MEDICANES AND CLIMATE CHANGE: Analysis with two different methods

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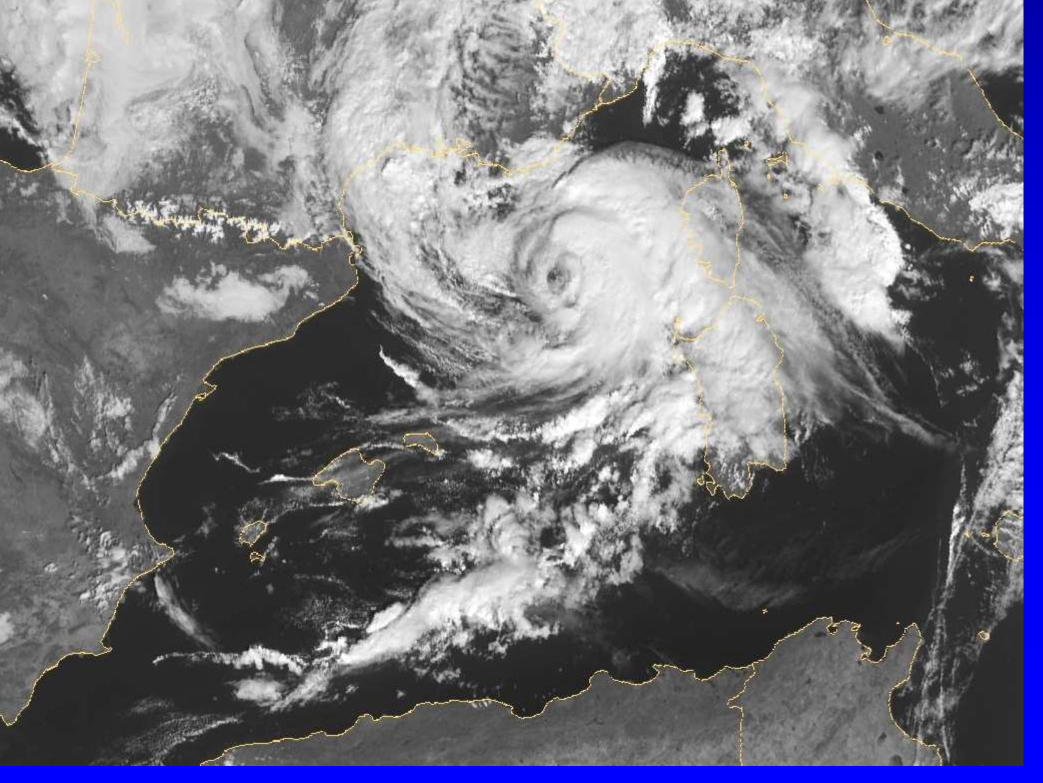
MOTIVATION

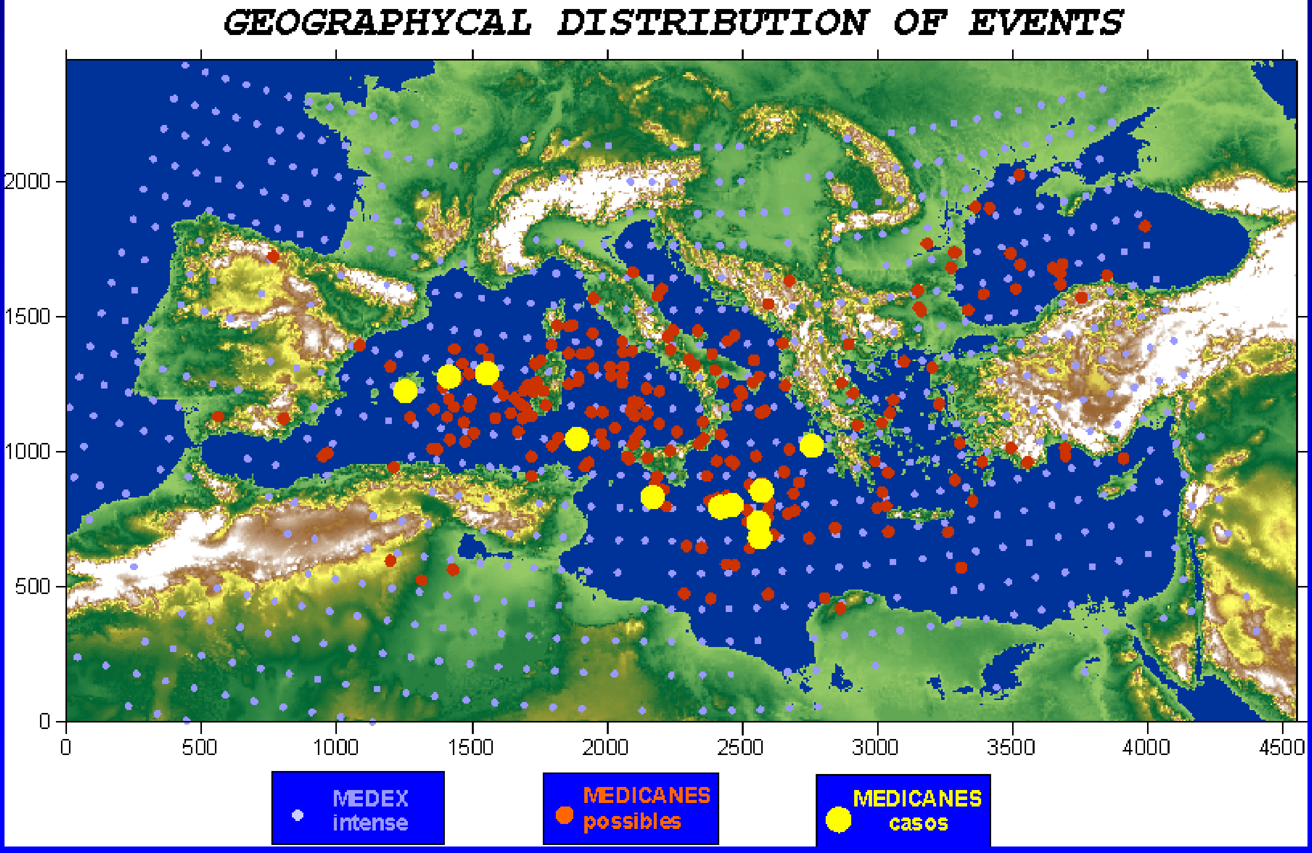
***Medicanes** are warm-core, surface flux-driven **extreme windstorms** potentially threatening the islands and coastal areas:*

- ***Are there favoured locations for medicane development ?***
- ***How intense can they become ?***
- ***How could they react in frequency and intensity to global warming ?***



MEDICANE RISK ???

With an average frequency of only 1-2 events per year and given the lack of systematic, multidecadal databases, an objective evaluation of the long-term risk of medicane-induced winds is impractical with standard methods



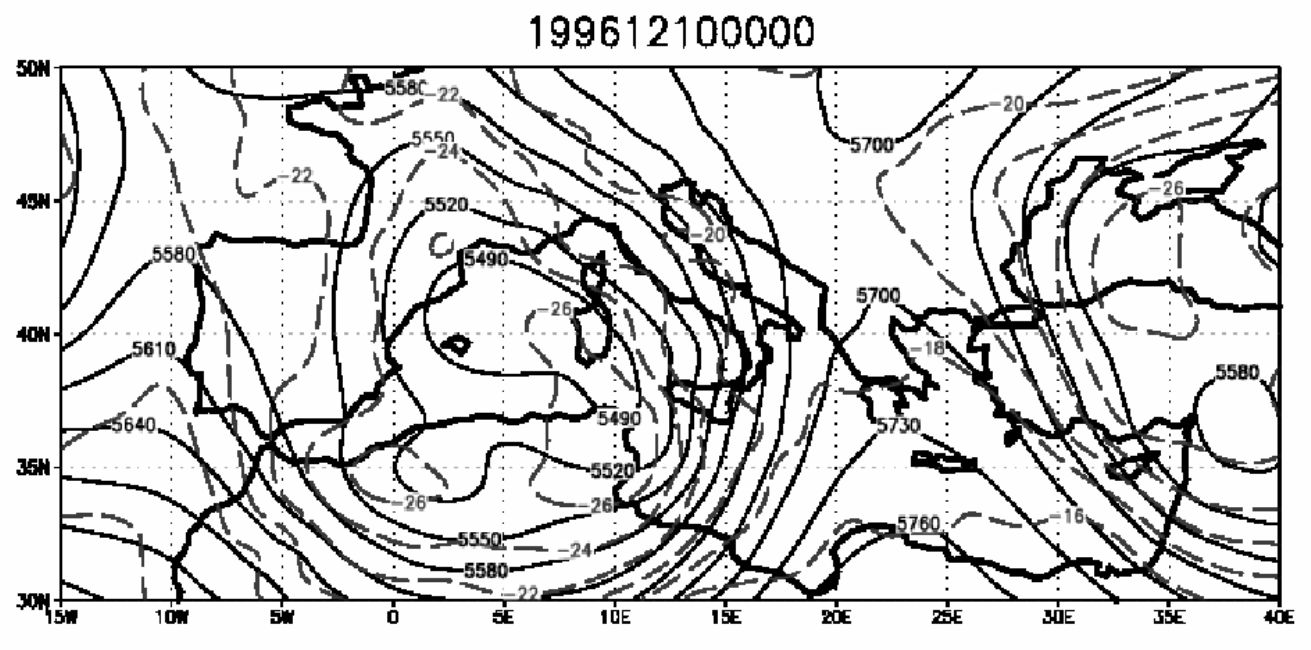
Database from satellite

(Tous and Romero, 2012)

APPROACH: Large-scale environmental proxies

***Synoptic** analyses of a few studied cases show that an inevitable precursor is the presence of a deep, **cut-off, cold-core** low in the upper and middle troposphere:*

- ***But** the infrequent occurrence of medicanes suggests that **additional and very special meteorological conditions** are necessary for these storms to occur …*



