Why are tropical cyclones so intense in CAM5 at ultra-high resolutions?

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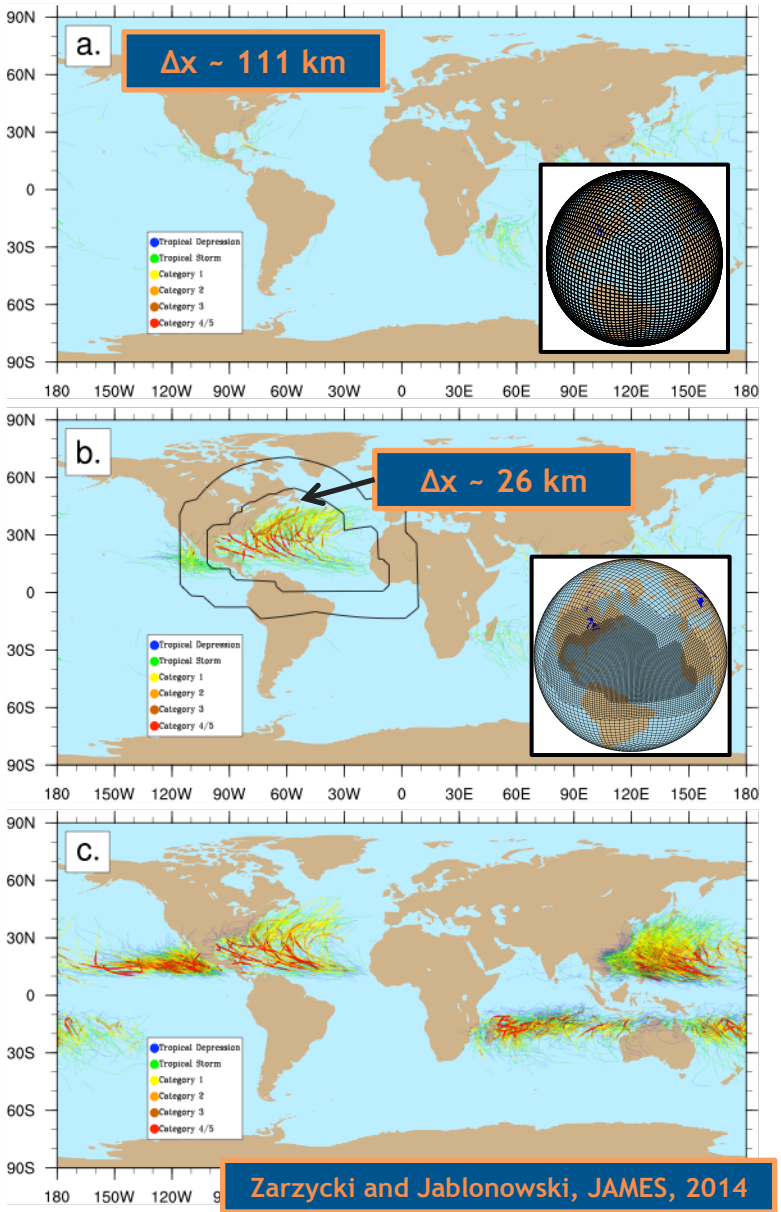
Tropical cyclones and horizontal resolution

