

Predictability of large scale drivers leading intense Mediterranean cyclones

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1. Introduction

Windstorms, extreme precipitations and instant floods seems to strike the Mediterranean area with increasing frequency. These events occur simultaneously during intense tropical-like Mediterranean cyclones. These *intense Mediterranean cyclones* (IMC, hereinafter) are frequently associated with wind, heavy precipitation and changes in temperature, generating high risk situations such as flash floods and large-scale floods with significant impacts on human life and built environment. Although the dynamics of these phenomena is well understood, little is know about their climatology. It is therefore very difficult to make statements about the frequency of occurrence and its response to climate change. Thus, intense Mediterranean cyclones have many different physical aspects that can not be captured by a simple standard approach.

Main Goals:

- The first challenge of this work is to provide an extended catalogue and climatology of these phenomena by reconstructing a database of intense Mediterranean cyclones dating back up to 1969 using the satellite, the literature and reanalyses within the framework of the [EFIMERA project](#)
- Applying a method based on dynamical systems theory we analyse and attribute their future changes under different anthropogenic forcings by using future simulations (CMIP).

2. Data

Observations

We have used satellite observations from Eumetsat and NOAA satellites (ref. 3, 4) from 1969 to 2018

Models

We use data from simulations of the present and future climate performed with 17 CMIP5 models, applying a bias correction to the simulated Z500 fields.

Reanalysis

we have used for z500, precipitation and sea-level-pressure (slp) from ERA5 (0.25x0.25) over the period 1979-2018, in order to describe and verify the actual tropical-like dynamical structure of the event detected from satellite data. We have used the ERA5 data also to compute the large-scale circulation analogues and perform the attribution part of the study.

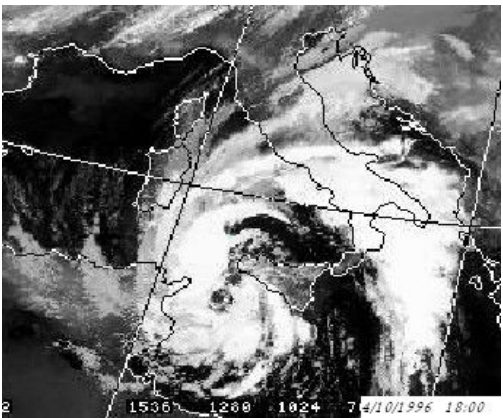


Figure 1: Example of a IMC in Sicily from the Satellite

01_bcc-csm1-1-m
02_bcc-csm1-1
03_BNU-ESM
04_CanESM2
05_CMCC-CMS
06_CNRM-CM5
07_GFDL-ESM2G
08_GFDL-ESM2M
09_HadGEM2-CC
10_IPSL-CM5A-MR
11_IPSL-CM5B-LR
12_MIROC-ESM-CHEM
13_MIROC-ESM
14_MPI-ESM-LR
15_MPI-ESM-MR
16_MRI-CGCM3
17_NorESM1-M

4. Methods

4.1 IMC Detection

4.1.1 IMC Reconstruction

Reconstruction of a database based on documented occurrences of IMC composed by 110 events lasting from 1 to 7 days documented in the literature and observed in the satellite

No.	Date (YYYYMMDD)	Duration (days)	Cluster	Name	Reference
25	2007/02/25	3	W		Gutierrez et al. 2016
26	2007/04/16	3	W	Orestano	Eumetsat
27	2007/03/19	5	W	Paul	Eumetsat
28	2007/01/01	4	E	Alidia	Eumetsat
29	2006/09/25	3	C	Quelid	Gutierrez et al. 2016
30	2005/12/13	4	E	Zen	Gutierrez et al. 2016
31	2005/09/26	3	C	Lauri	Logez et al. 2007
32	2005/09/27	3	E	Enachios	Eumetsat
33	2005/09/15	2	E	Antigone	Eumetsat
34	2004/11/02	4	C	Ias	Eumetsat
35	2004/09/07	4	C	Hoson	Eumetsat
36	2004/05/25	3	W	Accurio	Eumetsat
37	2004/04/15	7	W	Vicky	Eumetsat
38	2003/10/14	7	W	Adelina	Gutierrez et al. 2016

