# Estimating MEDICANE Extreme Rainfall Risk in the Context of Climate Change

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# ...Let's START with our JCLI-ARTICLE



DOI: 10.1175/JCLI-D-16-0255.1

## Climate Change and Hurricane-Like Extratropical Cyclones: Projections for North Atlantic Polar Lows and Medicanes Based on CMIP5 Models

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(Manuscript received 28 March 2016, in final form 14 September 2016)

ABSTRACT

A novel statistical–deterministic method is applied to generate thousands of synthetic tracks of North Atlantic (NA) polar lows and Mediterranean hurricanes ("medicanes"); these synthetic storms are compatible with the climates simulated by 30 CMIP5 models in both historical and RCP8.5 simulations for a recent (1986–2005) and a future (2081–2100) period, respectively. Present-to-future multimodel mean changes in storm risk are analyzed, with special attention to robust patterns (in terms of consensus among individual models) and privileging in each case the subset of models exhibiting the highest agreement with the results yielded by two reanalyses. A reduction of about 10%–15% in the overall frequency of NA polar lows that would uniformly affect the full spectrum of storm intensities is expected. In addition, a very robust regional redistribution of cases is obtained, namely a tendency to shift part of the polar low activity from the south Greenland–Icelandic sector toward the Nordic seas closer to Scandinavia. In contrast, the future change in the number of medicanes is unclear (on average the total frequency of storms does not vary), but a profound reshaping of the spectrum of lifetime maximum winds is found: the results project a higher number of moderate and violent medicanes at the expense of weak storms. Spatially, the method projects an increased occurrence of medicanes in the western Mediterranean and Black Sea that is balanced by a reduction of storm tracks in contiguous areas, particularly in the central Mediterranean; however, future extreme events (winds > 60 kt; 1 kt = 0.51 m s$^{-1}$) become more probable in all Mediterranean subbasins.

## 1. Introduction

Climate change adaptation strategies demand an analysis of the magnitude of the possible impacts on

examples of mesoscale maritime extratropical storms that from a physical point of view may operate much as tropical cyclones (Emanuel and Rotunno 1989; Emanuel

# 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:*

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

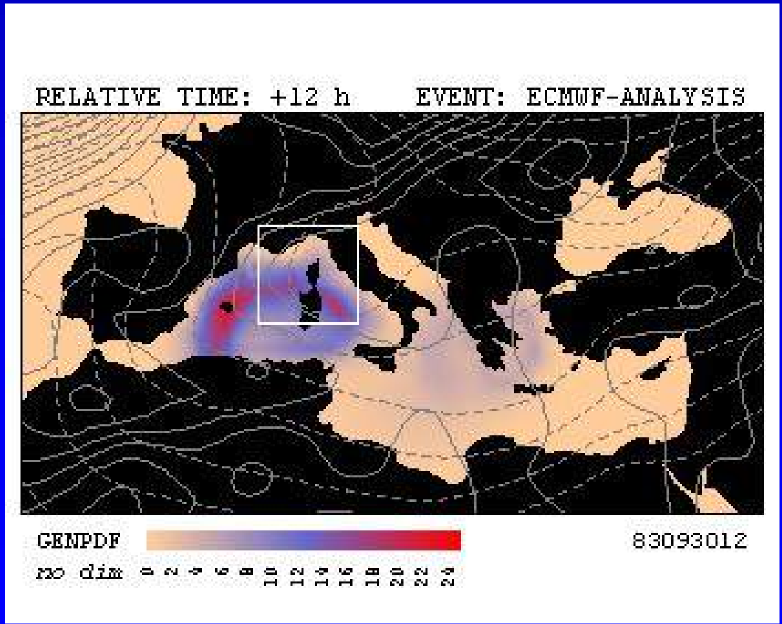
**GENIX parameter**
**(Emanuel and Nolan, 2004)**

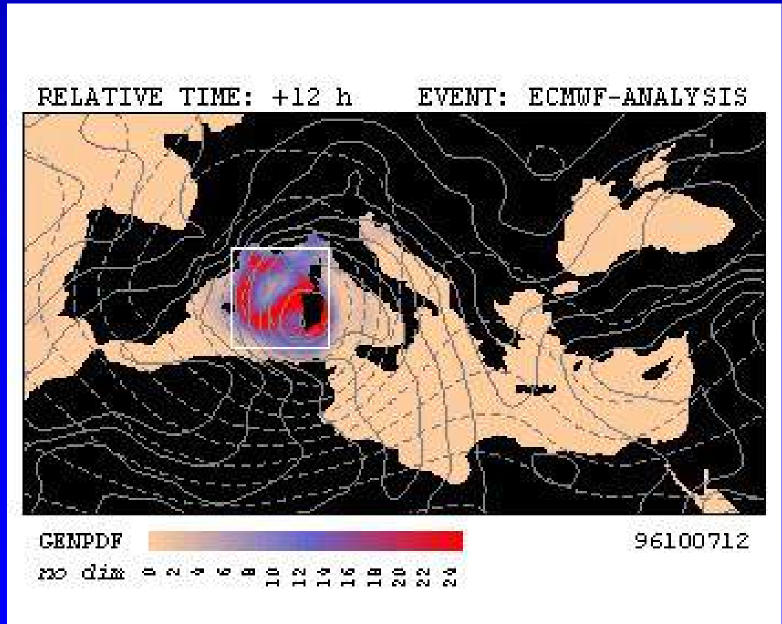
$\eta \equiv 850\, hPa\ absolute\ vorticity\ (s^{-1}),$

