

# Reference datasets for extratropical cyclone tracks: application to Mediterranean cyclones

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## **MedCyclones Cost Action 19109**

### **WG Tracks Task Team – > 3T initiative**

- Cyclone detection and tracking methods (CDTMs) have different approaches in defining and tracking cyclone centers. This leads to disagreements on extratropical cyclone climatologies.
- We present a new methodological approach that combines tracks from individual CDTMs to produce new composite tracks.
- Aim: To obtain composite tracks that can be used as reference datasets for climatological research in the Mediterranean.

## Article

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Research article | 

## A composite approach to produce reference datasets for extratropical cyclone tracks: application to Mediterranean cyclones

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### Abstract

Many cyclone detection and tracking methods (CDTMs) have been developed in the past to study the climatology of extratropical cyclones. However, all CDTMs have different approaches in defining and tracking cyclone centers. This naturally leads to cyclone track climatologies with inconsistent physical characteristics. More than that, it is typical for CDTMs to produce a non-negligible number of tracks of weak atmospheric features, which do not correspond to large-scale or mesoscale vortices and can differ significantly between CDTMs. Lack of consensus in CDM outputs and the inclusion of significant numbers of uncertain tracks therein have long prohibited the production of a commonly accepted reference dataset of extratropical cyclone tracks. Such a dataset could allow comparable results on the analysis of storm track climatologies and could also contribute to the evaluation and improvement of CDTMs.

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### Short summary

Cyclone detection and tracking methods (CDTMs) have different approaches in defining and...  
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The **database of tracks** is available for the community.

# Cyclone Detection and Tracking Methods

CDTMs are based on a serie of arbitrary choices:

- the atmospheric variables to best describe cyclones
  - the preprocessing operations
  - the criteria to define cyclone centers
  - the adopted approaches to track centers in time
- 
- 1 Cyclone centers are typically defined as local maxima of relative vorticity or as local minima of geopotential height or MSLP
  - 2 All CDTMs connect centres found in successives time steps to describe the displacement of the same single cyclone system.  
Maximum distance between two centres in consecutive time steps.

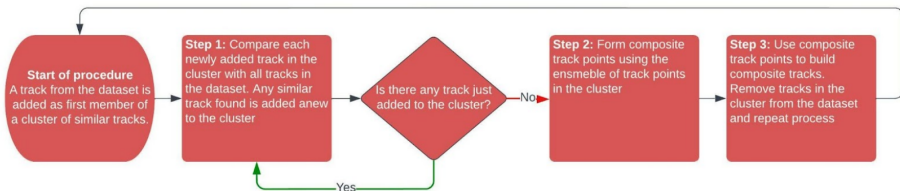


## 2. Datasets and method

Code	Main references for method description	Variable used to identify cyclone centers
M01*	Aragão and Porcù (2022)	Geopotential height at 1000 hPa
M02*	Flaounas et al. (2014)	MSLP
M03*	Ziv et al. (2015)	MSLP
M04*	Ayrault (1998), Sanchez-Gomez and Somot (2018)	Relative vorticity field at 850 hPa and MSLP
M05*	Ragone et al. (2018)	MSLP
M06*	Picornell et al. (2001), Campins et al. (2006)	MSLP
M07	Hodges (1994, 1995), as applied in Priestley et al. (2020)	Relative vorticity field at 850 hPa
M08*	Lionello et al. (2002), Reale and Lionello (2013)	MSLP
M09	Ullrich et al. (2021), Zarzycki and Ullrich (2017)	MSLP
M10	Wernli and Schwierz (2006), Sprenger et al. (2017)	MSLP

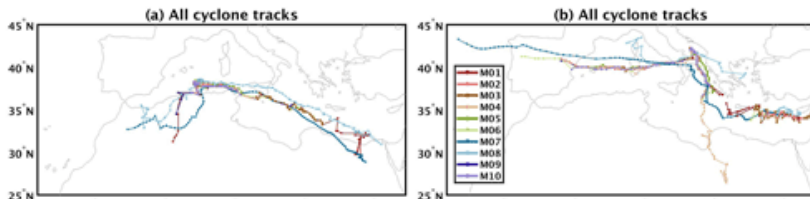
- ERA5 reanalysis, hourly,  $0.25^\circ \times 0.25^\circ$
- 42-year period of 1979–2020
- 25 track points

# Building composite tracks



- Step 1. **"Similar tracks"**: their track points overlap in space and time.
- Step 2. **Composite track points**: average locations of all track points identified as similar in step 1
- Step 3. **Composite track** built from composite track points.

