Simulation of medicanes over the Mediterranean Sea in regional climate model ensembles: impact of ocean-atmosphere coupling and increased resolution

Miguel Angel Gaertner, Juan Jesús González-Alemán, Raquel Romera, Marta Domínguez, Victoria Gil, Enrique Sánchez, Clemente Gallardo

University of Castilla-La Mancha (Toledo, Spain)

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Instituto de Ciencias Ambientales de Castilla-La Mancha

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Overall aims of the study

Analyse the ability of regional climate models to simulate tropical-like cyclones, also called medicanes, over the Mediterranean Sea

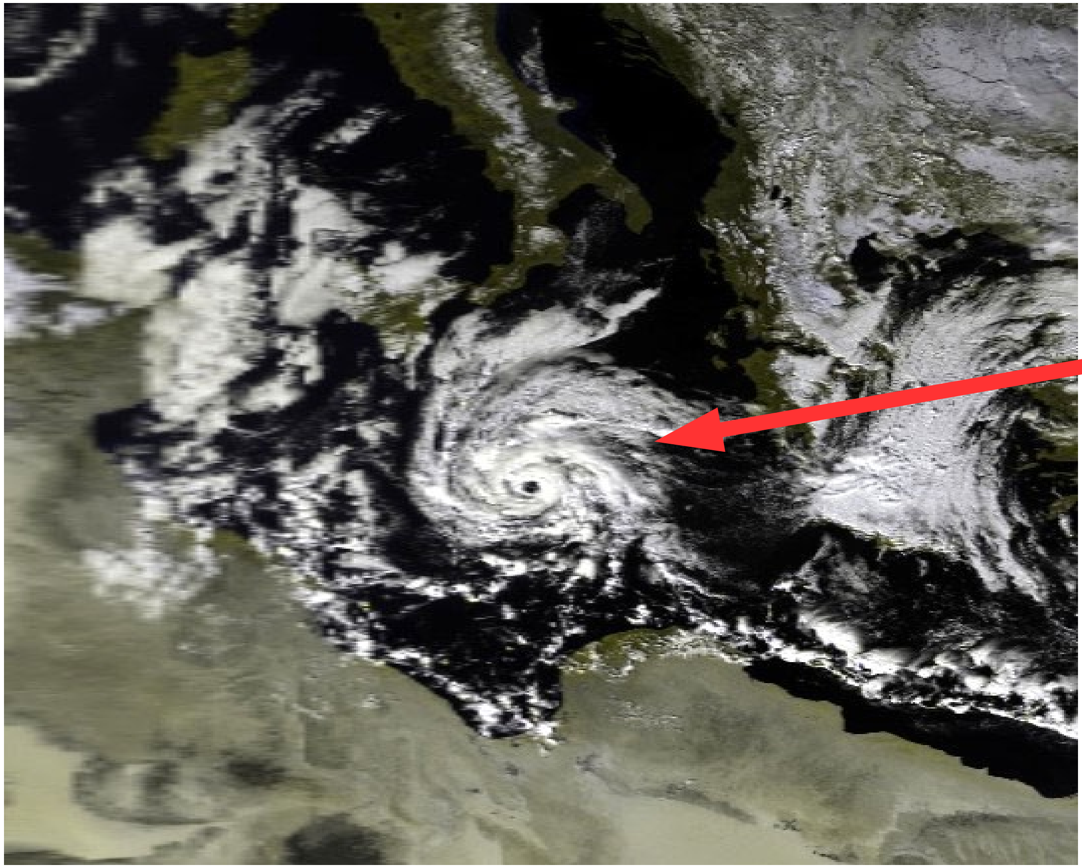
Analyse the impact of air-sea coupling and high resolution on the simulation of medicanes

Observed characteristics of medicanes

- Small size (typical radius of 150 km or less)