Criteria:

- Presence of a core and rotating structures
- Convective storms surrounding the core
- 200 km < size < 1000 km

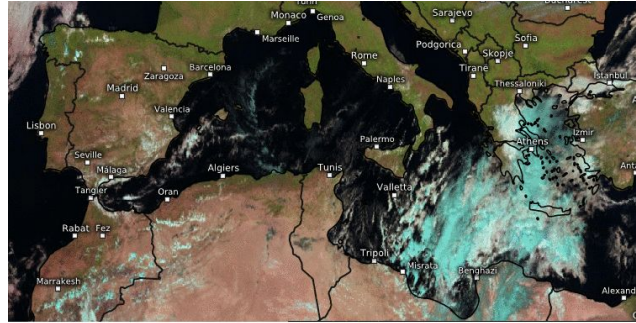


Figure 3: Example of one of the last IMC: Zorbas 27/09/2018

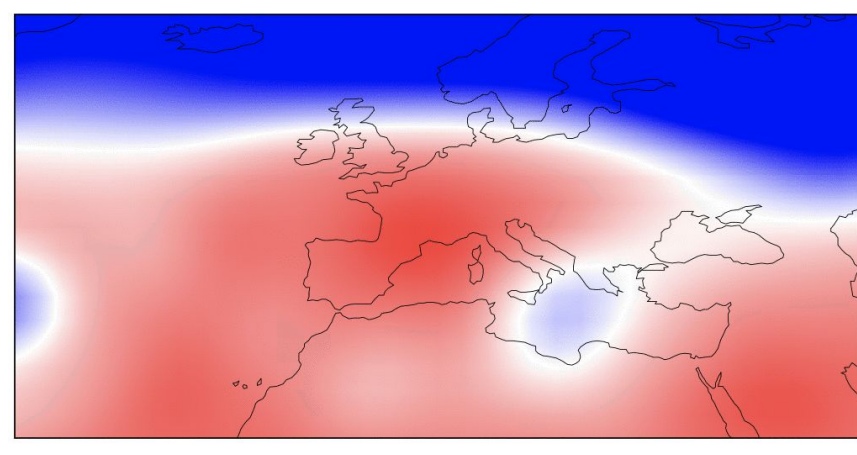


Figure 2: example of the new database of IMC reconstructed from the satellite data and b) frequency of IMC along the period 1969-2018

4.1.2 IMC Clusters

We have classified the IMC in three clusters depending on the location of the genesis: **West** IMC are the one developed around the Iberian Peninsula, **Central** are the IMC developed around Southern Mediterranean and usually impacting in the central Mediterranean sea, and **East** are the ones developed at Eastern Mediterranean (Balkans and eastern Europe)