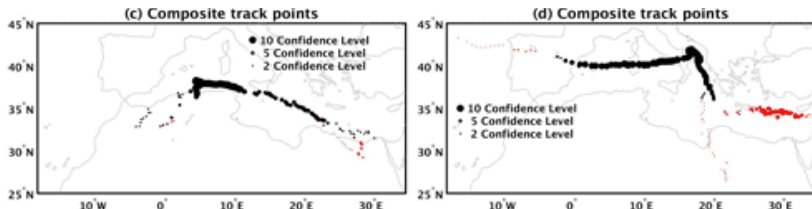
# Step 1



Step 1. "**Similar tracks**": their track points overlap in space and time.

- Spatial overlapping: they occur at the same time at a distance  $< 300km$
- Temporal overlapping: time period in which two tracks share the same segments (number of grid points that belong to the overlap between two tracks)

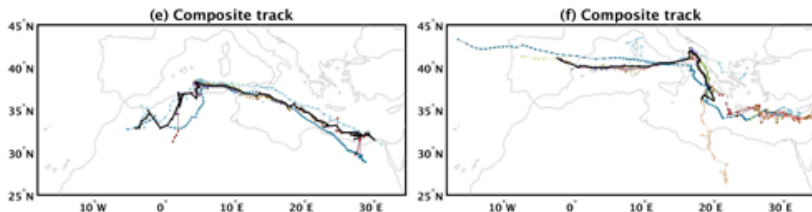
# Step 2



Step 2. **Composite track points:** average locations of all track points identified as similar in step 1

- **Confidence level:** number of methods used to create composite tracks. Measure of robustness, high or low agreement among CDTMs.
- Composite track points of higher c.l. tend to be concentrated in the middle section of the tracks

# Step 3

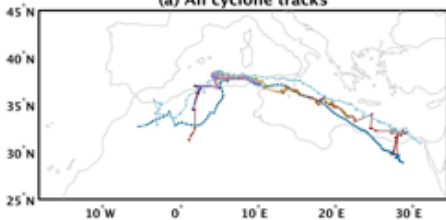


Step 3. **Composite track** built from composite track points.

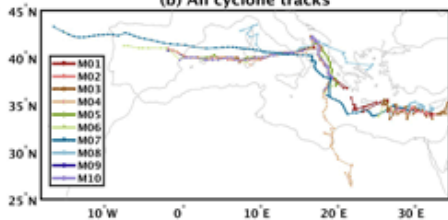
To connect two points

- must take place in consecutive time steps
- have to be located within the threshold distance
- two consecutive track points cannot have a confidence level of 1 (f)

