Comparison of three different methods of perturbing the potential vorticity field in mesoscale forecasts of Mediterranean heavy precipitation events: 10 June 2000 and 9 October 2002

Maria-del-Mar Vich[1]*

R. Romero[1] E. Richard[2] P. Arbogast[3] K. Maynard[3]

[1]Meteorology Group, Universitat de les Illes Balears, Palma de Mallorca, Spain

[2]Laboratoire d'Aérologie CNRS UMR 5560, Université de Toulouse, France

[3]Météo-France, Toulouse, France

*(mar.vich@uib.es)

La lluvia incomunicó un acceso principal en Font de sa Cala (Capdepera). FOTO: MARIA ANGELS FIUS

Background

Objectives

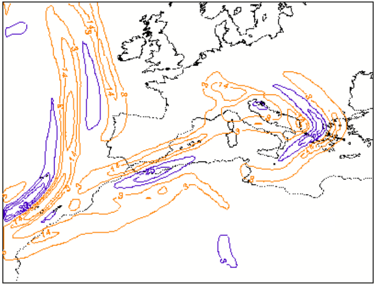
- Develop several ensemble prediction systems applied to Mediterranean high impact cyclones associated with heavy rain
  - PV-perturbed
    (initial and boundary conditions through three-dimensional PV structure)
    - semi-objectively
      with the most intense values and gradients PV zones
    - objectively
      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)

Background

Build the two PV-perturbed Ensemble Forecasts

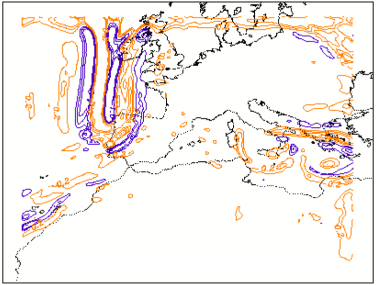
Introduce realistic perturbations randomly to the PV fields through a PV error climatology along the three-dimensional PV structure

- PV-adjoint:



MM5 adjoint model calculated sensitivity zones at 300 hPa

- PV-gradient:



The most intense values and gradients PV zones at 300 hPa

Background

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

Background

Results

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

Background

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.

$\boxed{6.2\ \mu\text{m}}$

synoptic-scale upper-level features

Introduction

WV brightness temperature related to upper-level dynamics

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

Introduction

Relation between WV image and potential vorticity

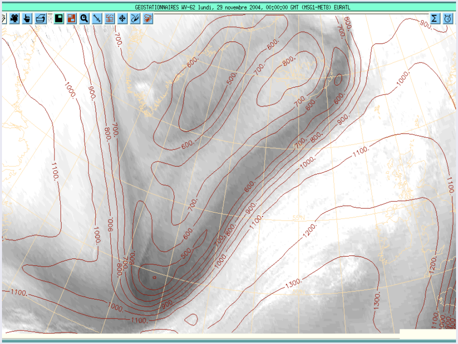
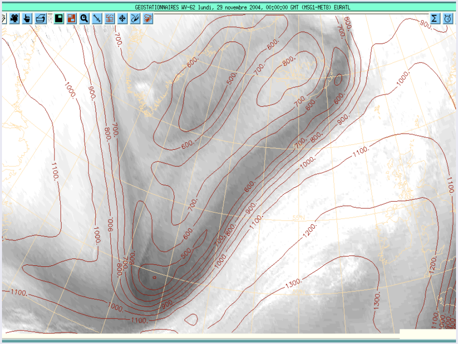


Figure: 1.5 PVU surface height (hPa) and WV brightness temperature (shading, K).
(*Santurette and Georgiev 2005*)

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

upper level PV anomaly → dark zones

WV brightness temperature related to upper-level dynamics



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

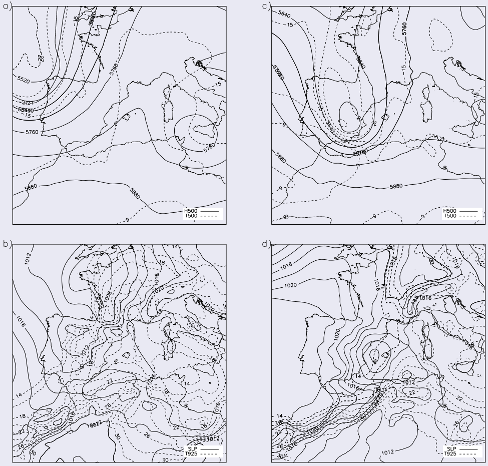
Introduction

Objectives

- Modify the PV field using the WV satellite channel as a guide (PV-satellite) in a case study.
- 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

