University of Salento

Free University of Berlin

Cyclone climatology in the Mediterranean region : comparison of two existing algorithms for cyclone tracking

MEDiterranean CLImate VARiability (MEDCLIVAR)
Marco Reale
contact: reale.marco82@gmail.com
supervisors: prof.dr.Uwe Ulbrich,prof.Piero Lionello, dr.Katrin Nissen,dr.Gregor C. Leckebusch

Contents

Chapter 1

Cyclones tracking: main issues

1.1 Introduction

Cyclones represent one of the most important factors determining the weather and climate in the Mediterranean region. Although many phenomena associated with cyclones in the Mediterranean region are beneficial from agricultural, hydrological and economical point of view, some of them are damaging and occasionally disastrous (e.g. MEDEX[1]). In fact the morphology of the region with highly populated, industrialized and tourist areas, makes it particularly sensitive to the impact of extremes events.
The relationship between cyclone characteristics and extreme events is highly non-linear, but an analysis of observed and projected future changes of cyclone activity in the region is an important step in the assessments of present day and future extreme event occurrence. It contributes to the understanding of the generation of such events, and to the credibility of model results, for example by identifying systematic trends in cyclone origins, depth or tracks. Thus, it aids strategic planning and adaptation efforts.
The main purpose of the project carried out at Freie Universitaet - Institute of Meteorology in Berlin under the supervision of prof. Uwe Ulbrich and prof. Piero Lionello in the period November-January has been :
1) to compare the existing algorithms for cyclone tracking used at Freie Universitaet in Berlin and at University of Salento in Lecce (called BeA and LeA , respectively, in this report)
2) to produce climatology and statistics of cyclones in the Mediterranean region. Both individual tracks and climatologies will be inserted in the MEDCLIVAR meta-data archive.

1.2 Cyclone tracking at mid-latitudes

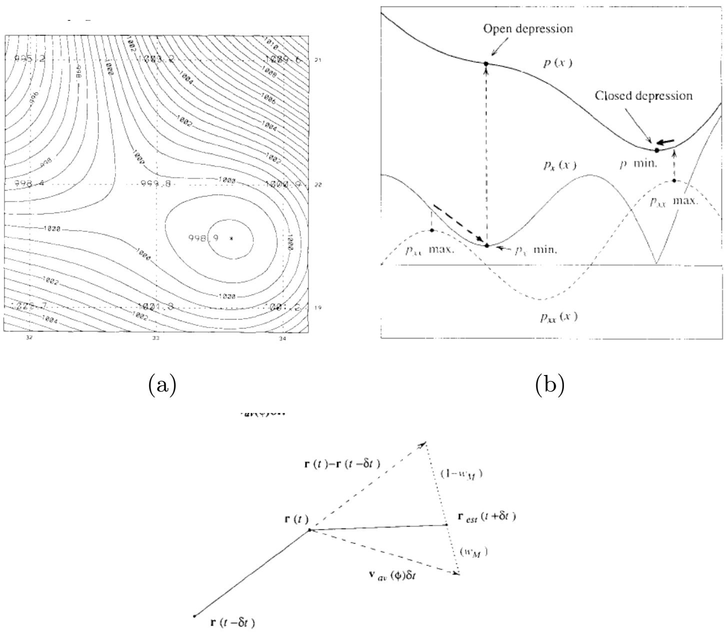
A manual cyclone identification and tracking is not possible when considering ensembles of model runs, and so automatic schemes are applied. Unfortunately, the results from the different cyclone identification and tracking methodologies only give broadly

[1] http://medex.aemet.uib.es/

similar results, but the main characteristics of cyclone activity may seriously depend on the methodology. The differences are ultimately assigned to the fact that mid-latitude cyclones are complex systems with highly variable temporal development, spatial structures and impacts [1] .

In most cases, cyclone cores are defined in terms of pressure minima at sea level, or minima in 1000 hPa geopotential heights. Alternatively, cyclones can be defined in terms of maxima in low level vorticity [14].This implies that one of the issues in tracking algorithms is the choice of the local minimum of SLP (Sea Level Pressure) or vorticity as a basic variable for identification/tracking ([2] , [4], [5]). The definition of a cyclone as a local mean sea level pressure (MSLP) grid point minimum often leads to the identification of numerous non significant systems which can be eliminated later on using a minimum intensity criterion. The search of vorticity maxima in cyclone identification was focuses on the small-spatial-scale end of the synoptic range and the number of systems identified from this quantity is much larger than what is obtained using sea level pressure [3]. Small-scales systems (like fast moving systems or cyclones in the early and late stages of their life cycle) are better identified from their local maxima in relative vorticity([2],[3],[7],[8]). In general while vorticity contains more information on the high-frequency synoptic scale, pressure better resolves the low-frequency scale [3].

The algorithm used at the Freie Universitaet has been initially developed by Murray and Simmonds for Southern Hemisphere ([7], [8]) and then it has been adapted for application in the Northern Hemisphere [14]. Since a mid-latitude depression is always associated with a marked concavity in the pressure field (Figure 1.1, a,b), this method searches for a maximum of laplacian of pressure that is related to geostrophic vorticity. The point where the laplacian of pressure is maximum is taken as the starting point for the search for a pressure minimum. If such a minimum is found, the cyclone is classified as a closed system, with its core located at the pressure minimum. If the search is not successful within a distance of about 1200 km (the distance equivalent to 12 degree in latitude), a second search is performed for the point with the minimum pressure gradient (inflection point), and the system is classified as an open depression[14]. The final step of the identification procedure is the removal of systems on the basis of thresholds. The values of the thresholds for different parameters (for example laplacian of pressure larger that 0.4 hPa/ degree latitude) have been carefully chosen considering more than one hundred individual cyclones [14]. For each identified cyclone, the algorithm predicts a subsequent position and the core pressure. The construction of trajectories can be achieved from a subsequent search for a center within a selected radius of each cyclone position recorded at previous analysis time. The procedure involves the estimation of new position of each system, the calculation of the probability of associations between the predicted and realized position and the research of matching of these associations with the highest overall probability (Figure 1.1,c). For more details see [7], [8] ,[14] .

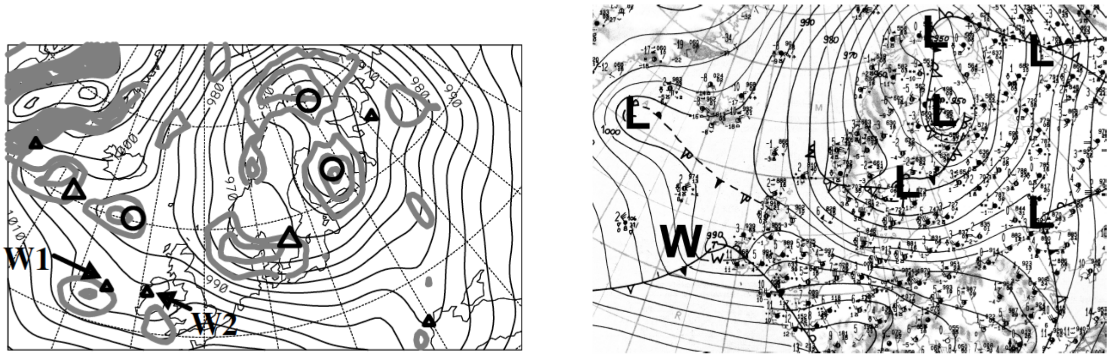


(a) (b)

(c)

Figure 1.1: Plot describing the procedure for the identification of the cyclones using BeA ([7], [8]). This method searches for a maximum of laplacian of pressure (a,b).The construction of trajectories can be achieved from a subsequent search for a center within a selected radius of each cyclone position recorded at previous analysis time. The procedure involves the estimation of new position of each system trough a weighted average of the displacement, the calculation of the probability of associations between the predicted and realized position (c)

Figure 1.2 (a,b) shows an example illustrating a successful cyclone identification using BeA on the interpolated NCEP SLP field for February 28th, 1990, 06 UTC (a) and the corresponding weather chart (b) of the same day with the objectively identified systems marked by symbols, including hand analyzed MSLP contours (black lines, interval: 5.0 hPa), cyclones (marked L) and fronts.



