Synoptic-scale variability in the Mediterranean

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Abstract

The synoptic-scale variability over the Mediterranean presents different peculiar aspects. They are reviewed and discussed here, with particular attention posed on the influence of orography on cyclone properties and cyclogenesis.

1. Introduction

The Mediterranean meteorological variability on the synoptic scale, i. e. in the range from a few hundreds to a few thousands of kilometres, can be attributed, to a large extent, to cyclones that, intermittently and mainly in the colder semester (October to April), affect the area. Mediterranean cyclones exhibit peculiar properties that have been subject of many scientific investigations, international programmes and field experiments, as Lee-Cy (1961-1964; see reference in Speranza, 1975), ALPEX (1982-1984; Kuettner, 1982); MEDEX (2000-2009; Jansà et al, 2001). The most significant aspects that attracted attention of many meteorologists in the past were related: (a) to the rapid (and difficult to be predicted, not being properly described by classical conceptual models) cyclogenesis process at the origin of many Mediterranean cyclones, (b) to the difficulties in detecting such depressions in their early stages due to their relatively small scale structure and (c) to the frequently associated severe weather, mainly heavy precipitation and strong winds. The most intriguing aspect was the high frequency of cyclogenesis as it emerged from studies between mid 1950's and early 1960's (Pisarski, 1955; Petterssen, 1956; Meteorological Office, 1962; Radinović, 1965). Such investigations revealed that Mediterranean cyclogenesis was concentrated in relatively small areas, mainly the Gulf of Genoa (but including the Gulf of Lion, the Tyrrhenian and the northern Adriatic sea), the Ionian sea and the Eastern Mediterranean around Cyprus. In particular, Petterssen's analysis, though made at relatively low resolution since it comprised the entire Northern Hemisphere, revealed that the Mediterranean exhibits the highest peak of cyclogenesis frequency over this hemisphere.

The studies aimed at characterizing cyclogenesis and cyclone tracks over the Mediterranean continued until nowadays, with rejuvenated interest in the last 10-15 years, after gridded surface pressure and geopotential fields, derived from operational analyses/reanalyses, became available to researchers. Alpert et al (1990) draw cyclone trajectories along the whole basin, including the eastern part, using operational ECMWF analyses. Maheras et al (2001), employing NCEP/NCAR 40-year reanalysis, compiled statistics of cyclone occurrence and of surface pressure drop in different seasons for the entire Mediterranean, considering also the daily cycle. Trigo et al (1999 and 2002) analyzed the climatology of cyclones and cyclogenesis in different sub-regions of the Mediterranean and in different seasons, using ECMWF reanalysis data. The same dataset type, but at higher resolution, was exploited by Gil et al (2002) to detect cyclone frequency in the Western and Eastern Mediterranean (hereafter WM and EM, respectively), in the context of MEDEX, counting more than 700 events per year in the EM and more than 900 in the WM. Such (surprisingly high) numbers, however, depend on the algorithm and spatial filtering applied. The tendency of getting unrealistically high numbers of cyclonic events over the Mediterranean, unless somehow more restrictive criteria are applied on cyclone definition and intensity, had been already discussed by Speranza (1975), who noted that shallow depressions of thermal origin, mainly confined to the atmospheric boundary layer, should not be confused with active, vertically deeper cyclones. More recently, Campins et al (2006), employing high-resolution (0.5 deg.), 8-year HIRLAM analyses, and Homar et al (2006), using a more climatologically representative data set (ERA-40), produced detailed statistics of Mediterranean cyclones, stratified by intensity and season, and their vertical structure.

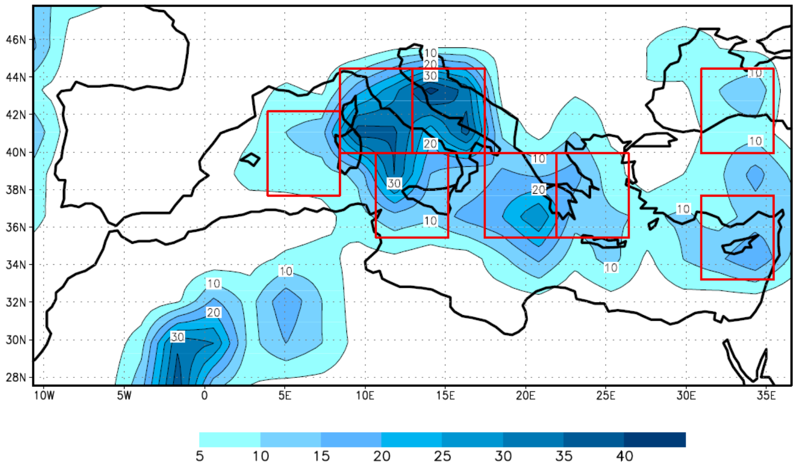

Figure 1: Number of 'intense' cyclones that achieve maximum circulation within the 2.25°x2.25° grid box over the 45 years ERA-40 period (Homar et al, 2006).

