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Synoptic-scale variability in the Mediterranean

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ECMWF
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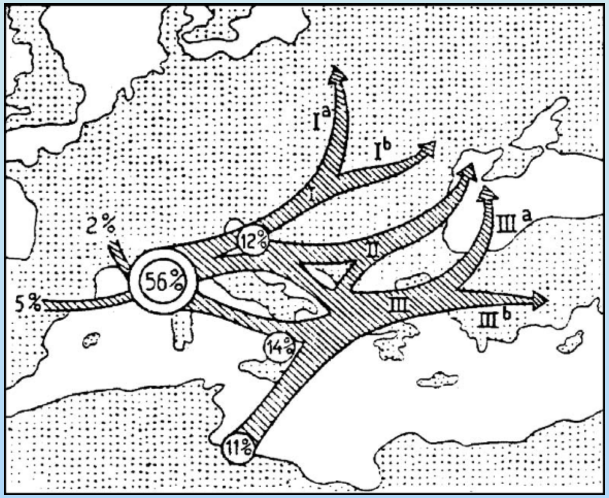
Outline →

- Mediterranean cyclogenesis and orographic cyclogenesis.
- Simple statistical properties of high-frequency "eddies" (baroclinic/Rossby waves) in the Mediterranean - "slave" of the Atlantic storm track or active on its own?
- Mediterranean cyclogenesis and cyclone life: a quick review of some observational and theoretical elements about mechanisms/processes.
- Mesoscale (β, γ) variability strictly related in the Mediterranean to the synoptic scale and possibly associated with high-impact weather: convection, symmetric instability, orographic rain, strong local winds...
- Hint on a typical though not frequent phenomenon: tropical-like Mediterranean cyclones (*Medicanes*).
- Observational project perspective (MEDEX, HYMEX...).
- Summary and conclusions

Recall Mediterranean topography: mainly west to east

The notion that frequency of cyclogenesis has peaks over the Mediterranean goes back at least to 1950-1960: Pisarski, 1955; Petterssen (1956), UK Met. Office, 1956, Radinovic (1965): all made by drawing manually synoptic charts and counting cyclones!

Pisarski, 1955



Petterssen, 1956

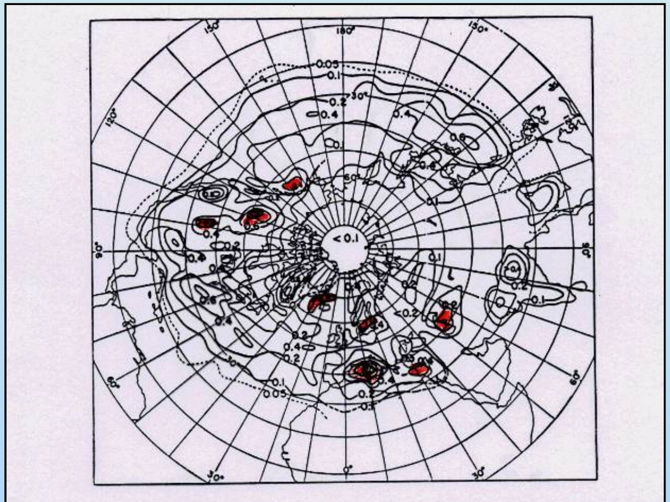
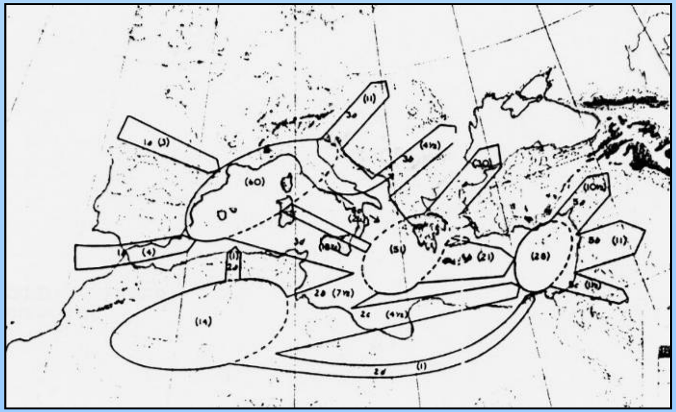


Fig. 1 Percentage frequency of cyclogenesis in squares of 100,000 km^2 in winter (Petterssen, 1956).

UK Met. Office, 1956



Radinovic, 1956

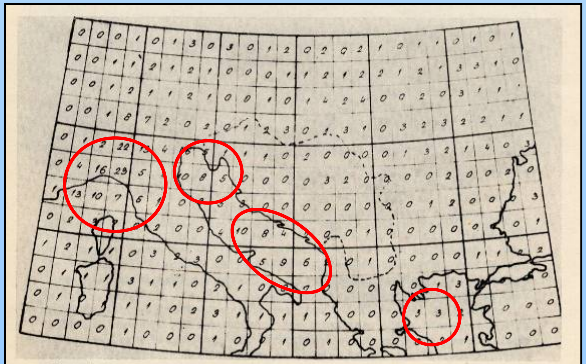
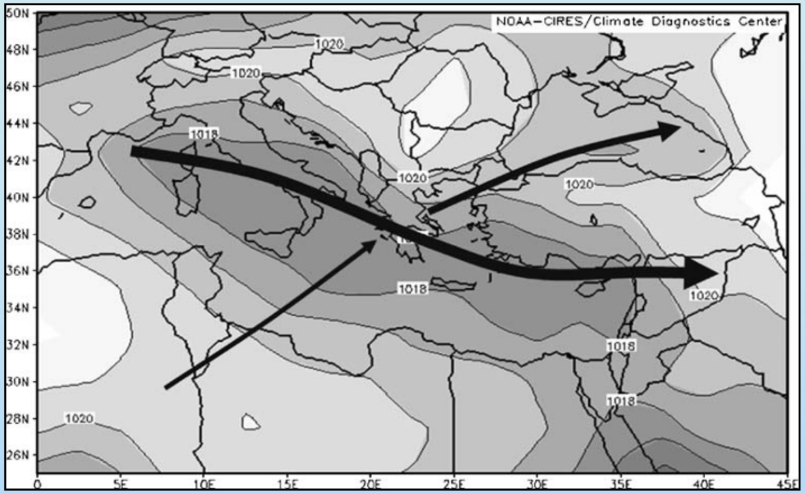
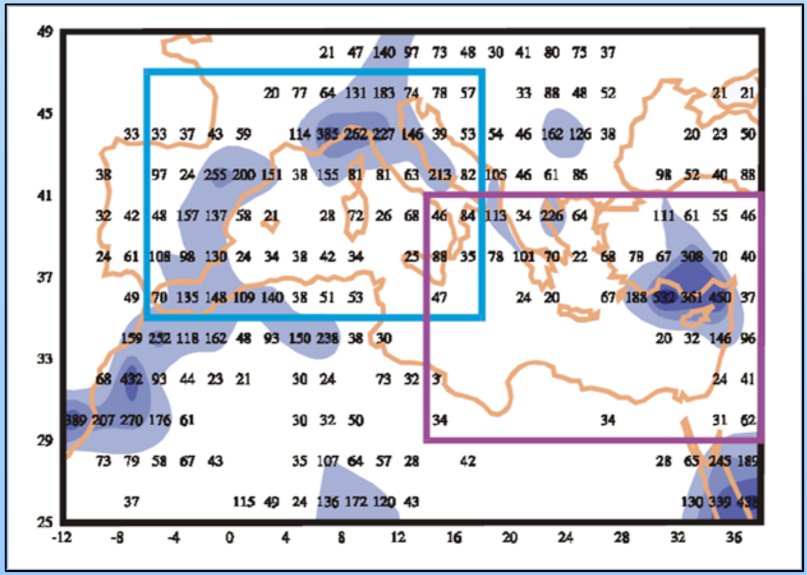


Fig. 11. Number of cyclones with intensity $20 < \nabla^2 p \leq 40$ mb/(500 km)^2 and positions of their centers at the time of the maximum development

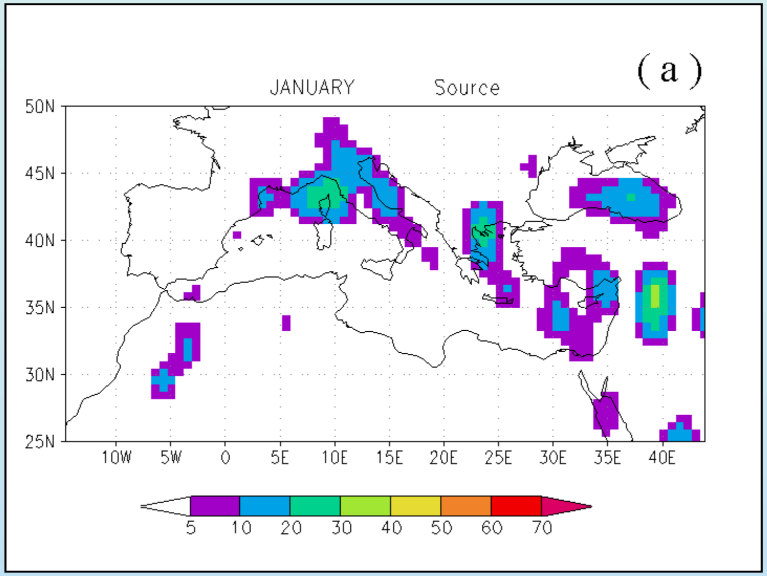
More recent climatological studies, taking advantage of the availability of reanalyses: frequency of cyclones, cyclogenesis and Mediterranean storm tracks

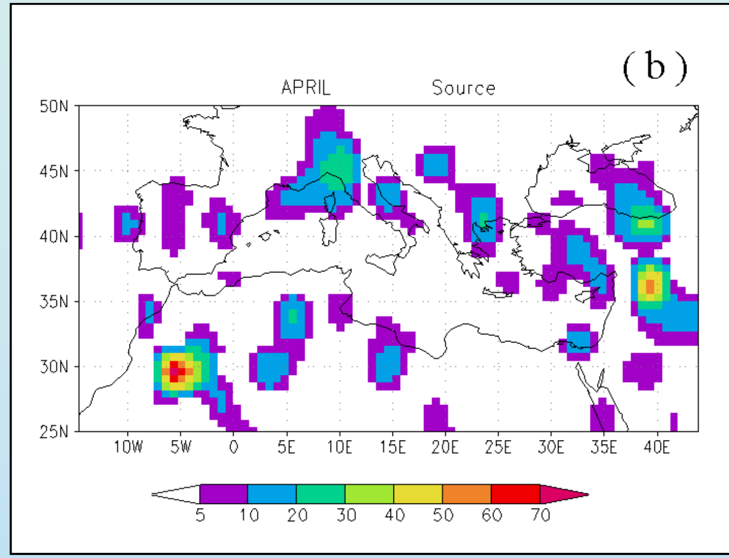


Ziv et al., 2010: (NCAR/NCEP, Jan.) Winter cyclone tracks, represented by the long-term mean SLP for January (NCEP/NCAR reanalysis data). Arrows: main tracks, as inferred from the individual tracks for Jan. 1983–1988 (Alpert et al. 1990). Thickness proportional to the track population.

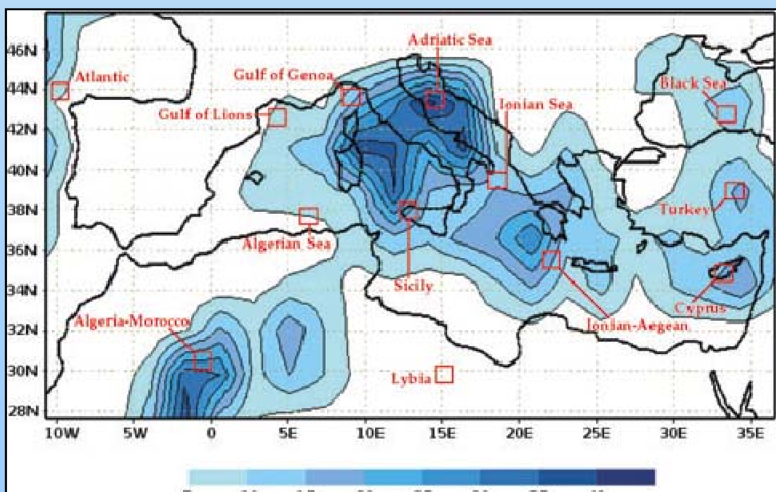


Gil et al, 2002: Number of cyclones, 3 year sample of ECMWF operational analyses (T319): 2248 cyclones detected in the East. Medit. and 2910 in the West. Med.).

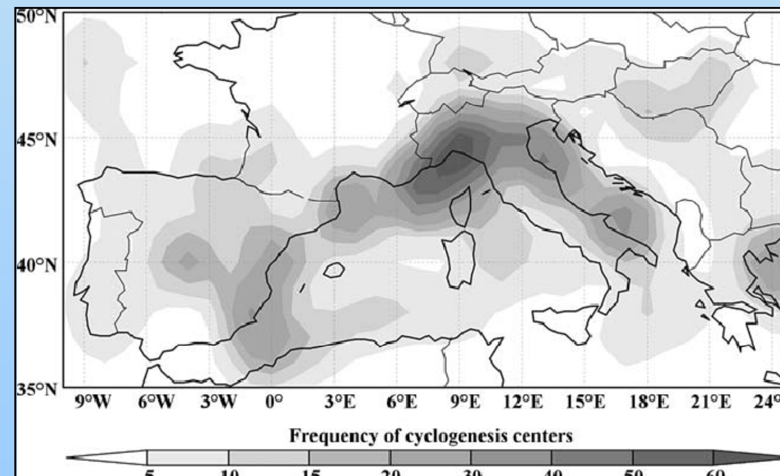




Trigo et al, 1999 and 2002: number of cyclogenesis events detected per 2.25° X 2.25° in January and April, from 1979 to 1996 in ECMWF re-analyses.

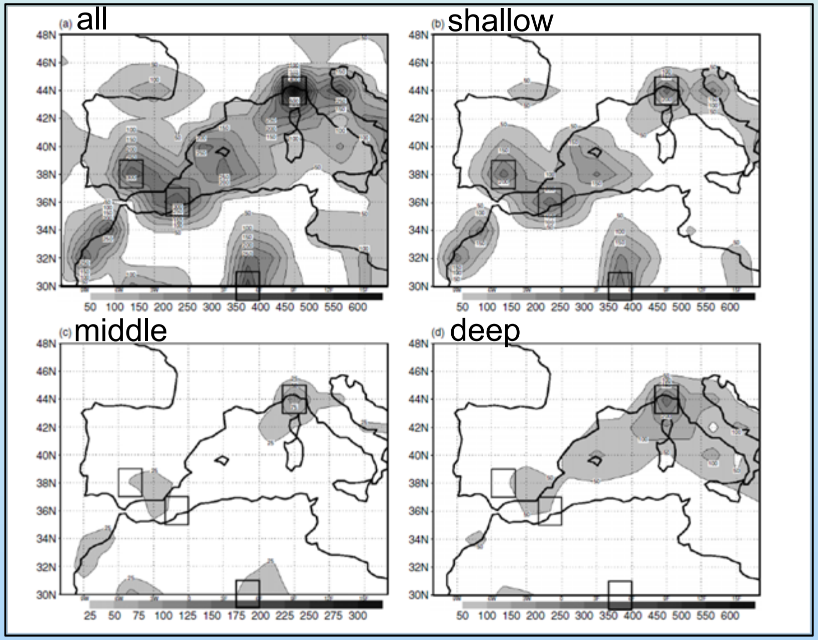


Homar et al., 2006: number of mature intense cyclones (ERA-40).

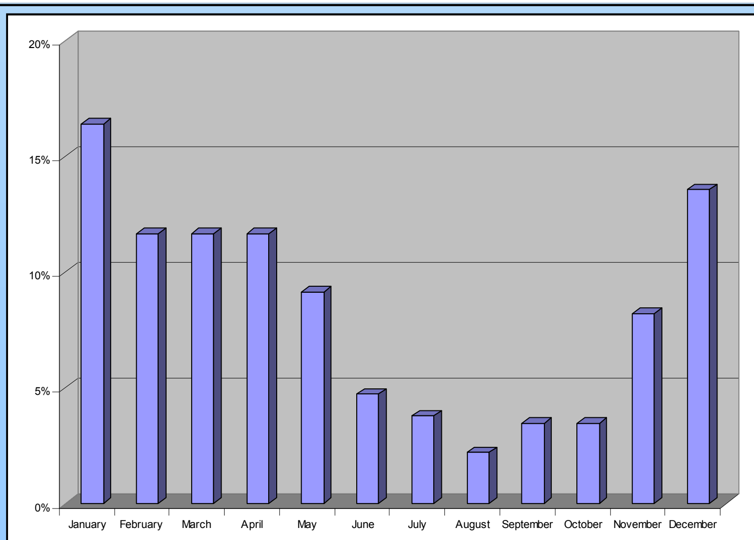


Bartholy et al, 2009: frequency of cyclogenesis, 1957-2002 all seasons (ERA-40)

Climatology of Mediterranean cyclones using the MEDEX project database

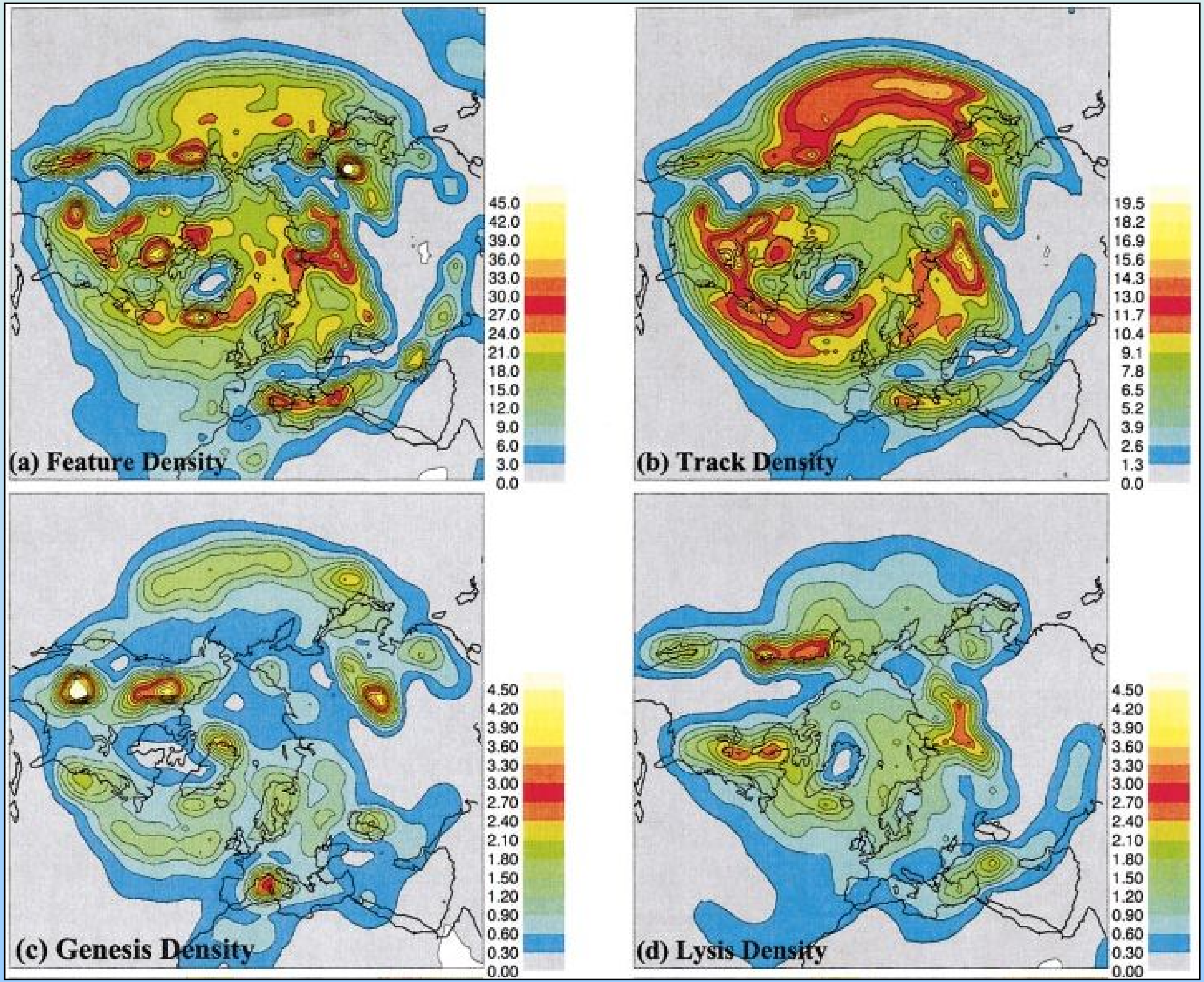


Campins et al, 2009: Total number of cyclone centres for (a) all the MEDEX database (1995-2003), (b) shallow, (c) middle-depth and (d) deep ones. Contour interval: 50 cyclone centres (25 for middle-depth centres).



