34 for African DB)

Development of H01 (operational)

Precipitation rate from SSMIS

(Sanò et al., 2013, Casella et al., 2013, IEEE , Mugnai et al., 2013 , NHESS)

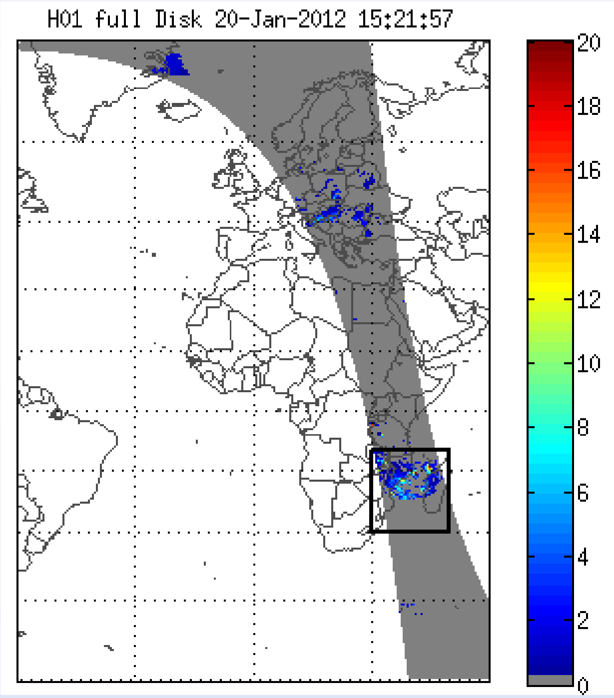
HUNGARY 1 December 2009 – light rain

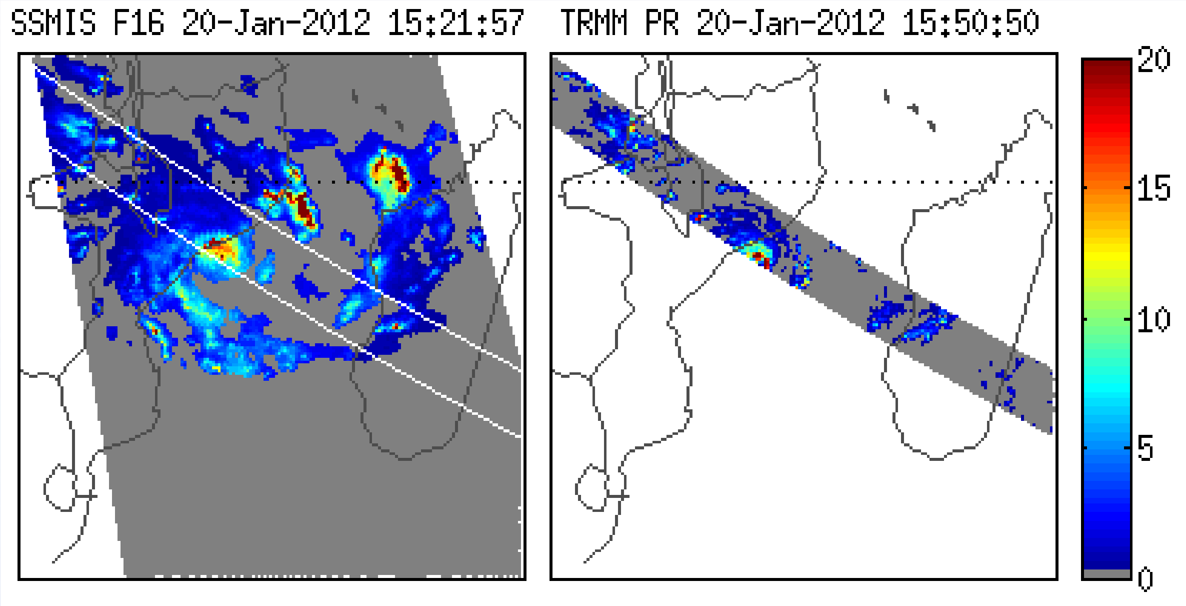


Extension to MSG Full Disk Area

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.

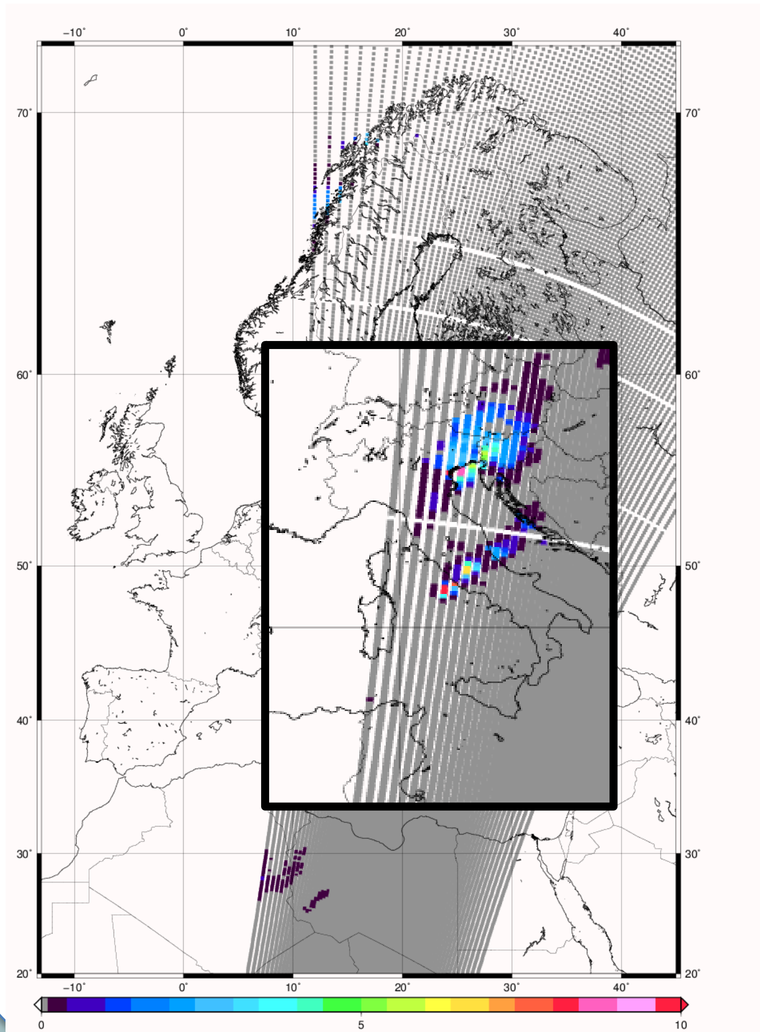
H SAF
Support to Operational Hydrology and Water Management

Development of H02 (operational)

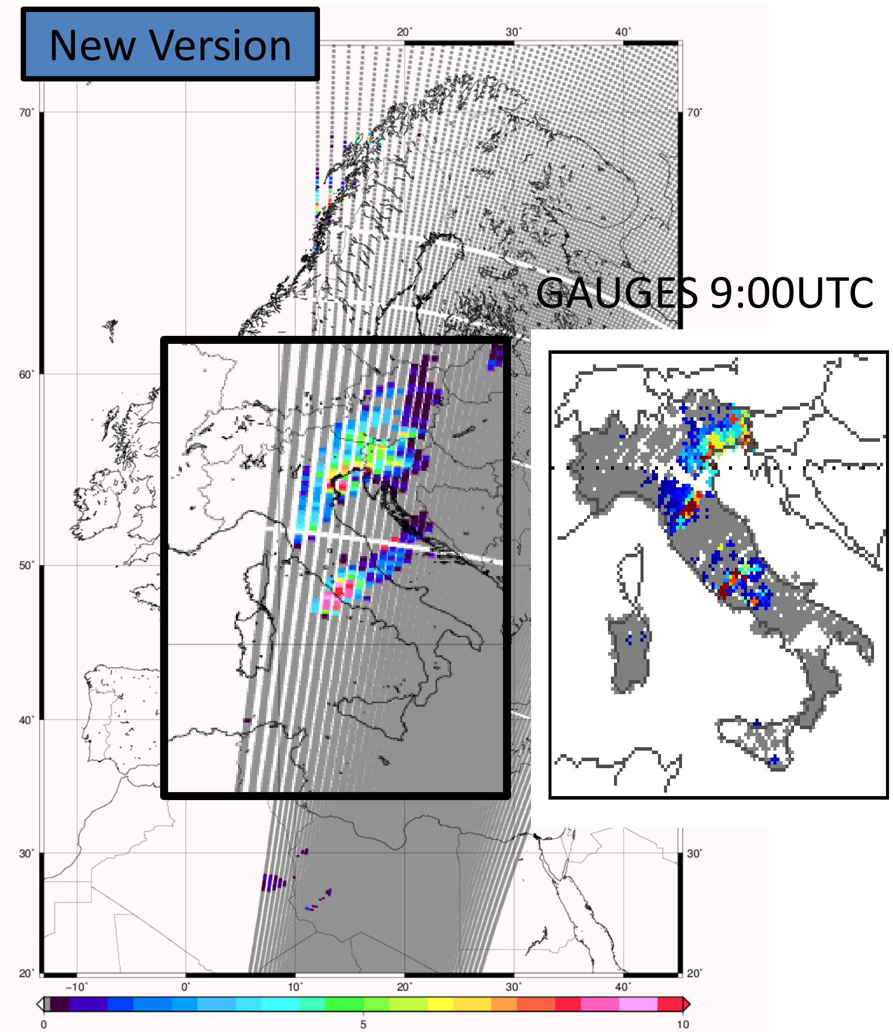
Precipitation rate from AMSU/MHS

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

ANN from Global database



New ANN from H-SAF area database



GAUGES 9:00UTC

e, Italy
n Flood
ct 2011

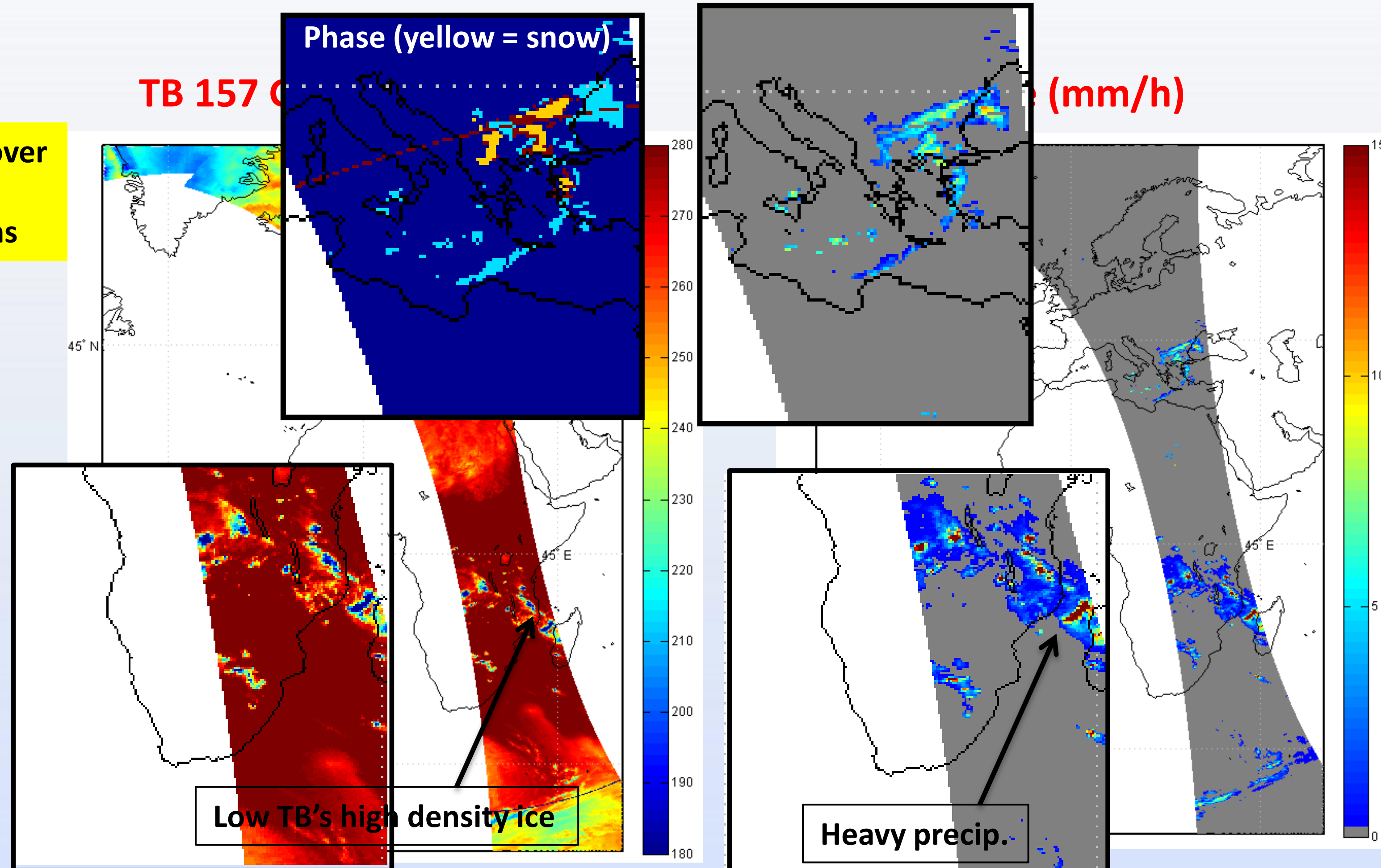
20 UTC
etOp-A
VISU/MHS

Ability of the PMW algorithms to retrieve precipitation in different meteorological/environmental conditions in the MSG Full Disk

H SAF
Support to Operational Hydrology and Water Management

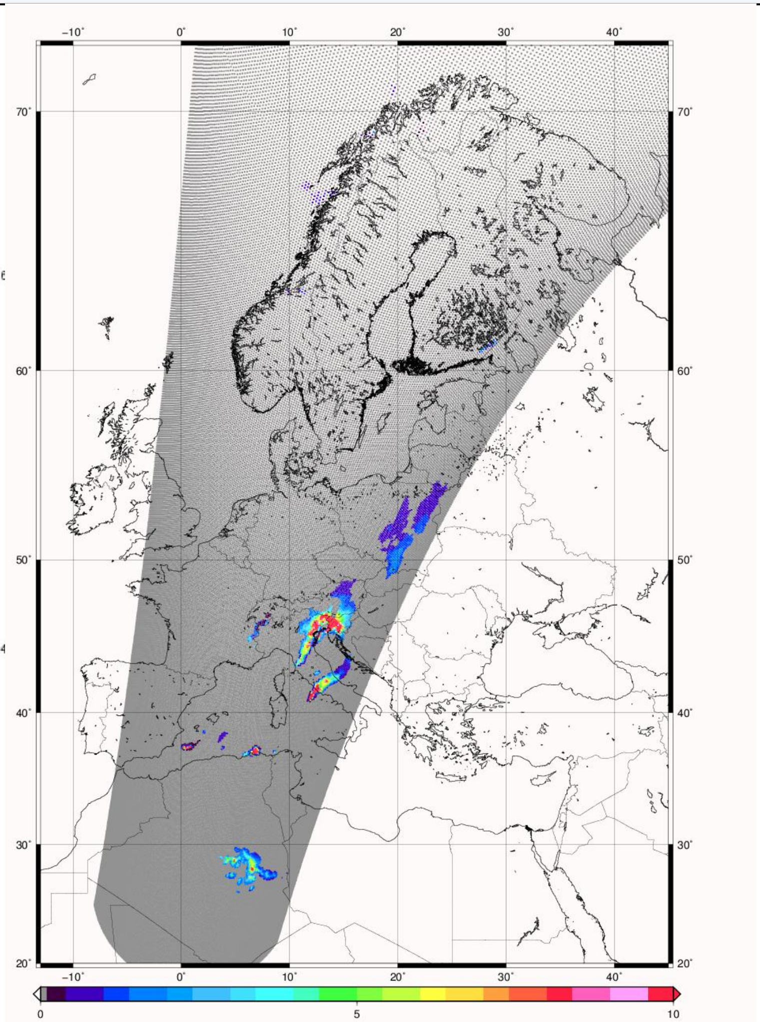
CASE STUDY: 06-Jan-2012 18:09 Satellite: METOP-A
Algorithm: H02 (PNPR)

Convective event over Mozambique and Madagascar regions

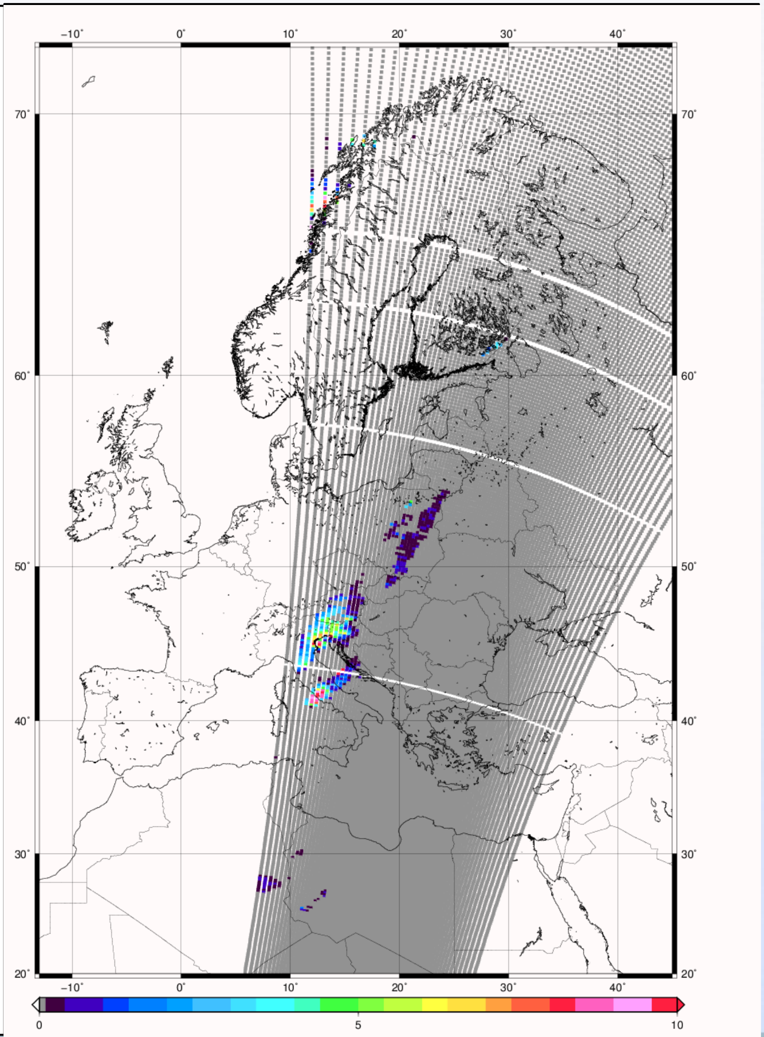


Consistency between retrievals from cross-track and conical scanning radiometers

CDRD (new H01) SSMIS 8:19 UTC



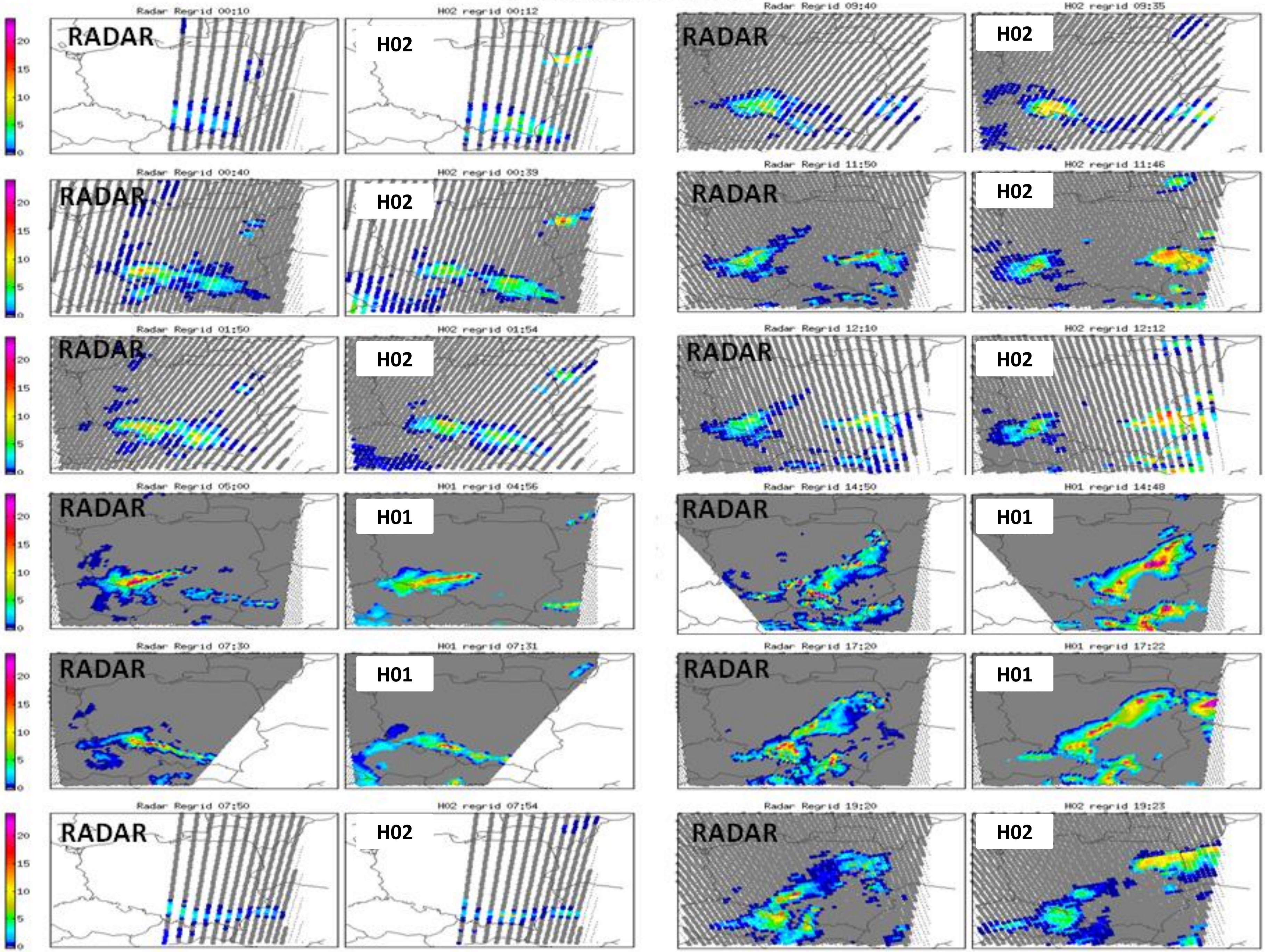
PNPR (new H02) AMSU/MHS 8:30 UTC



ROME FLOOD

20/10/2011

Poland, June 3, 2009



H SAF
Support to Operational Hydrology and Water Management

Current Precipitation Products

Identifier	Product Description	Algorithm	Resp. Inst.	Status
H01 PR-OBS-1	Precipitation rate at ground by MW conical scanners	Bayesian CDRD	ISAC-CNR Rome	Operational
H02 PR-OBS-2	Precipitation rate at ground by MW cross-track scanners	Neural Network	ISAC-CNR Rome	Operational
H03 PR-OBS-3	Precipitation rate at ground by GEO/IR supported by LEO/MW	Blending	ISAC-CNR Bologna	Pre-operational
H04 PR-OBS-4	Precipitation rate at ground by LEO/MW supported by GEO/IR	Morphing	ISAC-CNR Bologna	Pre-operational
H05 PR-OBS-5	Accumulated precipitation at ground by blended MW and IR	Time integration	CNMCA	Pre-operational
H15 PR-OBS-6	Blended SEVIRI Convection area / LEO MW precipitation -	Blending + NEFODINA	CNMCA	In development

