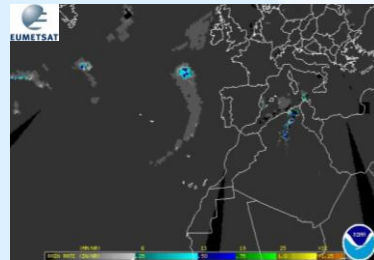


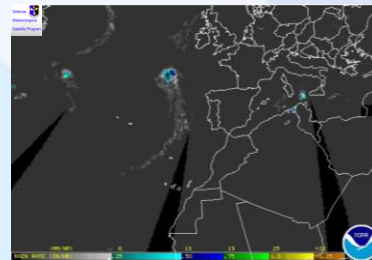
Satellite-Derived Rain Rate from Microwave Sensors Aboard Polar-Orbiting Satellites

Sheldon Kusselson
Retired, NOAA/NESDIS
Silver Spring, Maryland USA

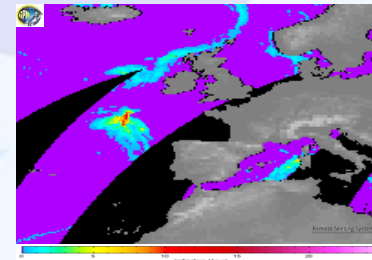
Contributions by
**Ralph Ferraro, Stanley Kidder,
John Forsythe, Limin Zhao,
Dustin Sheffler and Beth Ebert**



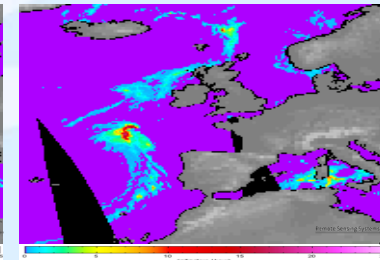
AMSU-B MHS Rain Rate



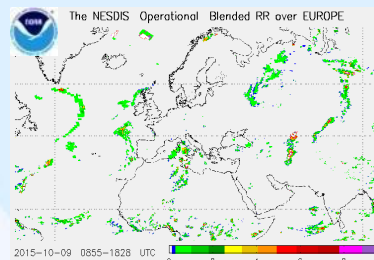
DMSP SSMIS Rain Rate



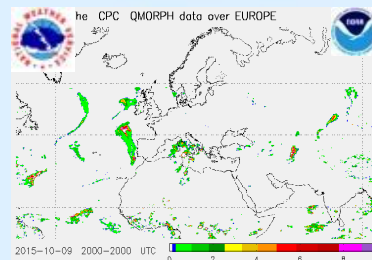
GPM GMI Rain Rate



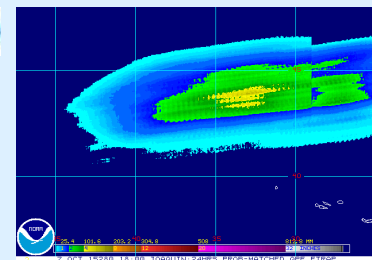
GCOM-W AMSR-2 Rain Rate



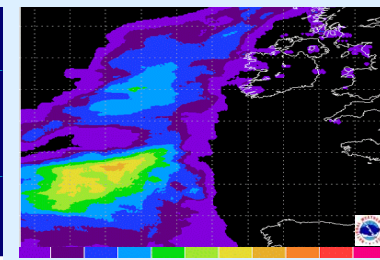
NOAA/ NESDIS Blended RR



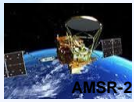
NOAA/ NWS QMORPH RR



NOAA/ NESDIS eTraP



QMORPH Rain Accumulation



EUMETSAT Precipitation Week

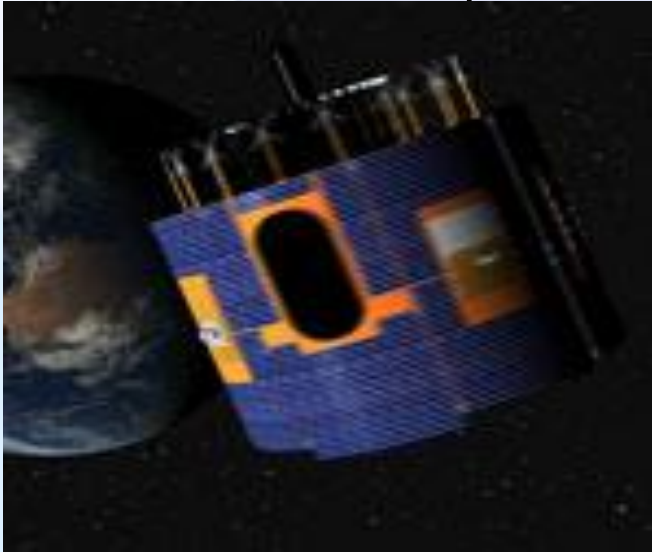
Session 3 - Microwave Sensors / Hydrologic Applications - 24 November 2015

Session Outline

- **Importance of Low Earth Orbiting (LEO) Microwave Rain Rate Products**
- **Operational and Research LEO Microwave (MW) Rain Rates (RR)**
- **Product from the LEO MW RR – eTRaP**
- **Blended MW RR Products and Applications**
- **A Couple of Heavy Rain/Flash Flood Cases**

No Single Satellite Can Do It All

Geostationary



Polar Orbiting Microwave



The Advantages

Higher resolution

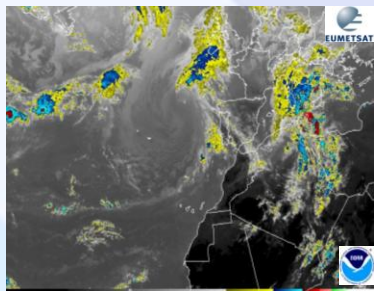
More timely

More frequent

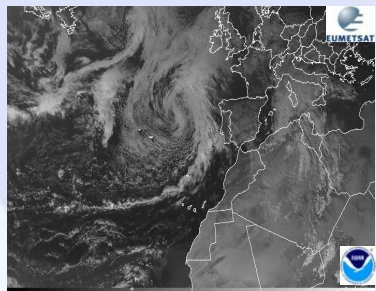
See through the clouds

Monitor the entire globe

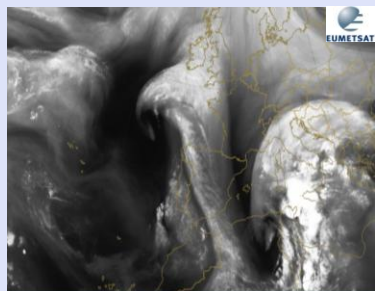
LEO MW RR to complement and/or supplement GEO and other LEO