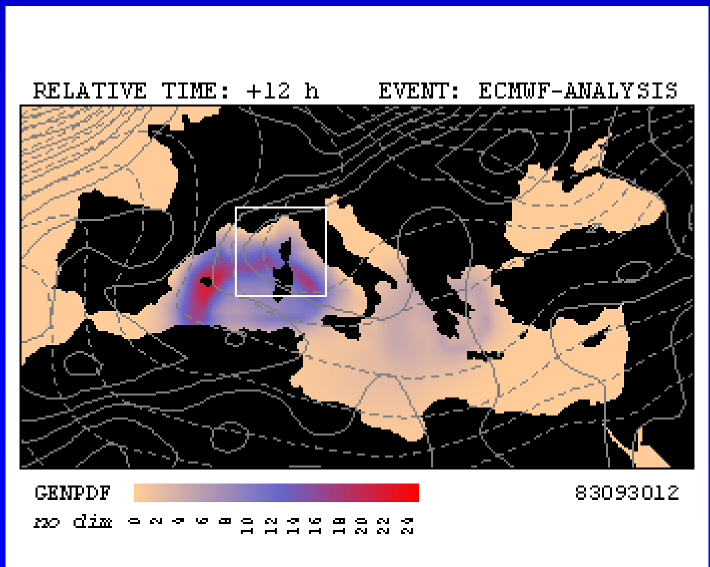
APPROACH: Large-scale environmental proxies

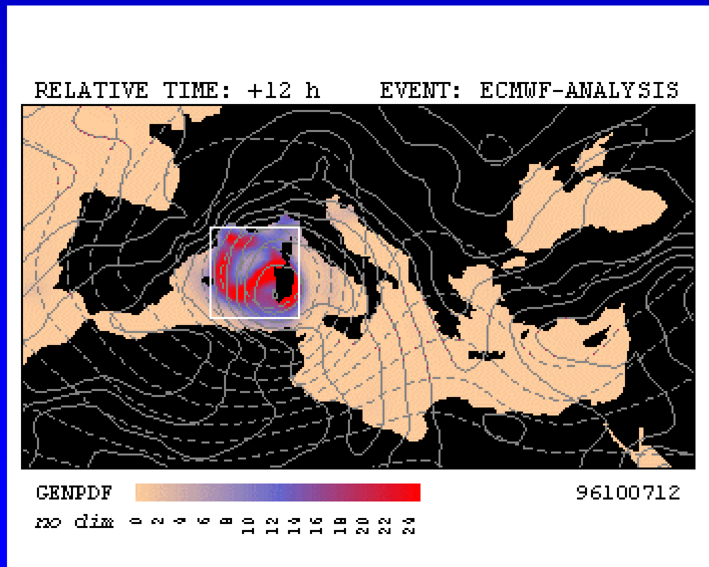
Application of an empirical index of genesis:

$$I = \left|10^5 \eta\right|^{3/2} \left(\frac{H}{50}\right)^3 \left(\frac{V_{pot}}{70}\right)^3 \left(1 + 0.1 V_{shear}\right)^{-2},$$

GENIX parameter
(Emanuel and Nolan, 2004)

- ***But these environmental proxies behave as necessary but no sufficient ingredients for the successful genesis of a medicane …***

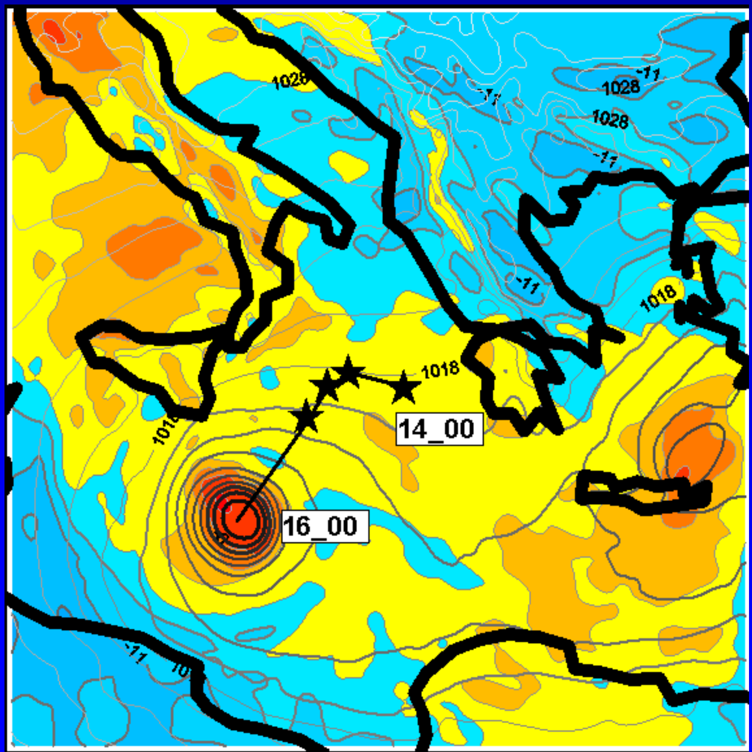


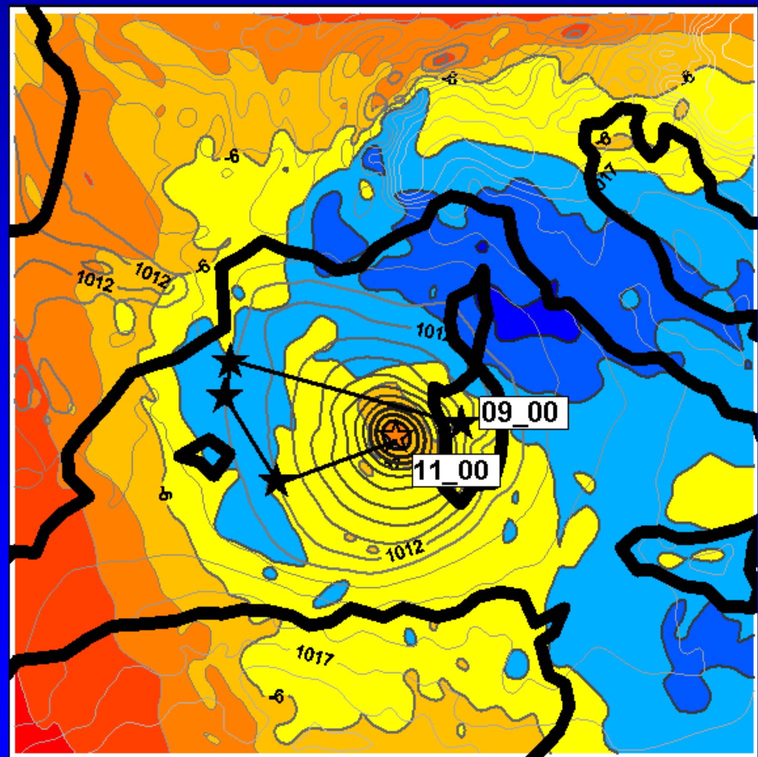


FIRST METHOD: Nested climatic simulations

***Detection and tracking** of symmetric warm-core cyclonic disturbances generated **in mesoscale simulations** forced by Reanalysis and GCM data:*

- ***But high computational cost**: Limited horizontal resolution; Too few climatic realizations to permit a full sampling of the PDF of storms …*





SECOND METHOD: Statistical-deterministic approach

Developed by Kerry Emanuel and his team in the context of the long-term wind risk associated with tropical cyclones:

- ***Low-cost generation of thousands of synthetic storms***
- ***Statistically robust assessment of risk (e.g. return periods for winds)***

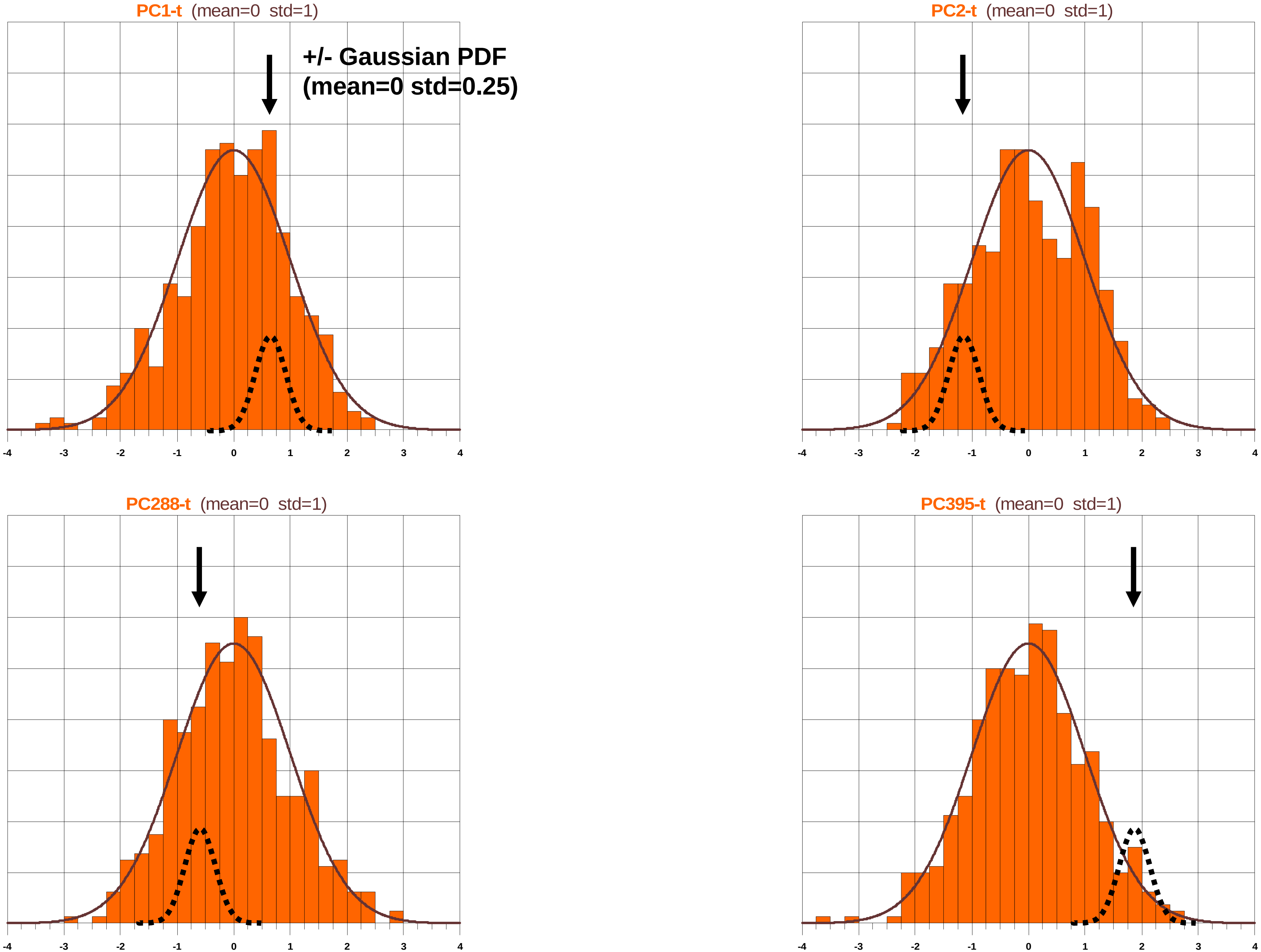
- ***Genesis: Random draws from observed PDF or Random seeding***
- ***Track: Randomly varying synthetic winds (respecting climatology)***
- ***Environment: Previous winds + monthly-mean thermodynamic fields***
- ***Intensity and radial distribution of winds: CHIPS model***

