# Characterization and monitoring of heavy precipitation events in the Mediterranean area using the H-SAF precipitation products

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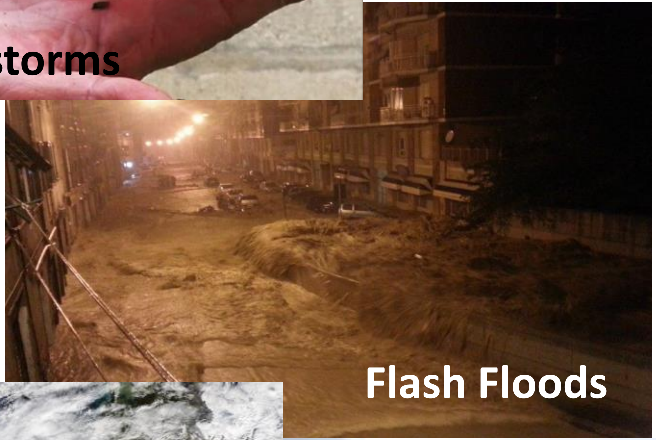
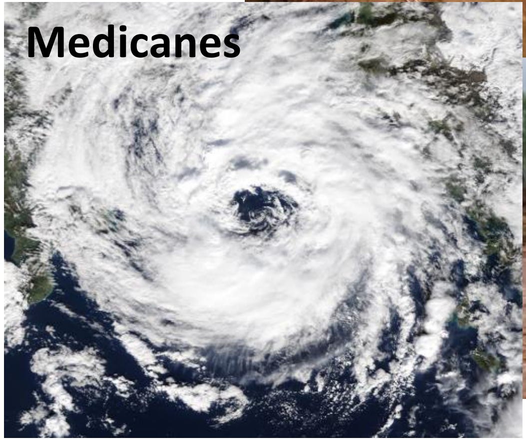
# Introduction

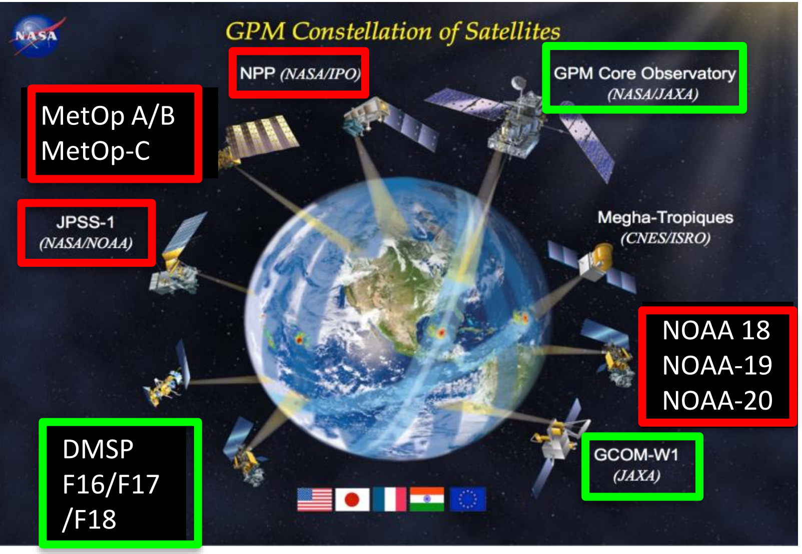
- The Mediterranean area is recognized as a climatic "hot spot": many interactions and feedbacks between oceanic, atmospheric and hydrological processes;
- Understanding link of these processes to extreme weather in a changing climate is essential for the environmental and socio-economic prosperity of the region;
- Extreme weather events often *originate off-shore* (no ground-based observations) and are often difficult to predict (e.g., fast developing deep convective systems);
- The improving global multi-mission EO technology provides today a unique potential to observe, describe, and monitor the evolution of these systems and of **precipitation** in such complex region


# The Global Precipitation Measurement mission

*https://pmm.nasa.gov/gpm*




*International effort* with 13 LEO satellites  equipped with 6 different microwave **(MW) radiometers (10-200 GHz)** + DPR (Ku and Ka band) (+ *CloudSat CPR W-band*)

3-h global coverage (1.5-h over the Mediterranean region, on average);

**Golden-era for remote sensing of precipitation:**

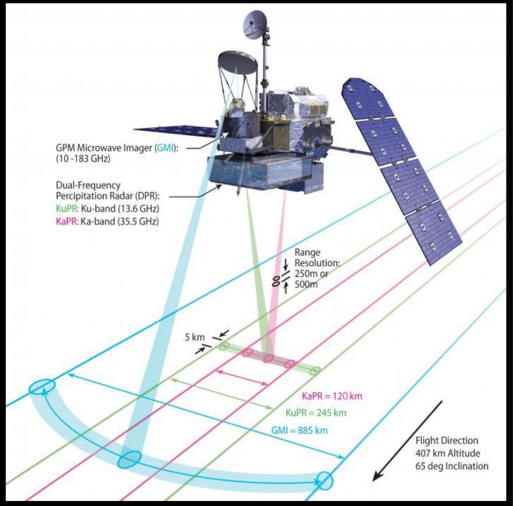
- *Advancement of global* precipitation products through the exploitation of global active/passive MW observational datasets

- **Analysis of extreme events (e.g., Mediterranean area)** (3D structure of precipitation, understand processes, improve forecast, hydrological applications);

## THE NASA/JAXA GPM CORE OBSERVATORY

**GPM Microwave Imager (GMI)**: 13 precipitation sensing channels (10-183 GHz) with the highest spatial resolution available (5-30 km);

**Dual-frequency Precipitation Radar (DPR)** (Ku and Ka band)



# EUMETSAT H SAF and GPM

**Scientific collaboration proposal on precipitation algorithm development and validation activity**

endorsed by EUMETSAT and the NASA PMM Research Program
(2014-present)

## H SAF Precipitation products

1) Exploitation of current (GPM) and future (EPS-SG) PMW radiometers (conically and cross-track scanning) on board LEO satellites, offering the most complete set of satellite based observations to retrieve surface precipitation
   - **PMW Level 2 precipitation rate products**
   - **MW-based Level 3 products (on a regular grid, e.g., daily, monthly estimates)**

2) Combination of LEO MW estimates and GEO IR observations (MSG and MTG) for NRT precipitation monitoring and applications to benefit from physical robustness of MW and space/time resolution of IR:
   - **MW/IR products (precipitation rate and accumulated)**

# Objectives

- Investigate to what extent spaceborne MW radiometers in the GPM era can be exploited to characterize and monitor the evolution of heavy precipitation systems in the Mediterranean area throughout their evolution
- Assess H SAF precipitation product quality, and evidence their strengths and weaknesses for different precipitation structures and regimes

# H-SAF Precipitation Products used

| Product ID | Algorithm Description | Currently available satellites | References |
|---|---|---|---|
| H01 | CDRD (Bayesian) for conically scanning **SSMIS** | DMSP F16/F17/F18 | Casella et al., 2013, Sanò et al., 2013, IEEE TGRS |
| H02B | PNPR (ANN) for cross-track scanning **AMSU/MHS** | MetOp-A/B (MetOp-C)<br>NOAA-18/19 | Sanò et al., 2015, AMT |
| H18 | PNPR (ANN) for cross-track scanning **ATMS** | Suomi NPP / NOAA-20 | Sanò et al., 2016, AMT |
| H-AUX-17 | CDRD (Bayesian) for conically scanning **AMSR2 (GPM-based a priori database)** | GCPOM W1 | Casella et al., 2017, IEEE JSTARS |
| H-AUX-20 | PNPR (ANN) for conically scanning **GMI (Global) (GPM-based training database)** | GPM | Sanò et al., 2018, Rem. Sens. |