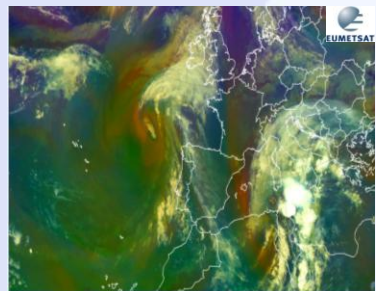
MSG IR



MSG Visible



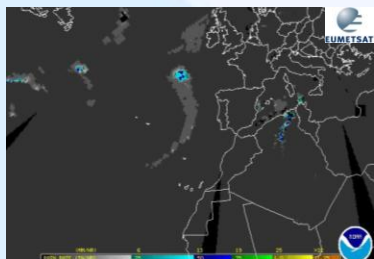
MSG Water Vapor



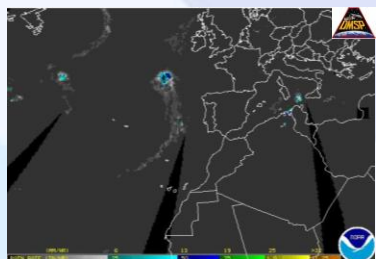
MSG Air Mass RGB

GEO

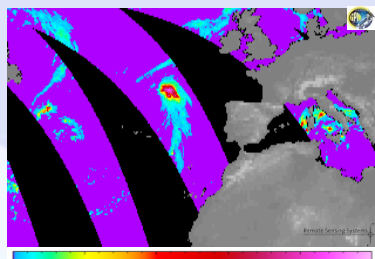
9 October 2015



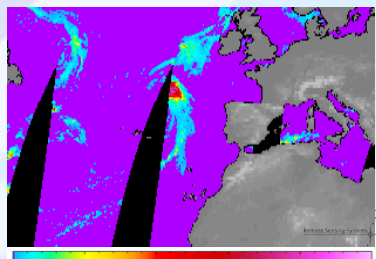
AMSU-B MHS Rain Rate



DMSPP SSMIS Rain Rate

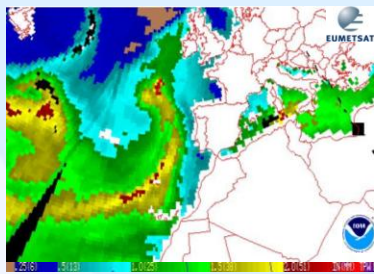


GPM GMI Rain Rate

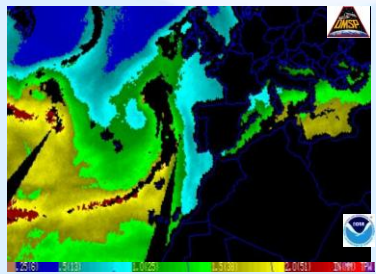


GCOM-W AMSR-2 Rain Rate

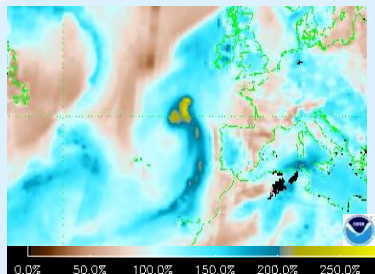
LEO



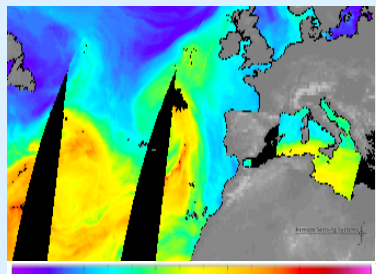
NOAA/METOP AMSU-A TPW



DMSPP SSMIS TPW



Percent of Normal TPW



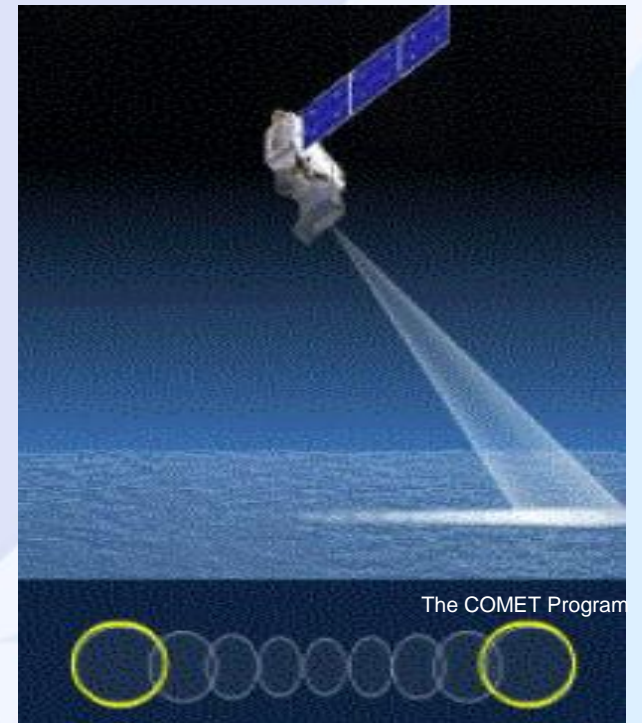
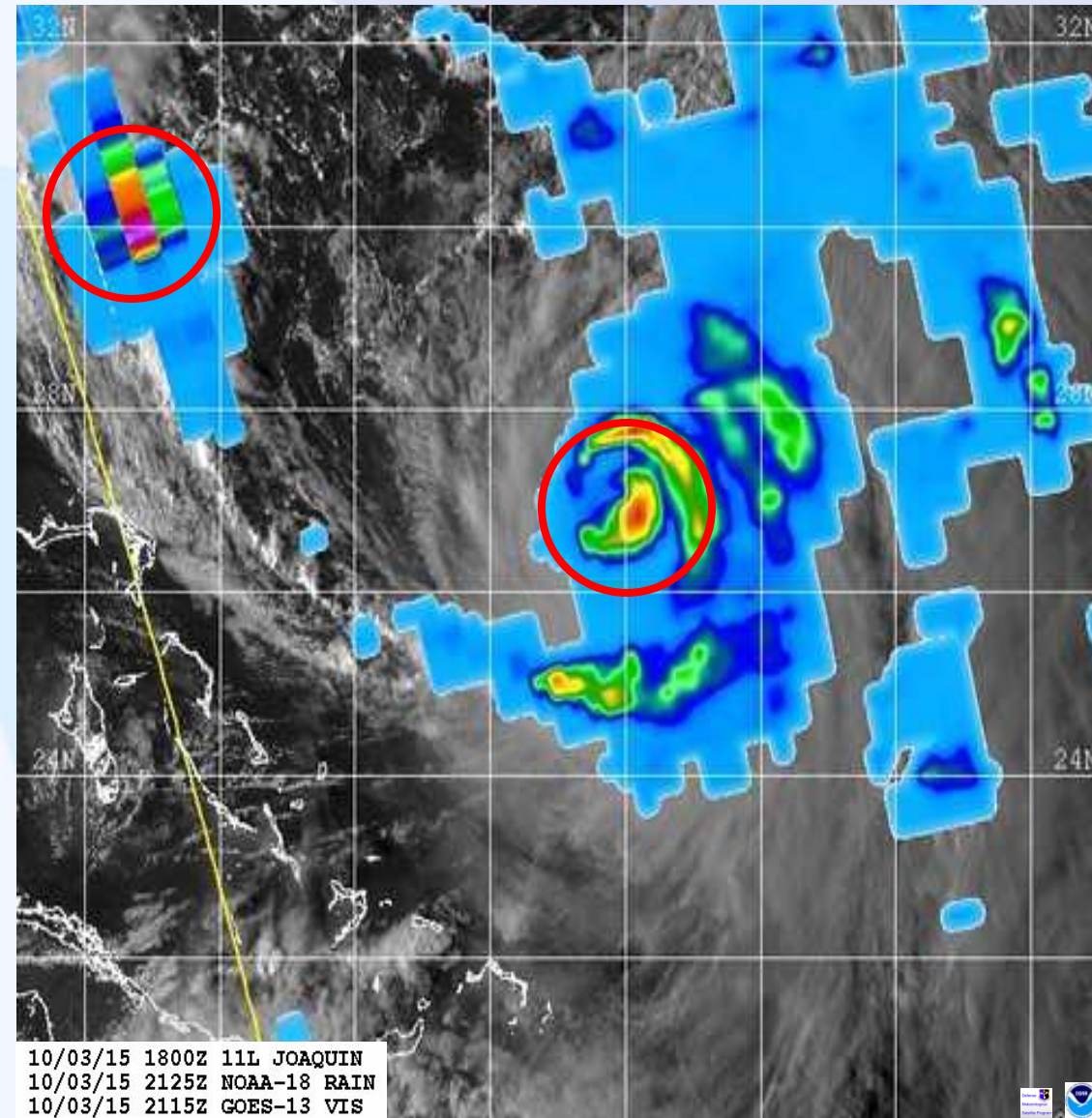
GCOM-W AMSR-2 TPW

other LEO



Value added information to improve analysis and forecasts

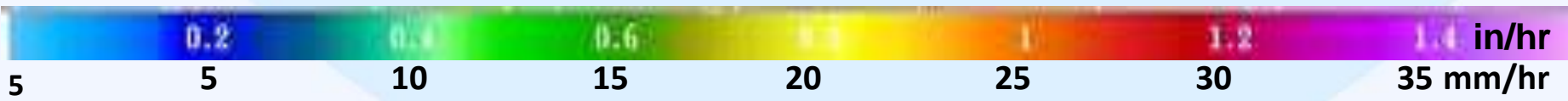
NOAA and METOP AMSU/MHS Satellites have Cross-track Scanning



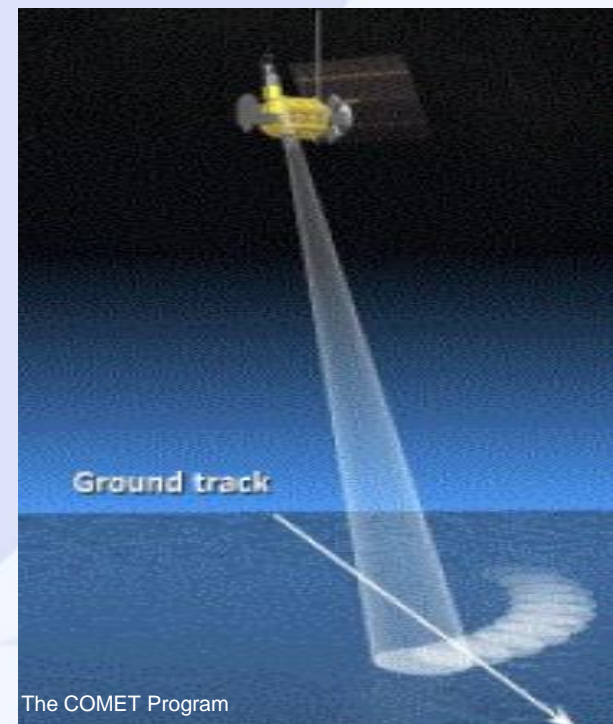
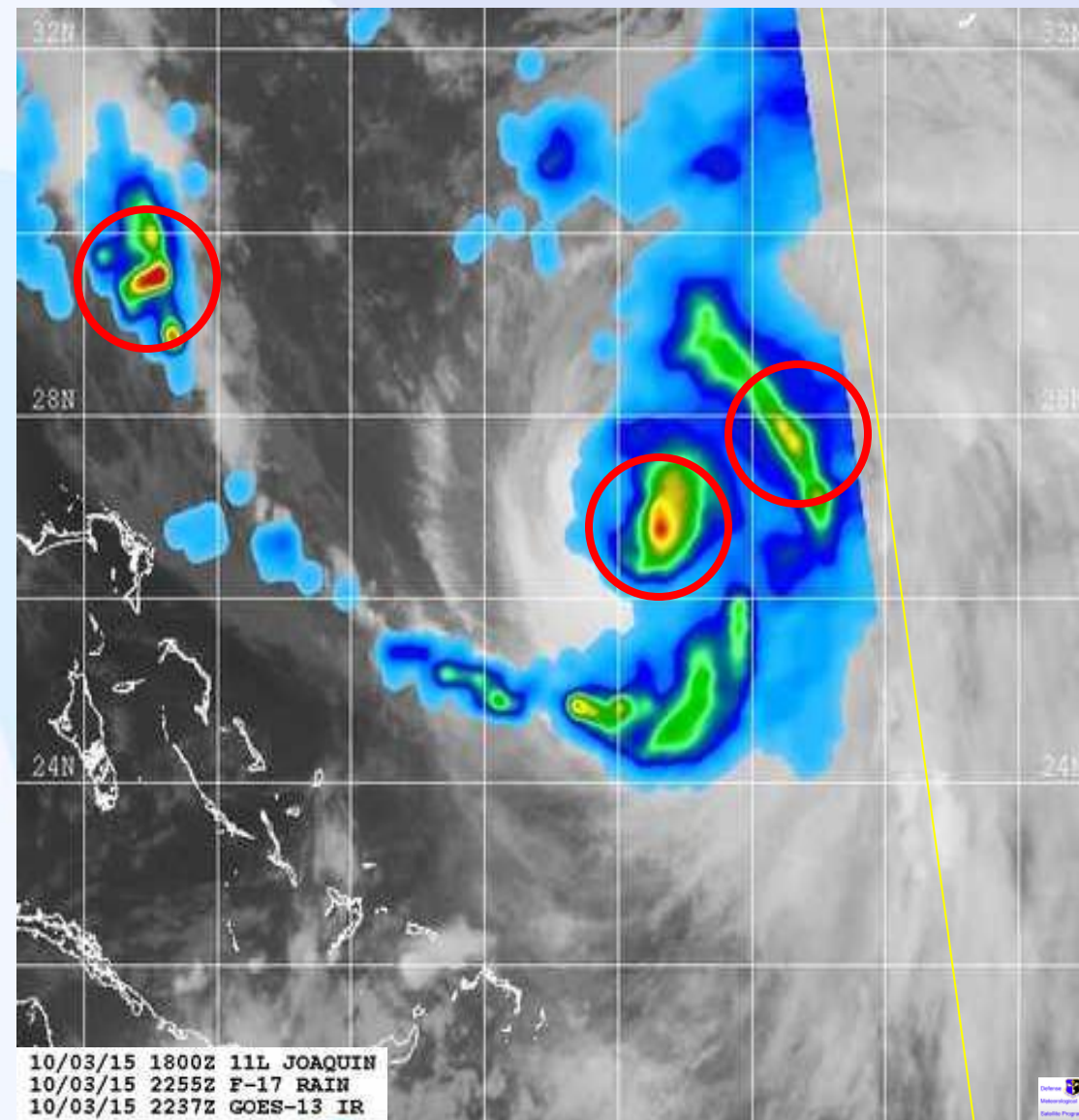
Cross-track scanners have **wider** scan swaths,

BUT

resolution can **degrade** toward the **edge of scan**.