(a) (b)

Figure 1.2: Synoptic situation over the North Atlantic and Europe for February 28th, 1990, 06 UTC - (a) MSLP (black lines, interval: 5.0 hPa) and laplacian of MSLP (grey lines, interval: 1.0 hPa/(deg. lat.)2) from NCEP-Reanalysis data (T62) on a 0.75 deg. lat. polar grid including identified systems. Large (small) symbols indicate strong (weak) identified system, and closed (open) ones are indicated by circles (triangles)(b): weather chart taken from Berliner Wetterkarte, including hand analyzed MSLP contours (black lines, interval: 5.0 hPa), cyclones (marked L) and fronts. (b)[14]

The methodology used at the University of Salento [6] carries out the partitioning of the SLP fields in depressions by the identification of sets of steepest descent paths leading to the same SLP minimum. Each grid point is connected to the lowest of the 8 nearest-neighbor grid points. This step is repeated until a pressure minimum, which is, obviously, a point where the SLP value is lower than the SLP at the 8 nearest grid points, is reached. All the points crossed by a path leading to the same minimum are assigned to the same depression. An example is shown in Figure 1.3. Figure 1.3,a shows the original SLP field, and Figure 1.3, b the results of its partitioning. The small depressions whose central minimum is at a distance less than 4 grid points from the boundary of a different and deeper depression are included in the latter, and the whole map thus contains only a few large depressions (Figure 1.3, c). A trajectory obtained by joining the location of the same low pressure center in successive maps was associated with each depression. The low pressure center is, approximately, the location of the pressure minimum, but it is slightly shifted when the low pressure distribution is asymmetric. A box is associated with each center identified in the map. In the meridional direction the box is centered at the location of the center, with a width of 1.4R, where R is the average distance of the grid points of the depression from its center. In the zonal direction the box is not symmetric, with its western side at a distance of 0.3R, and its eastern side at a distance of 0.8R. Moreover, the box is further extended in the direction of the former motion of the center, with an increase equal to the distance covered by it in the previous 6 h. A center in the map $i + 1$ is assumed to be the continuation of the cyclone in the map i if its center is inside such box. When no center is found inside the box, cyclone termination is assumed. The procedure results therefore in a trajectory, an initial and final point, a sequence of pressure minima, and a sequence of areas covered by the cyclone.

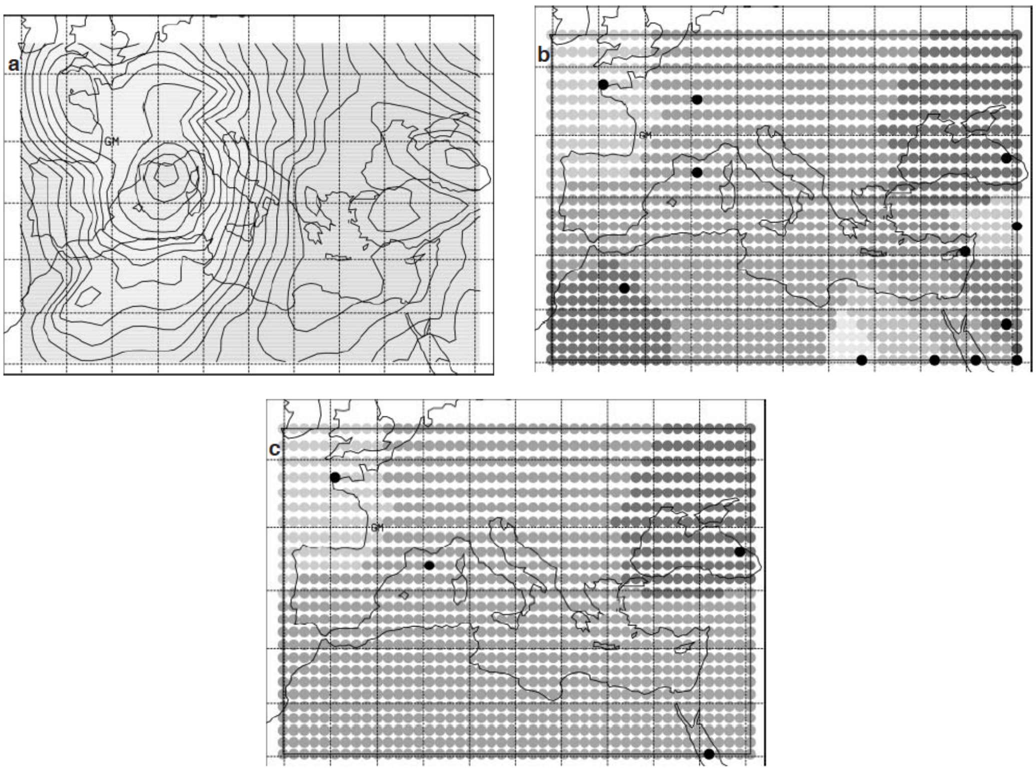
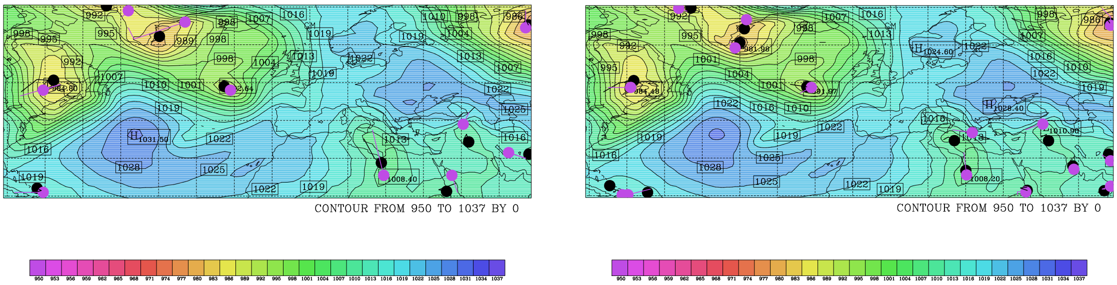


Figure 1.3: Plots showing the procedure for the identification of the cyclones using LeA [6]. (a) Original sea-level pressure (SLP) field. (b) Results of the partitioning procedure. Each dot represents a grid point, and the dots with the same gray level belong to the same partition. Black dots show the location of the pressure minimum of each partition. (c) Final set of large depressions that result from the merging of the small depressions whose central minimum is at a distance less than 4 grid points from the boundary of a different and deeper depression

Figure 1.4 shows the results of application of LeA to ERA-interim 1.5 (a) and ERA-interim 0.75 data (b).



(a) (b)

Figure 1.4: SLP fields (in hPa) at 12 UTC 1th january 1990 at 1.5 resolution (a) and 0.75 resolution (b) contained in ERA-interim and cyclones (black dot) and their maximum of vorticity (fucshia dot) detected using LeA

Chapter 2

Comparison of the cyclone detection and tracking methods

2.1 Data

This study applied two methodologies (LeA and BeA) for tracking to MSLP (Mean Sea Level Pressure) fields in the following datasets (reported with their spatial and temporal resolution) :

- ERA interim, 1.5°- 6h, 1 January 1989 - 31 March-2009

- ERA interim, 0.75°-6h, 1 January 1990 - 31 March-1990

- ECHAM5, 1.875°- 6h, 1 January 1991 -31 December-2000

The comparison of different reanalyses and GCM data and cyclone detection and tracking schemes focuses on cyclones having a minimum lifetime of 24h. The results of our methodologies for tracking consist , in all cases, of all individual cyclone tracks, described by a cyclone identifier, a sequence of positions (time, latitude, longitude) and the intensity (expressed as laplacian or SLP minimum).

The two ERA-interim datasets consist of a set of global analyses describing the state of the atmosphere and land and ocean-wave conditions (Figure 2.1) and represents an 'interim' reanalysis of the period 1989-present characterized with respect to ERA-40 by better data assimilation (better formulation of background error constraint, new humidity analysis, improved model physics, variational bias correction of satellite radiance data, improvements in bias handling, extensive use of radiances and improved fast radiative transfer model) and observations used [16] . One of the main advantages of reanalysis datasets is that model parameterizations and resolution are unchanged for the whole time period. Another advantage compared to operational analyses is that assimilated observations include late observational reports [14]. ERA-interim datasets are included in the Intercomparison protocol established by the European project IMILAST (Intercomparison of mid latitude storm diagnostics)[1].

