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2210-7

MedCLIVAR Workshop on: "Scenarios of Mediterranean Climate Change under Increased Radiative Active Gas Concentration and the Role of Aerosols

23 - 25 September 2010

Extreme Mediterranean Cyclone and Wind Events under increasing GHG Climate Forcing

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Extreme Mediterranean Cyclone and Wind Events Under Increasing GHG Climate Forcing

Uwe Ulbrich

CLIMATE CHANGE AND IMPACT RESEARCH: THE MEDITERRANEAN ENVIRONMENT

Circe

Special thanks to Katrin Nissen, Gregor Leckebusch and Joaquim Pinto

Agenda

- Current climate: Cyclone origins and tracks

  Cyclones producing extreme winds

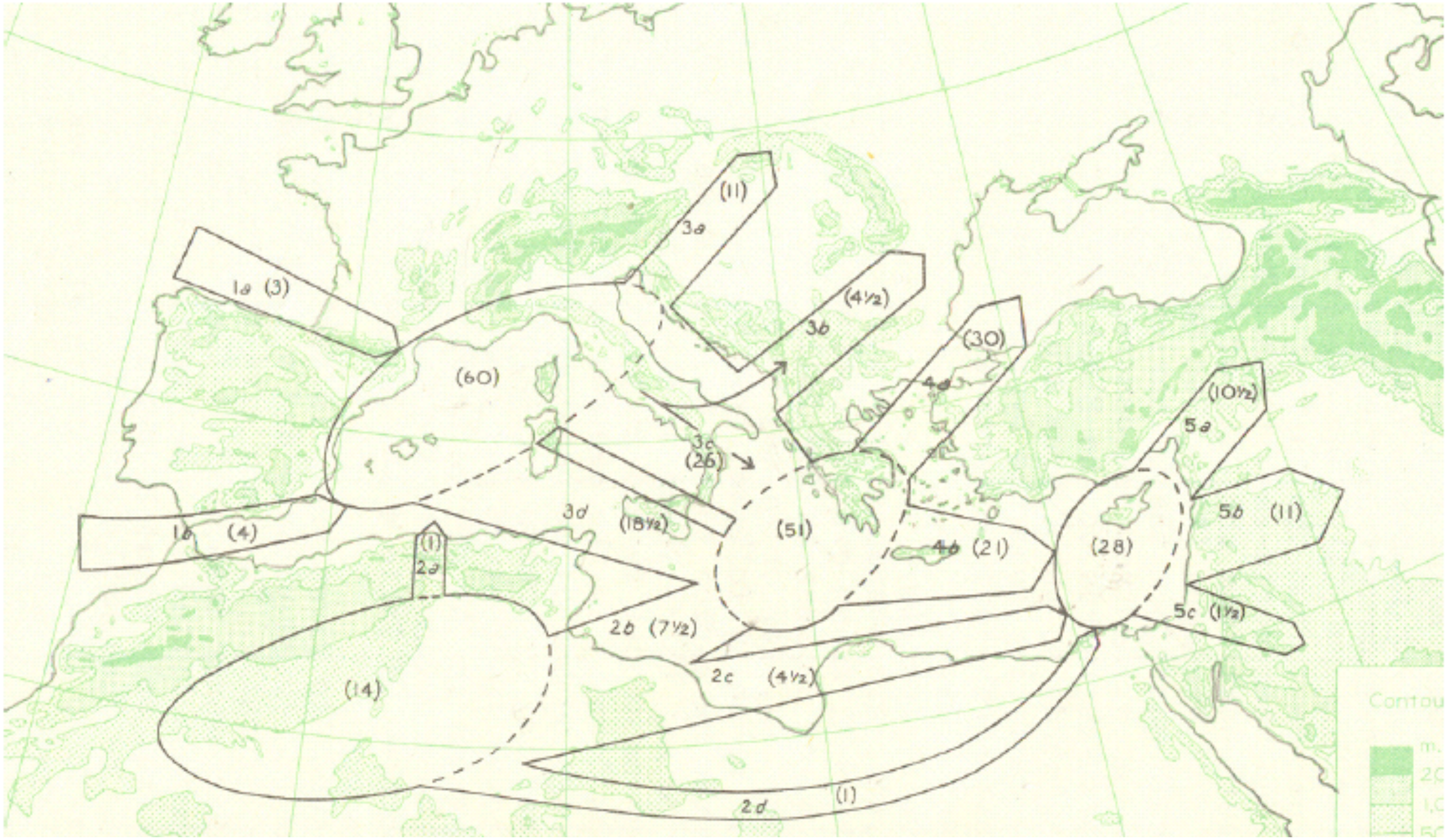
  Wind track densities

- Validation and signals of some climate models

- Wind storm intensities

CLIMATOLOGY of TRACK DENSITY

Number of cyclones per year (in paretheses)



HMSO (1962): 42% of Med cyclones formed outside basin

(from Romem et al., Adv. Geophys., 2007)

CLIMATOLOGY of TRACK DENSITY

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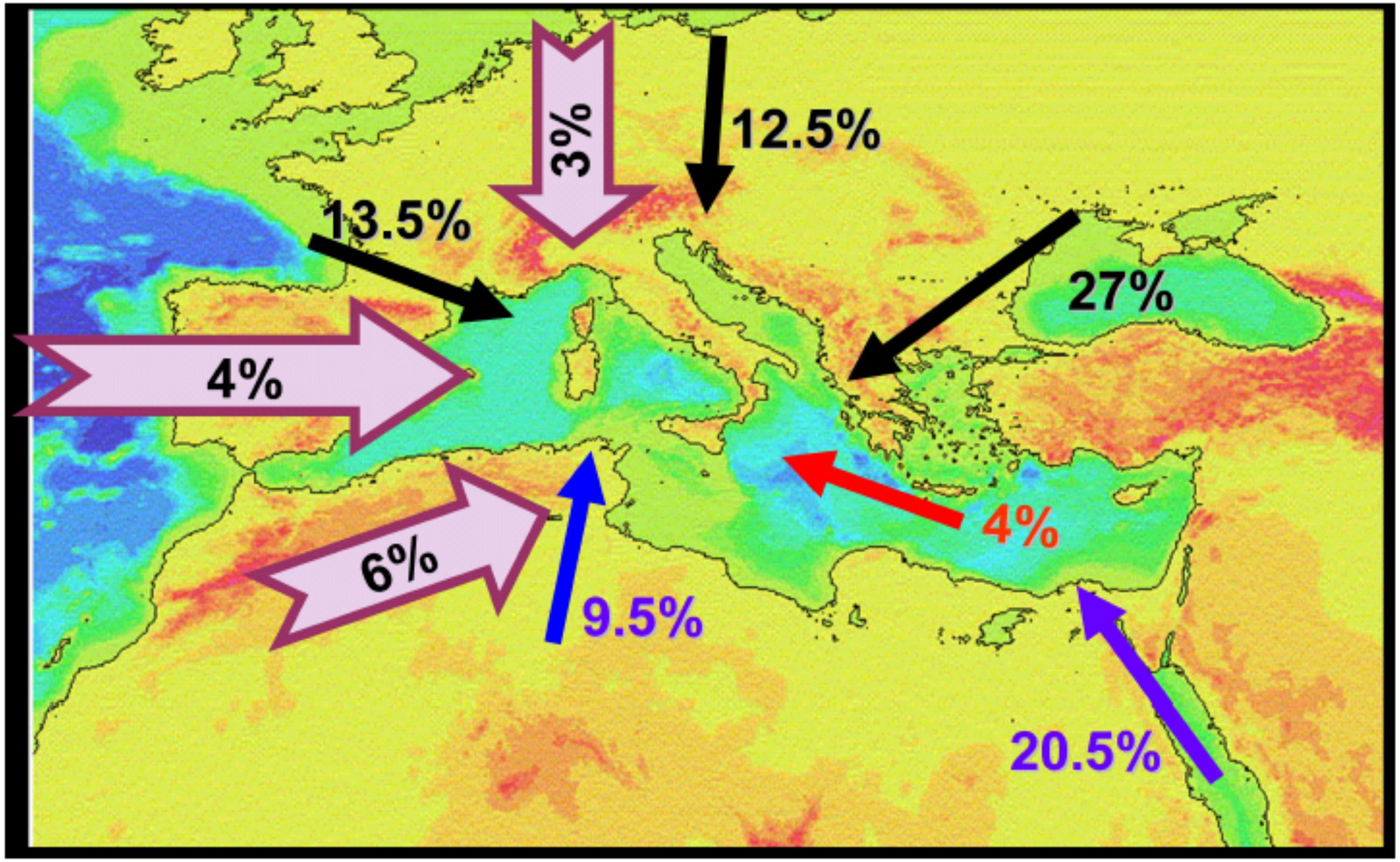
Number of cyclones per year , entering vs developing from troughs



Romem et al., Adv. Geophys., 2007

CLIMATOLOGY of TRACK DENSITY

HMSO 1962: **58%** of cyclones enter basin,
mainly from Atlantic and from Sahara

Romem et al. (2007): **13%** of Med cyclones formed outside,

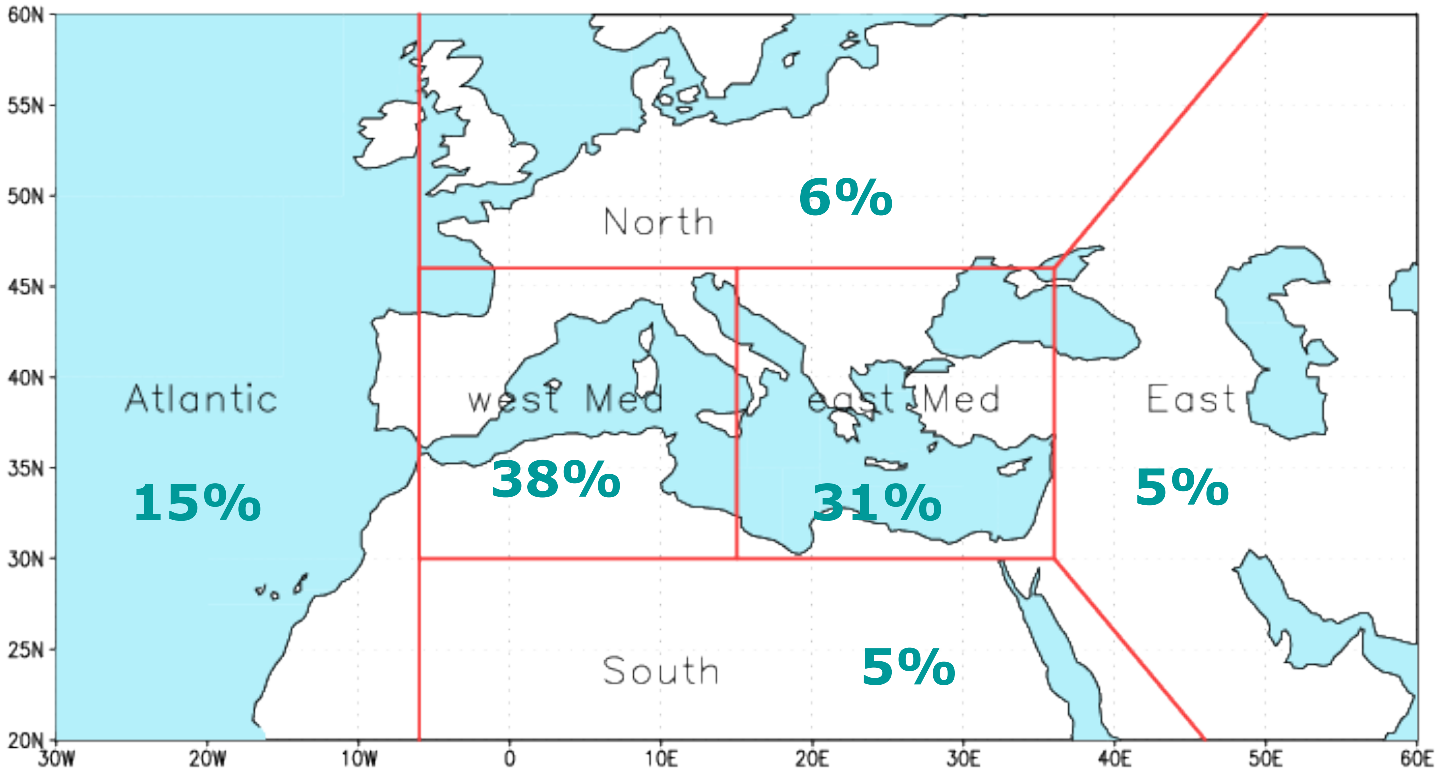
6% Sahara desert,
4% Atlantic ocean,
3% Europe

Reasons for difference?

HMSO includes many Sahara cyclones (April, May)
Romem et al restricted to October-March
NCEP, 1986/7,1991/2, 2001/2, 2002/3, 2003/4

ERA40 1960-1999 Oct-Mar

Region of cyclogenesis for cyclones crossing Mediterranean region



Percentage forming outside of the Mediterranean Region: 31%

Total crossing Mediterranean:3513

Identification and tracking of mid-latitude cyclone systems:

Nissen et al., NHESS 2010, based on Murray & Simmonds (1991)

1. Identification
   a) Gridded MSLP field is transformed to a regular 0.75°x0.75° grid by a polar stereographic projection via bicubic spline interpolation

   b) This grid is scanned for maxima of the quasi-geostrophic relative vorticity via the Laplacian of pressure ($\nabla^2 p$)

$$\xi = \frac{1}{\rho \cdot f} \nabla^2 p$$

   c) Iterative search of a pressure minimum in the vicinity of $\nabla^2 p$
   d) Removal of systems on basis of specific thresholds

Identification and tracking of mid-latitude cyclone systems:

Nissen et al., NHESS 2010, based on Murray & Simmonds (1991)

2. Tracking

a) For each identified cyclone a subsequent position and core pressure is predicted by using a ***prediction velocity***, which is an average of the velocity deduced from the previous displacement and a geostrophic steering velocity

b) Only those tracks were considered in which cyclones have been “closed” and “strong” at least once in their lifetime

c) Minimum lifetime is set to 24 h.

