CMIP5-Based Projections of Future Changes in the Frequency and Intensity of MEDICANES at Subregional Scale

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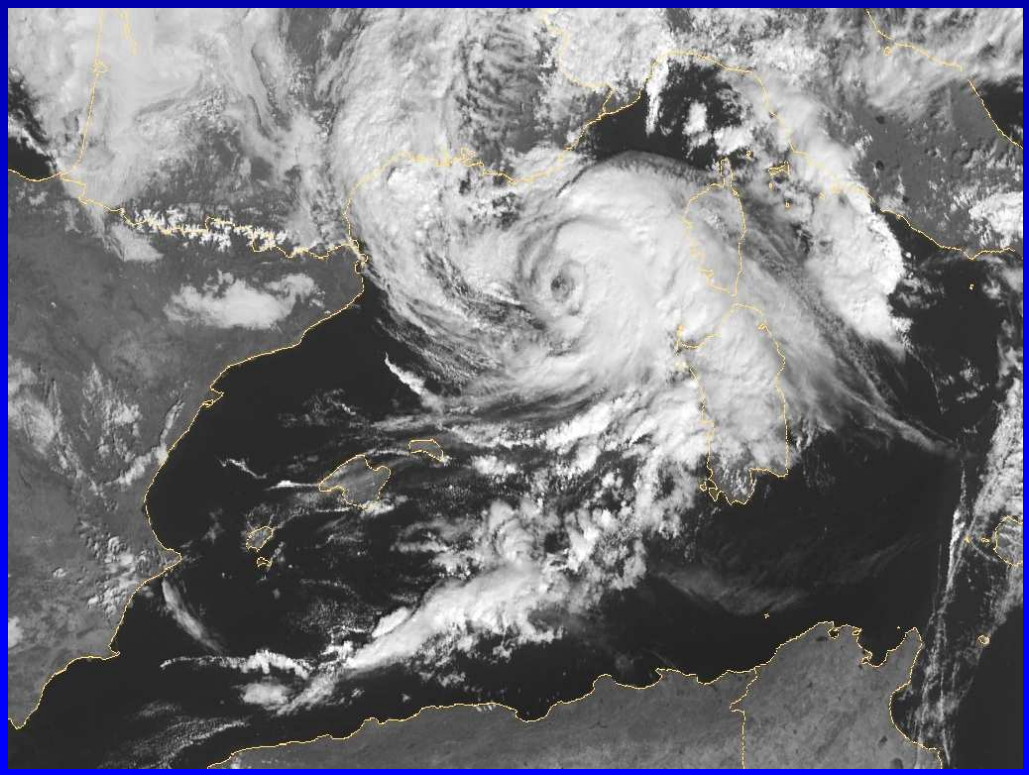
MOTIVATION

***Medicanes** are physically analogous to tropical cyclones (warm-core, surface flux-driven). These **extreme windstorms** pose serious **threat to** the affected islands and coastal regions and can adversely affect open sea activities such as fishing, cruises and recreational boating:*

- ***Future changes** in frequency, intensity or regional variability **?***
- *No systematic effort to answer this question **in the context of CMIP5***



THIS WORK: Statistical-deterministic approach

Developed by Emanuel at MIT 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 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, existing data of medicane genesis is 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*

- **Application of an empirical index of genesis:**

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

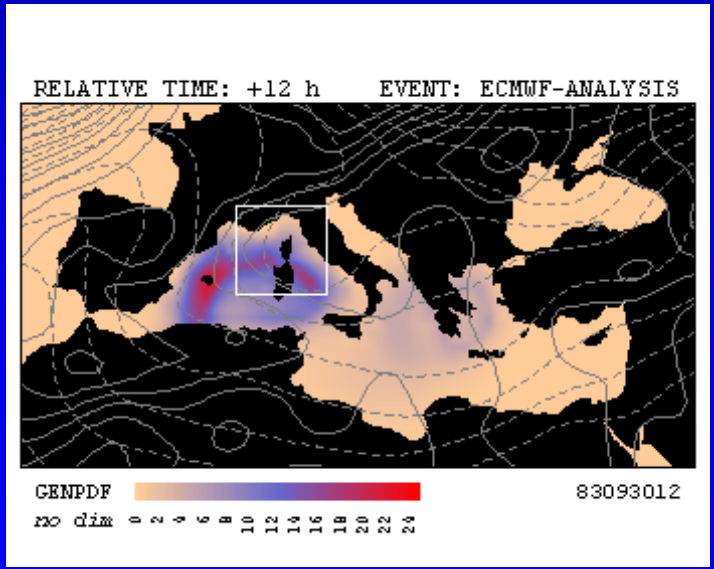
GENIX parameter
(Emanuel and Nolan, 2004)

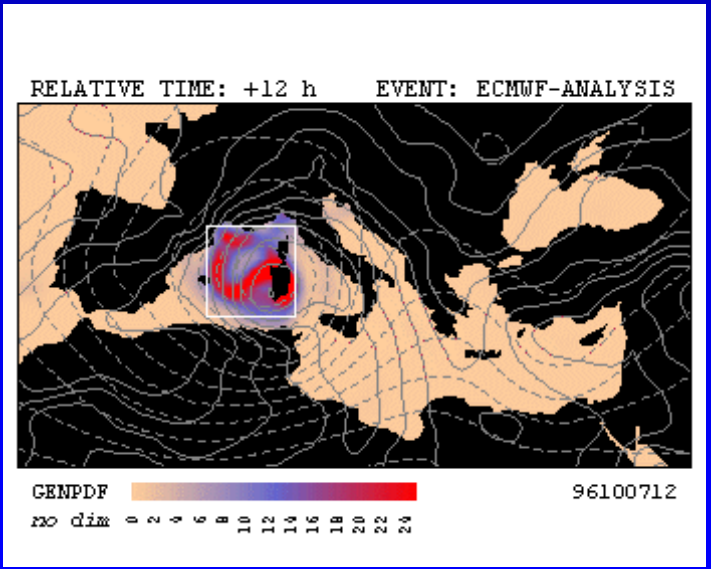
$\eta \equiv 850\,hPa\ absolute\ vorticity\ (s^{-1}),$

$H \equiv 600\,mb\ relative\ humidity\ (\%),$

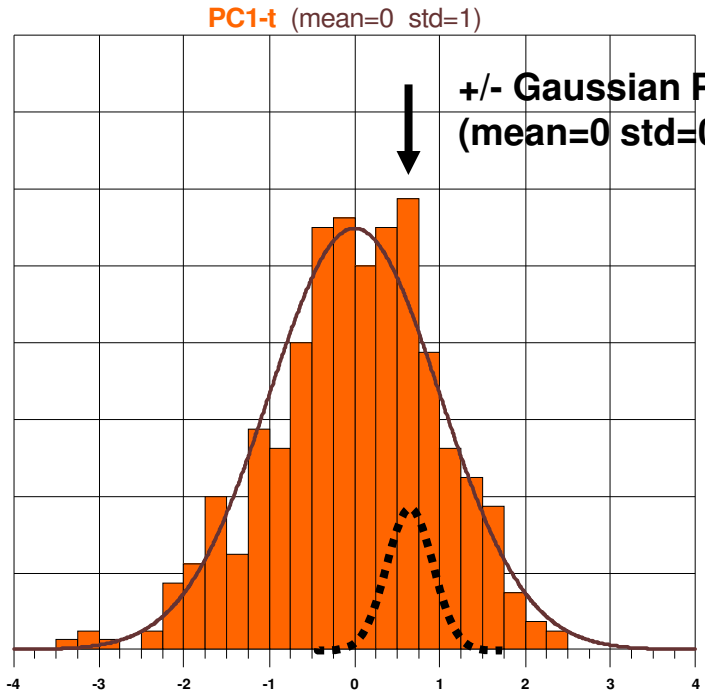
$V_{pot} \equiv Potential\ wind\ speed\ (ms^{-1}),$

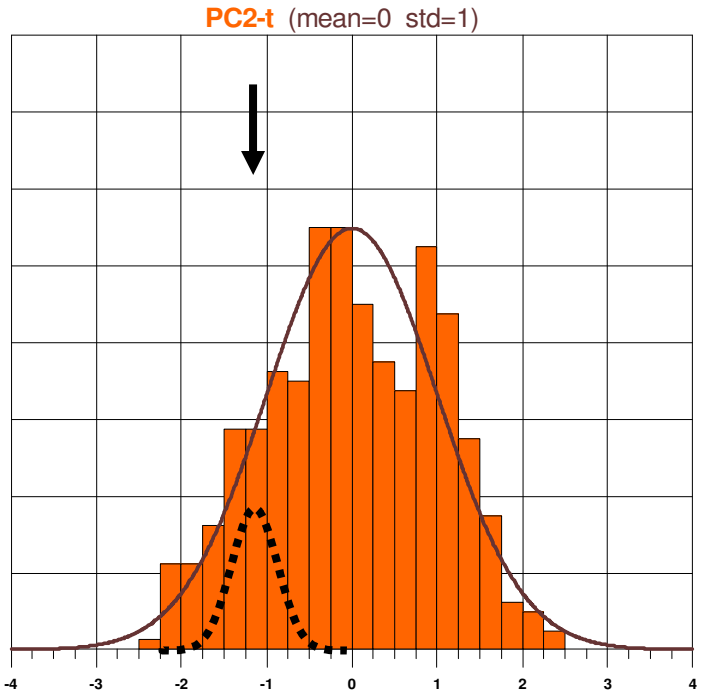
$V_{shear} \equiv \left|\mathbf{V}_{850} - \mathbf{V}_{250}\right| \quad (ms^{-1}).$