DMSP SSMIS Satellites have Conical Scanning



Conical scanning produces **narrower** scan widths,

BUT

maintains footprint resolution across the **entire scan**.

LEO Microwave Rain Rate Products

Operational

- NOAA and MetOp AMSU-B MHS, S-NPP ATMS
- DMSP SSMIS

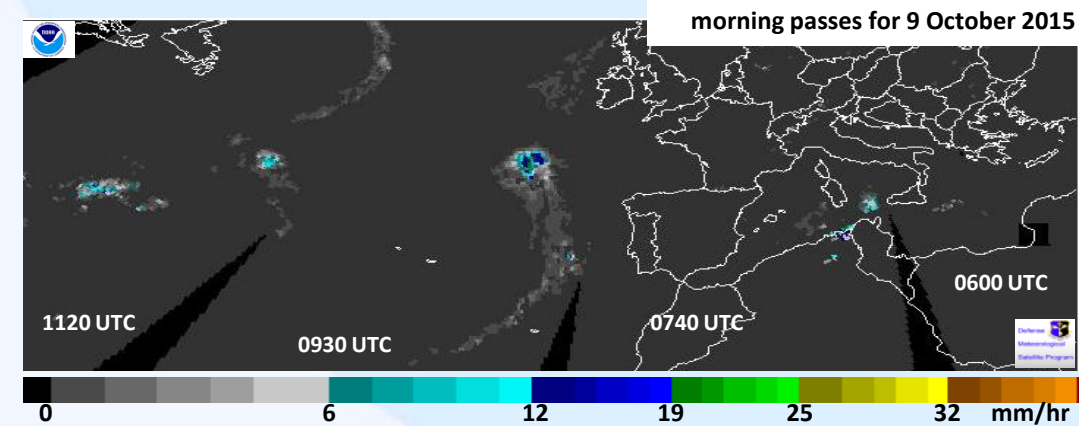
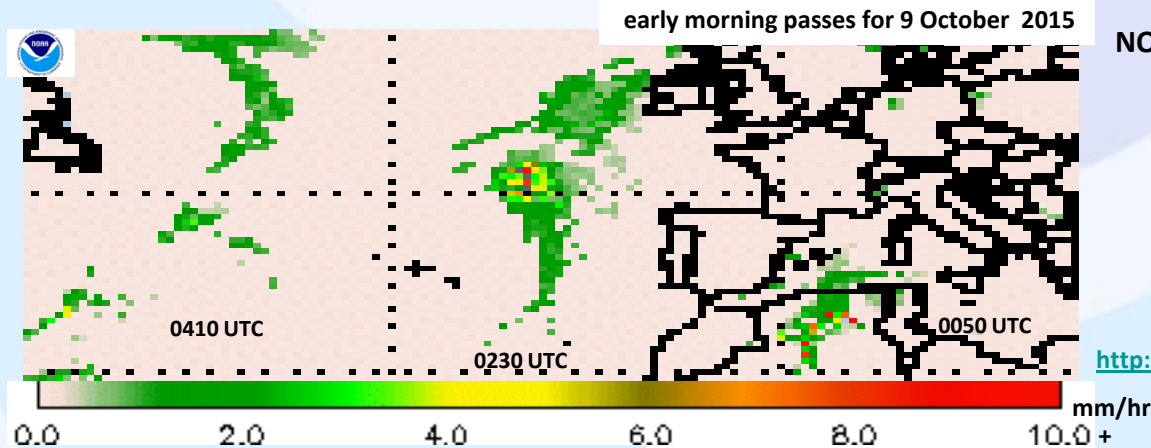
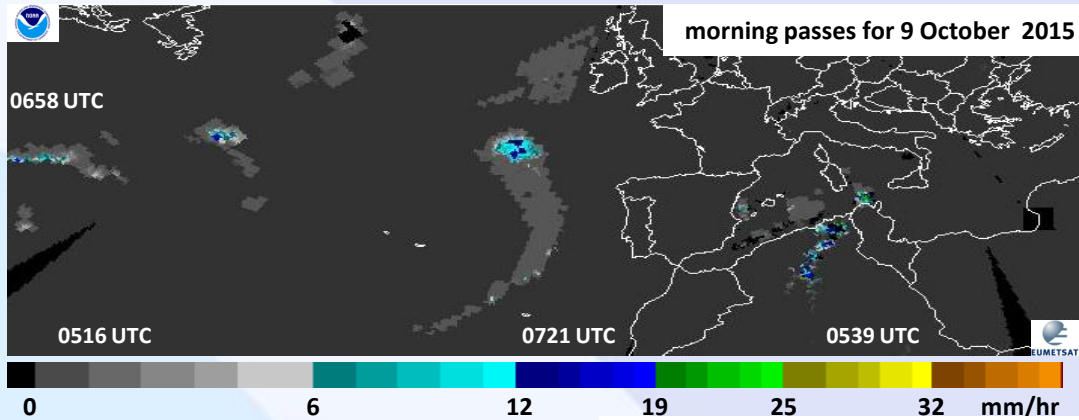
eTRaP

Research and/or Operational

- JAXA/NASA GCOM-W1 AMSR-2
- GPM GPI

Operational LEO Microwave Rain Rate Products

Estimates useful for: **identifying areal extent, intensity and trends including movement**



NOAA/MetOp Microwave Humidity Sounder (MHS) AMSU-B Rain Rate (RR)

Range of amount: 1 to 35 mm/hr

Polarization/Scanning: Single / Cross-track

Resolution: 15 km (nadir)

Satellites: METOP-A & B, N-19 & 18

New Imagery: 1 to 6 hours

<http://www.ssd.noaa.gov/poes/neatl/h5-loop-amrr.html>

NOAA Suomi National Polar-orbiting Partnership (NPP) ATMS MIRS Rain Rate (RR)

Range of amount: 1 to 25 mm/hr

Polarization/Scanning: Quasi / Cross-track

Resolution: 15 km

New Imagery: 12 hours

<http://www.ospo.noaa.gov/Products/atmosphere/mirs/rainrate.html>

DMSP SSMIS Rain Rate (RR)

Range of amount: 1 to 35 mm/hr

Polarization/Scanning: Dual / Conical

Resolution: 13 x 15 km

Satellites: SSMIS F-17 & 18

New Imagery: 3 to 10 hours

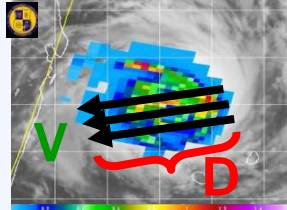
<http://www.ssd.noaa.gov/poes/neatl/h5-loop-ssrr.html>

Ensemble Tropical Rainfall Potential (eTRaP)

<http://www.ssd.noaa.gov/PS/TROP/etrap.html>



Basic Premise



$$TRaP = \frac{R_{avg} D}{V}$$

Assumptions

- accurate RRs
- forecast track
- steady state RRs

Not Included today

- No Orographics
- No Storm Rotation
- No Shear

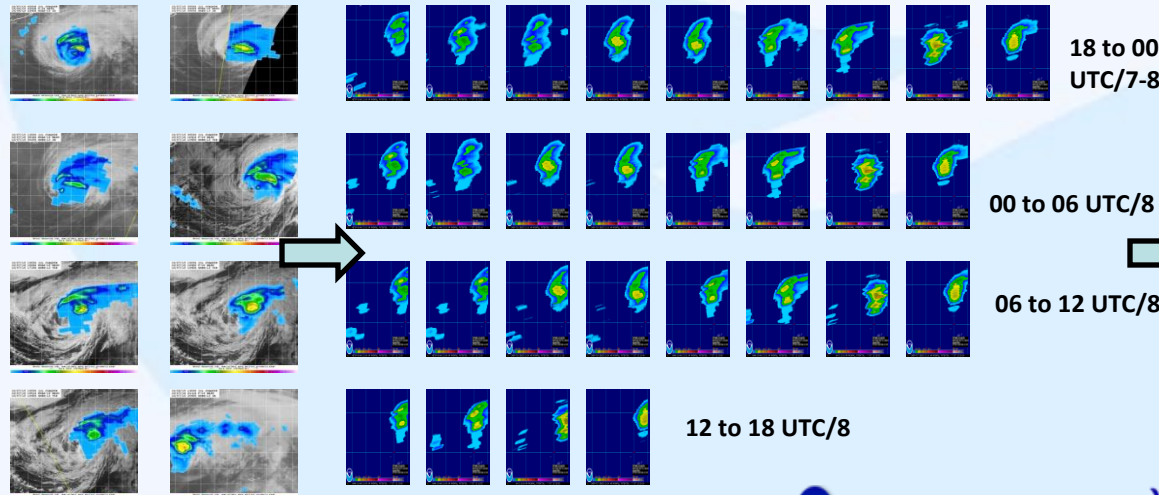
LEO MW and GEO IR Rain Rate Input : NOAA/METOP AMSU, DMSP SSMIS and H-E Track Forecast input: Worldwide RSMCs

eTRaP run started at 18 UTC 7 October 2015 for Joaquin

AMSU, SSMIS, and GEO RR images

LEO MW and GEO IR RR images + TC track forecasts to create 6h TRaPs forecasts for next 24hrs

