Improving Hurricane Track Prediction in a High-resolution GFDL Model

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Ref: Gao et al (2023, GRL 10.1029/2023GL103329)

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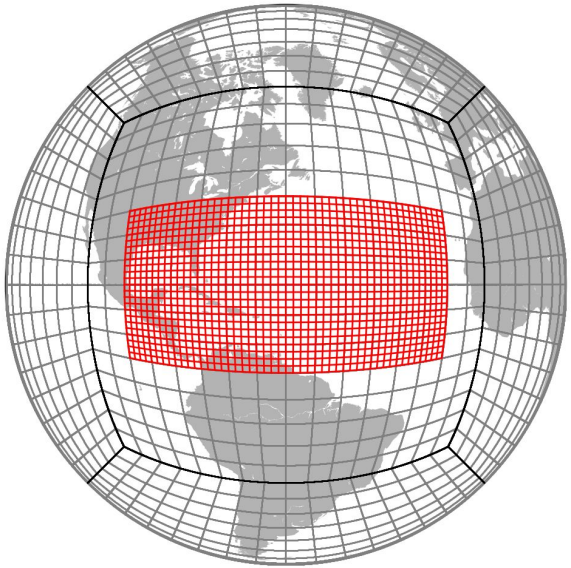
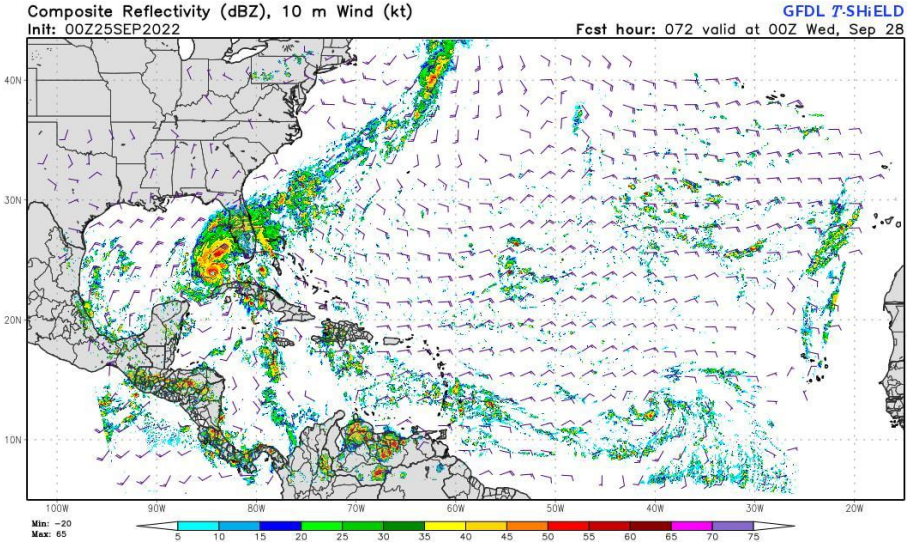
T-SHiELD: a Tropical configuration of GFDL SHiELD

- Two-way nested domain (13 km global + 3.25 km nest)
- Designed to resolve convective features over a large domain