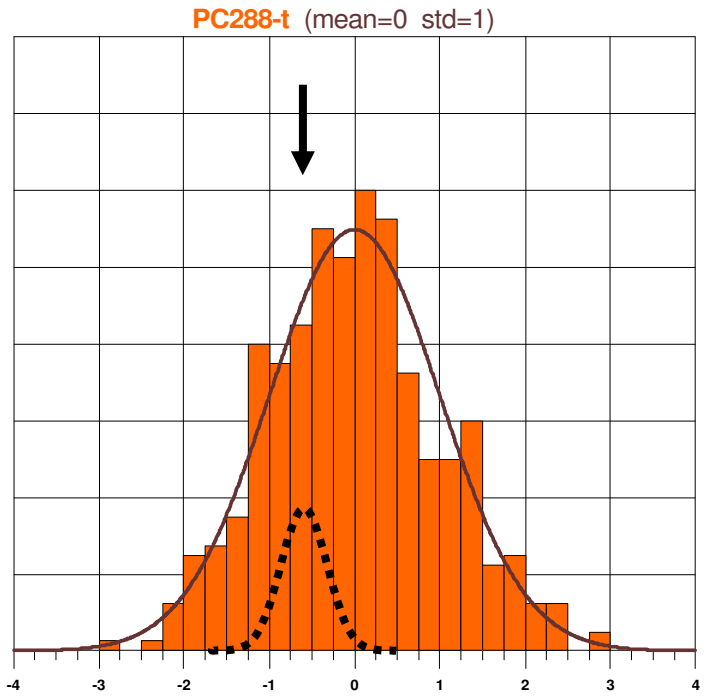


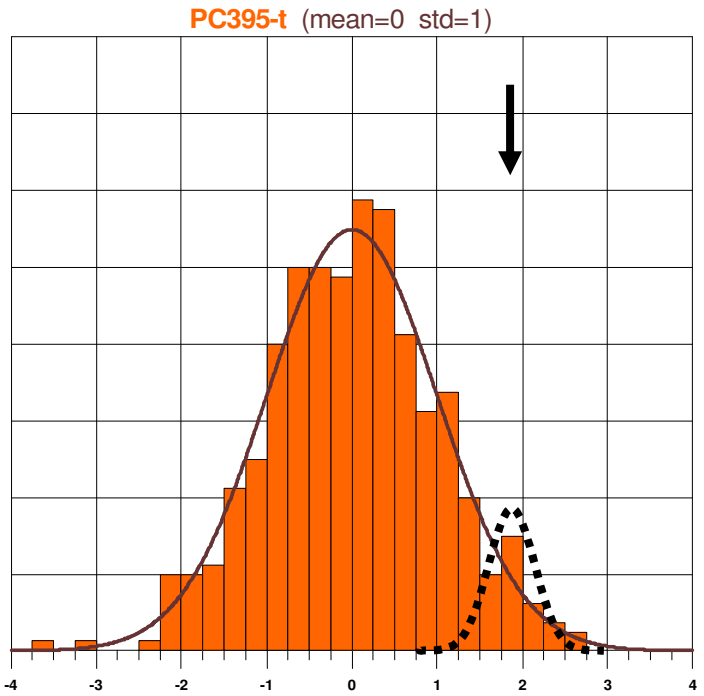
- **Necessary but no sufficient ingredient …**

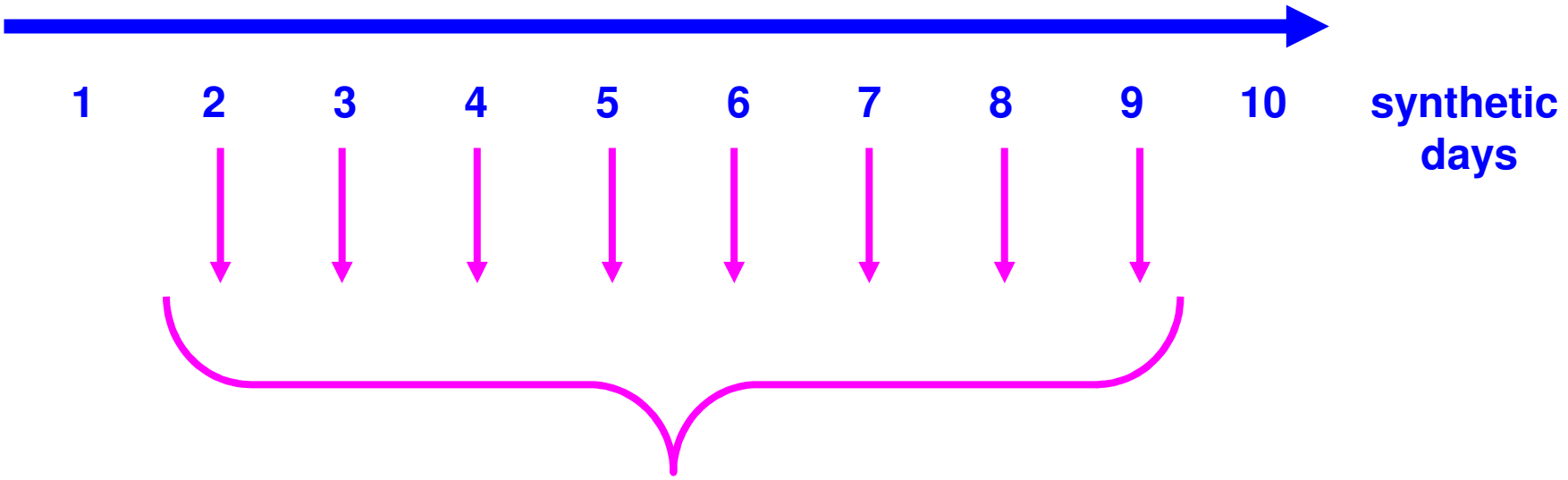




Production of synoptic evolutions that behave as analogs of locations actually visited in the climate phase space !!!







OPEN-SEA POINT + MAX OF GENIX > 10 + ABS VOR > 10 units ???

YES

Backward

(Max: 12 h)

Forward

(Max: 12 h over land)

POTENTIAL TRACK

(Δt = 30 min)

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

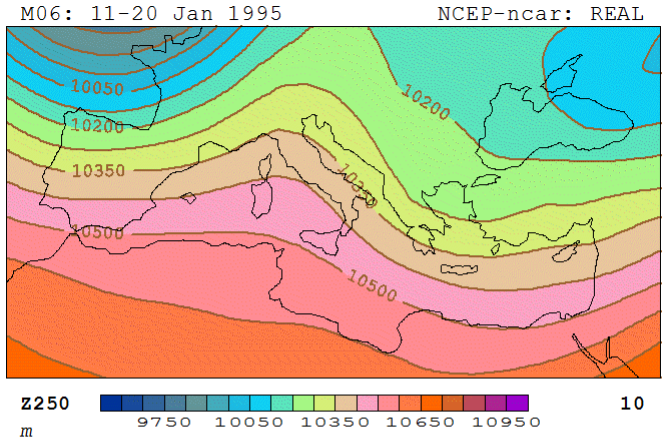
$\underline{AVG}_{time\text{-}space}$

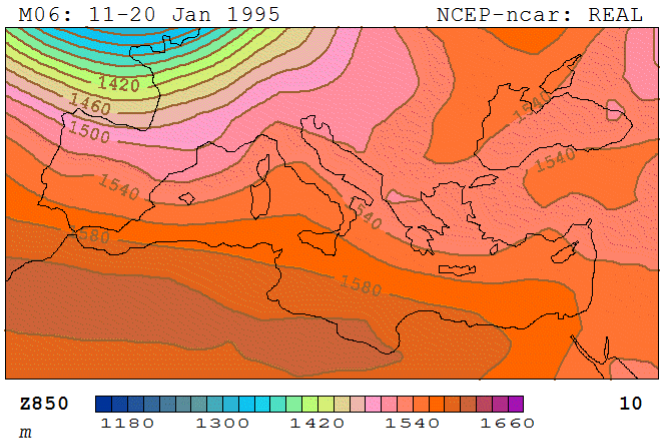
$\alpha = 0.8$

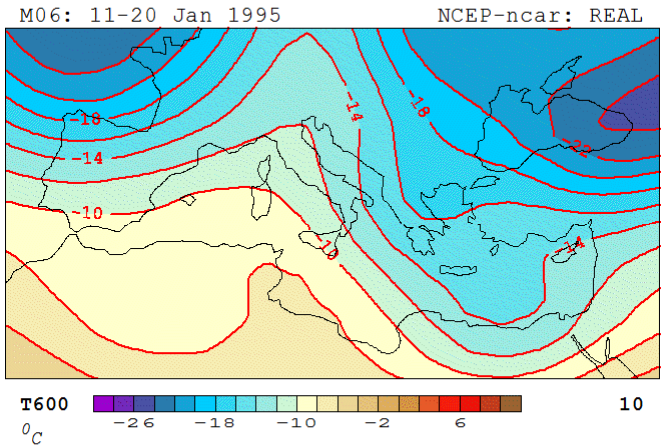
ILLUSTRATIVE EXAMPLE

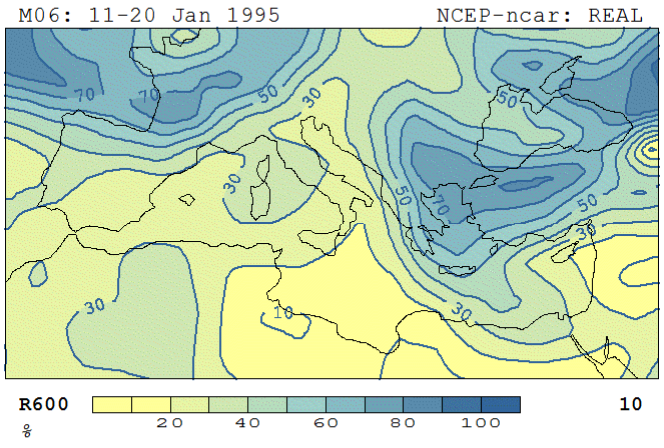
“LYBIAN” MEDICANE
Central Mediterranean, 15-16 January 1995

