ISTITUTO NAZIONALE
DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE

The Abdus Salam
International Centre
for Theoretical Physics

Explosive Cyclones activity over Northern Hemisphere Cordex domains

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Cyclones are important component of the atmosphere circulation at the mid-latitudes

They play a fundamental role in influencing :

a) the distribution and intensity of rains

b) dynamics of coastlines and waves

c) transport of moisture, momentum and energy

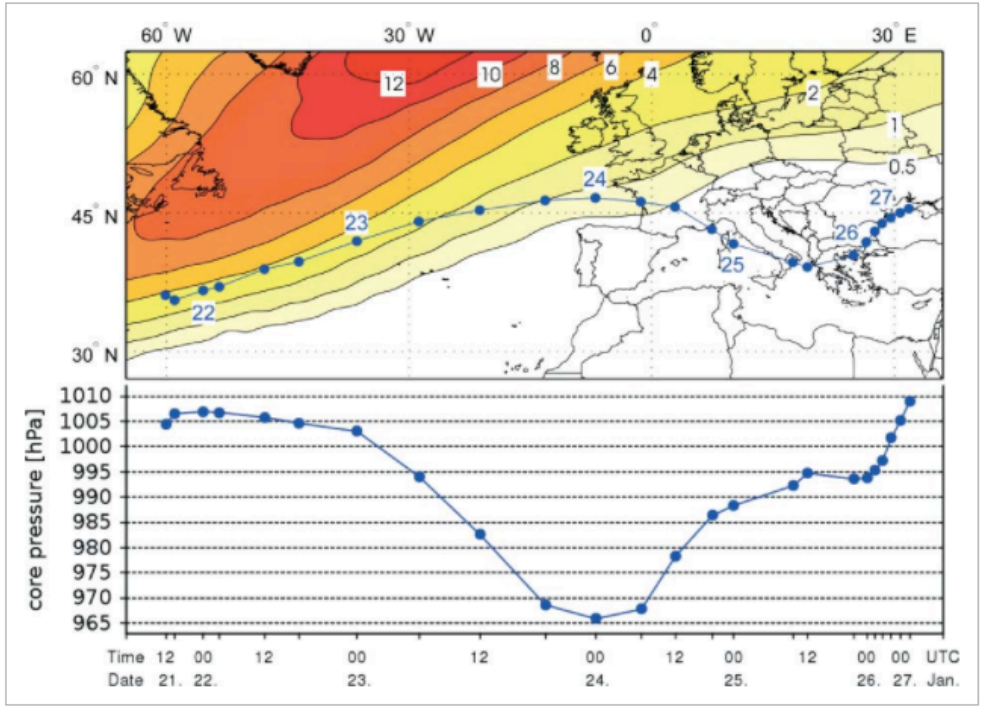
d) hydrological balance

e)vertical mixing during the cold season

Variation of nutrients content along the water column impacts on marine ecosystem dynamics

They are often linked to extreme events like floods, windstorms, coastal waves, severe precipitation, storm surges, landslides

Storm Lothar : Europe (in particular France and Spain) January 2009



$$NDR_c = \frac{\Delta p_c}{24\ \text{hPa}} \frac{\sin 60}{|\sin\phi|},$$

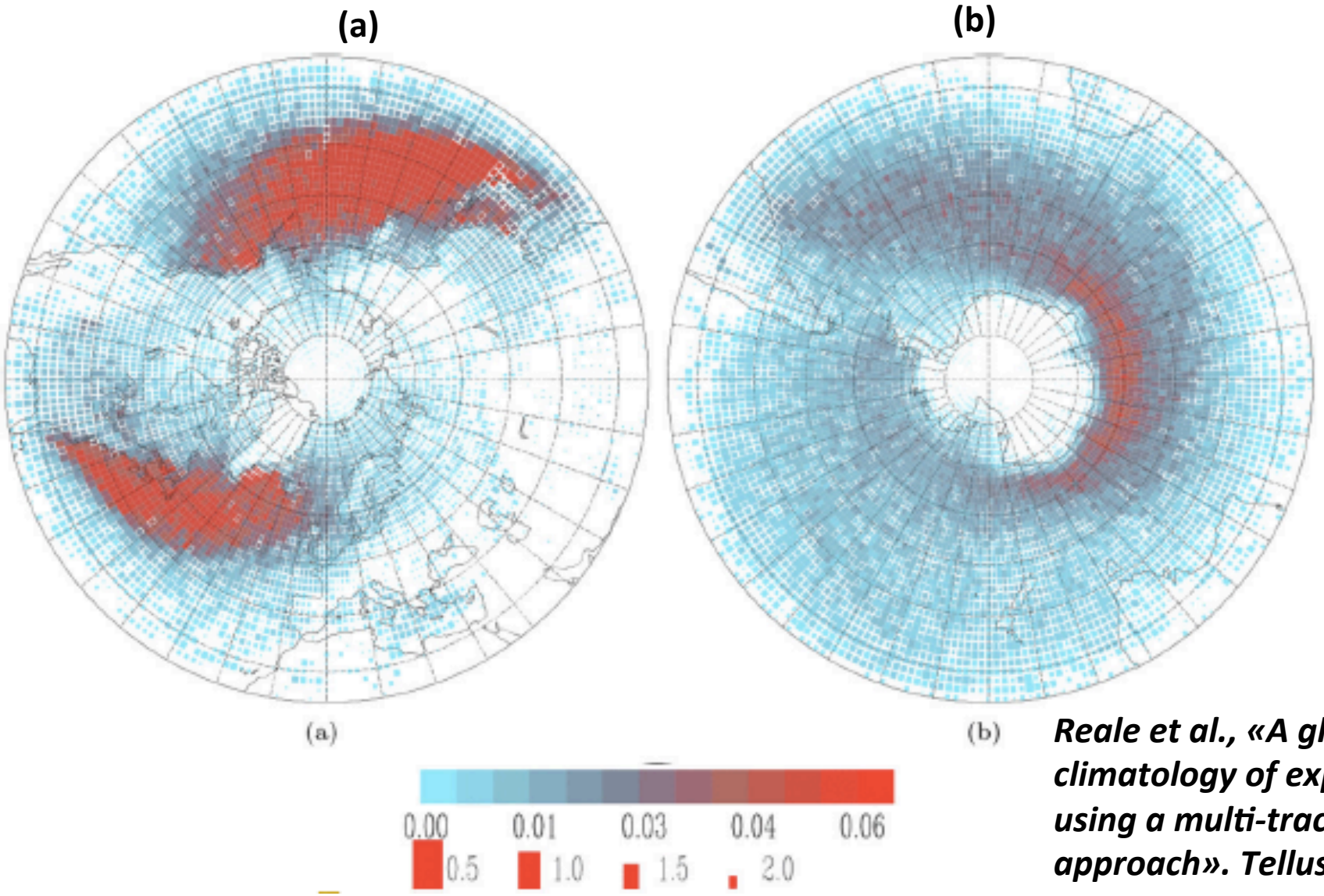
Due to the rapid decrease of the central pressure, these systems are associated with extreme strong circulation and thus with extreme events like wind gusts, heavy rain potentially leading to floods, and extreme height waves

Surface track of Klaus. The position of the storm at six-hourly intervals is marked with a filled circle. The corresponding core MSLP data are shown in the bottom panel for the period 1200 utc 21 January 2009 to 0600 utc 27 January 2009. Contour lines represent the track density of the major (extreme) cyclones (cyclone days/winter) over the NA European sector

Wind gusts : up to 55 m/s^{-1}
Heavy rain
Wave height up 15 m
26 people died
1.7 milions homes suffered power cuts