Figure 1 reports the number of sole intense cyclones present in the area at their maximum strength. The maxima of Fig. 1 are located at some distance downstream of the areas of highest frequency of cyclogenesis. However, the tendency of cyclones to appear over open seas located somewhere to the south or south-east of the main mountain chains (Alps, Dinaric Alps, Atlas mountains, Anatolia mountains) is confirmed by this analysis. A partial novelty with respect to earlier investigations is the prominence of cyclones situated over the Sahara desert, south-east of the Atlas chain. Accordingly to Homar et al (2006), intense cyclones are more frequent in the period from December to April.

Other relatively recent cyclone density statistics can be found in the context of Northern Hemisphere analyses, like those presented by Hoskins and Hodges (2002), Wernli and Schwierz (2007) and Raible et al (2008). In all such analyses, which apply innovative objective methods in tracking cyclonic disturbances and in characterizing their life cycle, the WM appears to maintain its prominent role as main cyclogenetic region, although the Pacific and Atlantic storm-track areas largely dominate in terms of cyclone frequency.

Even more recently, Horvath et al (2008) studied detailed trajectories and dynamical characteristics of Genoa-type and Adriatic-type cyclones, taking advantage of high resolution, operational ECMWF analyses. Bartholy et al (2009) computed statistics of cyclone genesis, intensity and tracks over southern Europe and the WM, using ERA 40. With the same dataset, Flocas et al (2010) analysed cyclone tracks over the EM.

In synthesis, the results of the different statistical investigations agree in indicating that cyclones of extratropical nature are frequent over the Mediterranean, have low-level centres located preferably over the sea (apart form cyclones originated south-east of the Atlas mountains), and concentrate their origin and frequency of occurrence in specific sub-areas of the basin, that are characterized by the presence of important topographic reliefs situated at some distance toward the north or north-west of such sub-areas.

In Section 2, additional statistical results of synoptic scale variability are presented and a simple interpretation of the orographic influence on baroclinic waves is reviewed. Section 3 is devoted to discuss of the problem of Mediterranean orographic cyclogenesis and related theories that have been proposed in the past. In Section 4, other aspects of the Mediterranean variability, with specific reference to different cyclone types and associated mechanisms and processes, are briefly reviewed.

2. Additional statistical properties of Mediterranean high-frequency variability

I have revisited earlier results presented by Buzzi and Tosi (1989) and Tosi and Buzzi (1989), with the aim of updating and generalizing them, using the ECMW ERA-Interim reanalysis, spanning the period 1989-2009 with 6-hour temporal resolution. Data of cold semesters (Oct. to Apr.) of 20 years were extracted and filtered, using a high-pass, tapered digital filter, retaining periods shorter than 8.5 days (cut-off values between 7 and 12 days have been tested, with no significant differences in results).