SHiELD website: https://www.gfdl.noaa.gov/shield/

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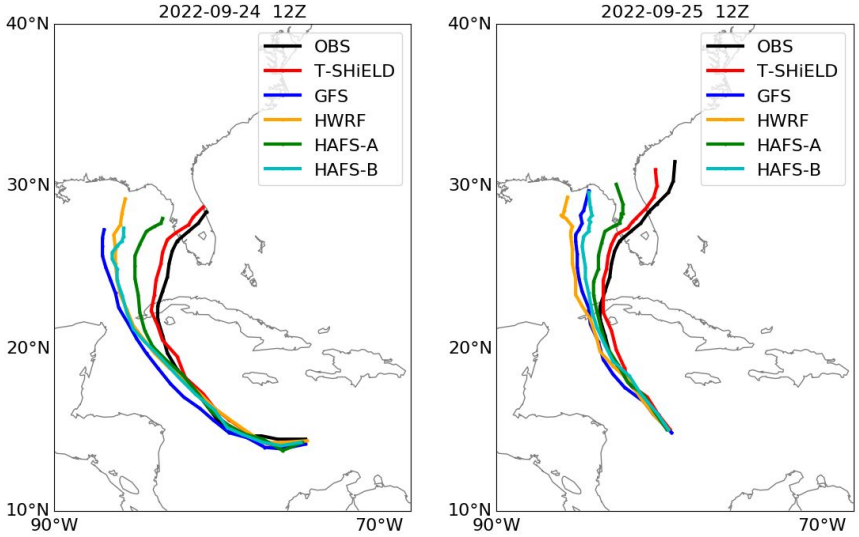
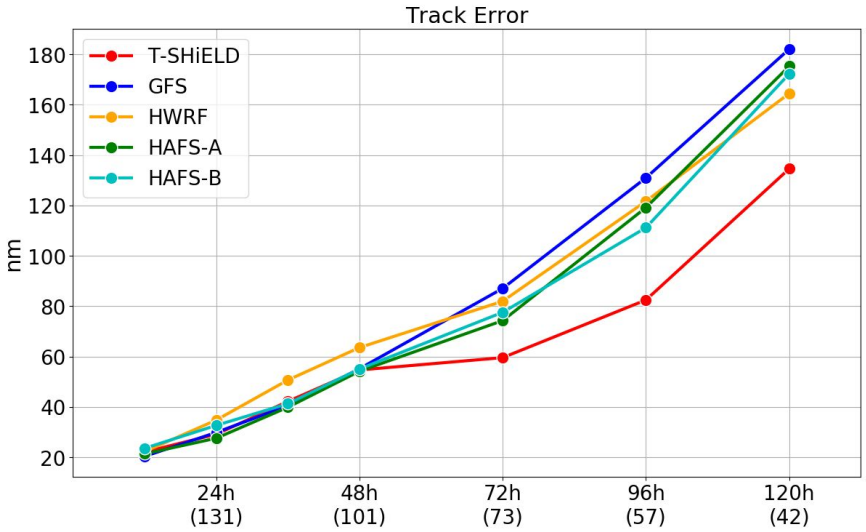
2022 Hurricane Season Highlight

Hurricane Ian Track Forecasts



2022 season mean track error



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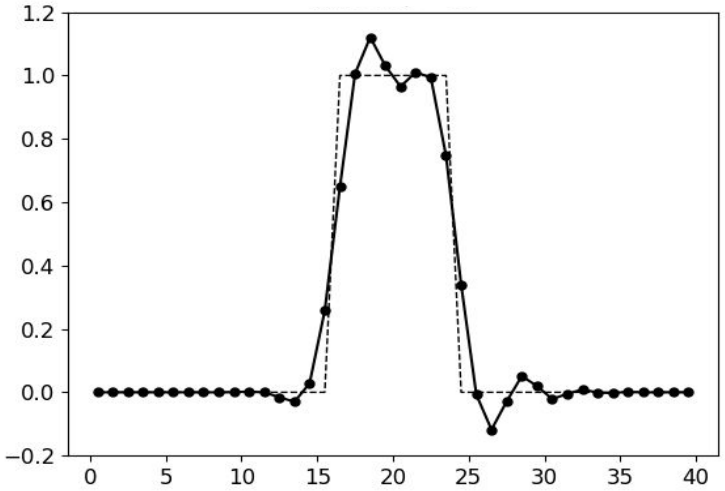
Main points

- The impact of convective processes (either parameterized or resolved) on hurricane prediction is well-known but the mechanisms are often not well understood.
- Here we show how the improved representation of resolved convection improves hurricane track prediction in 3km GFDL T-SHiELD, and also explain why.

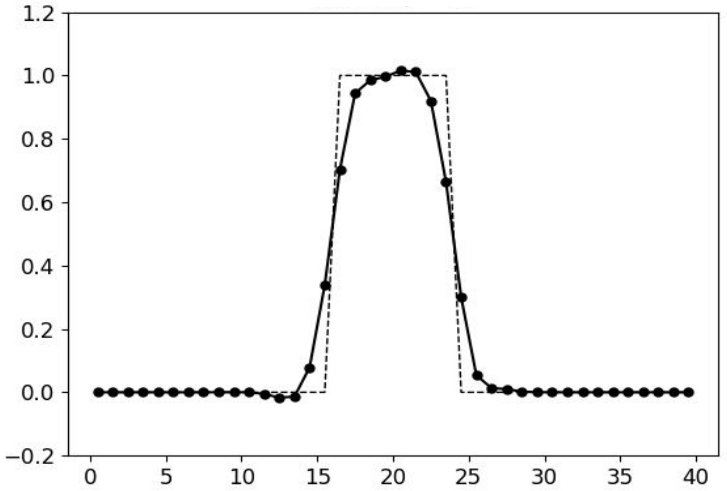
Two horizontal advection schemes

- hord5: virtually inviscid (the least diffusive option in FV3)
- hord6: minimally diffusive