Probabilistic and deterministic 6h and 24h eTRaPs



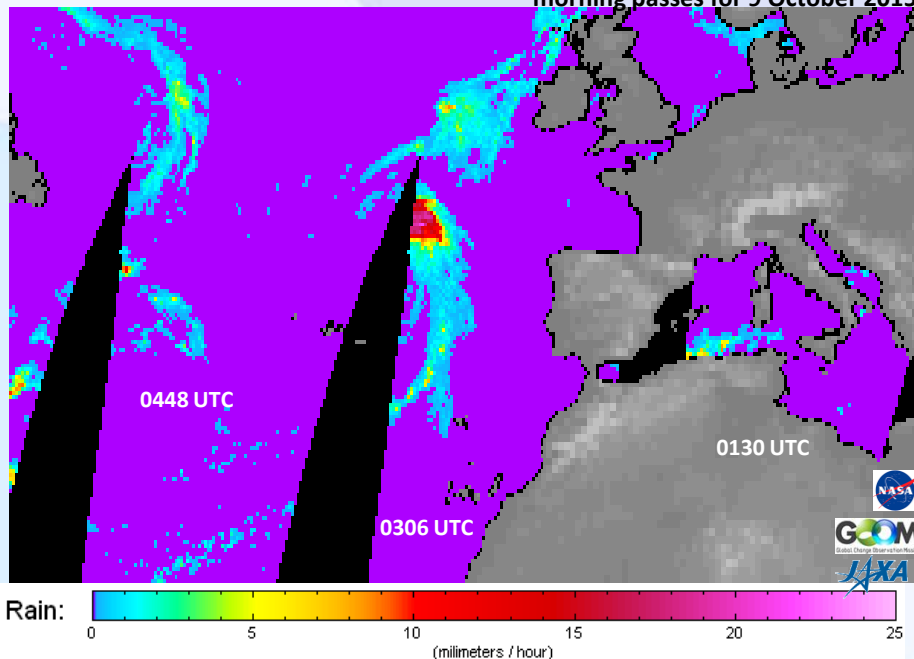
Forecast Period	PoP ≥ 25mm	PoP ≥ 50mm	PoP ≥ 75mm	PoP ≥ 100mm	Rain Amount
0-6hr (9 TRaP members)					
6-12hr (8 TRaP members)					
12-18hr (8 TRaP members)					
18-24hr (4 TRaP members)					
Forecast Period	PoP ≥ 50mm	PoP ≥ 100mm	PoP ≥ 150mm	PoP ≥ 200mm	Rain Amount
24hr Total (9 Independent TRaPs)					

NOAA Satellite and Information Service
National Environmental Satellite, Data and Information Service (NESDIS)

Research and/or Operational LEO Microwave Rain Rate Products

Estimates useful for: **identifying areal extent, intensity and trends including movement**

morning passes for 9 October 2015



AMSR-2 Composite

Range of amount: 1 to 25 mm/hr

Polarization: Dual

Resolution: ~ 5 km

Satellite: GCOM-W1

New Imagery: Every 12 hours

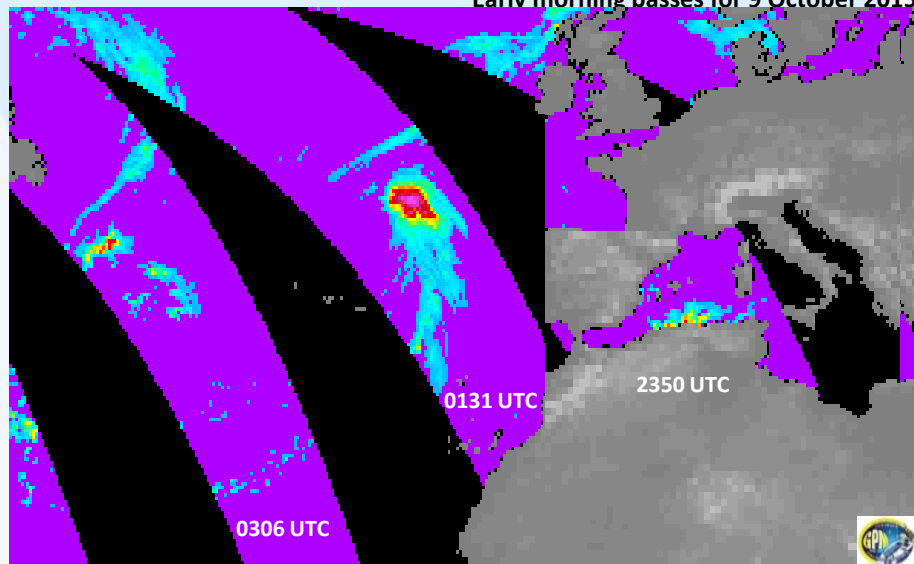
<http://www.ospo.noaa.gov/Products/atmosphere/gpds/> *

http://images.remss.com/amr/amr2_data_daily.html

<ftp://ftp.cira.colostate.edu/ftp/Kidder/Limin/RR/AMSR2>

http://www.nrlmry.navy.mil/tc_pages/tc_home.html

Early morning passes for 9 October 2015



GMI Composite

Range of amount: 1 to 25 mm/hr

Polarization: Dual

Resolution: ~ 5 km

Satellite: GPM

New Imagery: Every 12 hours

http://images.remss.com/gmi/gmi_data_daily.html *

http://www.nrlmry.navy.mil/tc_pages/tc_home.html

<http://mirs.nesdis.noaa.gov/gpmgmi.php>

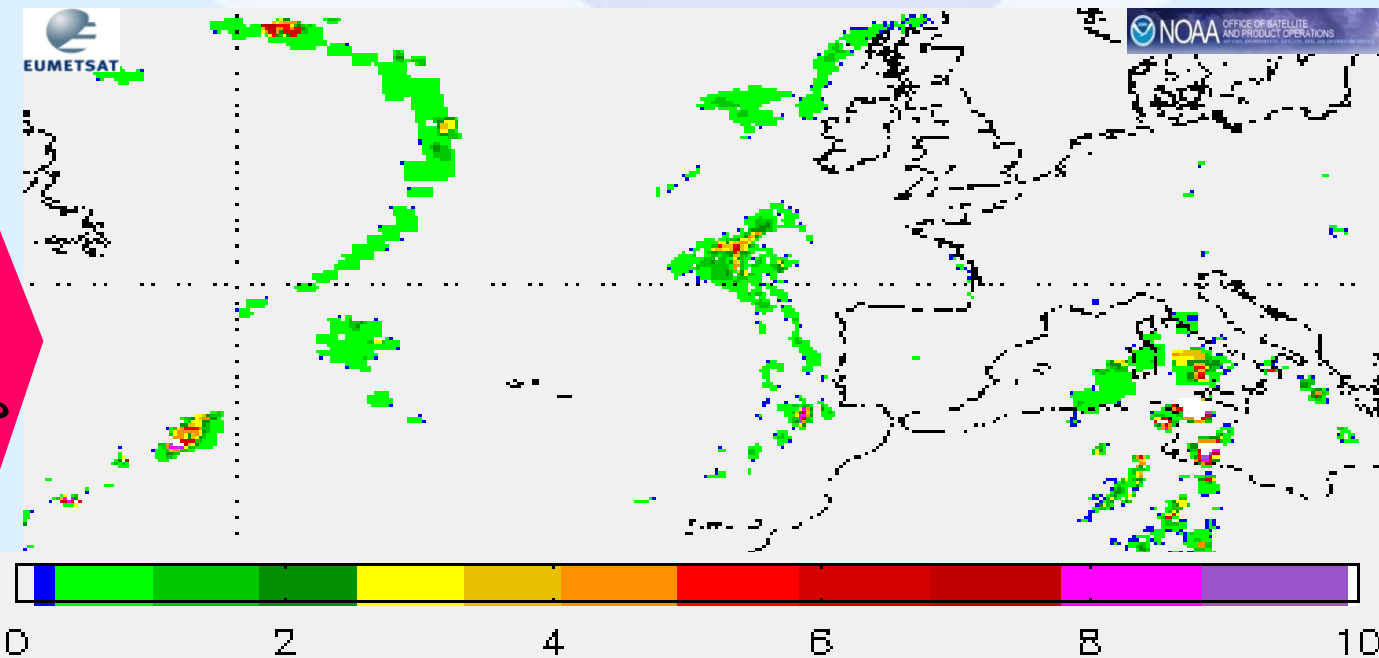
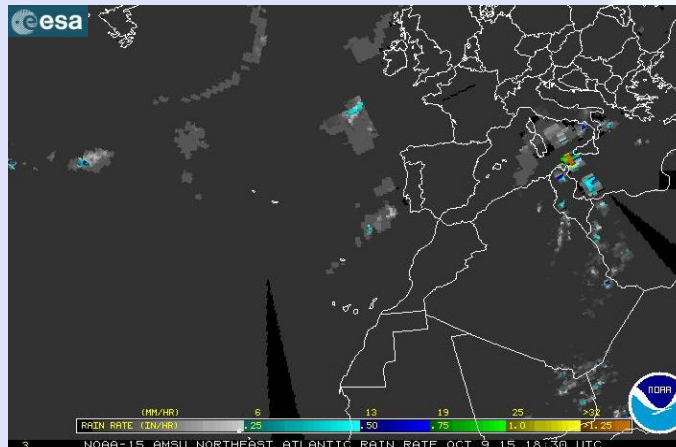
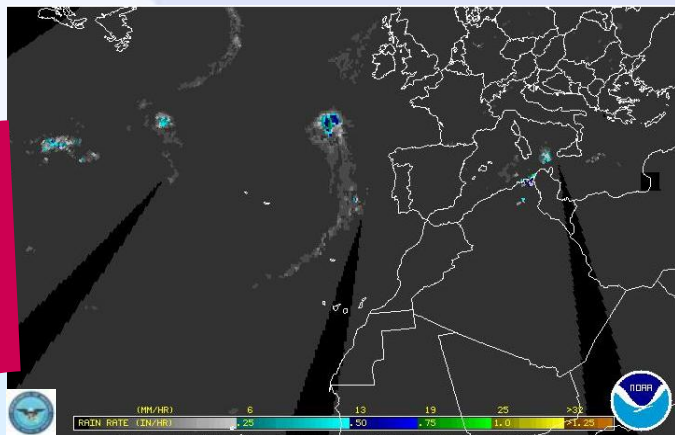
Blended RR Products and Applications

- **Operational Blended Microwave Rain Rate**
 - GEO Analysis
- **QMORPH**
 - short term accumulations

LEO Satellites Used to produce a Blended Rain Rate (RR) Product

DMSP SSMIS F-17 and 18

NOAA- 18, 19, METOP-A & B MHS AMSU-B
and Sunomi NPP ATMS



http://www.ospo.noaa.gov/Products/atmosphere/brr/brr_loops.html?product=EU&maptype=RR

