Catastrophic Flash Flood in Madeira Island, 20 february 2010

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Extreme Floods and Landslide events topic, 3 Dec 2014
Drought, Floods and Landslides – Event week 2014

Outline

1 – The event in Madeira (20 feb 2010)

2 – Satellite Observations and NWP

3 – Atmospheric Rivers

4 - The precipitation regime over the Island

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Where is Madeira?

Madeira Archipelago

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The event – 20 February 2010

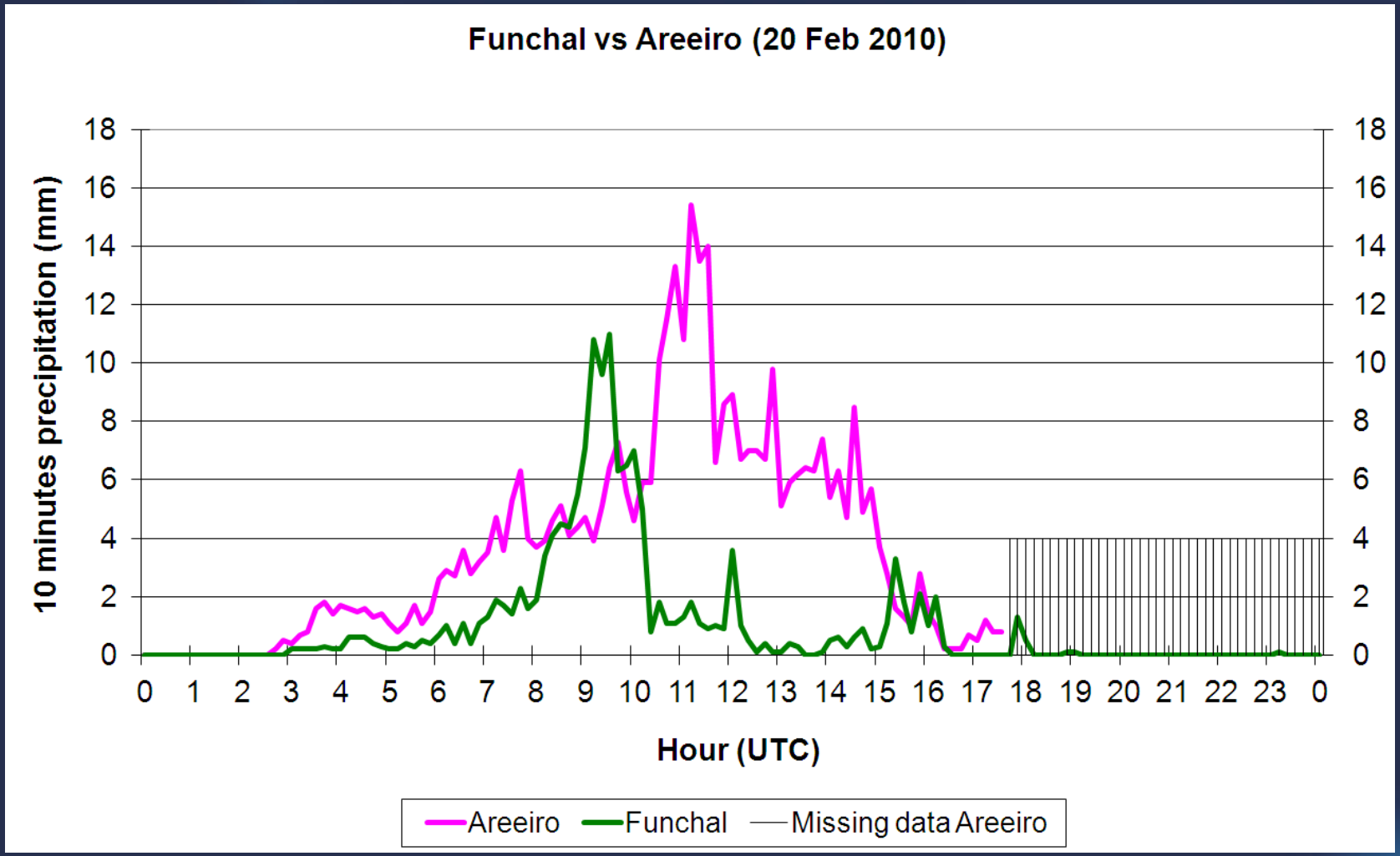
Consequences:

42 casualties

600 homeless

estimated loss of ~1000 million euros

Surface observations
10 minute Precipitation



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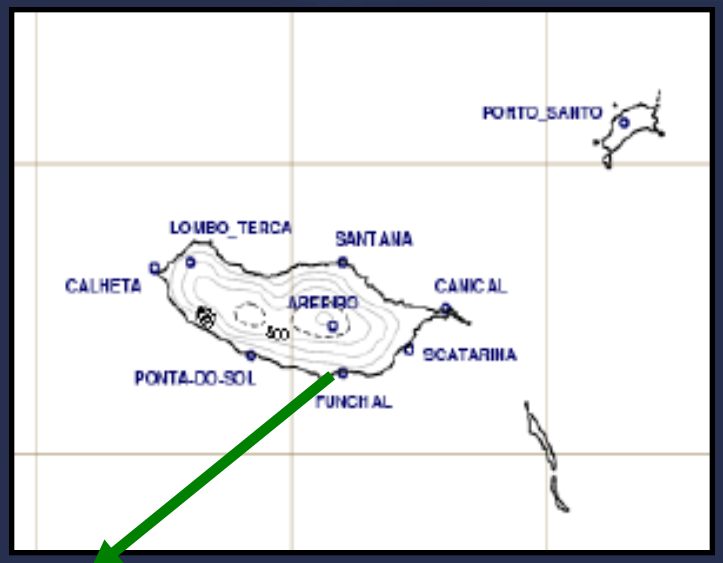
Surface observations
Maximum values



Funchal (Maxima on 20th)

10min: **11.0 mm** (09:20 – 09:30 UTC)

1h: **51.3 mm** (08:50 – 09:50 UTC)

6h: **111.5 mm**(05:10 – 11:10 UTC)

24h: **144.3 mm**(00:00- 24:00 UTC)

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Surface observations
Maximum values

Areeiro (Maxima on 20th)

10min: **15.4 mm** (11:00 – 11:10 UTC)

1h: **78.5 mm** (10:30 – 11:30 UTC)

6h: **272.1 mm**(08:50 – 14:50 UTC)

24h: **387.1 mm**(**00:00 - 17:10 UTC!**)

Funchal (Maxima on 20th)

10min: **11.0 mm** (09:20 – 09:30 UTC)

1h: **51.3 mm** (08:50 – 09:50 UTC)

6h: **111.5 mm**(05:10 – 11:10 UTC)

24h: **144.3 mm**(00:00- 24:00 UTC)

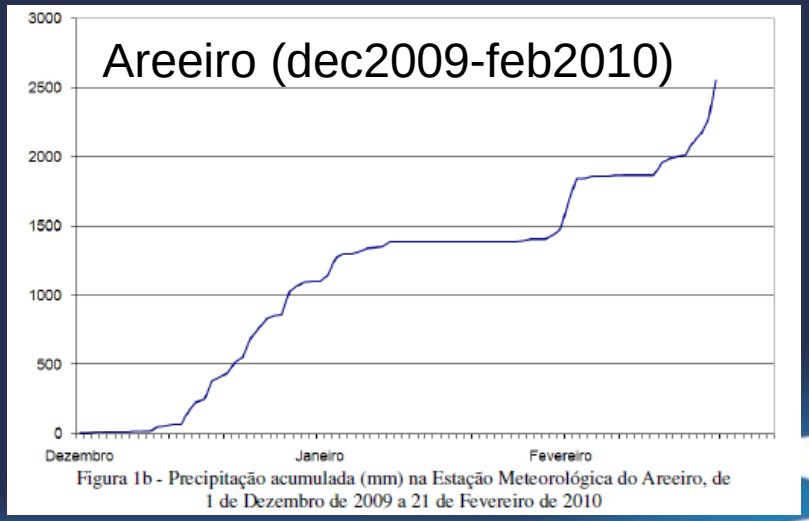

Figura 1b - Precipitação acumulada (mm) na Estação Meteorológica do Areeiro, de 1 de Dezembro de 2009 a 21 de Fevereiro de 2010

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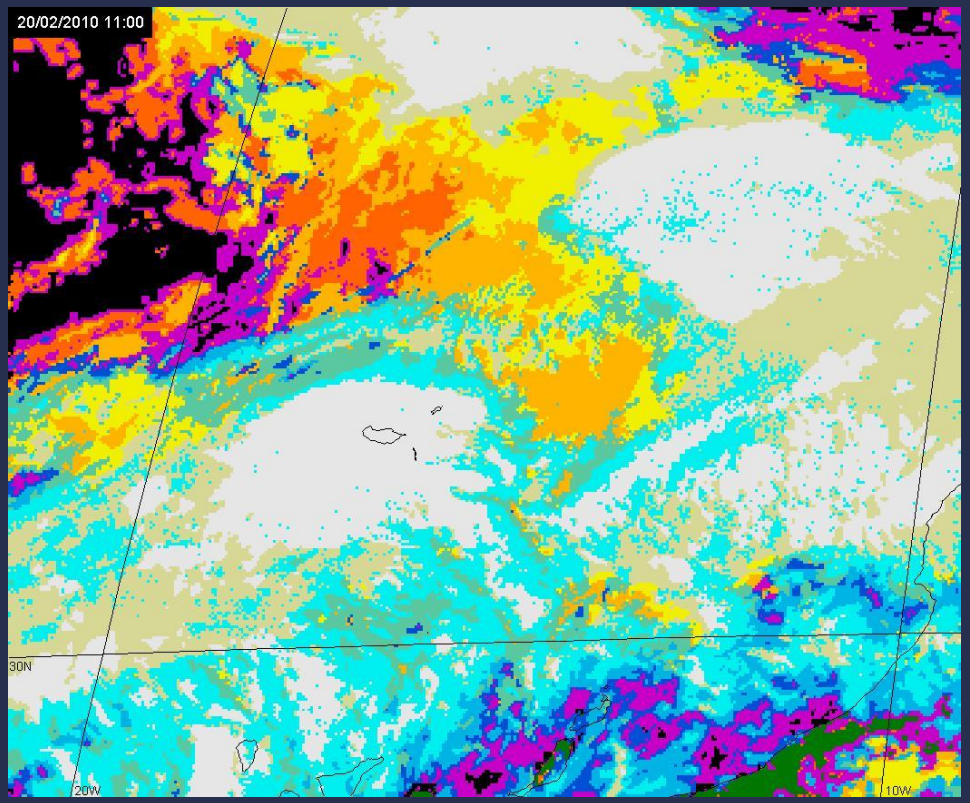
Meteosat Imagery - 20/02/2010