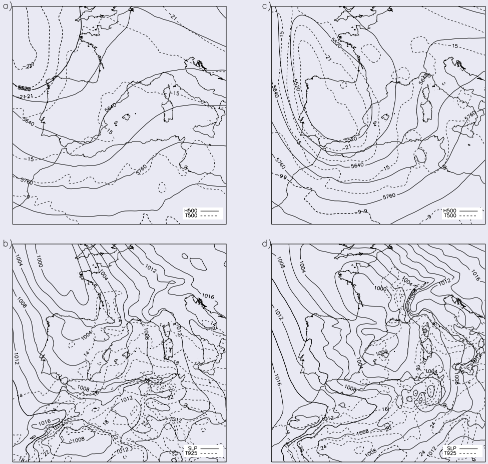
Quasi-stationary convective system

- 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

Development

MEDEX cyclone of 9th October 2002

Synoptic situation:



9th Oct. 2002 at 00 UTC

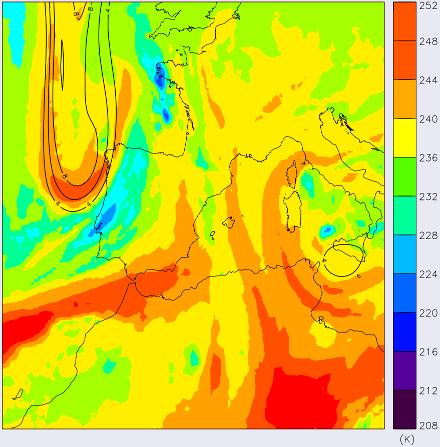
10th Oct. 2002 at 00 UTC

Quasi-stationary convective system

- Similar to June 2000
- Larger wave length trough

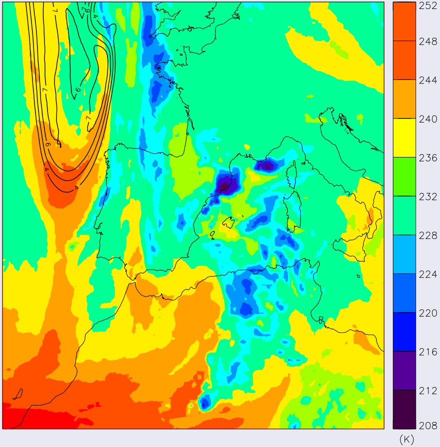
WV vs PV

June 2000



PV at 300 hPa

October 2002

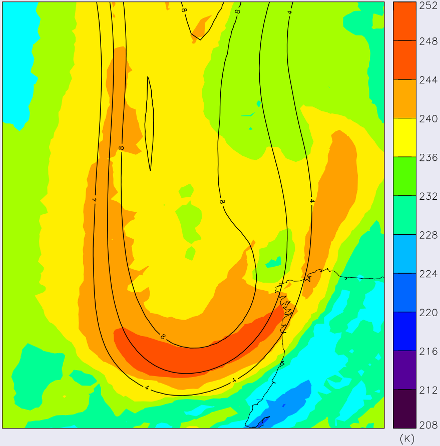


PV at 300 hPa

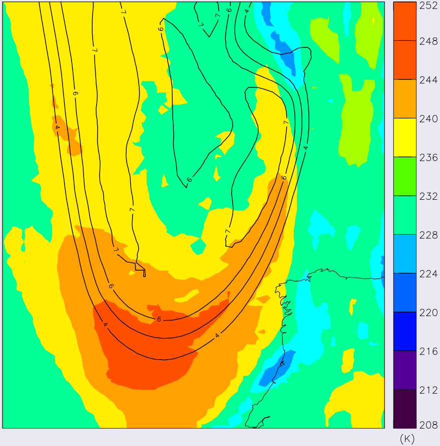
Development

WV vs PV

June 2000



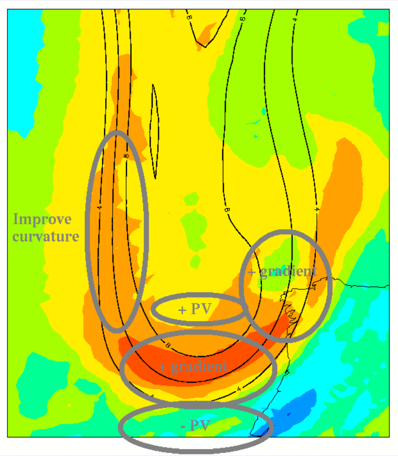
October 2002



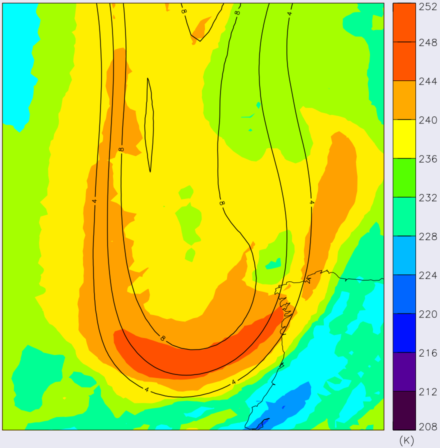
Development

WV vs PV

(June 2000)