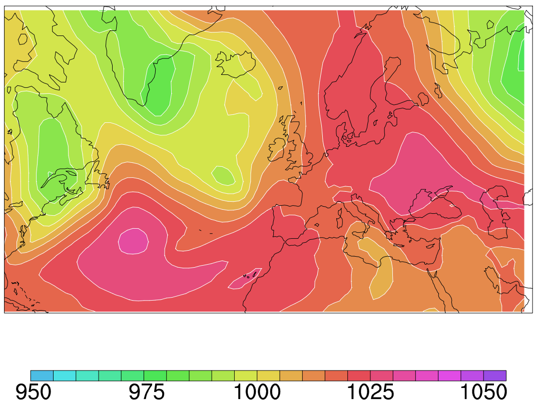


Figure 2.1: SLP fields (in hPa) at 12 UTC on 1th january 1990 at 1.5 resolution contained in ERA-interim

[1]http://www.proclim.ch/imilast/index.html

ECHAM5 [12] (Figure 2.2) represents the fifth-generation atmospheric general circulation model developed at the Max Planck Institute for Meteorology (MPIM) and differs from ECHAM4 for :

- new formulations of advection scheme for positive definite variables as long-wave radiation code, cloud cover parameterization, separate treatment of cloud water and cloud ice, cloud microphysics, sub-grid scale orographic effects, land surface processes and land surface dataset

- changes in the parameterization of shortwave radiation, vertical diffusion, cumulus convection, orbit calculation

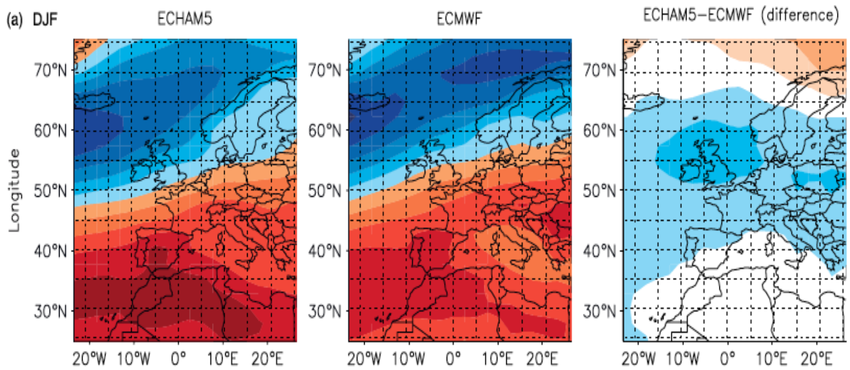


Figure 2.2: Mean sea level pressure during the winter 1961- 2000, based on ECHAM5-MPI/OM (left column), ECMWF-ERA40 (middle column) and the difference between the two (right column), normalized by the standard deviation [15]

2.2 Cyclone tracking

The following sections investigate the sensitivity of the two different cyclone and tracking schemes. First, similarities and differences of the schemes are discussed by case studies [1] selected from the Intercomparison protocol of IMILAST project or derived from previous analysis of daily precipitation data contained in ECA-KNMI dataset [2]. In the second step the focus is on investigating consequences of the individual differences between the schemes in term of total number of cyclones detected and distribution of track, cyclogenesis and cyclolysis processes occurrences [1]. The events contained in the Intercomparison protocol of IMILAST are reported in the list beneath together with the day of maximum intensity of storm , the country affected and the period of detection :

- Daria 25-1-1990 Germany 19/1/90 00UTC - 28/1/90 18UTC

- Vivian 26-02-1990 Germany 20/2/90 00UTC - 29/2/90 18UTC

- Dec92 9-12-1992 AquaAlta 3/12/92 00UTC - 12/12/92 18UTC

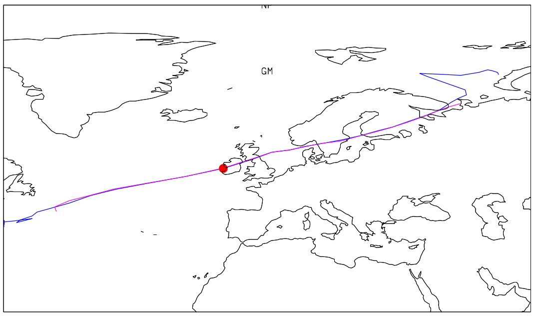
- Jeanette 27-10-02 Germany 21/10/02 00UTC - 30/10/02 18UTC

- Oratio 30-10-00 UK 24/10/00 00UTC-2/11/00 18UTC

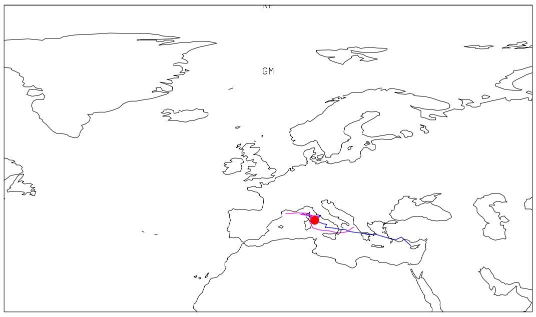
- Klaus 24-1-09 France 18/1/09 00UTC - 27/1/09 18UTC

Figure 2.3 shows the individual cyclone track (blue detected using LeA, fuchsia using BeA) corresponding to know winter storms "Daria" ,"Jeanette","Dec92" and "Oratio". As it may see the trajectories correspond to each other well at maximum intensity of storm (red dot) where the assignment is not ambiguous [14] but either scheme finds a longer trajectory than the other one [1], showing that identification procedures, settings and sensitivities of methodologies play a key role in the detection of storm in the early and late parts of the systems life cycles [14].

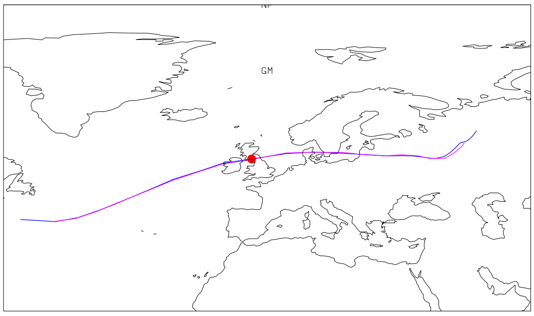
[2]http://eca.knmi.nl/



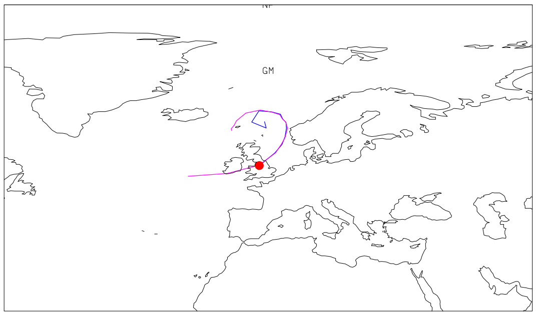
(a) Daria



(b) Dec92

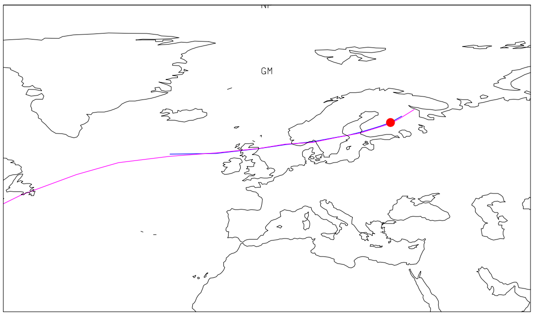


(c) Jeanette

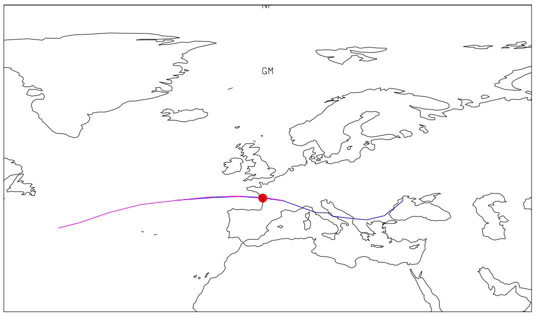


(d) Oratio

Figure 2.3: Examples of individual cyclone track (blue identified using LeA, fuchsia using BeA) corresponding to know winter storms reported in IMILAST intercomparison protocol.Red dot represents the position of storm in the day of maximum intensity



(a) Vivian



(b) Klaus

Figure 2.4: Examples of individual cyclone track (blue identified using LeA, fuchsia using BeA) corresponding to know winter storms reported in IMILAST intercomparison protocol.Red dot represents the position of storm in the day of maximum intensity

The tracks based on LeA settings begin earlier and end later because of problems with the correct identification of the system at weak stages of its lifetime [14]. Considering in Figure 2.4 the winter storms ”Vivian” and ”Klaus” LeA settings produce the ”split” of the entire cyclone track in two single tracks corresponding to two cyclones with lifetime shorter [1].