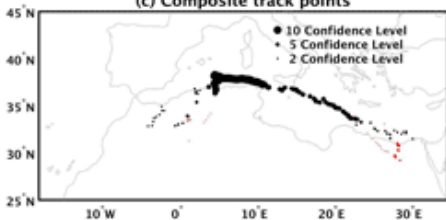
(a) All cyclone tracks



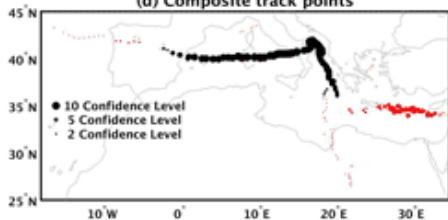
(b) All cyclone tracks



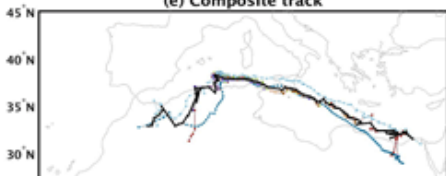
(c) Composite track points



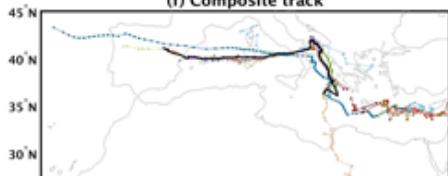
(d) Composite track points

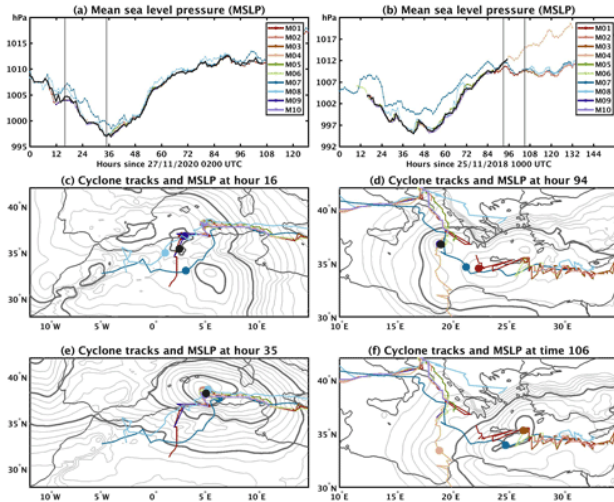


(e) Composite track



(f) Composite track





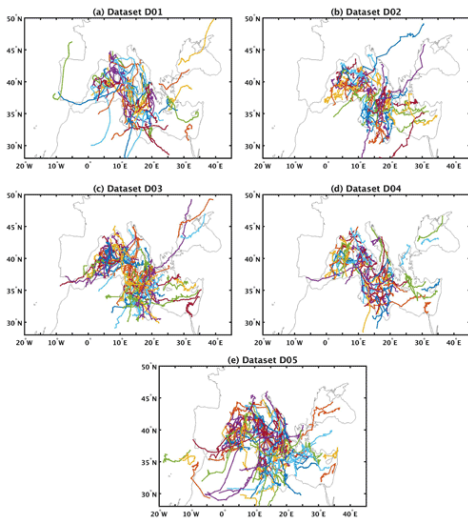
- After building a composite track, all of its composite track points have been assigned to the lower MSLP value within a  $2.5^\circ$  circular area

# Benchmarking the performance of cyclone-tracking methods

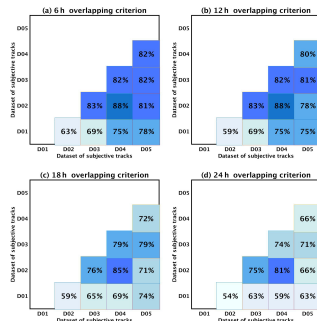
- A major challenge in the field of cyclone tracking is the absence of reference datasets for benchmarking the performance of CDTMs
- The evaluation remains intuitive and relies on qualitative evaluation.
- Confidence level: measure of robustness
- Subjective tracking procedure:
  - 1 to only document the clearest possible cyclone displacements.
  - 2 only retain tracks that last at least 24 h
  - 3 only using MSLP fields
- 117 well-documented cyclone cases. The table of cyclones is available for the community.



# Five datasets of subjective tracked cyclones

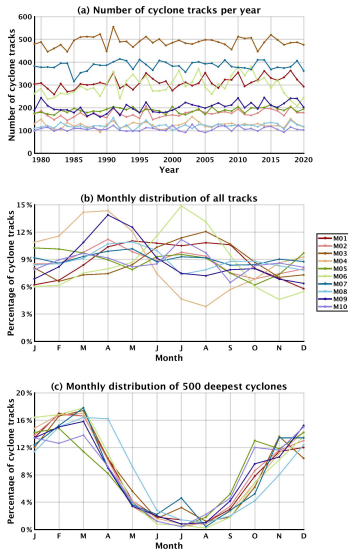


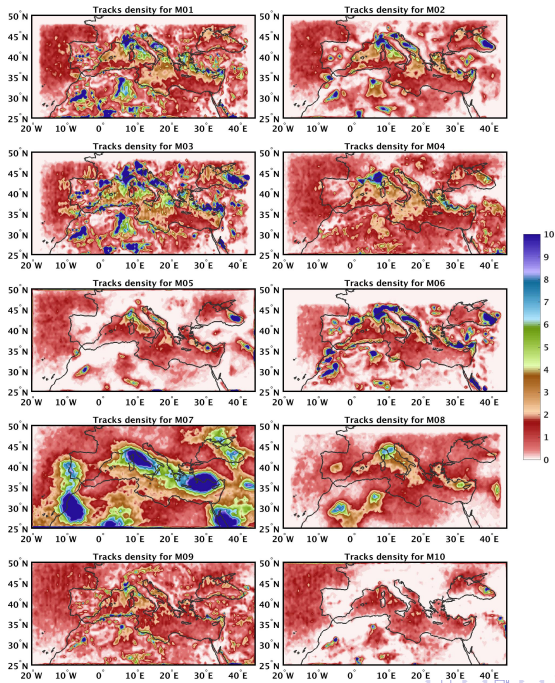
Number of cyclone cases	13	12	17	14	24	37
Number of subjective detections	0	1	2	3	4	5