<ftp://ftp.cira.colostate.edu/ftp/Kidder/Limin/RR/>

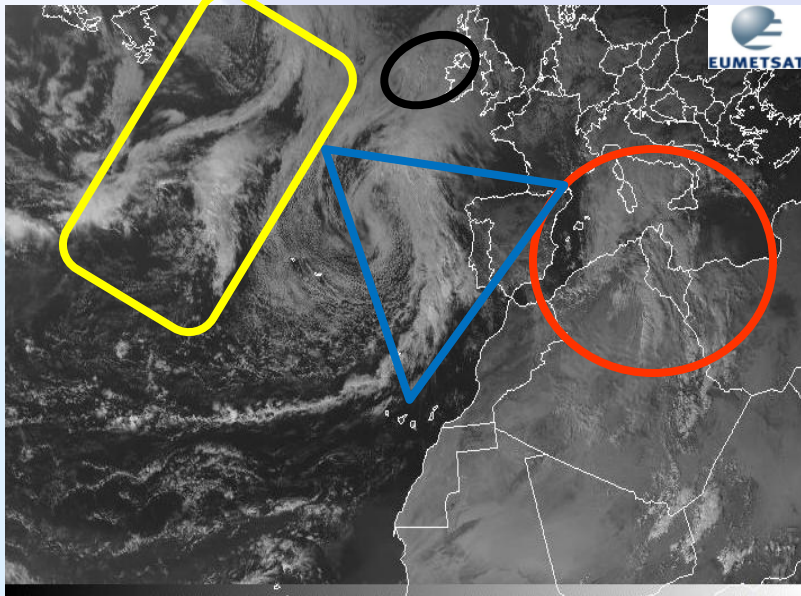
DMSP SSMIS
F-17 & 18

NOAA 18, 19 and
METOP - A & B
MHS AMSU-B

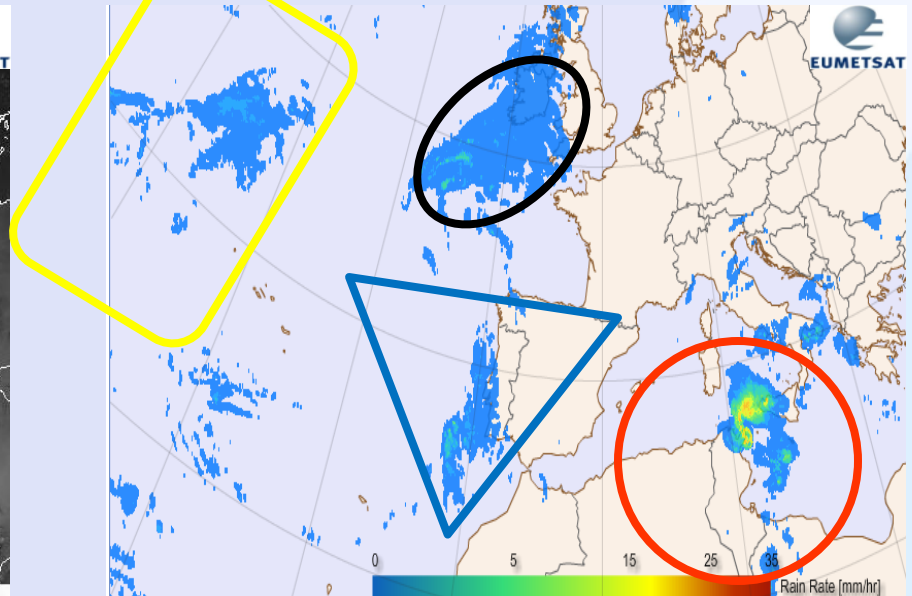
Future
GCOMW-1 AMSR-2

NOAA S-NPP ATMS

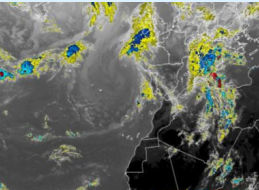
METSAT VIS 1500 UTC 9 October 2015



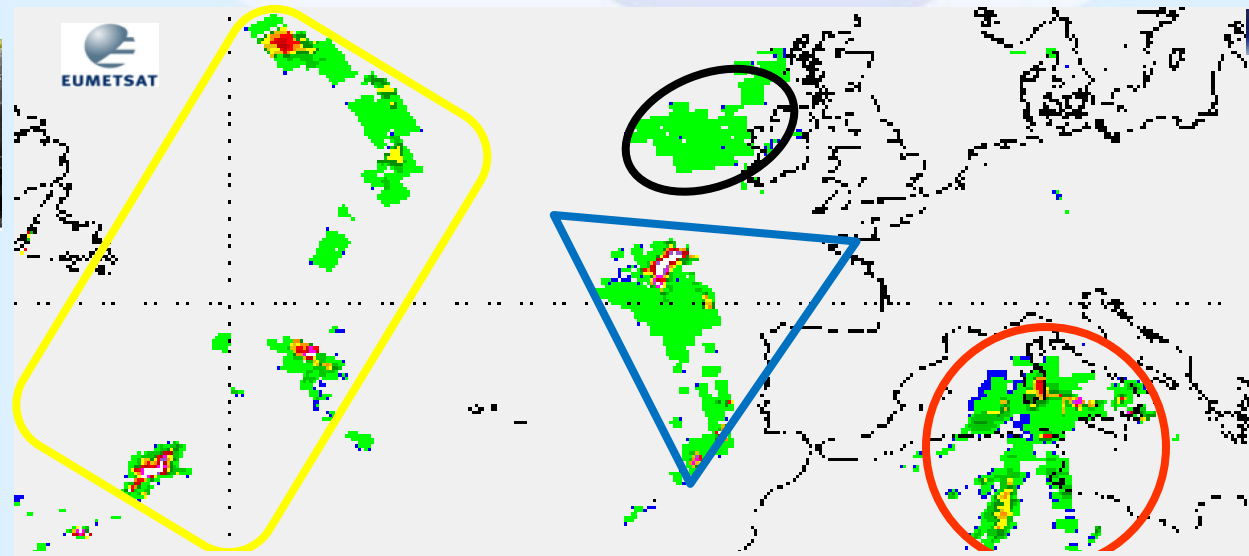
MPE 1800 UTC 9 October 2015



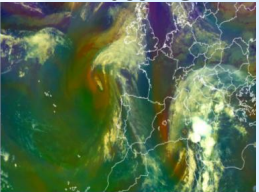
IR



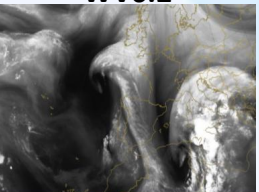
EUMETSAT



Airmass RGB



WV6.2



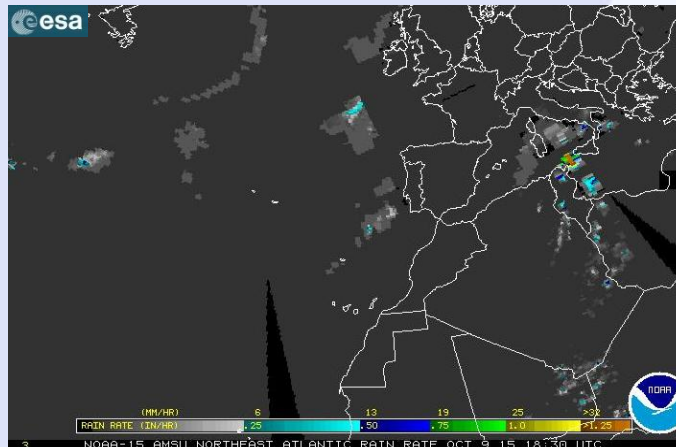
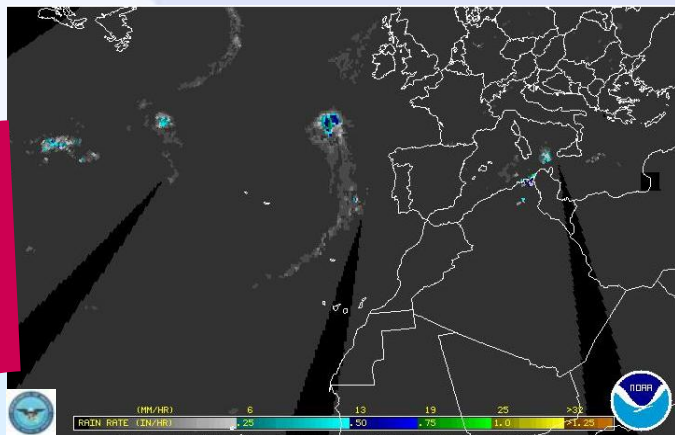
Blended RR
0800-1600 UTC
9 October 2015