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

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

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



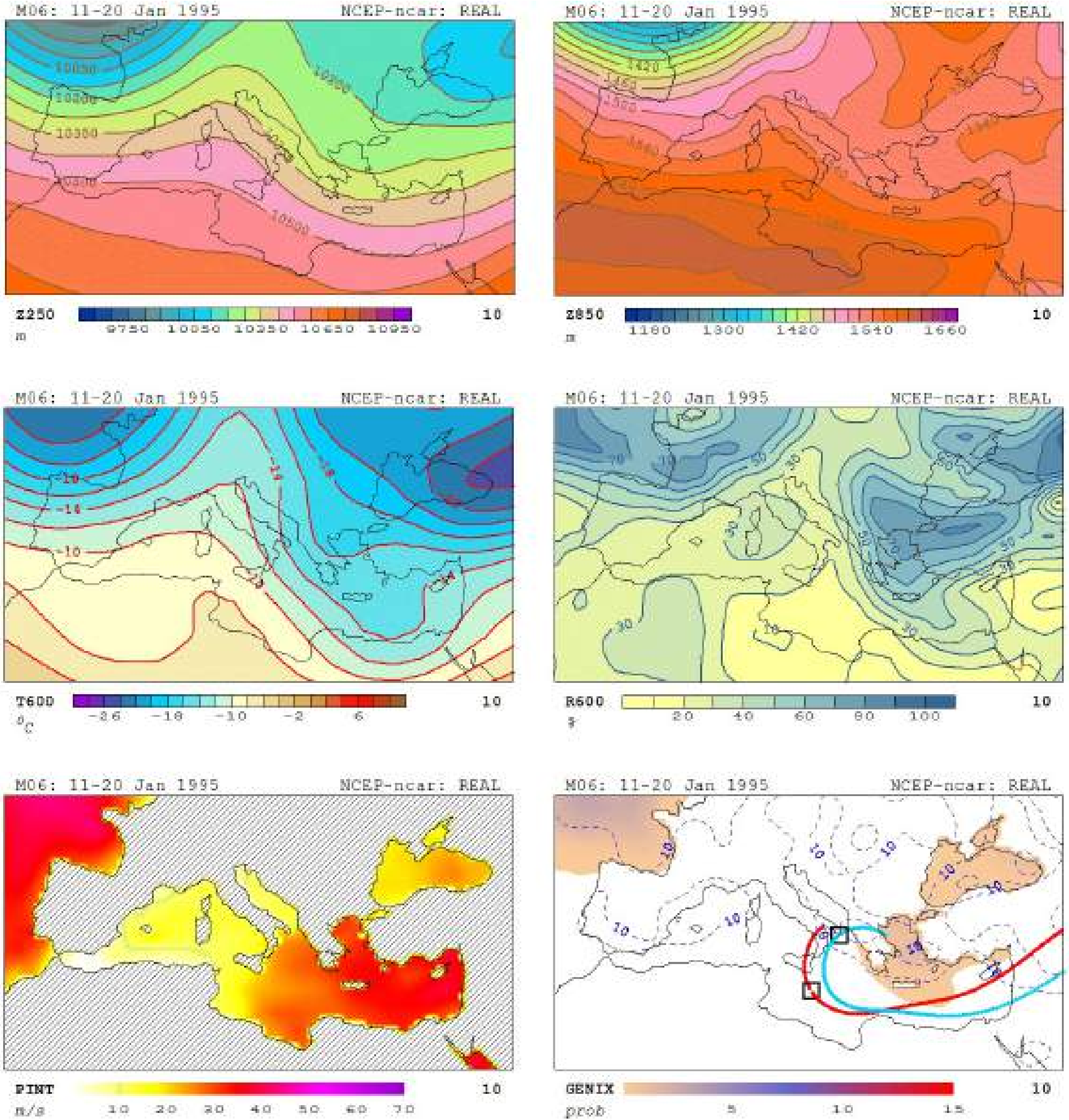

- *Necessary but no sufficient* ingredient …

# ILLUSTRATIVE EXAMPLE

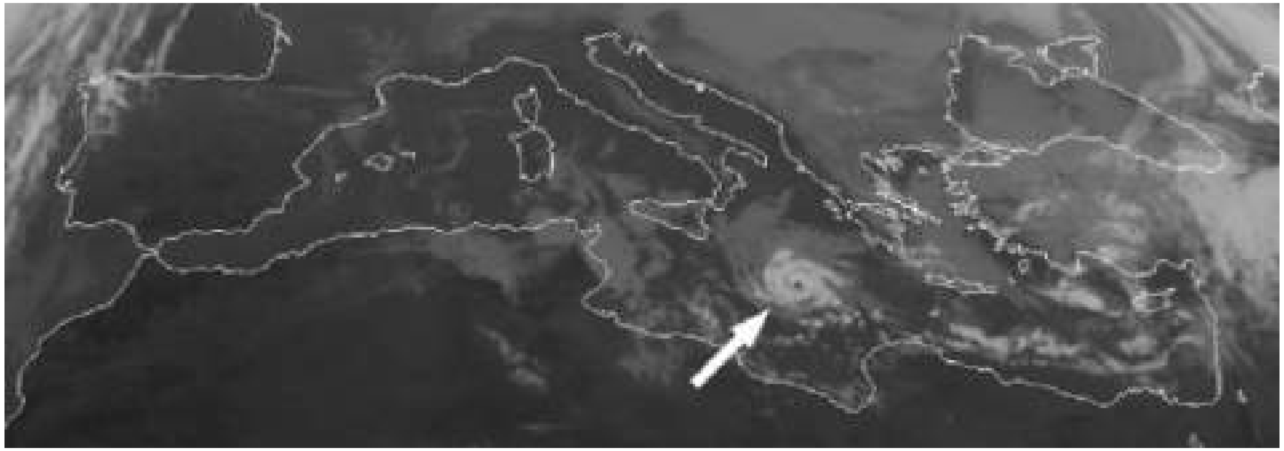
## "LYBIAN" MEDICANE

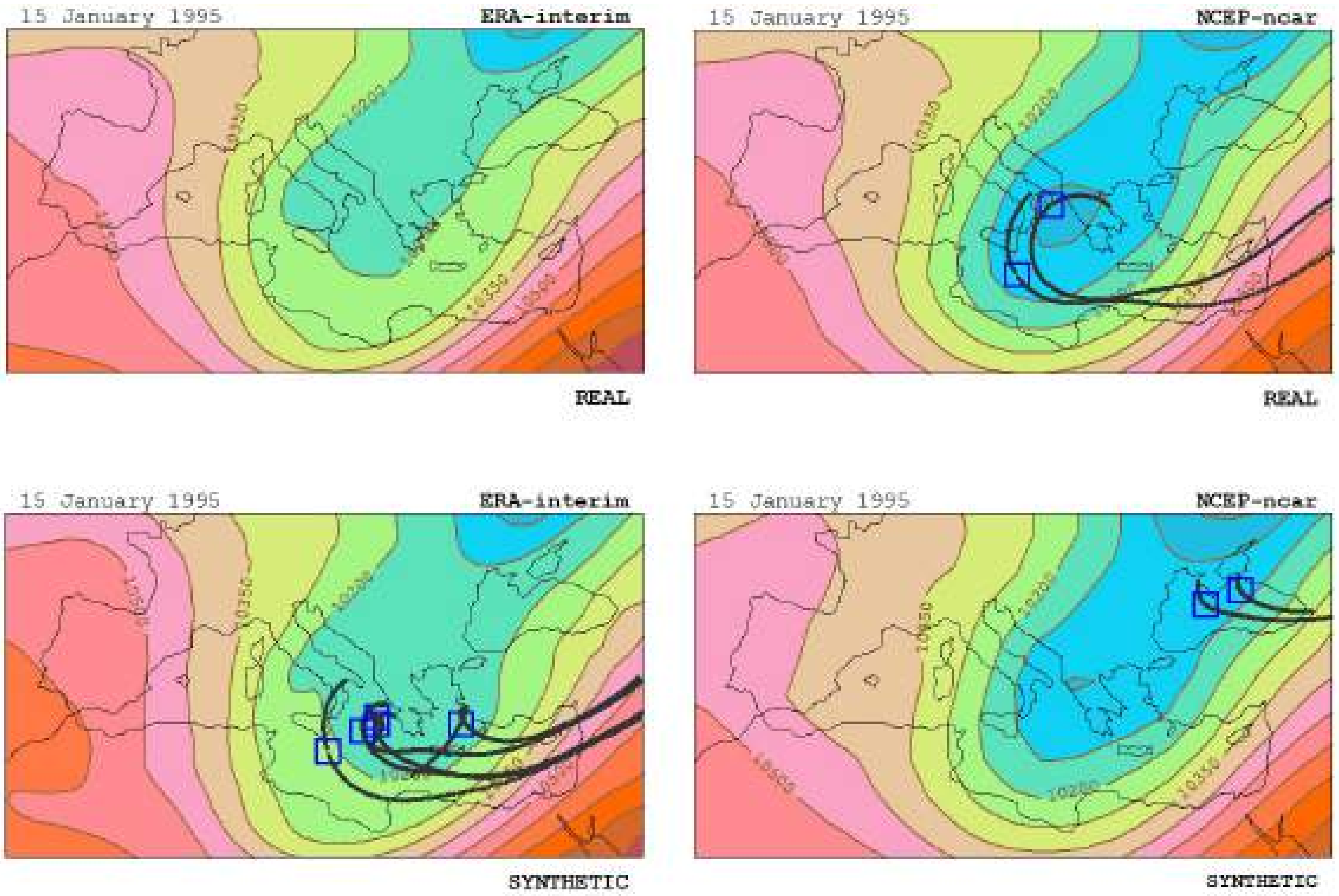
## Central Mediterranean, 15-16 January 1995