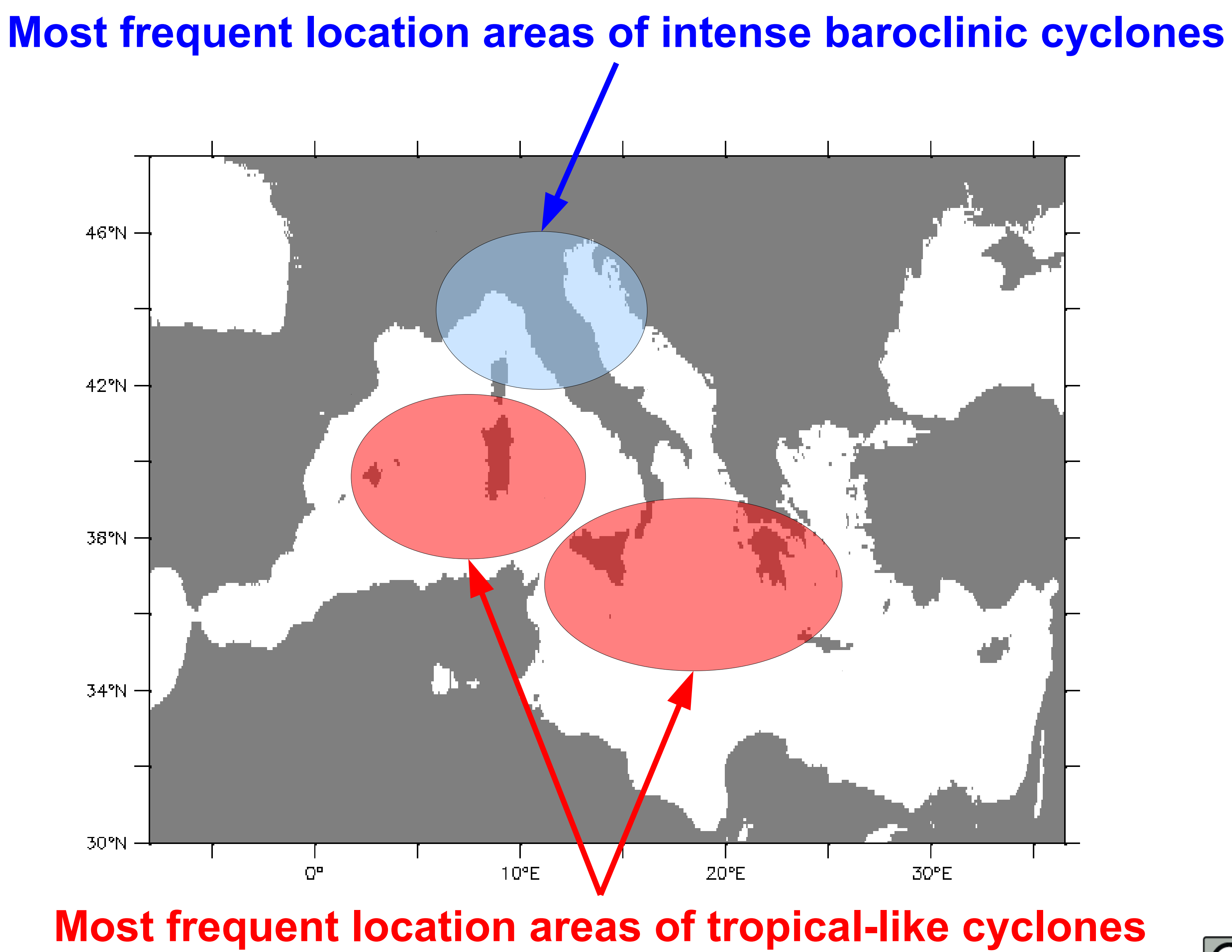
- Unfrequent (less than 2 medicanes per year; specific value depends on detection method)

- Most usual detection method: eye-like features, spiral banding in satellite images



January 1995 medicane

Observed characteristics of medicanes



Observed characteristics of medicanes

- Generation mechanism: tropical transition from an initial baroclinic cut-off low

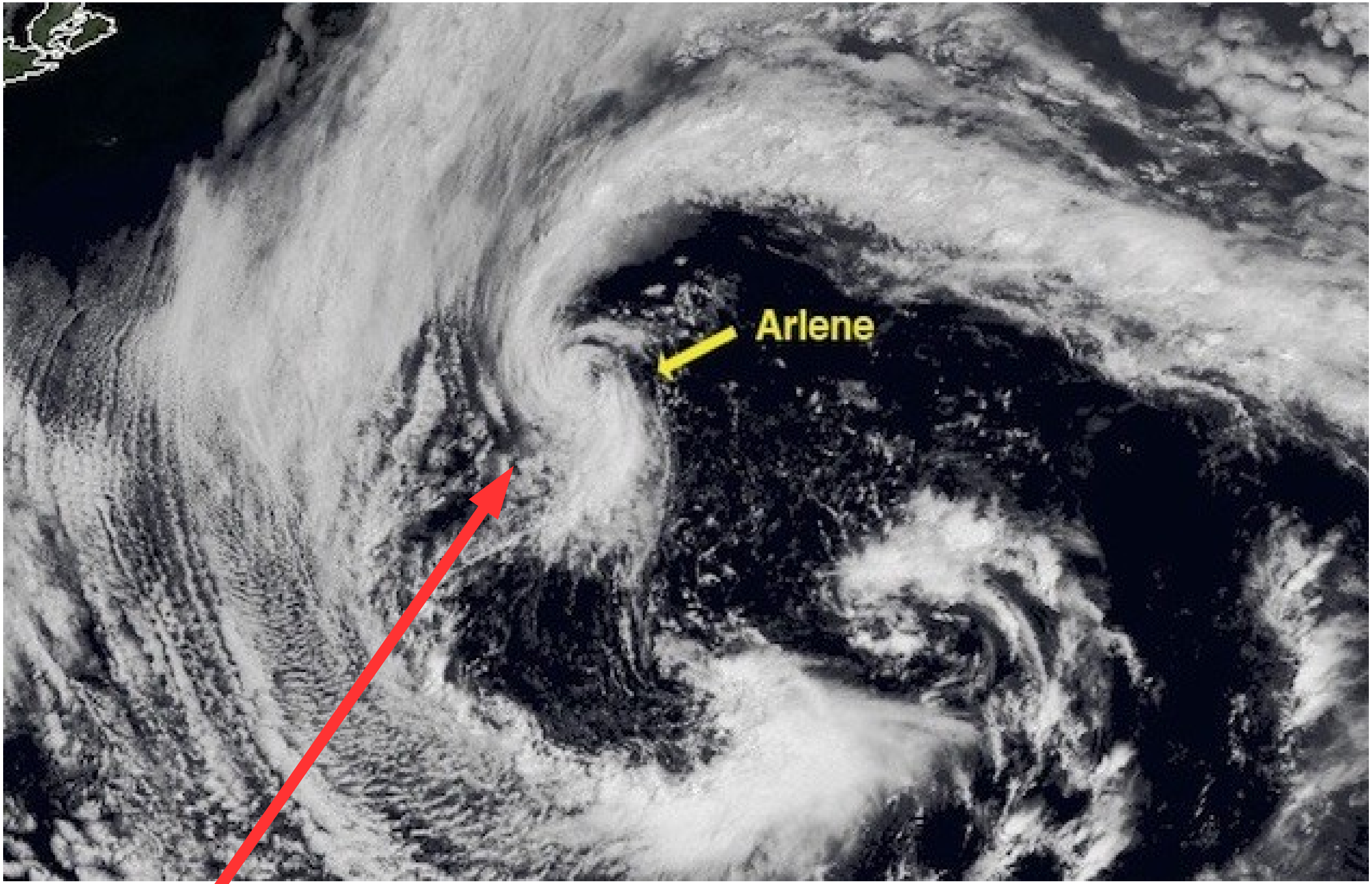
- Tropical transition does not require sea surface temperatures above 26ºC, and can occur at rather high latitude and even in winter