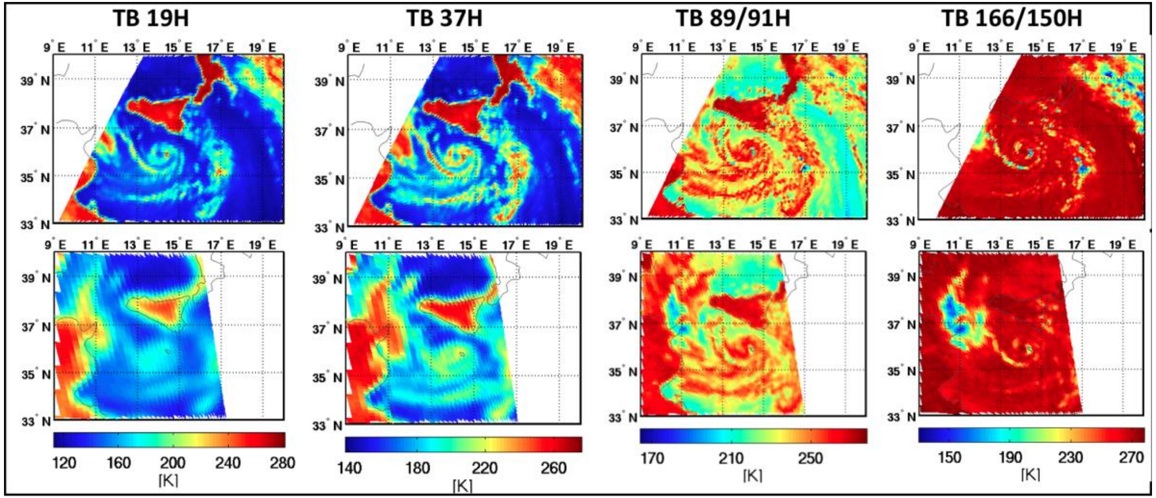
PMW Operational
PMW Auxiliary
MW Level 3
MW/IR

# Medicane Qendresa – November 7, 2014 15:40 UTC

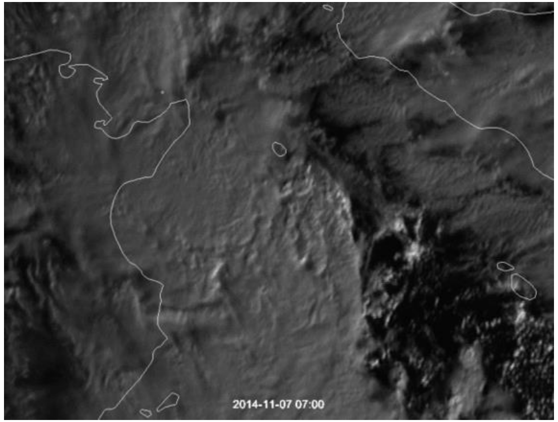
Coincident GMI and SSMIS overpasses

GMI

SSMIS




Effect of higher spatial resolution of GMI
(IFOV size 11x18 km$^2$ at 19 GHz, and 4x7 km$^2$ above 89 GHz)
SSMIS spatial resolution is three times lower




Met-10 HRV SEVIRI imagery, 7 Nov 07:00–11:45 UTC (Qendresa over Lampedusa Island)

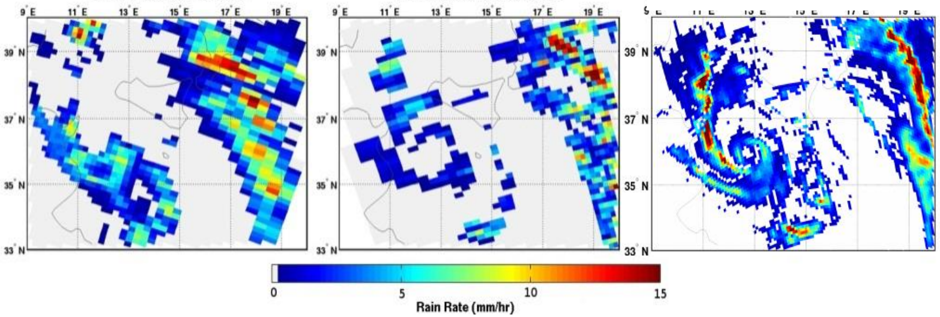
***Panegrossi et al., 2016***: *Use of the GPM constellation for monitoring heavy precipitation events over the Mediterranean region, IEEE JSTARS, DOI: 10.1109/JSTARS.2016.2520660*

# Medicane Qendresa November 7-8, 2014

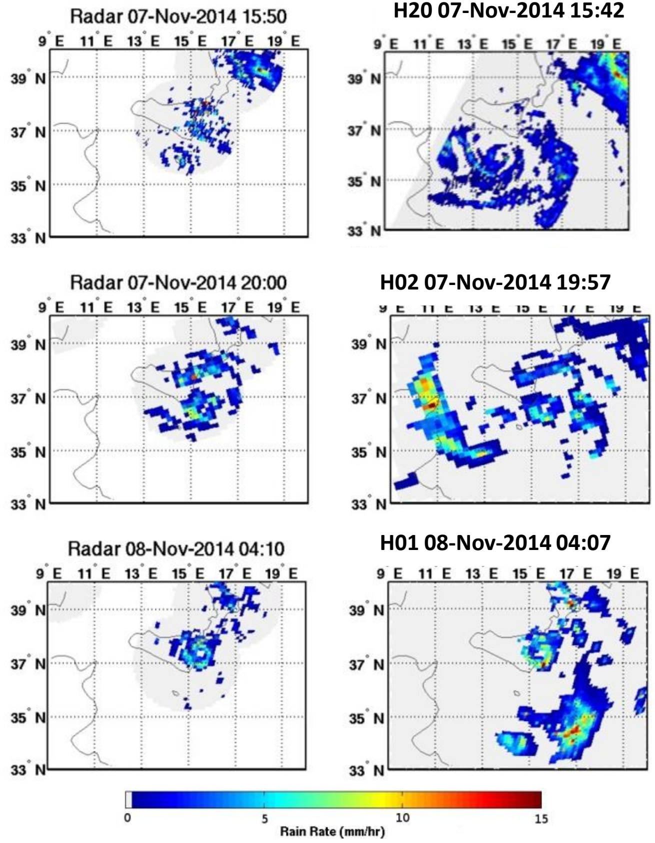
**23 overpasses by PMW radiometers available**

**MHS** | **ATMS** | **AMSR2**

H02 07-Nov-2014 09:25 | H18 07-Nov-2014 11:42 | H17 07-Nov-2014 12:07




| | H01 (SSMIS) | H02 (AMSU/MHS) |
|---|---|---|
| **POD** | 0.76 | 0.76 |
| **FAR** | 0.32 | 0.21 |
| **ME (mm/h)** | 1.00 | 0.55 |
| **CC** | 0.61 | 0.65 |




**GMI**

**MHS**

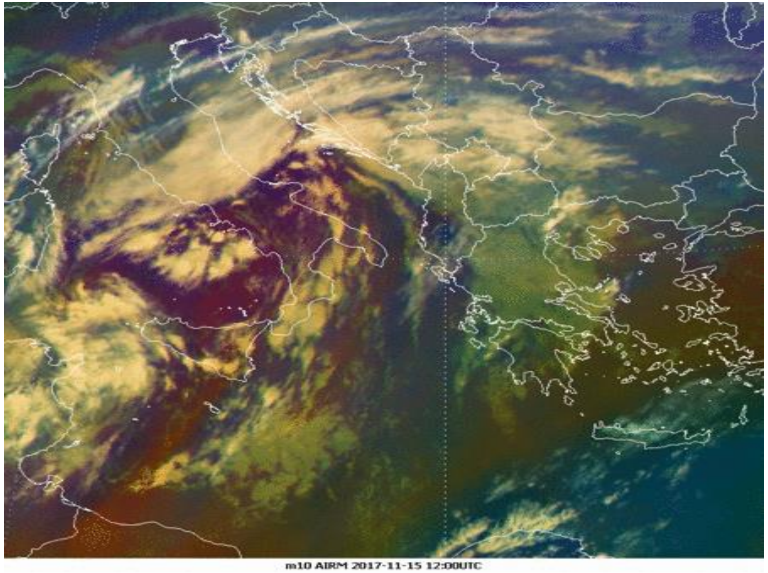
**SSMIS**

Comparison with rainfall rate estimates from Buccheri (Siracusa, Sicily) C-band Polarimetric radar (DPC)