What we want



What we have

Development

WV vs PV

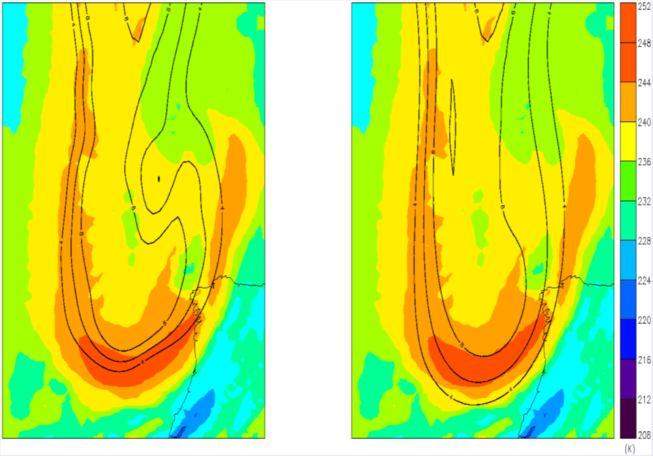
How do we get it?

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

Development

WV vs PV

What we've got: (June 2000)

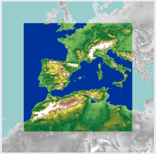


Perturbed Non-perturbed

Development

Simulations Characteristics

- Domain characteristics:
  - Resolution: 22.5 km
  - Center: 39.8 lat and 2.4 lon
  - Area: 120x120 grid



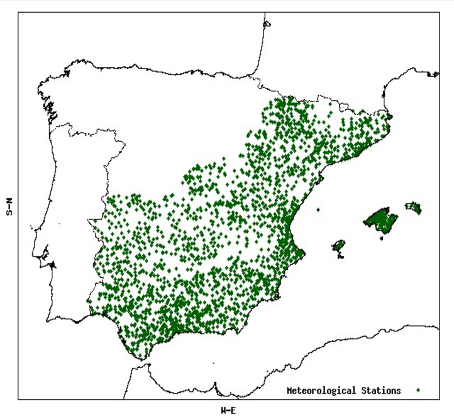
- Forecasting period is 54 h to simplify the posterior verification process (rainfall data is available at 24 h intervals starting each day at 06 UTC).
- The ensemble trial period corresponds to a collection of 19 MEDEX cyclones comprising 56 different simulation periods.

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

Development

Field of study: 24h accumulated precipitation

Available Observations



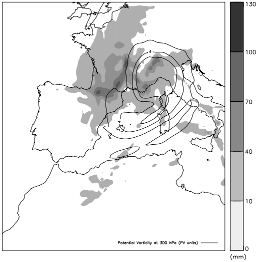
The forecasted gridded field is interpolated over the rain gauges to compare with the observed data

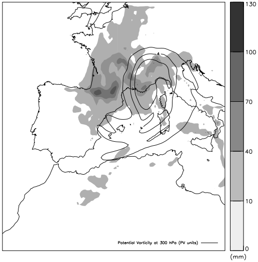
Rain gauge data is provided by AEMET (Spanish MetOffice)

24 h accumulated precipitation at 30-54 h simulation time

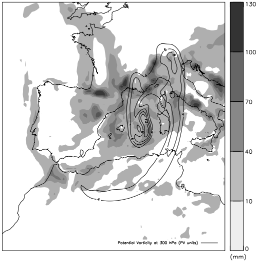
Non-pertubed | Perturbed

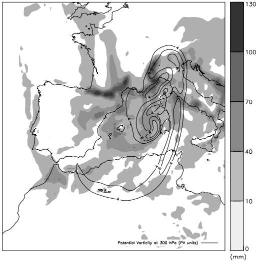
10 to 11 June at 6UTC





10 to 11 October at 6UTC





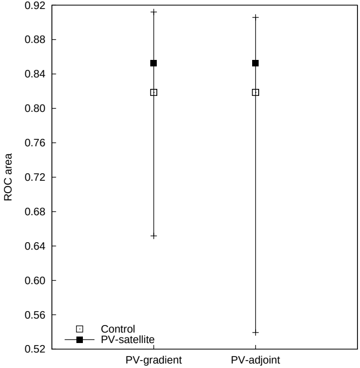
Comparison

ROC area

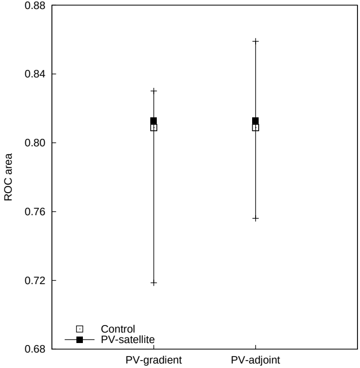
(Area under the ROC curve)

