Analysis of convective activity in Tropical Storm Delta in a warmer climate

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1. Introduction

Considering the increase in the North Atlantic **sea surface temperatures (SSTs)** due to anthropogenic climate change.

- ¿How are **tropical cyclones** (TCs) expected to behave in future warmer climates?
- ¿How is the **convective activity** within a TC affected by this increase in the SSTs?

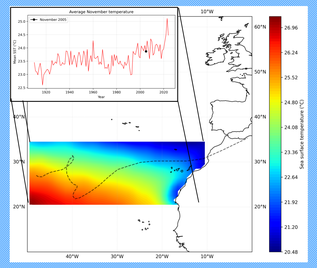


Fig. 1: Average November 2005 SSTs in the North Atlantic and annual evolution of the spatial mean. Data from HadISST.

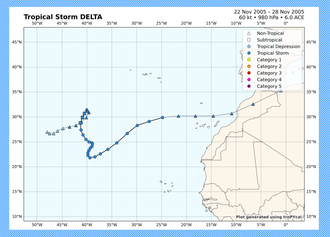


Fig. 2: Delta's trajectory from the best track from HURDAT.

Case study:

Tropical Storm Delta, a TC that affected the Canary Islands (Spain) and Madeira (Portugal) in November 2005. Delta arrived after experiencing the **extratropical transition** (ET).

2. Methodology

2 simulations with the **HARMONIE-AROME** model (2.5 km):

- **CONTROL:** with initial and boundary conditions from ERA5.
- **SST + 2 ºC:** adding a perturbation value of +2 ºC to the SSTs.

Convective cells associated to the cyclone are identified employing **TOBAC**, based on:

- **Brightness Temperature** (BT). Thresholds: 220, 205, 190 and 175 K.
- Distance. Less than 250 km from the center of the TC.
- Reflectivity. At least one grid point in the cell reaching 35 dBZ.

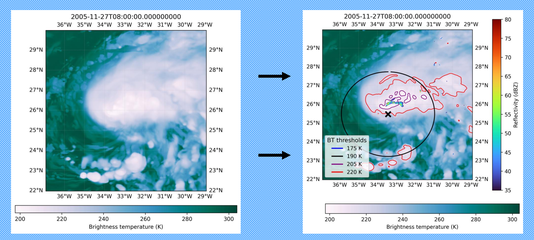


Fig. 3: Example of the BT input and the applied criteria to identify convective cells within the cyclone, in a specific timestep.

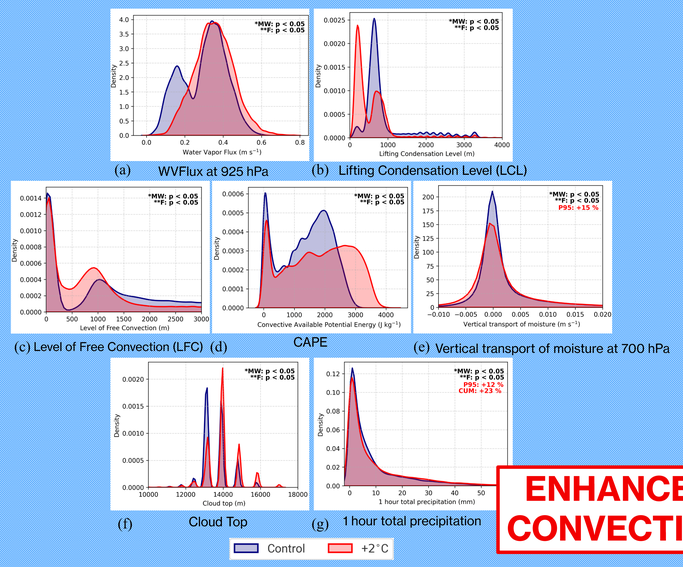
Input

Criteria to identify convective cells:

Variables in the distributions in Figure 4 are evaluated only in the convective cells fitting this criteria.

3. Results

3.1. Convective activity



(a) WVFlux at 925 hPa (b) Lifting Condensation Level (LCL) (c) Level of Free Convection (LFC) (d) CAPE (e) Vertical transport of moisture at 700 hPa (f) Cloud Top (g) 1 hour total precipitation

Fig. 4: Distributions in the convective cells of: (a) $WVFlux = \sqrt{q^2u^2 + q^2v^2}$ at 925 hPa (m), (b) Lifting Condensation Level (m), (c) Level of Free Convection (m), (d) Convective Available Potential Energy (J/kg), (e) vertical transport of moisture (wq) at 700 hPa (m/s), (f) cloud top (m), and (g) 1 hour total precipitation (mm).