Identification of closed and open systems

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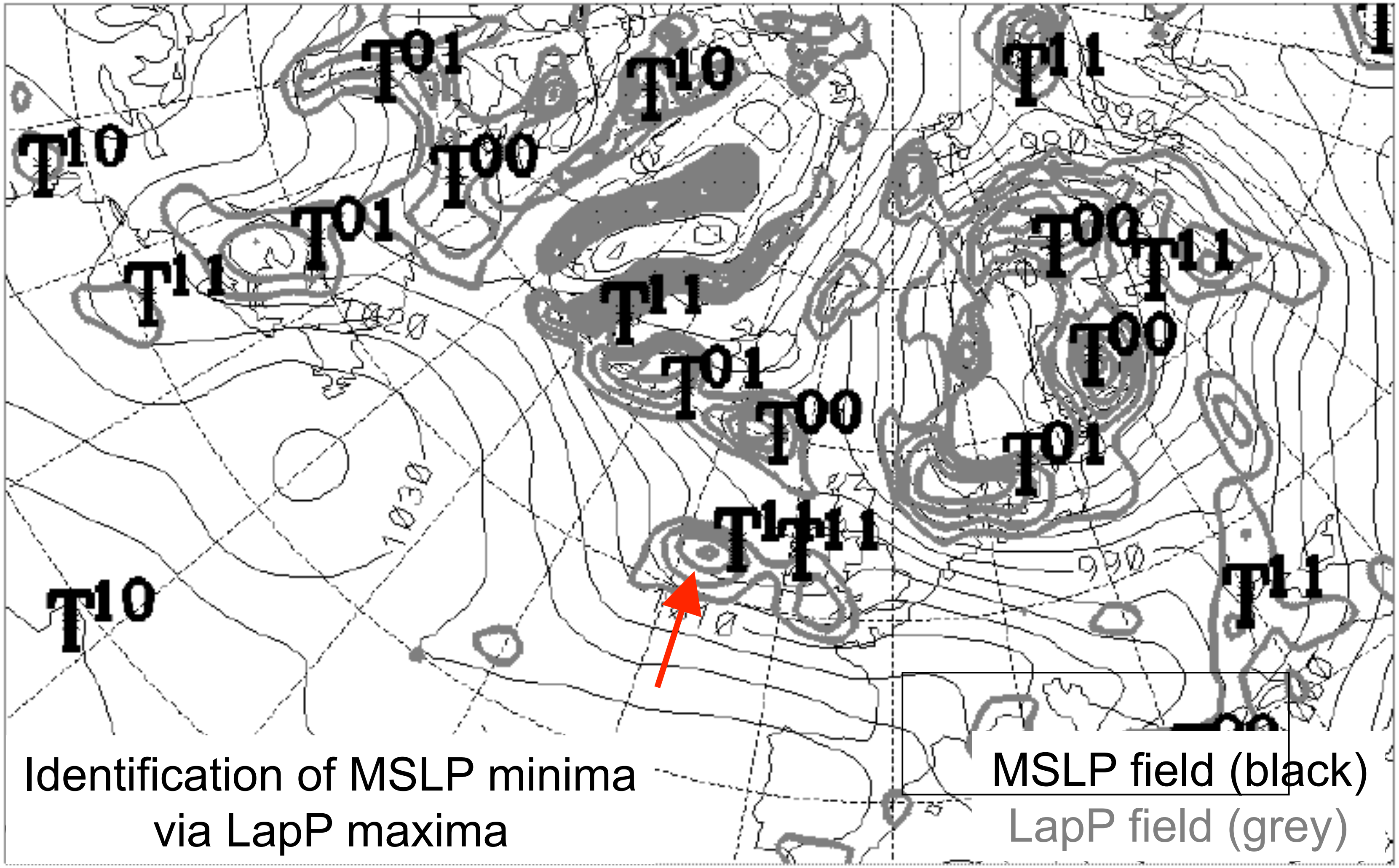

Pinto et al (2005) Met Z

Closed: T00 (strong), T10 (weak); Open: T01 (strong), T11 (weak)

WIND TRACKING AND CYLONE MATCHING

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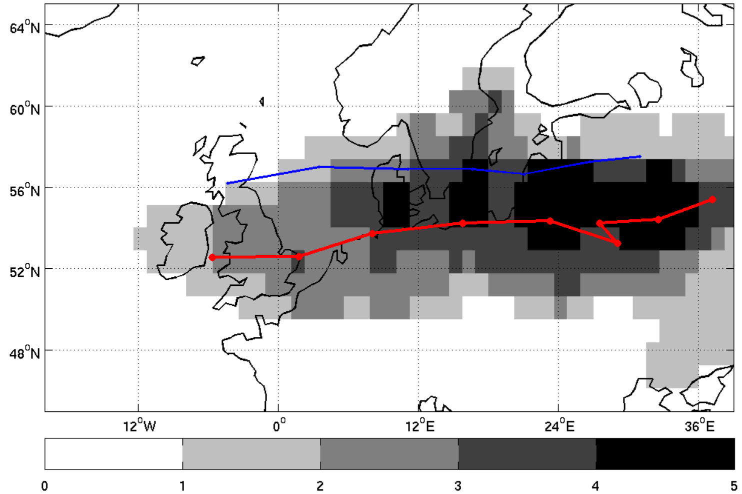
- Searching for clusters of grid boxes where the wind speed exceedes the **local 98th percentile = EXTEME**.

- Tracking of clusters with nearest neighbour approach (Leckebusch et al. 2010).

Wind storm Anatol

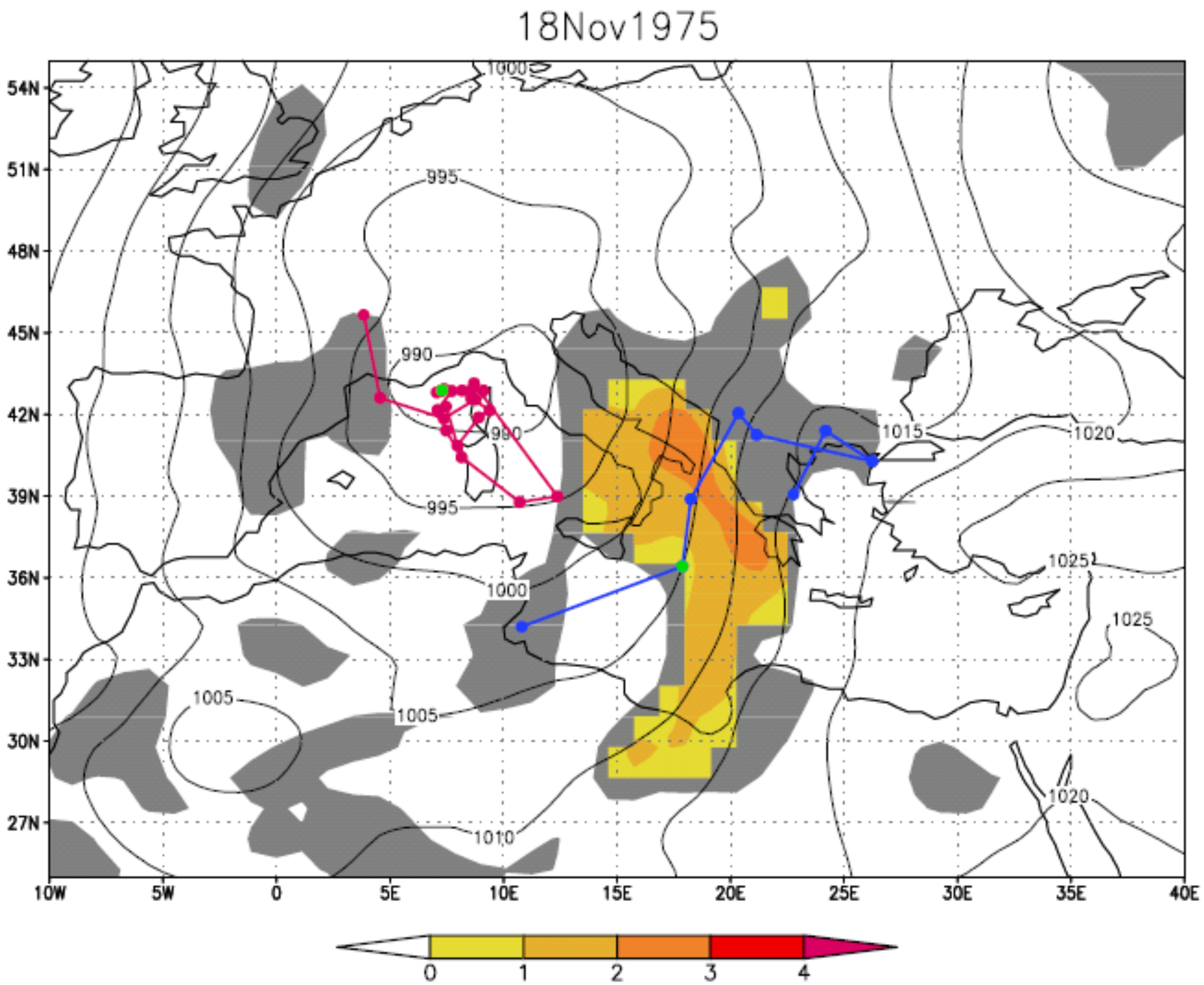


From Leckebusch et al. 2008

- Minimum thresholds for area and duration

- Cyclone associated with the wind track is selected from cyclone catalogue (Nissen et al. 2010).

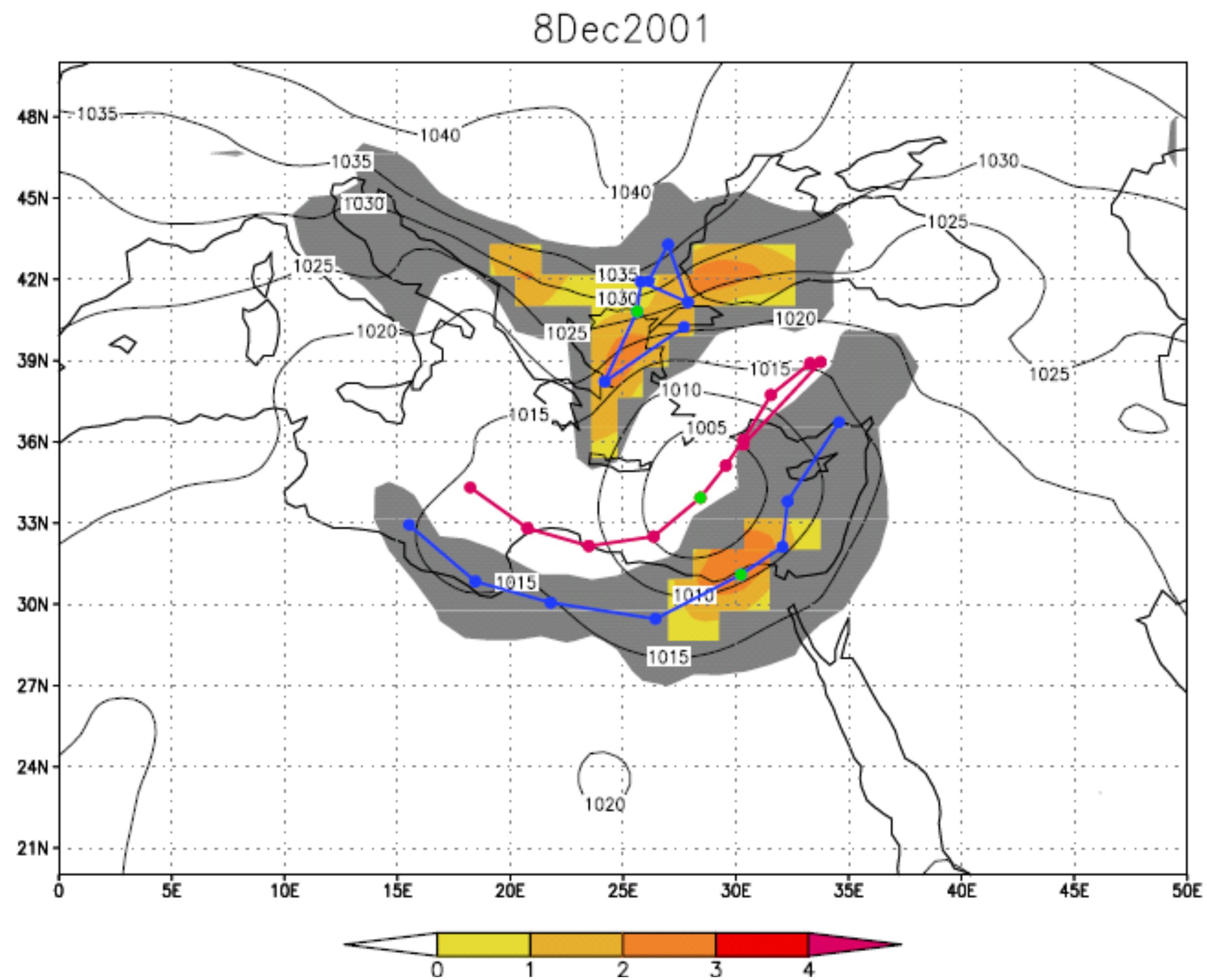
Cyclone causing flooding in Venice



Cyclone track (red),
wind-cluster track (blue),
MSLP field (isolines in hPa)
and exceedance of 98th
percentileof wind speed
(coloured shading in m/s above
local 98th
percentile)

18 November 1975 06:00.
Green dots:
current cyclone core and wind
cluster centre.

The total area with wind
speeds exceeding the 98th
percentile over the 2 day
period is shown in gray.