ADAPTATION OF THE SECOND METHOD

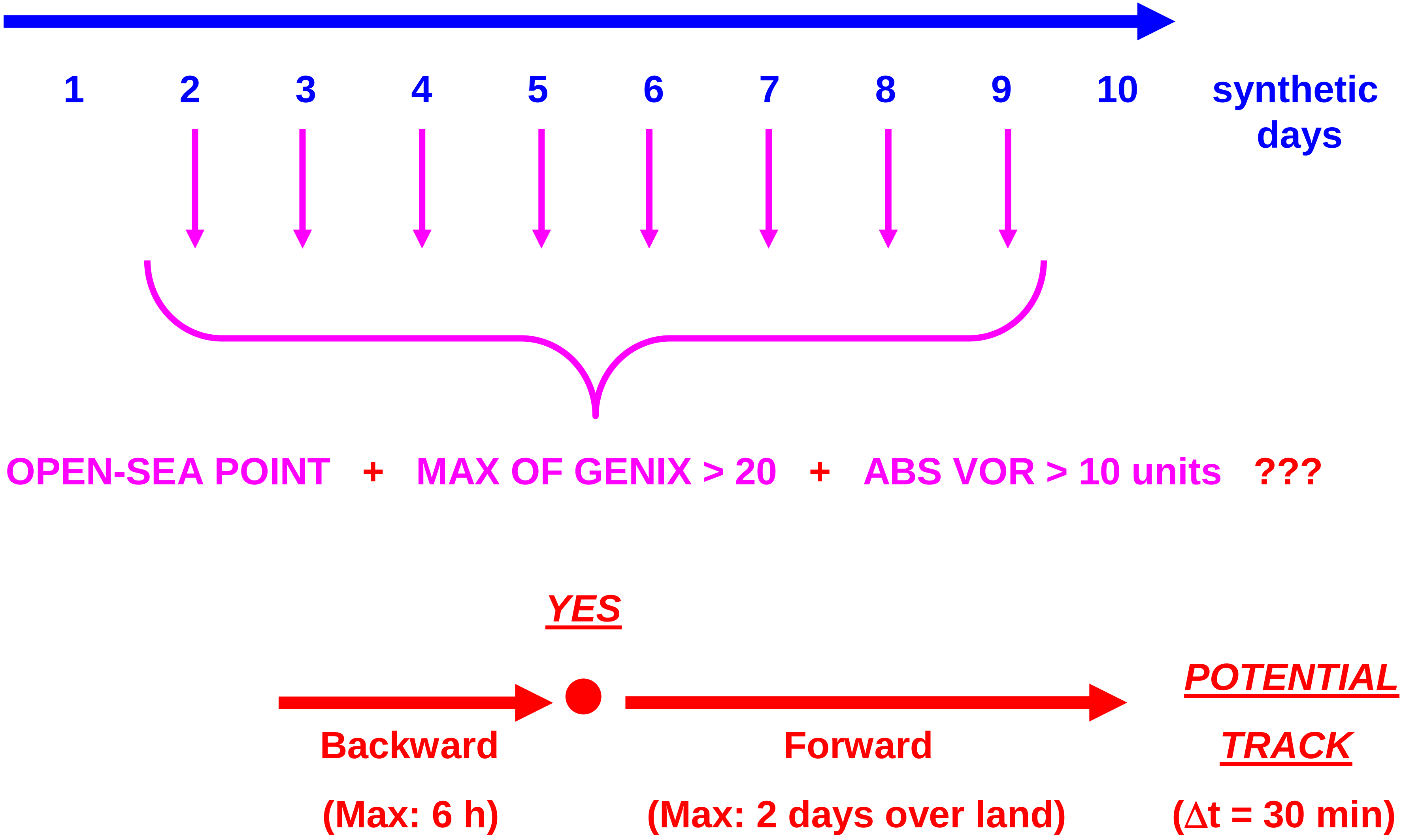
The separation of timescales made in the tropics between the synthetic wind field (fast scale) and the thermodynamic environment (slow scale) is not appropriate to represent the movement, growth and decay of mid-latitude weather systems. In addition, the history of medicane genesis is far too sparse to form a reasonable PDF of genesis, and random seeding would be very inefficient:

- ***For each month, decomposition through PCA of 10-day synoptic evolutions of z250, z850, T600, R600 and PINT into the new space of independent PCs***
- ***Random selection + random perturbation of the set of PCs***
- ***This perturbed set of PCs is converted back into physical space***
- ***This is tantamount to generating 10-day sequences of spatiotemporal coherent z250, z850, T600, R600 and PINT synthetic fields which also respect their mutual covariances***

- ***Potential Genesis: Based on the GENIX parameter***



PC1-t (mean=0 std=1)
+/- Gaussian PDF
(mean=0 std=0.25)
PC2-t (mean=0 std=1)
PC288-t (mean=0 std=1)
PC395-t (mean=0 std=1)
-4 -3 -2 -1 0 1 2 3 4



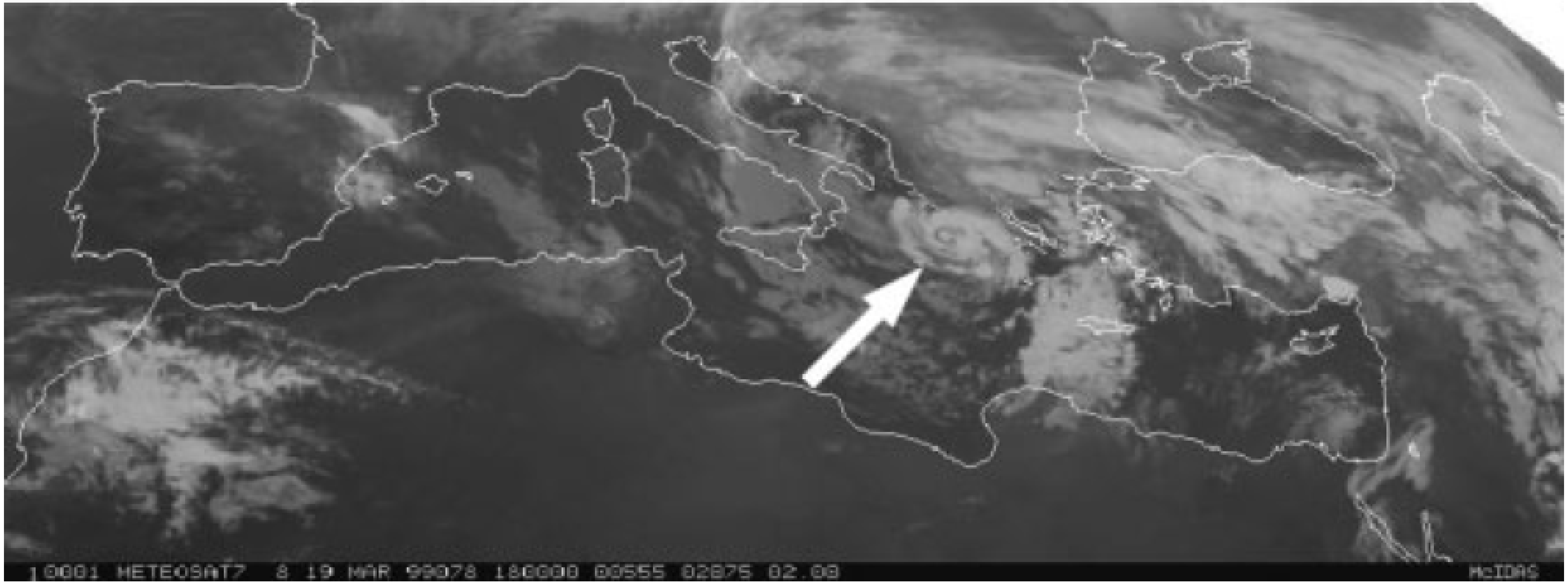
$$\begin{cases} u_{track} = \alpha\, u_{850} + (1 - \alpha)\, u_{250} \\ v_{track} = \alpha\, v_{850} + (1 - \alpha)\, v_{250} + v_{\beta} \end{cases}$$