Uniform 1°

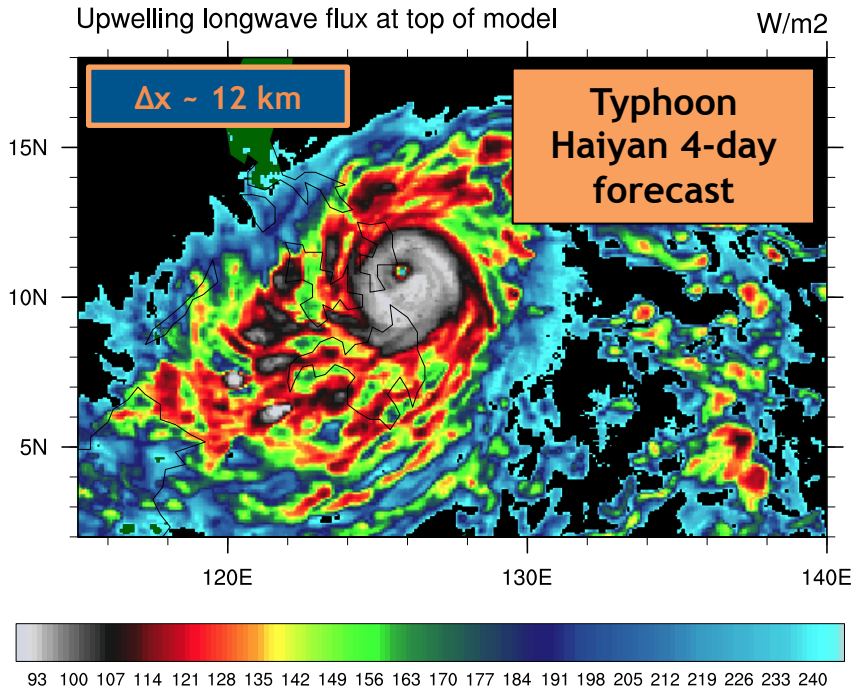
Var-res

Obs

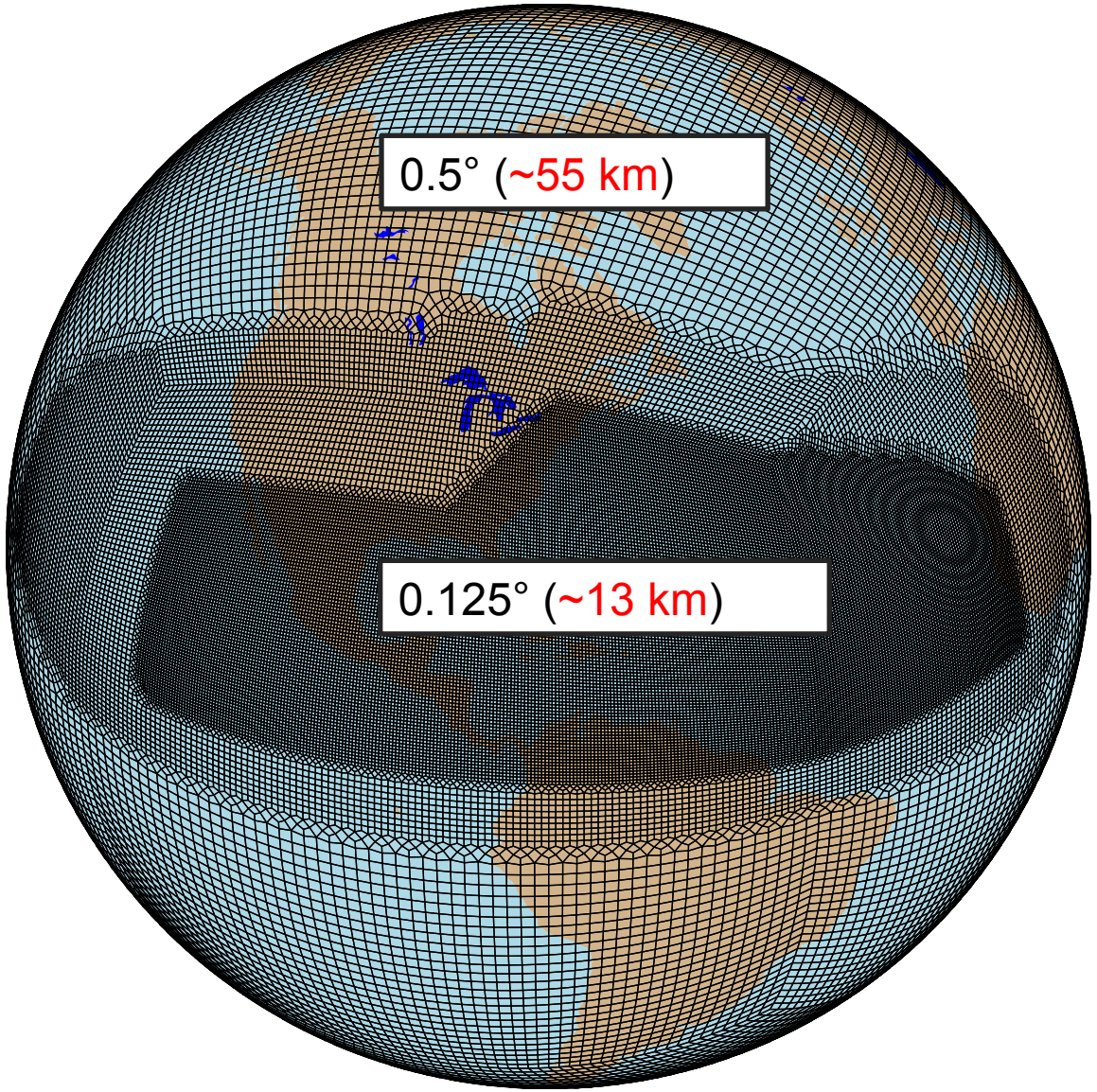


Zarzycki and Jablonowski, JAMES, 2014

- Tropical cyclone representation significantly more realistic at finer grid spacing in CAM



CAM-SE “forecast mode”