Cyclone weak according to MSLP, 2 extreme wind areas

Cyclone track (red),
wind-cluster track (blue),
MSLP field (isolines in hPa)
and exceedance of 98th
percentileof wind speed
(coloured shading in m/s above
local 98th
percentile)

Green dots:
current cyclone core and wind
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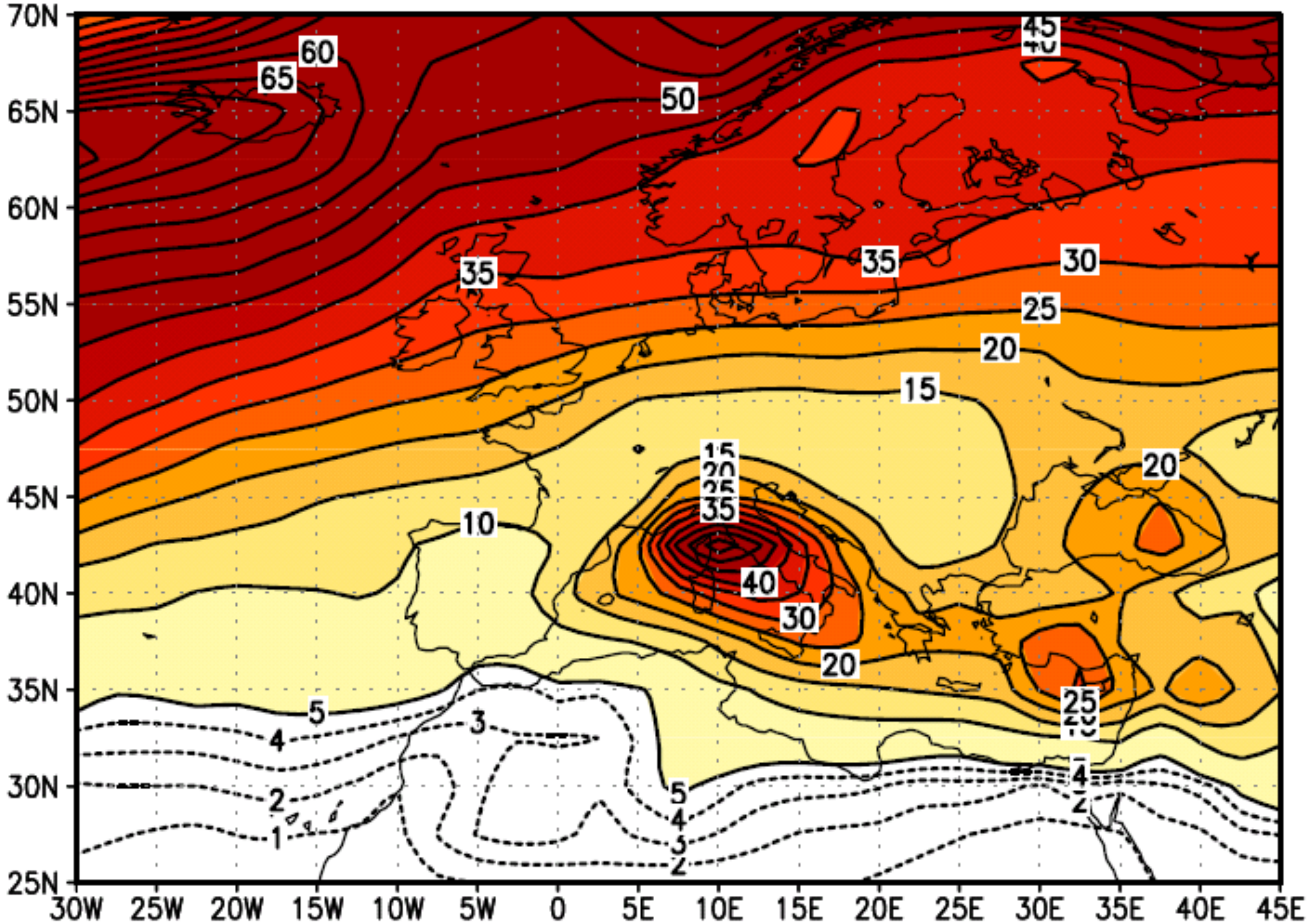
CLIMATOLOGY of TRACK DENSITY



ERA40: 1.125×1.125 October to March, 1957–2002.

TRACK DENSITY of Med. WINDSTORM PRODUCING CYCLONES

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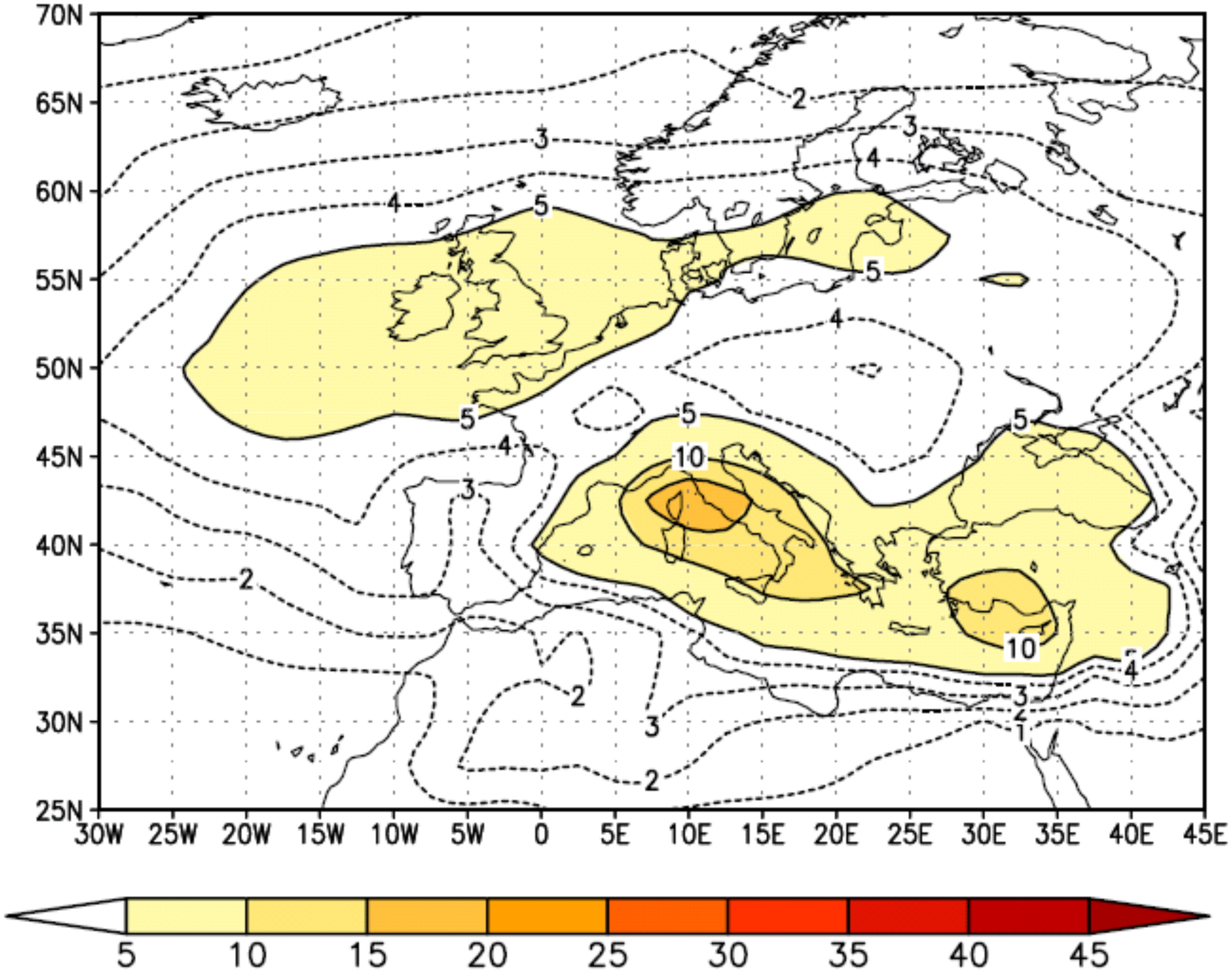
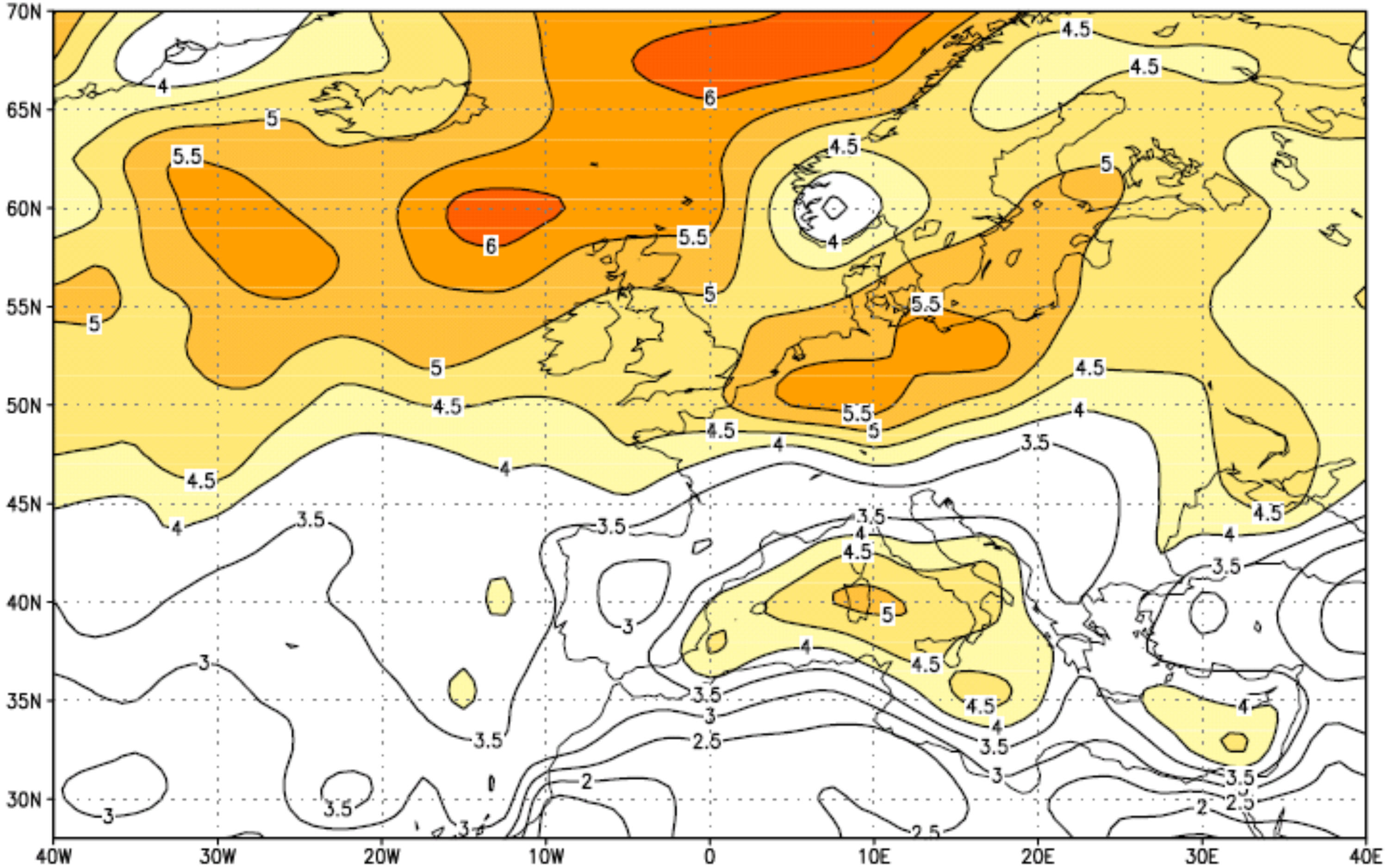


ERA40: 1.125×1.125 October to March, 1957–2002.

WIND TRACK DENSITY



ERA40: 1.125×1.125 October to March, 1957–2002.

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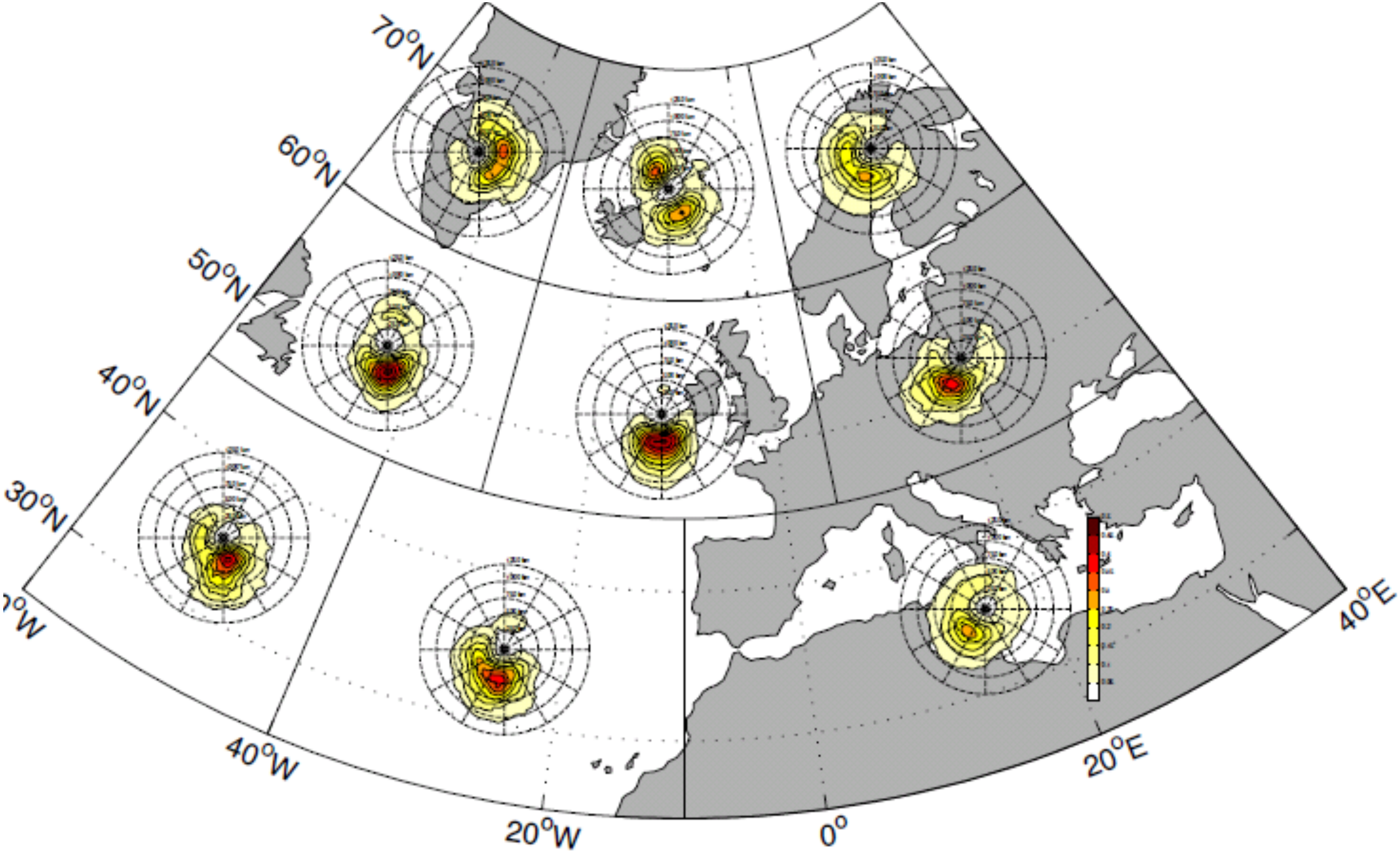


