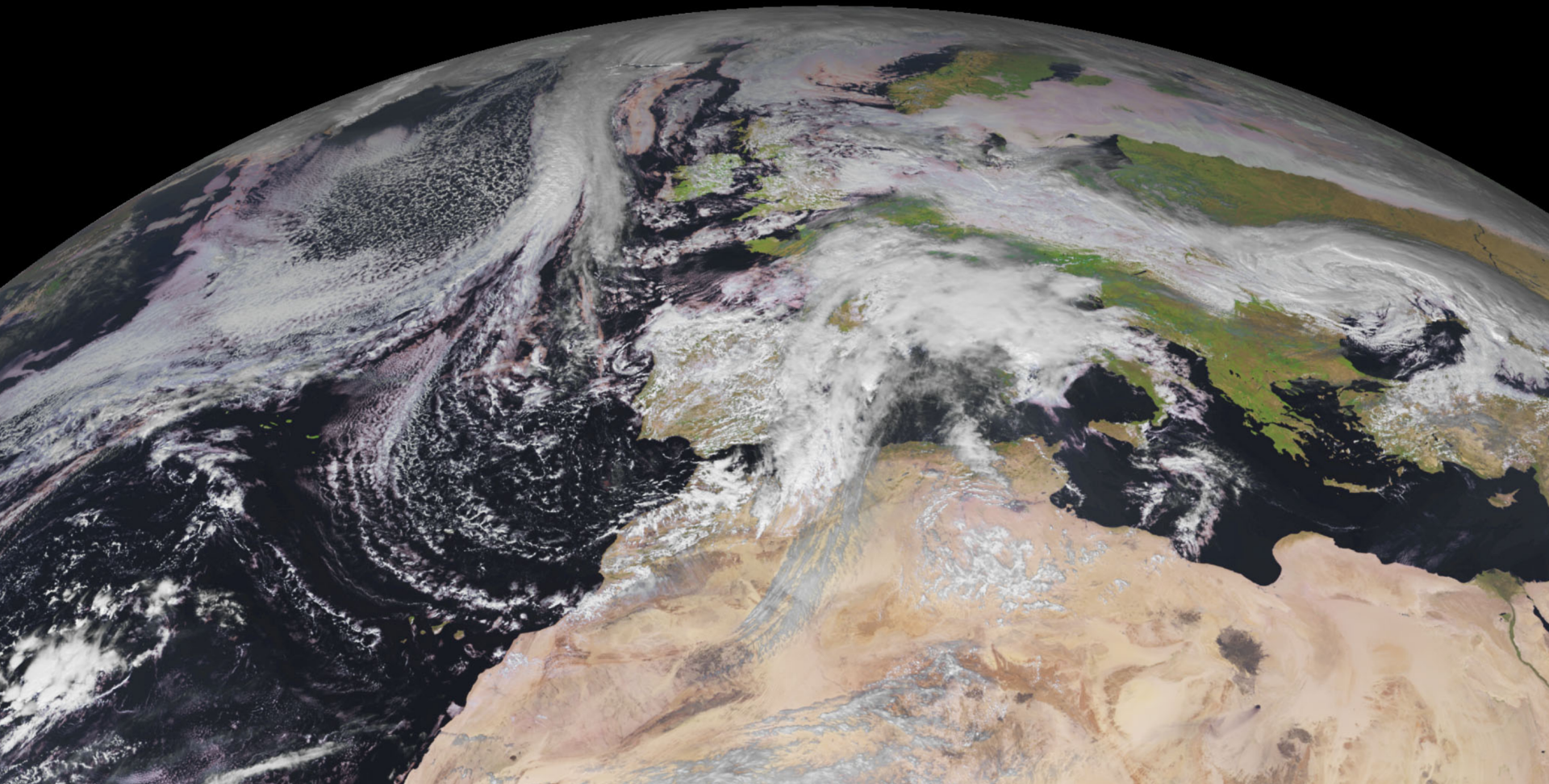


Cut-off Sanchez and its downstream impact over southern France – verification of probabilistic Météo-France forecasts

Hanin Binder, Gwendal Rivière, Philippe Arbogast, Bruno Joly, Carole Labadie

DIP NAWDEX meeting, 5 February 2018

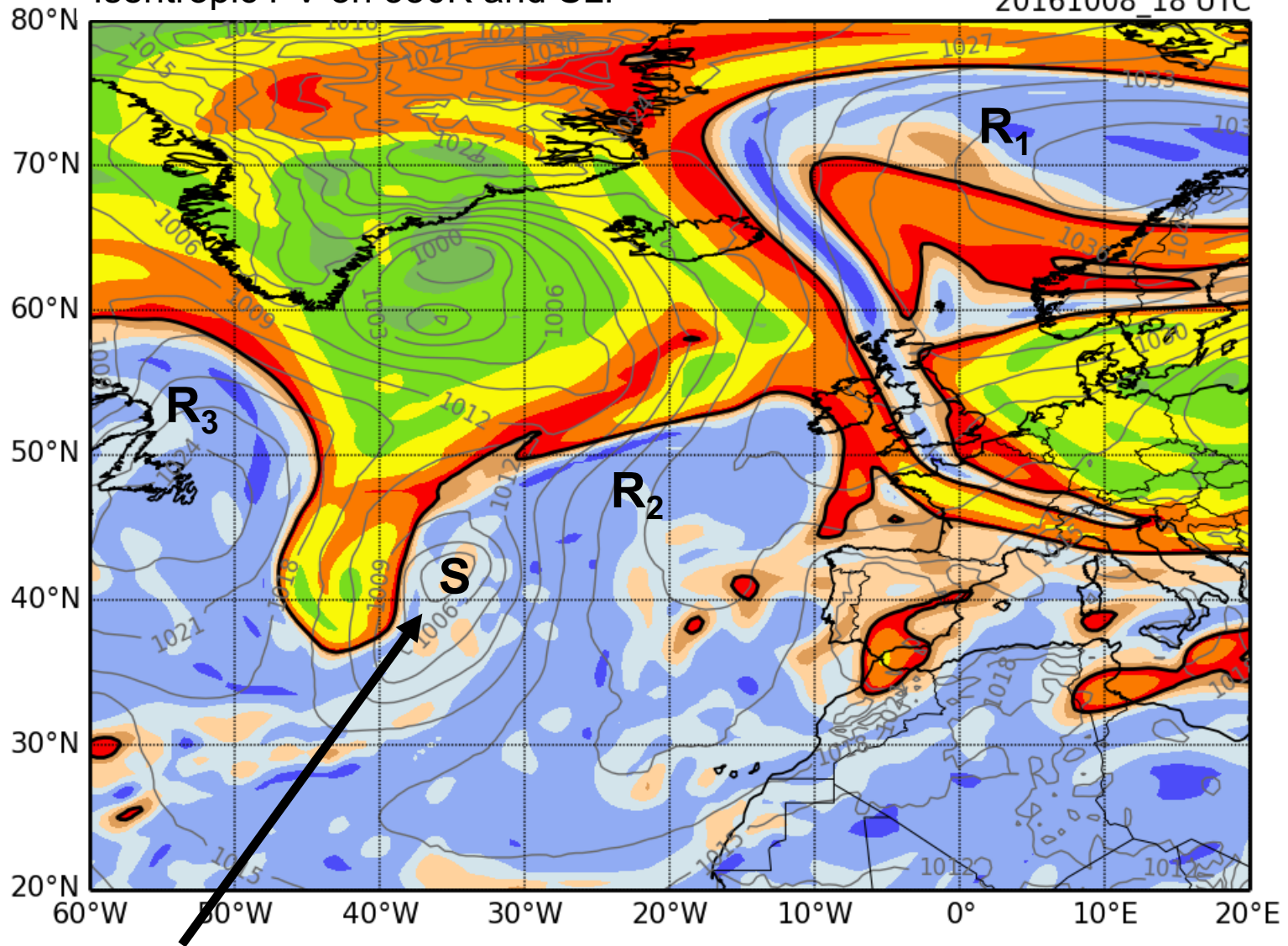


IOP 9, 9-14 October: Cut-off Sanchez and its downstream impact over southern France

- Brief overview of the meteorological situation leading to the high-impact weather (HIW)
- Objectives of the study
- First results

Isentropic PV on 330K and SLP

20161008 18 UTC

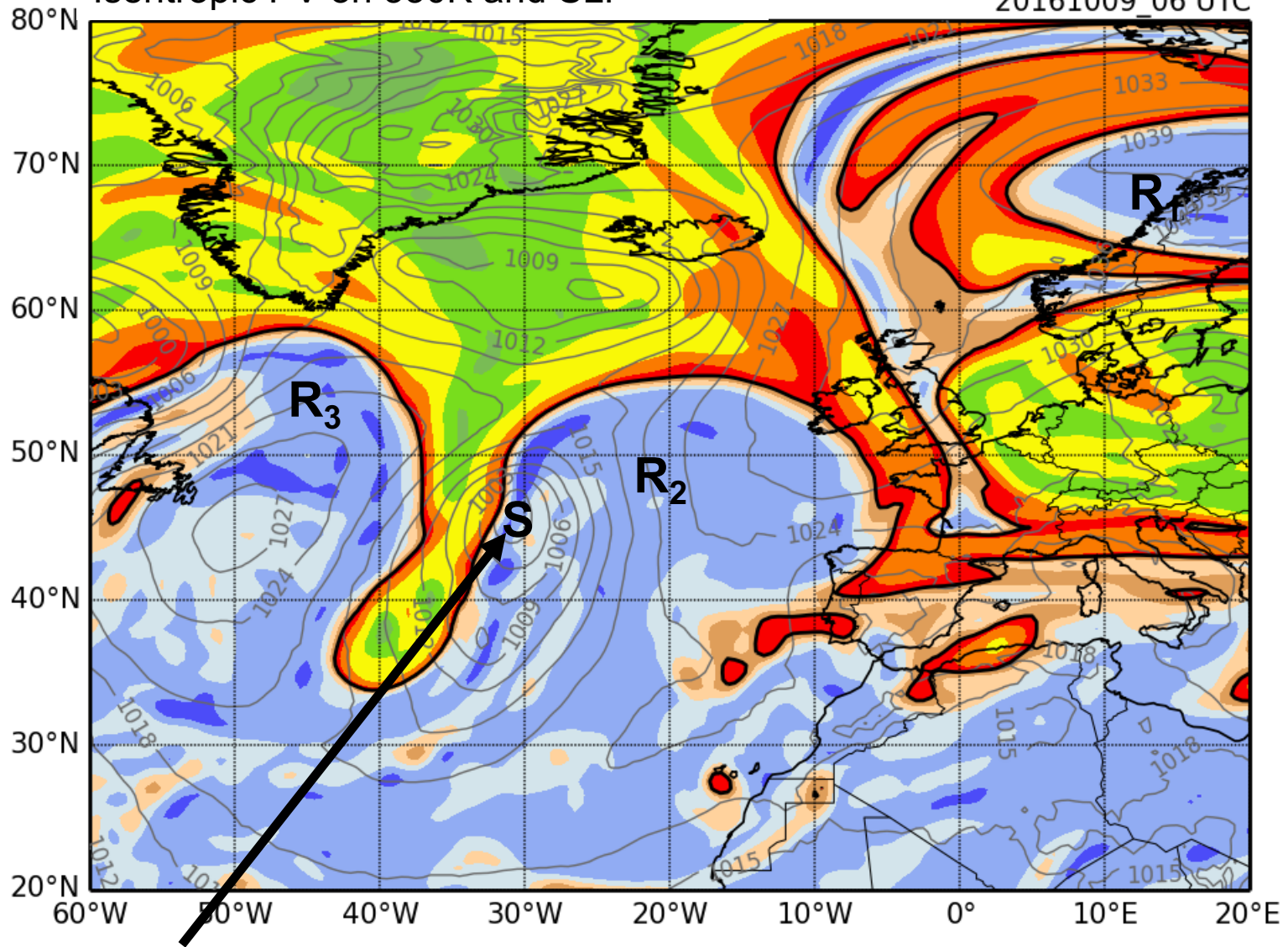


Surface cyclone
"Sanchez"

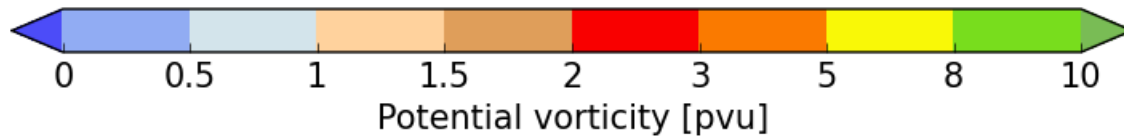


Isentropic PV on 330K and SLP

20161009 06 UTC

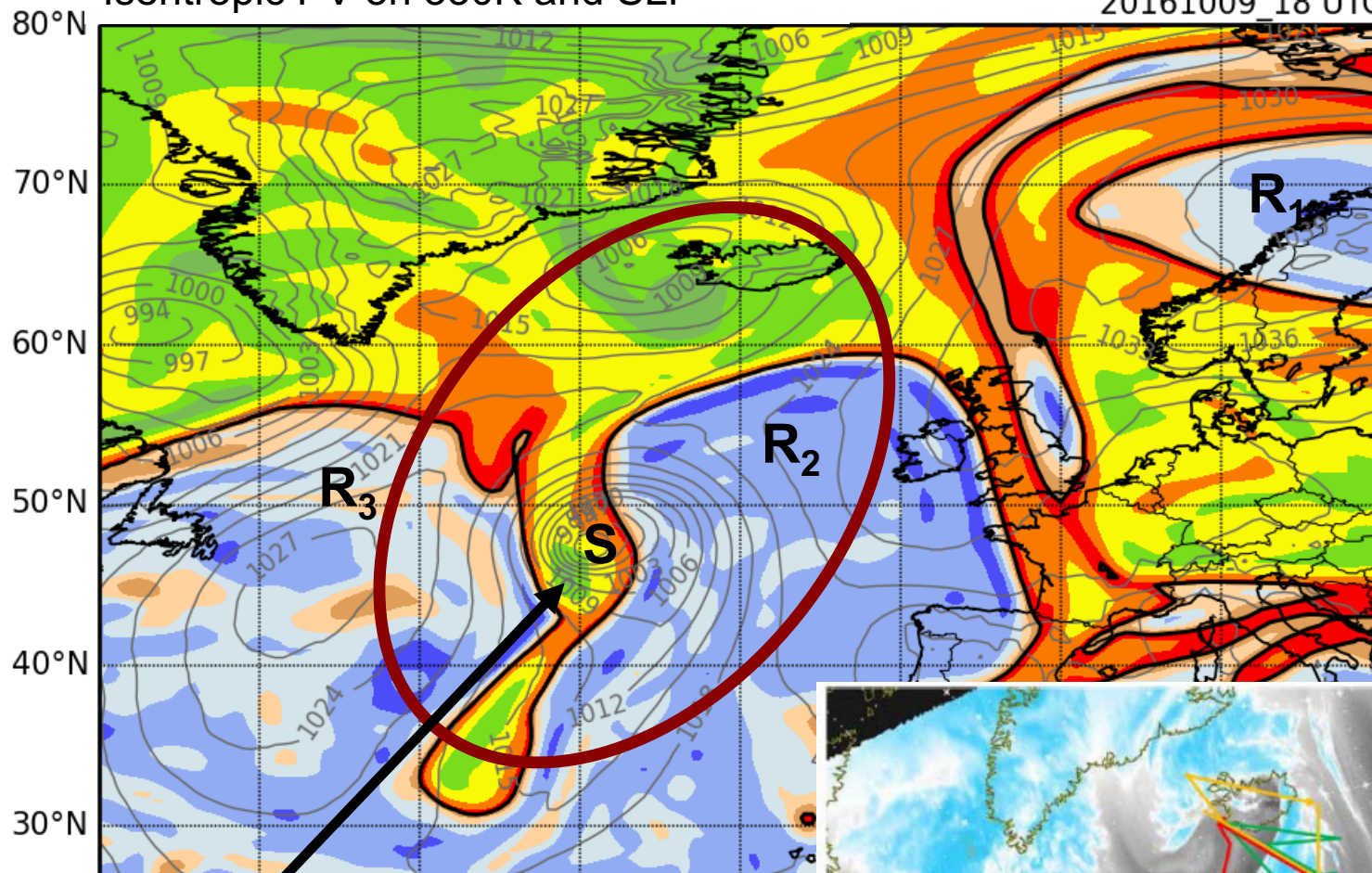


Surface cyclone
"Sanchez"

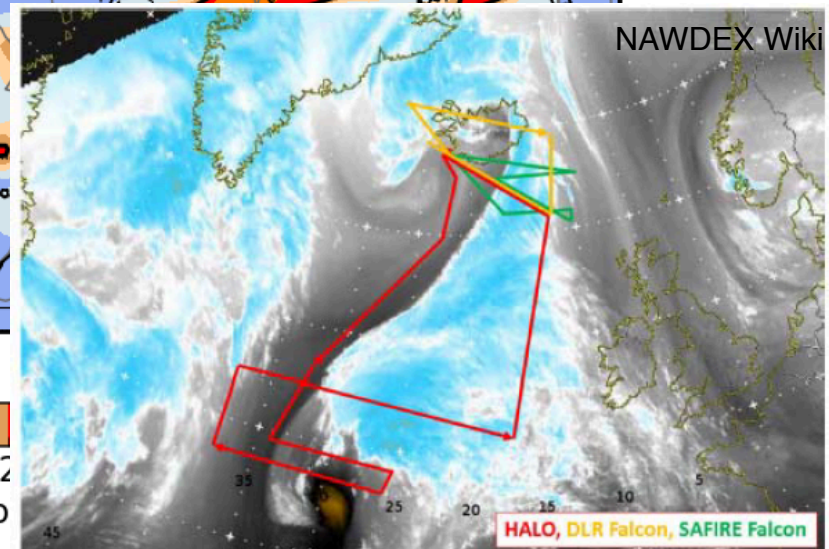
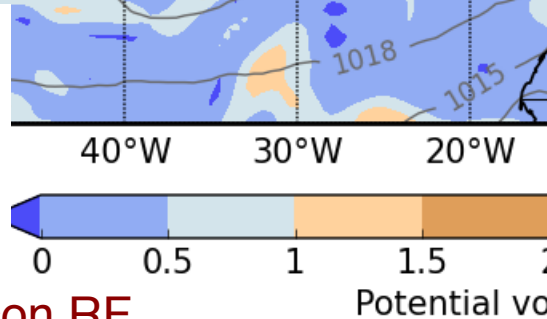


Isentropic PV on 330K and SLP

20161009 18 UTC



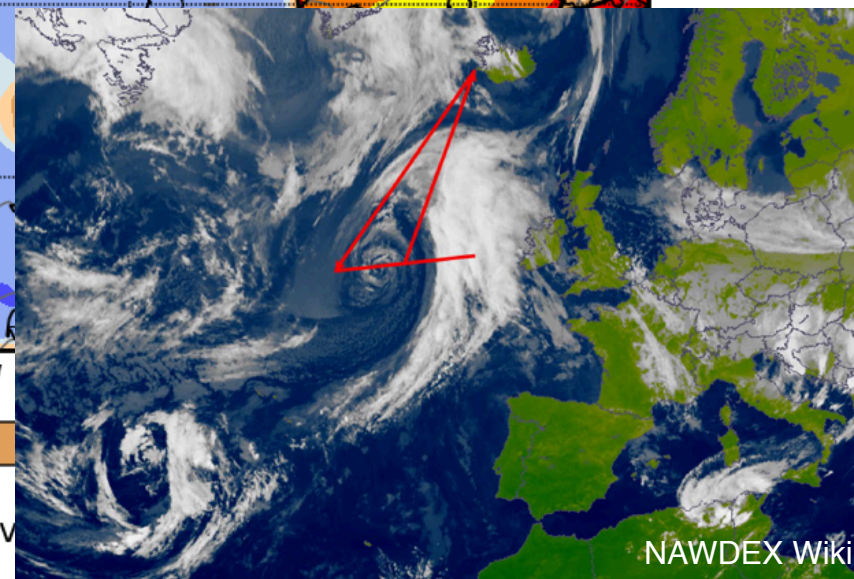
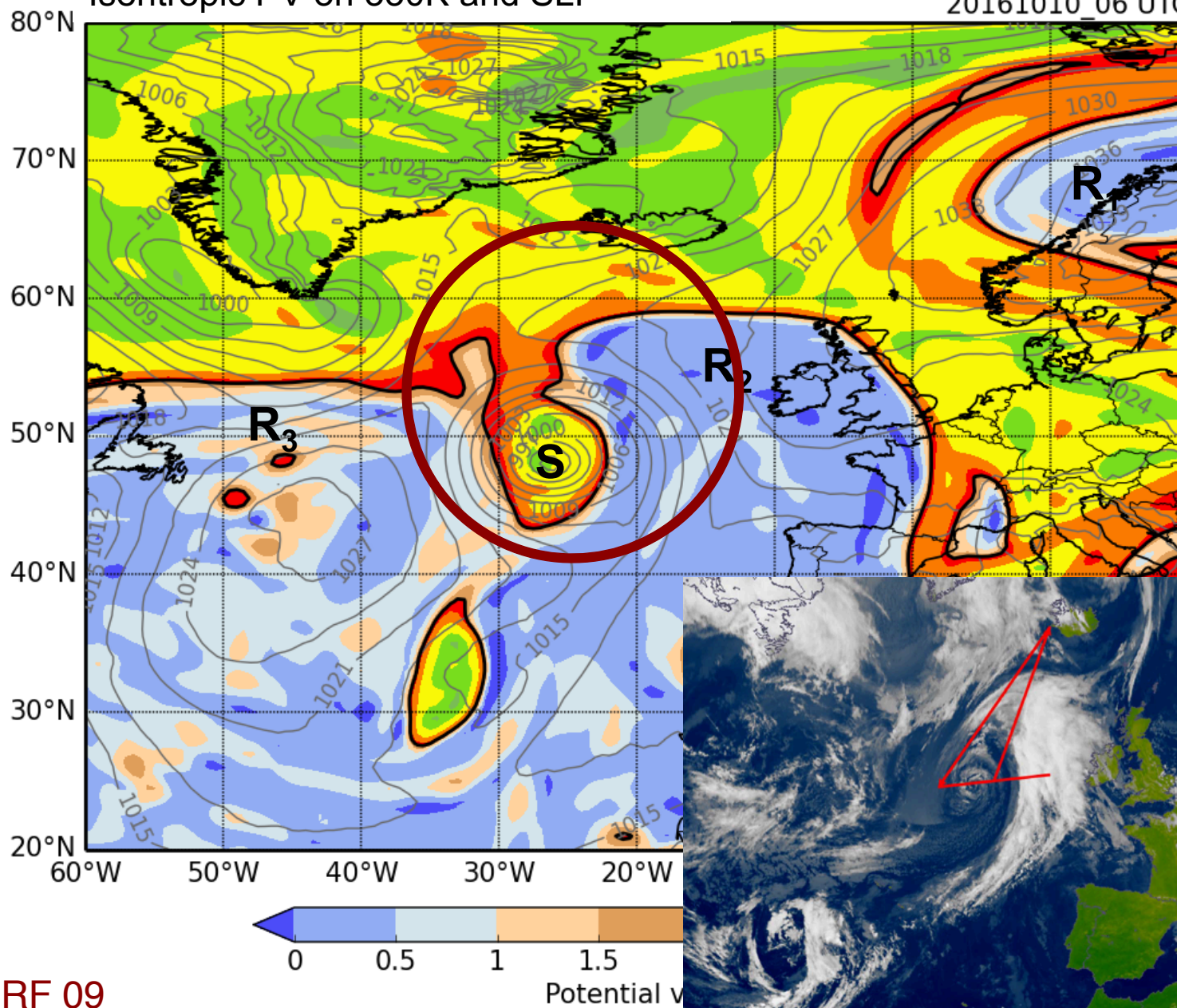
Surface cyclone
and upper-level
cut-off "Sanchez"