To help compliment and supplement GEO analysis

LEO Satellites Used to produce the QMORPH Rain Rate (RR) Product

DMSP SSMIS F-16, 17 & 18

NOAA- 18, 19, METOP-A & B MHS AMSU-B

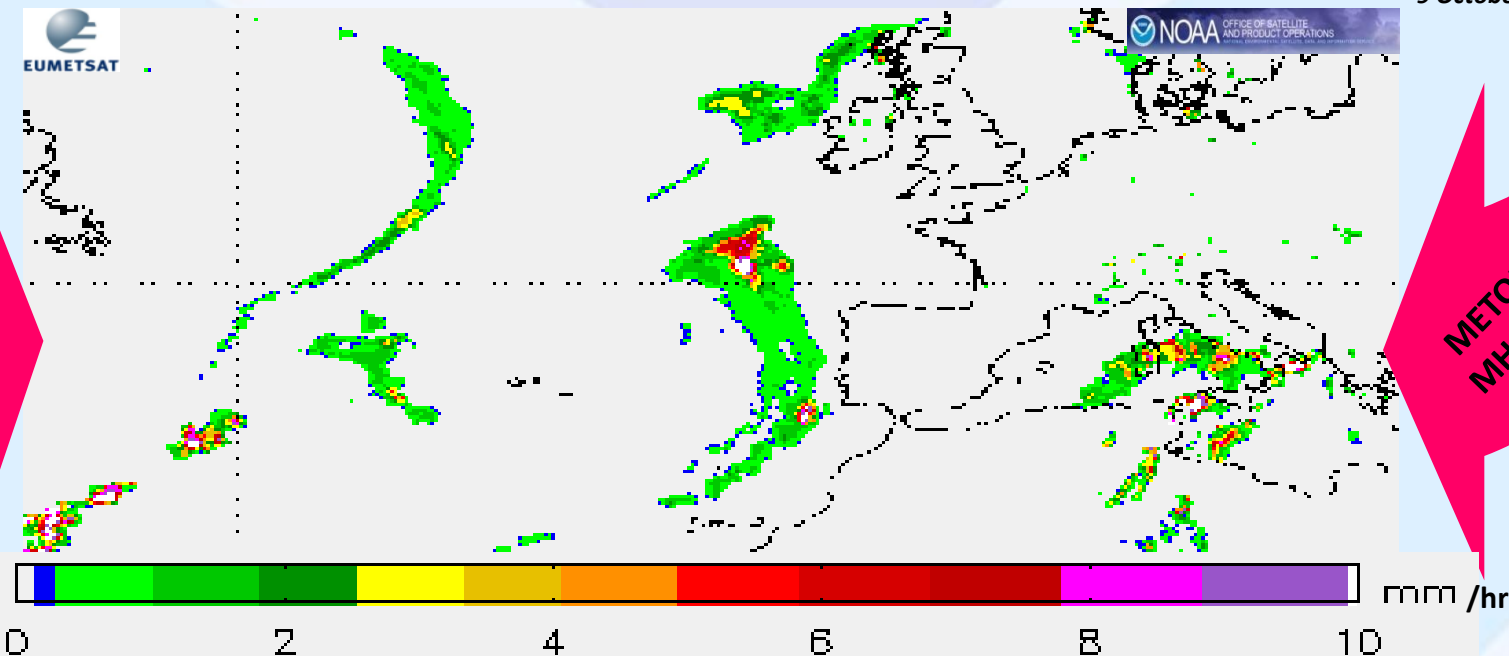


DMSP SSMIS
F-16

NOAA 18, 19
MHS AMSU-B

QMORPH Rain Rate

9 October 2015



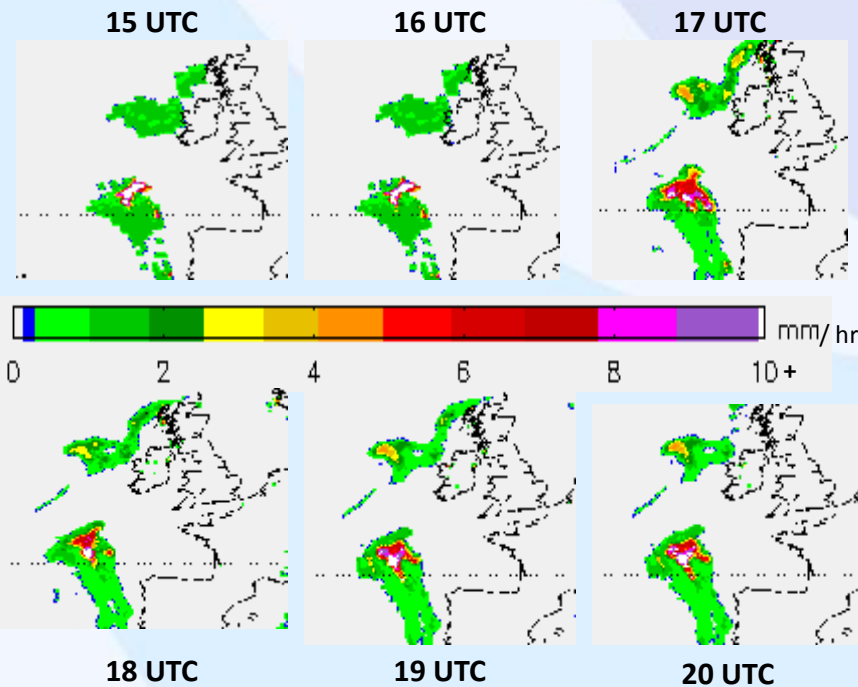
DMSP SSMIS
F-17, 18

METOP-A & B
MHS AMSU-B

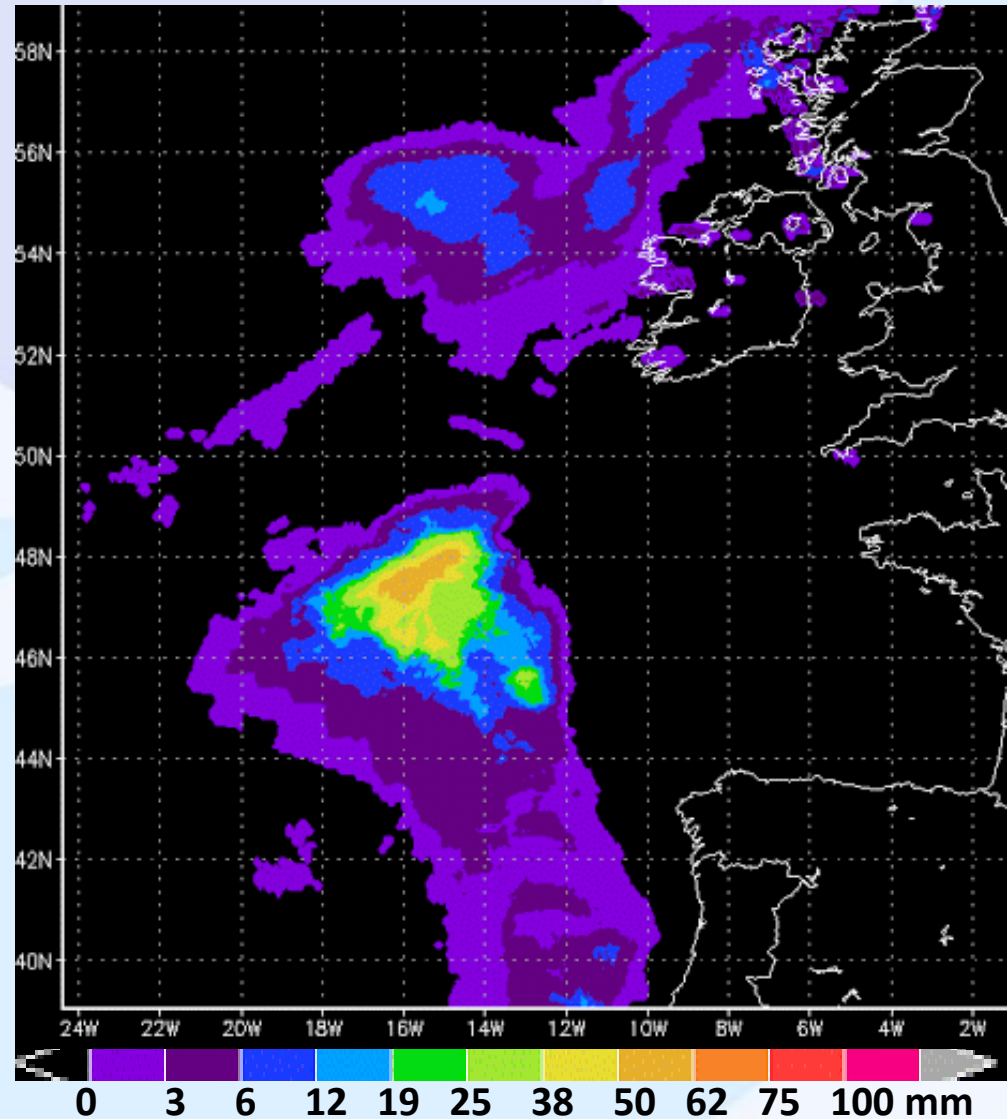
http://www.ospo.noaa.gov/Products/atmosphere/brr/brr_loops.html?product=EU&mapttype=QM

QMORPH Rain Accumulations Helpful for Short Term Forecasting

Hourly QMORPH Rain Rates



QMORPH 6 Hr Rain Accumulations ending 20 UTC 9 October 2015

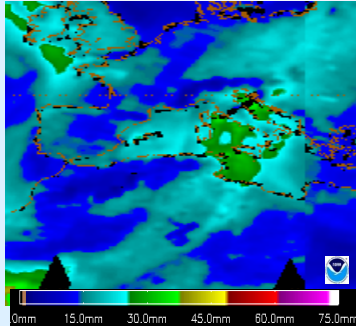




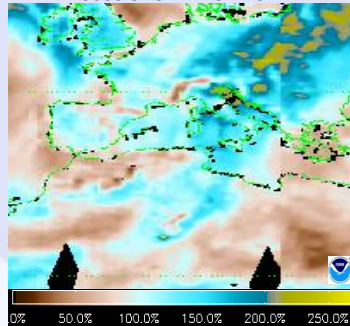
Two Flood Event Cases: Review of TPW and RR applications

The Tuscany Flood of November 2012

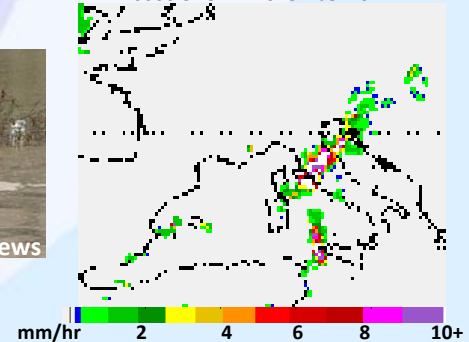
Blended Total Precipitable Water (TPW)
0600 UTC 12 Nov 2012



Blended TPW Percent of Normal
0600 UTC 12 Nov 2012



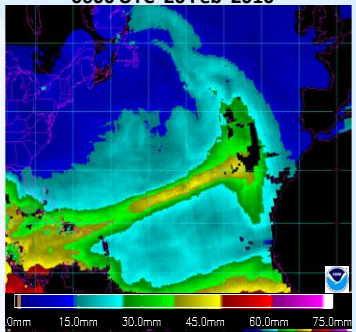
Blended Rain Rate
0600 UTC 12 November 2012



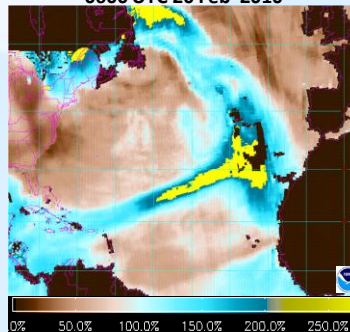
http://oiswww.eumetsat.org/WEBOPS/iotm/iotm/20121112_flood/20121112_flood.html

The Madeira Flood Event of February 2010

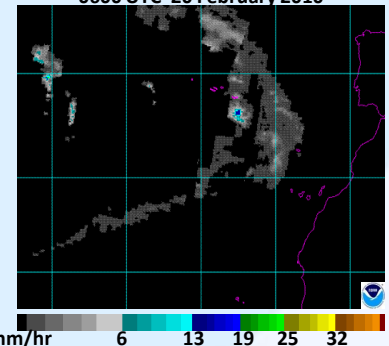
Blended Total Precipitable Water (TPW)
0600 UTC 20 Feb 2010