- Recent examples of tropical transitions over eastern and central North Atlantic:

Hurricane Alex (January 2016): formed south of Azores over 22ºC waters

Tropical storm Arlene (April 2017): formed west of Azores over 20ºC waters

Observed characteristics of medicanes



Tropical storm Arlene: small, embedded in a larger extratropical system, but classified as fully tropical cyclone by NHC

Are medicanes also tropical cyclones?

- Same formation latitude as previous examples of Atlantic tropical cyclones

- Form also from baroclinic cut-off lows

- A few medicanes develop a clear symmetric (non-frontal), warm-core structure, and should be considered tropical cyclones like their Atlantic counterparts

- Other cyclones included in medicane databases show only partially tropical characteristics: subtropical or hybrid cyclones

Motivation and data for the study

- Expected impact of high-resolution and atmosphere-ocean coupling on the simulation of medicanes over the Mediterranean Sea with RCMs:

    - Resolution: high resolution simulations should improve the representation of small-size cyclones

    - Air-sea interaction: for tropical cyclones, this interaction could reduce its intensity (lower SSTs through mixing)

- Simulations:

    - Pairs of higher and lower resolution climate simulations from EURO-CORDEX and Med-CORDEX

    - Pairs of uncoupled and coupled runs from Med-CORDEX

    - Evaluation runs (nested in reanalysis)

Method

- Cyclone detection and tracking: sea level pressure minima (Picornell et al., 2001)

- Intensity threshold: 17,5 m/s (tropical storm intensity)

- Analysis months: August-January

- Vertical structure of most intense cyclones: cyclone phase space method of Hart (2003)

- Criteria for selecting medicanes: cyclones reaching fully tropical characteristics at some time of its evolution (thresholds derived from Miglietta et al., 2013)

Simulation of observed medicanes

- Models simulate medicanes generally at dates that are not coincident with actual medicanes (probably due to small size of medicanes and due to genesis within the climate model domains)

- Some exceptions: intense observed medicanes with a long tropical phase

- Example of well reproduced observed medicane: November 2011 case (reproduced by all available simulations)

Simulation of observed medicanes

November 2011 medicane

Observations (SE France):

Sustained winds: 100 km/h

Gusts: 150 km/h

24-h precipitation: 135 mm

Classified as Tropical Storm by NOAA

Visible satellite image – 8/11/2011

Simulation of observed medicanes

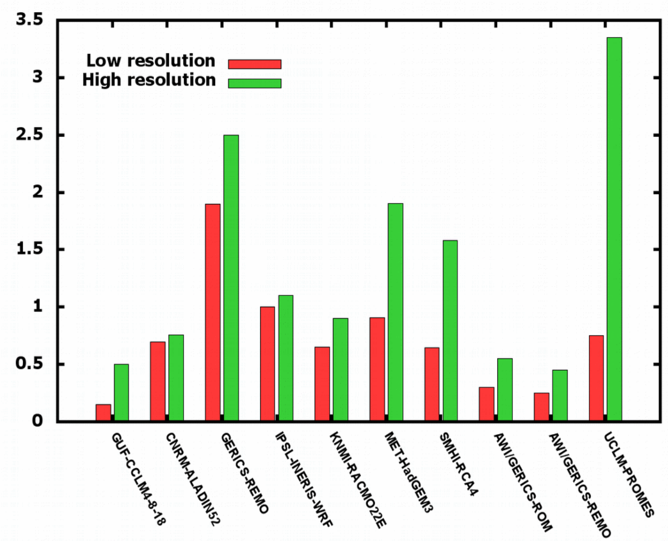
- Due to overall absence of coincidence on a case-by-case basis between climate simulations and observations: statistical evaluation of climate simulations