a) hord5

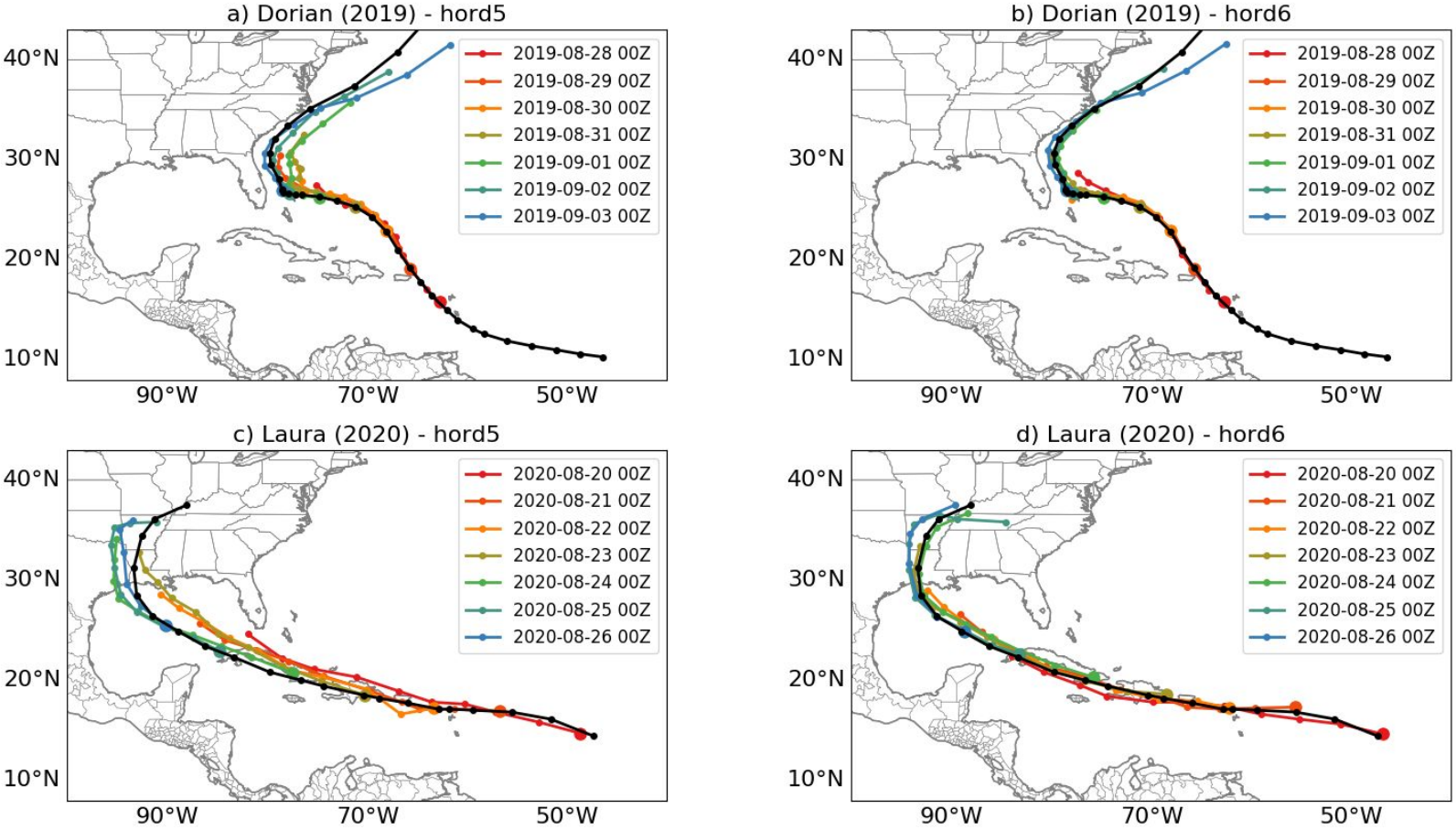


b) hord6

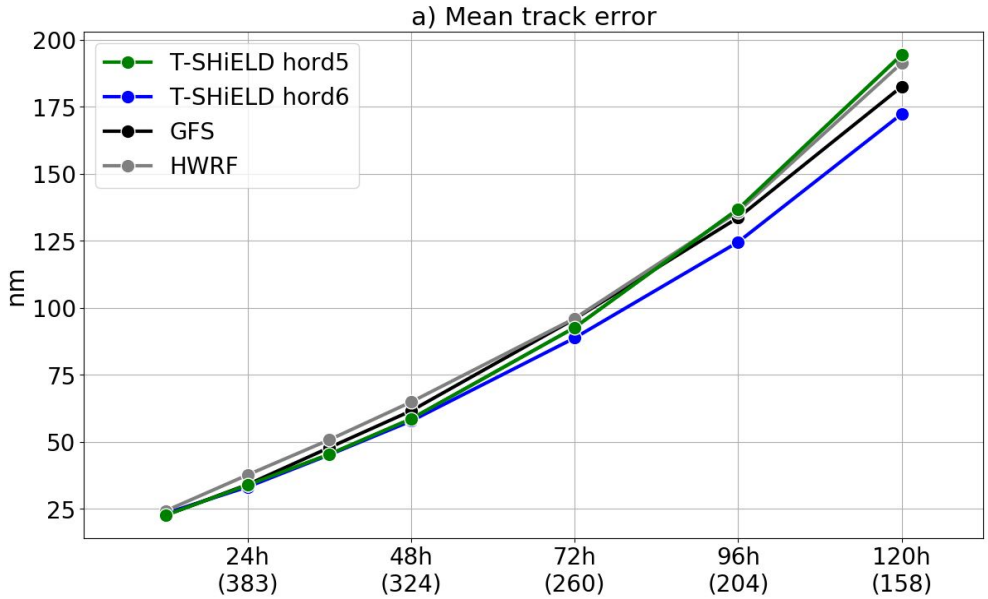


Both are suitable for high-resolution applications

Representative 5-day forecasts