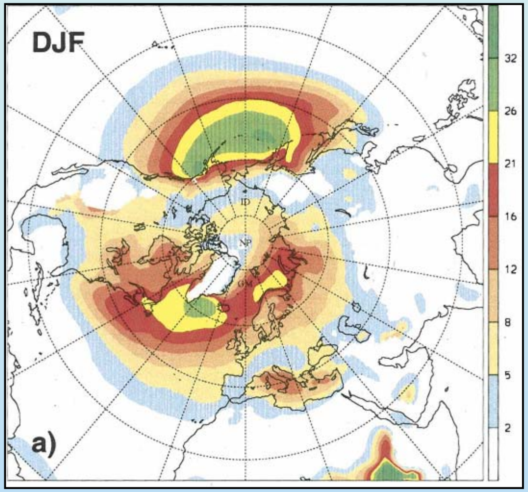
Campins et al, 2005: Monthly frequency of intense cyclones

... and characterizing storm tracks and cyclogenesis/ cyclolysis with features of positive vorticity centres, globally (ECMWF and NCEP reanalyses)

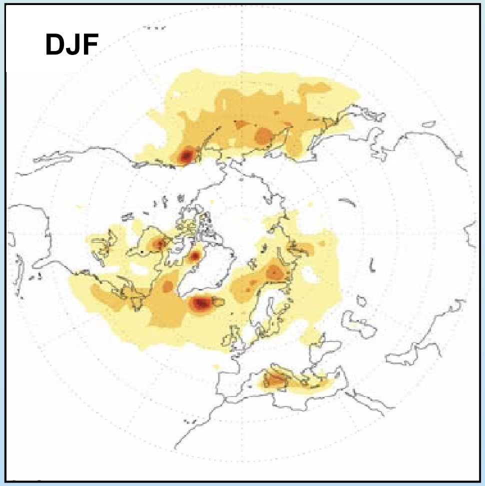


Tracking positive vorticity centres at 850 hPa – ERA40 (Hoskins and Hodges, 2002)

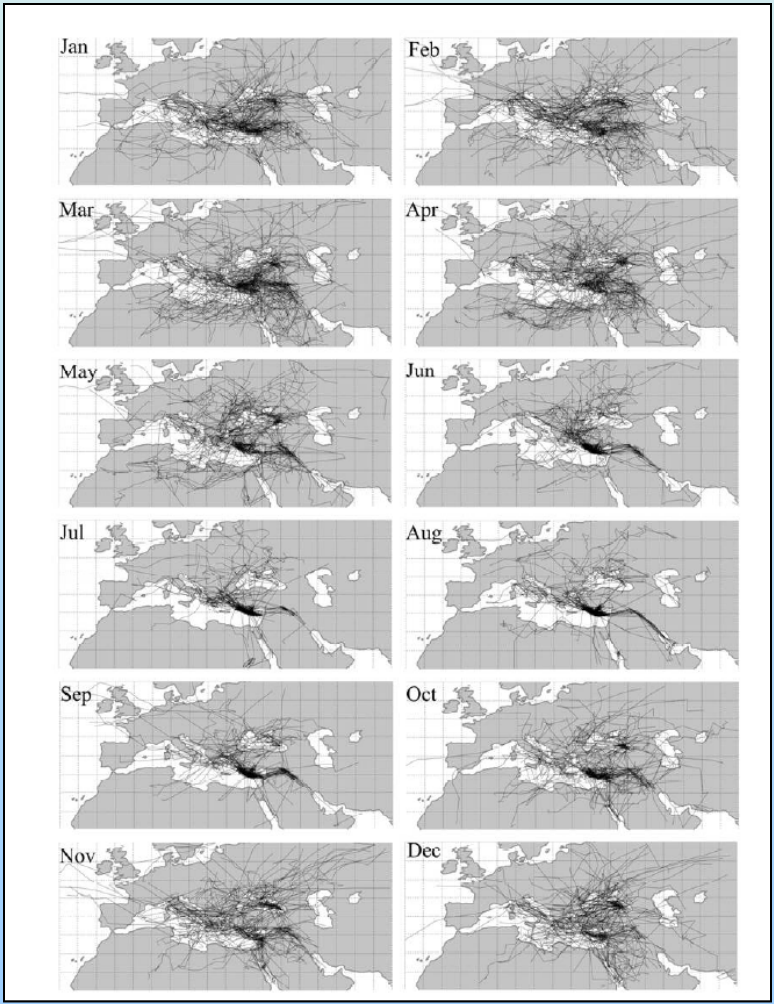
Even more recent examples of investigations of cyclone density and tracks in the Mediterranean, at different scales, from global to mesoscale



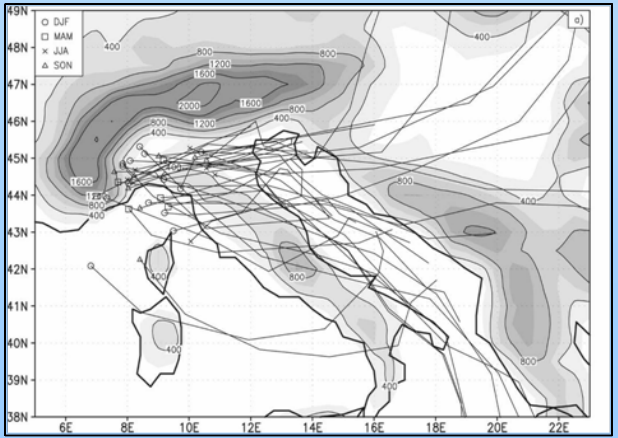
Wernli & Schwierz (2007): cyclone frequencies, ERA-40 (1958-2001).



Raible et al, 2008: cyclone center density exceeding a lifetime of 72 h, 1961–90 (ERA-40 & NCEP)



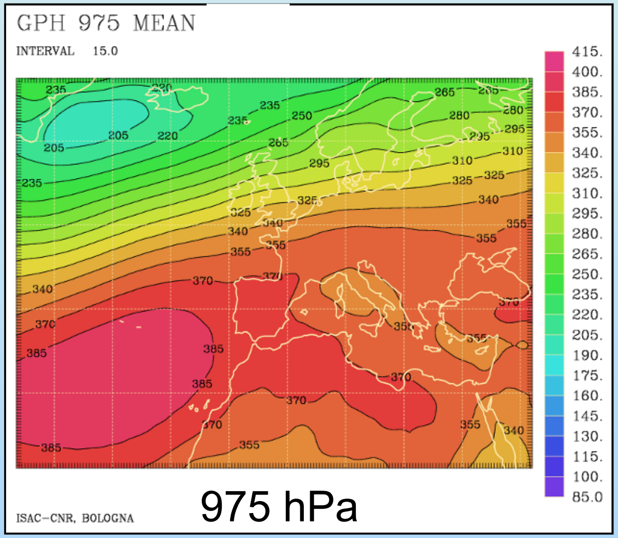
Flocas et al (2010): monthly analysis of cyclonic tracks passing over or originating in the Eastern Mediterranean (full life cycle).

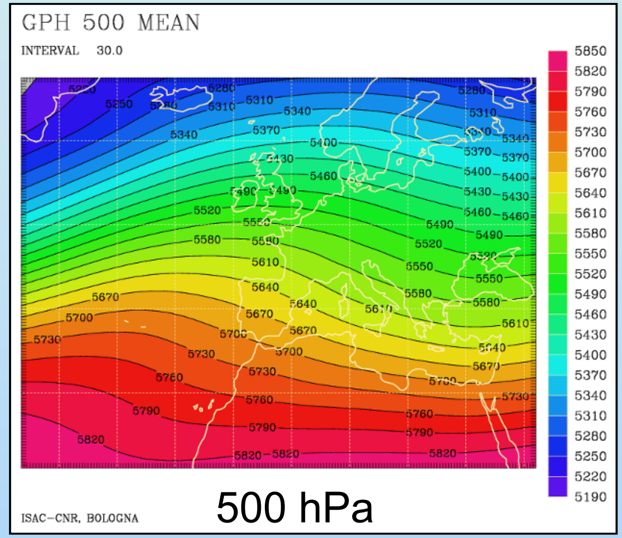


Horvath et al, 2010: trajectories of Genoa-type cyclones ("continuous").

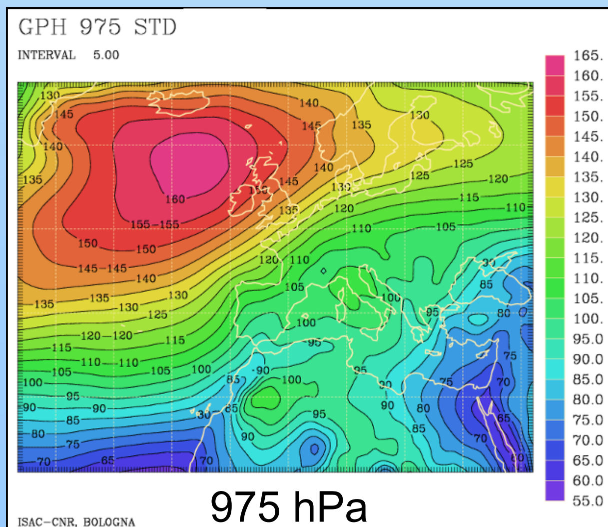
Elementary statistical properties synoptic variability in the high-frequency part of the spectrum (baroclinic/Rossby waves) in the Mediterranean: a revisit of earlier works (e.g. Buzzi & Tosi, 1988-89), dealing with orographic effects on cyclones

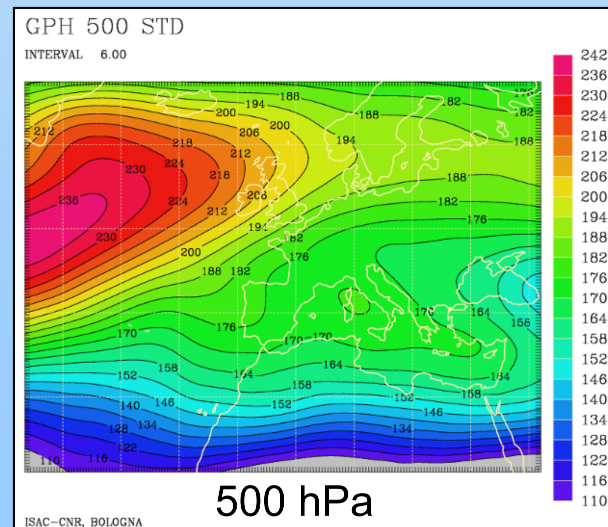
→ Dataset: ERA-Interim (1989-2009), using 20 "cold semesters" (October to April), 6-hourly data





Mean GPH (climatology)



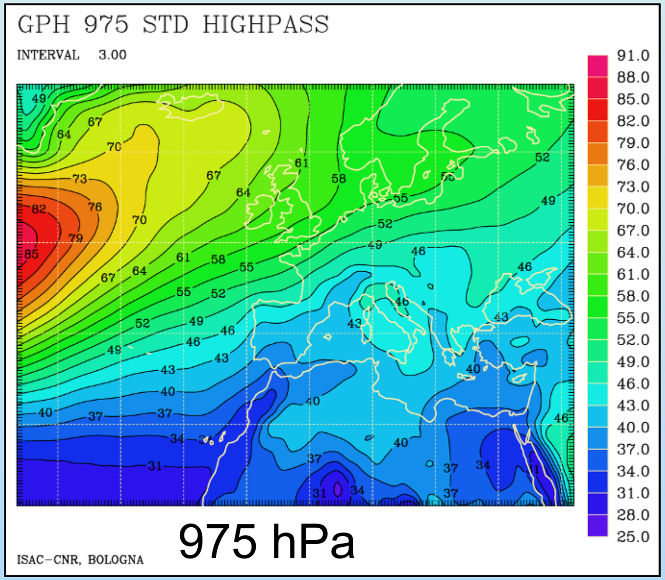


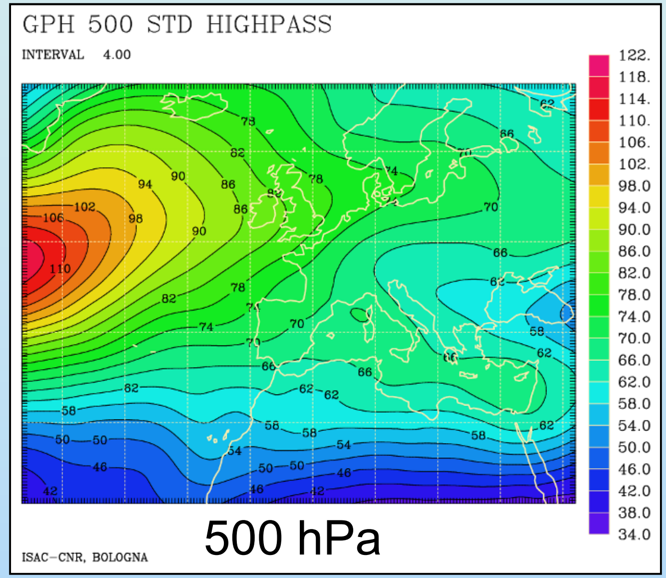
Standard deviation of GPH, divided by sin(φ)

Then a **high-pass filter is applied**, in order to preserve periods shorter than 8-9 days, defined here as "high frequency variability"

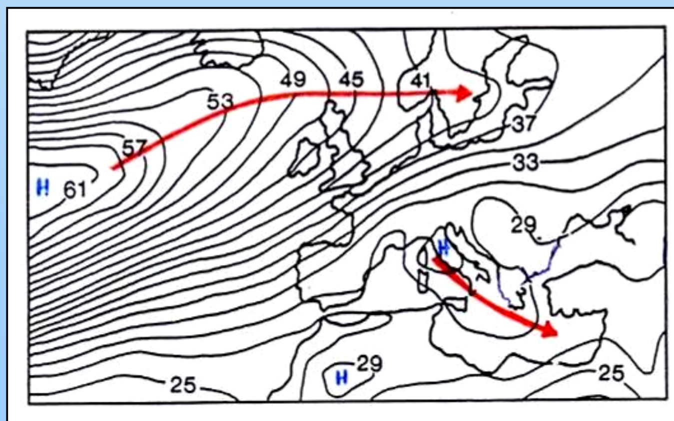
(cut-off values between 7 and 12 days do not imply sensibly different results)

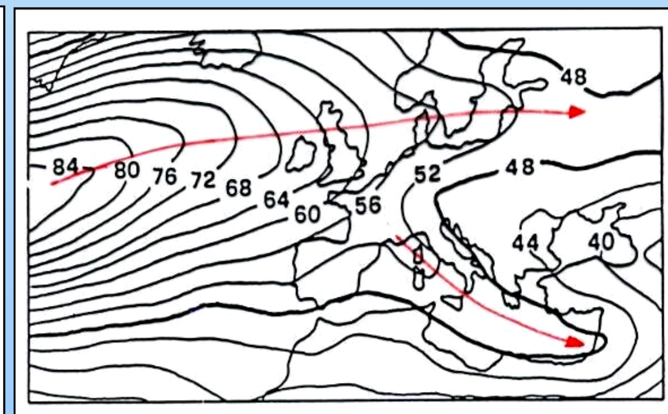
High-pass filtered standard deviation of GPH, (divided by sin(φ))





850 hPa





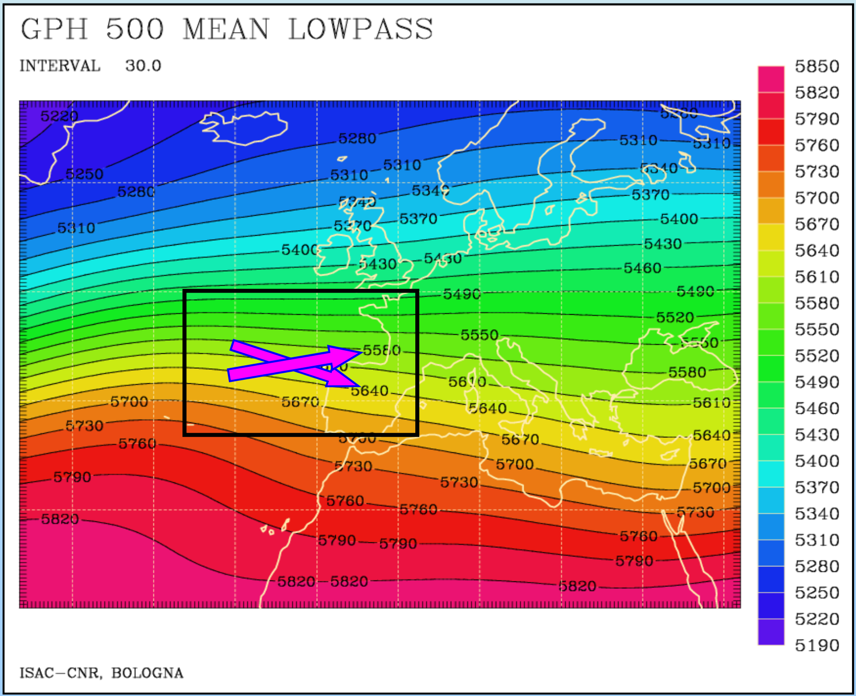
500 hPa

Comparison with older results (Buzzi & Tosi, 1989), based on the first 7-year ECMWF operational analysis (1979-1986, cold semester)

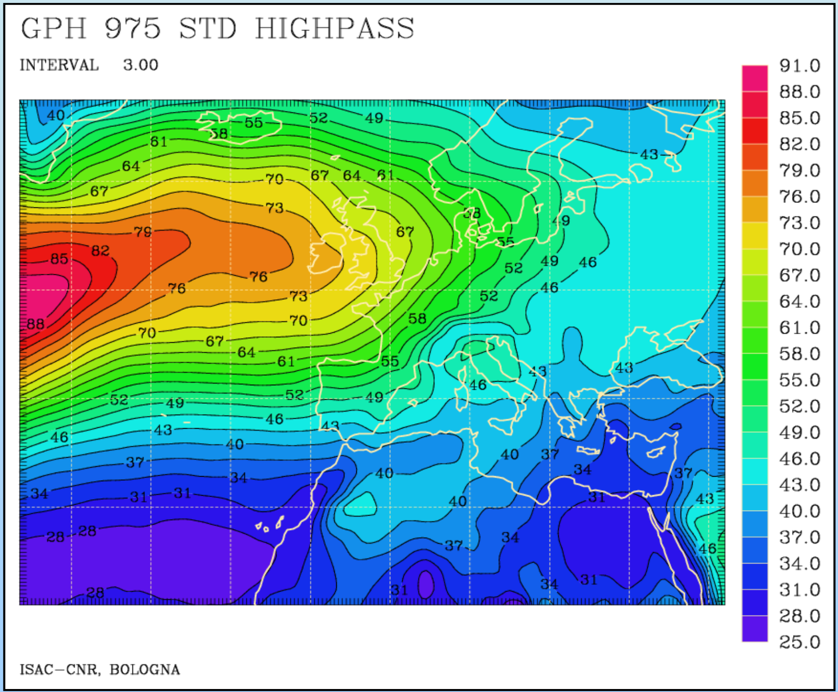
Selection criterion in order to focus synoptic-scale transients that enter the Mediterranean from the west:

• relatively low-latitude westerlies in the low-pass 500 hPa field, upstream over western Europe (within +- 30 deg.): *westerly regime.*

• about 25% of the total sample (Oct. to Apr.) is represented



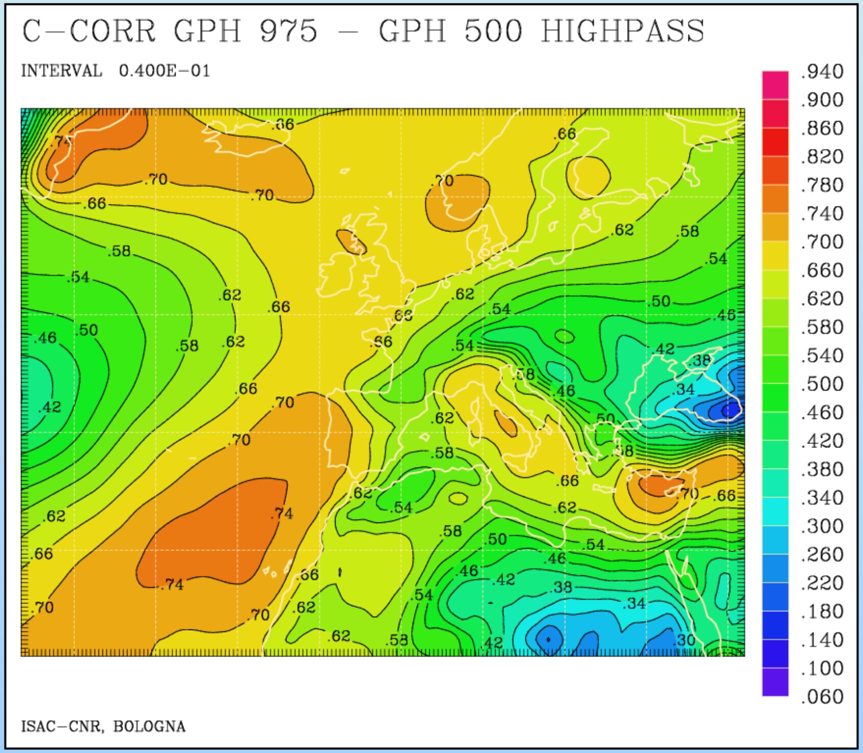
Mean 500 hPa GPH for selected times (*westerly regime*)



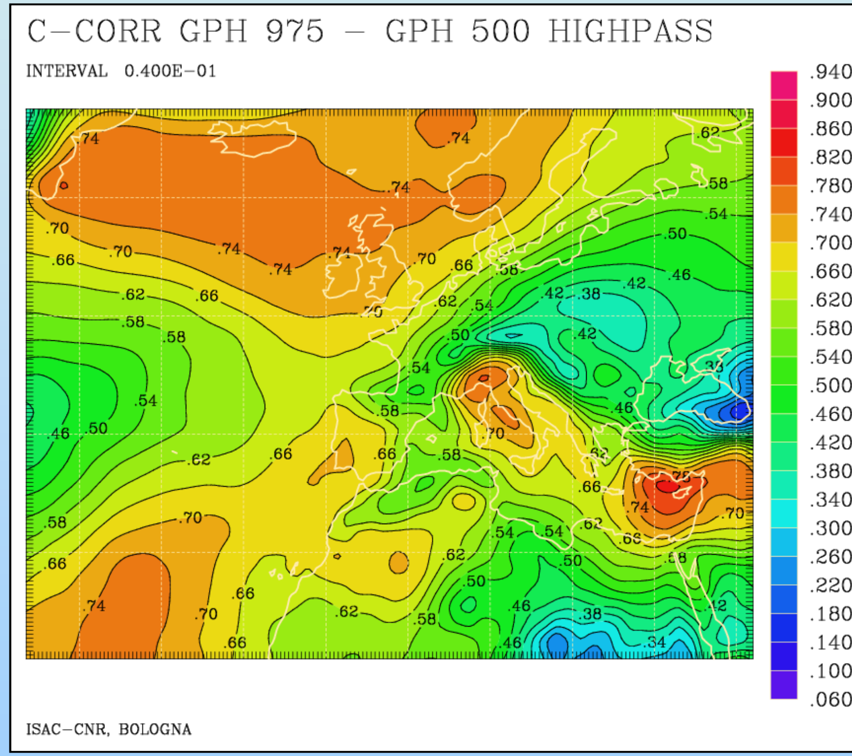
High-pass filtered standard deviation of 975 GPH [divided by sin(φ)] (*westerly regime*)

