

Modification of initial conditions through perturbing the potential vorticity field in mesoscale forecasts of Mediterranean heavy precipitation events: 10 June 2000 and 9 October 2002

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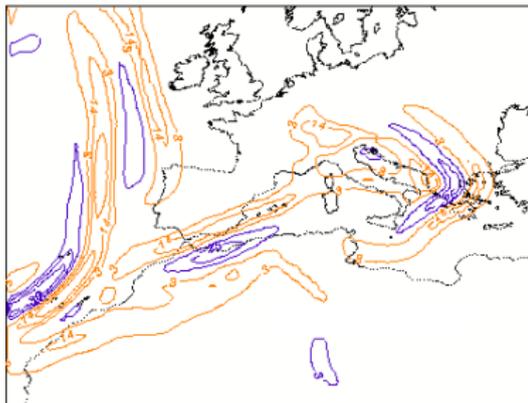
Objectives

- Develop several ensemble prediction systems applied to Mediterranean high impact cyclones associated with heavy rain
 - PV-perturbed
(initial and boundary conditions through three-dimensional PV structure)
 - semi-objectively
with the most intense values and gradients PV zones
 - objectively
with the MM5 adjoint model calculated sensitivity zones
- Compare the performance of the EPSs for the 24h accumulated precipitation field (30-54 h simulation time)

Build the two **PV-perturbed** Ensemble Forecasts

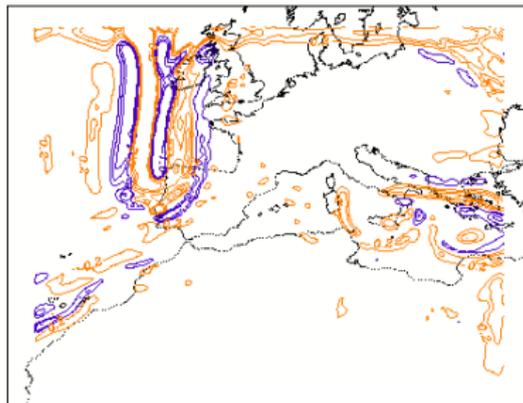
Introduce realistic perturbations randomly to the PV fields through a PV error climatology along the three-dimensional PV structure

- PV-adjoint:



MM5 adjoint model calculated sensitivity zones at 300 hPa

- PV-gradient:



The most intense values and gradients PV zones at 300 hPa

PV error climatology

Comparing the PV fields of
ECMWF **analysis** \longleftrightarrow ECMWF **24 h forecast**,
of a large collection of MEDEX cyclones,
one can define:

- The **displacement error** (DE): the minimum displacement of the 24 h forecast PV field showing local maximum correlation with the analysis PV field
- The **intensity error** (IE): the difference between the displaced 24 h forecast PV field and analysis PV field relative to the analysis PV average

Results

- The two ensembles have a good performance (better than a multiphysics EPS)
- PV-gradient performs better than PV-adjoint
- PV-adjoint higher computational cost than the PV-gradient

Now

- Add a PV modification technique guided by satellite water vapor observations
- Compare the performance of these three methods

Applications of satellite measures: Water Vapor channel

Bands highly absorbed by **water vapor** radiation:

- **6.2 μm** : sensitive to the water vapor content in mid and upper troposphere. Useful to be applied at synoptic scale for **upper-level** diagnosis.
- **7.3 μm** : sensitive to low-level moisture. Useful to study low level humidity features.

6.2 μm

synoptic-scale upper-level features

WV brightness temperature related to upper-level dynamics

- Upper level jet (strong gradient of 1.5 PVU surface heights) → grey-dark zones
- Upper level PV (dynamic tropopause) anomaly → dark zones
- Synoptic vertical motion
 - areas of ascending air → white zones
 - areas of subsiding air → dark zones