# TRACKING method



SYNTHETIC
analogues





# RESULTS

**REANALYSIS 1**

***ERA-interim***

20349 tracks
7918 survivors

200 storms/century

**REANALYSIS 2**

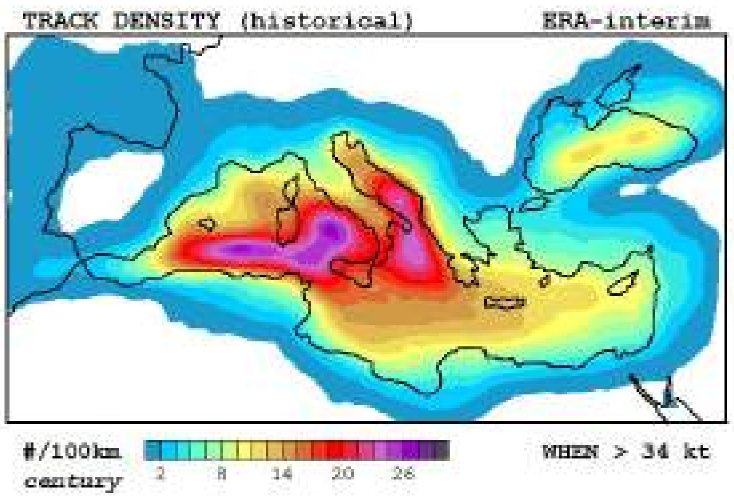
***NCEP-ncar***

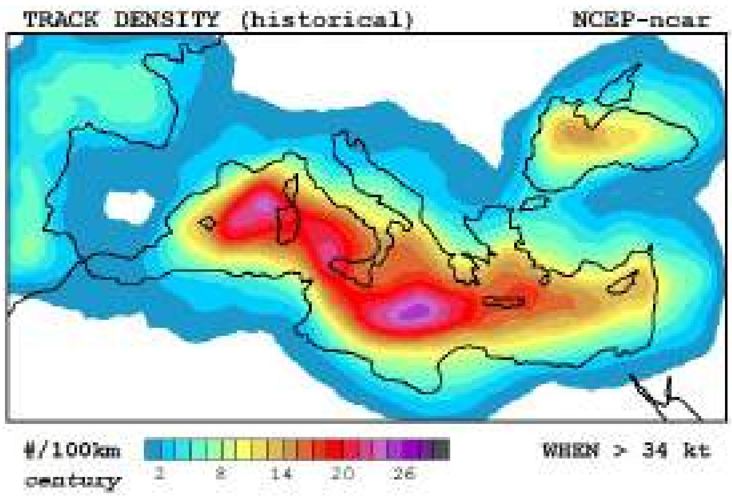
20276 tracks
6379 survivors

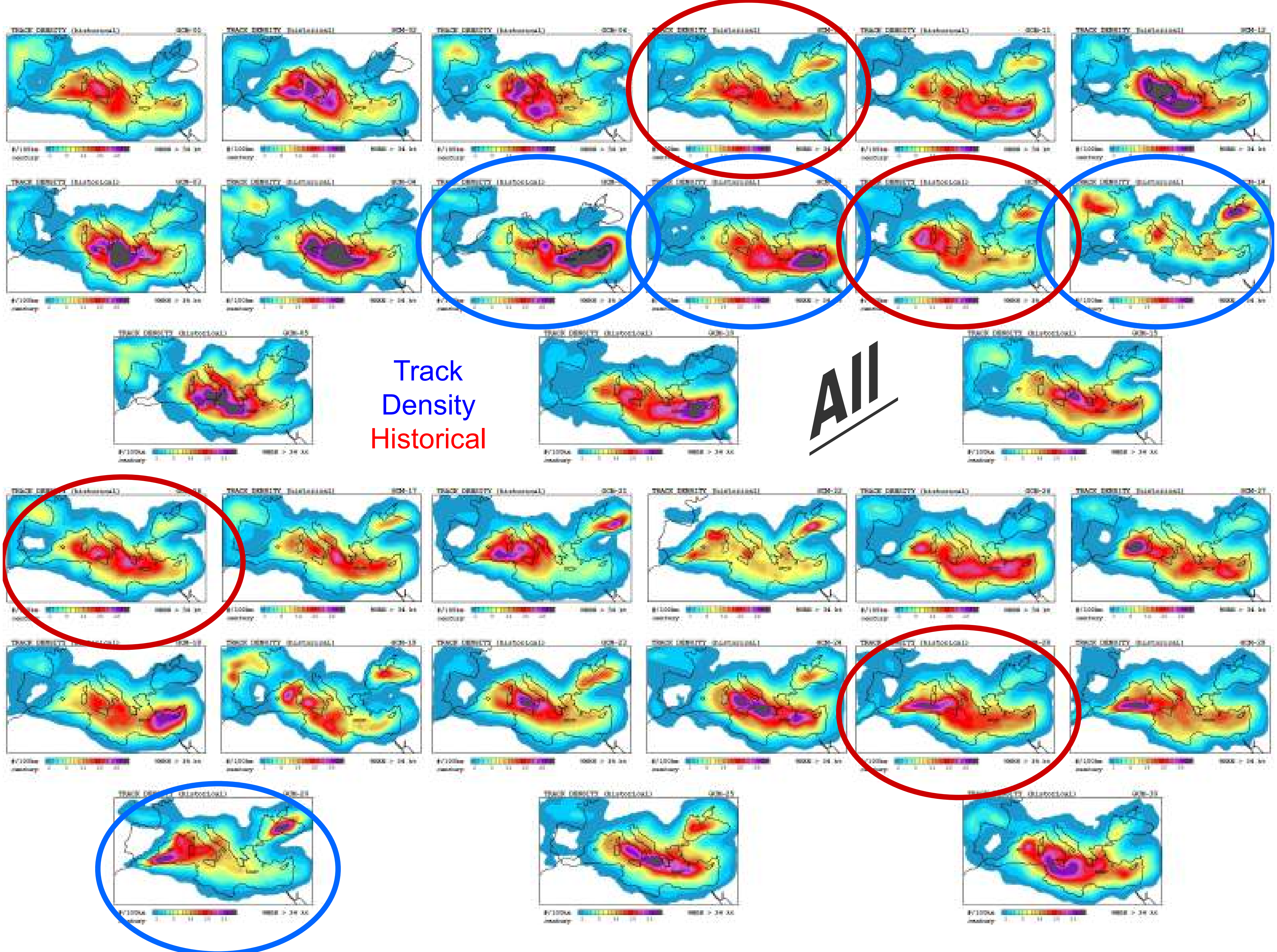
200 storms/century

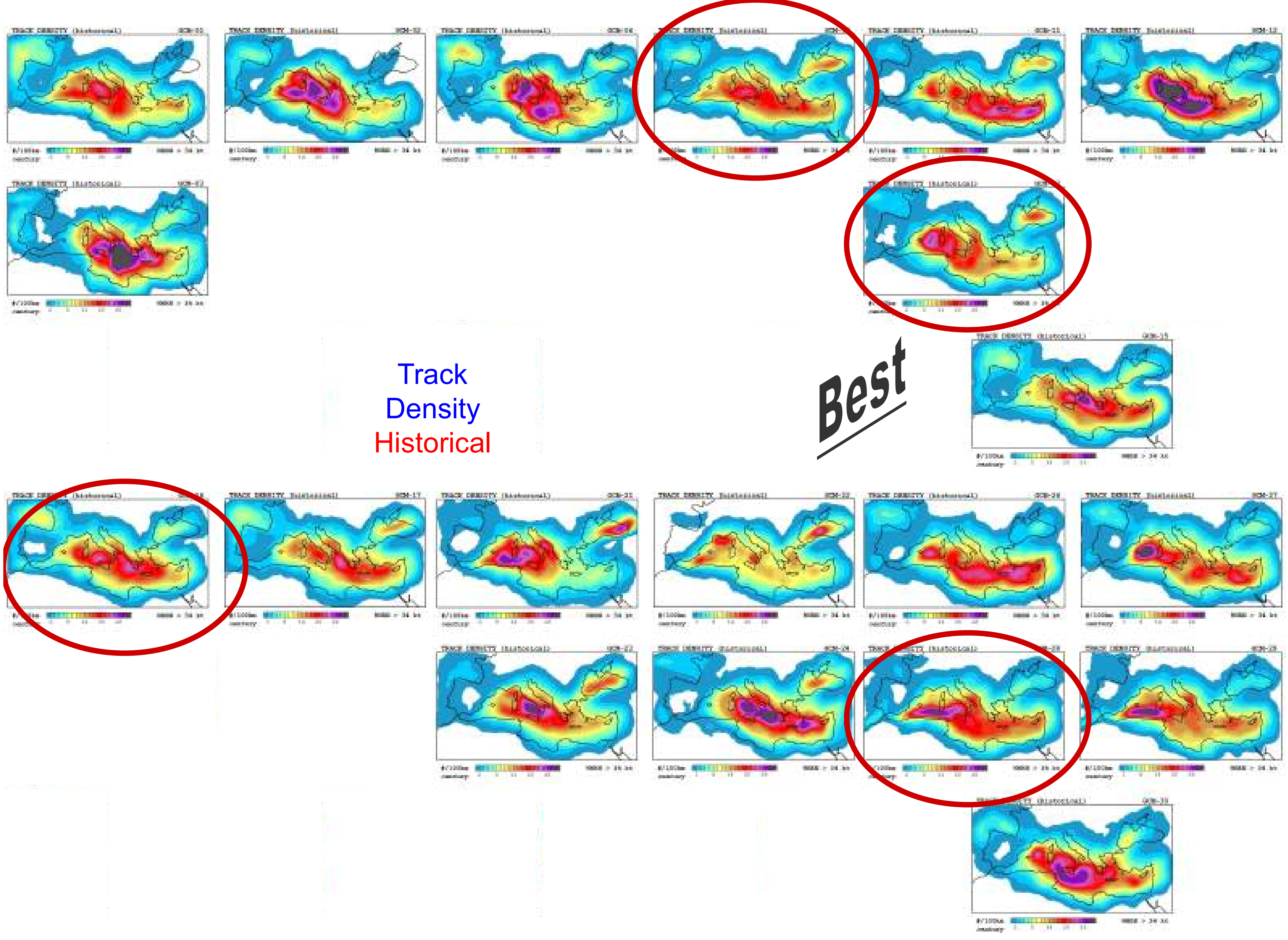
***HISTORICAL scenario***

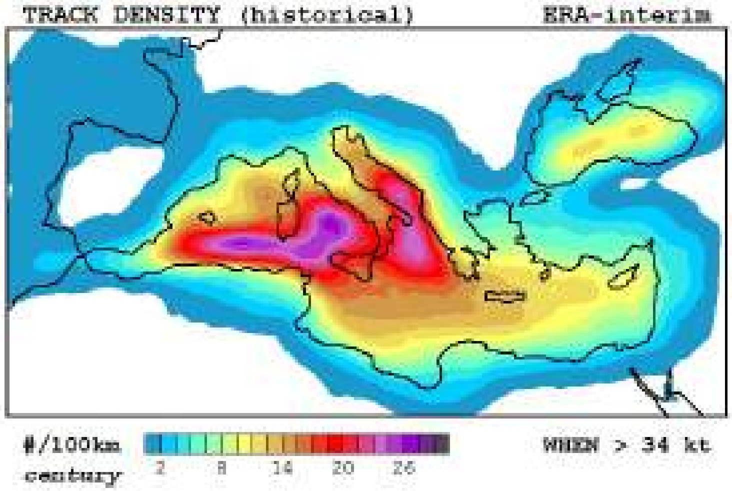
**200 storms (per century)**

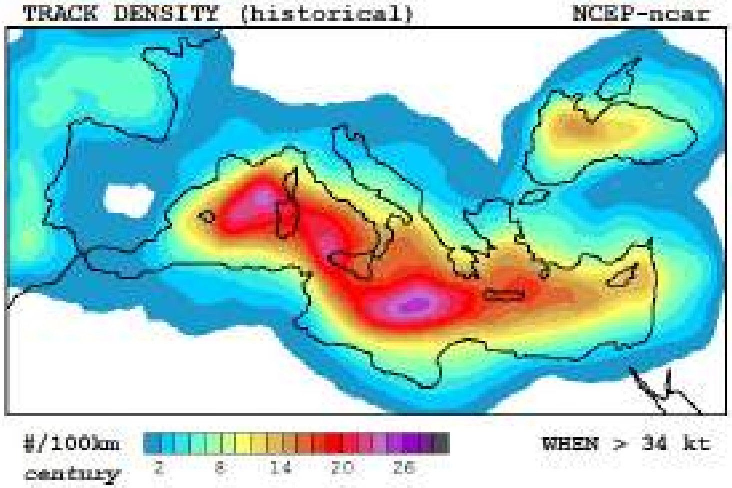



Track
Density
Historical
All


Track
Density
Historical
Best



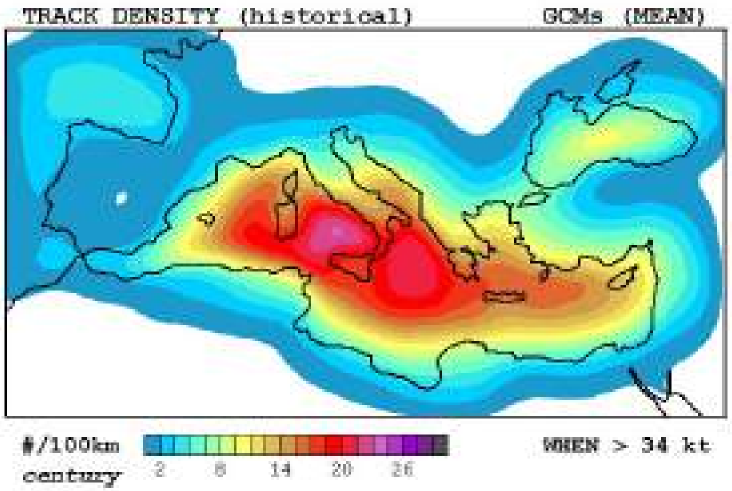



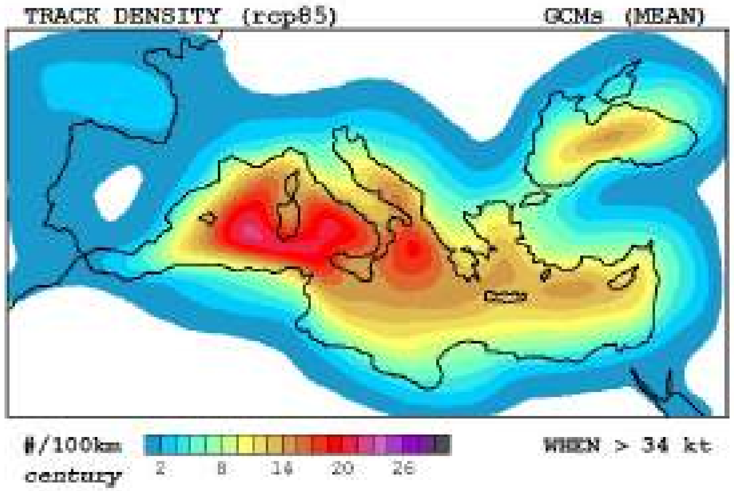

***CORR***

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

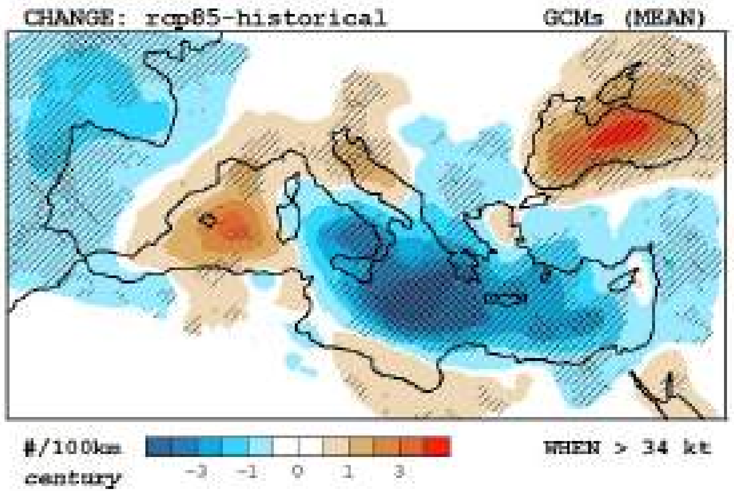
***RMSE***

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

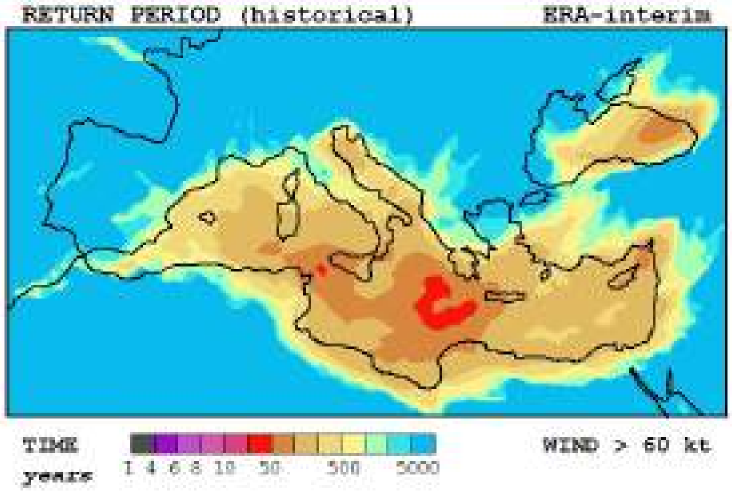


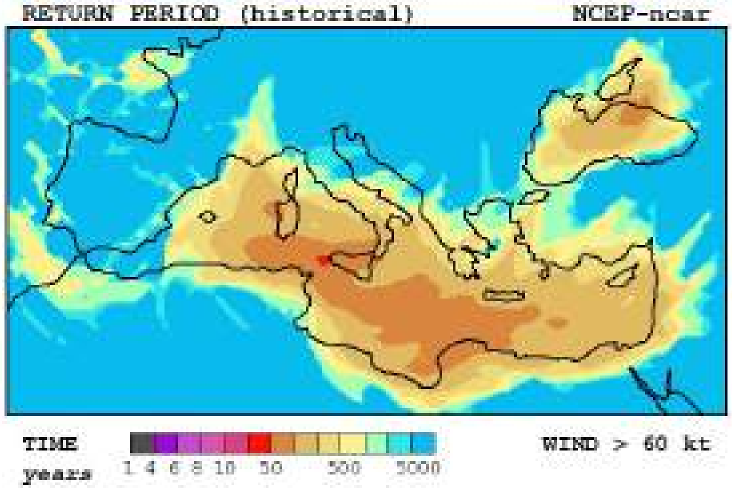