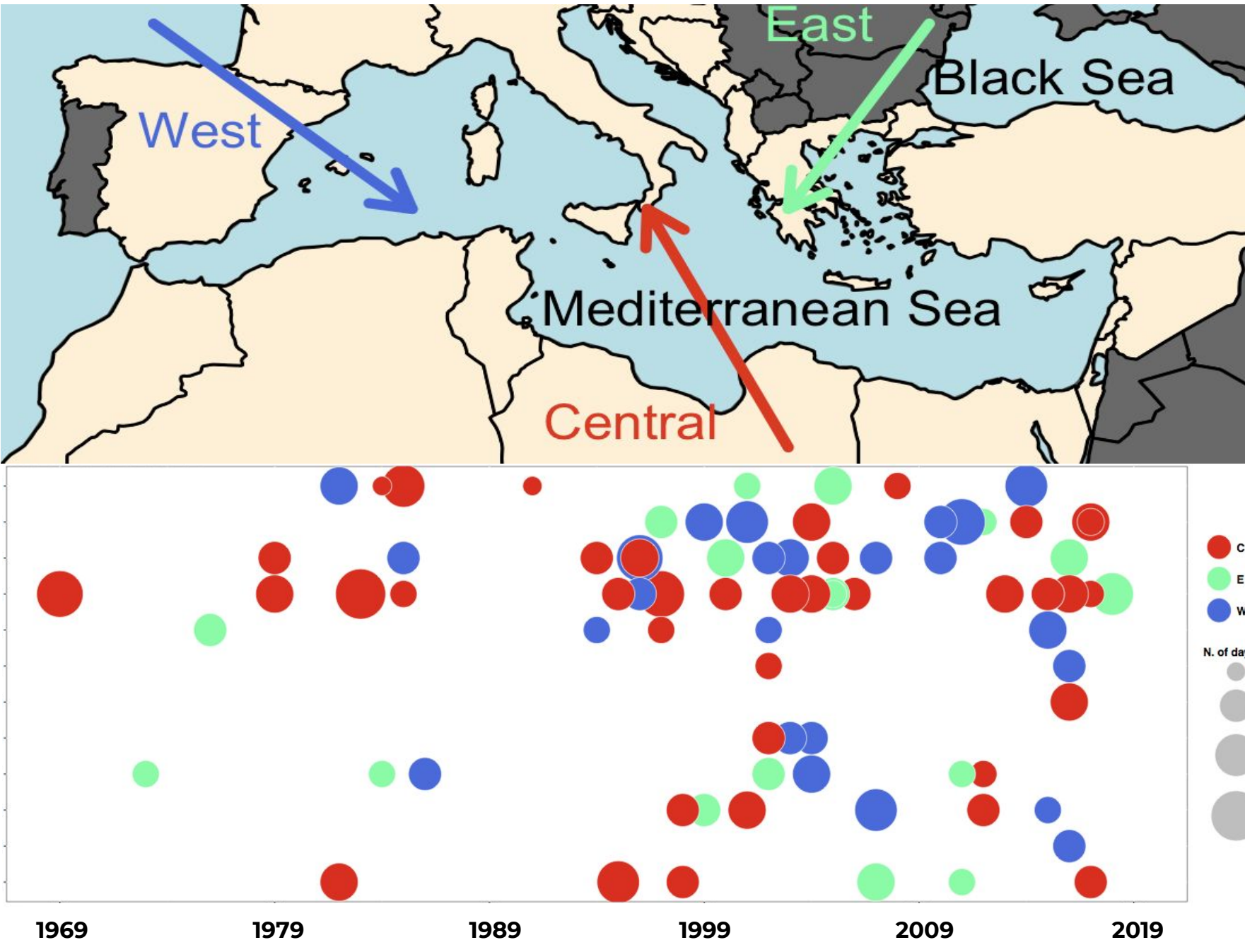


Figure 4: IMC Clusters: West, Central, and East

4.2 IMC Attribution

4.2.1 Dynamical Systems proxies

The atmospheric circulation's intrinsic predictability can be measured computing the local dimension **d** and the inverse of the persistence **θ**. Recent results have demonstrated their effectiveness in classifying **weather patterns** leading to climate extremes in the North Atlantic region (Faranda et al 2017). Using **d** and **θ** was demonstrated that Warmer SSTs in the North Atlantic correspond to more predictable atmospheric configurations, **hammad effect**, Faranda et al 2019