H SAF
Support to Operational Hydrology and Water Management

H03
(IR-MW Blending Technique)

(Turk et al. 2000, Torricella et al. 2007)

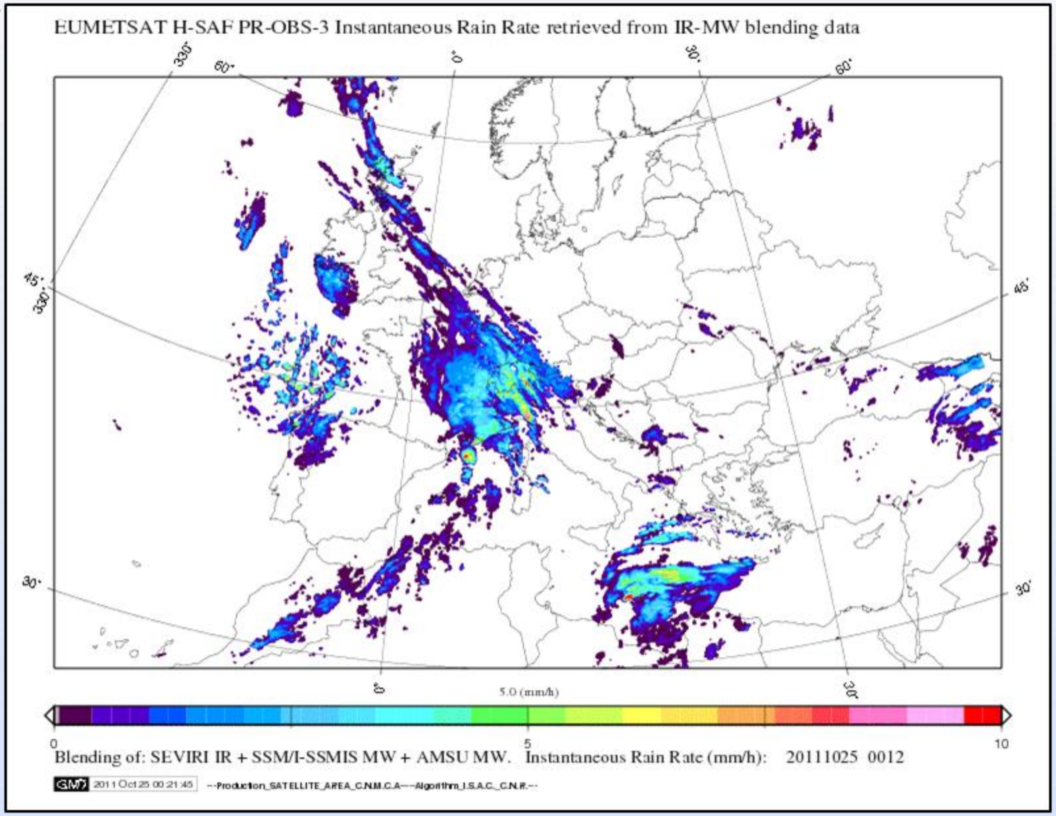
Precipitation rate at ground by LEO/MW supported by GEO/IR

Input: geolocated IR **10.8µm from MSG-SEVIRI** and PMW precipitation rates

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.

Pre-Operational
Timeliness: 15 min
Time resolution: 15 min
Hor. Resolution: SEVIRI
Sampling: 5 km

CINQUE TERRE FLOOD 25/10/2011

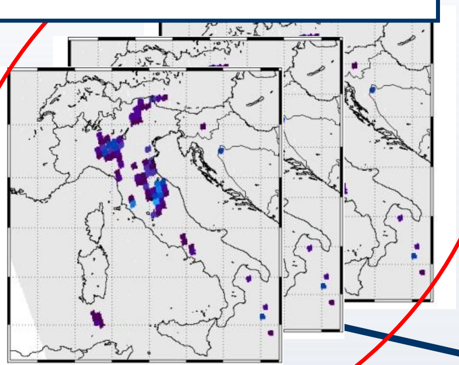


NRL Blending Algorithm & MW (SSM/I – SSMIS + AMSU/MHS) + IR (SEVIRI)

H SAF
Support to Operational Hydrology and Water

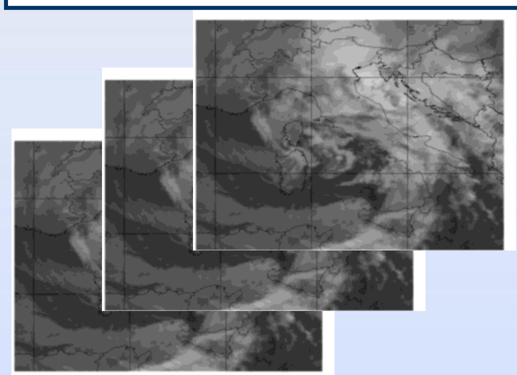
How the H03 algorithm works

Rain intensity maps from PMW data



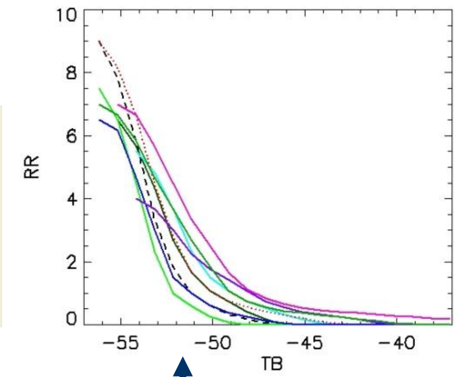
AT TIME t…

MSG- SEVIRI IR brightness temperatures at 10.8 µm



Extract space and time coincident locations from IR and MW data for each grid box 2.5°x2.5°

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

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).

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

H SAF
Support to Operational Hydrology and Water Management

H03 Quality Flag

Operational since July 2013

Two aspects were taken into account for the generation of the quality flag:

1. ***Quality of the precipitation products H01 and H02***
   H03 is based on the availability of PMW precipitation estimates used for the calibration of IR. **Thus the quality of the product is linked to the quality of the PMW rainfall estimation input to the algorithm**. The H01 and H02 quality flags are ingested in terms of percentage values by H03 algorithm and propagated through the codes up to the assignment of a quality flag to each IR-BT vs PMW rain rate relationship. ➔ **QF_mw**

2. ***Monitoring the H01 and H02 flux timeliness***
   It is fundamental to monitor the flux of the PMW precipitation products used as inputs, by considering the **time difference between the last PMW sensor overpass and the currently processing MSG slot (diff_time)**. This time tells the user how old the calibrations IR-BT vs PMW rain rates are and thus how adequate they are to be used for the rain rate assignment. An index was modeled to represent the downgrade of the product quality:

$$\mathrm{QF\_time} = \exp(-\,\mathrm{diff\_time}/\mathrm{time\_limit}) \quad \text{with } \mathrm{time\_limit} = 5\ \mathrm{h}$$

$$\mathrm{QF\_total} = \begin{cases} 0.5 * (\mathrm{QF\_time} + \mathrm{QF\_mw}) & \text{if } \mathrm{diff\_time} \le 5\mathrm{h} \\ 2/3 * \mathrm{QF\_time} + 1/3 * \mathrm{QF\_mw} & \text{if } \mathrm{diff\_time} > 5\mathrm{h} \text{ and } \mathrm{diff\_time} \le 10\mathrm{h} \\ \mathrm{QF\_time} & \text{if } \mathrm{diff\_time} > 10\mathrm{h} \end{cases}$$

H04
(IR-MW Morphing Technique)

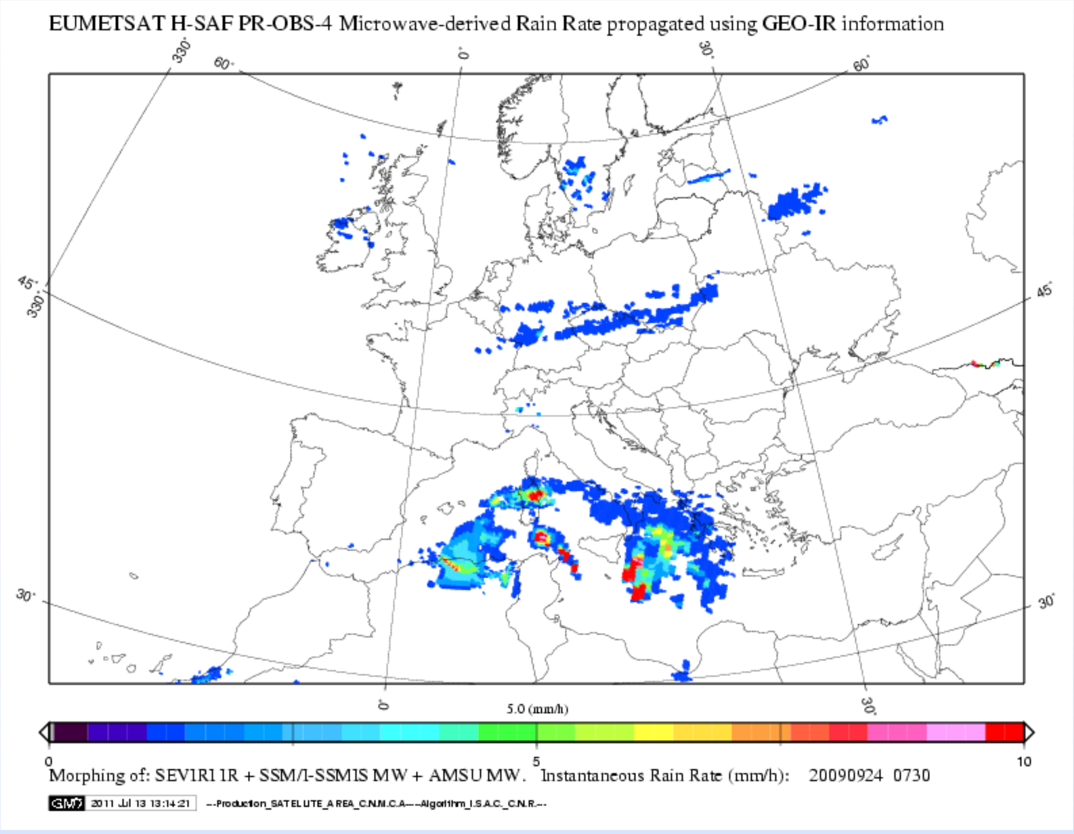
(Joyce et al., 2004)

Precipitation rate at ground by LEO/MW supported by GEO/IR

Input: geolocated IR **10.8µm from MSG-SEVIRI** and PMW precipitation rates

Time resolution: 30 min
Hor. Resolution: 8 km
Sampling: 8 km
OFF LINE product

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. **To be used for climatological purposes, not for near real-time monitoring.**



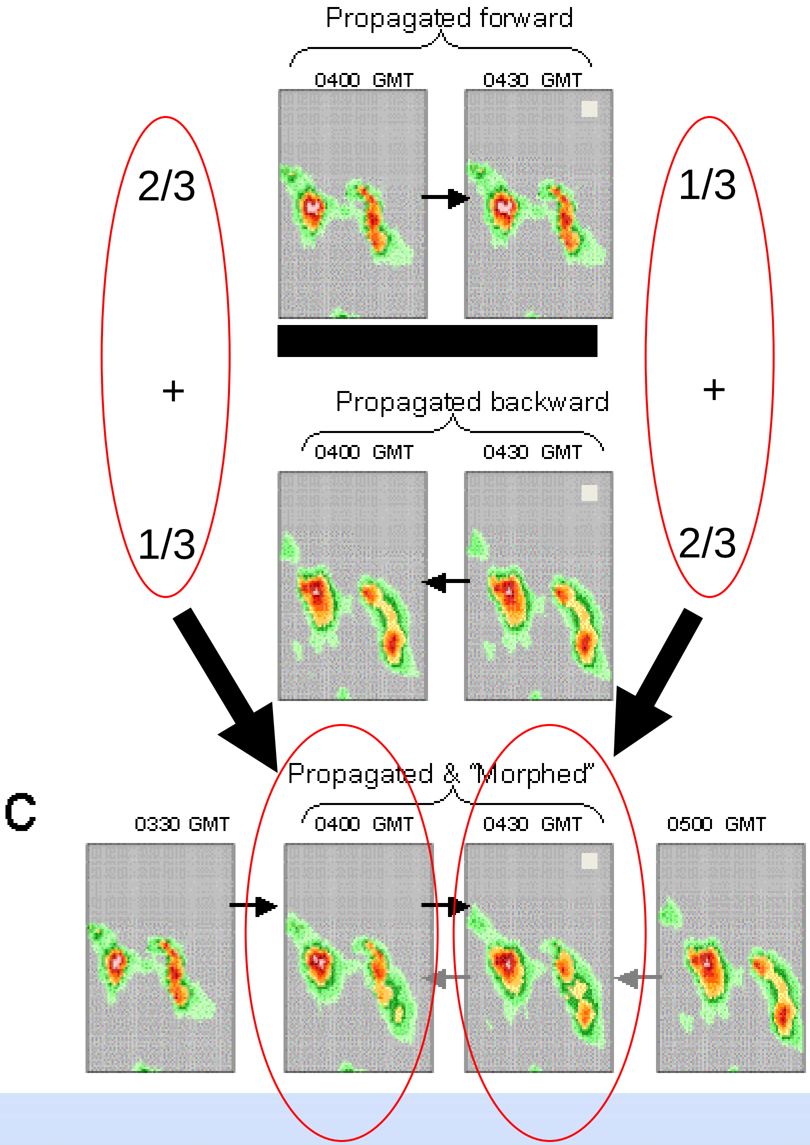
CMORPH Algorithm MW (SSM/I – SSMIS + AMSU – MHS) + IR (SEVIRI)

PR-OBS4 / H04

LEO + GEO Satellite Merging

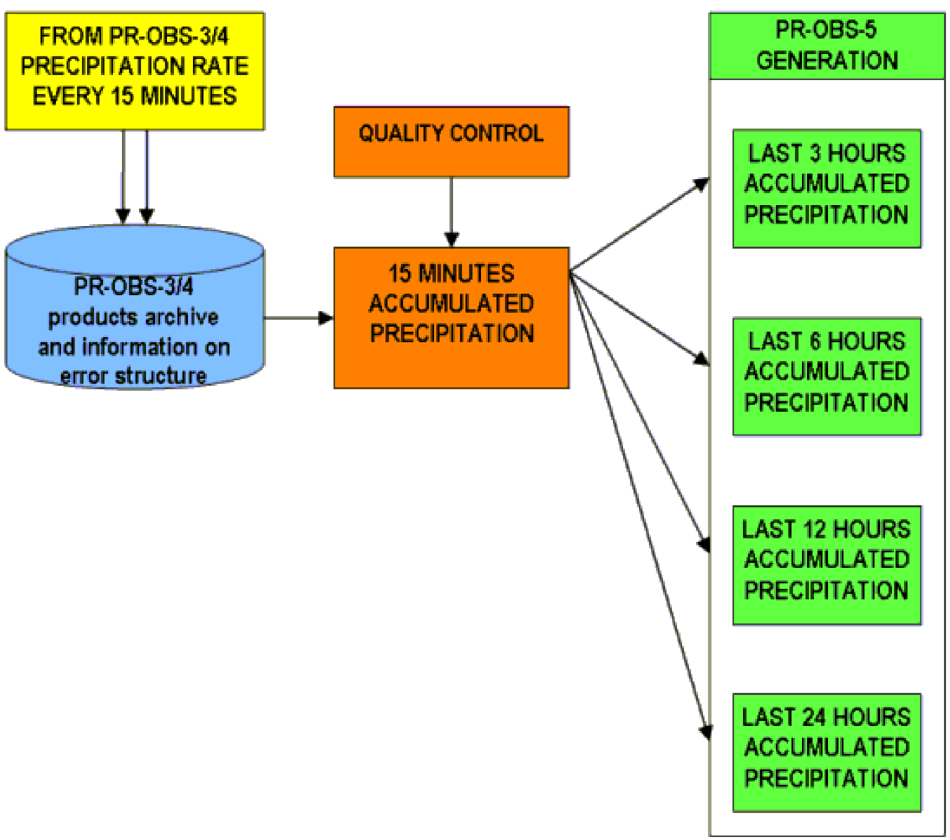
TRANSPORT METHOD

CMORPH



PR-OBS5 / H05

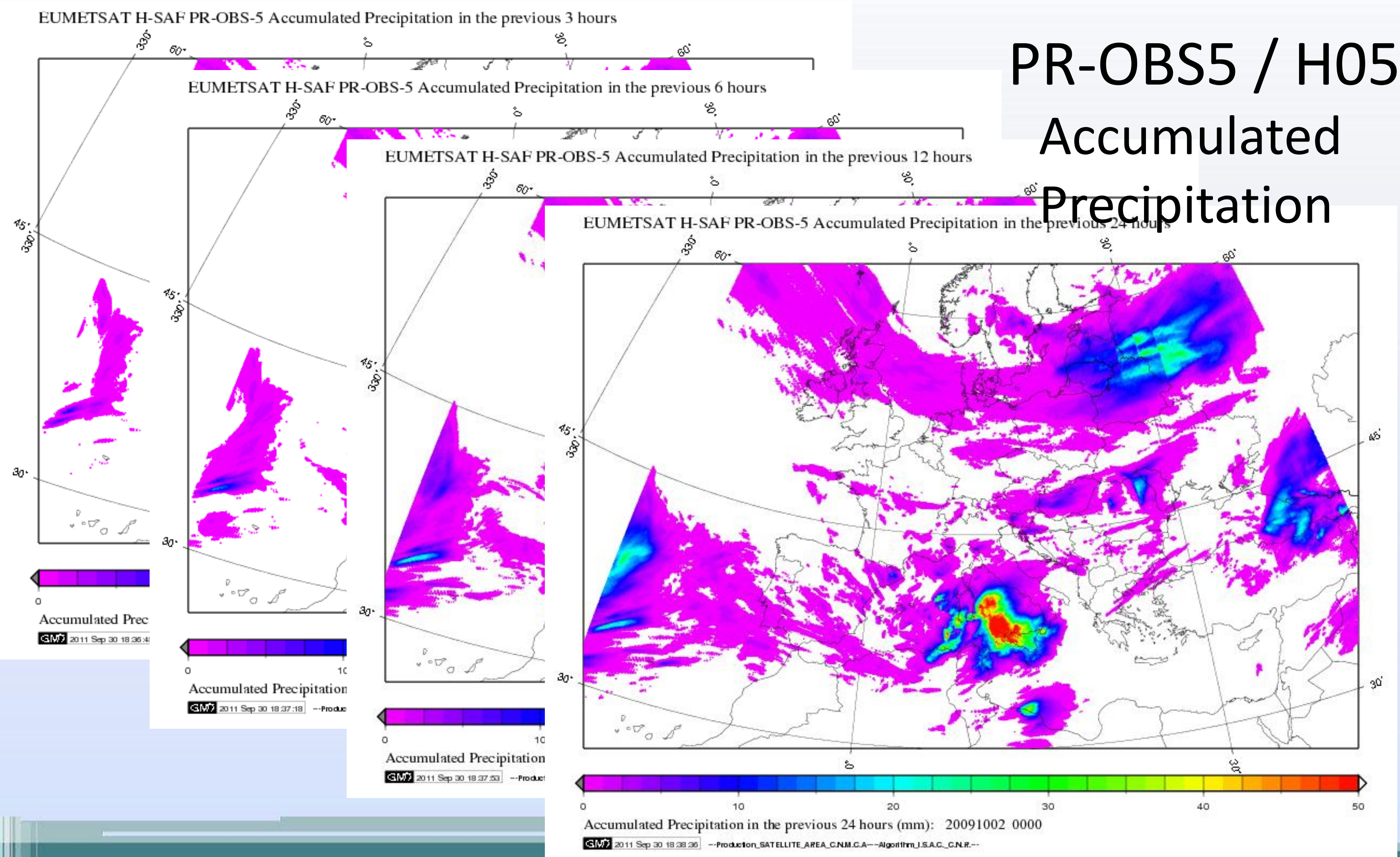
Accumulated Precipitation



- 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)**.