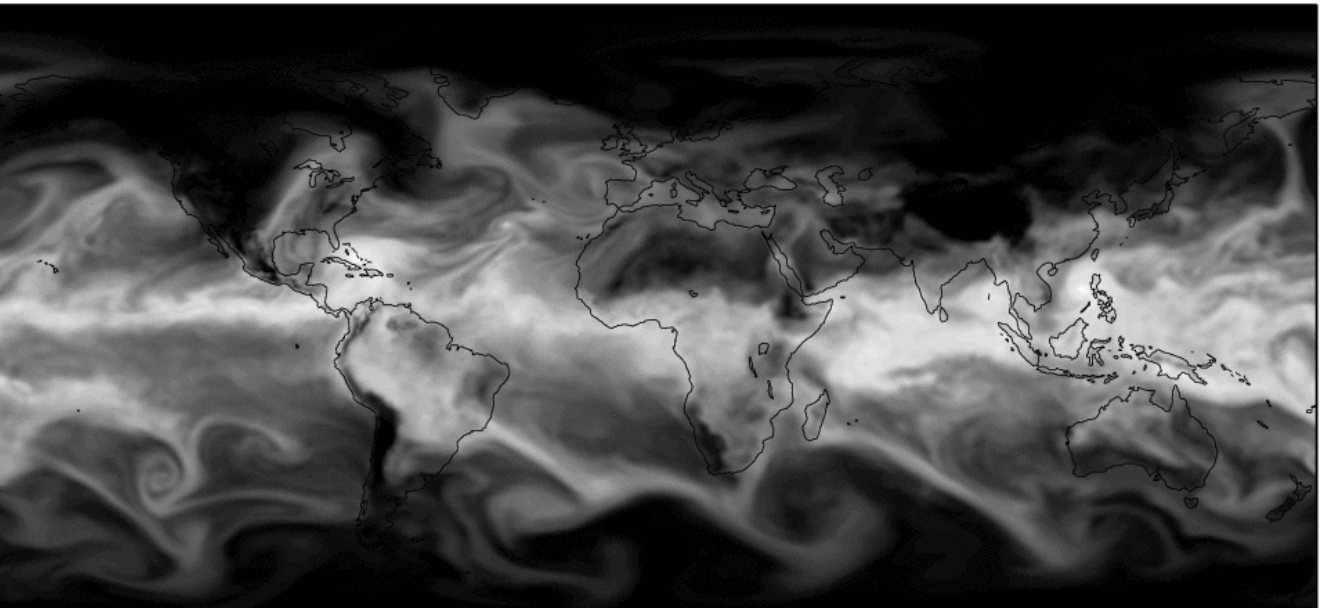


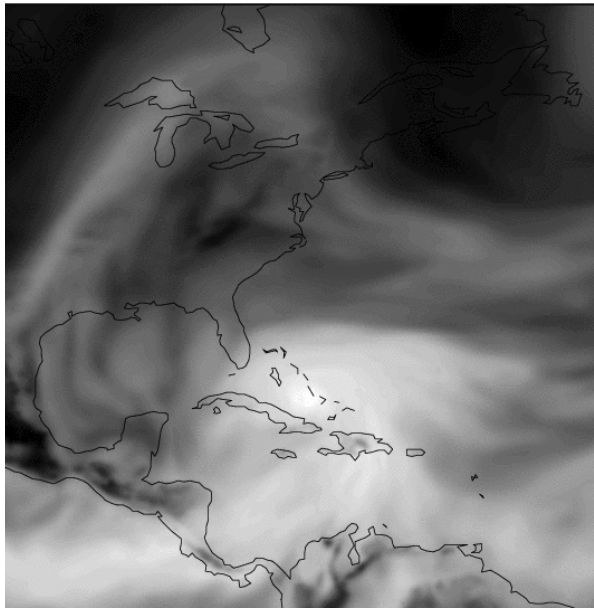
CAM-SE "forecast mode"

- Every 12 hours (00Z and 12Z) from August 1st to November 1st for 2012-2013
- 8 day forecast = ~1.5 hours of wall clock time on 800 cores (NCAR Yellowstone)
  - **~6-7x cheaper than a globally-uniform 13 km forecast**

Zarzycki et al., in prep.