$\alpha = 0.8 \quad v_{\beta} = 2.5$ m/s

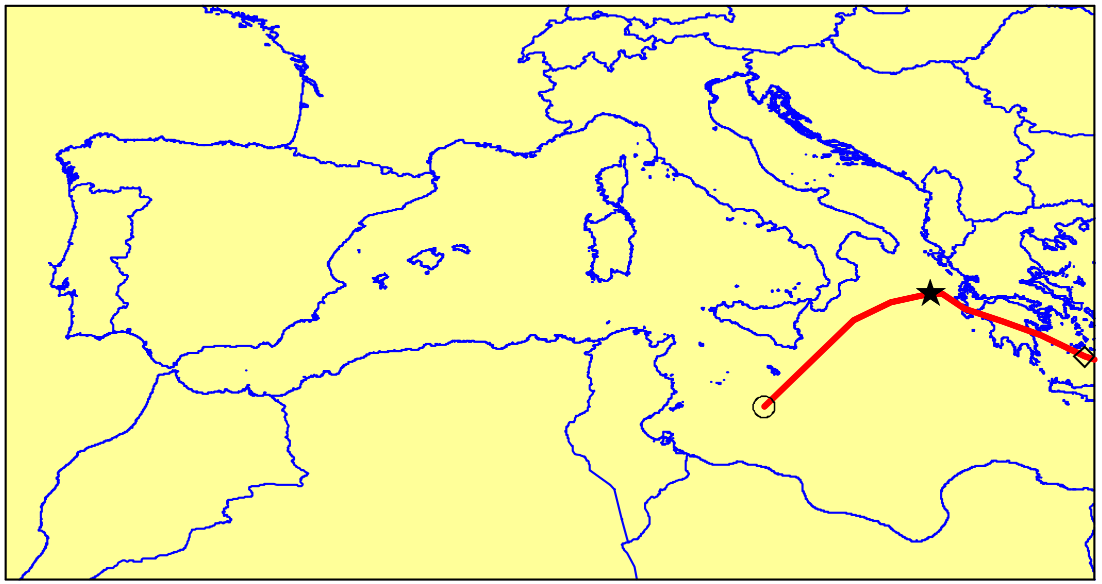
EXEMPLE FOR A

REAL EVENT

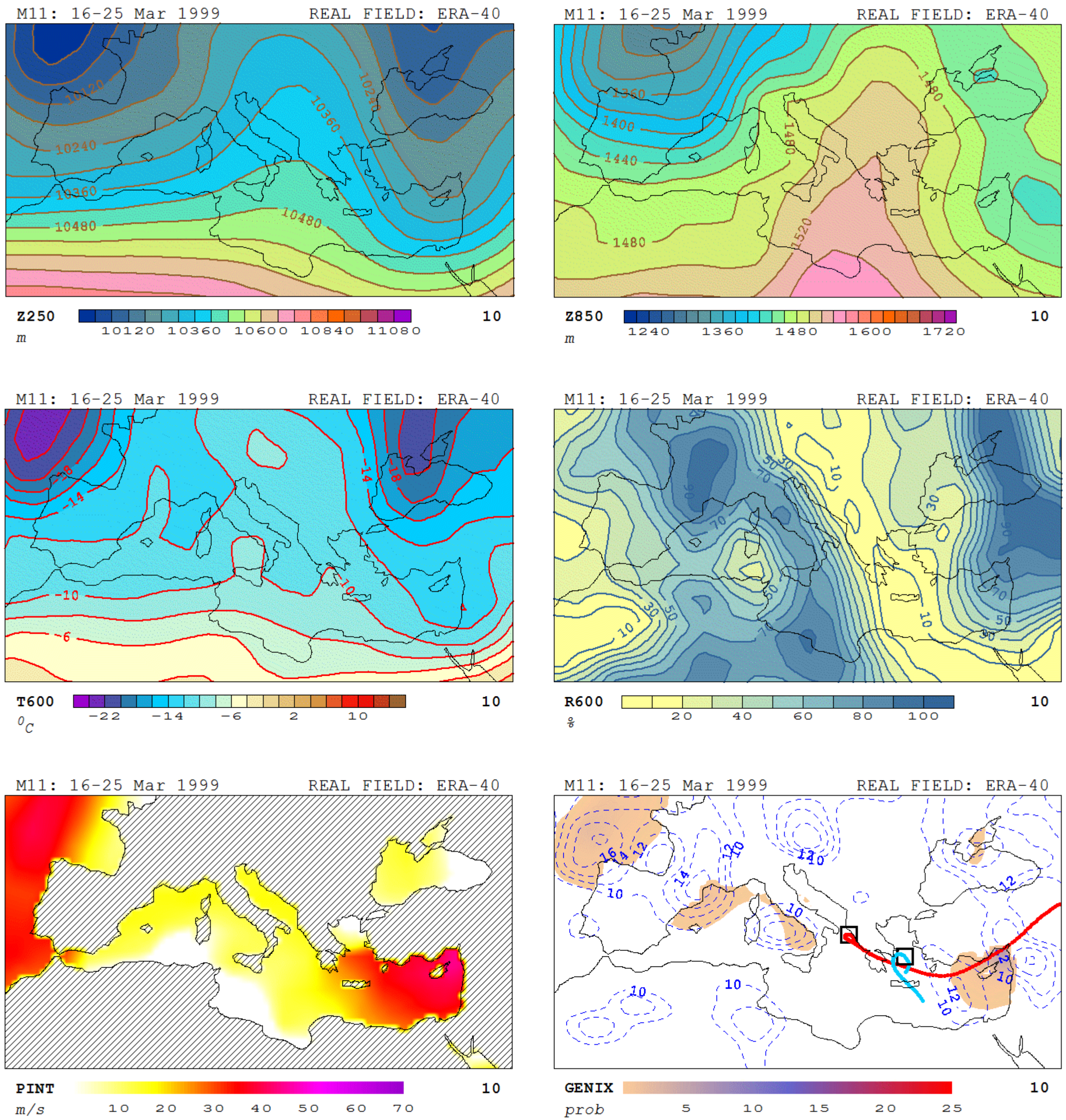
(d) 19-March-1999, 18 UTC



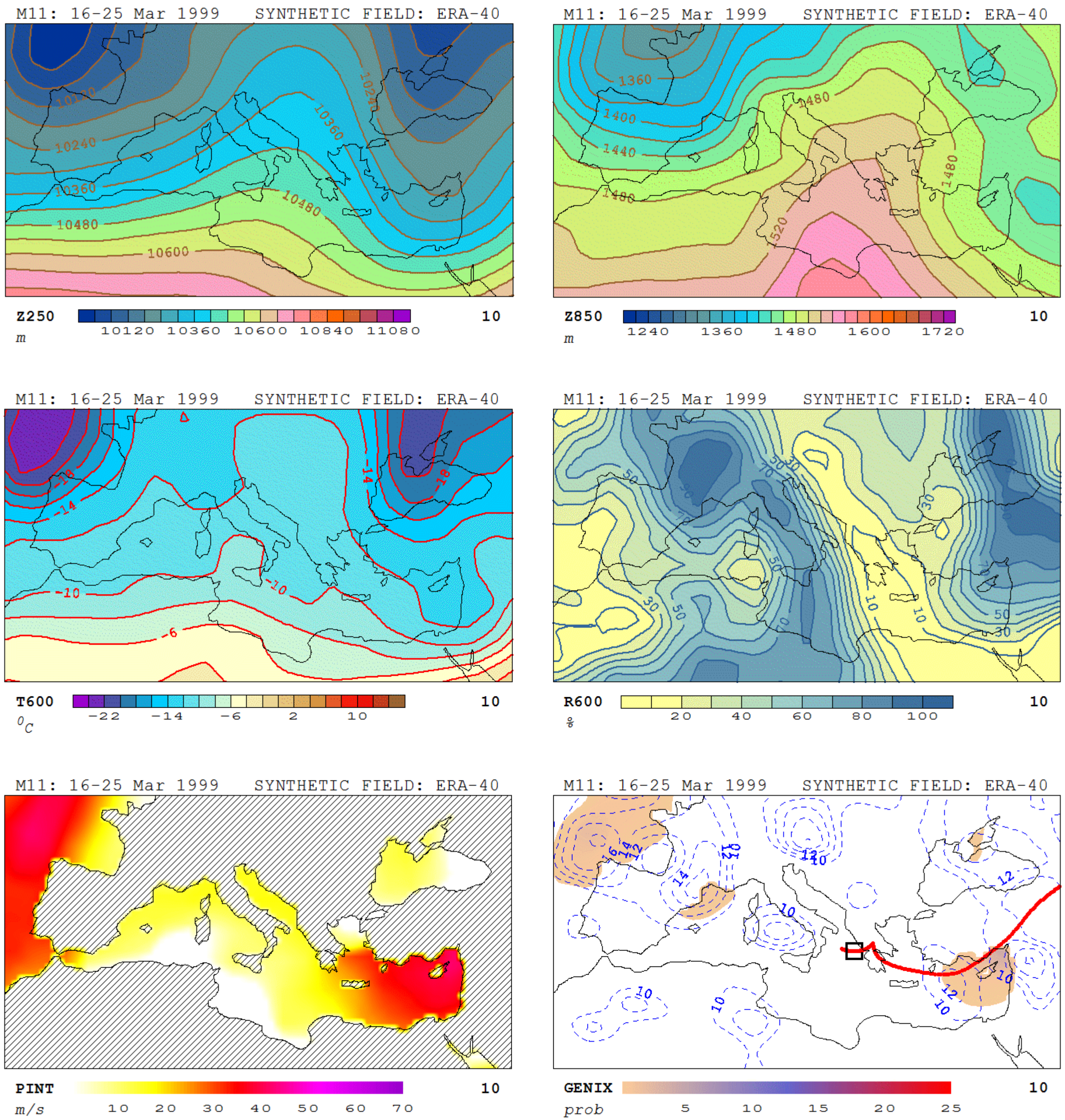
M11



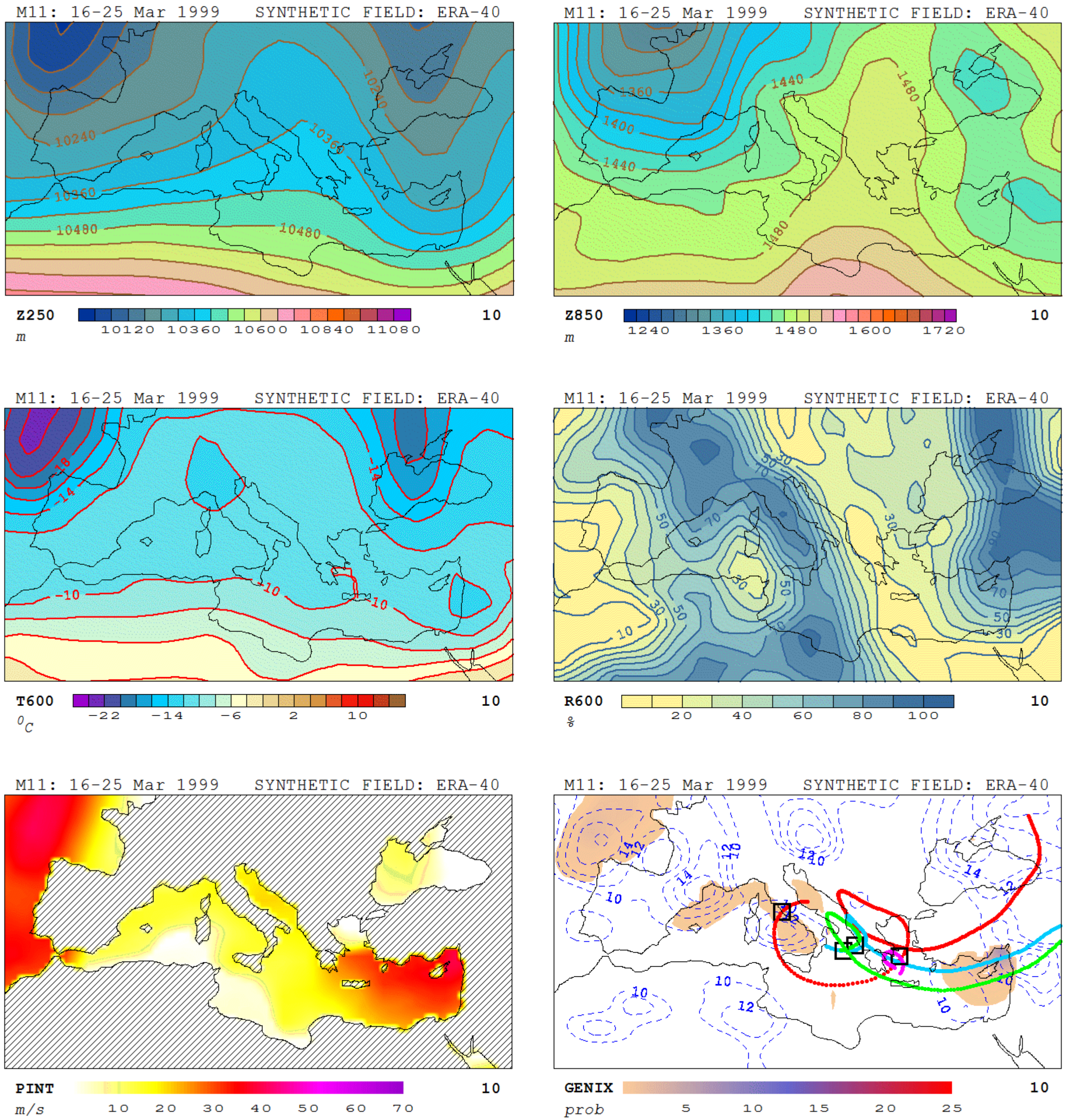
ERA-40
2 tracks



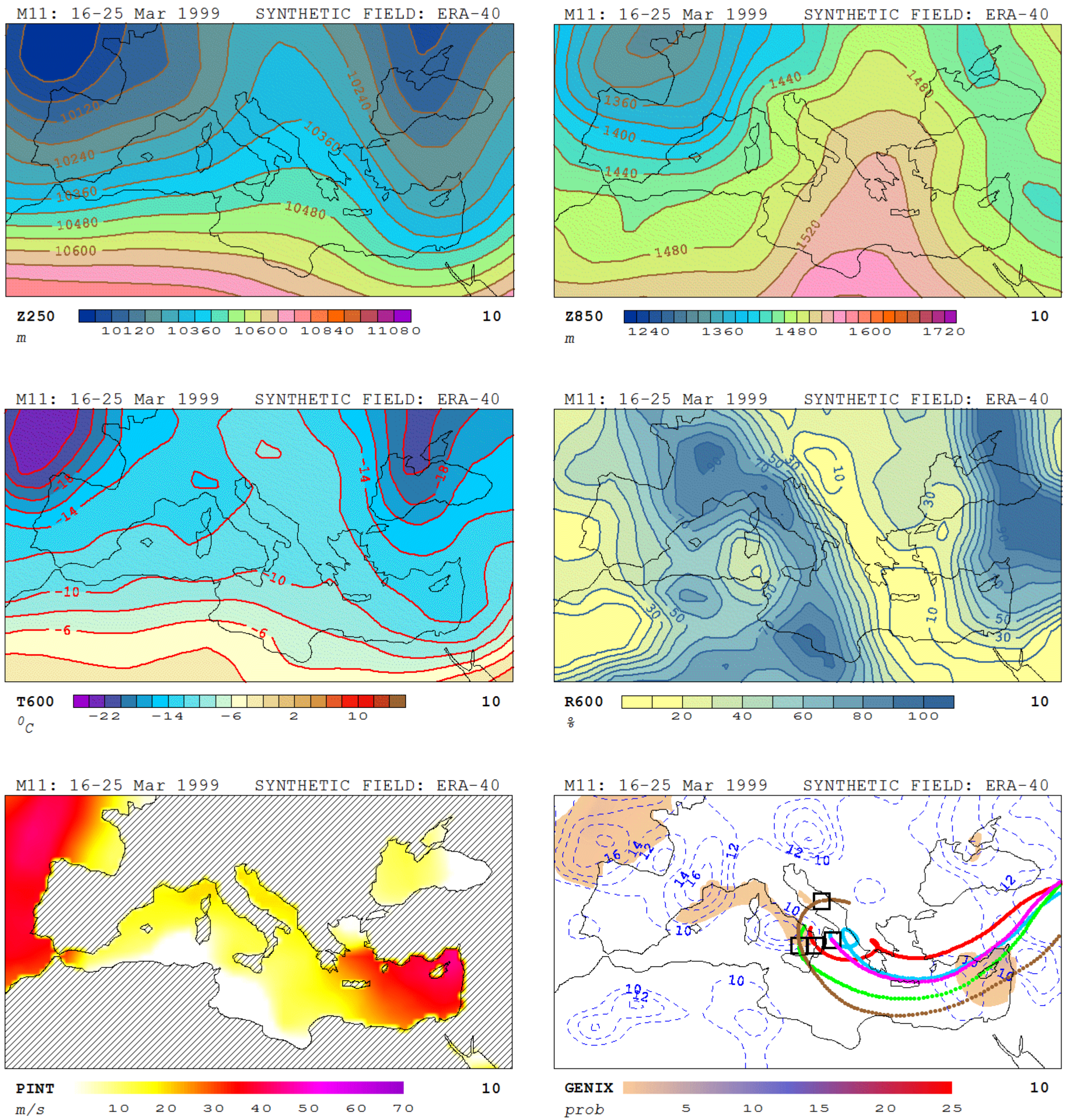