HALO RF 08 – G-Falcon RF
10 – F-Falcon RF 11/12

Isentropic PV on 330K and SLP

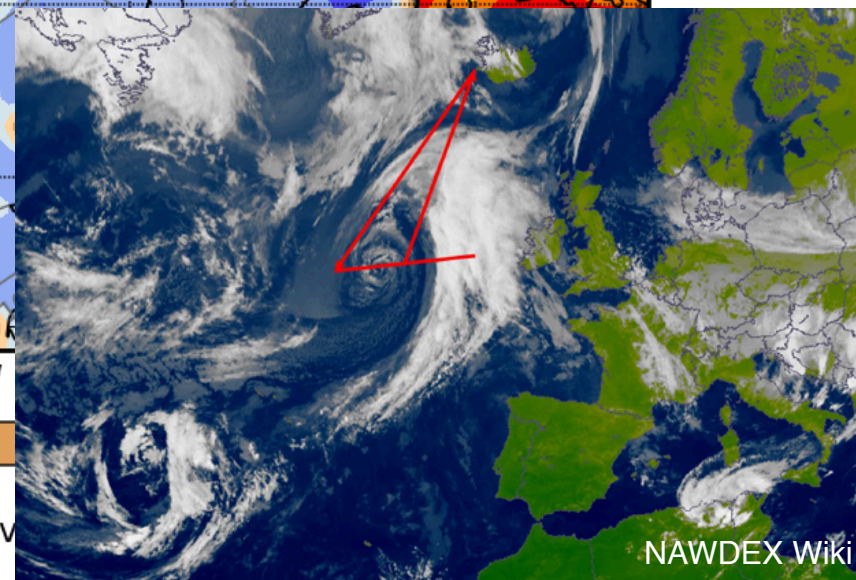
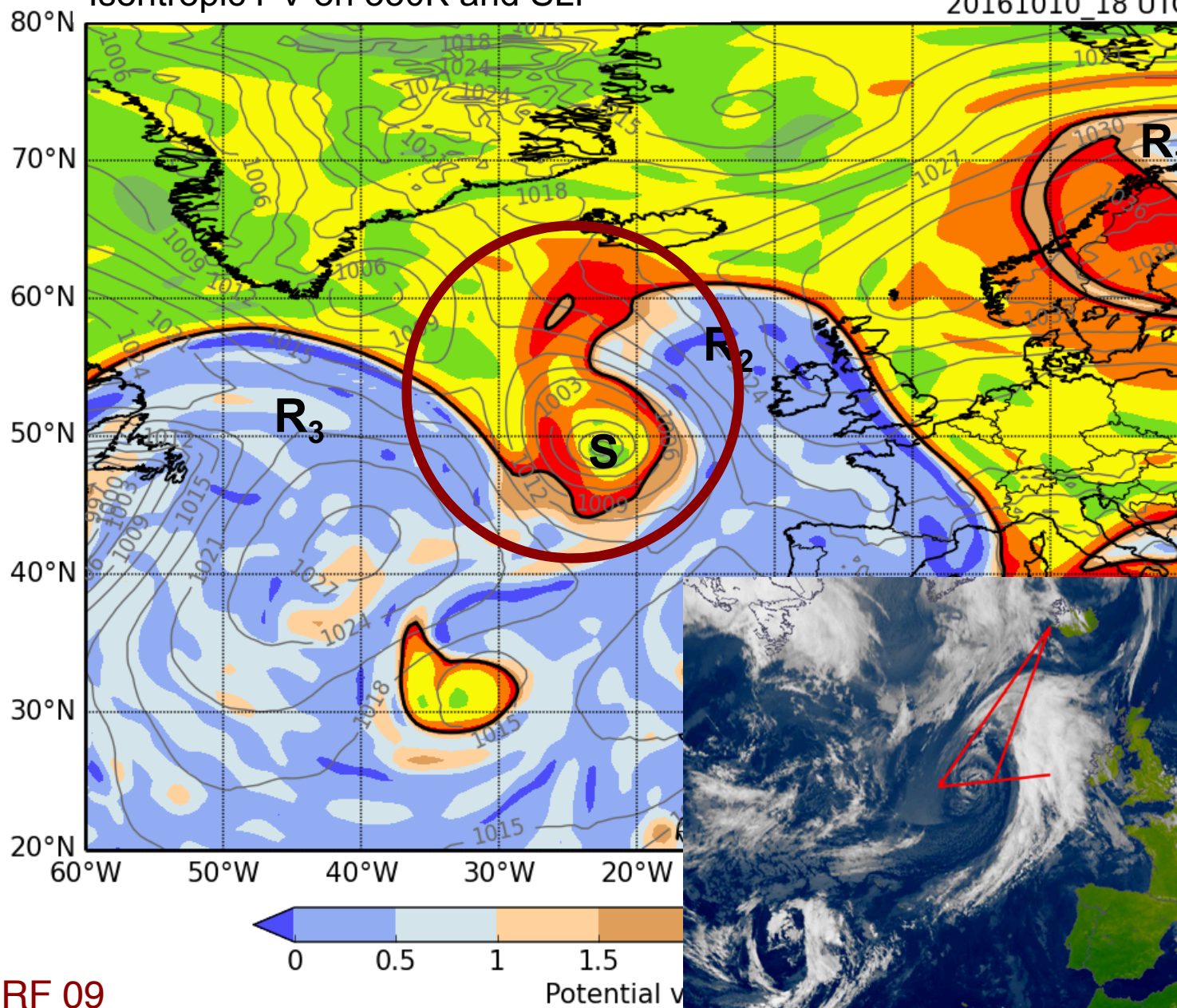
20161010_06 UTC