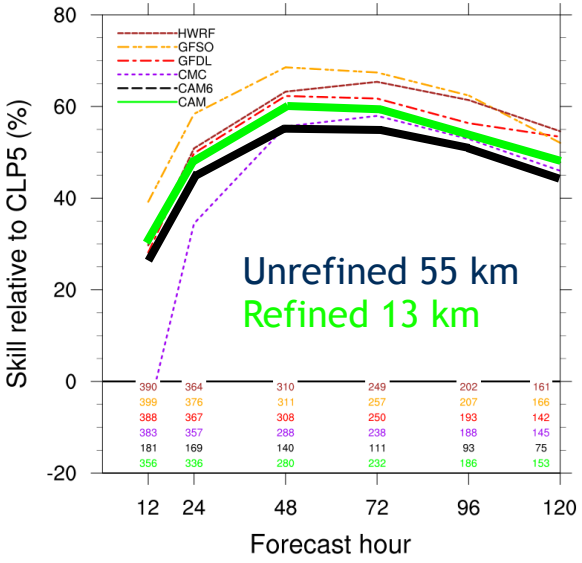
Sandy TPW: INIT 12Z 10/25/12



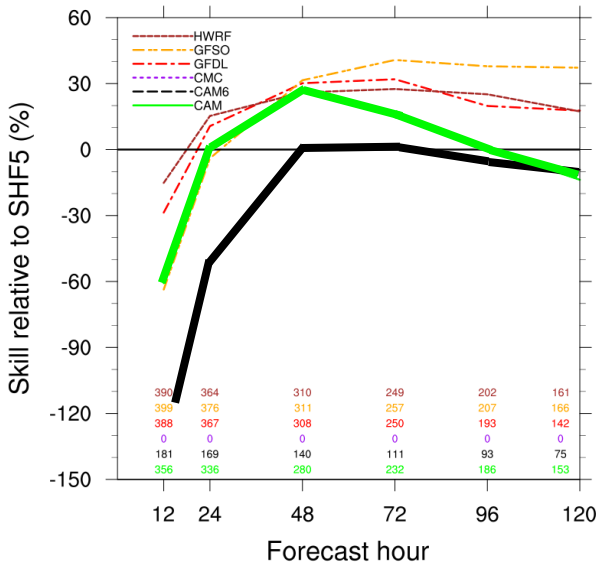


CAM-SE "forecast mode" control

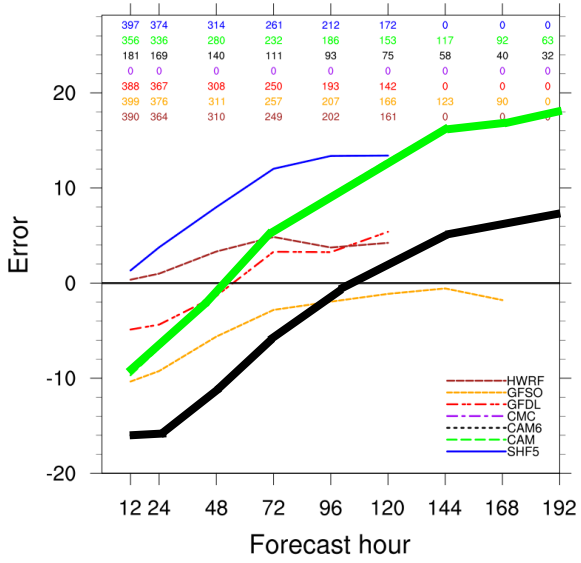
Track error



Absolute wind error



Wind bias



Zarzycki et al., in prep.

- Refinement improves both track, intensity skill
- Track behavior of TCs looks good…
- … CAM exhibits a high bias in TC intensity, especially as the solution moves away from initial state