- Intensity is generally underestimated in simulations

- Spatial distribution is well reproduced

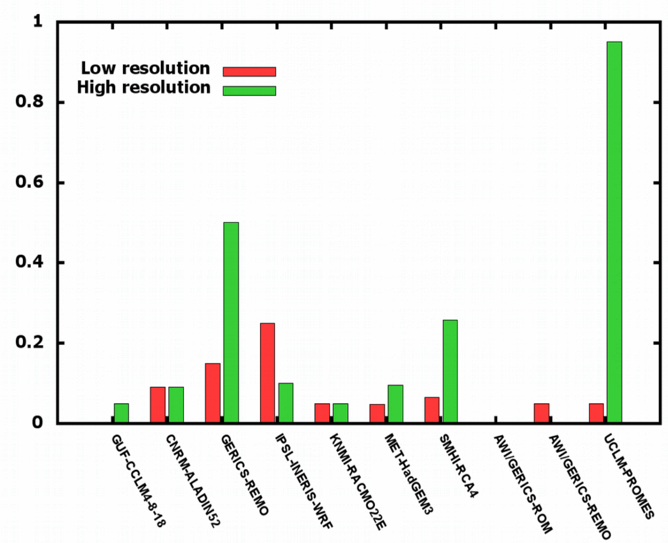
Impact of high resolution on the simulation of medicanes

Frequency of medicanes (number per year)



Increased resolution associated to increased frequency (systematic and clear impact)

Frequency of high-intensity medicanes (max. wind above 25 m/s)



Intensity underestimation not corrected by most higher-resolution runs

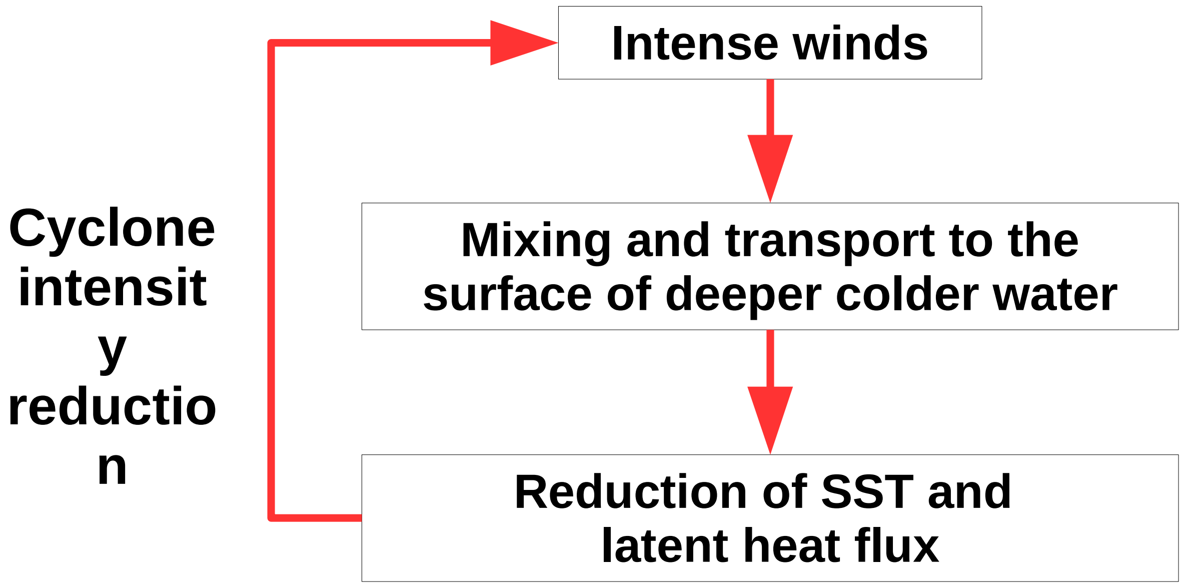
Intensity seems to depend more on the model formulation than on resolution