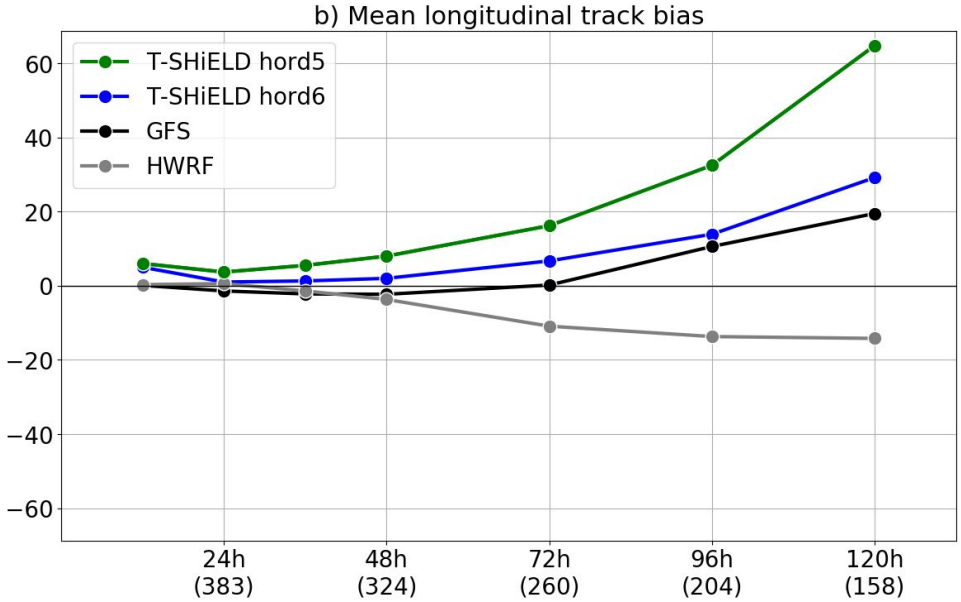


Mean track error in multi-season samples



- ~350 five-day forecasts from 2018-2022 North Atlantic hurricane seasons
- **Mean track error reduced by ~10% at days 4 and 5 in hord6 runs**

