Rossby wave interactions with Mediterranean and subtropical latitudes

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1. Abstract:

The downstream influence of a Rossby wave on weather conditions in the Mediterranean and North Africa is studied.

The objective is to gain a better understanding of the atmospheric processes in these regions and to improve their quantification. The emphasis is placed on high-impact weather events to improve numerical forecasts and warnings about these hazardous weather phenomena.

For this purpose, 4 days from 5 to 8 February 1997 are used to investigate both a Mediterranean low and a subtropical African convective situation. Sensitivity studies, using a potential vorticity inversion tool associated with the French atmospheric model ARPEGE, are presented.

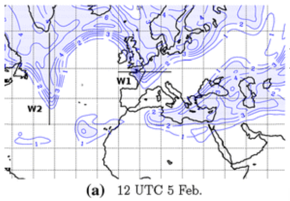
The Mediterranean surface low under study is shown to be associated with the mid-latitude upper level potential vorticity anomaly, itself associated with a Rossby wave. A subtropical convective cell is shown to be related to upward vertical motions associated with a cut-off low; this cut-off low coming from a mid-latitude Rossby wave.

2. Methodology:

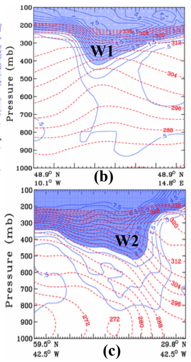
PV inversion technique is based on the PV invertibility principle (Hoskins et al. 1985) and was initially proposed by Davis and Emanuel (1991).
The spectral operational model ARPEGE (Action de Recherche Petite Echelle et Grande Echelle) (see Courtier et al. 1991 for more details) is run with T95 spectral resolution (which corresponds to about two degrees in the North Atlantic) and 27 vertical levels. All plots presented hereafter use this resolution.

Hereafter, an experiment in which some PV is removed or modified will be called a ''modified'' experiment. The PV inversion tool was implemented using the following strategy. Two simulations were performed with identical model tuning except for the initial conditions. The initial conditions for the first simulation (reference) were standard ARPEGE reanalyses. Initial conditions for the second simulation were obtained from a PV surgery method following Chaigne and Arbogast (2000). PV surgery was performed in three steps. First, the ARPEGE reanalyses were examined to locate subjectively interesting PV structures. Second, these identified structures were removed. Finally, the PV inversion tool was used to retrieve modified velocity and temperature fields corresponding to the modified PV field.

3. Figure 1: Analyses for 5 February 1200 UTC 1997



(a): 300 hPa PV reanalyses (every 1 pvu, shaded from 2 pvu). Bold lines correspond to the locations of Figs. 1b and 1c.

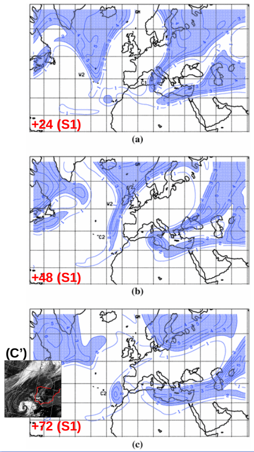


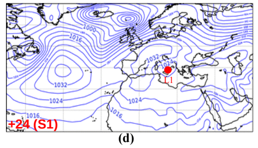
(b), (c): Vertical sections of PV (solid lines, shaded from 2 pvu, every 0.5 pvu) and potential temperature (dashed lines, every 4 K, up to 340 K) for 5 February 1200 UTC.

2 main characteristics can be seen in Fig. 1:
2 waves (W1 & W2) at mid-latitude; an approximately zonal structure more or less stretched to the south.

The mid-latitude wave propagates eastwards. The zonal elongated structure is located at the cyclonic-shear side of the subtropical jet.

4. Figure 2: Reference simulation (S1) initialized on 5 February 1200 UTC





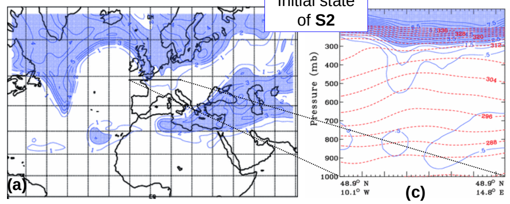
(a), (b), (c): 300 hPa PV (every 1 pvu, shaded from 2 pvu) for the (a) 24-h, (b) 48-h and (c) 72-h reference simulation (S1) initialized on 5 February 1200 UTC valid, respectively, on 6 February 1200 UTC, 7 February 1200 UTC and 8 February 1200 UTC. W1, W2 tips of main waves, C1, C2 corresponding cut-off lows. (c'): AVHRR longwave cloud image at 1437 UTC on 8 February.

(d): Mean sea level pressure (every 4 hPa) for the 24-h reference simulation (S1) valid on 6 February 1200 UTC. The red dot corresponds to the Mediterranean Low (L1).