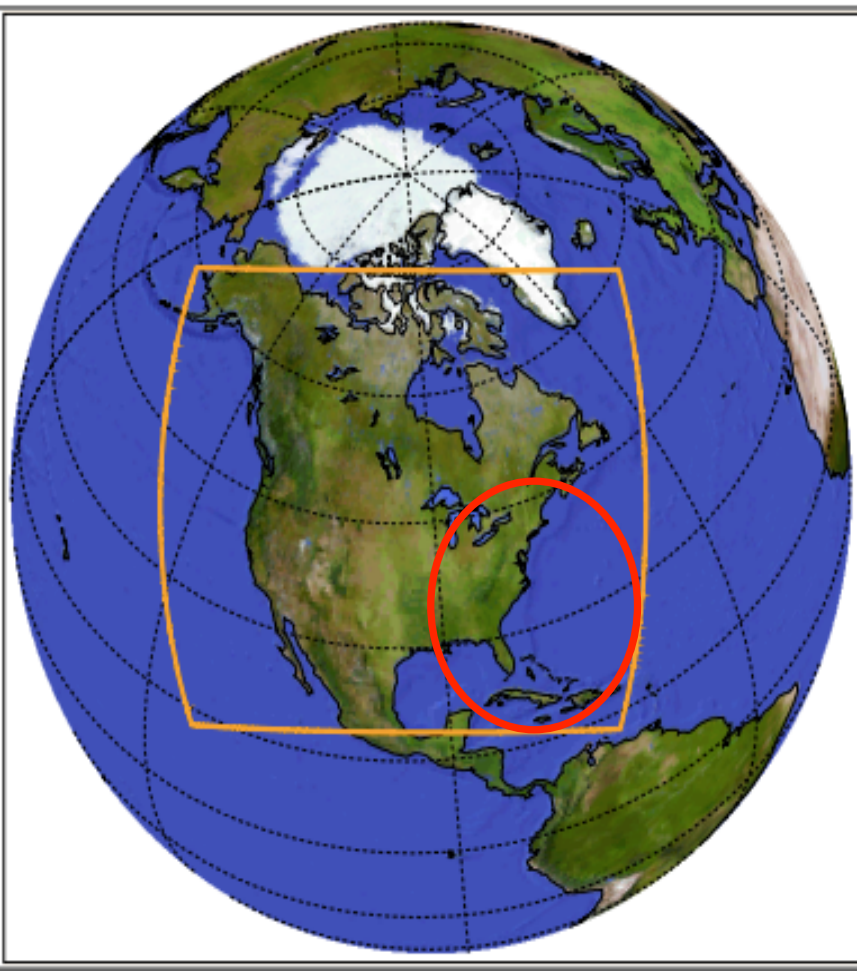
Liberato, M. L. R., Pinto, J. G., Trigo, I. F. and Trigo, R. M. (2011), Klaus – an exceptional winter storm over northern Iberia and southern France. Weather, 66: 330–334. doi:10.1002/wea.755

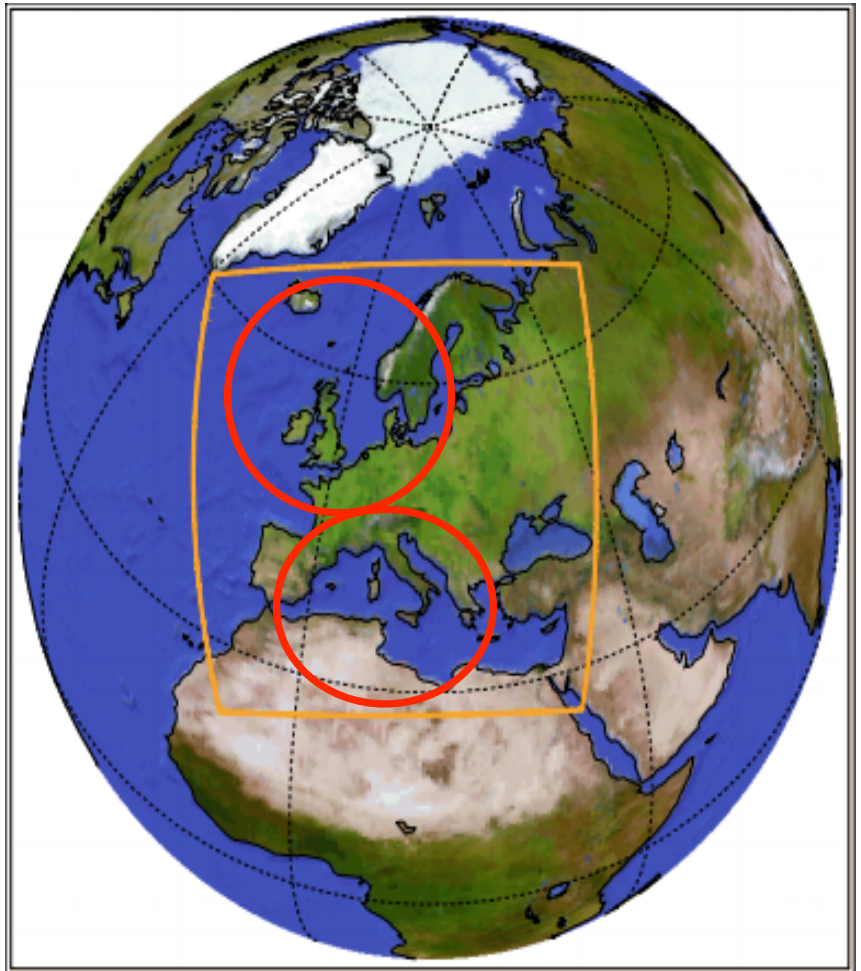
Density of explosive tracks in ERA-Interim according to a multi tracking approach schemes

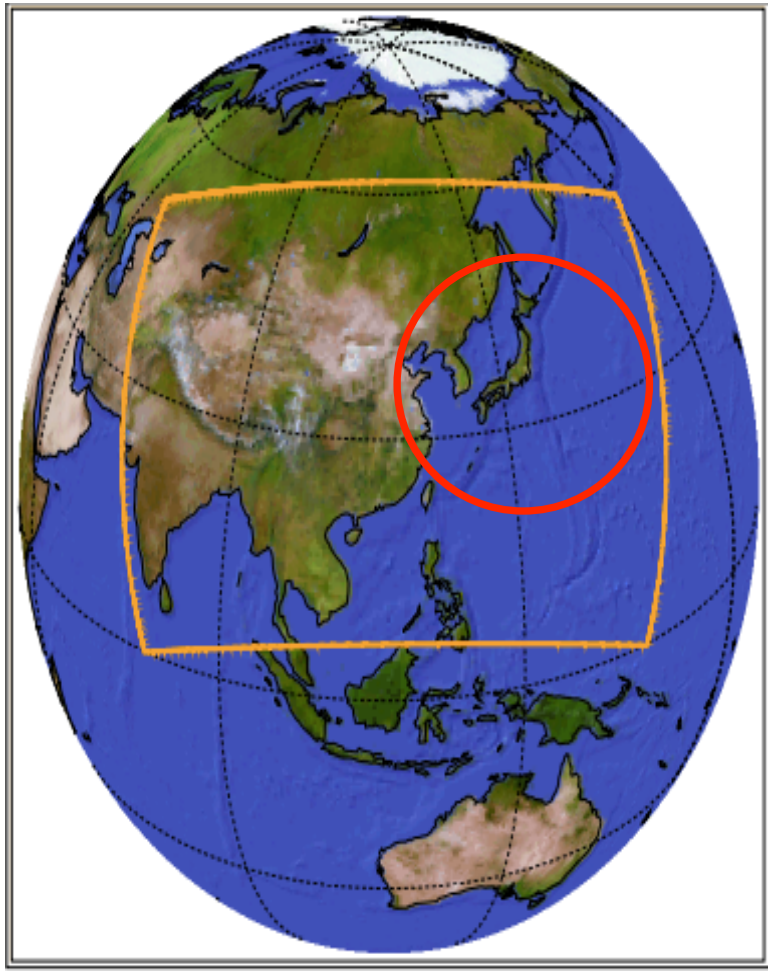


Reale et al., «A global climatology of explosive cyclones using a multi-tracking approach». Tellus A

- **Many areas characterized by high frequency of (explosive) cyclones activity** are in turn characterized **by high density of population, industrial and touristic settlements (just look at red circle)**
- **Many areas characterized by high frequency of (explosive) cyclogenesis activity** like **Eastern America,Western Asia, Western Europe, Med region** fall in some **Cordex domains** domains.
- **Changes in the (explosive) cyclone activity may thus affect milions of people ..**