CAM5 pressure-wind relationship

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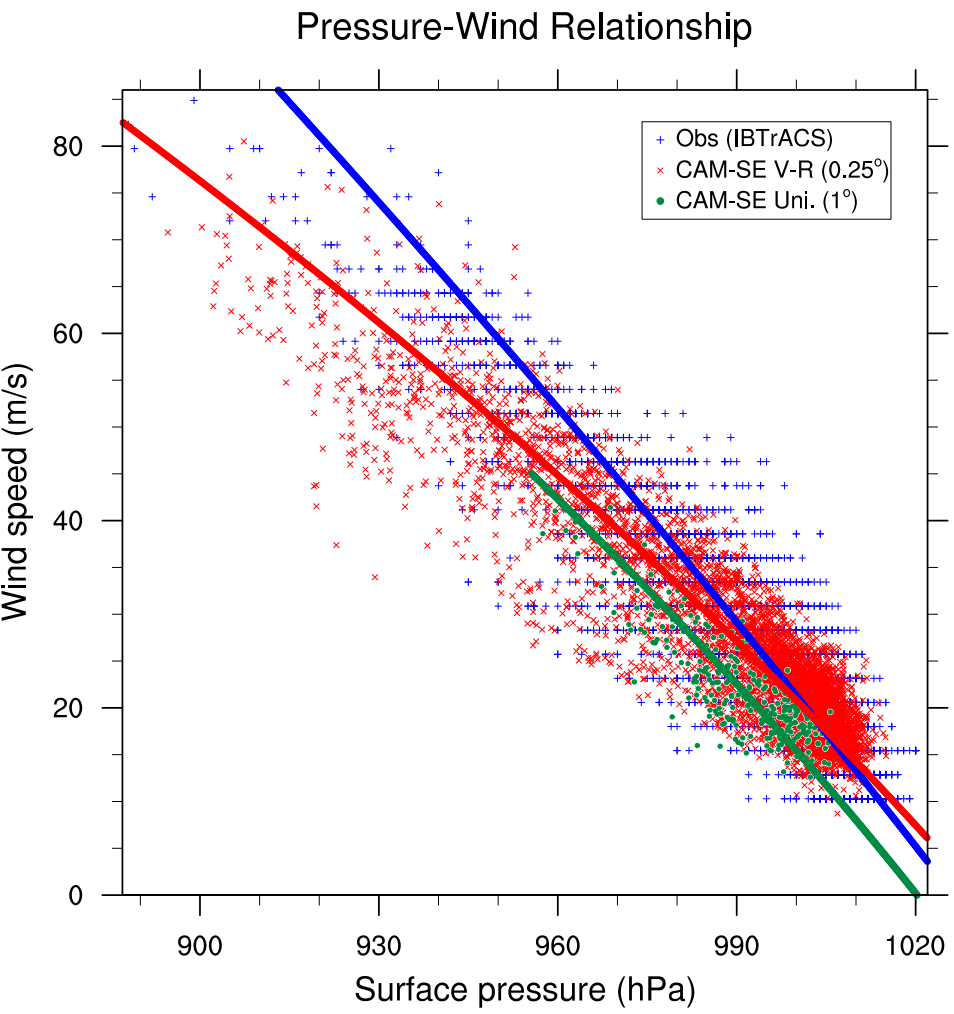