HALO RF 09
F-Falcon RF 13

Isentropic PV on 330K and SLP

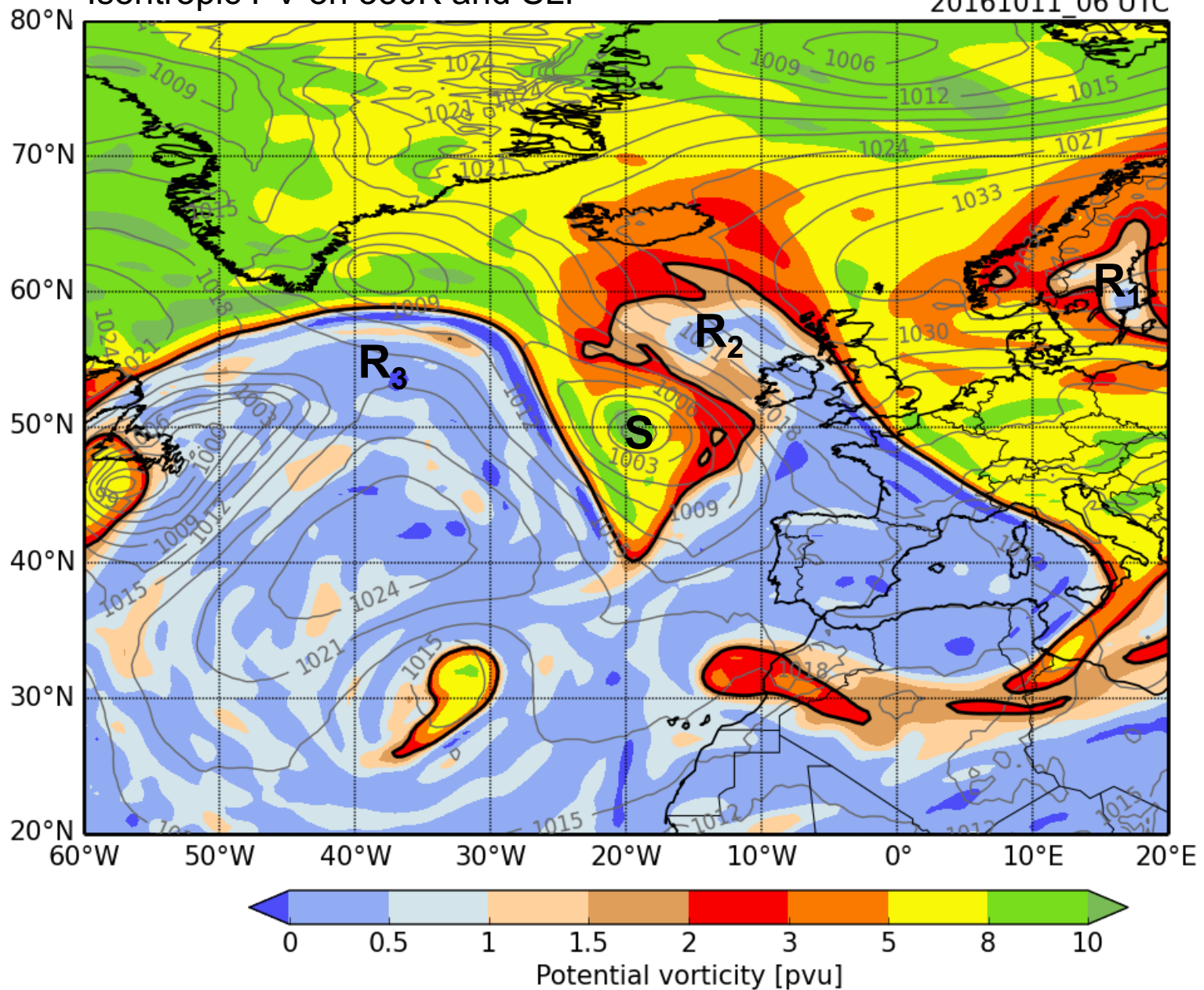
20161010_18 UTC



HALO RF 09
F-Falcon RF 13

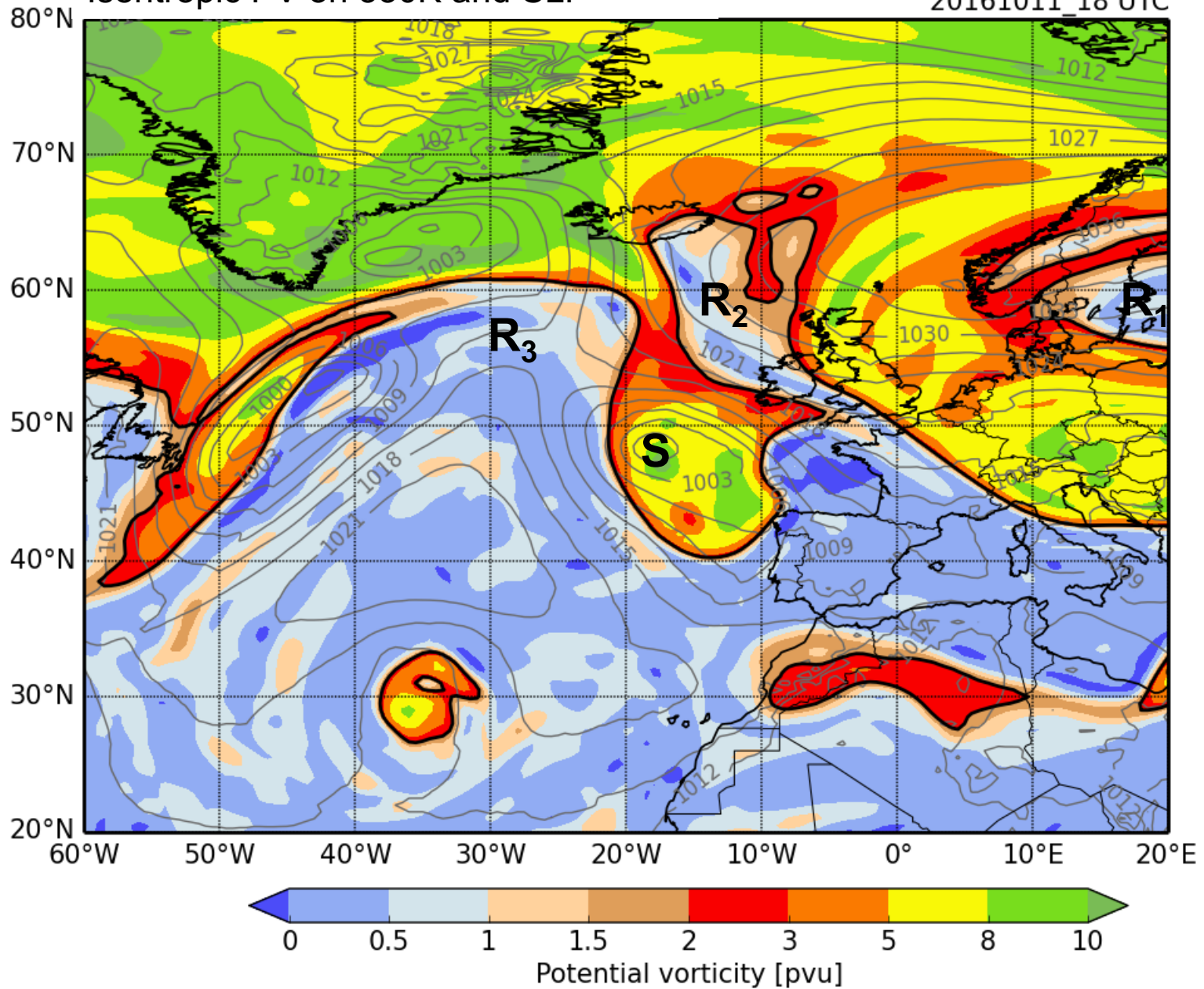
Isentropic PV on 330K and SLP

20161011_06 UTC



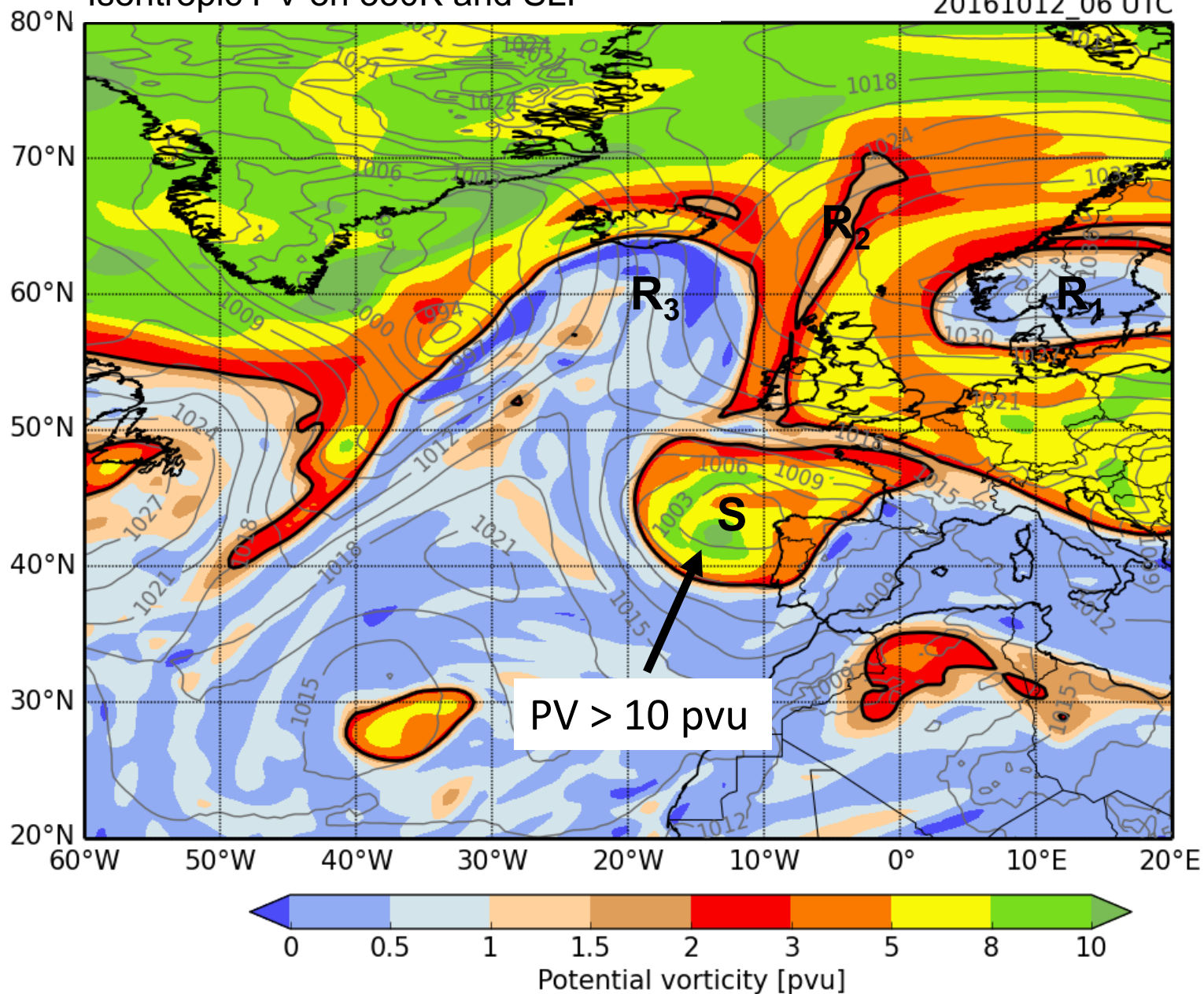
Isentropic PV on 330K and SLP

20161011_18 UTC



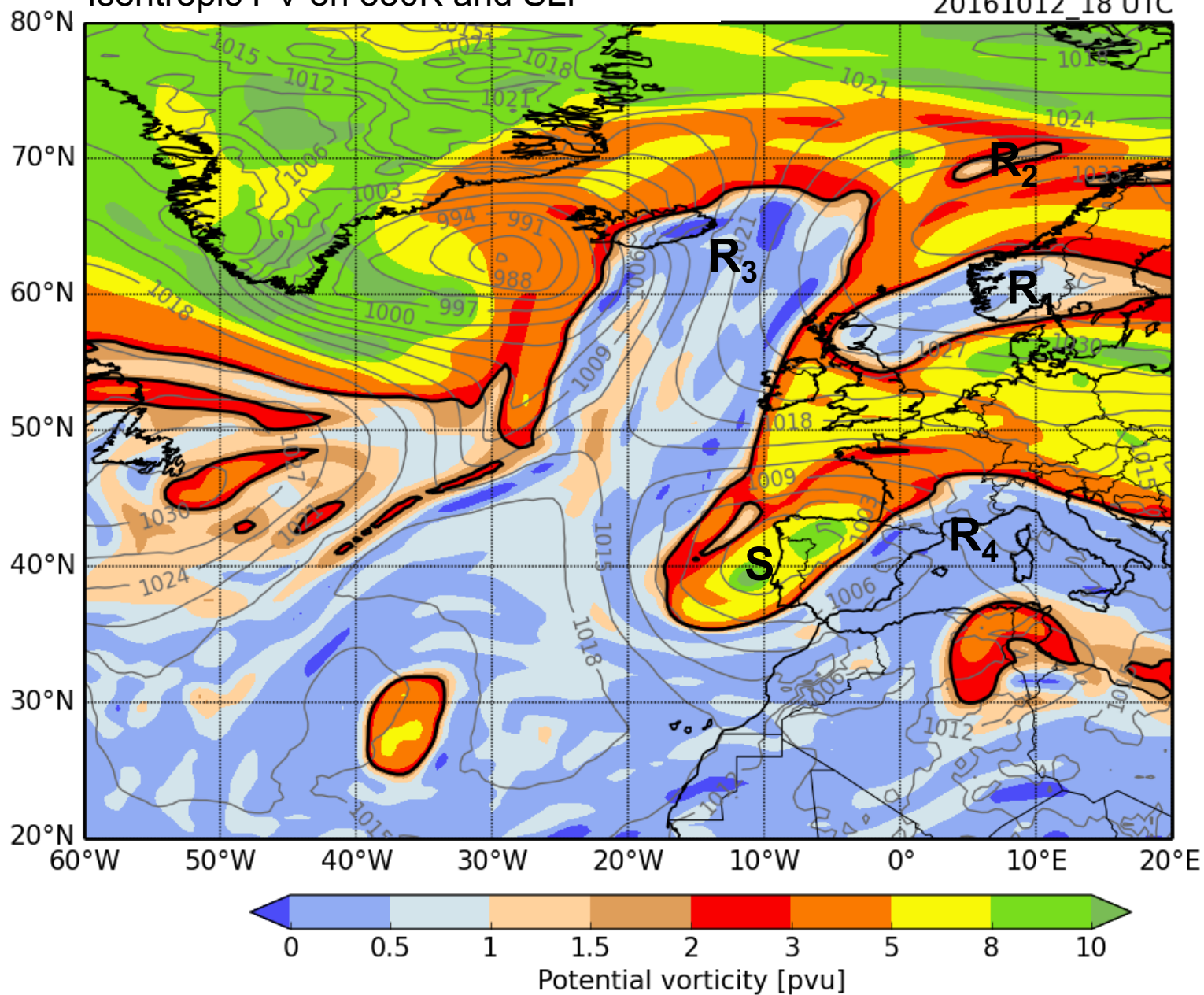
Isentropic PV on 330K and SLP

20161012_06 UTC



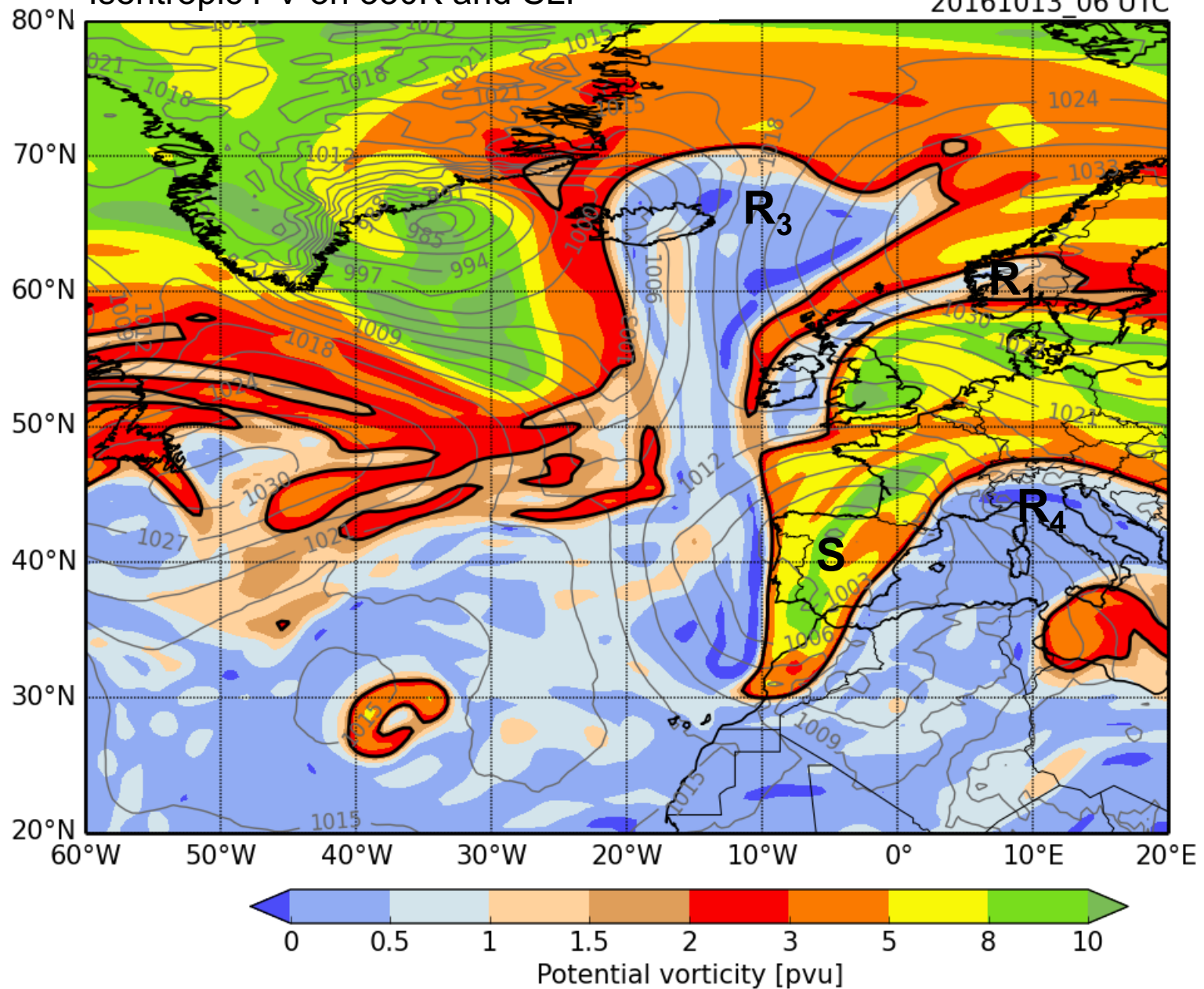
Isentropic PV on 330K and SLP

20161012_18 UTC



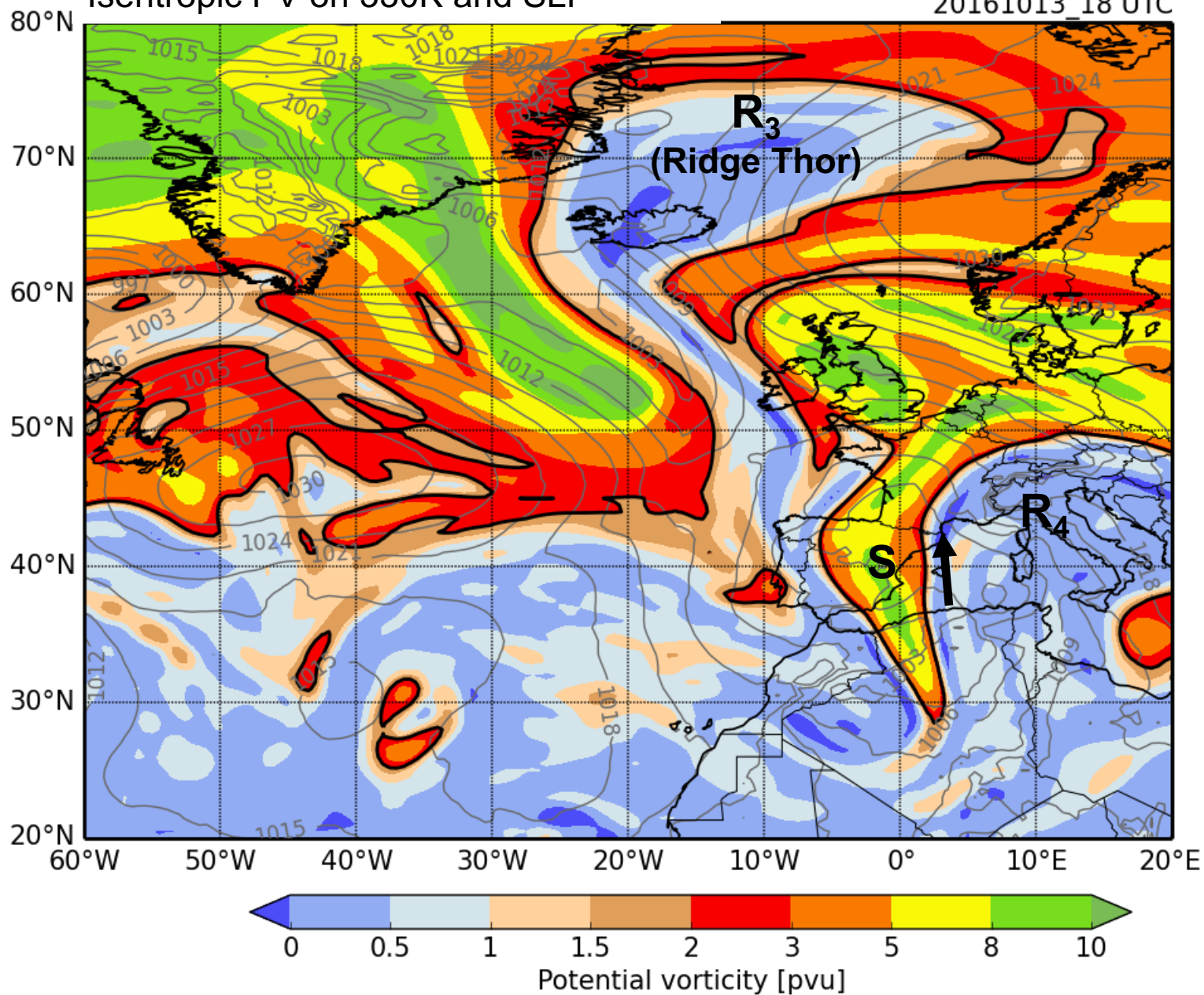
Isentropic PV on 330K and SLP

20161013_06 UTC



Isentropic PV on 330K and SLP

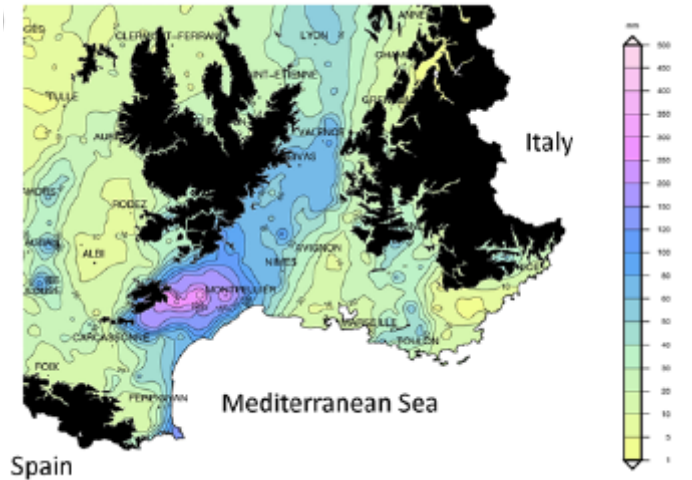
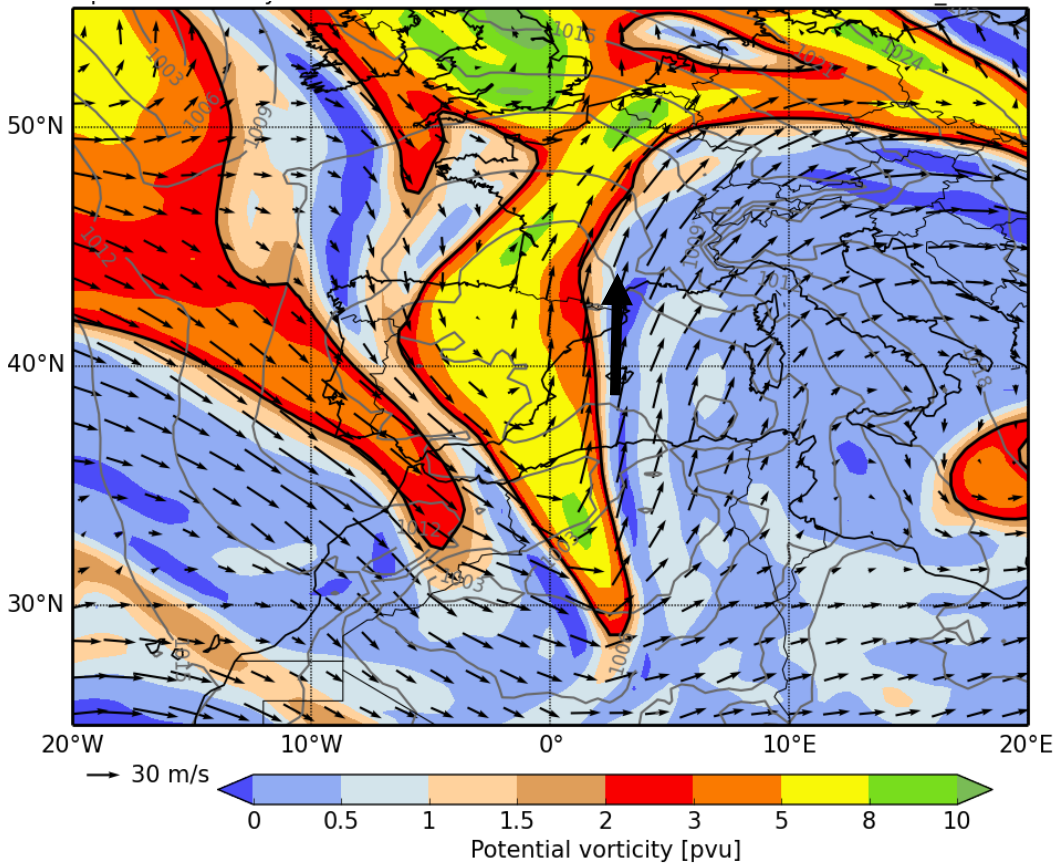
20161013_18 UTC



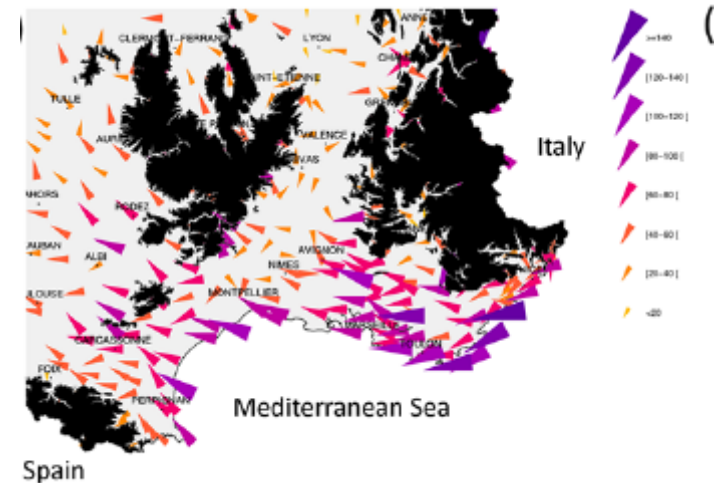
High-impact weather over southern France on 13 Oct 2016 related to cut-off cyclone “Sanchez”

18 UTC 13 Oct 2016

PV and wind on 250 hPa



Spain
~250 mm daily accumulated precipitation in the Hérault region

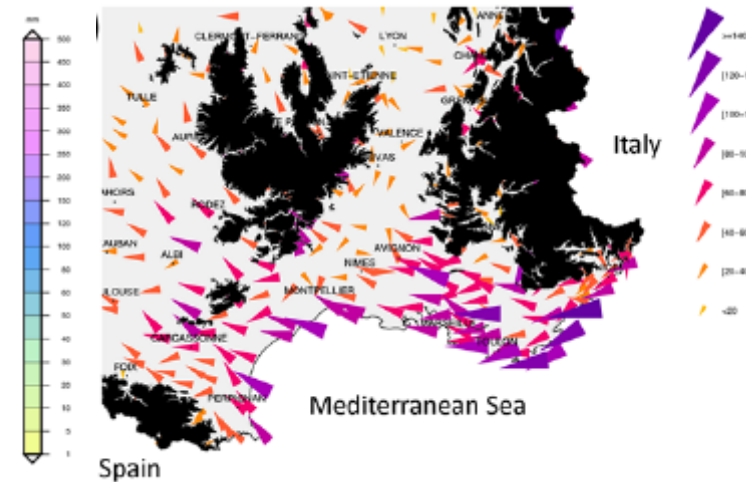
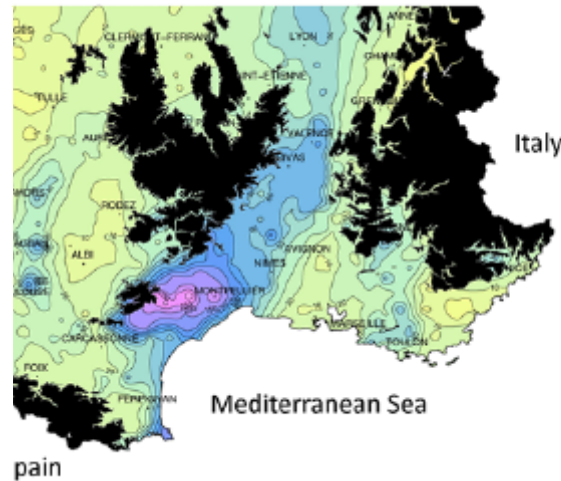
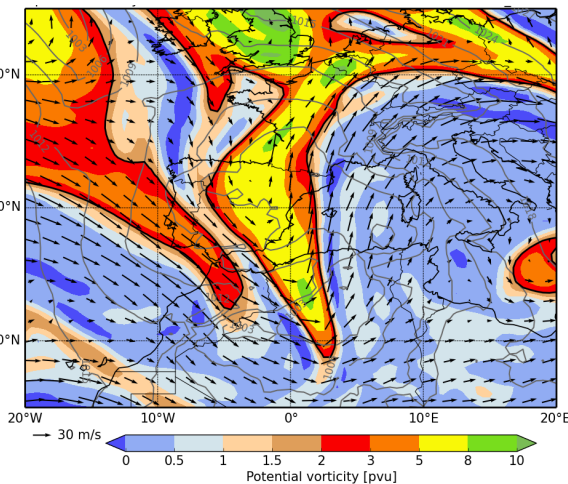


Spain
Strong wind gusts > 100 km/h

Objective

Evaluate the representation of the HIW event and the associated upper-level flow structure in probabilistic Météo-France forecast data

- Are the HIW forecasts sensitive to the representation of cut-off Sanchez?



Data

Ensemble reforecasts of the Météo-France global operational model
Arpege

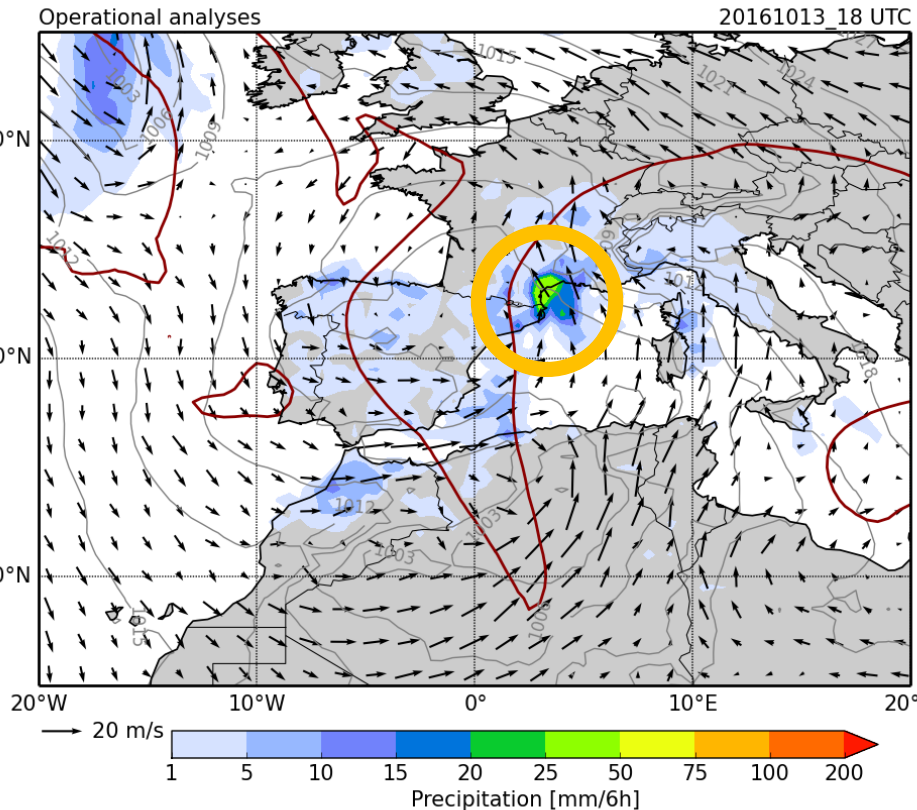
- 10 ensemble members
- Same initial conditions
- 10 different physical parameterizations to represent model uncertainties

see Descamps et al. 2015, Boisserie et al. 2016a,b

How well are the extreme precipitation and the associated PV streamer (ex-cutoff Sanchez) represented in the forecast data?

First results – forecast evaluation at 18 UTC 13 October 2016

Operational analyses

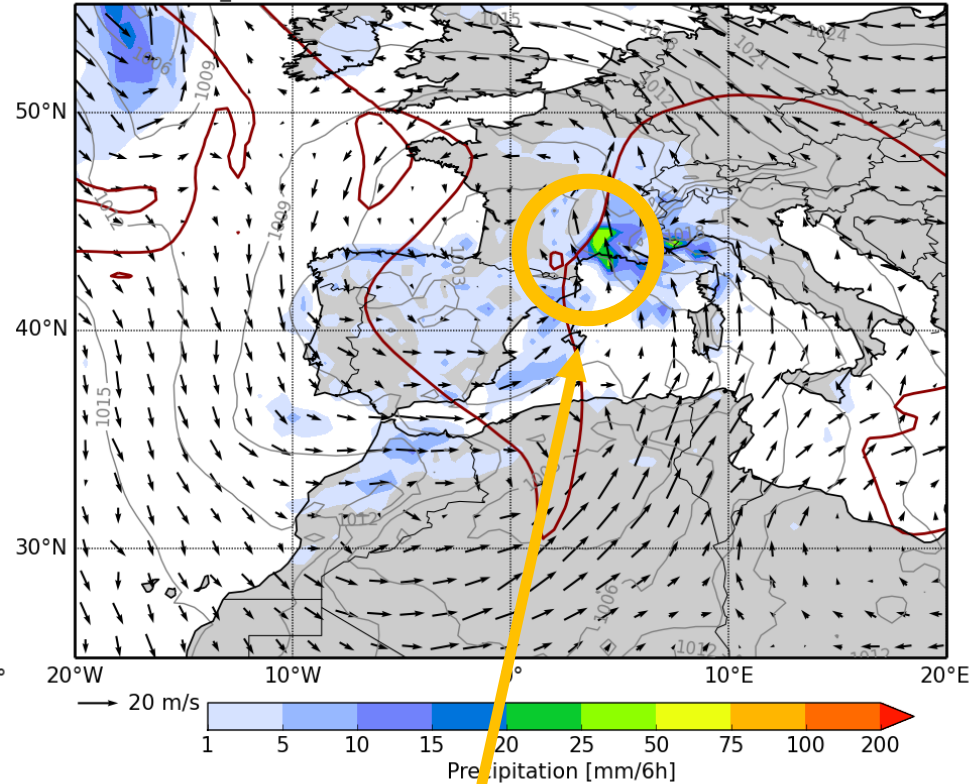


72h forecasts, BT 10/18, ensemble member 0

BT: 20161010_18 UTC+72h

VT: 20161013_18 UTC

Ensemble member 0



Shading: 6h-accumulated precipitation

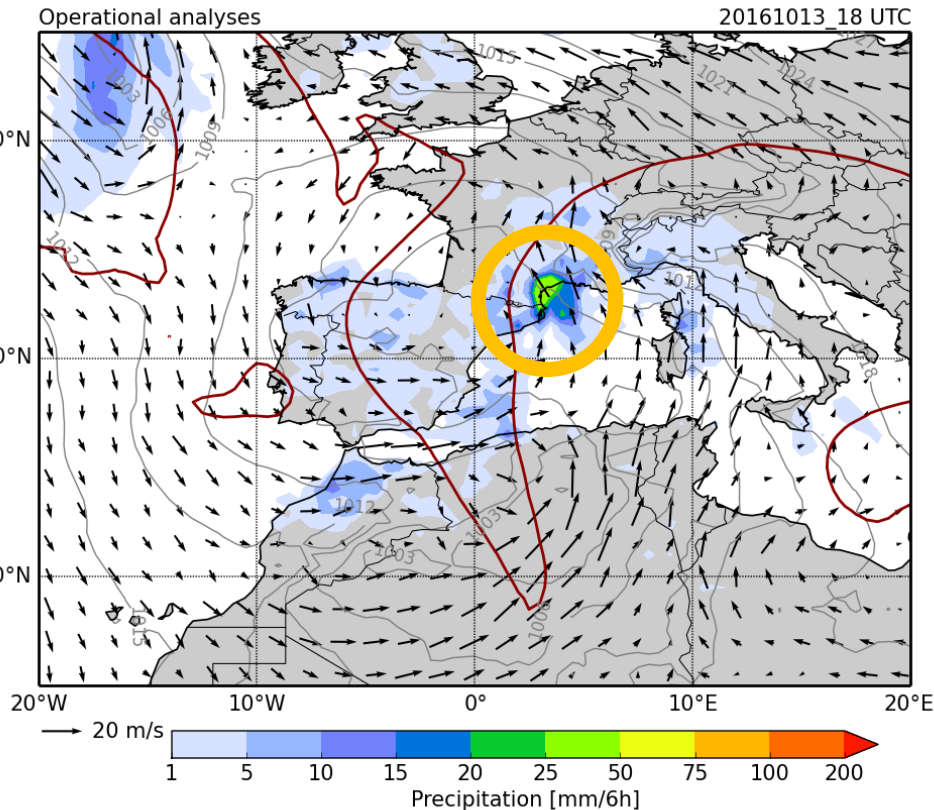
— 2pvu at 330 K ← 850-hPa wind

Compared to analyses:

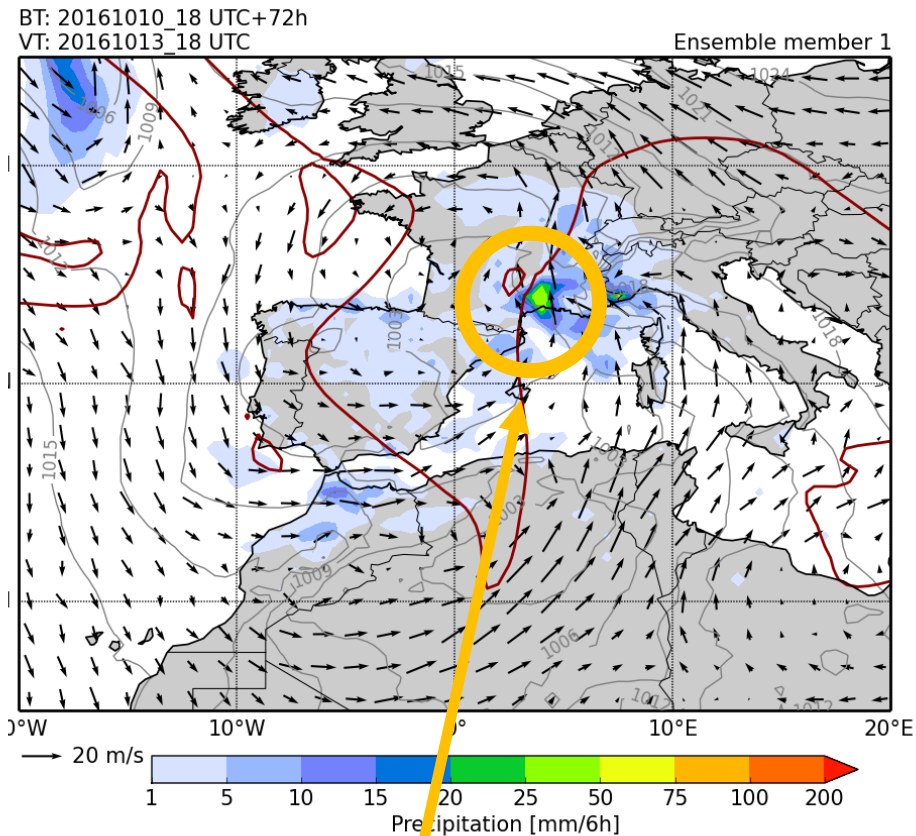
- NE-ward shift of precipitation maximum
- NE-ward shift and different tilt of 2pvu@330K over southern France

First results – forecast evaluation at 18 UTC 13 October 2016

Operational analyses



72h forecasts, BT 10/18, ensemble member 1



Shading: 6h-accumulated precipitation

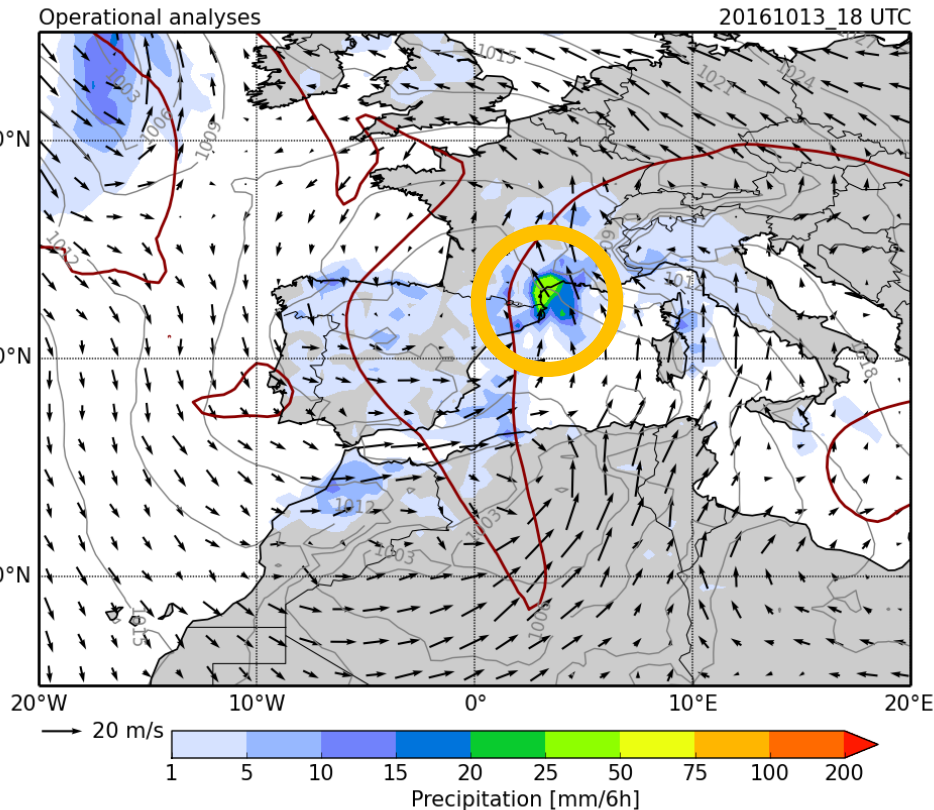
— 2pvu at 330 K ← 850-hPa wind

Compared to analyses:

- NE-ward shift of precipitation maximum
- NE-ward shift and different tilt of 2pvu@330K over southern France

First results – forecast evaluation at 18 UTC 13 October 2016

Operational analyses



Shading: 6h-accumulated precipitation

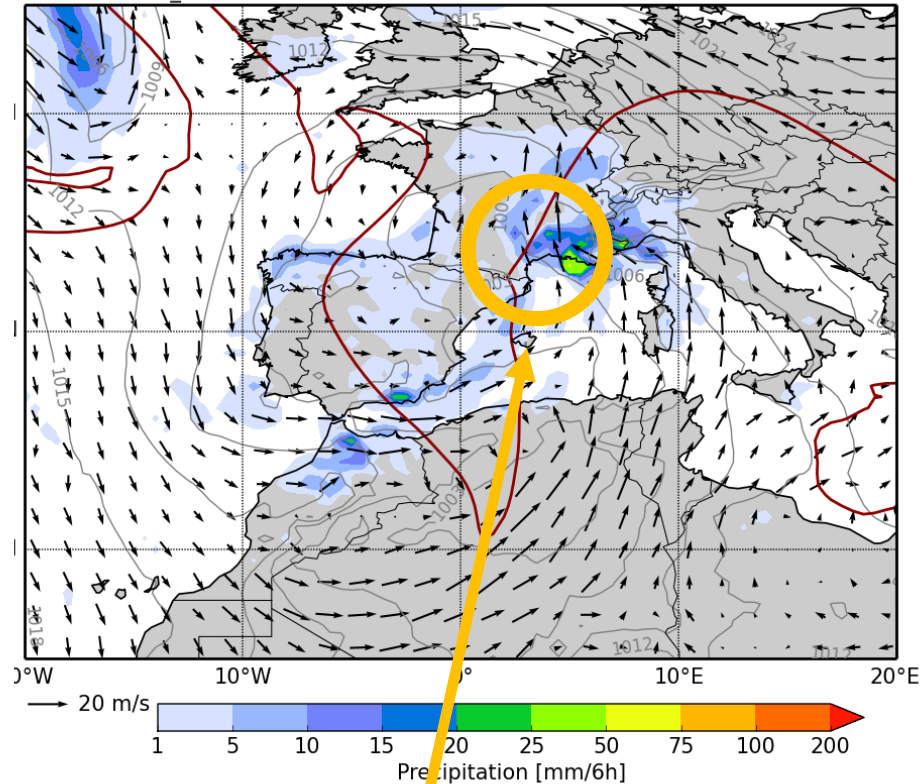
— 2pvu at 330 K ← 850-hPa wind

72h forecasts, BT 10/18, ensemble member 2

BT: 20161010_18 UTC+72h

VT: 20161013_18 UTC

Ensemble member 2

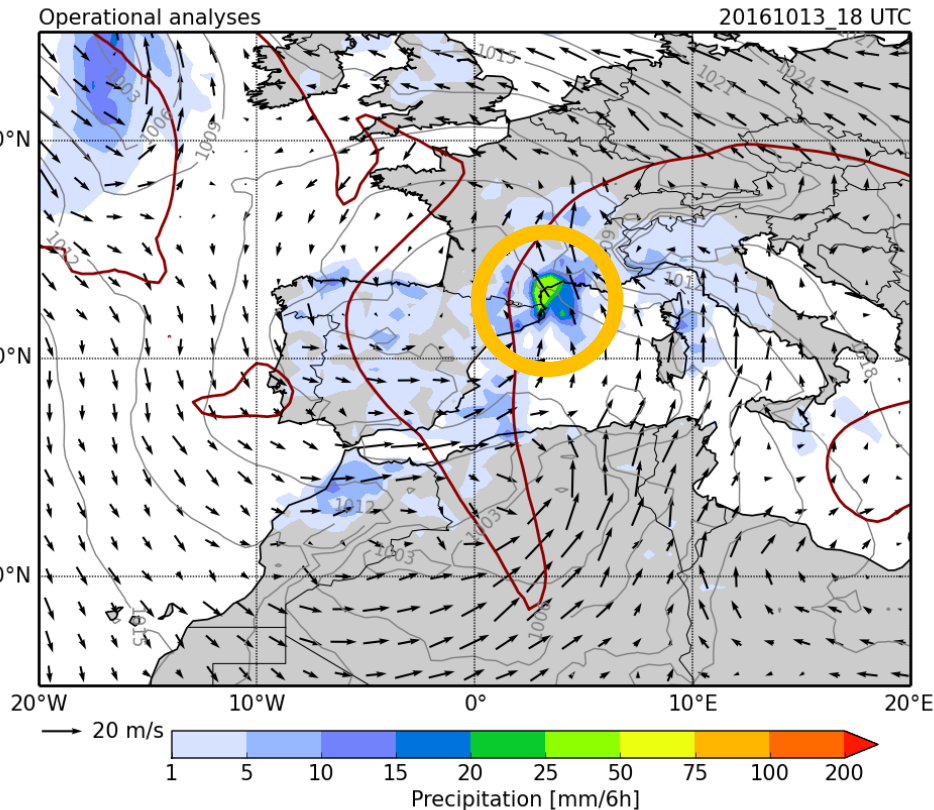


Compared to analyses:

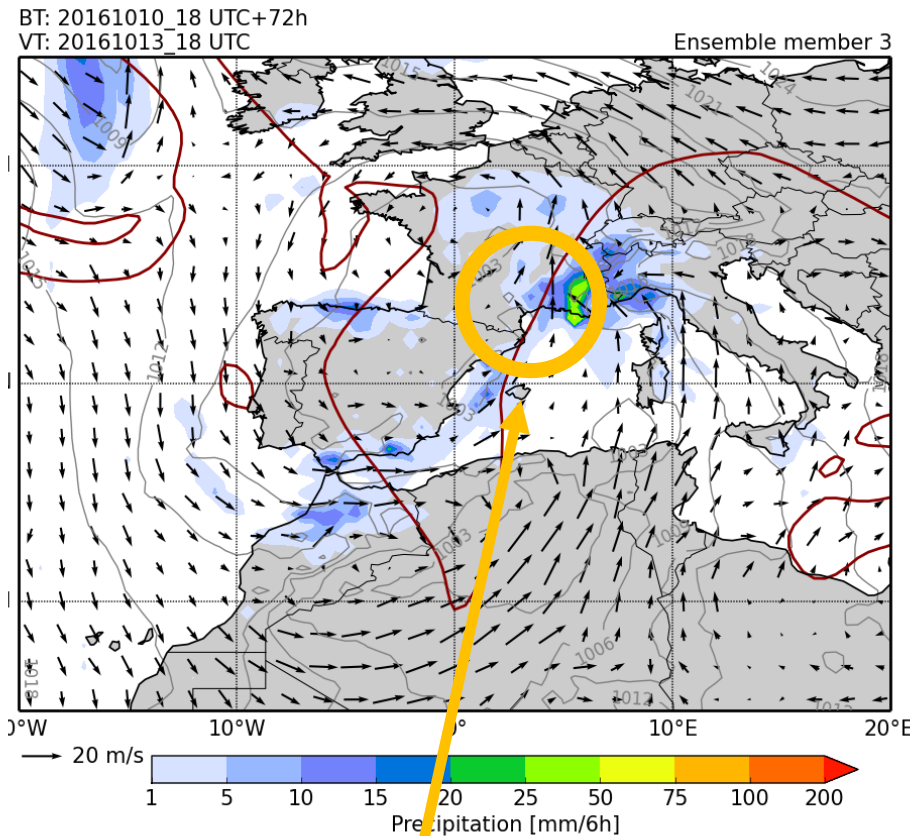
- NE-ward shift of precipitation maximum
- NE-ward shift and different tilt of 2pvu@330K over southern France

First results – forecast evaluation at 18 UTC 13 October 2016

Operational analyses



72h forecasts, BT 10/18, ensemble member 3



Shading: 6h-accumulated precipitation

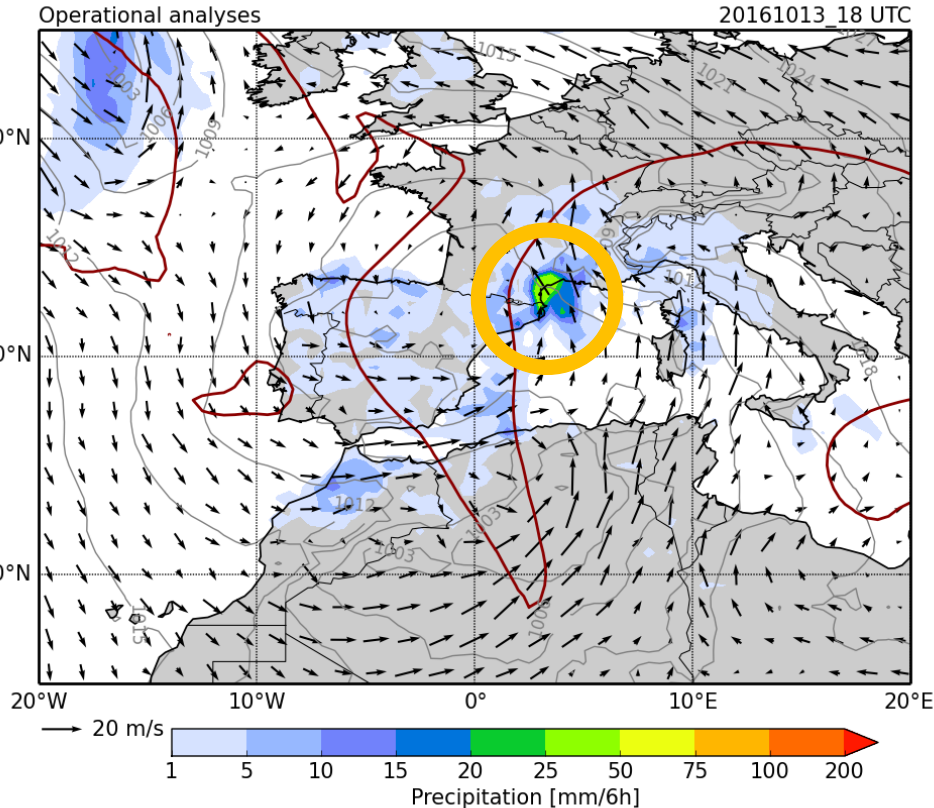
— 2pvu at 330 K ← 850-hPa wind

Compared to analyses:

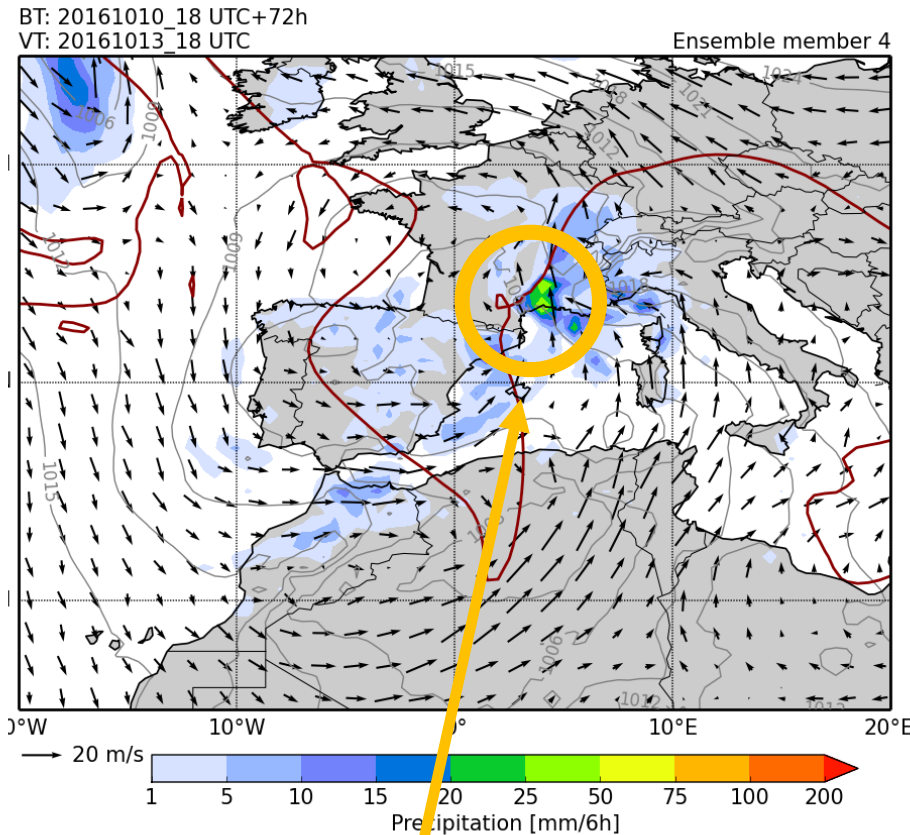
- NE-ward shift of precipitation maximum
- NE-ward shift and different tilt of 2pvu@330K over southern France

First results – forecast evaluation at 18 UTC 13 October 2016

Operational analyses



72h forecasts, BT 10/18, ensemble member 4



Shading: 6h-accumulated precipitation

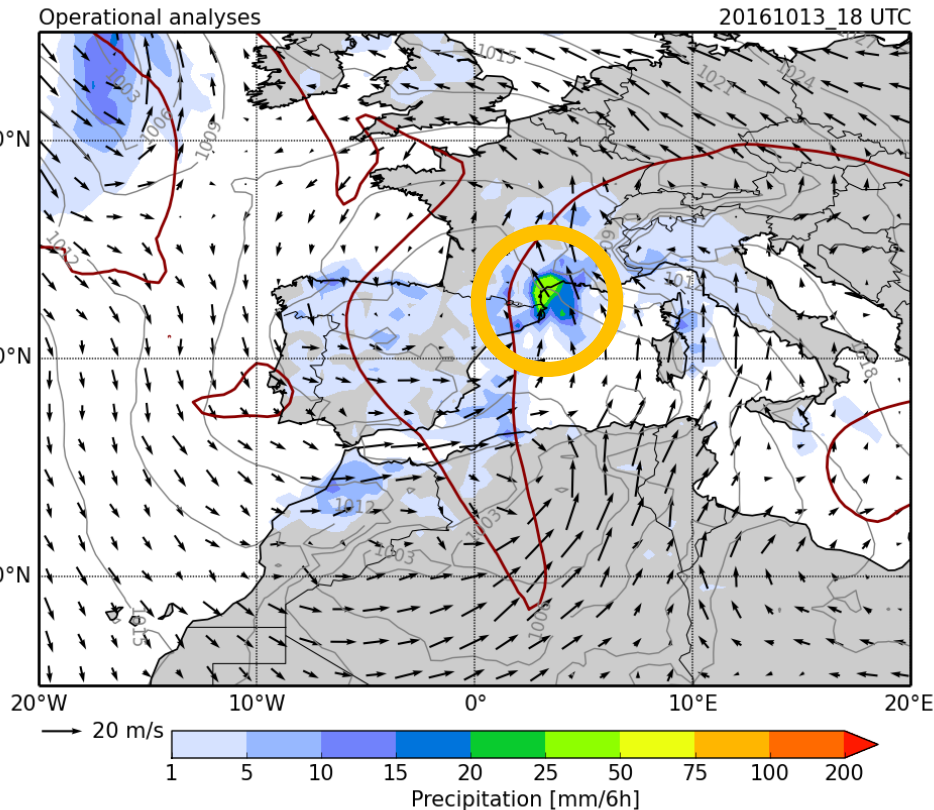
— 2pvu at 330 K ← 850-hPa wind

Compared to analyses:

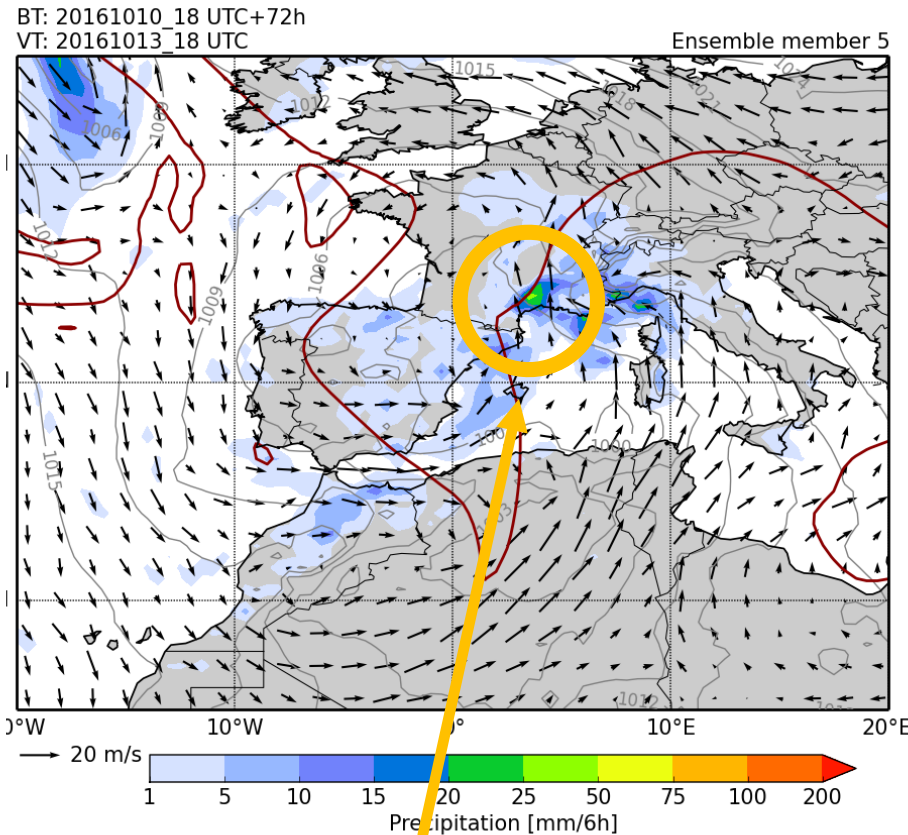
- NE-ward shift of precipitation maximum
- NE-ward shift and different tilt of 2pvu@330K over southern France