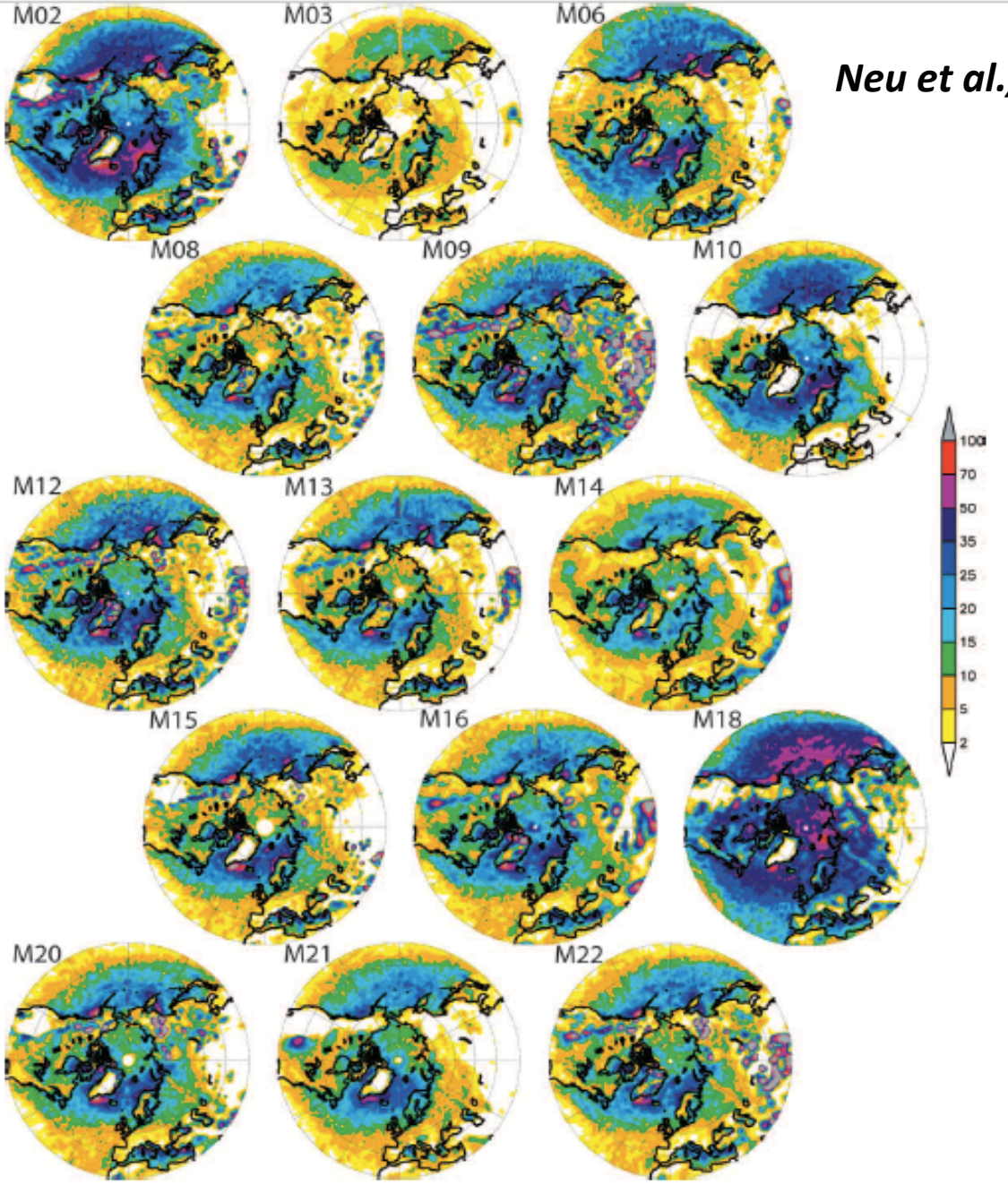


It does not exist an universal definition of cyclone and each available definition mirrors a physical aspect of a cyclone.for example a cyclone can defined as :

- *A minimum of MSLP*
- *A maximum of Vorticity*

Different definitions lead to different approaches/ automatic schemes in the identification of cyclones on the SLP maps

a different number of cyclones detected using the same original dataset (ERA-40 for example)



Neu et al.,2013

FIG. 1. Total cyclone center density in the NH for cyclones lasting 24 h or more (percentage of cyclone occurrence per time step and area of 1000 km^2; see sidebar) for all detection and tracking methods in DJF. The results of methods M03, M09, and M14 (which extrapolate the input data to a higher resolution for their calculation) are interpolated to the 1.5° × 1.5° grid.

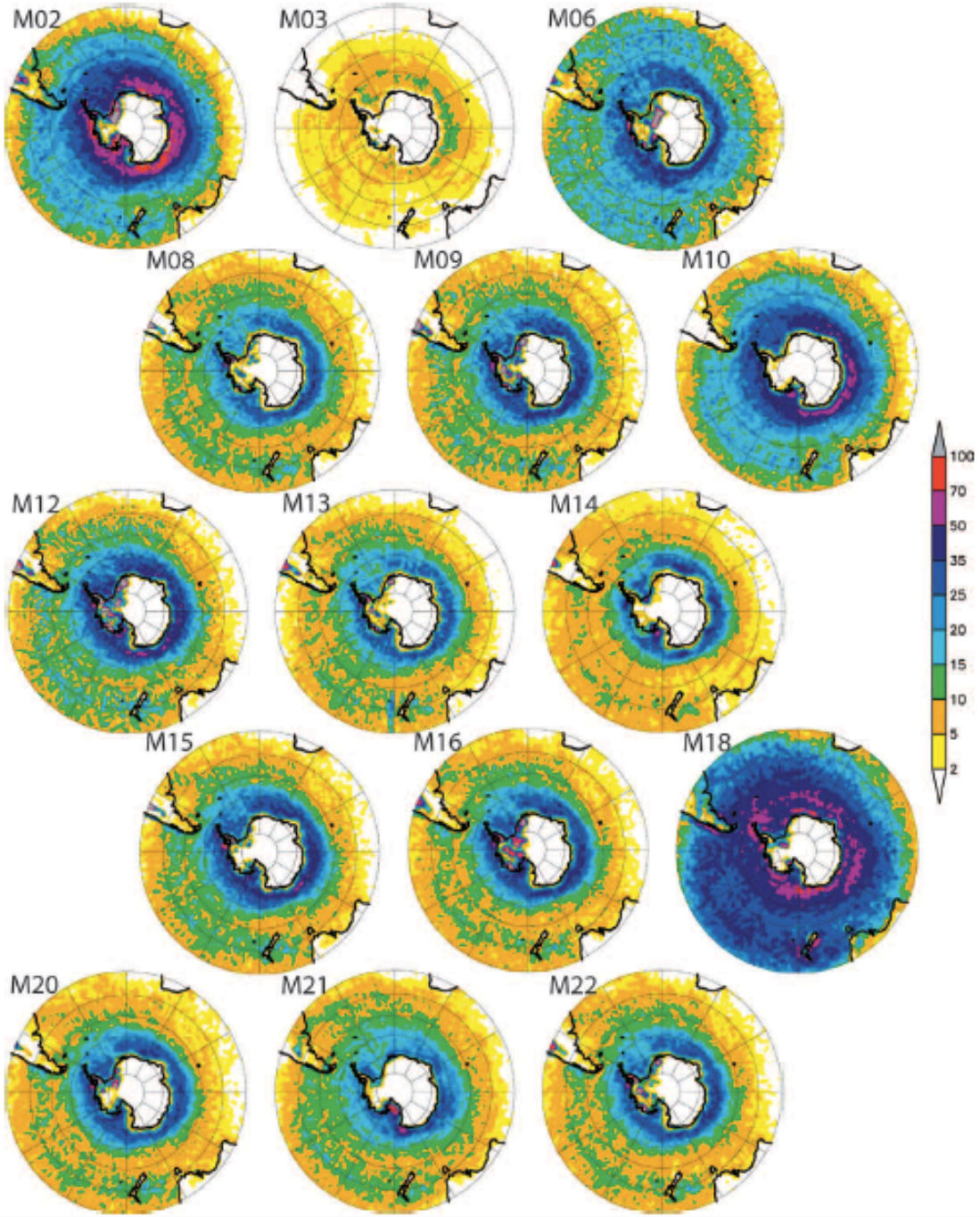


FIG. 2. As in Fig. 1, but for the SH in JJA.

TABLE 1. Different methods and some key characteristics: "variable used" (MSLP: mean sea level pressure; VORT: vorticity or Laplacian of MSLP; VORT Z850: vorticity at 850 hPa as computed by ERA-Interim; Z850: geopotential height at 850 hPa; grad.: gradient of MSLP; min: minimum), and "terrain filtering" (>1000 m; all cyclones positioned over terrain higher than 1,000 m MSL are eliminated). ***Neu et al.,2013***

Code*	Main references for method description	Variable used	Terrain filtering
M02	Murray and Simmonds (1991), Pinto et al. (2005)	MSLP (min), VORT	>1500 m
M03	Benestad and Chen (2006)	MSLP (min, grad.)	none
M06	Hewson et al. (1997), Hewson and Titley (2010)	MSLP (min), VORT, wind, fronts	Terrain-following
M08	Trigo (2006)	MSLP (min, grad.)	none
M09	Serreze (1995), Wang et al. (2006)	MSLP (min, grad.), VORT	none
M10	Murray and Simmonds (1991), Simmonds et al. (2008)	MSLP (min), VORT	>1000 m
M12	Zolina and Gulev (2002), Rudeva and Gulev (2007)	MSLP (min)	none
M13	Hanley and Caballero (2012)	MSLP (min)	>1500 m
M14	Kew et al. (2010)	Z850 (min, contour)	none
M15	Blender et al. (1997), Raible et al. (2008)	MSLP (min)	>1000 m
M16	Lionello et al. (2002)	MSLP (min)	none
M18	Sinclair (1994, 1997)	Z850 VORT	>1000 m
M20	Wernli and Schwierz (2006)	MSLP (min)	>1500 m
M21	Inatsu (2009)	Z850 VORT	none
M22	Bardin and Polonsky (2005), Akperov et al. (2007)	MSLP (min, contour)	none