Relation between WV image and potential vorticity

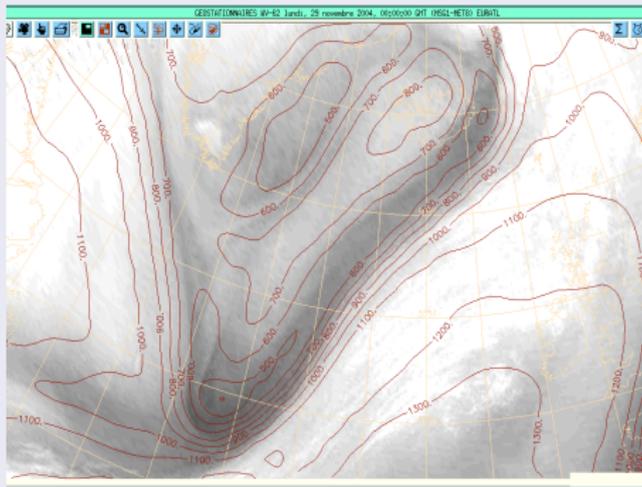


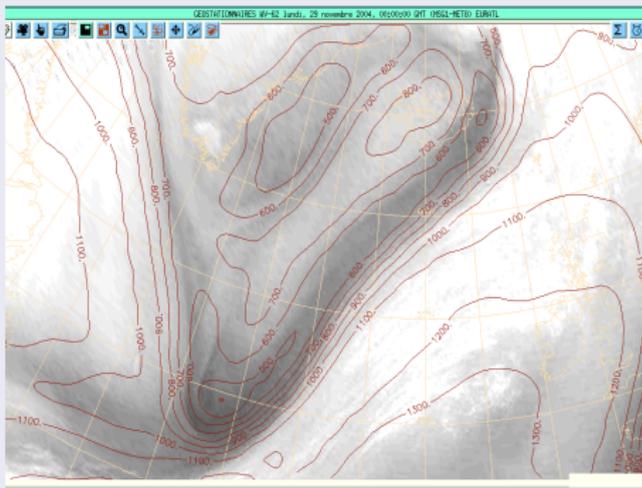
Figure: 1.5 PVU surface height (hPa) and WV brightness temperature (shading, K).
(*Santurette and Georgiev 2005*)

At the vicinity of a jet, where the stratospheric intrusions occur

upper level PV anomaly → dark zones

Introduction

WV brightness temperature related to upper-level dynamics



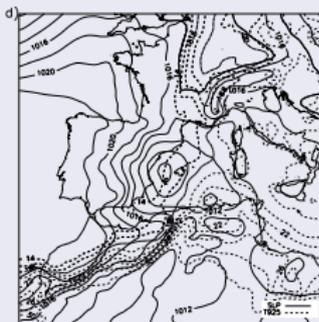
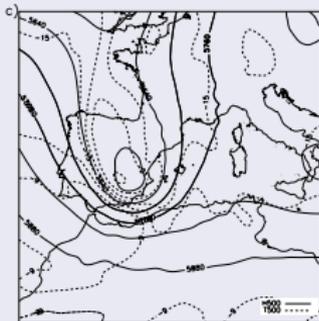
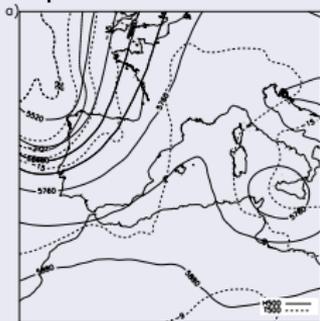
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Objectives

- Modify the PV field using the WV satellite channel as a guide (**PV-satellite**) in two **case studies**.
- Compare these modifications to the ones obtained by the **PV-gradient** and the **PV-adjoint** ensemble for the 24h accumulated **precipitation** field (30-54 h simulation time)

MEDEX cyclone of 9th June 2000

Synoptic situation:



9th June 2000 at 00 UTC

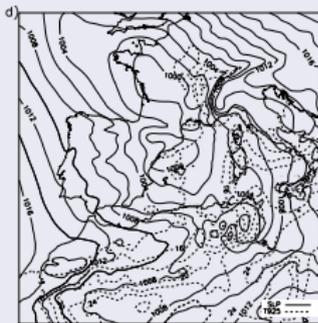
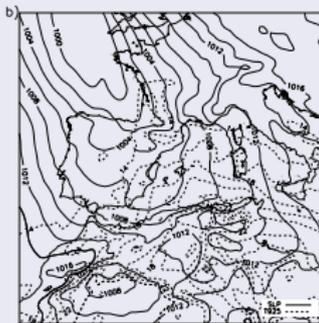
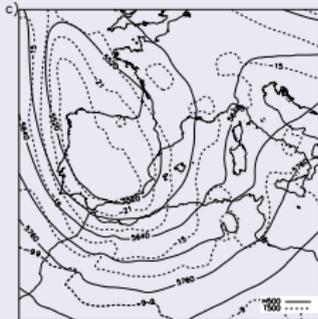
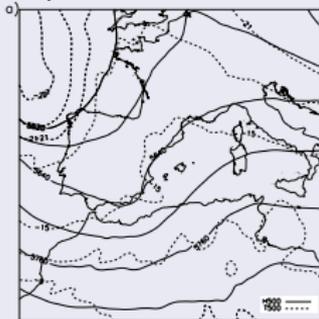
10th June 2000 at 00 UTC