SAF Nowcasting Cloud Type



Play animation: CT_201002200000_2330.mpg

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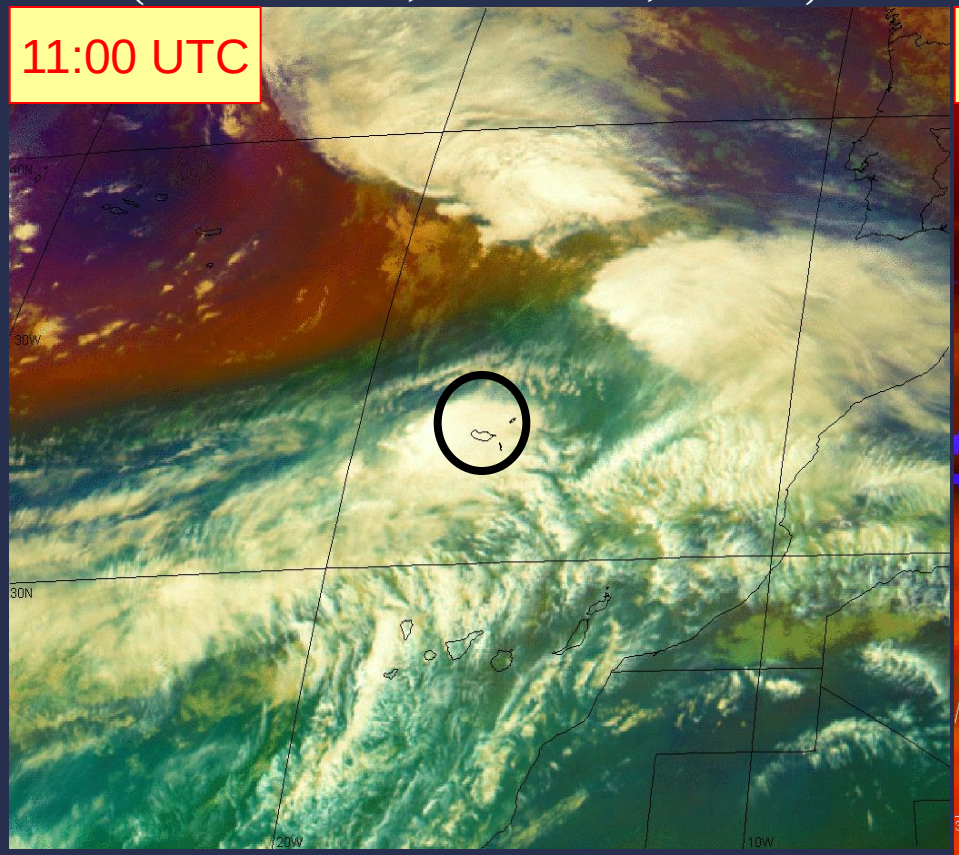
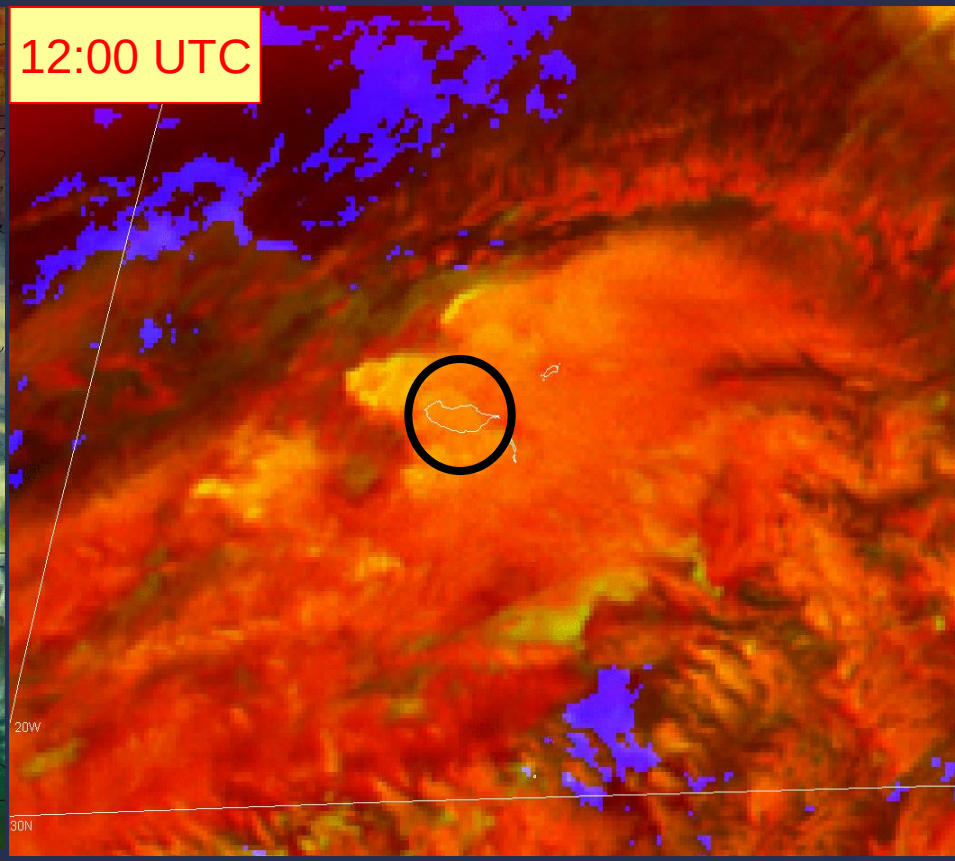
Meteosat Imagery - 20/02/2010

Air mass RGB
(WV6.2-WV7.3;IR9.7-IR10.8; WV6.2i)



Deep Convection RGB
(WV6.2-WV7.3;IR3.9-IR10.8; NIR1.6-VIS0.6)



Convective System over Madeira

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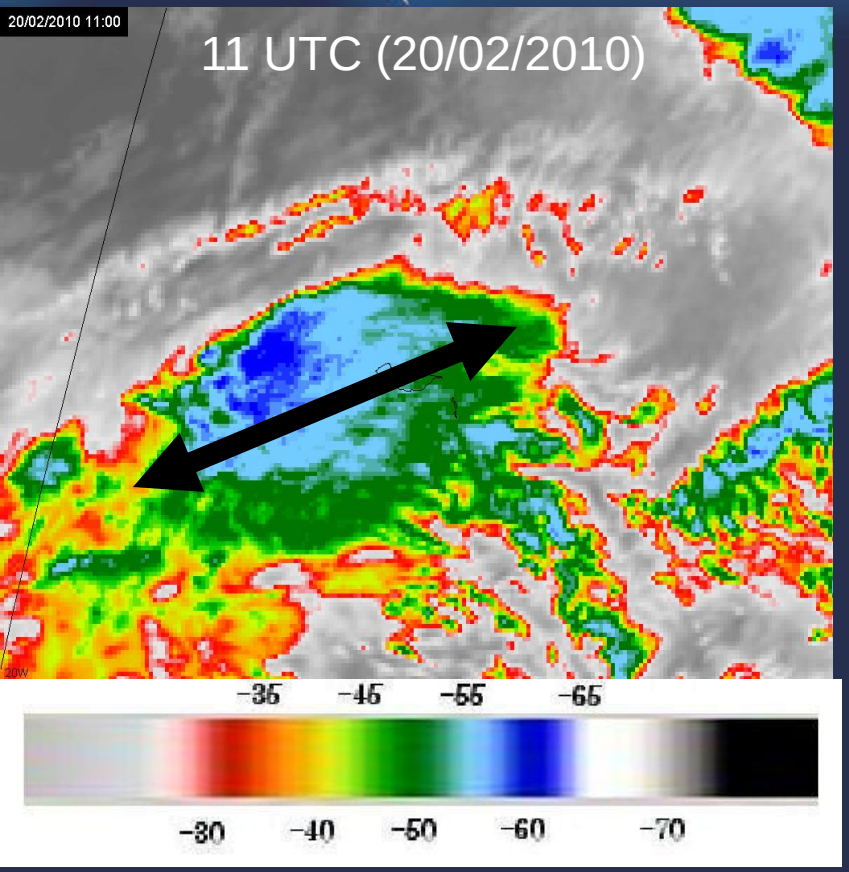
Convective System – Size and duration



350 km of maximum extent (one axis)

cloud top temperature < -35ºC

System forms WSW of Madeira
between 6:00 and 7:00 UTC.

Moves over Madeira
between 10:00 and 12:30 UTC (~2.5 hours)

Total duration 6 - 7 hours (until 13 UTC)

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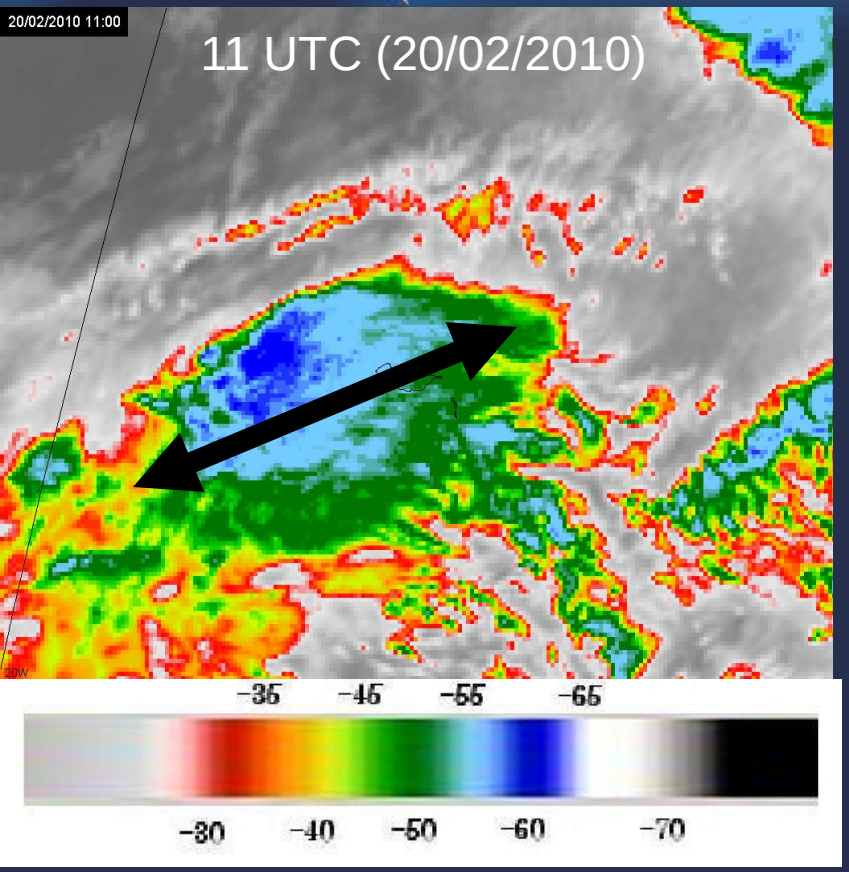
Convective System – Size and duration



