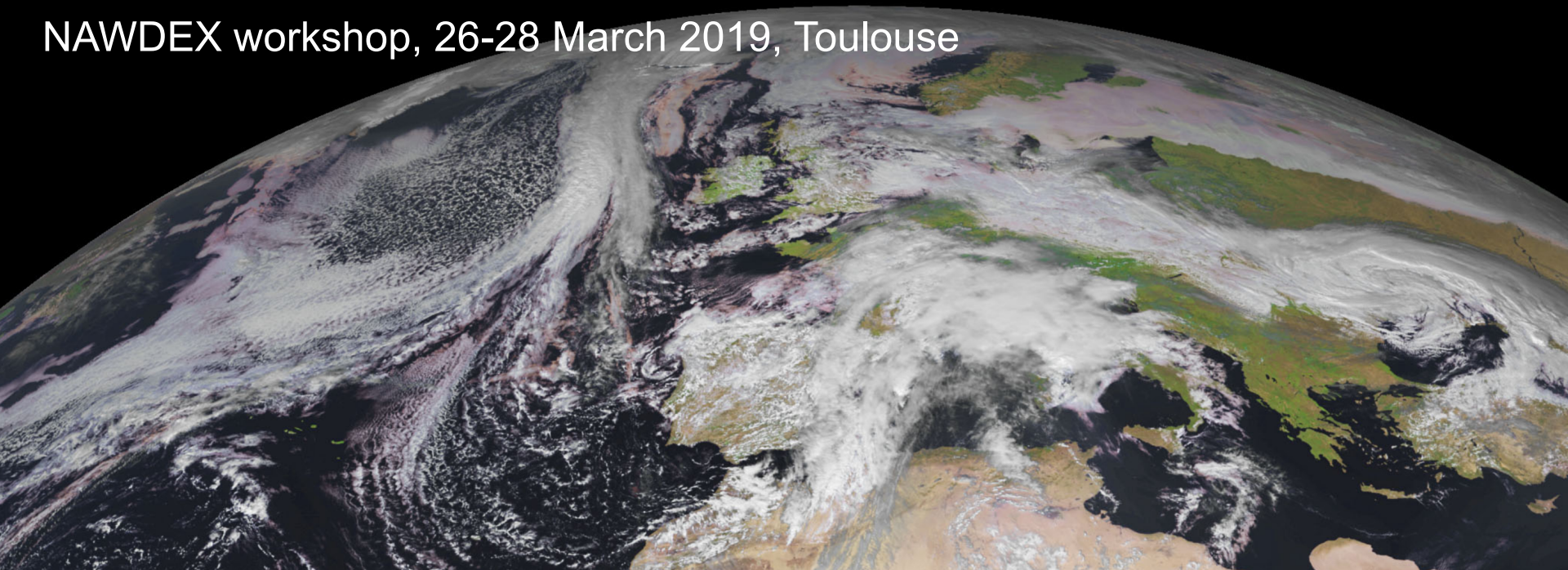


Understanding the dynamics of cut-off Sanchez and its downstream impact over southern France using probabilistic and deterministic Météo-France forecasts

Hanin Binder¹, Gwendal Rivière², Philippe Arbogast³, Bruno Joly³,
Carole Labadie³ and Karine Maynard³

¹LMD-ENS Paris/SNSF ²LMD-ENS Paris/CNRS ³CNRM/Météo-France

NAWDEX workshop, 26-28 March 2019, Toulouse

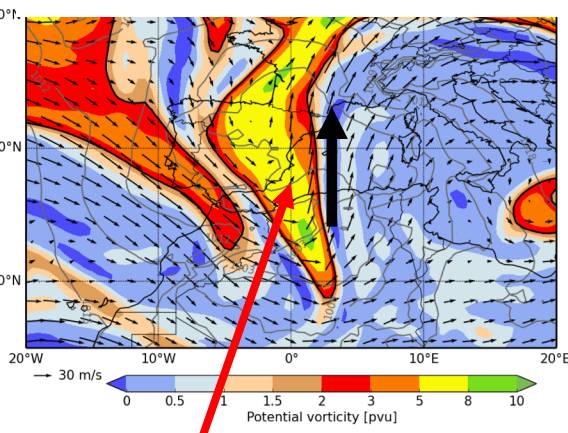


High-impact weather over southern France on 14 Oct 2016 related to PV streamer “Sanchez”

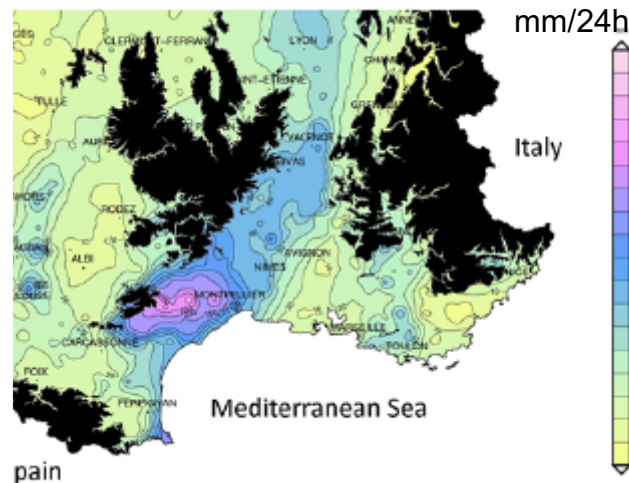
Objectives:

- Evaluate the representation of the HIW event and PV streamer Sanchez in Météo-France forecasts.
- Assess the sensitivity of the HIW to the representation of the upstream upper-level flow and the low-level moisture at earlier times.

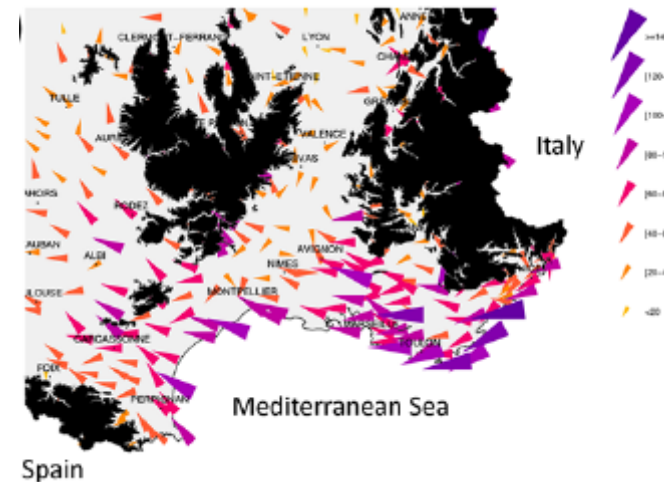
PV and wind at 250 hPa
18 UTC 13 Oct 2016



PV Streamer „Sanchez“



~250 mm daily accumulated
precipitation over S France



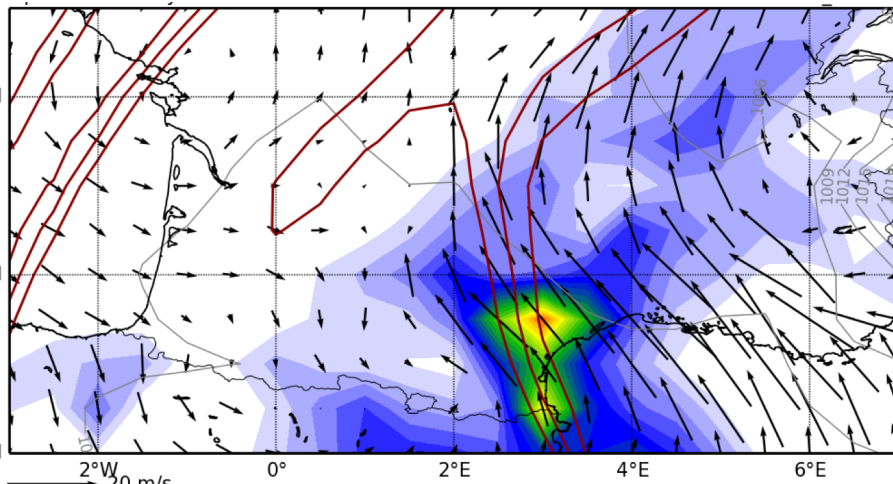
Strong wind gusts > 100 km/h

Data

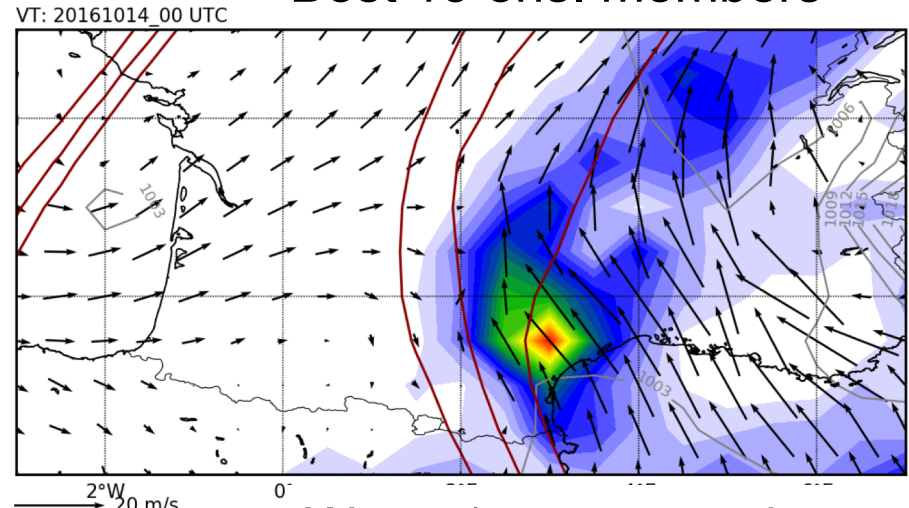
1. **Ensemble reforecasts** of the Météo-France global operational model Arpege, version PEARP4 (Descamps et al. 2015, Boisserie et al. 2016a,b)
 - 10 ensemble members
 - Same initial conditions (Arpege op. analyses)
 - 10 different physical parameterization sets to represent model uncertainties associated with
 - shallow and deep convection
 - solar radiation
 - turbulence
 - cloud cover
2. **High-resolution deterministic** Arpege forecasts for **PV inversion** experiments (Arbogast et al. 2008)

00 UTC 14 Oct 2016, 15 best vs. worst precipitation forecasts in terms of ACC, BT10/00Z to 12/00Z

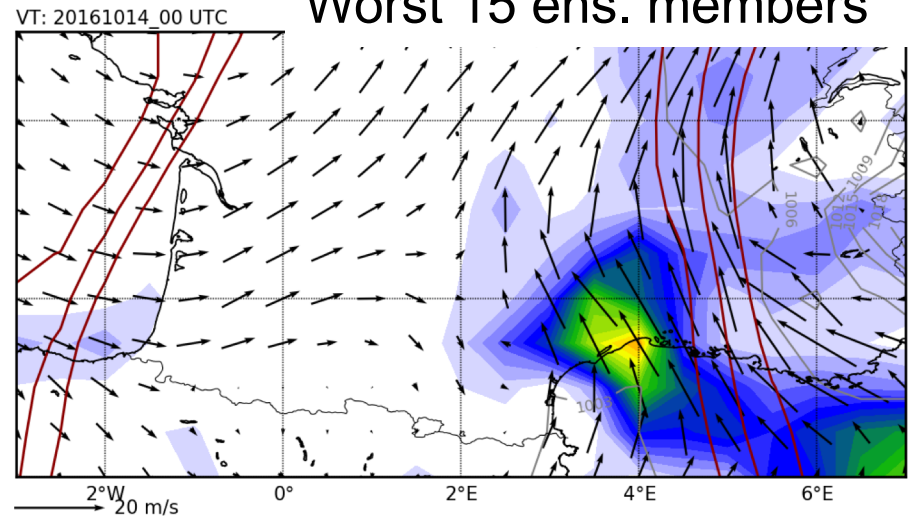
Analysis



Best 15 ens. members

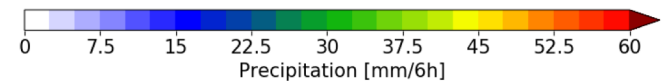


Worst 15 ens. members



30mm contour of 6h accum. precip.

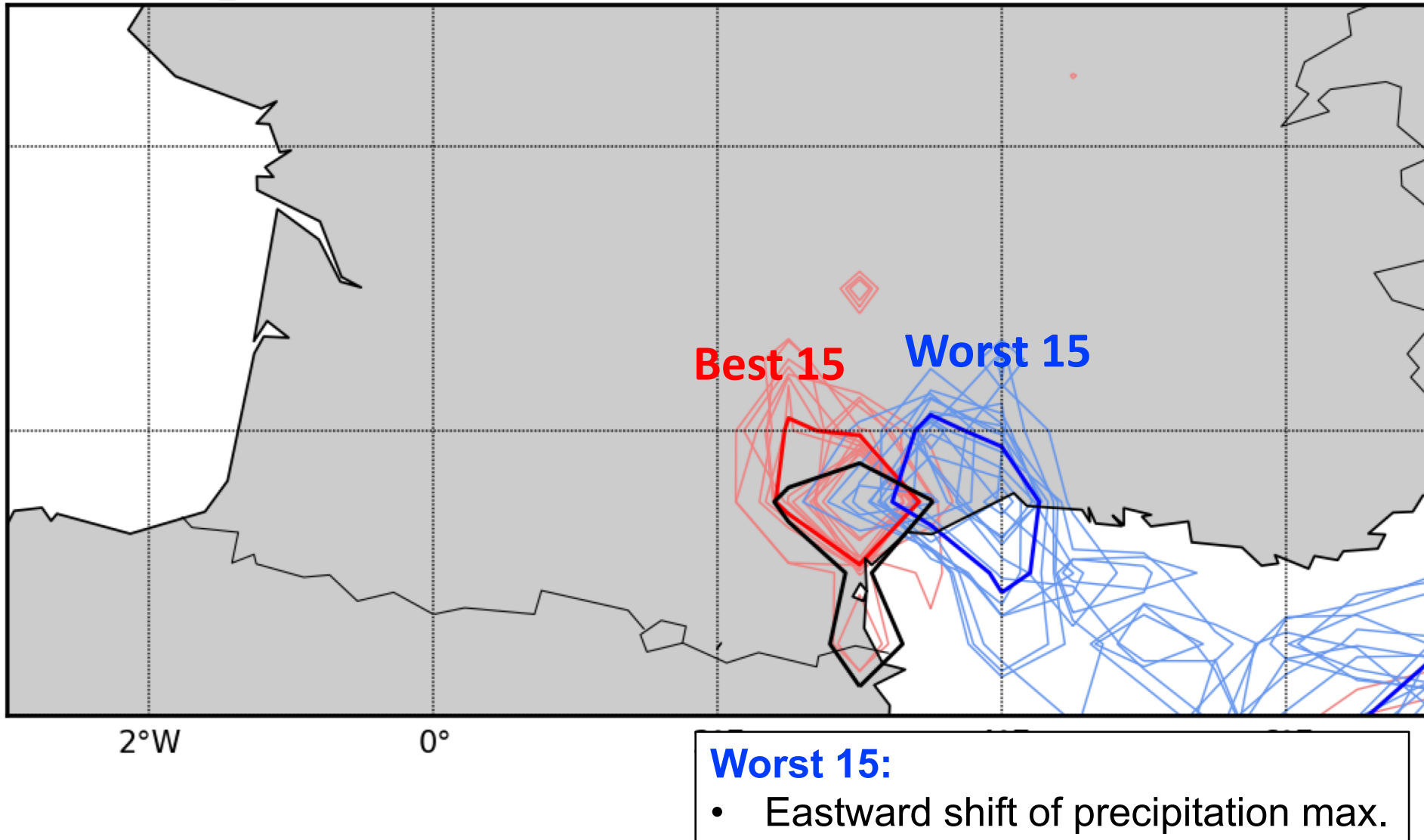
— Best — Worst — Analysis



— 1,2,3pvu at 330 K ← 850-hPa wind

15 best vs. worst precipitation forecasts at VT14/00Z

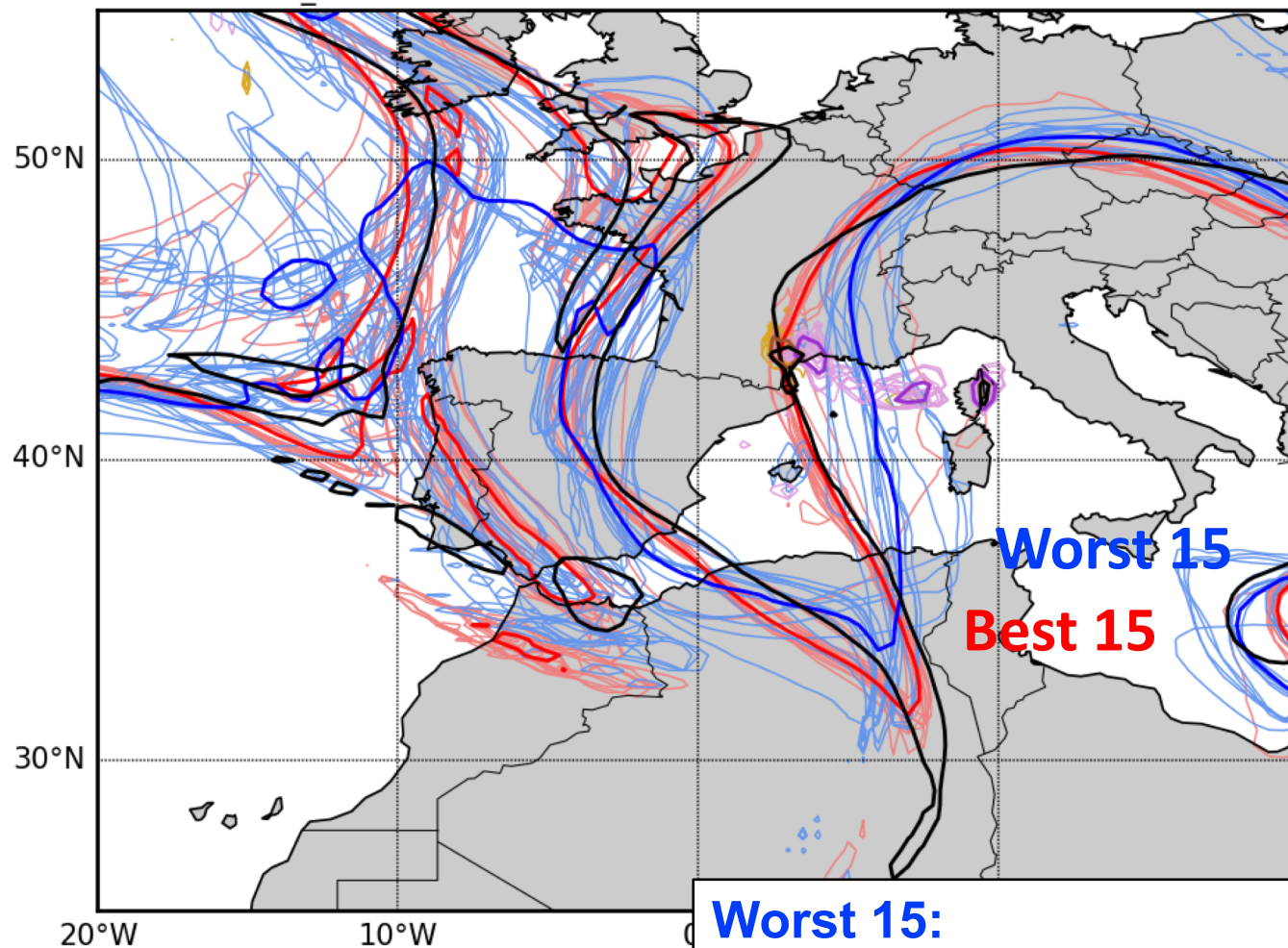
(BT10/00Z to 12/00Z)



15 best vs. worst precipitation forecasts at VT14/00Z

2pvu at 330K and 30mm contour of 6h accum. precipitation

VT: 20161014_00 UTC



Worst 15

Best 15

Worst 15:

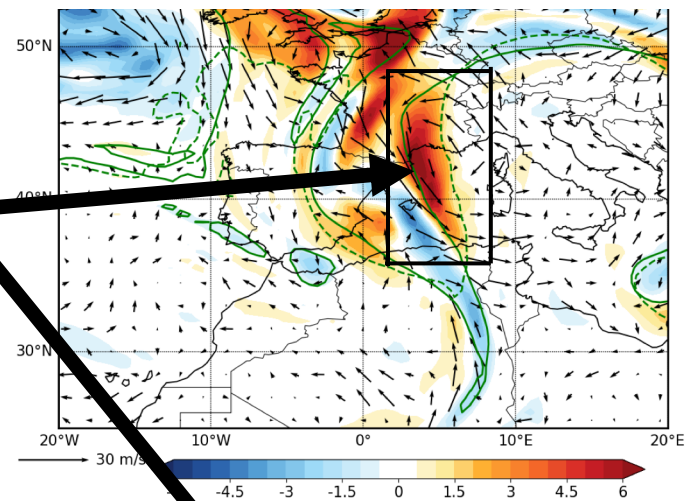
- Eastward shift of precipitation max.
- Eastward shift and different tilt of 2pvu@330K

Best Worst Analysis

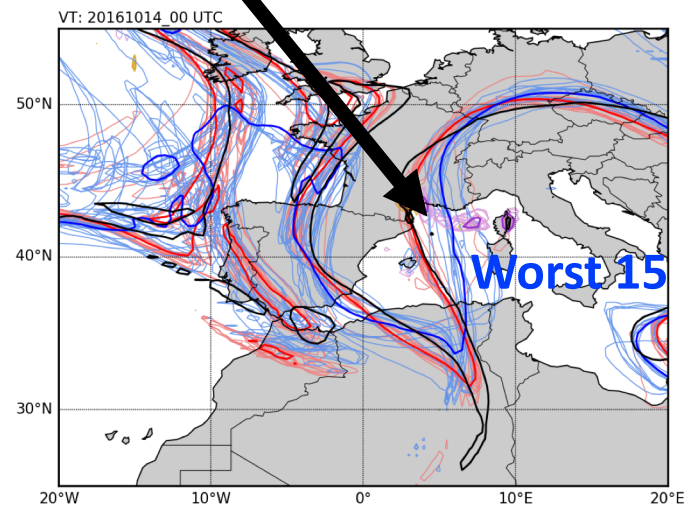
Origin of positive ULPV error in bad fc

?

ULPV error worst 15, 14/00Z

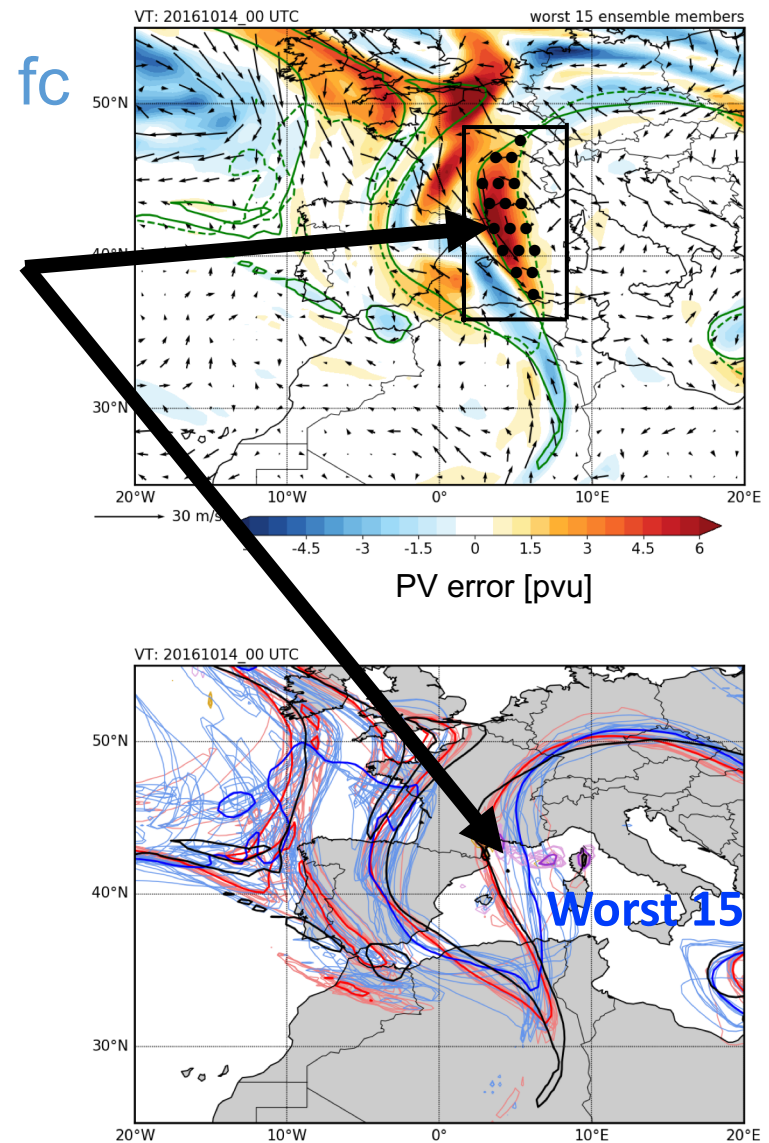


PV error at 330 K [pvu]



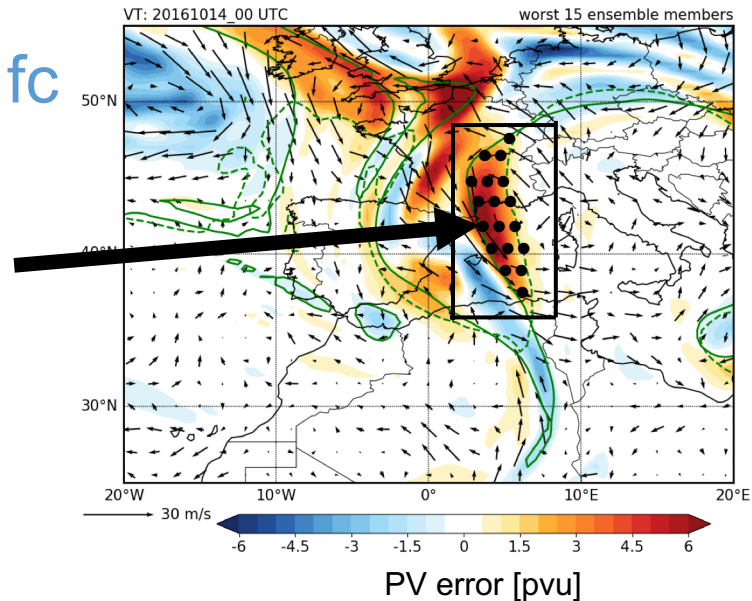
Origin of positive ULPV error in bad fc

48h **backw. traj.** starting at 14/00Z from grid points where ens. mean ULPV error of 15 worst fc > 2pvu (with LAGRANTO, Wernli & Davies, 1997)

