Dynamical Contribution of Mean Potential Vorticity pseudo-observations derived from MetOp/GOME2 Ozone data into weather forecast, a Mediterranean High Precipitation Event study

Siham Sbii[1,2]*, Mimoun Zazoui[1], Noureddine Semane[2]
[1]University of Hassan II Mohammedia, Faculty of sciences and techniques, Laboratory of condensed matter, Renewable Energy, Mohammedia, Morocco
[2]National Center for Meteorological Research, National Meteorological Service, Casablanca, Morocco
*Corresponding author E-mail:sihamsbii@gmail.com

Introduction

In the absence of observations covering the upper troposphere - lower stratosphere, headquarters of several disturbances, and knowing that satellites are uniquely capable of providing uniform data coverage globally, a methodology is developed to convert Total Column Ozone, observed by MetOp/GOME2, into pseudo-observations of Mean Potential Vorticity (MPV). The aim is to assess the dynamical behavior of the short range forecast at upper levels during a Mediterranean Heavy Precipitation Event observed during 28-29 September 2012 in the context of HYMEX.

Methodology

•Ozone data

The Global Ozone Monitoring Experiment-2 (GOME-2) is one of the European instruments carried on MetOp. It is a scanning spectrometer that captures light reflected from the Earth's surface and atmosphere. The measured spectra are mainly used to derive ozone total column (TCO) and other trace gases, as well as cloud properties and aerosols.

Throughout the study, the ozone data used correspond to the GOME-2 observed between 09h and 15h which corresponds to the ALADIN-Morocco operational assimilation window.

•Experiment setup

The simulations are based on the operational Moroccan version of ALADIN, running on 10km horizontal resolution and 60 vertical levels. ALADIN is a limited-area spectral model that uses lateral boundary conditions from the global model ARPEGE/IFS. The version used in this study has its own data assimilation system, based on a 3D-Var scheme with an incremental formulation.

The first guess at 12h00 UTC is a 6-hour forecast from the previous assimilation cycle.

•Mean Potential Vorticity Formulation

The proposed approach [1] of assimilating MPV in a 3D-Var framework is based on a linear regression between Ozone from MetOp/GOME2 and vertical integrated Ertel PV [2] . The PV computation utilizes ALADIN-Morocco dynamical fields based on the following formulation:

$$PV = -g\zeta_a \frac{\partial\theta}{\partial P} - g\frac{fP}{R}\left(\frac{P_0}{P}\right)^{R/C_p}\left[\left(\frac{\partial u}{\partial P}\right)^2 + \left(\frac{\partial v}{\partial P}\right)^2\right]$$

Where: g the gravity, ζ_a the vertical component of the absolute vorticity, u,v the horizontal wind components, ϑ The potential temperature, R = gas constant, P the pressure , P_0 = a reference pressure, C_p specific heat at constant pressure and f Coriolis parameter.

Then the MPV is estimated, by an integration of the PV between the levels P1=500hPa et P2=100hPa using the following expression:

$$MPV = \int_{P_1}^{P_2} PV.dP$$

•Correlation between MPV and O3

The linear regression model that links TCO and MPV is given by :

$$MPV = \alpha * 10^{-2} * O_3 - \beta$$

Given the fact this equation is found to be monthly dependent [1], the MPV pseudo-observations are computed using different equations depending on the studied events .

For the present High Precipitation Event study , the link is as follows

$$MPV = 5.31*10^{-2} * O_3 - 13.44$$

with a correlation coefficient about 0,8265

- **Coding the Foreward, Tangent-linear and Adjoin MPV Code in the 3D-Var Framework**

1. Forward code:

If we consider the following variables:

MPV_n the vertical mean PV from level 1 to level n
MPV_{n-1} the vertical mean PV from level 1 to level n-1
PV_n the PV at level n
ΔP_n the pressure difference between level n and level n-1

The expression of the Vertical Mean PV at level n is :

$$MPV_n = MPV_{n-1} + \Delta P_n * PV_n$$

2. Tangent linear code:

The tangent linear operator is $\delta MPV_n = \delta MPV_{n-1} + \Delta P_n * \delta PV_n + PV_n * \delta\Delta P_n$

If expressed in matrix form

$$\begin{bmatrix} \delta PV_n \\ \delta\Delta P_n \\ \delta MPV_{n-1} \\ \delta MPV_n \end{bmatrix} = \underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \Delta P_n{}^5 & PV_n{}^5 & 1 & 0 \end{bmatrix}}_{P} * \begin{bmatrix} \delta PV_n \\ \delta\Delta P_n \\ \delta MPV_{n-1} \\ \delta MPV_n \end{bmatrix}$$

3.Adjoint code:

$$\begin{bmatrix} \delta PV_n^* \\ \delta\Delta P_n^* \\ \delta MPV_{n-1}^* \\ \delta MPV_n^* \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & \Delta P_n{}^5 \\ 0 & 1 & 0 & PV_n{}^5 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} * \begin{bmatrix} \delta PV_n^* \\ \delta\Delta P_n^* \\ \delta MPV_{n-1}^* \\ \delta MPV_n^* \end{bmatrix}$$