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Total duration 6 - 7 hours (until 13 UTC)

Meets the criteria for MCS

* Larger axis (if oval) > 200km for Temperature < -32ºC
* Mean duration in Europe: 5.5 hours

"*Virtually all flash floods are produced by MCSs*"
Doswell *et al* (1996)

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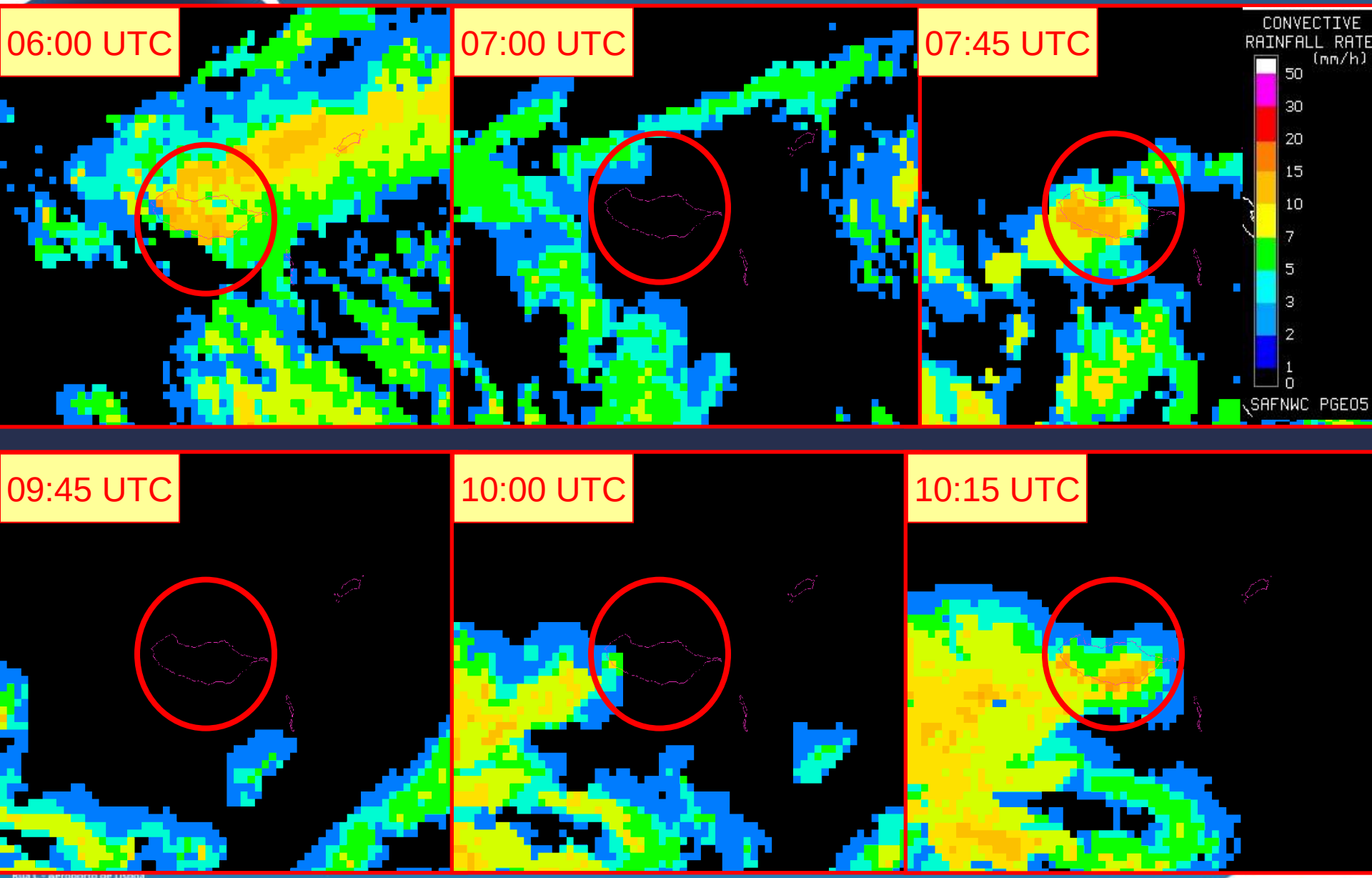
Convection before the MCS
Convective Rainfall Rate (SAF Nowcasting)



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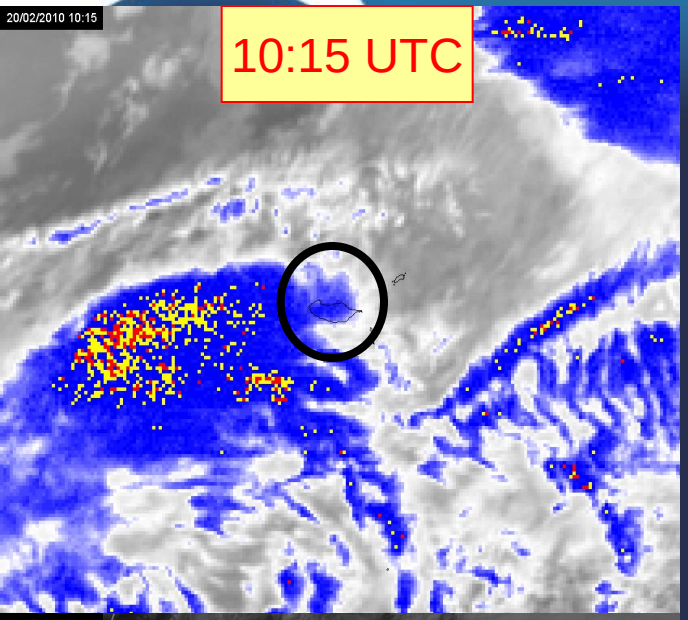
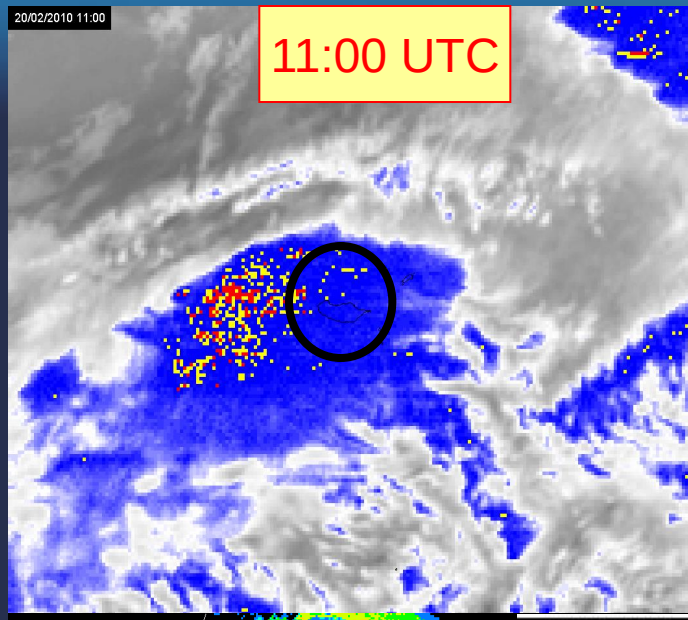
The MCS – Meteosat 9

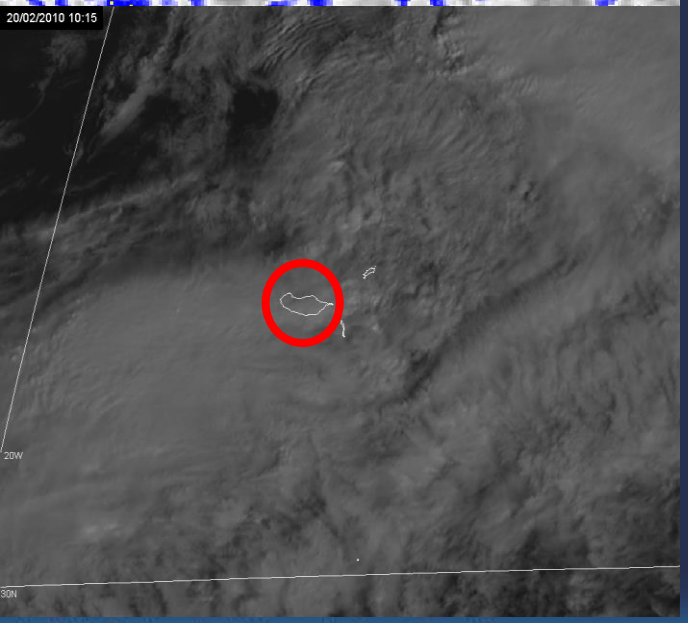


10:15 UTC

Overshootings (IR10.8-WV6.2)

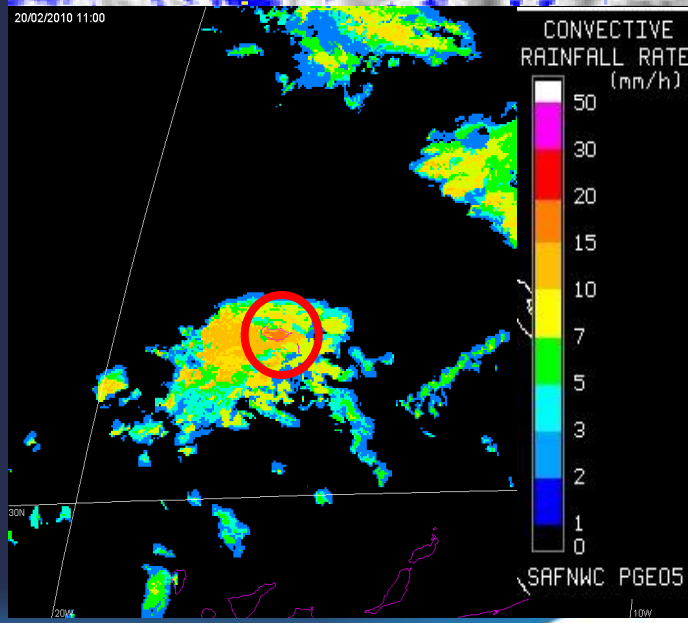


11:00 UTC



High Resolution Visible

Convective Rainfall Rate (SAF Nowcasting)