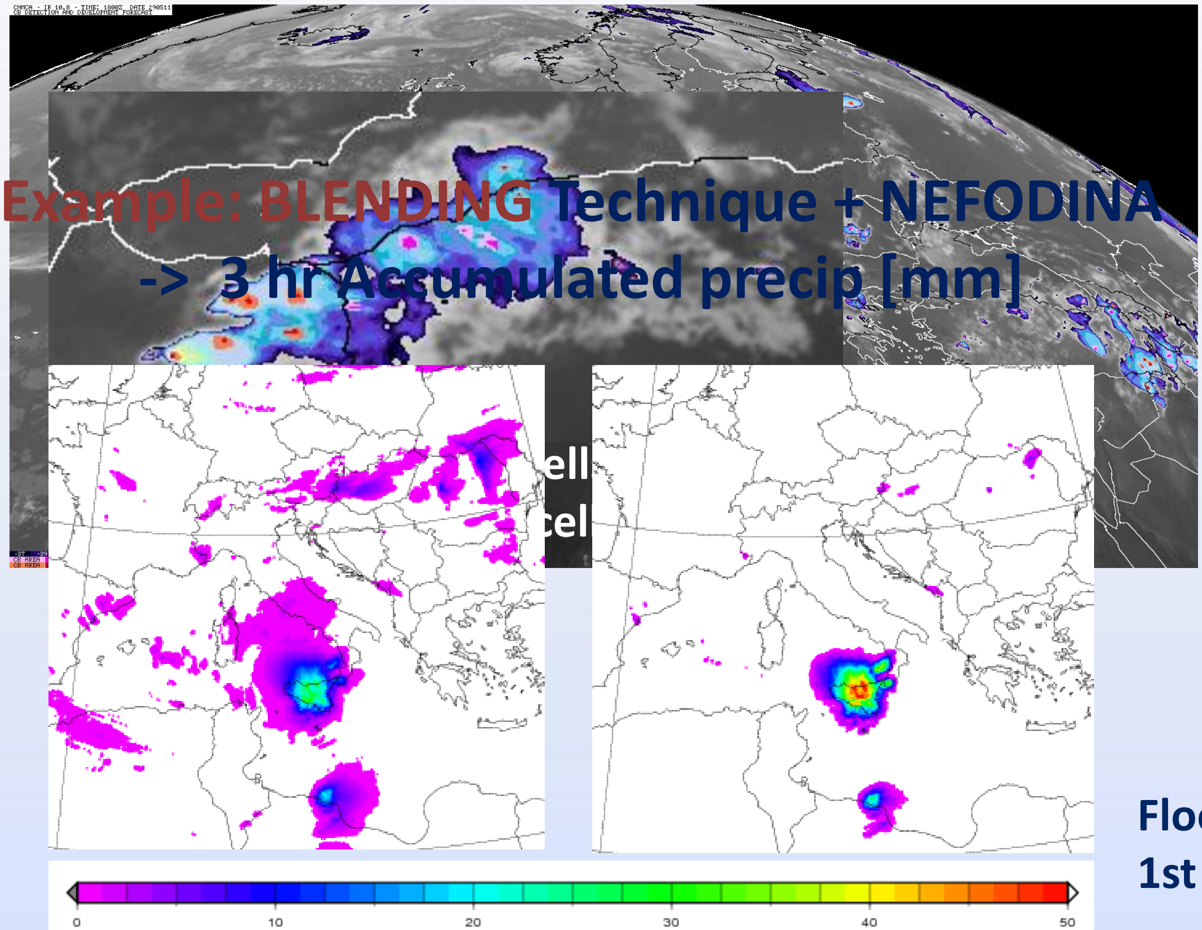
H05: examples

PR-OBS5 / H05 Accumulated Precipitation



PR-OBS-6/H15 – Current status

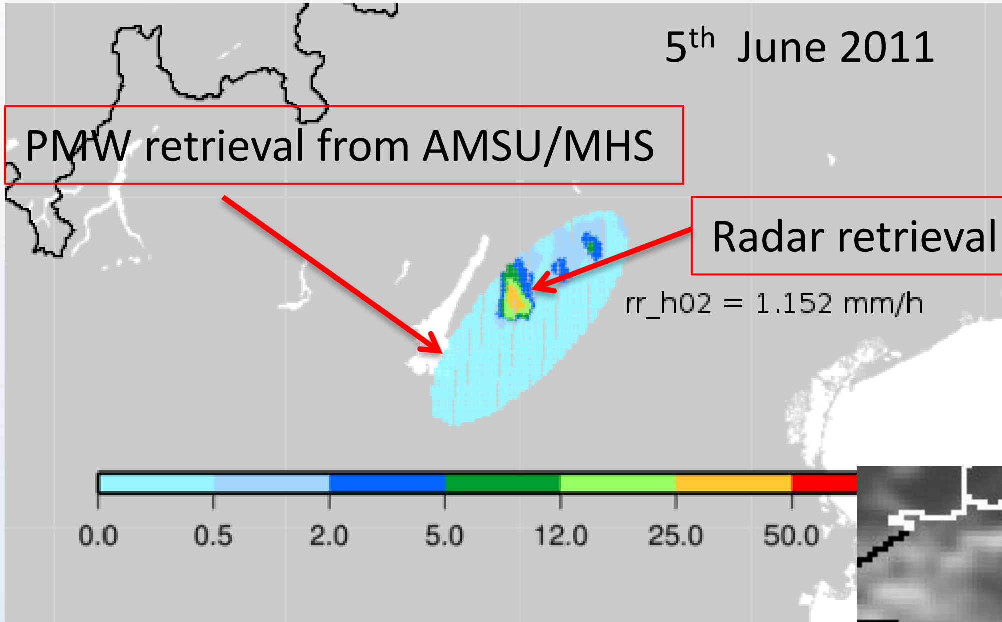
Blended SEVIRI Convection area / LEO MW precipitation



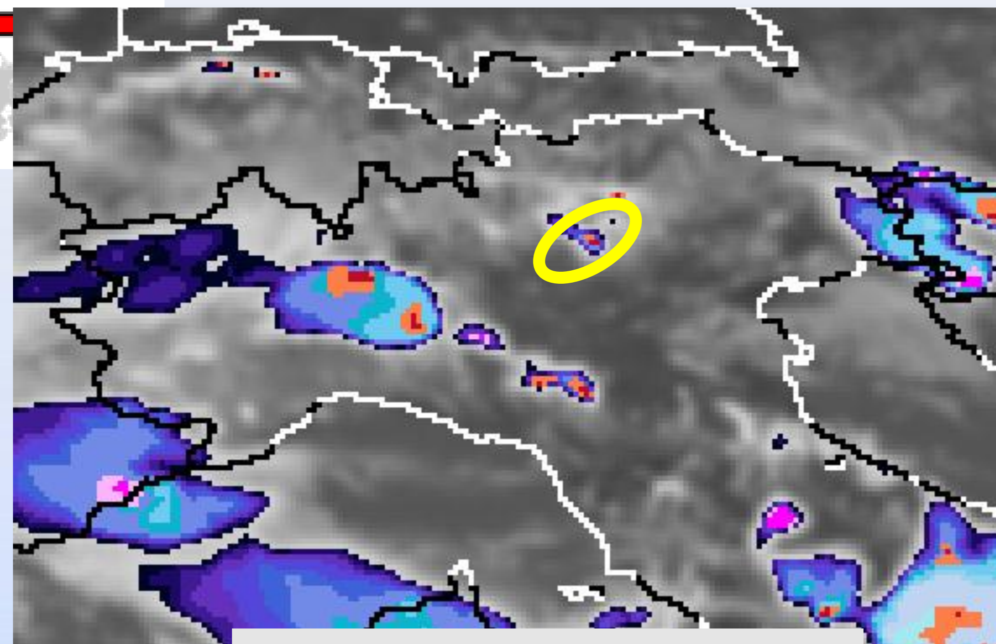
Compensate for the intrinsic PMW underestimation of precipitation for *small* convective areas by taking into account convection development phase and detection from Nefodina software (based on IR and WV bands of SEVIRI-MSG).

Flood in Sicily:
1st October 2009

H15 basic methodology



Rain redistribution based on convective cell's area



NEFODINA: 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.

http://nefodina.meteoam.it

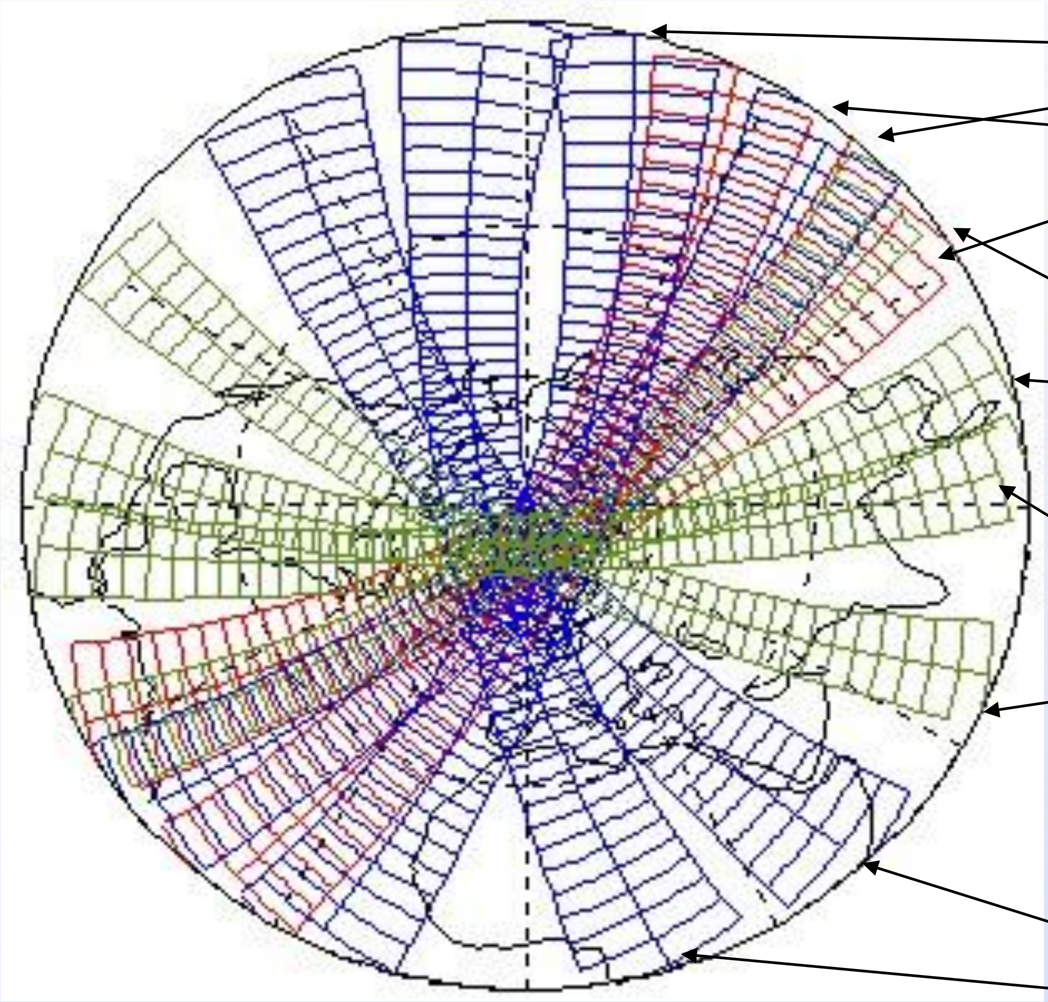
Future perspective: Higher temporal sampling and exploitation of GPM

- 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 configuration (< 3 hour time interval almost globally) with best available instruments (GMI+DPR) which needs to be exploited;
- Continue to work towards achieving *accuracy* and *consistency* of precipitation retrieval from *all* the available cross-track and conically scanning radiometers

- **Outcomes:**
- Optimal precipitation monitoring;
- Improvement in products based on morphing/blending techniques of MW/IR observations for monitoring precipitation at higher spatial/temporal resolution (strongly dependent on quality, consistency, and number/frequency of PMW observations);
- Impact on hydrological applications (relying on MW/IR combined products, and/or on MW products).

H SAF
Support to Operational Hydrology and Water Management

3-hr Coverage by MW/LEO satellites currently used operationally in Hsaf



NOAA-18 (ECT 15:23 asc)
(AMSU-A , MHS)

MetOp-A (ECT 9:30 desc)
(AMSU-A , MHS)
MetOp-B (LST 9:30 desc)
(AMSU-A , MHS)

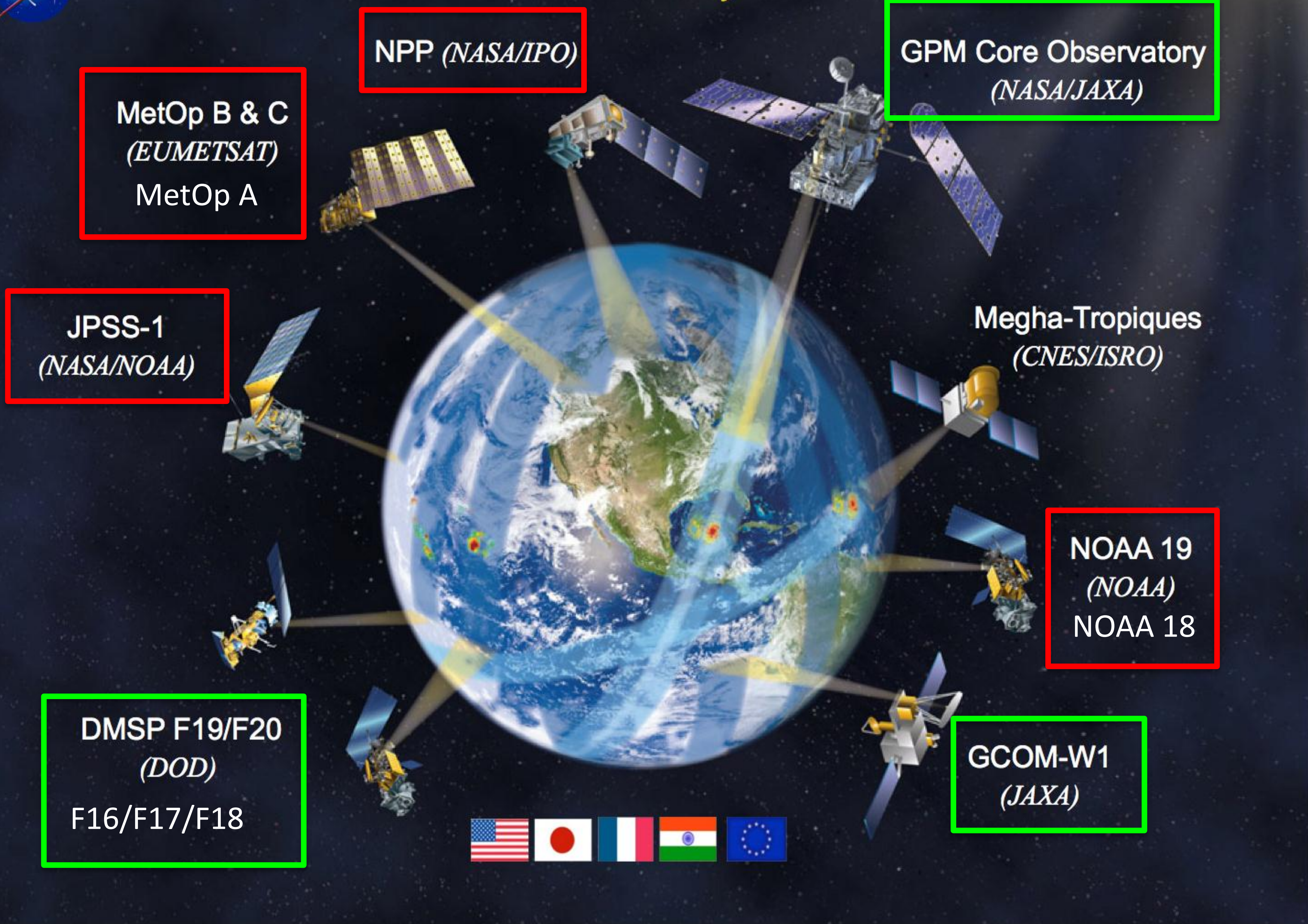
DMSP-17 (ECT 5:49 desc)
(SSMIS)

DMSP-18 (ECT 8:06 desc)

DMSP-16 (ECT 5:22 desc)
(SSMIS)

NOAA-19 (ECT 13:39 asc)
(AMSU-A , MHS)

GPM Constellation of Satellites



Passive Microwave Sensor Characteristics

H SAF
Support to Operational Hydrology and Water Management

V – Vertical Polarization H – Horizontal Polarization

Constellation microwave sensor channel coverage

Channel	6 GHz	10 GHz	19 GHz	23 GHz	31/36 GHz	50-60 GHz	89/91 GHz	150/166 GHz	183/190 GHz
SSMIS			19.35 V/H	22.235 V	37.0 V/H	50.3-63.28 V/H	91.65 V/H	150 H	183.31H
MHS							**89**	**157**	**183.311 190.311**
AMSU-A				**23.8**	**31.4**	**50.2-58**	**89**		
AMSR-2	6.925 V/H	10.65 V/H	18.7 V/H	23.8 V/H	36.5 V/H		89.0 V/H		
GMI		10.65 V/H	18.70 V/H	23.80 V	36.50 V/H		89.0 V/H	165.5 V/H	183.31 V
ATMS				**23.8**	**31.4**	**50.3-57.29**	**87-91**	**164-167**	**183.31**

Mean Spatial Resolution (km)

Channel	6 GHz	10 GHz	19 GHz	23 GHz	31/36 GHz	50-60 GHz	89/91 GHz	150/166 GHz	183 GHz
SSMIS			**59**	**59**	**36**	**22**	**14**	**14**	**14**
MHS							**17**	**17**	**17**
AMSU-A				**48**	**48**		**48**		
AMSR-2	**56**	**38**	**21**	**24**	**12**		**5**		
GMI		**26**	**15**	**12**	**11**		**6**	**6**	**6**
ATMS				**74**	**74**	**32**	**16**	**16**	**16**

NASA-JAXA GPM Core Observatory

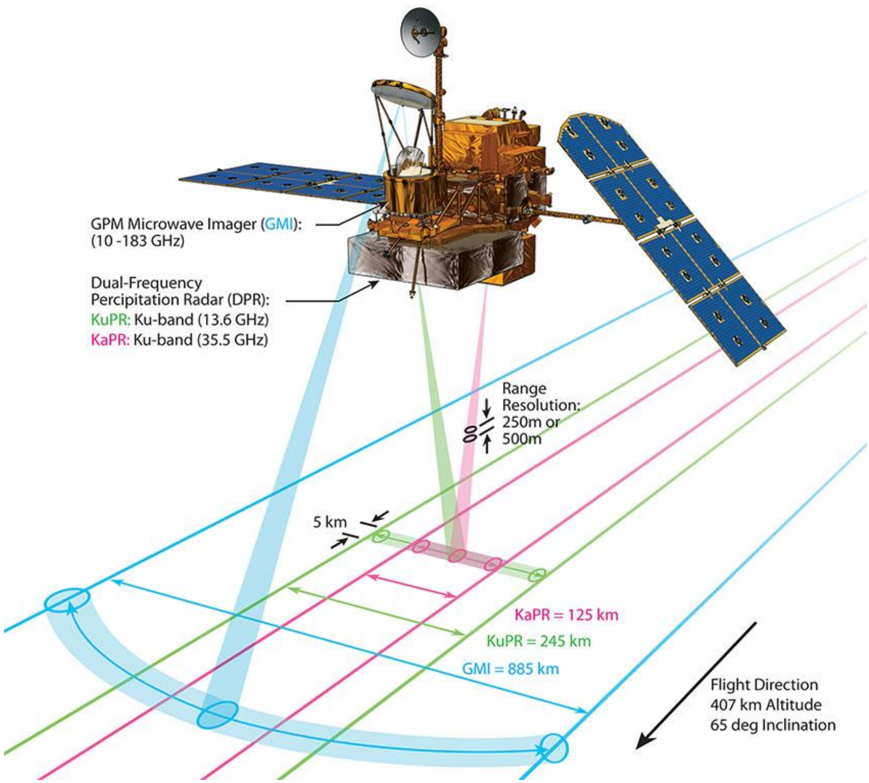
GPM Core Observatory Measurement Capabilities

Dual-Frequency (Ku-Ka band) Precipitation Radar (DPR):

- *Increased sensitivity (~12 dBZ) for light rain and snow detection relative to TRMM*
- *Better measurement accuracy with differential attenuation correction*
- *Detailed microphysical information (DSD mean mass diameter & particle no. density) & identification of liquid, ice, and mixed-phase regions*

Multi-Channel (10-183 GHz) GPM Microwave Imager (GMI):

- *Higher spatial resolution (IFOV: 6-26 km)*
- *Improved light rain & snow detection*
- *Improved signals of solid precipitation over land (especially over snow-covered surfaces)*
- *4-point calibration to serve as a radiometric reference for constellation radiometers*