Tracking scheme M16

- *Lionello et al.,(2002)* Cyclones in the Mediterranean region: The present and the doubled CO_2 climate scenarios
- *Lionello et al.,(2008)* Future changes in cyclone climatology over Europe as inferred from a regional climate simulation
- *Reale et Lionello (2013)* Synoptic climatology of winter intense precipitation events along the Mediterranean coasts
- *Ulbrich et al.,(2013)* Are Greenhouse Gas Signals of Northern Hemisphere winter extra-tropical cyclone activity dependent on the identification and tracking algorithm?
- *Neu et al.,(2013)* IMILAST – a community effort to intercompare extratropical cyclone detection and tracking algorithms: assessing method-related uncertainties
- *Lionello et al.,(2016)* Objective Climatology of Cyclones in the Mediterranean Region: a consensus view among methods with different system identification and tracking criteria
- *Flaounas et al., (2018)* Assessment of an ensemble of ocean-atmosphere coupled and uncoupled regional climate models to reproduce the climatology of Mediterranean cyclones
- *Reale et al., (in press)* A global climatology of explosive cyclones using a multi-tracking approach

Tracking scheme

- *Search of the minimum in the SLP gridded fields*

- *The procedure involves the partitioning of the SLP fields in depressions by the identification of sets of steepest descent paths leading to the same SLP minimum, which is a point where the SLP value is lower than the SLP at the 8 nearest grid points.*

- *There are some criteria to merge two minima based on the difference of SLP and distance between the centers.*

IDENTIFICATION AND TRACKING OF CYCLONES

SLP FIELD

LOCAL MINIMA

LOW PRESSURE SYSTEMS

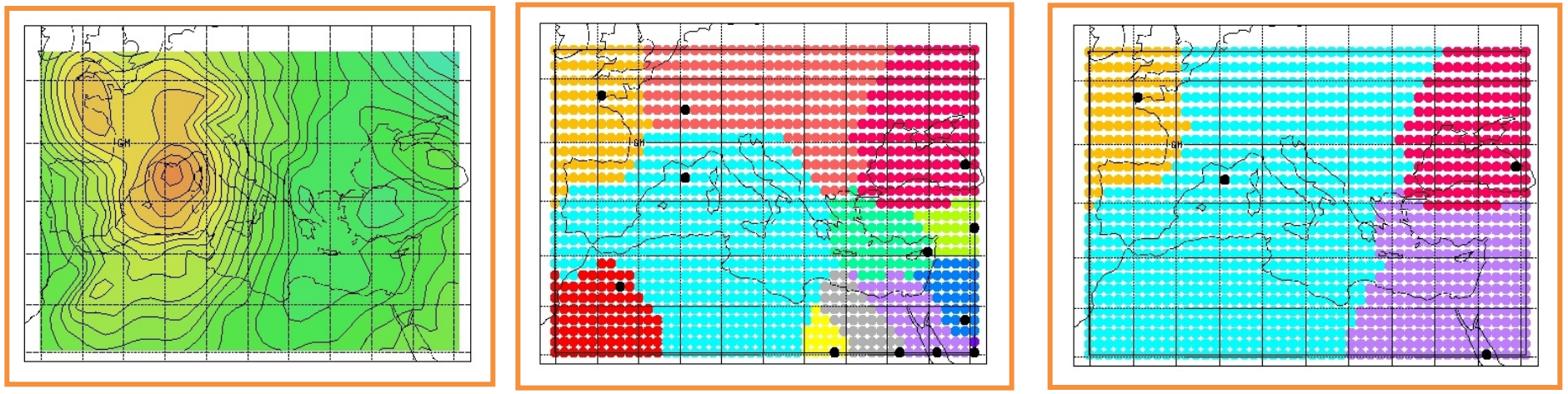


Fig. 1. Example of the procedure for the identification of the cyclones. **(a)** Original sea-level pressure (SLP) field. **(b)** Results of the partitioning procedure. Each dot represents a grid point, and the dots with the same gray level belong to the same partition. Black dots show the location of 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.

Based on P. Lionello et Al. Clim Res Vol. 22: 147–159, 2002

This tracking procedure involves some parameters, mainly for low pressure system merging and for tracking cyclones in successive maps, which are depending of the time and space resolution of input data

The association of grid points to cyclones has the potential of providing "easily" information for computation of several variable characterizing each cyclone (extension, gradient max and average, vorticity max and average, depth …)

Input variable :

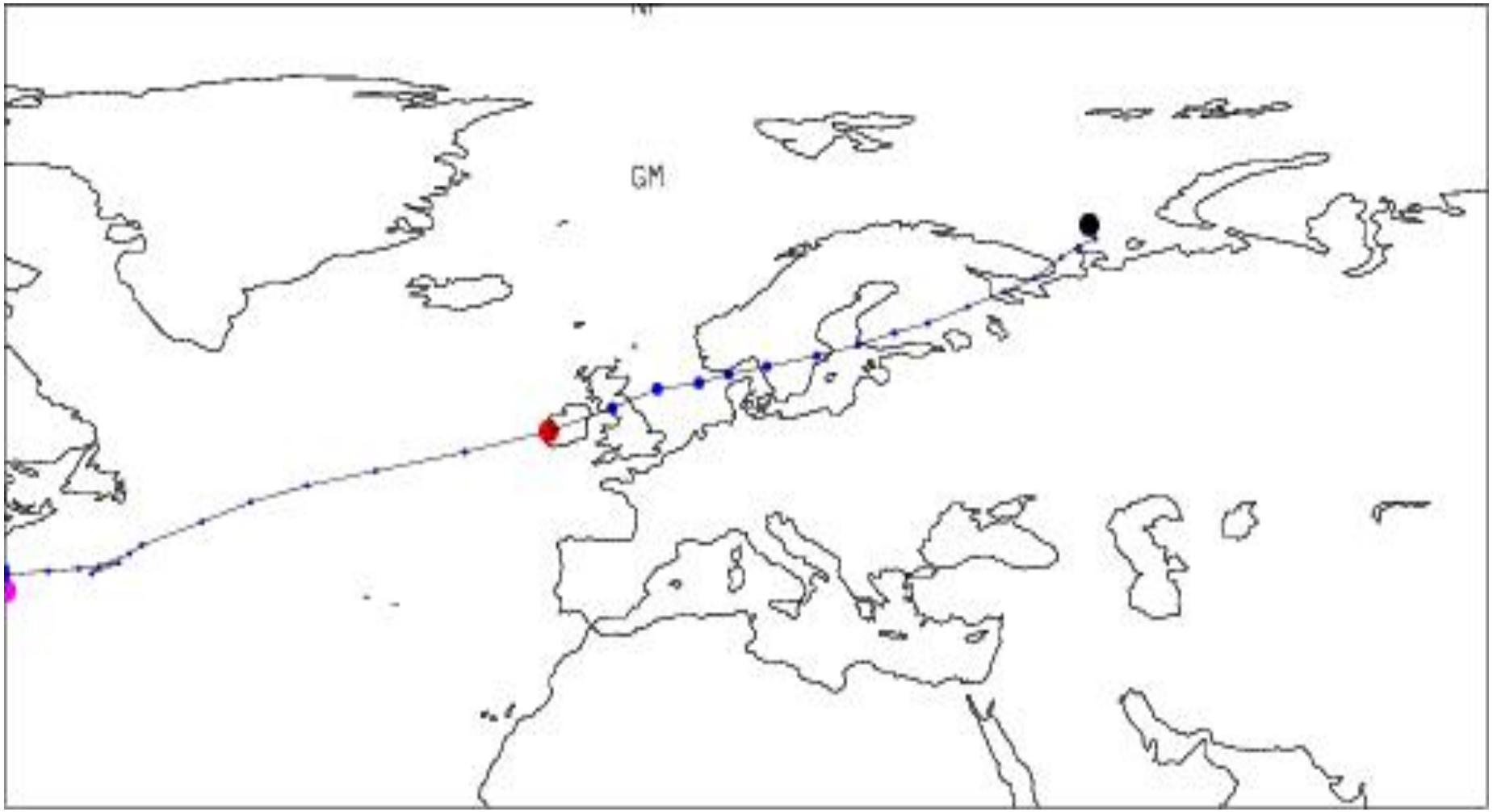
- **MSLP (but the method has been tested also using GPH500)**

Output parameters:

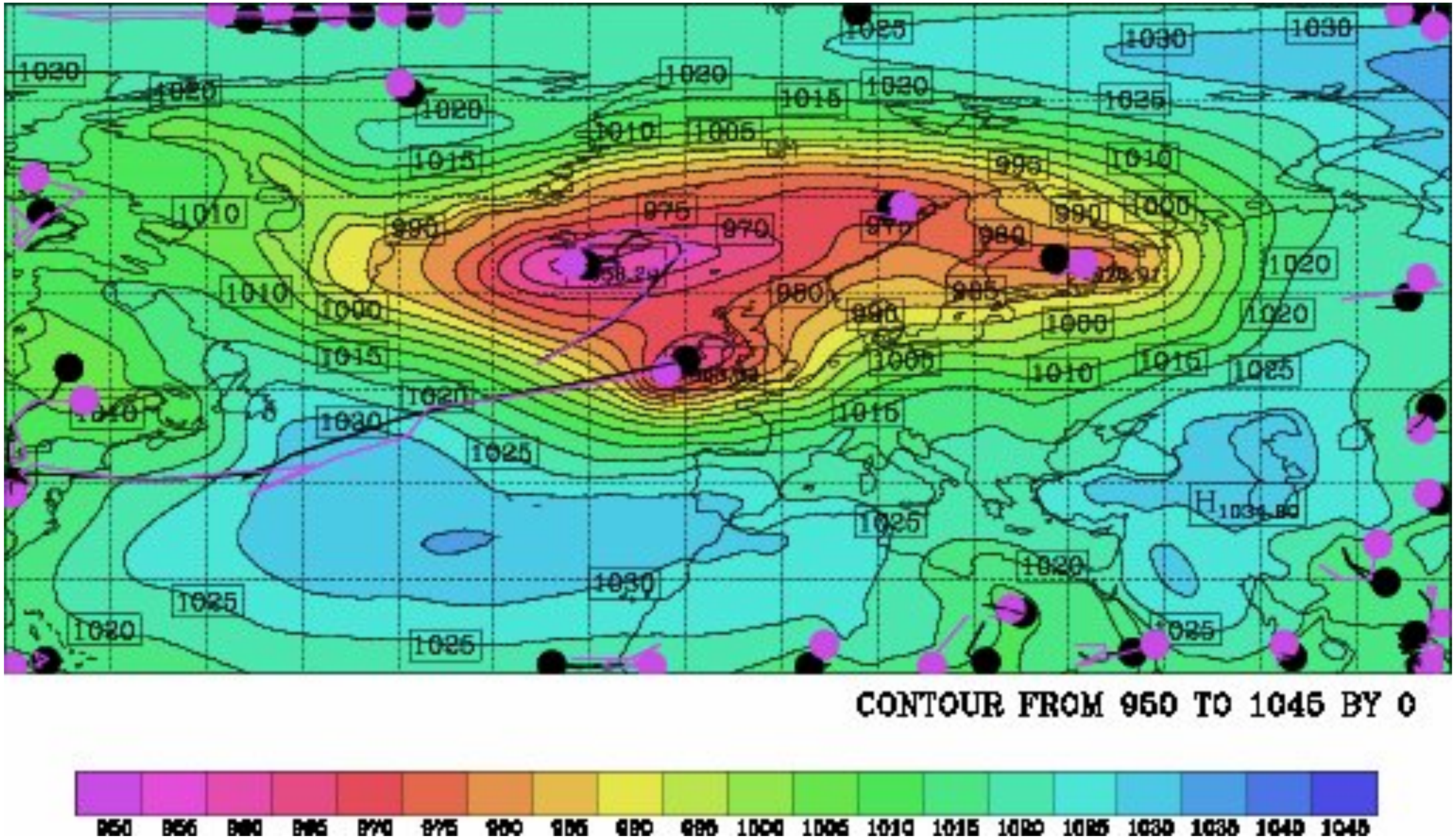
- **complete individual tracks with pressure minima, time, latitude, longitude (but also extension, max laplacian, max gradient, depth are possible)**

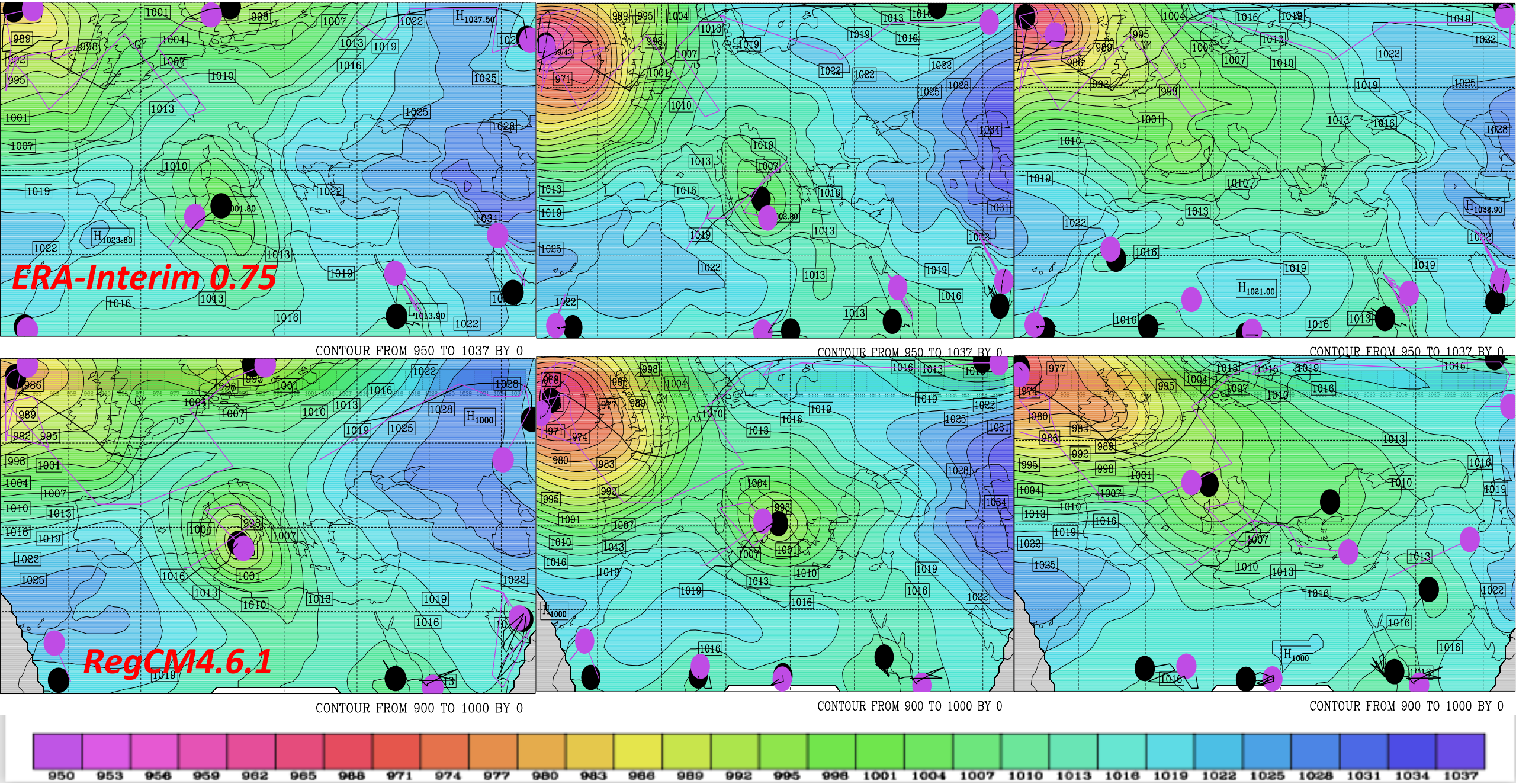
CODE	CYCLONEN0	TIMESTEP_TR	DATE	YEAR	MONTH	DAY	TIMESTEP	LON	LAT	SLP_MIN	LAPL	DEPTH	GRAD	SIZE	LON_MAX_GRAD	LAT_MAX_GRAD	LON_MAX_LAPL	LAT_MAX_LAPL
90	1	5																
16	1	1	1994010100	1994	1	1	0	33.91	23.15	1013.7	0.261E-09	0.676E+01	0.116E-04	0.143E+02	40.5	21.0	25.50	21.75
16	1	2	1994010106	1994	1	1	6	34.55	22.20	1009.5	0.261E-09	0.493E+01	0.226E-04	0.850E+01	40.5	21.0	28.50	23.25
16	1	3	1994010112	1994	1	1	12	35.52	23.24	1010.8	0.245E-09	0.421E+01	0.155E-04	0.721E+01	40.5	21.0	30.75	23.25
16	1	4	1994010118	1994	1	1	18	36.83	22.68	1010.2	0.203E-09	0.427E+01	0.141E-04	0.656E+01	35.2	21.8	33.00	23.25
16	1	5	1994010200	1994	1	2	0	37.48	22.86	1011.5	0.228E-09	0.332E+01	0.117E-04	0.634E+01	40.5	21.0	34.50	22.50
90	2	8																
16	2	1	1994010100	1994	1	1	0	27.75	59.55	991.2	0.188E-09	0.269E+02	0.391E-04	0.254E+02	39.0	57.0	43.50	56.25
16	2	2	1994010106	1994	1	1	6	28.45	59.67	994.2	0.200E-09	0.189E+02	0.419E-04	0.175E+02	42.8	58.5	48.00	57.75
16	2	3	1994010112	1994	1	1	12	32.07	58.26	997.8	0.251E-09	0.154E+02	0.464E-04	0.122E+02	48.0	59.2	50.25	57.75
16	2	4	1994010118	1994	1	1	18	33.33	58.03	998.9	0.147E-09	0.130E+02	0.340E-04	0.114E+02	33.8	55.5	48.00	55.50
16	2	5	1994010200	1994	1	2	0	36.27	58.20	1000.1	0.183E-09	0.111E+02	0.373E-04	0.101E+02	40.5	57.0	54.00	56.25
16	2	6	1994010206	1994	1	2	6	39.72	58.36	1001.5	0.177E-09	0.940E+01	0.390E-04	0.899E+01	45.8	58.5	54.00	57.00
16	2	7	1994010212	1994	1	2	12	45.69	58.85	1004.6	0.158E-09	0.927E+01	0.343E-04	0.707E+01	42.0	57.8	54.00	56.25
16	2	8	1994010218	1994	1	2	18	50.72	59.09	1008.1	0.122E-09	0.793E+01	0.292E-04	0.569E+01	53.2	57.8	54.00	56.25