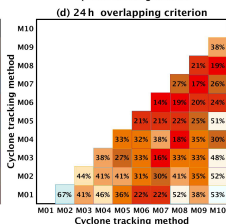
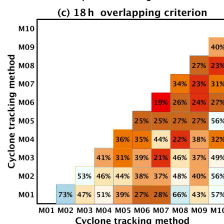
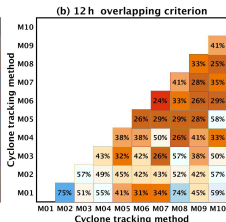
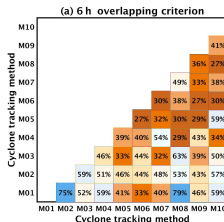
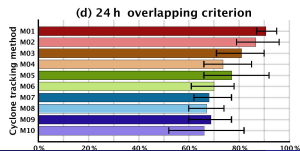
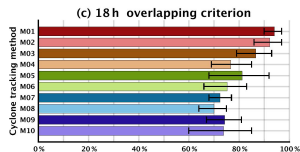
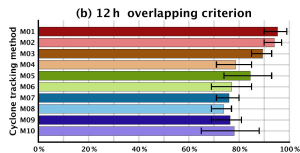
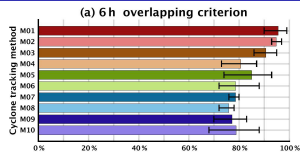
Similarity scores: number of similar tracks in 2 datasets divided by the number of tracks in the smallest dataset.

# Mediterranean tracks from individual CDTMs





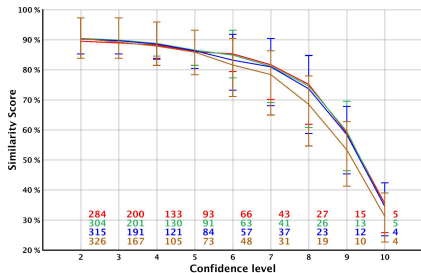
# Similarity of outputs from individual CDTMs



Similarity scores between 10 CDTMs

Average similarity scores 10CDTMs -5 SUBTs

# 4. Composite tracks compared to individual tracks



Similarity scores composite tracks -5 SUBTs, overlapping criteria 6 (red), 12 (green), 18 (blue), 24 (brown)

Cyclone tracking method	2	3	4	5	6	7	8	9	10	
	M01	63%	79%	90%	95%	98%	99%	100%	100%	100%
	M02	44%	63%	83%	93%	98%	99%	100%	100%	100%
	M03	69%	73%	78%	81%	84%	90%	96%	100%	100%
	M04	27%	38%	50%	63%	74%	85%	92%	97%	100%
	M05	33%	43%	58%	71%	82%	91%	96%	99%	100%
	M06	48%	53%	60%	65%	72%	80%	85%	94%	100%
	M07	46%	59%	66%	71%	76%	81%	86%	91%	100%
	M08	27%	40%	50%	57%	62%	69%	77%	88%	100%
	M09	39%	49%	59%	68%	76%	84%	88%	94%	100%
	M10	27%	35%	47%	59%	69%	77%	86%	94%	100%
Confidence level										

Contribution of CDTMs to the production of composite tracks (12h criterion)