RND 1
1 tracks



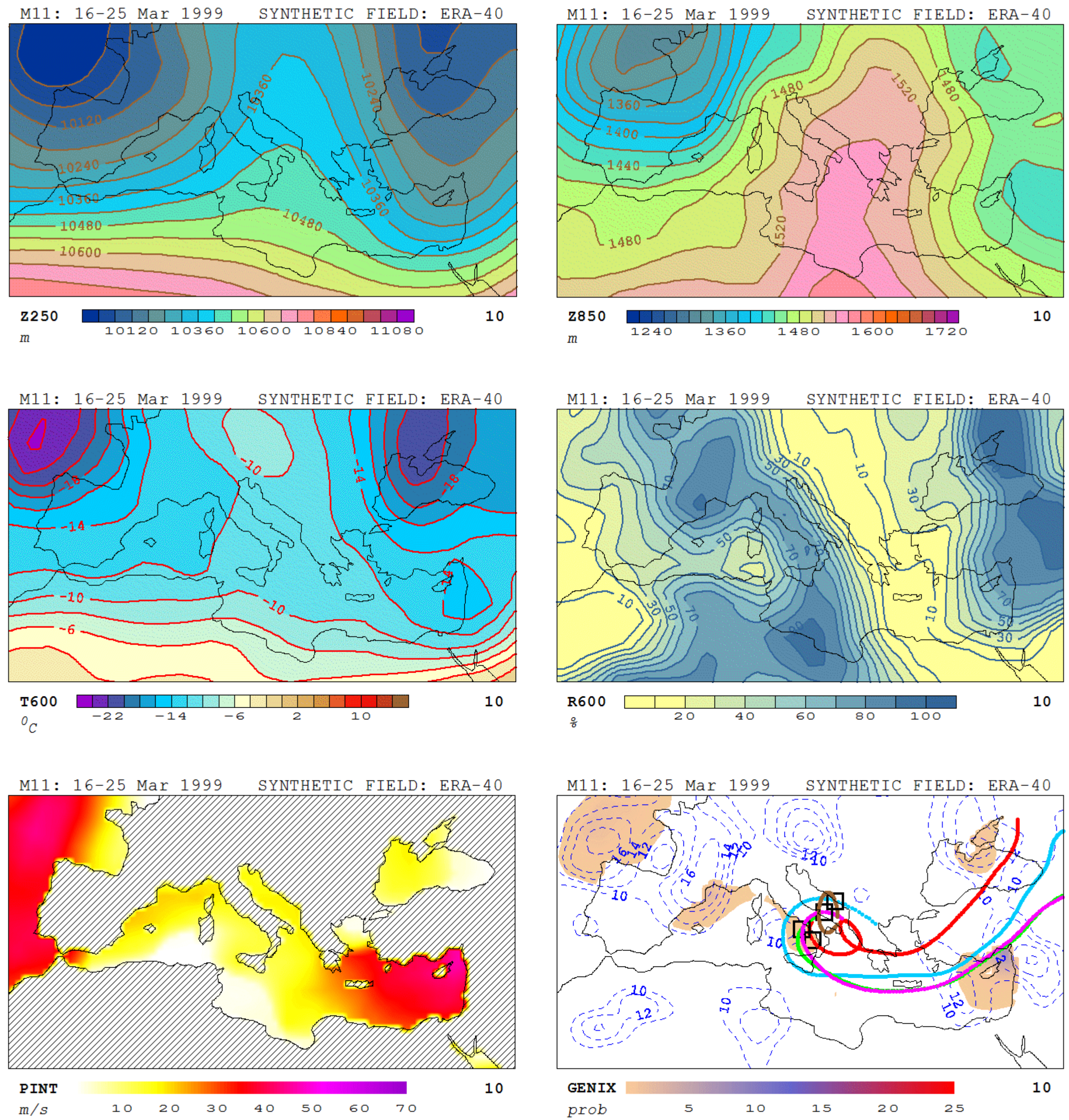
RND 2
4 tracks



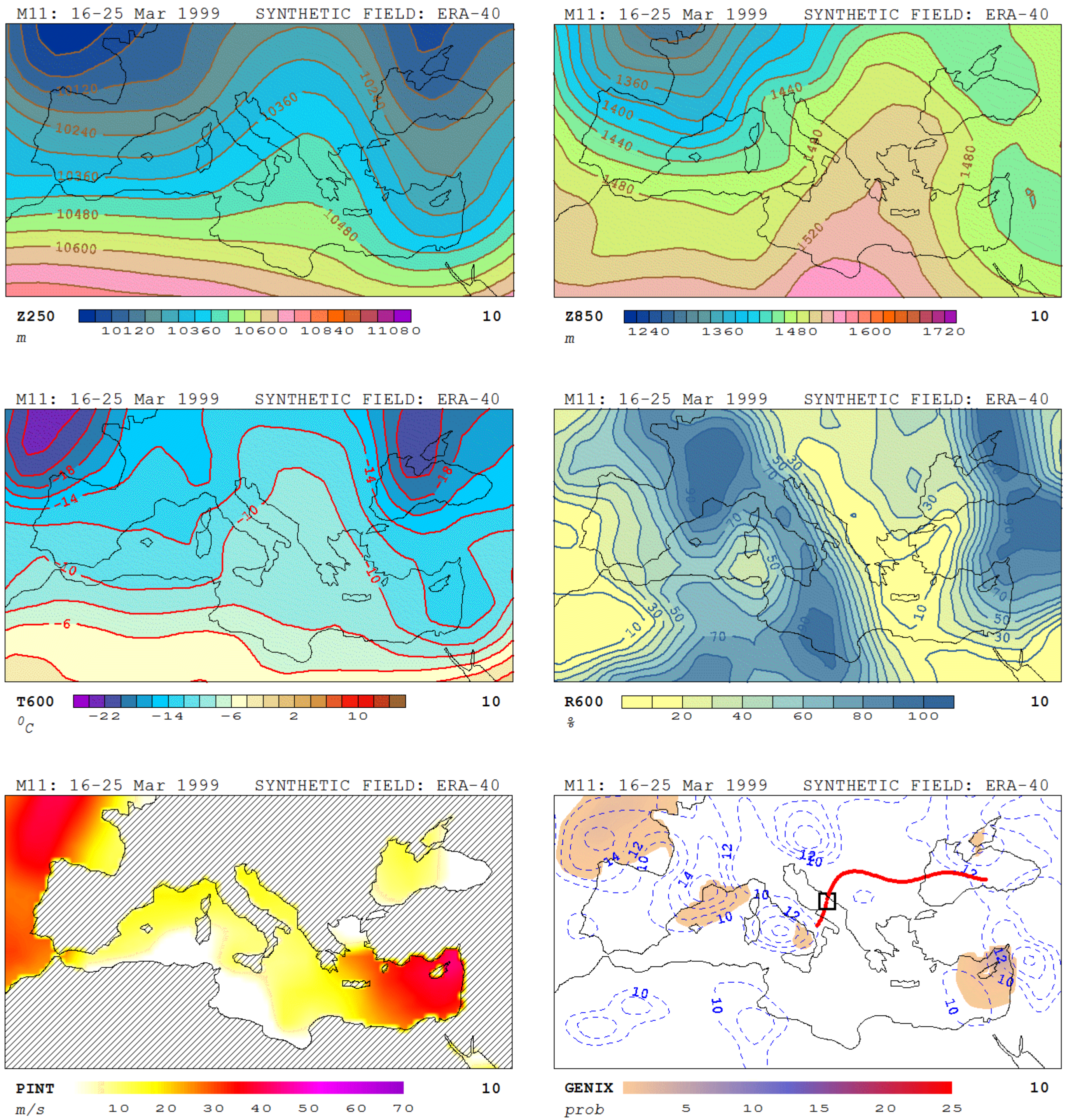
RND 3
5 tracks



RND 4
5 tracks



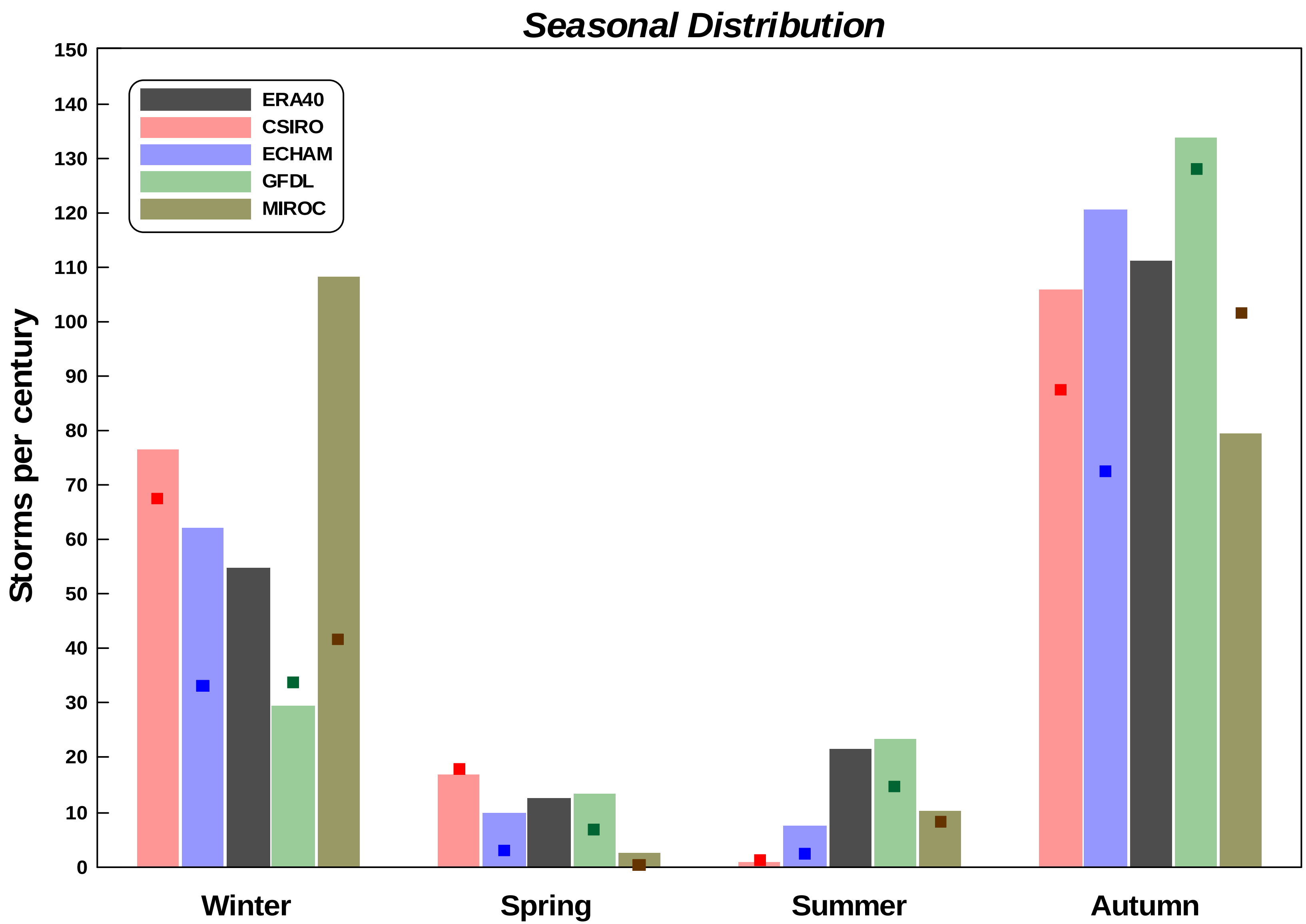
RND 5
1 tracks



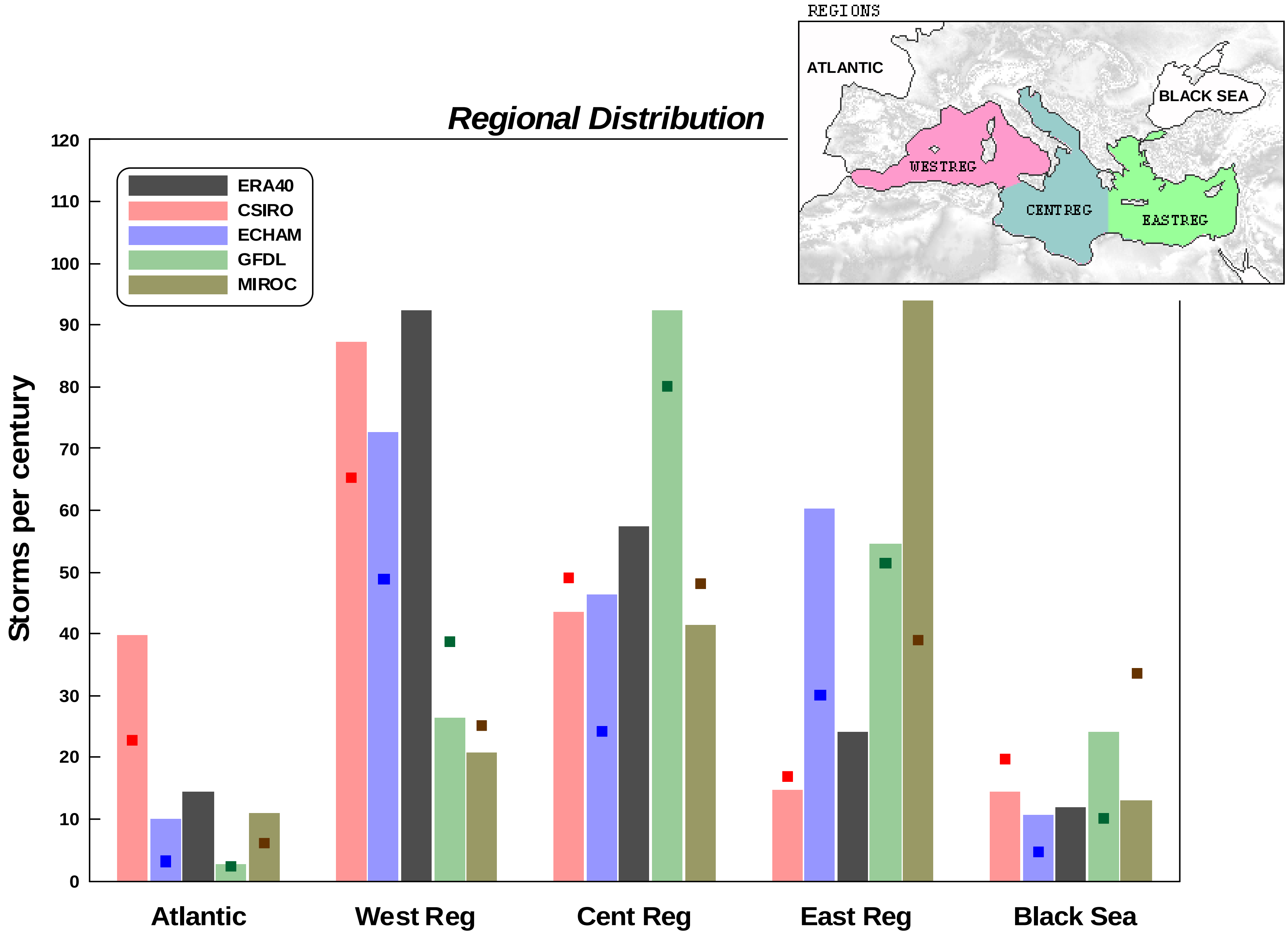
APPLICATION OF THE SECOND METHOD

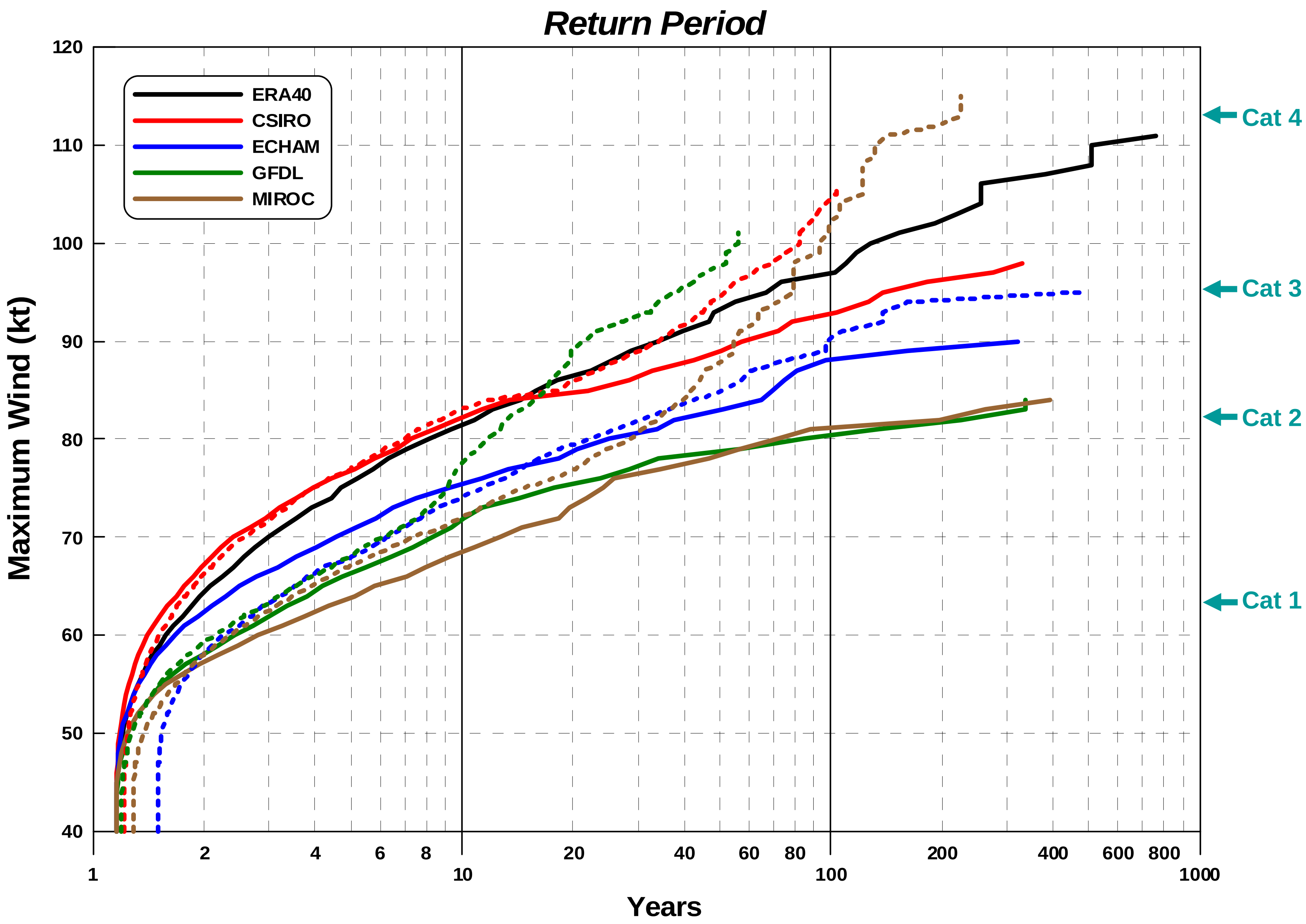