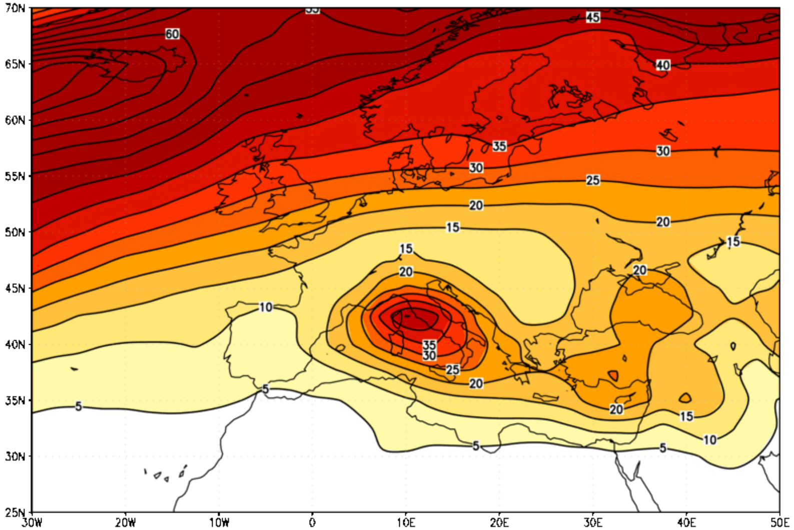
DATA

ECHAM5 MPIOM Ensemble
Horizontal resolution: 1.875°x1.875°
3x 20C 1961-2000
3x A1B 2001-2100
3x A2 2001-2100

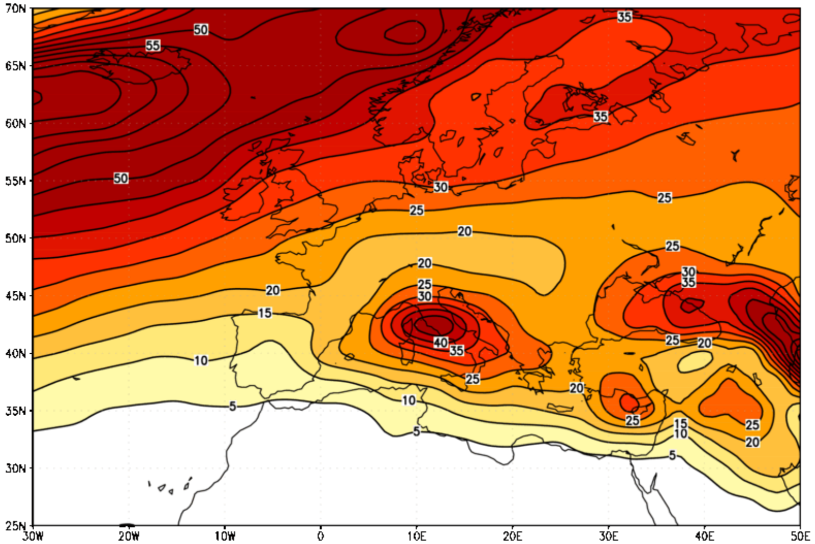
INGV CMCC Simulation
Horizontal resolution: 0.75°x0.75°
1x 20C 1951-2000
1xA1B 2001-2050

VALIDATION CYCLONES

ERA40

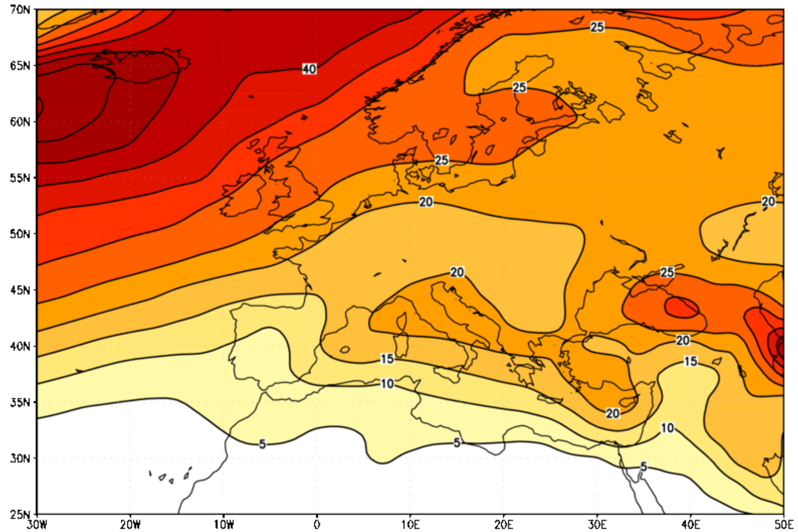


INGV CMCC



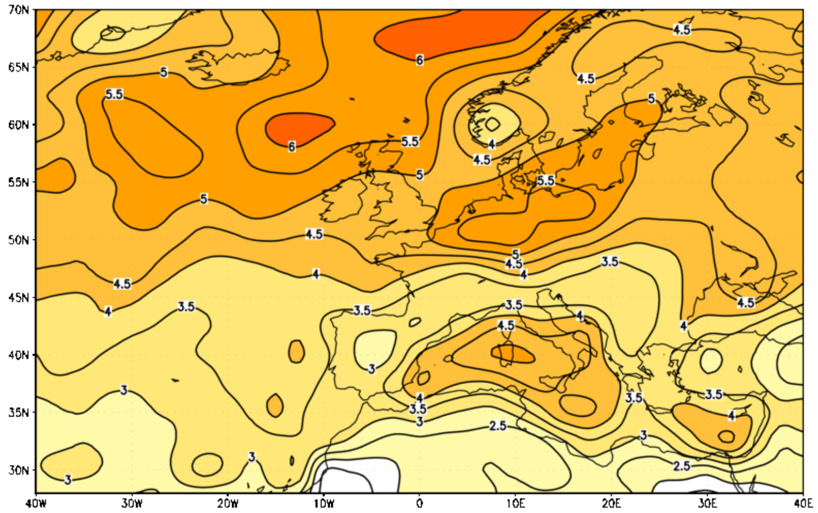
lower horizontal resolution

ENSEMBLE ECHAM5 MPIOM



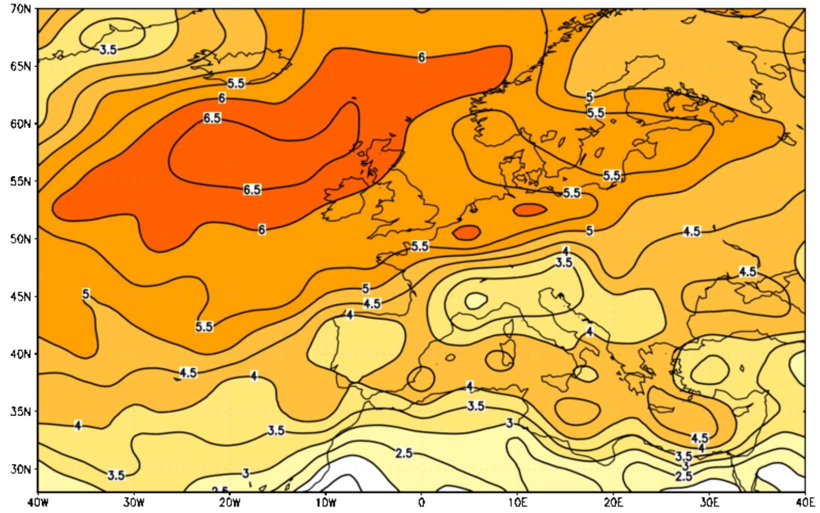
VALIDATION WIND TRACKS

ERA40

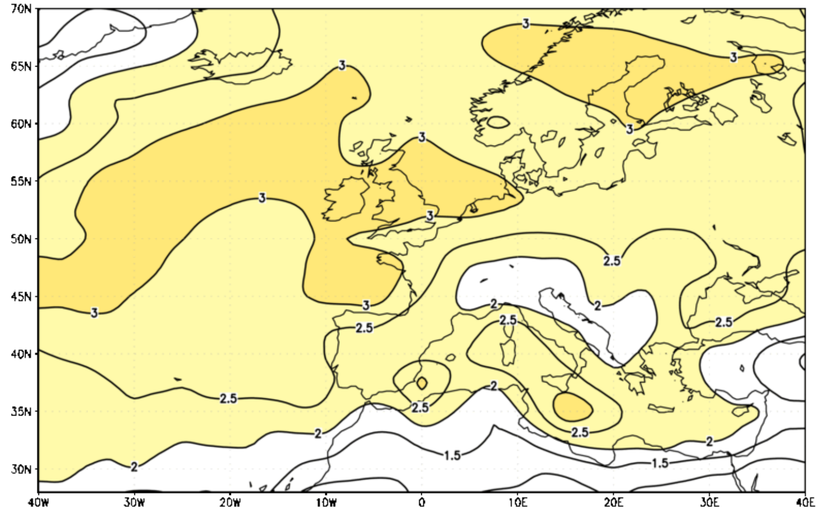


Threshold effected area 2.8x higher due to lower horizontal resolution

INGV CMCC



ENSEMBLE ECHAM5 MPIOM



VALIDATION CYCLONES WITH WIND TRACK
in Mediterranean Region

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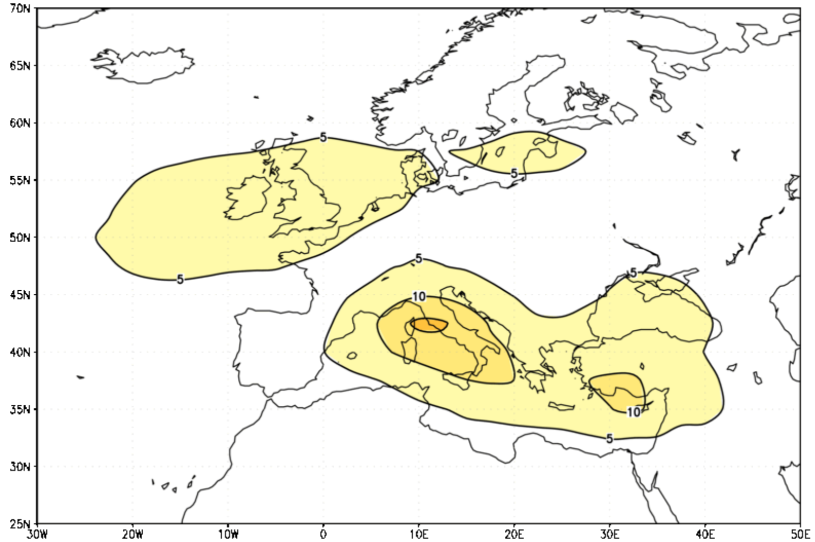
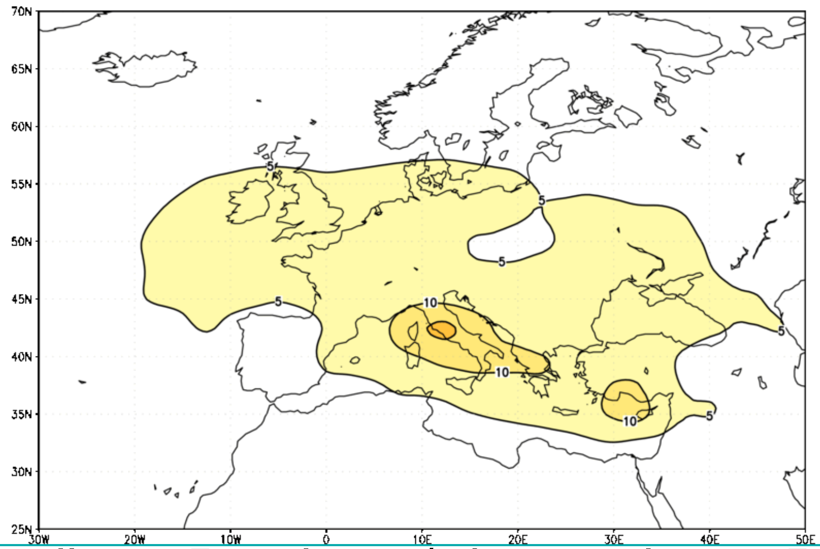
ERA40



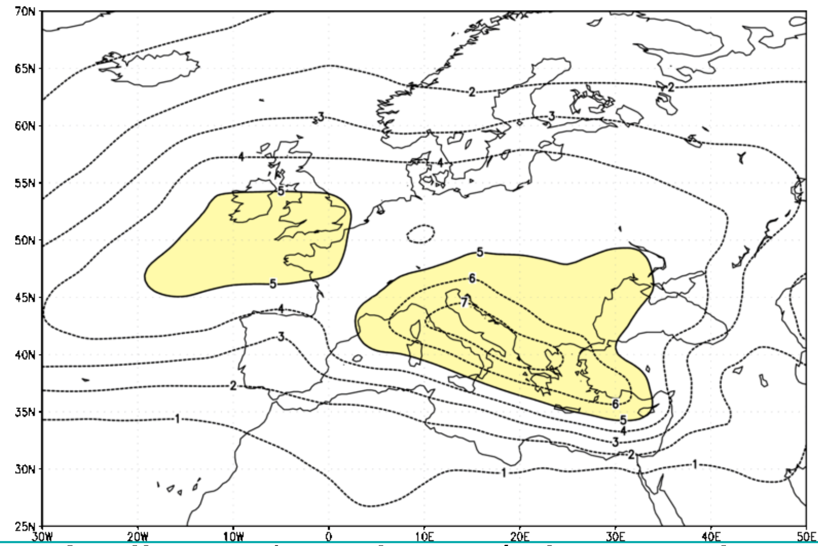
lower due to lower number of wind tracks