First results – forecast evaluation at 18 UTC 13 October 2016

Operational analyses



72h forecasts, BT 10/18, ensemble member 5



Shading: 6h-accumulated precipitation

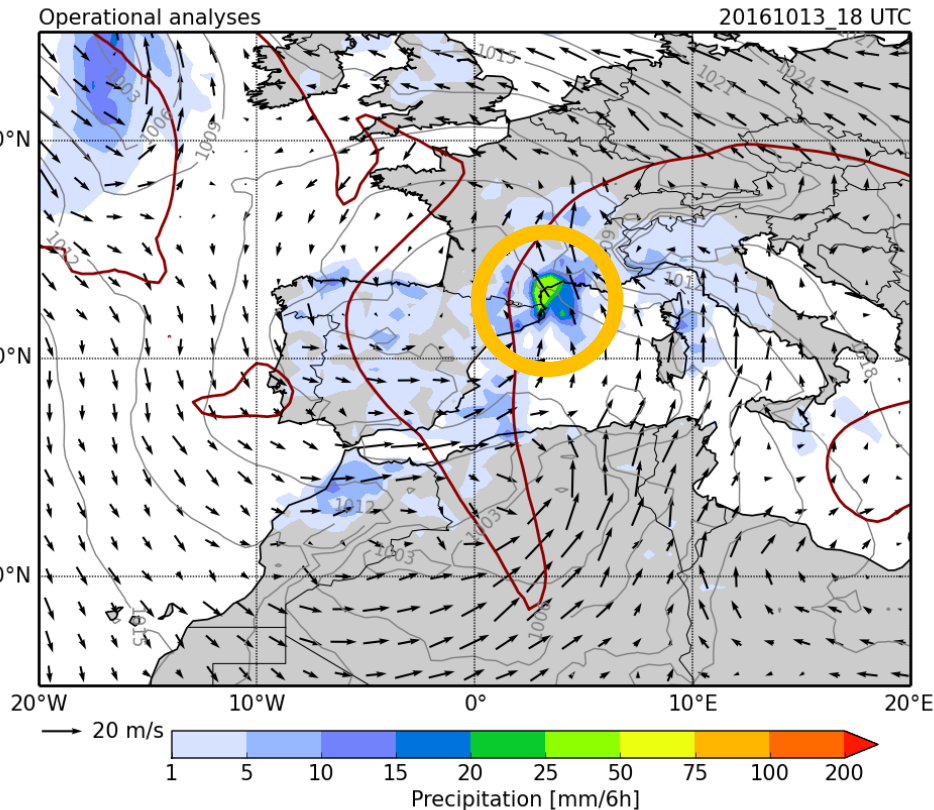
— 2pvu at 330 K ← 850-hPa wind

Compared to analyses:

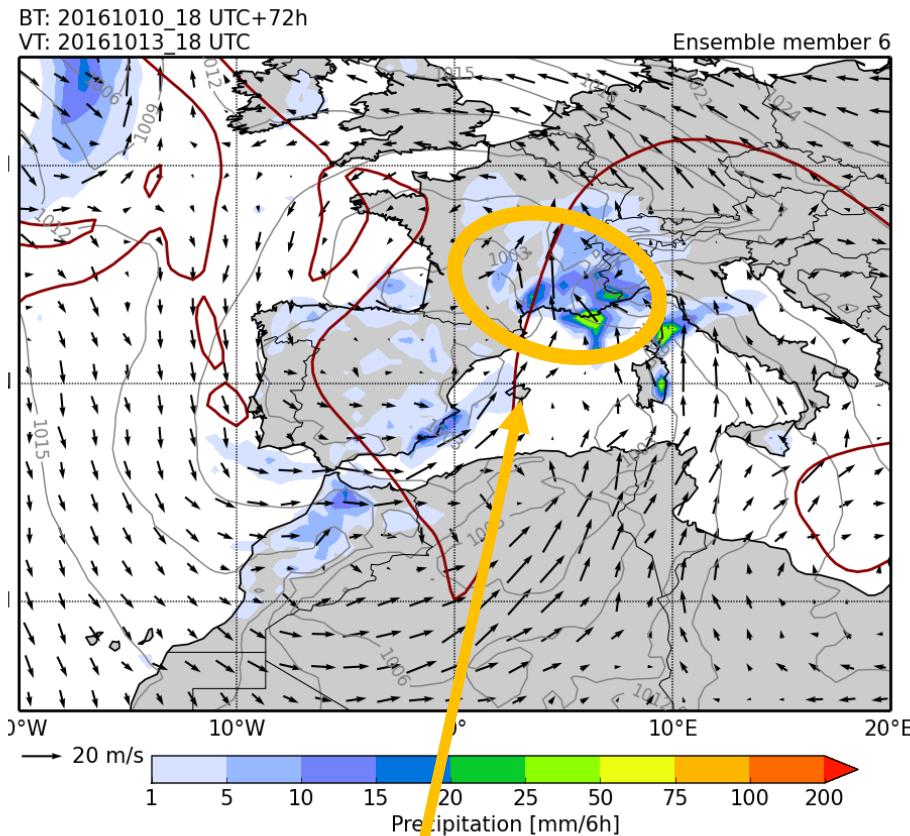
- NE-ward shift of precipitation maximum
- NE-ward shift and different tilt of 2pvu@330K over southern France

First results – forecast evaluation at 18 UTC 13 October 2016

Operational analyses



72h forecasts, BT 10/18, ensemble member 6



Shading: 6h-accumulated precipitation

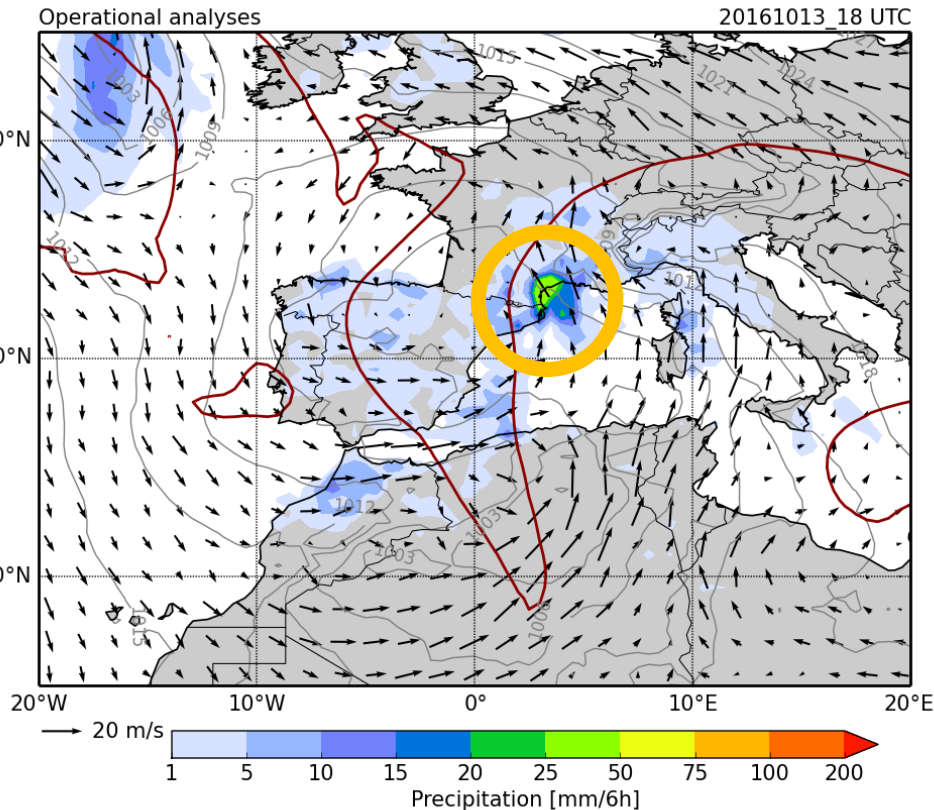
— 2pvu at 330 K ← 850-hPa wind

Compared to analyses:

- NE-ward shift of precipitation maximum
- NE-ward shift and different tilt of 2pvu@330K over southern France

First results – forecast evaluation at 18 UTC 13 October 2016

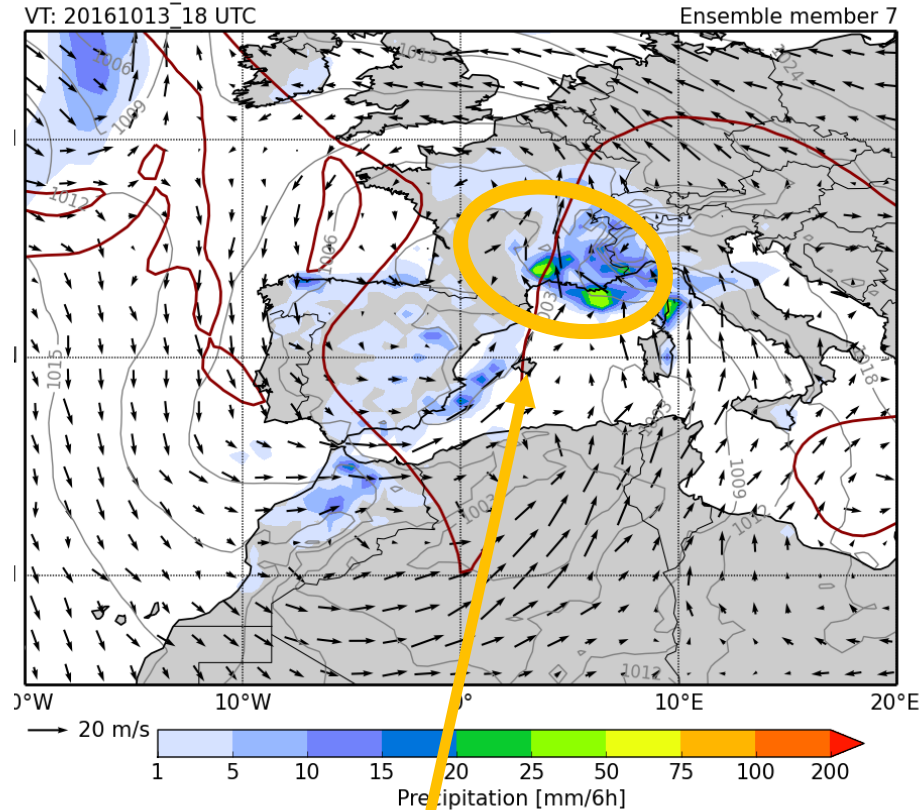
Operational analyses



Shading: 6h-accumulated precipitation
— 2pvu at 330 K ← 850-hPa wind

72h forecasts, BT 10/18, ensemble member 7

BT: 20161010_18 UTC+72h
VT: 20161013_18 UTC

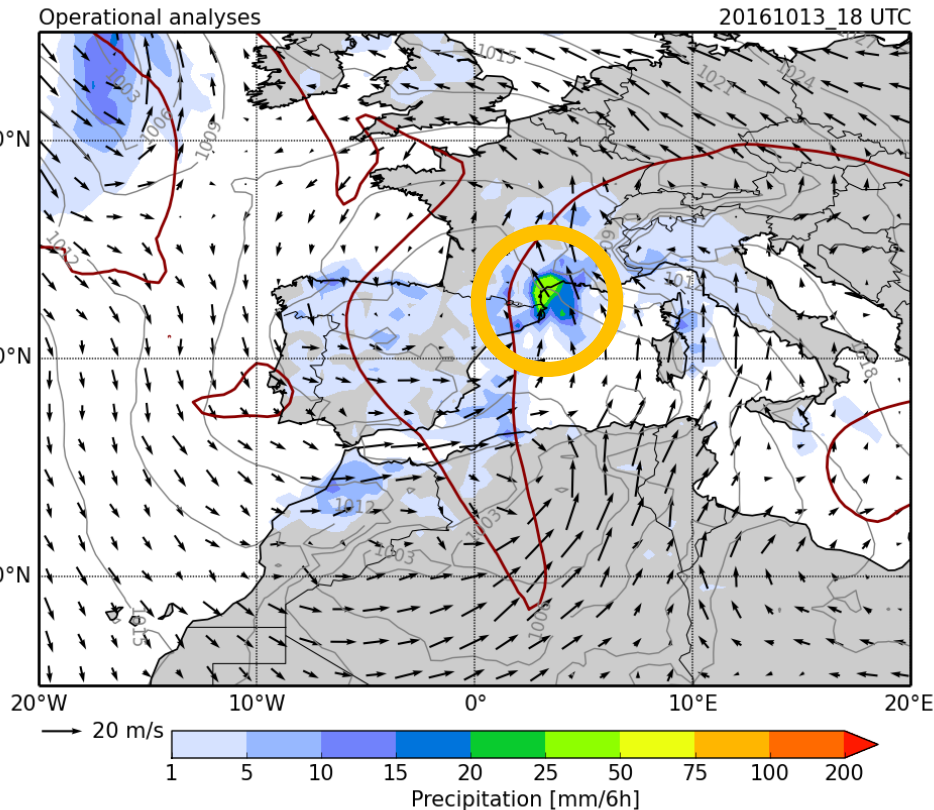


Compared to analyses:

- NE-ward shift of precipitation maximum
- NE-ward shift and different tilt of 2pvu@330K over southern France

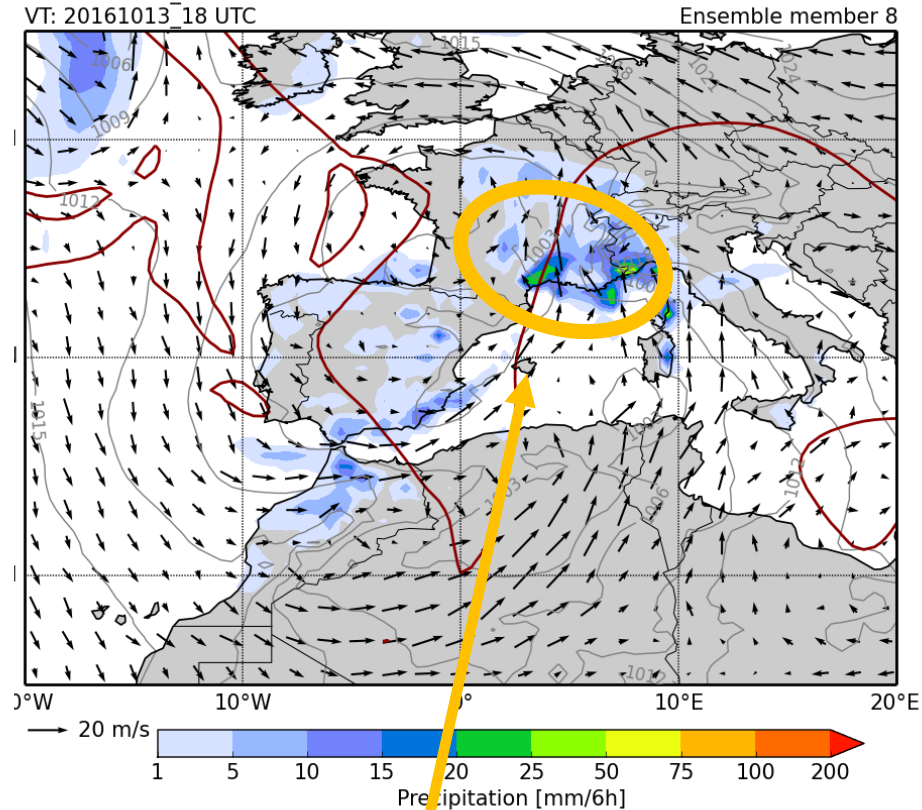
First results – forecast evaluation at 18 UTC 13 October 2016

Operational analyses



72h forecasts, BT 10/18, ensemble member 8

BT: 20161010_18 UTC+72h
VT: 20161013_18 UTC



Shading: 6h-accumulated precipitation

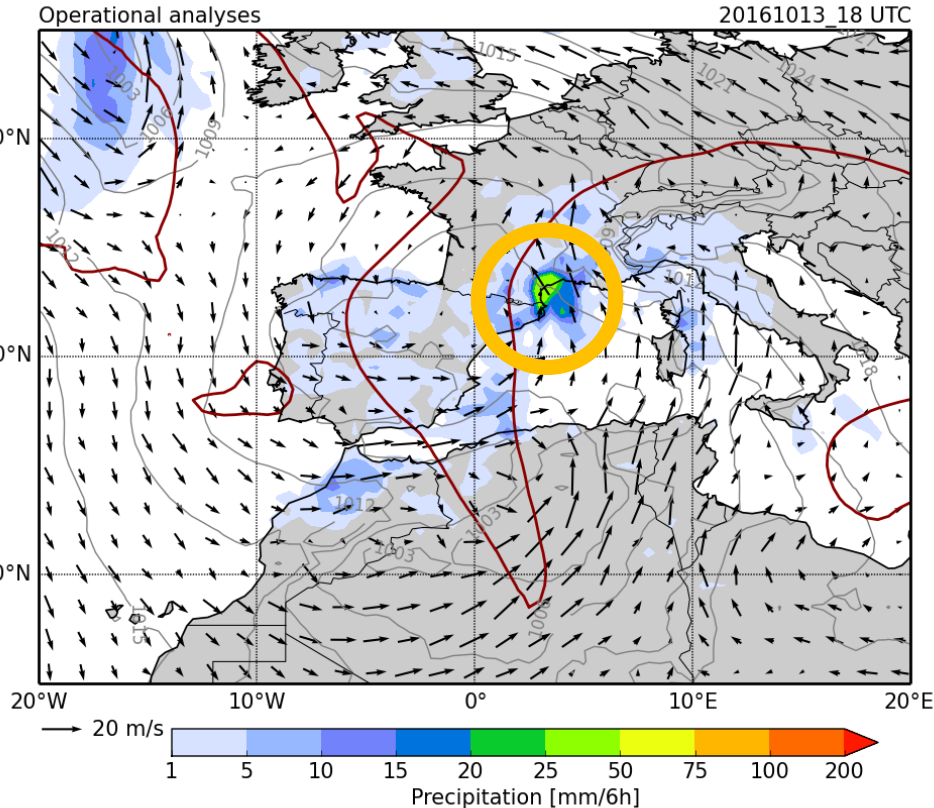
— 2pvu at 330 K ← 850-hPa wind

Compared to analyses:

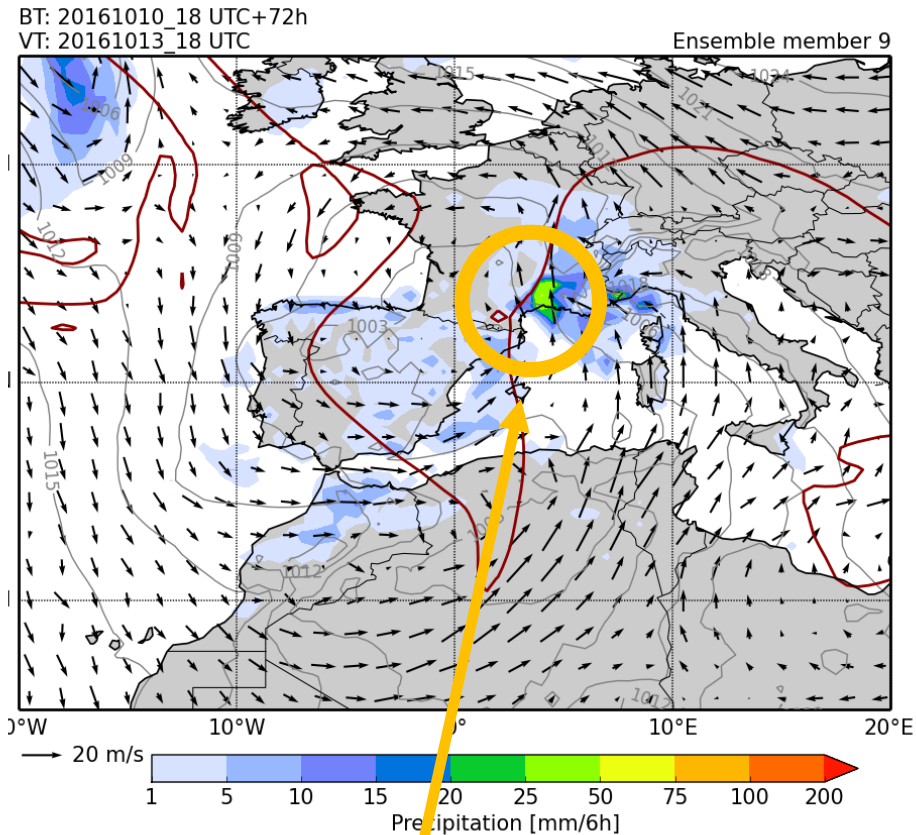
- NE-ward shift of precipitation maximum
- NE-ward shift and different tilt of 2pvu@330K over southern France

First results – forecast evaluation at 18 UTC 13 October 2016

Operational analyses



72h forecasts, BT 10/18, ensemble member 9



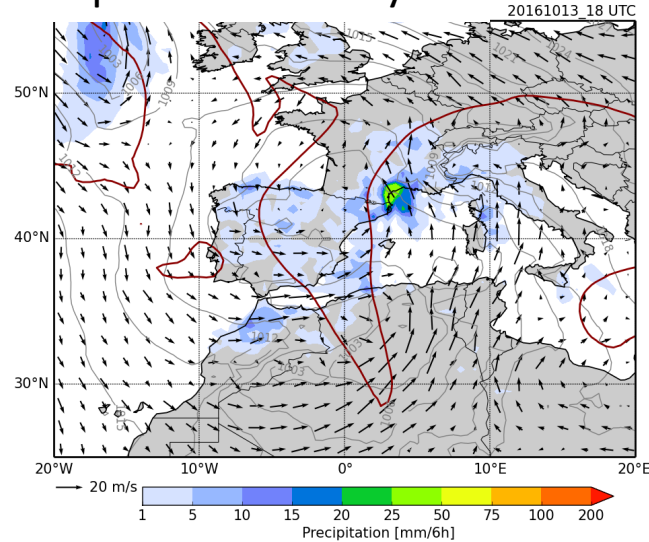
Shading: 6h-accumulated precipitation
— 2pvu at 330 K ← 850-hPa wind

Compared to analyses:

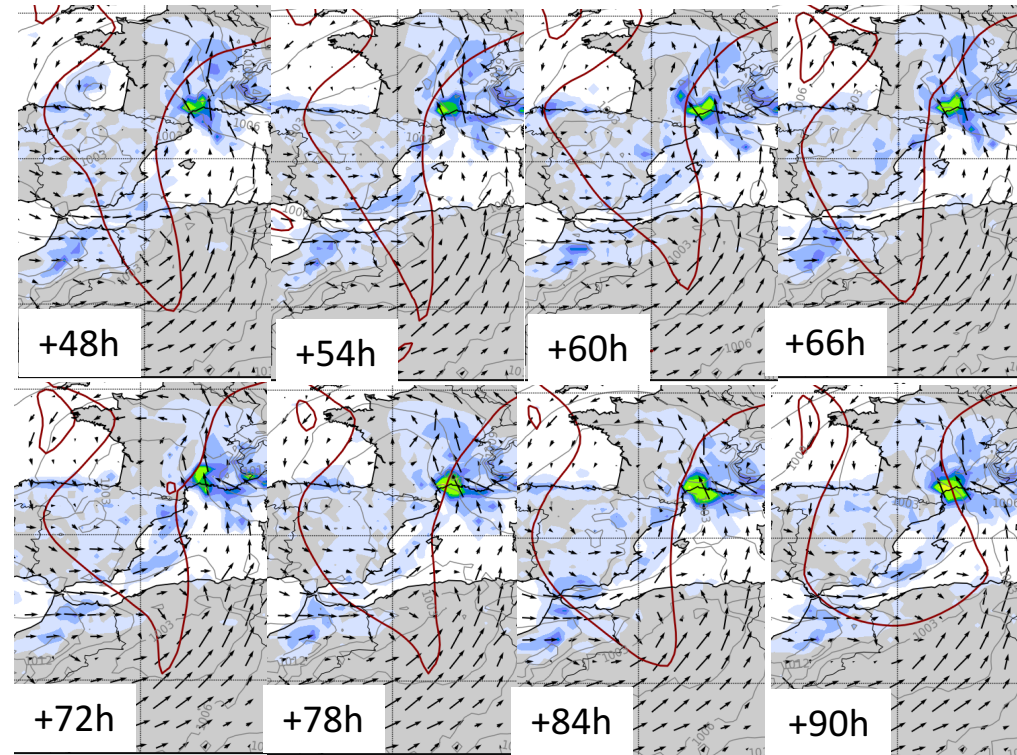
- NE-ward shift of precipitation maximum
- NE-ward shift and different tilt of 2pvu@330K over southern France

First results – forecast evaluation at 18 UTC 13 October 2016

Operational analyses



Ensemble member 0, different base times



Compared to analyses:

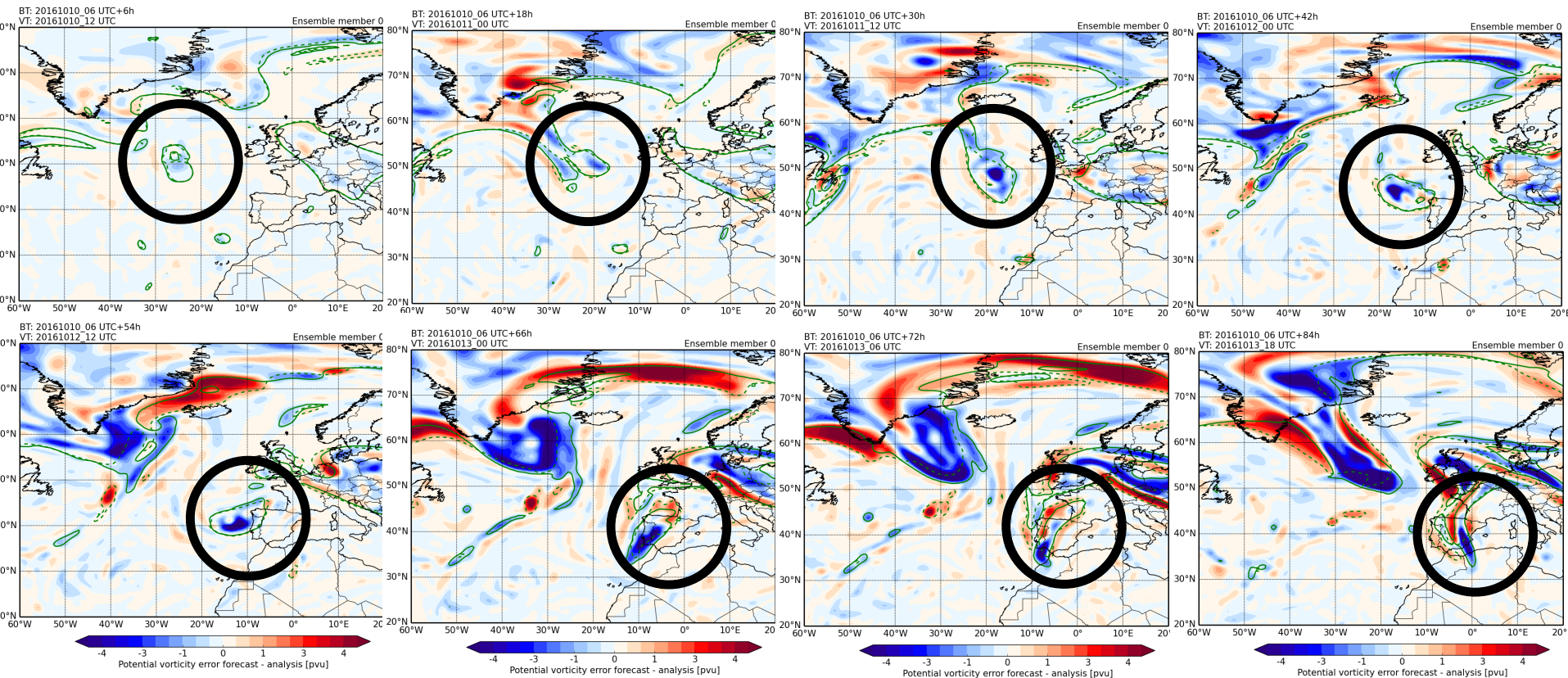
- NE-ward shift of precipitation maximum
 - NE-ward shift and different tilt of 2pvu@330K over southern France
- **robust signal among different ensemble members and base times**

Shading: 6h-accumulated precipitation
— 2pvu at 330 K ← 850-hPa wind

How did the error associated with the
PV streamer evolve in time?

Evolution of the error in the upper-level PV streamer

BT 10/06, ensemble member 0



Shading: PV error on 320K: forecast – analysis

Red: Overestimation of forecasted UL PV

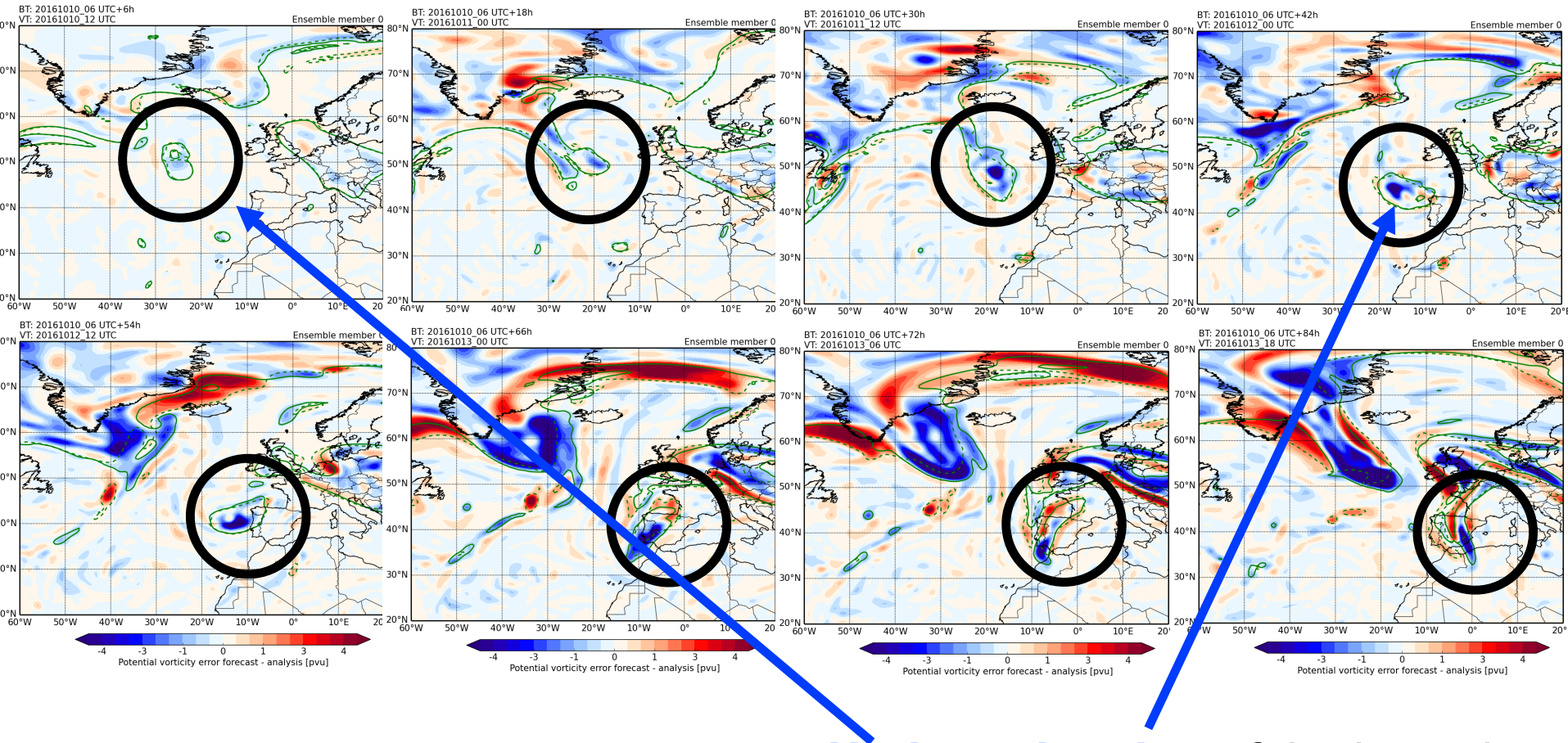
Blue: Underestimation of forecasted UL PV

— 2pvu at 320K in the analysis

... 2pvu at 320K in the forecast

Evolution of the error in the upper-level PV streamer

BT 10/06, ensemble member 0



Underestimation of the intensity of cut-off Sanchez in most areas in the days preceding the HIW

Shading: PV error on 320K: forecast – analysis

Red: Overestimation of forecasted UL PV

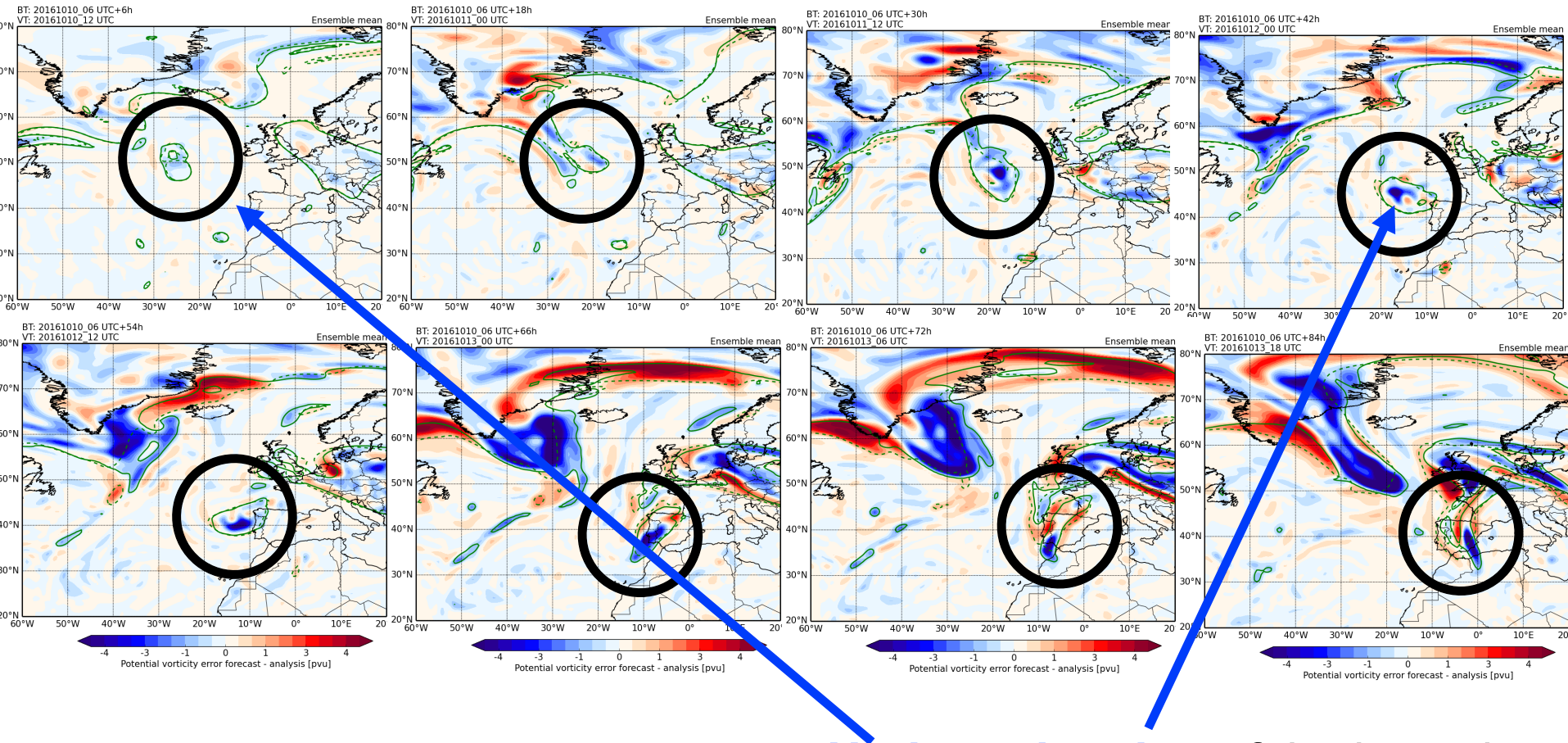
Blue: Underestimation of forecasted UL PV

— 2pvu at 320K in the analysis

... 2pvu at 320K in the forecast

Evolution of the error in the upper-level PV streamer

BT 10/06, ensemble mean



Underestimation of the intensity of cut-off Sanchez in most areas in the days preceding the HIW

Shading: PV error on 320K: forecast – analysis

Red: Overestimation of forecasted UL PV

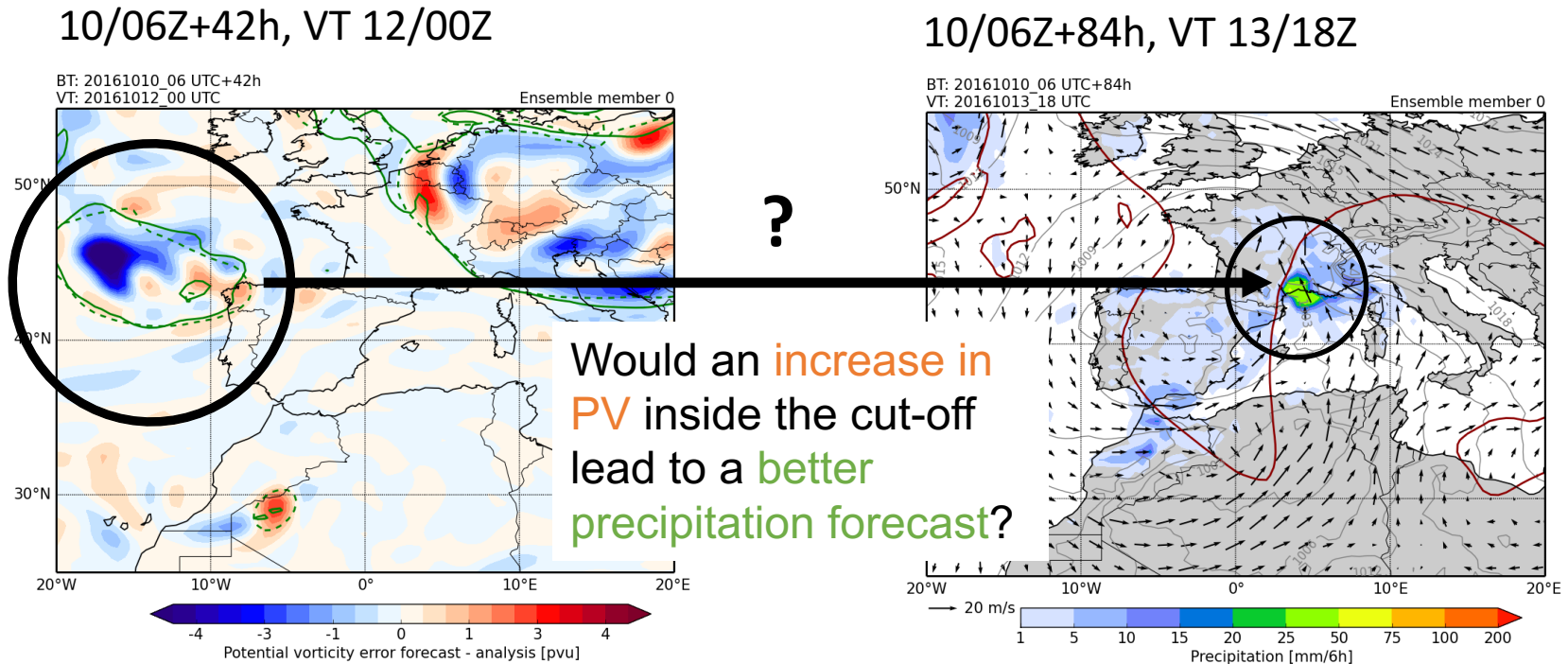
Blue: Underestimation of forecasted UL PV

— 2pvu at 320K in the analysis

... 2pvu at 320K in the forecast

Underestimation of the intensity of the cut-off

Are the errors in the intensity of the UL cut-off at early fc times important for the errors in the representation of the extreme precipitation at 18 UTC 13 Oct?



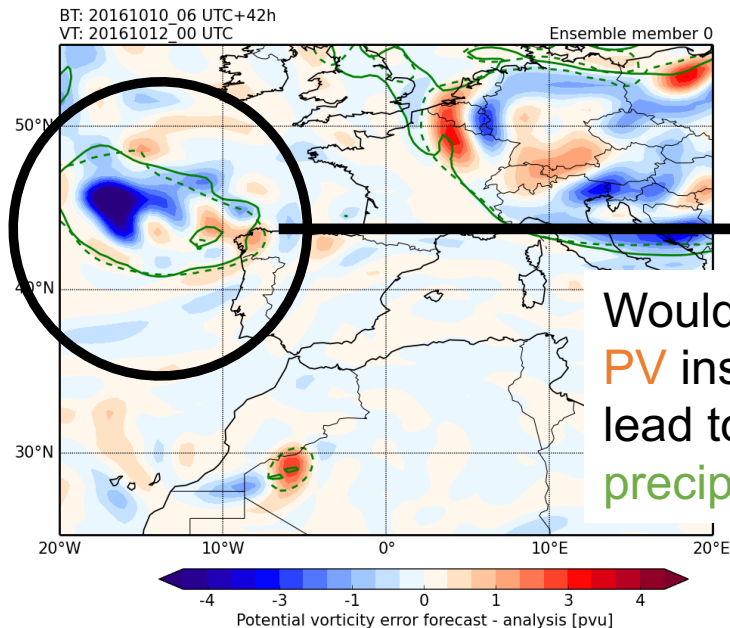
-> Ensemble sensitivity analysis (ESA)

Ensemble sensitivity analysis (ESA)

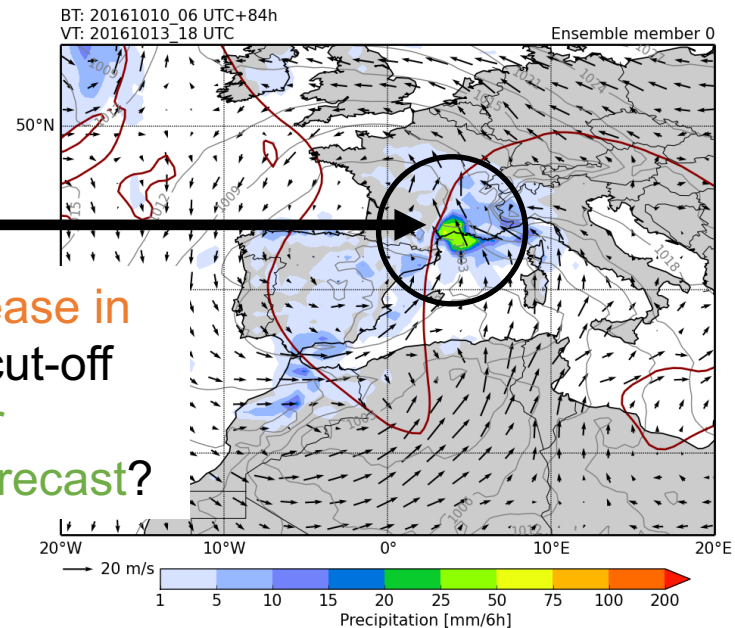
Ancell and Hakim 2007, MWR
Torn and Hakim 2008, MWR

How does the change in an **initial state variable x** (e.g., **PV at 320K on 12/00 UTC**) change a **forecast metric J** (e.g., **fc quality of precipitation over southern France on 13/18 UTC**)?

10/06Z+42h, VT 12/00Z



10/06Z+84h, VT 13/18Z



?

Would an **increase in PV** inside the cut-off lead to a **better precipitation forecast**?