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



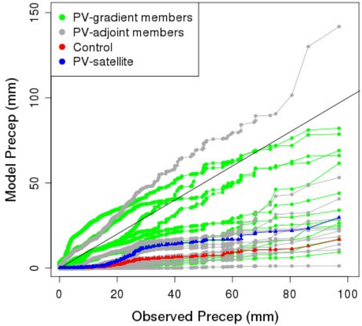
October 2002

Comparison

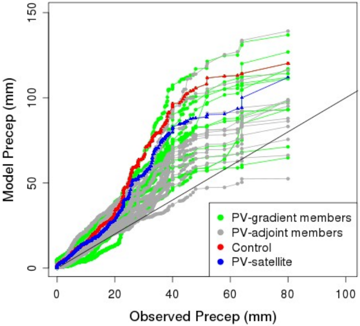
Q-Q plot

Compares the observed and forecasted distributions in terms of quantiles

Perfect score: diagonal



June 2000

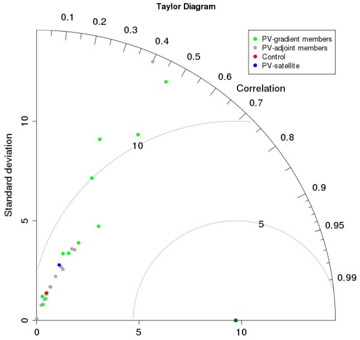


October 2002

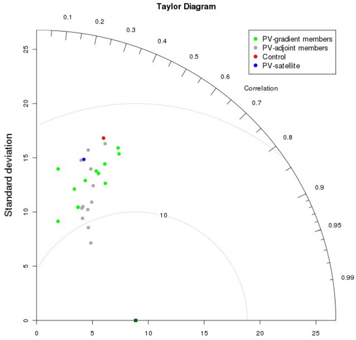
Taylor diagram

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 statistically significance, and the characteristics of the rainfall, like the spatial distribution. In spite of all this:

- For both case studies, the PV-satellite result 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 perturbations done by an expert forecaster, at least for these case studies.

Conclusions

In the future:

- Compare performance of PV-satellite with each member of the ensemble, to see if 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.

Extra: Background

PV error climatology

Comparing the PV fields of

ECMWF analysis $\longleftrightarrow$ ECMWF 24 h forecast,

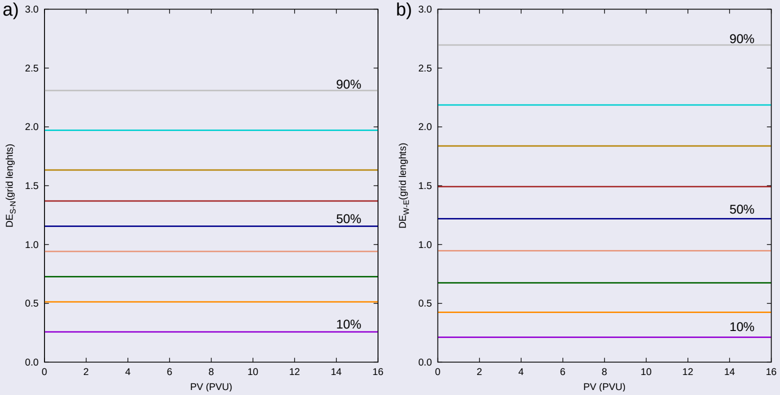
of a large collection of MEDEX cyclones,
one can define:

- 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

Extra: Background

PV error climatology: Percentile levels at 300 hPa

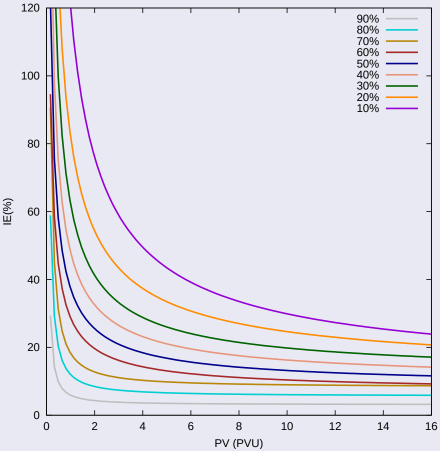
Displacement Error



Extra: Background

PV error climatology: Percentile levels at 300 hPa

Intensity Error



Extra: Background

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