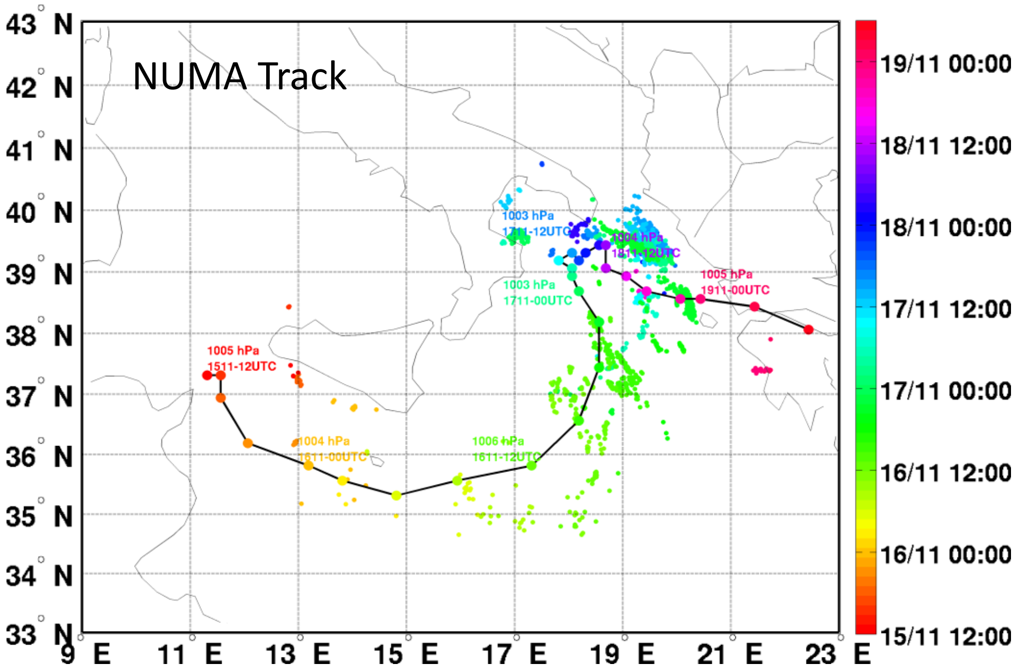
*Panegrossi et al., 2016 IEEE JSTARS*

# MEDICANE NUMA 15-19 November 2017

Evolution of Numa in the sequence of Meteosat-10 Airmass RGBs




Source: https://www.eumetsat.int/




ECMWF minimum mslp and total LINET strokes within a 200 km radius from the minimum in 1 hour

**Marra, A. C., et al., 2019:** The Precipitation Structure of the Mediterranean Tropical-Like Cyclone Numa: Analysis of GPM Observations and NumericalWeather Prediction Model Simulations, Remote Sens. doi:10.3390/rs11141690, 2019

# Numa observed by the GPM constellation

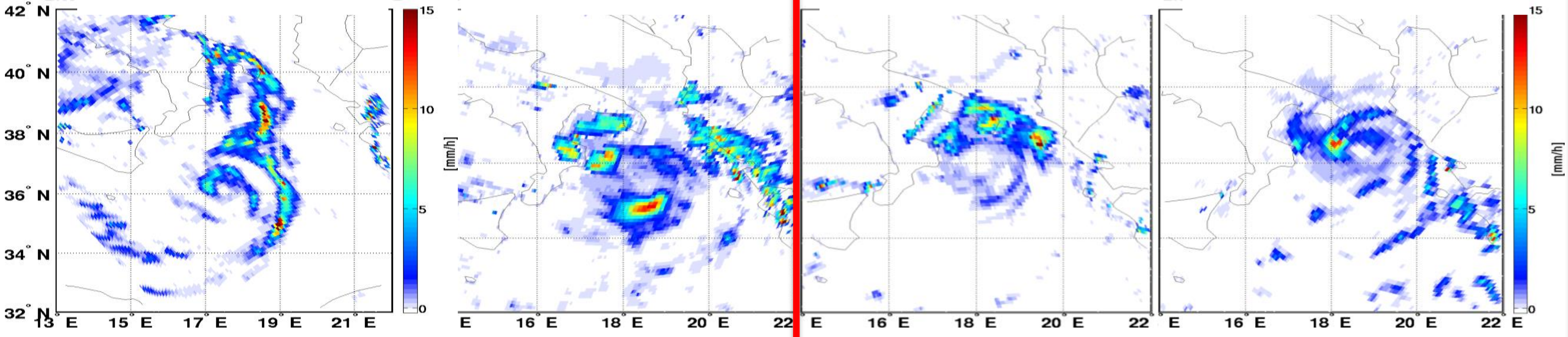
**53 overpasses between 15 Nov  12 UTC and 19 Nov 12 UTC**
**15 overpasses during TLC-phase (17 Nov 12 UTC - 18 Nov 12 UTC)**

**GMI**
**16-Nov-2017**
**13:49 UTC**

**AMSR2**
**17-Nov-2017**
**00:51 UTC**

**AMSR2**
**17-Nov-2017**
**11:55 UTC**

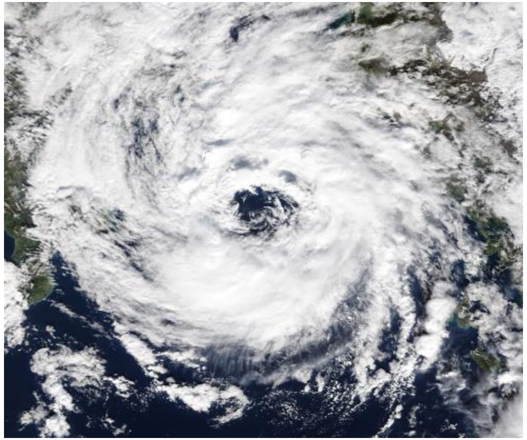
**GMI**
**18-Nov-2017**
**03:59 UTC**




*Marra et al., 2019, Rem. Sens.*

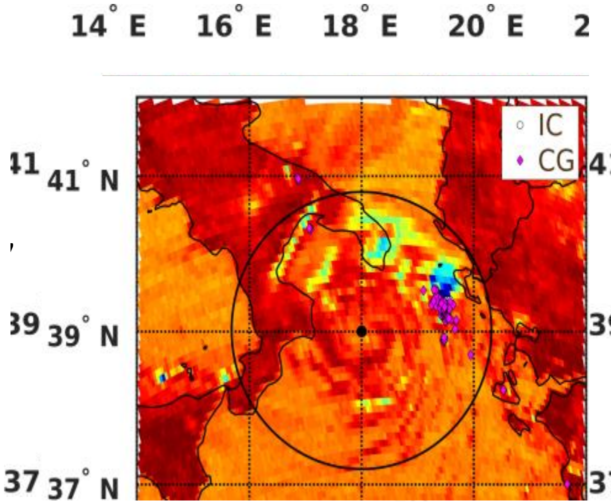
# Medicane NUMA: Mature phase

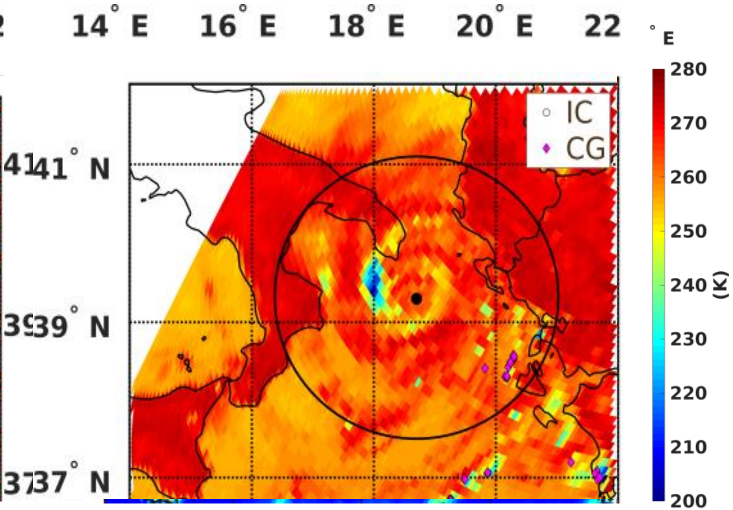
MODIS/Aqua
17 Nov 2017
12:00 UTC



MODIS/Terra
18 Nov 2017
10:30 UTC.