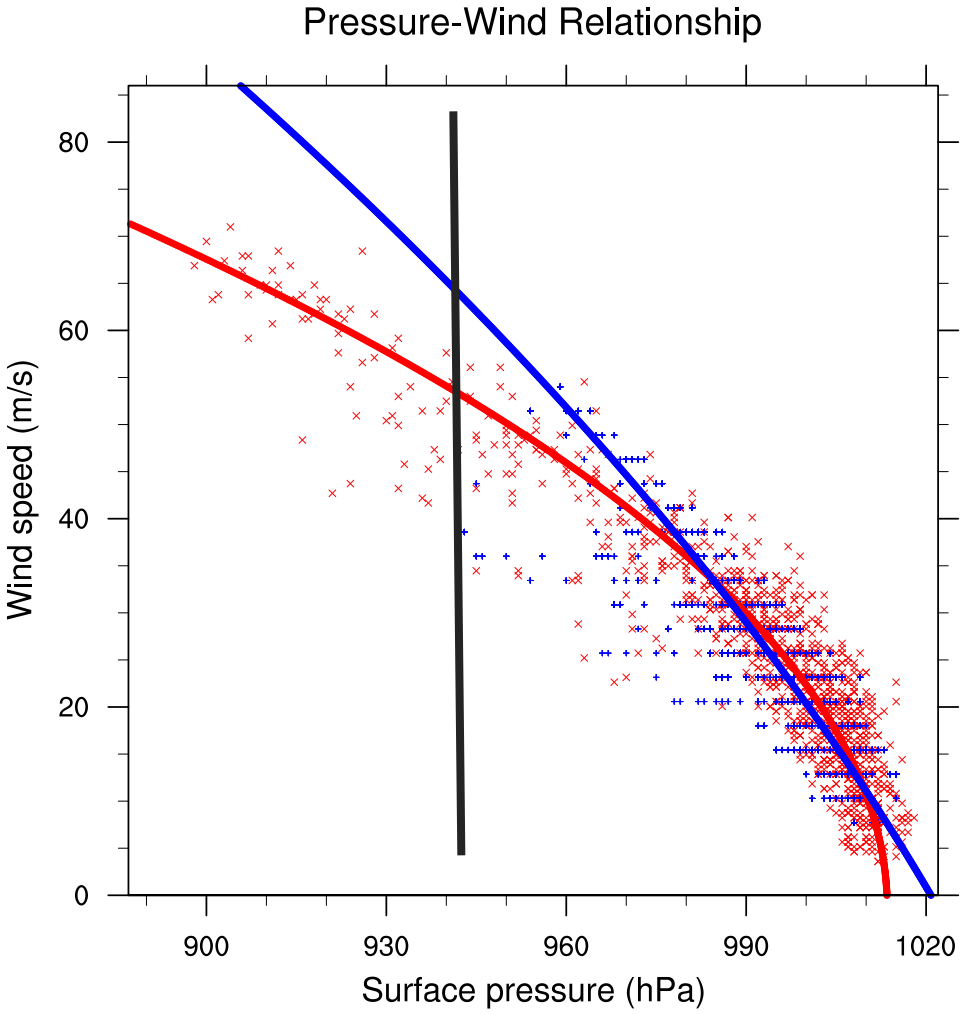
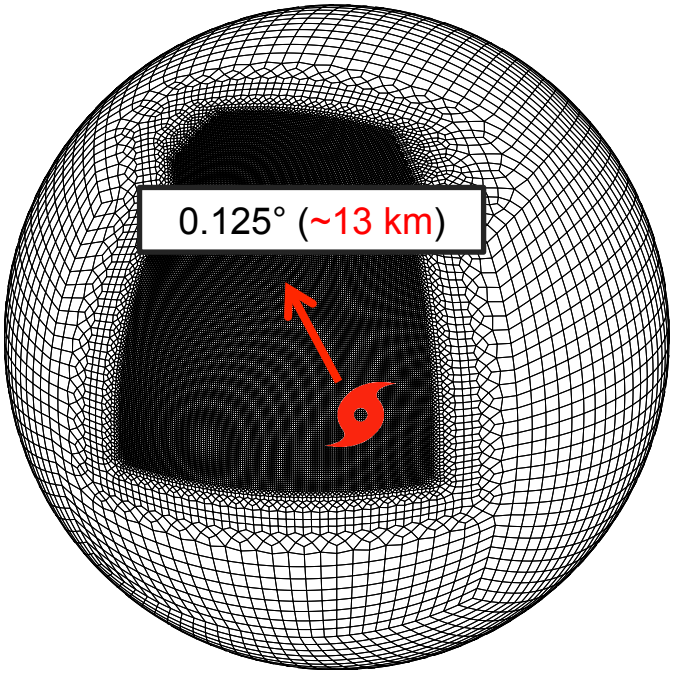
Δx ~ 26 km