INGV CMCC



Isolines: 5 cyclones/winter, colour > 5

ENSEMBLE ECHAM5 MPIOM



Isolines: 1 cyclones/winter, colour > 5

CYCLONE TRACK DENSITY CHANGE
2019-2049 vs. 1969-1999

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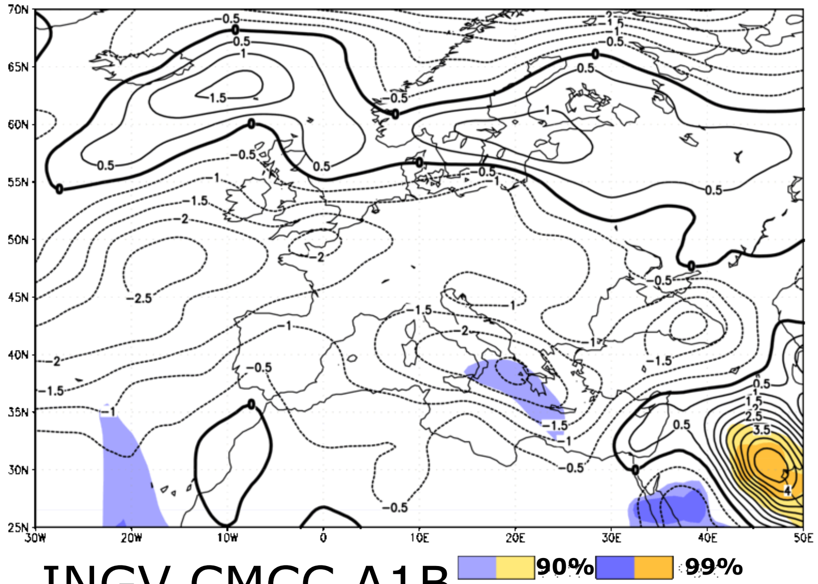
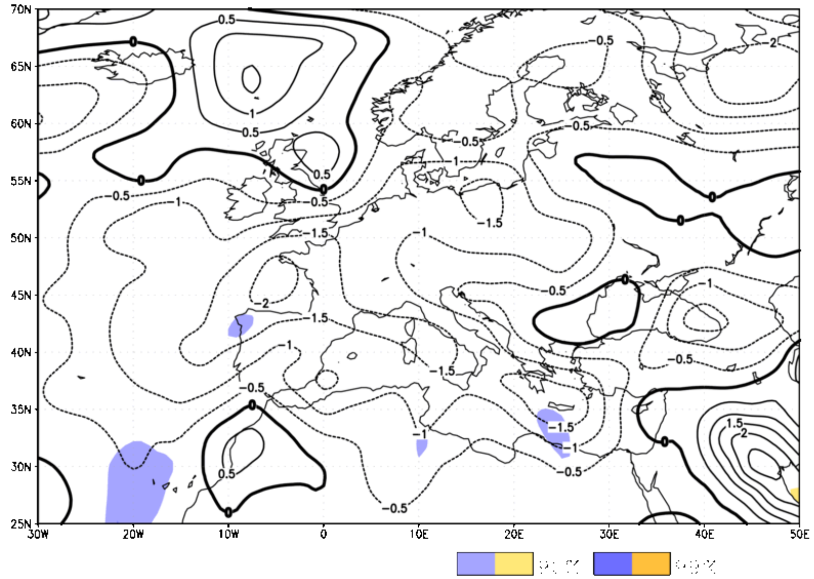
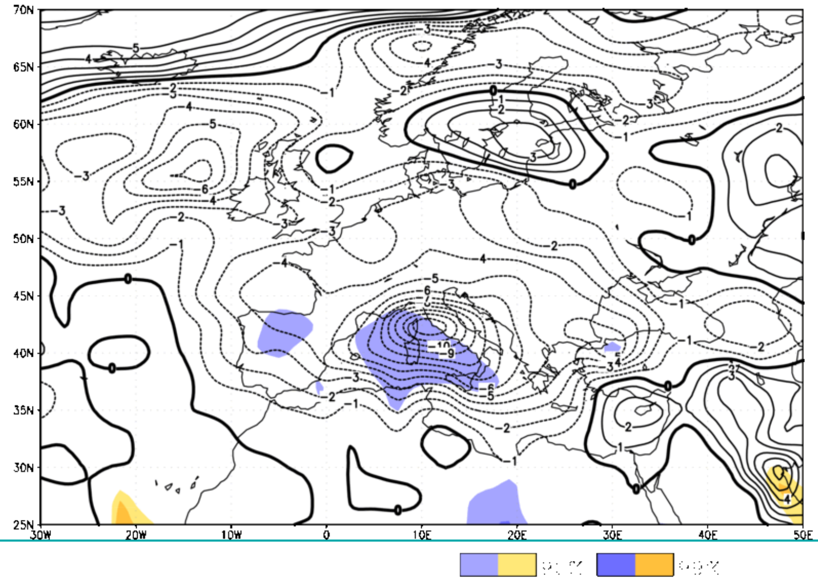
ECHAM5 A1B ENSEMBLE



ECHAM5 A2 ENSEMBLE



INGV CMCC A1B



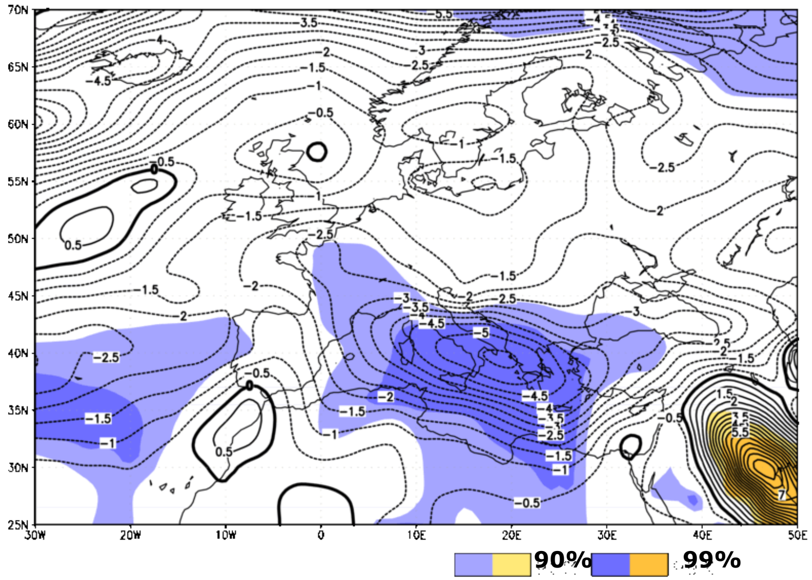
Differences in cyclone track density

Note INGV model just to 2049 !

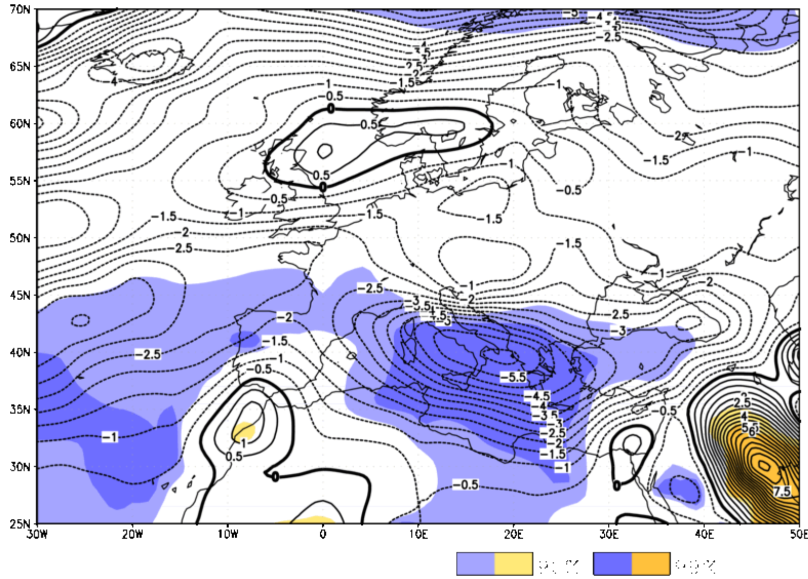
CYCLONE TRACK DENSITY CHANGE
2069-2099 vs. 1969-1999