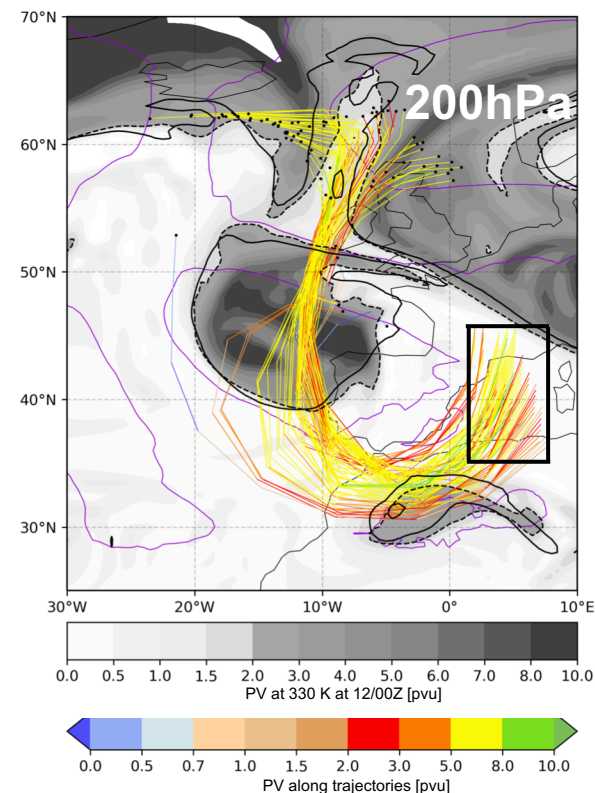


Origin of positive ULPV error in bad fc

48h **backw. traj.** starting at 14/00Z from grid points where ens. mean ULPV error of 15 worst fc > 2pvu (with LAGRANTO, Wernli & Davies, 1997)



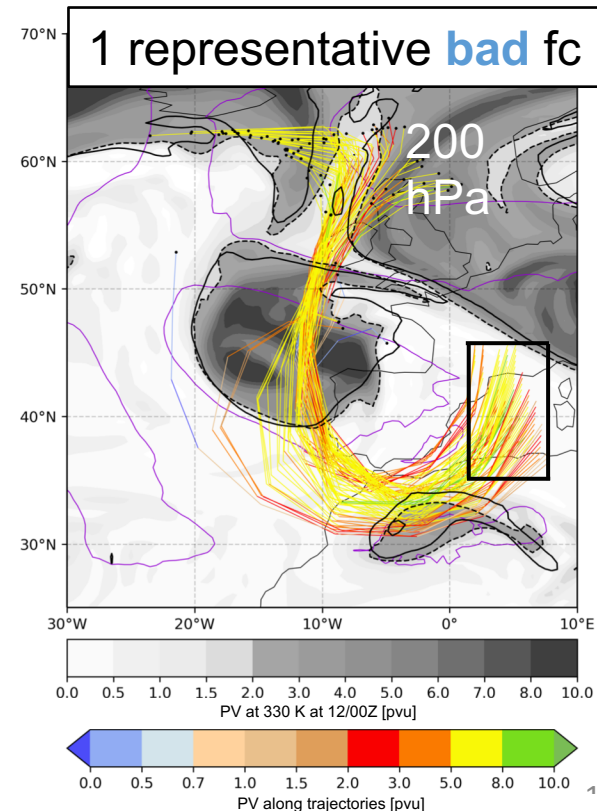
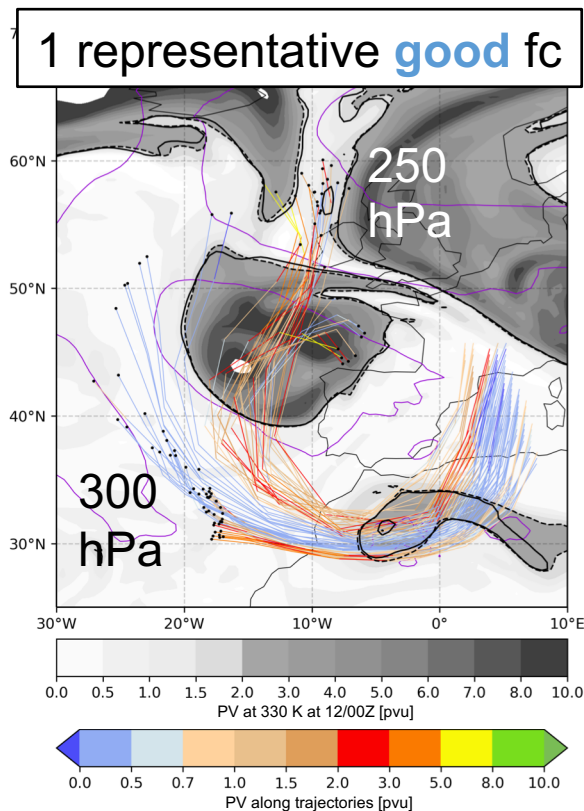
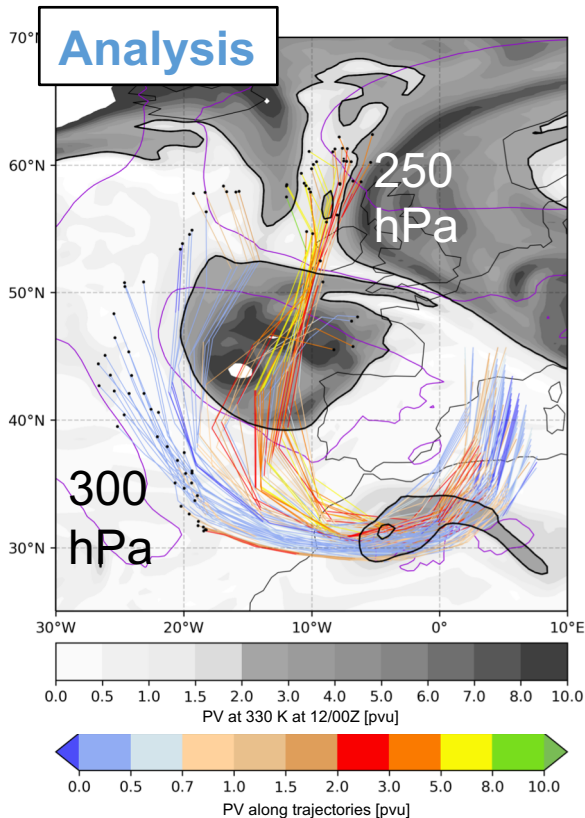
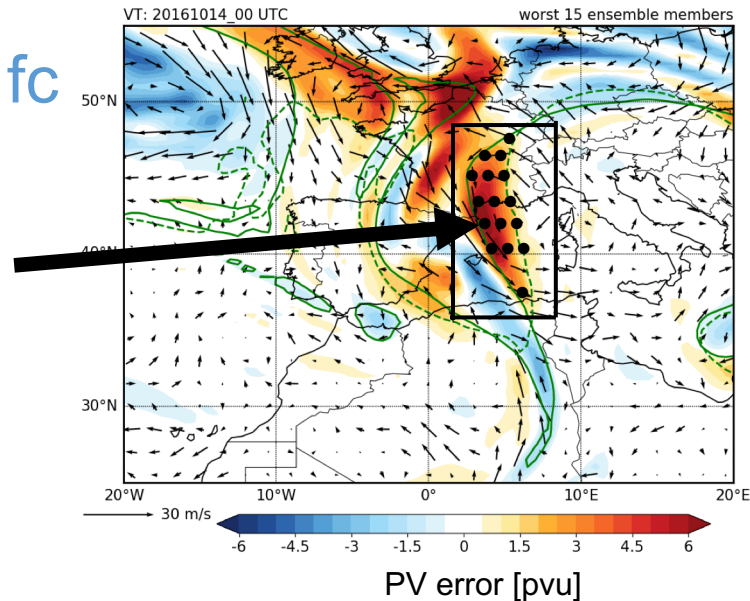
PV evolution along traj. of a representative **bad** fc and PV at 330K at 12/00Z



Origin of positive ULPV error in bad fc

48h **backw. traj.** starting at 14/00Z from grid points where ens. mean ULPV error of 15 worst fc > 2pvu (with LAGRANTO, Wernli & Davies, 1997)

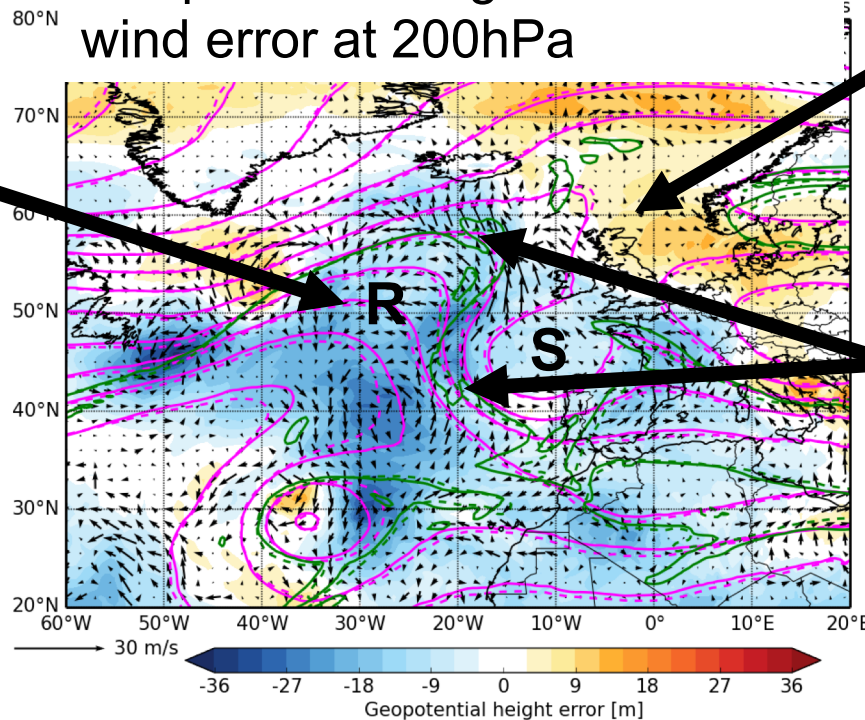
PV evolution along trajectories



Upper-level errors in 15 worst fc 2 days before HIW

**Underestimation
of ridge Thor**

Geopotential height error and
wind error at 200hPa

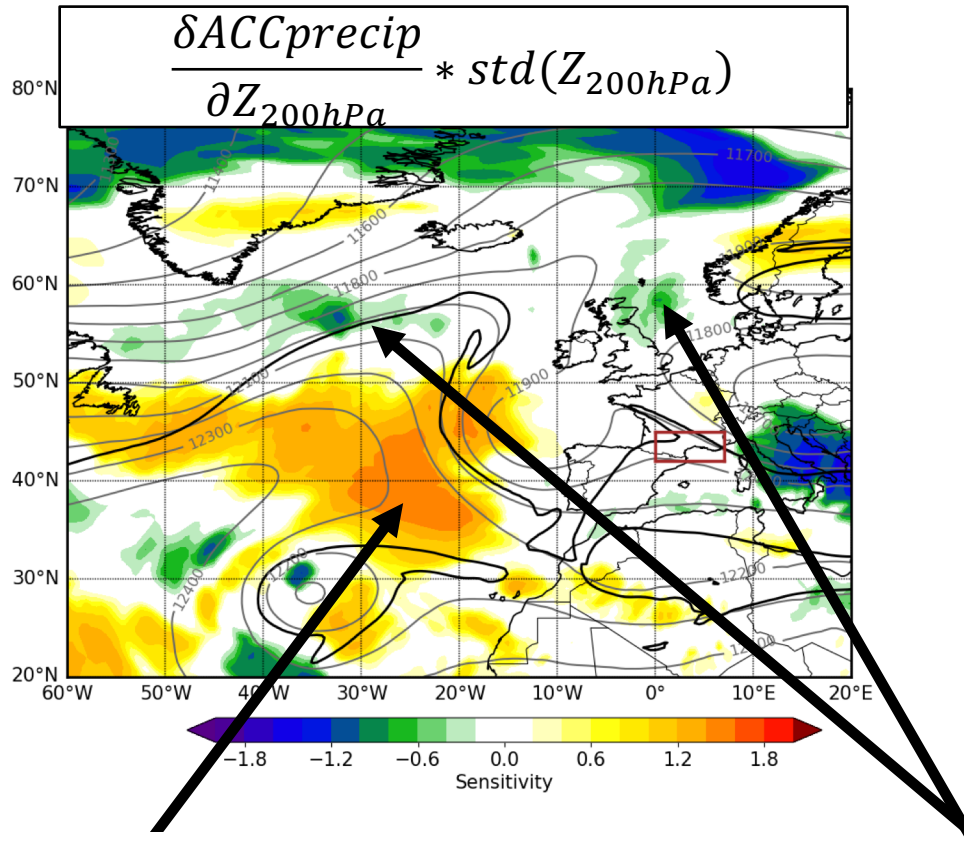


Overestimation of
Z in stratosphere

**Underestimation
of jet S of Iceland
and W of cutoff**

Sensitivity of the precip. to Z200hPa & the jet strength at 12/00Z

Ensemble sensitivity analysis with 160 members at 12/00Z

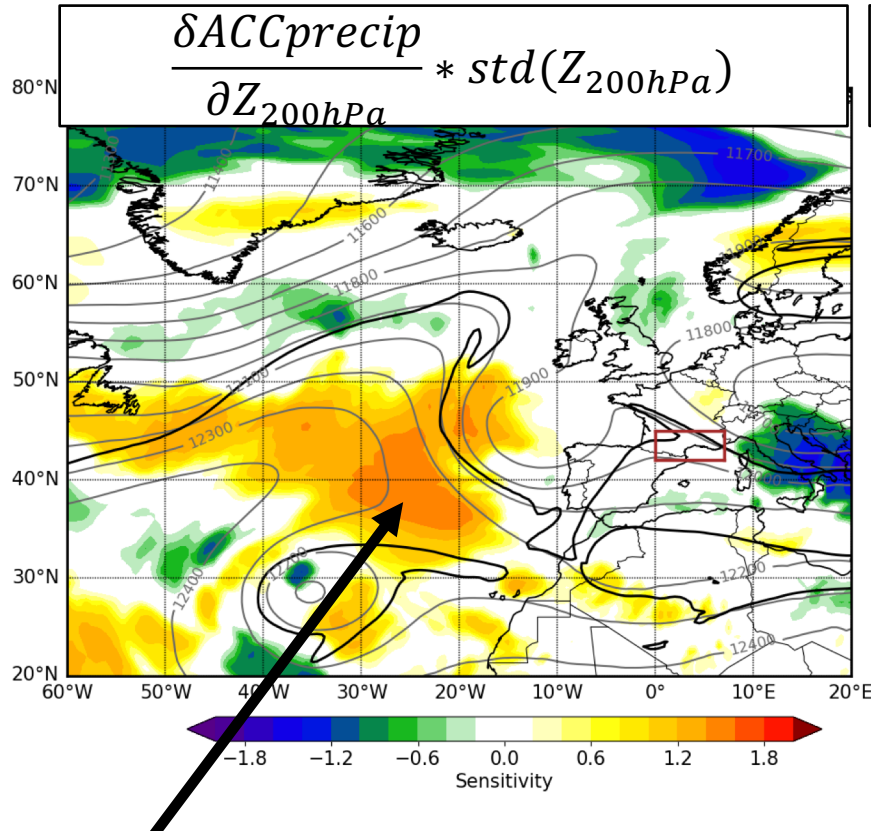


Pos. sensitivities: the higher the geopot. height (= **stronger ridge**) at 12/00Z the **better the precip. fc** over Sfrance at 14/00Z

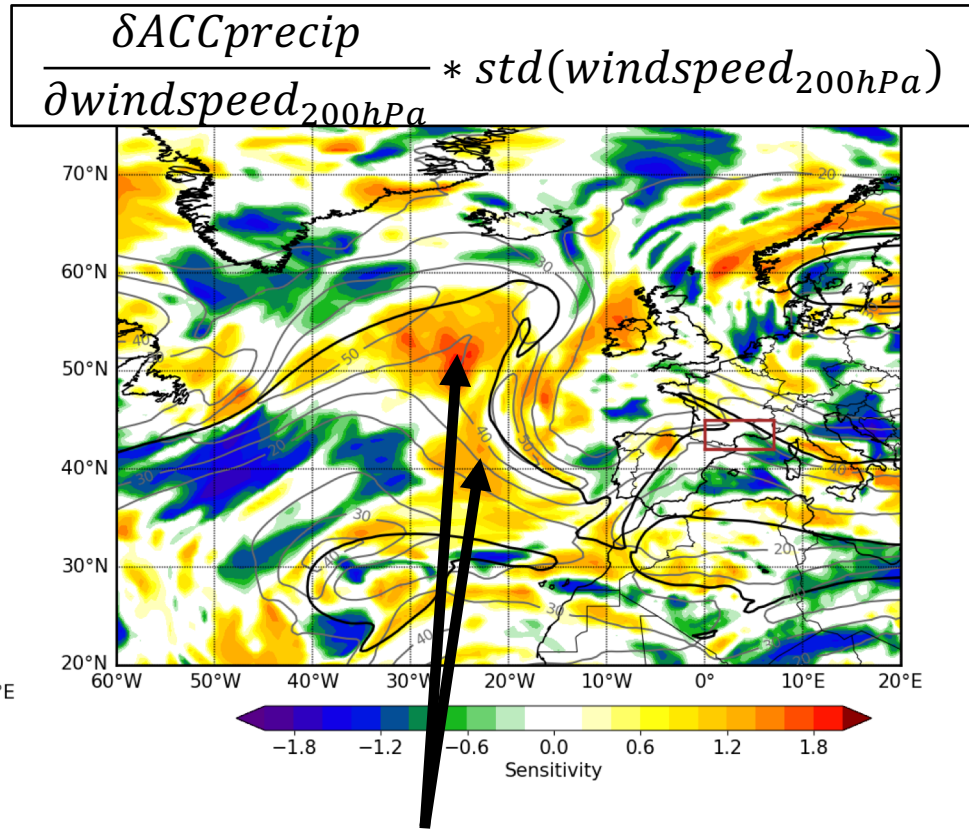
Neg. sensitivities: the lower the geopot. height at 12/00Z in that area the **better the precip. fc** over Sfrance at 14/00Z

Sensitivity of the precip. to Z200hPa & the jet strength at 12/00Z

Ensemble sensitivity analysis with 160 members at 12/00Z



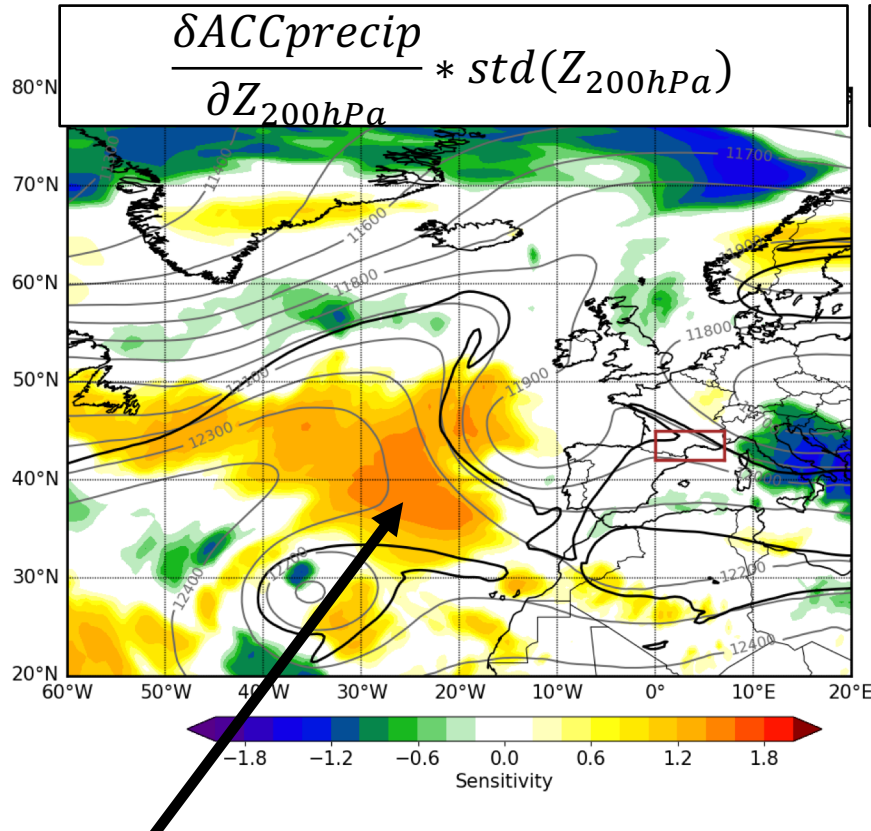
Pos. sensitivities: the higher the geopot. height (= **stronger ridge**) at 12/00Z the **better the precip. fc** over Sfrance at 14/00Z



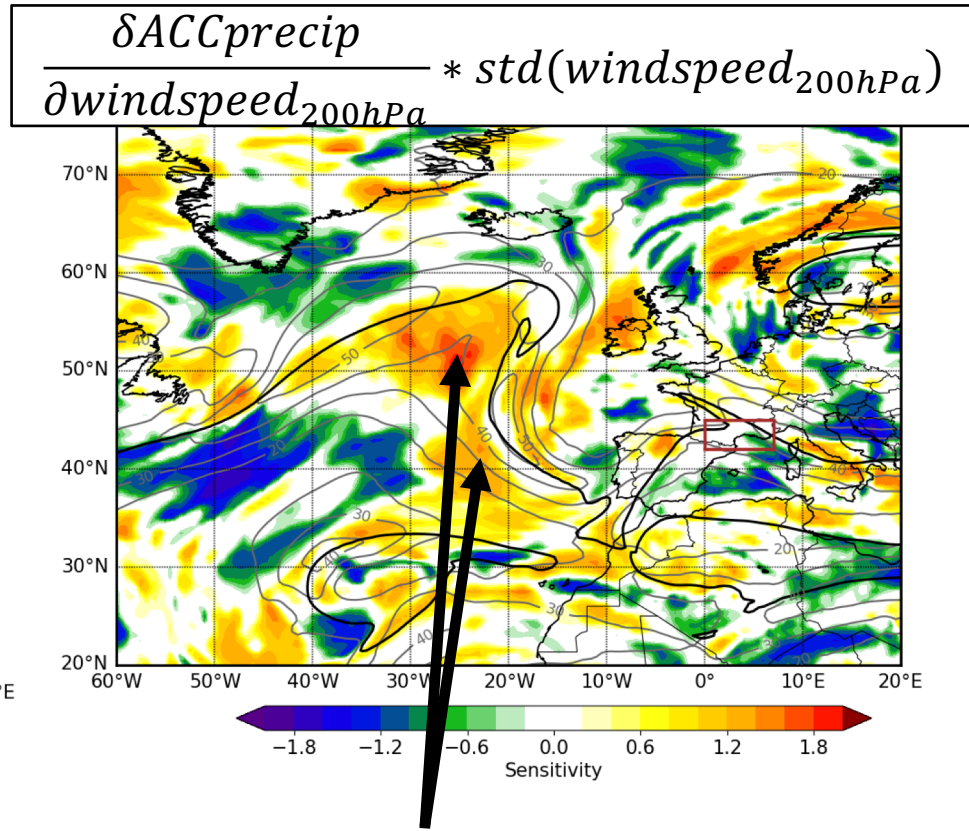
Stronger jet at 12/00Z = **better precip. fc** over Sfrance at 14/00Z

Sensitivity of the precip. to Z200hPa & the jet strength at 12/00Z

Ensemble sensitivity analysis with 160 members at 12/00Z



Pos. sensitivities: the higher the geopot. height (= **stronger ridge**) at 12/00Z the **better the precip. fc** over Sfrance at 14/00Z



Stronger jet at 12/00Z = **better precip. fc** over Sfrance at 14/00Z

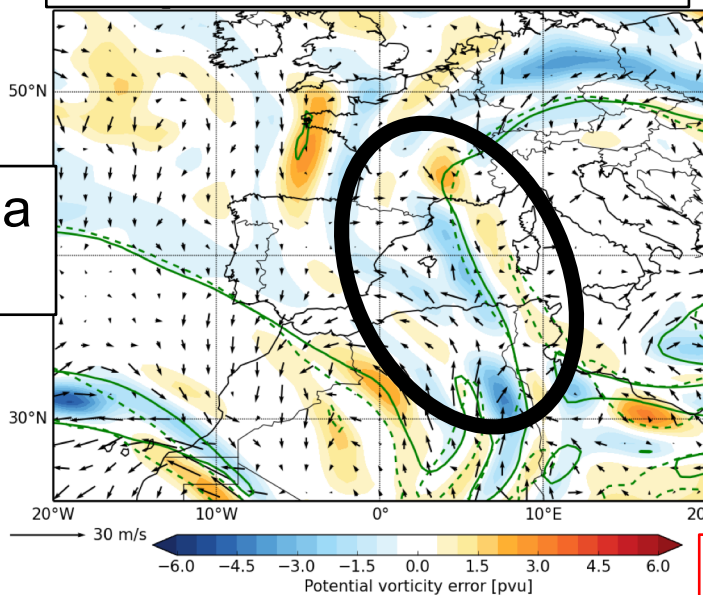
→ PV inversion experiments to isolate impact of initial upstream UL errors on ULPV and precipitation errors at 00 UTC 14 Oct

PV inversion experiments in high-resolution deterministic runs

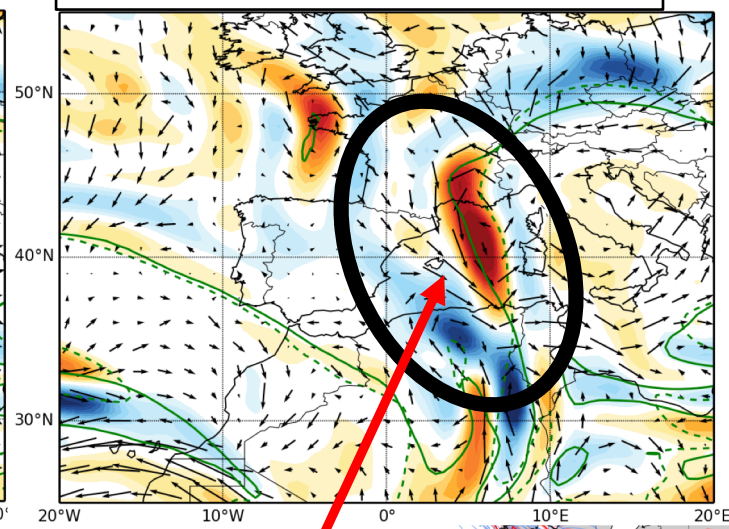
Two control runs:

1. A **good fc** in terms of UL PV and precip. at 14/00Z: BT12/00Z
2. A **bad fc** in terms of UL PV and precip. at 14/00Z: BT10/18Z

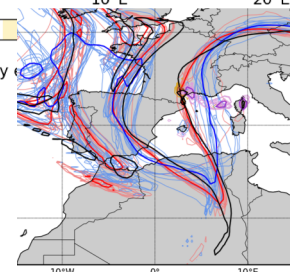
Good forecast: BT12/00Z



Bad forecast: BT10/18Z



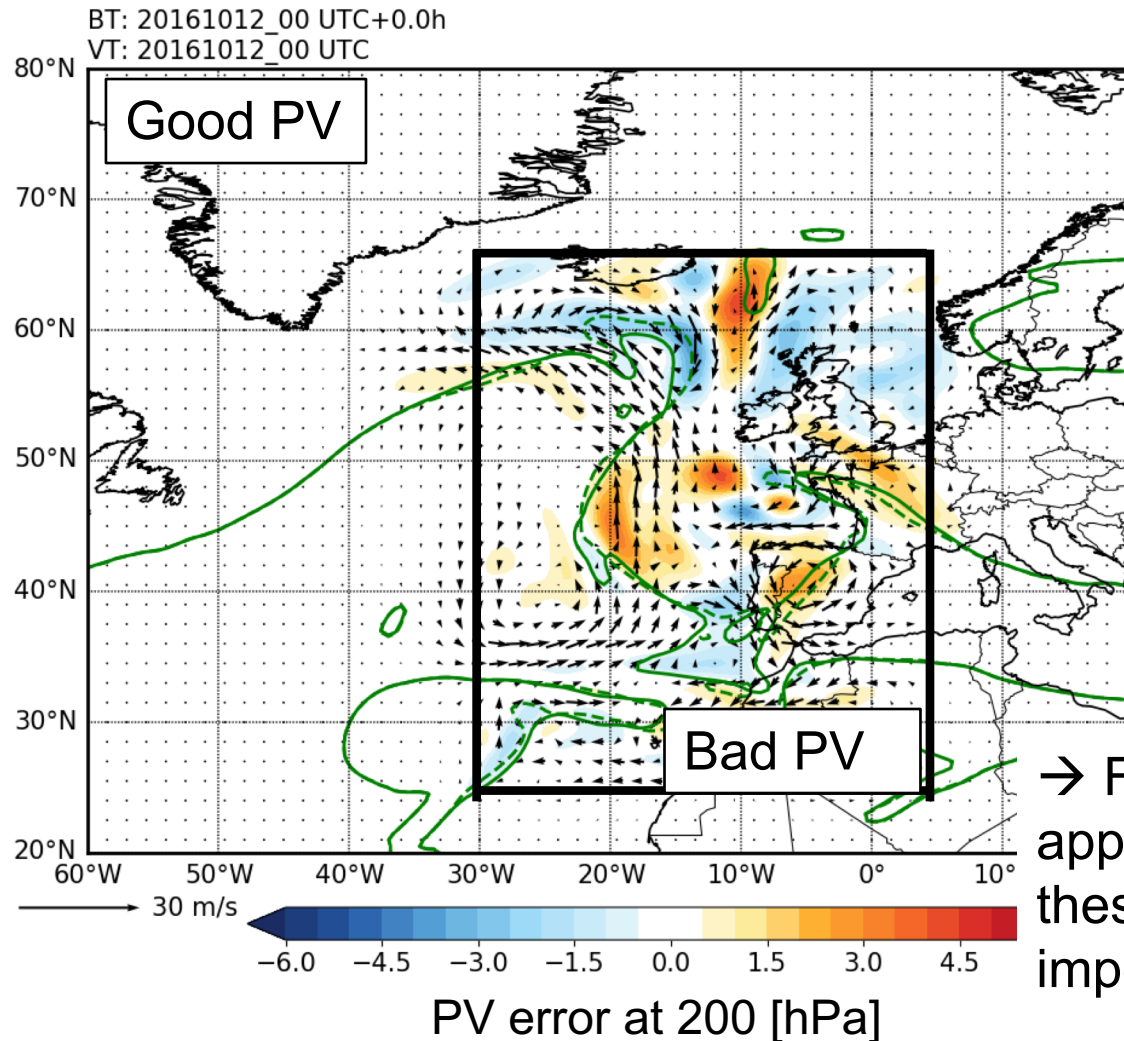
Eastward shift of
2pvu@200hPa



PV error at 200 hPa
(fc-ana) at 14/00Z

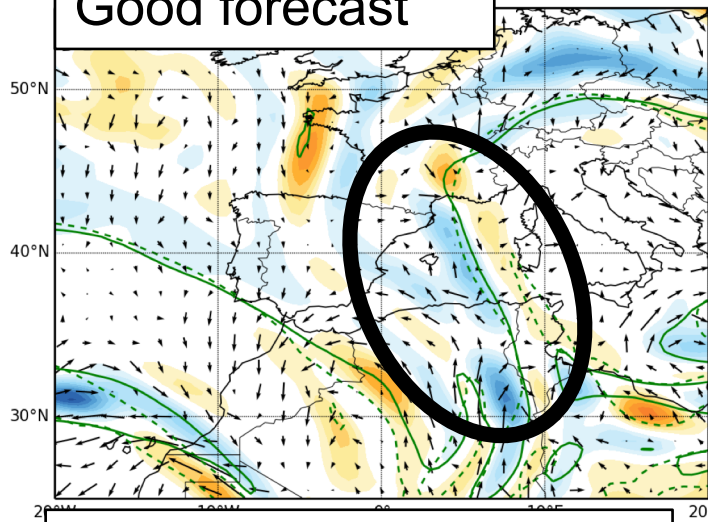
PV inversion experiments in high-resolution deterministic runs

Exp 1) At 12/00Z, the **good PV** is replaced by the **bad PV** at 100-600 hPa in the domain 25-68N/30W-5E

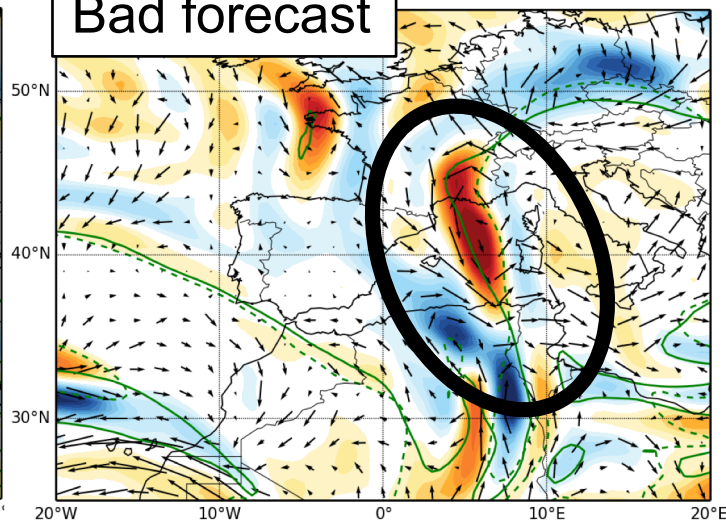


PV error at 200 hPa, forecast – analysis, at 14/00Z

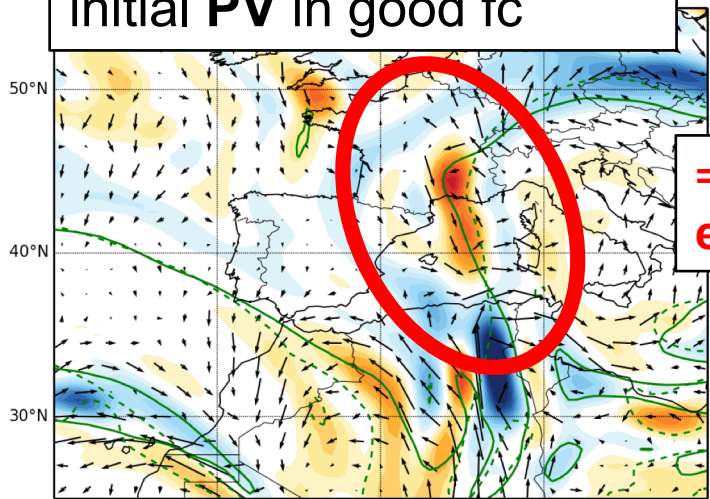
Good forecast



Bad forecast

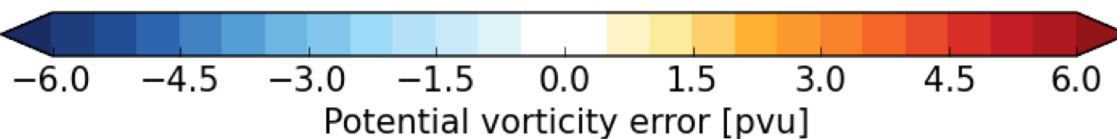


Exp1) **Bad** upstream
initial **PV** in good fc



⇒ **ULPV**
error ↑

30 m/s



PV error tendency equation

Davies and Didone 2013, Baumgart et al. 2018

$$\begin{aligned} \frac{\partial}{\partial t} PV^* &= \frac{\partial}{\partial t} PV_{\text{forecast}} - \frac{\partial}{\partial t} PV_{\text{analysis}} \\ &= \underbrace{-\vec{v}^* \vec{\nabla} PV_{\text{ana}}}_{\text{Advection of analysis PV by wind error}} - \underbrace{\vec{v}^* \vec{\nabla} PV^*}_{\text{Advection of PV error by wind error}} - \underbrace{\vec{v}_{\text{ana}} \vec{\nabla} PV^*}_{\text{Advection of PV error by analysis wind}} + \text{Noncons}^* \end{aligned}$$

$$PV^* = \text{PV error} = PV_{\text{forecast}} - PV_{\text{analysis}}$$

PV error tendency equation

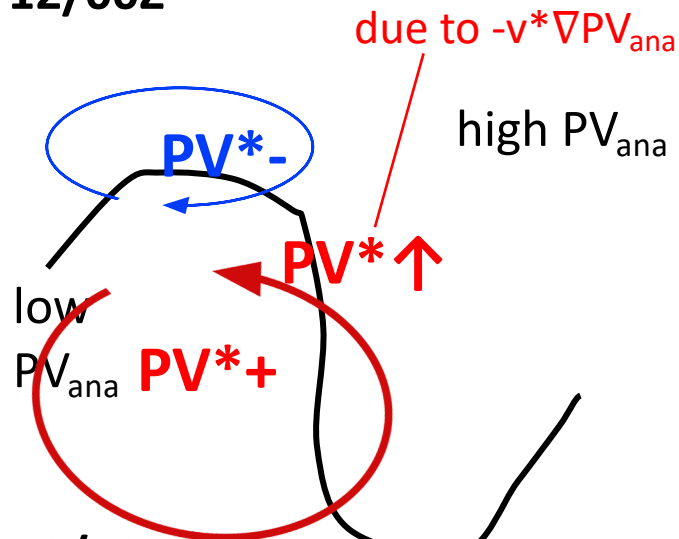
Davies and Didone 2013, Baumgart et al. 2018

$$\begin{aligned}\frac{\partial}{\partial t} PV^* &= \frac{\partial}{\partial t} PV_{\text{forecast}} - \frac{\partial}{\partial t} PV_{\text{analysis}} \\ &= \underbrace{-\vec{v}^* \vec{\nabla} PV_{\text{ana}}}_{\text{Advection of analysis PV by wind error}} - \underbrace{\vec{v}^* \vec{\nabla} PV^*}_{\text{Advection of PV error by wind error}} - \underbrace{\vec{v}_{\text{ana}} \vec{\nabla} PV^*}_{\text{Advection of PV error by analysis wind}} + \text{Noncons}^*\end{aligned}$$

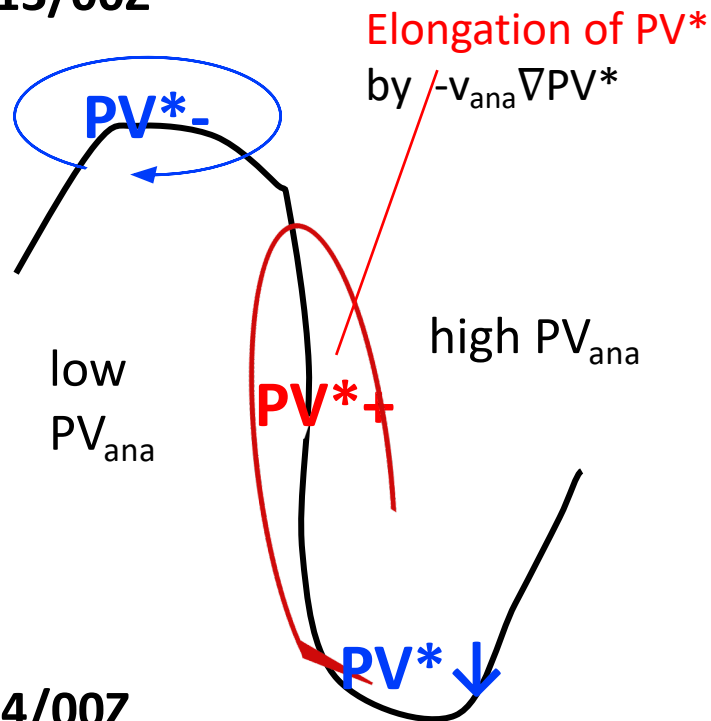
$$PV^* = PV \text{ error} = PV_{\text{forecast}} - PV_{\text{analysis}}$$

PV error propagation

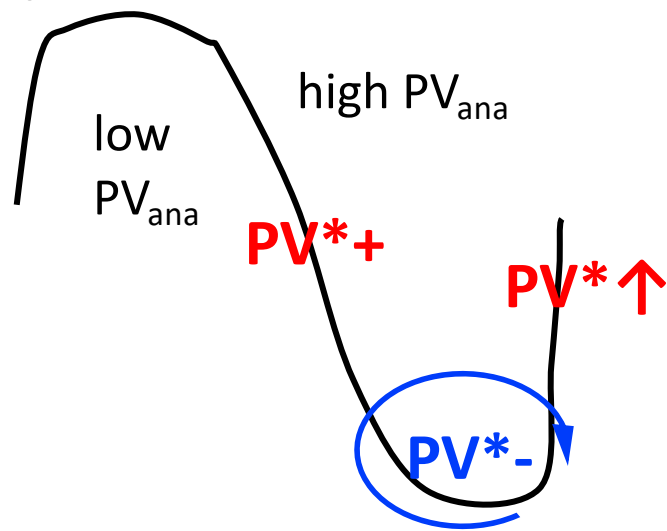
1) 12/00Z



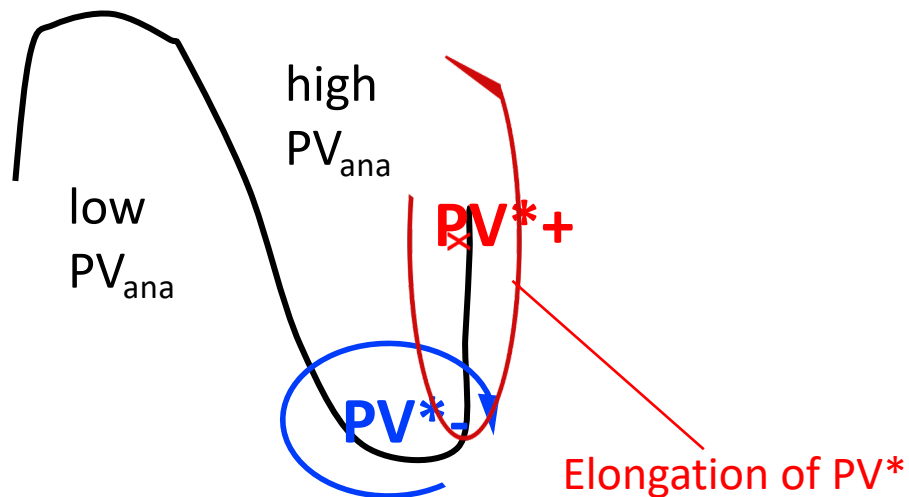
2) 13/00Z



3) 13/12Z



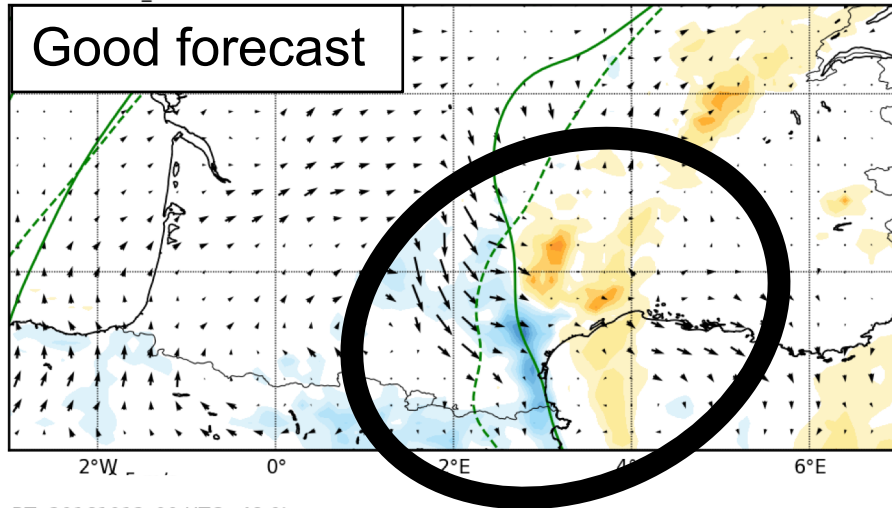
4) 14/00Z



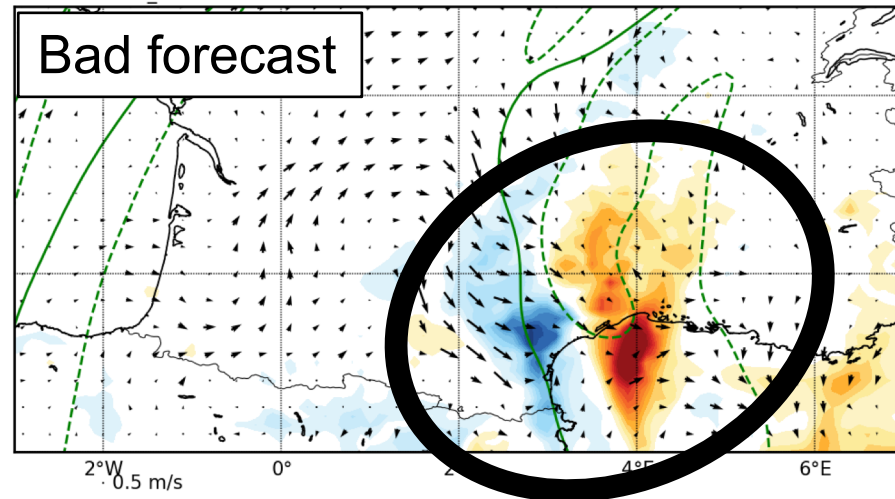
$$\frac{\partial}{\partial t} PV^* = -\vec{v}^* \cdot \vec{\nabla} PV_{ana} - \vec{v}^* \cdot \vec{\nabla} PV^* - \vec{v}_{ana} \cdot \vec{\nabla} PV^* + \text{Noncons}^*$$

Precipitation error, forecast – analysis, at 14/00Z

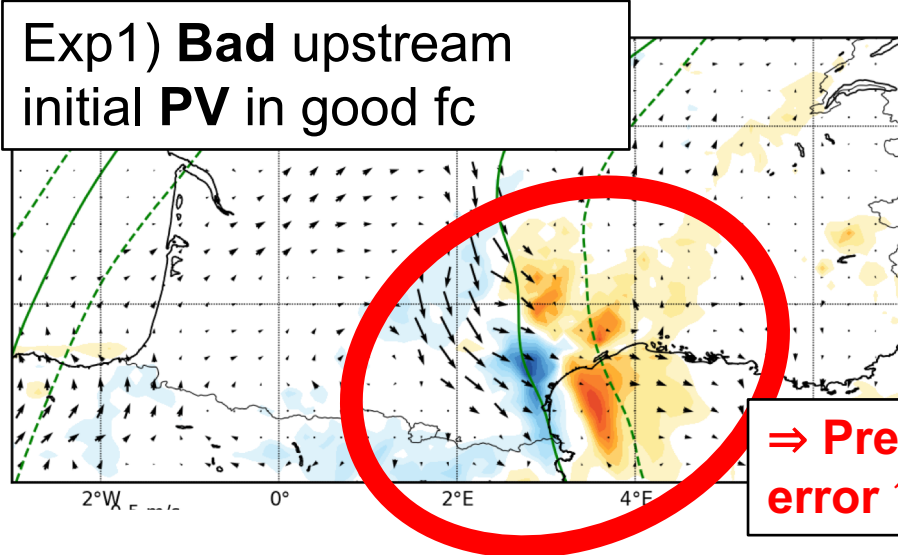
BT: 20161012_00 UTC+48.0h
VT: 20161014_00 UTC



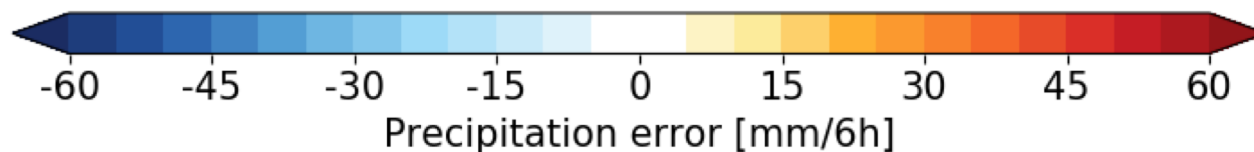
BT: 20161010_18 UTC+78.0h
VT: 20161014_00 UTC



BT: 20161012_00 UTC+48.0h

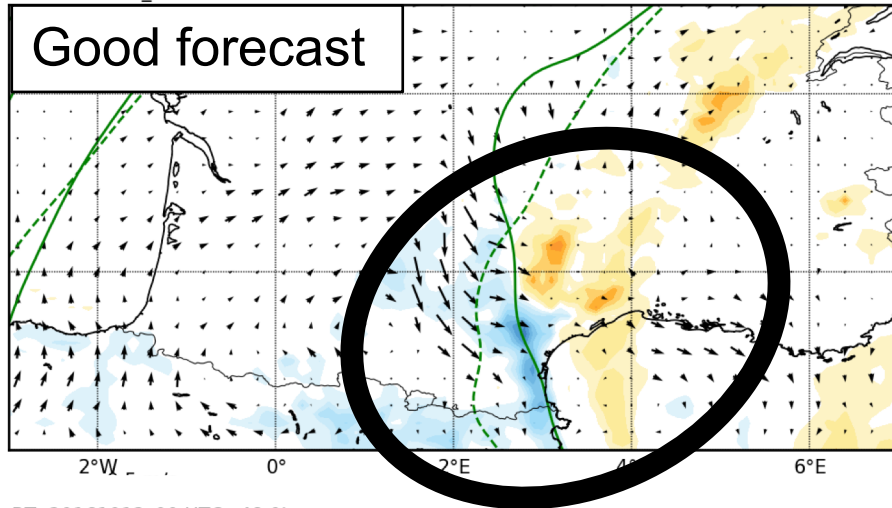


⇒ **Precipitation
error ↑**

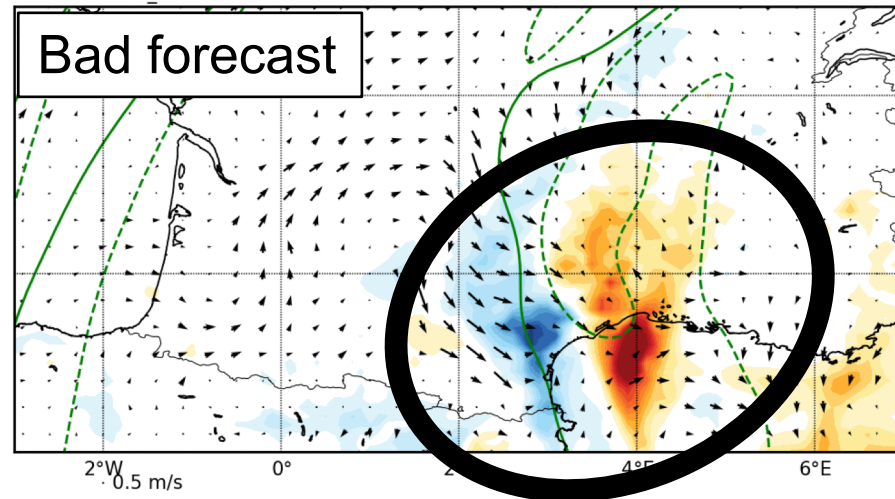


Precipitation error, forecast – analysis, at 14/00Z

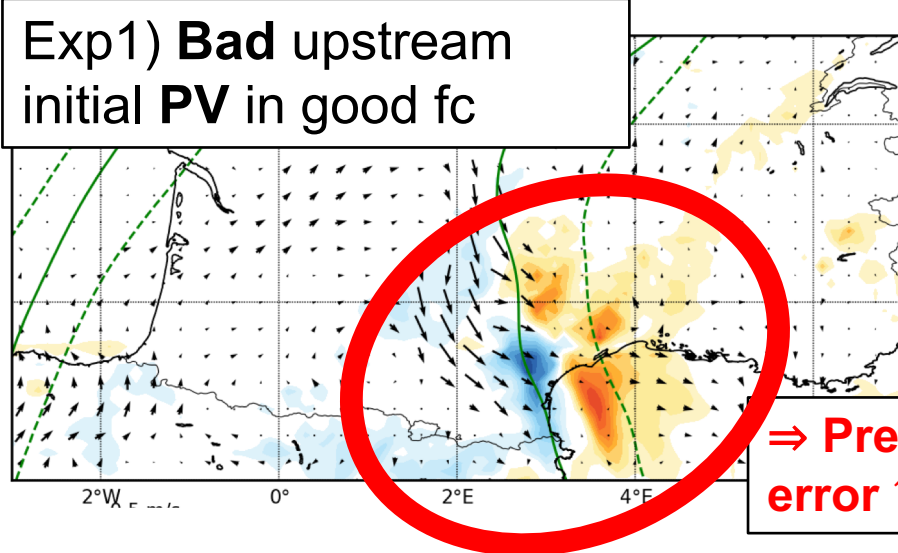
BT: 20161012_00 UTC+48.0h
VT: 20161014_00 UTC