Blended TPW Percent of Normal
0600 UTC 20 Feb 2010



Blended Rain Rate
0600 UTC 20 February 2010

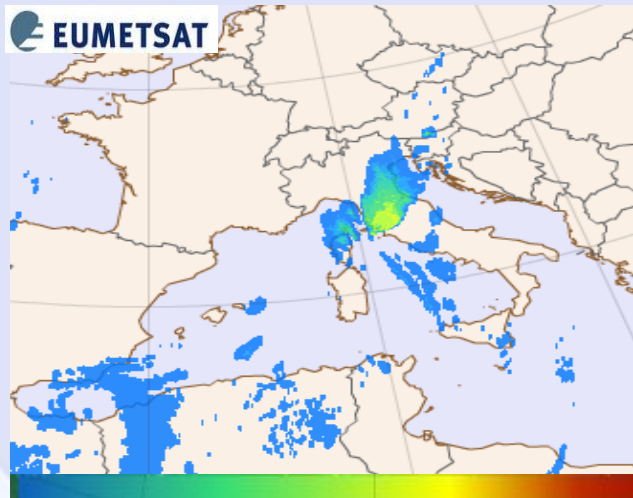
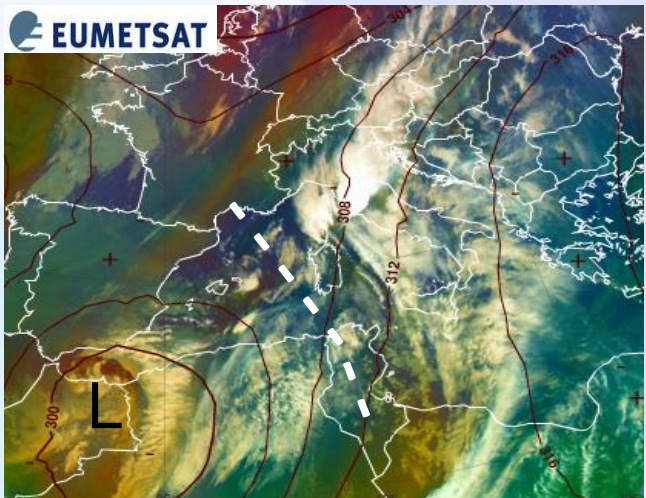


The Madeira Island Floods of 20 February 2010 <http://nws.met.psu.edu/severe/2010/20Feb2010.pdf>

The 20 February 2010 Madeira flash-floods: synoptic analysis and extreme rainfall assessment:
<http://www.nat-hazards-earth-syst-sci.net/12/715/2012/nhess-12-715-2012.pdf>

Meteosat-9 RGB Air Mass and H700
06 UTC 12 Nov 2012

Meteosat-9 MPE
06 UTC 12 Nov 2012

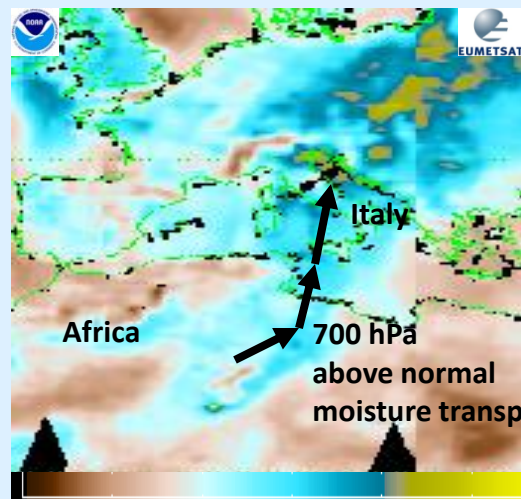
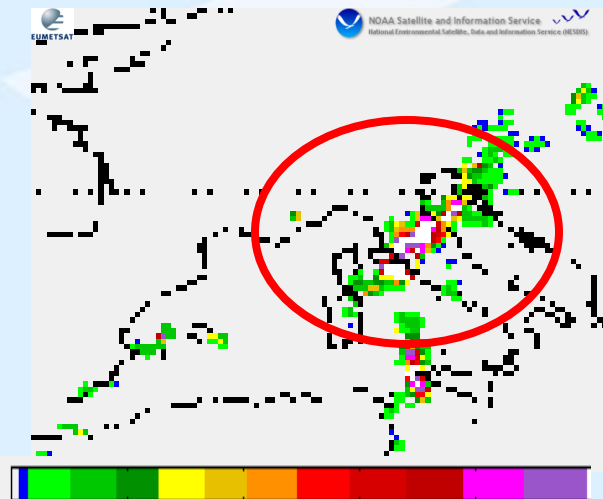
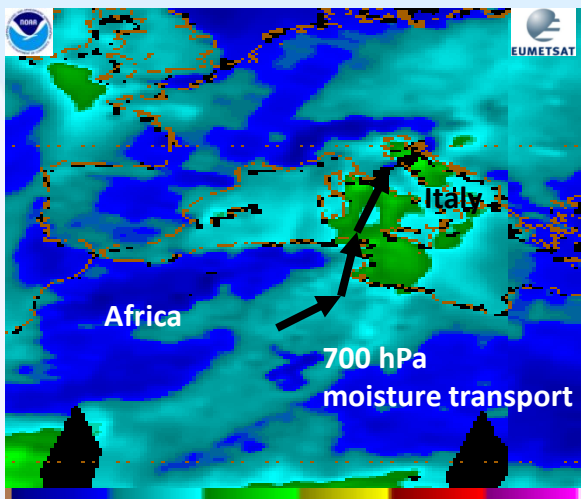


Severe Convective Storms/flooding Over Italy 11-12 November 2012

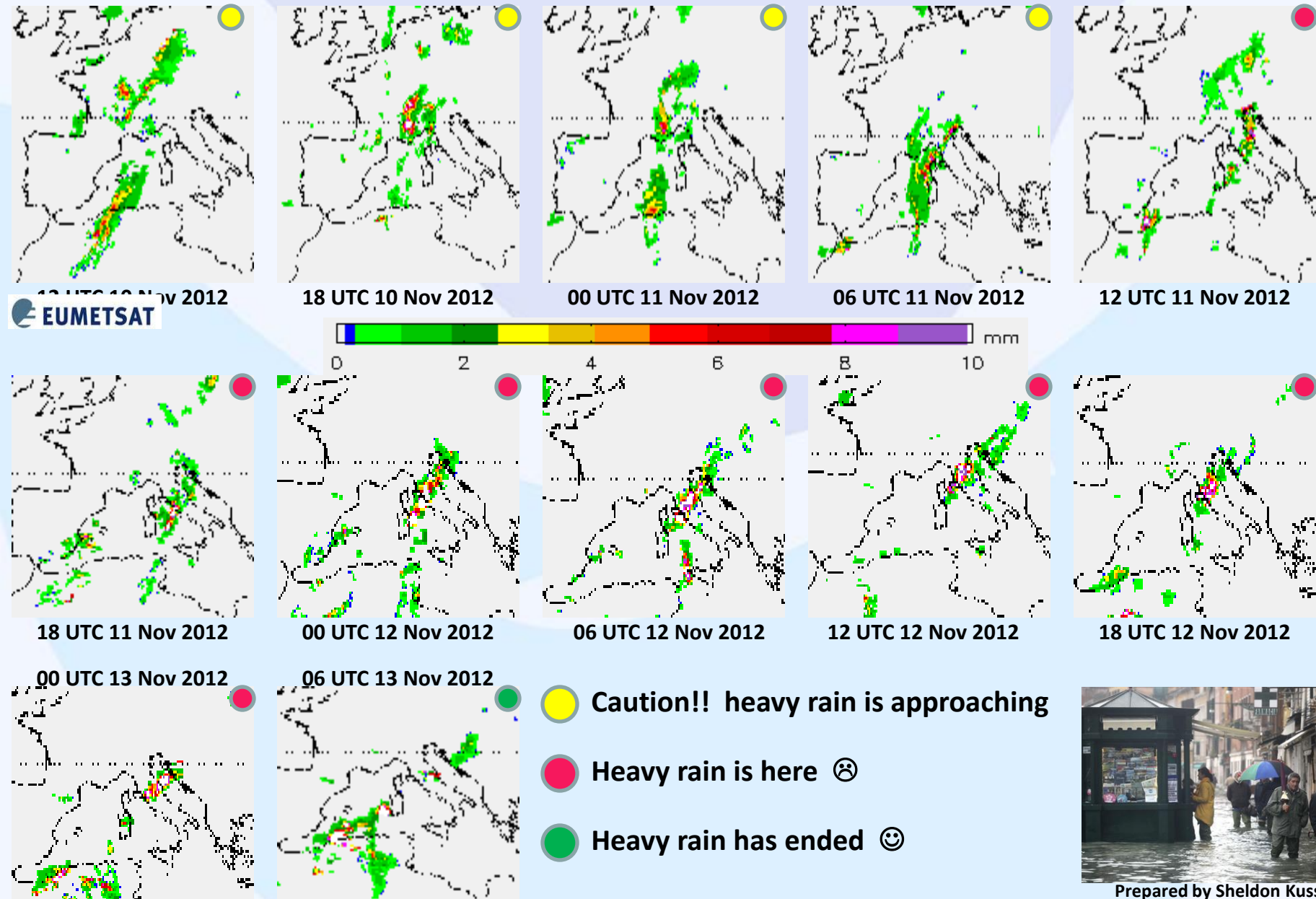
Blended Total Precipitable Water (TPW)
06 UTC 12 Nov 2012

Blended LEO Instantaneous Rain Rates
06 UTC 12 Nov 2012

Blended TPW Percent of Normal
06 UTC 12 Nov 2012



Blended LEO Instantaneous 15km Areal Average Rain Rate For Italian Heavy Rain/Flooding Event



