A combined use of Meteosat WV imagery and potential vorticity inversion to improve the numerical prediction of the Algiers 2001 superstorm

S. Argence[1]*, D. Lambert[1], E. Richard[1], N. Söhne[1], J.-P. Chaboureau[1] & P. Arbogast[2]

[1]Laboratoire d'Aérologie**, UMR CNRS/UPS 5560, Toulouse, France

[2]DPrévi/Labo, Météo-France, Toulouse, France

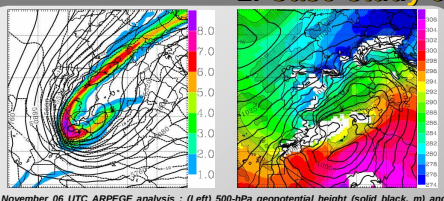
(*) sebastien.argence@aero.obs-mip.fr (**) http://www.aero.obs-mip.fr

Introduction

In spite of recent improvement in operational forecasting, numerical weather predictions regularly failed to reproduce intensity and distribution of precipitation of heavy rainstorms at the mesoscale. Generally, forecast errors arise from imperfect parametrizations of the numerical model used or errors in the representation of the initial state of the atmosphere, especially over data sparse areas such as Mediterranean sea and Atlantic ocean. In order to overcome initial conditions problems, several methods have been developed. For example, new methods consisting of assimilating mesoscale data (such as temperature, humidity) in initial fields provided to high resolution models have been recently used and have proven their ability to improve precipitation forecast on many case studies.

This study proposes an alternative method using the link existing between water vapour (WV) Meteosat imagery and potential vorticity (PV) analysis. The close relationship linking Meteosat WV imagery and PV positive anomalies allows one to detect significant upper-level dynamical structures associated with synoptic developments. This approach consisting of assessing and correcting initial conditions (by local PV modifications) provided to numerical models have been successfully used for some case-studies over the North Atlantic ocean, especially for the improvement of extratropical cyclones prediction. Contrary to these previous studies focused on the positive contribution of such a method at the synoptic scale, our study focused on its utility at the mesoscale. In the framework of the French CYPRIM project (CYclogénèses et PRécipitations Intenses en Méditerranée), the Algiers 2001 superstorm is investigated using this approach coupled with high resolution numerical simulations performed with the French non-hydrostatic Meso-NH model.

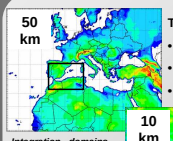
1. Case-study & Model setup



10 November 06 UTC ARPEGE analysis : (Left) 500-hPa geopotential height (solid black, m) and temperature (dashed, °C) and 350-hPa PV (colours, PVU) ; (Right) Mean sea level pressure (solid black, hPa), 900-hPa relative humidity (shaded, values greater than 70% only) and potential temperature (colours, K)

- Presence of an upper-level trough associated with a deep stratospheric intrusion over Spain and North Morocco inducing cold advection over North Africa
- Development of a surface cyclone centred on North Algeria leading to warm and moist advection on North Africa coasts

Large-scale environment promoted convection on a wide area over Algeria and Morocco and resulted in more than 100 mm of rainfall in many coastal areas with a maximum of about 260 mm on Algiers between 9 and 12 November 2001



Integration domains and topography (m) of the Meso-NH simulations

Three 1-way nested grid:

- Model 1: 8300 x 7100 km, **50 km** mesh-size
- Model 2: 2000 x 1500 km, **10 km**
- Model 3: 300 x 300 km, **2 km**

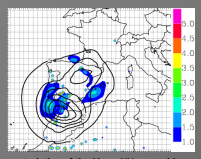
Simulations start from either **reference or modified (by PV inversion)** ARPEGE analysis and are integrated for both 24-h and 12-h:

- 9 November 2001 12UTC → 10 November 12UTC
- 10 November 2001 00UTC → 10 November 12UTC

2. Sensitivity study

Idea: Assessing the sensitivity of rainfall intensity and distribution to the high level PV anomaly sub-structures

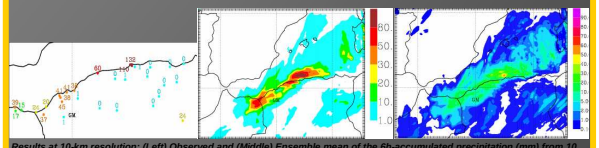
Method: Generation of a small ensemble of 9 members starting from 10 November 2001 00UTC and integrating on 12 hours. It is composed of a reference run and 8 simulations initialized with perturbed initial conditions using a PV inversion tool. It is expected that this initialization technique models some kind of uncertainties in the upper-level analysis at the mesoscale



Characteristics of the Meso-NH ensemble on the initial state (10 November 2001 00UTC): Standard deviation of the 500-hPa geopotential height (solid black, m) and of the intensity of the 950-hPa wind (colours, m/s)