BT: 20161010_18 UTC+78.0h
VT: 20161014_00 UTC

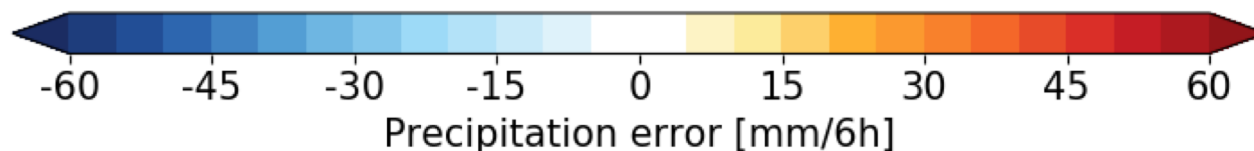


BT: 20161012_00 UTC+48.0h



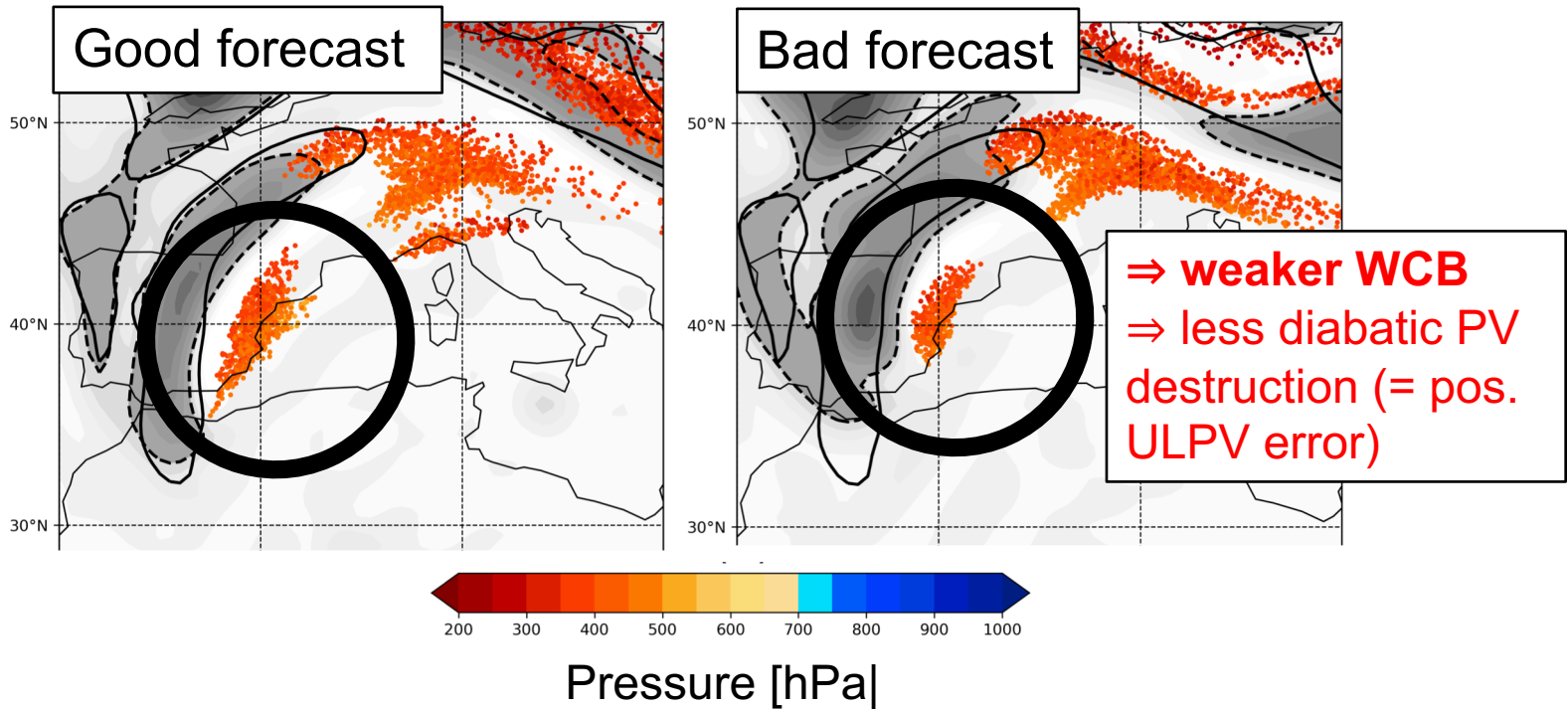
⇒ **Precipitation error** ↑

⇒ Previous upstream UL errors are important for precipitation error and misrepresentation of PV streamer Sanchez, but other processes contribute as well.



Do diabatic processes contribute to the ULPV errors?

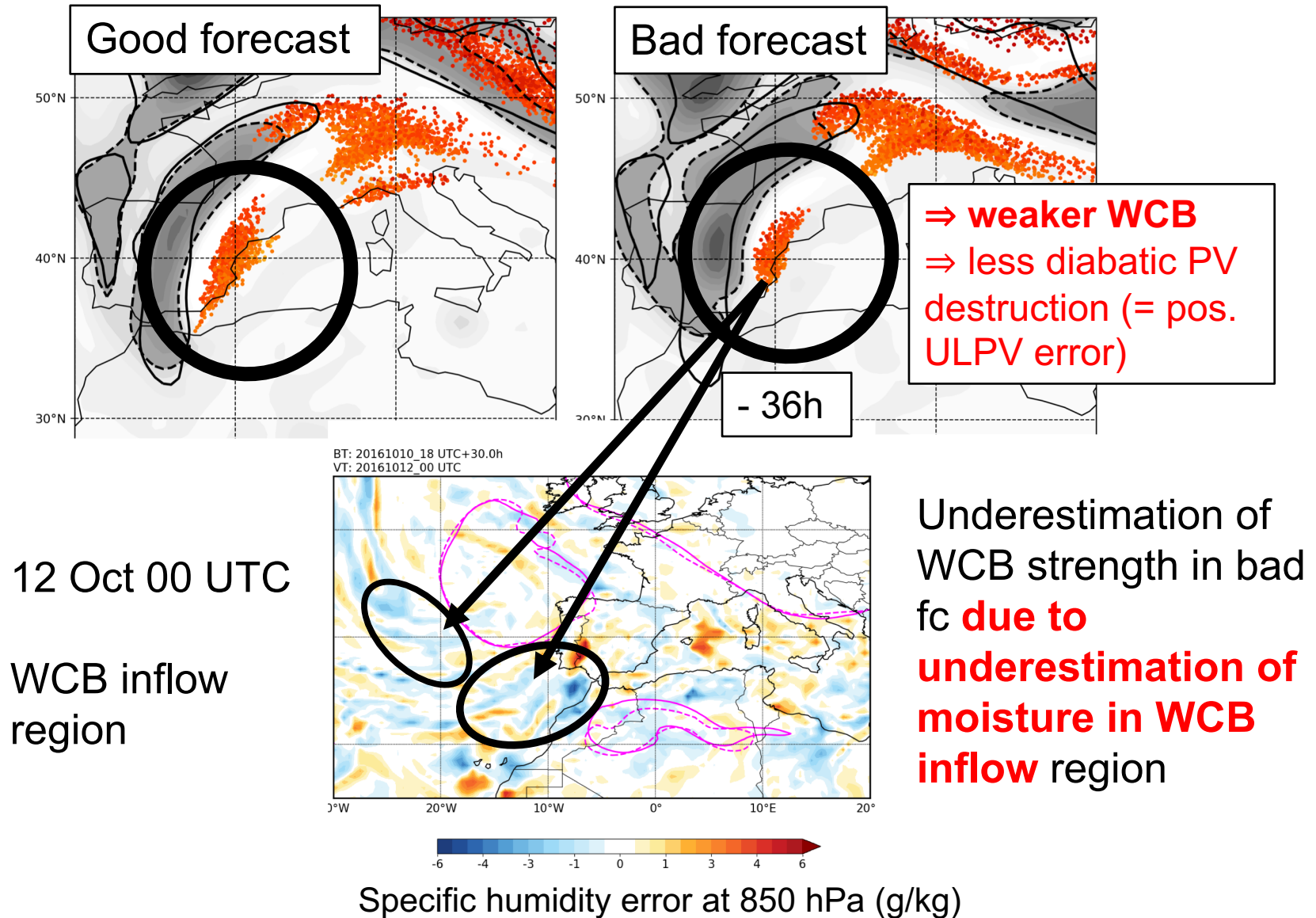
PV at 320K and WCB intersections with 320 K at 13/12Z



“WCB”: ascent > 400hPa/48h

Do diabatic processes contribute to the ULPV errors?

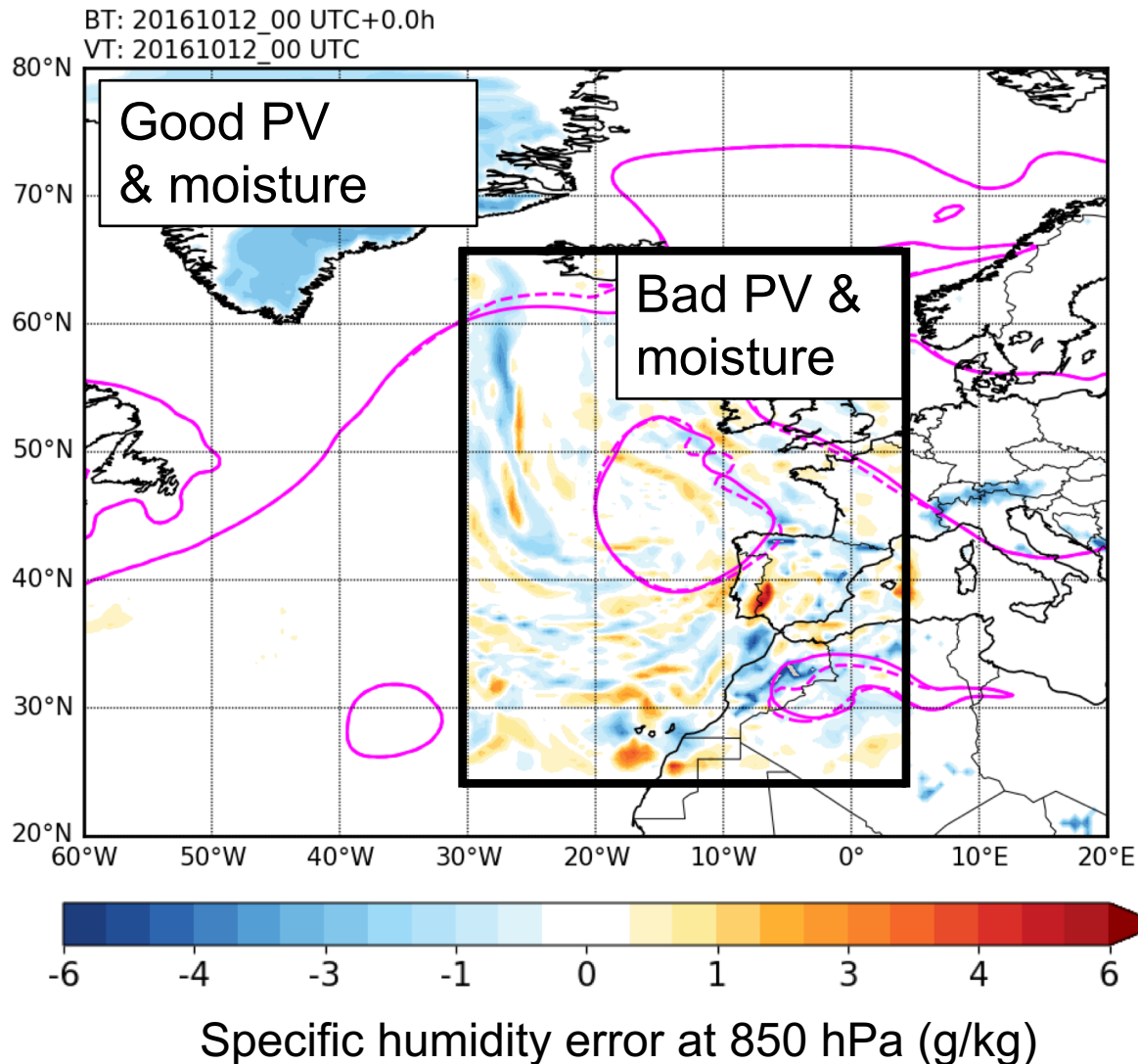
PV at 320K and WCB intersections with 320 K at 13/12Z



“WCB”: ascent > 400hPa/48h

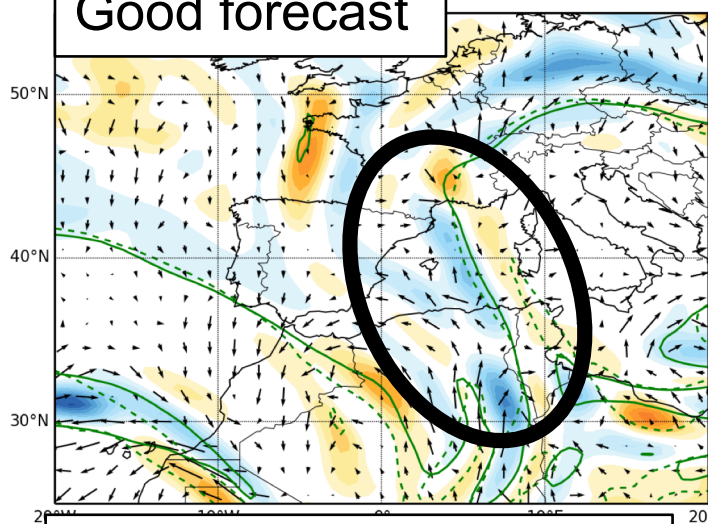
PV inversion and moisture modification

Exp 2) At 12/00Z, the good **UL PV** and the good **moisture** (1050-500 hPa) are **replaced by the bad** ones in domain 25-68N/30W-5E

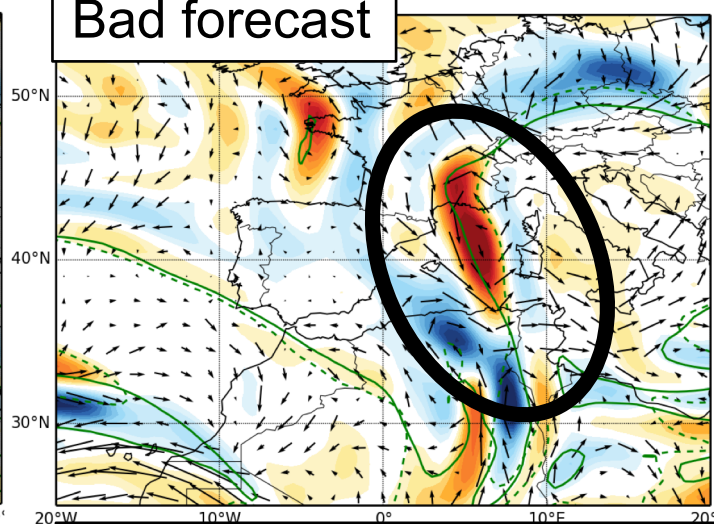


PV error at 200 hPa, forecast – analysis, at 14/00Z

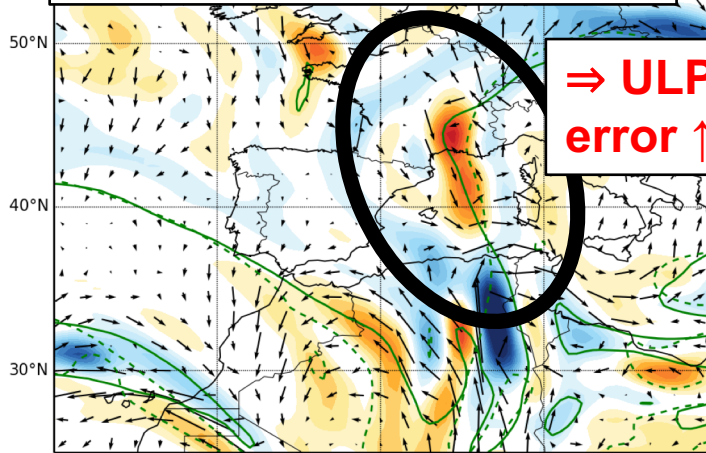
Good forecast



Bad forecast

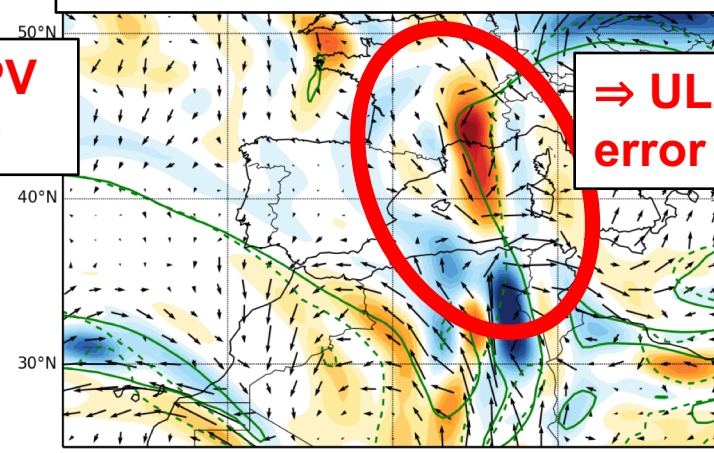


Exp1) **Bad** upstream initial **PV** in good fc



⇒ ULPV
error ↑

Exp2) **Bad** upstream initial **PV**
& **moisture** in good fc



⇒ ULPV
error ↑↑

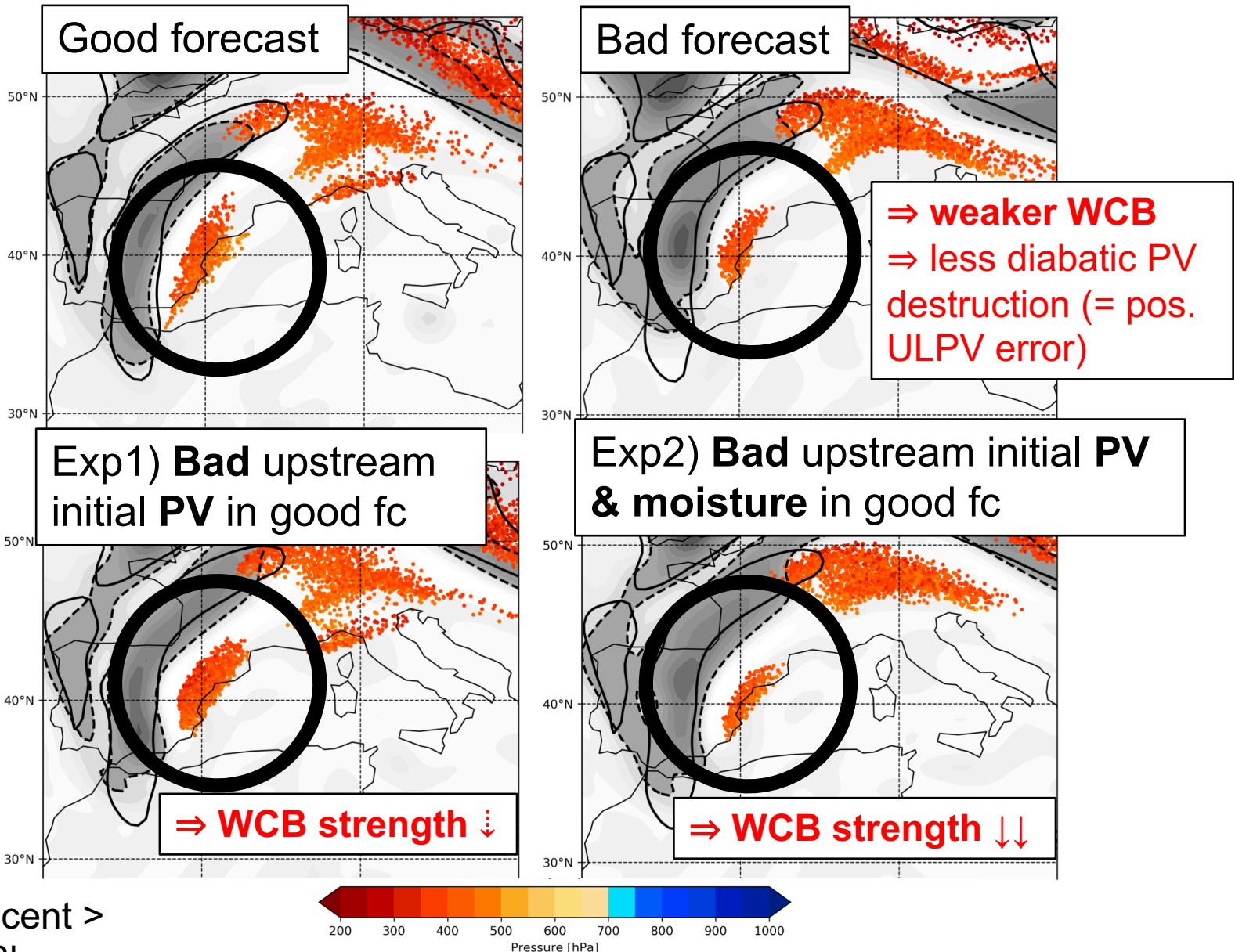
30 m/s

-6.0 -4.5 -3.0 -1.5 0.0 1.5 3.0 4.5 6.0

Potential vorticity error [pvu]

Contribution of diabatic processes to ULPV errors

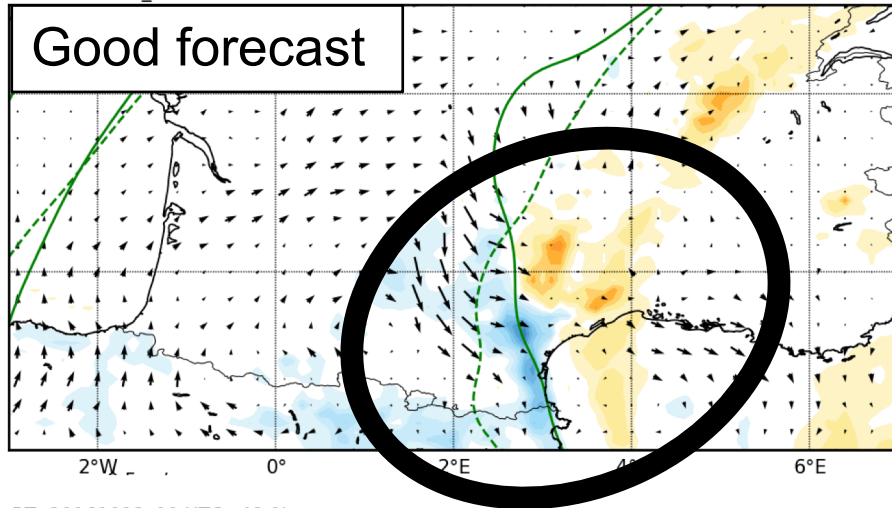
PV at 320K and WCB intersections with 320 K at 13/12Z



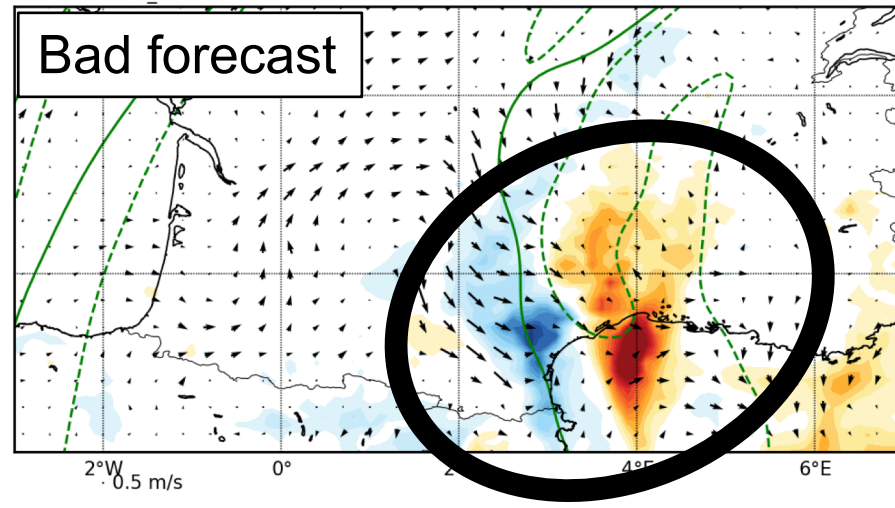
“WCB”: ascent >
400hPa/48h

Precipitation error, forecast – analysis, at 14/00Z

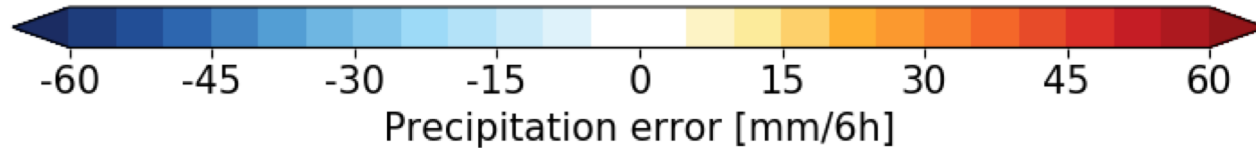
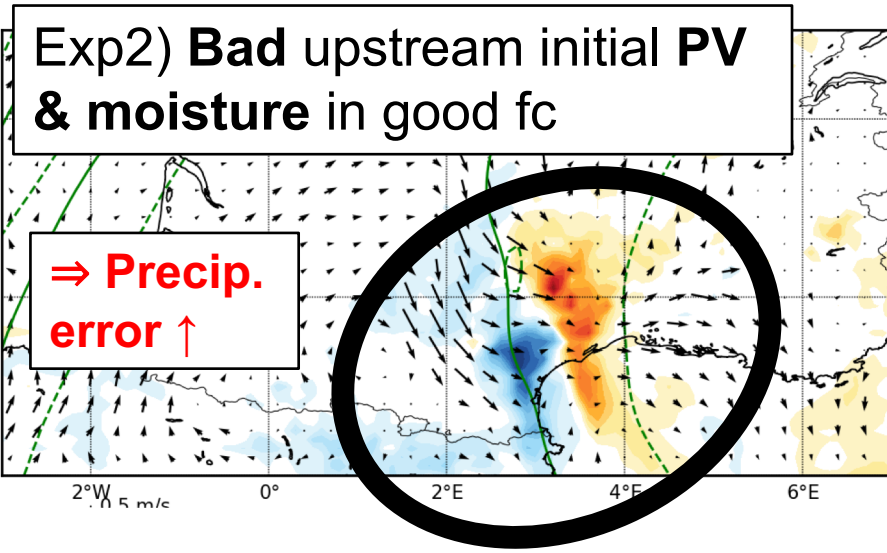
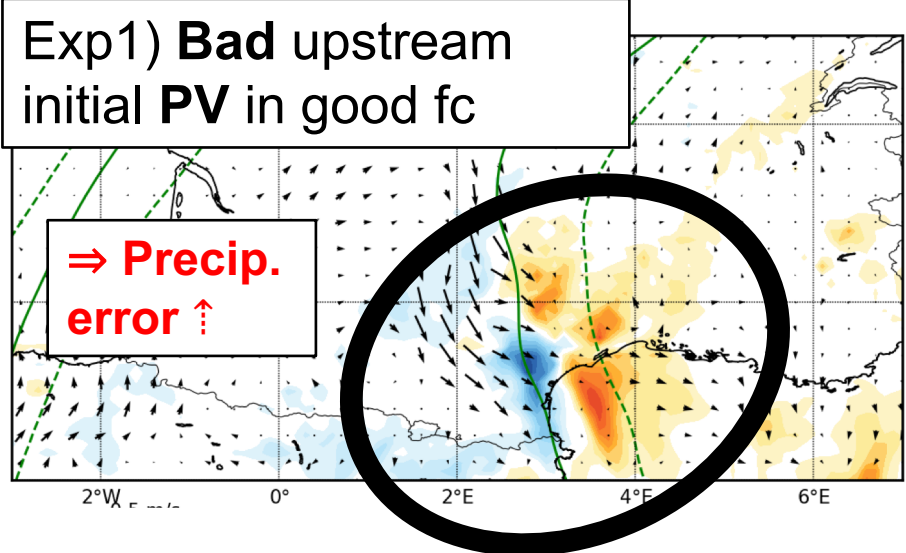
BT: 20161012_00 UTC+48.0h
VT: 20161014_00 UTC