Pairs of low/high resolution runs

Impact of ocean-atmosphere coupling on the simulation of medicanes

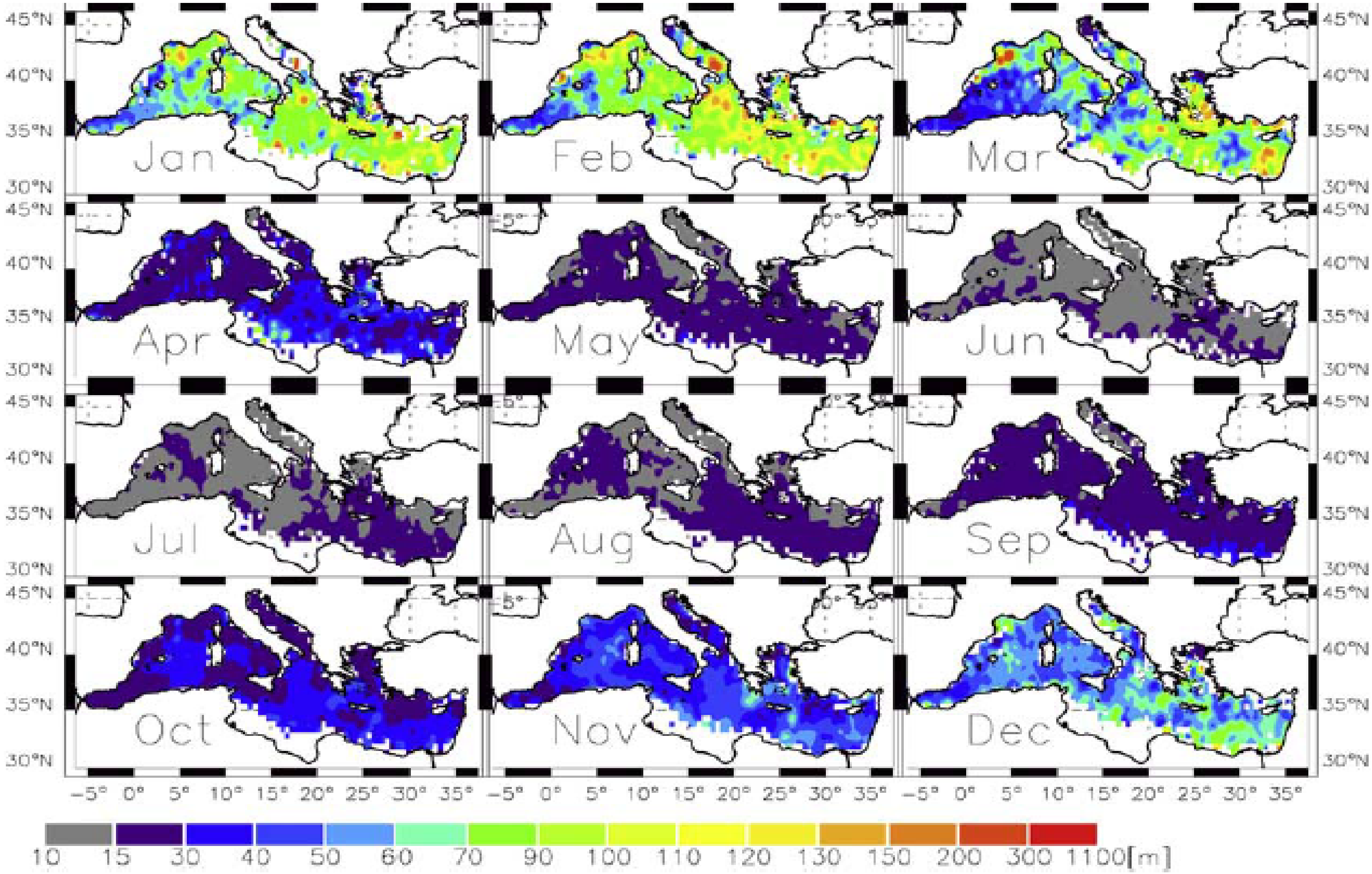
- **Air-sea exchanges are particularly important for these cyclones**

Initial hypothesis:
Ocean-atmosphere coupling could reduce the intensity of medicanes through a negative feedback



Negative intensity feedback depends on oceanic mixed layer depth

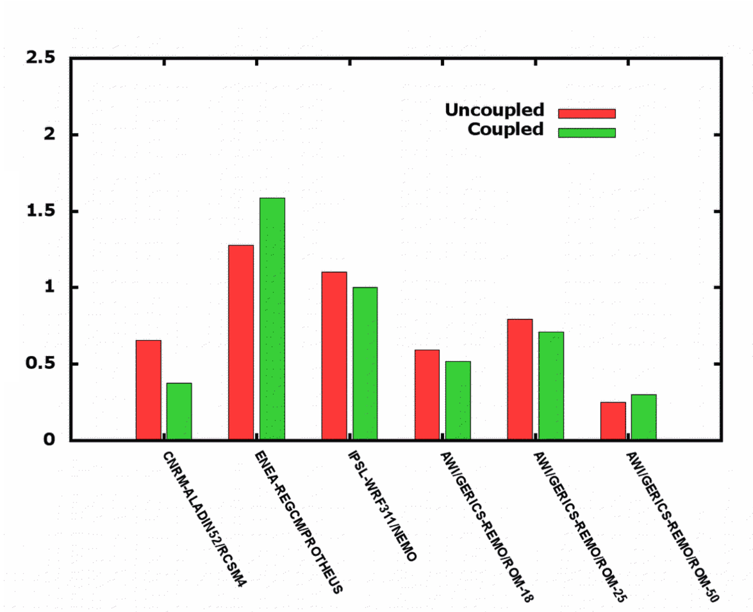
- **Shallow mixed layers** (typical in summer in the Med. Sea) **favour the negative feedback**
- **Deep mixed layers** (typical in winter in the Med. Sea) **limit the negative feedback**