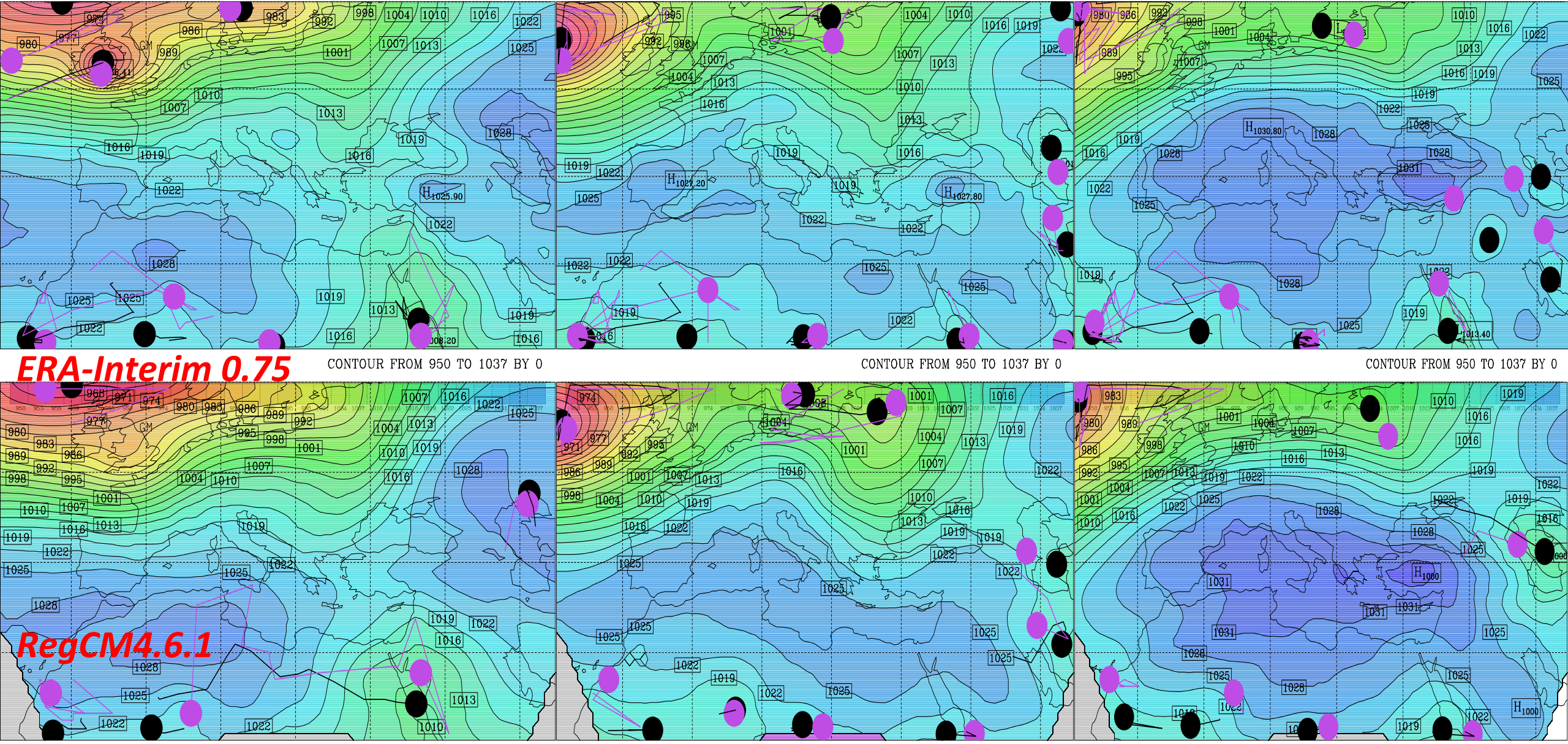
Storm «DARIA»



Track Daria 25.01.1990, Germany 19.01.90 00UTC-28.01.1990 18UTC


CONTOUR FROM 950 TO 1045 BY 0
950 955 960 965 970 975 980 985 990 995 1000 1005 1010 1015 1020 1025 1030 1035 1040 1045


ERA-Interim 0.75
RegCM4.6.1
CONTOUR FROM 950 TO 1037 BY 0
CONTOUR FROM 950 TO 1037 BY 0
CONTOUR FROM 950 TO 1037 BY 0
CONTOUR FROM 900 TO 1000 BY 0
CONTOUR FROM 900 TO 1000 BY 0
CONTOUR FROM 900 TO 1000 BY 0
950 953 956 959 962 965 968 971 974 977 980 983 986 989 992 995 998 1001 1004 1007 1010 1013 1016 1019 1022 1025 1028 1031 1034 1037