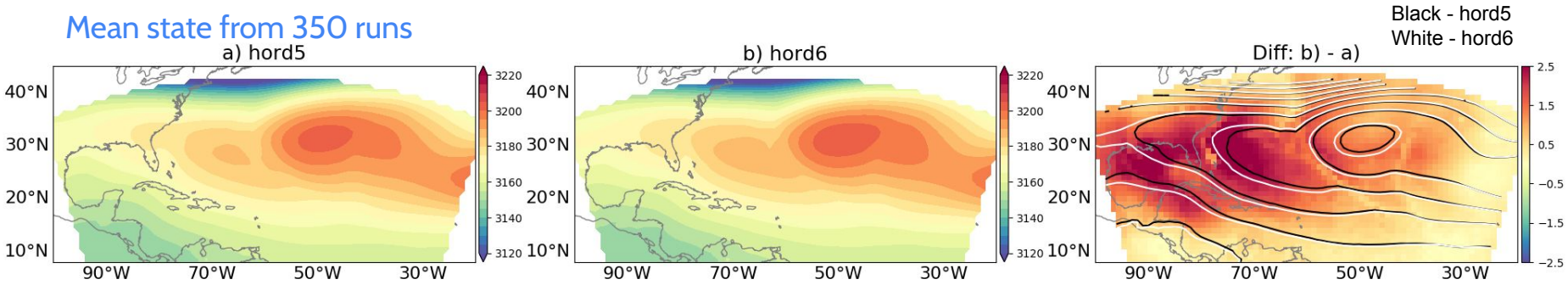
Mean track bias in multi-season samples



Significant reduction of eastward track bias in hord6 runs

Mean state - 700mb geopotential height

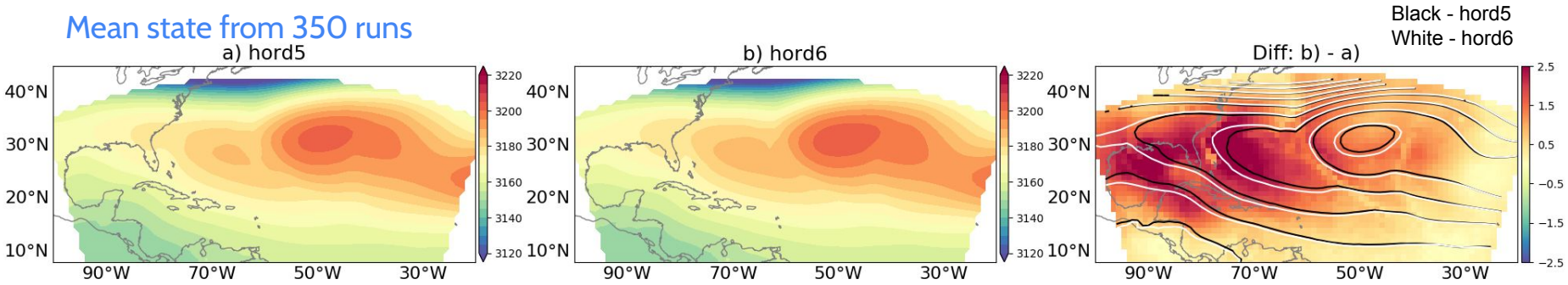
Mean state from 350 runs



- The subtropical ridge hord6 runs extends further west, which explains the reduced eastward TC track bias
- Question remains: how are all of these related to change of *hord*?

Mean state - 700mb geopotential height

Mean state from 350 runs



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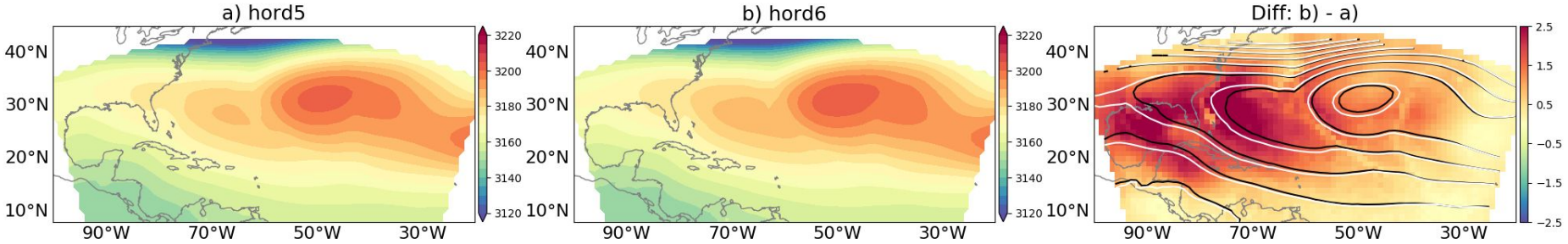
Our hypothesis:

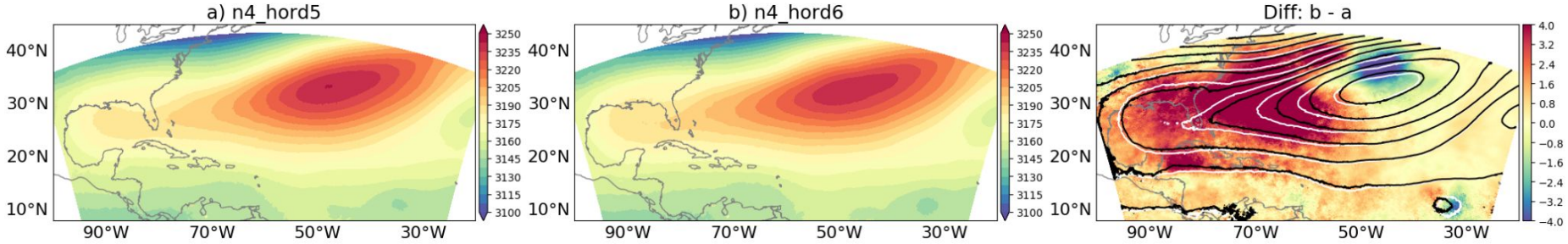
- The change of *hord* affects the behavior of explicit convection
- The sensitivity is resolution dependent