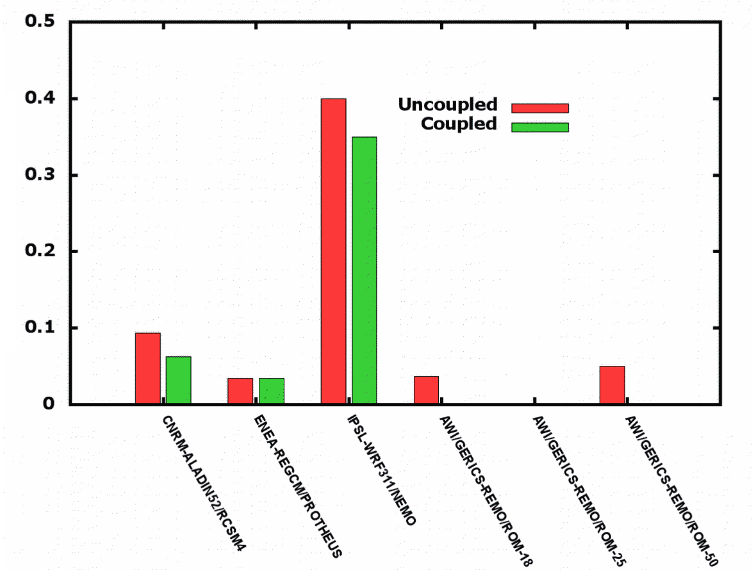
Annual cycle of Mediterranean mixed layer depth (d'Ortenzio et al., 2005)

Impact of ocean-atmosphere coupling on the simulation of medicanes

Frequency of medicanes (number per year)



Frequency of high-intensity medicanes (max. wind above 25 m/s)



Pairs of uncoupled/coupled runs

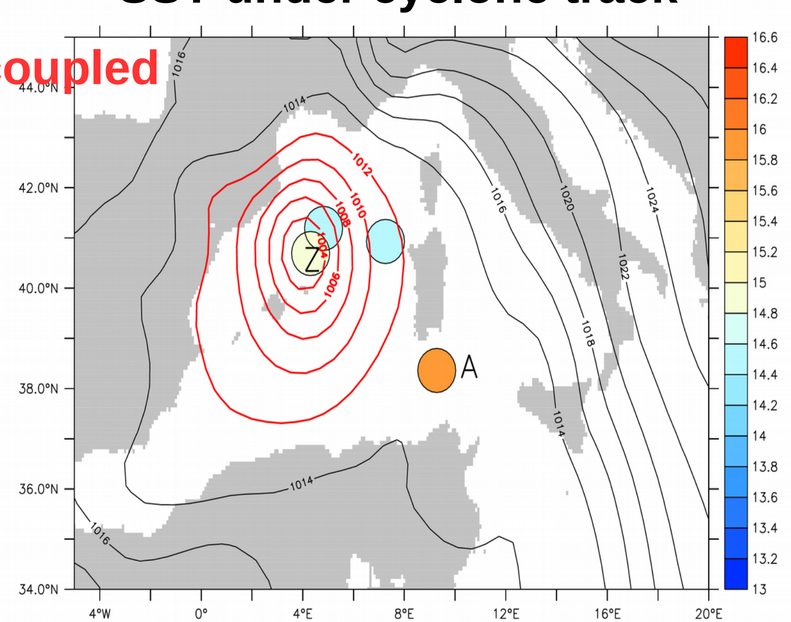
No clear aggregate impact of coupling of frequency and intensity of medicanes (slight decrease of high-intensity medicanes)

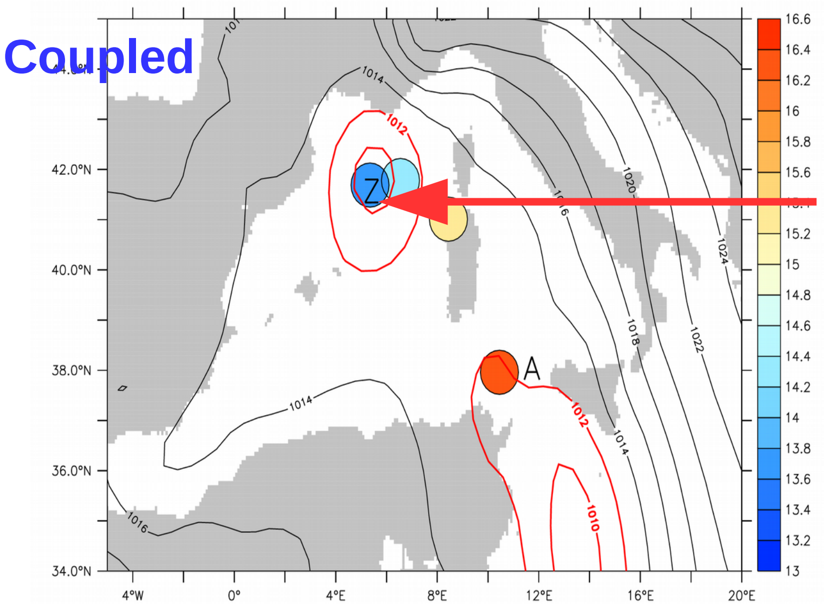
But monthly distribution shows shift of medicanes from autumn to winter in coupled simulations: ¿effect of mixed layer depth?

Aggregated values might be hiding different types of air-sea interactions: What happens in specific cases?