Freie Universität Berlin

ECHAM5 A1B ENSEMBLE

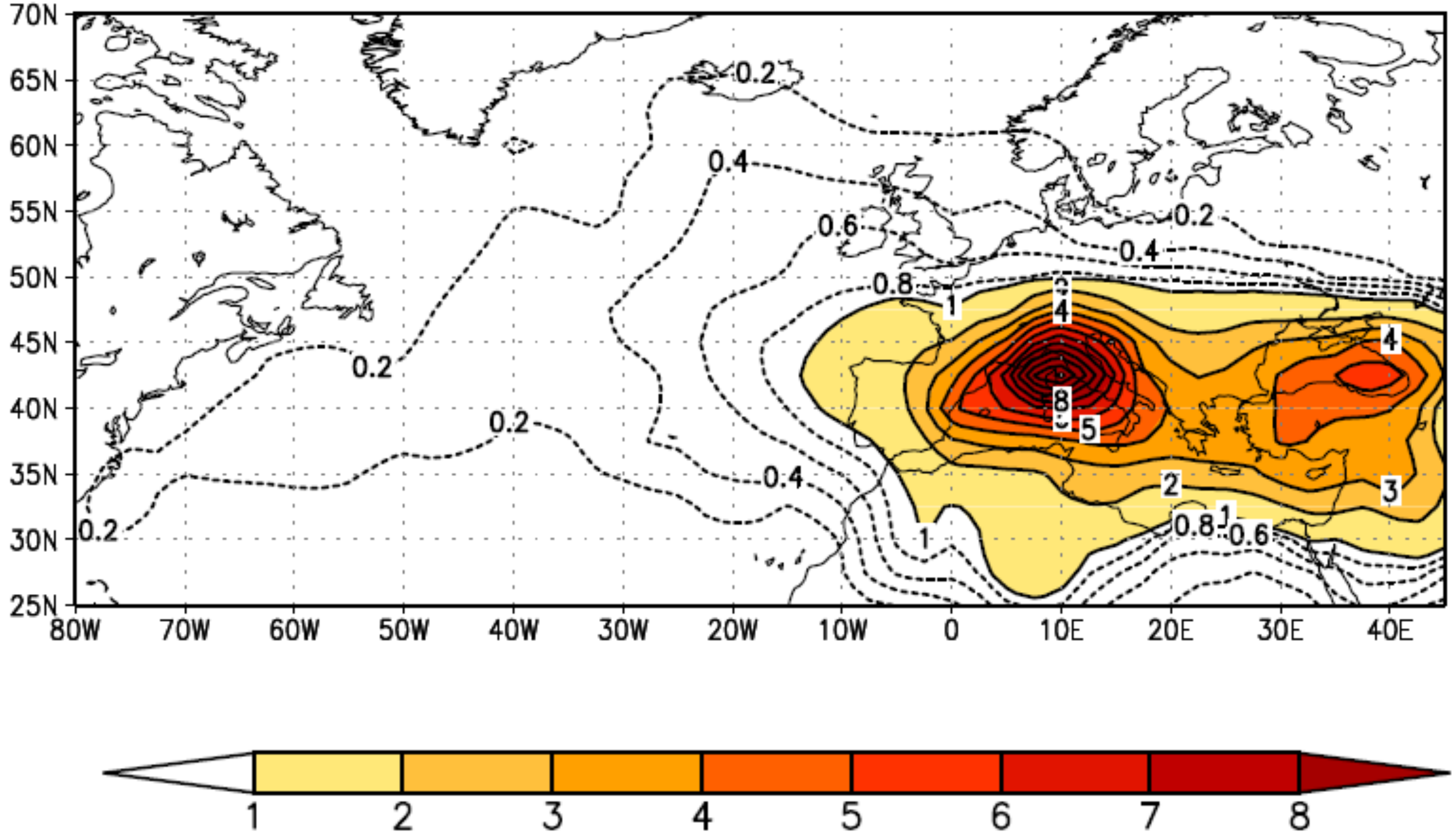


ECHAM5 A2 ENSEMBLE



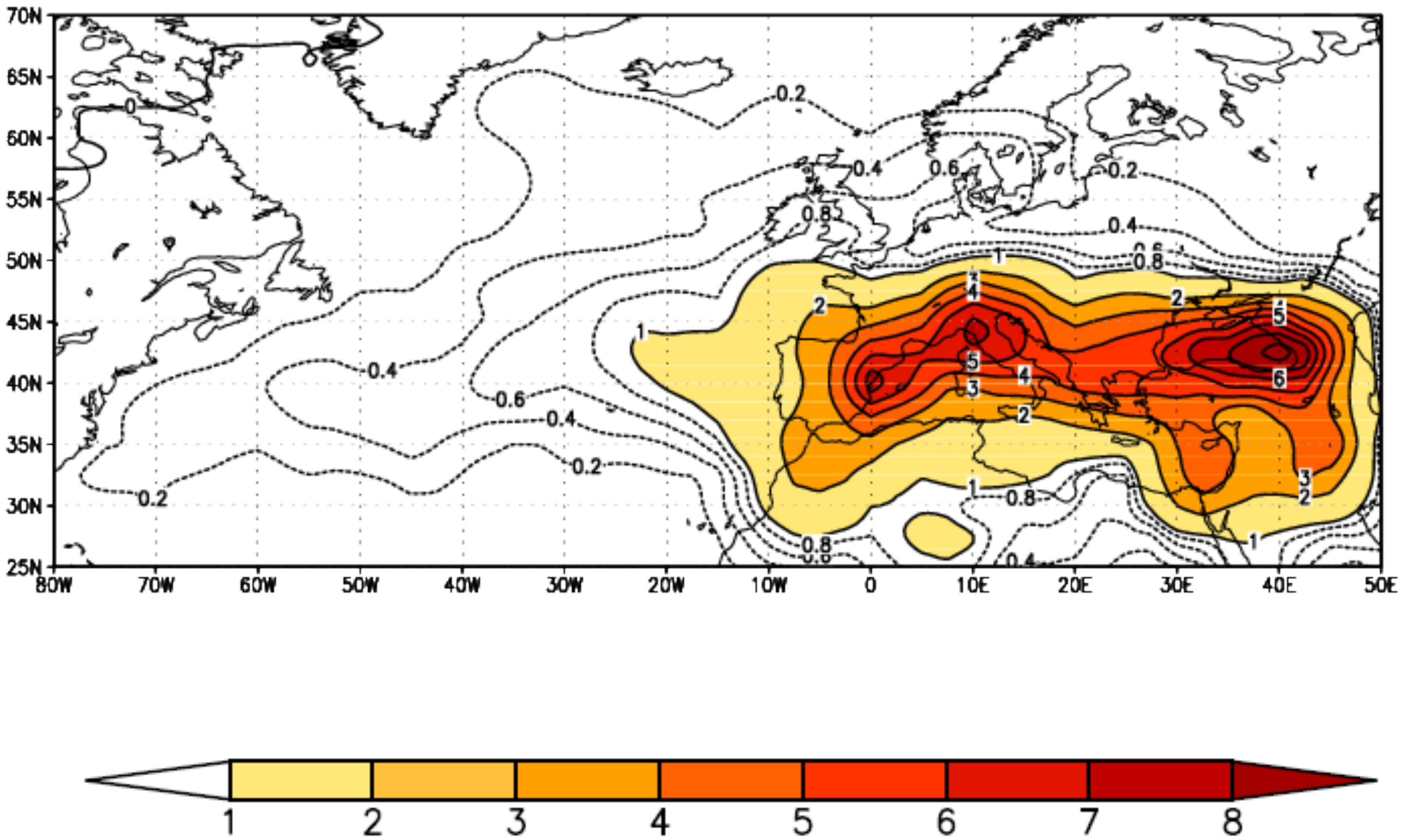
Differences in cyclone track density

Cyclogenesis ERA40



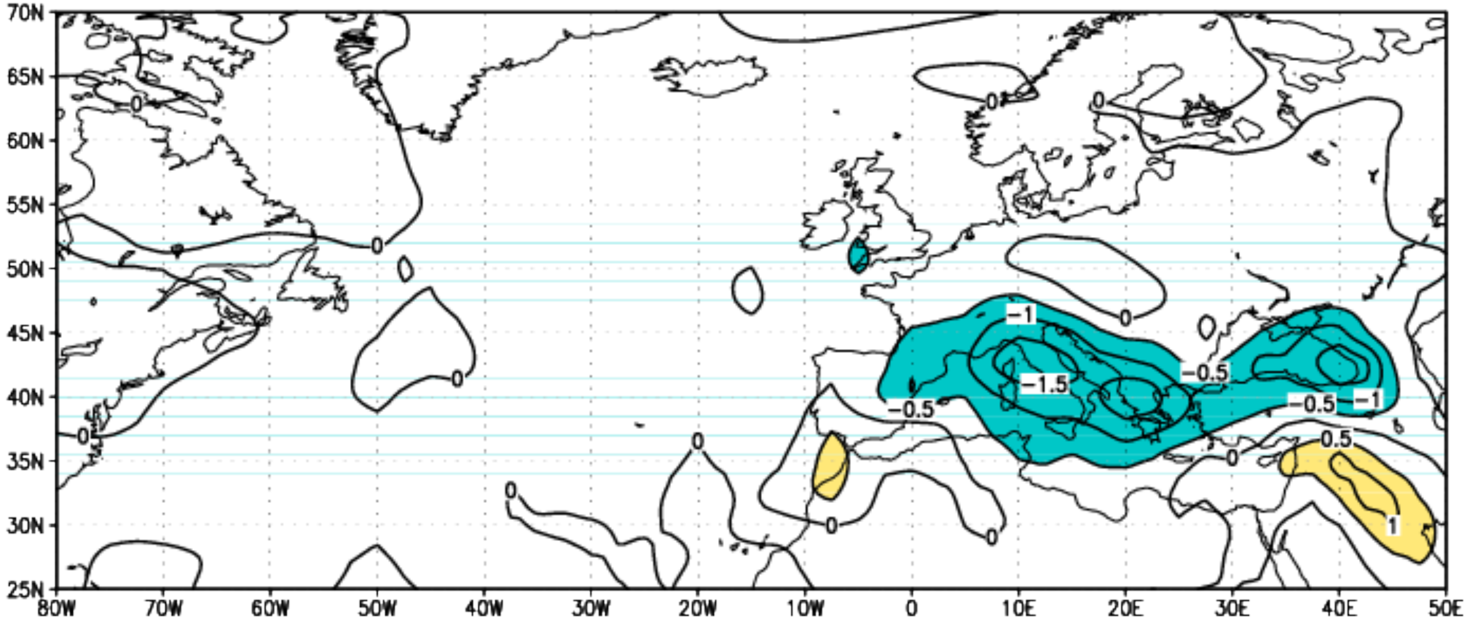
Region of cyclogenesis for cyclones crossing the Mediterranean region in events/winter/(deg.lat)^2

Cyclogenesis ECHAM5 20C_1



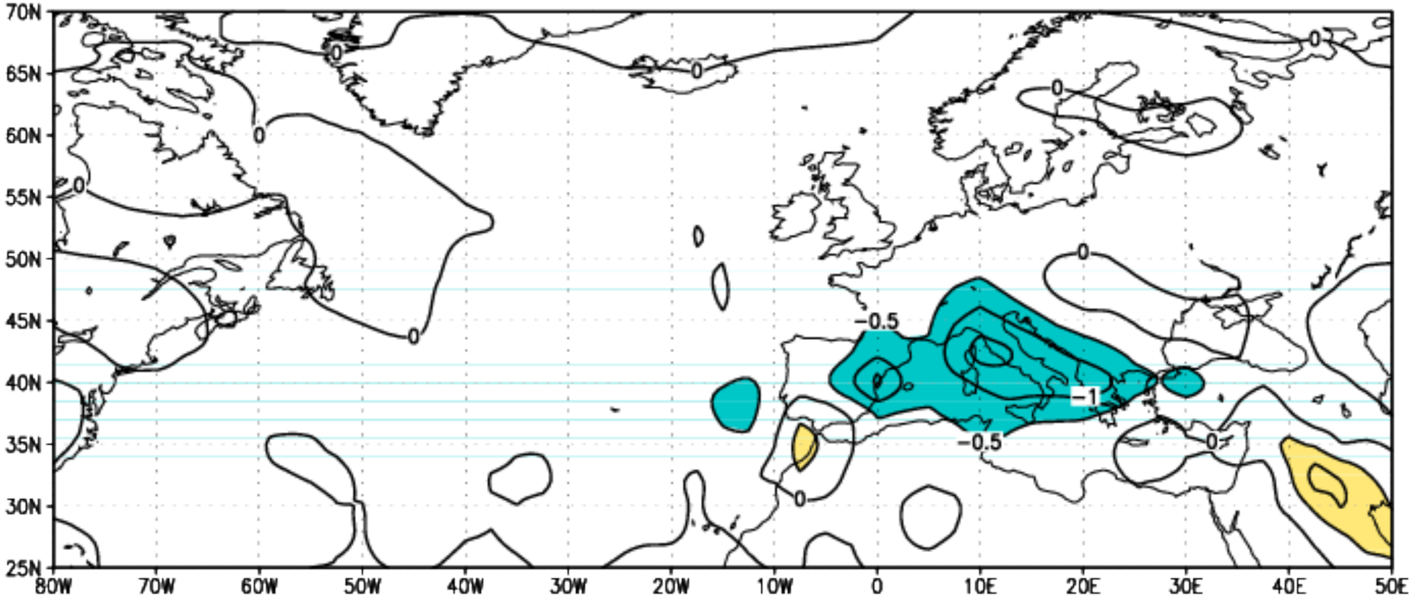
Region of cyclogenesis for cyclones crossing the Mediterranean region in events/winter/(deg.lat)^2

Cyclogenesis CLIMATE SIGNAL A1B



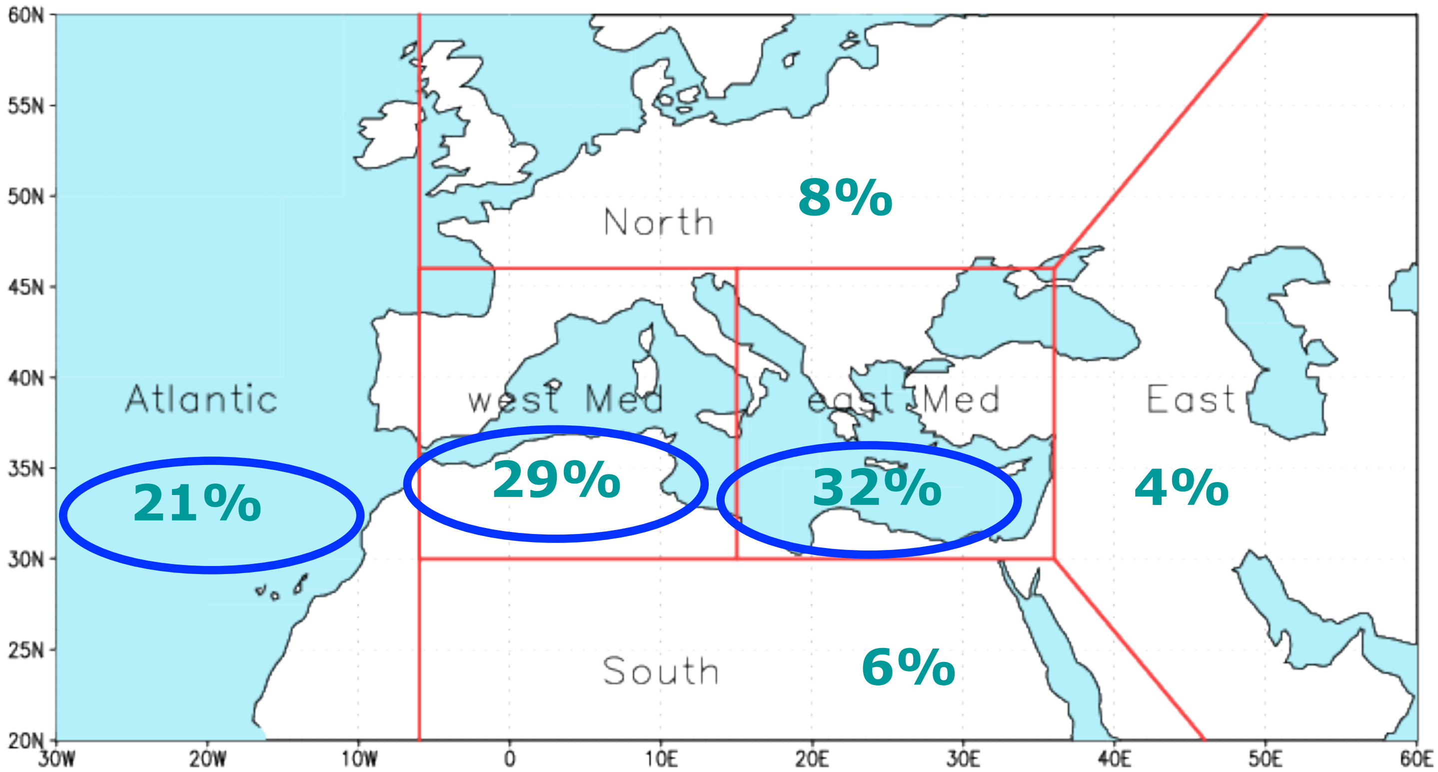
Difference A1B_1 (2060-2099) - 20C_1(1960-1999)
in events/winter/(deg.lat)^2

Cyclogenesis CLIMATE SIGNAL A2



Difference A2_1 (2060-2099) - 20C_1(1960-1999)
in events/winter/(deg.lat)^2

ECHAM5MPIOM 20C_1 1960-1999



Total crossing Mediterranean:3718

ECHAM5MPIOM A1B_1 2060-2099

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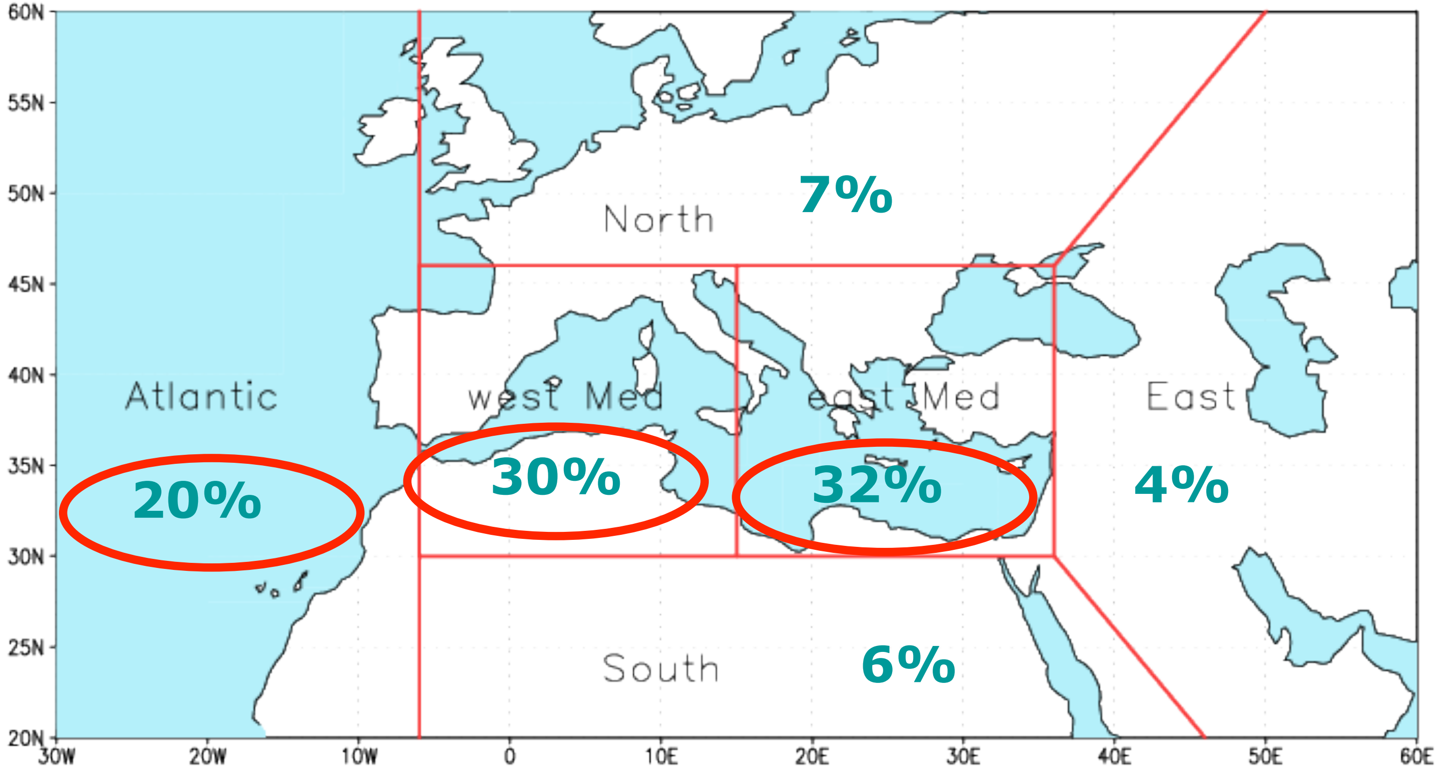