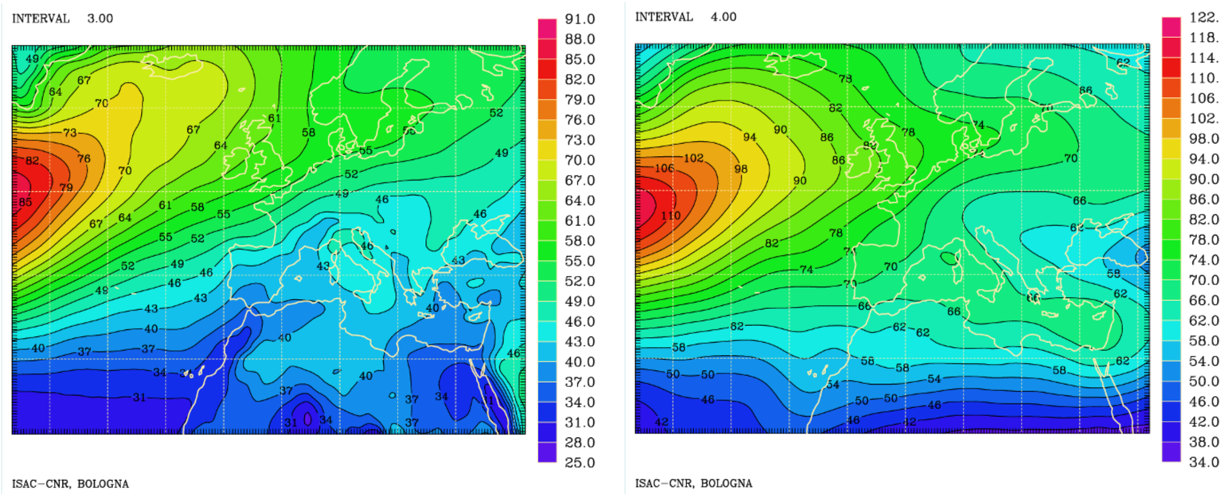

Figure 2: Standard deviation of the high-pass filtered (see text) GPH at 975 hPa (left) and 500 hPa (right) levels, for the cold semester (20 years), in the sector 21.0°N - 67.5°N, 41.5°W - 42.0°E.

Figure 2 shows the variability, in terms of standard deviation weighted with the inverse of sine of latitude, of geopotential height near the surface (975 hPa) and at a mid tropospheric level (500 hPa), respectively. While at both pressure levels the decaying part of the Atlantic storm track is well represented, significant differences between the two levels can be observed over the Mediterranean. At 500 hPa (Fig. 2, right), a distinct SE directed branch, due to a bifurcation of the Atlantic track, affects the entire Mediterranean, with a small isolated maximum near Corsica. Conversely, at 975 hPa (Fig. 2, left) no elongated Mediterranean storm track appears, but rather an isolated, comparatively weak maximum of variability located south of the Alps, extending to embrace the Italian peninsula and adjacent seas and protruding towards the area south-east of the Atlas mountains. One difference with the results of Buzzi and Tosi (1989, see their Fig. 2, referred to the 850 hPa level) is that the Mediterranean maximum does not seem to affect the EM, namely the Cyprus area, perhaps due to the different levels and period of time considered.

If a selection criterion is applied in order to include in the analysis only time intervals characterized by the occurrence of mean westerlies (using the complementary 500 hPa low-pass filtered series as reference, that is selecting days characterized by circulation regimes that are favourable to the propagation of baroclinic/Rossby wavetrains from the Atlantic to the WM in a latitude belt comprised between 38 and 50 N), a corresponding high-pass filtered standard deviation at 975 hPa is obtained as shown in Fig. 3 (left). In this case, that comprises about 20% of the total sample, the maxima of low-level geopotential height (GPH) variability south of the Alps and south of the Atlas become more evident, revealing a statistical property of the orographic modification of transient ‘eddies’ in an approximately westerly flow that reflects also the pattern of intense cyclone frequency shown in Fig. 1, at least over the WM and North Africa.