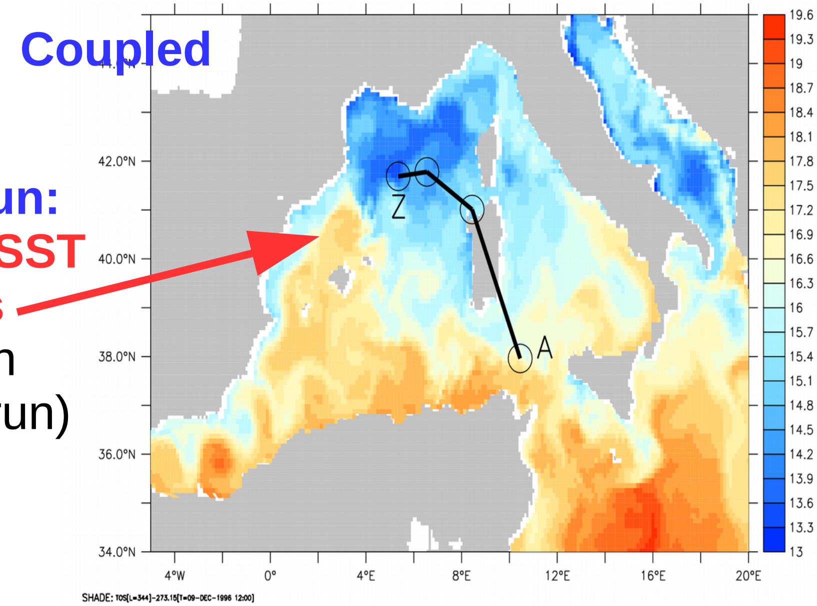
Specific case: intensity reduction in coupled simulation

SLP at maximum intensity and SST under cyclone track



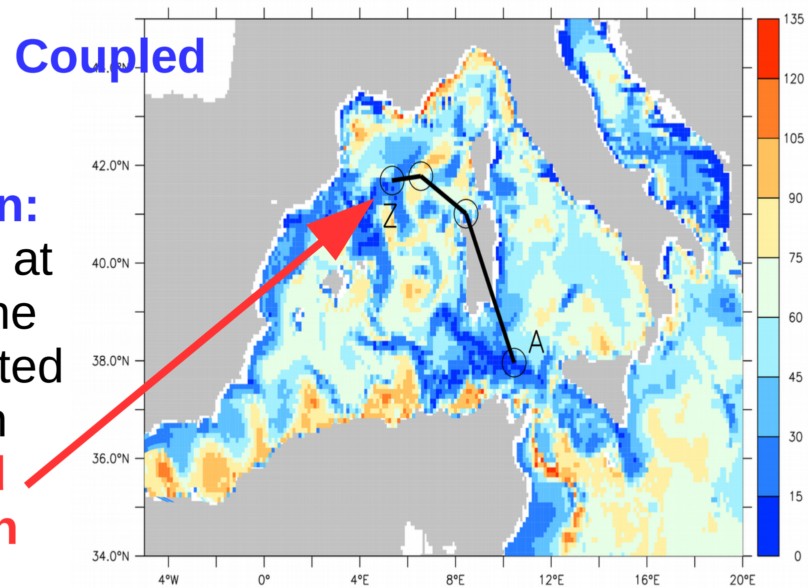


SST and cyclone track



Coupled run:
Mesoscale SST features
(absent in uncoupled run)

Coupled run:
Lower SSTs at the end of the track associated to area with **low mixed layer depth**