Ensemble sensitivity analysis (ESA)

Ancell and Hakim 2007, MWR
Torn and Hakim 2008, MWR

How does the change in an **initial state variable x** (e.g., **PV at 320K on 12/00 UTC**) change a **forecast metric J** (e.g., **fc quality of precipitation over southern France on 13/18 UTC**)?

$$\frac{\delta J}{\partial x} = \frac{cov(J, x)}{var(x)}$$

-> Sensitivity of the ensemble mean value of fc metric J to the initial state variable x for an **ensemble of size M**

x and **J**: 1 x M ensemble estimates of the initial state variable x and the forecast metric J, respectively

- We measure the **forecast quality J** by the anomaly correlation coefficient (**ACC**) of 6h-accumulated precipitation over S France at 13/18 UTC
- The **ACC** is a broad measure for forecast quality, it lies between -1 and 1, with higher values indicating better forecasts

Ensemble sensitivity analysis (ESA)

Ancell and Hakim 2007, MWR
Torn and Hakim 2008, MWR

For an ensemble of size M , the sensitivity of the ensemble mean value of fc metric J to the initial state variable x is given by

$$\frac{\delta J}{\partial x} = \frac{cov(J, x)}{var(x)}$$

At each grid point G :

ACC of 6h-accum.
prec. over SFrance
at 13/18 UTC

Sum over all ens.
members M

Ens. mean PV
at that GP G

Ens. mean ACC of
forecasted precip.

$$\frac{\delta ACC}{\partial PV_G} = \frac{cov(PV, ACC)}{var(PV)} = \frac{\sum_{e=1}^M (PV_{G,e} - \overline{PV_G})(ACC_e - \overline{ACC})}{\sum_{e=1}^M (PV_{G,e} - \overline{PV_G})^2}$$

PV@320K at
12/00 UTC

Ensemble sensitivity analysis (ESA)

Ancell and Hakim 2007, MWR
Torn and Hakim 2008, MWR

For an ensemble of size M , the sensitivity of the ensemble mean value of fc metric J to the initial state variable x is given by

$$\frac{\delta J}{\partial x} = \frac{\text{cov}(J, x)}{\text{var}(x)}$$

At each grid point G :

ACC of 6h-accum.
prec. over SFrance
at 13/18 UTC

Sum over all ens.
members M

Ens. mean PV
at that GP G

Ens. mean ACC of
forecasted precip.

$$\frac{\delta \text{ACC}}{\partial \text{PV}_G} = \frac{\text{cov}(\text{PV}, \text{ACC})}{\text{var}(\text{PV})} = \frac{\sum_{e=1}^M (\text{PV}_{G,e} - \overline{\text{PV}_G})(\text{ACC}_e - \overline{\text{ACC}})}{\sum_{e=1}^M (\text{PV}_{G,e} - \overline{\text{PV}_G})^2}$$

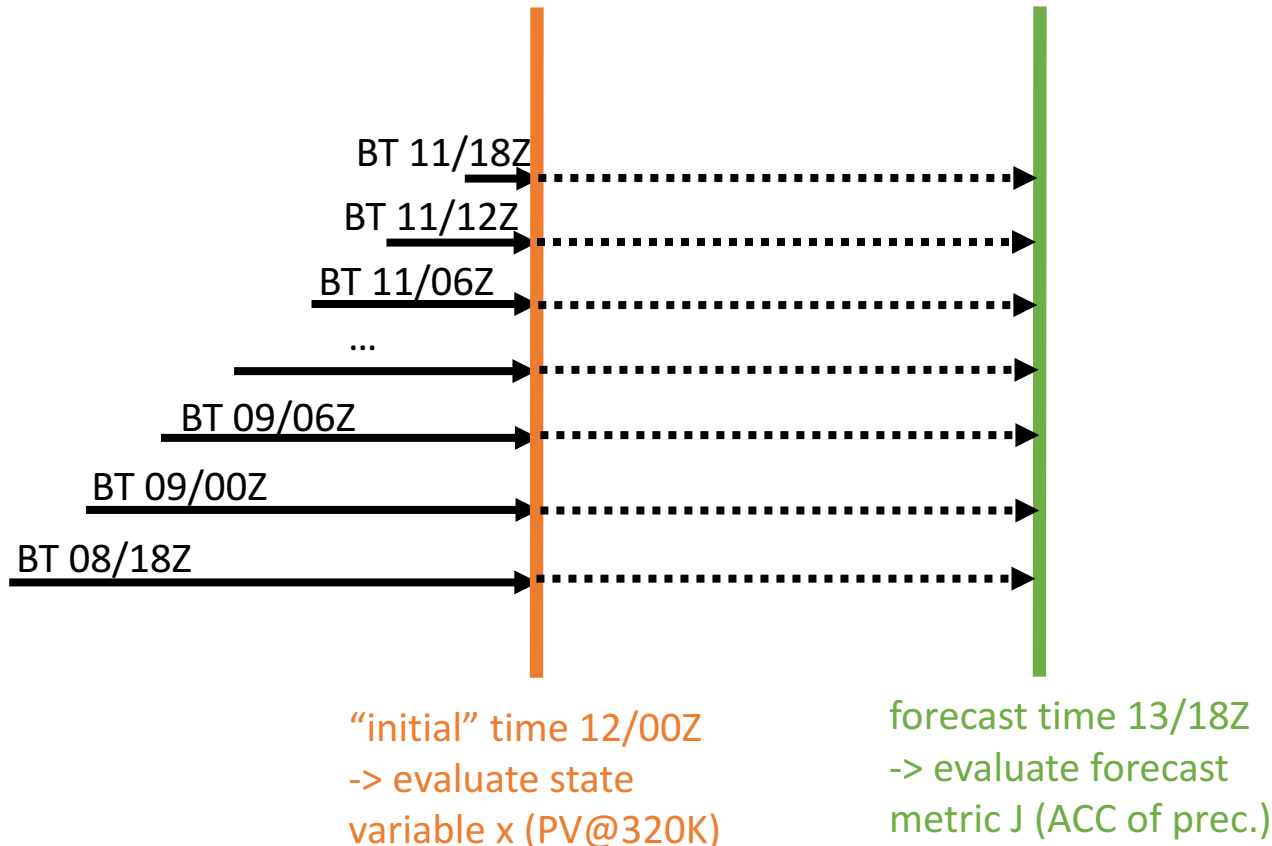
PV@320K at
12/00 UTC

➤ $\frac{\delta \text{ACC}}{\partial \text{PV}_G} > 0$: an increase in PV at 12/00Z at grid point G would be associated with an increase in the ACC of precip. over SFrance at 13/18Z (-> improved forecast)

Ensemble sensitivity analysis (ESA)

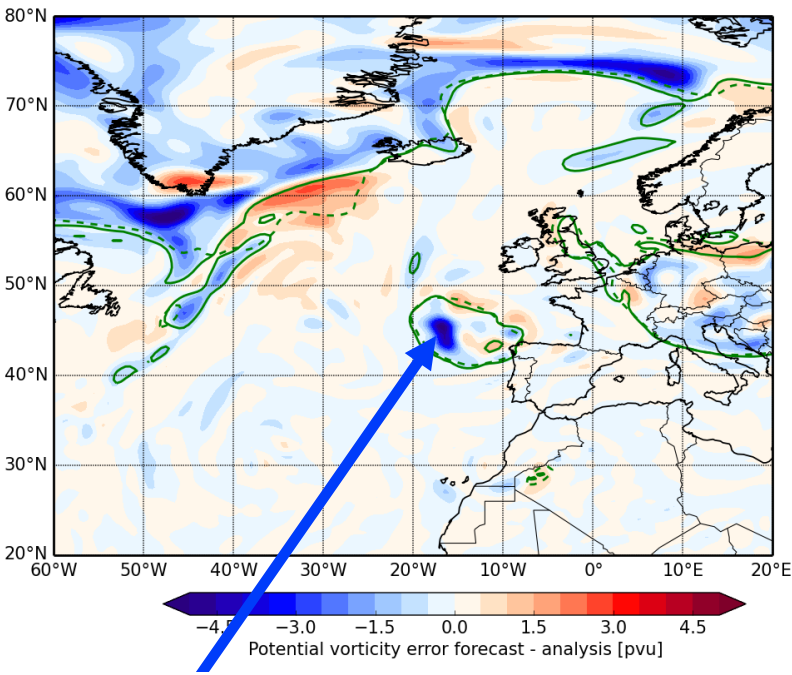
Ancell and Hakim 2007, MWR
Torn and Hakim 2008, MWR

- Ensemble size M must be large to remove signal to noise ratio
- 10-member ensemble of Arpege reforecast data is not enough
 - increase ensemble size by using fcst from different base times, specifically, BT 08/18 to 11/18
 - $M = [(3 \text{ days} \times 4\text{fc/day}) + 1] \times 10 \text{ members} = 130 \text{ members}$



Ensemble sensitivity analysis, $M = 130$ ensemble members

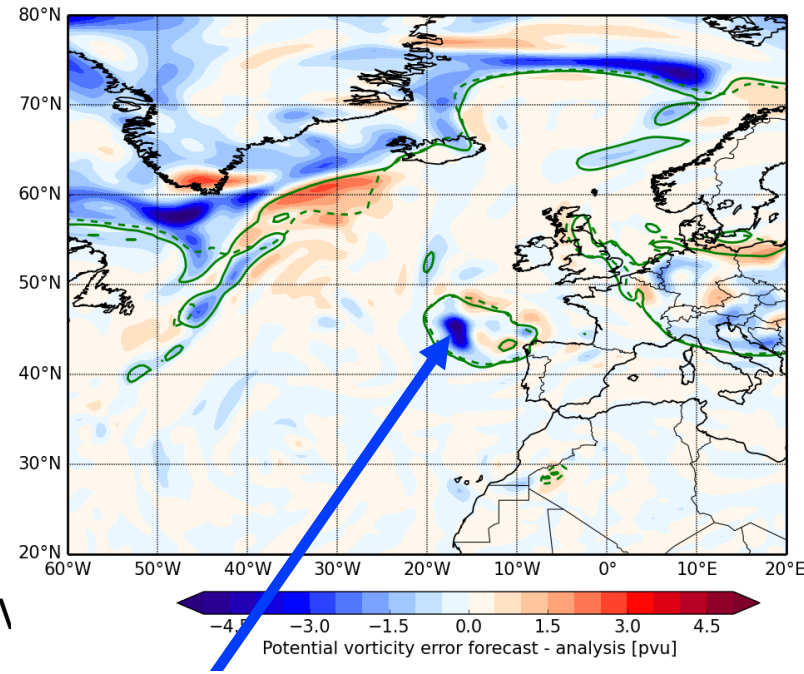
Ensemble mean PV error at 320 K at 12/00Z



Underestimation of cut-off intensity in SW part

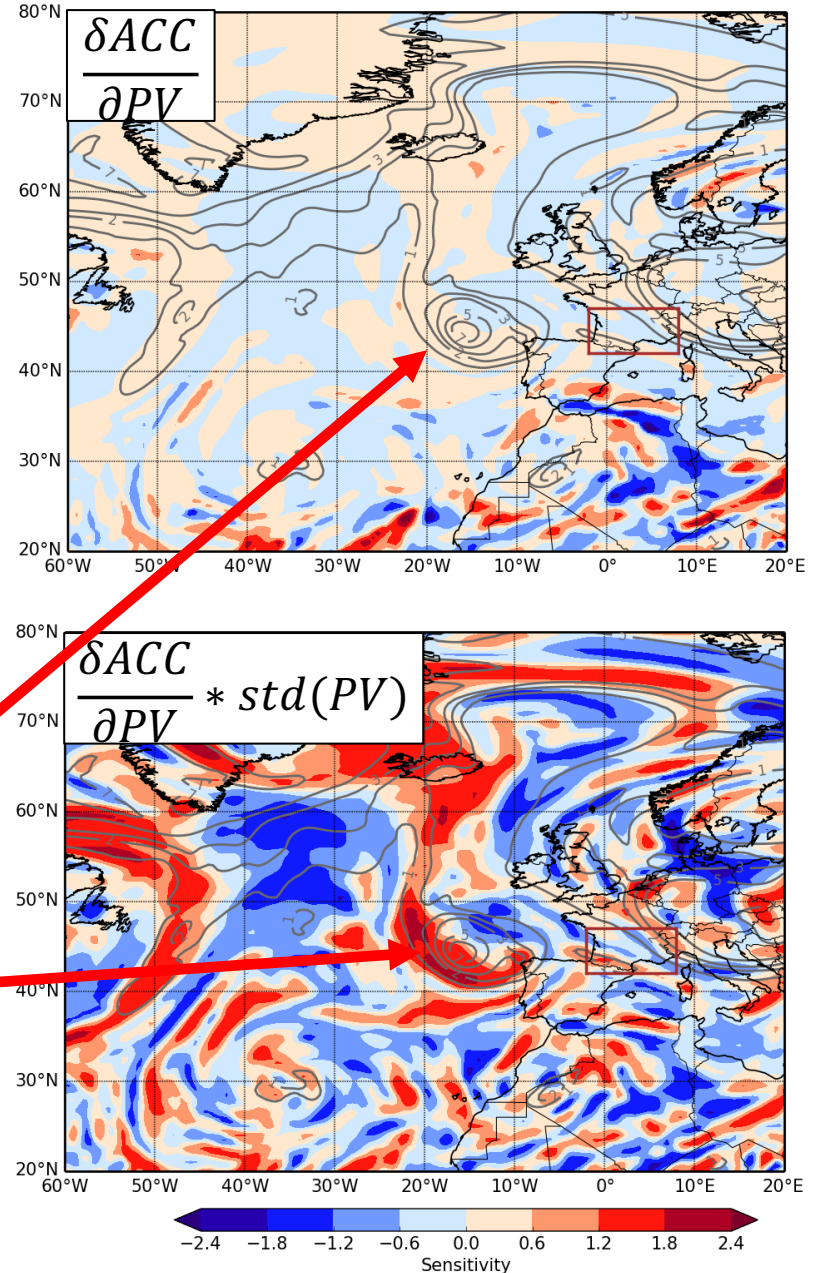
Ensemble sensitivity analysis, M = 130 ensemble members

Ensemble mean PV error at 320 K at 12/00Z



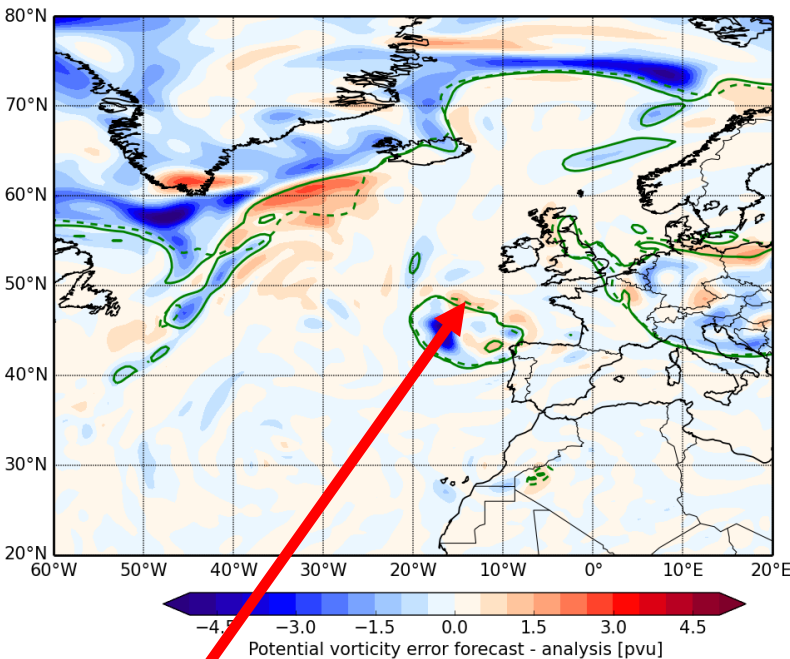
Underestimation of cut-off intensity in SW part

Pos. sensitivity values:
An **increase** in PV at 12/00Z would **increase the ACC** of precip. over SFrance on 13/18Z



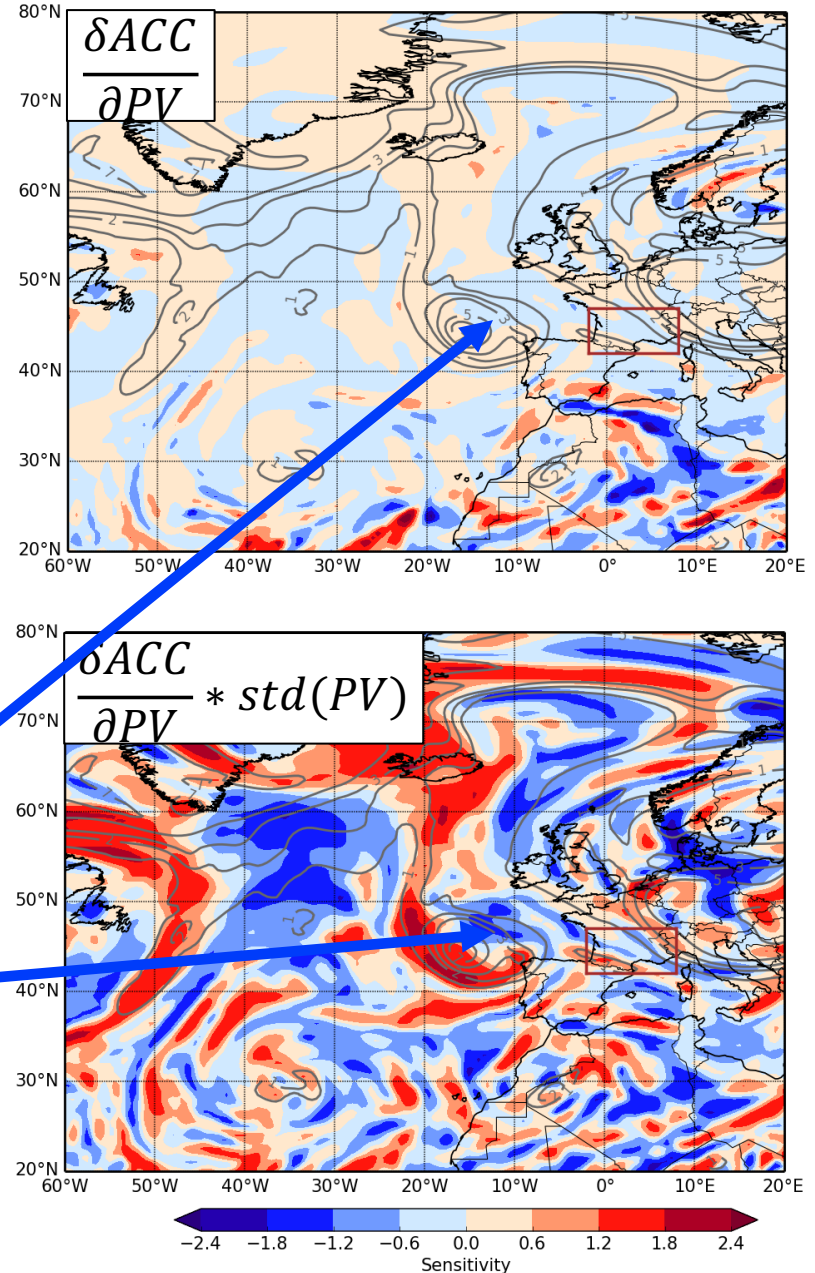
Ensemble sensitivity analysis, M = 130 ensemble members

Ensemble mean PV error at 320 K at 12/00Z



Overestimation of cut-off
intensity in NE part

Neg. sensitivity values:
A **decrease in PV** at 12/00Z
would **increase the ACC** of
precip. over SFrance on
13/18Z



Why is the intensity of cut-off Sanchez underestimated in the forecasts?

Underestimation of the intensity of the cut-off

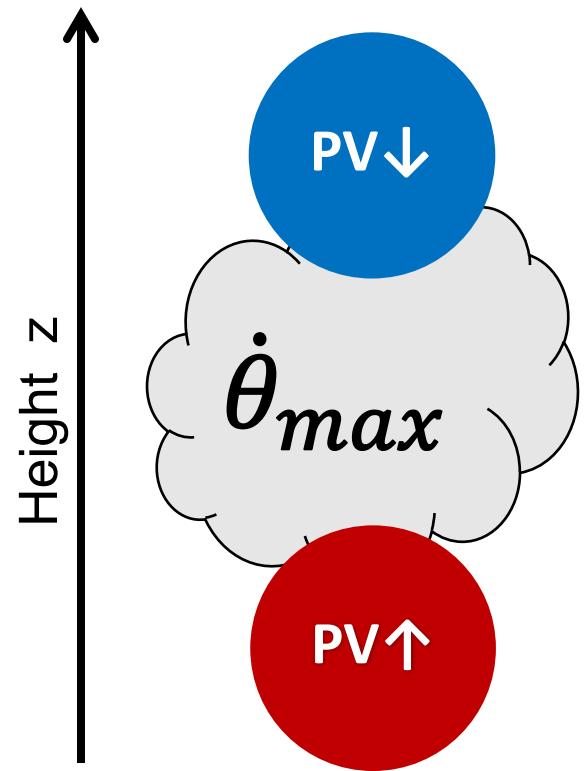
Hypothesis: The errors in the intensity of the upper-level cut-off are linked to errors in the representation of the **diabatic processes** associated with the cyclone located below the cut-off

Underestimation of the intensity of the cut-off

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⇒ **PV production below** and **destruction above** maximum in diabatic heating $\dot{\theta}_{max}$



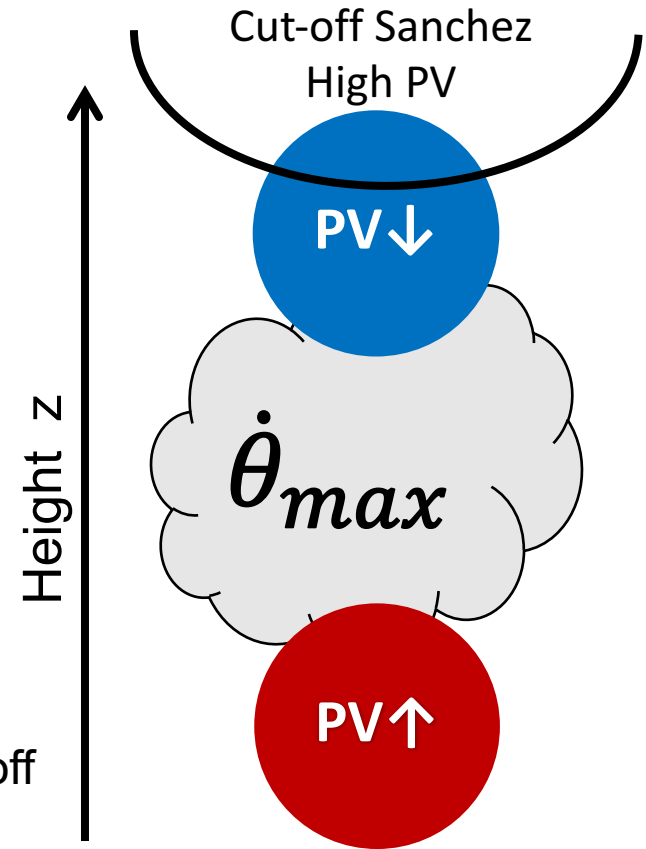
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⇒ **PV production below** and **destruction above** maximum in diabatic heating $\dot{\theta}_{max}$

⇒ Too strong diab. heating, e.g., associated with too intense parameterized convection, could result in **too strong UL PV destruction** -> **underestimation** of the cut-off intensity (and vice versa)