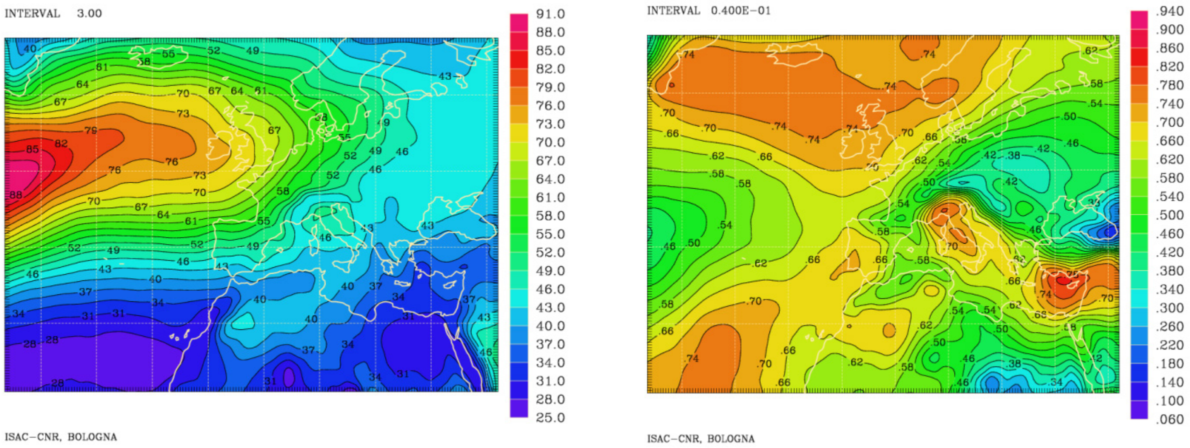

Figure 3: Left: as fig. 2, left, but for selected periods of approximately westerly flow regime over the eastern Atlantic and the Mediterranean. Right: cross-correlation between the high-pass filtered 975 and 500 hPa GPH, still for westerly flow regime.

Another simple indicator that exhibits interesting peculiar features over the Mediterranean and surrounding areas is the cross-correlation index (defined in the range - 1. to + 1.) between the high-pass filtered series computed at 975 and at 500 hPa. Figure 3 (right) shows this index distribution, again for periods of westerly flow regimes over the WM: relatively low values (+ 0.5 or less) are found a few degrees south of the main Atlantic track and mainly over land, while high values (> + 0.7) characterize the main cyclonic areas of the Mediterranean, the northern Atlantic (to the north of the storm track) and the subtropical ocean. For the present purpose, the strong gradient of this parameter, visible across the main mountain chains surrounding the northern flank of the Mediterranean basin, is particularly significant and is in agreement (though in the present case with higher resolution) with the result of Buzzi and Tosi (1989). Moreover, it is consistent with the much earlier findings of Ficker (1920) regarding the vertical structure of pressure perturbations along transects crossing the Alps (see also Blackmon et al, 1979).

I have reconsidered here Buzzi and Tosi's earlier interpretation of the GPH vertical correlation as an indicator of the vertical tilt with height of the transient eddies, by computing lagged correlations in space, in both the longitudinal and latitudinal directions, still from the ERA-Interim data. Figure 4 (left) indicates that, although almost everywhere a westward (negative) tilt with height characterizes eddies, such a tilt changes significantly, ranging from about - 11 deg. north-east of the Alps to less than - 4 deg. south of the Alps and less than - 2 deg. over the EM.

Figure 4 (right) shows the maximum correlation obtained at varying the spatial (longitudinal) lag. This quantity is a measure of the signal coherence, that is the coherence of GPH variability between the two levels considered, after the phase lag is taken into account. The figure indicates that this coherence is relatively high (> 70%) and uniform over Europe and the Mediterranean. This confirms the interpretation that a significant difference in phase tilt with height characterizes the GPH transients on either side of the main mountain chains, bordering the northern side of the Mediterranean. A corresponding test based on N-S lags does not provide significant gains in GPH correlation.