AMSR2 TBs
89 GHz (V)
17 Nov 2017
11:55 UTC




GMI TBs
89 GHz (V)
18 Nov 2017
03:59 UTC

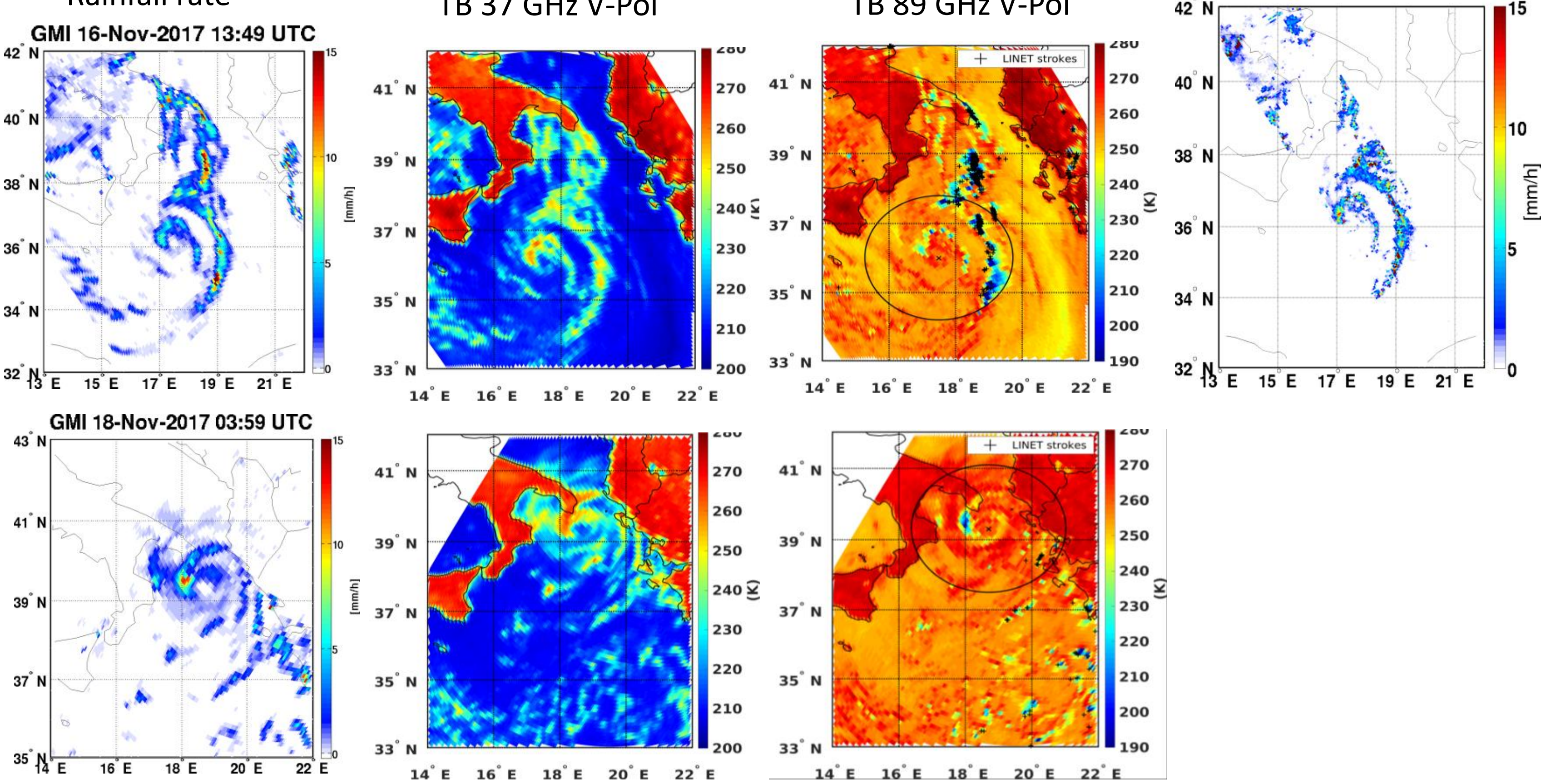
*(Marra et al., 2019, Rem. Sens.)*

# NUMA: GPM overpasses

Rainfall rate | TB 37 GHz V-Pol | TB 89 GHz V-Pol | 2A-DPR NS (Ku band)

**GMI**
16 Nov
13:49 UTC
**Initial phase**

**GMI**
18 Nov
03:59 UTC
**Mature (TLC) phase**




*Marra et al., 2019, Rem. Sens.*

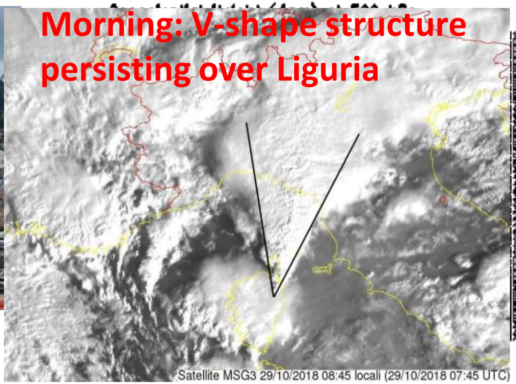
# Italy October 2018 event

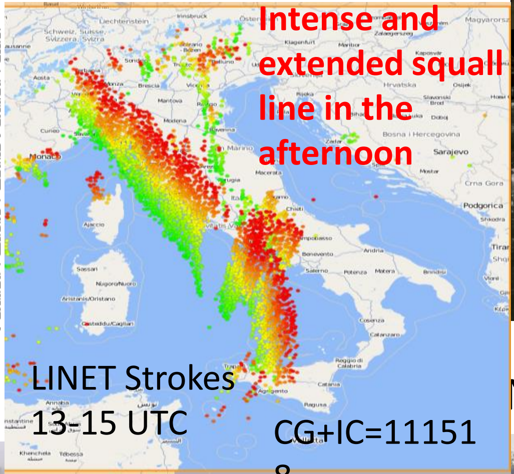
Between 27-29 October 2018: typical autumn synoptic pattern over the western Mediterranean responsible for one of the most severe weather events over Italy in the last century

Hundreds of mm of rainfall (over 250 mm in 24 hours, over 600 mm in 72 hours) were registered in several locations (peaks in the Eastern Alpine region)

Deep cyclone, MSLP around 978 hPa, localized for over 24 hours in the N Tyrrhenian Sea