Other cyclones considered in this report (here only few results) produce precipitation events that were characterized by large accumulated total precipitation in some locations in the Mediterranean region (the ECA-KNMI dataset has been used for precipitation data). The following list reports the location where precipitation occurred, the starting day of the event (year/month/day), the total amount of precipitation (in mm) , the day respect to starting day in which the peak of precipitations occurrs and the duration of the event :

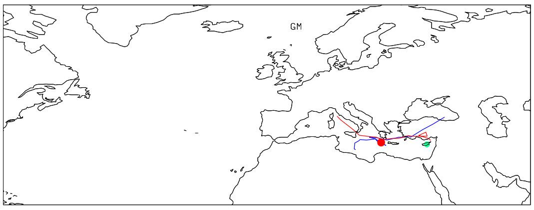
- Larnaca (Cyrprus)-1991/12/6-100-1-2

- Polis (Cyprus)-1991/12/6-100-2-2

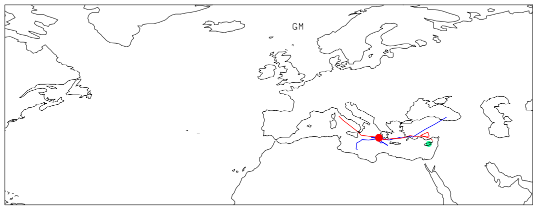
- Corfú (Greece)-1994/12/ 21-203-3-6

- Brindisi(Italy)-1995/12/16-79,6-4-4

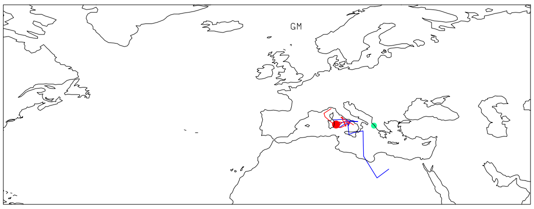
Figure 2.5 shows the individual cyclone track (blue detected using LeA, fuchsia using BeA) corresponding to winter storms producing these precipitation events. Green dot represents the location where precipitation occurs. Red dot represents the position of cyclone in the day of maximum intensity of precipitation. To identify it we applied a criterion about distance. Cyclone producing extreme events is that one located to a distance (from the location where intensive precipitation occurs) less than 1500 km. In some cases more than one cyclones corresponded to this criterion. For that a manual identification of cyclones has been required. Figure 2.5 shows the overall result of cyclone tracks in the case of small scale system (as in the case of Mediterranean cyclones) is very sensitive to the choice of the settings and in particular for those related with the identification of "raw" cyclones [14]. Those produce some differences in the heads and tails of tracks.



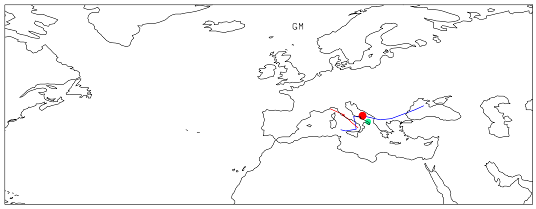
(a) Larnaca



(b) Polis



(c) Corfú



(d) Brindisi

Figure 2.5: Examples of individual cyclone track (blue identified using LeA, fuchsia using BeA) corresponding to cyclone producing extreme precipitations event in the location reported.Red dot represents the position of cyclone in the day of maximum of intensity;green dot is the location where intensive precipitation has been recorded

Another important characteristic of cyclone is its intensity. There are various definitions of cyclone intensity [1]. In this report it has been used as measure of storm "intensity" the value of minimum of SLP associated to the core of the storm in the day of its maximum intensity (as reported by IMILAST) or in the day of maximum intensity of precipitation as derived analyzing ECA-KNMI data. Tab. 2.1 shows a comparison of these values for some cases selected. Obviously the values reported differ between two methodologies. The main reasons are in the interpolation of data , operated in BeA , that tends to smooth the SLP fields leading to produce less pronounced minima [1] and in the different methodologies producing, in same cases, a different number of points belonging to the same storm and for that a different location of the core. Regarding the interpolation it's important notice that LeA uses no interpolation schemes to optimize the finding of low pressure centers, instead of BeA where is applied a bicubic spline interpolation to better locate the minimum between grid point [14] obtaining from a regular grid of 1.5 a new regular grid of 0.75.

Storm	Lecce	Berlin
Vivian	948.59	954.07
Dec92	997.13	998.86
Jeanette	976.70	976.71
Klaus	969.09	980.41
Larnaca	1009.900	1010.720
Corfú	999.4800	1001.640
Brindisi	1007.200	1010.220

Table 2.1: Value of minimum of SLP (in hPa) associated to the core of the storm in the day of its maximum intensity (as reported by IMILAST) or in the day of maximum intensity of precipitation as derived analyzing ECA-KNMI data

Region	longitude	latitude
Mediterranean (MR)	-10W-38E	30N-45N
Western Mediterranean (WM)	0E-15E	40N-46N
Cyprus (EM)	27E-35E	35N-40N
North Africa (NA)	-5N-5E	30N-34N
Ionian (IR)	17E-25E	30N-37.5N

Table 2.2: Areas selected in the Mediterranean region and their geographical coordinates

2.3 Cyclone climatology based on reanalysis data

We focus our analysis on Mediterranean region and specific areas inside it. The geographical coordinates of the regions selected together with their abbreviation (that will be always used in this report) are reported in Tab. 2.2. Figure 2.6 reports the MR and the others areas as individuated by the geographical coordinates defined in Table 2.2 [13] . Cyclone activity in these regions is quantified in terms of track, cyclogenesis and

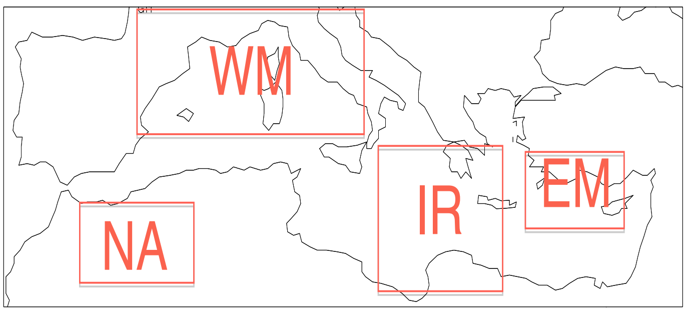


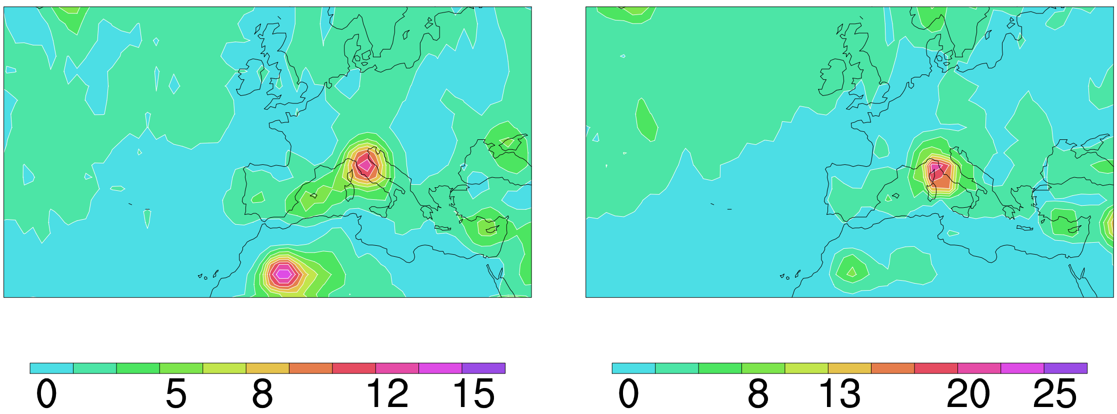
Figure 2.6: Mediterranean region (MR) and the areas reported in the Tab.2.2

cyclolysis density. Other studies have shown that track density is a variable primarily influenced by fast moving cyclones , unlike cyclone counts, where slow systems are over-represented (as they are counted more often for the same grid box than faster moving

Region	Lecce	Berlin
MR	1630(77)	2177(103)
WM	470(22)	730(34)
EM	117(5)	186(8)
NA	97(4)	89(4)
IR	63(3)	63(3)

Table 2.3: Number of cyclogenesis processes detected in ERA-interim 1.5 in the period 1989-2009 using LeA (first value) and BeA (second value) for tracking. The values reported between brachets represented the annual average