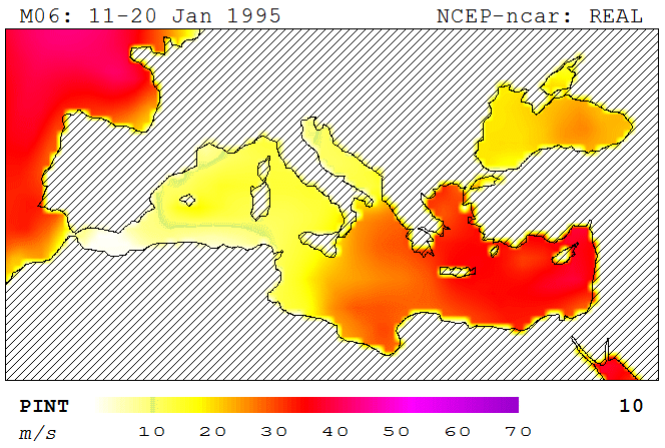
TRACKING method

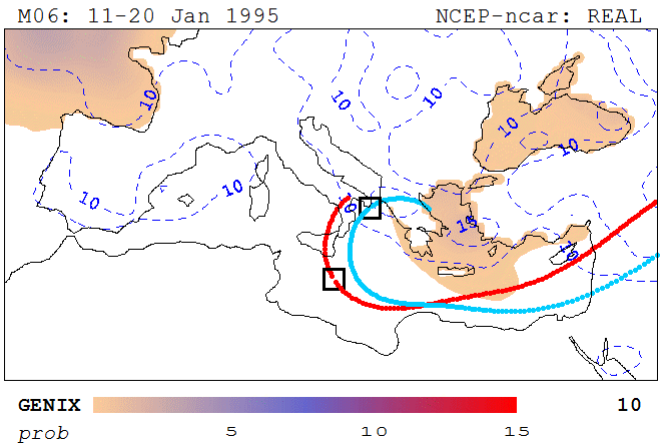




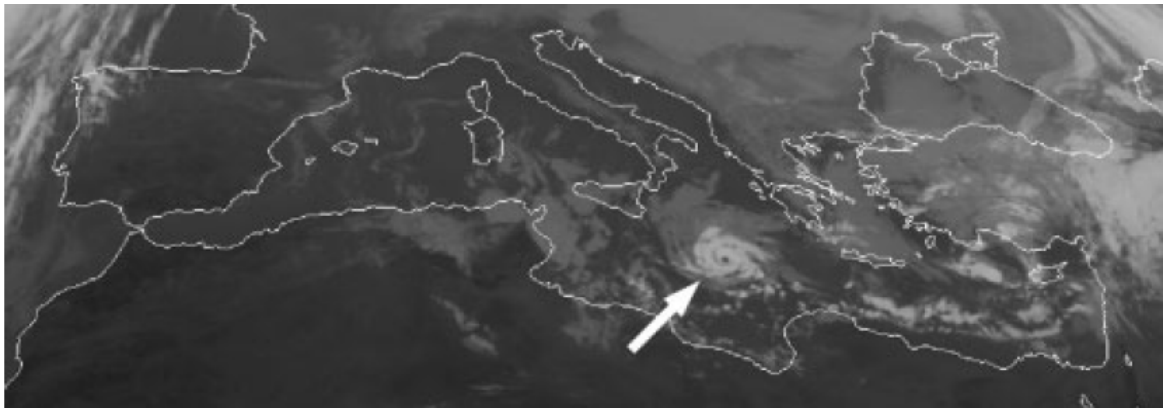


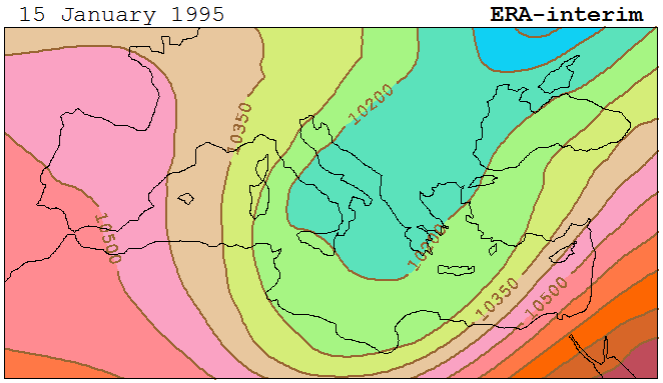




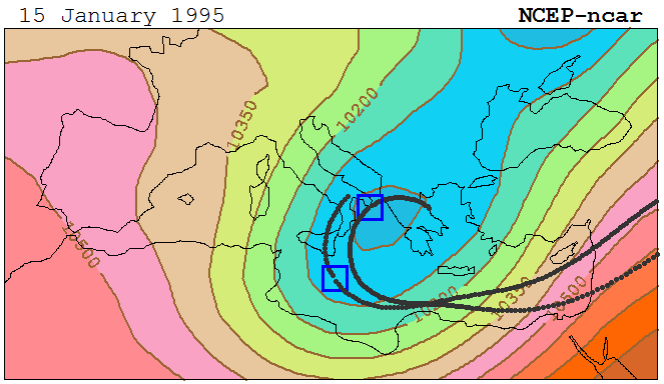


SYNTHETIC analogues

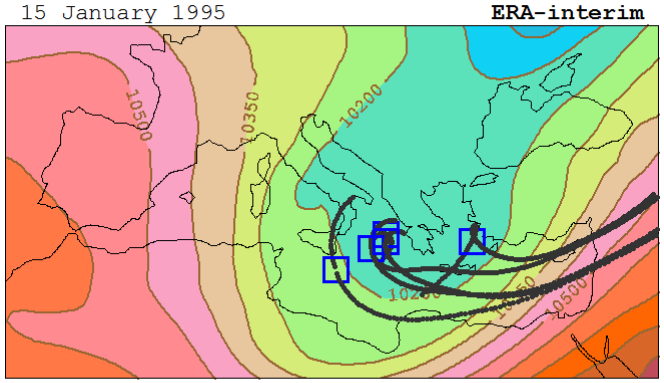




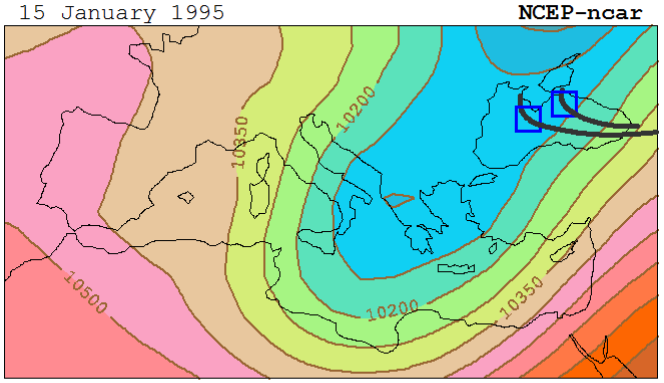
REAL



REAL



SYNTHETIC



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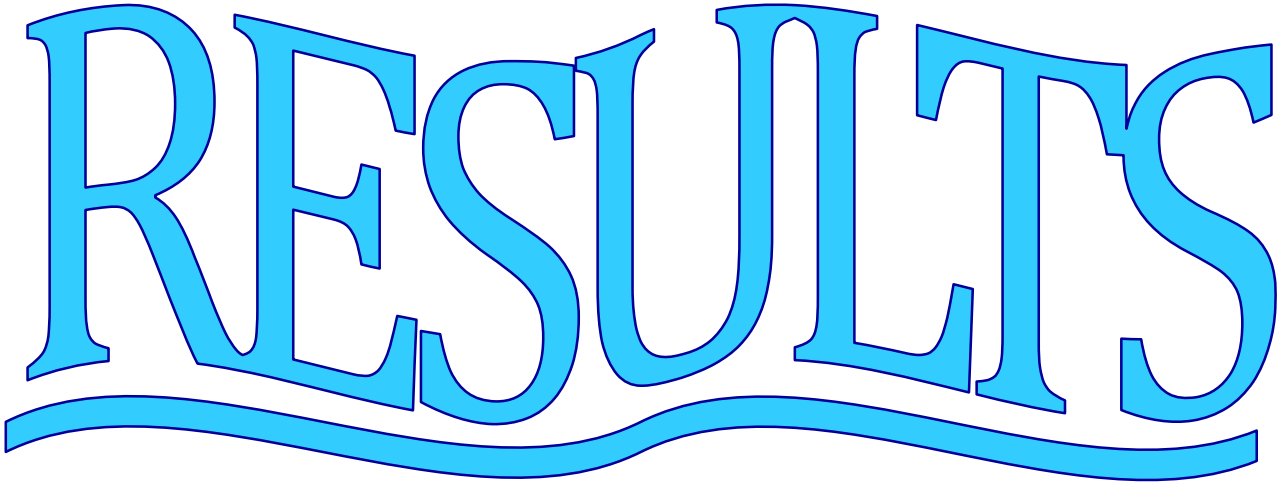