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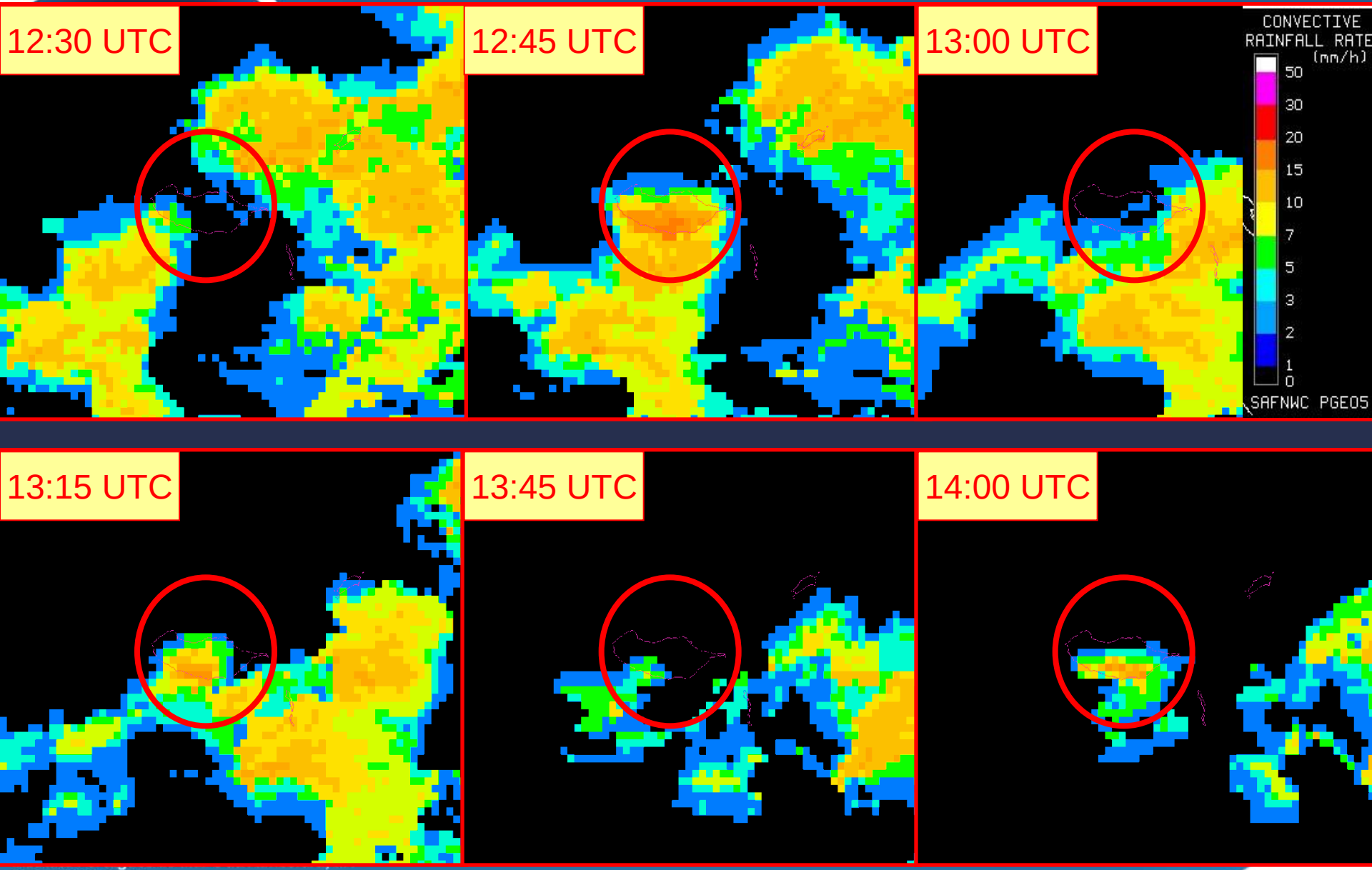
Convection after the MCS
Convective Rainfall Rate (SAF Nowcasting)



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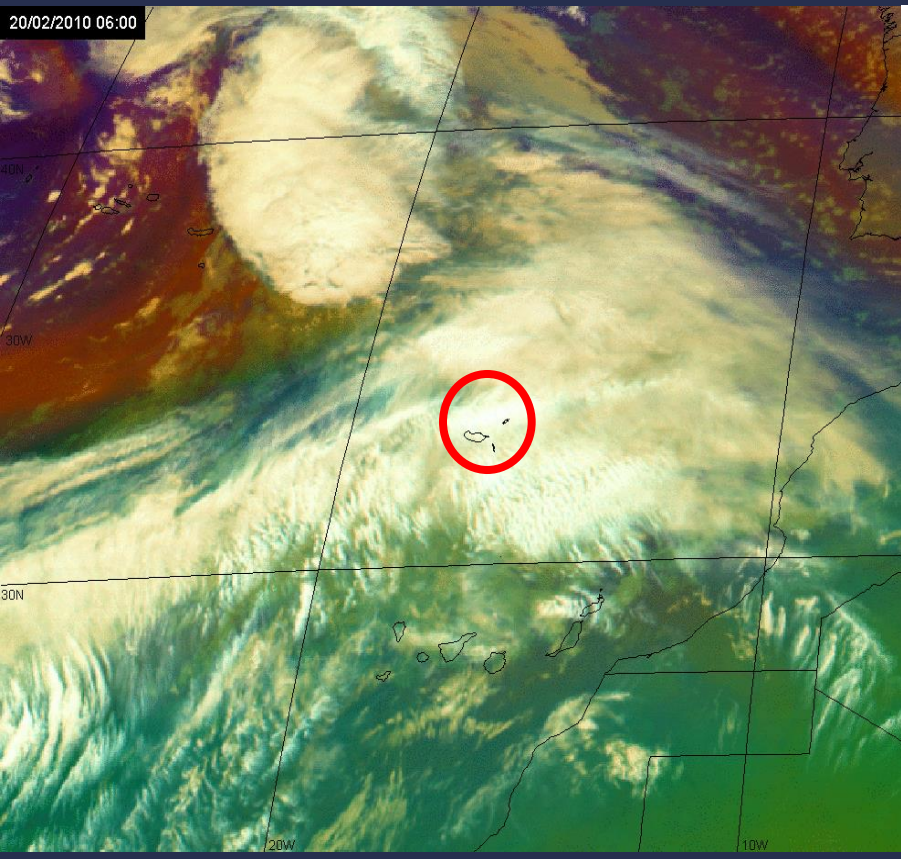
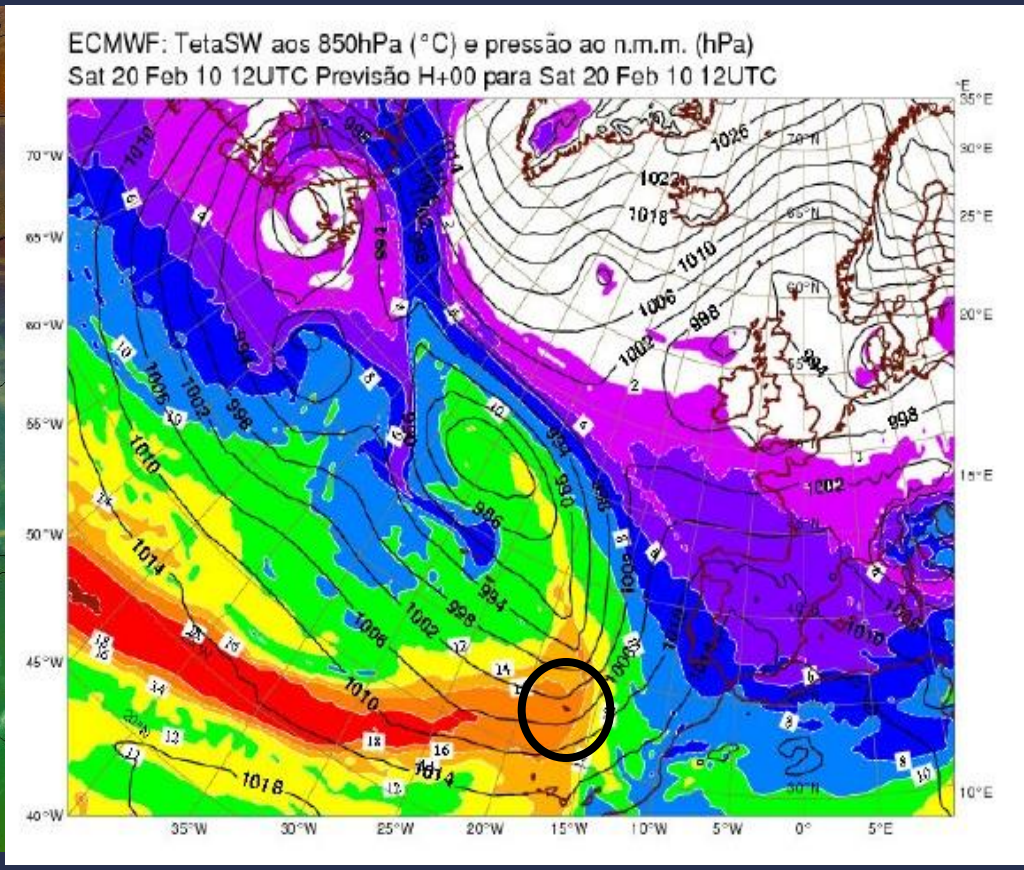
Synoptic Environment – 20Feb2010