# Composite track datasets

## ERA5 1979–2020

TRACKS\_CL2.dat

TRACKS\_CL3.dat

TRACKS\_CL4.dat

TRACKS\_CL5.dat

TRACKS\_CL6.dat

TRACKS\_CL7.dat

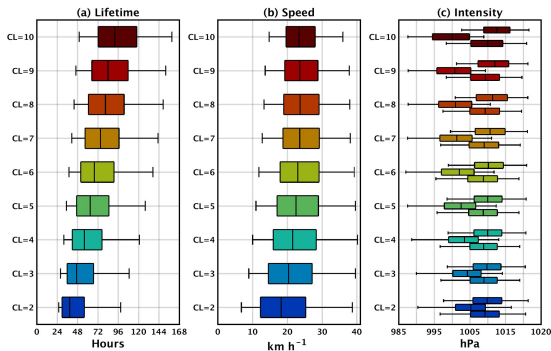
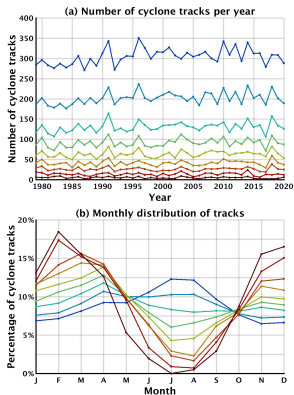
TRACKS\_CL8.dat

TRACKS\_CL9.dat

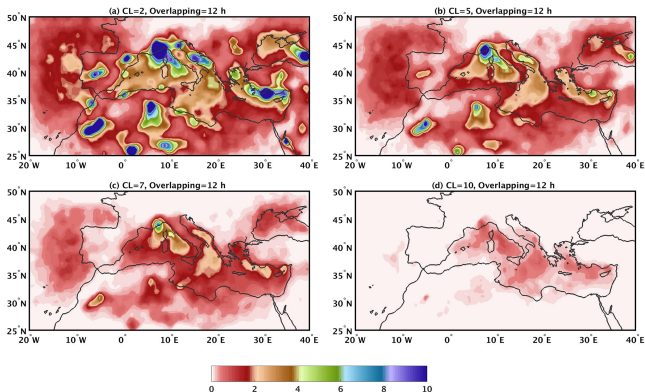
TRACKS\_CL10.dat

Id	lon	lat	yy	mm	dd	hh	MSLP
00000001	-017.750	0048.120	1979	01	03	01	00995.45
00000001	-017.447	0048.163	1979	01	03	02	00993.78
00000001	-016.979	0048.143	1979	01	03	03	00992.60
00000001	-016.344	0048.078	1979	01	03	04	00991.93
00000001	-015.679	0048.031	1979	01	03	05	00990.32
00000001	-015.096	0048.043	1979	01	03	06	00988.34
00000001	-014.640	0048.105	1979	01	03	07	00986.10
00000001	-014.321	0048.183	1979	01	03	08	00984.71
00000001	-014.112	0048.237	1979	01	03	09	00983.51
00000001	-013.961	0048.230	1979	01	03	10	00984.09
00000001	-013.817	0048.139	1979	01	03	11	00983.95
00000001	-013.637	0047.966	1979	01	03	12	00984.22
00000001	-013.376	0047.738	1979	01	03	13	00983.72
00000001	-012.993	0047.475	1979	01	03	14	00983.26
00000001	-012.464	0047.212	1979	01	03	15	00983.32
00000001	-011.775	0046.999	1979	01	03	16	00983.38
00000001	-010.957	0046.853	1979	01	03	17	00983.61
00000001	-010.100	0046.754	1979	01	03	18	00983.78
00000001	-009.294	0046.692	1979	01	03	19	00983.39
00000001	-008.582	0046.674	1979	01	03	20	00983.19
00000001	-007.957	0046.690	1979	01	03	21	00983.18
00000001	-007.390	0046.717	1979	01	03	22	00984.60
00000001	-006.871	0046.738	1979	01	03	23	00984.20
00000001	-006.396	0046.756	1979	01	04	00	00983.80

# Composite tracks



# Composite tracks

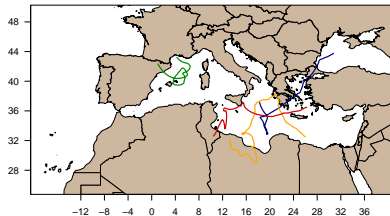


$5 < \text{Confidencelevel} < 7$ : Climatological studies

$8 < \text{Confidencelevel} < 10$ : To analyze most intense cyclones

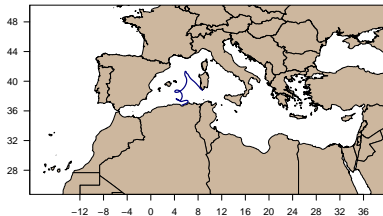


# Composite tracks



Medicane tracks: Rolf (green), Qendresa (red),

Zorba (blue) and Ianos (yellow) from TRACKS09.dat



2001 11 11 cyclone

from TRACKS08.dat