Quasi-stationary
convective system

- Atlantic upper-level trough and low-level cold front
- Generation of a mesoscale cyclone
- Advection of warm and moist air toward Catalonia from the Mediterranean Sea

MEDEX cyclone of 9th October 2002

Synoptic situation:



9th Oct. 2002 at 00 UTC

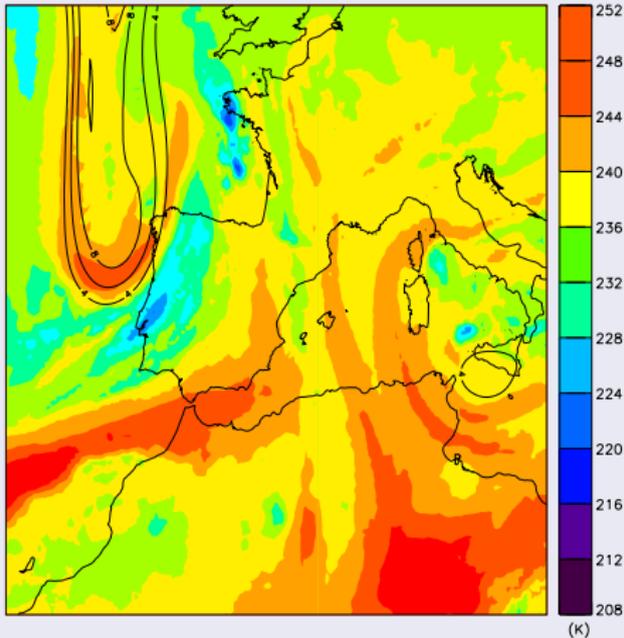
10th Oct. 2002 at 00 UTC

Quasi-stationary
convective system