ERA-Interim 0.75
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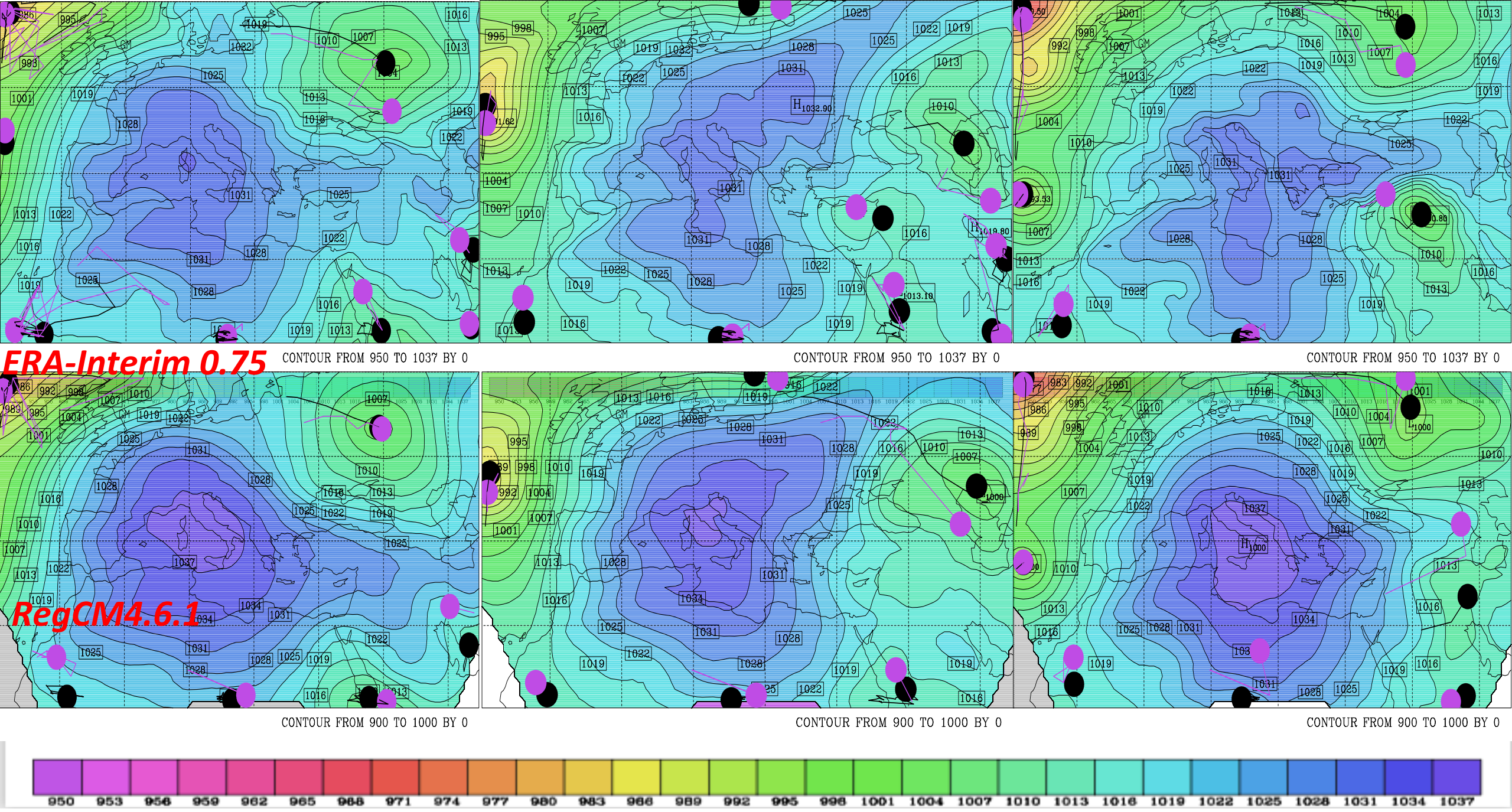
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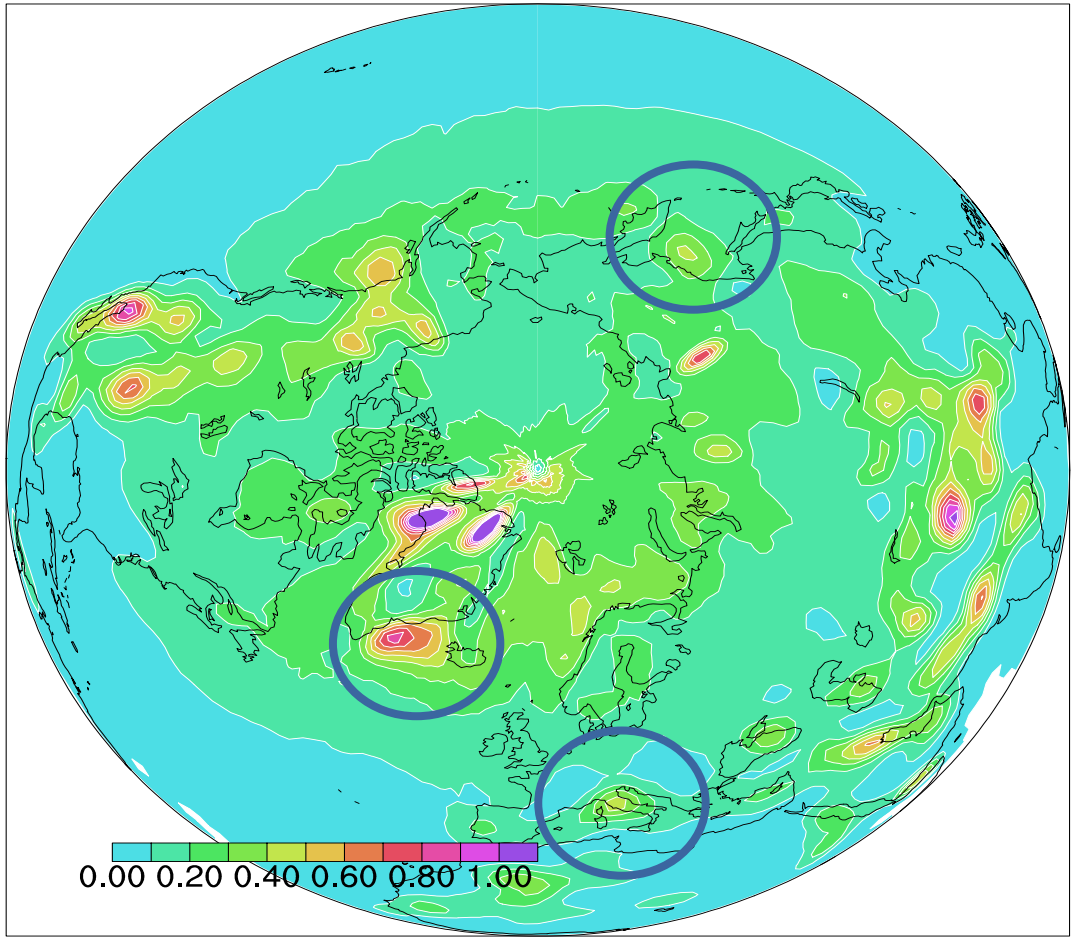
950 953 956 959 962 965 968 971 974 977 980 983 986 989 992 995 998 1001 1004 1007 1010 1013 1016 1019 1022 1025 1028 1031 1034 1037

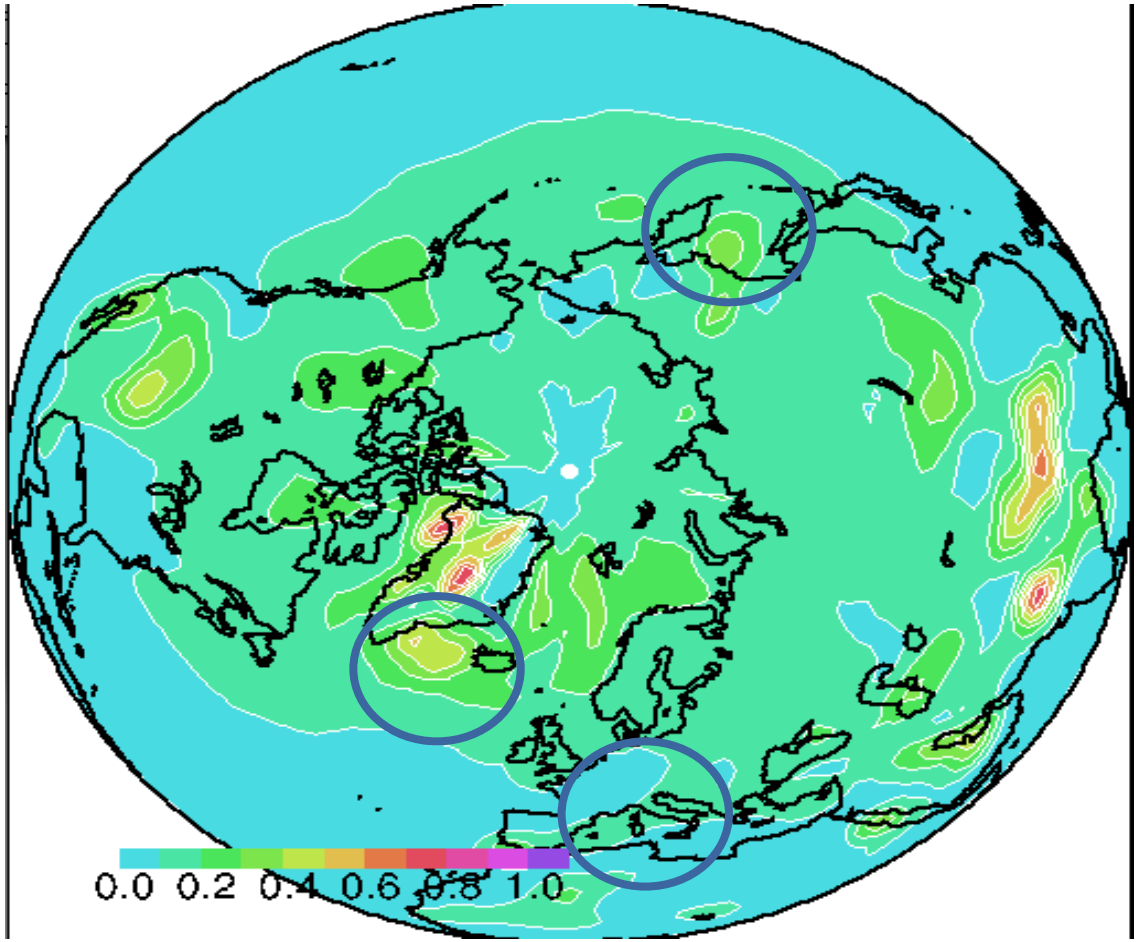
- **Studies on cyclones in GCMs can help to identify the sensitivity of these features of atmospheric circulation to ocean boundary conditions (Ulbrich et al.,2009) and to increasing greenhouse gases concentration**
- **GCMs are generally able to reproduce the structure of the storm tracks in the Northern Hemispheres with relative high value of spatial correlation (till 0.9) if compared with the reanalysis dataset..**
- **..BUT they tend to simulate a lower number of cyclones and weaker systems due to, for example, lower resolution (both temporal and spatial) adopted. Specifically a lower resolution is not suitable to resolve properly the orography and air-sea interactions in areas (like the Mediterranean region, Rocky mountains,etc) where these factores are important in fueling the cyclone development.**

Density of tracks in ERA-Interim (a) and ECHAM5 (b)