A statistical indicator of high-frequency variability that appears peculiar of the Mediterranean area:

cross-correlation between low-level and mid level GPH transients

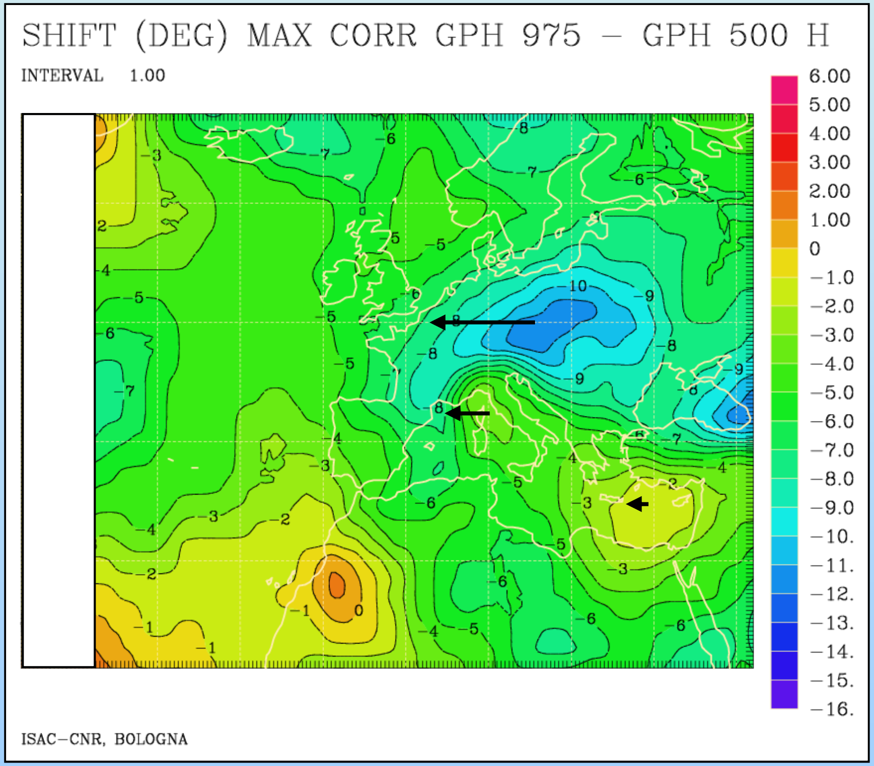


Correlation between high-pass filtered GPH at 975 and 500 hPa (total sample)

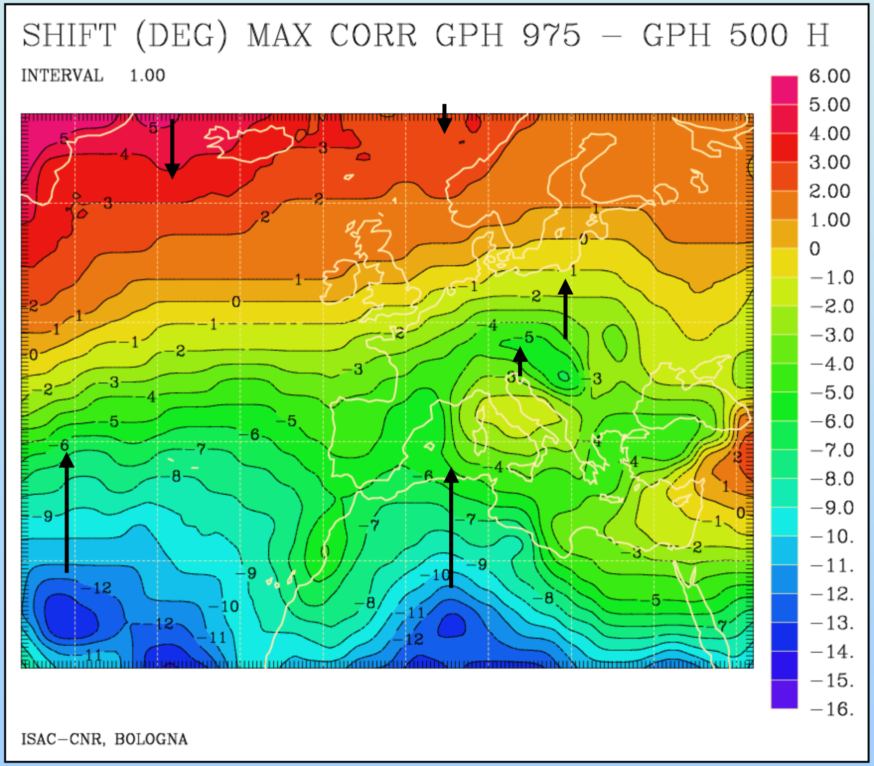


As left, but for selected times (*westerly regime*)

The vertical correlation of GPH transients is directly associated with the vertical tilt (phase lag, mainly in the E-W direction), as first noted by Heinrich von Ficker, early 1900, in transects of pressure across the Alps (but note that it exceeds the scale of the Alps).



E-W shift/lag (degrees long.) for max. correlation between high-pass filtered GPH at 975 and 500 hPa
(*westerly regime*)



As left, but for N-S shift/lag (deg. lat.)

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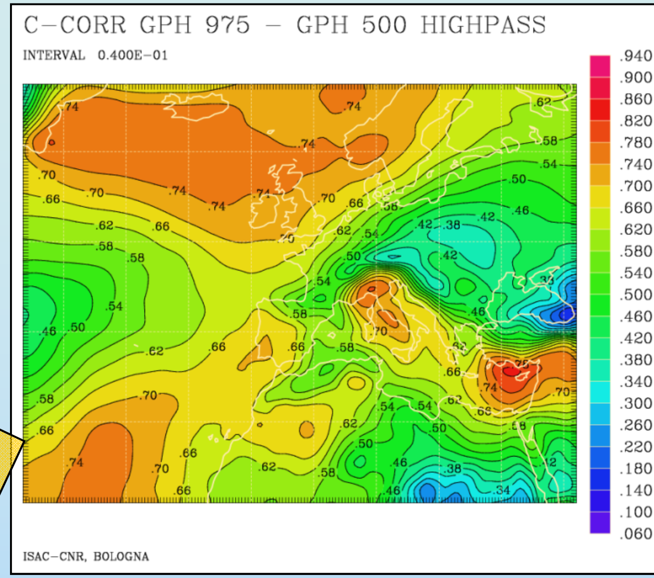
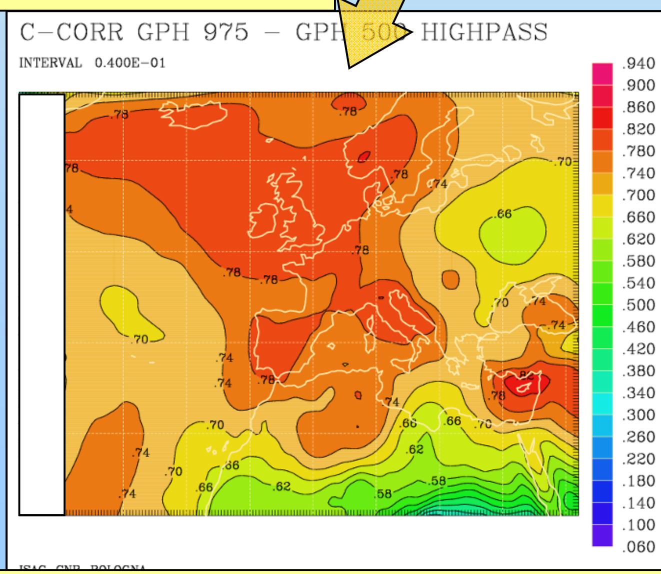
What about the max. correlation for shifts in long. or lat. (*westerly regime*)?

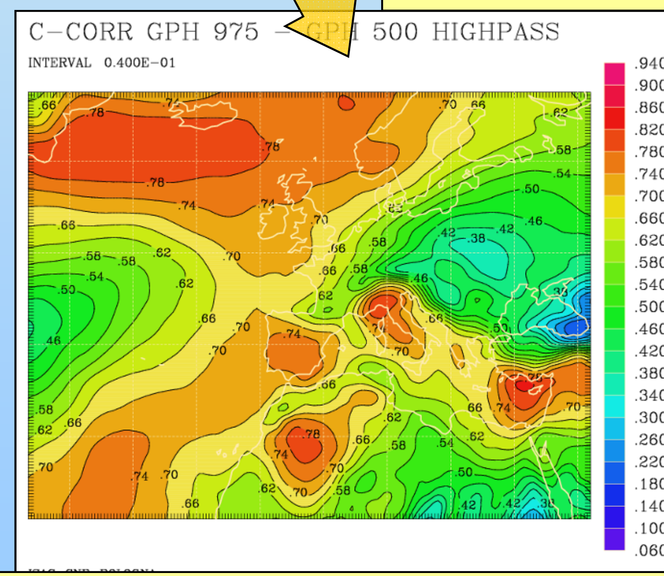


Correlation between high-pass filtered GPH at 975 and 500 hPa (*westerly regime*)

Corresponding max. correlation for any shift in longitude (large gain)

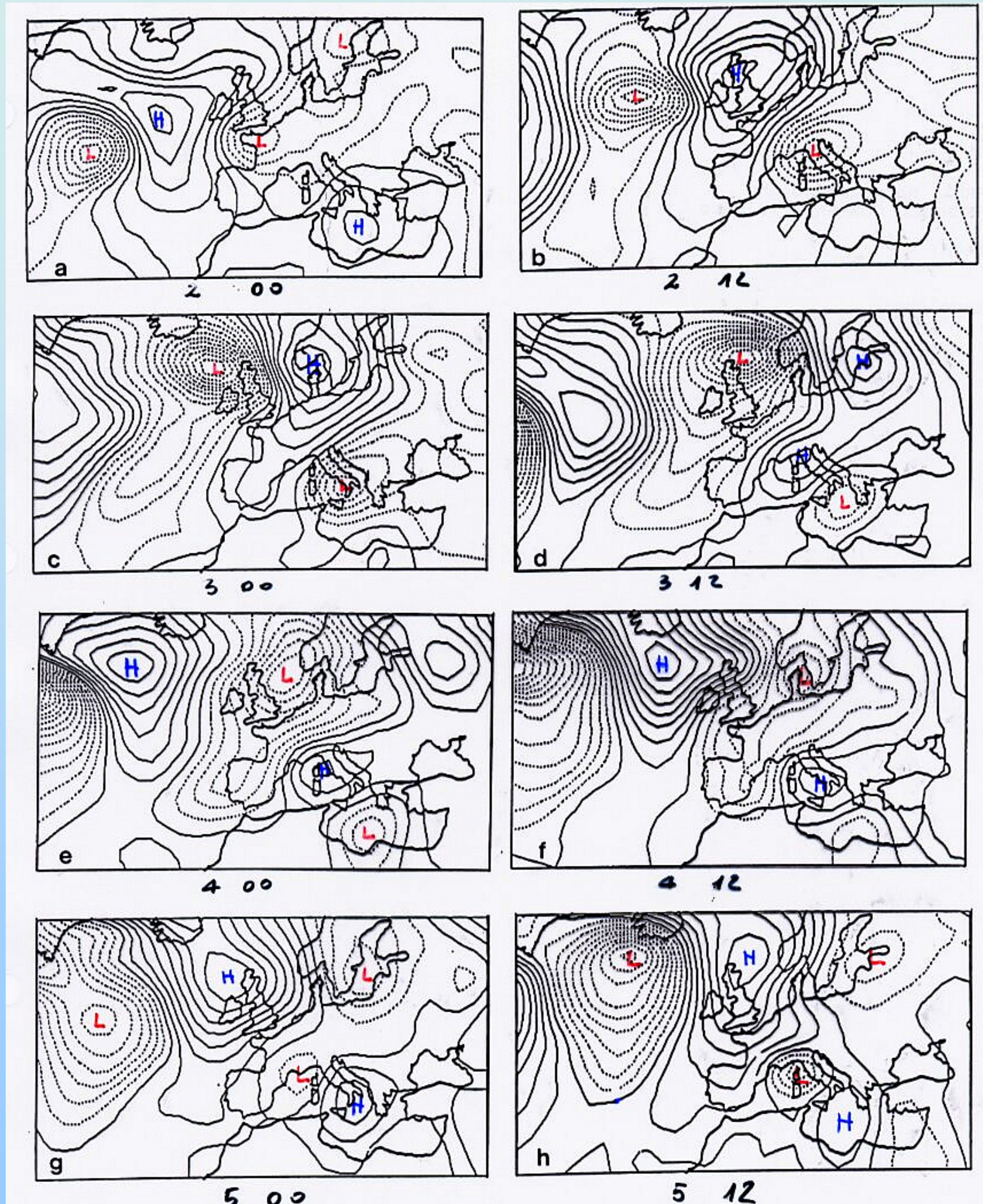


Corresponding max. correlation for any shift in latitude (little gain)



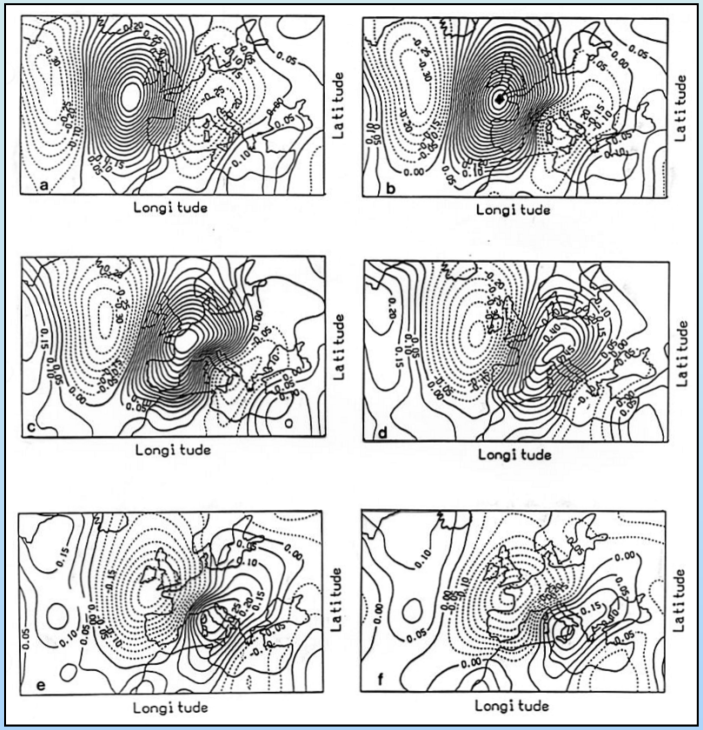
Therefore correlation between GPH variability at different levels is a good indicator of phase tilt with height (except over the Sahara where coherency is low).

High-pass filtered geopotential fields can be used to visualize the modifications that waves undergo arriving over the Mediterranean from the Atlantic storm track...



High-pass filtered individual maps of GPH at 850 hPa, 2 to 5 March, 1982 (**ALPEX project**), 12 hour intervals.

... and to construct one-point correlation maps (Wallace et al, 1988), a simple method to extract shape and evolution of transient eddies:



Buzzi & Tosi,1988: one-point lag-correlation maps of high-pass filtered GPH at 850 hPa (7 winter semesters).
Lag times from -12 hours to +48 hours.

... or composites:

Bell and Bosart, 1994: composites of 500 hPa height tendencies. Lag times from -24 hours to +24 hours of cyclone formation.

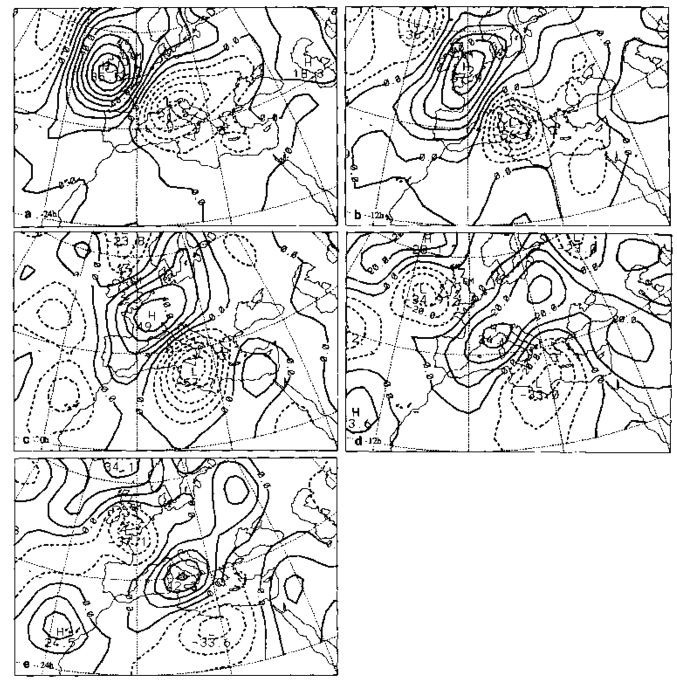
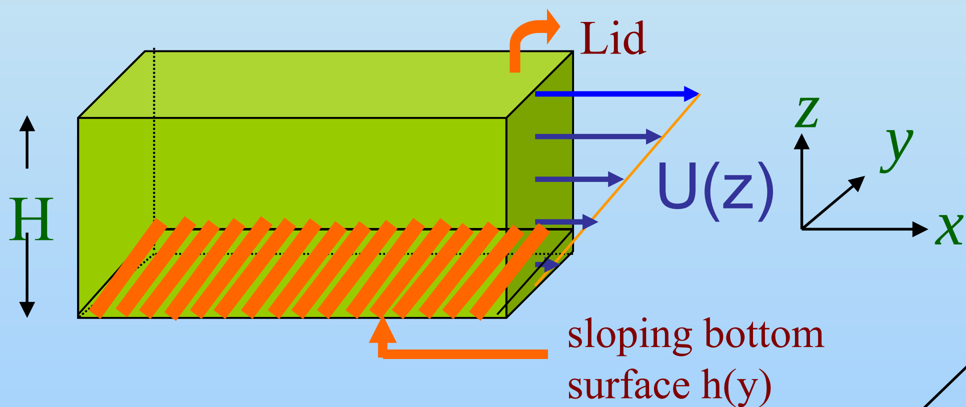
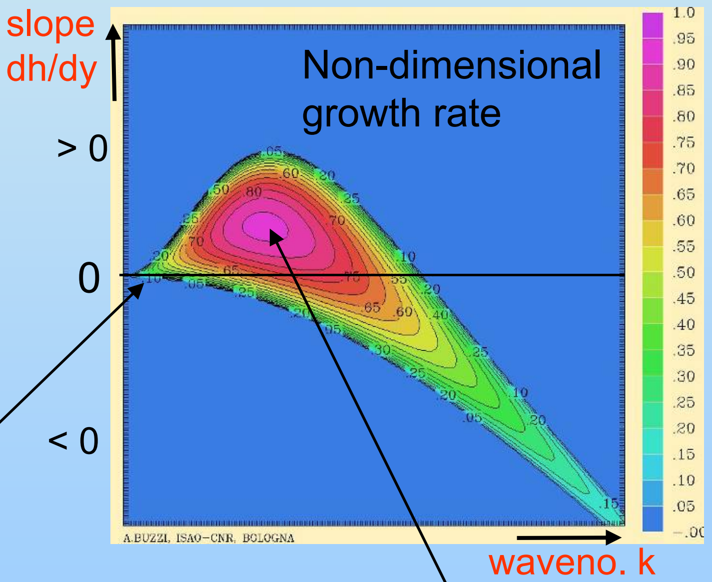


FIG. 12. Alps composite 500-hPa 12-h height tendencies ending (a) one day before, (b) 12 h before, (c) at the onset time of, (d) 12 h after, and (e) one day after closed cyclone formation. The contour interval is 10 m (12 h)$^{-1}$.

Vertical phase tilt of baroclinic/Rossby waves appears as a distinctive signature of orographic modification, for mountain chains whose crest is mainly aligned along the mean flow (i.e. across the mean temperature gradient)

The simplest (actually over-simplified but informative) theoretical model goes back to Blumsack and Gierasch (1972) who studied the effect of a bottom slope on classical (Eady) baroclinic instability problem.