- Similar to June 2000
- Larger wave length trough

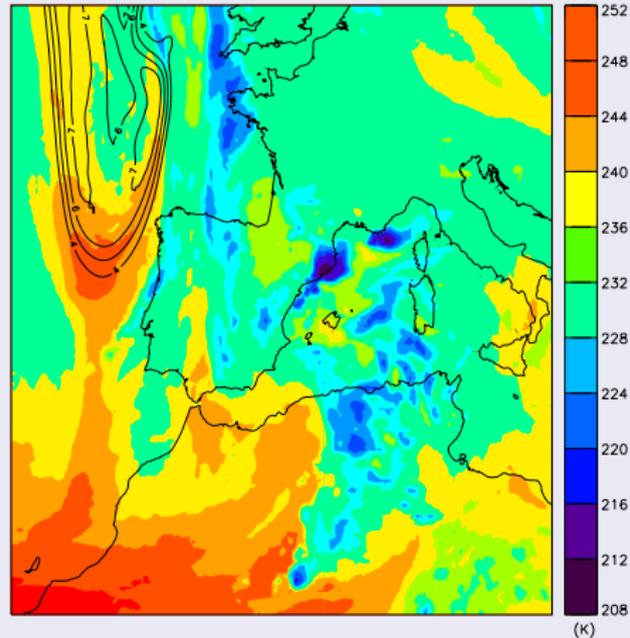
WV vs PV

June 2000



PV at 300 hPa

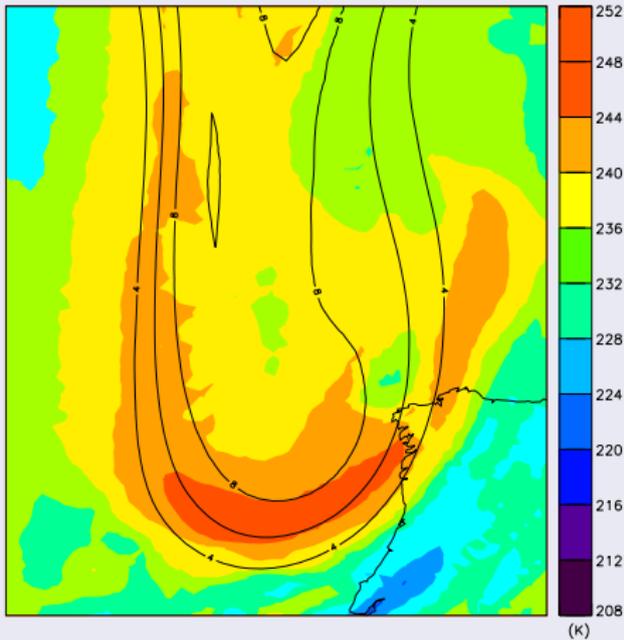
October 2002



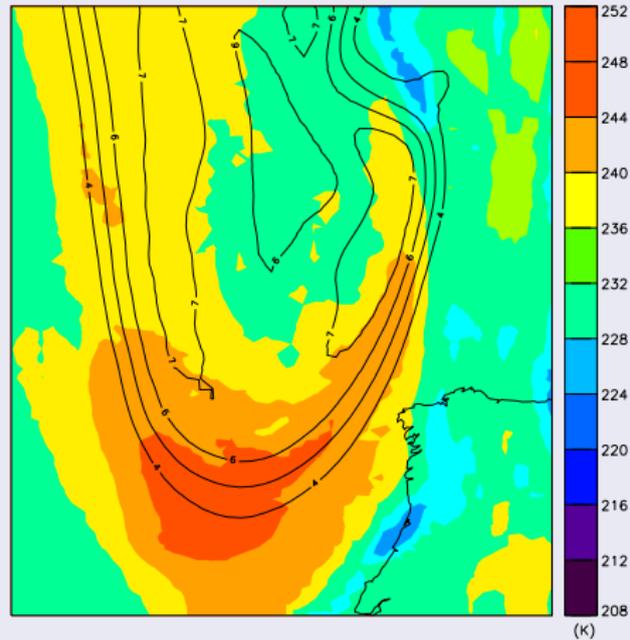
PV at 300 hPa

WV vs PV

June 2000

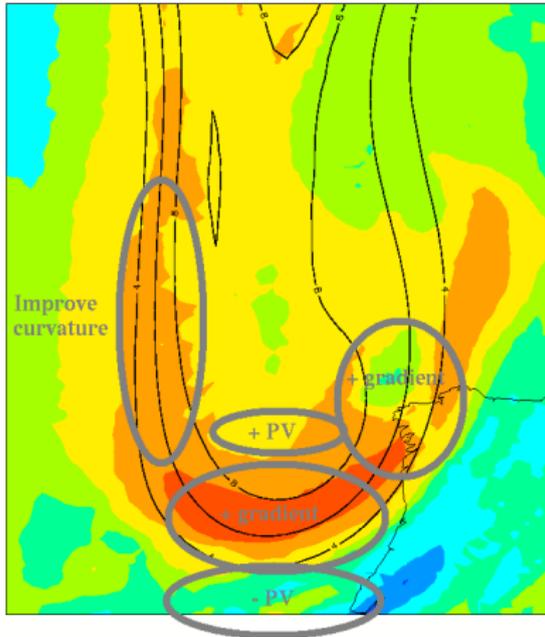


October 2002

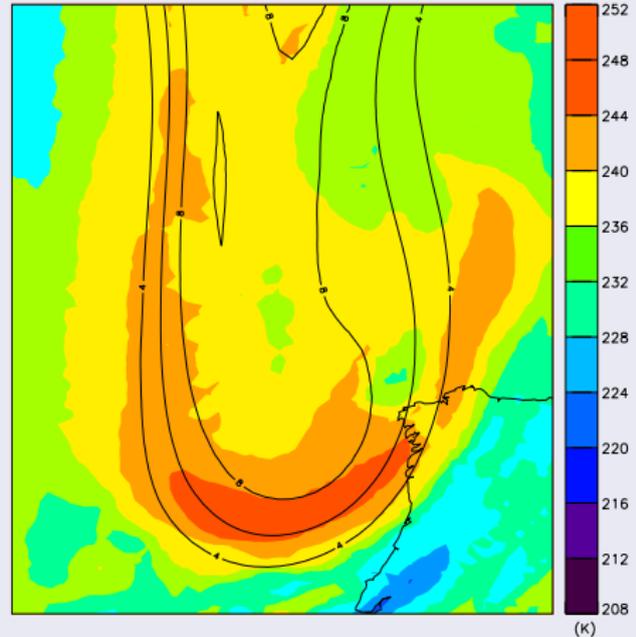


WV vs PV

(June 2000)