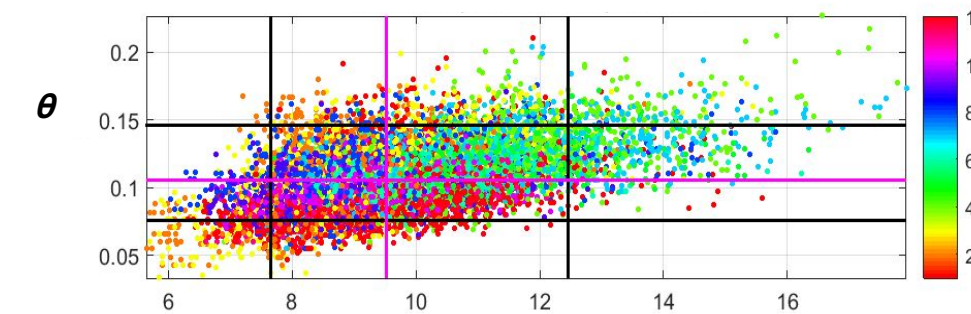


Figure 5: Example of the Attractor of the SLP using two dynamical proxies local dimension (d) and inverse of the persistence (theta). Each point on the attractor can be characterised by the local dimension (d), which indicates the number of degrees of freedom active locally around the point.

4.2.2 Analogues of circulation

The Analogues are days within the database which have a similar circulation to the day of interest.

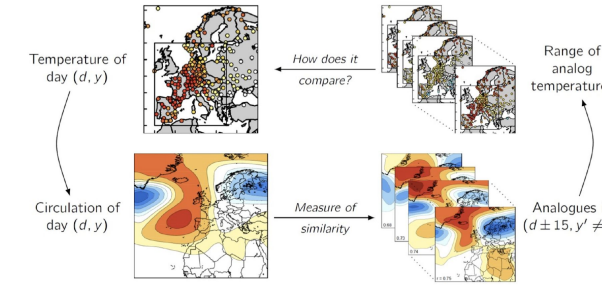


Figure 6: Example of flow analogues

4.2.3 Attribution method

The trajectories of the Z500 patterns associated to IMC are added to historical, RCP 4.5 and RCP 8.5 simulations. We compute the 2% best analogues of these IMC fields and consider three indicators:
-The mean **distance** of the analogues
-The local **dimension** (proxy of predictability)
-The **persistence** of the fields