Total crossing Mediterranean:3069

Wind storm producing cyclones
ERA40 1960-1999

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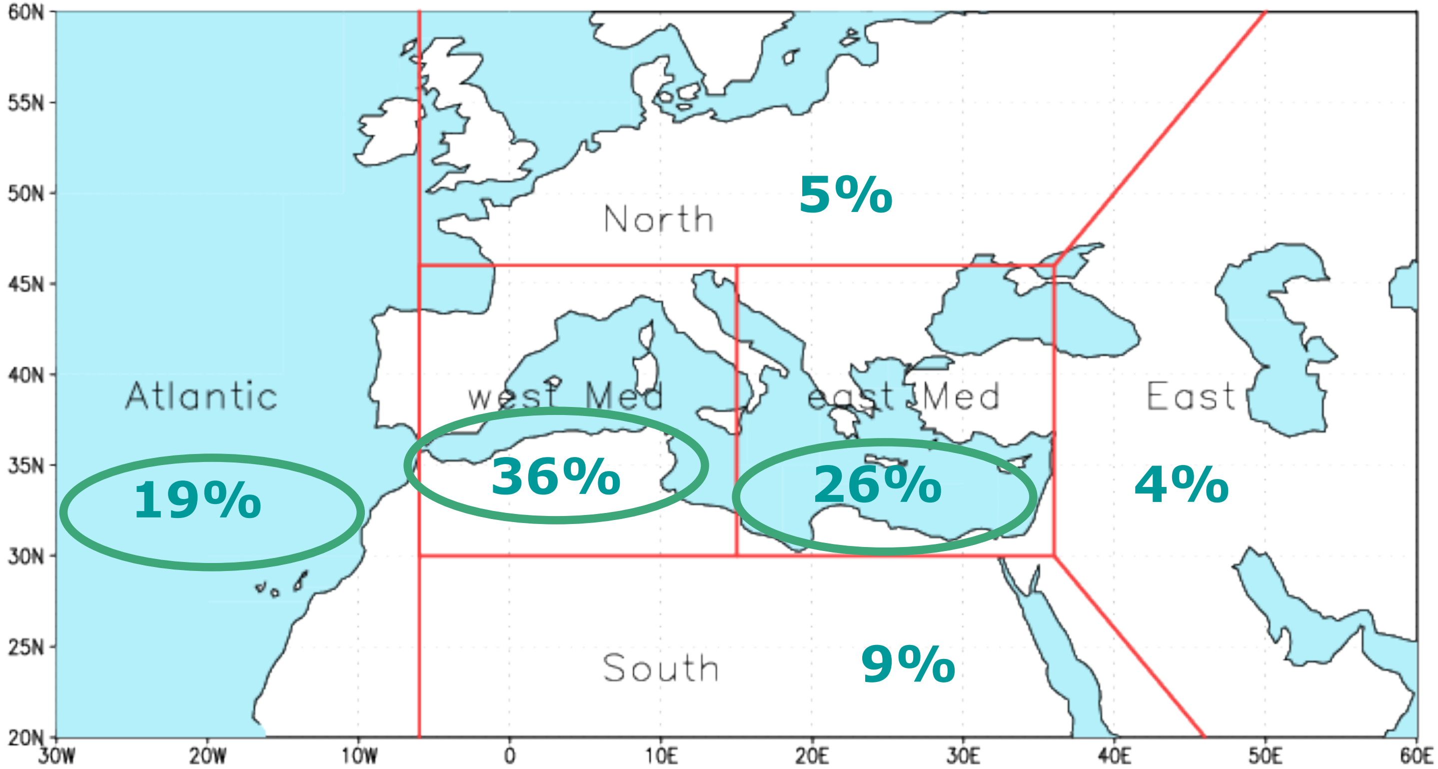
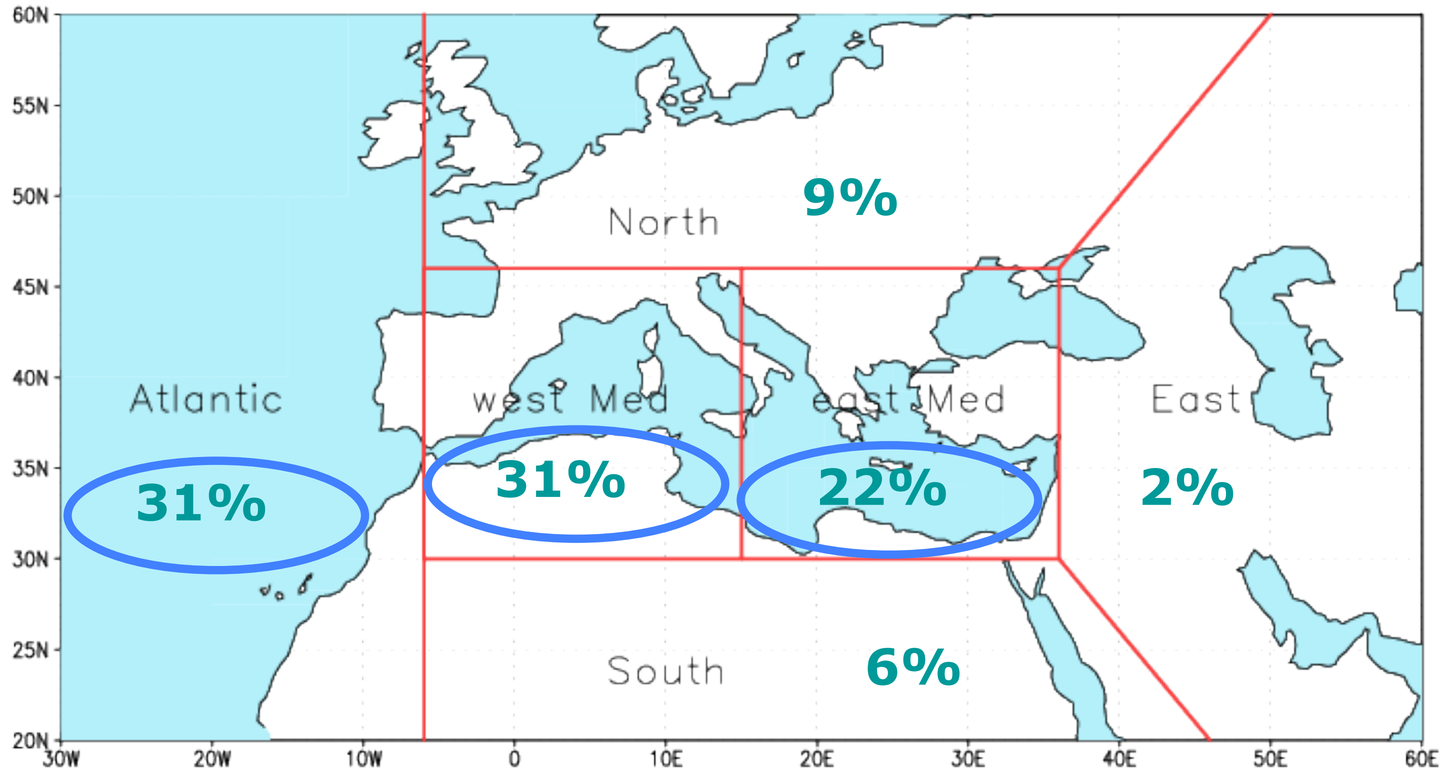


Total: 1162

Wind storm producing cyclones
ECHAM5MPIOM 20C_1 1960-1999

Freie Universität Berlin



Total: 804

Wind storm producing cyclones ECHAM5MPIOM A1B_1 2060-2099

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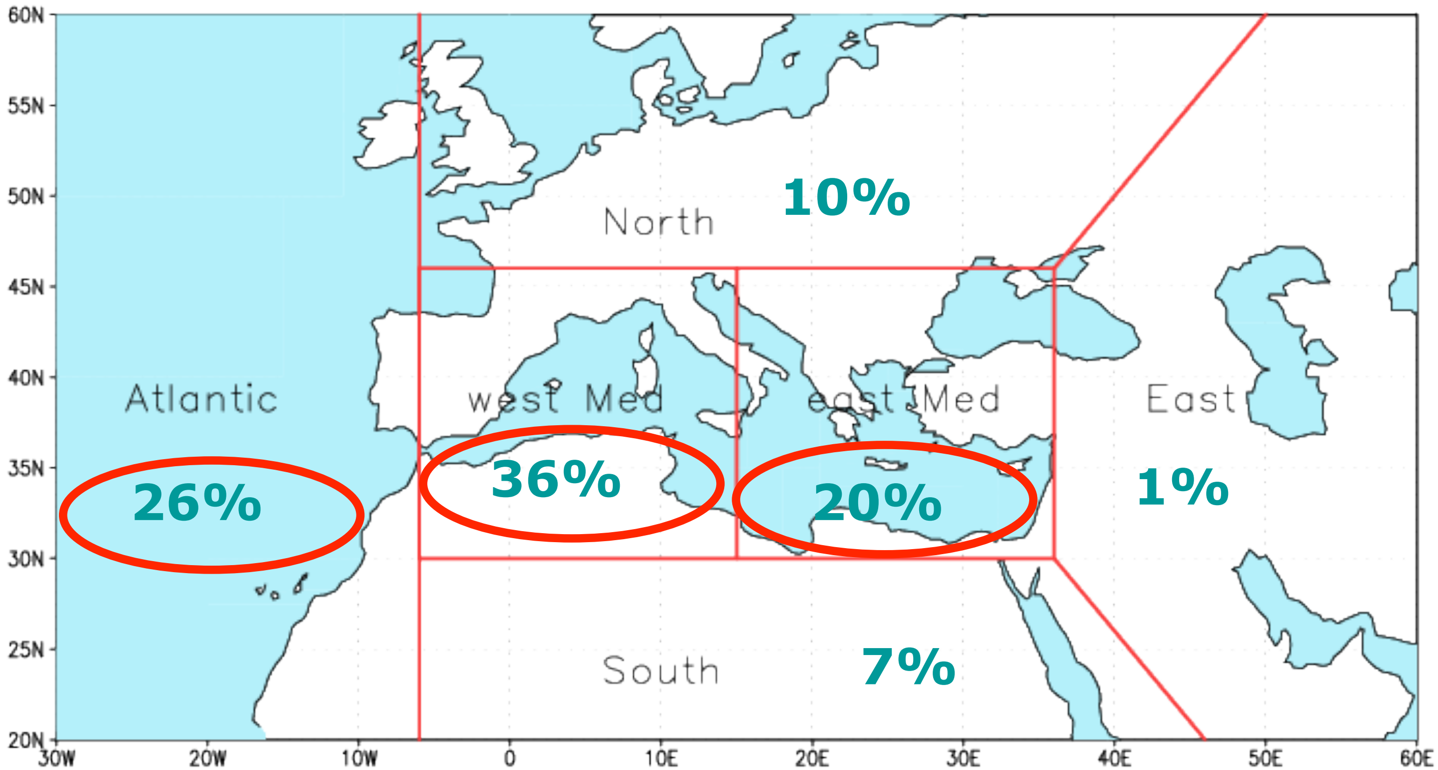


Total: 646

INTENSITY

So far only the frequency of events has been analysed.

How about intensity?