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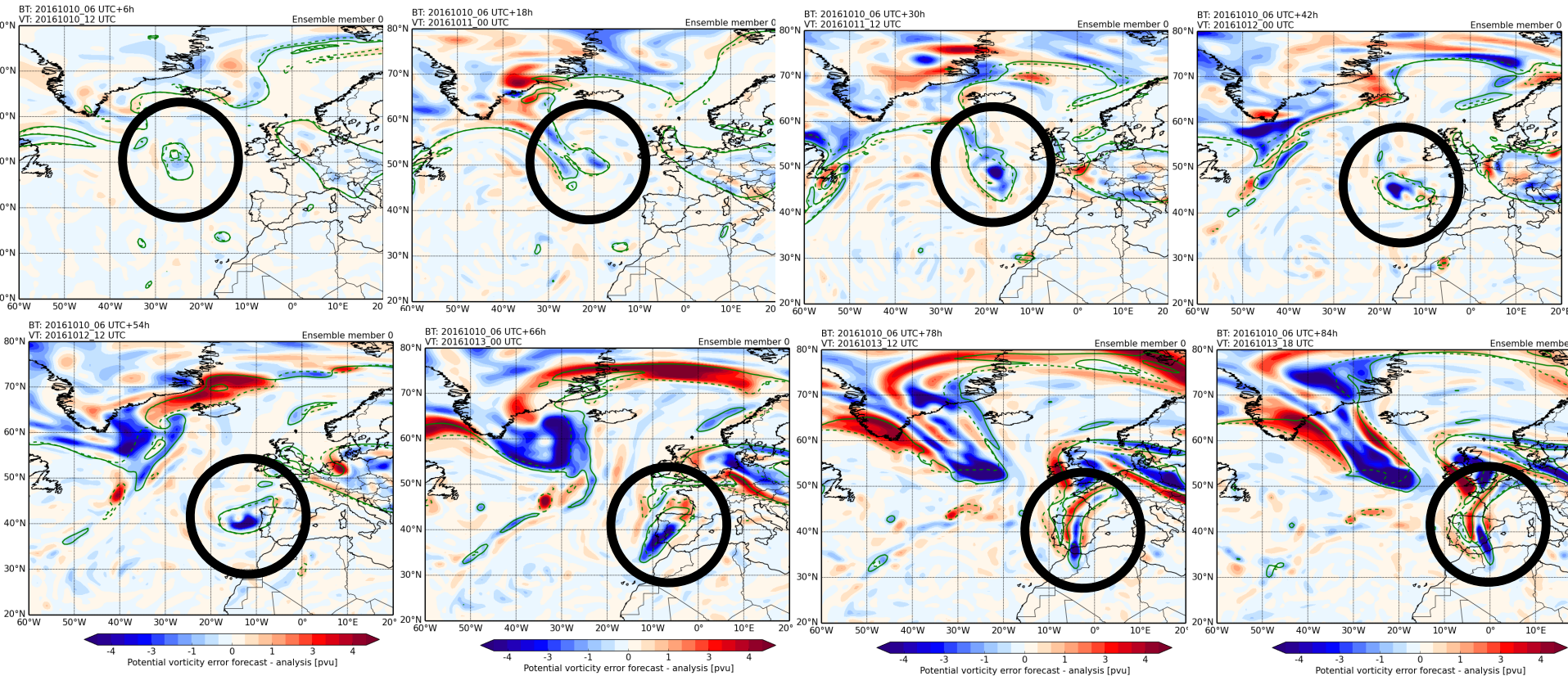
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- In the days preceding the HIW, the intensity of cut-off Sanchez was in most areas underestimated
- ESA indicates that a better representation of cut-off Sanchez 2 days before the HIW would lead to a better precipitation forecast (in terms of ACC); but noisy signal, with many other areas with high sensitivity values as well

Future work

- PV inversion: modify PV in cut-off Sanchez at 12/00Z to test impact on precipitation forecast
- Investigate in more detail difference between the ensemble members (and their physical parameterizations) in terms of forecast quality
- Test hypothesis that errors in the representation of cut-off Sanchez are linked to errors associated with the parameterization of diabatic processes (e.g., convection)
- Use other metrics to evaluate the forecasts (e.g., the object-based method „SAL“ that allows to verify the structure, amplitude and location of the precipitation objects from Wernli et al. 2008, MWR)

Evolution of the error in the upper-level PV streamer

BT 10/18, ensemble member 0



➤ **Underestimation of the intensity of cut-off Sanchez in the days preceding the HIW**

Shading: PV error on 320K: forecast – analysis

Red: Overestimation of forecasted UL PV

Blue: Underestimation of forecasted UL PV

— 2pvu at 320K in the analysis

... 2pvu at 320K in the forecast

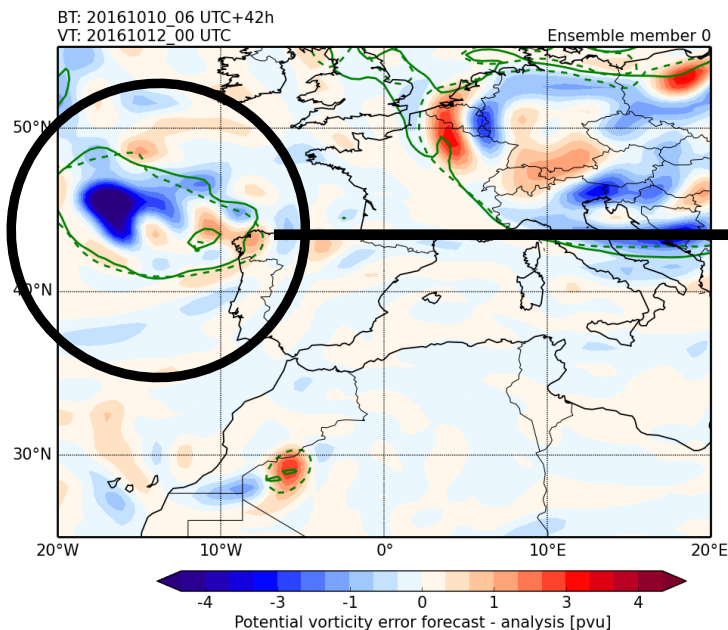
Ensemble sensitivity analysis (ESA)

Ancell and Hakim 2007, MWR
Torn and Hakim 2008, MWR

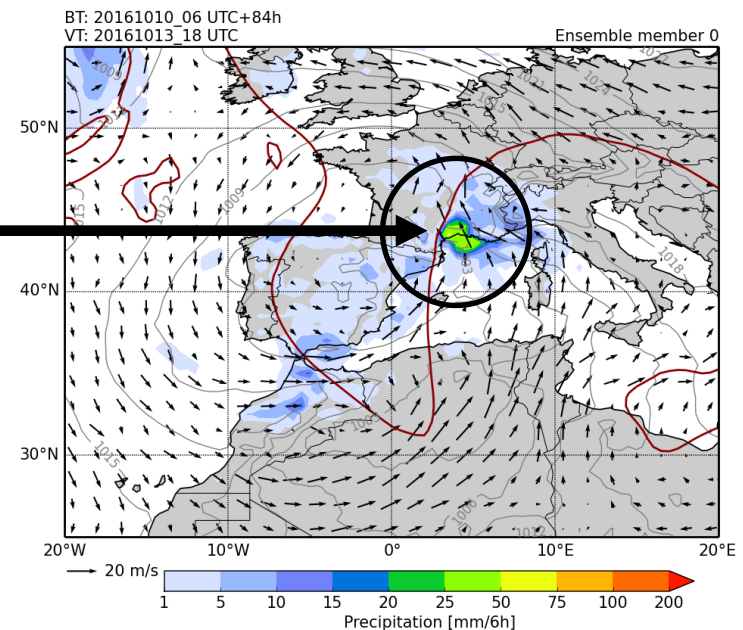
$$\frac{\delta J}{\partial x} = \frac{cov(J, x)}{var(x)}$$

A **pos. sensitivity value** at a certain GP indicates that an **increase in PV** at 12/00Z would be associated with an **increase in the ACC** of precip. over SFrance at 13/18Z (-> **improved forecast**)

10/06Z+42h, VT 12/00Z

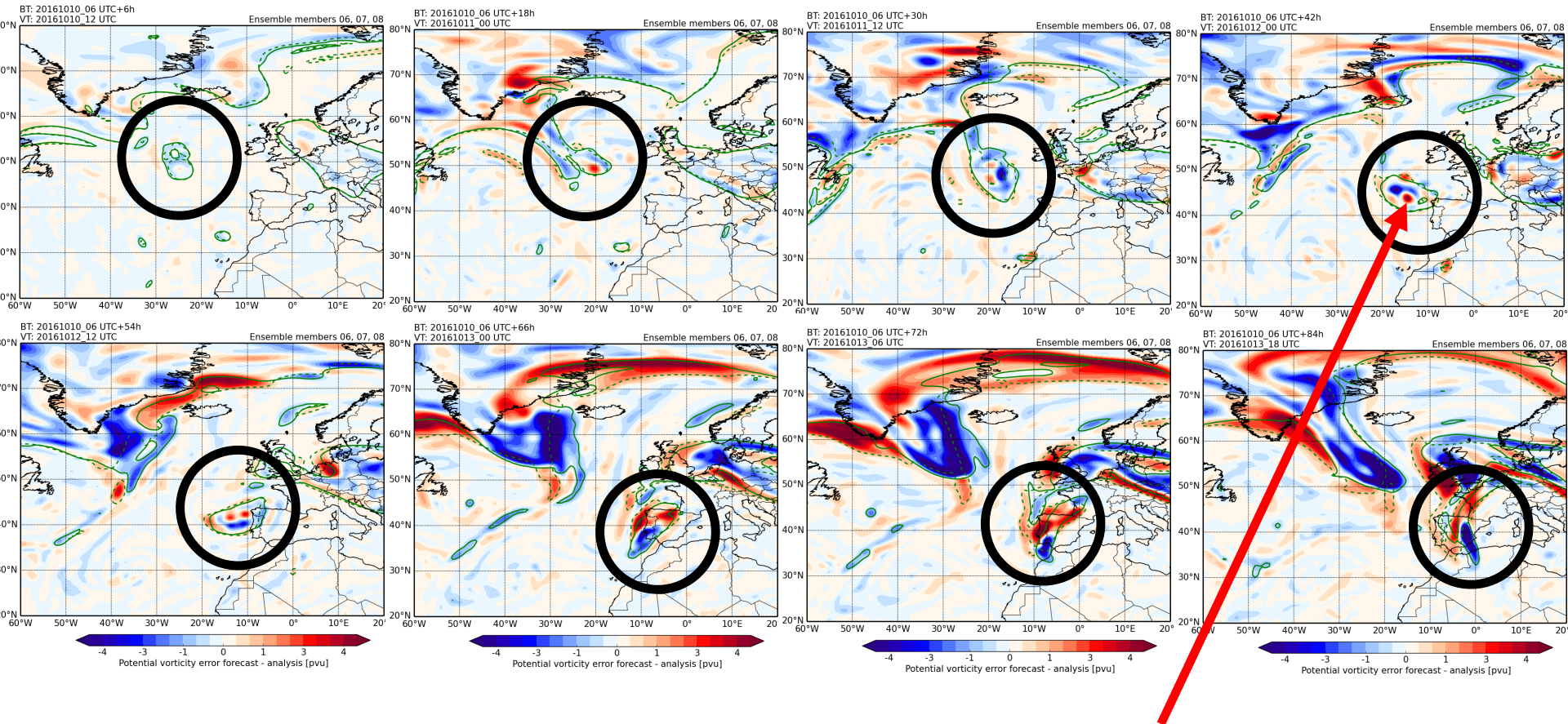


10/06Z+84h, VT 13/18Z



Evolution of the error in the upper-level PV streamer

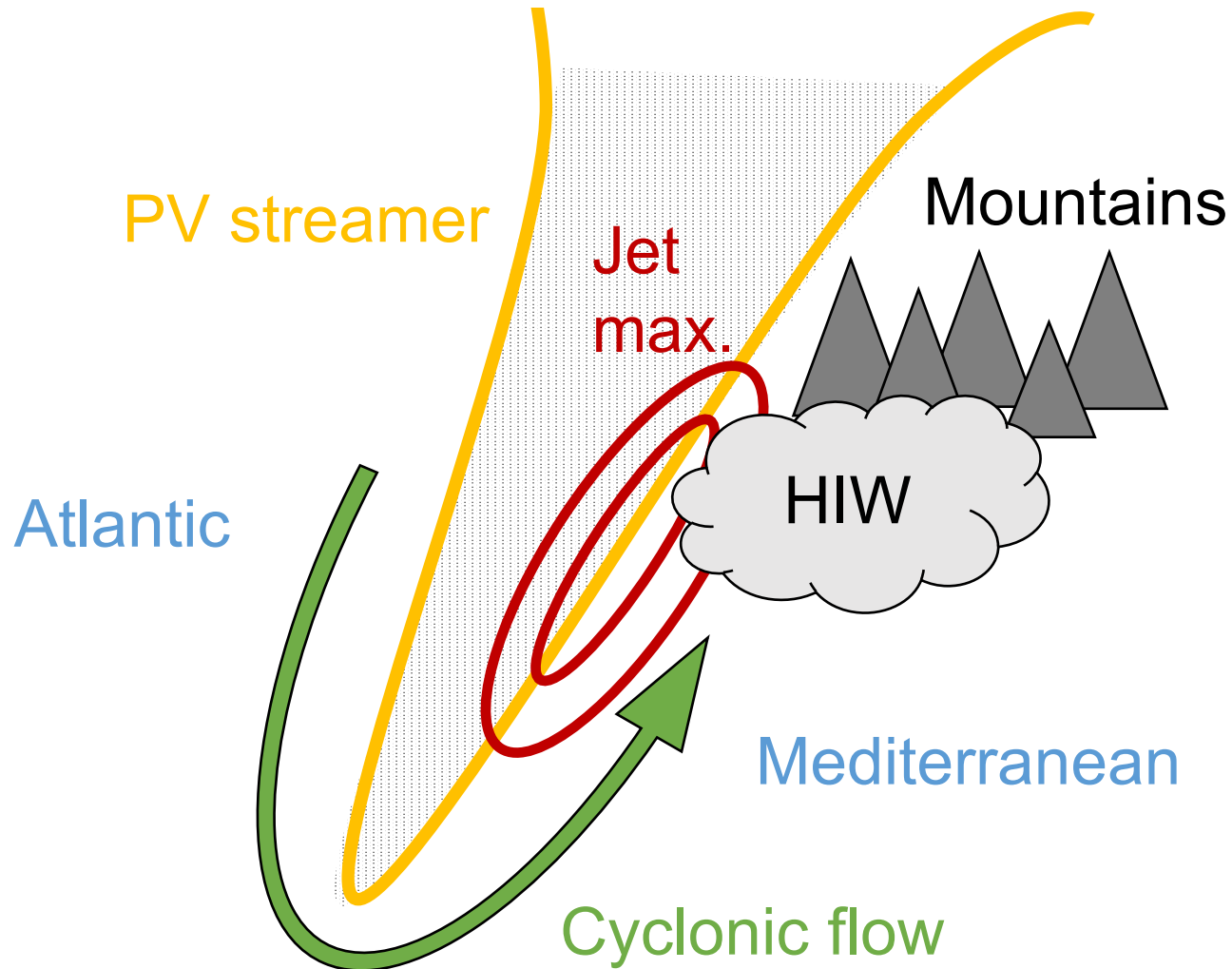
BT 10/06, mean over ensembles 6, 7 and 8 (new deep convection scheme)



Regions where the cut-off intensity is **overestimated**, in addition to the regions with **underestimation**

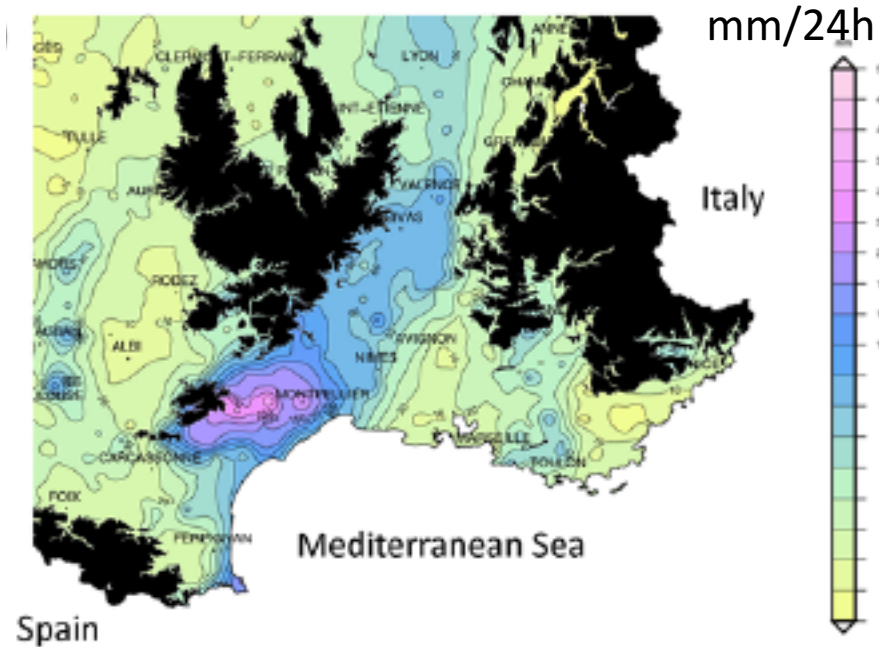
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Upper-level PV streamers and their link to European HIW



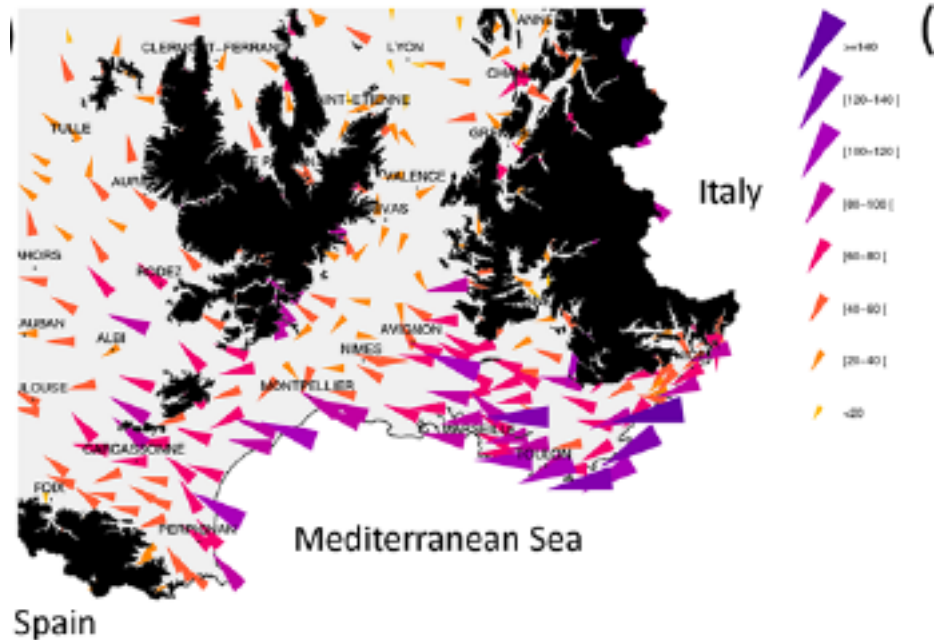
High-impact weather over southern France on 13 Oct 2016

Daily accumulated precipitation



Heavy precipitation: ~250 mm/24h
in the Hérault region

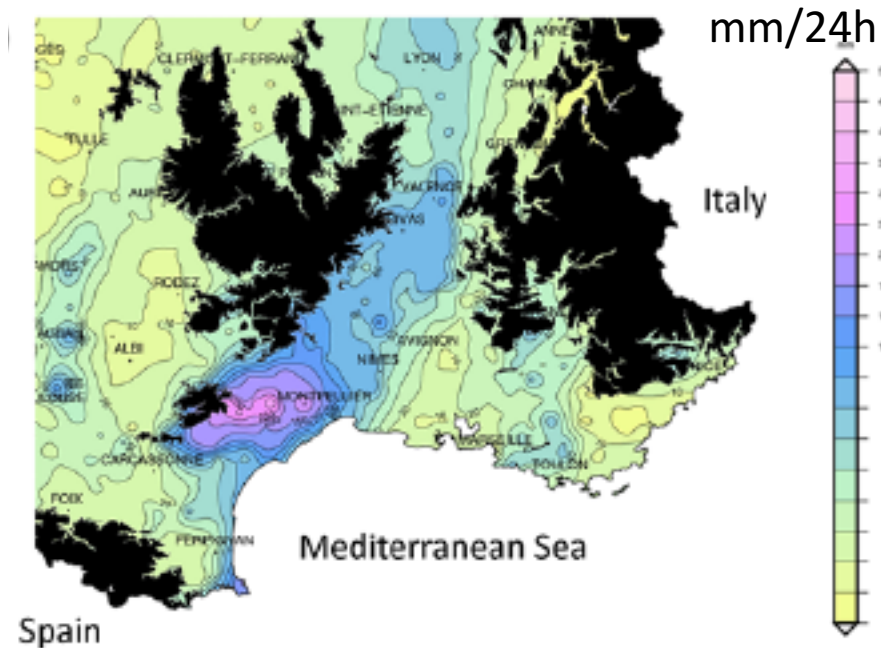
Daily max. of instantaneous surface winds



Strong wind gusts > 100 km/h

HIW related to cut-off cyclone “Sanchez”

Daily accumulated precipitation



18 UTC 13 Oct 2016

PV and wind on 250 hPa

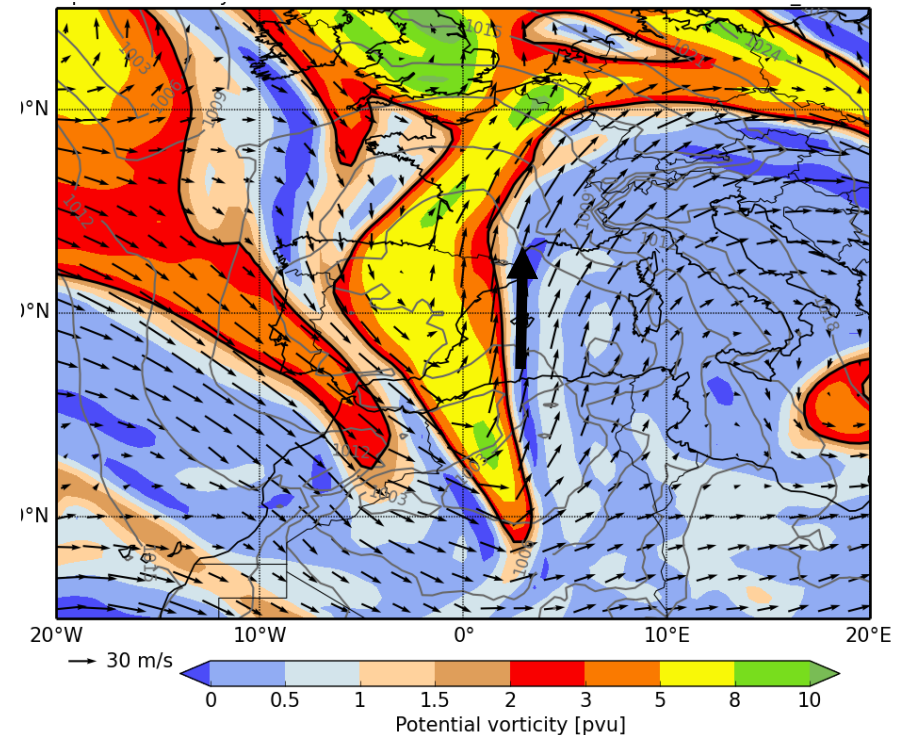


Figure provided by Philippe Arbogast,
Météo-France