5. Results

5.1 Large scale patterns

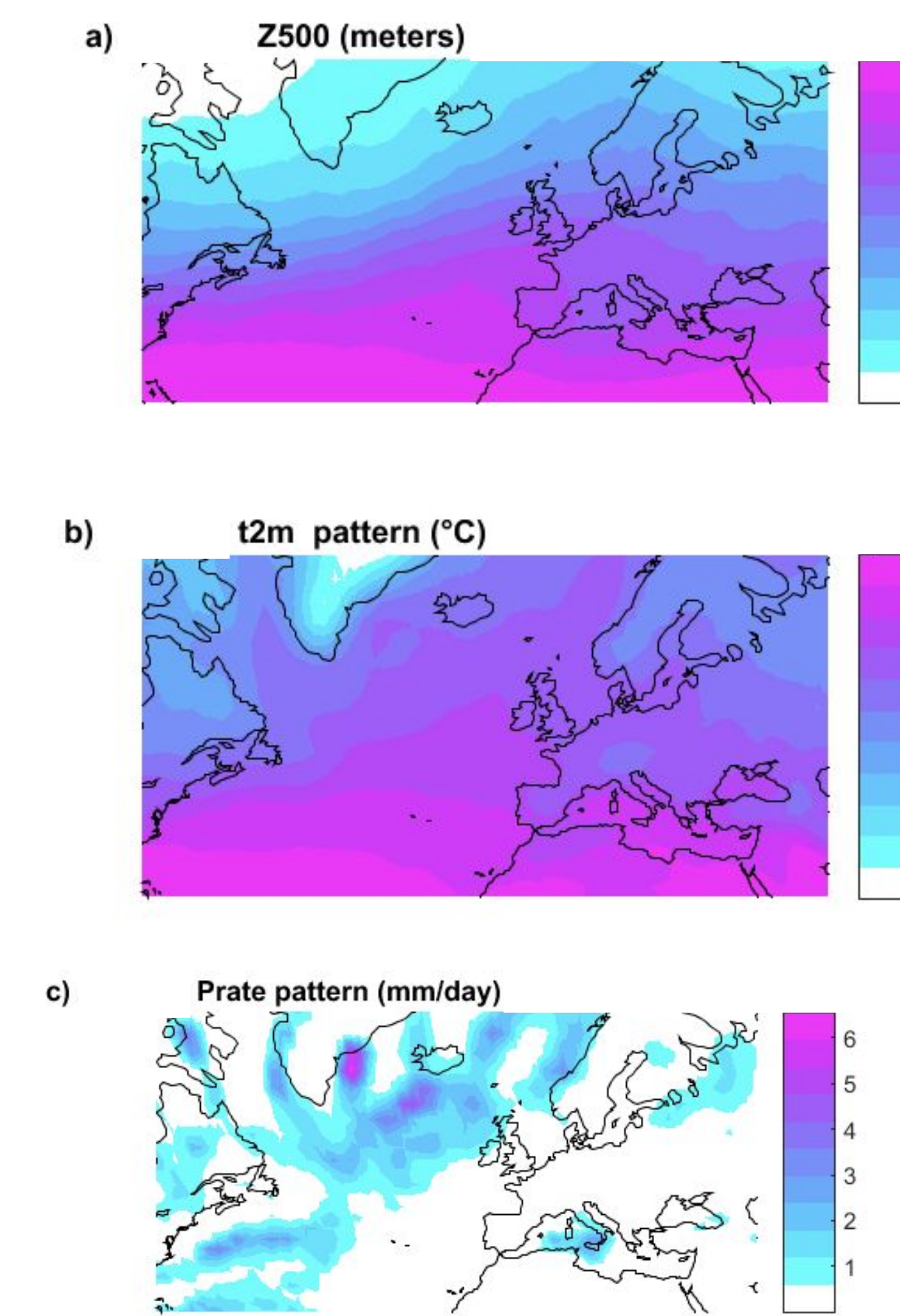


Figure 7: Average Patterns of Z500 a), t2m b) and Prate c) during all the events of IMC (110)

- Preliminary results show a decrease of the large-scale circulation patterns favoring IMC in all the seasons except summer.
- Is this enough to state that we are likely to observe a decrease of these events in the future? No, indeed the warming expected of the Mediterranean Sea could favor convective storms that can organize into tropical cyclones without the need of large-scale circulation drivers.

5. 2 IMC Attribution

In general:

- the analogues fields associated to IMC are of better quality for the historical simulations than for the RCP scenarios: **IMC associated large scale circulation drivers tend to decrease in the future.**
- the analogues fields associated to IMC have larger dimensions in the RCP 4.5 and RCP 8.5 scenarios: **Large scale fields associated to IMC become less predictable.**
- the analogues fields associated to IMC have lower persistence: **Large scale fields associated to IMC last less**