Can we reproduce the H700 changes in TC-free forecasts? YES!

Mean state from 350 runs



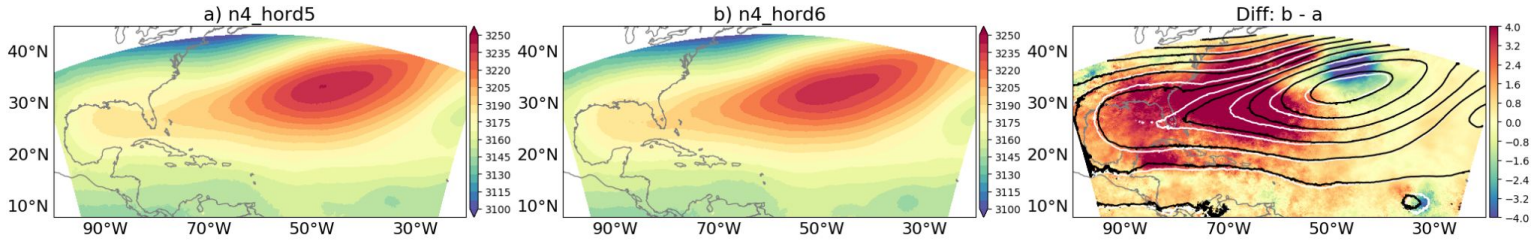
5-day mean of one single TC-free run (initialized on 2020-08-30 00Z)



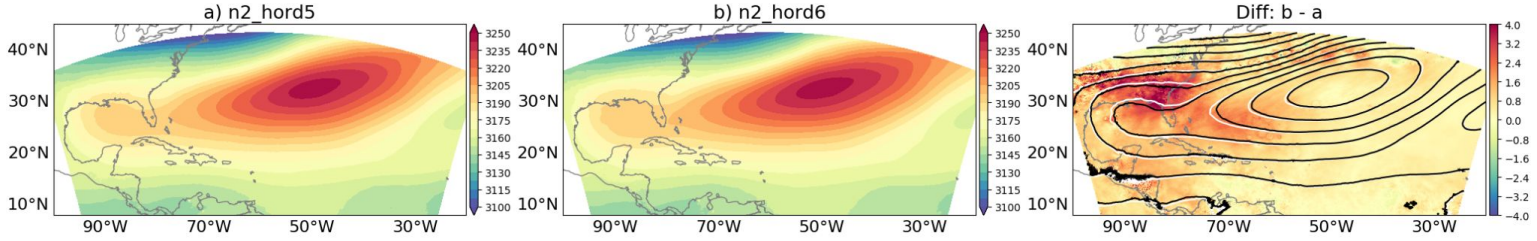
Does the sensitivity to *hord* depends on resolution?