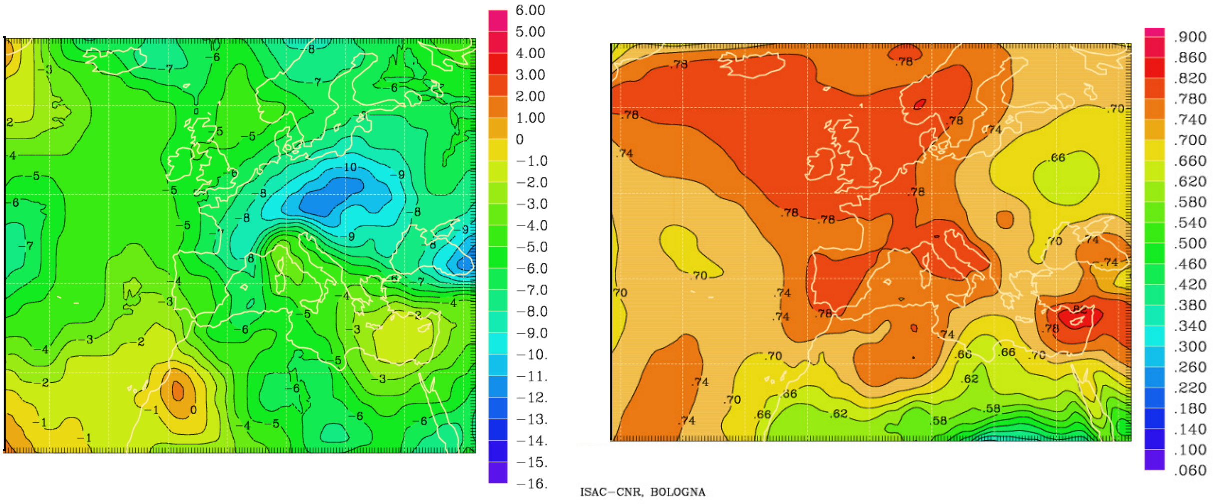

Figure 4: Left: E-W shift (lag in degrees longitude) giving maximum correlation between high-pass filtered GPH at 975 and at 500 hPa (westerly flow periods). Right; as left, but maximum correlation for any E-W lag.

In order to better characterize the properties of high-frequency eddies entering the Mediterranean from the west or the north-west, high-pass filtered GPH fields were used also to plot individual filtered map sequences (Tosi and Buzzi, 1989), composite maps (Bell and Bosart, 1994) and one-point lagged correlation maps (Buzzi and Tosi, 1989), the latter being the result of a simple technique that allows to visualize typical shape and propagation properties of time-filtered eddies (Wallace et al, 1988). The above mentioned analyses revealed that transients eddies entering the Mediterranean undergo, at low levels, a rapid shrinking of their north-south extension, associated with a NE-SW tilting of phase, with large GPH gradients developing across the main mountain chains. In practice, in this statistical representation the disturbances over the Mediterranean increase their amplitude and retard they movement south of the main topographic reliefs, while the opposite occurs north of them. The orographic perturbation induced over the atmospheric transients decreases with height, explaining while eddies become less/more tilted with height south/north of the barriers, respectively.

3. Mediterranean orographic cyclogenesis and related theories

All the statistical properties discussed in the previous Section, though not immediately ascribed to individual Mediterranean cyclones, are basically accounted for by theories of modifications introduced on baroclinic/Rossby waves by orography aligned with the basic westerly flow. In practice, for a westerly sheared flow on which the most unstable baroclinic waves have a long N-S extent with main meridional flows, an orography extending in the zonal direction (e.g. a long ridge), with the largest slopes of either sign in the meridional direction, maximizes the interaction with such waves. It is shown below that this geometry of wave-topography interaction can represent the effects of the Mediterranean mountains on transient eddies moving from the west or the north-west.

The seminal study in this respect is due to Blumsack and Gierasch (1972: BandG), who studied how the presence of a slope in the bottom surface modifies the Eady's (1949) classical baroclinic instability problem. BandG showed that a maximum growth rate of unstable waves, larger by about 20% than in the case of flat bottom (classical Eady problem), is obtained for a moderate positive slope of the orography, that is height of the lower surface increasing towards the colder air. This maximum is found at wavelengths slightly longer than those of the most unstable classical Eady wave. Conversely, for negative slope, the growth rate is strongly diminished and unstable waves, as the slope magnitude increases, survive only in a narrow wavelength band of decreasing values. However, a too steep orography stabilizes the growing modes also in the case of positive slope. BandG noted that, while in the case of positive slope the vertical velocity induced at the bottom by the meridional motion of the baroclinic waves have the same sign of the mid-tropospheric vertical velocity, the opposite occurs for a negative slope, inhibiting, in the latter case, the energy conversion associated with the optimal correlation between trajectories in the meridional plane and temperature fluctuations. Analysis of the eigenmode structure shows that unstable modes in the case of positive slope possess a smaller vertical tilting, of the order of 10 longitude degrees, than corresponding unstable modes in the case of negative slope. Assuming that baroclinic disturbances over the Mediterranean in the preferential cyclogenetic regions 'feel' a positive slope (having the main topographic divide to the north), while disturbances over Central Europe and/or north of the main mountains are in the opposite situation, it is possible to interpret, on the basis of the still over-simplified BandG model, why eddy strength is larger/smaller and vertical tilt is smaller/larger on the southern/northern side of the mountain chains, respectively.