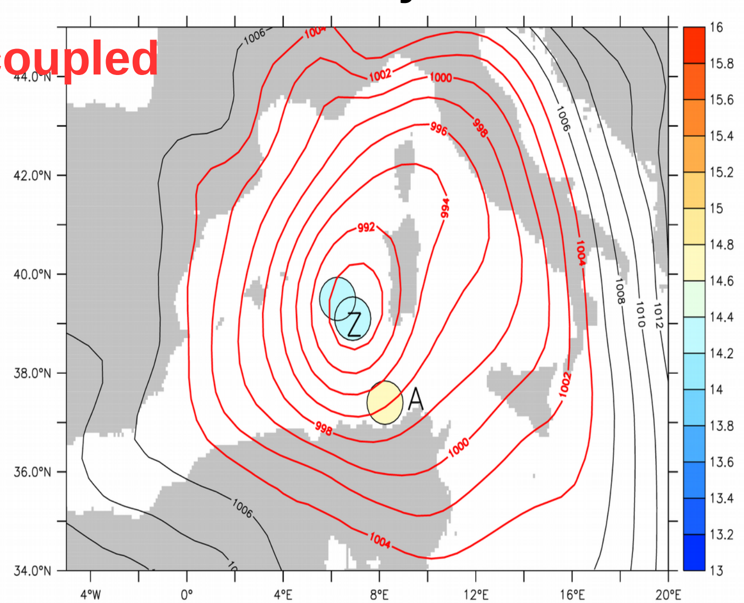


Mixed layer depth and cyclone track

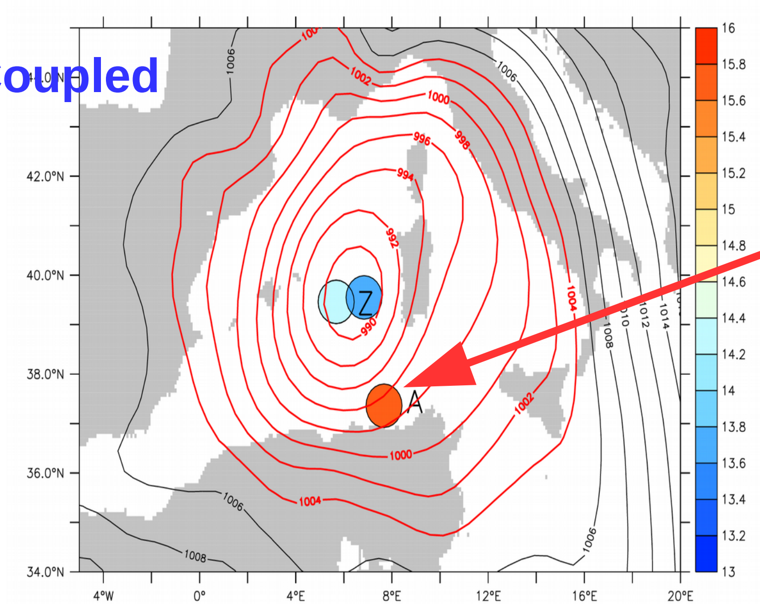
Specific case: intensity increase in coupled simulation

SLP at maximum intensity and SST under cyclone track

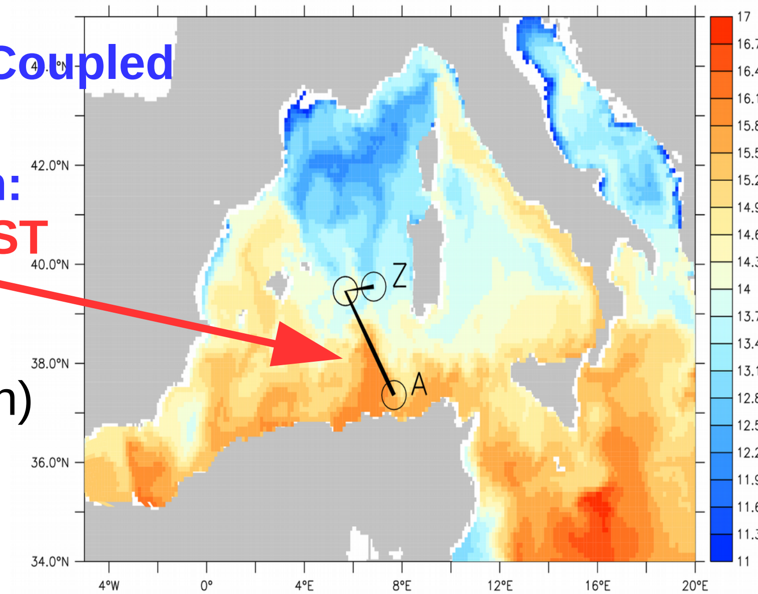
Uncoupled



Coupled

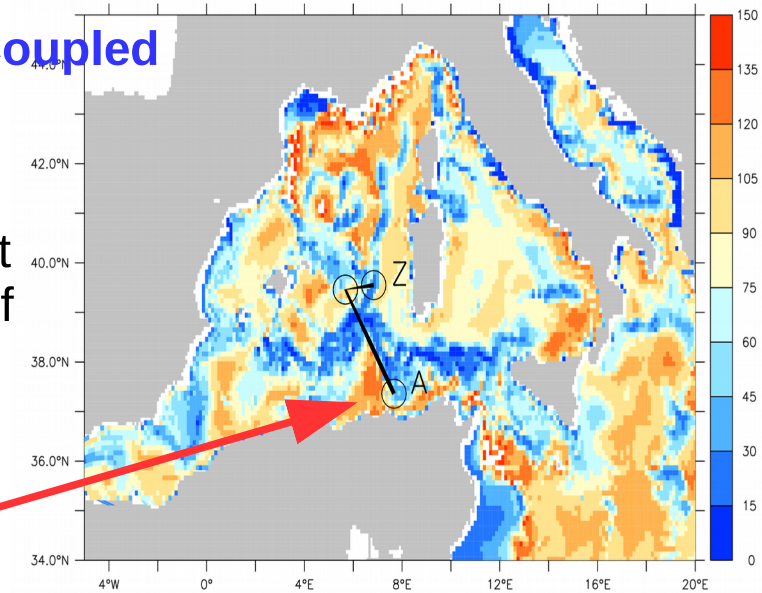


Coupled



Coupled run: **Mesoscale SST features** (absent in uncoupled run)

Coupled



Coupled run: **Higher SSTs** at the beginning of the track, associated to area with **high mixed layer depth**

Concluding remarks

- **Simulation of medicanes in RCMs should be statistically evaluated (simulated and observed medicanes do not coincide in general)**
- **Medicane intensity is underestimated by simulations**
- **Added value of high resolution runs: higher frequency**
- **No intensity increase in general in high resolution runs (only in a few models)**

Concluding remarks

- **No general negative intensity feedback on medicanes in coupled simulations**

- **Possible reasons:**

  - Simulations underestimate medicane intensity: weaker air-sea interactions

  - Negative intensity feedback limited or absent for deep oceanic mixed layer

- **Specific cases: contradicting intensity changes probably associated to mesoscale mixed layer depth and SST features**

- **Coupled runs introduce sea surface mesoscale features, not present in uncoupled runs, that may affect medicanes**

Reference:

Gaertner, M.A. et al. (2016): Simulation of medicanes over the Mediterranean Sea in a regional climate model ensemble: impact of ocean-atmosphere coupling and increased resolution. *Clim. Dyn.,* doi: 10.1007/s00382-016-3456-1