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Intensification of tropical cyclones: impact of fine scale processes

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Background

Tropical cyclones (TCs) are rapidly rotating storms driven by ocean–atmosphere surface exchanges [1]. Currently, **large uncertainties** persist in predicting their **intensity**. Improving our understanding of intensification is therefore essential for mitigating TCs societal impacts.

I have previously investigated how a fine-scale **upper-level** process, the **stratospheric intrusion**, affects TC evolution. These interactions can contribute both to **rapid intensification** and to the **onset of dissipation** [2], demonstrating the importance of resolving small-scale dynamical features.

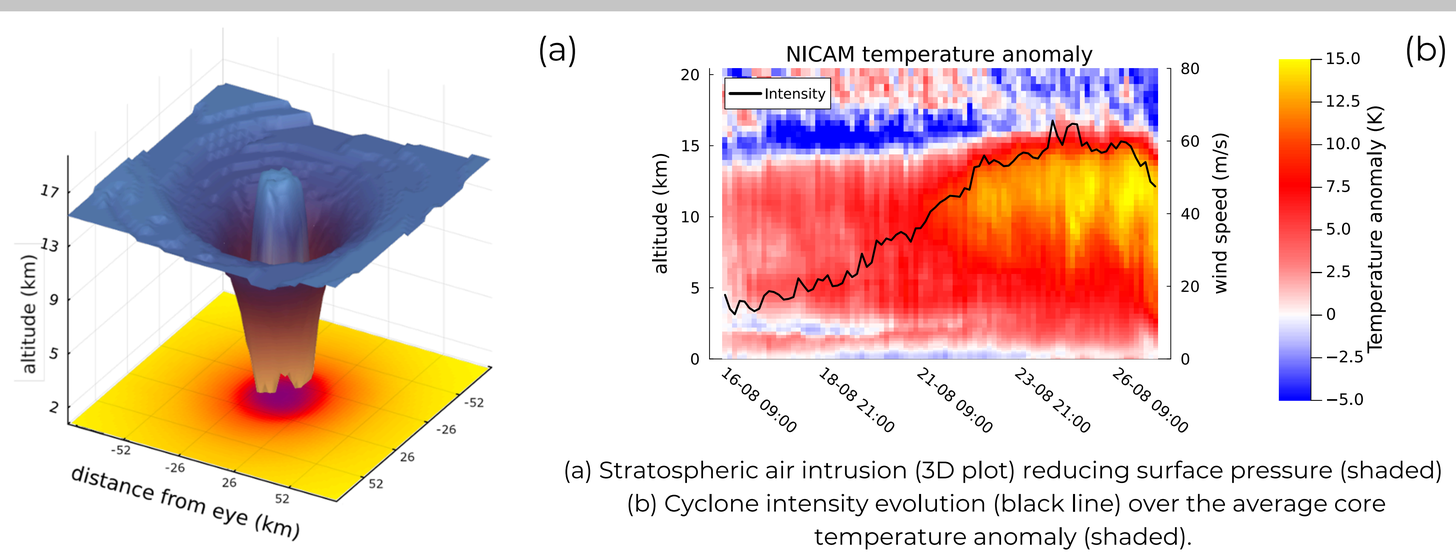
At the **surface**, TC interactions with **spatial anomalies** in Sea Surface Temperature (**SST**) are expected to play a similarly relevant role: a previous study [3] indicated that the relationship between SST variance and TC intensity can be **either positive or negative**, depending on the mean SST state.

Tropical Cyclone Freddy as seen from the International Space Station. At the mature stage, typical features such as the cloudless eye become easily visible.