RESULTS

REANALYSIS 1

ERA-interim

20349 tracks
7918 survivors

200 storms/century

REANALYSIS 2

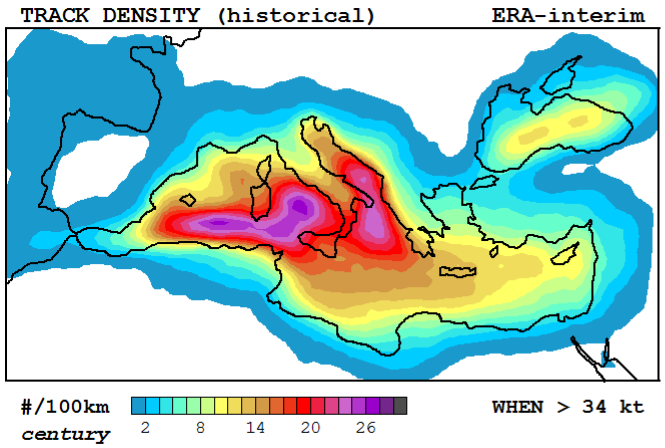
NCEP-ncar

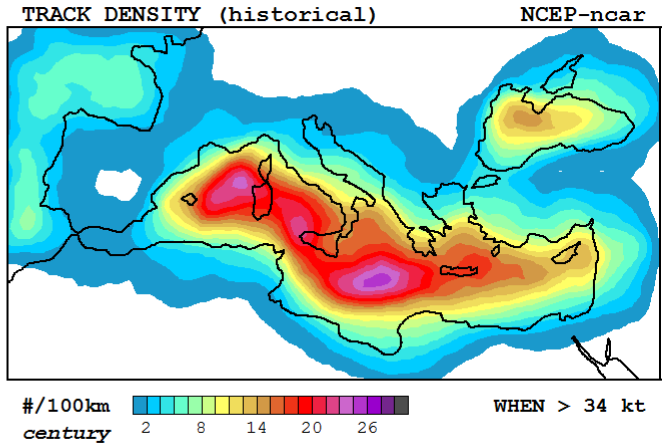
20276 tracks
6379 survivors

200 storms/century

HISTORICAL scenario

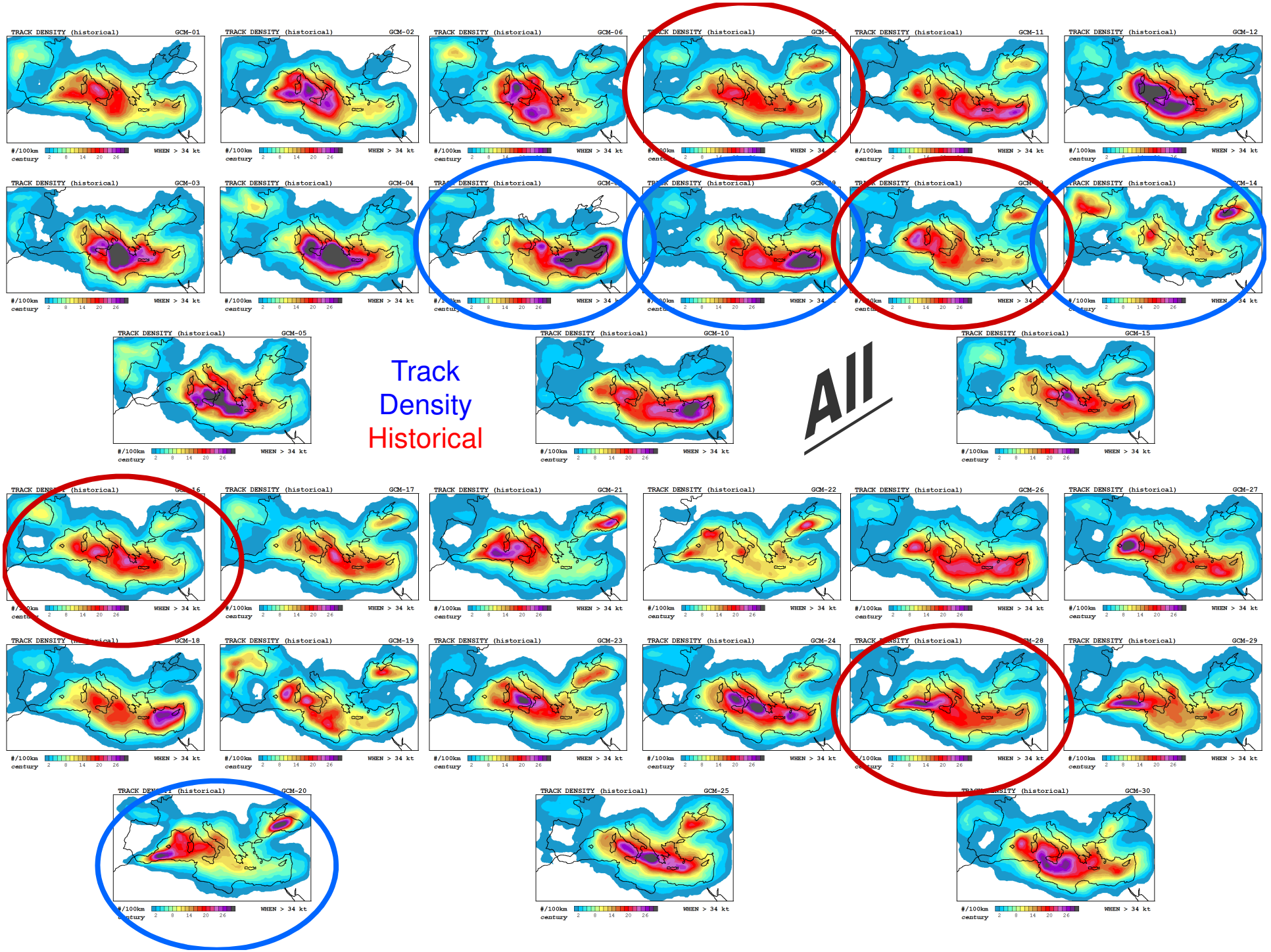
200 storms
(per century)