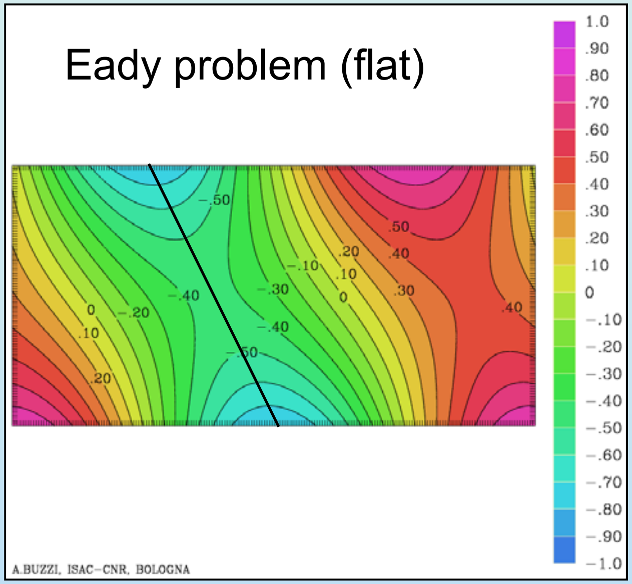


For dh/dy = 0, the classical Eady problem stability diagram is recovered

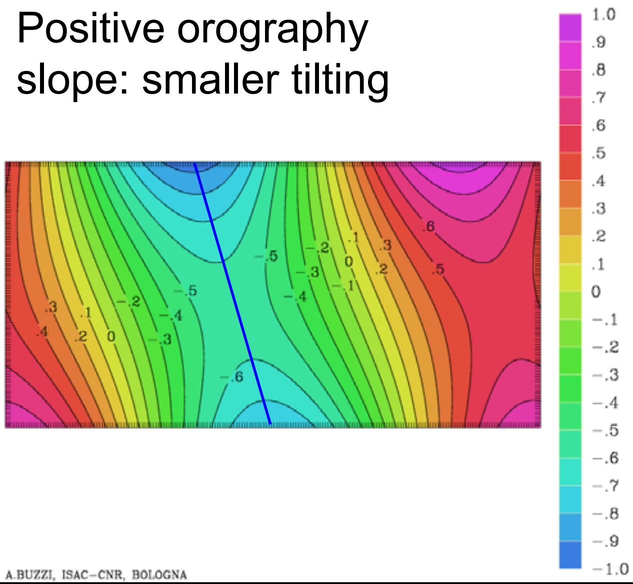
The max. growth rate is attained for a (moderate) dh/dy > 0, i.e. slope having the same sign of the slope of the basic isentropic surfaces

Streamfunction as a function of x and z, for the eigenmode with the wave no. of max. growth rate for flat Eady (about 3700 km)

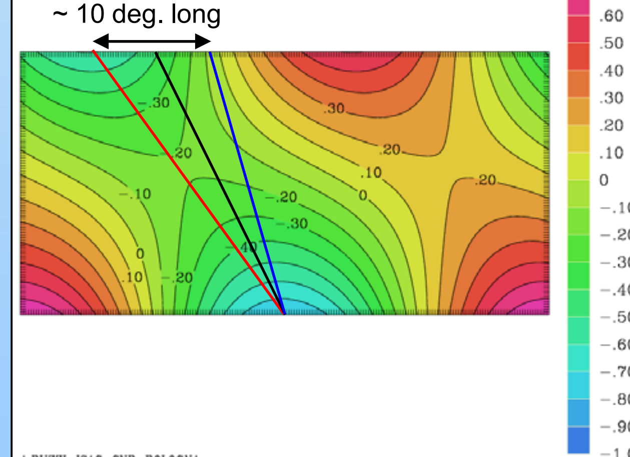
Eady problem (flat)



Positive orography slope: smaller tilting



Negative orography slope: larger tilting



Many studies and different "theories" of orographic cyclogenesis followed the ALPEX project (field phase in 1982).
One of them, based on the modification of baroclinic unstable modes by orography, was presented starting with Speranza et al (JAS, 1985) and with successive generalizations (P.E., non-linear aspects, initial value problem vs. normal modes...)

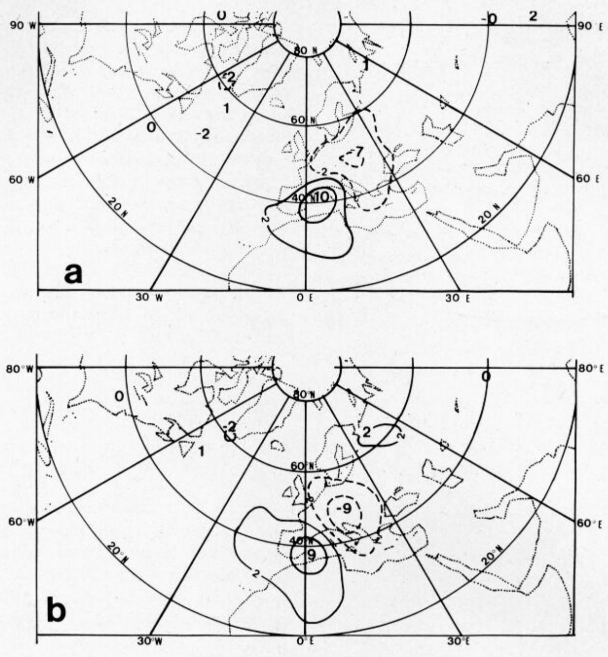
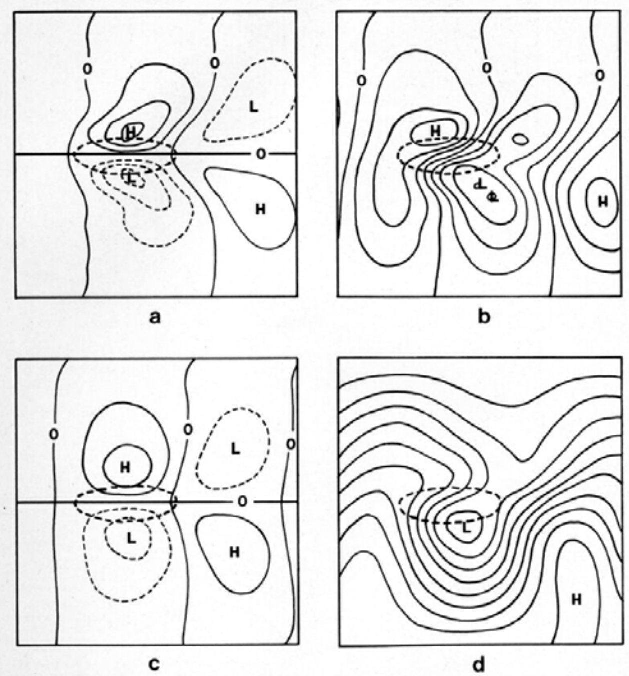


FIG. 2. Geopotential differences (dam) at (a) 1000 mb and (b) 500 mb after 48 h integration, between a control experiment with smooth orography and an experiment with enhanced Alps. After Tibaldi and Buzzi (1983).

Tibaldi & Buzzi, 1983: the orographic modification resembles a dipole (experiments with ECMWF model as in 1982)



surface

mid level

FIG. 5. Solution for a baroclinic wave in the continuous Eady model in long periodic channel with isolated topography. Dashed lines mark topographic contour (e^{-1} the max height). The parameter values are: $U = 2.0$, $A = 1.0$, $\hat{m} = 5.0$, $\epsilon = 1.0$, $\bar{x} = 1.5$, $\bar{y} = 0.5$, $L_x = 30.0$, $L_y = 8.0$, ω_i (growth rate) $= 0.51$. A portion of the channel of 8 × 8 nondimensional length units is shown. (a) Streamfunction of orographic perturbation only at $z = 0$; (b) total streamfunction of modified baroclinic wave at $z = 0$; (c) and (d) as in (a) and (b), respectively, but at $z = 0.5$, and with a half ($= 0.4$) contouring interval. The basic zonal wind is added in (d).

Speranza et al, 1985: orographic perturbation (left) and total streamfunction (right) in the Eady problem with isolated topography.

The ideal case of zonally infinite ridge depicts eigenvector structure as modified by the orography, for different mountain widths and heights:

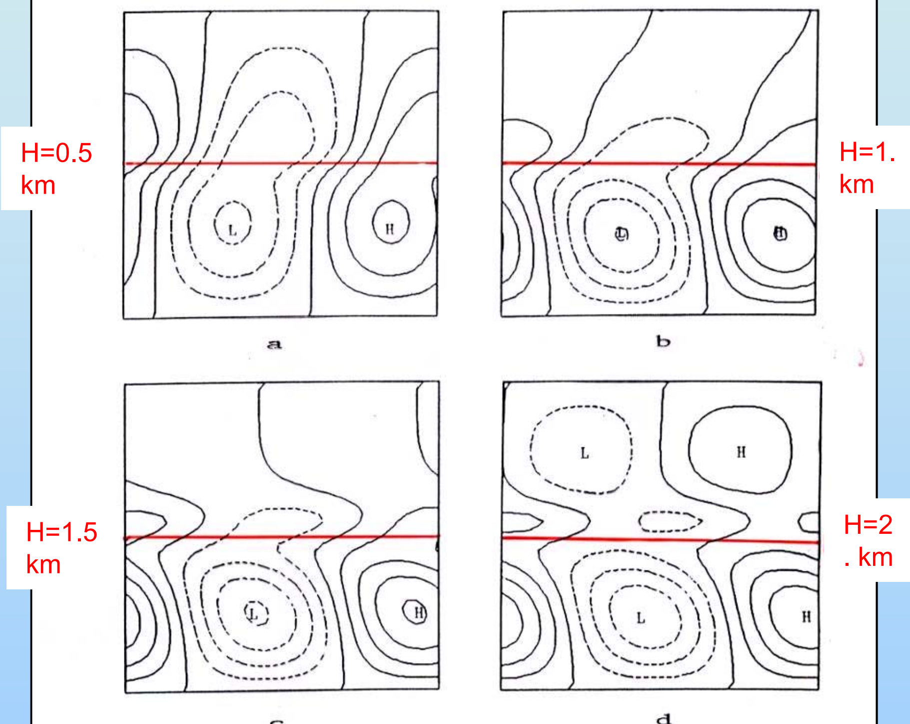


FIG. 1. Streamfunction at $z = 0.1$ of the fastest growing mode for the Eady problem, with a finite-amplitude Gaussian ridge located at the center of the channel, oriented from west to east. Different ridge heights characterize the different figures: (a) $\bar{H} = 0.5$, (b) $\bar{H} = 1.0$, (c) $\bar{H} = 1.5$, (d) $\bar{H} = 2.0$. The Gaussian ridge half-width is $\bar{y} = 0.3$. One wavelength is shown with arbitrary amplitude, phase and contour interval. Broken lines mark negative values. Other nondimensional parameter values are: $U = 3.0$, $L = 5.0$, $k = 1.26$.

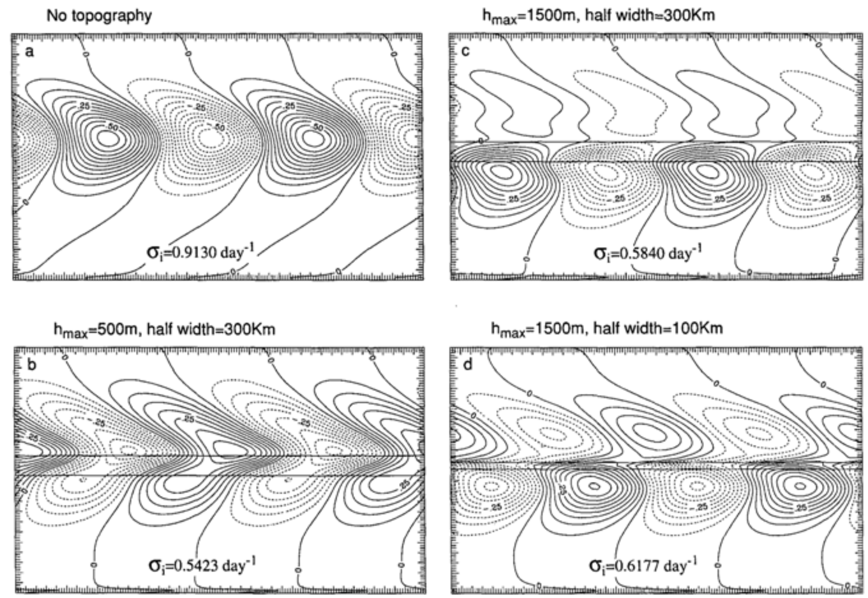


FIG. 9. Normalized surface pressure anomalies in the linear simulations of flow with a zonal mountain. The horizontal lines indicate the mountain half-width. The contour interval is 0.05, and negative contours are dashed. (a) No topography, (b) a low wide mountain, (c) a high wide mountain, and (d) a high narrow mountain. The mountain parameters are shown above each panel. Tick marks are placed approximately every 60 km.

Buzzi and Speranza, 1986
(Q.G. model)

Orlanski and Gross, 1994
(P.E. model)

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Summarizing →

Observed Mediterranean cyclones:

• are more or less conditioned by the topography both in their origin and life cycle;

• tend to be meridionally confined and hence to have smaller scale than their "unconstrained" counterparts;

• are well identified near the surface, but often a parent/precursor disturbance (an upper trough or PV anomalies/streamers) can be traced back upstream out of the Mediterranean area;

• orography, surface fluxes and other "factors" influence cyclone life cycle.

According to theoretical and numerical modifications introduced by orography on baroclinic modes, the "lows" and "highs" are, if compared to the flat case:

• enhanced in amplitude south of the ridge and weakened north of it;

• shifted to the west south of the ridge and to the east north of it (this accounts for the different vertical tilting, considering that the orographic modification decays with height).

Notes:

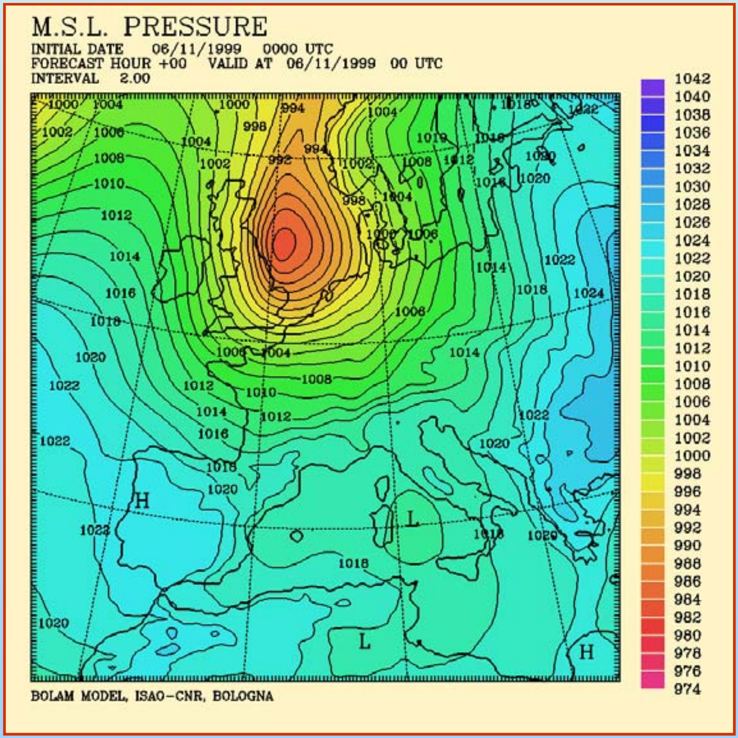
- Criticisms to "normal mode based" theories of orographic cyclogenesis (e.g. Egger, 1988) were based partly on the consideration that there is a gap between baroclinic wave dynamics and individual cyclone dynamics, especially for rapid and intense local cyclogenesis induced by propagating and growing upper level PV anomalies/streamers that are precursor of deep cut-off vortices (see example in the following two slides). This problem, of course, is true for cyclogenesis everywhere, not only for the Mediterranean.

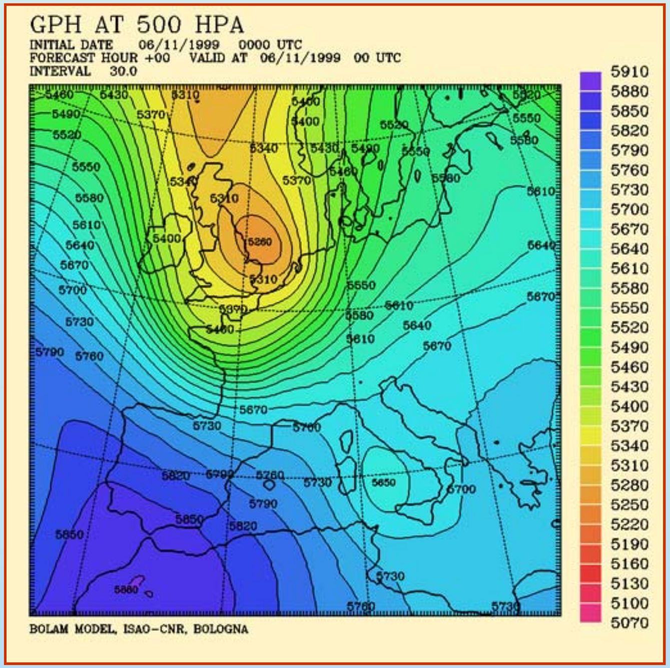
- The role of upper PV anomalies ("PV-thinking") was underlined in a number papers concerning orographic cyclogenesis (e.g. Mattocks and Bleck, 1986; Bell and Bosart, 1994, … McTaggart-Cowan et al, 2010).

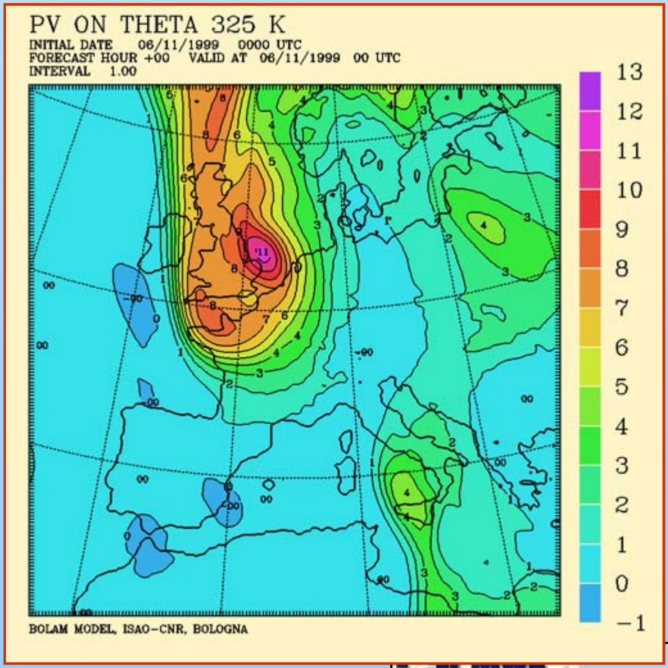
- Role of low level PV generation (Aebisher & Schär, 1998).

- However, in my opinion, the role played by the orography, that includes important non-linear and non-geostrophic effects and strongly depends on stratification properties, has not been fully clarified in this context.

An example of typical strong and rapid event of cyclogenesis in the lee of the ALPS (well analyzed studied because occurred during the Mesoscale Alpine Programme - MAP - 1999 - e.g. Hoinka et al, 2003; Buzzi et al, 2003).

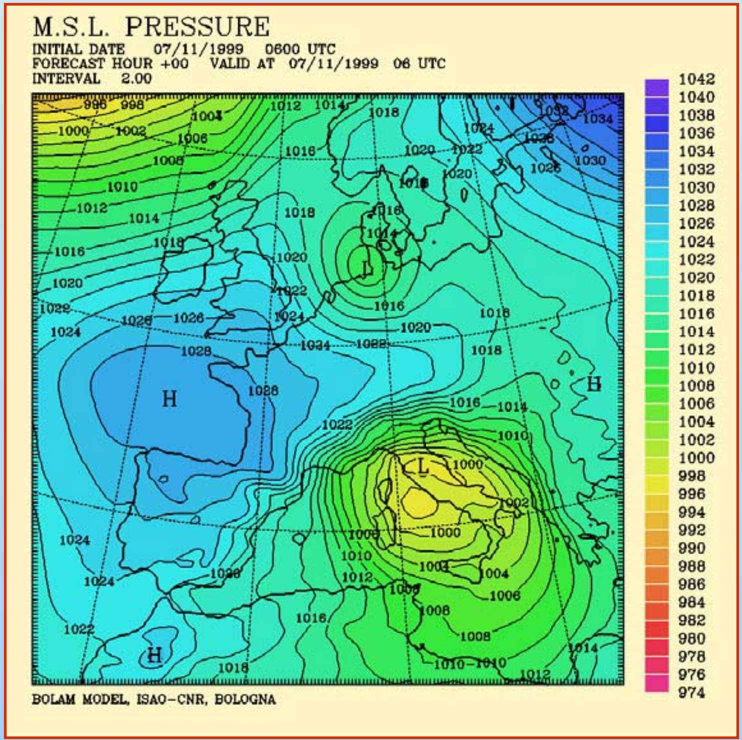


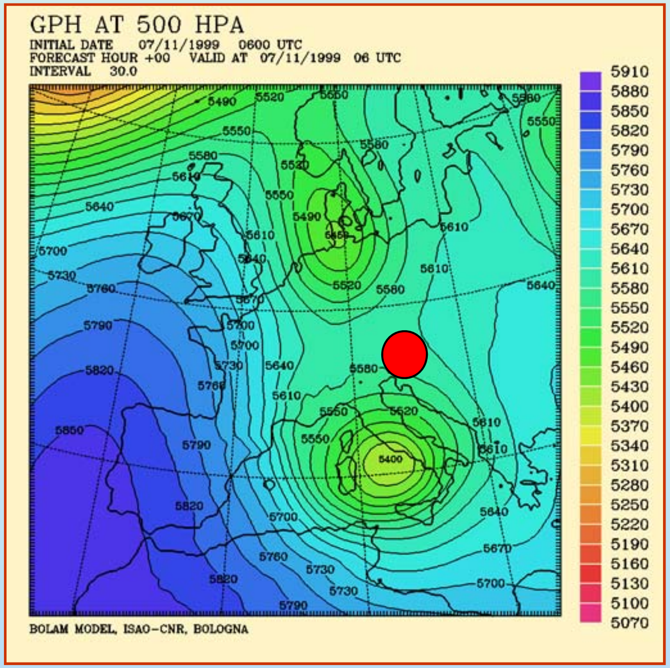


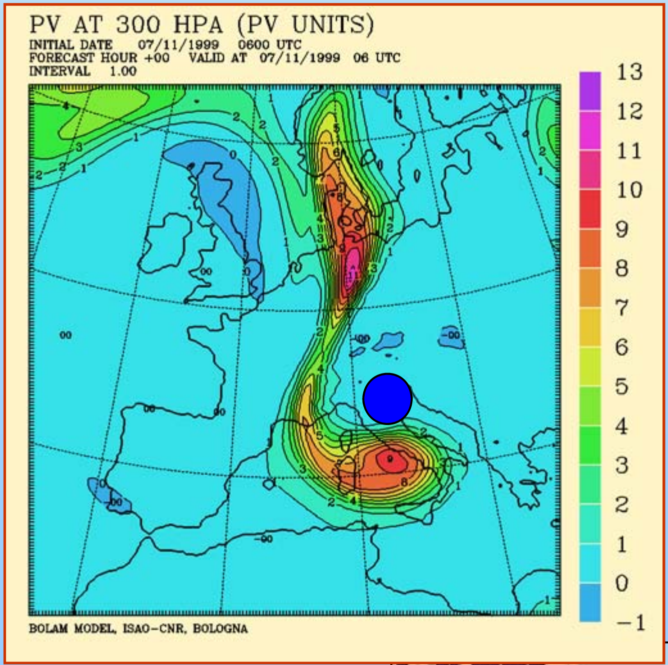


ECMWF analysis fields,
6 Nov 1999, 00 UTC

Trusting numerical. exp.'s, the formation of the upper cut-off would have taken place also without orography; however, without orography the upper PV maximum would have been located about 400 km N (blue spot), and the surface cyclone (unique) would have been centred over Slovenia (red spot).