A generalization of BandG prototypal theory, applicable to realistic mountain shapes over the Earth, is due mainly to the 'Bologna dynamic meteorology school' in the 80's and 90's, after the ALPEX project had stimulated studies on orographic cyclogenesis, in particular cyclogenesis occurring in the lee of the Alps. Tibaldi and Buzzi (1983), on the basis of numerical experiments, noted that the signature of the modification induced by the Alps on cyclones has the shape of a geopotential dipole. Speranza et al (1985) presented the first analytical results on the modifications induced by 2-D and 3-D orography on baroclinic growing modes, using the quasi-geostrophic approximation, both in 2-layer and continuous models. The theory of modifications of baroclinic unstable waves induced by topography was then generalized to wider conditions in a subsequent number of papers: Buzzi and Speranza (1986): finite amplitude topography; Malguzzi et al (1987): steep orography in primitive vs. quasi-geostrophic equations; Buzzi et al (1987) and Tibaldi et al (1988): application to different topographies of the Earth; Buzzi et al (1988): statistical intercomparison between linear and nonlinear effects; Malguzzi and Trevisan (1991): solution of the initial value problem as opposed to the normal mode; Trevisan and Giostra (1990): dynamical criteria for orographic cyclogenesis in parameter space; Orlanski and Gross (1994): extended numerical experimentation with zonally oriented topography; Benzi et al (1997): combined effects of orography and humidity; Fantini and Davolio (2001): secondary absolute and convective instability induced by topography on a neutral Eady wave.

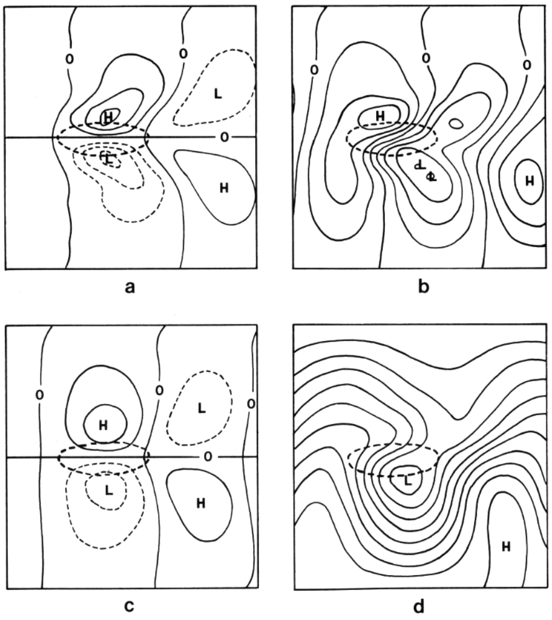

Figure 5: Baroclinic growing wave in an Eady model with isolated topography (dashed). a: streamfunction of the orographic perturbation, at z = 0; b: corresponding total streamfunction of the modified baroclinic wave; c and d: as a and b, but for z = 0.5 (middle troposphere).

In the meantime, alternative theories of orographic cyclogenesis had appeared in the literature, some of them based on analytical solutions (e.g. Smith, 1984, 1986; Pierrehumbert, 1985). Analytical theories where tested by Egger (1988) and Tafferner and Egger (1990), and were found more or less inadequate to explain all the observed or modelled characteristics of lee cyclone formation, especially for the flow characteristics near the mountain. Other, more heuristic/conceptual theories that appeared in the literature (Mattocks and Bleck, 1986; Zupanski and McGinley, 1989; Bell and Bosart, 1994; Aebisher and Schär, 1998; McTaggart-Cowan et al, 2010) underlined the role of upper level potential vorticity (PV) anomalies and associated jet propagating over a low level temperature or PV anomaly.

This kind of theoretical/diagnostic interpretation, based both on observations and numerical experimentation, have highlighted important aspects of the problem. However, they have not provided, in my opinion, general explanations of the dynamical role played by the orography which includes non-linear and non-geostrophic effects and strongly depends on atmospheric stratification. It is true that individual cyclones of large amplitude, including Mediterranean cyclones that grow in the lee of the orography, reflect only crudely the structure of baroclinic growing normal modes, and also that rapid isolated cyclogenesis generally occurs in the presence of a PV maximum aloft. However, numerical simulations of orographic cyclones indicate that the upper PV anomaly is modified in its evolution by the presence of the orography itself: the cut off process is enhanced and the propagation of the upper PV maximum is substantially different with and without the orography, via the modifications intervened in the cyclogenetic process. This complex mechanism, which involves small scale and nonlinear processes, can be modelled with state-of-the-art meteorological models but is not easy to be described by relatively simple theories or even conceptual models.