BT: 20161010_18 UTC+78.0h
VT: 20161014_00 UTC

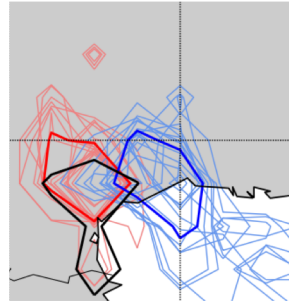
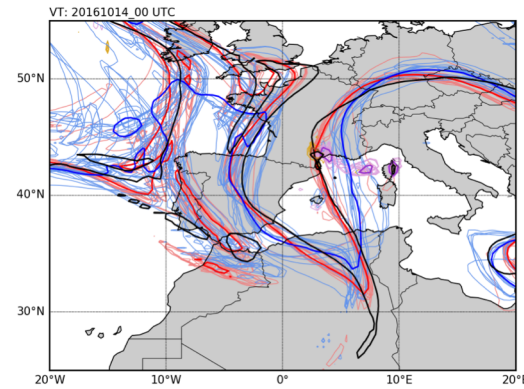


BT: 20161012_00 UTC+48.0h



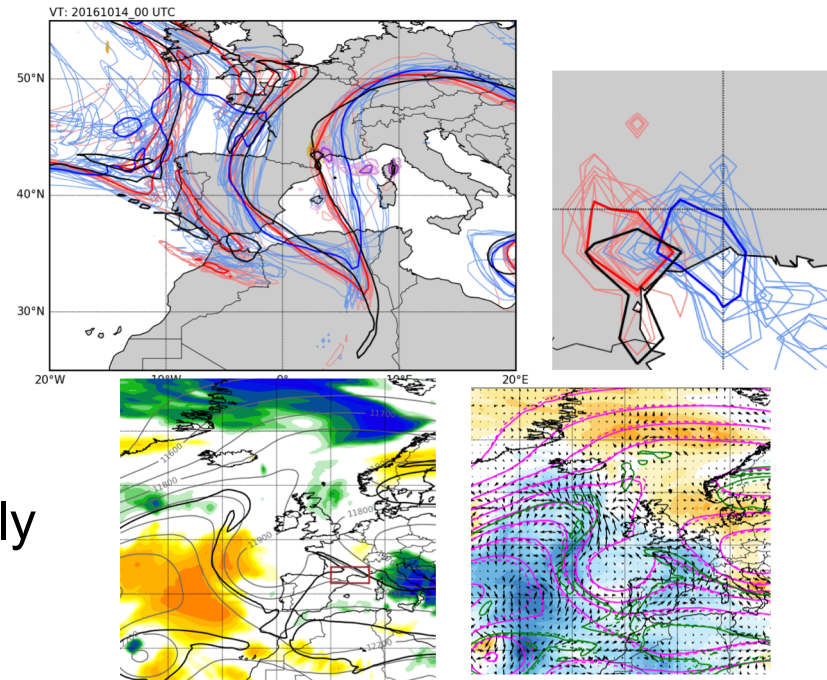
Summary and conclusions

- Eastward shift of forecasted precipitation max. and PV streamer Sanchez in many probabilistic and deterministic 2-4 day forecasts.



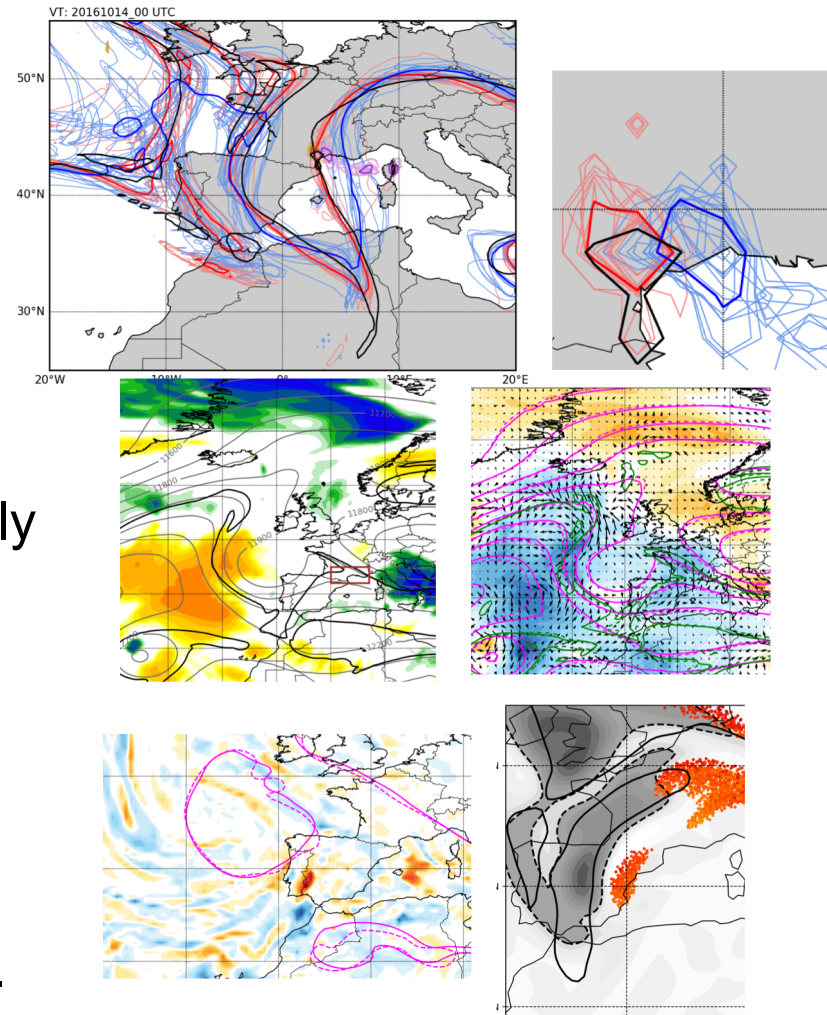
Summary and conclusions

- Eastward shift of forecasted precipitation max. and PV streamer Sanchez in many probabilistic and deterministic 2-4 day forecasts.
- The misrepresented PV streamer primarily results from the propagation of upstream UL errors starting with a too weak jet south of Iceland 2 days before the HIW.
- .



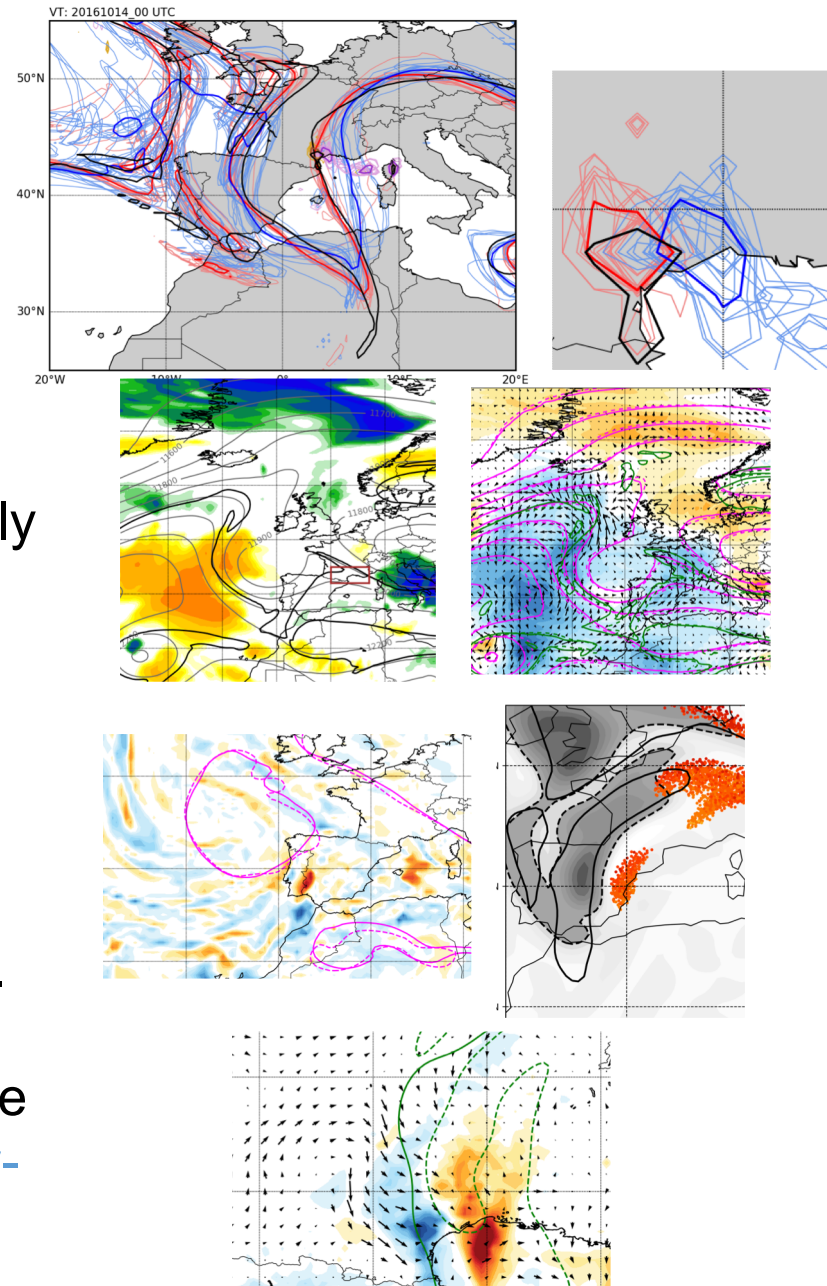
Summary and conclusions

- Eastward shift of forecasted precipitation max. and PV streamer Sanchez in many probabilistic and deterministic 2-4 day forecasts.
- The misrepresented PV streamer primarily results from the propagation of upstream UL errors starting with a too weak jet south of Iceland 2 days before the HIW.
- Diabatic processes, in particular the underestimation of the initial moisture in the WCB inflow, amplify the ULPV errors.



Summary and conclusions

- Eastward shift of forecasted precipitation max. and PV streamer Sanchez in many probabilistic and deterministic 2-4 day forecasts.
- The misrepresented PV streamer primarily results from the propagation of upstream UL errors starting with a too weak jet south of Iceland 2 days before the HIW.
- Diabatic processes, in particular the underestimation of the initial moisture in the WCB inflow, amplify the ULPV errors.
- The precipitation fc is sensitive to both the representation of the UL flow and the low-level moisture over the eastern North Atlantic 2 days before the HIW.

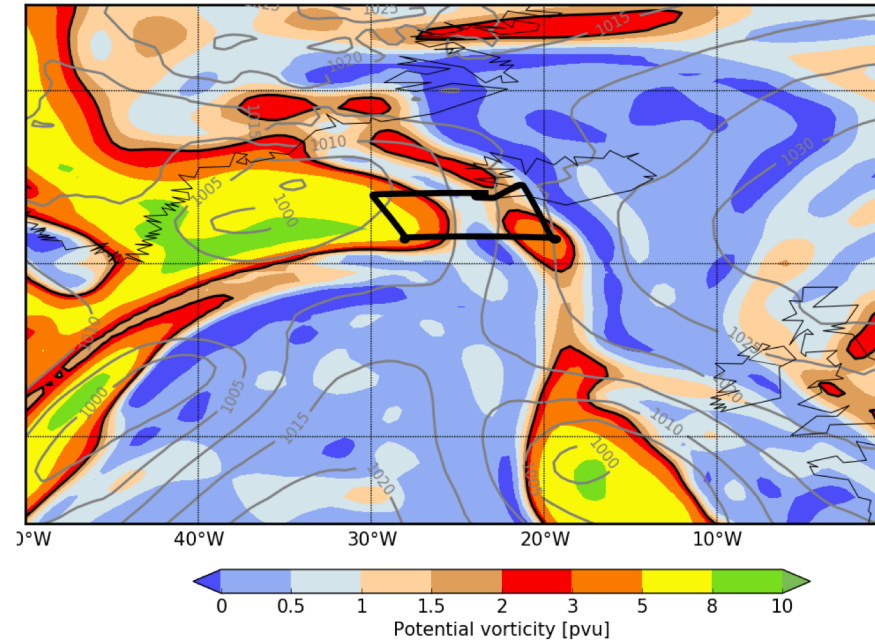


Future work

Use of NAWDEX observations to investigate a potential link between diabatic processes and the initial upstream UL errors (underestimation of ridge Thor and the jet strength)

French Falcon RF14, 11/18Z

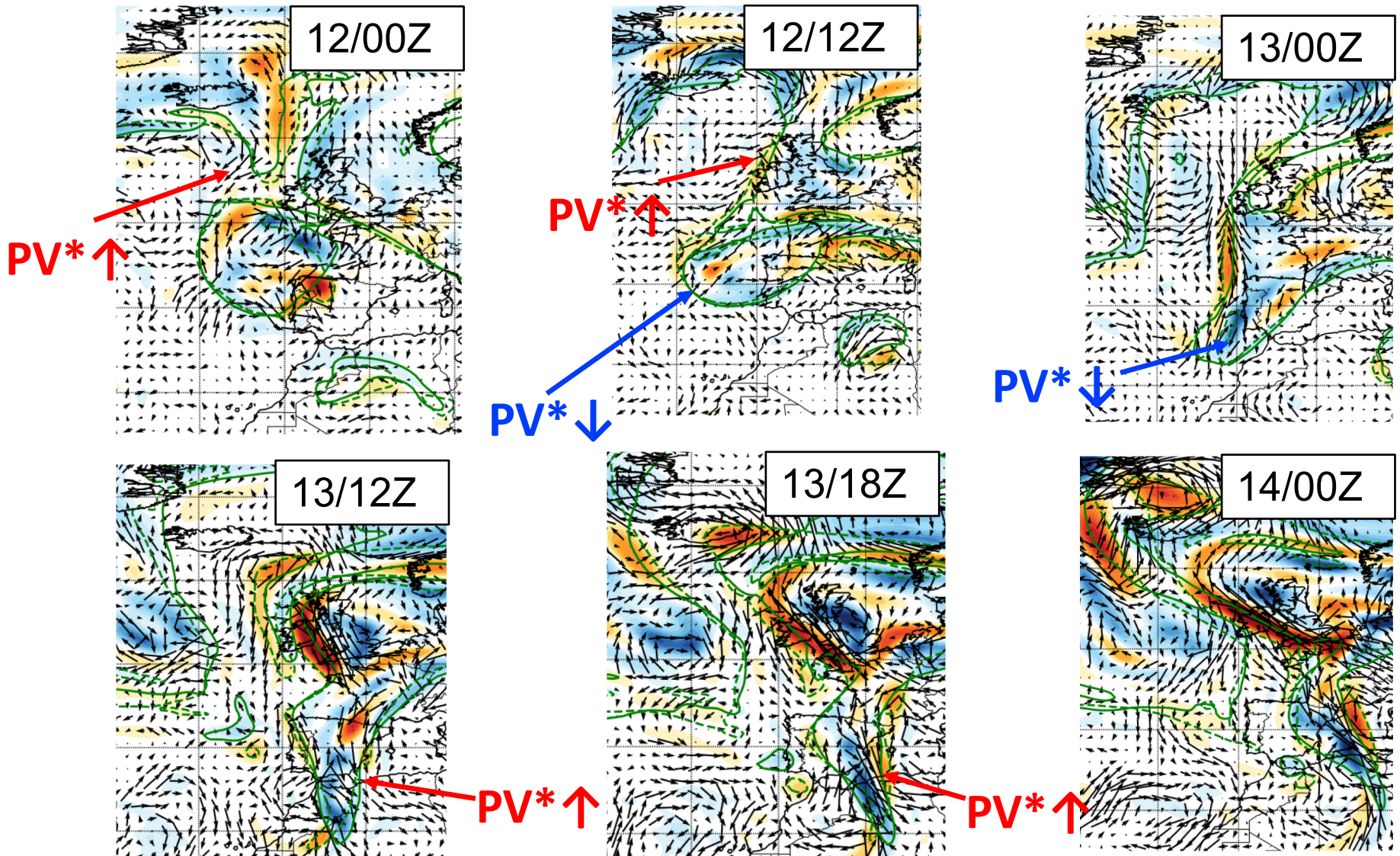
300hPa 000h 20161011H18P vol F14



Additional slides

PV error propagation in bad high-resolution fc

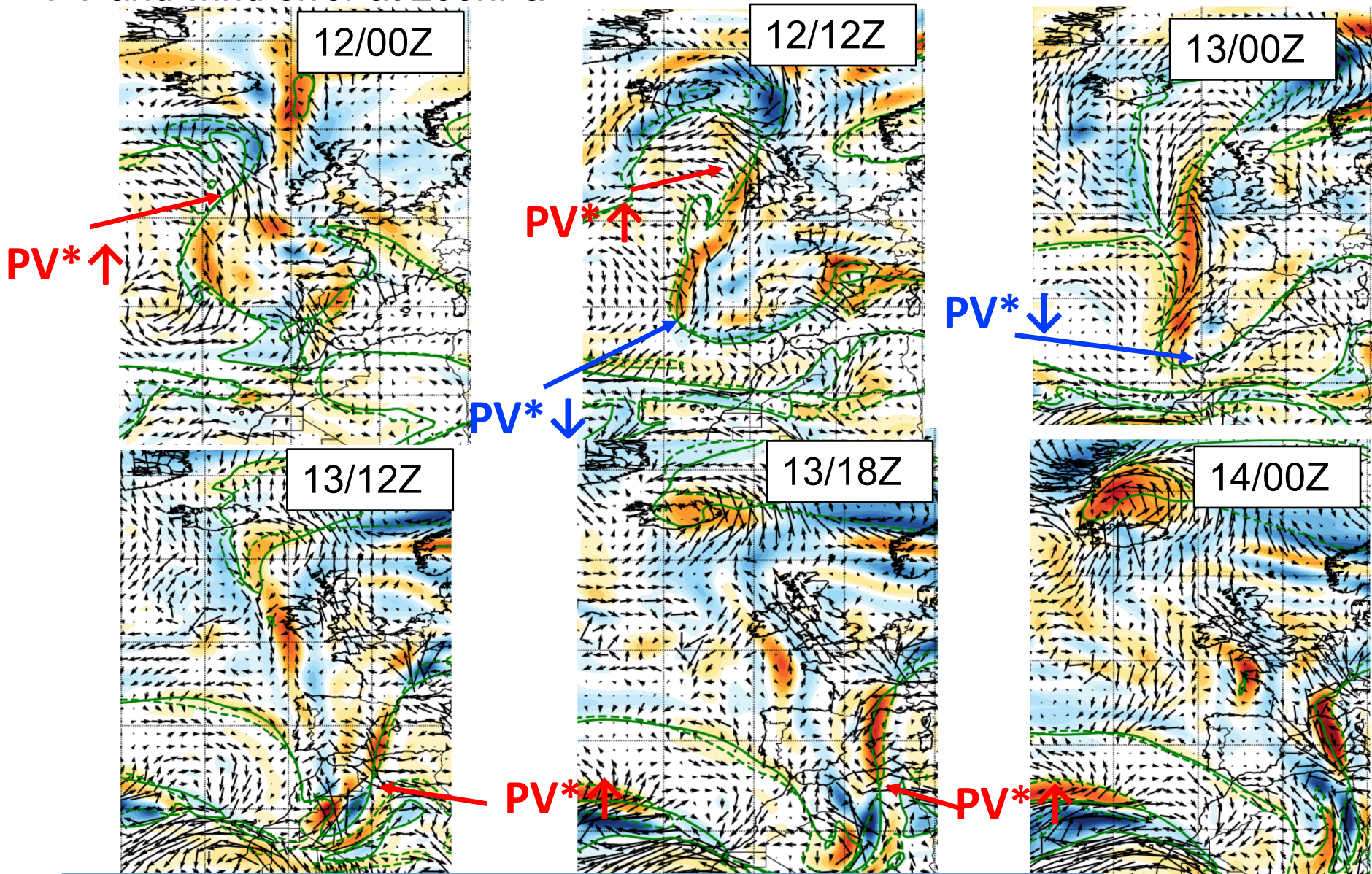
PV and wind error at 330K



$$\frac{\partial}{\partial t} PV^* = -\vec{v}^* \cdot \vec{\nabla} PV_{ana} - \vec{v}^* \cdot \vec{\nabla} PV^* - \vec{v}_{ana} \cdot \vec{\nabla} PV^* + \text{Noncons}^*$$

PV error propagation in bad high-resolution fc

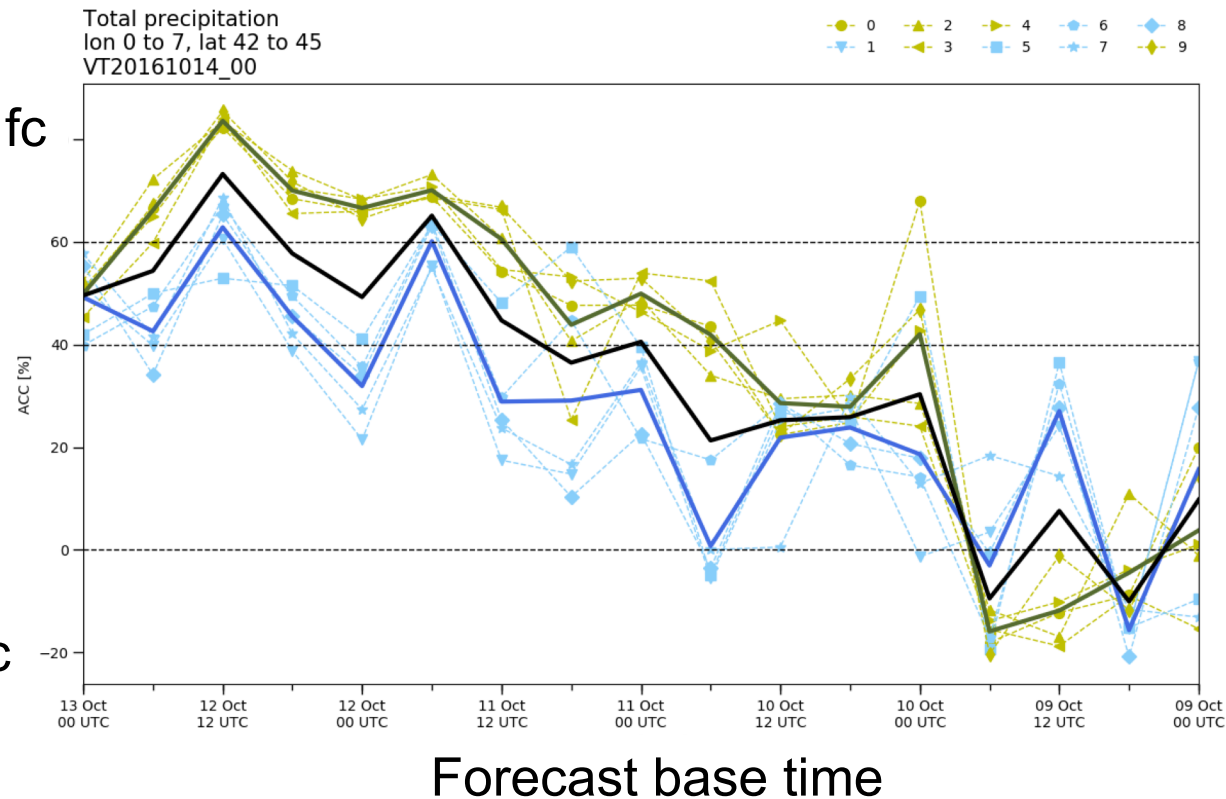
PV and wind error at 200hPa



$$\frac{\partial}{\partial t} PV^* = -\vec{v}^* \vec{\nabla} PV_{ana} - \vec{v}^* \vec{\nabla} PV^* - \vec{v}_{ana} \vec{\nabla} PV^* + \text{Noncons}^*$$

Forecast quality of precipitation at 00 UTC 14 Oct 2016

Anomaly correlation coefficient (ACC) over southern France



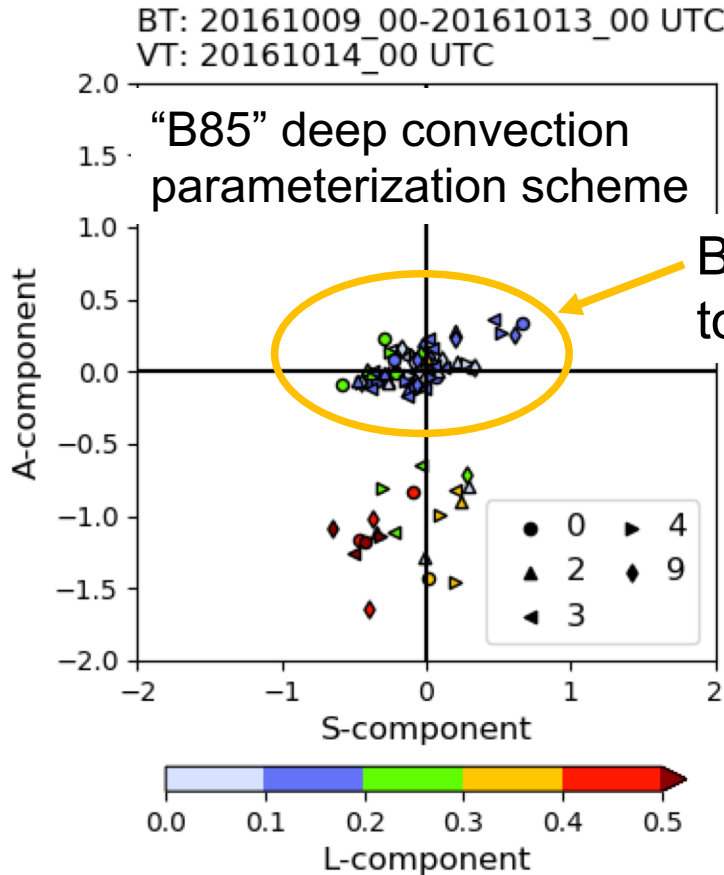
Deep convection
parameterization:

- Mass flux scheme (Bougeault 1985)
- PCMT (Prognostic Condensates Microphysics and Transport)

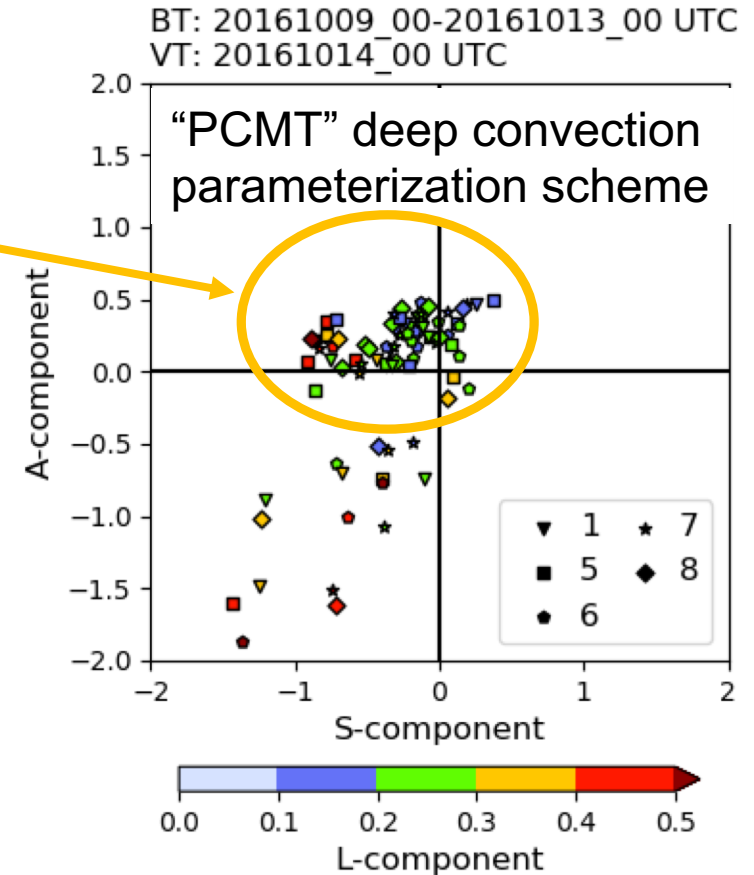
- Most forecasts are relatively poor in terms of ACC
- FC quality decreases with increasing lead time
- FC quality depends on deep convection scheme (B85 generally better than PCMT)

Forecast quality of precipitation at 00 UTC 14 Oct 2016

SAL (Wernli et al. 2008, MWR) → Perfect when $S=0$, $A=0$ & $L=0$



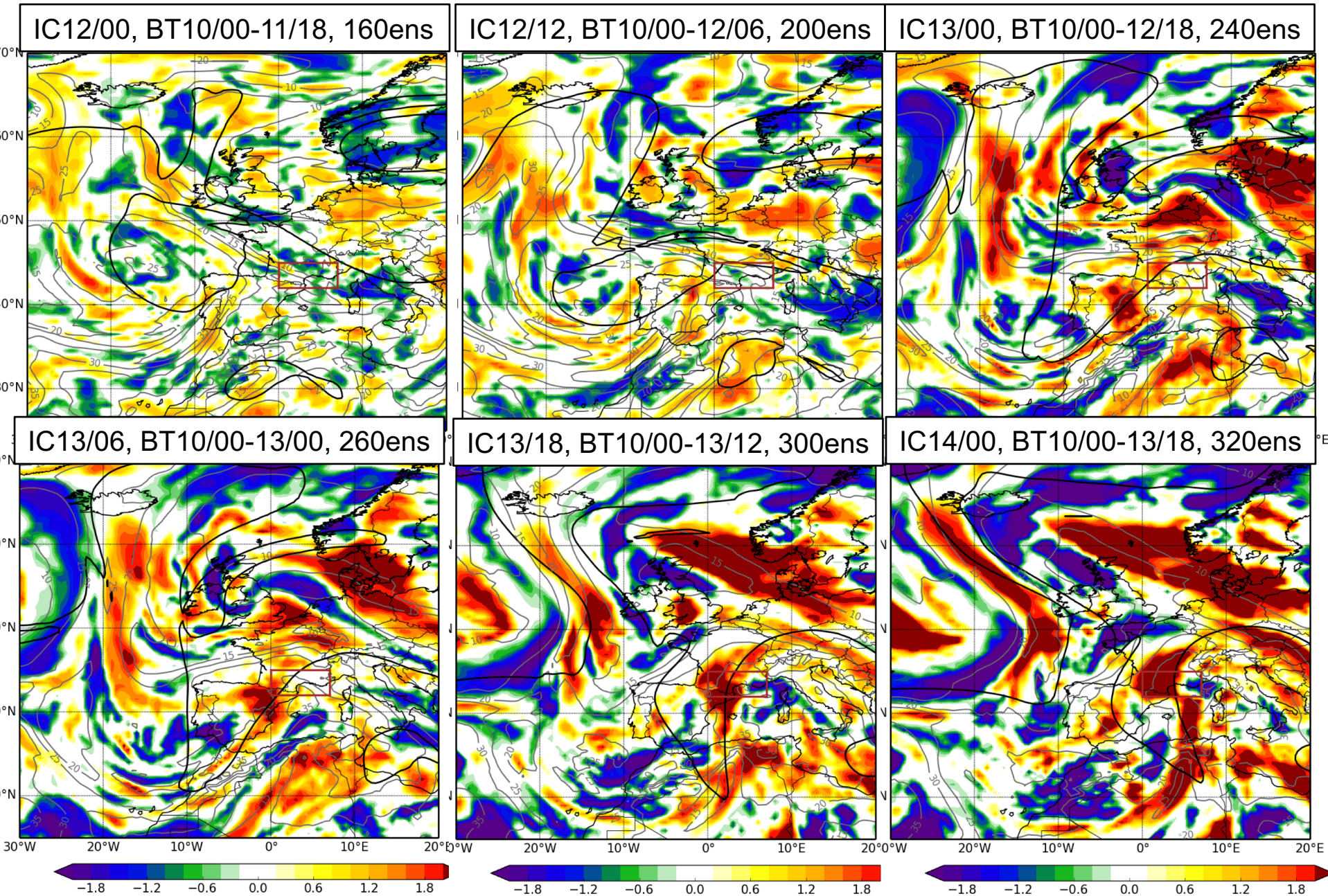
BT10/00Z
to 13/00Z



- From BT10/00Z onward fcsts of most B85 members are relatively good
- PCMT members: location error ($L>0$), amplitude slightly overestimated ($A>0$) and structure error ($S<0$)

Ensemble sensitivity analysis, IWW

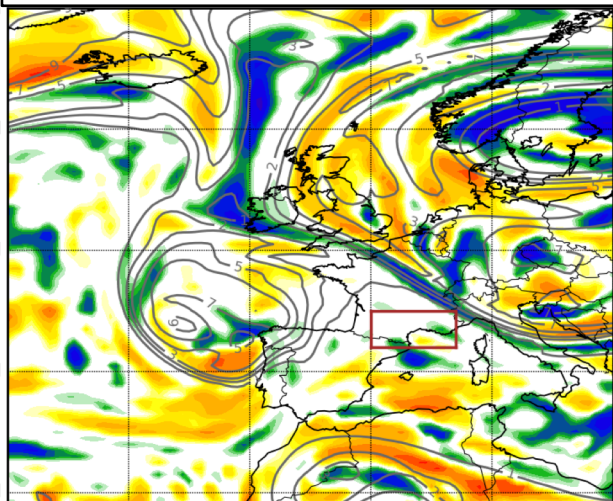
$$\frac{\delta ACC}{\partial IWW} * std(IWW)$$



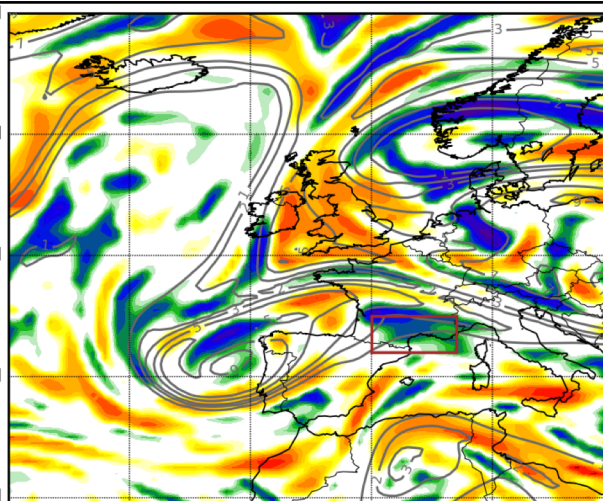
Ensemble sensitivity analysis, PV@330K

$$\frac{\delta ACC}{\partial PV_{330K}} * std(PV_{330K})$$

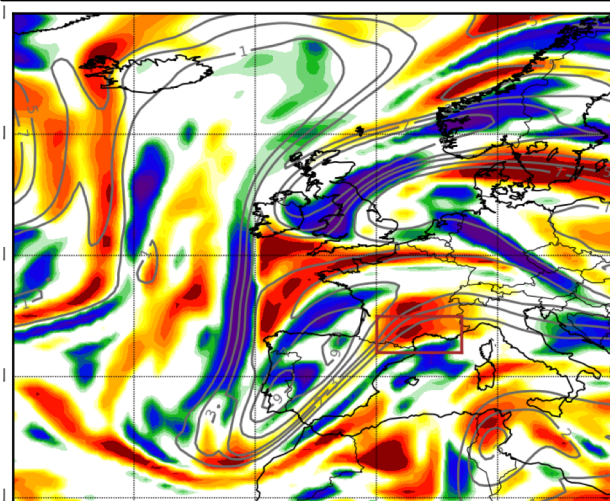
IC12/00, BT10/00-11/18, 160ens



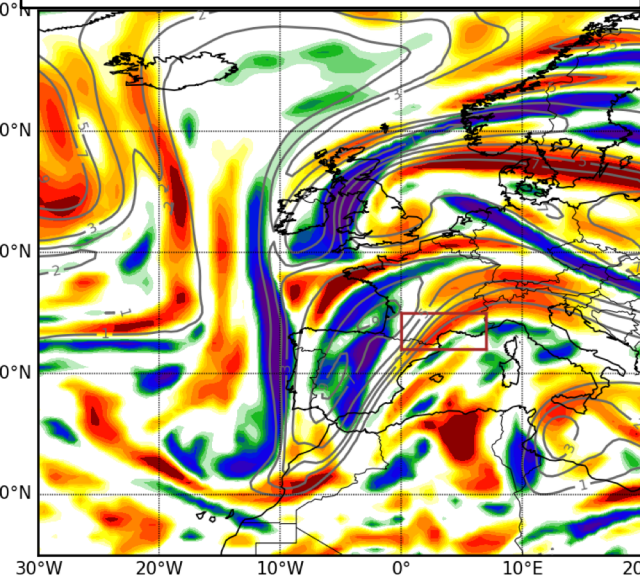
IC12/12, BT10/00-12/06, 200ens



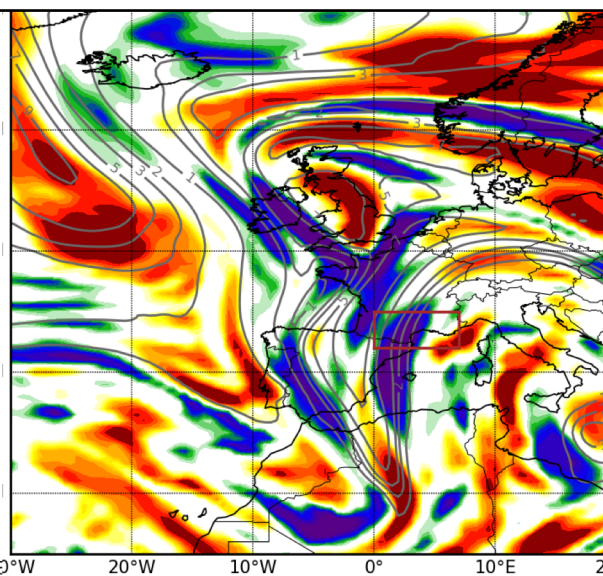
IC13/00, BT10/00-12/18, 240ens



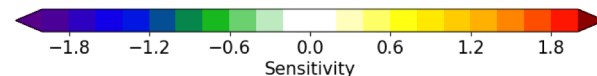
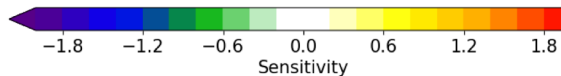
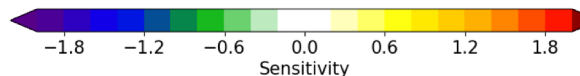
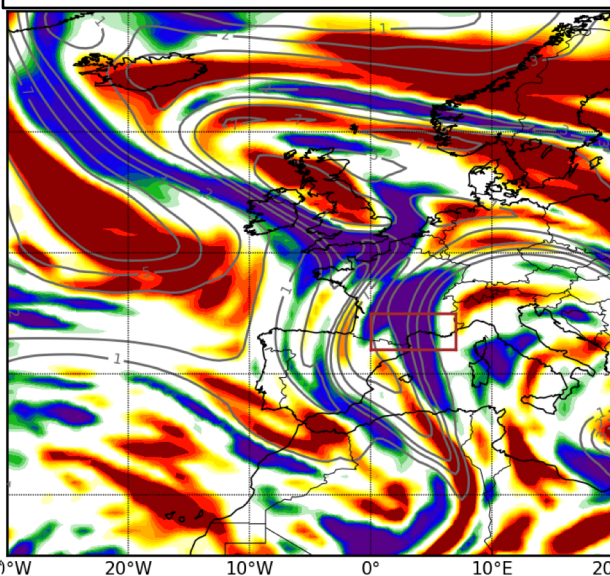
IC13/06, BT10/00-13/00, 260ens



IC13/18, BT10/00-13/12, 300ens

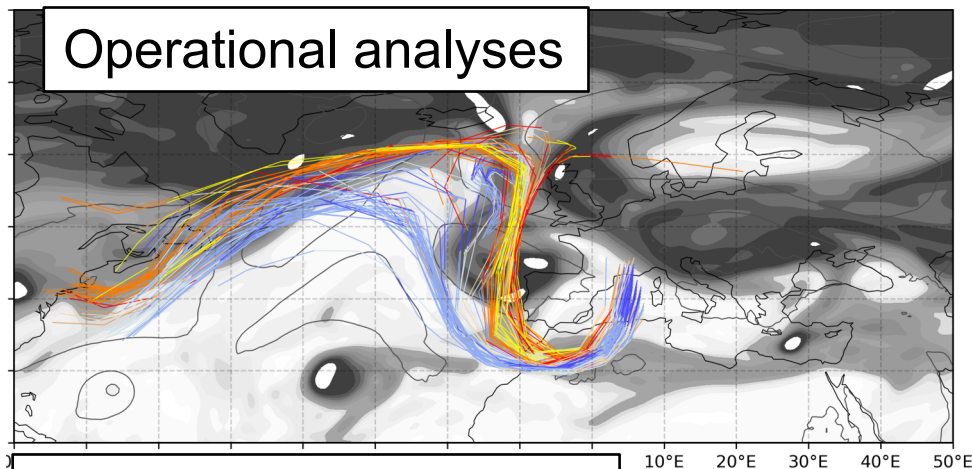


IC14/00, BT10/00-13/18, 320ens

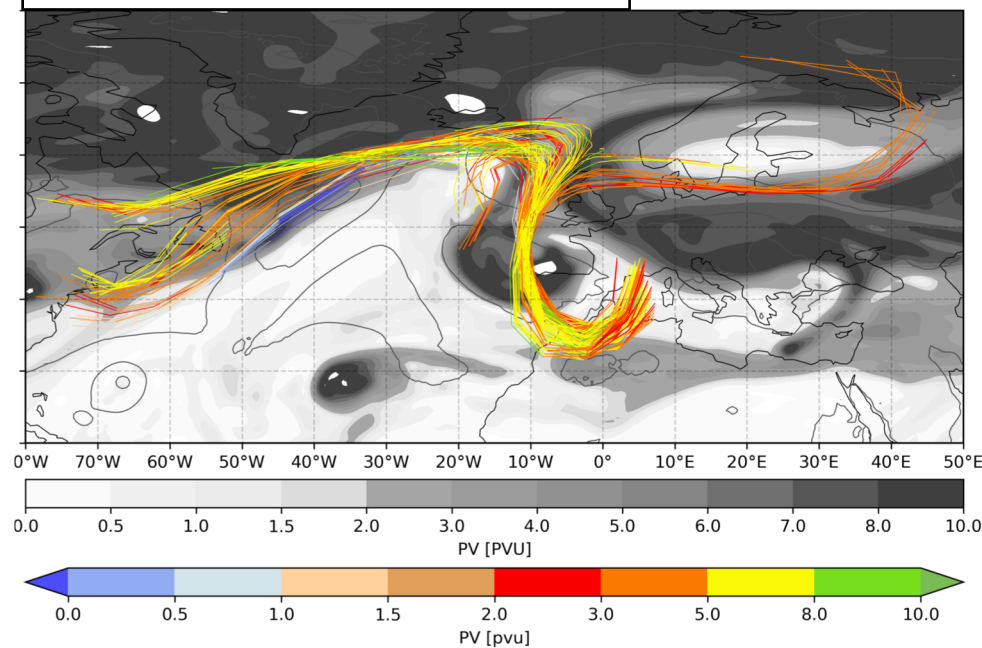


78h backw tra. starting at 20161014_00 and PV at 200hPa at 20161012_00

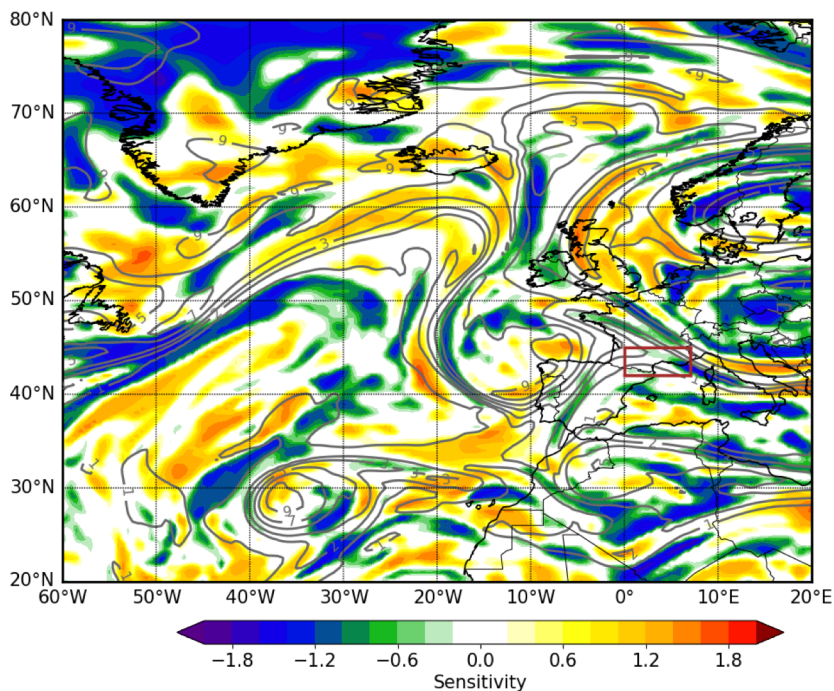
Operational analyses



Bad forecast: BT10/18Z



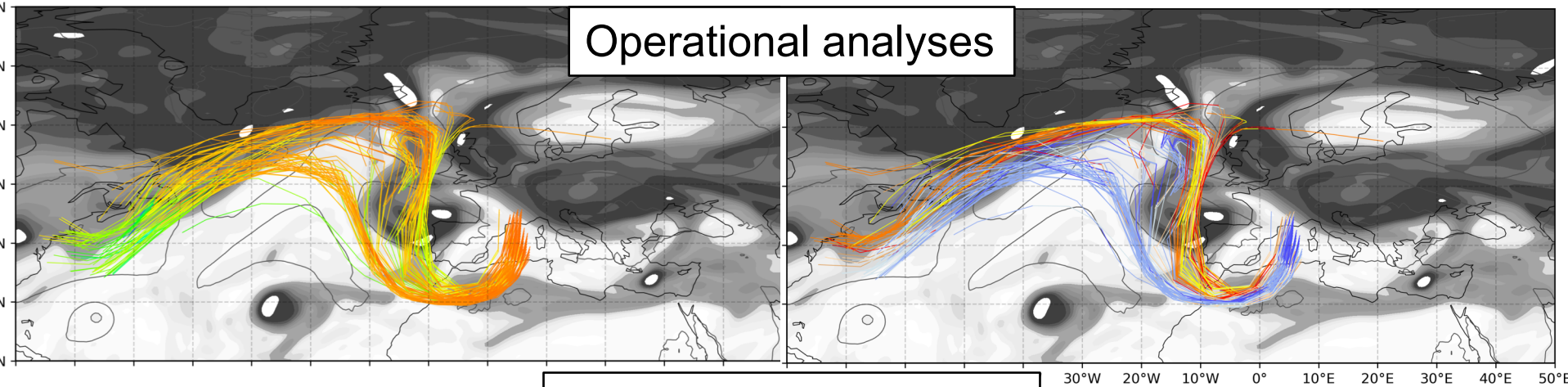
$$\frac{\delta ACC}{\partial PV_{200hPa}} * std(PV_{200hPa})$$



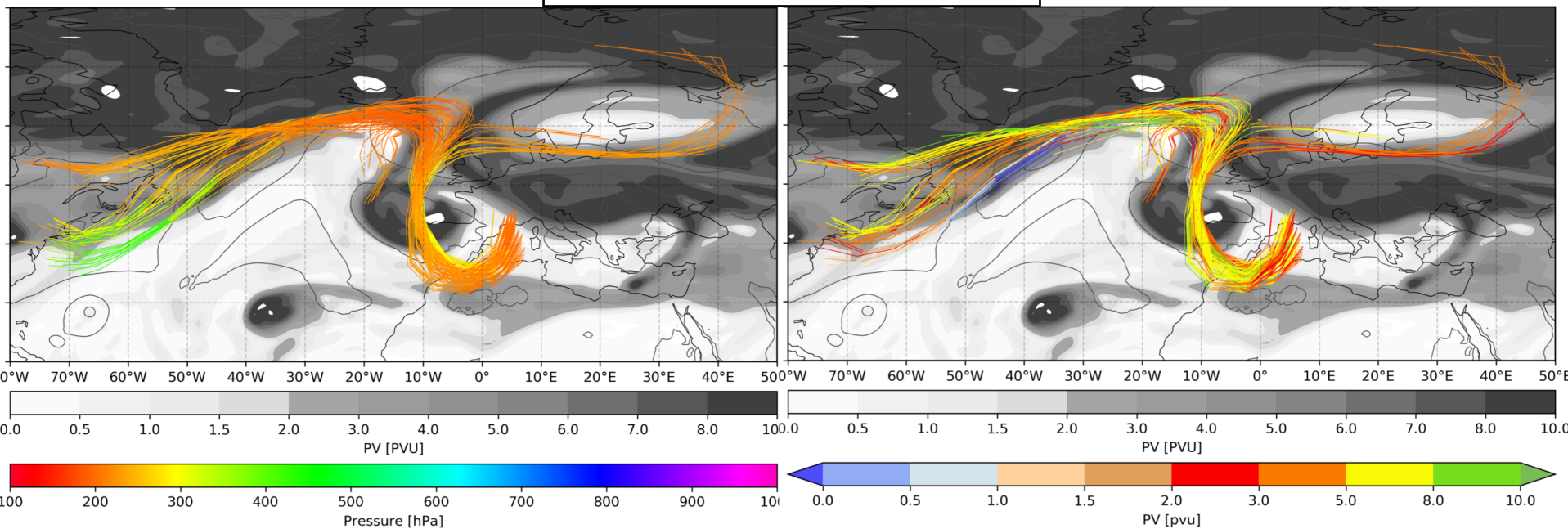
78h backw tra. starting at 20161014_00 and PV at 200hPa at 20161012_00