hord5 | **hord6** | **hord6 - hord5**

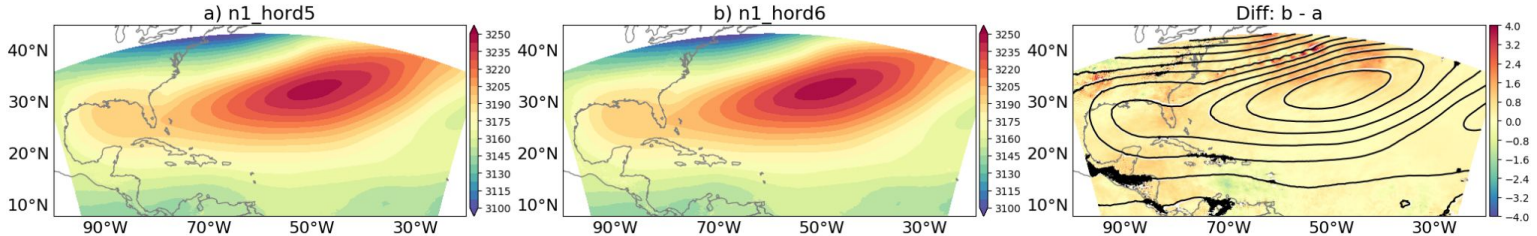
dx = 3.25km



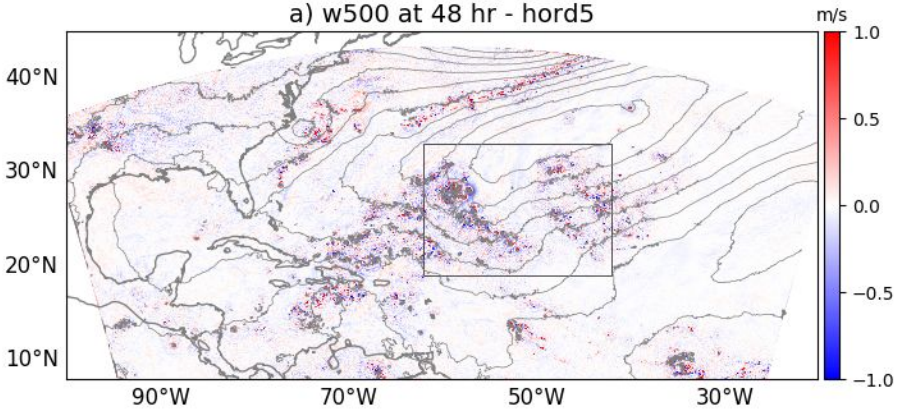
dx = 6.5km

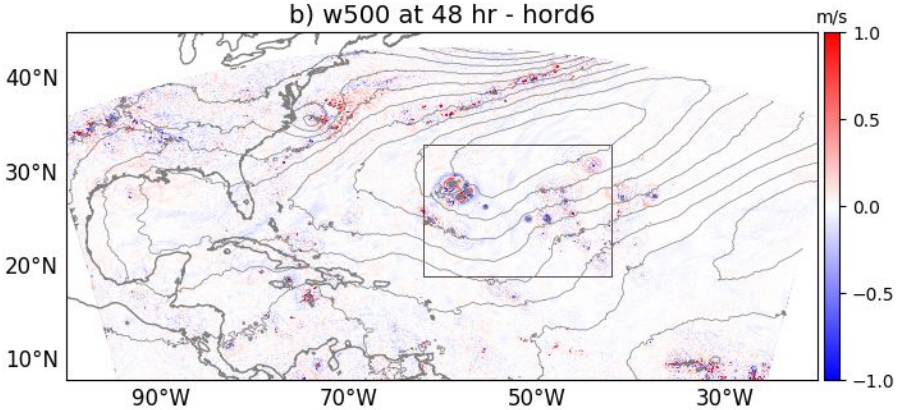


dx = 13km

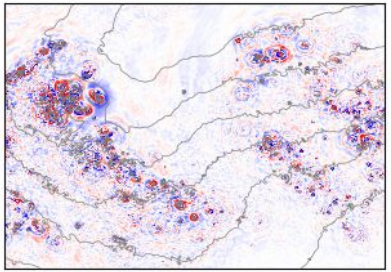


Snapshots of 500mb vertical velocity (48hr forecast; dx = 3.25km)