Track
Density
Summary



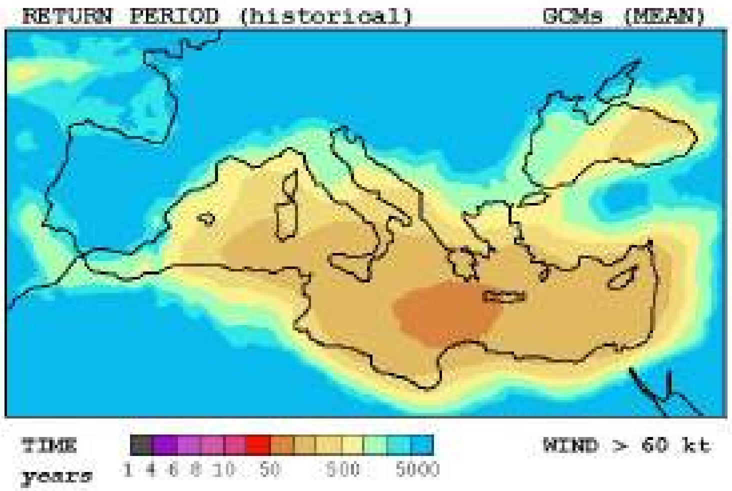

**BEST**

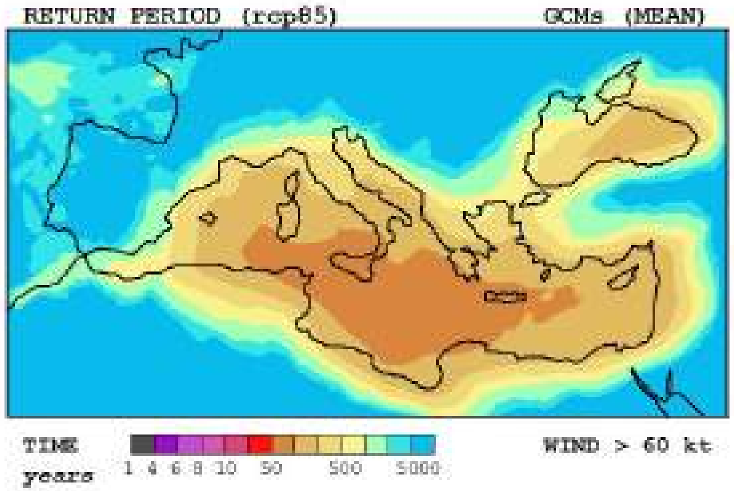


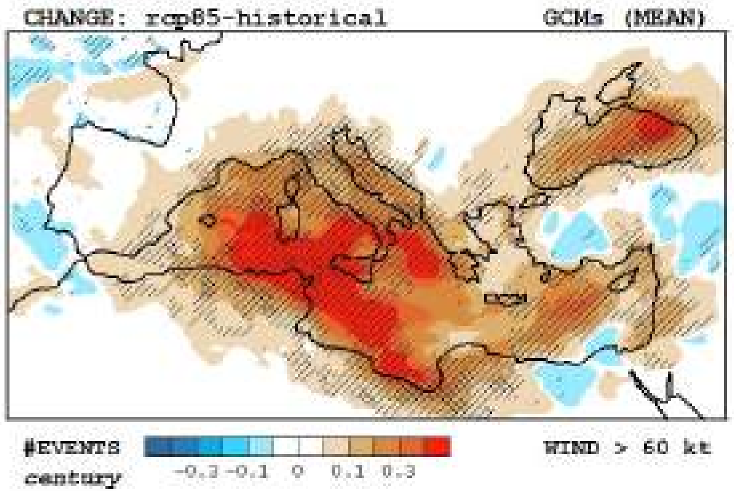

***CORR***
REAn01 = 0.604
REAn02 = 0.649
MEAN = **0.626**

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




Return
Period 60 kt
Summary




***BEST***

# RAINFALL

TRAM SIMULATIONS

...see TRAM details in the QJRMS-ARTICLE

Received: 31 May 2023 | Revised: 24 November 2023 | Accepted: 28 November 2023

DOI: 10.1002/qj.4639

Quarterly Journal of the Royal Meteorological Society RMetS

RESEARCH ARTICLE

# TRAM: A new non-hydrostatic fully compressible numerical model suited for all kinds of regional atmospheric predictions

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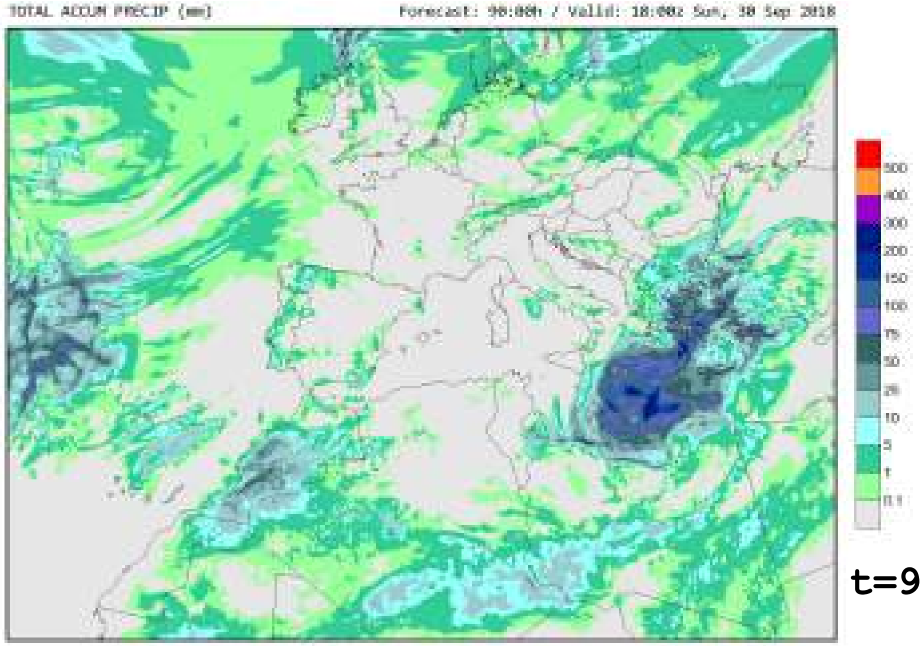
**Funding information**
Agencia Estatal de Investigación, Grant/Award Number: PID2020-113036RB-I00 / AEI / 10.13039/501100011033