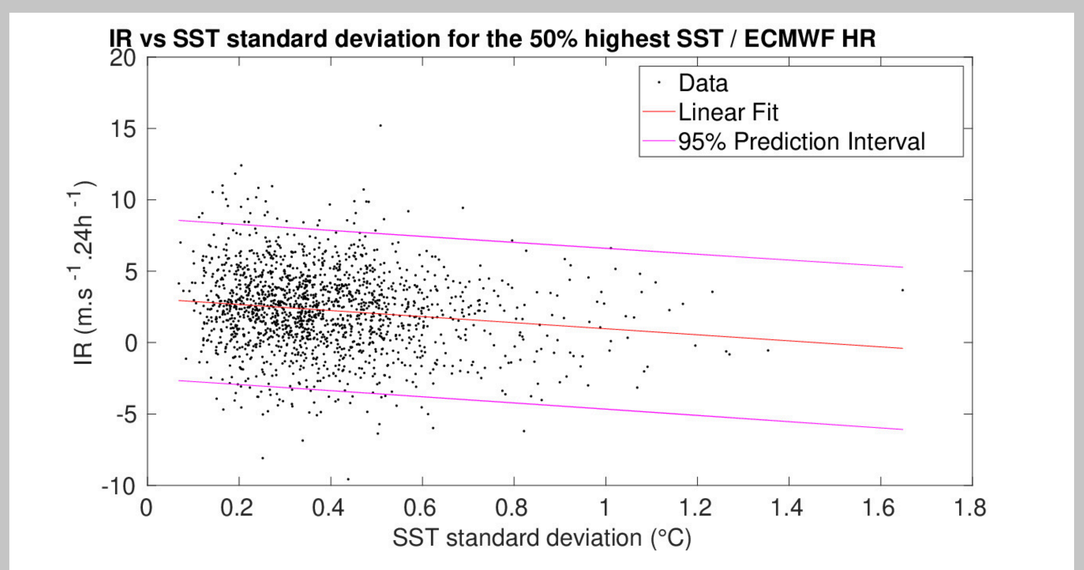
What was done

When warm, dry stratospheric air descends towards the eye, it forms warm anomalies known as **High-level Warm Cores** (HWCs).

Using fine-scale numerical simulations, my analysis showed that HWCs **at the same time** promote intensification, by **reducing hydrostatic pressure** at the surface, but also trigger the dissipation phase, by **increasing the static stability** of the air column and, thus, inhibiting deep convection.



(a) Stratospheric air intrusion (3D plot) reducing surface pressure (shaded) (b) Cyclone intensity evolution (black line) over the average core temperature anomaly (shaded).



The negative correlation between intensification rate and SST variability for TC in warm average SST regime. Data from ERA5, courtesy of L. Bernini

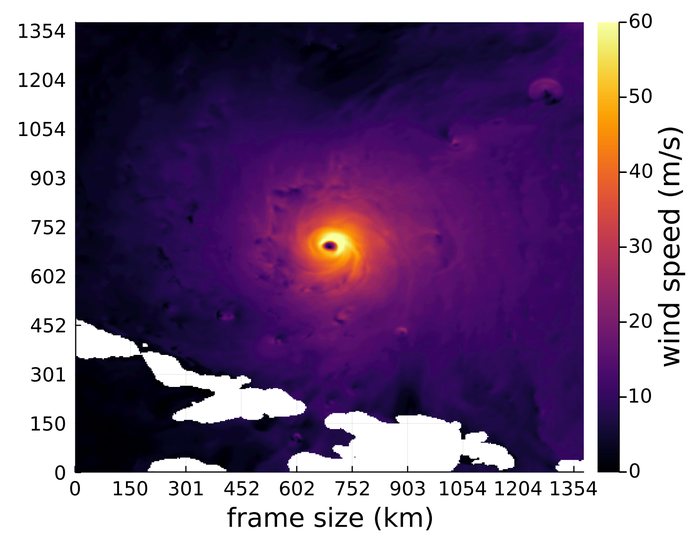
The next stage

In **warm conditions**, increased SST heterogeneity **reduces intensification**, whereas in cool regimes it may promote it and vice versa. I plan to investigate this process by:

- Running ensembles of **idealised** high-resolution simulations using prescribed SST fields fixed in time, featuring either mesoscale eddies or latitudinal SST gradients.
- Observing how TC intensification is affected by modifying the **average SST** or the **magnitude of the anomalies** of those fields
- Performing statistical and dynamical analyses of the results to assess:
  - how SST variance modifies surface fluxes and boundary-layer thermodynamics;
  - the physical mechanisms responsible for **regime-dependent responses**
  - the surface conditions that favour interaction with the stratosphere

The role of HPC and storage facilities

Access to **Leonardo** computing system enabled multiple 1-km-resolution test simulations with **WRF model**, completing two-month simulations within only a few hours, a performance that can be further improved by optimising the WRF configuration for **idealised experiments**.
The **TeRABIT** project will provide the computational resources required to run the full suite of simulations **in a short time** and, crucially, **the long-term storage** needed to archive the generated datasets, facilitating **data sharing** and **collaboration** within the research community.
These outputs will constitute a valuable resource also for **broader investigations** of fine-scale dynamics in TCs



Example of wind speed field in a high-resolution (3.75km) model (NICAM). With resources provided by TeRABIT, the resolution can be further increased

References

[1] WMO (2021). Review for the forty years of the WMO tropical cyclone programme (1980-2020) [2] Davin, A et al., Stratospheric Influence on Tropical Cyclone Evolution (under review)
[3] Bernini, L. (2021). Physical and biogeochemical oceanography influence of sea surface temperature spatial variability on tropical cyclones intensification (Master thesis)

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