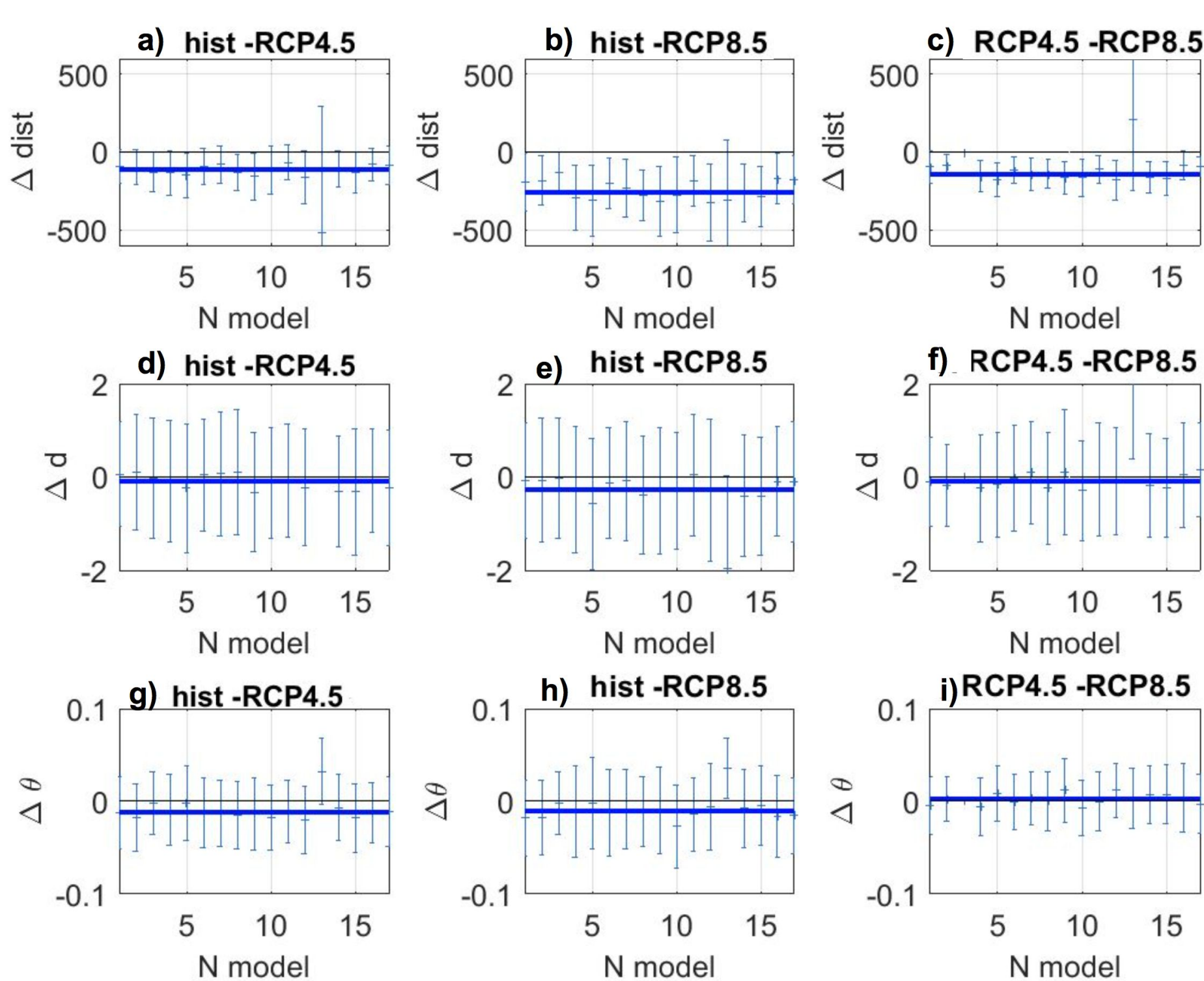


Figure 8: Difference between historical and RCP4.5 (a,d,g) simulations, historical and RCP8.5 (b,e,h) simulations, RCP4.5 and RCP8.5 (c,f,i) simulations for distance (a, d, g), local dimension (d,e,f) and theta(g,h,i) during all the events of IMC.