**Abstract**

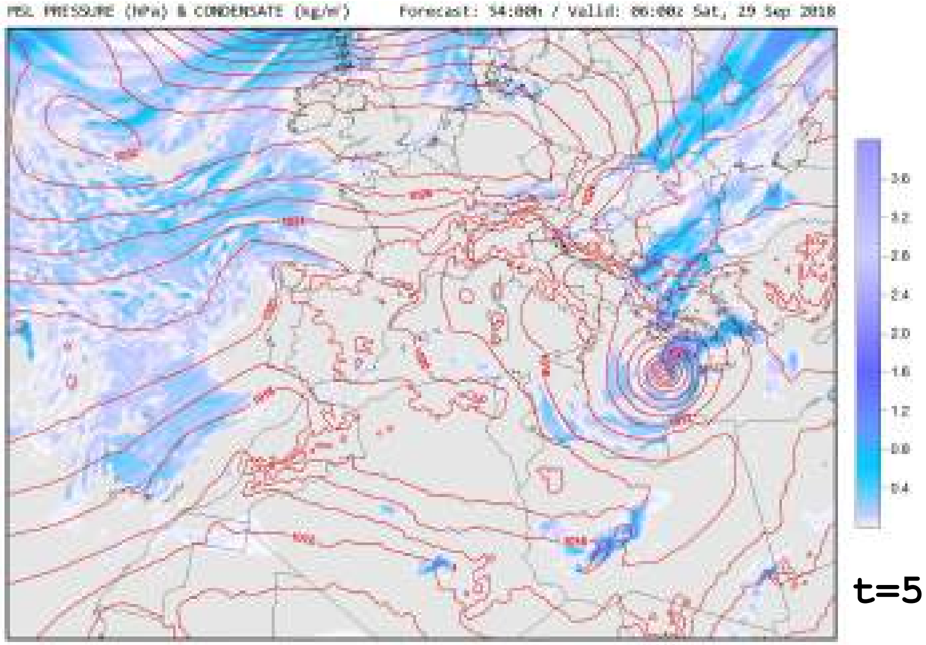
A new limited-area numerical model (TRAM, for Triangle-based Regional Atmospheric Model) has been built using a non-hydrostatic and fully compressible version of the Navier–Stokes equations. Advection terms are solved using a Reconstruct–Evolve–Average (REA) strategy over the computational cells. These cells consist of equilateral triangles in the horizontal. The classical z-coordinate is used in the vertical, allowing arbitrary stretching (e.g., higher resolution in the Planetary Boundary Layer, PBL). Proper treatment of terrain slopes in the bottom boundary conditions allows for accurately representing the orographic forcing. To gain computational efficiency, time splitting is used to integrate fast and slow terms separately and acoustic modes in the vertical are solved implicitly. For real cases on the globe, the Lambert map projection