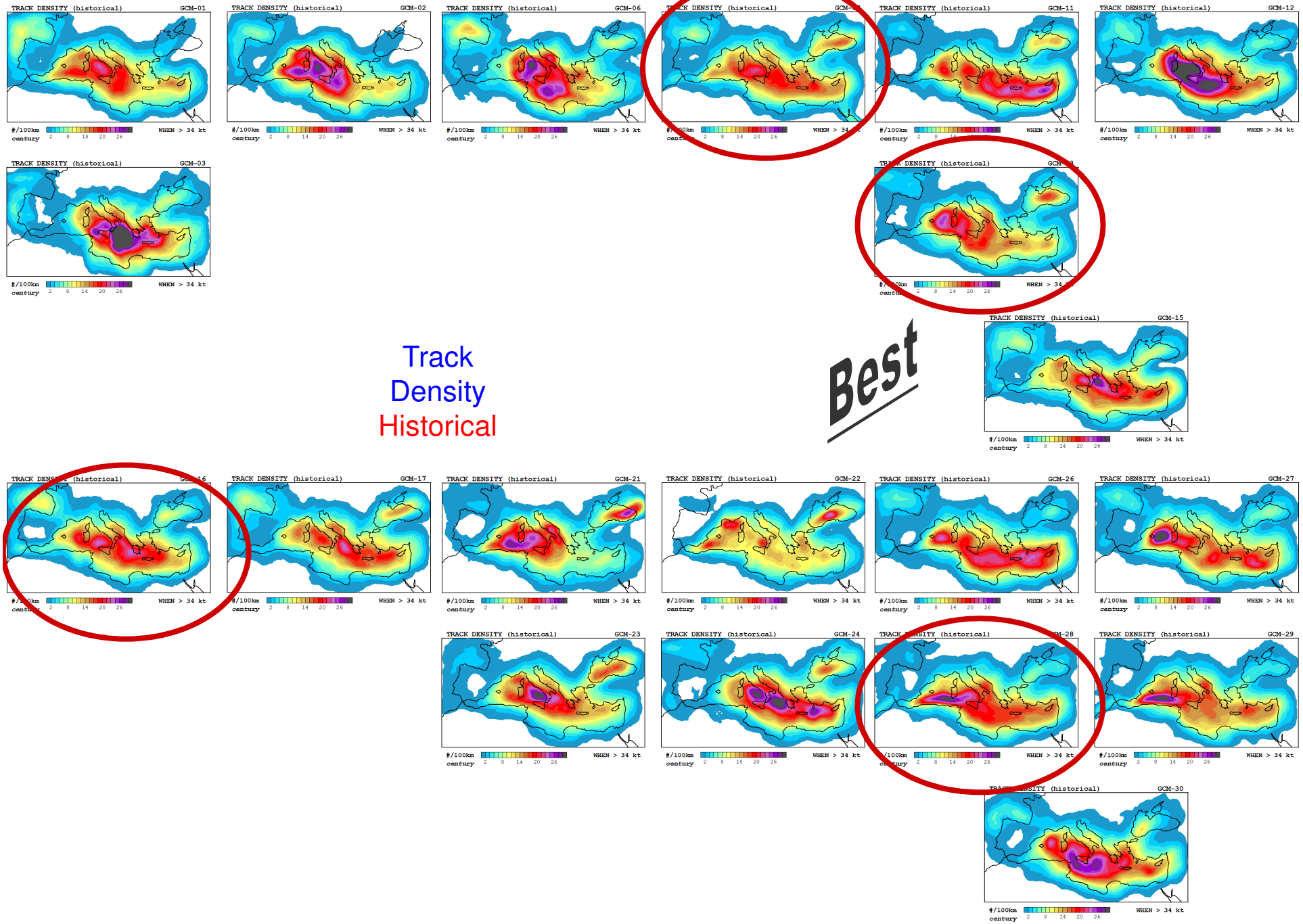




GCM-01 ***ACCESS1.0*** 20325 tracks 7188 survivors 200 storms/century	**GCM-02** ***ACCESS1.3*** 20086 tracks 7281 survivors 200 storms/century	**GCM-06** ***CanESM2*** 20097 tracks 5268 survivors 200 storms/century	**GCM-07** ***CCSM4*** 20405 tracks 7012 survivors 200 storms/century	**GCM-11** ***CNRM-CM5*** 20329 tracks 6535 survivors 200 storms/century	**GCM-12** ***CSIRO-Mk3.6.0*** 20048 tracks 6034 survivors 200 storms/century
GCM-03 ***BCC-CSM1.1*** 20083 tracks 3045 survivors 200 storms/century	**GCM-04** ***BCC-CSM1.1(m)*** 20142 tracks 5167 survivors 200 storms/century	**GCM-08** ***CMCC-CESM*** 20106 tracks 4733 survivors 200 storms/century	**GCM-09** ***CMCC-CM*** 20085 tracks 6368 survivors 200 storms/century	**GCM-13** ***EC-EARTH*** 20180 tracks 7793 survivors 200 storms/century	**GCM-14** ***FGOALS-g2*** 20481 tracks 1925 survivors 200 storms/century
GCM-05 ***BNU-ESM*** 20071 tracks 2946 survivors 200 storms/century	***HISTORICAL scenario*** **200 storms (per century)**	**GCM-10** ***CMCC-CMS*** 20119 tracks 5738 survivors 200 storms/century	ALL	**GCM-15** ***GFDL-CM3*** 20475 tracks 5307 survivors 200 storms/century	
GCM-16 ***GFDL-ESM2G*** 20444 tracks 5309 survivors 200 storms/century	**GCM-17** ***GFDL-ESM2M*** 20374 tracks 5596 survivors 200 storms/century	**GCM-21** ***IPSL-CM5A-MR*** 20178 tracks 4919 survivors 200 storms/century	**GCM-22** ***IPSL-CM5B-LR*** 20592 tracks 5681 survivors 200 storms/century	**GCM-26** ***MPI-ESM-LR*** 20082 tracks 6015 survivors 200 storms/century	**GCM-27** ***MPI-ESM-MR*** 20745 tracks 5678 survivors 200 storms/century
GCM-18 ***HadGEM2-CC*** 20392 tracks 7860 survivors 200 storms/century	**GCM-19** ***INM-CM4*** 20018 tracks 5047 survivors 200 storms/century	**GCM-23** ***MIROC5*** 20651 tracks 6651 survivors 200 storms/century	**GCM-24** ***MIROC-ESM*** 20268 tracks 5709 survivors 200 storms/century	**GCM-28** ***MRI-CGCM3*** 20541 tracks 5647 survivors 200 storms/century	**GCM-29** ***MRI-ESM1*** 21203 tracks 5898 survivors 200 storms/century
GCM-20 ***IPSL-CM5A-LR*** 20176 tracks 5064 survivors 200 storms/century		**GCM-25** ***MIROC-ESM-CHEM*** 20026 tracks 5517 survivors 200 storms/century		**GCM-30** ***NorESM1-M*** 20022 tracks 6558 survivors 200 storms/century	

GCM-01 ***ACCESS1.0*** 22539 tracks 7521 survivors **209.27** storms/century	**GCM-02** ***ACCESS1.3*** 28304 tracks 8335 survivors **228.95** storms/century	**GCM-06** ***CanESM2*** 14750 tracks 3843 survivors **145.90** storms/century	**GCM-07** ***CCSM4*** 20560 tracks 6236 survivors **177.87** storms/century	**GCM-11** ***CNRM-CM5*** 30505 tracks 8689 survivors **265.92** storms/century	**GCM-12** ***CSIRO-Mk3.6.0*** 12085 tracks 2382 survivors **78.95** storms/century
GCM-03 ***BCC-CSM1.1*** 20439 tracks 2932 survivors **192.58** storms/century	**GCM-04** ***BCC-CSM1.1(m)*** 13761 tracks 3523 survivors **136.37** storms/century	**GCM-08** ***CMCC-CESM*** 17277 tracks 3772 survivors **159.39** storms/century	**GCM-09** ***CMCC-CM*** 22778 tracks 7300 survivors **229.27** storms/century	**GCM-13** ***EC-EARTH*** 32781 tracks 12359 survivors **317.18** storms/century	**GCM-14** ***FGOALS-g2*** 29286 tracks 2730 survivors **283.64** storms/century
GCM-05 ***BNU-ESM*** 27750 tracks 3820 survivors **259.34** storms/century	***RCP85 scenario*** **198.52 storms (per century)**	**GCM-10** ***CMCC-CMS*** 20675 tracks 6194 survivors **215.89** storms/century	ALL	**GCM-15** ***GFDL-CM3*** 17779 tracks 4171 survivors **157.19** storms/century	
GCM-16 ***GFDL-ESM2G*** 20348 tracks 4686 survivors **176.53** storms/century	**GCM-17** ***GFDL-ESM2M*** 16884 tracks 3996 survivors **142.82** storms/century	**GCM-21** ***IPSL-CM5A-MR*** 14172 tracks 2382 survivors **96.85** storms/century	**GCM-22** ***IPSL-CM5B-LR*** 23922 tracks 6328 survivors **222.78** storms/century	**GCM-26** ***MPI-ESM-LR*** 19684 tracks 6708 survivors **223.04** storms/century	**GCM-27** ***MPI-ESM-MR*** 21590 tracks 6969 survivors **245.47** storms/century
GCM-18 ***HadGEM2-CC*** 24510 tracks 7503 survivors **190.92** storms/century	**GCM-19** ***INM-CM4*** 12250 tracks 2844 survivors **112.70** storms/century	**GCM-23** ***MIROC5*** 29654 tracks 9216 survivors **277.13** storms/century	**GCM-24** ***MIROC-ESM*** 27239 tracks 5499 survivors **192.64** storms/century	**GCM-28** ***MRI-CGCM3*** 22758 tracks 5993 survivors **212.25** storms/century	**GCM-29** ***MRI-ESM1*** 23950 tracks 6432 survivors **218.11** storms/century
GCM-20 ***IPSL-CM5A-LR*** 23722 tracks 5438 survivors **214.77** storms/century	**15 models** ▼▼▼	**GCM-25** ***MIROC-ESM-CHEM*** 26010 tracks 5283 survivors **191.52** storms/century	**15 models** ▲▲▲	**GCM-30** ***NorESM1-M*** 22427 tracks 5914 survivors **180.36** storms/century	


TRACK DENSITY (historical) GCM-01
TRACK DENSITY (historical) GCM-02
TRACK DENSITY (historical) GCM-06
TRACK DENSITY (historical) GCM-11
TRACK DENSITY (historical) GCM-12
TRACK DENSITY (historical) GCM-03
TRACK DENSITY (historical) GCM-04
TRACK DENSITY (historical) GCM-14
TRACK DENSITY (historical) GCM-05
TRACK DENSITY (historical) GCM-10
TRACK DENSITY (historical) GCM-15
Track
Density
Historical
All
TRACK DENSITY (historical) GCM-17
TRACK DENSITY (historical) GCM-21
TRACK DENSITY (historical) GCM-22
TRACK DENSITY (historical) GCM-26
TRACK DENSITY (historical) GCM-27
TRACK DENSITY (historical) GCM-18
TRACK DENSITY (historical) GCM-19
TRACK DENSITY (historical) GCM-23
TRACK DENSITY (historical) GCM-24
TRACK DENSITY (historical) GCM-29
TRACK DENSITY (historical) GCM-20
TRACK DENSITY (historical) GCM-25
TRACK DENSITY (historical) GCM-30
#/100km
century
WHEN > 34 kt