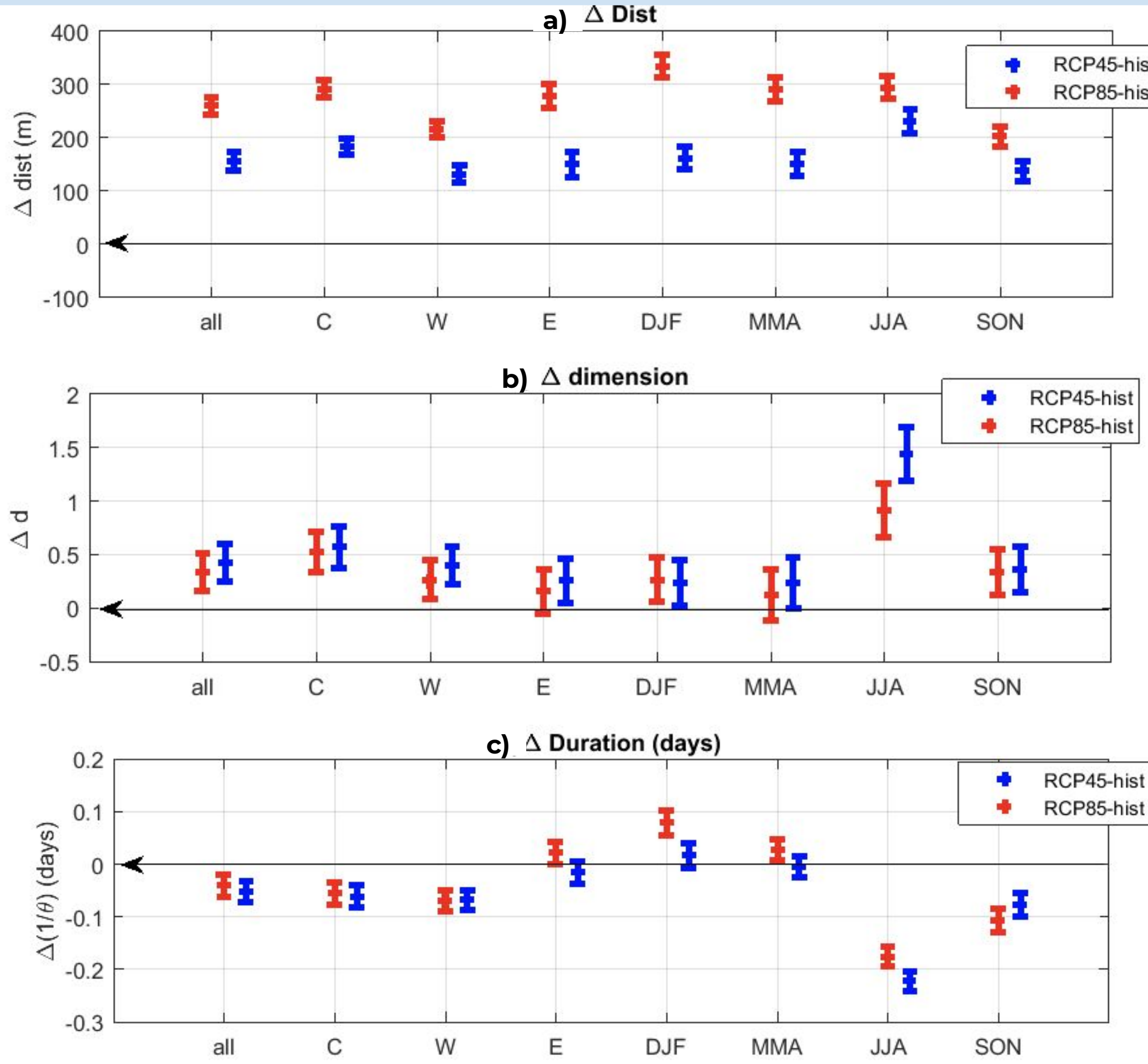


Figure 9: Distance a), local dimension b) and duration c) of the IMC in RCP45 (blue) and RCP85 (red) versus the historical period.

6. Conclusions

- Despite their damage potential and their frequency of occurrence they **have received little attention from the meteorological/climatology community**
- A unique definition of IMC is very difficult because of their hybrid nature, very often, in fact, tropical-cyclone like disturbances in the Mediterranean basin can develop from more common Mediterranean (baroclinic) storms.
- Our preliminary analysis **shows that the large scale drivers associated to IMC tend to be reduced in the future.**
- Few numerical simulations, **few studies on the climate change, few studies on the potential trajectories.**

7. References

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