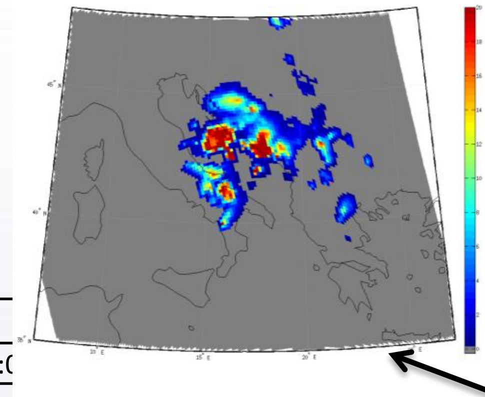


Combined Radar-Radiometer Retrieval

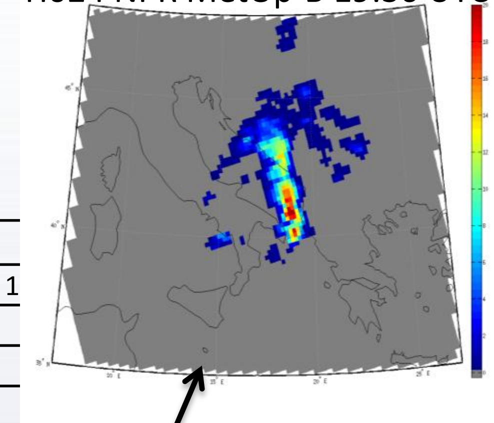
- *DPR & GMI together provide greater constraints on possible solutions to improve retrieval accuracy*
- *Observation-based a-priori cloud database for constellation radiometer retrievals*

Flood in Gargano – Italy
1 September 2014

H01 CDRD F16 15:02 UTC



H02 PNPR MetOp-B 19:36 UTC



		00:00-04:00	04:0		00	1	
SSMIS	F16	X			X		
	F17		X		X		
	F18						
MHS	MetOp-A			X			X
	MetOp-B			X		X	
	NOAA18	X			X		
	NOAA19	X			X		

		X	X X		X X		X			X	X	X	X X	X X		X	X X		X		X X	X			

GPM Observations from Non-Sun-Synchronous Orbits filling gaps between those of polar orbiters at fixed time of the day

Different center frequencies, viewing geometry, effect of beam filling, and spatial resolution must be reconciled

H SAF
Support to Operational Hydrology and Water Management

No-cost proposal

"H-SAF and GPM: precipitation algorithm development and validation activity"

Approved by the NASA PMM Research Program

- The goal is to contribute toward the establishment of a long term collaboration between EUMETSAT H-SAF and GPM on the following aspects:
  - ***precipitation retrieval algorithm development***, through a fruitful interaction on several critical aspects of interest both to H-SAF and GPM (**ISAC-CNR, CNMCA**); ***Scientific coordinator: Giulia Panegrossi (ISAC-CNR)***
  - ***validation activity***, through the connection between the well established H-SAF product validation (**DPC, IMGW, and PPVG)** and hydrological validation ((**IMGW**) programs and the Ground Validation/Calibration activity of GPM**;** ***Scientific Coordinator: Silvia Puca (DPC)***
- **Active participation of H-SAF to GPM EM phase and beyond:**
  - Daily download of "Europe" subset of GPM products
  - Analysis of case studies and validation over Europe of GPM products
  - Algorithm development for all GPM constellation of radiometers;

H-SAF PMW Precipitation retrieval algorithm development

It will benefit from interaction on several aspects of interest to H-SAF *and* GPM

- **Verification of consistency** of precipitation detection and retrieval from different sensors of the GPM constellation.
- **Background surface characterization** (surface emissivity and SST or Skin Temperature), snow/ice, vegetation, soil moisture, etc.) both in the database and at time of observation
- **Ambiguity** in the interpretation of MW multichannel TB: use of ancillary data to guide retrieval towards the solution: going towards use of satellite data?
- **Detetection/retrieval of precipitation (solid and liquid) at high latitutdes**

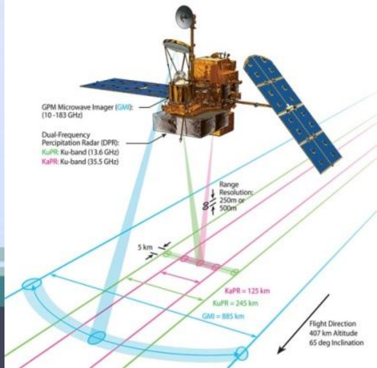
  Correct parameterization of scattering properties of iced hydrometeors (shape, DSD, density); critical for snowfall and light stratiform rain retrieval relying on high frequency channels (sensitive to low density ice crystals)
- **Account for orography**

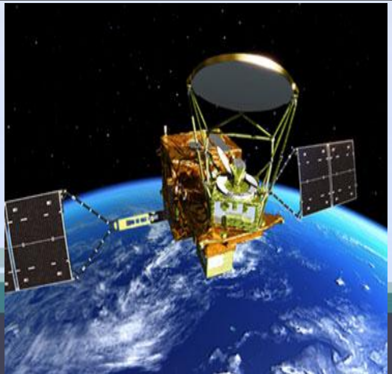
H SAF
Support to Operational Hydrology and Water Management

In development Products

PMW Precipitation Products

H17	Precipitation rate at ground by MW conical scanners (GCOM-W1 AMSR2)	Algorithms assessment expected in 2015 Expected Operations in 2016
H18	Precipitation rate at ground by MW cross-track scanners (Suomi NPP ATMS)	
H19	Rainfall intensity from GMI (GPM- Microwave Imager)	
H20	Rainfall intensity from GMI (GPM - Microwave Imager) [Neural Network] algorithm] (Global)	
H21	High frequency MW delineation of cloud areas with new development of hydrometeors (MHS)	
H22	Snowfall intensity (MHS)	





H SAF
Support to Operational Hydrology and Water Management

In development MW/IR Products

Extension to MSG Full Disk

H03B PR-OBS-3B	Precipitation rate at ground by GEO/IR supported by LEO/MW	Algorithms to be assessed by end 2014 Expected Operations in 2016
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	

MTG-based Products

H40 PR-OBS-3 -FCI	Precipitation rate at ground by GEO/IR supported by LEO/MW and MTG FCI	Algorithms assessment expected in 2016 Expected Operations in CDOP3 (next phase)
H41 PR-OBS-4-FCI	Precipitation rate at ground by LEO/MW supported by GEO/IR (with flag for phase) and MTG FCI	
H42 PR-OBS-5-FCI	Accumulated precipitation at ground by blended MW and IR and MTG FCI	
H50 PR-OBS-11	Rainfall intensity from MTG LI	

H SAF
Support to Operational Hydrology and Water Management

Eumetrain event week *December 1-5, 2014*
Droughts, Floods and Landslides
Session 7: Satellite Precipitation Products and Applications

Precipitation Products from the Hydrology SAF:

Part 2: application to extreme event monitoring

H SAF
Support to Operational Hydrology and Water Management

H-SAF Products

Applications to extreme events: Precipitation Products used

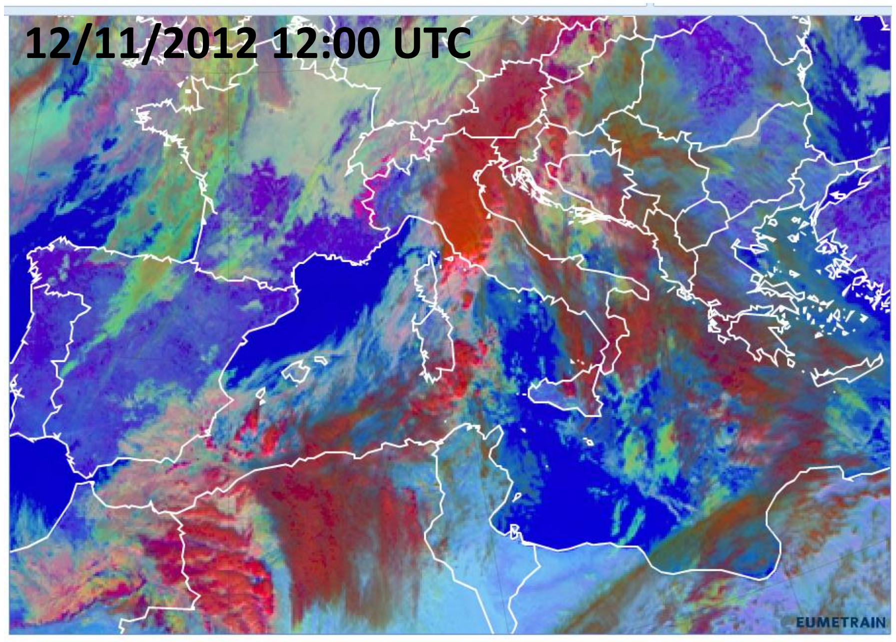
H01 PR-OBS-1	Precipitation rate at ground by MW conical scanners	Operational	3 min (input 2,5 h from first acquisition time)
H02A PR-OBS-2A	Precipitation rate at ground by MW cross-track scanners	Operational	30 sec (input < 20 min from first acquisition time)
H03A PR-OBS-3A	Precipitation rate at ground by GEO/IR supported by LEO/MW	Pre-operational	1 min (input < 5 min)

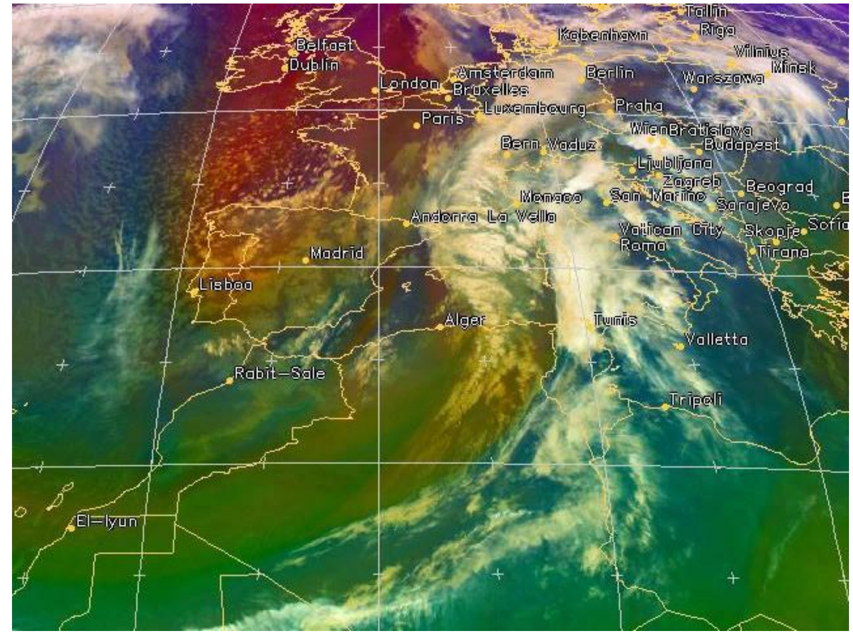
Case study	Date
Cinque Terre Flood	25 October 2011
Genoa Flood	4 November 2011
Southern Tuscany/Tevere	11-12 November 2012
Catania Flash Flood	21 February 2013
Catania Flash Flood	5 November 2014

Case study: 11-12 November 2012
Southern Tuscany

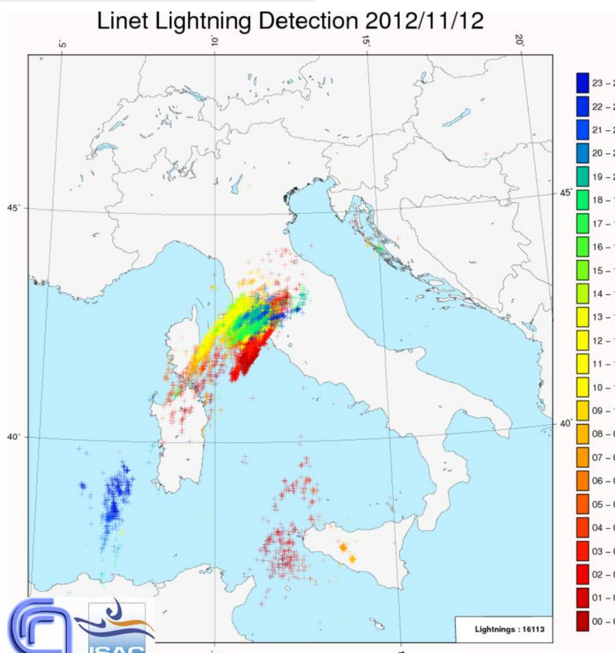
http://oiswww.eumetsat.org/WEBOPS/iotm/iotm/20121112_flood/20121112_flood.html

Southern Tuscany Flood 11-12 Novembre 2012





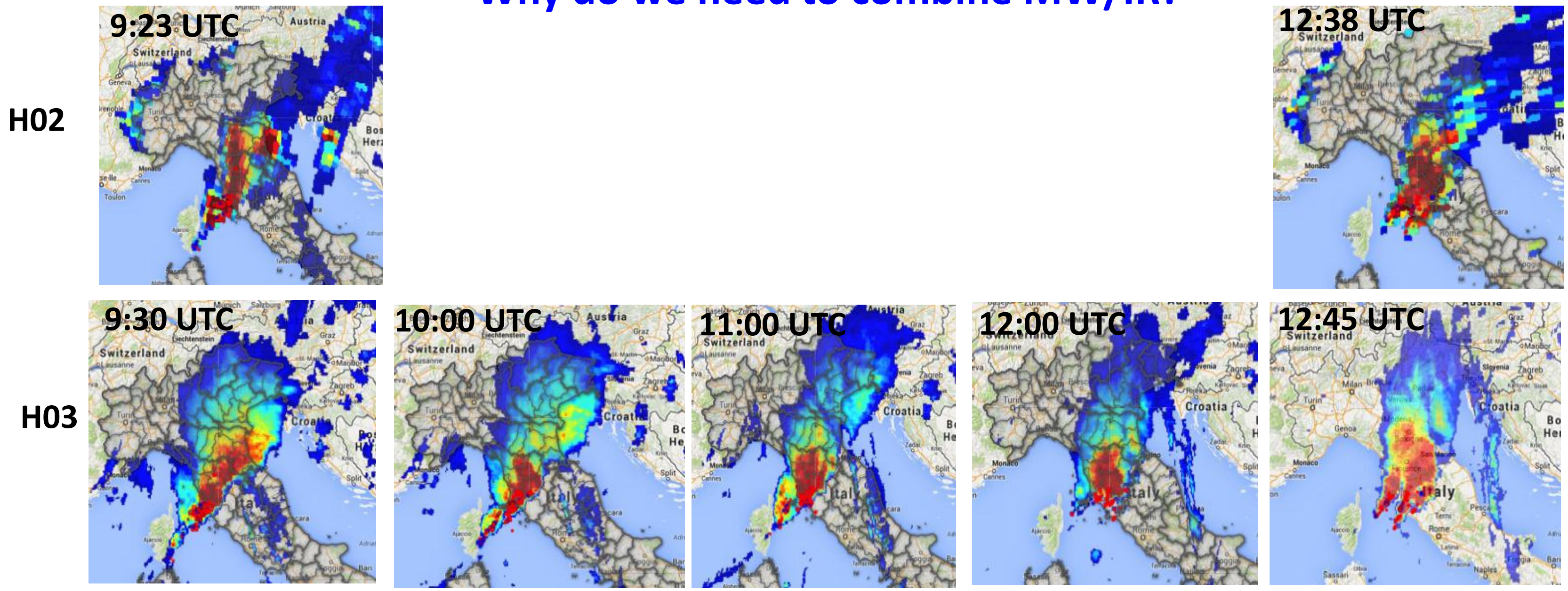
www.eumetrain.org
RGB Day Microphysics

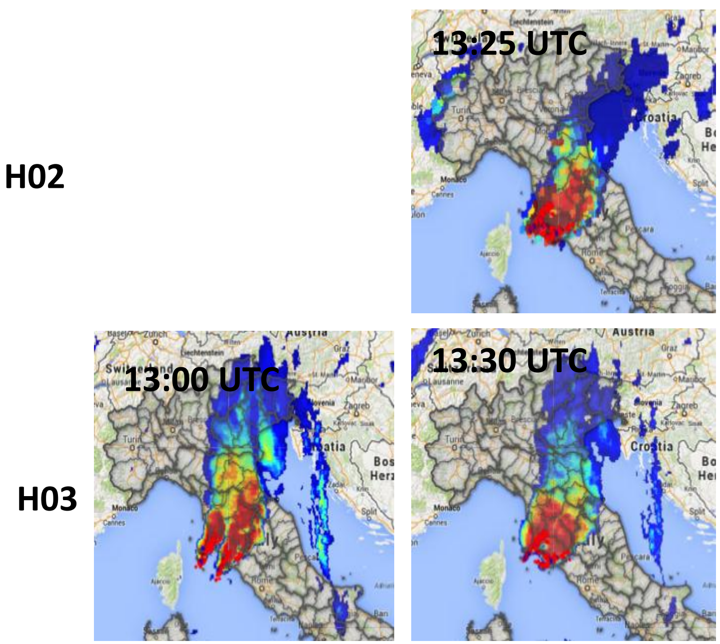


www.eumetrain.org
Airmass RGB

24 hours LINET Strokes
(Betz et al., Atmos. Res., 2009)

Why do we need to combine MW/IR?