What we want



What we have

WV vs PV

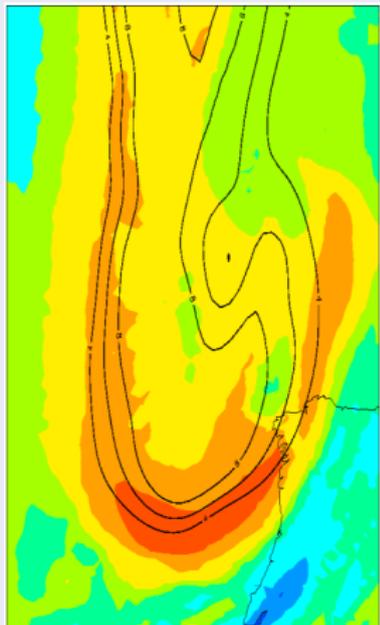
How do we get it?

- **adding/subtracting** PV structures and **shifting** them at a chosen vertical level and then extend the perturbation in the vertical conserving the vertical gradient.

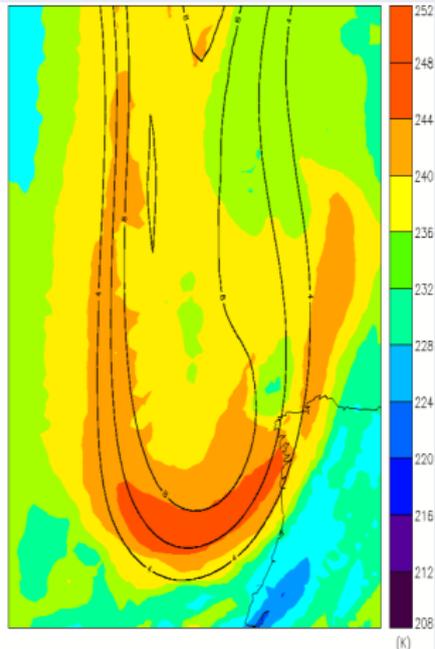
WV vs PV

What we've got:

(June 2000)



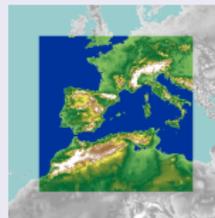
Perturbed



Non-perturbed

Simulations Characteristics

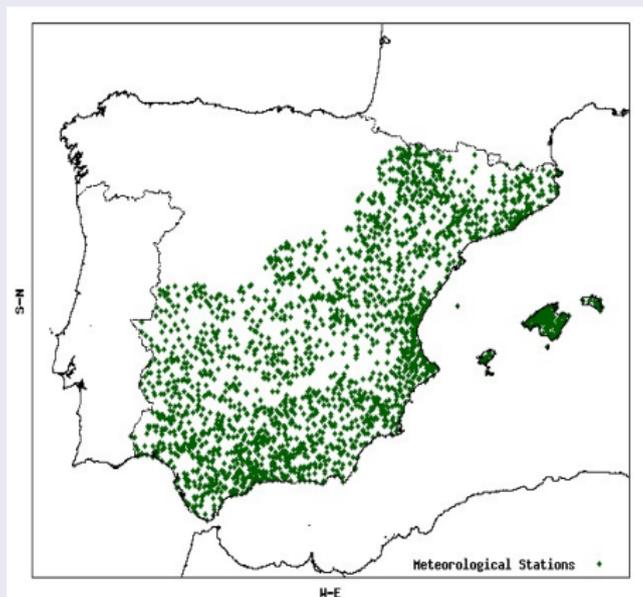
- Domain characteristics:
 - Resolution: 22.5 km
 - Center: 39.8 lat and 2.4 lon
 - Area: 120x120 grid
- Forecasting period is 54 h to simplify the posterior verification process (rainfall data is available at 24 h intervals starting each day at 06 UTC)