We synthetically generate a total of ~15000 potential tracks for each climate/model. These are simulated with CHIPS and checked for intensification above TS category (34 kt):

Climate Scenario	Reanalysis or GCM	Successful Storms	Storms per century
PRESENT 1981 – 2000	ERA40	3048	200
	CSIRO	3286	200
	ECHAM	1924	200
	GFDL	1343	200
	MIROC	1567	200
FUTURE 2081 – 2100 SRES A2	CSIRO	2857	174
	ECHAM	1072	111
	GFDL	1226	183
	MIROC	2389	152



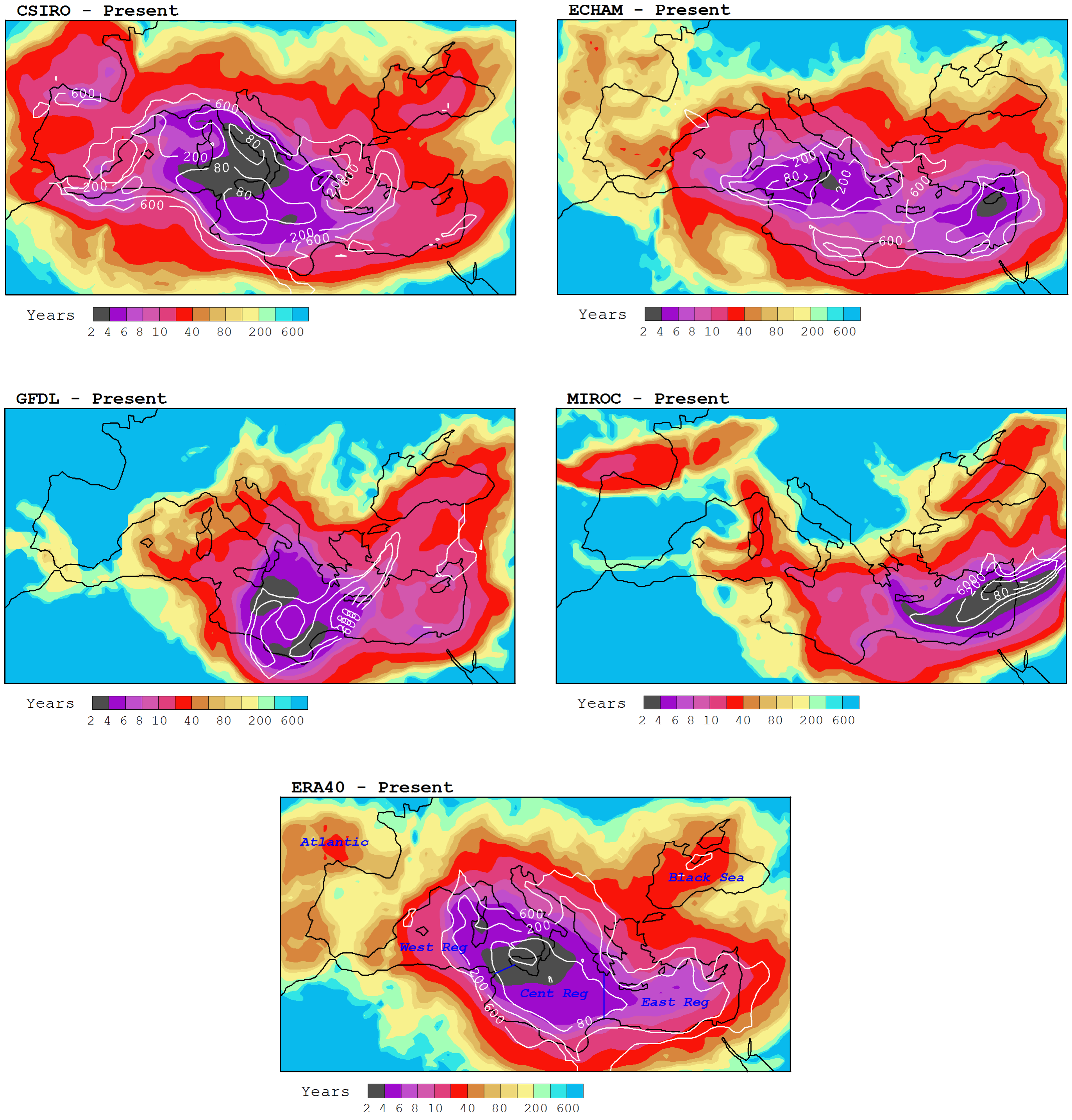
Seasonal Distribution
Storms per century
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ERA40
CSIRO
ECHAM
GFDL
MIROC
Winter
Spring
Summer
Autumn