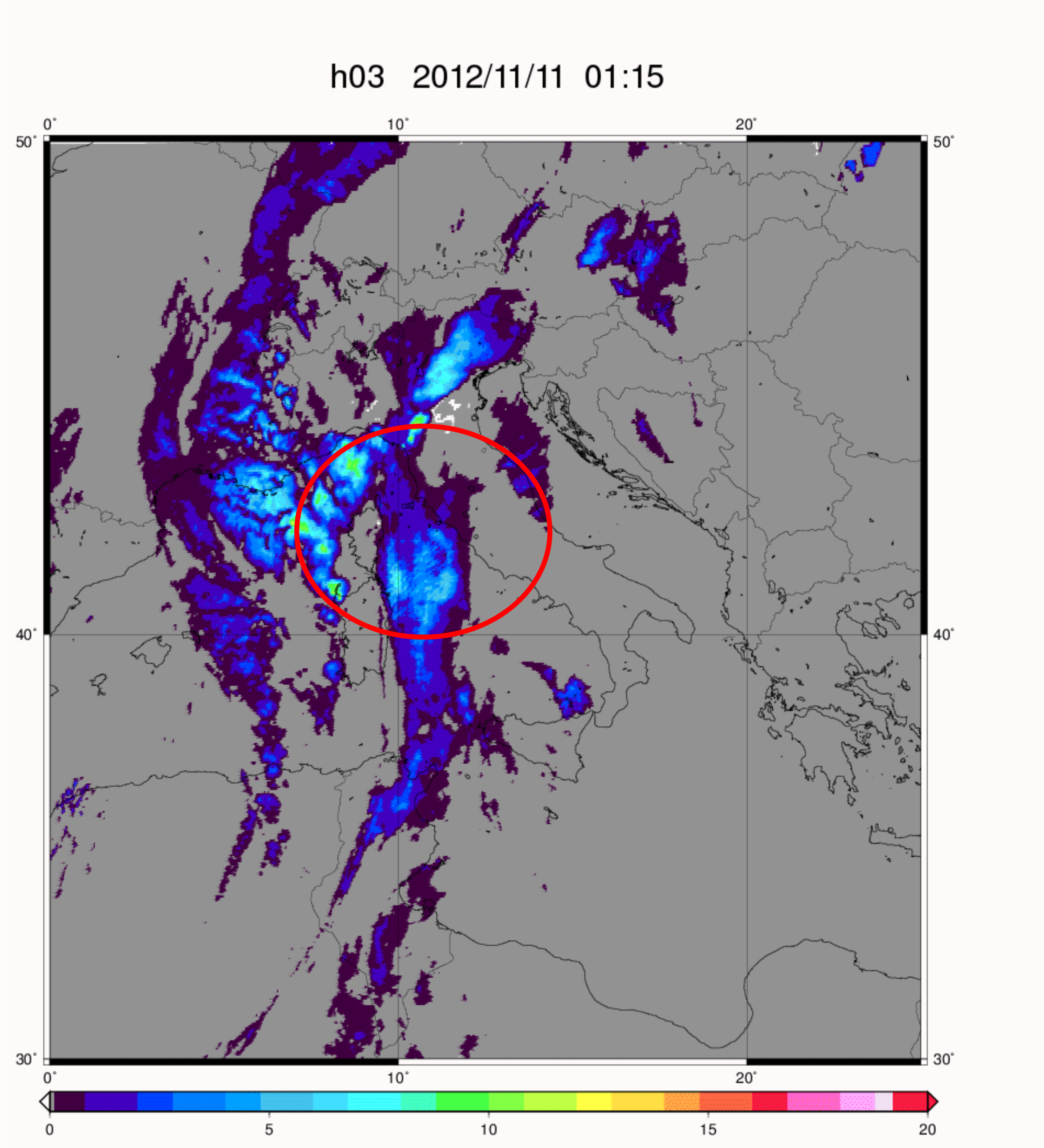




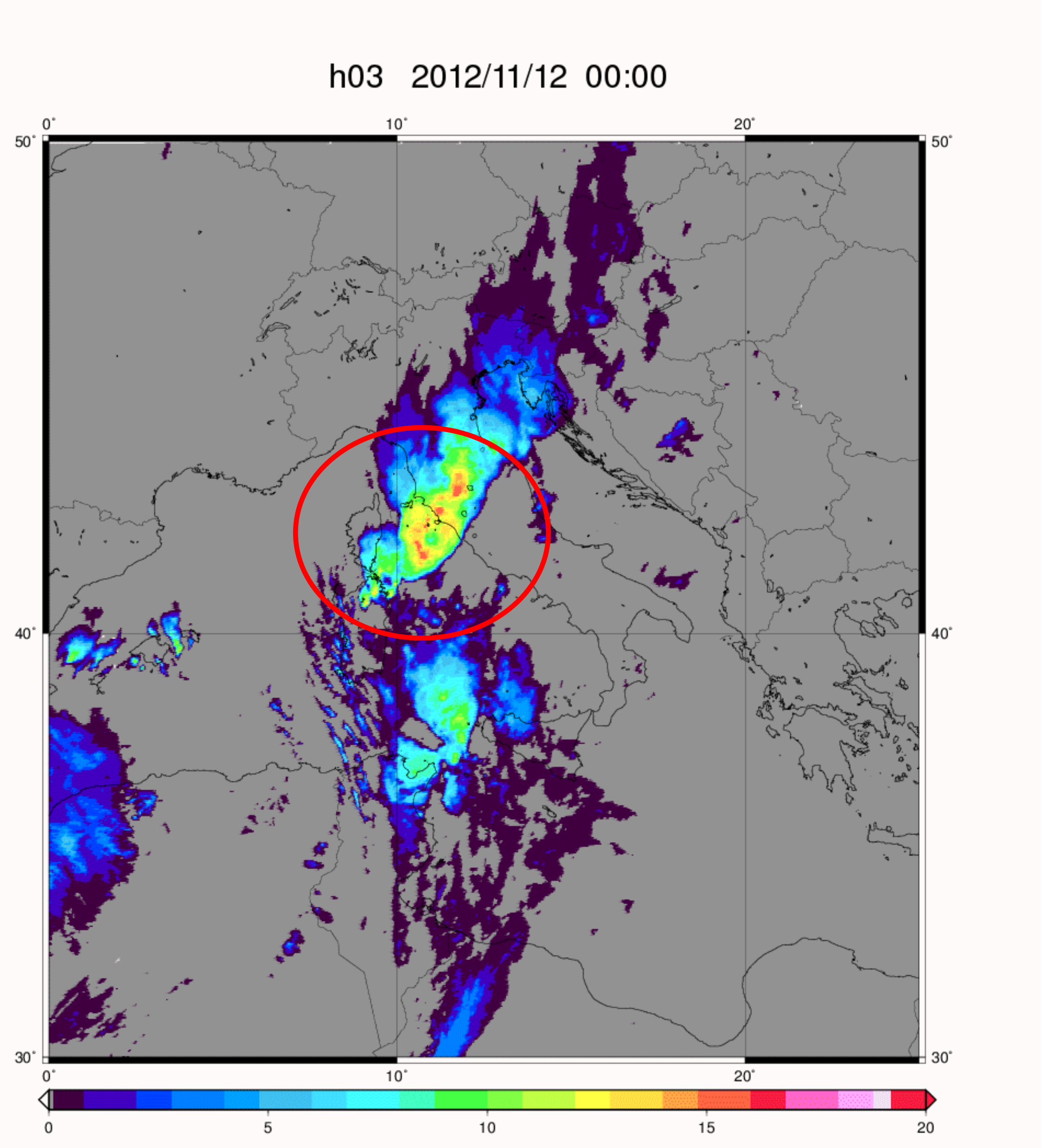
Southern Tuscany Flood
12 November 2012

Red dots are LINET strokes

Southern Tuscany Flood 11-12 Novembre 2012

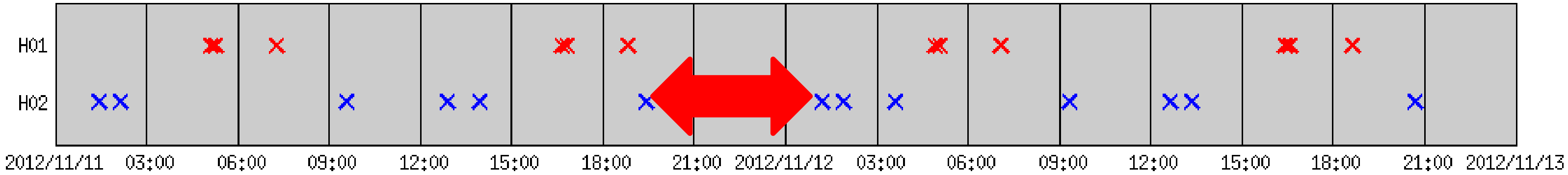


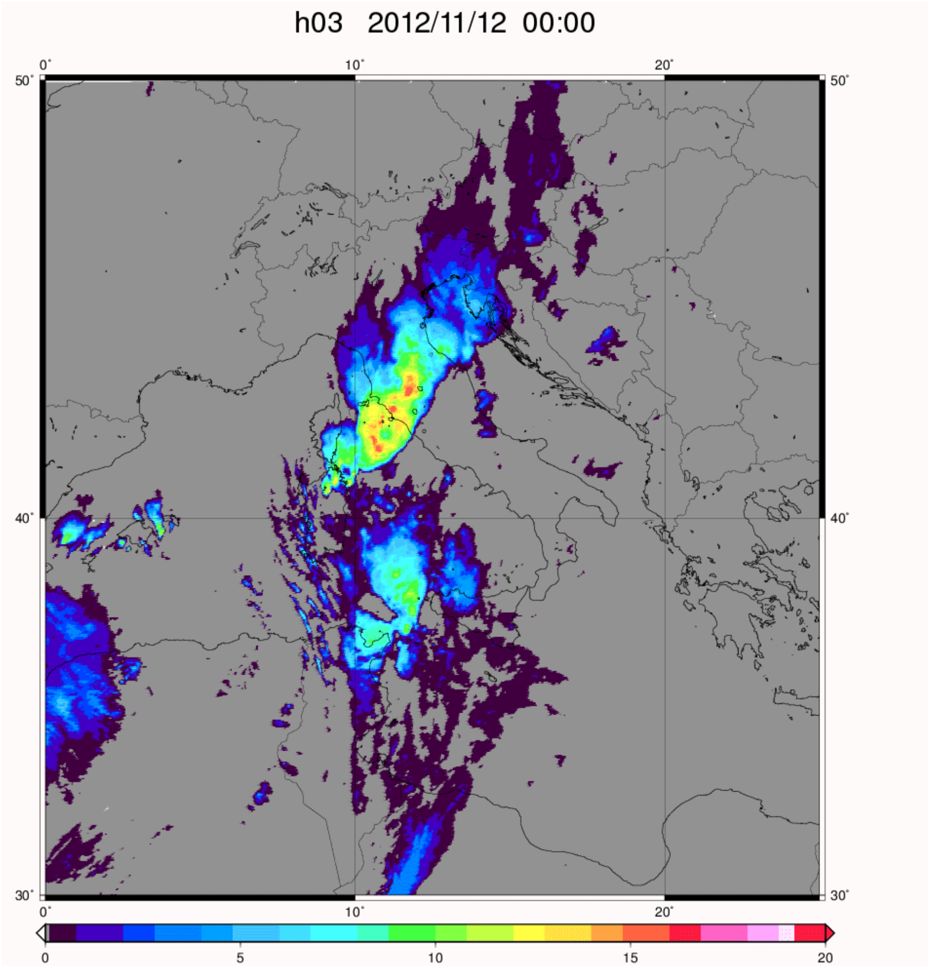
Southern Tuscany Flood 11-12 Novembre 2012



Southern Tuscany Flood 11-12 Novembre 2012

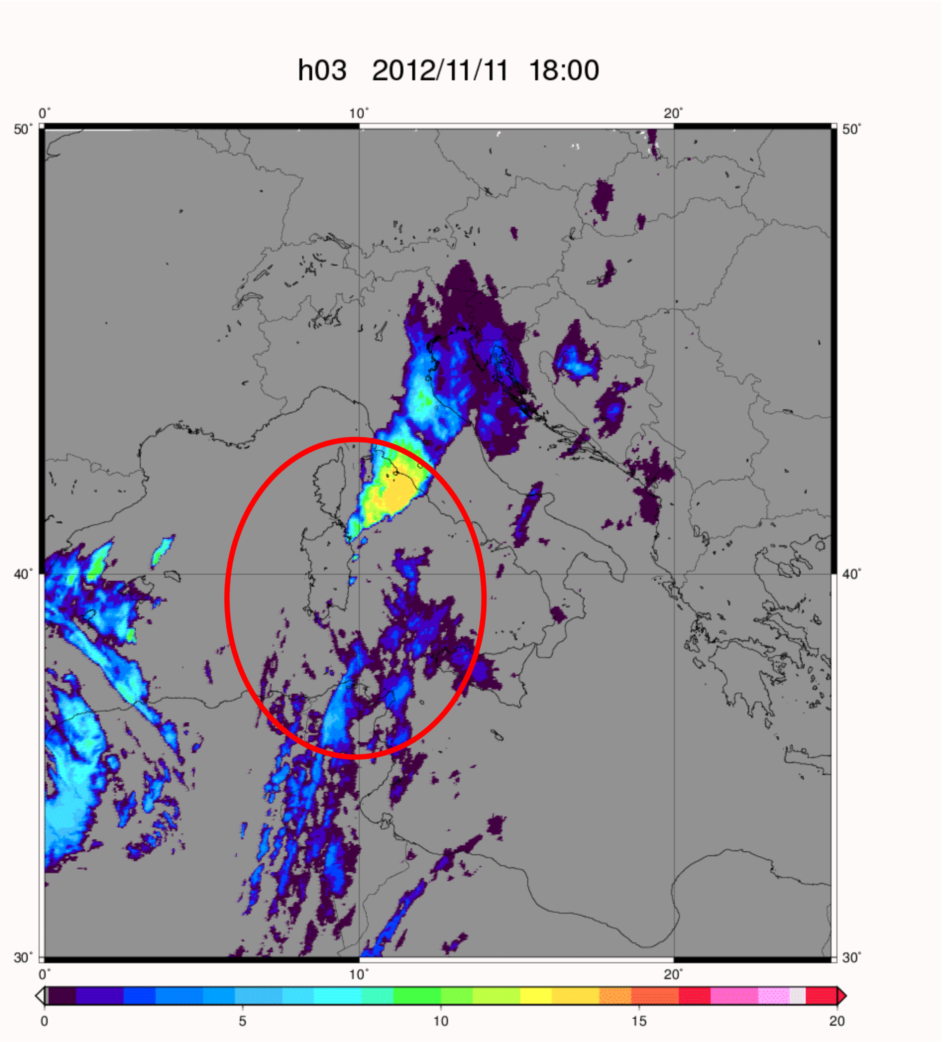
check the discontinuity in H03





Southern Tuscany Flood 11-12 Novembre 2012

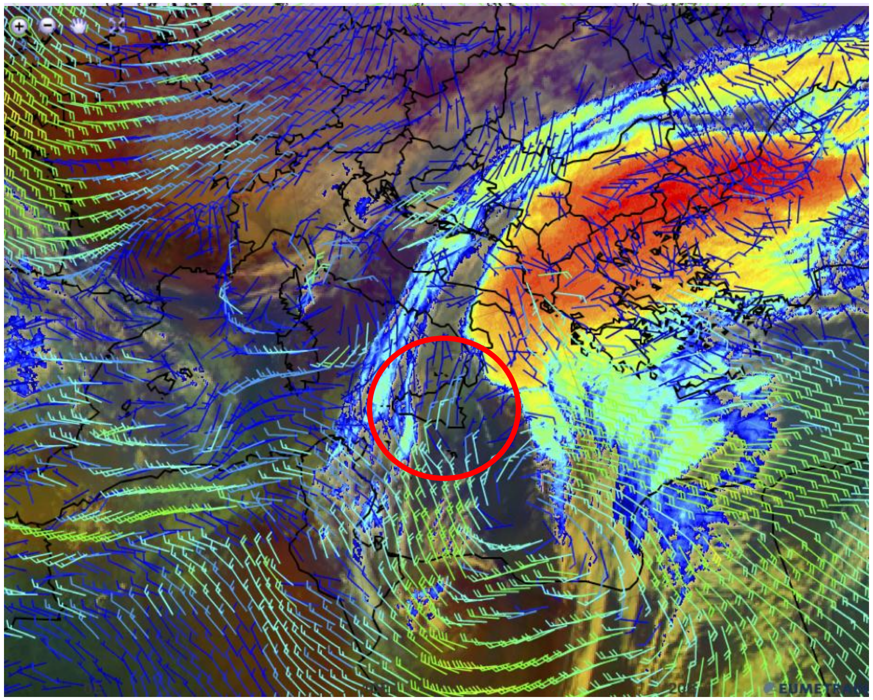
A broader look from satellite



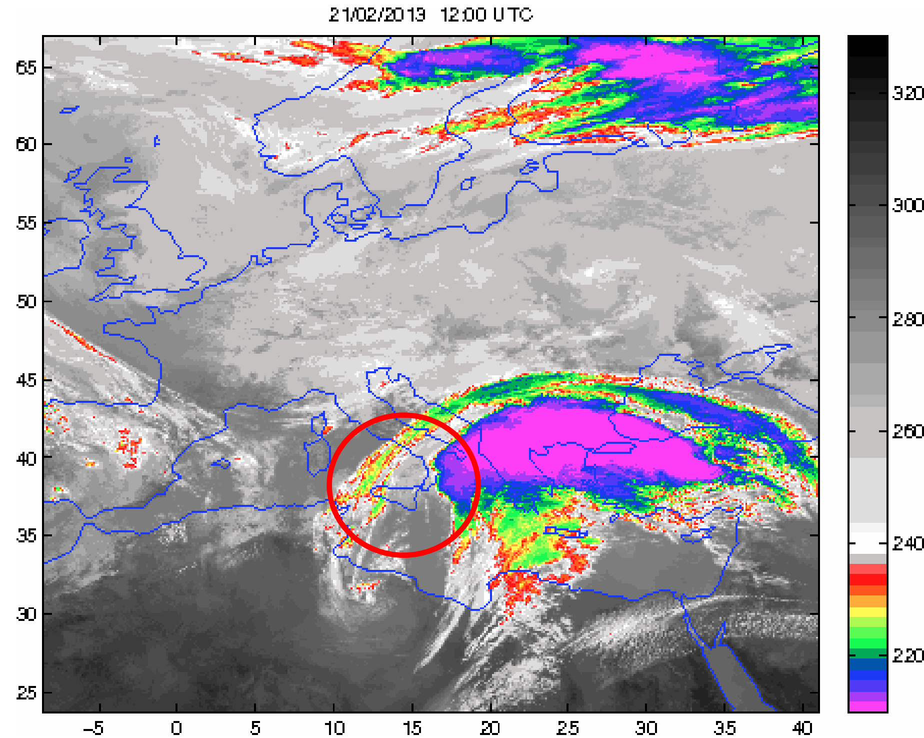
H SAF
Support to Operational Hydrology and Water Management

Comparing two cases:
Catania Floods
21 February 2013
5 November 2014

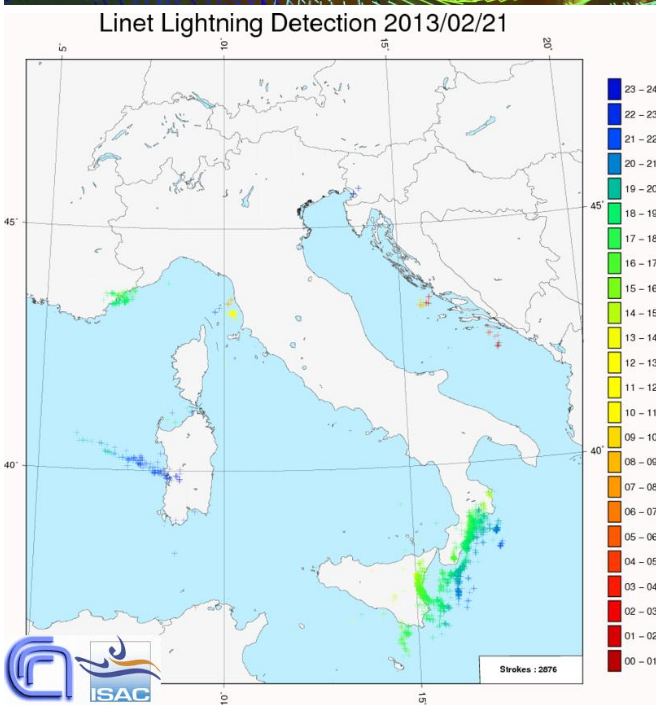
Catania Flash Flood 21 February 2013



www.eumetrain.org
1200 UTC Airmass RGB, Enhanced IR (10.8 nm) and Geopotential height (500 hPa)

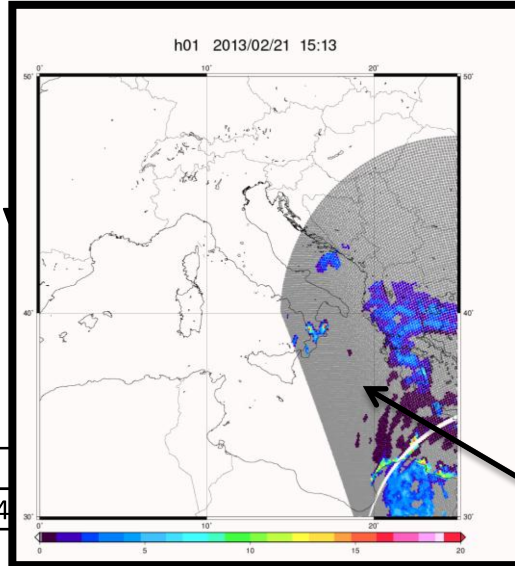


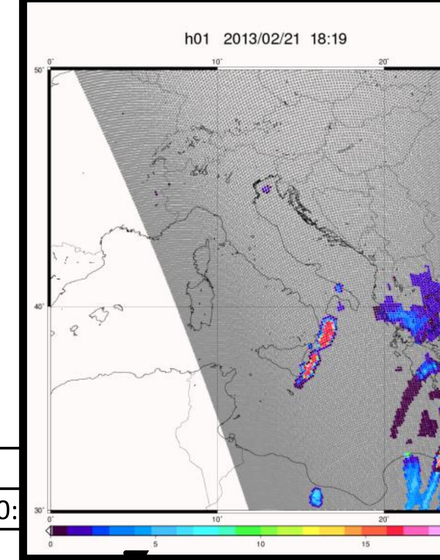
MSG SEVIRI 10.8 nm



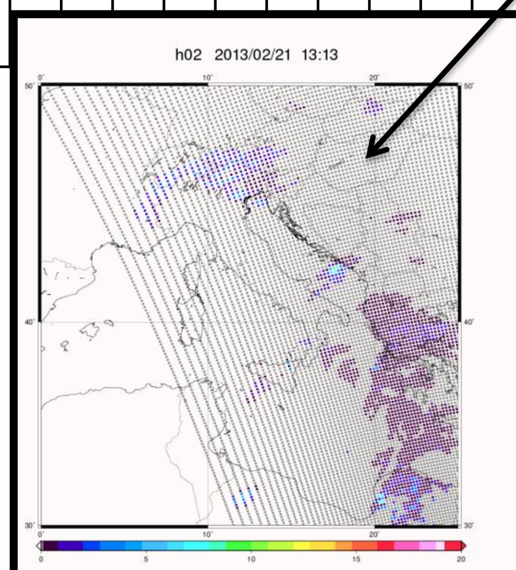
24 hours LINET Strokes
(Betz et al., Atmos. Res., 2009)

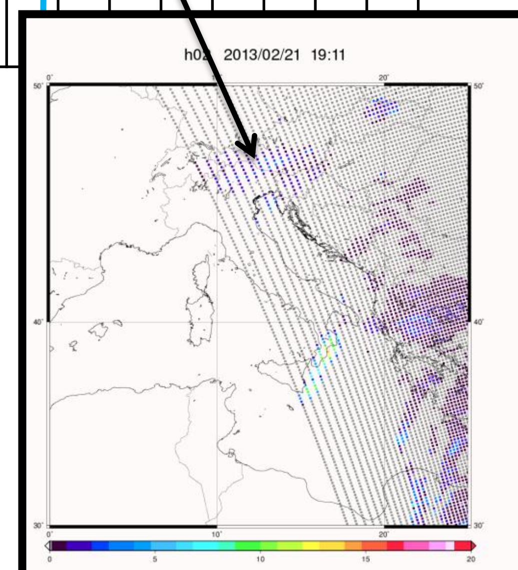
Flood in Catania, Sicil
21/2/2013



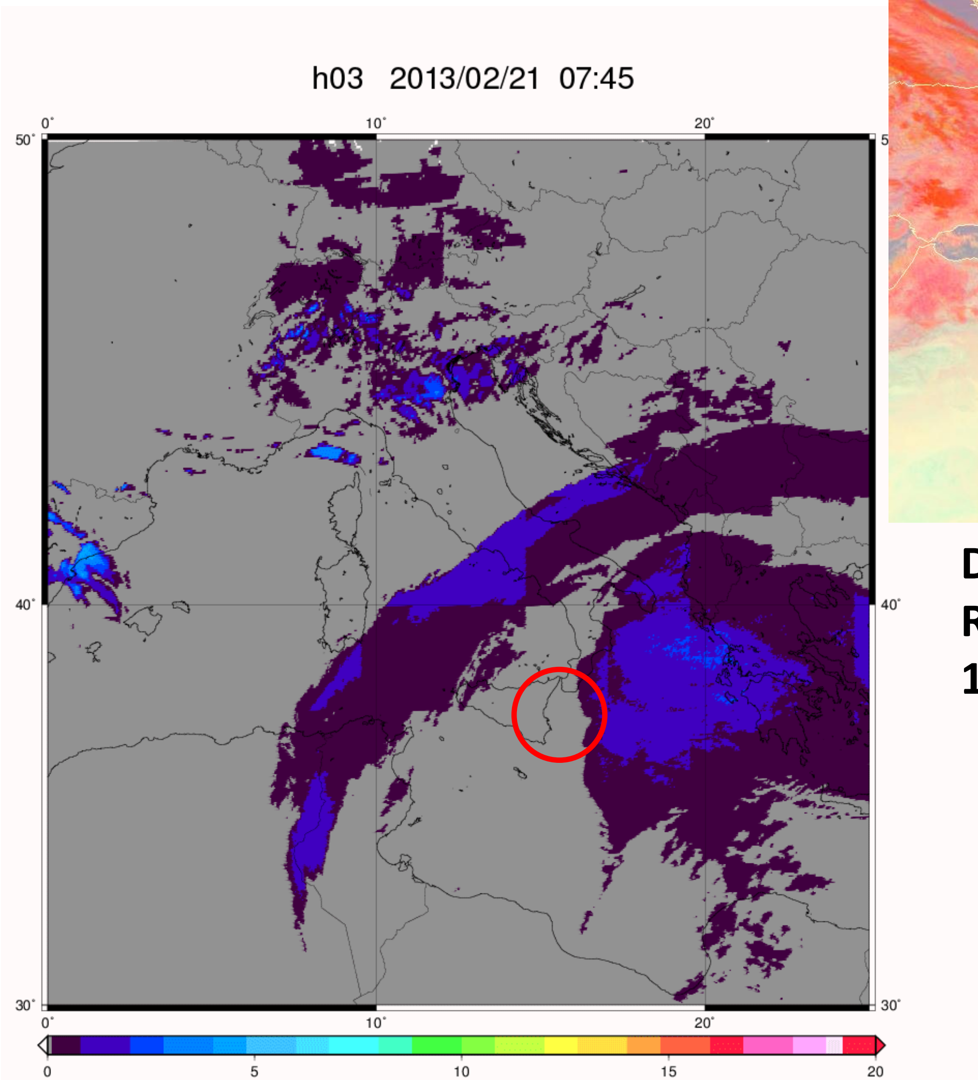


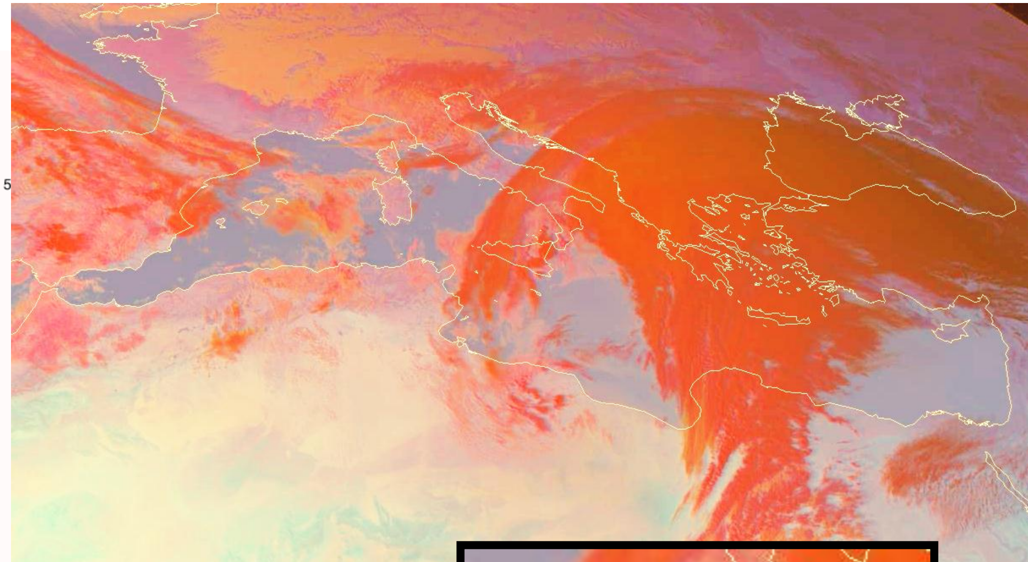
		00:00-04			12:00-16:00	16:00-20:	
SSMIS	F16				X		
	F17		X				
	F18					X	
MHS	MetOp-A			X			X
	MetOp-B			X		X	
	NOAA18	X			X		
	NOAA19	X		X			
		X X	X	X X X	X X	X X X	X