Summarizing Sections 3 and 4, it is possible to conclude that most of the Mediterranean cyclones are more or less directly conditioned by the topography in their origin and life-cycle. They tend to be meridionally confined and hence to have smaller scales than their ‘unconstrained’ (oceanic) counterparts. Although often the cyclogenetic process at the surface over the Mediterranean may appear as ‘autonomous’, in most cases a parent/precursor disturbance (an upper trough associated with a southward propagating jet and with an upper PV anomaly/streamer) can be traced back upstream, outside the Mediterranean area. Moreover, according to theoretical and modelled modifications introduced by orography on baroclinic modes, the ‘lows’ and ‘highs’ are, if compared to the flat topography case, (a) enhanced in amplitude south of the ridge and weakened north of it; (b) shifted to the west south of the ridge and to the east north of it. This accounts also for the different tilt with height, considering that the orographic modifications tend to decay with height.

4. Other aspects of Mediterranean cyclones and associated variability

By about late '90s the practical problem of forecasting Mediterranean cyclogenesis and cyclone tracks was considered, at least for short-range forecasting, nearly solved, thanks mainly to NWP models having reached adequate resolution. The main scientific and practical interest then was oriented mainly on QPF (Quantitative precipitation Forecast), in relation with frequent flooding events that affect Mediterranean coastal areas, facing orography slopes, and, in general, on high-impact/severe weather. This means that the main attention has been increasingly focused on mesoscale phenomena and processes: ‘wet’ aspects (interaction between dynamics and diabatic effects including microphysics), small scale orographic effects, PBL phenomena, air-sea interaction, etc. However, Mediterranean cyclones are still being regarded as the main source of mesoscale variability, including heavy precipitation (orographic and convective) and strong winds. Moreover, the special variety of Mediterranean Tropical Like Cyclones (TLC) have also received increasing attention, as a peculiar aspect of Mediterranean meteorology. In the following, a review summary of recent results on these subjects is presented. The reader is referred also to Lionello et al (2006) for a recent review paper of Mediterranean cyclones in the context of climate and environment.

The connection between Mediterranean synoptic variability and hemispheric Rossby wave propagation, applying planetary wave tracking and analyzing the predictability of situations conducive to heavy precipitation associated with strong southerly flows, has been presented by Grazzini (2007).

On the small scale side, i.e. the mesoscale (high impact) weather, many studies have been published in recent years concerning heavy precipitation (mainly orographic and convective), strong winds, storm surges etc., associated with Mediterranean phenomena. Only a few examples are mentioned here. Regarding winds, a very recent paper by Nissen et al. (2010) investigates the relationship between the occurrence of strong winds over the sea and Mediterranean cyclones, while Cavaleri et al. (2010) have studied the predictability of storm surges and high waves caused by Mediterranean storms. Events of very intense cyclones, producing severe weather in terms of wind and precipitation, like the ‘superstorm’ that caused a disastrous flood in Algiers and destructive winds in the Balearic Islands in November 2001 (Arreola et al., 2003; Tripoli et al, 2005; Argence et al, 2009, among others), received much attention in terms of mechanisms, sensitivity to initial and boundary conditions and predictability. In this type of events, often originated in the lee of the Atlas (Horvath et al, 2006), both the upper level ‘forcing’ (a pronounced PV maximum) and surface fluxes of latent and sensible heat, in the presence of strong surface winds (WISHE mechanism, Tripoli et al, 2005), are very important to explain the intensity attained by the cyclonic circulation.

The combined role of surface fluxes over the sea and of a very strong low level jets carrying large amounts of moisture can explain ‘extreme’ events of mixed orographic, frontal and convective precipitation, as the case of the November 1966 ‘century’ storm that hit Italy, causing very extensive flooding, storm surges and land slides. This event was studied, among others, by Malguzzi et al (2006), using a chain of numerical models, starting from the ERA40 dataset and additional experimental, higher resolution reanalyses prepared at ECMWF.