Regional Distribution
Storms per century
120
110
100
90
80
70
60
50
40
30
20
10
0
ERA40
CSIRO
ECHAM
GFDL
MIROC
Atlantic
West Reg
Cent Reg
East Reg
Black Sea
REGIONS
ATLANTIC
BLACK SEA
WESTREG
CENTREG
EASTREG

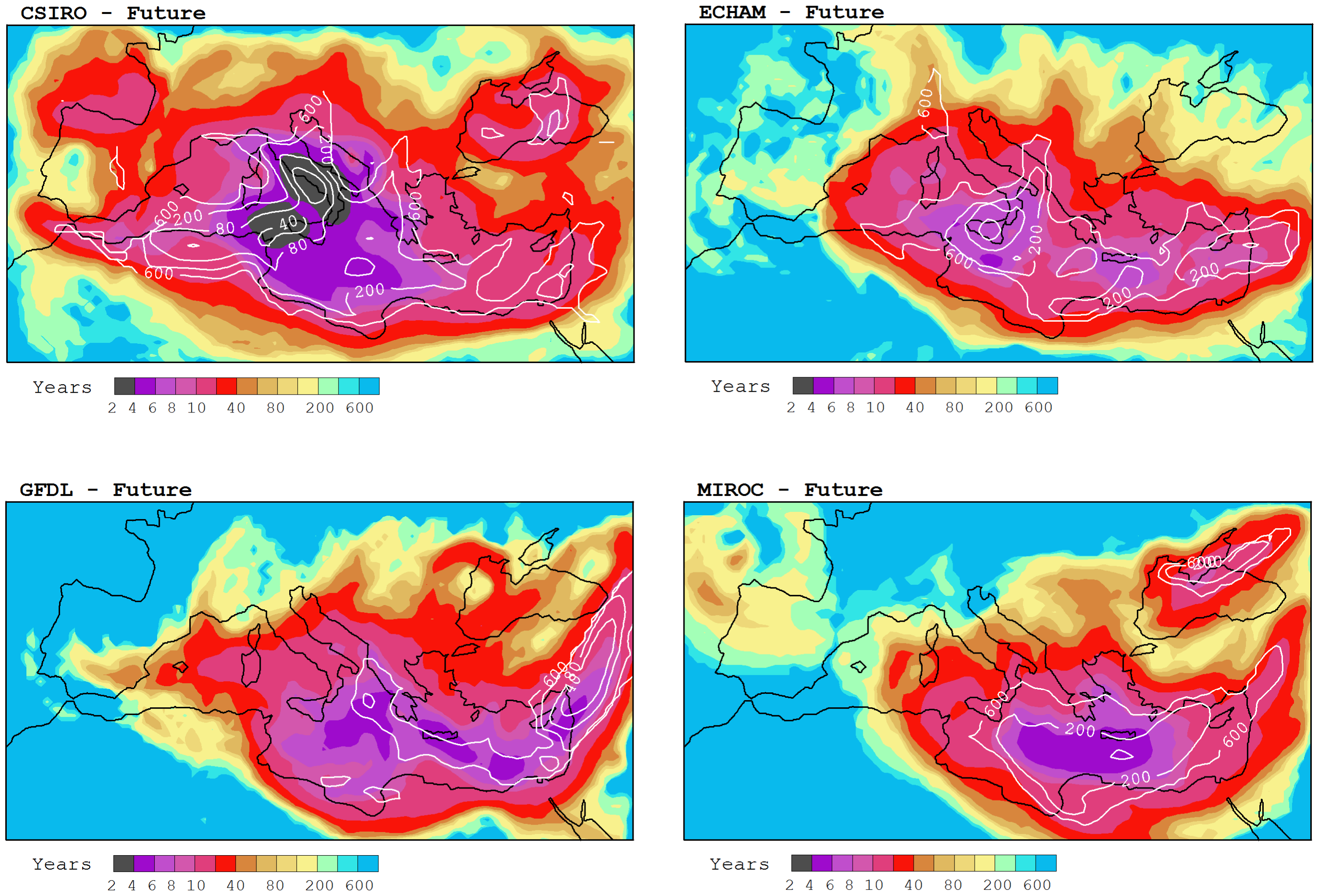


Return Period
Maximum Wind (kt)
Years
ERA40
CSIRO
ECHAM
GFDL
MIROC
Cat 4
Cat 3
Cat 2
Cat 1
120
110
100
90
80
70
60
50
40
1
2
4
6
8
10
20
40
60
80
100
200
400
600
800
1000

20C3M scenario

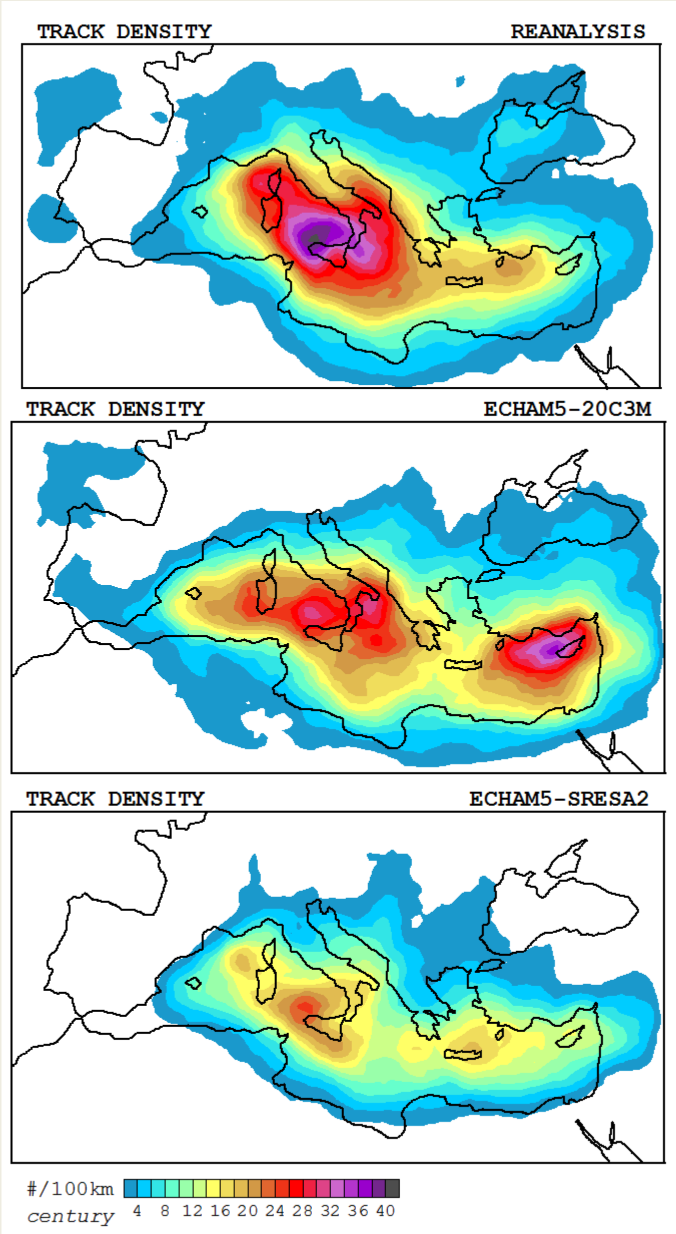


SRESA2 scenario

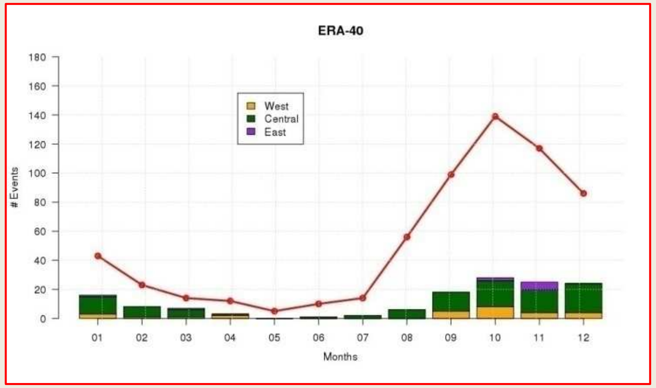


COMPARISON OF BOTH METHODS

SYNTHETIC generation

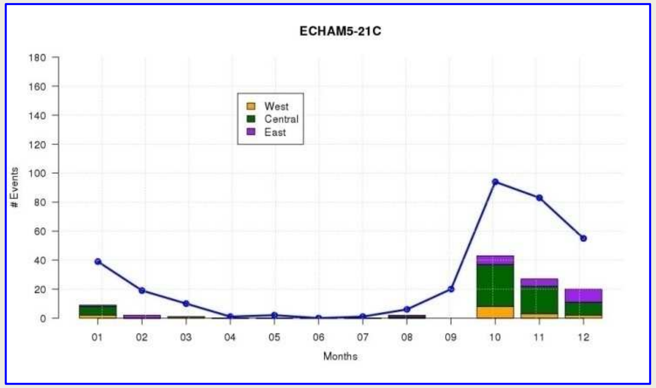


DYNAMICAL downscaling



28
101
9

60
105
45



16
64
23

CONCLUSIONS

- ***The statistical-deterministic approach is a good alternative to computationally expensive classical methods (e.g. dynamical downscaling of medicanes), with the extra benefit of producing statistically large populations of events***

- ***We attained unprecedented medicane-wind risk maps for the Mediterranean region***

- ***General agreement with the “known” phenomenology of medicanes in the current climate (e.g. maximum in the cold season and central Mediterranean) and between both methods***

- ***In spite of some geographical uncertainties, GCMs tend to project fewer medicanes at the end of the century compared to present but a higher number of violent storms, suggesting an increased probability of major economic and social impacts as the century progresses***