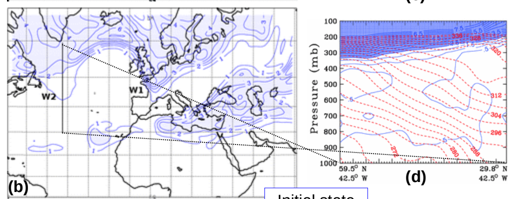
The ARPEGE reference simulation is in good agreement with the reanalyses.
W2 seems to be transformed in the C2 cut-off low.
The intense PV maximum C1 seems to have its origin in W1.
Is the surface low L1 coupled to C1 by barocline interaction mechanism?
Is C2 (and the associated cloud) coupled to W2?

5. Figure 3: Modified analyse for 5 February 1200 UTC

Initial state of **S2**



(c), (d): Vertical sections of PV (solid lines, shaded from 2 pvu, every 0.5 pvu) and potential temperature (dashed lines, every 4 K, up to 340 K).

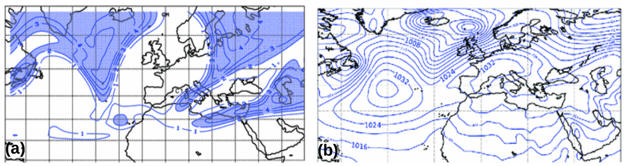


Initial state of **S3**

(a), (b): 300 hPa PV (every 1 pvu, shaded from 2 pvu).

Fig. 3 presents the modified initial state for 2 sensitivity tests. Using the PV inversion tool, we remove W1 and W2 (as seen when comparing Fig. 3 and Fig. 1).

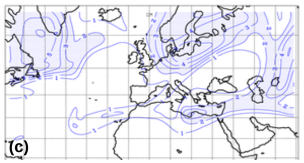
6. Figure 4: 24-h modified simulation (S2)



(a): 300 hPa PV (every 1 pvu, shaded from 2 pvu) valid on 6 February 1200 UTC.

(b): Mean sea level pressure (every 4 hPa) valid on 6 February 1200 UTC.

Figure 5: 72-h modified simulation (S3)



(c): 300 hPa PV (every 1 pvu, shaded from 2 pvu) valid on 8 February 1200 UTC.

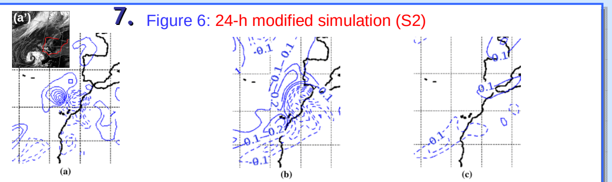
When comparing S1 and S2 for the 24-h simulation of 300 hPa PV (Figs. 2a and 4a, respectively), we can see there is no modification in location but C1 is lower in S2 (3 pvu) than in S1 (5 pvu).

The consequence for cyclogenesis is the non-formation of the closed Mediterranean low (L1) east of Sardinia in the modified forecast S2 (Fig. 4b compared to Fig. 2d).

When comparing S1 and S3 for the 72-h simulation of 300 hPa PV (Figs. 2c and 4c, respectively), we note there is no interaction between W2 and C2. Unlike for S1, C2 is not reinforced in S3.

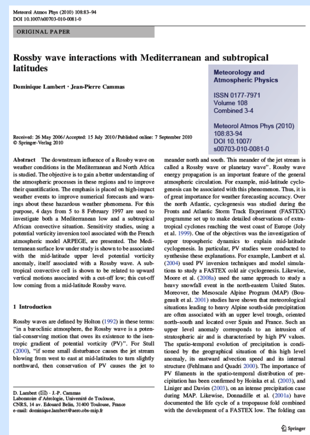
This sensitivity study shows a coupling between the mid-latitude Rossby wave and the subtropical latitude cut-off low.

7. Figure 6: 24-h modified simulation (S2)



500 hPa total ''AB'' vertical velocity (Pa s^{-1}, every 0.1 Pa s^{-1}) on 8 February 1200 UTC. Upward motion in dashed lines and downward motion in solid lines. (a) Reanalysis, (a') AVHRR longwave cloud image at 1437 UTC on 8 February(b), (c) the 72-h reference (S1) and ''modified'' (S3) simulations, respectively, valid on 8 February 1200 UTC

The cyclonic shape of the cloud structure shown by the satellite image at about midday on 8 February 1997 (Fig. 6a') suggests the presence of a surface low associated with convective cells. These convective cells are characterised by intense ascending motion.
These two cores form a vertical motion dipole which could be associated with the cut-off low C2 (characterised by 1 pvu isoline reaching 650 hPa, not shown) with ascending motion downwind and subsiding motion upwind of the cutoff low.
The ascending pole is co-located with convective clouds.
The dipole is well shown for S1 (Fig. 6b) whereas it is not present for S3 (Fig. 6c).
The combined use of the vertical velocity diagnostics and the sensitivity test with the inversion tool shows the vertical wind dipole associated with a cut-off low. The mid-latitude Rossby wave breaking makes the environment favourable to the subtropical convective cell.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ORIGINAL PAPER

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