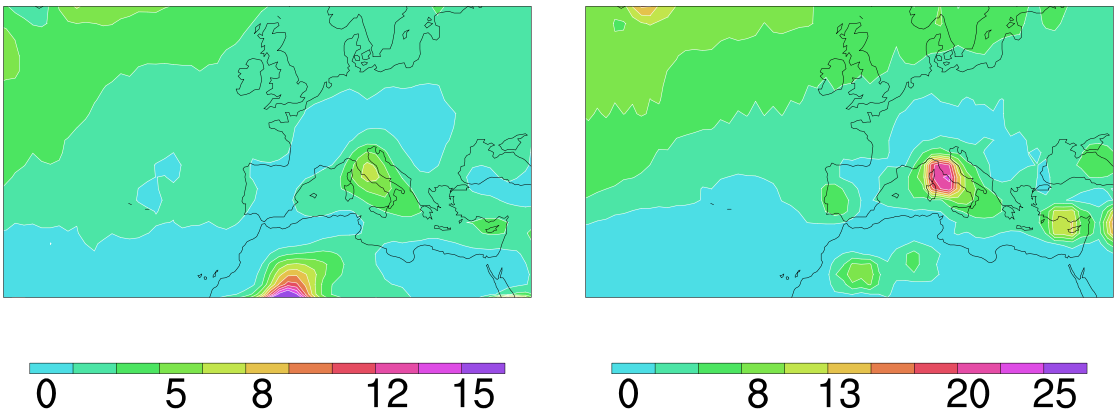
ones) [14].
Tab.2.3 shows that a first obvious discrepancy between the methods is found in the total number of cyclogenesis processes detected. BeA identifies more cyclogenesis processes than LeA inside MR, mainly in WM and EM. A reason for these differences is that parameter settings in LeA is more strict (closed contour condition) [1] and avoids to identify open depressions during their entire lifespan. In BeA list of cyclones open depressions are identified trough a parameter (IO). Considering this parameter BeA identified (in the beginning of their lifespan) 986 open and 1186 closed depressions in MR, 301 open and 429 closed depressions in WM , 62 open and 124 closed depressions in EM. A cyclone open in the beginning can turn out to be closed, open and closed again during its lifespan. All these reasons can lead to strong differences in the magnitude of density observed in the maps of cyclogenesis (Figure 2.7), track (Figure 2.8) , cyclolysis (Figure 2.9) and in the number of cyclones becoming explosive inside the MR.
Figure 2.7 shows that both methods locate the main cyclogenesis areas in the MR over North-Western Mediterranean, Northern Africa, Iberian Peninsula, Cyprus, Middle East (not shown), Eastern Black Sea [17].



(a) (b)

Figure 2.7: Density of cyclogenesis processes (10·average annual frequencies for each grid point) detected using LeA (a) and BeA (b) on ERA-interim 1.5 in the period 1989-2009

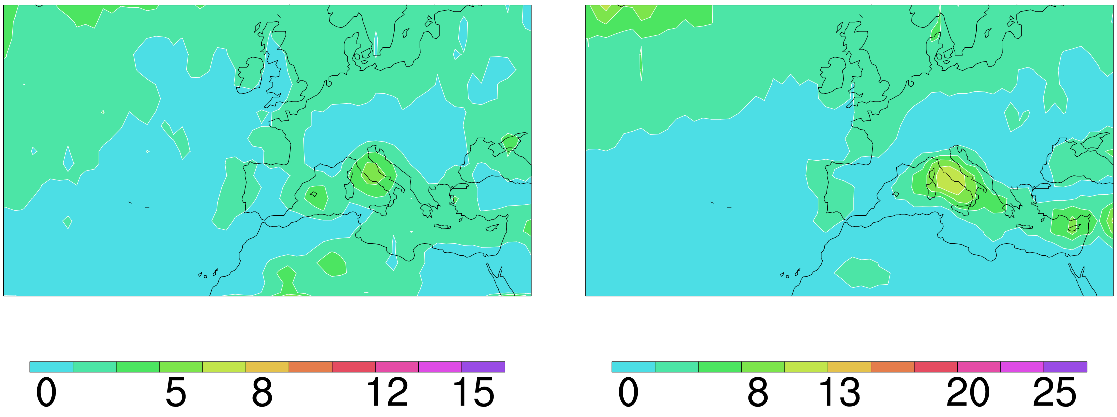
Besides LeA underestimates the main cyclone track in the MR (Figure 2.8), characterized in both cases by a prevailing southeastward direction, extending through Italy, down to the Albanian and Greek coasts [17]. As observed before closed contour requirements in LeA produces shorter trajectories [1] but the differences in density of tracks derive also from the use in BeA of bicubic spline interpolation to better locate the position of minimum between two points of grid [14] . This leads BeA to identify better two systems (or two tracks) as separated in regions like MR characterized by high density of cyclones tracks and centers but also , when we use a common grid of 1.5 °to produce the maps of density , to over-represent the density of tracks of some kind of cyclones contained in BeA list such as stationary-lows or quasi-stationary lows common over Eastern Black and Cyprus in summer [17] that are counted more often in the same grid point. This improved spatial resolution leads also to identify some oscillations in the tracks as observed over North Atlantic (Figure 2.8, b). The maximum in LeA (Figure 2.8,a) over NA depends on how it works at grid boundaries. Additional analysis (not shown here) reveals that cyclones contained in Berlin list are faster than those contained in Lecce list.



(a)

(b)

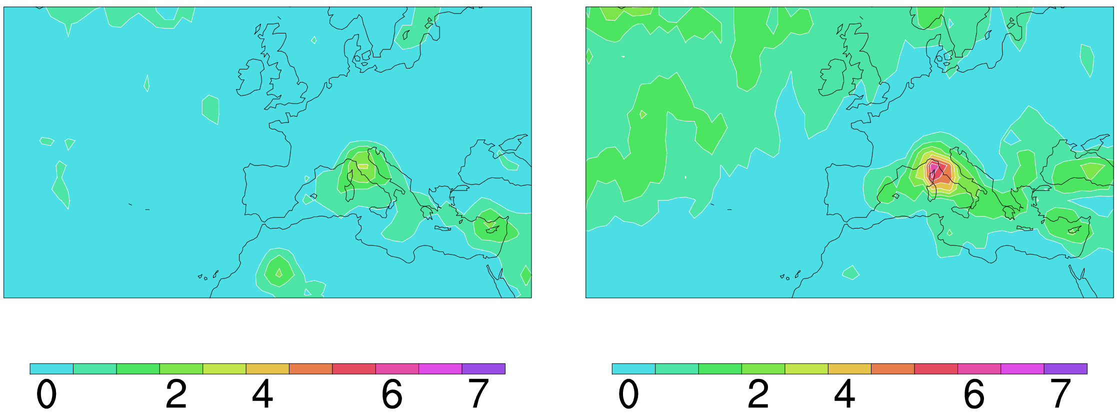
Figure 2.8: Density of tracks (average annual frequencies for each grid point) detected using LeA (a) and BeA (b) on ERA-interim 1.5 in the period 1989-2009



(a) (b)

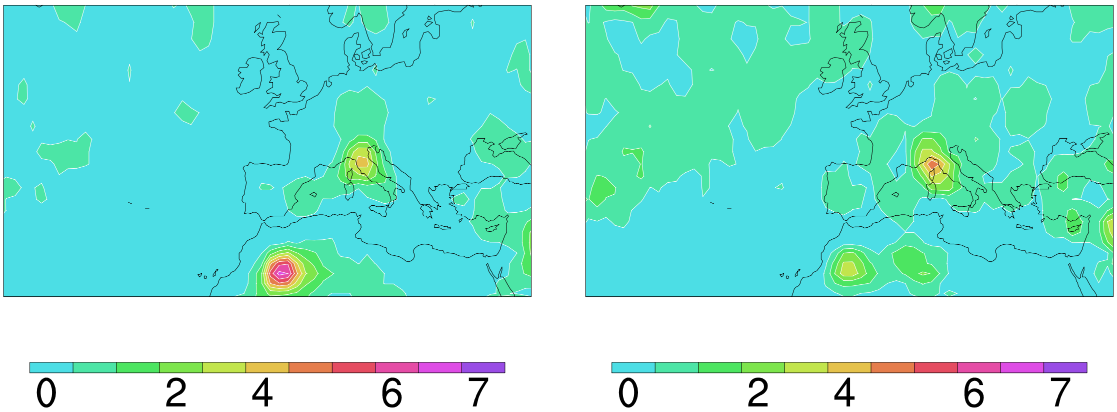
Figure 2.9: Density of cyclolysis processes (10·average annual frequencies for each grid point) detected using LeA (a) and BeA (b) on ERA-interim 1.5 in the period 1989-2009

At seasonal scale (Figure 2.10, Figure 2.11, Figure 2.12) the number of cyclogenesis processes detected by BeA is higher than LeA in winter (Figure 2.10) , but in spring (Figure 2.11) and summer (Figure 2.12) the situation is reverse. In fact LeA finds a number of cyclogenesis processes greater then BeA over NA and Eastern Black Sea. This suggests that the two schemes react differently to heat lows generating in summer and spring in these areas [17]. Therefore it might need retuning some parameters to detect heat lows more properly [1].