Rapallo, Liguria


8

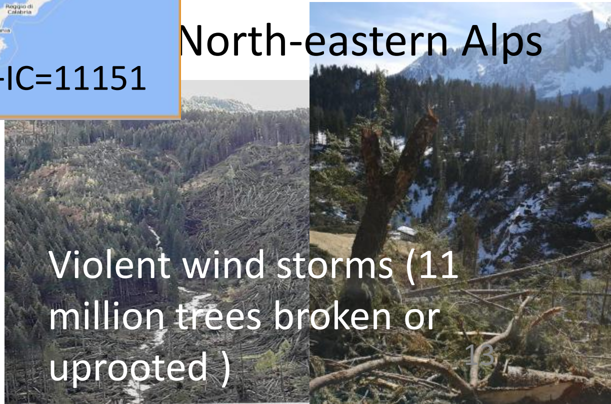
Venice

UTC

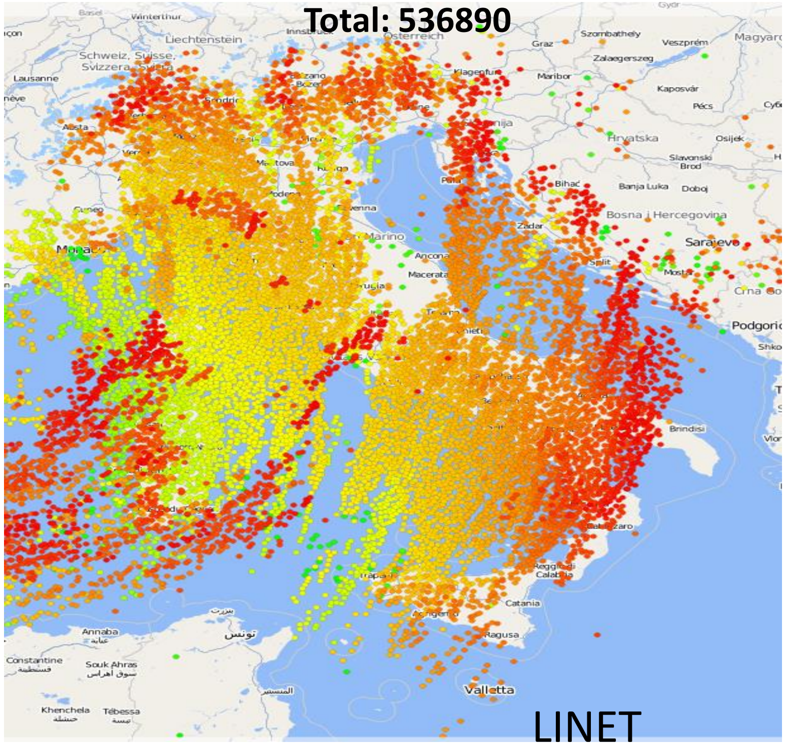
Terracina, Lazio


Pontremoli, Tuscany


North-eastern Alps



# Italy 29 October 2018

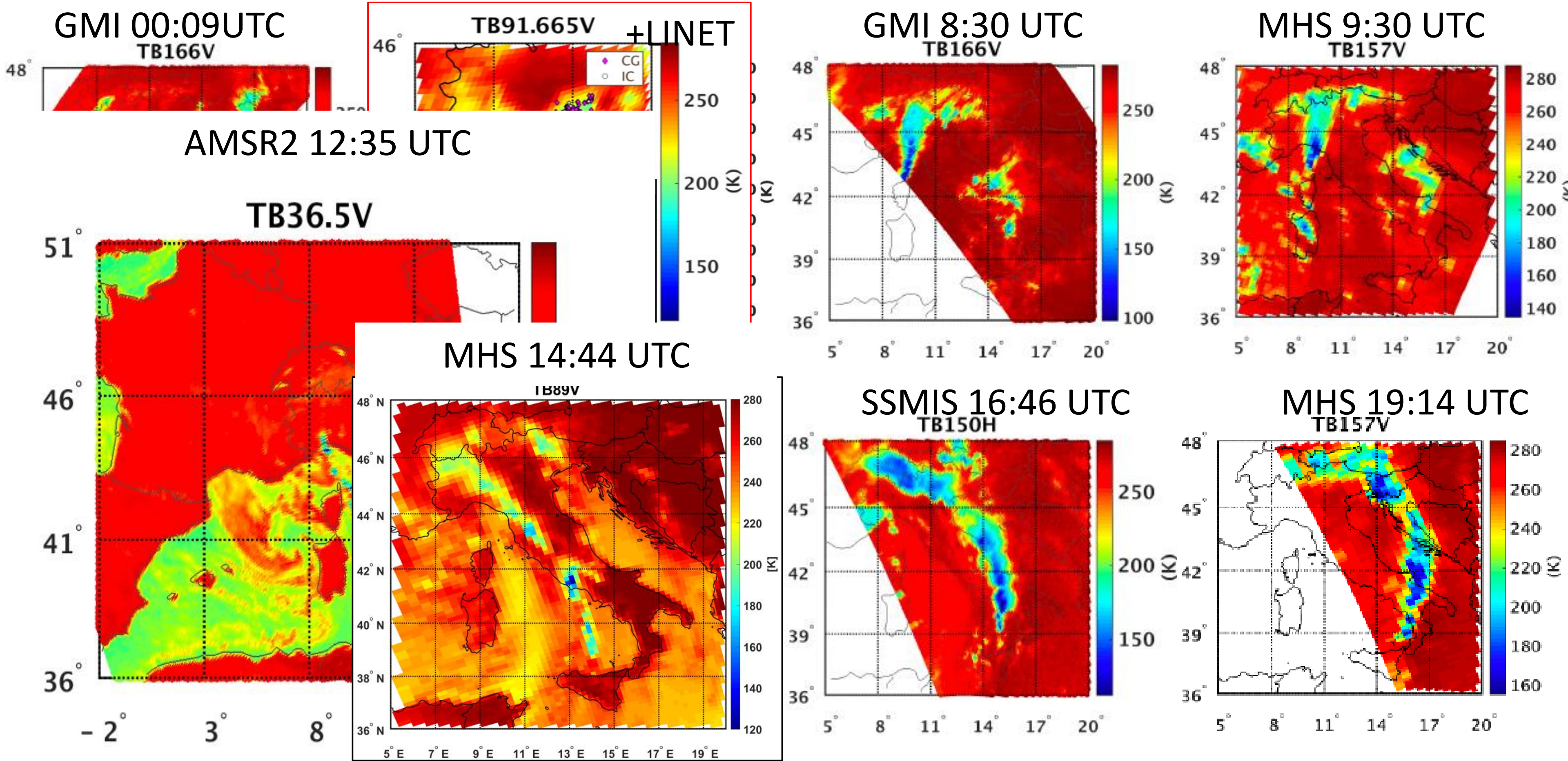



LINET
Strokes 00-24 UTC

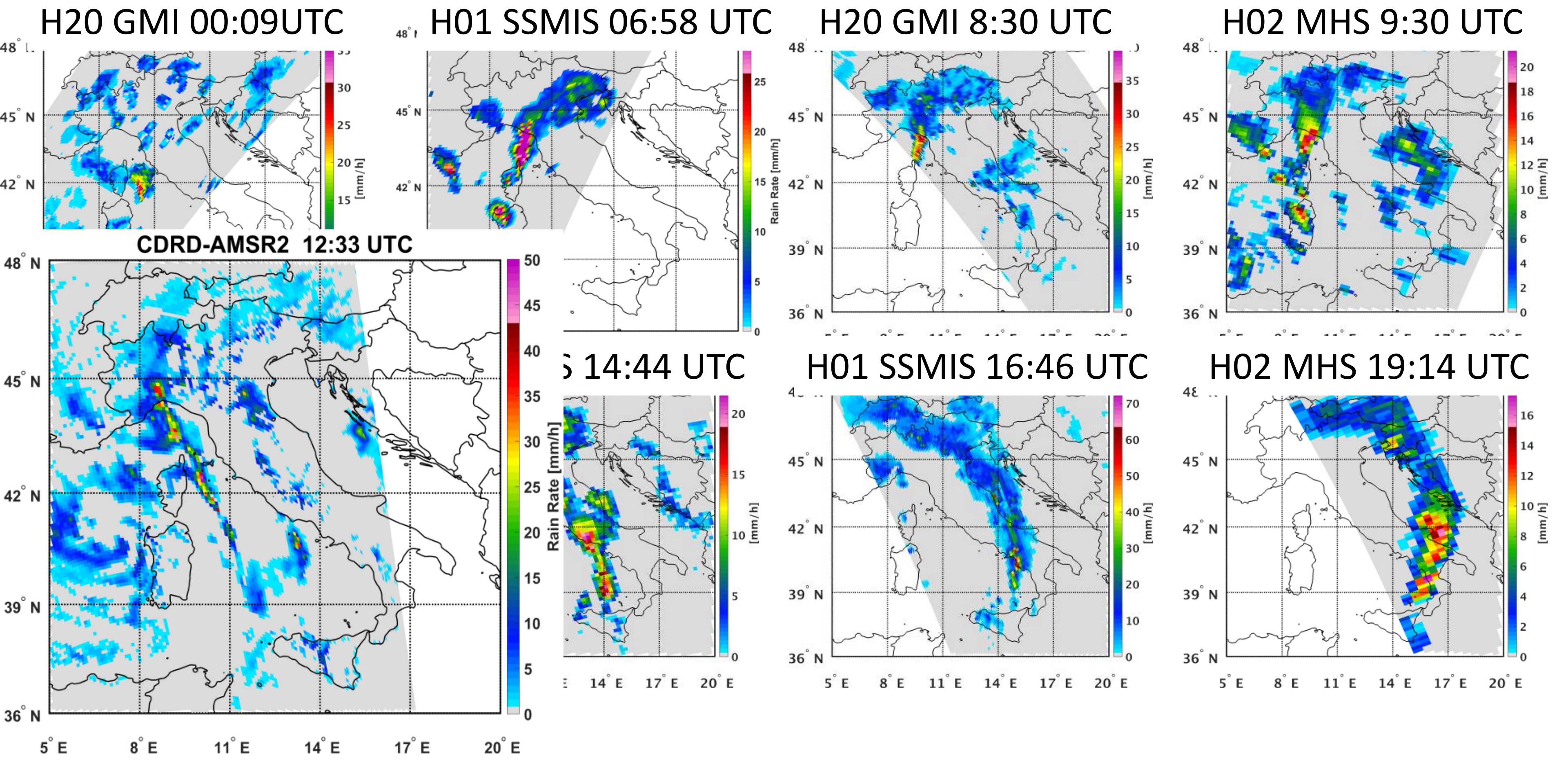
## List of GPM constellation MW Radiometer overpasses

| Time (UTC) | GMI | SSMIS | AMSR2 | MHS | ATMS | All |
|---|---|---|---|---|---|---|
| 00:00/01:00 | X | | | | | X |
| 01:00/02:00 | | | X | | | X |
| 02:00/03:00 | | | | | | |
| 03:00/04:00 | | X | | | | X |
| 04:00/05:00 | | XX | | | | XX |
| 05:00/06:00 | | X | | | | X |
| 06:00/07:00 | | X | | | | X |
| 07:00/08:00 | | | | X | | X |
| 08:00/09:00 | X | | | XX | | XXX |
| 09:00/10:00 | | | | X | | X |
| 10:00/11:00 | | | | | | |
| 11:00/12:00 | | | | | X | X |
| 12:00/13:00 | | | X | | X | XX |
| 13:00/14:00 | | | | | | |
| 14:00/15:00 | | XX | | | | XX |
| 15:00/16:00 | | X | | | | X |