MEDEX: Mediterranean Experiment on Cyclones that produce High Impact Weather in the Mediterranean

Field of study: 24h accumulated precipitation

Available Observations



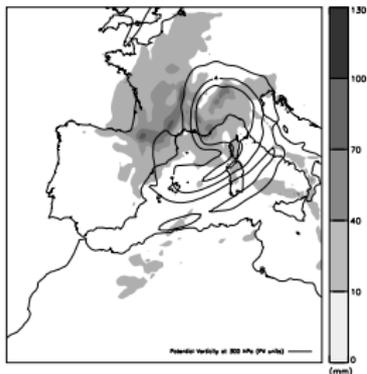
The forecasted gridded field is **interpolated** over the rain gauges to compare with the observed data

Rain gauge data is provided by AEMET (Spanish MetOffice)

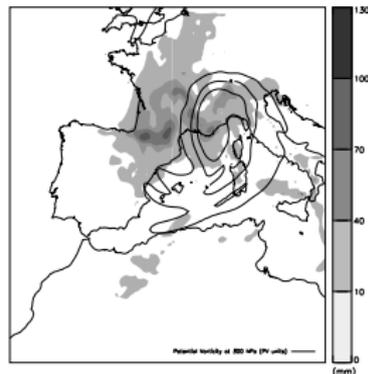
Results 24 h accumulated precipitation from 30 to 54 h simulation time

10 to 11 June
at 6UTC

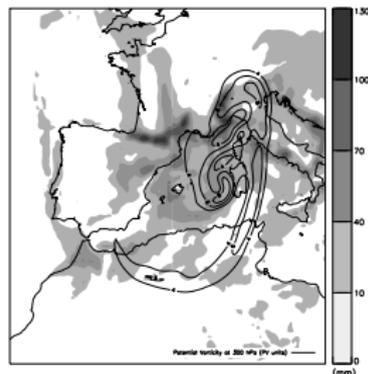
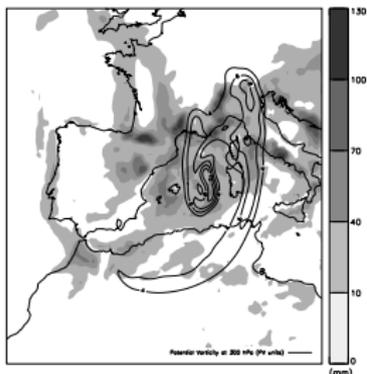
Non-perturbed



Perturbed



10 to 11 October
at 6UTC

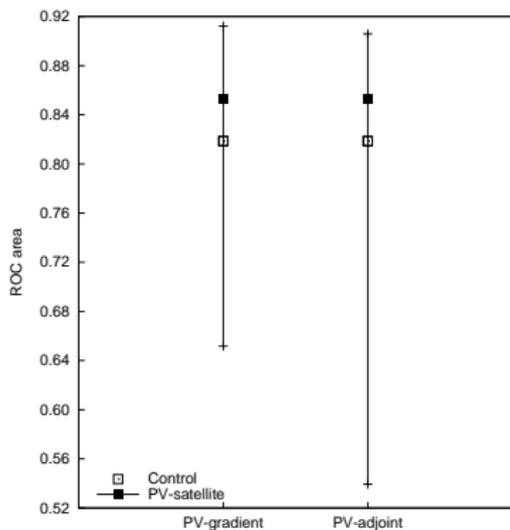


ROC area

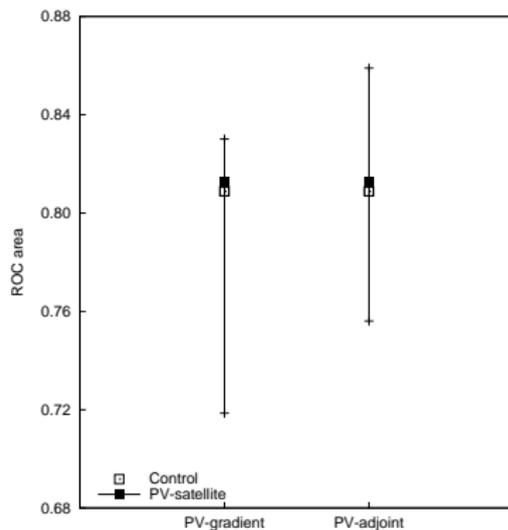
(Area under the ROC curve)

What is the ability of the forecast to discriminate between events and non-events?