## > "ZORBAS" Ionian Sea Medicane (IC: 00 UTC 27 Sept 2018)

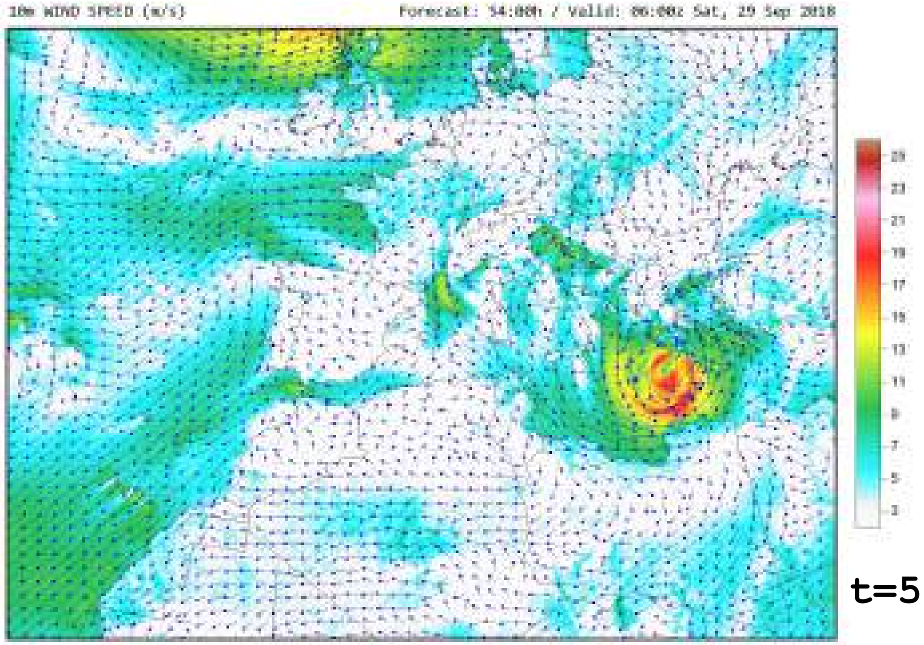
(MR_double:dx=12.5km,dzm=250m,stretch=10,dt=25s,Nstep=6,90h)