| 16:00/17:00 | | X | | | | X |
| 17:00/18:00 | | X | | | | X |
| 18:00/19:00 | | | | X | | X |
| 19:00/20:00 | | | | XX | | XX |
| 20:00/21:00 | | | | X | | X |
| 21:00/22:00 | | | | | | |
| 22:00/23:00 | | | | | | |
| 23:00/00:00 | X | | | | | X |

# 29 October 2018 event monitored by some GPM constellation MW radiometers: measurements



# 29 October 2018 event monitored by some GPM constellation MW radiometers: HSAF precipitation rate products

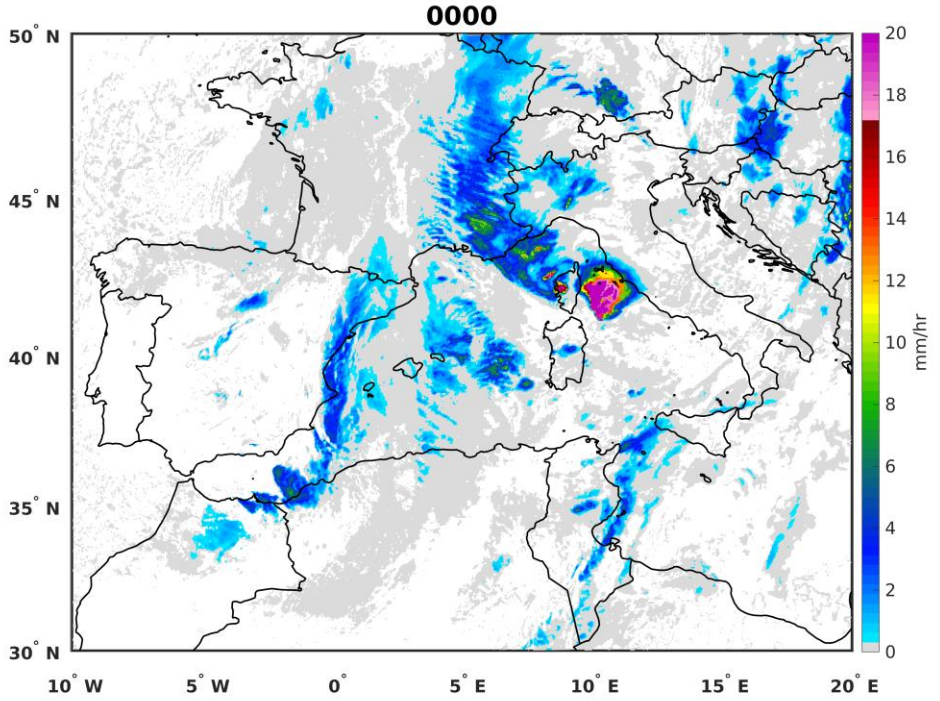


# MW-IR combined product Evolution of Precipitaion rate on 29 October 2018

**H03 HSAF Product:**
MW/IR Rapid Update Technique: Precipitation rate (mm/h) estimated from GEO IR observations calibrated in NRT with MW precipitation rate estimates

- Spatial Resolution: SEVIRI IR (around 5 km)
- Temporal resolution: 15 min
- Available in NRT (after 20-30 min GEO observation time)

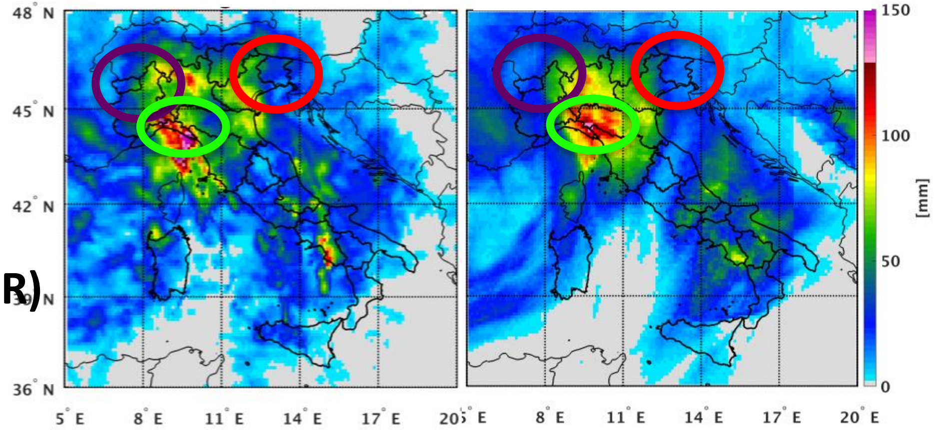
**H03 H SAF product – 29/10/2018 00:00-06:00 UTC**