Meteosat 9
Air mass RGB, 06:00 UTC



ECMWF – Wet Bulb Potential
Temperature 850hPa 12 UTC



Tropical Air mass with thick clouds

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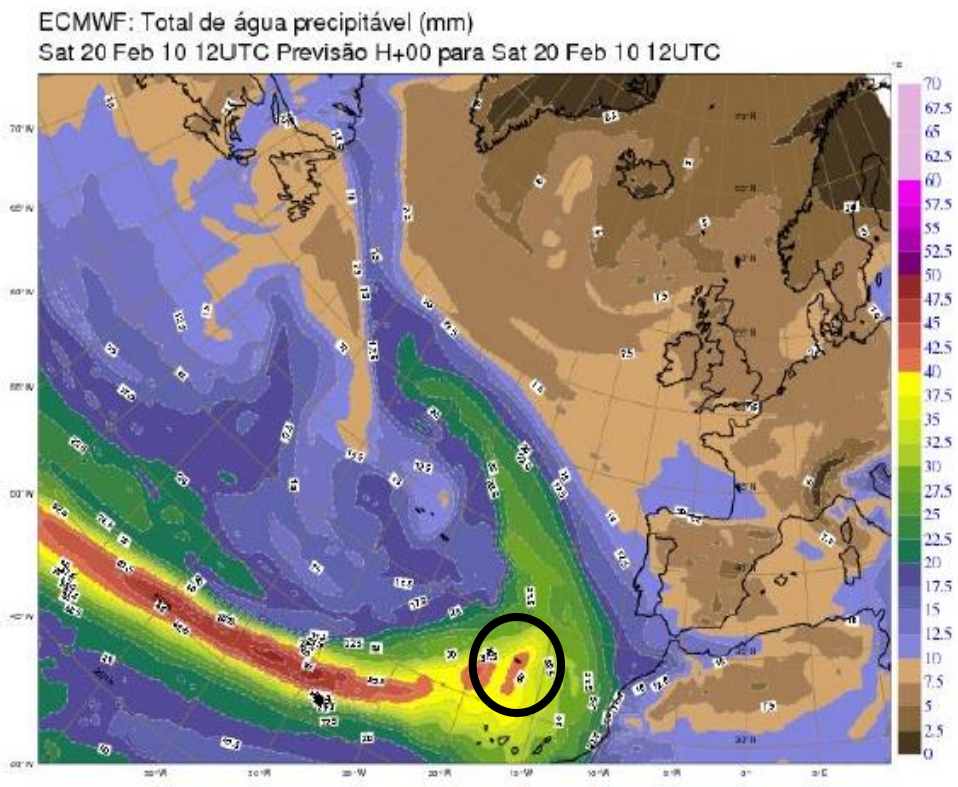
Synoptic Environment – 20Feb2010

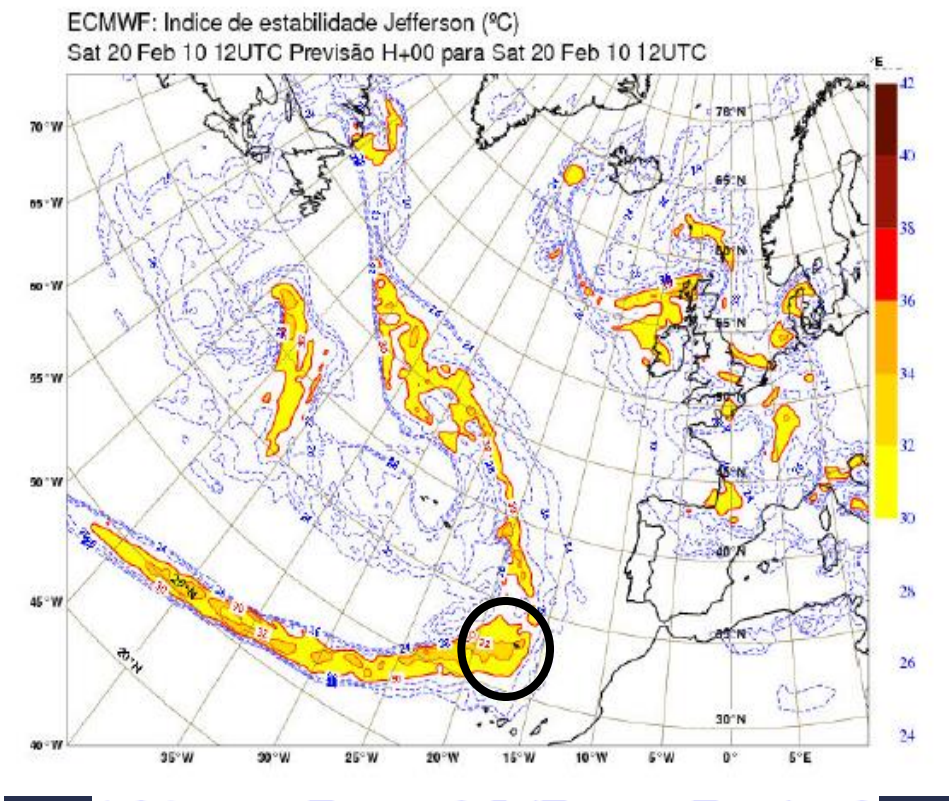
ECMWF

Total Precipitable Water , 12 UTC



ECMWF

Jefferson Index, 12 UTC



$$1.6\theta_{sw850} - T_{500} - 0.5\,(T_{700} - T_{d700}) - 8$$

Very moist (TPW ~ 40 mm)

and unstable (Jefferson > 30ºC) air mass

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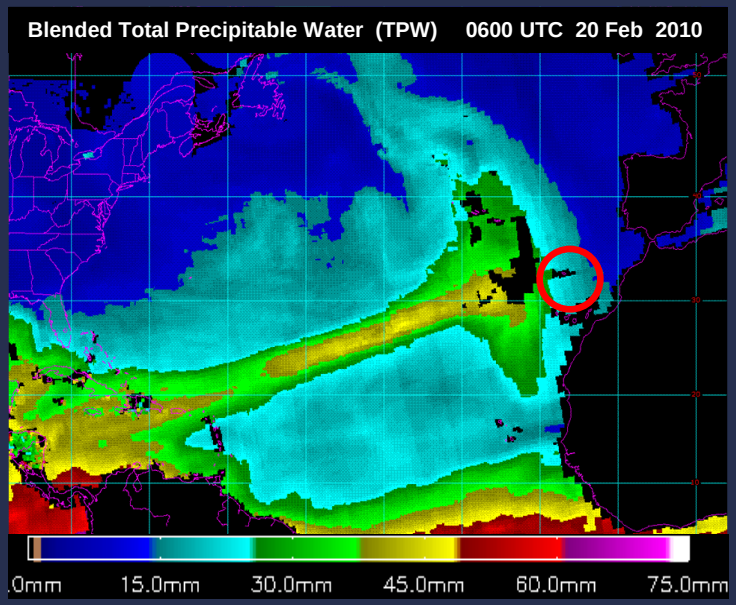
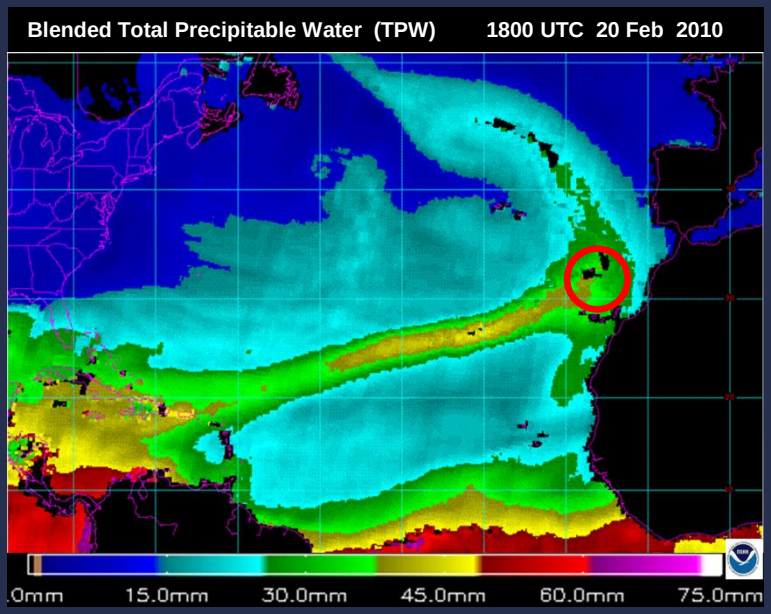
An Atmospheric River over Madeira

NOAA Blended Total Precipitable Water (TPW)





Kusselson (2012)

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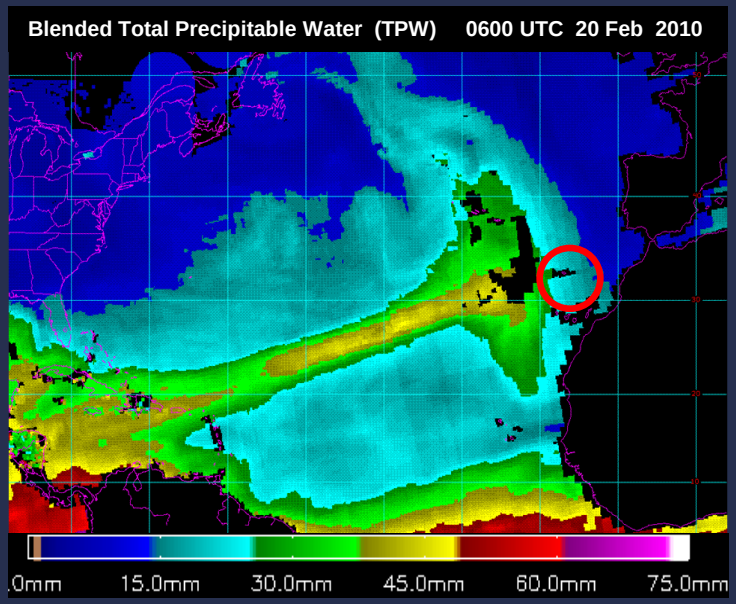
The Madeira Island Floods of 20 February 2010 http://nws.met.psu.edu/severe/2010/20Feb2010.pdf

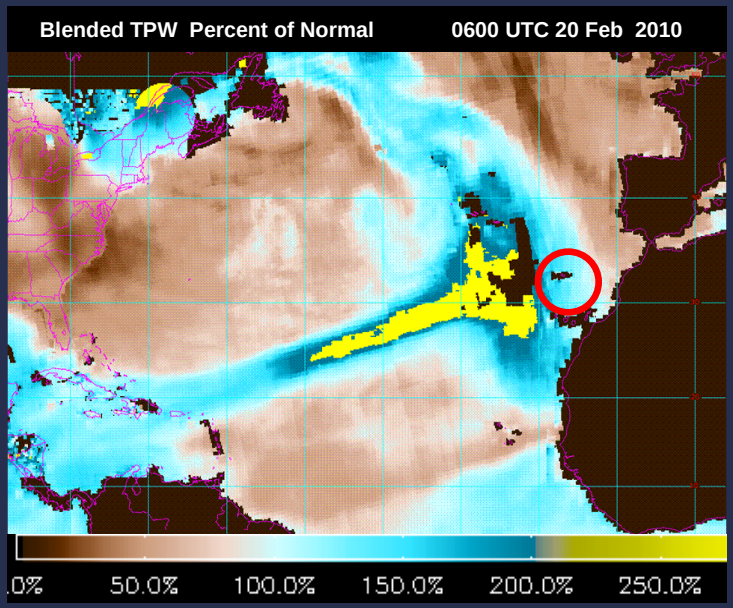
The 20 February 2010 Madeira flash-floods: synoptic analysis and extreme rainfall assessment http://www.nat-hazards-earth-syst-sci.net/12/715/2012/nhess-12-715-2012.pdf