Range: 0 to 1, No skill: 0.5, Perfect score: 1



June 2000

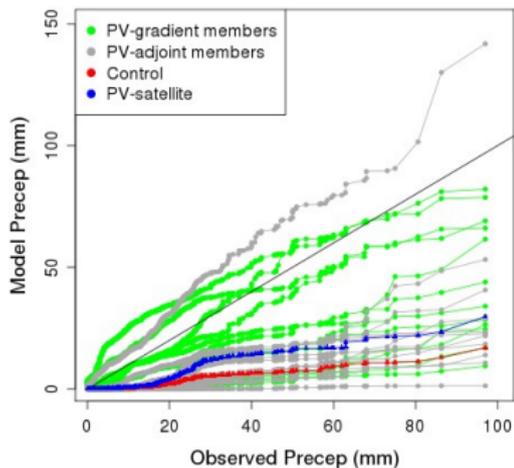


October 2002

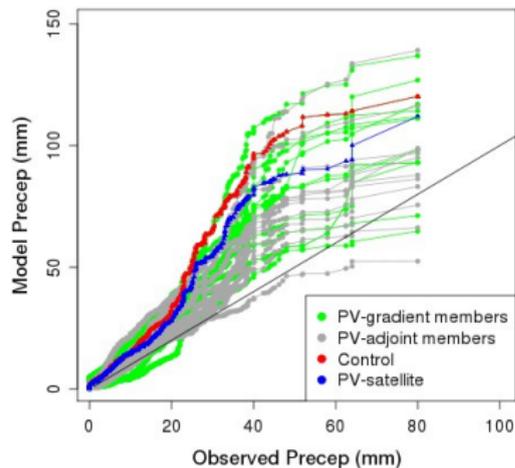
Q-Q plot

Compares the observed and forecasted distributions in terms of quantiles

Perfect score: diagonal



June 2000

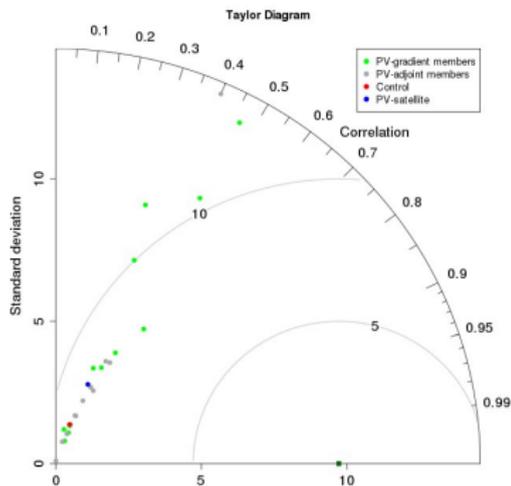


October 2002

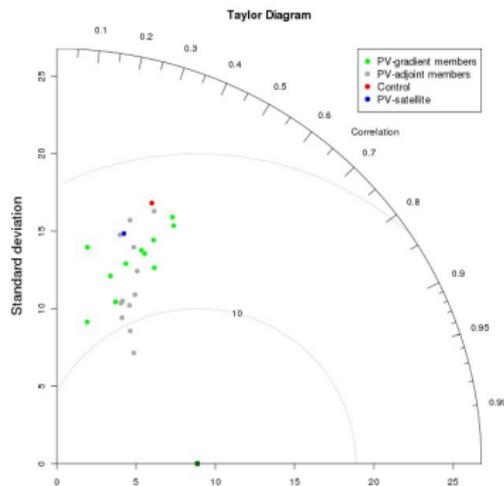
Taylor diagram

Plots in one graph the correlation coefficient and the centered pattern RMS difference between the forecast and the observed field, and the standard deviation of both fields

Perfect score: over the observation



June 2000



October 2002

Conclusions

We all know that it's hard to verify **extreme** events and **precipitation** due to the small statistical significance, and the characteristics of the rainfall, like the spatial distribution. In spite of all this:

- For both case studies, the **PV-satellite** results are **within** the range obtained by both PV-perturbed ensembles, and **better** than the control/non-perturbed ensemble member.
- The random perturbations (using a PV error climatology) **captures** the **mismatch between PV and WV** better than a manually perturbed ensemble member done by an expert forecaster, at least for these case studies.