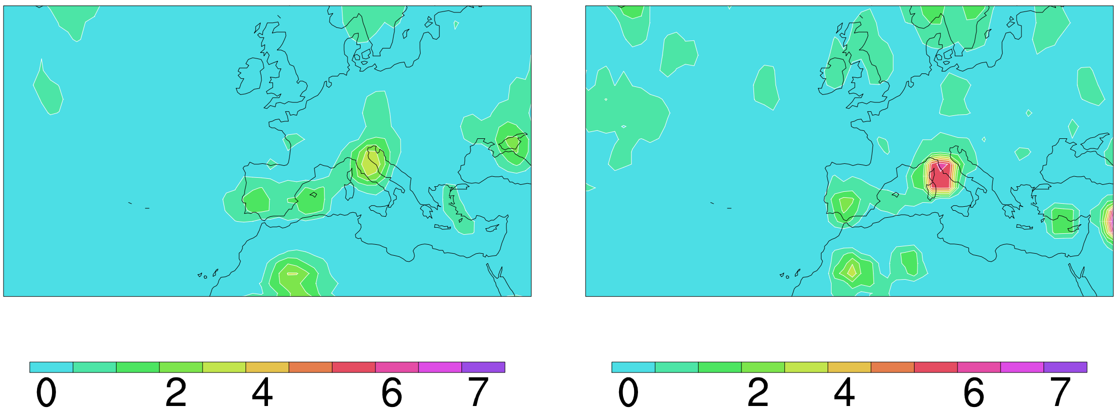
(a) (b)

Figure 2.10: Density of cyclogenesis processes (10·average annual frequencies for each grid point) detected in winter using LeA (a) and BeA (b) on ERA-interim 1.5 in the period 1989-2009



(a) (b)

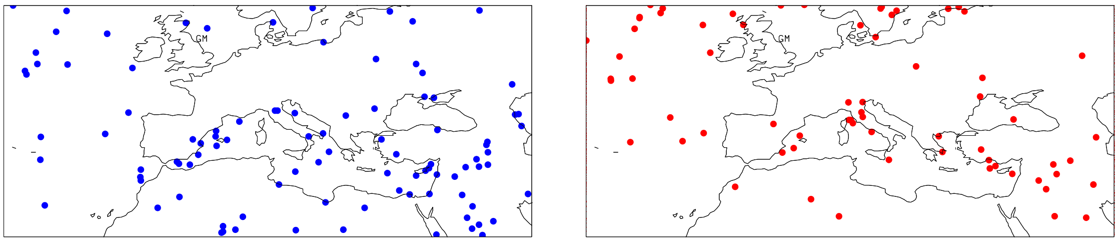
Figure 2.11: Density of cyclogenesis processes (10·average annual frequencies for each grid point) detected in spring using LeA (a) and BeA (b) on ERA-interim 1.5 in the period 1989-2009



(a) (b)

Figure 2.12: Density of cyclogenesis processes (10·average annual frequencies for each grid point) detected in summer using LeA (a) and BeA(b) on ERA-interim 1.5 in the period 1989-2009

Using high resolution data of ERA-interim 0.75°the number of cyclogenesis processes inside MR detected by LeA is slightly greater than BeA (Figure 2.13) . This depends on the fact the BeA is derived by Murray and Simmonds scheme [7] [8] that is set optimally to identify large-scale midlatitudes cyclones [1]. Avoiding the smoothing of the Laplacian field [1], [14] leads to a more realistic representation of smaller-scale cyclones in the MR.



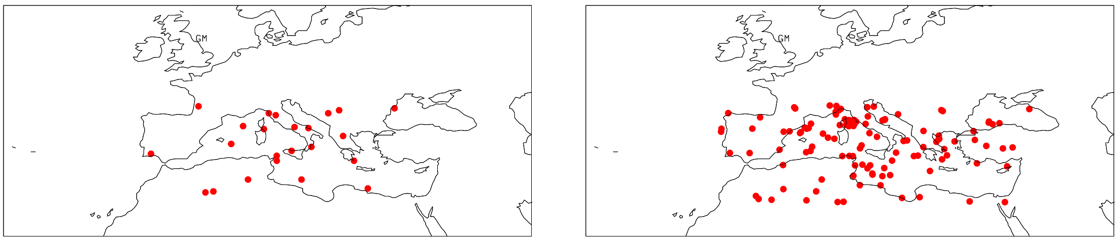
(a) (b)

Figure 2.13: Cyclogenesis processes detected using LeA (a, blue dot) and BeA (b, red dot) on ERA-interim 0.75 in the period january-march 1990

The different behavior of our methods with the first stages of lifespan of cyclones can influence the number of explosive cyclones detected. An explosive cyclone (or bomb) is characterized by exceptionally ad unusually large deepening in the mid-latitudes, with rate of at least 1 hPa/h for 24 h (or 12 h) and more. Explosive cyclogenesis is a cold period phenomenon , which mainly occurs in a maritime environment and its characteristics are similar to those of tropical cyclones , such as warm core systems with an eye of clear air, associated with a band of strong winds and surrounded with a spiraling wall of deep cumulonimbus and strong convection [9], [10]. Explosive cyclones were identified following the criterion of [11], in terms of what is referred as the normalized central pressure deepening rate (NDRc), which is defined as :

$NDRc = \frac{\Delta P}{12} \times \frac{\sin 60}{\sin \phi}$

where ΔP is the central pressure change of system over 12h that occurs at latitude ϕ. In this work we take in account all cyclones becoming explosive inside the MR. Applying this criterion it has been found that the number of cyclogenesis processes producing cyclones becoming explosive inside MR detected by BeA is greater than LeA. Both methods show that cyclones are produced mainly in WM [13] , in winter [13] (analysis at seasonal scale not shown here). This result and its explanation are consistent with what already found in the previous analysis. In fact LeA tends to detect cyclones at a later stage than BeA. Since most explosive cyclones experience the fastest deepening rate during the first stages of their development, LeA underestimates with respect to BeA their number. Figure 2.14 shows the position of cyclogenesis processes producing cyclones becoming explosive inside MR detected in ERA-interim 1.5°.



(a) (b)

Figure 2.14: Cyclogenesis processes producing cyclones becoming explosives inside MR detected using LeA (a, blue dot) and BeA (b,red dot) on ERA-interim 1.5 in the period 1989-2009

Analyzing Era-interim 0.75°(Figure 2.15) only BeA has found cyclones becoming explosive inside MR. These two cases are likely becoming explosive while they are open depressions.

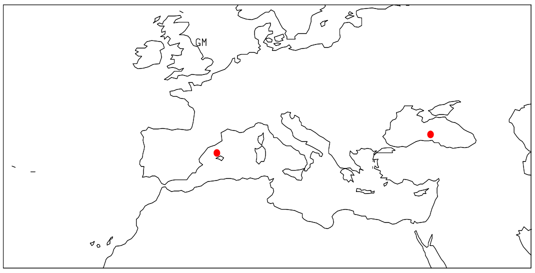


Figure 2.15: Cyclogenesis processes producing cyclones becoming explosives inside MR detected using BeA on ERA-interim 0.75 in the period 1989-2009

2.4 Cyclone climatology derived from GCM data

One purpose of using automatic schemes is their application to GCM produced datasets. Studies on cyclones in GCMs can help to identify mechanisms influencing cyclone climatologies, for example their sensitivity to variable ocean boundary conditions or to rising greenhouse gas concentrations [4]. GCMs are particularly well suited for this purpose as the cyclones in a GCM are the sole result of the numerical integration, in contrast to reanalysis which incorporates observational data [4]. Usually in the analysis of cyclone activity the large-scale features are reasonably well simulated by the majority of the models with deficiencies at the ends of the storm tracks and in mountain lee cyclogenesis [4].