An Atmospheric River over Madeira

Blended Total Precipitable Water (TPW)



Blended TPW Percent of Normal



Kusselson (2012)

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The Atmospheric Rivers (AR) …

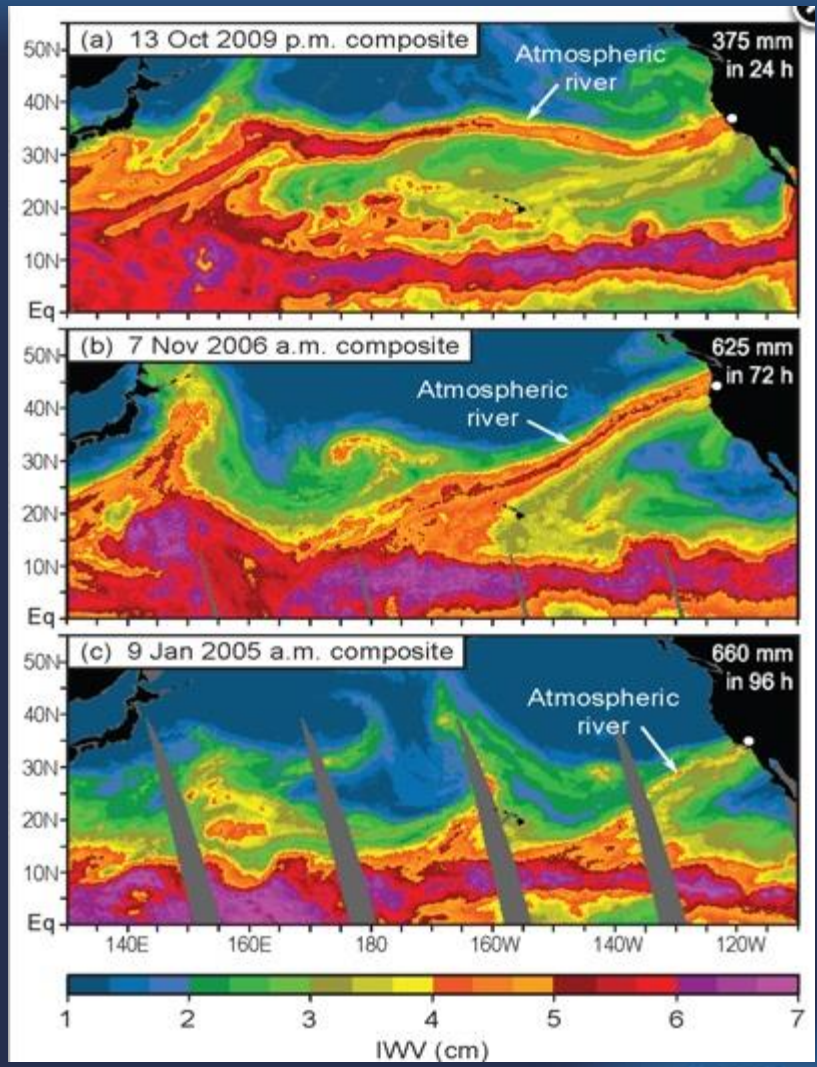
- Relatively **narrow regions** in the atmosphere that are responsible for most of the horizontal **transport of water vapor outside of the tropics**.

- On average Atmospheric Rivers are **400-600 km wide**

- Term first used in **1998**

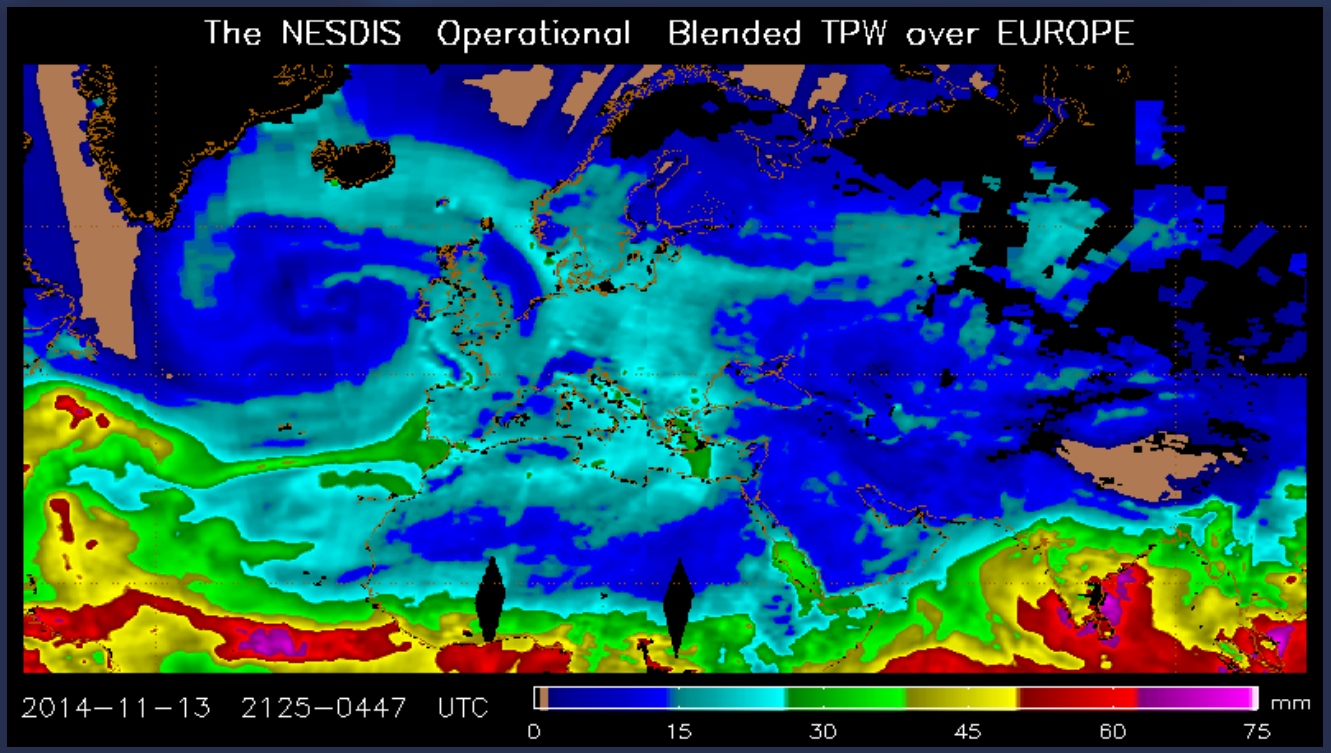
- Many examples studied over the Pacific and North America West Coast

- During **10 years** in California, **42 Atmospheric River** were found and some considered the cause for flooding



http://www.esrl.noaa.gov/psd/atmrivers/

Atmospheric rivers – frequent?
Recent case: 13-14nov2014



http://www.ospo.noaa.gov/Products/bTPW/TPW_Animation.html?product=EUROPE_TPW

"*Top 20 days of the ranking of precipitation anomalies for the Iberian Peninsula includes 19 days that are clearly related with AR events*."

Dataset:
daily precipitation
1950-2008

Ramos *et al* (2014)

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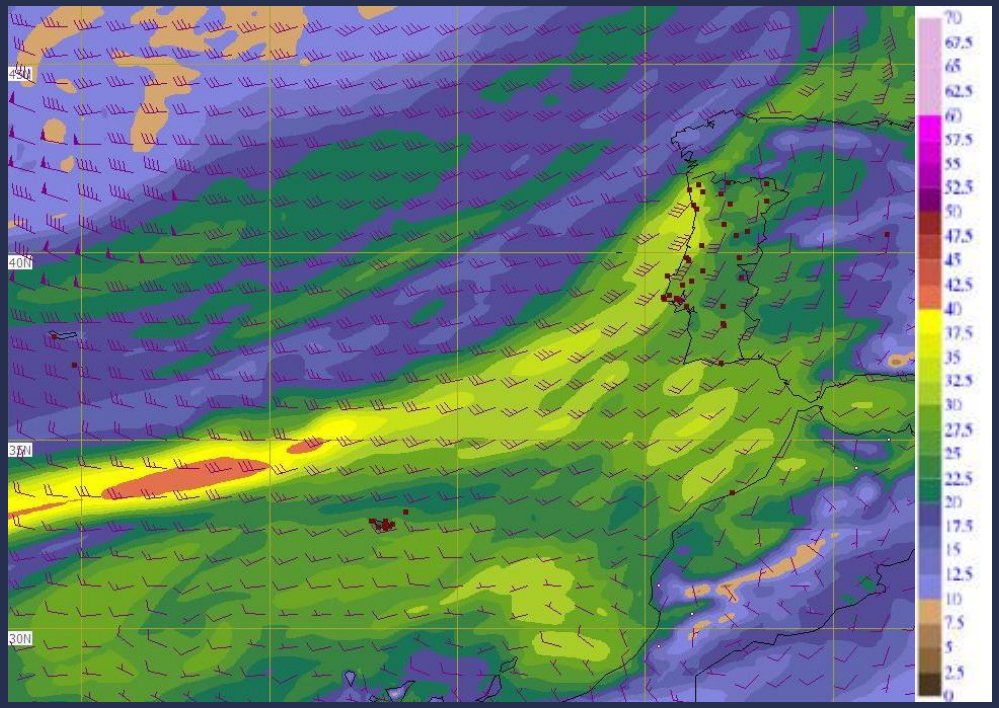
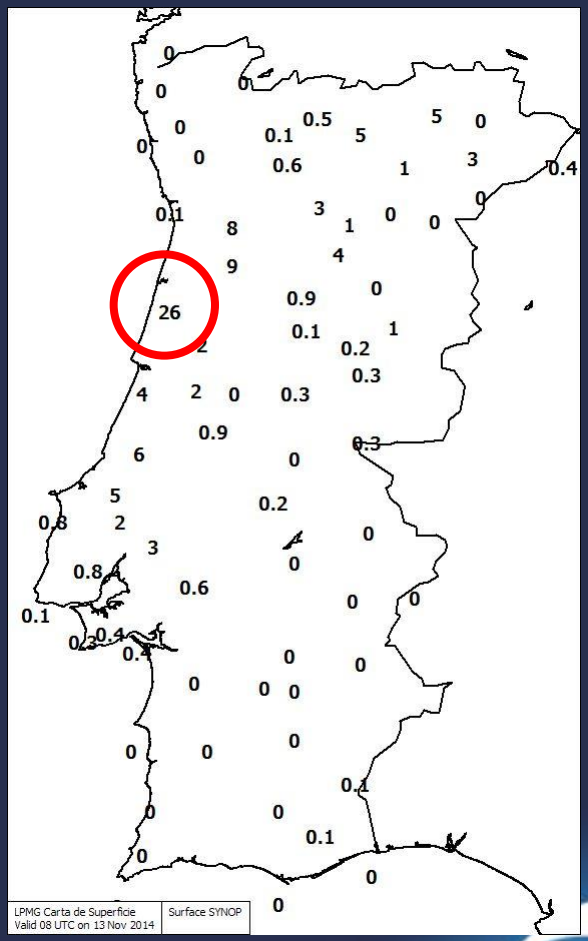
Atmospheric rivers – frequent?
Recent case: 13-14nov2014