t=90h

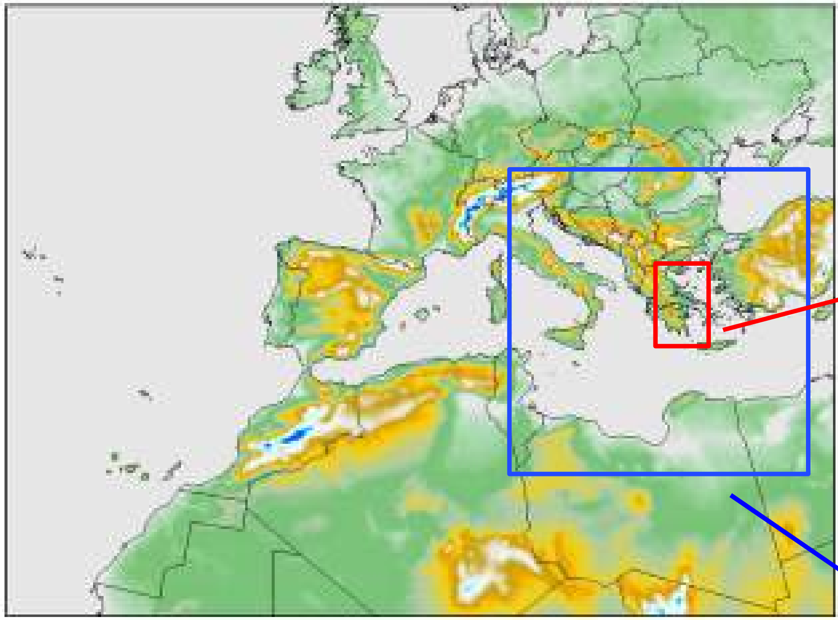


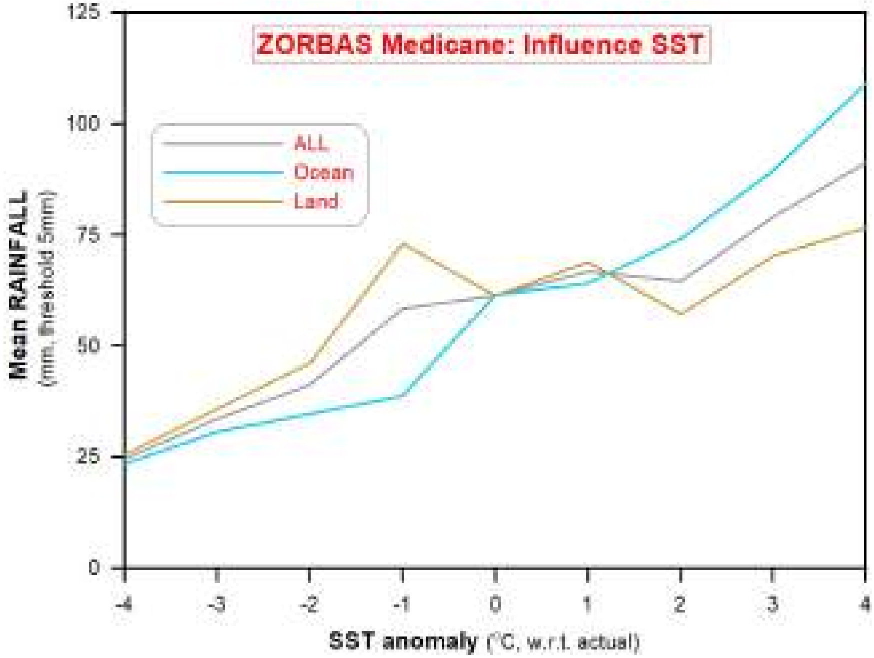

t=54h

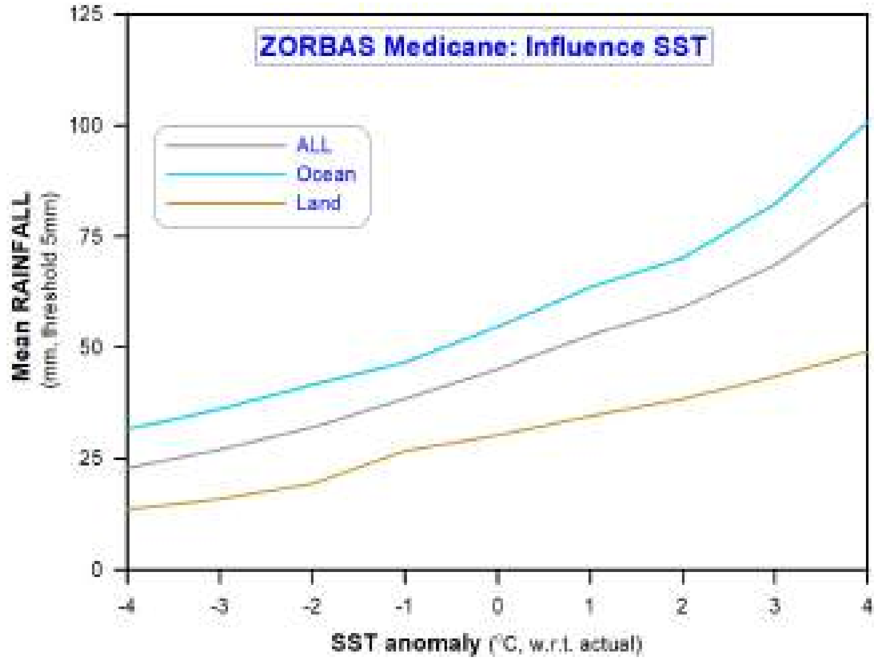



t=54h

## > "ZORBAS" Ionian Sea Medicane (IC: 00 UTC 27 Sept 2018) 90h-RUN





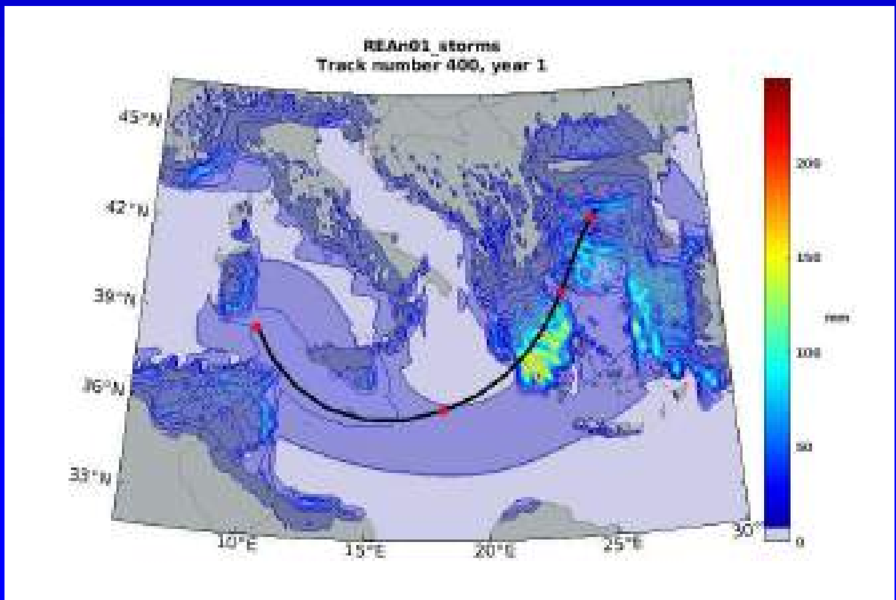



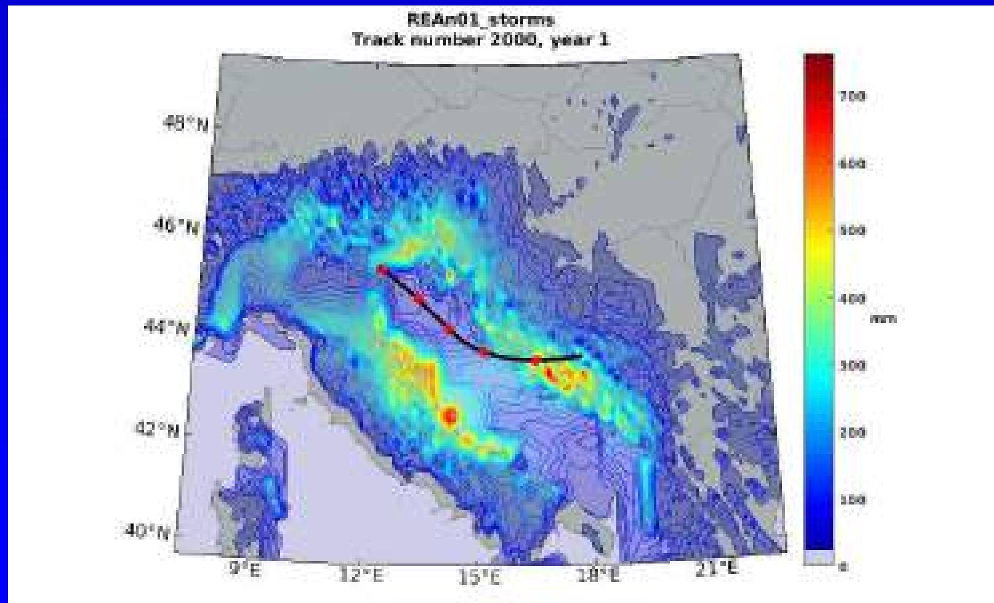
# *RAINFALL ALGORITHM:* **Feldmann & Emanuel et al. (JAMC, 2019)**

- ***Principle**: Uses the net vertical velocity and the saturation specific humidity to calculate the vertical vapor flux, and this, multiplied by a precipitation efficiency, is assumed to equal the precipitation rate.*

- ***CHIPS**: w is a model variable, but poorly resolved outside the inner core and is not recorded. Additionally, topographical effects and asymmetries owing to interactions between the TC and environmental flow and surface friction are not accounted for in the model itself.*

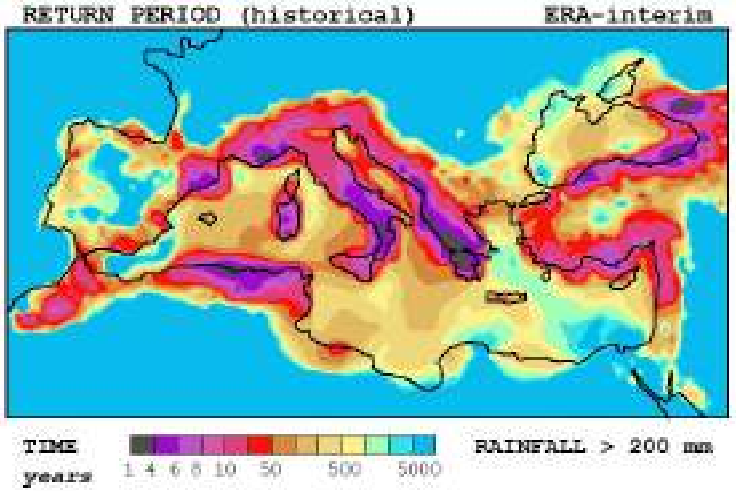
- ***Estimation**: w is estimated at any point within the storm's wind field by summing five components due to: topography, boundary layer convergence, storm vorticity changes, baroclinic interactions, and radiative cooling.*