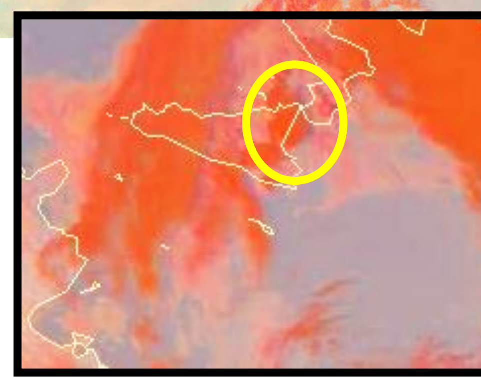
21 February 2014, Flash Flood Catania (Sicily) Italy





Day microphysics RGB 21/2/2013 15:00 UTC

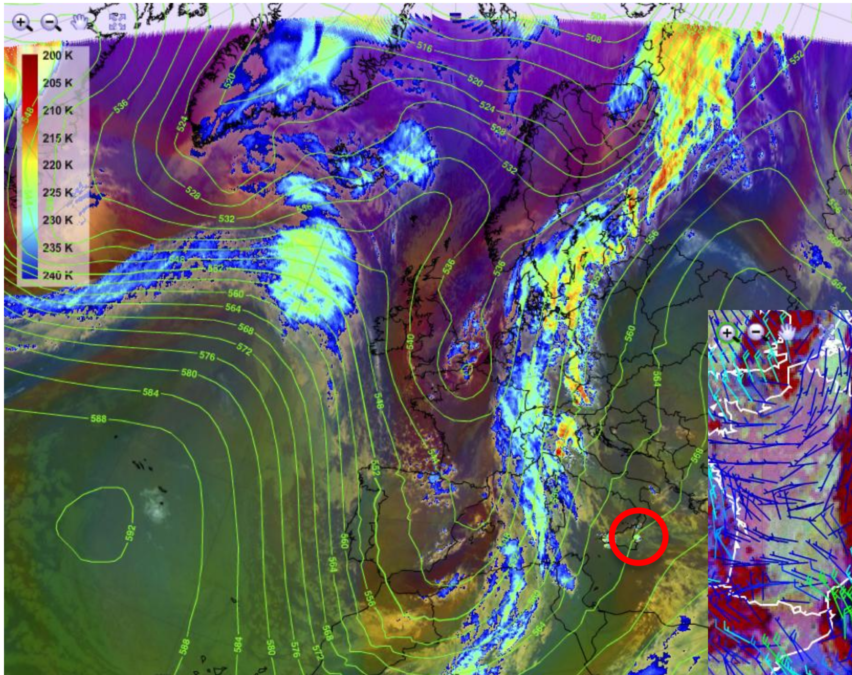
Red	=	VIS0.8	0 to 100%
Green	=	IR3.9r	0 to 60%
Blue	=	IR10.8	+203 to +323K

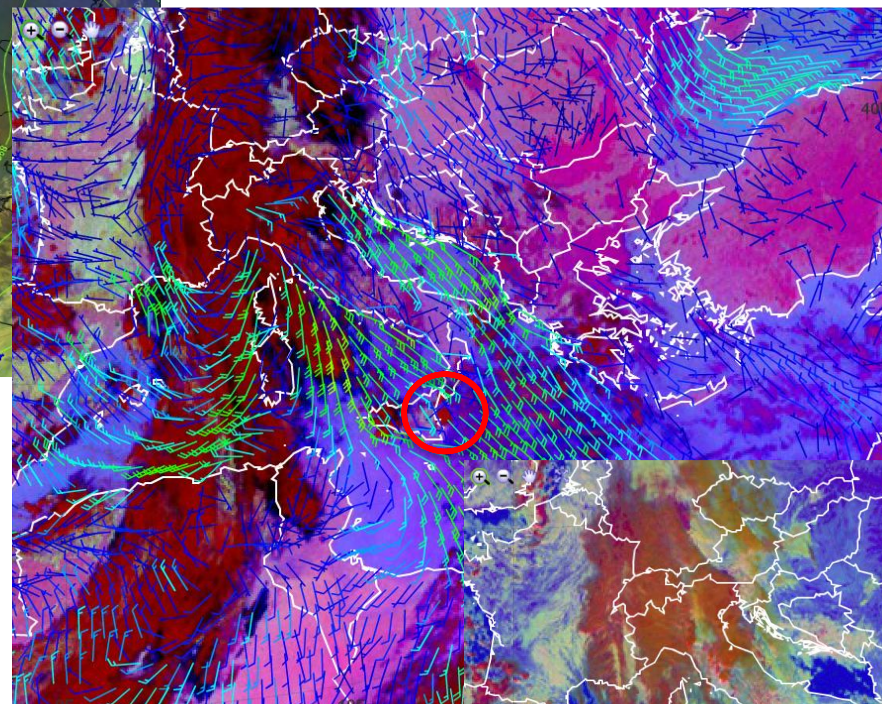


Catania Flash Flood 5 November 2014

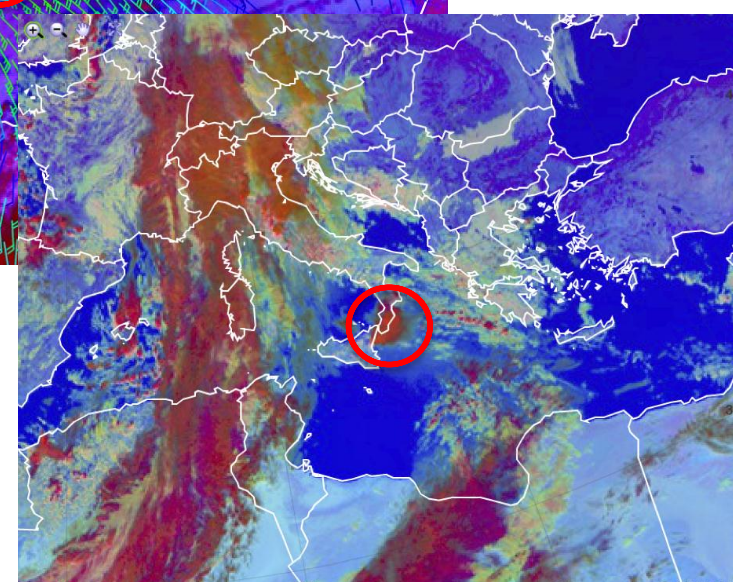
www.eumetrain.org

0600 UTC Airmass RGB, Enhanced IR (10.8 nm)
and Geopotential height (500 hPa)



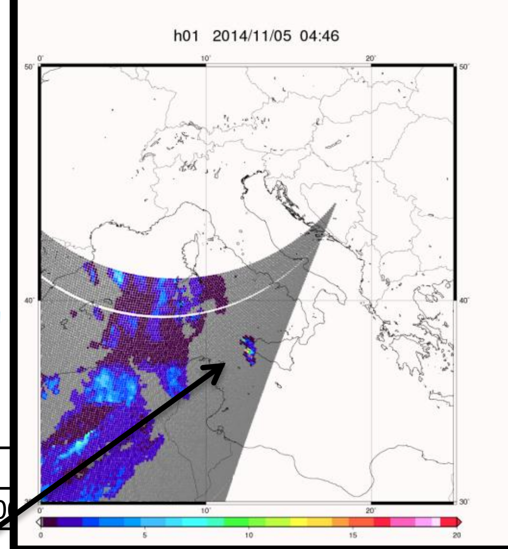


0600 UTC
Night Microphysics RGB
10 m Wind

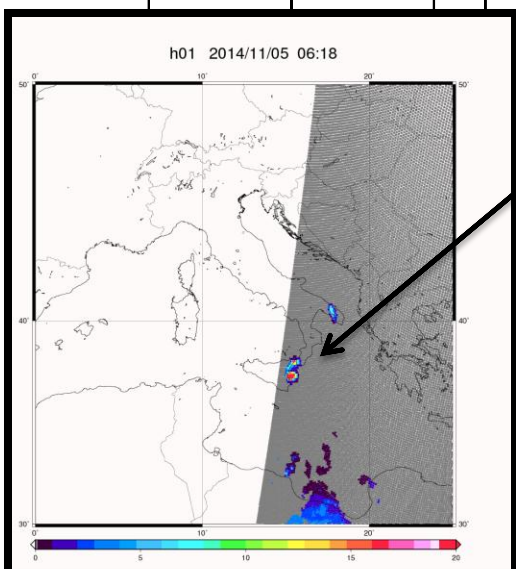


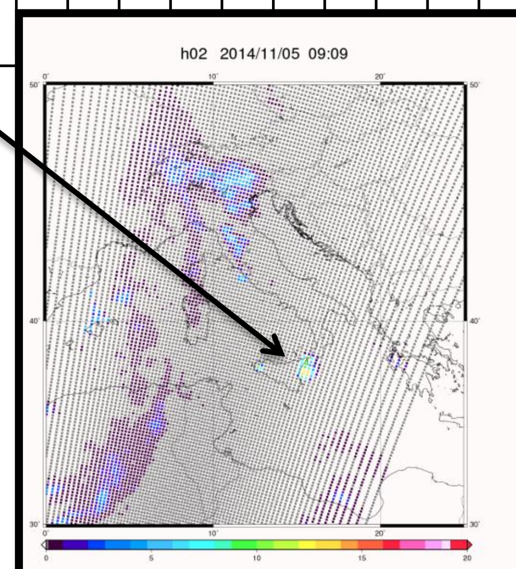
1200 UTC
RGB Microphysics

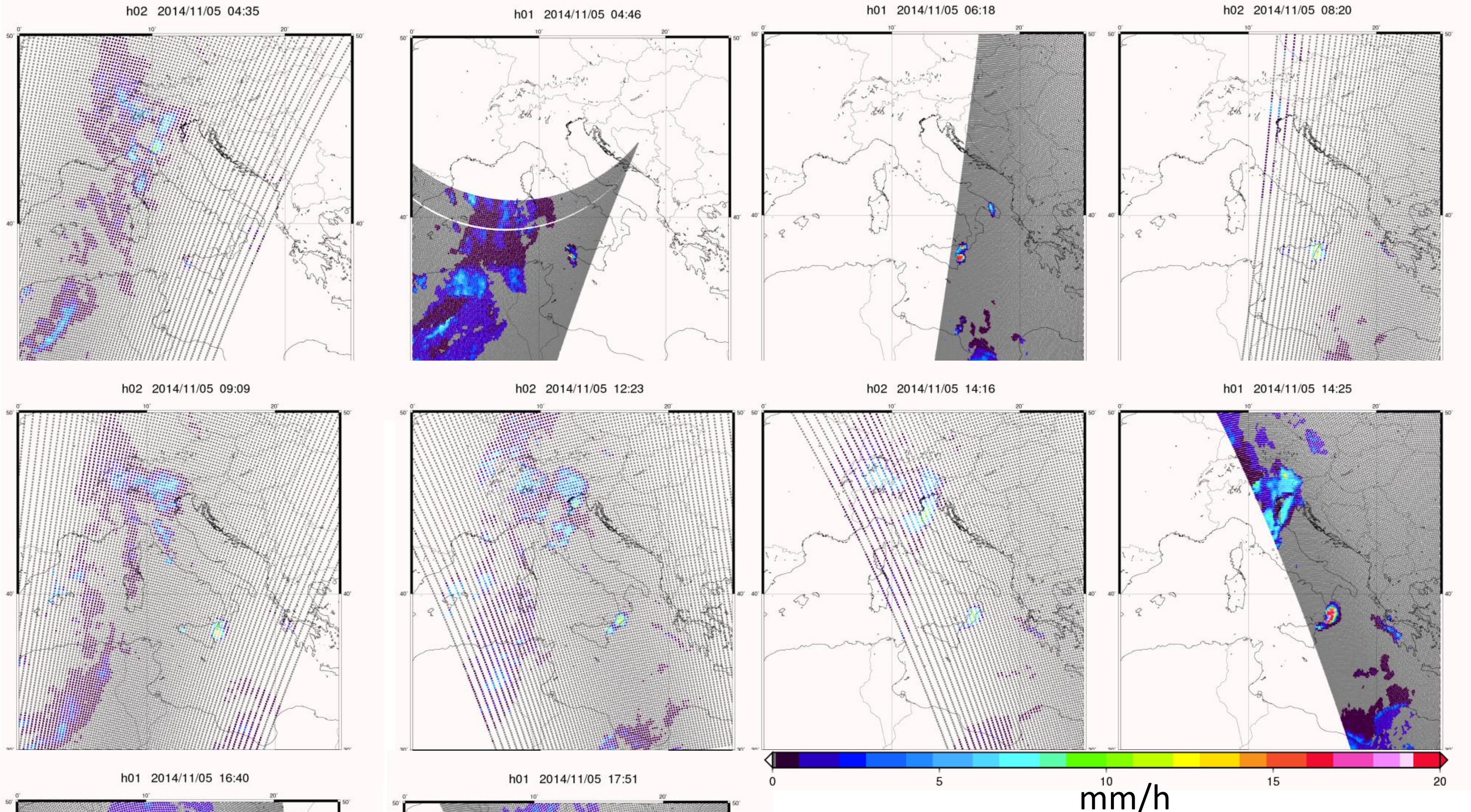
Flood in Catania, Sicily– Italy
5/11/2014

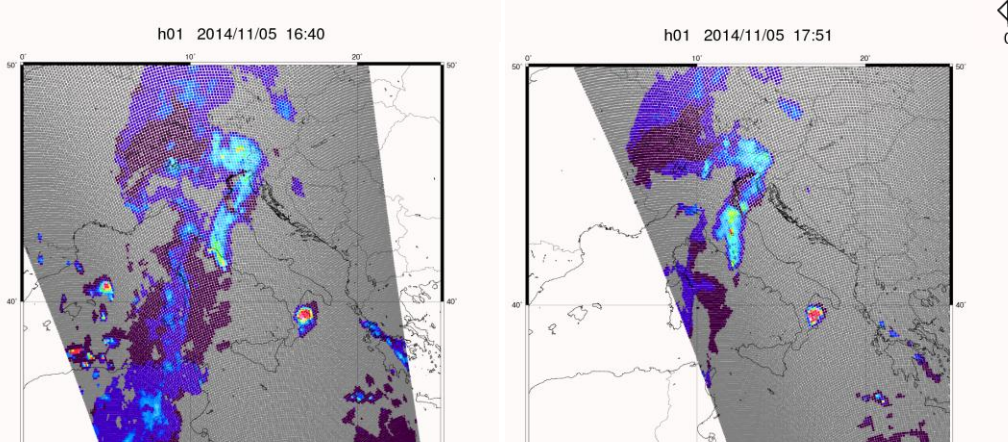


		00:00-04:00	04:00-08:0			6:00-20:00	20:00-24:00
SSMIS	F16				X		
	F17		X			X	
	F18		X			X	
MHS	MetOp-A			X		X	
	MetOp-B			X			X
	NOAA18	X	X		X		
	NOAA19	X			X		
		X X	X X X	X X	X X	X X X	X