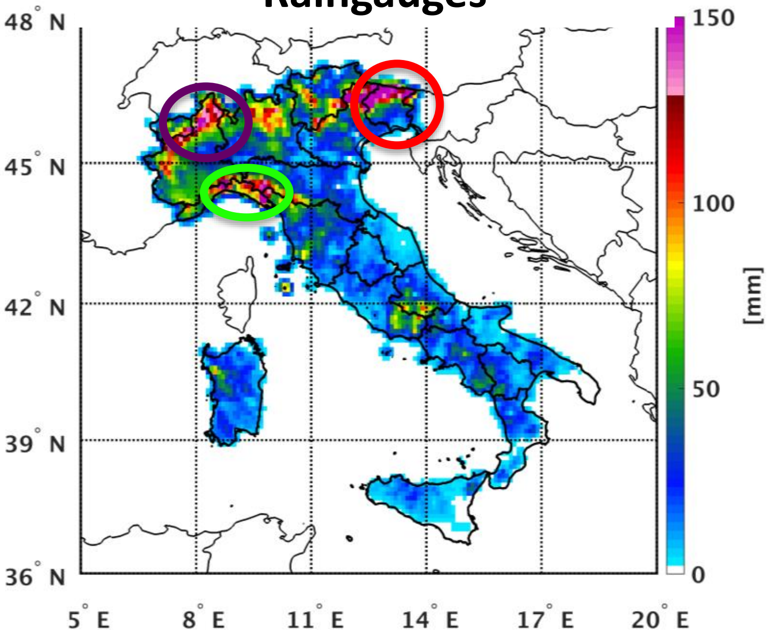
# Total (24 h) Precipitation on 29 October 2018

**HSAF products (ISAC-CNR)**

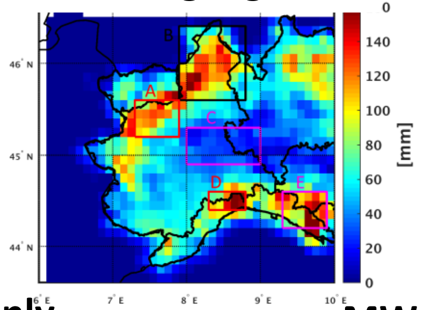
**MW-only (H67)** **MW/IR (H03)**

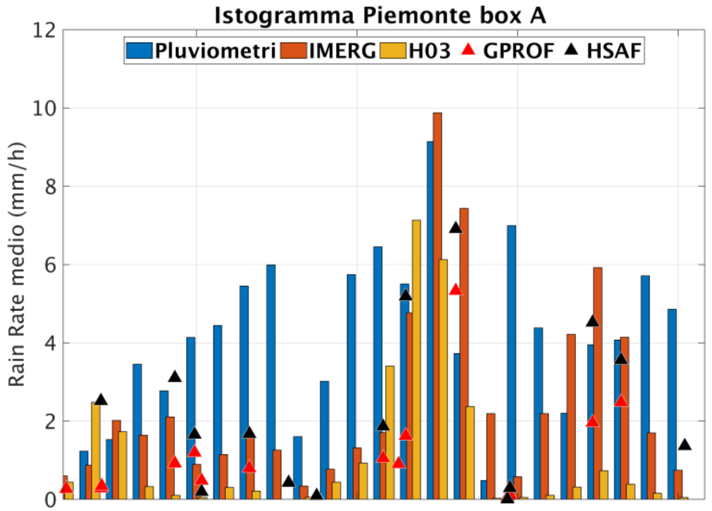



**Raingauges**



## Raingauges

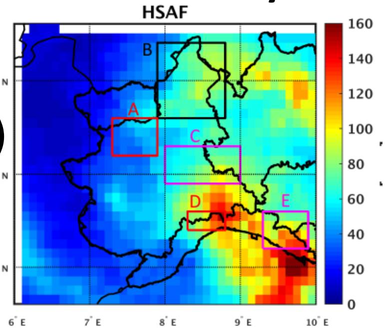


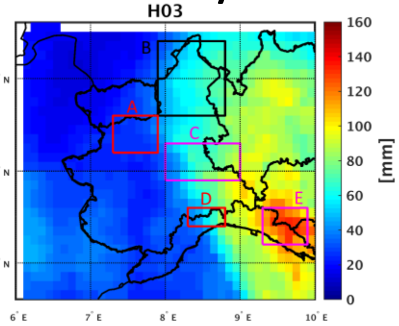



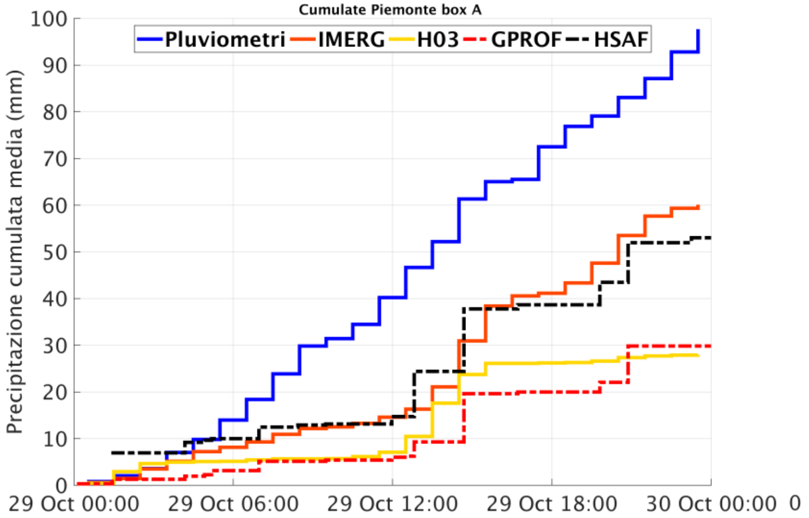

## MW-only

## MW/IR

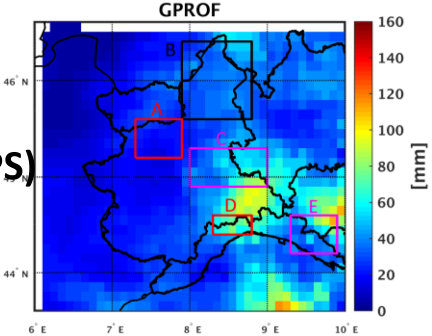
**HSAF (ISAC-CNR)**

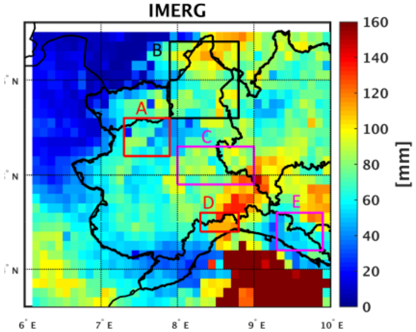



**GPM V05 (NASA PPS)**



# Concluding remarks

- The constellation of MW radiometers can be used for the analysis and monitoring of precipitation, to evidence distinct features as the systems evolve over the Mediterranean sea, and for QPE
  - ✓ The GPM constellation provides unprecedented temporal sampling and observation quality
- H-SAF precipitation products can be very effective towards the characterization and monitoring of heavy precipitation events in the Mediterranean region, also over coastal areas
  - ✓ Intrinsic limitations of PMW precipitation retrieval must be considered (e.g., orographic precipitation, warm rain)
  - ✓ Gaps between MW overpasses still affect the MW-based daily precipitation estimates
  - ✓ Comparison with NASA GPM global products reveal significant differences especially for localized, deep convective systems over coastal areas (H SAF in better agreement with ground-based measurements): global vs. regional products?
- IR/MW (e.g. HSAF H03, NASA IMERG) techniques are needed for real-time applications and operational applications (higher temporal and spatial resolution) but subject to larger uncertainties