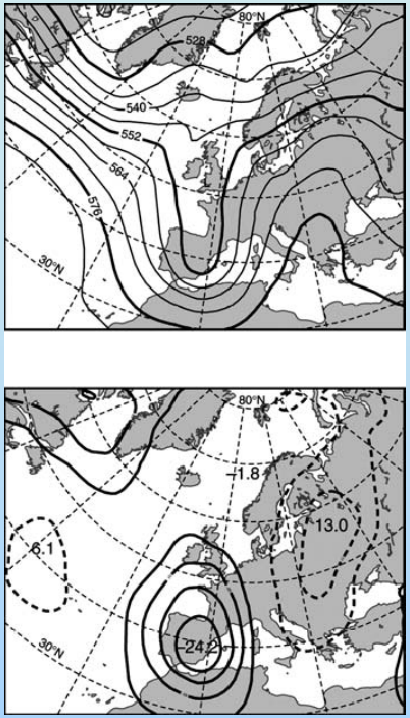


ECMWF analysis fields,
7 Nov 1999, 06 UTC

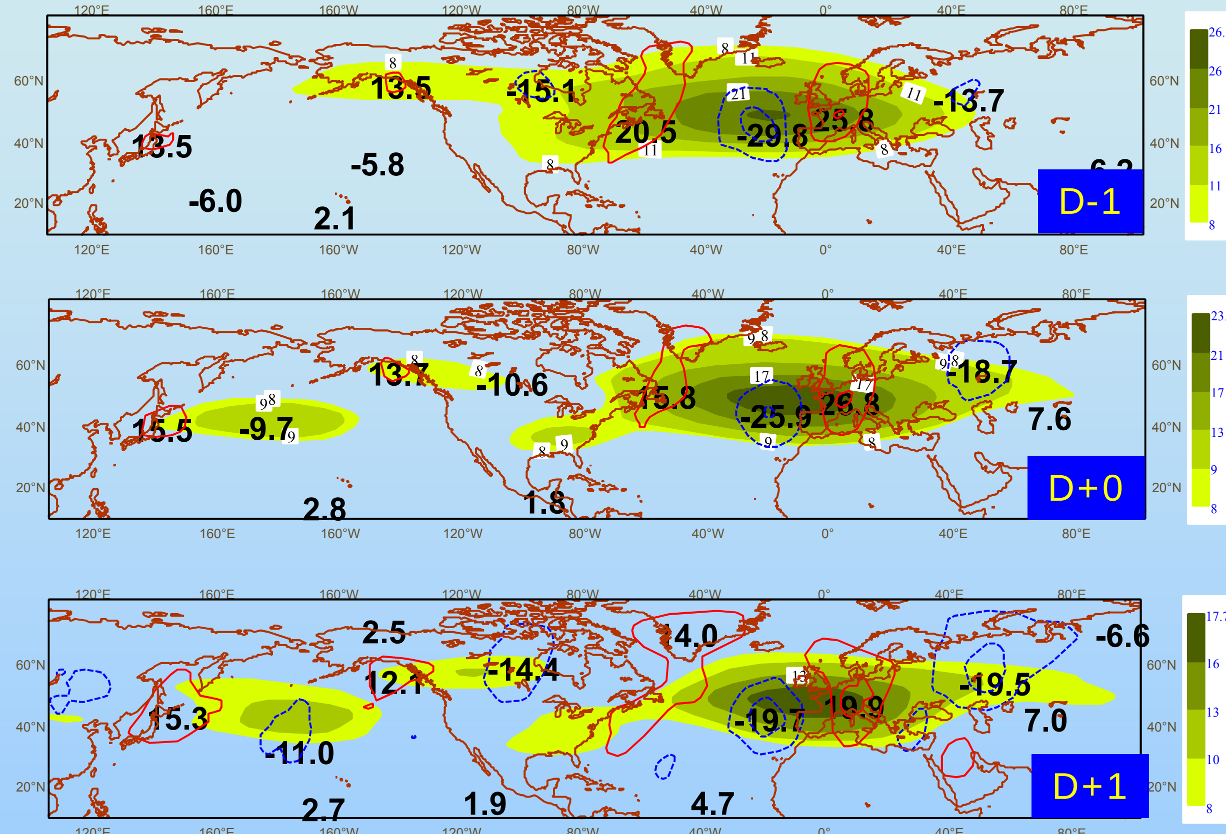
Moving on...

- By about late '90's, the practical problem of forecasting Mediterranean cyclogenesis and cyclone tracks was considered, at least for short-range forecasting, nearly solved, thanks mainly to model horizontal resolution.
- Operational meteorological demand gradually focused on QPF, in relation with numerous flooding events that affected Mediterranean coastal areas, facing orography slopes, and high-impact weather.
- Scientific interest was devoted more and more to the mesoscale: wet processes, orographic effects on the small scales part of the spectrum, PBL phenomena.
- However, Mediterranean cyclones are still regarded as the main source of mesoscale variability, including convection, heavy precipitation (orographic and convective) and strong winds.
- The variety of Mediterranean Tropical Like Cyclones (TLC) (or *Medicanes*) have received increasing attention, especially in modelling.
- The availability of reanalyses (as ERA-40, ERA Interim) have allowed to revisit, using detailed modelling, past severe events.

Synoptic-scale variability and heavy precipitation in the Mediterranean: associated with cyclones, inducing strong southerly flow (SSF) and related to mid-latitude long-distance propagation of Rossby wave packets (Grazzini, 2006, 2010).

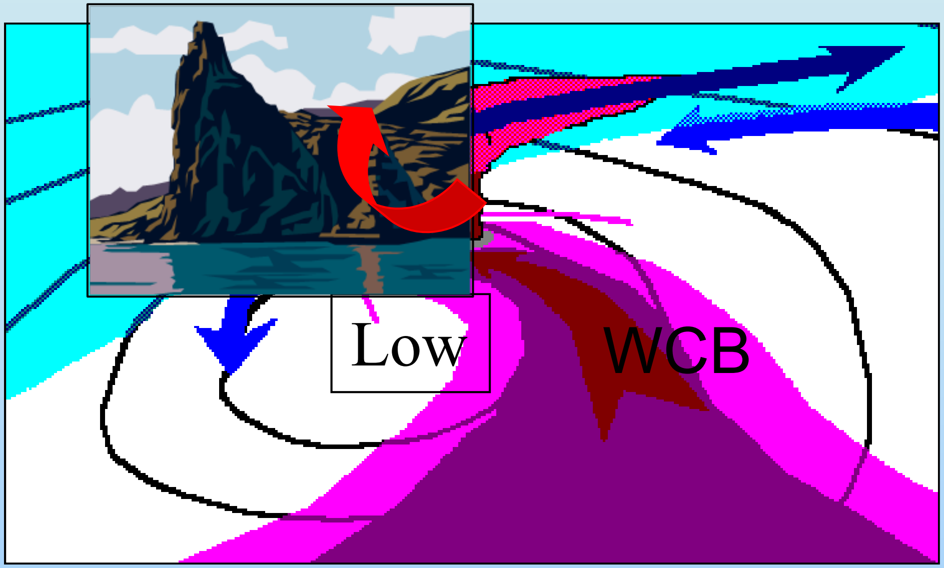


500 hPa height and anomaly associated with SSF and heavy precip. over western Mediterranean (Grazzini 2006).



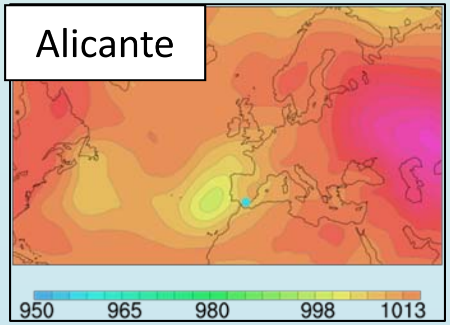
Lag composite of 250 hPa v-component and envelope SSF cases between 1980-2001 (ERA40). Autumn (45 cases). Courtesy of Grazzini (2010).

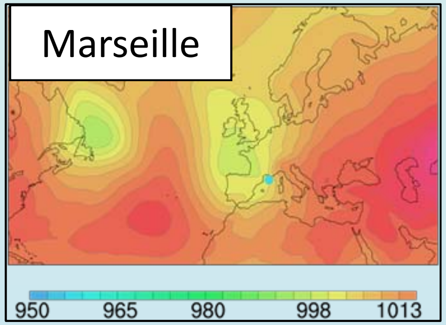
Dynamical and statistical relationship between Mediterranean cyclones and heavy precipitation (orographic or not)

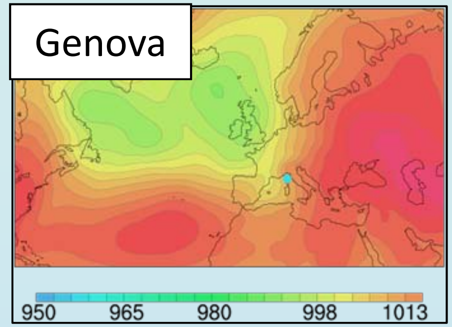


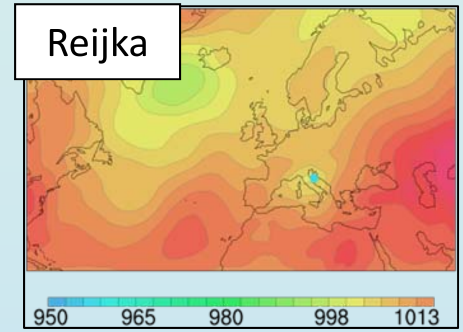
A simple conceptual model (Jansa, 2001)

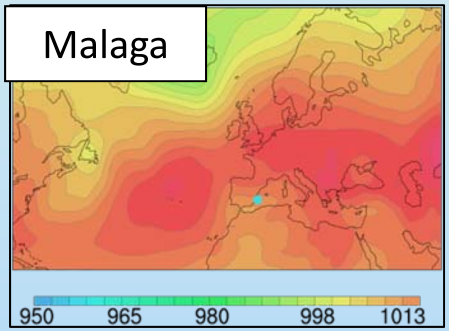
By adding a mountain a the end of the WCB can largely enhance precipitation, especially in cases of nearly neutral moist lapse rate.

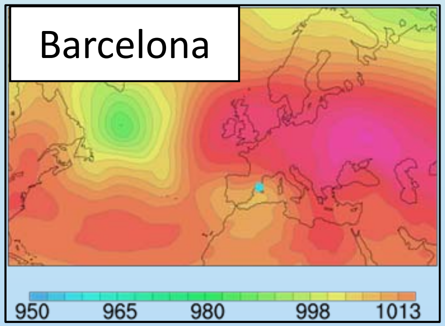


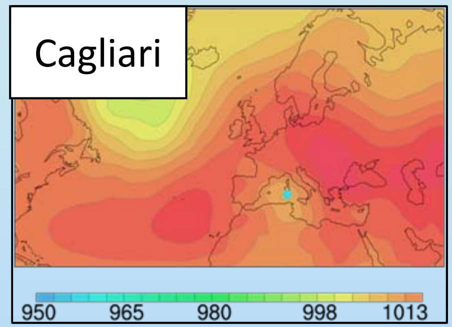


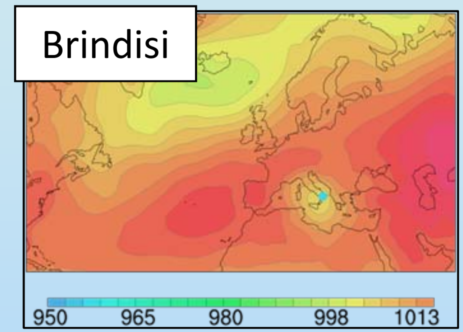




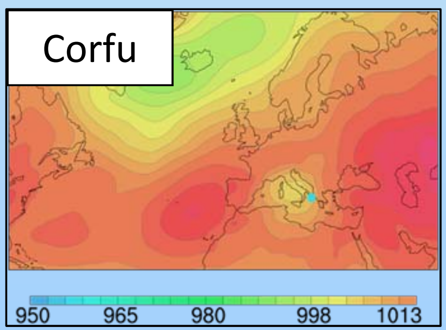


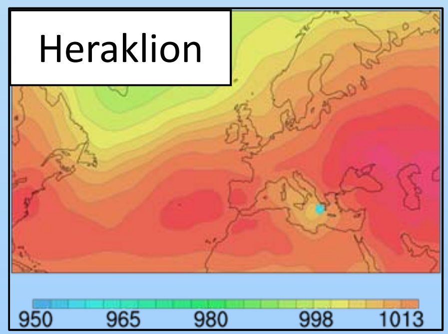


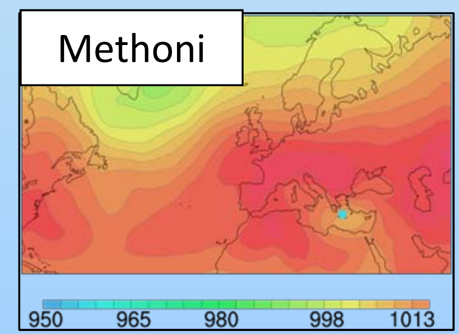


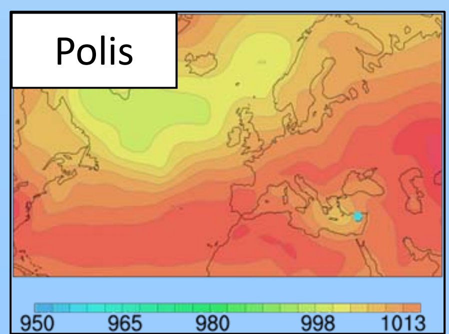


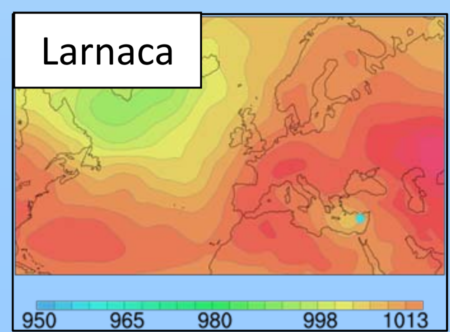
Composites of SLP fields associated with severe precipitation events (intensity > 99 percentile) in winter, at the 14 selected locations.
Green dots are points where precipitation was recorded (courtesy of Lionello and Reale, 2010).

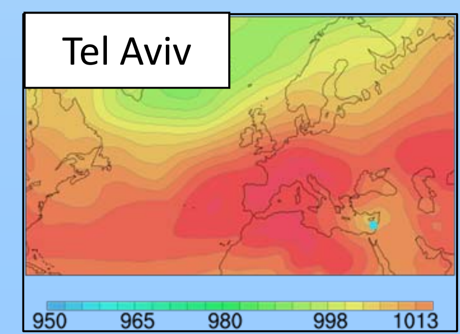




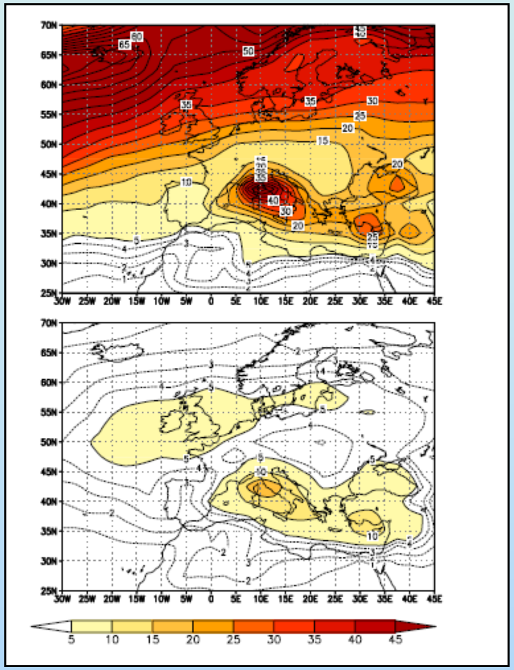




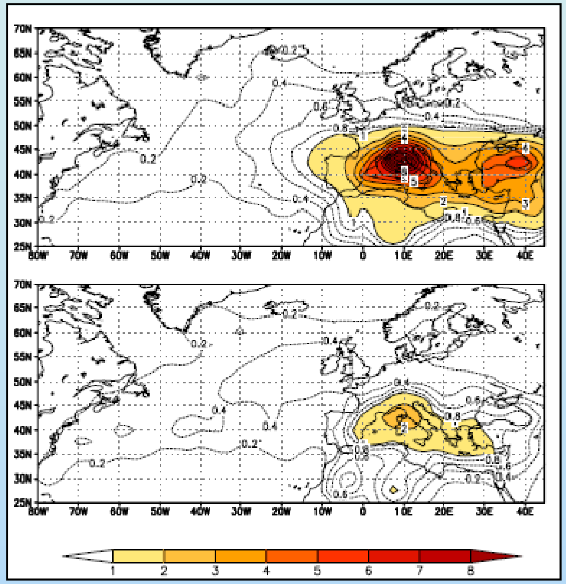




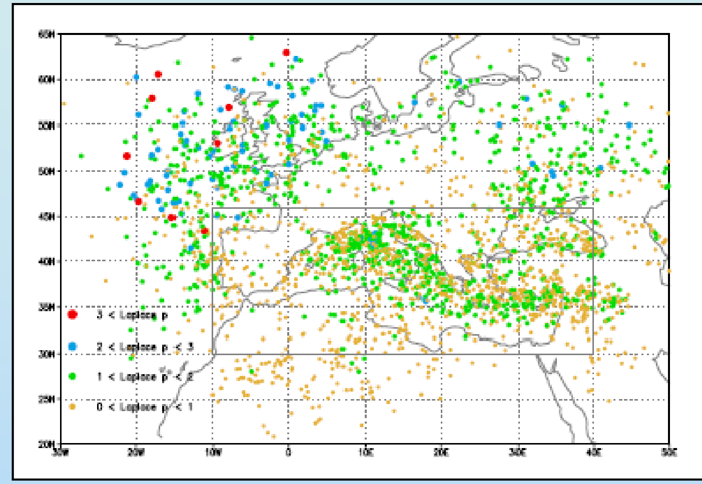
Mediterranean cyclones and wind storms (Nissen et al, 2010)



Cyclone track density in number of cyclones per extended winter season (ERA-40) per (deg.lat.)^2. Top: for all cyclones. Bottom: for all cyclones causing wind storms in the Mediterranean region.



As left, but for cyclogenesis density.



Position of cyclones causing wind storms in the Mediterranean area (time of max. wind speed). Colour coding and size denote strength of cyclones via ∇p.

Winds in the Mediterranean are strongly related by the topography on small mesoscale (downslope, channelling, blocking, gap flows, vorticity banners...). Realistic simulations can be obtained only with high res. models (< 10 km).

Cyclogenesis mechanisms and modifying factors as inferred from data analysis and numerical experimentation and diagnostics (studied extensively in recent years, often applying the "factor separation method" of Stein & Alpert,1993 and following papers):

- baroclinic instability
- upper-low level interactions: PV anomaly propagation, surface anomalies, jet streak propagation
- topography (different effects at different scales)
- low-level PV (topographically - e.g. PV banners and diabatically generated)
- surface heat fluxes (sensible and latent: role of the sea)
- latent heat release
- convection
- quasi-tropical cyclones (Medicanes): surface fluxes and latent heat release.

Associated mesoscale features:

- "wet": rain bands (moist symmetric instability), organized convection, orographic precipitation (in stratified and neutral conditions), water vapour ("atmospheric rivers").
- "dry": low-level strong winds and jets (orographic, gap-flow, conveyor belts, PV/vorticity banners etc.), frontal dynamics and propagation etc.

A type of intense Mediterranean cyclones (not very prominent in climatology because relatively infrequent): cyclones generated by large amplitude upper level trough, plunging over north-western Africa.

This type of cyclones often originate, at the surface, in the lee of the Atlas mountains.