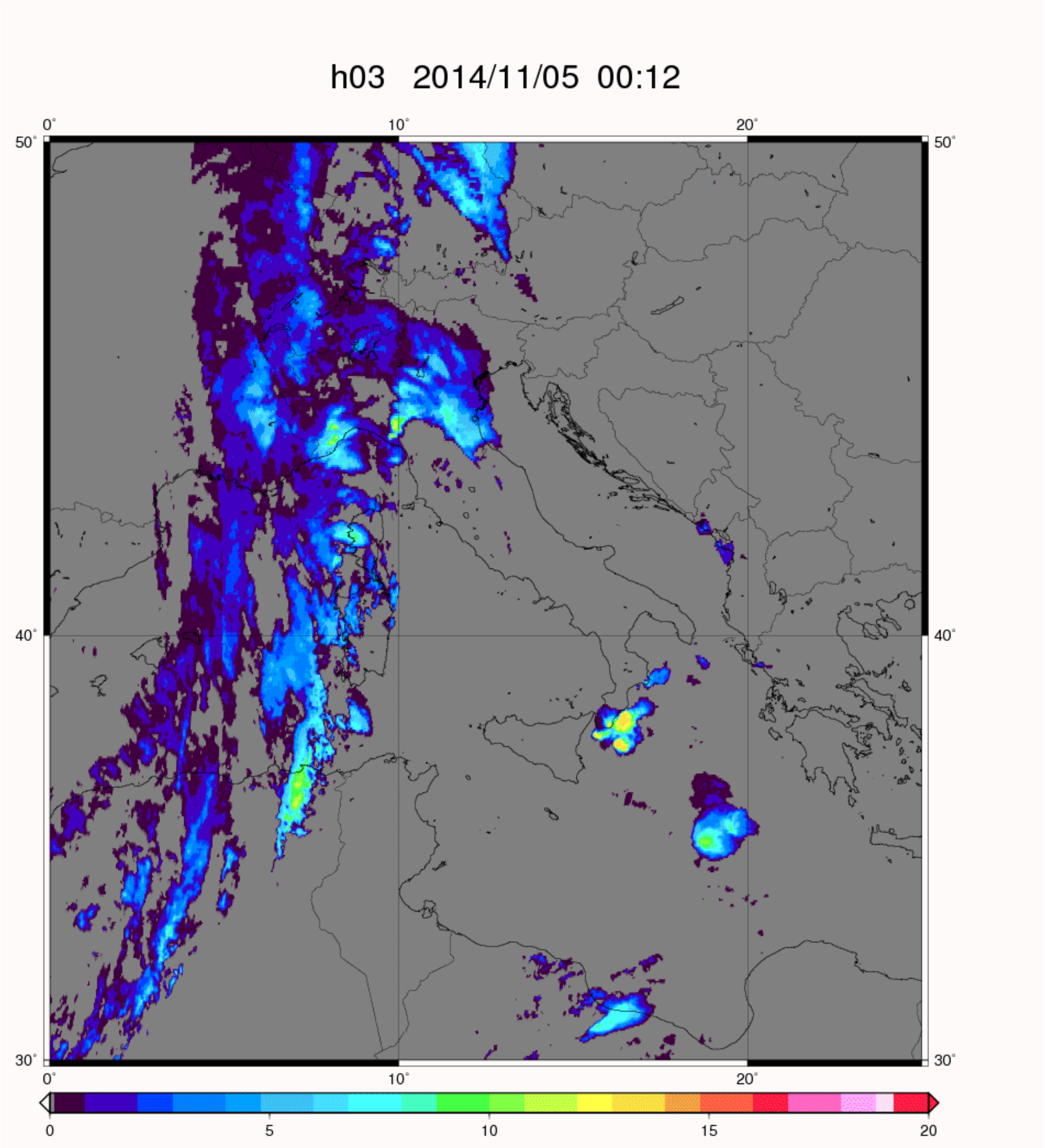






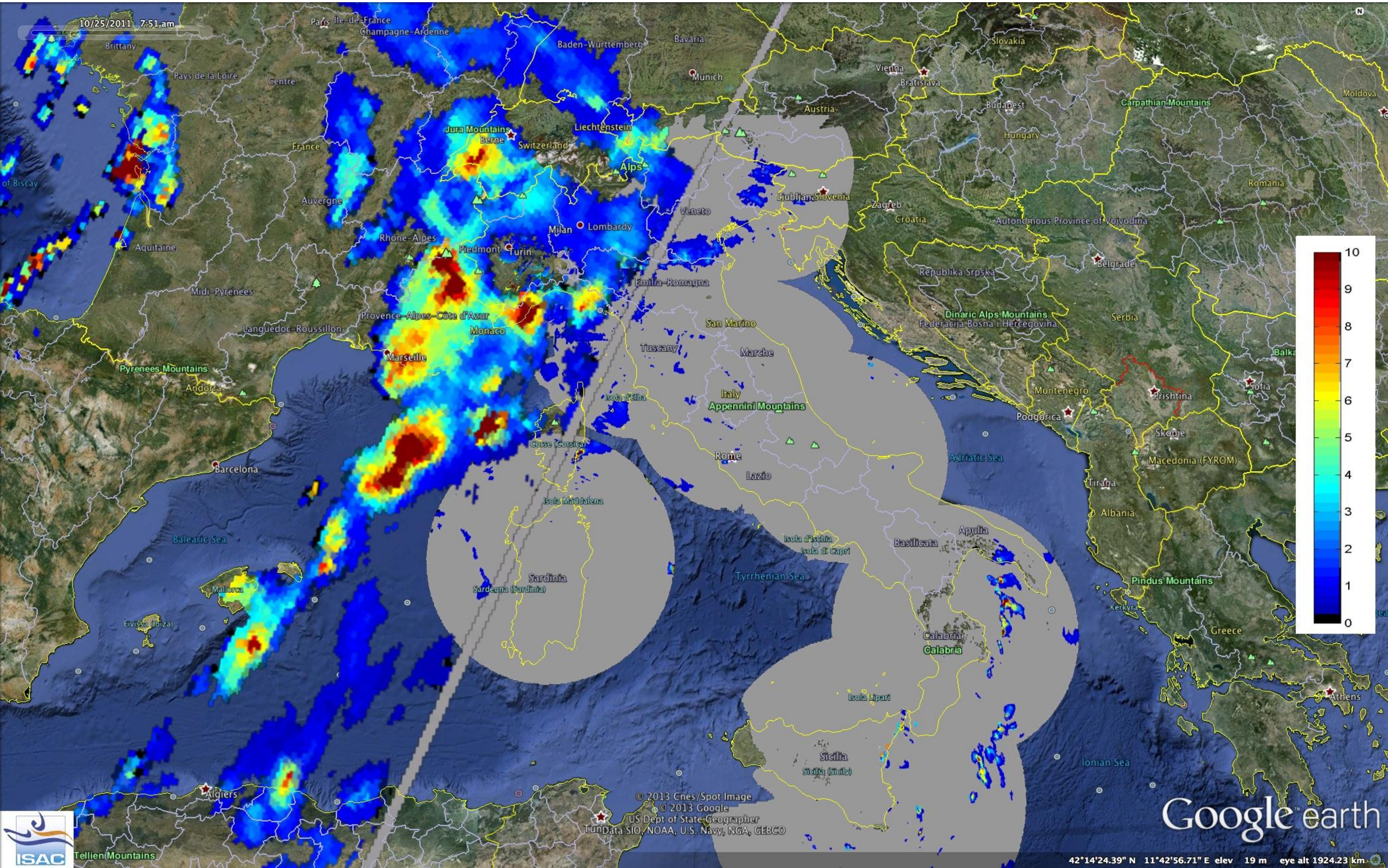
Catania Flood 5/11/2014

5 November 2014, Flash Flood Catania (Sicily) Italy



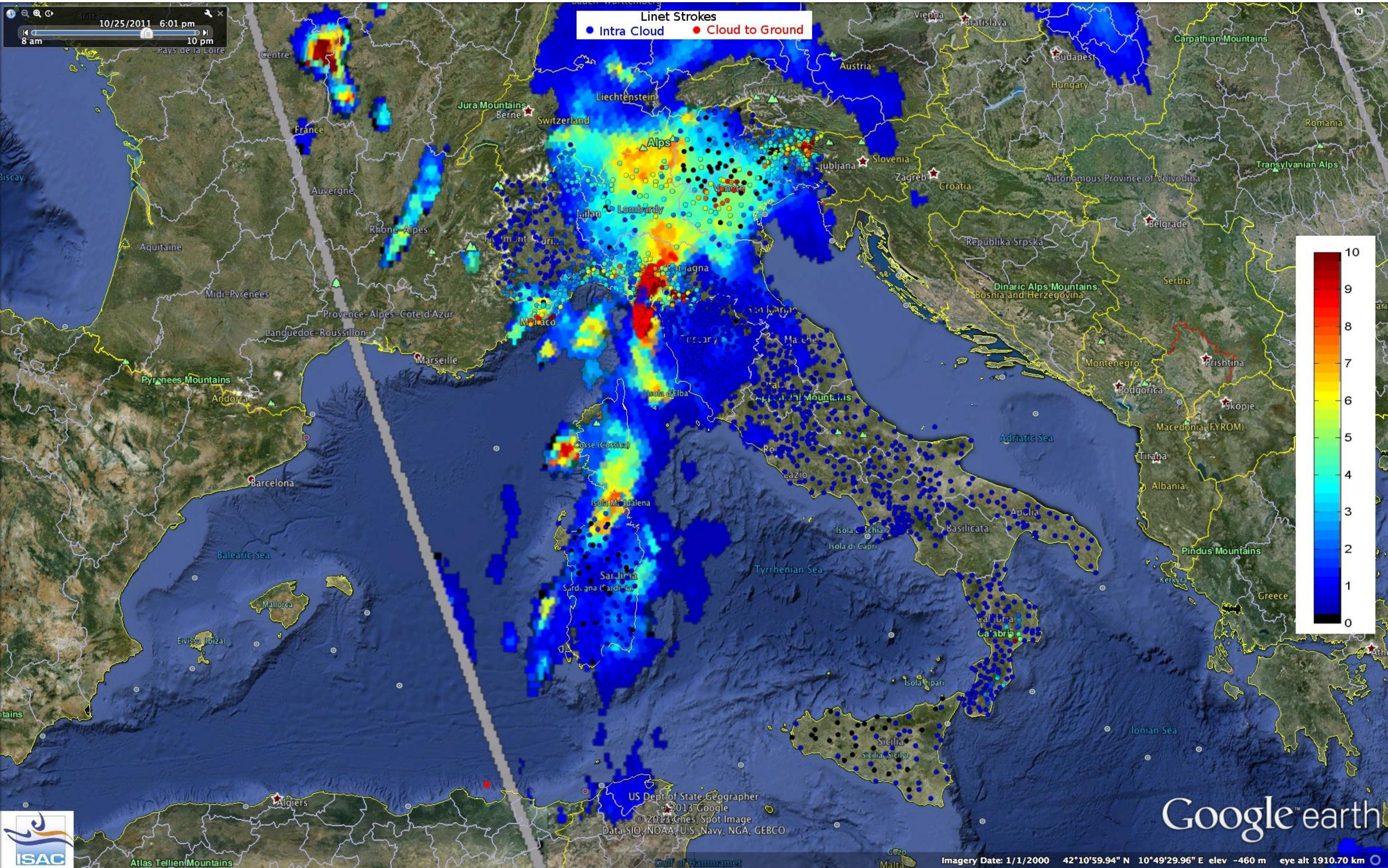
25 October 2011 –Cinque Terre Flood

National Radar Mosaic (DPC) + H01 (SSMIS) - 05:50 UTC



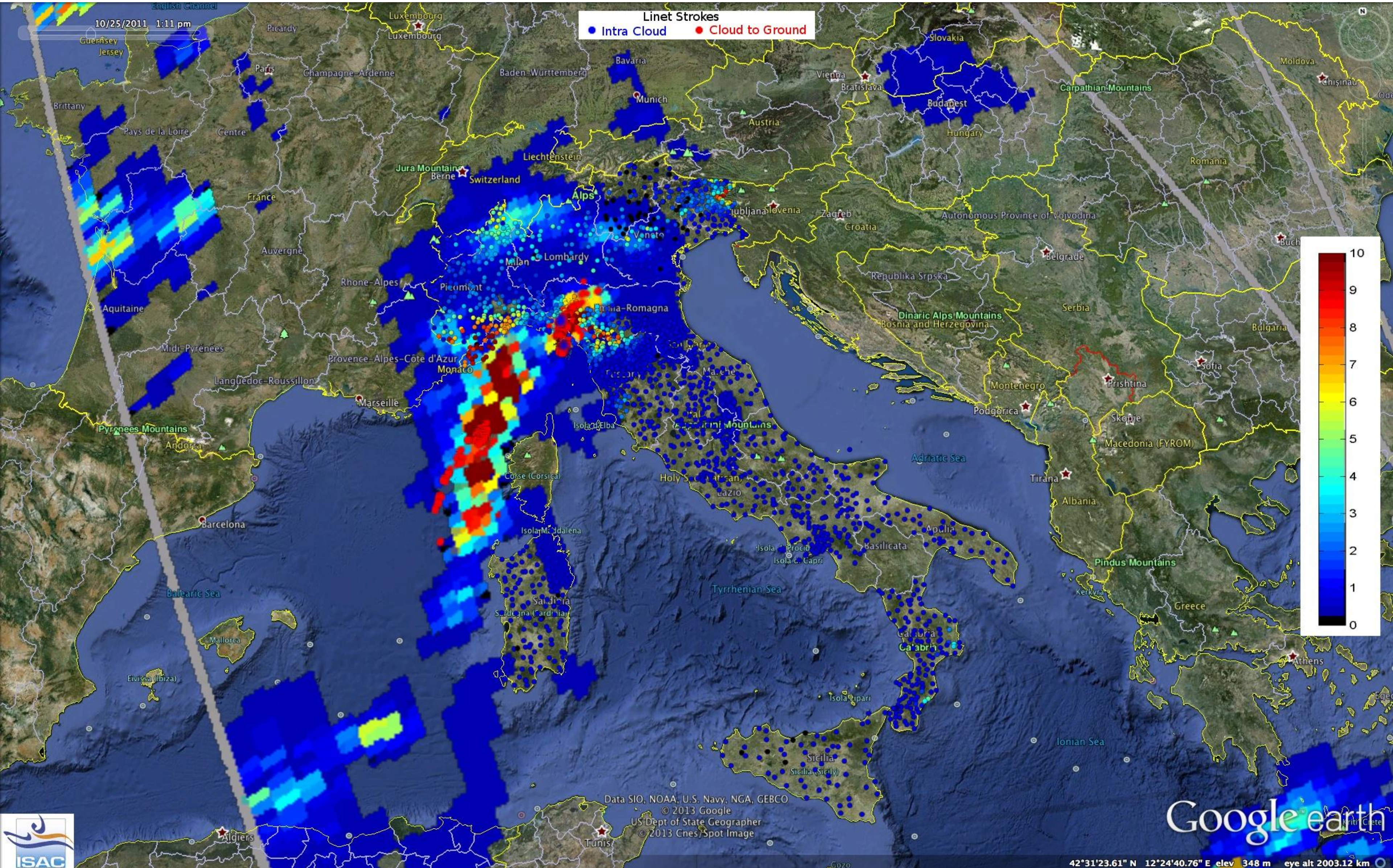
25 October 2011 –Cinque Terre Flood

H01 (SSMIS) + Raingauges + lightning – 16:00 UTC



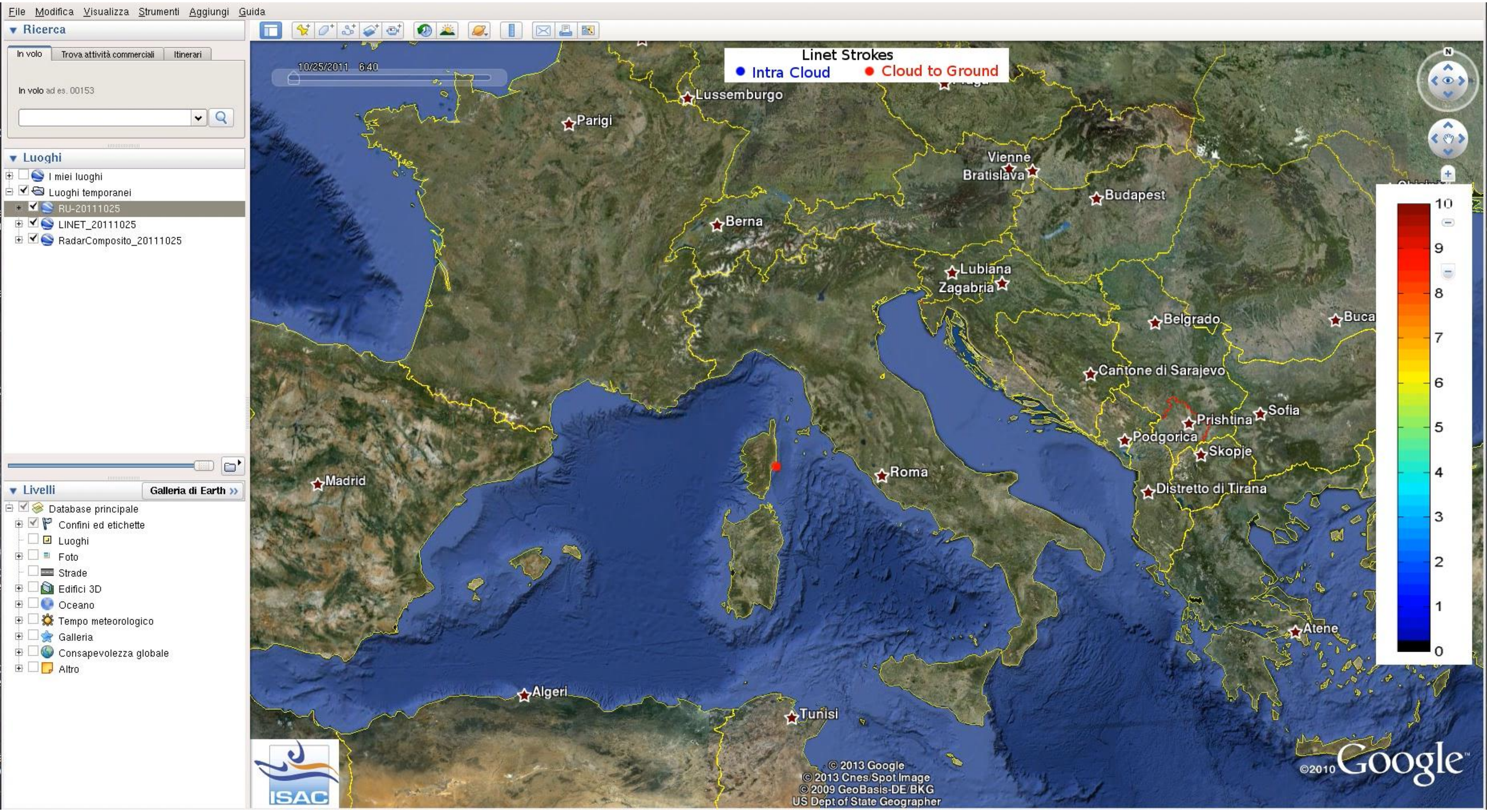
25 October 2011 –Cinque Terre Flood

H02 (AMSU/MHS) + Raingauges + lightning- 11:11 UTC



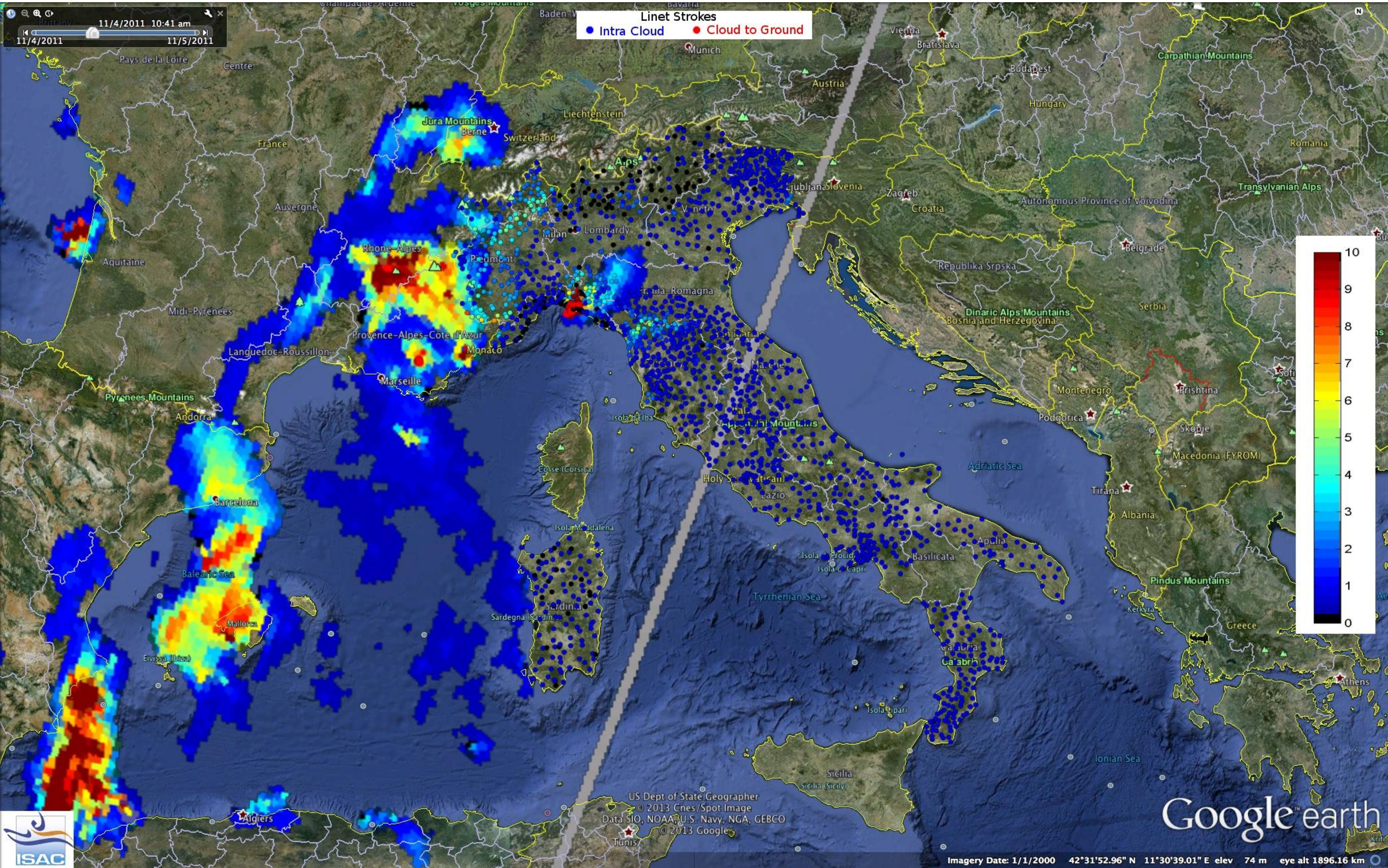
25 October 2011 –Cinque Terre Flood

H03 + lightning + Radar



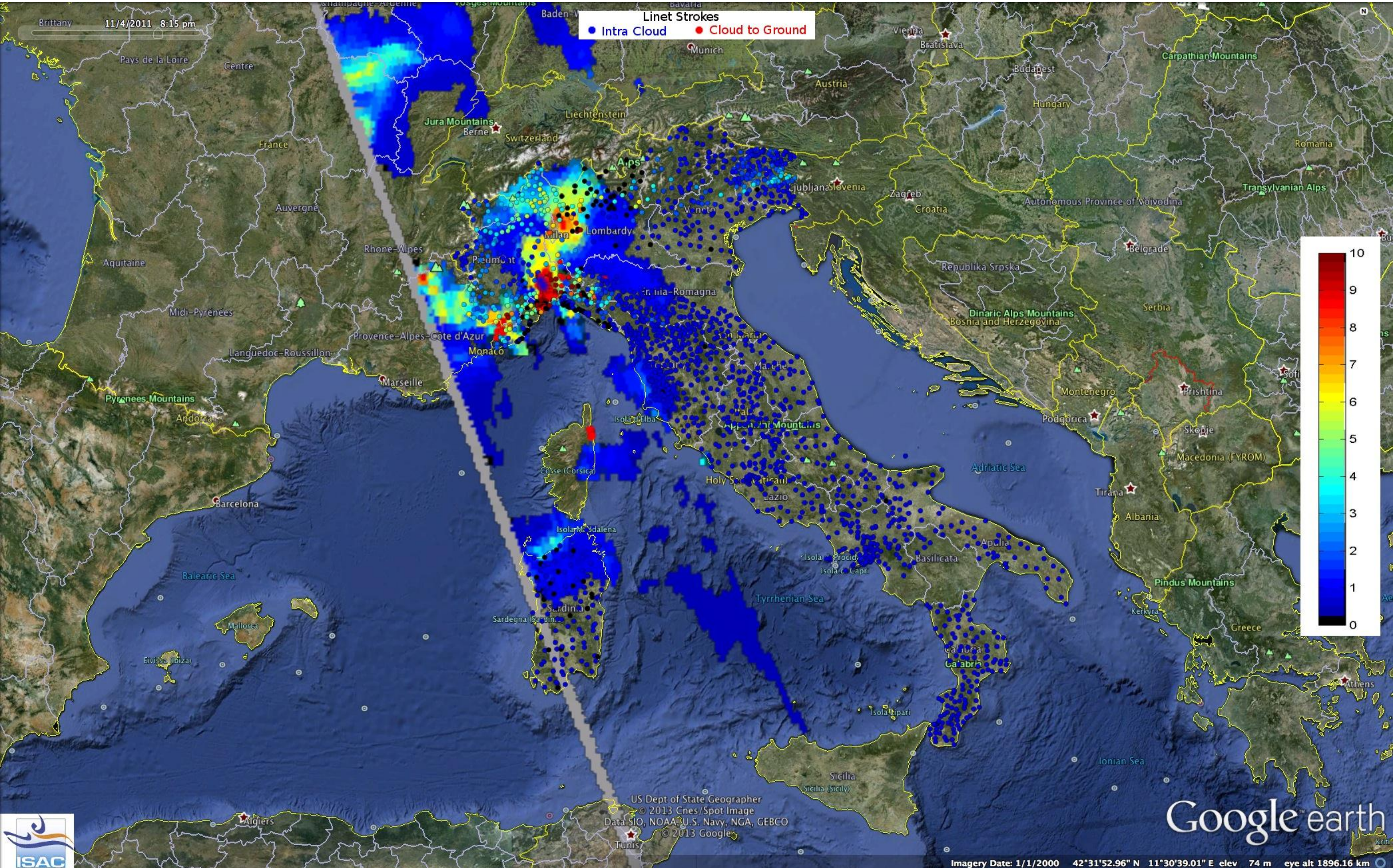
4 November 2011 –Genoa Flood

H01 + radar+ lightning + raingauges – 08:50 UTC



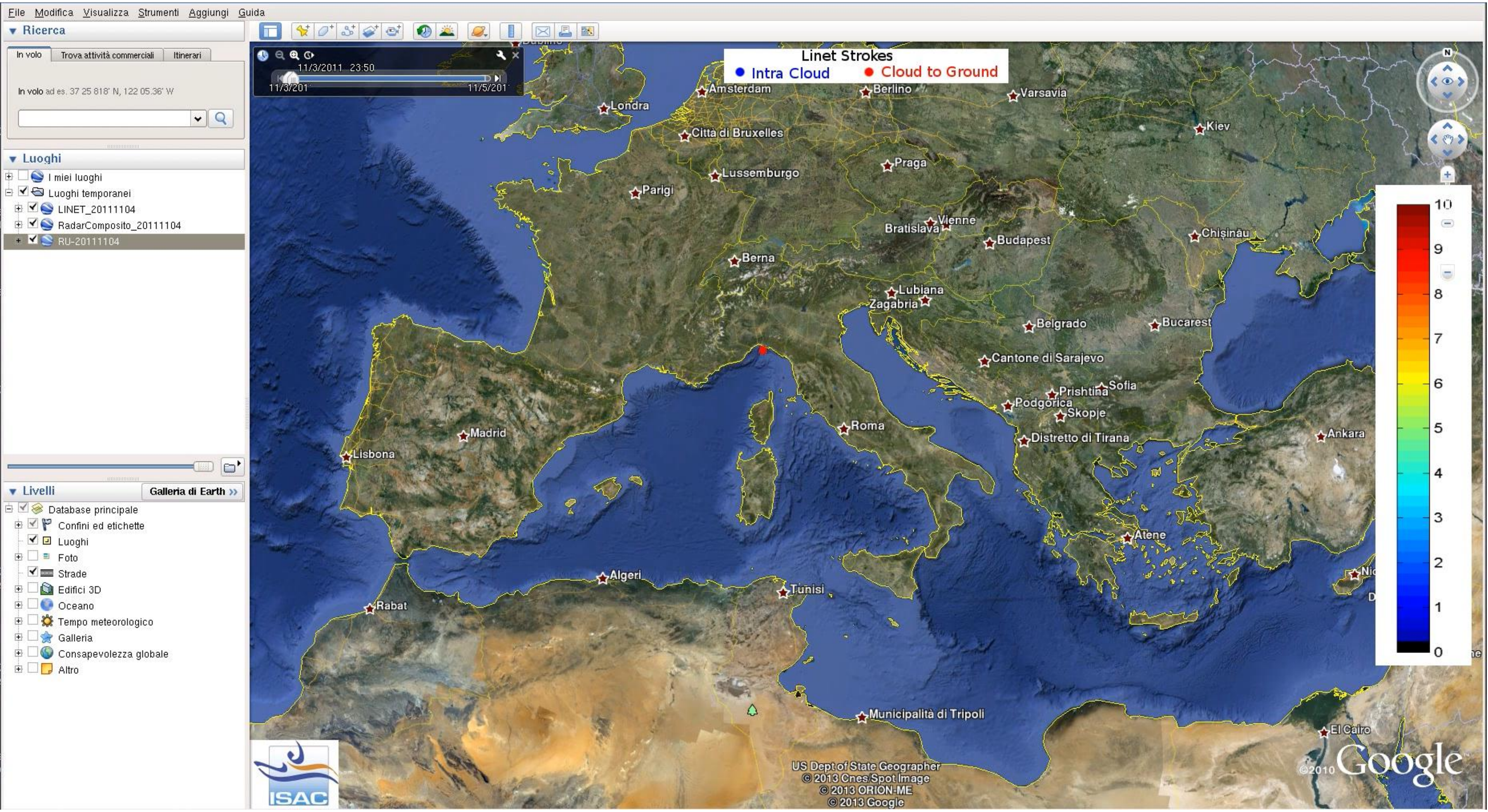
4 November 2011 –Genoa Flood

H01 + lightning + raingauges – 18:15 UTC



4 November 2011 –Genoa Flood

H03 + Radar + lightning



Future PMW temporal sampling in H-SAF

Example for Genoa Flood 11 October 2014

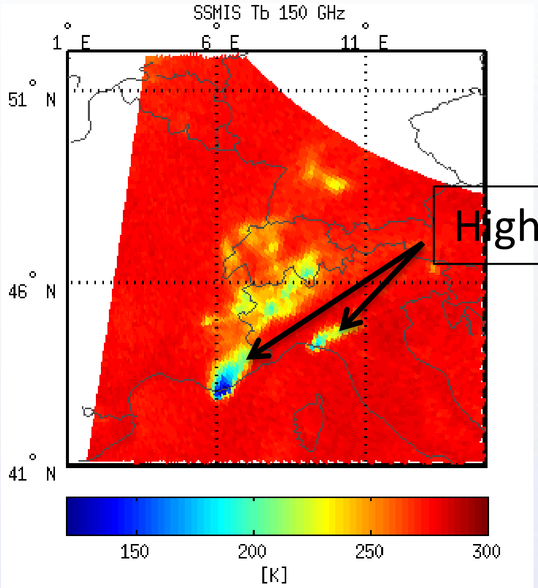
		2014/10/11																							
		00:00-04:00				04:00-08:00				08:00-12:00				12:00-16:00				16:00-20:00				20:00-24:00			
SSMIS	F16					X										X									
	F17						X												X						
	F18									X									X						
MHS	MetOp-A									X		X									X				
	MetOp-B										X											X			
	NOAA18					X											X								
	NOAA19			X									X		X										
AMSR2	GCOM-W		X											X											
ATMS	NPOESS	X	X										X												
GMI	GPM	X								X															
		X X	X X	X		X X	X			X X X	X	X	X X	X	X	X	X		X X		X	X			

11 October 2014, SSMIS F16

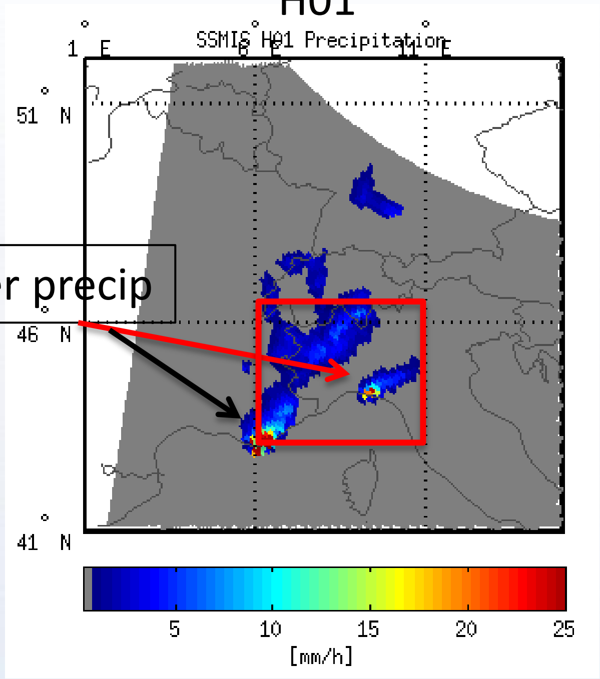
H SAF
Support to Operational Hydrology and Water Management

High potential of PMW products to detect heavy precipitation area, convective cores, etc.

0542 UTC



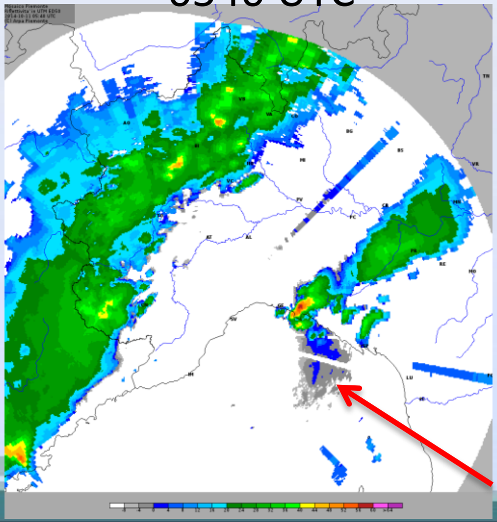
H01



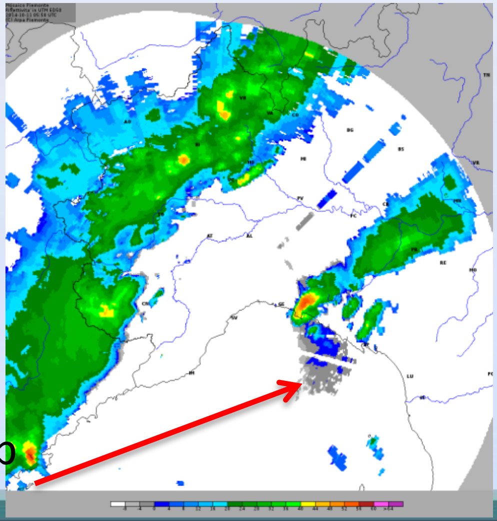
Higher precip

Radar Composite Lowest Beam Reflectivity

0540 UTC



0550 UTC



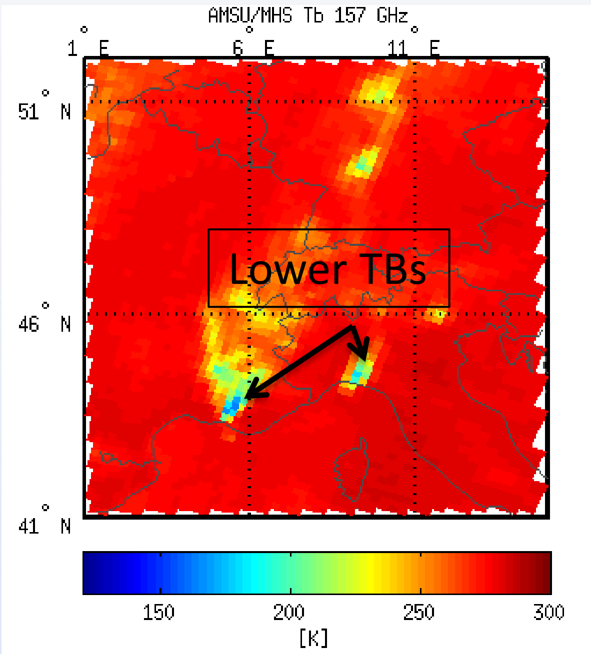
2nd trip signal

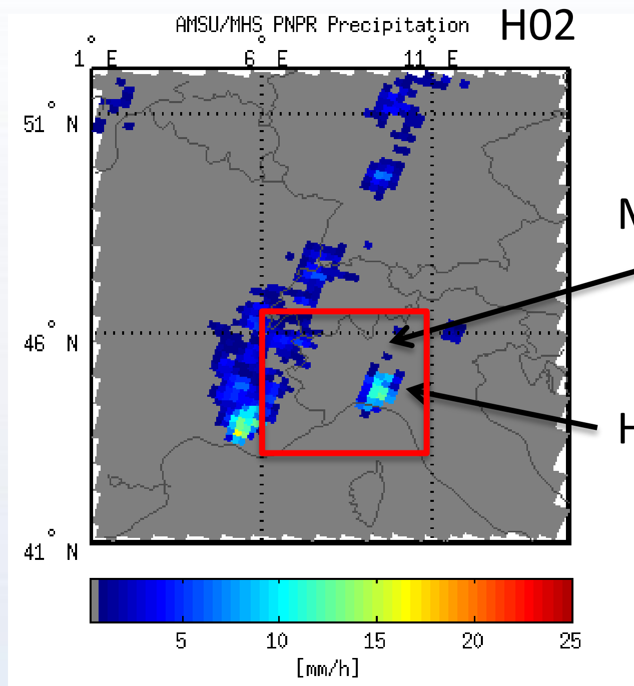
Courtesy of ARPA Piemonte

H SAF
Support to Operational Hydrology and Water Management

11 October 2014, AMSU/MHS

0214 UTC



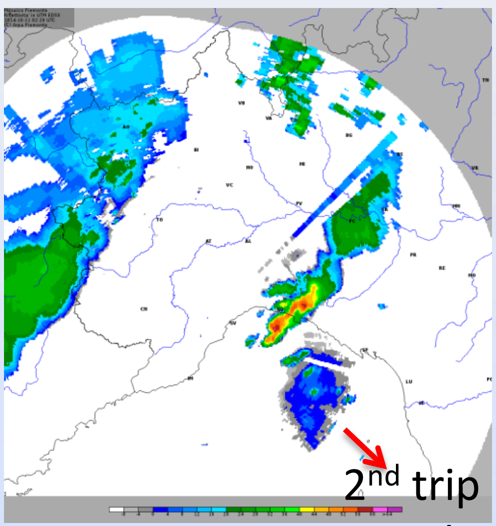


Missed light precip

Higher precip

0220 UTC

Radar Composite LBR



2nd trip signal

Courtesy of ARPA Piemonte

Future PMW temporal sampling in H-SAF

Example for Genoa Flood 11 October 2014

2014/10/11							
		00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00
SSMIS	F16		X		X		
	F17		X			X	
	F18			X		X	
MHS	MetOp-A			X X		X	
	MetOp-B			X			X
	NOAA18		X		X		
	NOAA19	X		X	X		
AMSR2	GCOM-W	X			X		
ATMS	NPOESS	X X		X			
GMI	GPM	X		X			

X X	X X	X		X X	X			X X X	X	X	X X	X	X	X	X		X X		X	X			

Very promising, but for near real-time applications there is the need to reduce latency and rely on combined MW/IR techniques

H SAF
Support to Operational Hydrology and Water Management

Summary

- PMW products offer the best estimates for extreme events
  - The exploitation of GPM constellation of PMW radiometers will provide higher temporal sampling
  - Instrinsic limitations of PMW precipitation retrieval must be considered
- IR/MW (H03, H05) techniques are needed for real-time applications and to fill gaps between MW overpasses
  - Look at the number of recent MW overpasses available (quality flag)
  - Check for strong discontinuities in the IR/MW precipitation
- Cumulated precipitation product available in quasi-real time can be used for hydrological applications:
  - 3-6-12-24 h cumulated precipitation
  - 24 h cumulated precipitation from MW only products
- Always consider lightning data, ground radar, and rain gauges if available

Thanks to …

De Leonibus Luigi[1], Francesco Zauli[1], Daniele Biron[1], Davide Melfi[1], Antonio Vocino[1],
Dietrich Stefano[2], Casella Daniele[2], Sanò Paolo[2],
Levizzani Vincenzo[3], Cattani Elsa[3],Laviola Sante[3],
Massimiliano Sist[4], Michele De Rosa[4], Matteo Picchiani[4] ,
Puca Silvia[5] , Gianfranco Vulpiani[5], Federico Porcù[6],
Flavio Gattari[7], Emiliano Agosta[7] , Roberto Rinaldi[7]
all the H-SAF Precipitation Product Validation Team
and the NASA PMM Science Team

1 - Centro Nazionale di Meteorologia e Climatologia Aeronautica/Ufficio Generale Spazio Aereo e Meteorologia (USAM)
2 - Istituto di Scienze dell'Atmosfera e del Clima (ISAC) / Consiglio Nazionale delle Ricerche (CNR), Roma
3 - Istituto di Scienze dell'Atmosfera e del Clima (ISAC) / Consiglio Nazionale delle Ricerche (CNR), Bologna
4- GEO-K s.r.l.
5 - Dipartimento della Protezione Civile (DPC)/Presidenza del Consiglio dei Ministri
6 - University of Ferrara
7 - Telespazio

… and you for your attention!