# Future perspectives:
# need to maintain/improve precipitation EO system

It is fundamental to obtain ***accurate and continuous* observations of *global* precipitation** as one of the key variables involved in the energy and water cycles, and in weather extremes, and to monitor its evolution in a changing climate;

**Constellation concept**: need to maintain *the constellation of satellites equipped with MW radiometers with precipitation-sensing channels to be used in synergy with one (or more) spaceborne (multi-frequency) precipitation radar*

- *Future operational radiometers: U.S. JPSS ATMS,* ***EPS-SG MWI*** (ICI)***, MWS***
- *Cubesats*
- *EarthCare*

***Challenge****: reconcile differences among radiometers, and keep up with an ever-changing constellation (number and type of sensors, measurement quality and stability, etc.) also for climate applications*

**Work in progress:**

- *Snowfall (SLALOM, Rysman et al., 2018, 2019)*
- *Assimilation of DPR 3D reflectivity volumes and H SAF precipitation products over the Mediterranean Sea in NWP model to improve short-term precipitation forecast*

# THANK YOU

**Contact:** g.panegrossi@isac.cnr.it

## References

Marra, A. C., et al.: The Precipitation Structure of the Mediterranean Tropical-Like Cyclone Numa: Analysis of GPM Observations and NumericalWeather Prediction Model Simulations, Remote Sens. 2019, 11, 1690; doi:10.3390/rs11141690, 2019.

Marra A. C., et al.: Observational analysis of an exceptionally intense hailstorm over the Mediterranean area: Role of the GPM Core Observatory, Atmos. Res., 182, 72-90, doi: 10.1016/j.atmosres.2017.03.019, 2017

Panegrossi, G. et al.: Heavy precipitation systems in the Mediterranean area: The role of GPM. In: Satellite precipitation measurement.; Satellite precipitation measurement.; Springer.; V. Levizzani, C. Kidd, D. B. Kirschbaum, C. D. Kummerow, K. Nakamura, F. J. Turk, Eds.: Dordrecht, 2019, *in press*.

Panegrossi G.et al.,: Use of the GPM constellation for monitoring heavy precipitation events over the Mediterranean region, IEEE J. of Sel. Topics in Appl. Earth Obs. and Rem. Sens. (J-STARS), Volume 9, Issue 6, Pages: 2733 - 2753, doi: 10.1109/JSTARS.2016.2520660, 2016.

# Extra Slides

# PMW Sensor Characteristics in the GPM era

## Constellation microwave sensor channel coverage

V – Vertical Polarization  H – Horizontal Polarization

| 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**<br>**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)

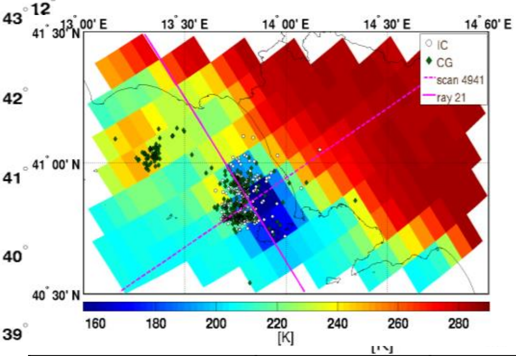
| Channel | 6 GHz | 10 GHz | 19 GHz | 23 GHz | 31/36 GHz | 50-60 GHz | 89/91 GHz | 150/166 GHz | 183 GHz |
|---|---|---|---|---|---|---|---|---|---|
| **SSMIS** | | | **59** | **59** | **36** | **22** | **14** | **14** | **14** |
| **MHS** | | | | | | | **17** | **17** | **17** |
| **AMSU-A** | | | |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

**Cross-track radiometers: resolution decreases along the scan**

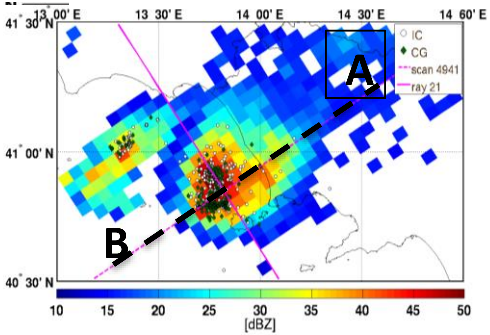
(Hou et al., 2015)

# Naples hailstorm 5 September 2015 (Marra et al., Atmos. Res., 2017)

GMI TB 19 GHz V-Pol




DPR-Ku Z (median)

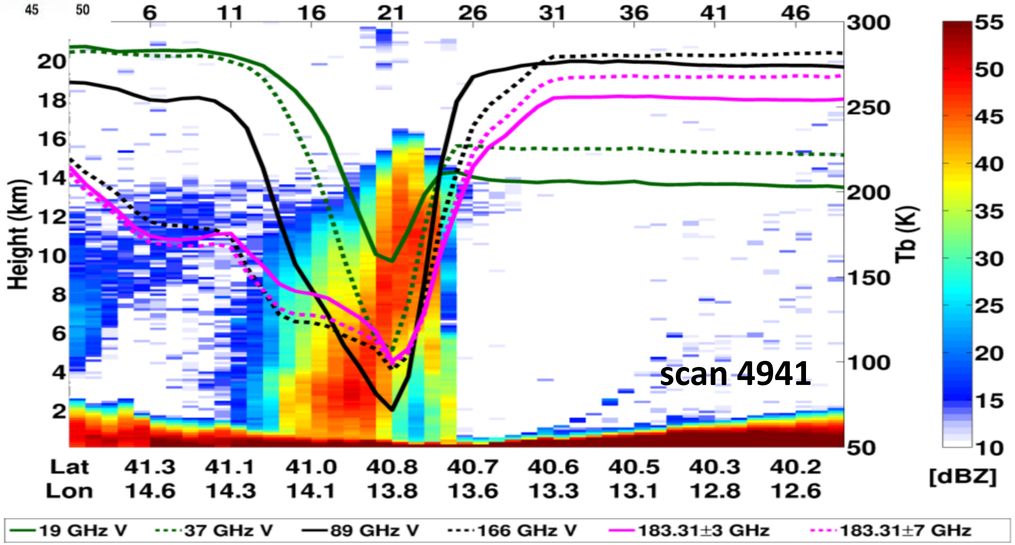




| GMI channels | TB/PCT Min value | Thresholds for hail detection (TRMM) (Cecil, 2009) |
|---|---|---|
| 18.7 GHz | 158 K | 230 K |
| 36.5 GHz | 100 K | 180 K |
| 89 GHz | 68 K | 70 K |

Extremely low values compatible with hailstone sizes larger than 7.5 cm

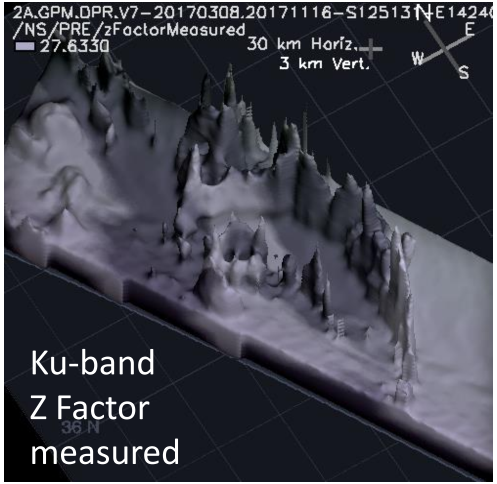
**(2nd lowest values recorded globally in GPM era, the lowest in Northern Hemisphere)**




TBs in all GMI MW channels evidence very rare features

DPR Ku-band echo top height: 40 dBZ at 14 km, 20 dBZ at 16 km

# NUMA: GPM-CO DPR overpass at initial phase




16 Nov 13:49 UTC