78h backw tra. starting at 20161014_00 and PV at 200hPa at 20161012_00

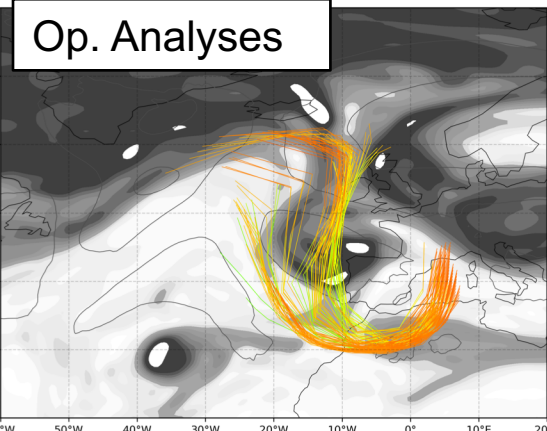
Operational analyses



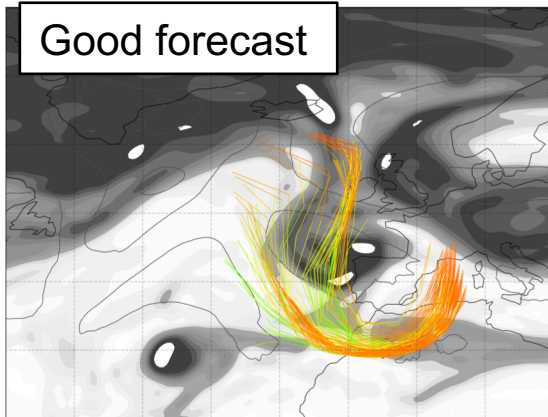
Bad forecast: BT10/18Z



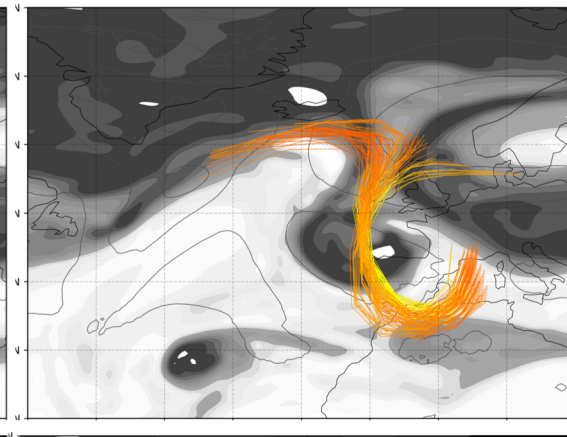
Op. Analyses



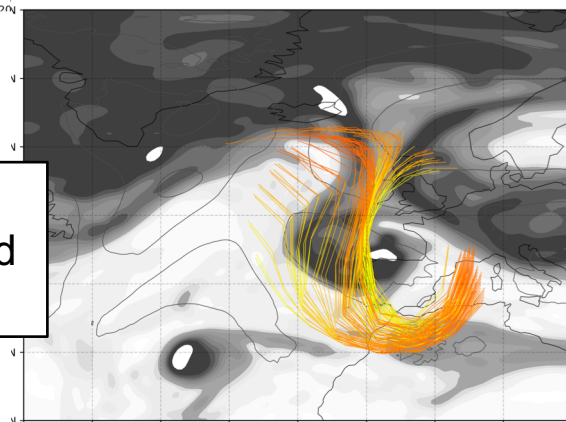
Good forecast



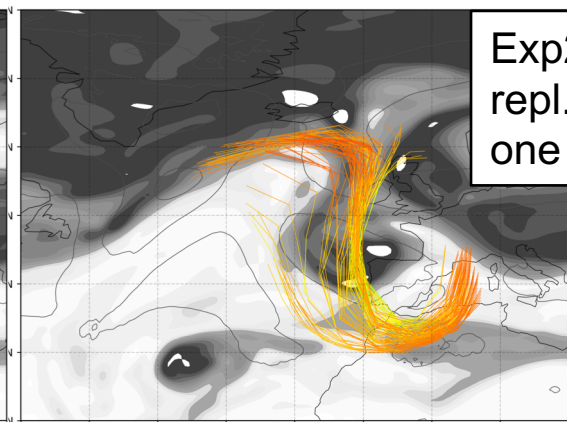
recast



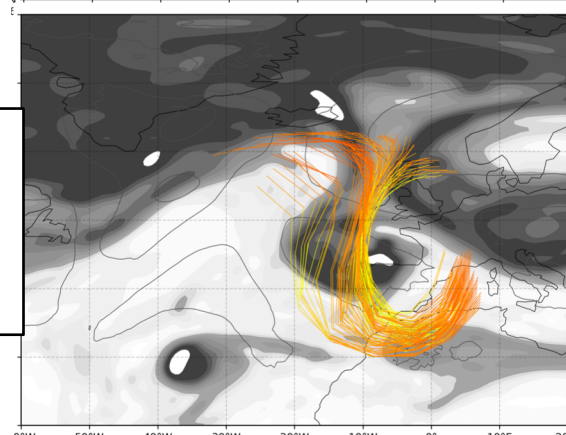
Exp1: good PV
replaced by bad
one at 12/00Z



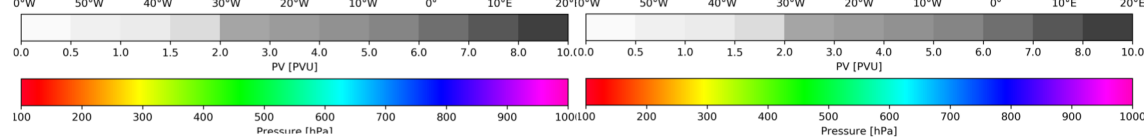
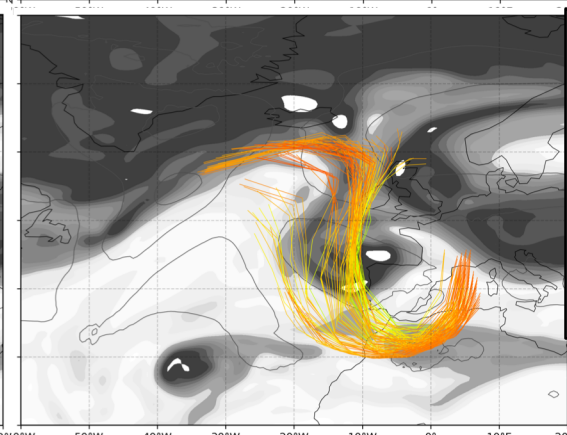
Exp2: bad PV
repl. by good
one at 12/00Z

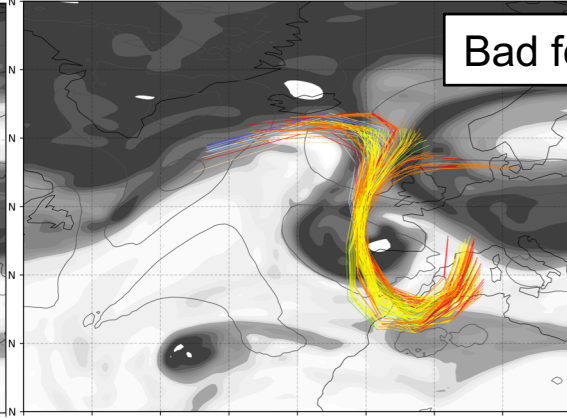
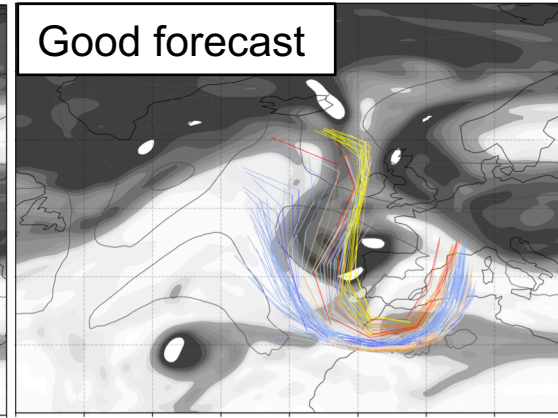
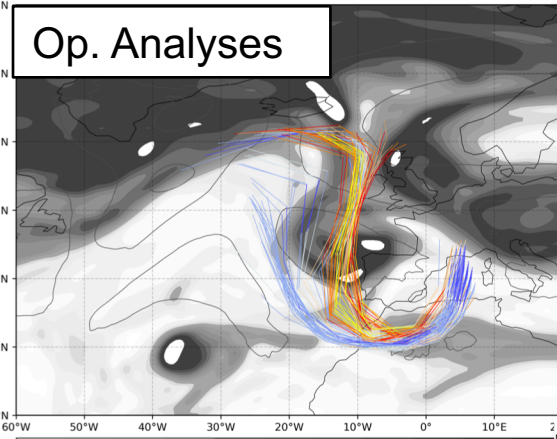


Exp3: good PV
& moisture
replaced by bad
ones at 12/00Z

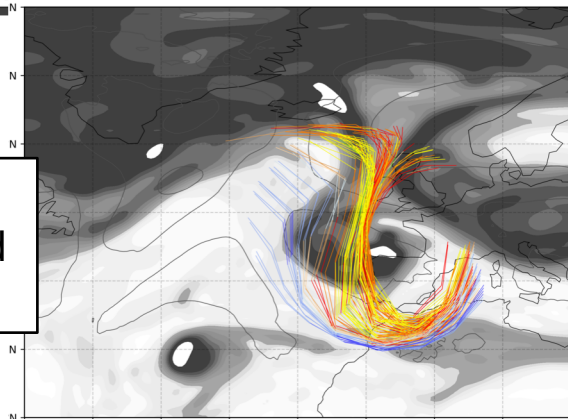


Exp4: bad
PV &
moisture
repl. by
good ones
at 12/00Z

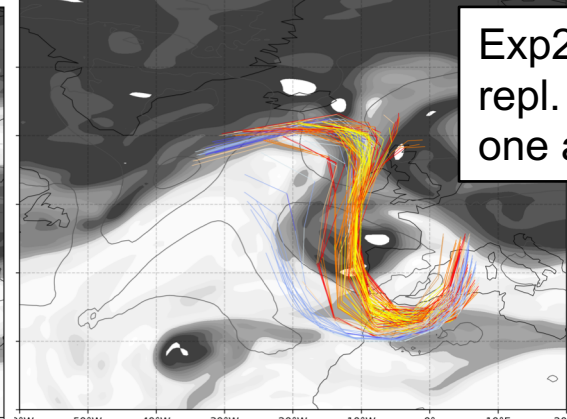




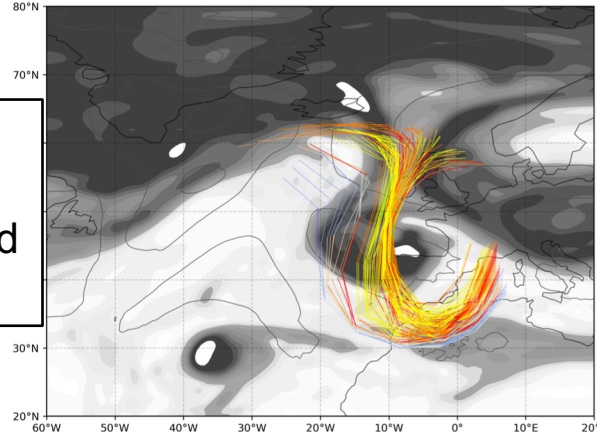
**Exp1: good PV
replaced by bad
one at 12/00Z**



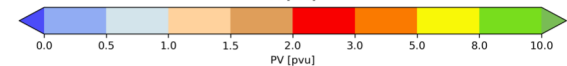
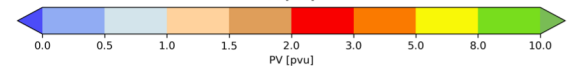
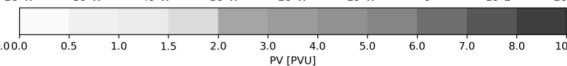
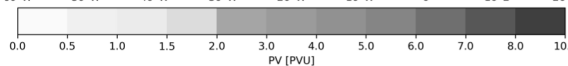
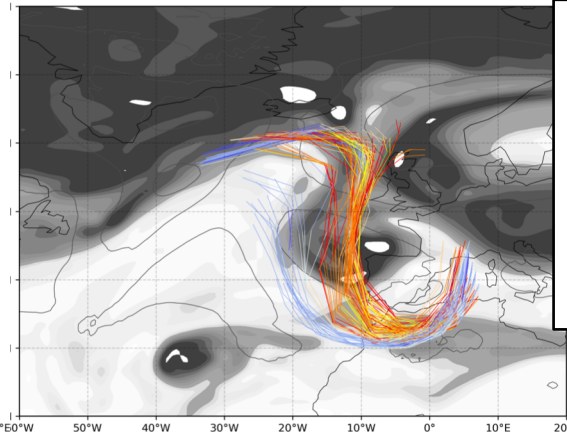
**Exp2: bad PV
repl. by good
one at 12/00Z**



**Exp3: good PV
& moisture
replaced by bad
ones at 12/00Z**



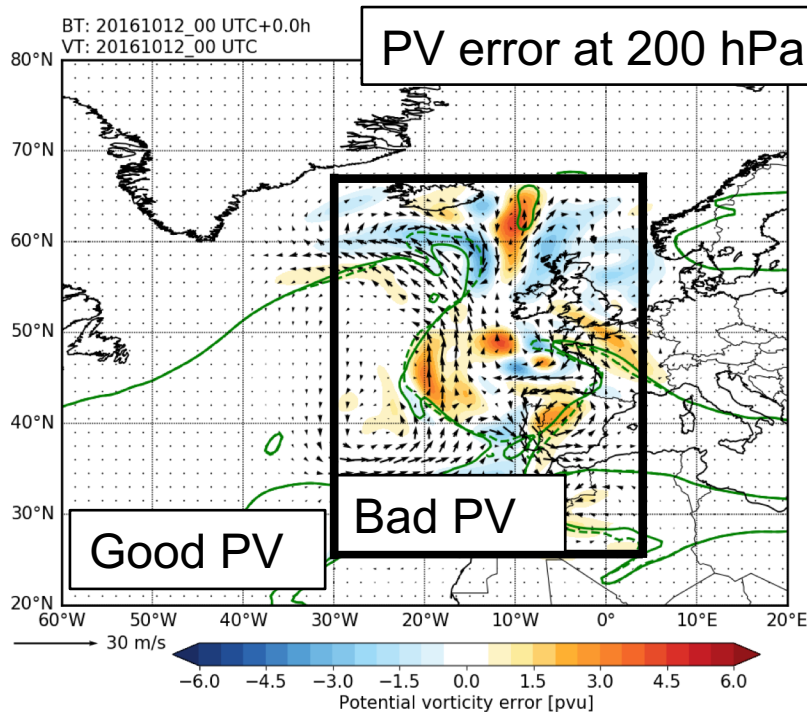
**Exp4: bad
PV &
moisture
repl. by
good ones
at 12/00Z**



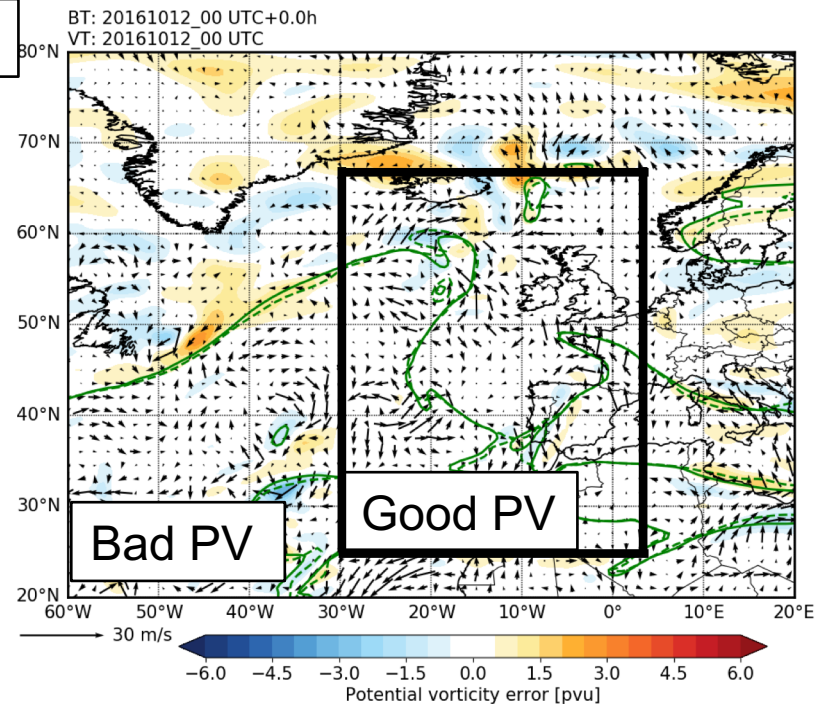
PV inversion experiments in high-resolution deterministic runs

Exp 1a) At 12/00Z, the **good PV** is replaced by the **bad PV** at 100-600 hPa in the domain 25-68N/30W-5E

Exp 1b) Opposite of Exp. 1a (bad PV replaced by good PV in the same domain)



→ Fc expected to approach bad one

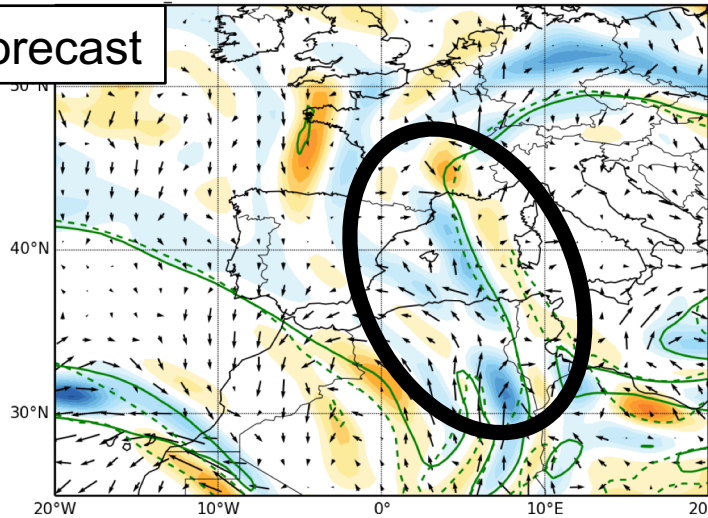


→ Fc expected to approach good one

PV error at 200 hPa, forecast – analysis, at 14/00Z

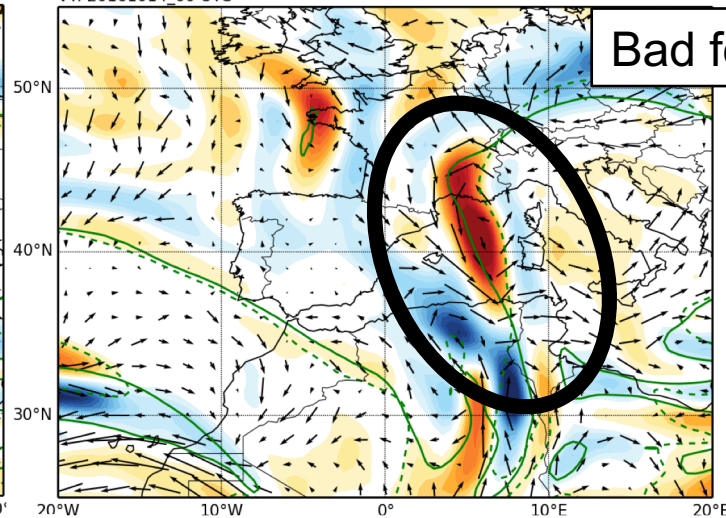
BT: 20161012_00 UTC+48.0h
VT: 20161014_00 UTC

Good forecast

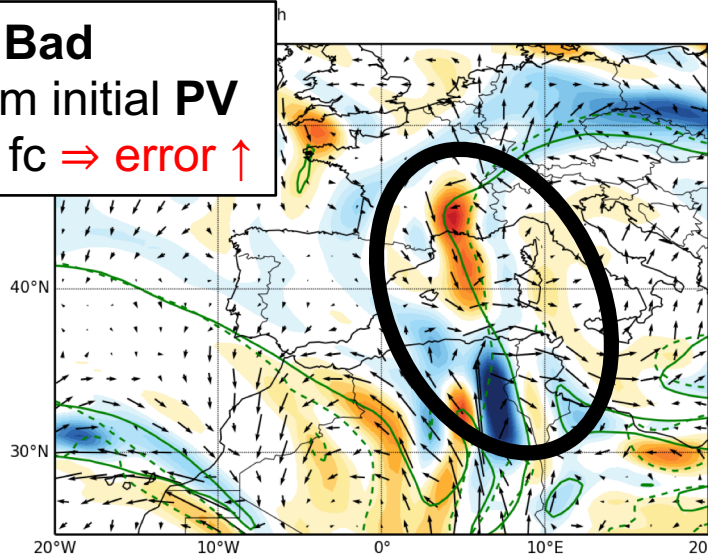


BT: 20161010_18 UTC+78.0h
VT: 20161014_00 UTC

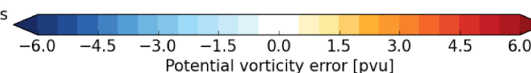
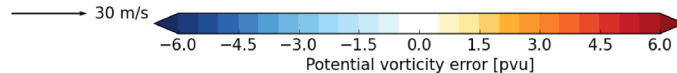
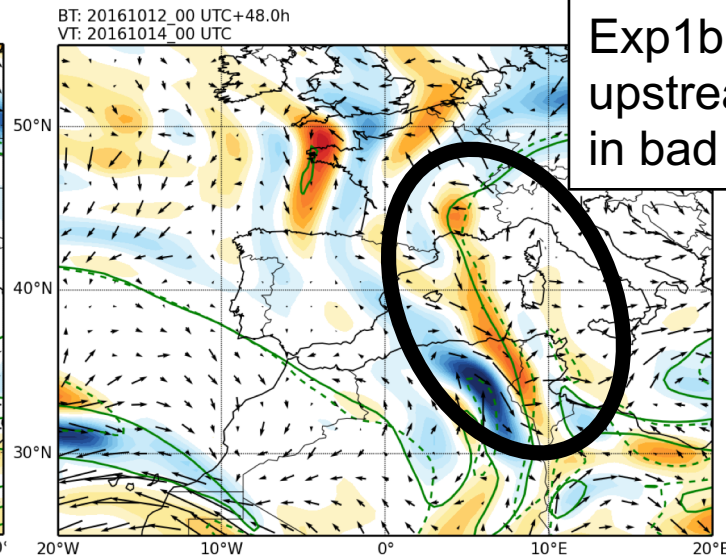
Bad forecast



Exp1a) **Bad**
upstream initial **PV**
in good fc $\Rightarrow$ error $\uparrow$



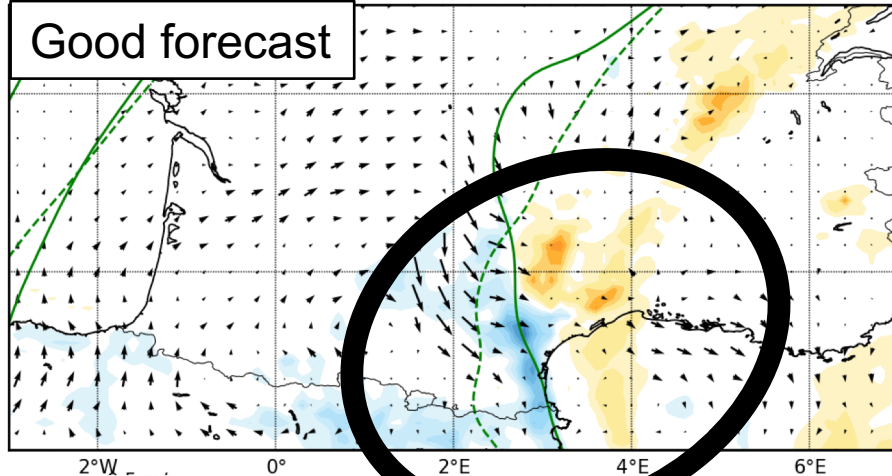
Exp1b) **Good**
upstream initial **PV**
in bad fc $\Rightarrow$ error $\downarrow$



Precipitation error, forecast – analysis, at 14/00Z

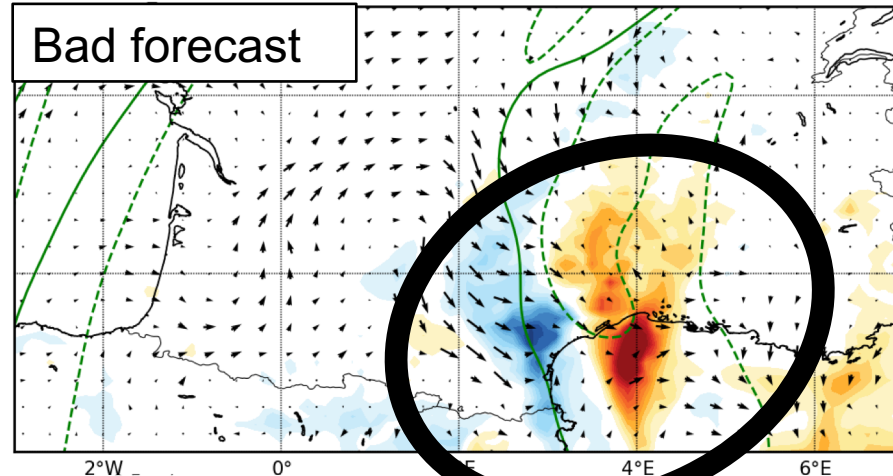
BT: 20161012_00 UTC+48.0h
VT: 20161014 00 UTC

Good forecast

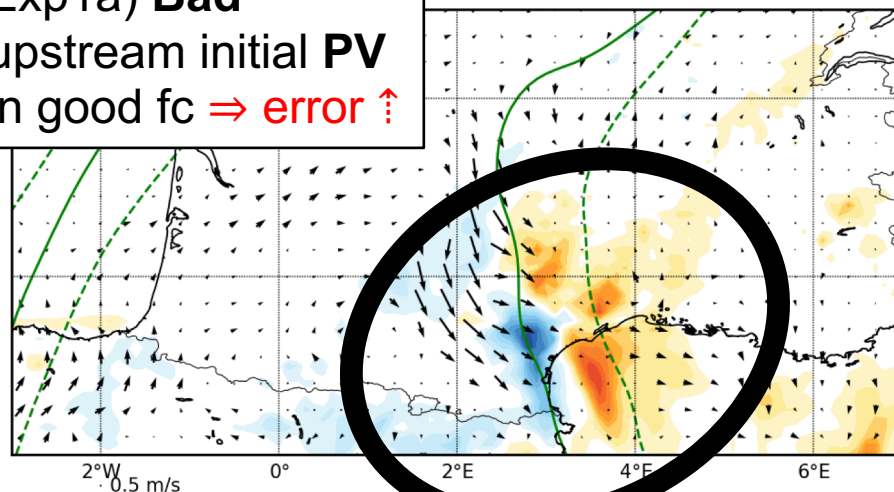


BT: 20161010_18 UTC+78.0h
VT: 20161014 00 UTC

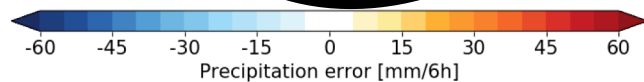
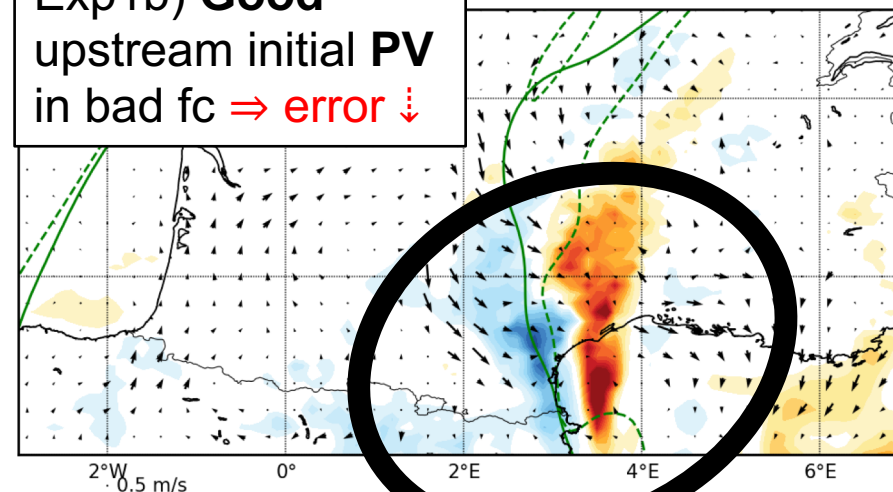
Bad forecast