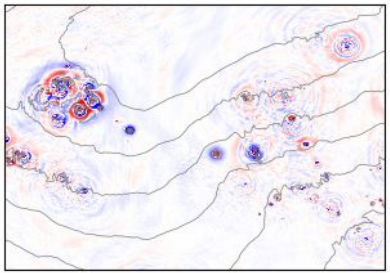




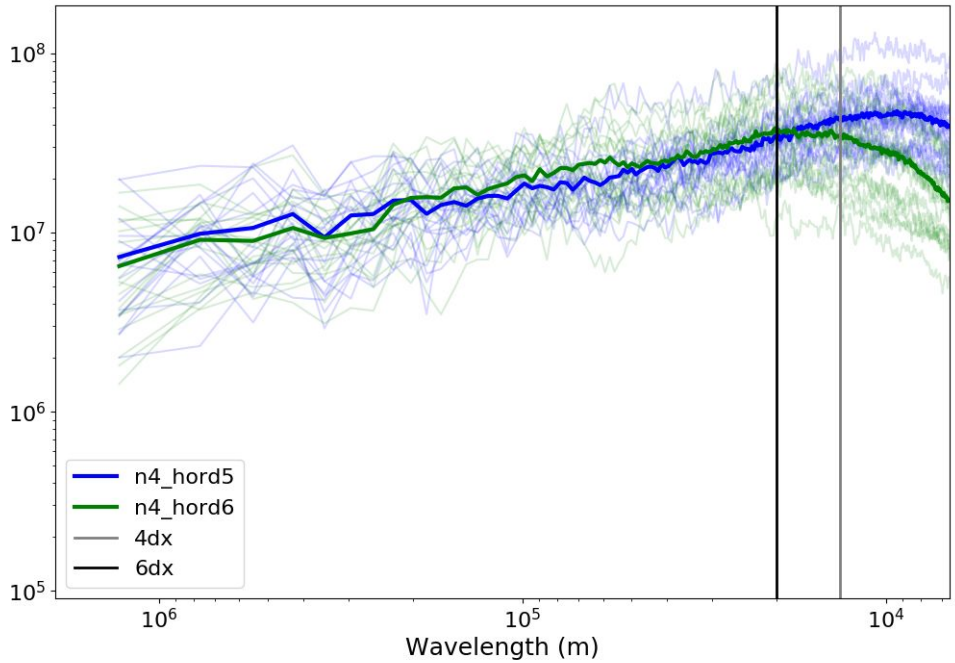
c) w500 in selected area - hord5



d) w500 in selected area - hord6



Variance spectrum of 500mb vertical velocity (dx = 3.25 km)



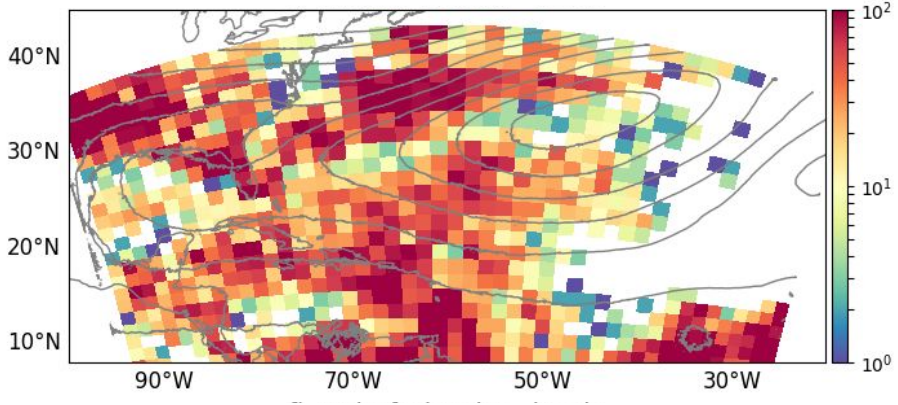
Based on one single TC-free run

Noticeable difference at spatial scale below 4*dx

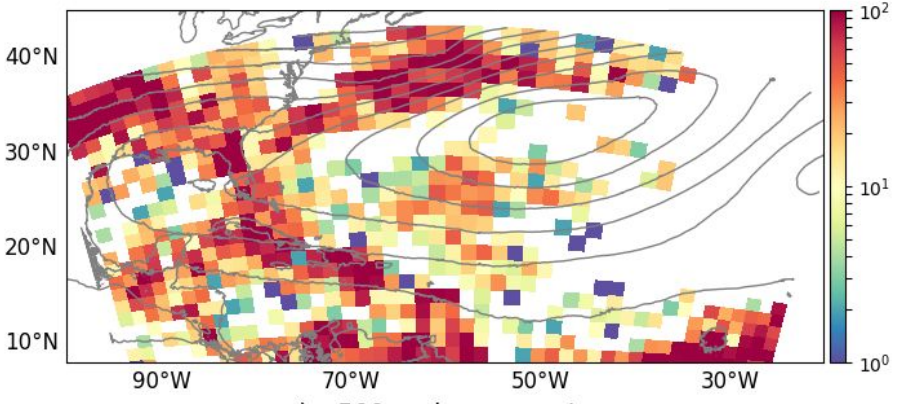
Spatial distribution of intense updafts (dx = 3.25km)

Updraft density : defined as the counts of *w500* greater than 3m/s in 1x1 degree boxes during the 5-day forecast

a) hord5



b) hord6



Based on one single TC-free run

Summary

- Better regulation of fine-scale explicit convection activity reduces track error by 10% at days 4 and 5 in GFDL T-SHiELD.
- Explicit convection can be controlled by either the model numerics (e.g., advection scheme) or physics (e.g., explicit diffusion, convection scheme).
- We encourage the community to pay more attention to the behavior of the marginally resolved convection in high-resolution hurricane models, and more broadly the global storm-resolving models.

More details at Gao et al (2023, GRL 10.1029/2023GL103329)