For all wind tracks affecting the Mediterranean region the Storm Severity Index is determined (Leckebusch et al 2008):

$$SSI_{T,K} = \sum_{t}^{T} \sum_{k}^{K} \left[\left(\max(0, \frac{v_{k,t} - v_{percentile}}{v_{percentile}} \right)^3 * A_{k,t} \right]$$

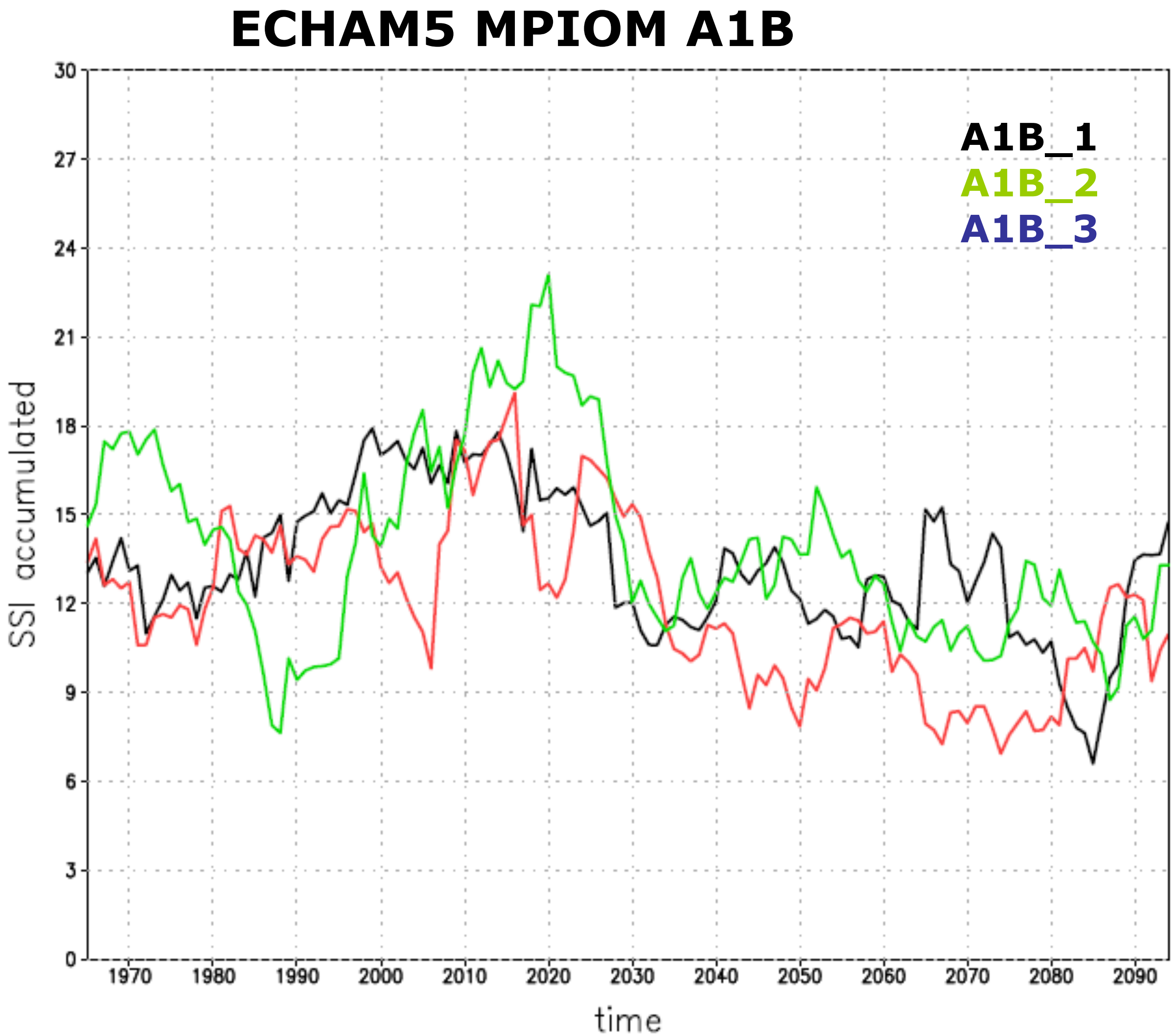
T: considered time range

K: considered grid boxes

A: area

Only grid boxes inside the Mediterranean region are considered.

SSI time series



1o-year running mean of SSI for Mediterranean region accumulated over the winter season

SSI time series

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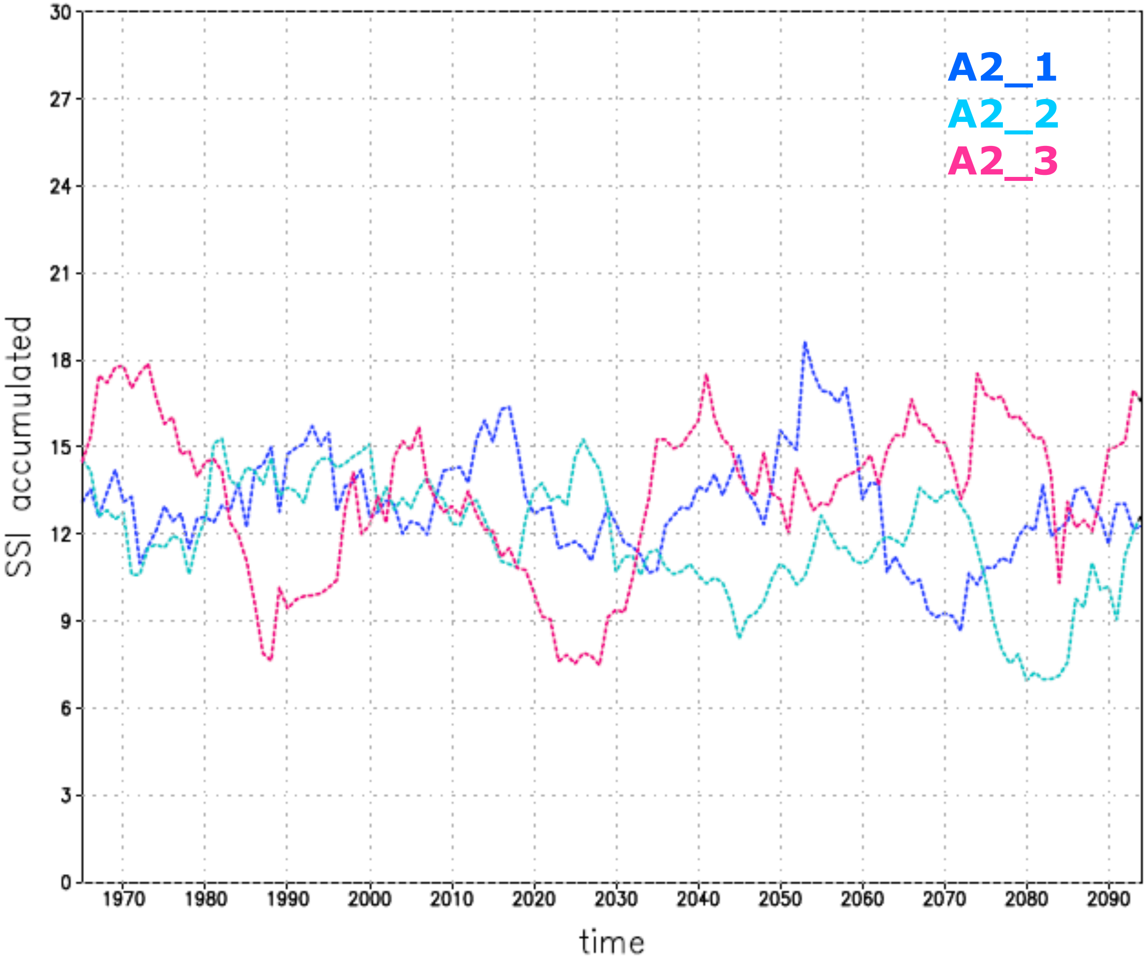
ECHAM5 MPIOM A2



1o-year running mean of SSI for Mediterranean region accumulated over the winter season

SSI Return periods

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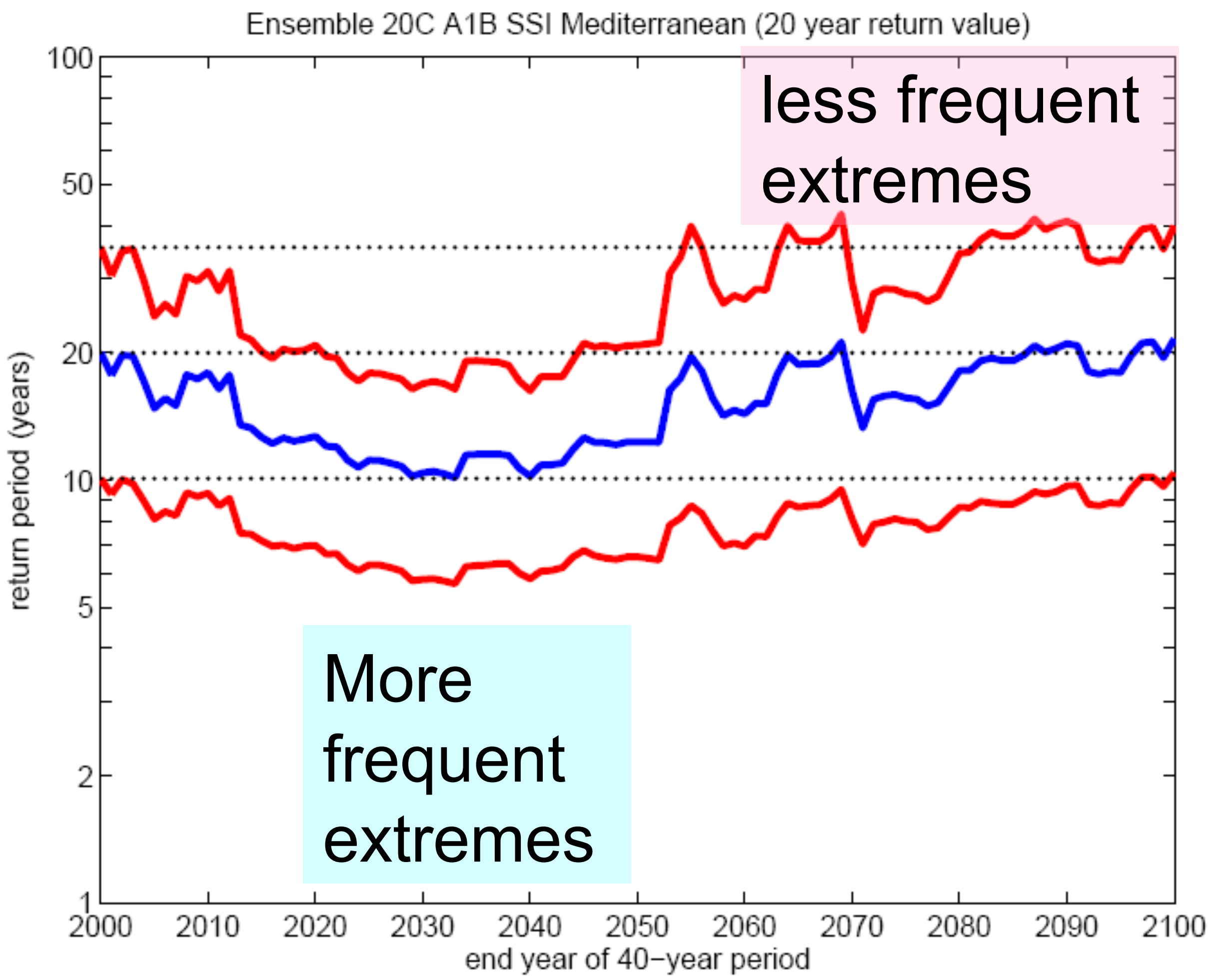
ECHAM5 MPIOM
Ensemble 20C-A1B



Evolution return period of 20-year present-day-climate return value, determined using 40-year running mean

SSI Return periods

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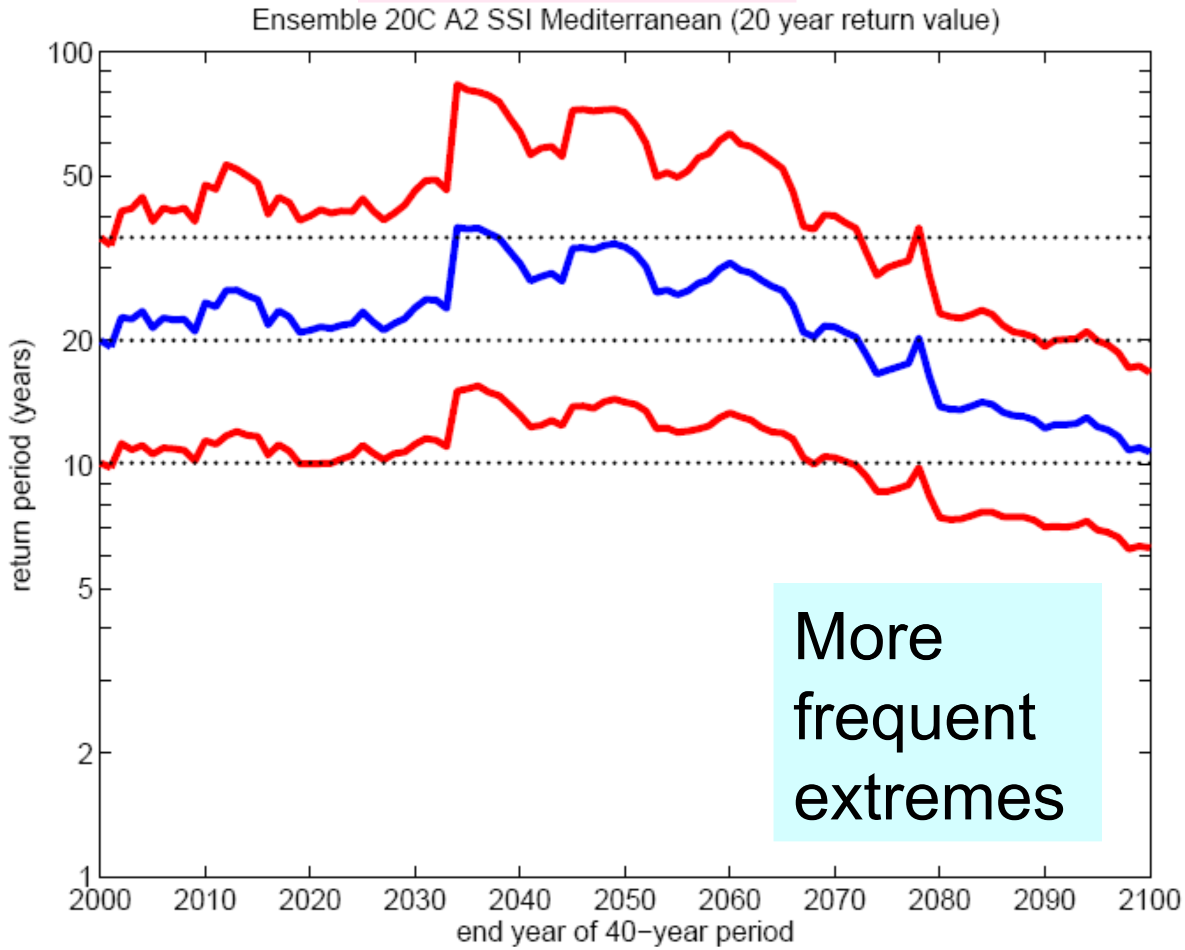
ECHAM5 MPIOM
Ensemble 20C-A2

less frequent extremes



Evolution return period of 20-year present-day-climate return value, determined using 40-year running mean

Conclusions

- Automatic cyclone detection studies can help producing observational climatologies:
- Some **30% of Med. winter cyclones have an origin outside of Med. region**
- Models considered are approx. realistic, producing a few more cyclones travelling from the Atlantic
- Climate signals show overall **decrease of cyclones and wind storms**
- **Extreme wind storms seem to vary considerably** on a decadal time scale:

  statistical noise or specific reasons?

Savona, 1992

Thank you for your attention!