ENHANCED CONVECTION

In the **SST + 2 ºC** simulation, relative to **CONTROL**, it is found:

- Higher Water Vapor Flux in the lower levels of the cyclone: **more moisture.**
- Decreases in the height of the LCL and the LFC: smaller distance necessary for an updraft to reach them and develop Deep Moist Convection.
- Important increases in **CAPE** in the convective cells: higher buoyancy.
- Vertical transport of moisture turns broader: the most intense moist **updrafts** turn more frequent.
- Rise in the cloud top: larger **vertical extension** of the convective cells.
- Higher hourly **precipitation** rate and accumulated values.

4. Conclusions

- Increases in low level moisture, CAPE, intense moist updrafts and precipitation rate reflect an enhanced convective activity during Delta's tropical phase over the higher SSTs.
- Delta intensifies due to the latent heat released by the enhanced convection and becomes a hurricane.
- Delta experiences an ET which starts earlier and takes longer to be completed, and turns much more severe, being extremely dangerous to the affected areas.

3.2. General features

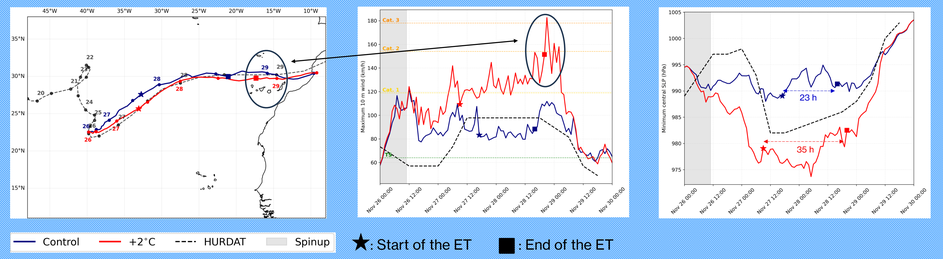


Fig. 5: Comparison of different aspects of Delta in both simulations: (a) Trajectory, (b) Maximum sustained 10 m wind speed (km/h), and (c) Minimum sea level pressure (hPa)

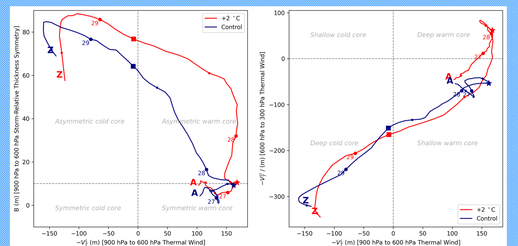


Fig. 6: Cyclone Phase Space diagrams for Delta in both simulations.

The enhanced convection and latent heat release in **SST + 2 ºC** intensify the cyclone during the tropical phase, relative to **CONTROL:**

- Delta reaches **hurricane** status, with sustained wind speeds over 120 km/h and pressure below 980 hPa.
- The peak intensity is produced after completing the ET, when Delta is closest to the affected islands, with sustained wind speeds **over 180 km/h.**
- The ET starts earlier and takes more time to be completed, as Delta develops an asymmetric structure while keeping its warm core.

3.3. Impacts

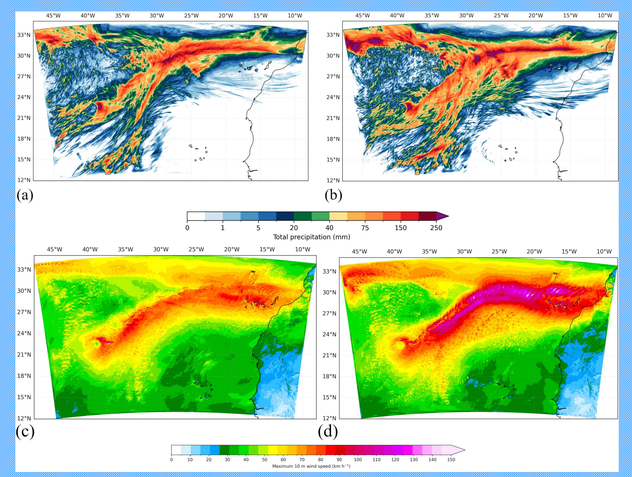


Fig. 7: Maps of: total accumulated precipitation in **(a)** Control scenario, **(b)** +2º C scenario; and maximum 10 m sustained wind speed in **(c)** Control scenario, and **(d)** +2º C scenario.

In the **SST + 2 ºC** simulation, relative to **CONTROL**, it is found:

- **Higher precipitation** values and area.
- Important increase in the wind speeds, with a large area of **hurricane force wind speeds.**
- The strongest wind speeds and highest accumulated precipitation values are produced during **the extratropical phase**.
- High impacts over Madeira (Portugal) and the Canary Islands (Spain).

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