ECMWF 6h forecast
13nov2014 - 0600UTC
wind925hPa + TPW



1h observed precipitation
13nov2014 - 0800UTC



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Are Atmospheric Rivers a sufficient condition for floods?

YES

NO

Heavy precipitation events (oct/nov 2012) search for ingredients …*TPW*

Prec 6H > 30mm

✓ TPW >> 20mm

Analysis of TPW ECMWF

Observed 6H Precipitation

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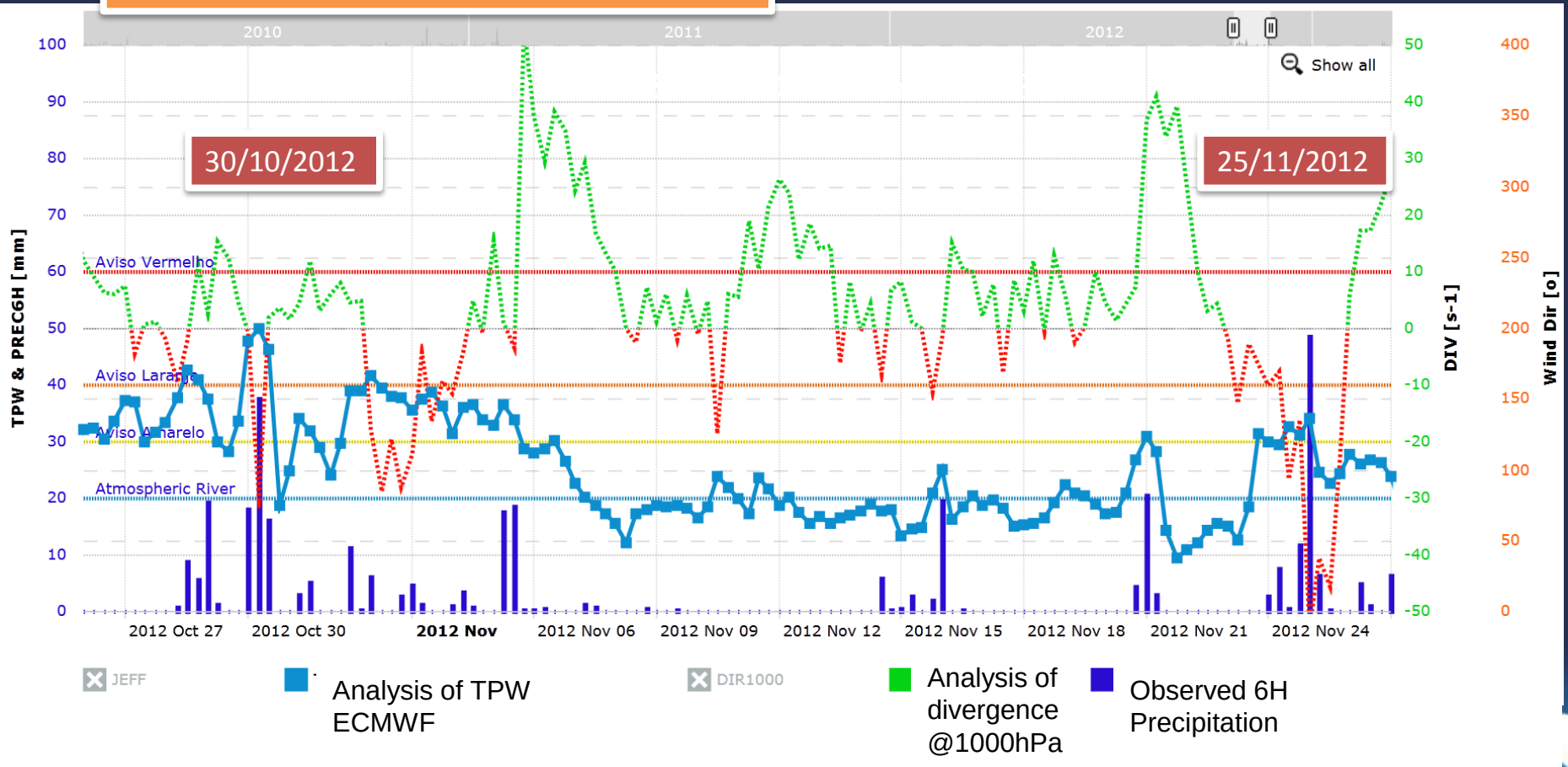
Heavy precipitation events (oct/nov 2012) search for ingredients … *Convergence*

Prec 6H > 30mm
- ✓ TPW >> 20mm
- ✓ High Convergence



Analysis of TPW ECMWF

Analysis of divergence @1000hPa

Observed 6H Precipitation

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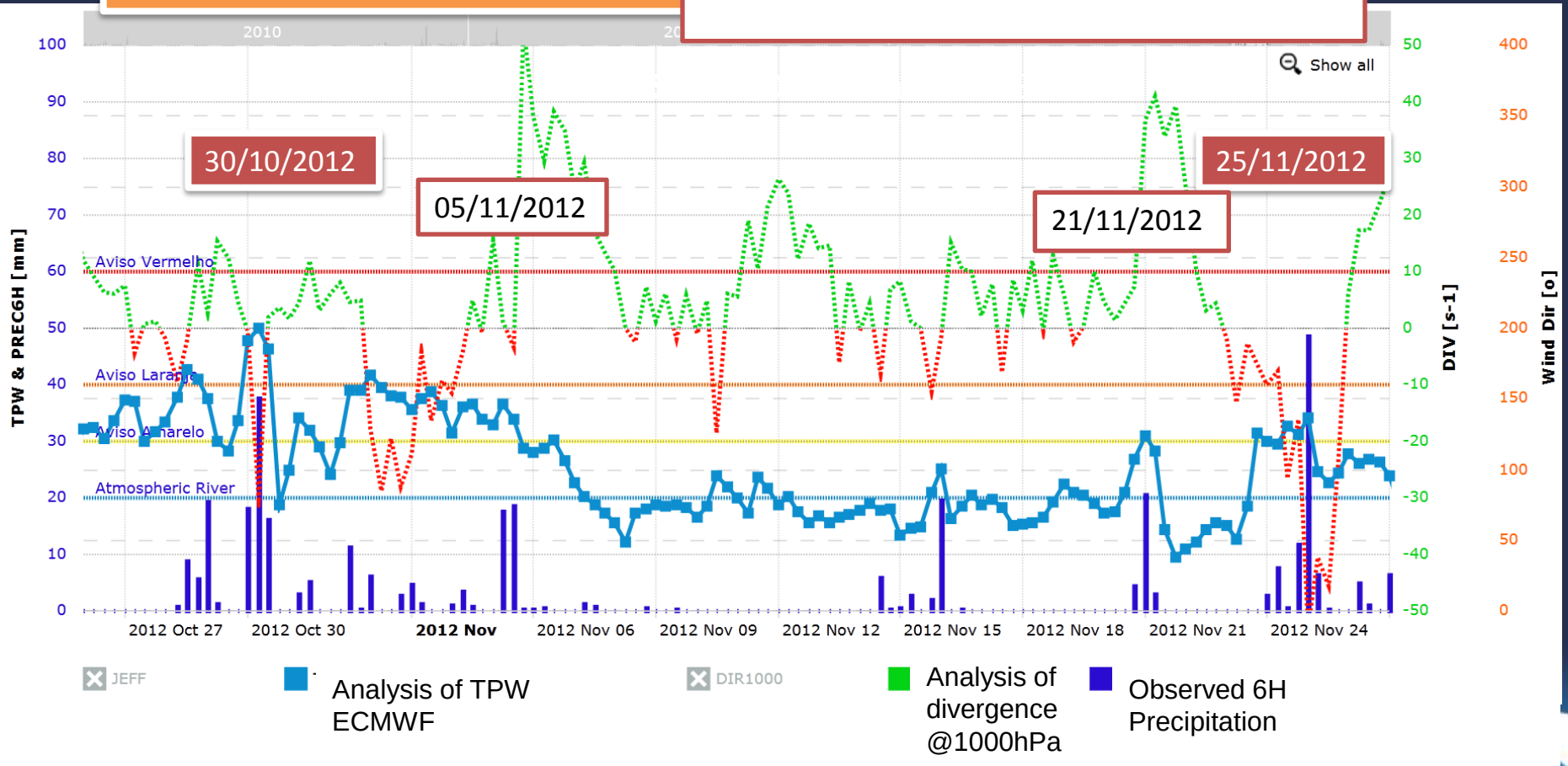
Heavy precipitation events (oct/nov 2012) search for ingredients … *Divergence ?*