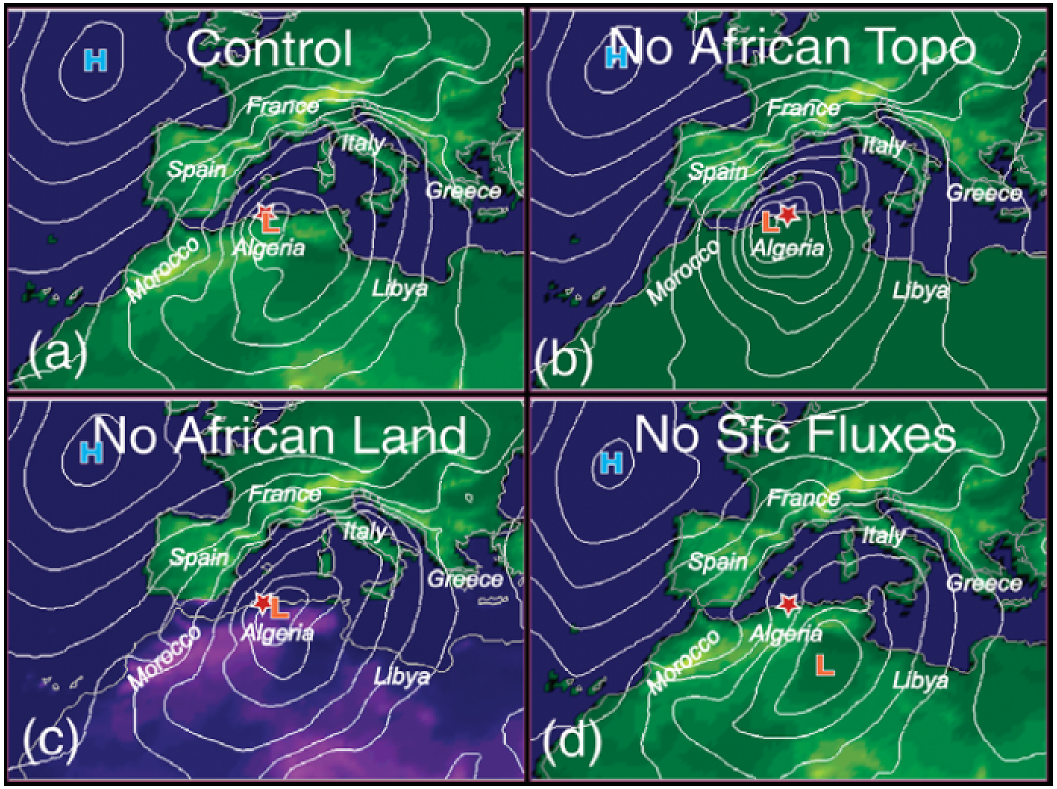


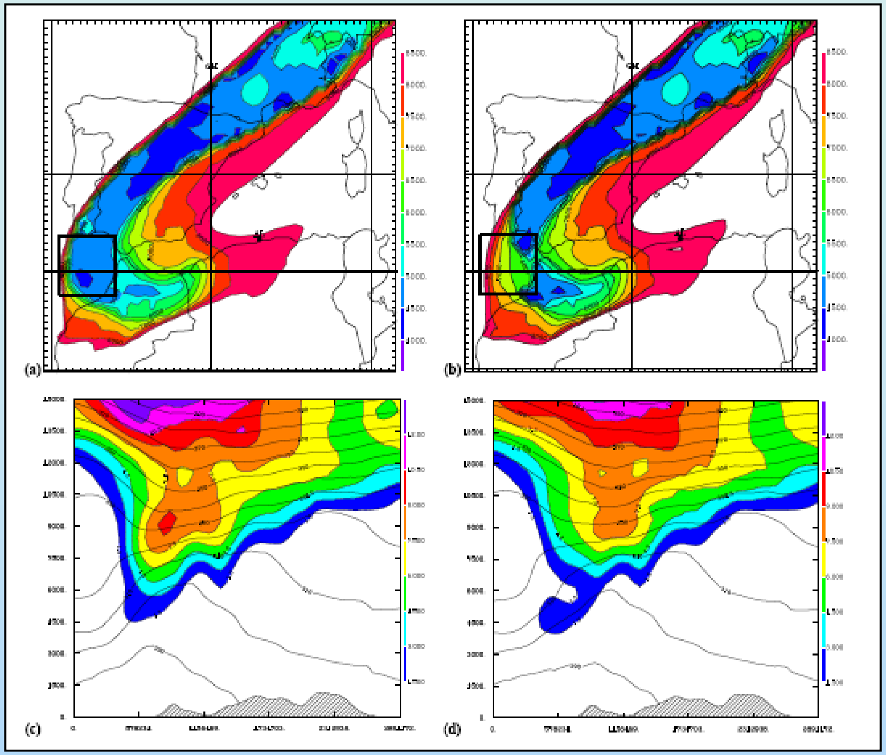
FIG. 8. Simulation of surface pressure field at 1200 UTC 10 Nov for control and three sensitivity experiments employing only the outer grid. City of Algiers is denoted by a red star. Topography is shaded, with higher elevations indicated by more yellow and purple hues. Note in (c), there is no African land surface, but topography variation is assumed in water surface. Surface pressure is contoured at 4-hPa interval with low- and high-pressure centers labeled.

An 'extreme' case: Algiers flood and Balearic Islands "superstorm" (Arreola et al., 2004; Romero et al, 2004; Lambert et al, 2004; Tripoli et al, 2005):

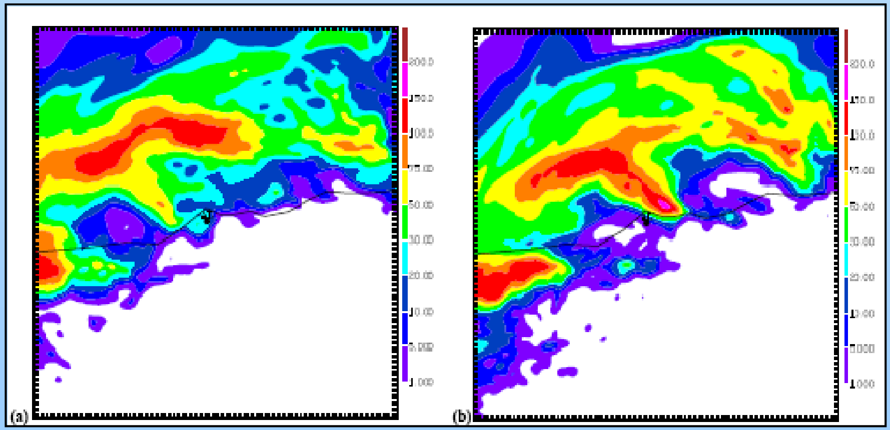
Figure from Tripoli et al, 2005

Argence et al, 2006: Small changes in upper level forcing had important effects
(High resolution numerical study of the Algiers 2001 flash flood: sensitivity to the upper-level potential vorticity anomaly)

Model: MESO-NH (2 km hor. res.)



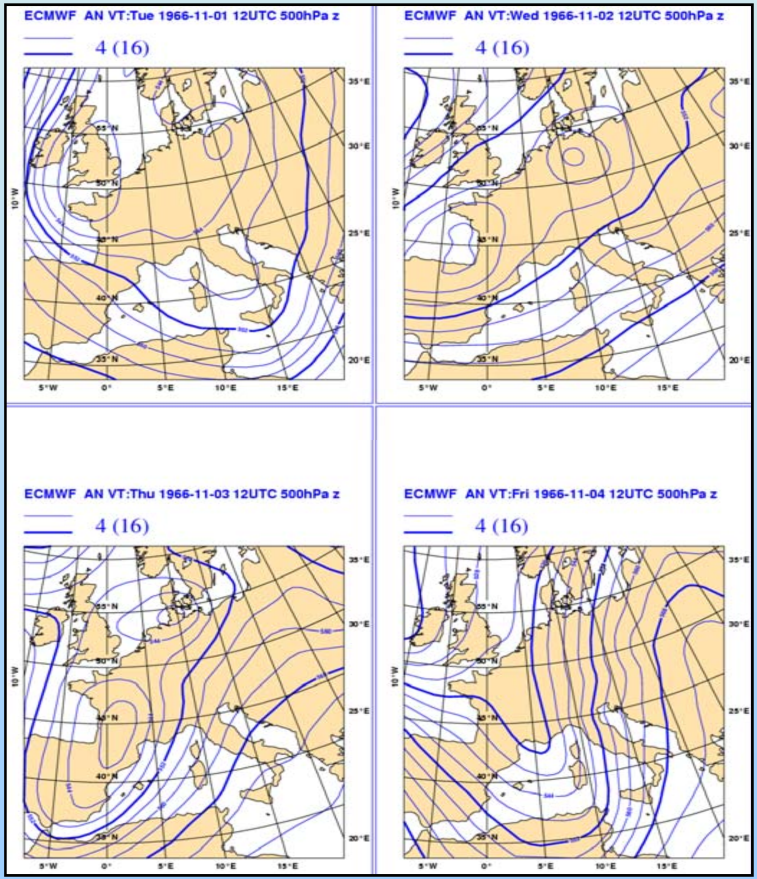
PV anomaly was subjectively adjusted, guided by satellite observations.
Gave stronger and more correct precipitation.



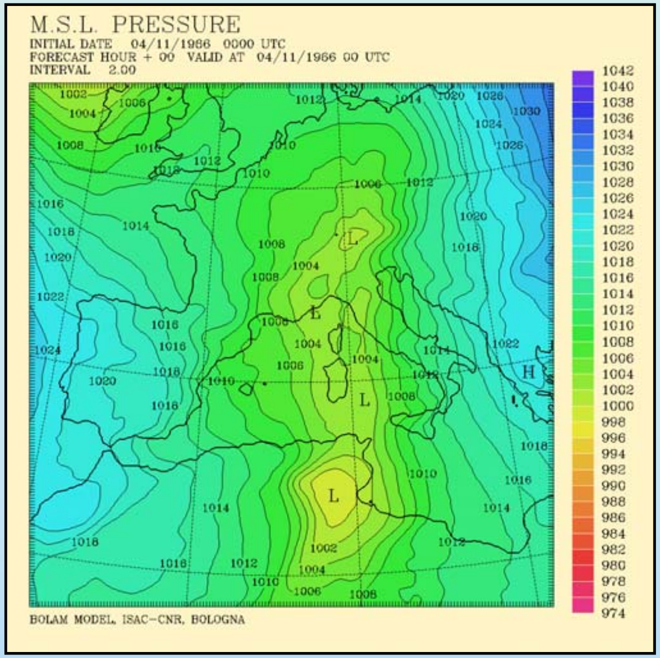
(Courtesy of E. Nordeng, Mediterranean School of Mesoscale Meteorology, Alghero, 2006)

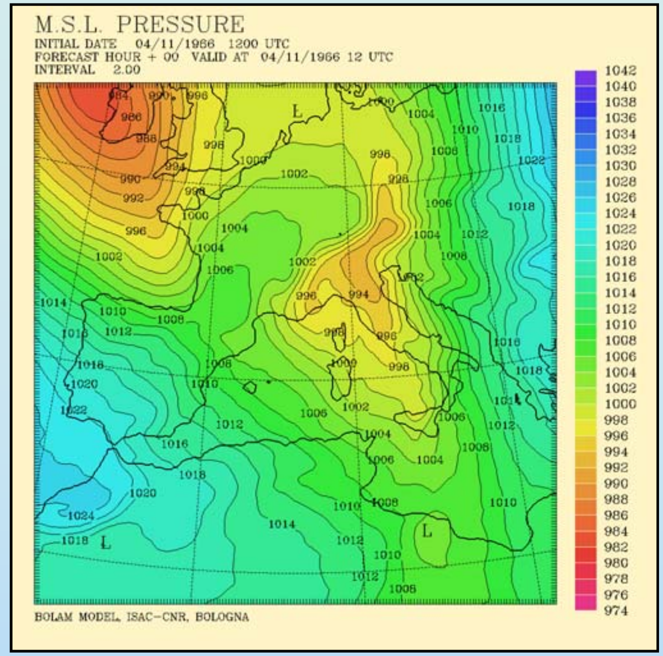
"Reconstruction" of an extreme storm: 3-4 November 1966 (Malguzzi et al, 2006)

Max. storm surge record in Venice (1.98 m)



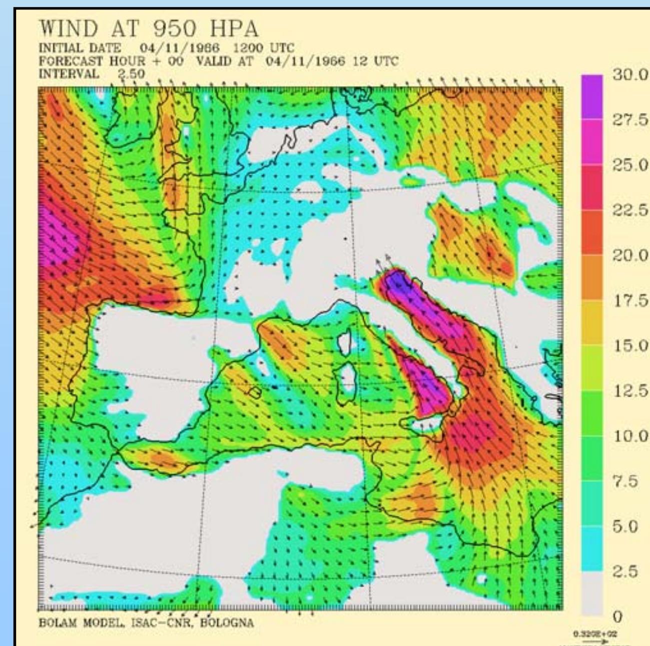
T_L511L60 reanalysis, 500 hPa, 12UTC of 1-4 November 1966.



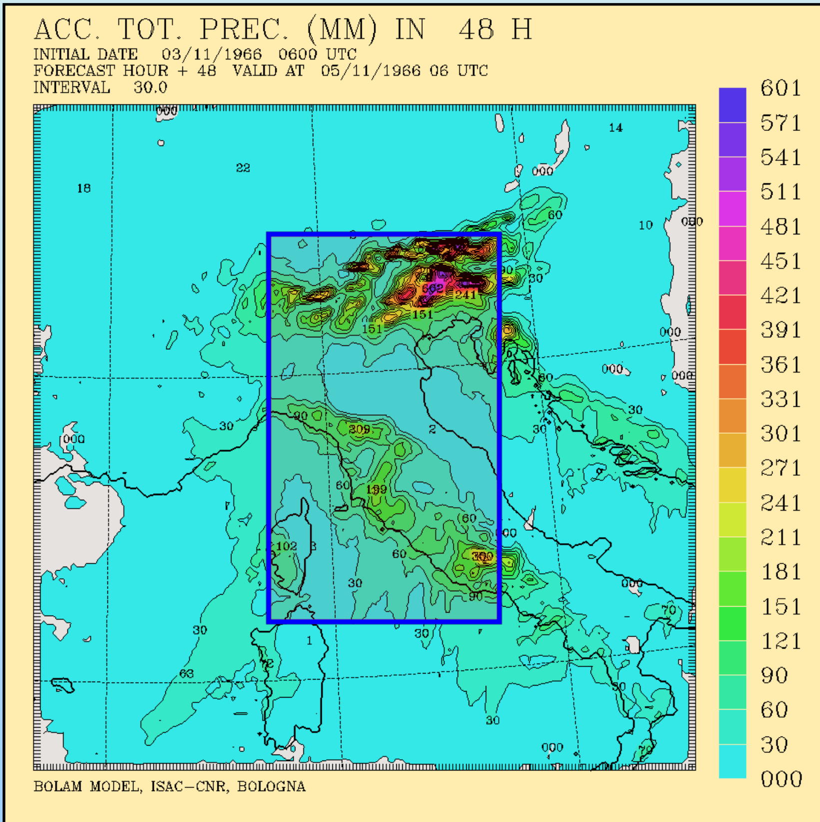


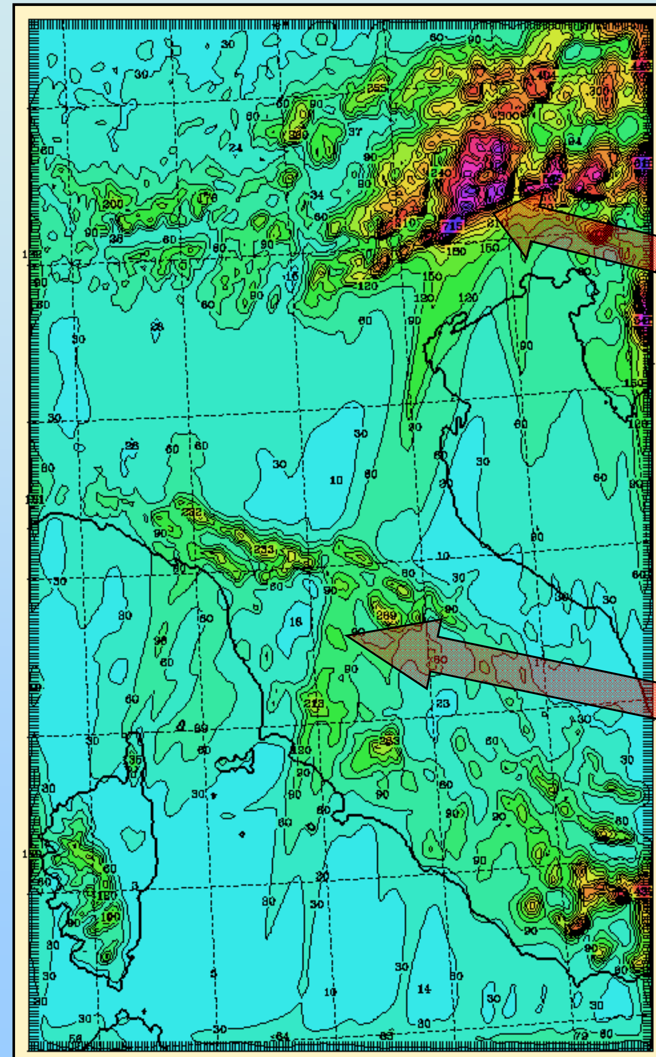
MSLP , 4 Nov. 1966, 00 and 12 UTC. 950 hPa wind, 12 UTC.

ECMWF ERA-40 special high-resolution (Buizza et al. - TL511L60), interpolated on the BOLAM grid



BOLAM (7 km) nested in ECMWF reanalysis, and MOLOCH 2 km nested in BOLAM: 2 day (3-4 Nov.) accum. precipitation forecasts over Tuscany and the eastern Alps

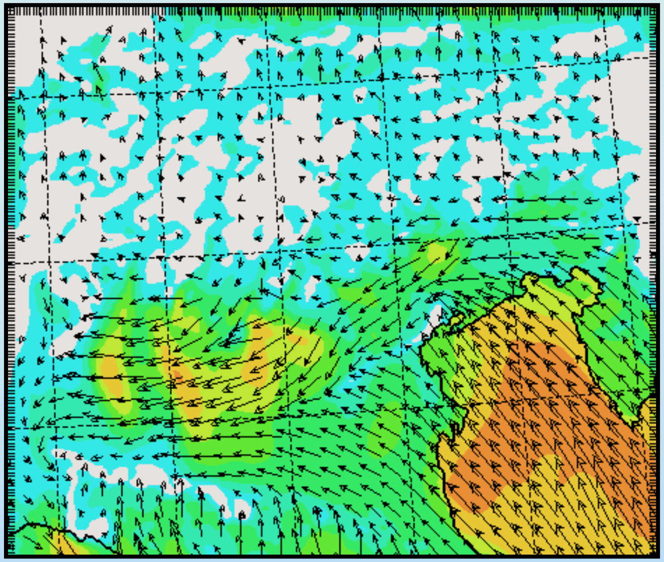


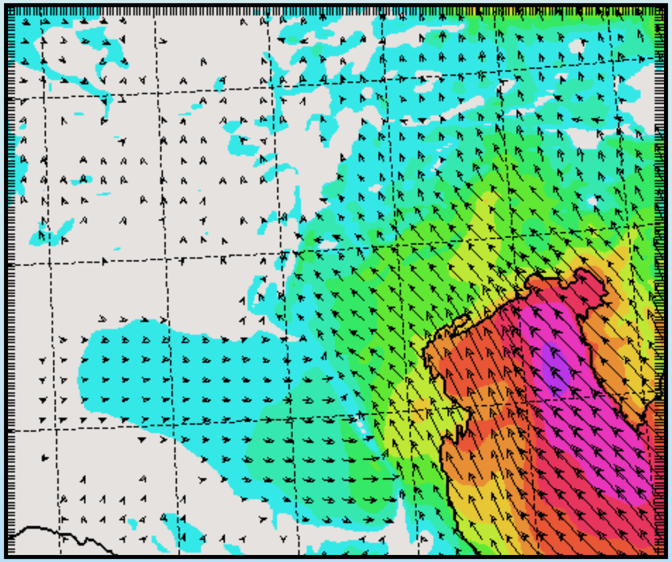


Orographic precip. (obs. max. 740 mm) - better predicted

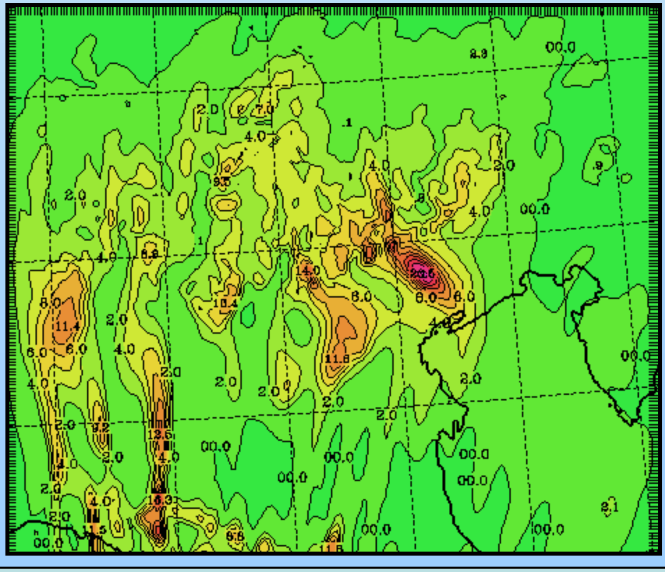
Convective precip. (obs. max. ~ 300 mm)

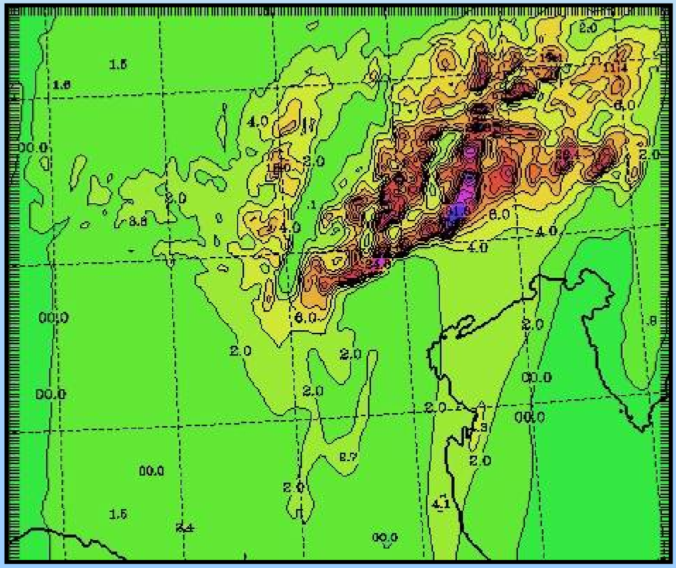
Importance of different orographic flow regimes for orographic precipitation upstream and over the eastern Alps:





10 m wind





1h acc. prec.

Blocked flow stage, 3 Nov. 1966, 11 UTC

Non-blocked flow stage, 4 Nov. 1966, 05 UTC

Importance of *pre-conditioning* of Mediterranean (and surrounding areas as north Africa) atmospheric state prior to cyclone formation (moisture, static stability, …).