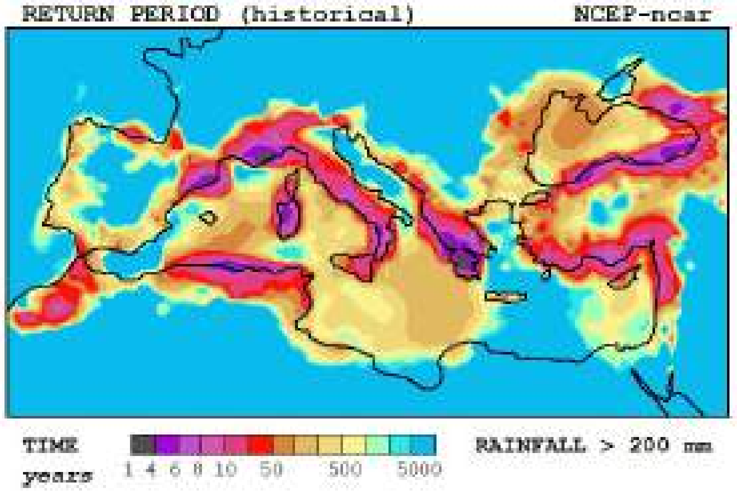


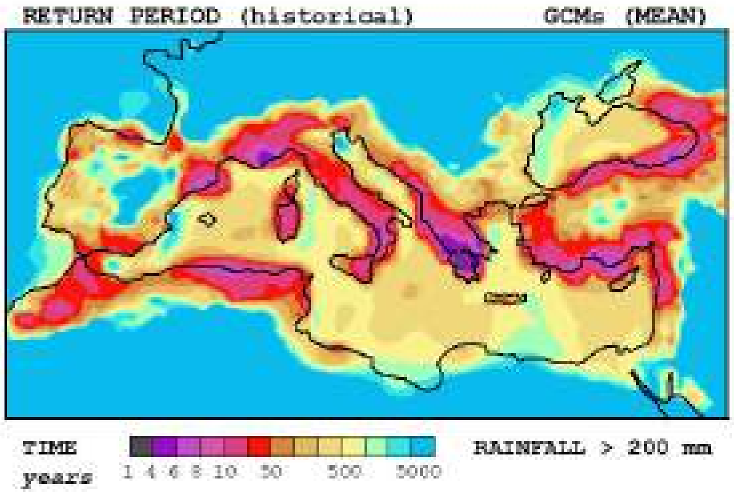



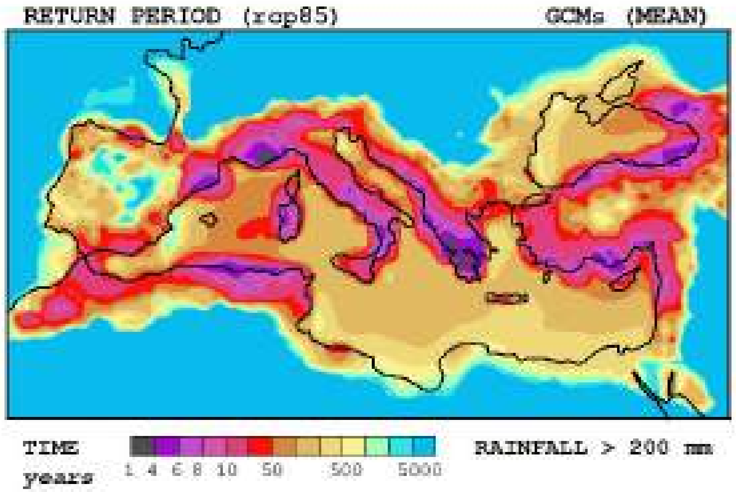
# Return Period for

# RAINFALL > 200 mm

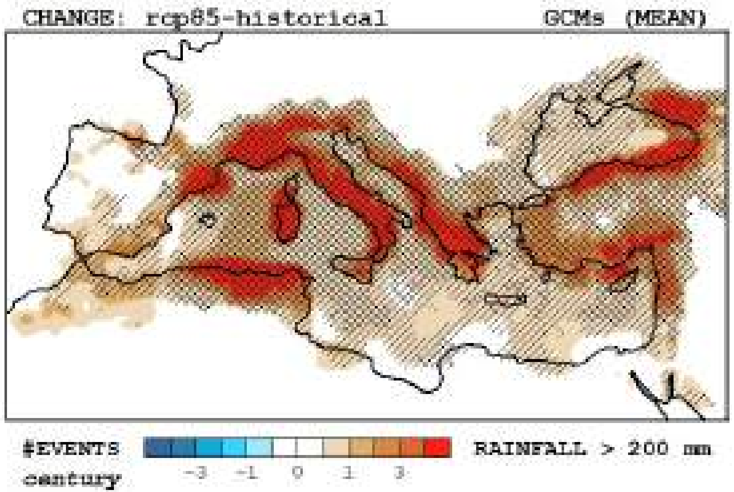


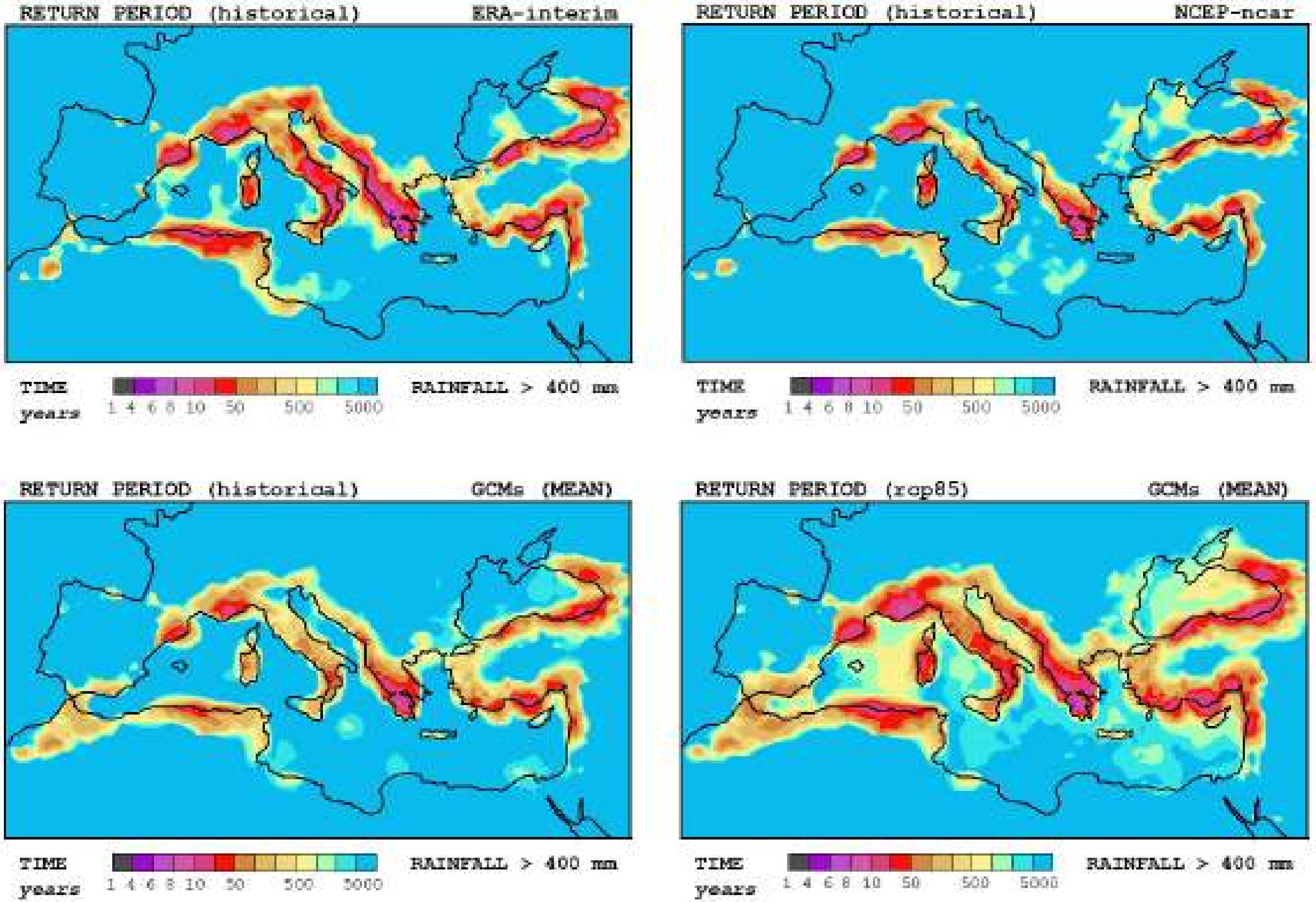

Return Period
200 mm
Summary

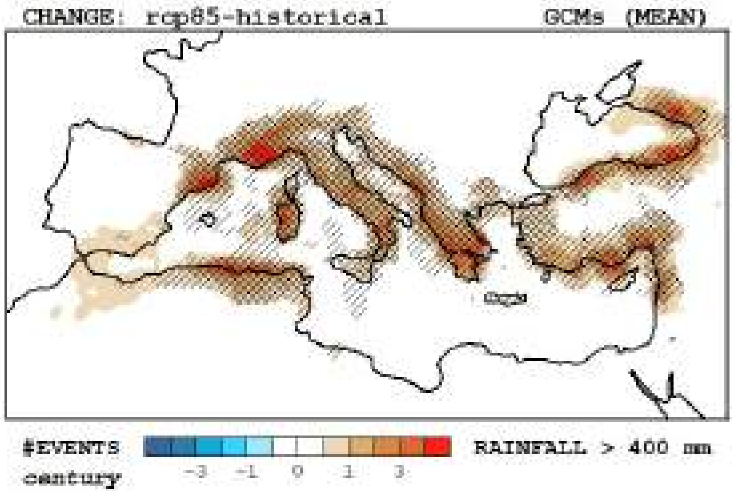



BEST

# Return Period for

# RAINFALL > 400 mm




Return Period
400 mm
Summary

BEST

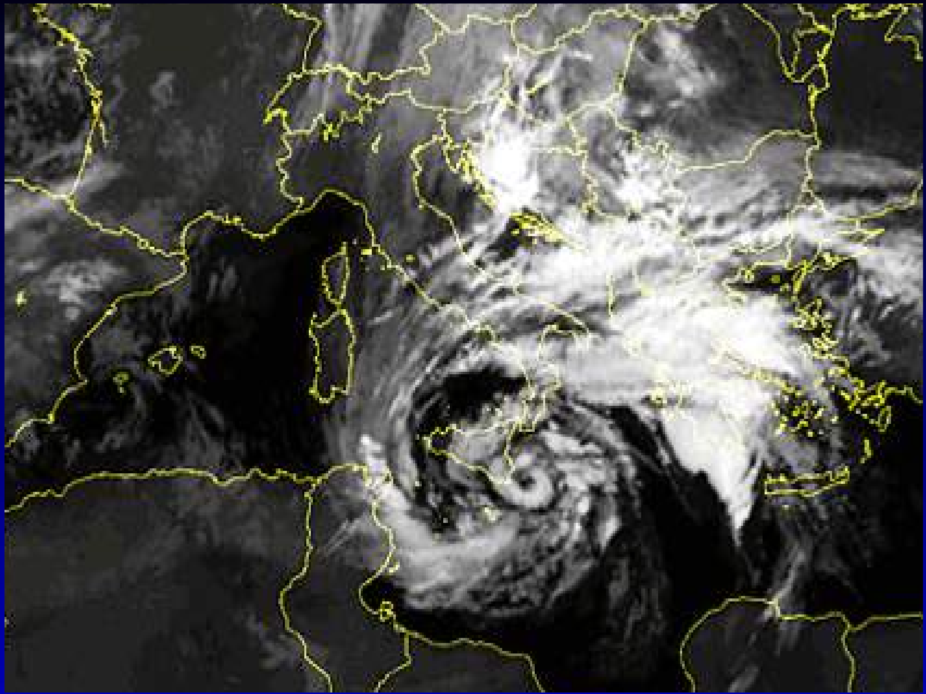
# CONCLUSIONS

- Our 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. CMIP6 / 7 ???

- Future change in the number of medicanes is unclear (on average the total frequency of storms does not vary) but a profound redistribution is found. Our method projects an increased occurrence of medicanes in the western Mediterranean and Black Sea, balanced by a reduction of storm tracks in contiguous areas, particularly in the central Mediterranean

- We found a remarkable modification of the spectrum of lifetime maximum WINDS: the results project a higher number of moderate and violent medicanes at the expense of weak storms. In particular, future extreme events (winds > 60 kt) become more likely in all Mediterranean regions, and the probability of violent medicanes (winds > 90 kt) for the basin as a whole more than doubles the current risk.

- The projected intensification of medicanes is mirrored in terms of RAINFALL: future scenarios indicate a notable increase in the occurrence of potentially flood-producing accumulations (e.g. storm total rainfalls exceeding 200 or 400 mm). There is a strong consensus among models that the the current risk will more than double in many coastal areas.



THANK YOU !!!