Prec 6H > 30mm
- ✓ TPW >> 20mm
- ✓ High Convergence

Prec 6H > 10mm
- ✓ TPW is similar
- ✓ High Divergence or Null Div



Analysis of TPW ECMWF

Analysis of divergence @1000hPa

Observed 6H Precipitation

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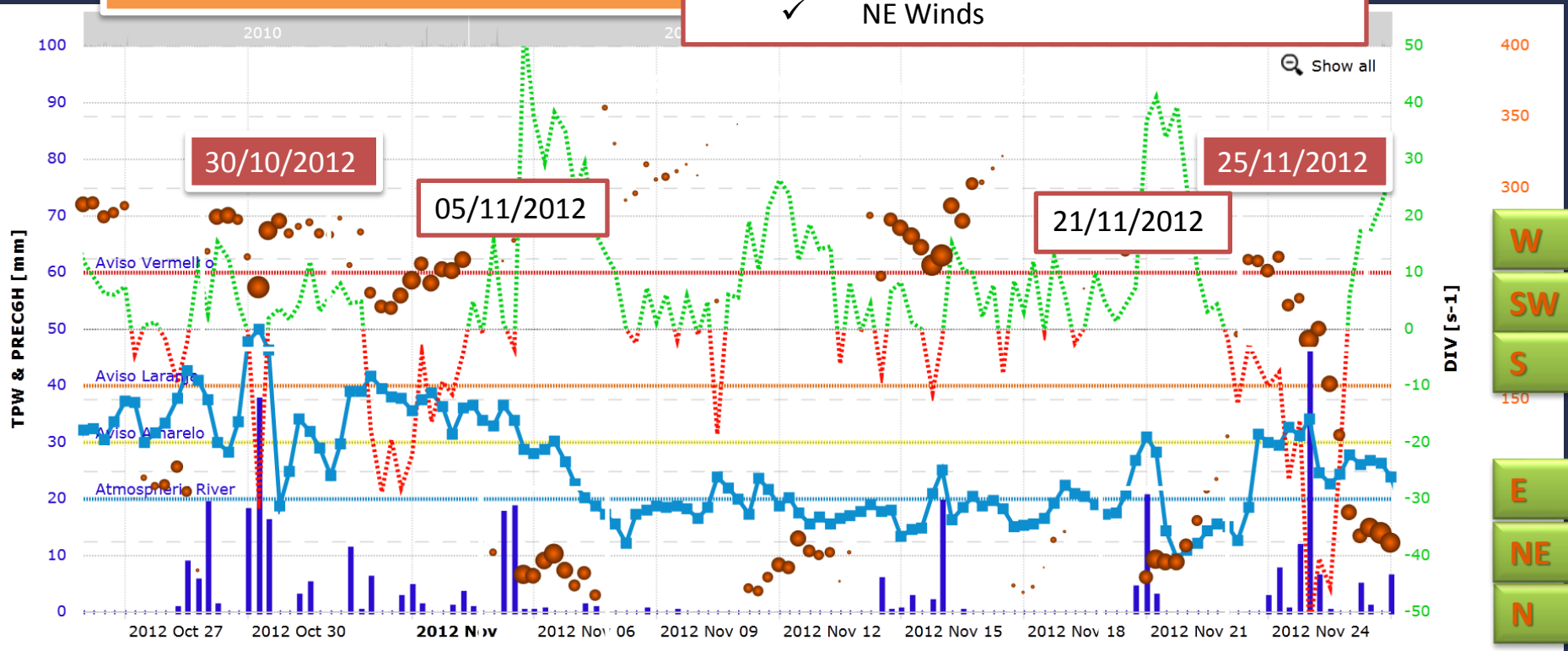
Heavy precipitation events (oct/nov 2012) search for ingredients … *Wind Direction*

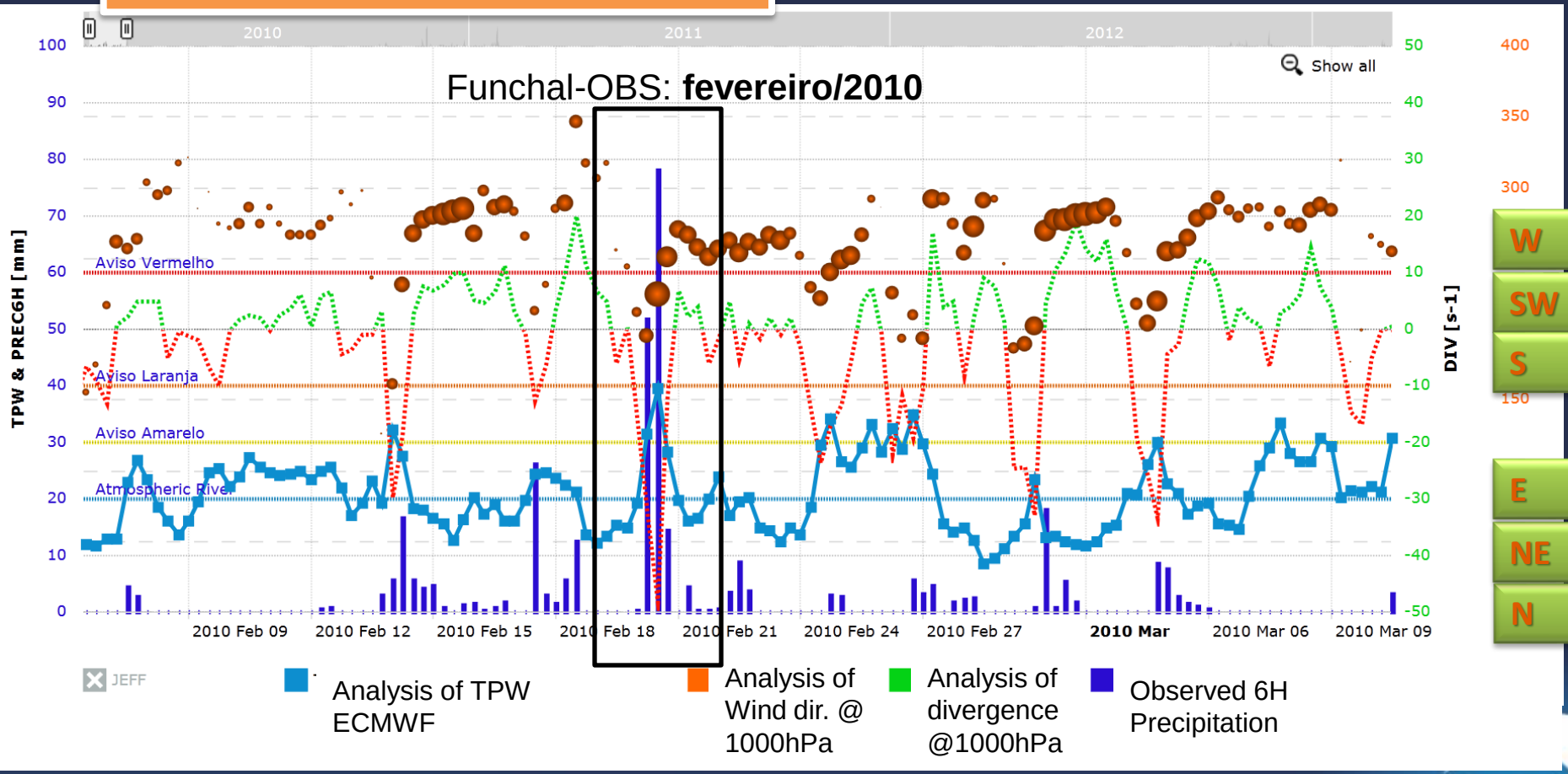
Prec 6H > 30mm
- ✓ TPW >> 20mm
- ✓ High Convergence
- ✓ W/SW Winds

Prec 6H > 10mm
- ✓ TPW is similar
- ✓ High Divergence or Null Div
- ✓ NE Winds



Which combination of ingredients on 20 feb 2010?

Prec 6H > 30mm
- ✓ TPW >> 20mm
- ✓ High Convergence
- ✓ W/SW Winds



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Other Studies on Heavy precipitation in Madeira

Patterns:
Low pressure systems
& frontal systems

Orography as dominant factor
for intensification of precipitation
(anabatic flows)

2002 -2012
AQUA Atmospheric Infrared Sounder (AIRS) and Surface Observations data - **Couto *et al* (2013)**

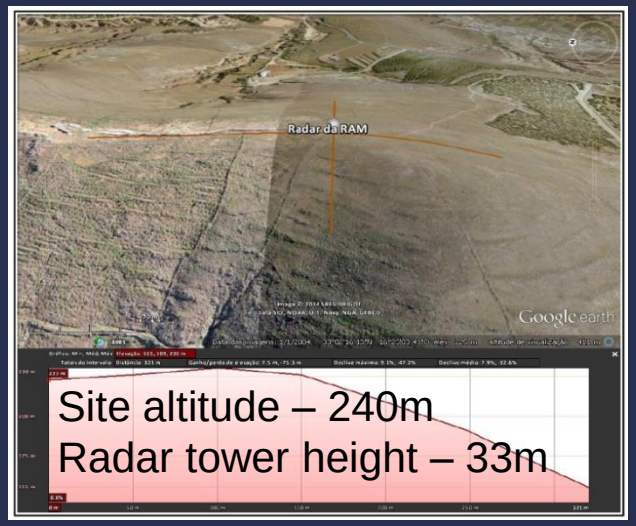
Patterns:
Negative NAO
& Polar jet down to 30ºN
& Blocking with High pressure system
to the east

Warm moist air,
saturated atmosphere from the surface,
warm advection in lower levels,
orography forcing

2010 (7 episodes)
Surface and upper air observations,
Meteosat 2nd generation images,
ECMWF analysis - **Novo *et al* (2011)**

The future – Radar in Madeira / Porto Santo

Two major islands:
Madeira and Porto Santo



Barbosa and Narciso (2014)

Expected to be operational
by the end of 2015

Final remarks

The catatrophic event on 20th Feb 2010 in Madeira happened during an atmospheric river episode

A Mesoscale Convective System (MCS) and orographic forcing played a major role on the precipitation regime and therefore on the flooding and landslides

High values of TPW and convergence under south quadrant flow were found in this event as well as in other similar events (although not as severe)

After 2015 the precipitation regime description over Madeira will also include (frequent) images from a surface radar in addition to satellite imagery, surface observations or radiosounding data

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Ramos, A., Trigo, R. and Liberato, M., 2014: Daily precipitation extreme events for the Iberian Peninsula and its association with Atmospheric Rivers. Geophysical Research Abstracts. Vol. 16, EGU2014-131, 2014.

Websites:
http://www.esrl.noaa.gov/psd/atmrivers/
https://www.meted.ucar.edu

Youtube videos:
https://www.youtube.com/watch?v=KKRgPzrKQ2k
http://www.youtube.com/watch?v=q1218WeWUgQ
https://www.youtube.com/watch?v=WeuV_gKRHiE

Thank you

Questions ?