For example:

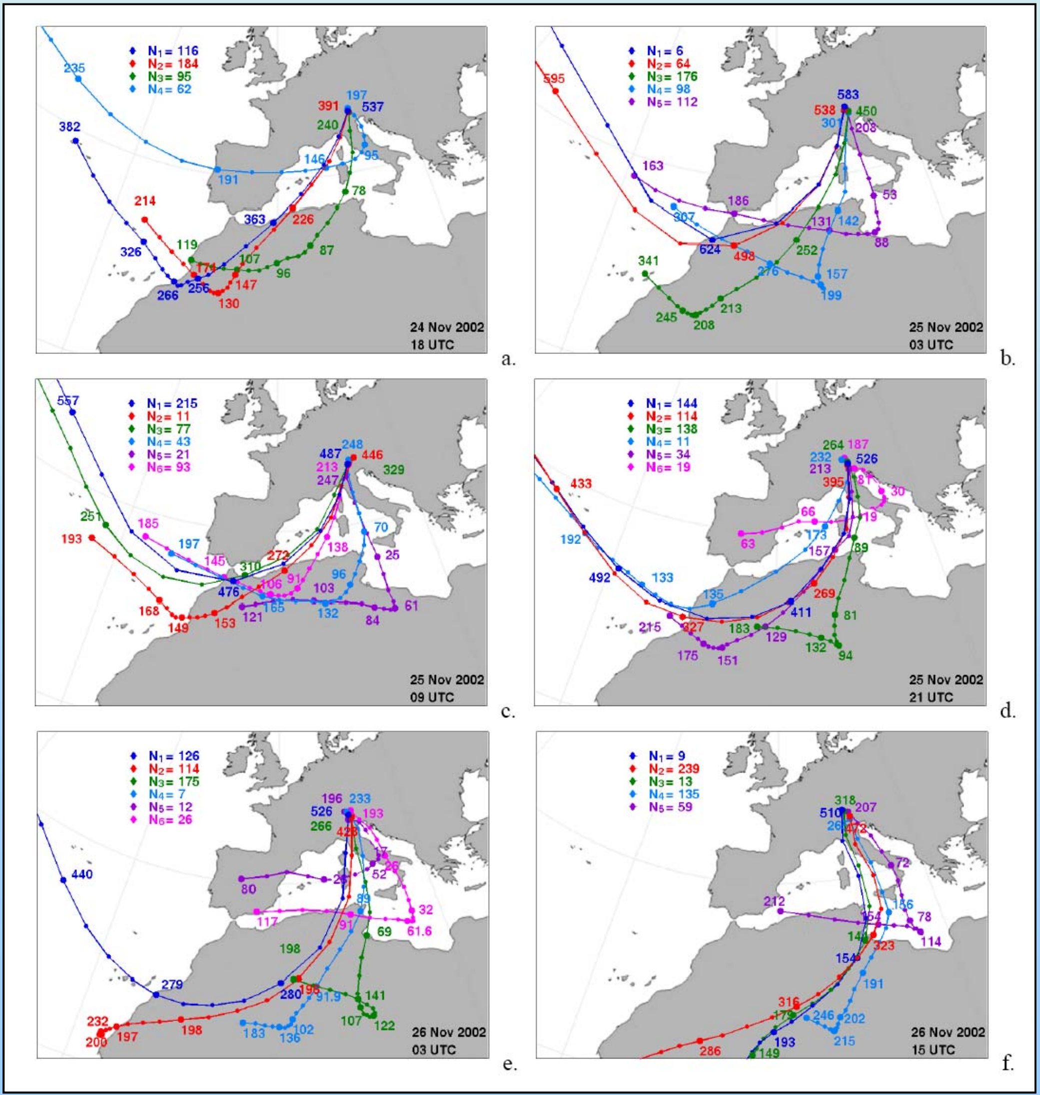
- moisture sources and transport;
- role of tropical cyclones (in the Atlantic);
- tropical moisture injection into mid-latitudes.

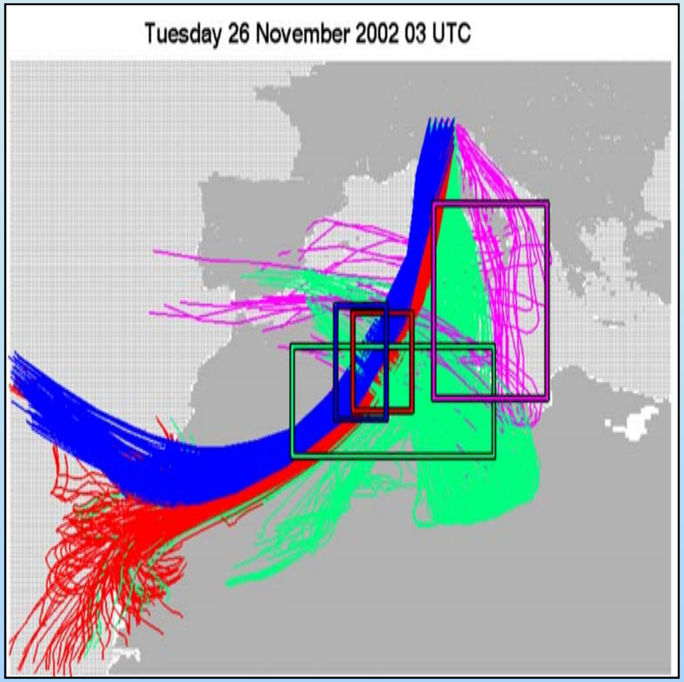
(Krichak et al, 1998; Reale et al., 2001; Pinto et al, 2002; Turato et al, 2004; Bertò et al, 2004; Krichak et al, 2004 and others).

- Moisture sources for precipitation in the Mediterranean can be local as well as remote.

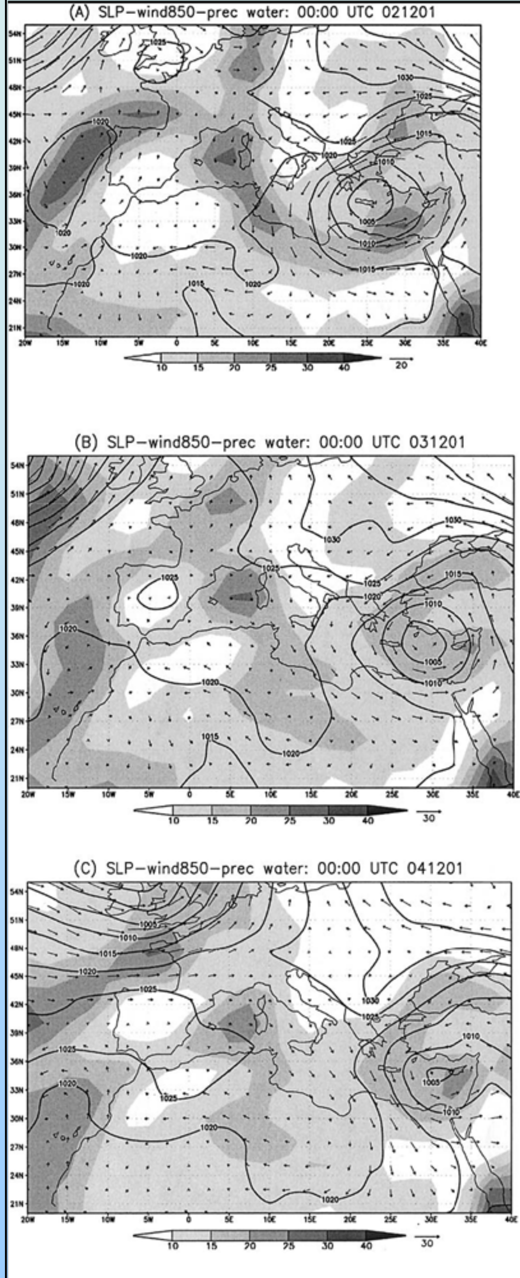
-The importance of transport of Sahara pbl air mass (elevated neutral layer) and of desert dust has been documented in the literature.

Role of larger scale flow in transporting the water vapour: trajectory clustering analysis

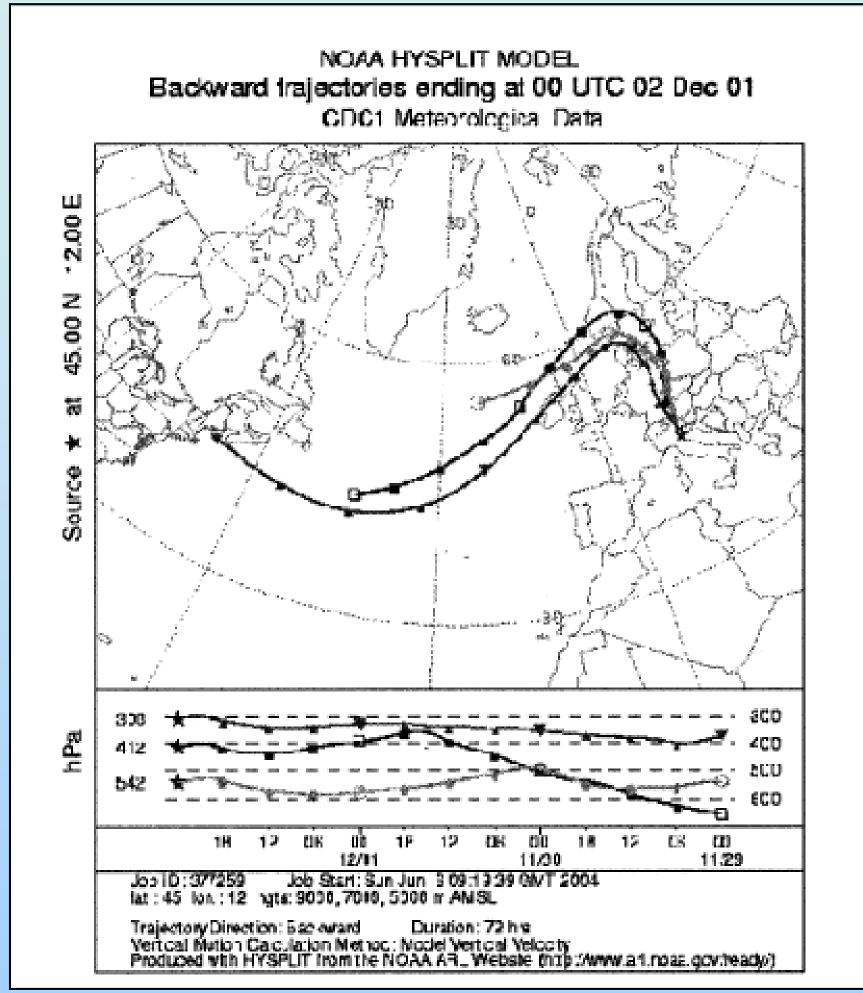




Bertò, Buzzi & Zardi (2004).



850 hPa wind and precip. water



Role of hurricane Olga in Dec. 2001 E. Med. cyclone and torrential rain in Israel

Krichak et al, 2004

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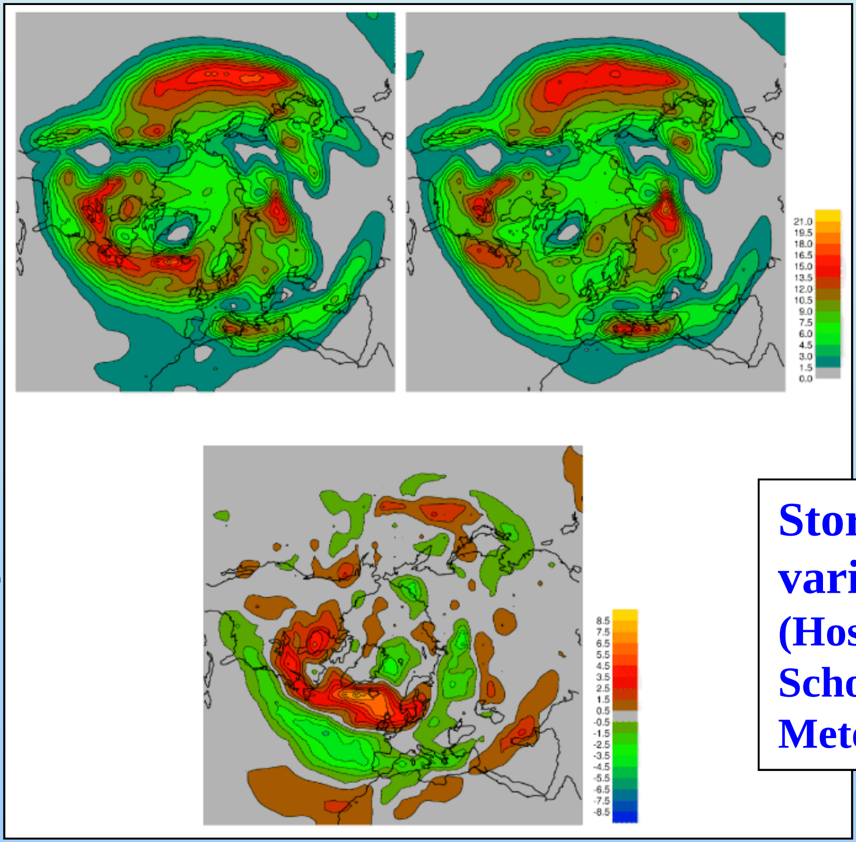
In cases of prevailing blocking regime over the European-Atlantic sector, and/or in case of negative NAO, cyclonic activity in the Mediterranean is generally enhanced:

positive NAO

negative NAO

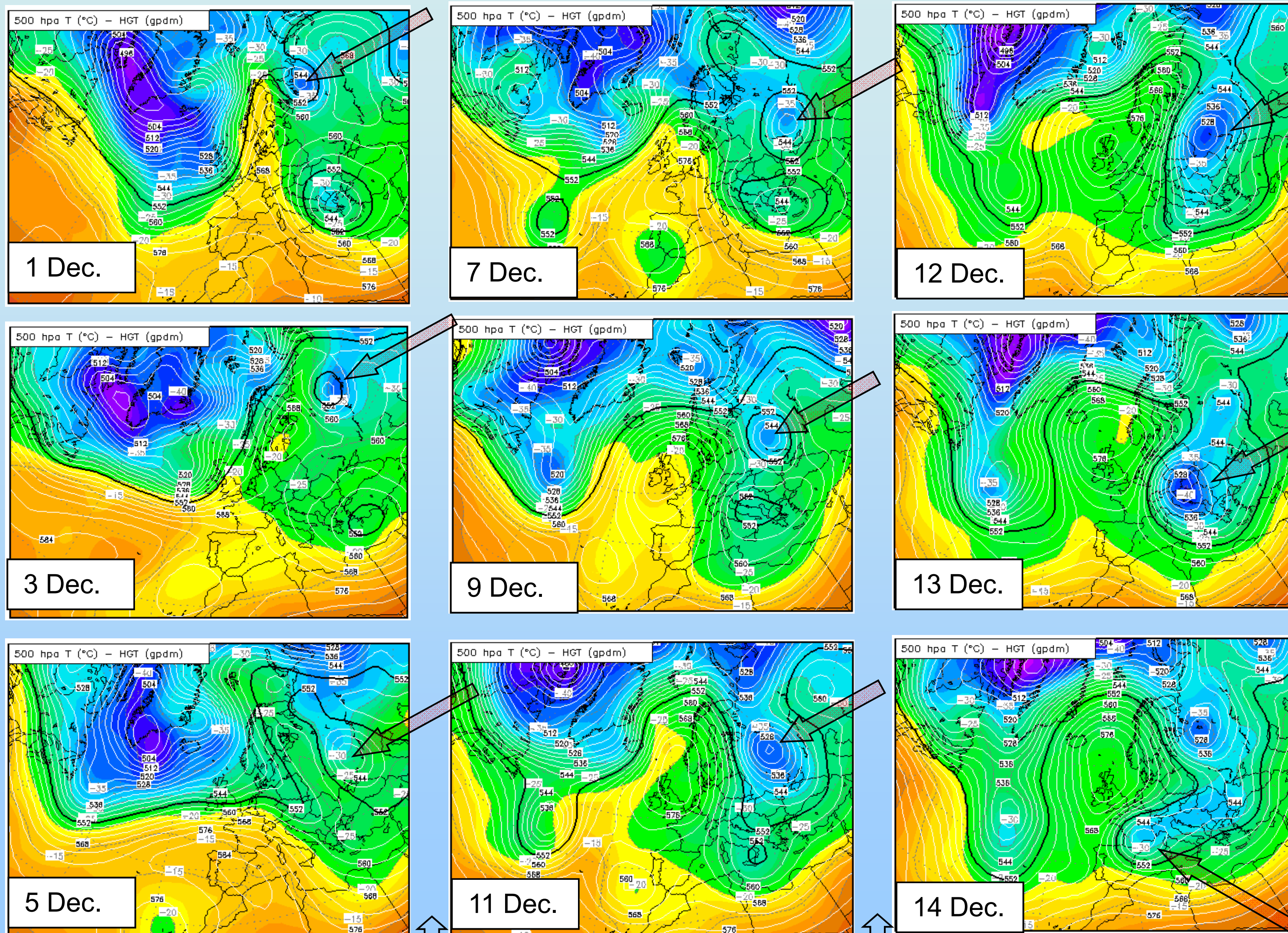
difference pos - neg



Storm track density variation with NAO (Hoskins, Mediterranean School of Mesoscale Meteorology, Alghero, 2006)

An example follows of Mediterranean impact of retrogressive upper level cut-off lows/PV maxima in winter, in a case of strong European blocking: ⇨

1-14 Dec. 2001: re-intensification of an upper-level cut-off low over Eastern Europe, eventually causing cyclogenesis and snowstorms over Italy:



time

GPH (lines) and T (colour) at 500 hPa

NCEP analysis - Source: www.wetterzentrale.de

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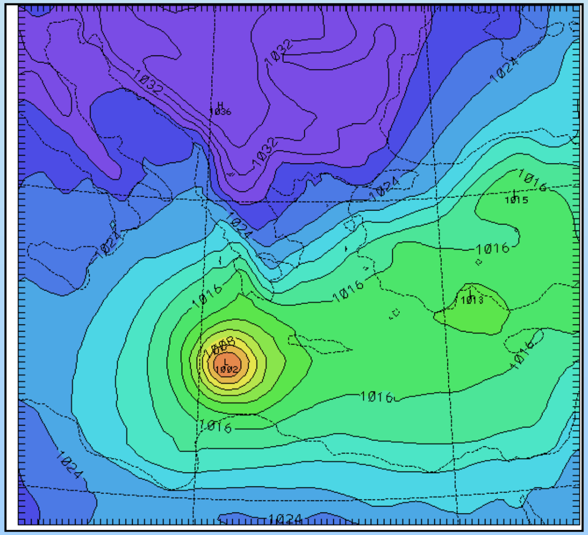
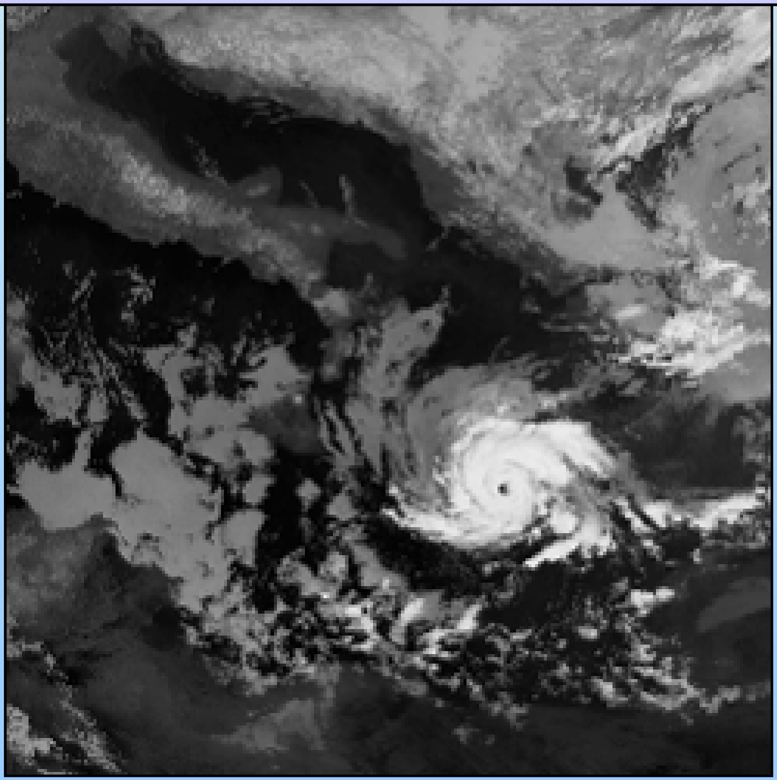
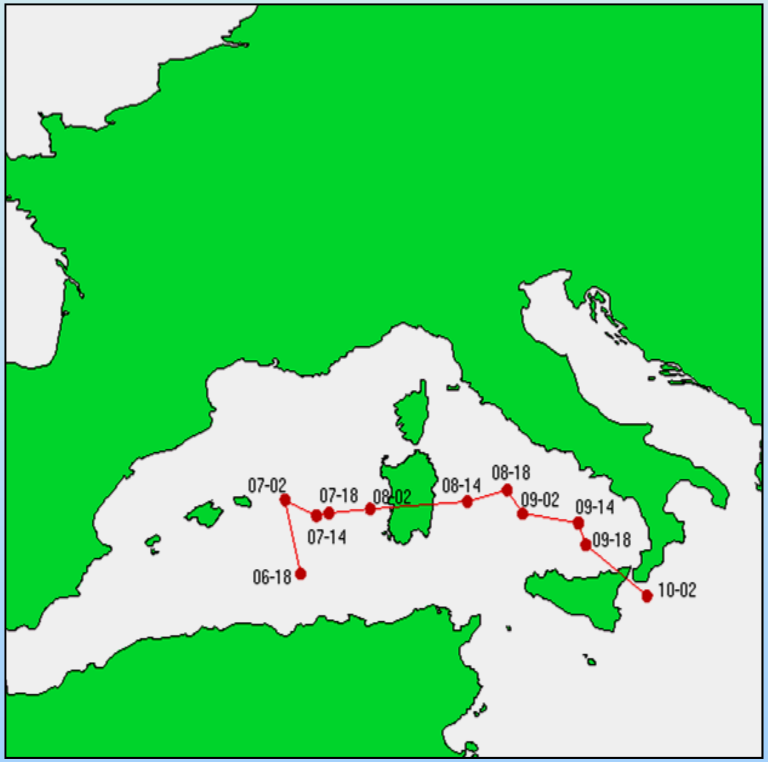
Mediterranean *hurricane-like cyclones*: similar also to "polar lows" (Rasmussen and Zick, 1983; Lagouvardos et al, 1999; Reale and Atlas, 2001; Pytharoulis et al, 2000). Numerical simulations of these systems have helped in discriminating the role of precursor upper-level cold disturbances and air-sea interaction processes (Homar et al., 2003; Emanuel, 2005; Fita et al, 2007; Moscatello et al, 2008; Davolio et al, 2009).