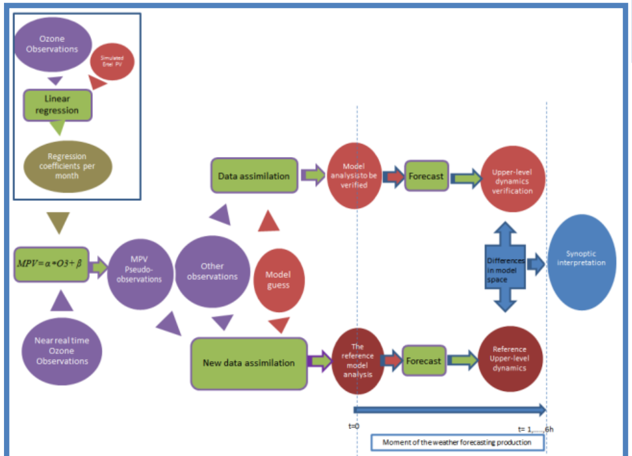
The corresponding adjoint operator is:

$$\delta PV_n^* = \delta PV_n^* + \Delta P_n{}^5 * \delta MPV_n^*$$
$$\delta\Delta P_n^* = \delta\Delta P_n^* + PV_n{}^5 * \delta MPV_n^*$$
$$\delta MPV_{n-1}^* = \delta MPV_{n-1}^* + \delta MPV_n^*$$

The use of the developed framework to internally monitor the short-range model dynamics behavior in upper levels

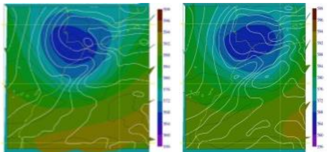
•Design and Development

In addition to the traditionall use of the visual comparison of the PV anomalies to Water Vapor Satellite images, we have developed, as described in the following scheme, a valuable tool to internally monitor upper-level dynamics.



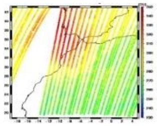
- **Validation of the tool during a Mediterranean High Precipitation Event**

This studied event corresponds to the Special Observation Period n°1 of the Hymex Program. The event is characterized by a cut-off low, which was first centered on the South West of the Iberian Peninsula on 28th September 2012, then moved towards the North East.



Geopotential height (shaded) and temperature (dashed lines) at 500hPa together with mean sea level pressure (solid lines) on 28/09/2012 at 12UTC (left) and 18UTC (right) from ECMWF analysis.

Regarding the O3 distribution, a pronounced cell is localized over Spain and the North West of Morocco.

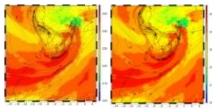


GOME2 Total Column Ozone observed on the 28th September 2012 between 09UTC and 15UTC.

The first experiment (CTL) has as initial condition a 3D-Var analysis of conventional data, and the second (NEW) incorporates MPV data in addition to those of the first experiment.

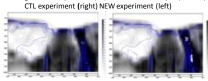
Results

Regarding the Water Vapor images from MSG (independent observations), the CTL experiment shows an excellent agreement between the PV anomaly and warm areas in WV distribution.



3-h forecasted of geopotential height (lines) on 1.5PVU superposed on MSG brightness temperature (°K) in WV Chanel 6.2 µm (shaded). CTL experiment (right) NEW experiment (left)

Cross-section maps of relative humidity and PV along the axis of the anomaly displacement confirm the space-time evolution agreement between CTL and NEW



Cross-section of 3-h forecasted of PV (lines) superposed on Relative Humidity (shaded). CTL experiment (right) NEW experiment (left)

Conclusion

After a successful assimilation of MPV pseudo-observations using a 3D-Var approach within the Moroccan version of the ALADIN limited-area model, the present study confirms that MPV assimilation offers the possibility to internally monitor the model upper-level dynamics in addition to the use of Water Vapor Satellite images during High Precipitation Events.

Acknowledgement

We are grateful to Dr. Yann Michel, Dr. Philippe Arbogast, Dr. Peter Knipetrz for offering advice in the beginning of this work. Also, we acknowledge Meteo-France and the HyMeX program for supplying the data, sponsored by Grants MISTRALS/HyMeX and ANR-11-BS56-0005 IODA-MED project.

References

[1] Sbii, S. Zazoui, M., Semane, N., Michel., Y. and Arbogast, P., "Exploring the Potential Application of MetOp/GOME2 Ozone Data to Weather Analysis", International Journal of Computer Science Issue, Vol. 10 (2013), Issue 2, No 3, 260-263.
[2] Guerin, R., Desroziers, G. and Arbogast, P.(2006), 4D-Var analysis of potential vorticity pseudo-bservations. Q.J.R. Meteorol. Soc., 132:1283–1298.