In the future:

- Compare performance of PV-satellite with each member of the ensemble, to see if it is more *stable*. In other words, if it maintains the same position in a rank made up from the ensemble member and itself.
- Repeat the experiment for all the MEDEX events (19) used in both ensembles verification.

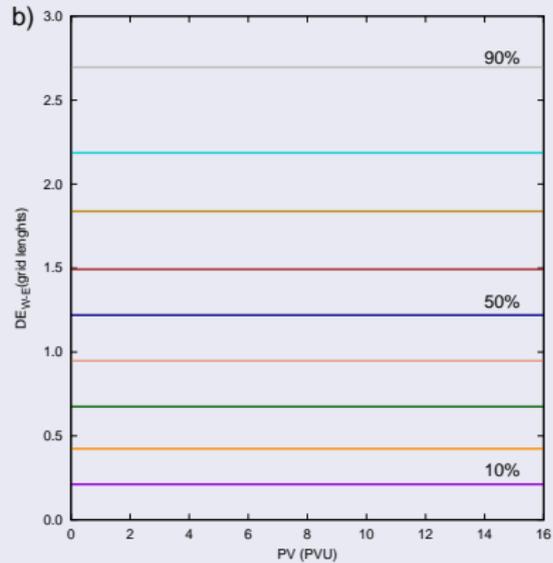
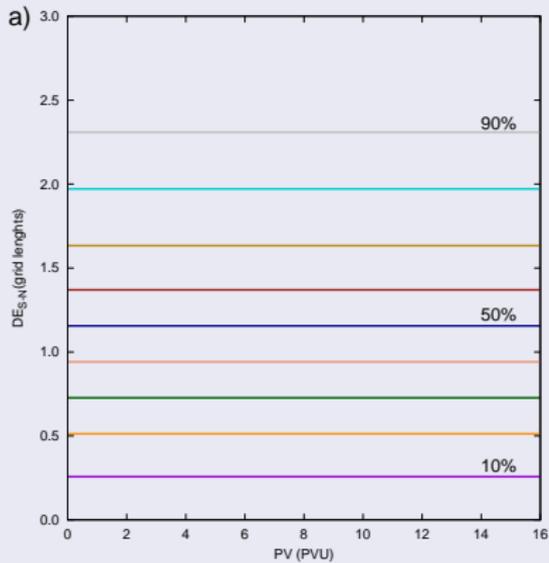
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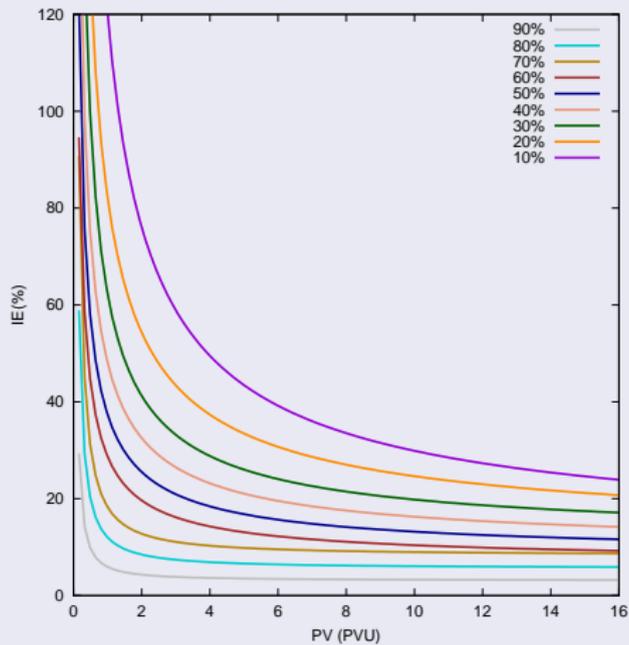
PV error climatology: Percentile levels at 300 hPa

Displacement Error



PV error climatology: Percentile levels at 300 hPa

Intensity Error



After introducing the realistic perturbations randomly into the PV fields along the corresponding zones

- Apply PV Inversion Technique to original and perturbed fields to obtain the balance fields (T, H and Winds)
- Define the ensemble member by the difference between the original and perturbed balance fields