(1) Good dispersion of the ensemble in upper-levels, especially over Iberian Peninsula and North Morocco
(2) Weaker perturbation of the low-level flow

Useful dispersion of the ensemble to focus the sensitivity study on upper-levels



Results at 10-km resolution: (Left) Observed and (Middle) Ensemble mean of the 6h-accumulated precipitation (mm) from 10 November 2001 06UTC to 12UTC and (Right) standard deviation of the accumulated precipitation (mm)

(1) Meso-NH ensemble mean reproduces reasonably the rainfall pattern and its intensity. Good location of the maximum located on North-West Algeria but northward shift of the one observed on Algiers
(2) Standard deviation of 12-accumulated rainfall underlines the large dispersion of the precipitation forecast along North Algerian coasts. The 900-hPa geopotential height spread (not shown) confirms the high-correlation between the low-level Cyclone position and the rainfall pattern

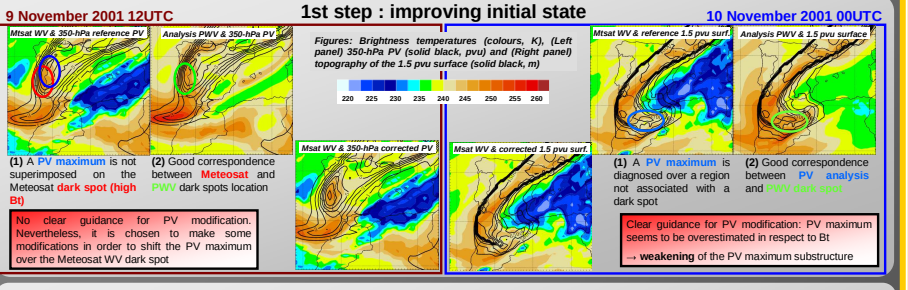
Throughout its influence on the cyclogenesis development, the PV anomaly seems to control the position of Algiers precipitation maximum

4. "Objective" modifications of initial conditions

Experimental design: We focus the study on short range and very-short range forecasting. ARPEGE analysis of 9 November 12 UTC and 10 November 00 UTC are used as reference analysis for PV – WV – PWV comparisons

1st step : improving initial state

9 November 2001 12UTC — **10 November 2001 00UTC**



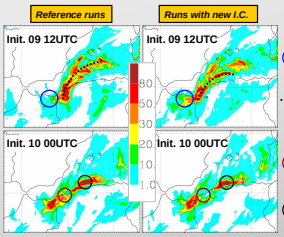
(1) A **PV maximum** is not superimposed on the Meteosat **dark spot (high Bt)** **(2)** Good correspondence between **Meteosat** and **PWV** dark spots location

No clear guidance for PV modification. Nevertheless, it is chosen to make some modifications in order to shift the PV maximum over the Meteosat WV dark spot

(1) A **PV maximum** is diagnosed over a region not associated with a dark spot **(2)** Good correspondence between **PV analysis** and **PWV dark spot**

Clear guidance for PV modification: PV maximum seems to be overestimated in respect to Bt
→ **weakening** of the PV maximum substructure

2nd step : evaluation on precipitation forecast



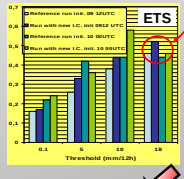
Results at 10-km resolution: 6h-accumulated precipitation (mm) from 10 November 2001 06 to 12UTC for (Left) reference runs and (Right) runs with modified initial state

Differences between new I.C. and reference runs

- Increase of convection, more realistic rainfall
  Deviation of the surface cyclone trajectory, the precipitation pattern is closer to the coast offshore Algiers
- Decrease of rainfall, degradation of the precipitation forecast
  Displacement of the heavy rain core (of about 50 km) almost on Algiers

Because of the limited number of available data, statistical results have to be considered carefully

Statistical results at 10-km resolution: 6h-accumulated rainfall - 10 November 2001 06UTC to 12UTC



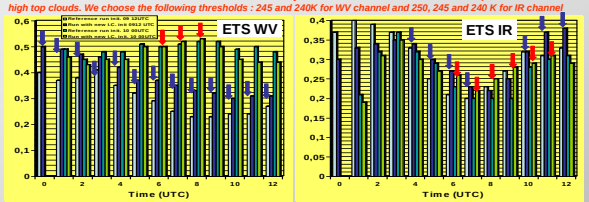
Runs initialized on 10 November 00UTC have smaller scores than those initialized at 9 November 12UTC probably because of an underestimation of coastal rainfall between Algiers and Morocco

Runs	Ref.	Modif.	Ref.	Modif.
Init. (Day-hour)	9-12	9-12	10-00	10-00
Correlation	0.45	0.49	0.49	0.55
Slope	0.37	0.33	0.38	0.33
RMS	8.4	7.7	7.9	7.2
Bias	-0.16	-0.3	-0.18	-0.45