Region	Lecce	Berlin
MR	1257(125)	1229(122)
WM	189(18)	190(19)
EM	97(9)	103(10)
NA	48(4)	56(5)
IR	42(4)	20(2)

Table 2.4: Number of cyclogenesis processes detected in ECHAM5 in the period 1991-2000 using LeA (first value) and BeA (second value).The values reported between brackets represented the annual average

Tab.2.4 reports the number of cyclogenesis processes detected in ECHAM5 using the two schemes. Obviously the differences are not large in WM, as observed before in the reanalysis, but they are present in the entire MR, EM , NA and IR. Considering the characterization of open and closed depressions in Berlin list, BeA finds in EM 44 open and 59 closed depressions, 14 open and 42 closed depressions over NA. Over MR and IR LeA finds a number of cyclogenesis processes greater than BeA. The differences observed derive from different criteria in the two schemes to deem a minimum as a cyclone and remove artificial systems produced in the model simulation. Observing the density maps for cyclogenesis processes (Figure 2.16) we can see that they are quite different from the analysis ones (Figure 2.7), because there is an unrealistic maximum between Iberian Peninsula and NA , that is found by both methodologies.

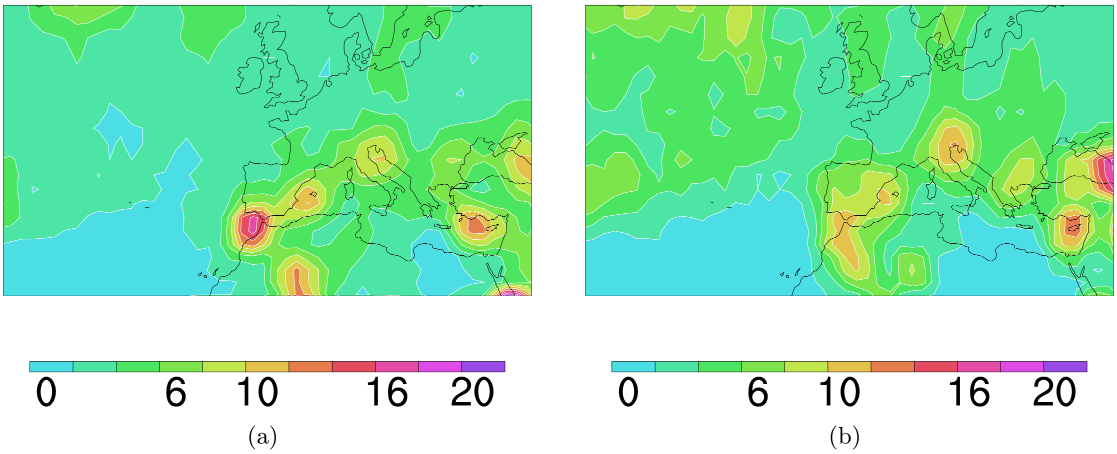
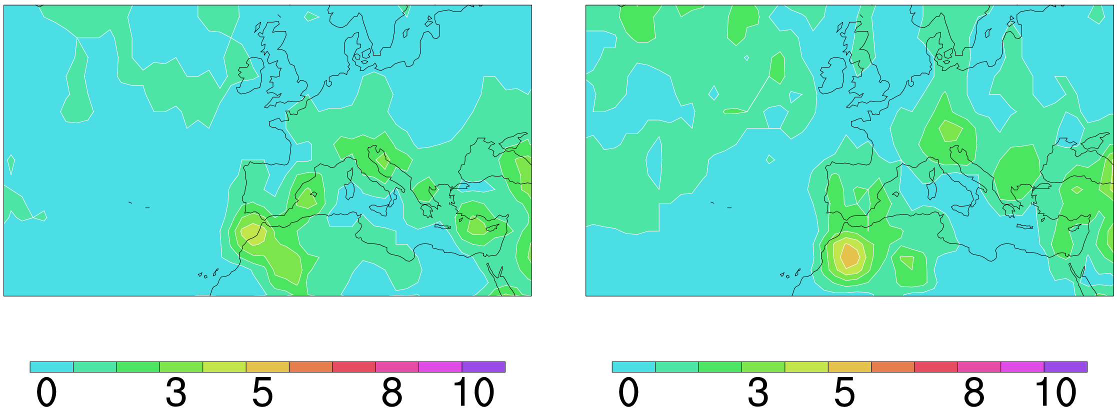


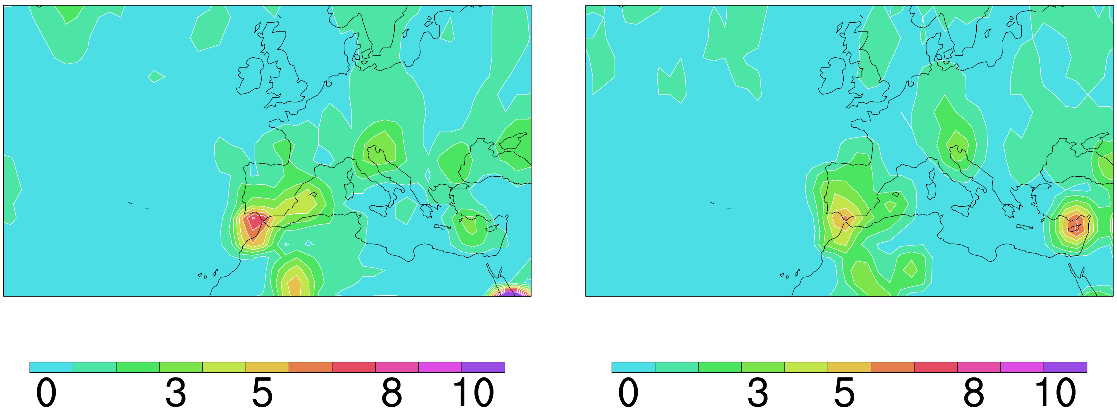
Figure 2.16: Density of cyclogenesis processes (10·average annual frequencies for each grid point) detected using Lecce (a) and Berlin (b) on ECHAM5 data in the period 1991-2000

This maximum is also present in the same areas in spring (Figure 2.17) and summer (Figure 2.18).



(a) (b)

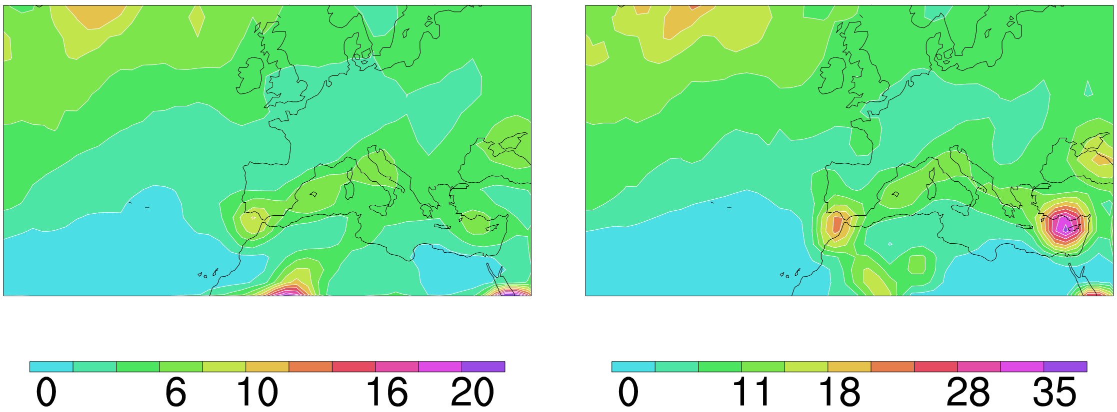
Figure 2.17: Density of cyclogenesis processes (10·average annual frequencies for each grid point) detected in spring using LeA (a) and BeA(b) on ECHAM5 in the period 1991-2000



(a) (b)

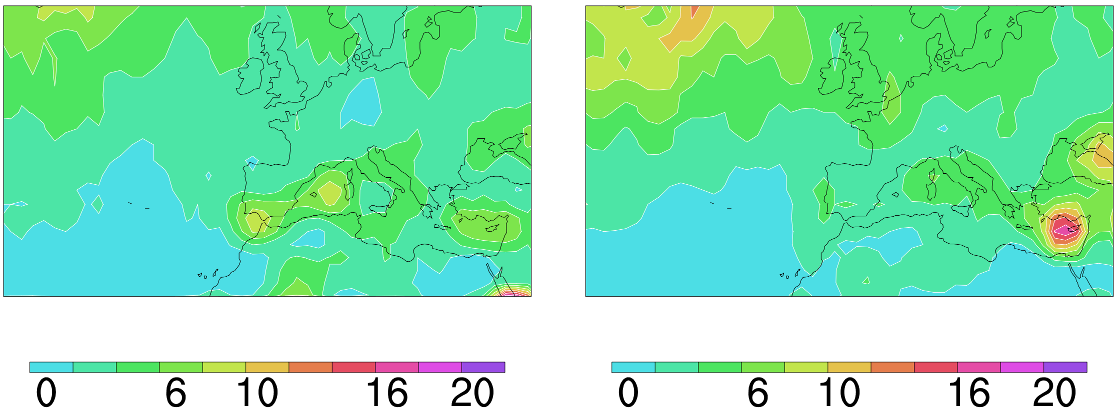
Figure 2.18: Density of cyclogenesis processes (10·average annual frequencies for each grid point) detected in summer using LeA (a) and BeA(b) on ECHAM5 in the period 1991-2000