Questions?

g.panegrossi@isac.cnr.it

Support to Operational Hydrology and Water Management

References for H-SAF precipitation products:

Casella D., G. Panegrossi, P. Sanò, A. Mugnai, E. A. Smith, G.J. Tripoli, S. Dietrich, M. Formenton, W.Y. Leung, A. Mehta, Transitioning from CRD to CDRD in Bayesian Retrieval of Rainfall from Satellite Passive Microwave Measurements: Part 2. Overcoming Database Profile Selection Ambiguity by Consideration of Meteorological Control on Microphysics. IEEE Trans. Geo. Rem. Sens., vol.51, no.9, 4650-4671, 2013 doi: 10.1109/TGRS.2013.225816

Casella D., Panegrossi G., Sanò P., L. Milani, Petracca M., S. Dietrich, A novel algorithm for detection of precipitation in tropical regions using PMW radiometers, Atmos. Meas. Tech. Disc., doi:10.5194/amtd-7-9237-2014

Laviola, S., and V. Levizzani: The 183-WSL fast rainrate retrieval algorithm. Part I: Retrieval design. Atmos. Res., 99, 443-461, 2011.

Laviola, S., V. Levizzani, E. Cattani, and C. Kidd: The 183-WSL fast rainrate retrieval algorithm. Part II: Validation using ground radar measurements. Atmos. Res., 134, 77-86, 2013.

Mugnai, A., Smith, E.A., Tripoli, G.J., Bizzarri, B., Casella, D., Dietrich, S., Di Paola, F., Panegrossi, G., and Sanò, P.: CDRD and PNPR satellite passive microwave precipitation retrieval algorithms: EuroTRMM / EURAINSAT origins and H-SAF operations, Nat. Hazards Earth Syst. Sci., 13, 887–912, doi: 10.5194/nhess-13-887-2013, 2013.

Mugnai, A., Casella, D., Cattani, E., Dietrich, S., Laviola, S., Levizzani, V., Panegrossi, G., Petracca, M., Sanò, P., Di Paola, F., Biron, D., De Leonibus, L., Melfi, D., Rosci, P., Vocino, A., Zauli, F., Puca, S., Rinollo, A., Milani, L., Porcù, F., and Gattari, F.: Precipitation products from the Hydrology SAF, Nat. Hazards Earth Syst. Sci., 13, 1959–1981, 2013.

Panegrossi G., D. Casella, S. Dietrich, P. Sanò, M. Petracca, and A. Mugnai, A verification study over Europe of AMSU-A/MHS and SSMIS passive microwave precipitation retrievals, Proc. 2013 Joint EUMETSAT/AMS EUMETSAT Meteorology Satellite Conference, Vienna, Austria, 2013

Panegrossi G., D. Casella, S. Dietrich, A. C. Marra, L. Milani, M. Petracca, P. Sanò, and A. Mugnai, CDRD and PNPR passive microwave precipitation retrieval algorithms: extension to the MSG full disk area, , Proc. 2014 EUMETSAT Meteorology Satellite Conference, Geneva, Switzerland, 2014

Sanò P., D. Casella, A. Mugnai, G. Schiavon, E.A. Smith, G.J. Tripoli, Transitioning from CRD to CDRD in Bayesian Retrieval of Rainfall from Satellite Passive Microwave Measurements: Part 1. Algorithm Description and Testing. IEEE Trans. Geo. Rem. Sens., vol. 51, no. 7, 4119-4143, july 2013, doi: 10.1109/TGRS.2012.2227332.

Sanò P., Panegrossi G., D. Casella, Di Paola F., L. Milani, A. Mugnai, Petracca M., S. Dietrich, The Passive microwave Neural network Precipitation Retrieval (PNPR) algorithm for AMSU/MHS observations: description and application to European case studies, Atmos. Meas. Tech. Disc. , doi:10.5194/amtd-7-1-2014.

Smith E.A., et al.. Transitioning from CRD to CDRD in Bayesian Retrieval of Rainfall from Satellite Passive Microwave Measurements: Part 3. Identification of Optimal Meteorological Tags. Nat. Hazards Earth Syst. Sci, 13, 1185–1208, 2013

Forecast situation:
Convection in remote region with potential flash flooding

Which satellite precipitation product would you choose?

Want rapid time sampling → geostationary imagery

Blended IR+microwave (H03) (better than IR-only)

Forecast situation:
Tropical storm moving onshore

Which satellite precipitation product would you choose?

Rapid time sampling perhaps less critical

High temporal sampling from PMW
Over the ocean microwave-only may be better than blended IR+microwave

Forecast situation:
Mid-latitude cold front moving onshore

Which satellite precipitation product would you choose?

Want good time sampling → geostationary imagery

Blended IR+microwave better than IR-only

The models generally handle this situation quite well – you might want to use satellite estimates for verification

Forecast situation:

Shallow rain showers moving onshore

Which satellite guidance would you choose?

NONE!! (or PMW if not over the coast)

Reasons:

- IR algorithms only expect rain in deep systems
- Although microwave instruments can measure warm rain over the sea, at low frequencies the microwave footprint is to big to "see" small-sized showers – You might see rainfall over sea

Forecast situation:
Orographic rainfall in the mountains

Which satellite guidance would you choose?

None, unless convection also developed

Reasons:

- IR algorithms only expect rain in deep systems
- Over land microwave instruments cannot measure rain from warm-topped clouds.