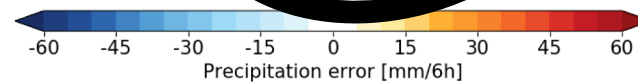
Exp1a) **Bad**
upstream initial **PV**
in good fc $\Rightarrow$ error $\uparrow$



Exp1b) **Good**
upstream initial **PV**
in bad fc $\Rightarrow$ error $\downarrow$



Precipitation error [mm/6h]

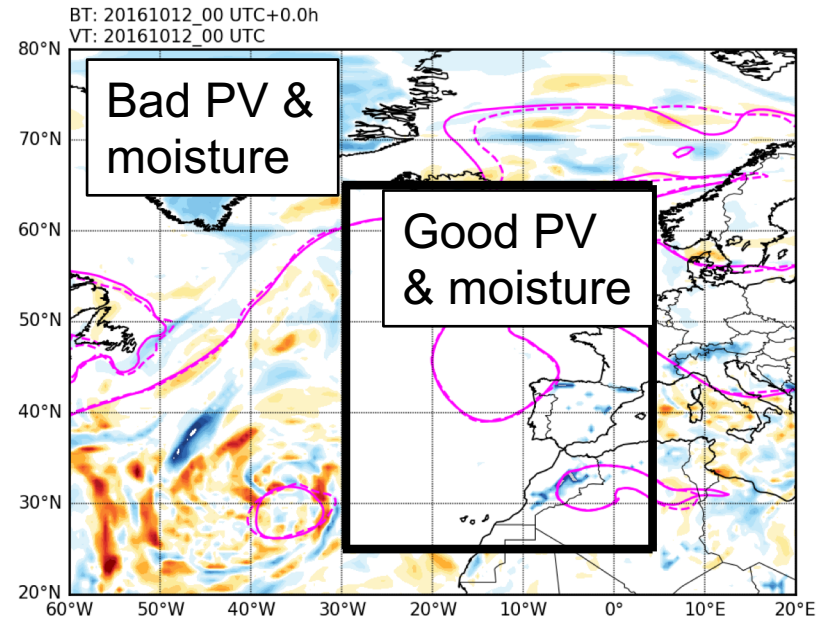
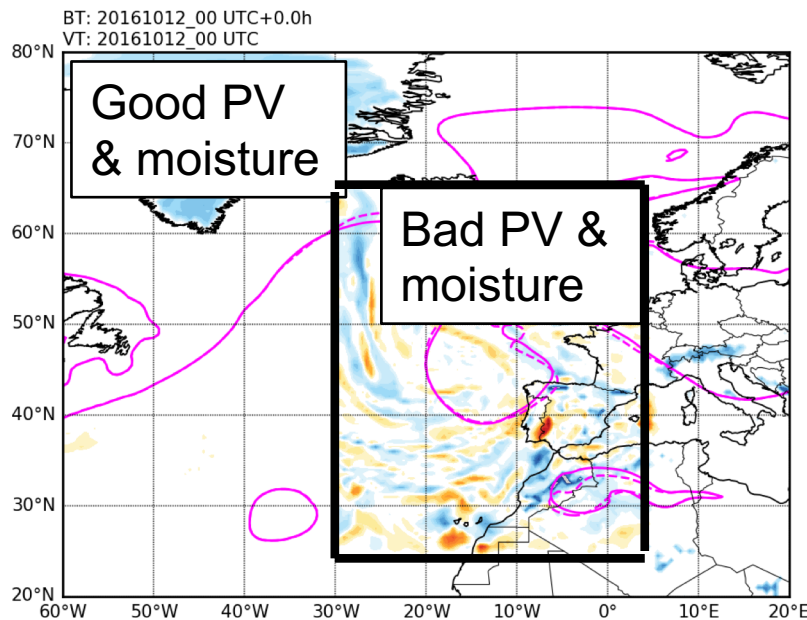


Precipitation error [mm/6h]

PV inversion and moisture experiments

Exp 2a) At 12/00Z, the good **UL PV** and the good **moisture** (1050-500 hPa) are **replaced by the bad** ones in domain 25-68N/30W-5E

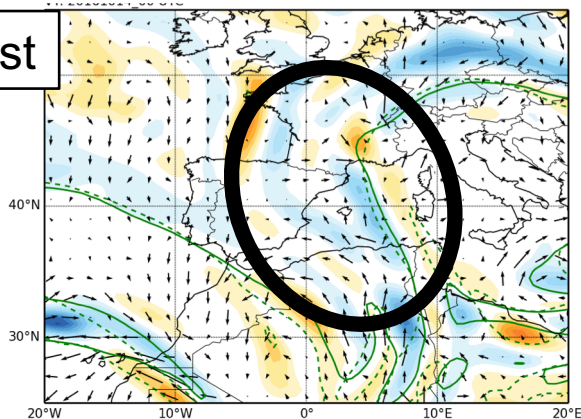
Exp 2b): Opposite of Exp. 2a) (bad **PV** and **moisture** replaced by good ones)



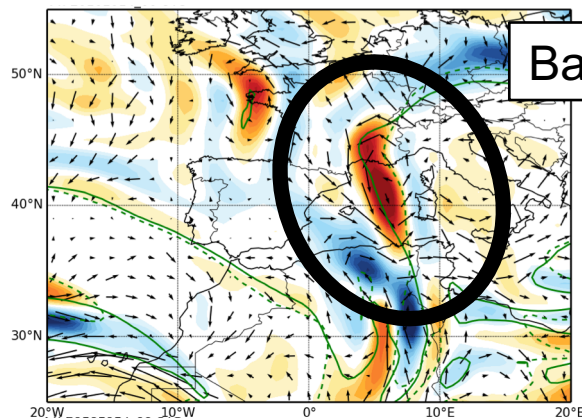
Specific humidity error at 850 hPa (g/kg)

PV error at 200 hPa, forecast – analysis, at 14/00Z

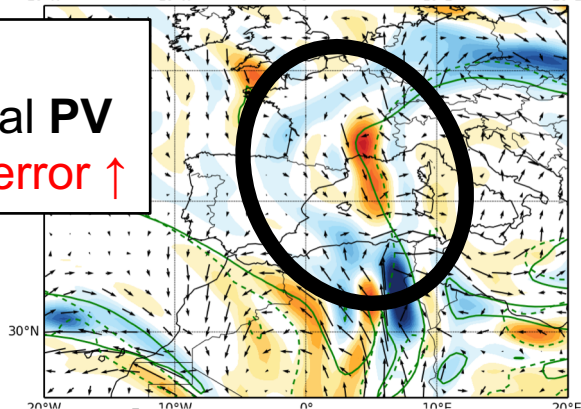
Good forecast



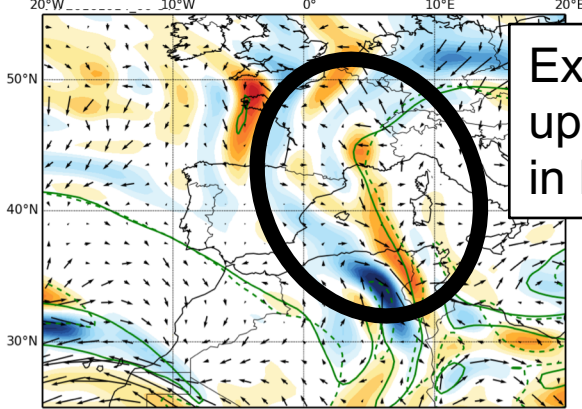
Bad forecast



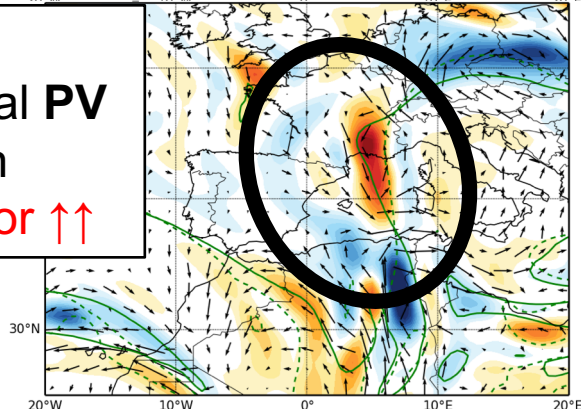
Exp1a) **Bad**
upstream initial **PV**
in good fc $\Rightarrow$ error $\uparrow$



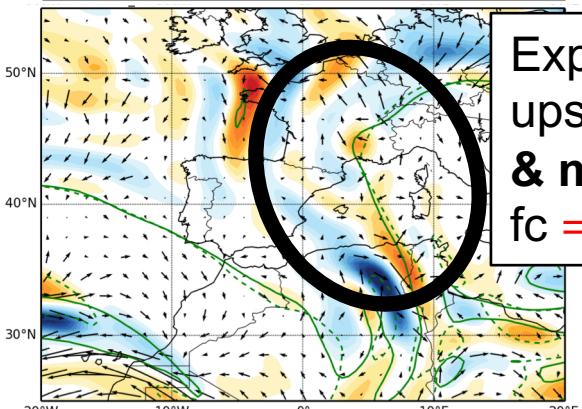
Exp1b) **Good**
upstream initial **PV**
in bad fc $\Rightarrow$ error $\downarrow$



Exp2a) **Bad**
upstream initial **PV**
& **moisture** in
good fc $\Rightarrow$ error $\uparrow\uparrow$



Exp2b) **Good**
upstream initial **PV**
& **moisture** in bad
fc $\Rightarrow$ error $\downarrow\downarrow$



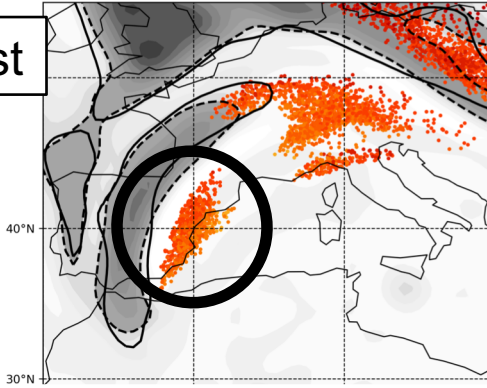
Potential vorticity error [pvu]

Potential vorticity error [pvu]

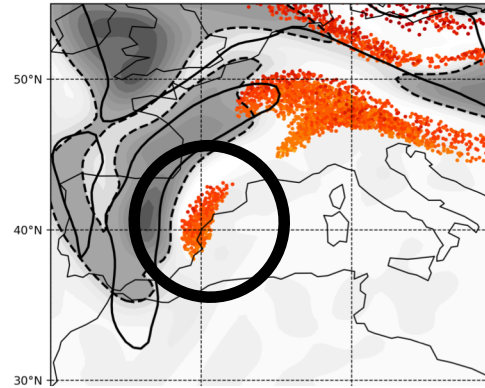
Contribution of diabatic processes to ULPV errors

PV at 320K and WCB intersections with 320 K at 13/12Z

Good forecast

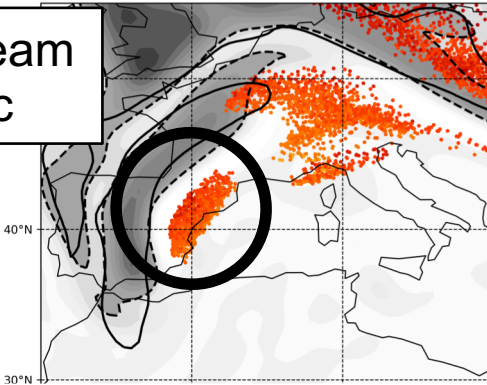


Bad forecast

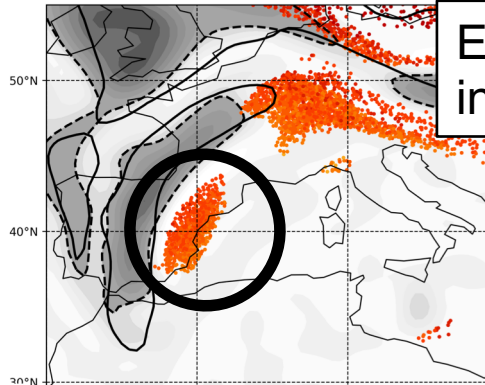


⇒ weaker WCB
⇒ less diabatic PV
destruction (= pos.
ULPV error)

Exp1a) **Bad** upstream
initial **PV** in good fc

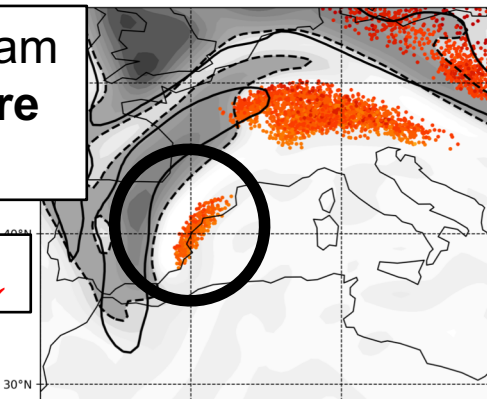


Exp1b) **Good** upstream
initial **PV** in bad fc

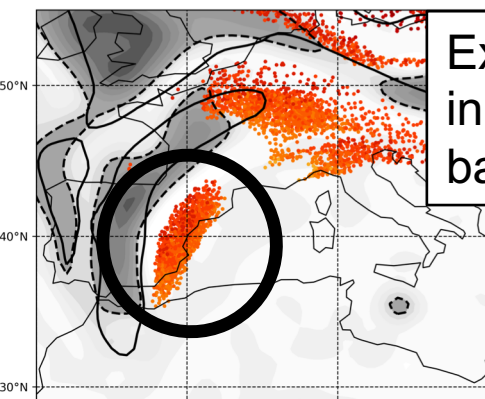


⇒ WCB strength ↑

Exp2a) **Bad** upstream
initial **PV & moisture**
in good fc



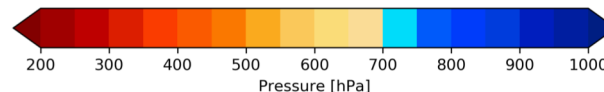
Exp2b) **Good** upstream
initial **PV & moisture**
in bad fc



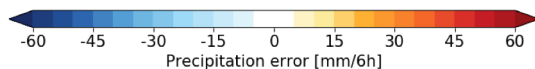
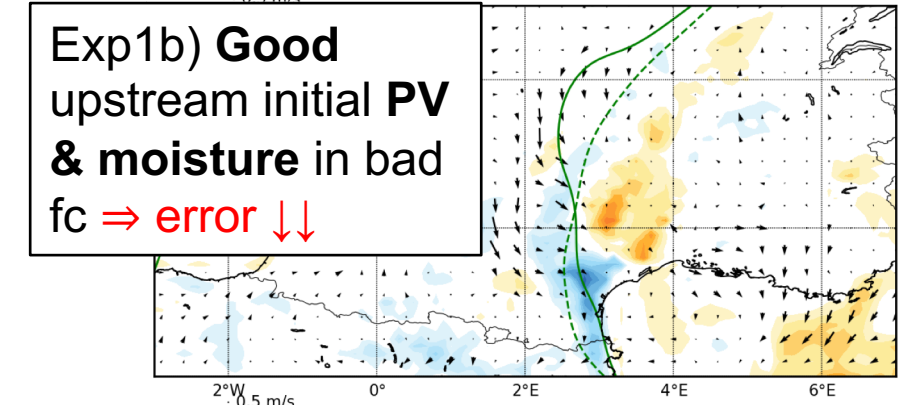
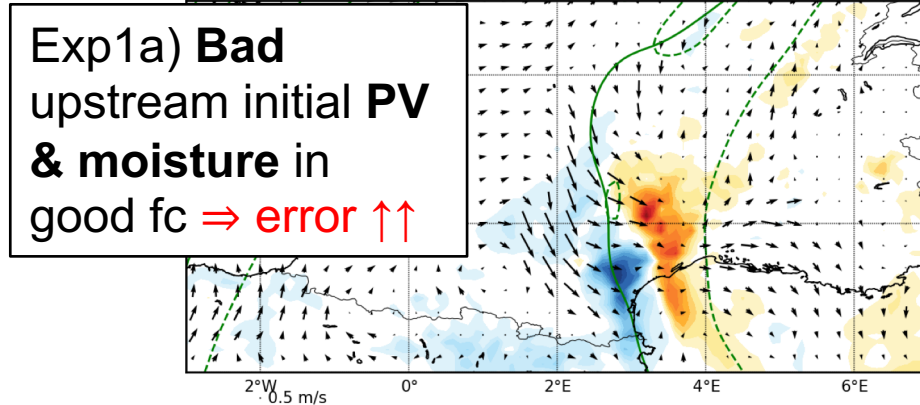
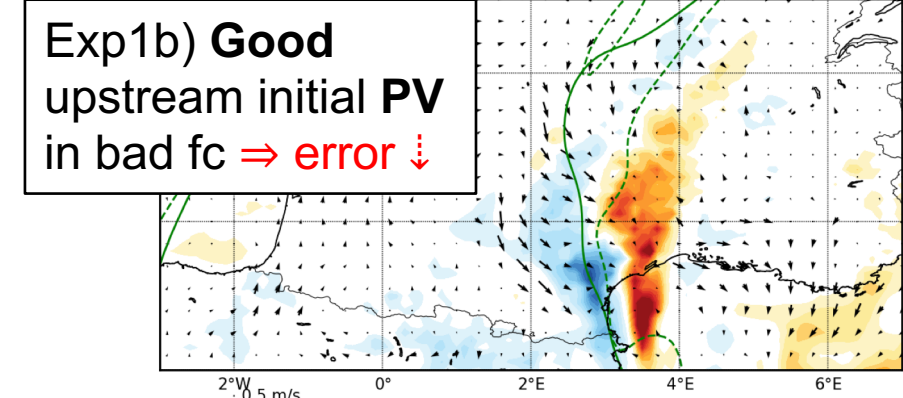
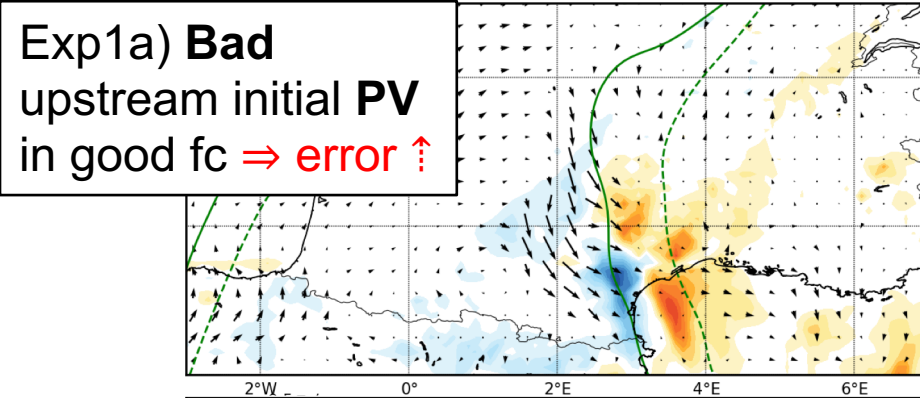
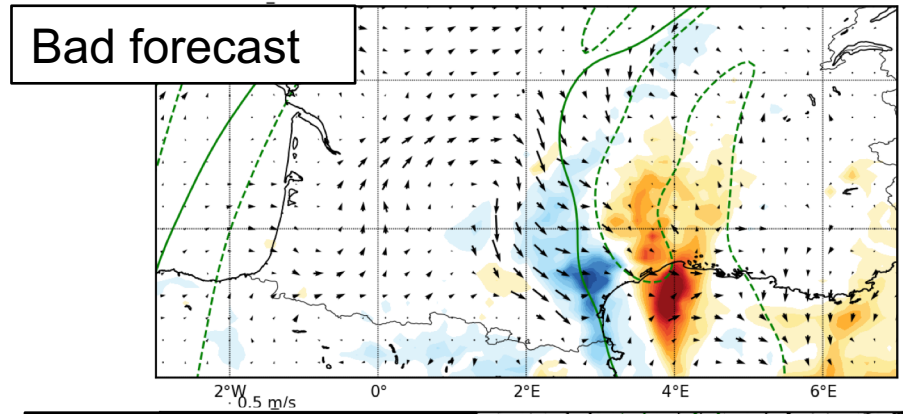
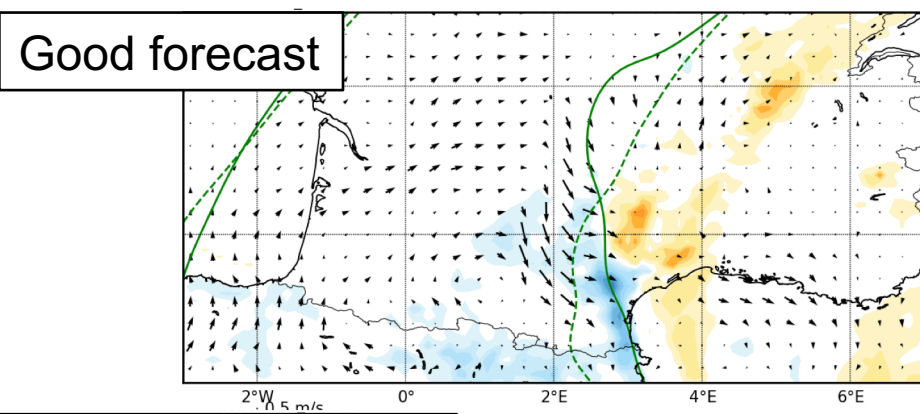
⇒ WCB strength ↑↑

⇒ WCB strength ↓↓

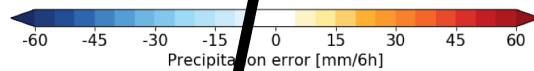
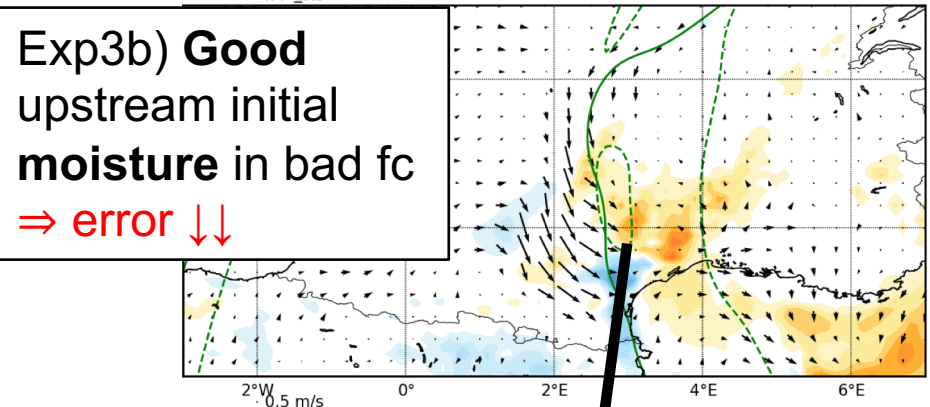
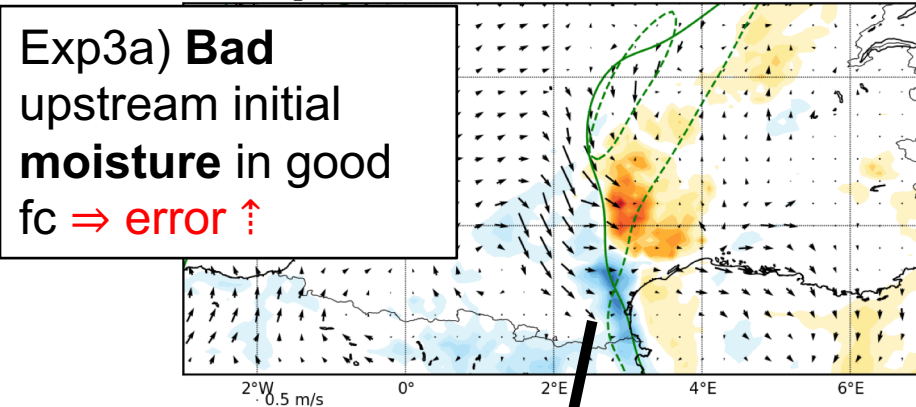
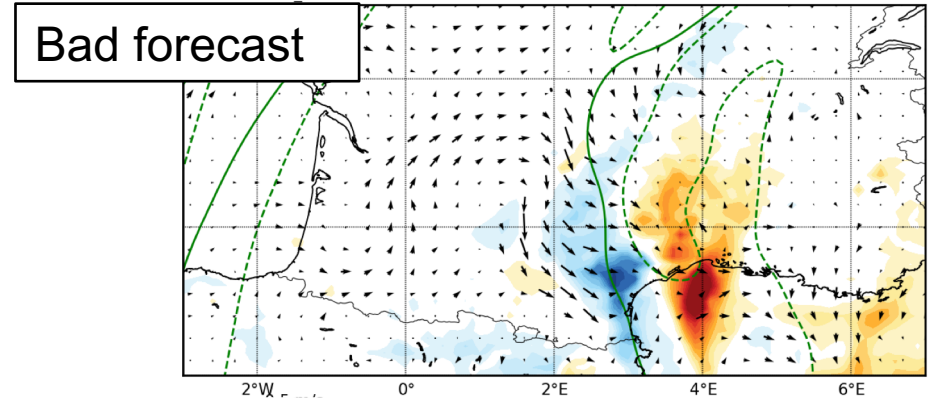
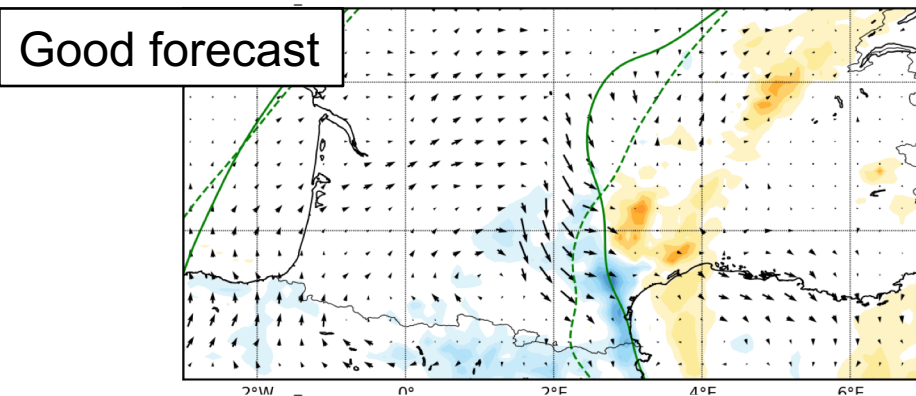
“WCB”: ascent >
400hPa/48h)



Precipitation error, forecast – analysis, at 14/00Z



Precipitation error when only the initial moisture is modified but not the initial PV



The bad initial moisture alone
does not lead to a bad precip. fc
(bad ULPV needed as well)

not
symmetric

The good initial moisture alone leads
to a good precipitation forecast
(despite the bad ULPV structure)