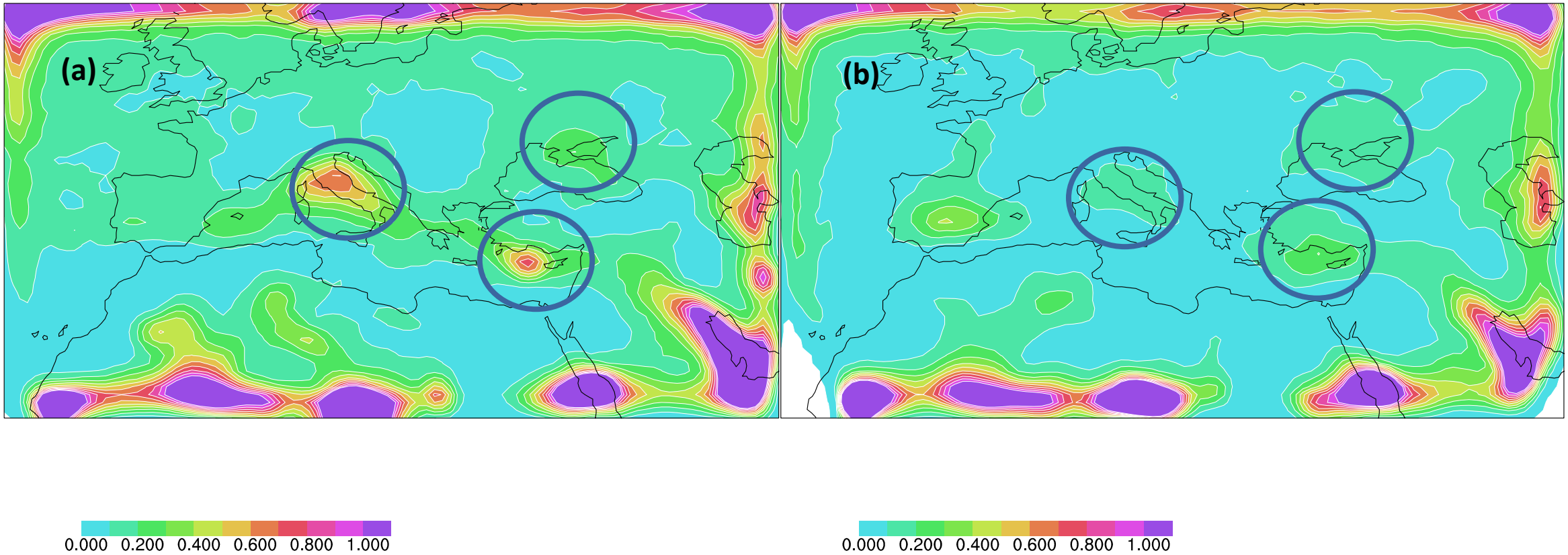
Era-interim(a)



ECHAM5 (b)



Density of tracks in ERA-Interim (a) and RegCM.4.6.1 (b) (period 1994-2006)

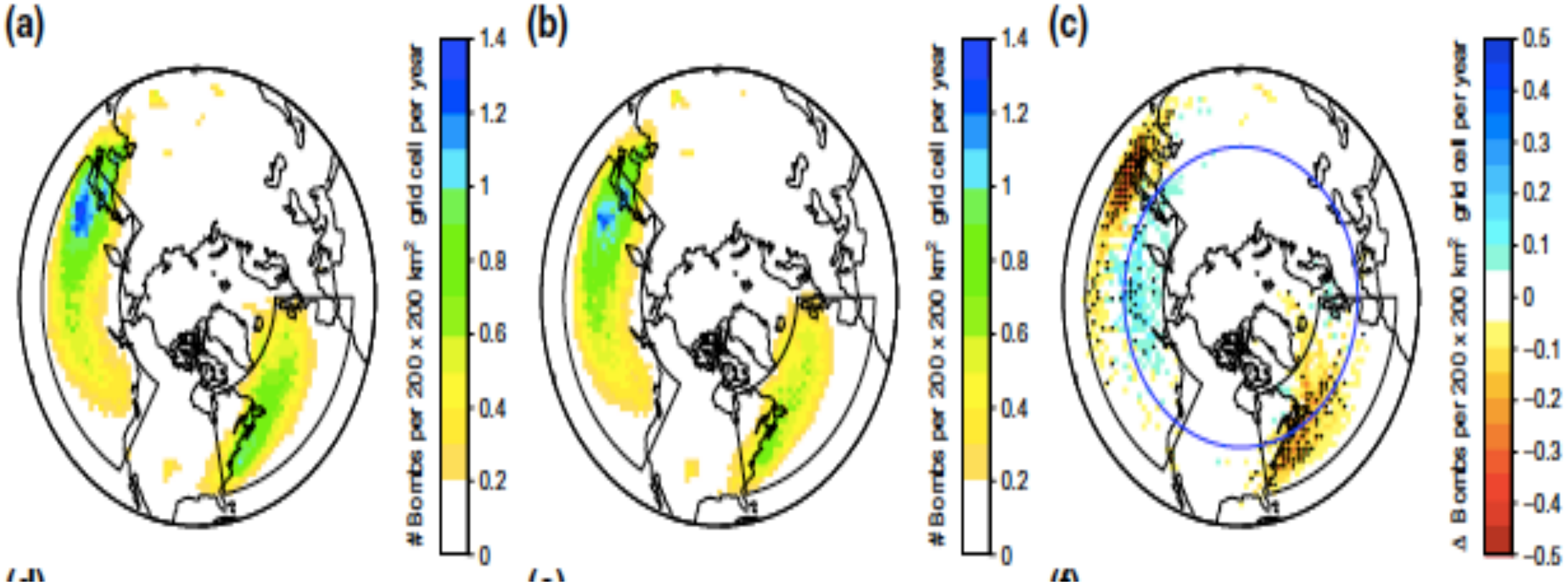


CMIP5 model have been shown to reproduce properly spatial and temporal variability of explosive cyclones in the Northern Hemisphere (Seiler and Zwiers, 2016)

- **..BUT they tend to simulate a lower number of bombs..due to lower resolution not suitable to resolve properly the intensity of the jet stream and meridional gradient in the temperature which plays a primary role in the formation of these systems.**

Many results based on GCMs (including CMIP5) show:

a) A general increase of extreme cyclones (despite there is a discussion on how to define a cyclone as an extreme)
b) A general decrease of the number of cyclones on hemispheric scale
c) A poleward shift of storm track over both Pacific and Atlantic with an higher storm activity at higher latitudes.
d) For the explosive cyclones a shift in the storm track in the Pacific and a decrease in the frequency along the north Eastern America coastlines



Multi-model mean annual explosive cyclone frequency simulated for a 1981–1999 and projected for 2081–2099 under RCP8.5, and c the corresponding projected absolute changes based on 23 CMIP5 models. (Seiler and Zwiers, 2016)

So we have some questions to answer:

Cordex Simulations :
Regional climate models forced by different GCMs with two different emission scenarios RCP8.5/RCP2.6

- ***How much different are the explosive cyclones simulated by the ensemble of these regional models with respect to Era-interim? Is there any additional value or improvements with respect to the forcing GCMs (I mean in term of seasonal cycle, density of tracks and cyclogenesis, minimum of SLP, adjusted deepening rate, normalized deepening rate, maximum of speed and duration)?***

- ***How much different will explosive cyclones be in the future in the two scenarios rcp8.5 and rcp2.6 with respect to the present? (I mean with differences : seasonal cycle, tracks, cyclogenesis areas, minimum of SLP, adjusted deepening rate, normalized deepening rate, maximum of speed and duration)?***

Paper structure

List of authors: Marco, Abraham, Michelle, Filippo, Erika..

….??? (anyone else)

- **Introduction : A summary of what we know about explosive cyclones, features, behavior, future projections for cyclone activity , discussions of possible source of biases.**
- **Data and methods: description of the tracking scheme , list of regional climate model(s)and general circulation model(s) analyzed (how many?with how many different GCMs), statistical tools (if used), description of the datasets of (explosive/ordinary) cyclones.**
- **Results:**

1. **Comparison between Multimodel Regional Models /General circulation Models Mean and Era-interim for the period (???) in terms of trends, seasonal cycles,density of tracks, maximum value of speed, duration, minimum value of Mean Sea Level Pressure, Adjusted deepening rate and Normalized Deepening rate**
2. **Comparison between Multimodel Regional Models Mean for the period 1981-2010 (?) and 2080-2100 (?) for density of tracks, maximum value of speed, duration, minimum value of Mean Sea Level Pressure, Adjusted deepening rate and Normalized Deepening rate**

- **Conclusions**

We need you…and your data! (6-hourly MSLP data)

Boarding this afternoon, after lunch…

Thanks a lot for your attention!!!

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