TRACK DENSITY (historical) GCM-01
TRACK DENSITY (historical) GCM-02
TRACK DENSITY (historical) GCM-06
TRACK DENSITY (historical) GCM-11
TRACK DENSITY (historical) GCM-12
TRACK DENSITY (historical) GCM-03
TRACK DENSITY (historical) GCM-15
Track
Density
Historical
Best
TRACK DENSITY (historical) GCM-17
TRACK DENSITY (historical) GCM-21
TRACK DENSITY (historical) GCM-22
TRACK DENSITY (historical) GCM-26
TRACK DENSITY (historical) GCM-27
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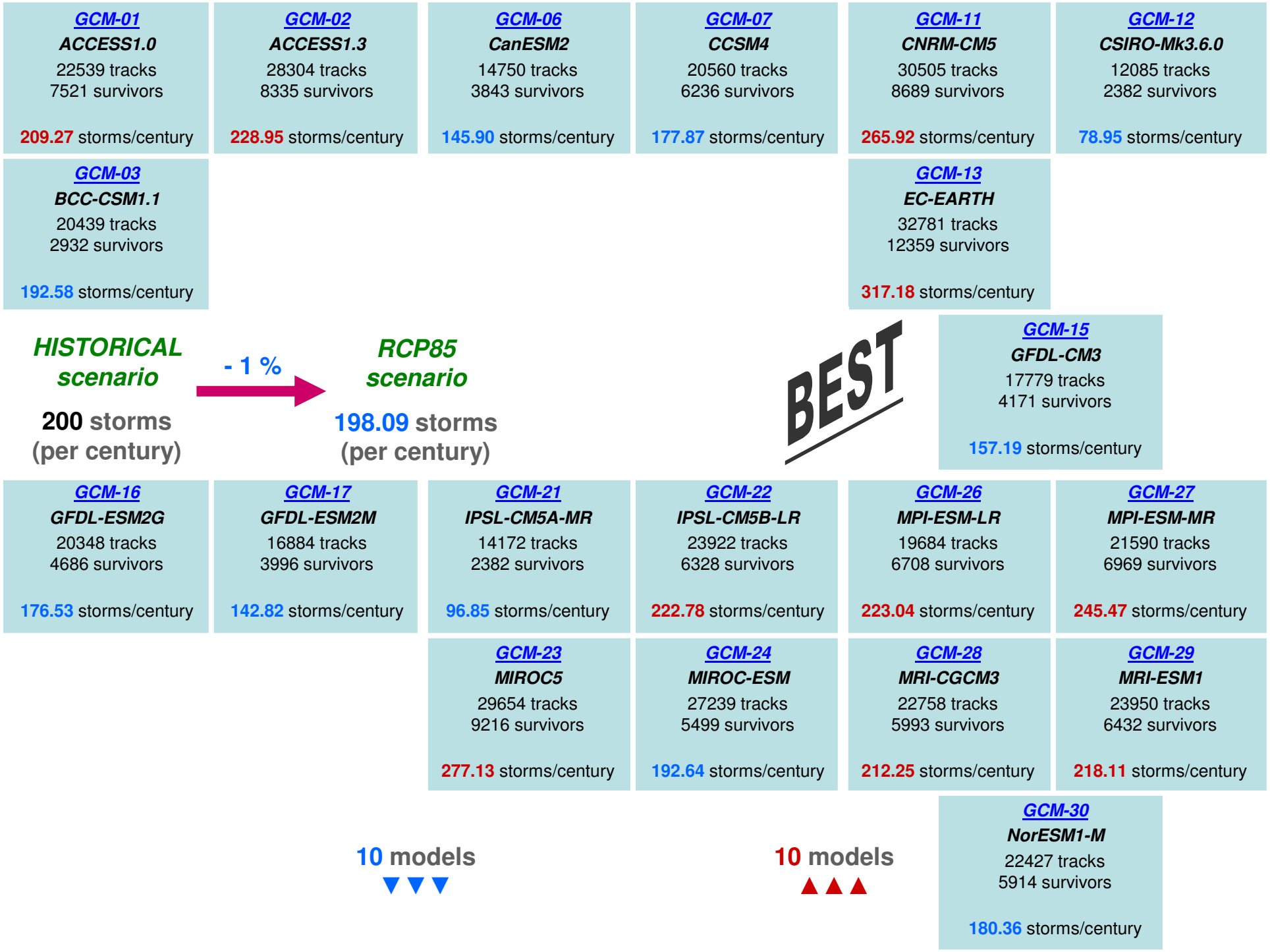
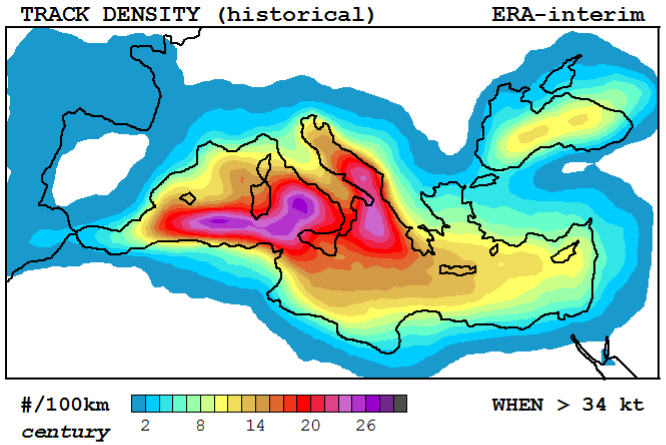
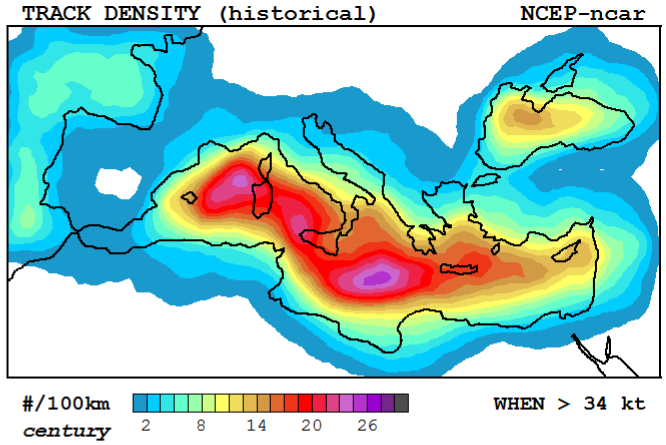
TRACK DENSITY (historical) GCM-29
TRACK DENSITY (historical) GCM-30
#/100km
century
WHEN > 34 kt


GCM-01
ACCESS1.0
22539 tracks
7521 survivors
209.27 storms/century
GCM-02
ACCESS1.3
28304 tracks
8335 survivors
228.95 storms/century
GCM-06
CanESM2
14750 tracks
3843 survivors
145.90 storms/century
GCM-07
CCSM4
20560 tracks
6236 survivors
177.87 storms/century
GCM-11
CNRM-CM5
30505 tracks
8689 survivors
265.92 storms/century
GCM-12
CSIRO-Mk3.6.0
12085 tracks
2382 survivors
78.95 storms/century
GCM-03
BCC-CSM1.1
20439 tracks
2932 survivors
192.58 storms/century
GCM-13
EC-EARTH
32781 tracks
12359 survivors
317.18 storms/century
HISTORICAL scenario
200 storms (per century)
- 1 %
RCP85 scenario
198.09 storms (per century)
BEST
GCM-15
GFDL-CM3
17779 tracks
4171 survivors
157.19 storms/century
GCM-16
GFDL-ESM2G
20348 tracks
4686 survivors
176.53 storms/century
GCM-17
GFDL-ESM2M
16884 tracks
3996 survivors
142.82 storms/century
GCM-21
IPSL-CM5A-MR
14172 tracks
2382 survivors
96.85 storms/century
GCM-22
IPSL-CM5B-LR
23922 tracks
6328 survivors
222.78 storms/century
GCM-26
MPI-ESM-LR
19684 tracks
6708 survivors
223.04 storms/century
GCM-27
MPI-ESM-MR
21590 tracks
6969 survivors
245.47 storms/century
GCM-23
MIROC5
29654 tracks
9216 survivors
277.13 storms/century
GCM-24
MIROC-ESM
27239 tracks
5499 survivors
192.64 storms/century
GCM-28
MRI-CGCM3
22758 tracks
5993 survivors
212.25 storms/century
GCM-29
MRI-ESM1
23950 tracks
6432 survivors
218.11 storms/century
10 models
10 models
GCM-30
NorESM1-M
22427 tracks
5914 survivors
180.36 storms/century



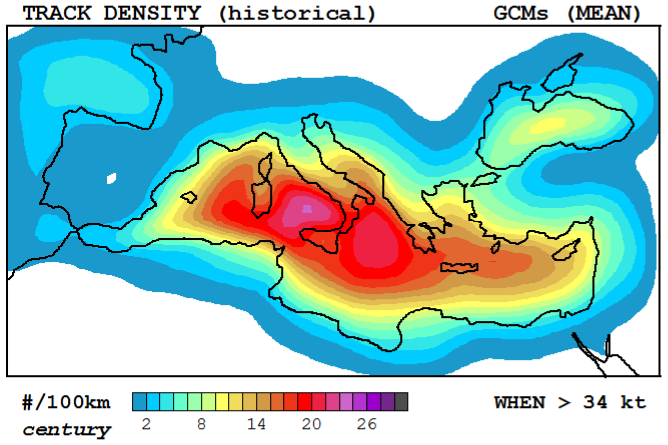


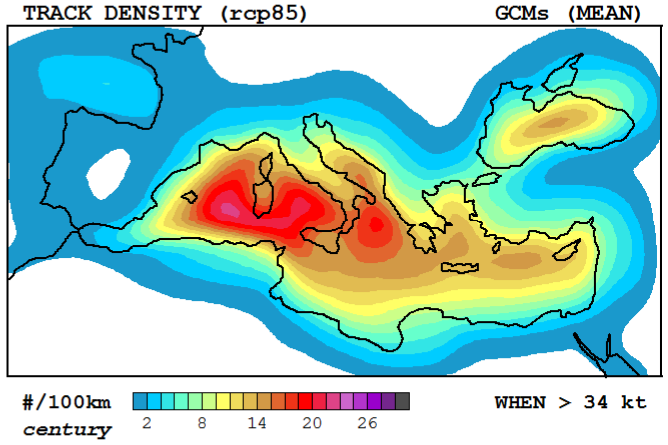
CORR

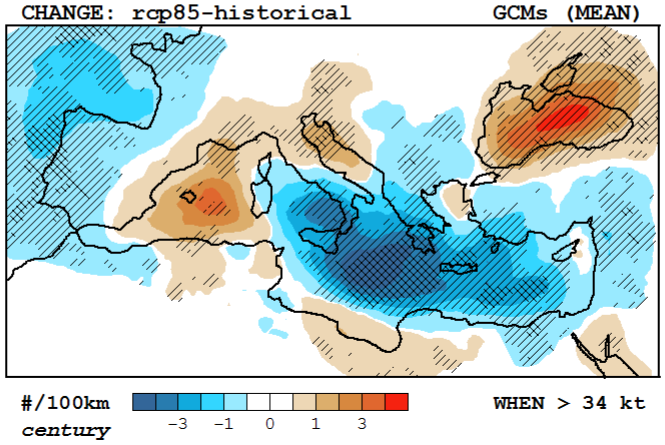
REAn01 = 0.948
REAn02 = 0.942
MEAN = **0.945**