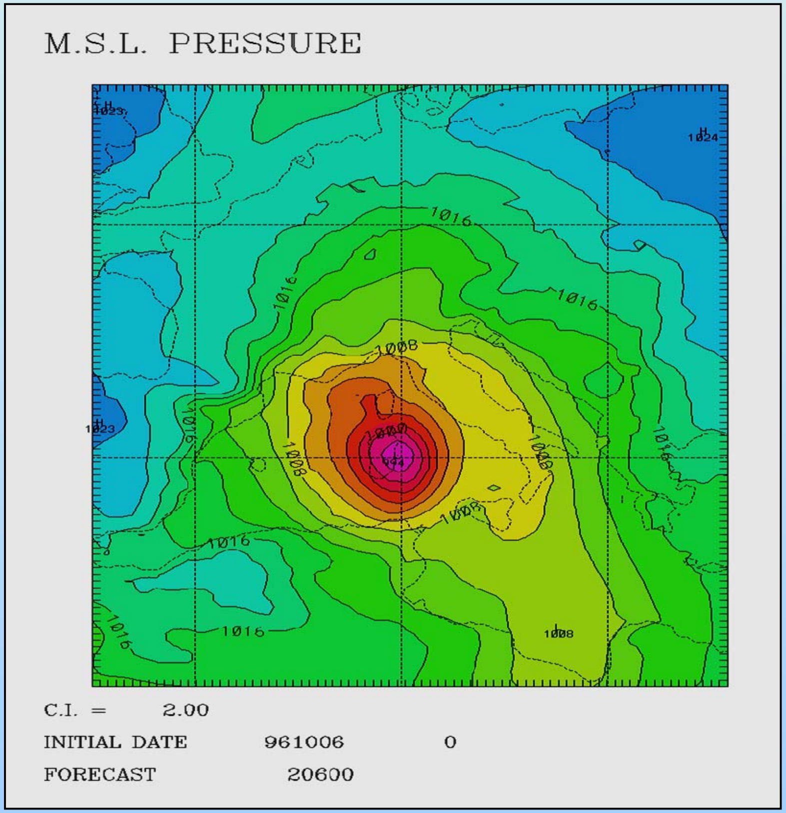
"Medicane" of 15 January 1995 (Lagouvardos et al, 1999).



Some *Medicanes* occasionally cross land, so that local observations are possible: e.g. 7-10 October 1996:



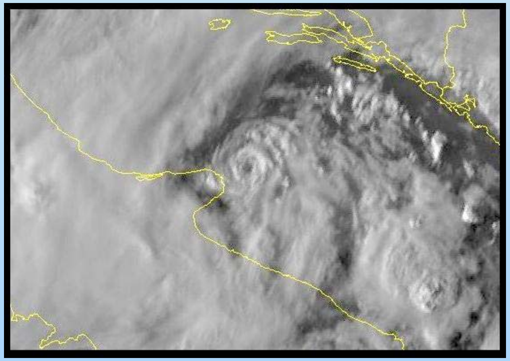
Observed cyclone track



BOLAM model simulation, +54 h, verif. 8 Oct. 2006.

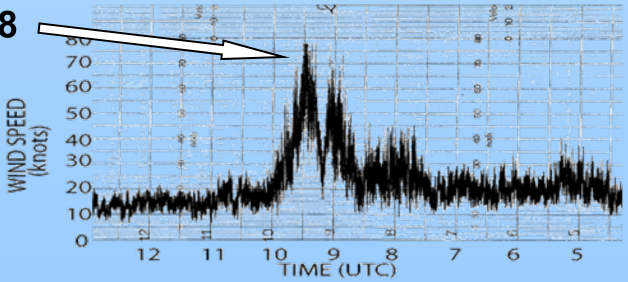
… and 26 September 2006 (Moscatello et al, 2008; Davolio et al , 2009)

Radar reflectivity

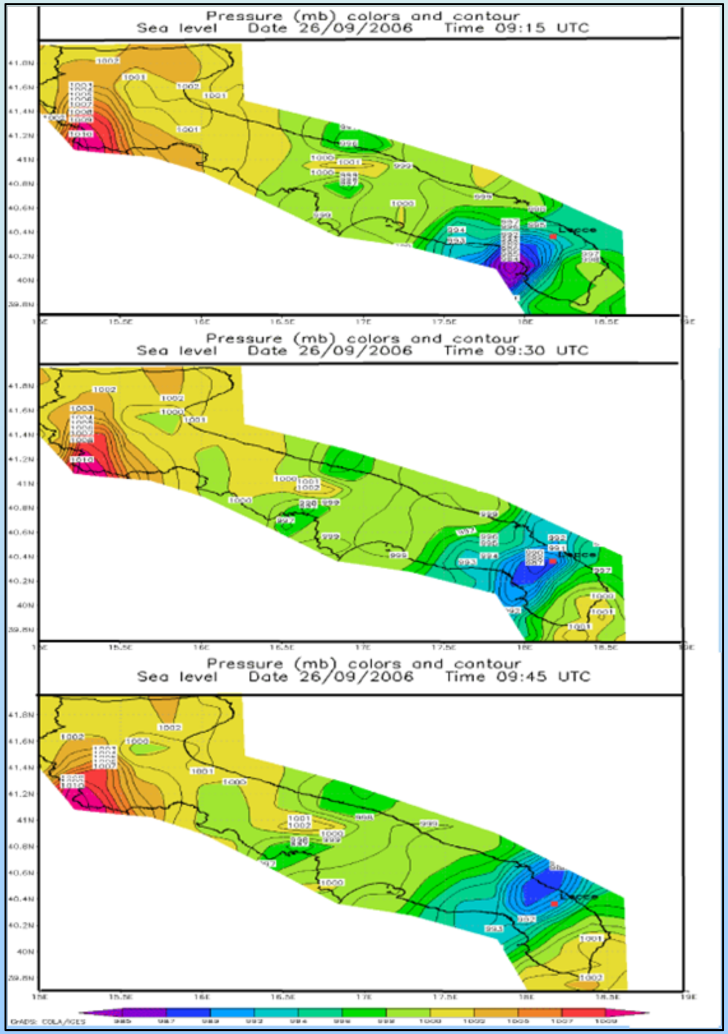


Meteosat, VIS, 14:45 UTC

Max. 78 knots



Wind speed at Galatina airport



MSPL (min 986 hPa), 09:15 UTC

MSPL (min 987 hPa), 09:30 UTC

MSPL (min 988 hPa), 09:45 UTC

MSLP mesoscale analysis

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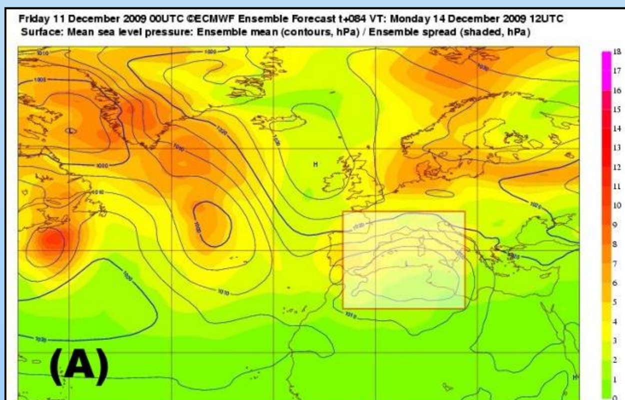
Ongoing projects: MEDEX, HYMEX

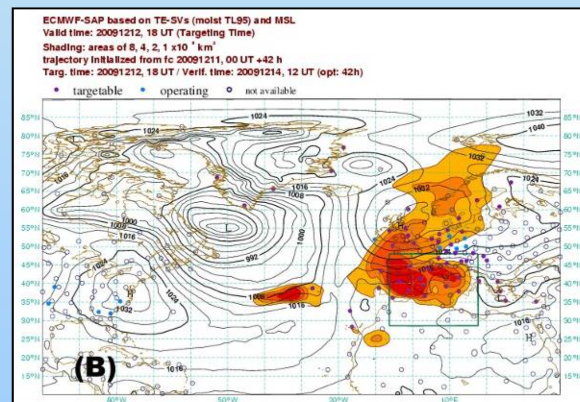
Among the long-term international projects, MEDEX has been oriented to better understanding and predicting Mediterranean cyclones that are associated with high-impact weather.

A Data Targeting System campaign (DTS-MEDEX-2009) operated last year (cooperation of AEMET, ECMWF, EUCOS and Météo-France).

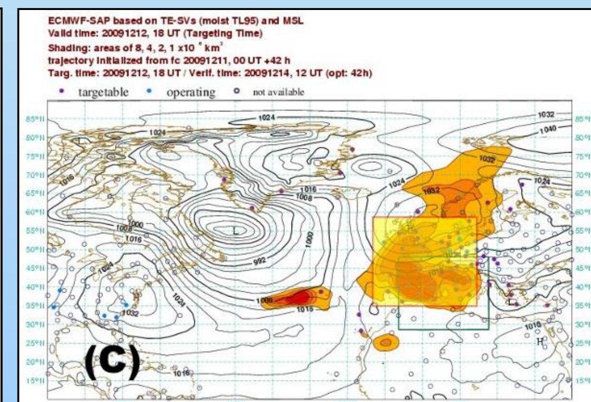
- A field experiment in which the data targeting (DT) was applied to operational observing systems (RAOBS and AMDAR) to test the improvement of the forecasting of cases of high impact weather, related to cyclones in the Mediterranean.
- DTS-MEDEX-2009 is a culminant item of the international MEDEX project.
- DTS software has been developed at ECMWF.



Target area selected for a pre-defined Verification Time (VT), to compute sensitivities.



ECMWF sensitivities (based on singular vectors) at the Target Time (TT).



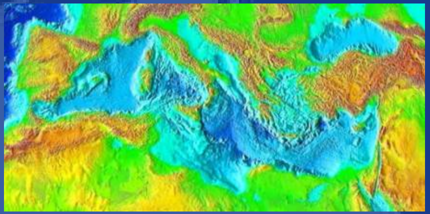
Yellow shaded rectangle: area selected to perform extra observations at TT, to improve forecast at VT in the target area (green rectangle)

A. Jansa, AEMET, 2010 - 4th HyMeX Workshop, Bologna, June 2010.

HyMeX objectives

Motivations, societal stakes

The Mediterranean basin:



A nearly enclosed ***sea*** *surrounded by* ***very urbanized littorals*** *and* ***mountains*** *from which numerous* ***rivers*** *originate*

⇒ **A *unique highly coupled system***

⇒ **A region prone to *high-impact events*:**

→ Heavy precipitation, flash-flooding during fall

→ Severe cyclogenesis, strong winds, large swell during winters

→ Droughts, heat waves, forest fires during summers

⇒ ***Water resources: a critical issue***

→ Freshwater is rare and unevenly distributed in a situation of increasing water demands and climate change

⇒ The Mediterranean is one of the two main ***hot spot regions*** of the climate change

⇒ **Need to advance our knowledge on *processes related to water cycle within all Earth compartments*, to progress in the *predictability of high-impact weather* events and their evolution with *global change*.**

HyMeX objectives

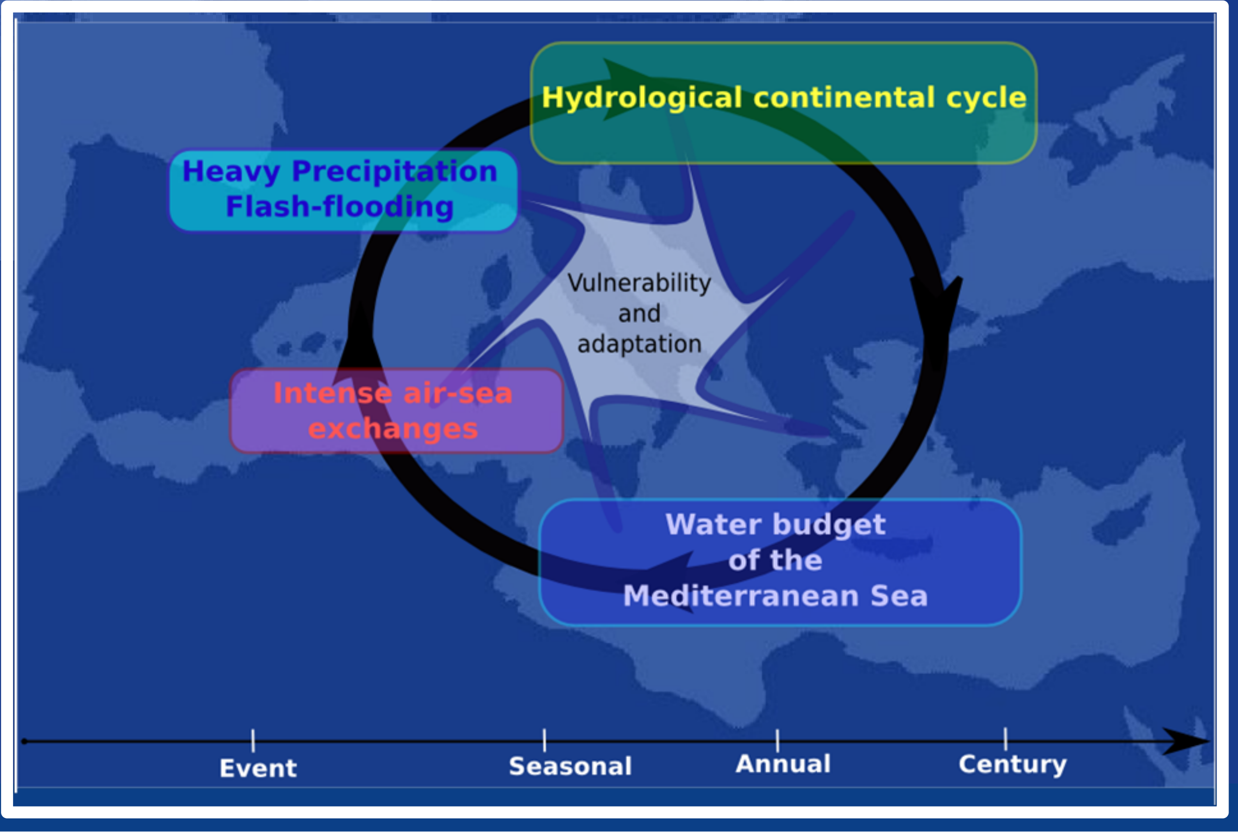
Scientific topics

❑ **to improve our understanding of the *water cycle*, with emphases on the *predictability and evolution* of *intense events***

⇨ by monitoring and modelling:

the Mediterranean ***coupled system***, its ***variability*** (from the event scale, to the seasonal and interannual scales) and characteristics over ***one decade (2010-2020), in the context of global change***

❑ **to evaluate the *societal and economical vulnerability* to extreme events and the *adaptation capacity*.**



P. Drobinski, V. Ducrocq, P. Lionello, HyMeX ISSC, 4th HyMeX Workshop Bologna, June 2010.

Summary and conclusions

✓ Mediterranean synoptic variability: partly induced by the outside storm tracks (mainly Atlantic, but different circulation types are important, e.g. European blocking) and partly generated (or re-generated) *in situ*, especially in the lower troposphere.

✓ Orographic effects are crucial for understanding and forecasting Mediterranean cyclones and weather in general, from the synoptic scale to the meso-γ scale.

✓ The presence of a closed sea, with desert to its south, is another unique Mediterranean feature that determines air mass properties (preconditioning and transformation).

✓ Surface fluxes are important in modifying cyclone life-cycle and in allowing the formation and maintenance of tropical-like small-scale cyclones.

✓ International projects, including field experiments, have been dedicated to observing and understanding Mediterranean meteorological variability and to improving forecasting, with an increasing degree of integration.


THANK YOU!

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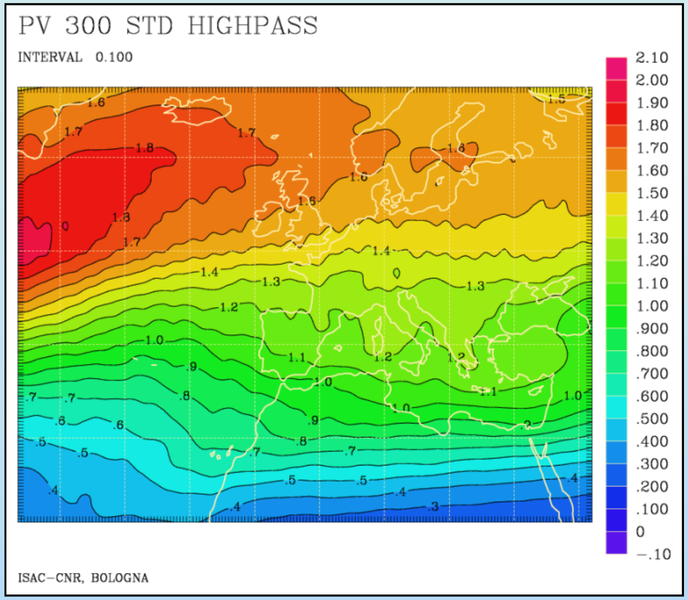
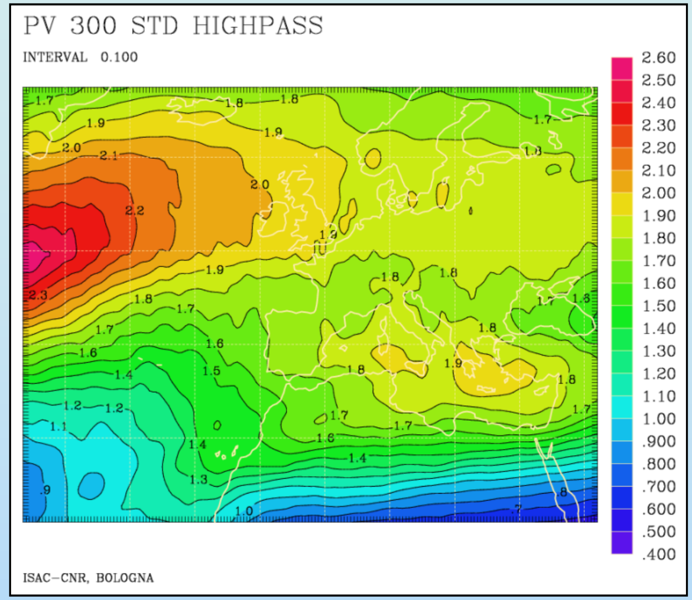
Other high-pass filtered variables characterizing the synoptic scale transients and storm-tracks

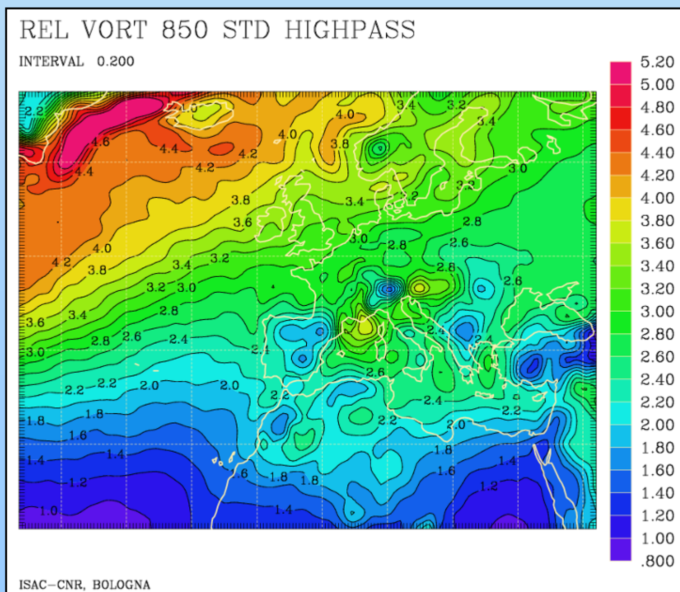
Standard deviation of **Ertel PV at 300 hPa**

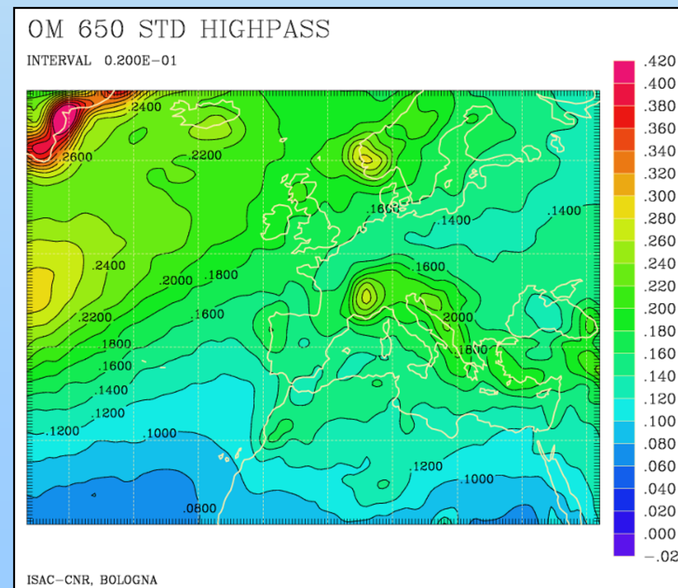




As left but weighted with 1/sin(φ)

Standard deviation of **rel. vorticity at 850 hPa**





Standard deviation of vert. velocity ω at 650 hPa