EUMETSAT



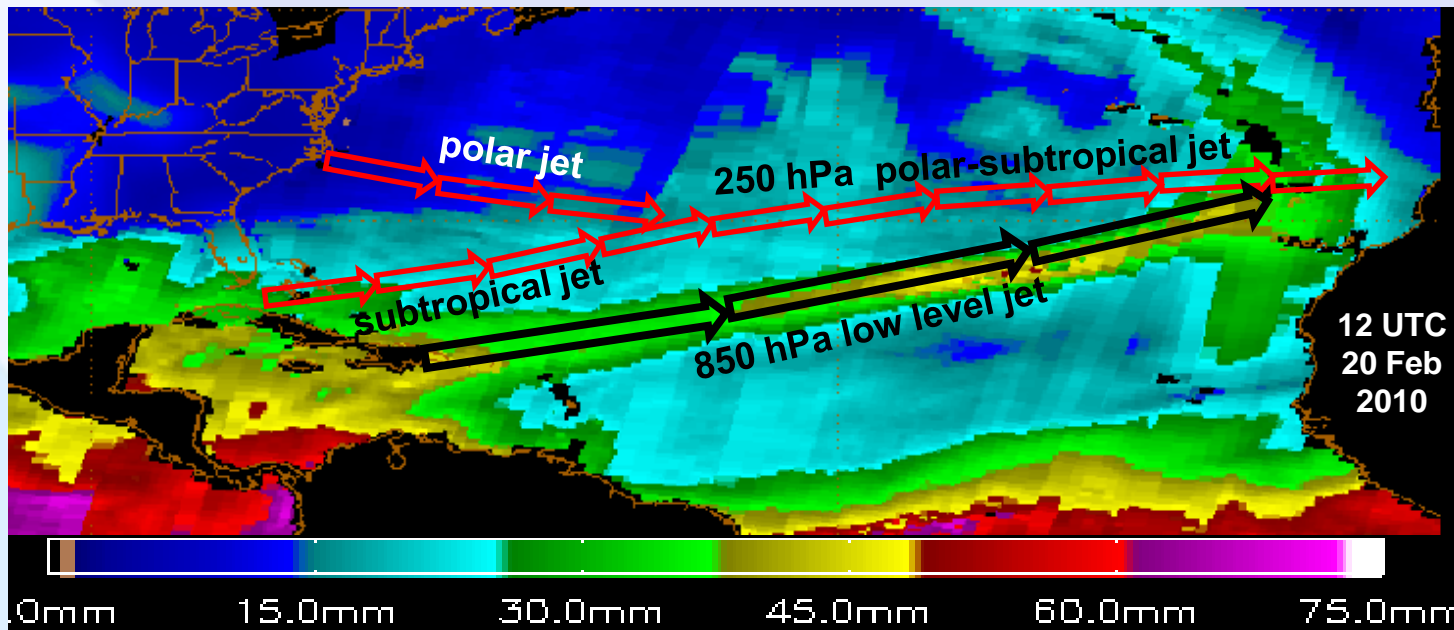
- Caution!! heavy rain is approaching
- Heavy rain is here ☹️
- Heavy rain has ended 😊



Prepared by Sheldon Kusselson

Blended
TPW

AP



Unusually strong
high level jet
crossing moisture
plume

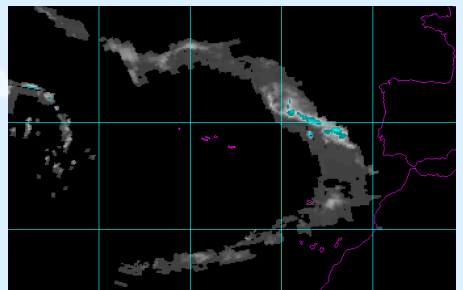
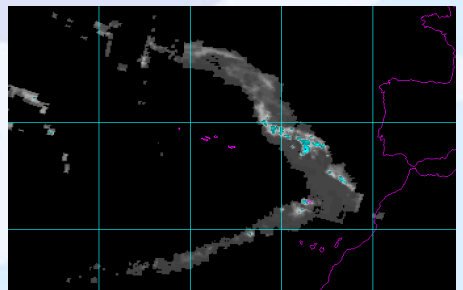
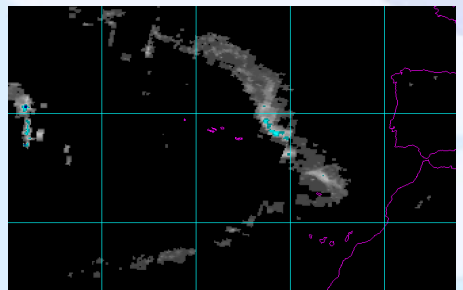
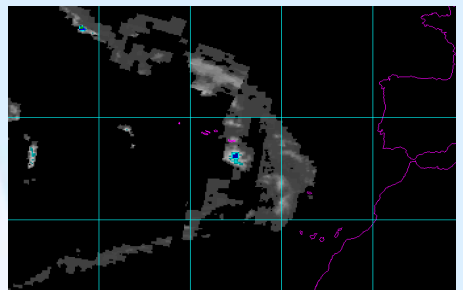
Unusually strong
low level jet
parallel highest
moisture for
maximum moisture
transport

early morning 20 Feb 2010

mid morning 20 Feb 2010

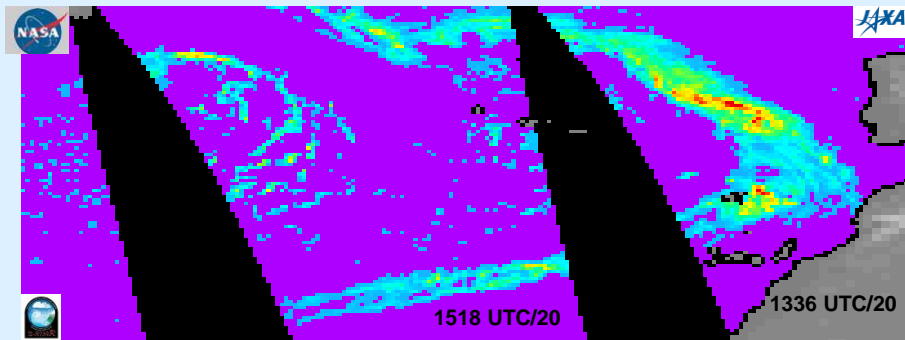
midday 20 Feb 2010

early afternoon 20 Feb 2010



6 13 19 25 32 mm/hr

15 km Blended RR

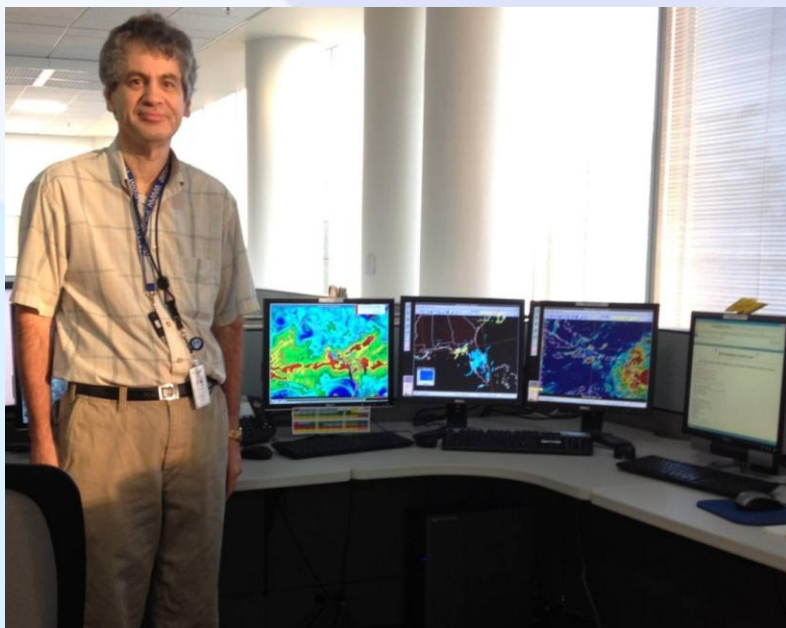


6 km NASA/JAXA AMSR-E RR

5 10 15 20 25 mm/hr

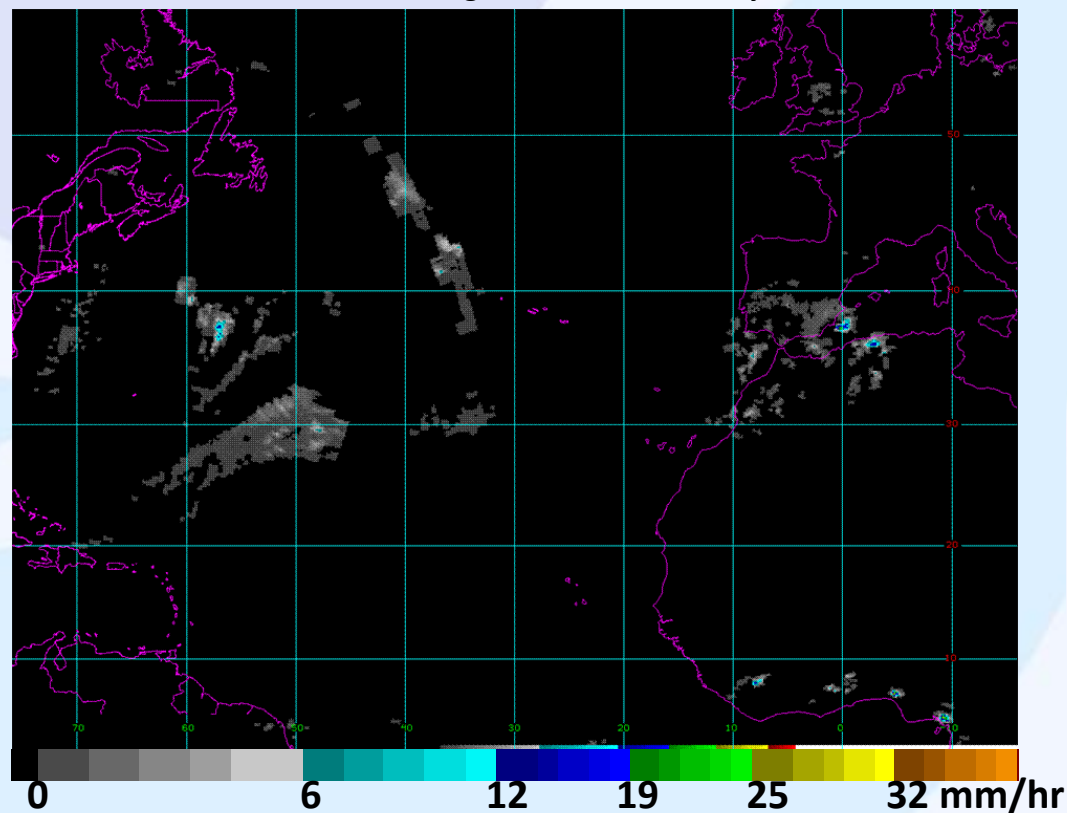
land ice no data

I want your analyses, forecasts and research to be the best !



http://www.ospo.noaa.gov/Products/atmosphere/brr/brr_loops.html?product=EU&mptype=QM

Blended Rain Rate Loop
18 UTC 18 Feb through 18 UTC 20 February 2010



Thank you for your attention.
¿¿ Any more questions ??

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