The latter the forecast start, the better it is. It is also shown that modifications of I.C. lead to a better forecast in each experiment

3rd step : evaluation via model to satellite approach

The calculation of mean ETS is established to assess the ability of different runs to simulate the stratospheric intrusion and high top clouds. We choose the following thresholds : 245 and 240K for WV channel and 250, 245 and 240 K for IR channel



Statistical results at 10-km resolution based on model to satellite approach : (upper panel, yellow background figures) Mean Equitable Threat Score. Arrows denote times when runs with modified I.C. have greater score than reference runs (blue and red for runs initialized on 9 Nov. 12 UTC and 10 Nov. 00 UTC respectively) ; (Right panel, tables) Continuous scores averaged on 10 Nov. 2001 over different periods (red and blue for WV and IR channel respectively)

Runs initialized on 9 November 2001 12UTC

Period (10 Nov.)	00 to 06UTC	06 to12UTC
Correlation Ref.	0.78 (0.60)	0.74 (0.58)
Correlation Modif.	0.79 (0.63)	0.74 (0.56)
Slope Ref.	0.77 (0.58)	0.78 (0.54)
Slope Modif.	0.80 (0.58)	0.81 (0.53)

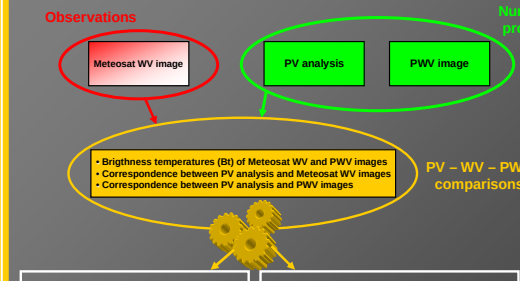
Runs initialized on 10 November 2001 00UTC

Period (10 Nov.)	01 to 07UTC	06 to12UTC
Correlation Ref.	0.78 (0.59)	0.74 (0.53)
Correlation Modif.	0.78 (0.60)	0.74 (0.53)
Slope Ref.	0.79 (0.58)	0.81 (0.52)
Slope Modif.	0.80 (0.58)	0.82 (0.53)

Modifications introduced in initial conditions have a positive impact over the critical period of 10 November from 06 to 12UTC, suggesting a better position of cloud systems associated with rainfall. New forecast starting from 9 November 2001 12UTC involves a greatest improvement of clouds simulation than the one initialized on 10 November 00UTC

3. Correction procedure

Idea: As the precipitation forecast exhibits sensitivity to the upper-level dynamical structures and a wrong location of the heavy rain core close to Algiers, it is decided to use a correction method of the initial state provided to Meso-NH. The technique is based on comparison of some related-PV fields (e.g. 350-hPa PV and topography of the dynamical tropopause), Meteosat WV imagery and pseudo WV (PWV) images (derived from a radiative transfert code (RTTOV) coupled with the model) in order to correct upper-level dynamics by PV modifications



Any clear mismatch between observation and numerical outputs

Clear instance of mismatch between observation and numerical outputs : sign of model error
→ Adjustment of the initial state with local PV modifications

forecast errors may arise from model parameterizations or other fields not taken into account in WV imagery processing…

New Meso-NH run initialized with modified analysis

Conclusion & Perspectives

The first objective of this study was to objectively assess the influence of upper-level dynamical structures on the intensity and distribution of rainfall over North Africa during the 10 November 2001 morning. Experiments revealed that precipitation pattern, at synoptic- and meso- scale, was strongly related to the upper-level PV anomaly throughout its interaction with the low-level trough position. As any of the ensemble members used was able to reproduce intense rainfall over Algiers, it was decided to focus our attention on the initial state provided to Meso-NH using the link existing between Meteosat WV imagery and positive PV anomalies. Therefore, starting from two analysis at different time, two new initial states were built by making PV corrections and served as initial conditions for new Meso-NH runs. Qualitative and quantitative evaluations showed a good improvement of the precipitation forecast, mainly due to a better cyclone trajectory prediction. This result also appears when the model to satellite approach is used, the greatest improvement being done for forecast initialized on 9 November 2001 12UTC.

The sensitivity study presented was able to provide some ideas to assess predictability of this Mediterranean rainstorm. However, a more consistent initialization method and more case-studies are needed to optimally use the PV inversion method in the framework of an ensemble strategy. The use of WV imagery to validate initial conditions provided to numerical weather prediction models (currently used at Météo-France) has proven its utility in this particular case-study for rainfall prediction at the mesoscale. Nevertheless, a question remains: which one of, the probabilistic or the deterministic approach, is the more useful when applied to severe weather in the Mediterranean area? This question is currently studied.

2nd THORPEX International Science Symposium, 4-8 December 2006, Landshut, Germany