RMSE

REAn01 = 1.907
REAn02 = 1.930
MEAN = **1.918**

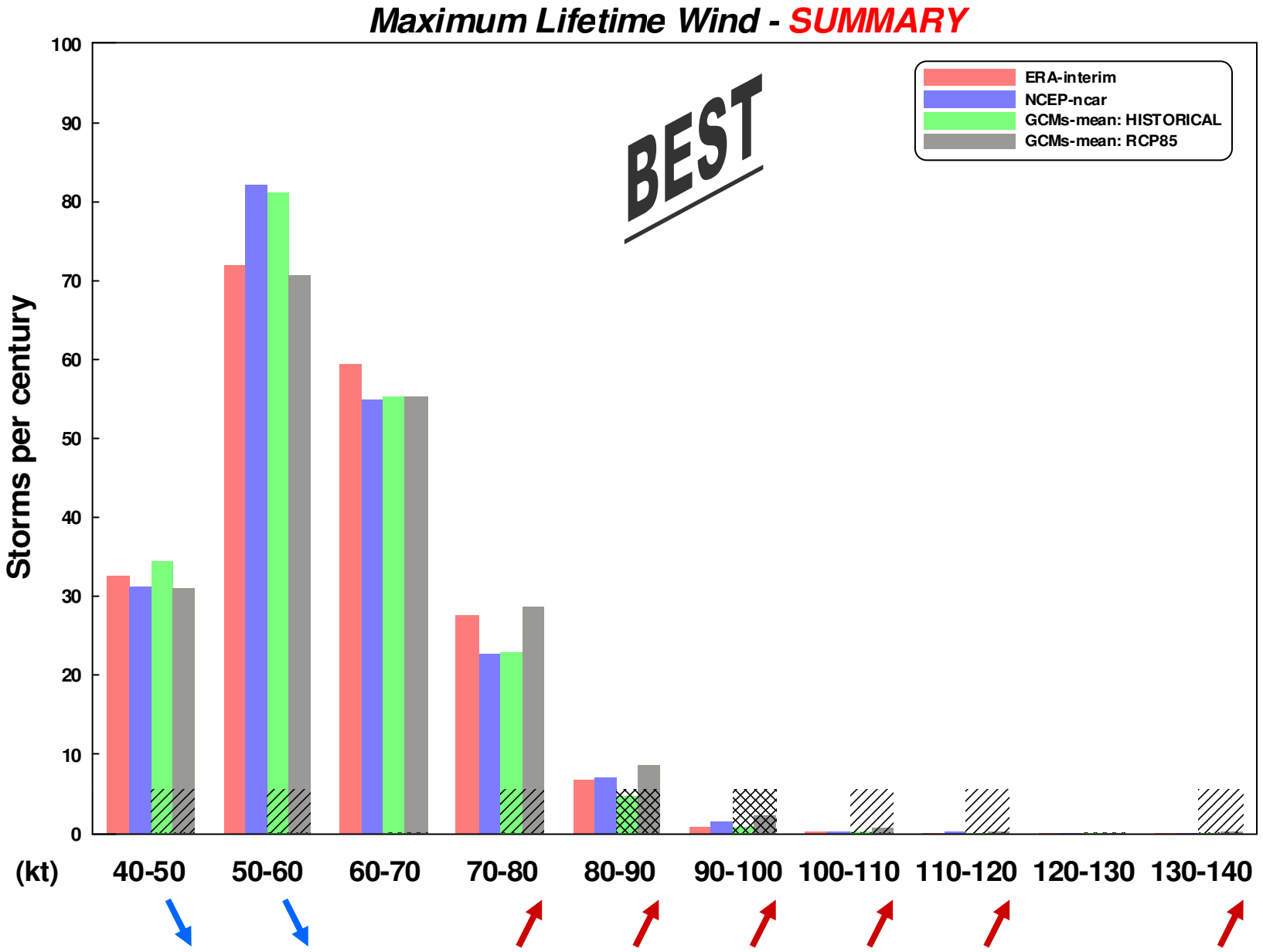


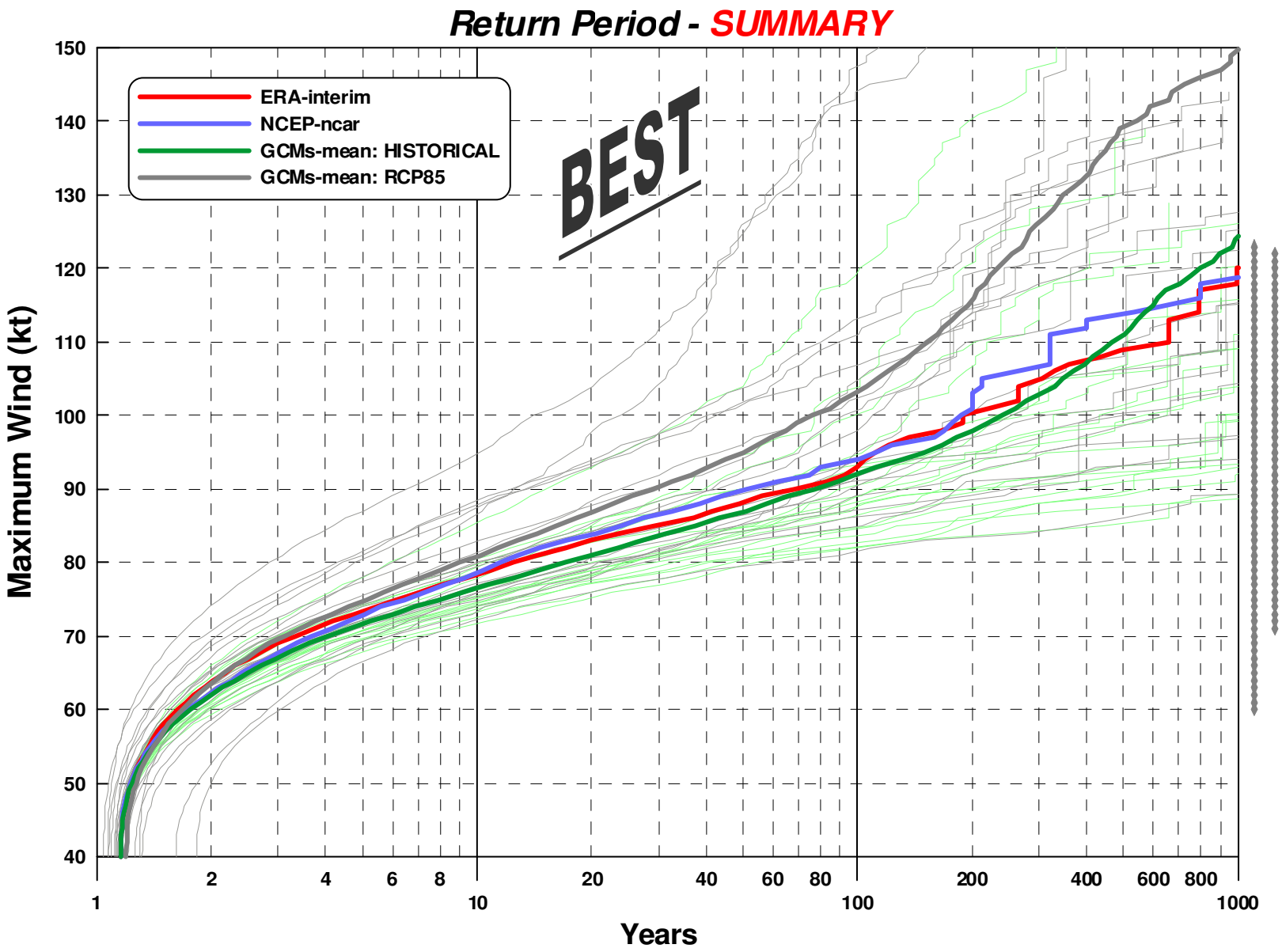


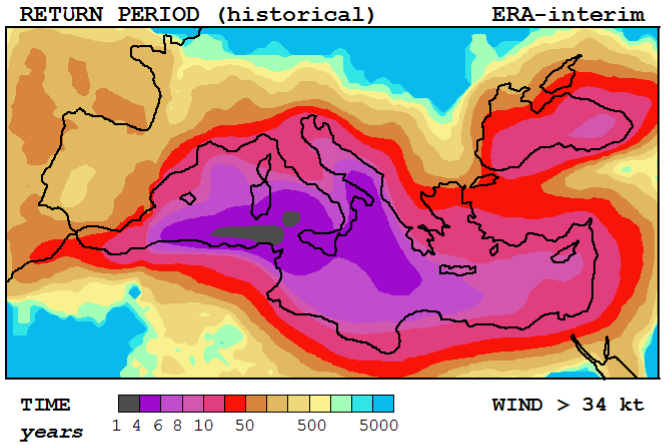


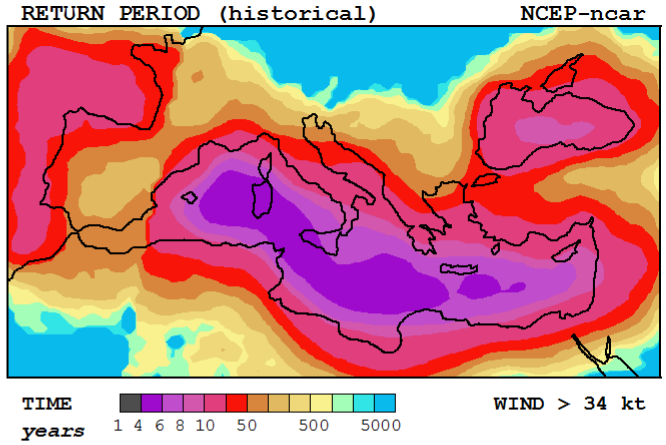
Track Density Summary

BEST


Maximum Lifetime Wind - SUMMARY
BEST
ERA-interim
NCEP-ncar
GCMs-mean: HISTORICAL
GCMs-mean: RCP85
Storms per century
100
90
80
70
60
50
40
30
20
10
0
(kt)
40-50
50-60
60-70
70-80
80-90
90-100
100-110
110-120
120-130
130-140


Return Period - SUMMARY
ERA-interim
NCEP-ncar
GCMs-mean: HISTORICAL
GCMs-mean: RCP85
BEST
Maximum Wind (kt)
150
140
130
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
Years