The important role played by diabatic effects (including surface fluxes, latent heat release, moisture ‘preconditioning’ and long-distance transport) in cyclone lifecycle was emphasized in ‘attribution’ studies like those based on the ‘factor separation method’ of Stein and Alpert (1993), including subsequent developments and applications (Doswell et al, 1998; Buzzi et al, 1998; Michaelides et al, 1999; Krichak and Alpert, 2002) and in ‘sensitivity’ studies (Homar and Stensrud, 2004; Garcies and Homar, 2009; Horvath and Ivančan-Picek, 2009). Other papers have tackled the problem of water vapour transport that contributes to precipitation and also to cyclone generation (Krichak et al, 1998: Reale et al, 2001; Turato et al, 2004; Bertò et al, 2004; Krichak et al, 2007; Sodemann et al, 2009; Ziv et al, 2010). Although large amounts of vapour in the troposphere can derive from evaporation of Mediterranean waters in cases of strong surface winds, long-distance transport of vapour, from the Atlantic, from sub-tropical regions and even from hurricanes, can be important in some cases to explain torrential rainfall and cyclone characteristics. In addition, the presence of the north Africa continent, including the Sahara desert, determines the properties of the air masses that enter into the Mediterranean cyclones from the south, for example forming elevated dry mixed layers (Tripoli et al, 2005) and also affecting radiative and microphysical properties in cases of important atmospheric loading of Sahara dust (Alpert et al, 2002; Carmona et al, 2008).

A couple of additional aspects are worth of mention in connection with Mediterranean variability and vortices, although they pertain more to the mesoscale than to the synoptic scale. First, a class of cyclonic events is related to the arrival from northern latitudes of upper-level cut-off lows (UCL, called also ‘tropopause polar vortices’). These are cyclonic vortices initially confined in the middle and upper troposphere, usually not characterized by a specific baric signature near the surface, that can affect mid latitudes after a detachment of a ‘cold drop’ from a trough in the main polar (Arctic) vortex at high latitudes. They have been recognized to constitute a meteorological phenomenon distinct from usual baroclinic cyclones that characterize the storm-tracks. UCL's can survive for periods of days to weeks, sometimes with retrogressive (east to west) motion, especially when they form on the eastern flank of blocking anticyclones in the European sector (see the climatological study of Nieto et al., 2007). When such upper level disturbances move over the Mediterranean, especially during winter, they can cause cyclogenesis at the surface, favoured by surface fluxes and latent heat release (Llasat et al, 2007; Porcù et al, 2007). Second, in the Mediterranean a special class of small-scale (of the order of one hundred km or less) cyclones is observed, though not very frequently, called TLC or ‘Medicanes’, because they share some dynamical aspects with tropical hurricanes and also with polar lows (Rasmussen and Zick, 1987; Lagouvardos et al, 1999; Pytharoulis et al, 2000; Reale and Atlas, 2001). Numerical simulations of these systems have helped in discriminating the role of precursor upper-level disturbances and air-sea interaction processes sustaining the strong circulation and associated quasi-symmetric annular cloud structure (Homar et al., 2003; Emanuel, 2005; Fita et al, 2007; Moscatello et al, 2008; Davolio et al, 2009).

5. Summary and conclusions

The synoptic scale variability characterizing the Mediterranean area (especially the WM) has been examined mainly from the point of view of high-frequency properties, as deduced from reanalysis time series, and their relationship with storm-tracks, cyclones and cyclogenesis. Some distinctive properties of Mediterranean cyclogenesis have been attributed to orographic modifications induced by the peculiar topography of the Mediterranean on disturbances coming mainly from the Atlantic. Among the mechanisms of cyclone formation and maintenance, the baroclinic instability in the presence of topography, elongated perpendicularly to the basic thermal gradient, has been identified as a relevant aspect. However, the surface fluxes of latent and sensible heat and the latent heat release are important processes associated with cyclone intensification and life-cycle.

A variety of different cyclone types is observed in the Mediterranean, including those originated by upper level disturbances migrating over the sea from high latitude regions and Tropical-Like Cyclones, the latter being a phenomenon, intermediate between polar lows and hurricanes, that seems specific of the Mediterranean, although it can be hardly considered as a synoptic scale feature.

The physical aspects reviewed in this paper and related forecasting problems have been and are among the main objectives of the already-mentioned MEDEX project, of its Data Targeting System Campaign (DTS-MEDEX, Jansà, 2010), and of the international project HyMeX (Hydrological cycle in Mediterranean Experiment, Ducroq et al, 2010).

Note: the reader is referred, for additional illustrations, to the corresponding presentation given at the 2010 ECMWF Annual Seminar, available as pdf file at:
http://www.ecmwf.int/newsevents/meetings/annual_seminar/2010/presentations/index.html

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