Also in the analysis of GCM data LeA underestimates with respect to BeA the density of track in the MR (Figure 2.19) for the same reasons considered in the comparison of reanalysis in the previous paragraph. It 's interesting observing that, in that case, mid-latitudes storm track over north Atlantic is well simulated by ECHAM5 instead of Mediterranean storm track that doesn't present the prevailing southeastward direction, through Italy, down to the Albanian and Greek coasts [17]. LeA continues to present some "false" maxima in density of tracks over NA related to the way by which it works at grid boundaries. The comparison (analysis not shown here) of the value of their speed has shown (as observed in reanalysis) that BeA cyclones are faster than LeA cyclones .



(a) (b)

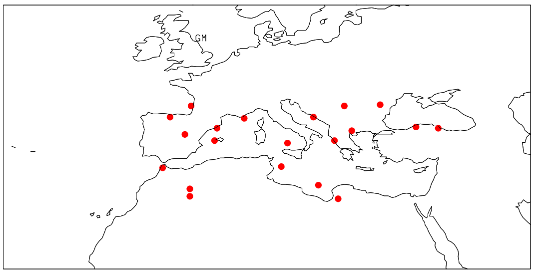
Figure 2.19: Density of tracks (average annual frequencies for each grid point) detected using LeA (a) and BeA(b) on ECHAM5 in the period 1991-2000



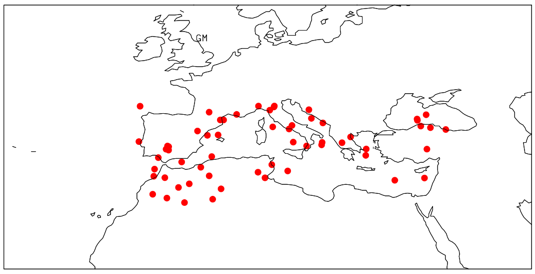
(a) (b)

Figure 2.20: Density of cyclolysis processes (10·average annual frequencies for each grid point) detected using LeA (a) and BeA(b) on ECHAM5 in the period 1991-2000

The differences between the two methods while describing the first stages of the cyclones development influence the number of explosive cyclones detected. The two schemes find (Figure 2.11) that cyclones are produced mainly in WM [13] , in winter [13] (analysis at seasonal scale not shown here). The number of cyclogenesis processes producing cyclones becoming explosive inside MR detected by BeA is greater than LeA.



(a)



(b)

Figure 2.21: Cyclogenesis processes producing cyclones becoming explosive inside MR detected using LeA (a) and BeA(b) algorithm on ECHAM5 data in the period 1991-2000

Chapter 3

Conclusions and future developments

The present study provides a comparison between two cyclone detection and tracking methods, illustrating the basic characteristics of each scheme as well as their weakness and strengths using reanalysis and GCM data. It shows that potential user of such cyclone detection and tracking methods should always proceed with caution, as the interpretation of cyclone tracks may depend on the scheme or the specific parameter setting chosen by the user [1]. The distribution of cyclone frequencies and other properties are resulted to be sensitive to a variety of factors related to the operations of the schemes as interpolations, resolution of grid , criteria used in the definition of a low, tracking errors and so on . This could be really important in the analysis of extremes events [7] [8] .

This intercomparison study , that could be object of a paper in the next future, represents a contribution in form of a poster to European Geophysical Union (EGU) general meeting that will be held in Wien on 3-8 April 2011. The publication in the Medclivar data archive of lists of cyclones, obtained applying these methodology is expected to be useful for the Medclivar community because it contributes to the assessment of climate variability at different space and time scales . The occurrence of extreme events and the analysis of their impacts in the MR represent an interesting field for future collaborations between Freie Universitaet in Berlin and University of Salento in Lecce.

Chapter 4

Acknowledgements

I want to thank the European Science Foundation and Medclivar community project for having given me this opportunity to visit Free University in Berlin and to work with prof.Uwe Ulbrich. I want to thank prof. Uwe Ulbrich , dr.Katrin Nissen and dr. Greg Leckebusch to have hosted me at institute of Meteorology in Berlin as well as prof. Piero Lionello to have supported my visit.

My visit at Free University was held in a quiet and well-organized institute where collegues and supervisors were always ready to meet my needs and careful to create an ideal working atmosphere. All these aspects contributed to make this internship experience interesting, educational and important for my future work in the research.

List of Figures

List of Tables

Bibliography

[1] Raible C.C., P. M. Della-Marta, C. Schwierz, H. Wernli, R. Blender, 2008: Northern Hemisphere Extratropical Cyclones: A Comparison of Detection and Tracking Methods and Different Reanalyses. Mon Wea Rev. 136: 880-897.

[2] Sinclair MR (1997) Objective identification of cyclones and their circulation, intensity and climatology. Weather Forecasting 12:591-608

[3] Hodges K.I, B.J. Hoskins, J. Boyle, C. Thorncroft, 2003: A Comparison of Recent Reanalysis. Datasets Using Objective Feature Tracking: Storm Tracks and Tropical Easterly Waves. Mon Wea Rev 131: 2012-2037.

[4] Ulbrich U., G.C. Leckebusch, J.G. Pinto, 2008: Extra-tropical cyclones in the present and future climate: a review. Theor Appl Clim, in press.

[5] Rudeva, I., and S.K. Gulev, 2007: Climatology of cyclone size characteristics and their changes during the cyclone life cycle. Monthly Weather Review, 135, pp. 2568-2587.

[6] Lionello P, F.Dalan, E.Elvini ,2002: Cyclones in the Mediterranean Region: the present and the doubled CO2 climate scenarios, Clim. Res., 22, 147-159

[7] Murray, R. J., and I. Simmonds, 1991b: A numerical scheme for tracking cyclone centres from digital data. Part II: Application to January and July general circulation model simulations. Australian Meteorological Magazine, 39, 167180.

[8] Murray, R. J., and I. Simmonds, 1991a: A numerical scheme for tracking cyclone centres from digital data.Part I: Development and operation of the scheme. Australian Meteorological Magazine, 39, 155166.

[9] Bttger, Horst; Eckardt, Matthias; Katergiannakis, Ute,1975 : Forecasting Extratropical Storms with Hurricane Intensity Using Satellite Information.Journal of Applied Meteorology, vol. 14, Issue 7, pp.1259-1265

[10] Bosart LF,1981.The Presidents' Day snowstorm of February 1979: A sub-synoptic scale event. Mon. Wea. Rev. 109:1542-1566.

[11] Sanders, Frederick; Gyakum, John R.,1980.Synoptic-Dynamic Climatology of the Bomb.Monthly Weather Review, vol. 108, issue 10, p. 1589

[12] http://www.mpimet.mpg.de/fileadmin/publikationen/Reports/max_scirep_349.pdf (a detailed report on ECHAM5)

[13] J. Kouroutzoglou, H. A. Flocas, K. Keay, I. Simmonds, M. Hatzaki: Climatological aspects of explosive cyclones in the Mediterranean. Int.J.Climatol.(2010)

[14] Pinto, J. G., Spangehl, T., Ulbrich, U., Speth, P., 2005. Sensitivities of a cyclone detection and tracking algorithm: individual tracks and climatology./Meteorologische Zeitschrift/,*14*, 823-838

[15] M. Demuzere, M. Werner, N. P. M. van Lipziga and E. Roecknerc,2009.An analysis of present and future ECHAM5 pressure fields using a classification of circulation patterns.Int. J. Climatol. 29: 17961810

[16] ECMWF, 1995: User guide to ECMWF products. Edition 2.1. Meteorological Bull. M3.2., 71 pp.

[17] I. Trigo,T. Davies,G.R. Bigg (1999),Objective Climatology of Cyclones in the Mediterranean Region: Journal of Climate