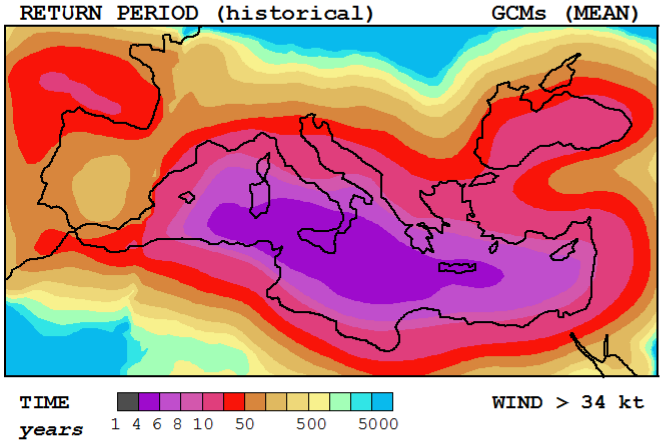


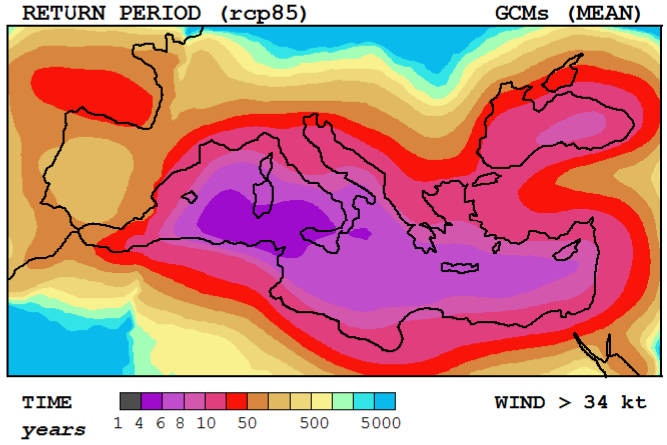
CORR

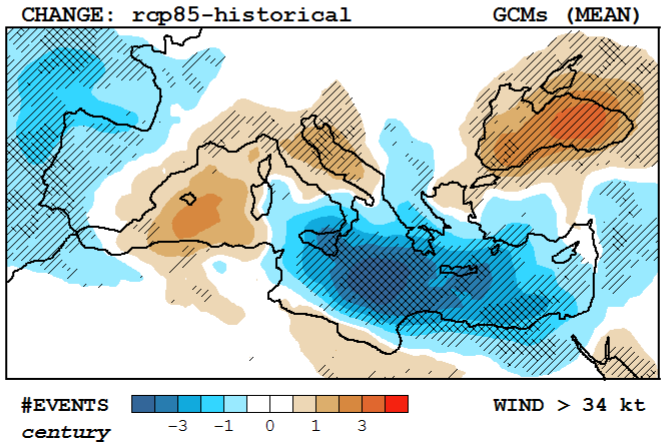
REAn01 = 0.768
REAn02 = 0.742
MEAN = **0.755**

RMSE

REAn01 = 2.157
REAn02 = 4.131
MEAN = **3.144**

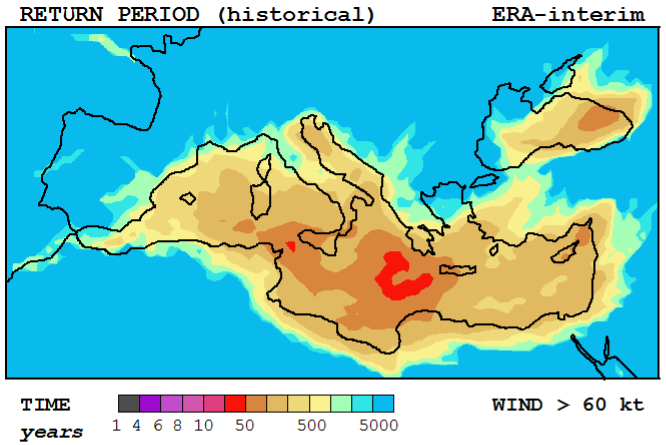


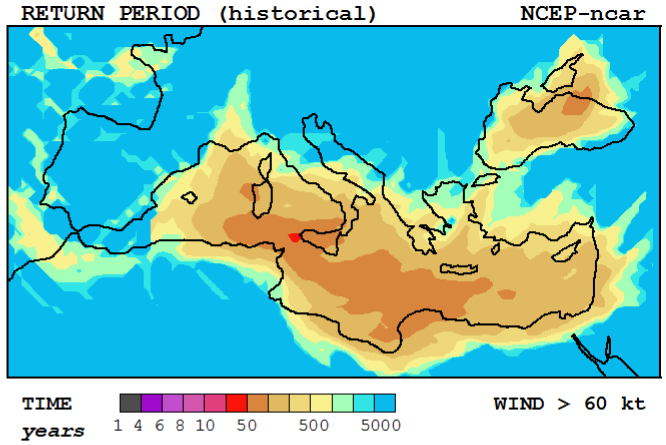




Return Period 34 kt Summary

BEST



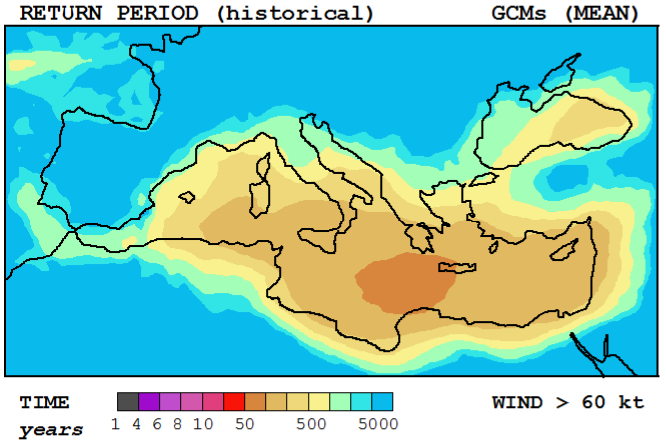


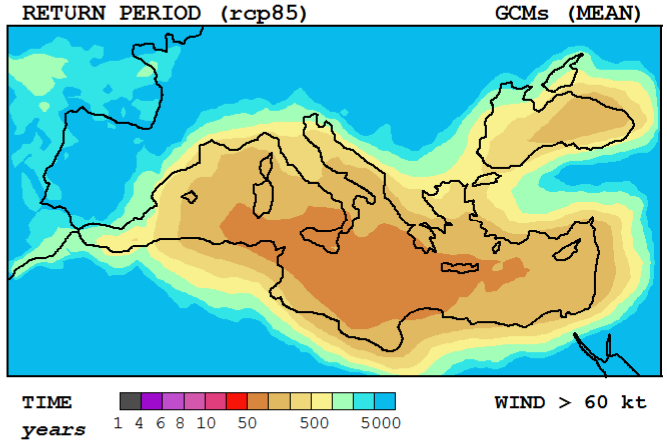
CORR

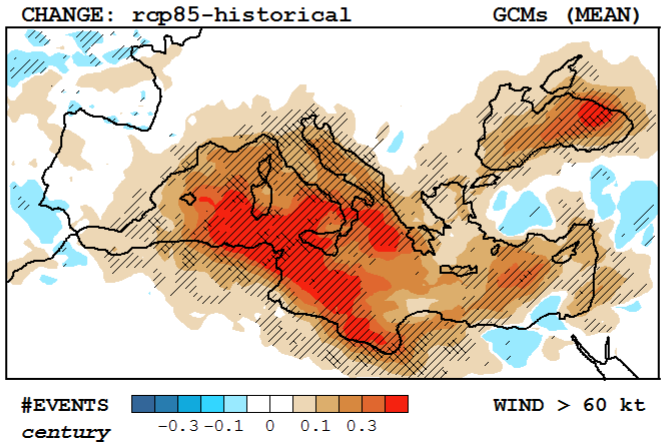
REAn01 = 0.604
REAn02 = 0.649
MEAN = **0.626**

RMSE

REAn01 = 4.972
REAn02 = 8.418
MEAN = **6.695**

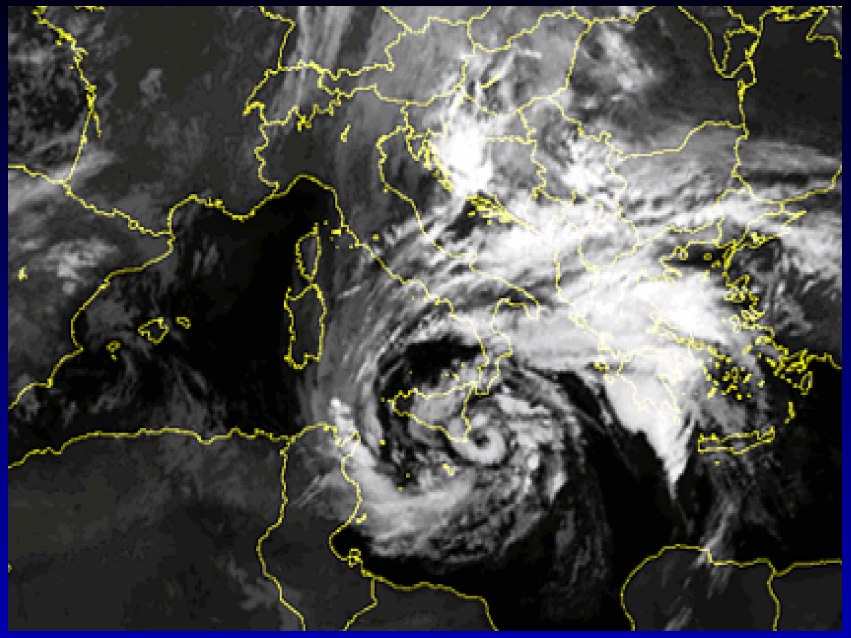






Return Period 60 kt Summary

BEST



THANK YOU !!!