Δx ~ 13 km



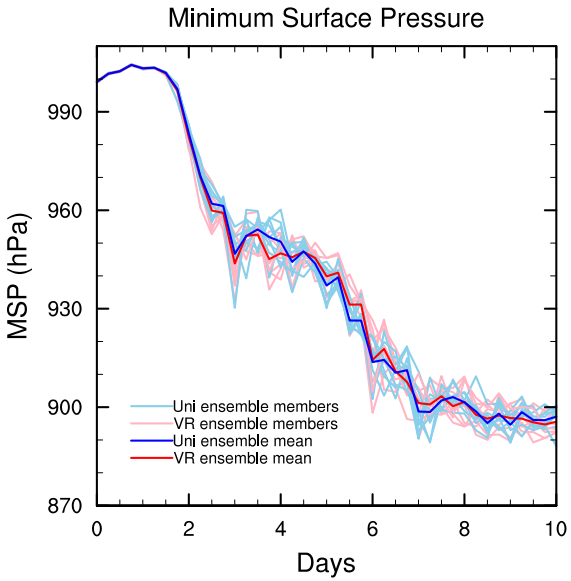
Idealized, high-res TC sensitivity ensembles

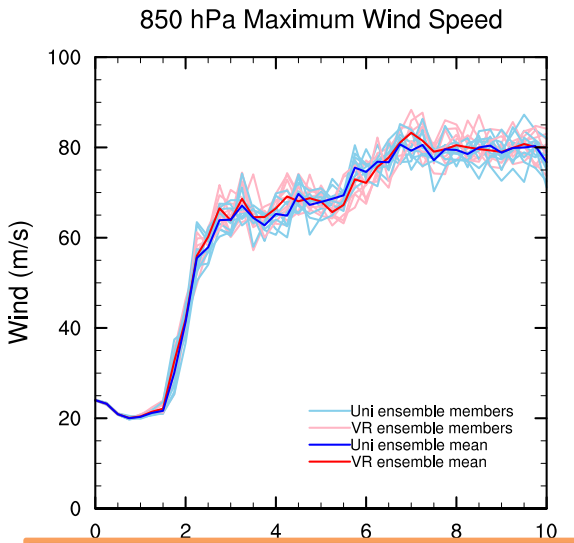


Model configuration:

- Aquaplanet
- Δt = 1800 sec / default CAM5 physics
- SST = 29° C
- Reed-Jablonowski (2012) TC
- TC initialized at 10° N
- Tropical vertical temperature/moisture profiles
- No background flow, beta drift

- 9 member ensemble
  - Perturb initial vortex of location by Δx/2
  - Ensemble average provides robust results, “smooth” behavior

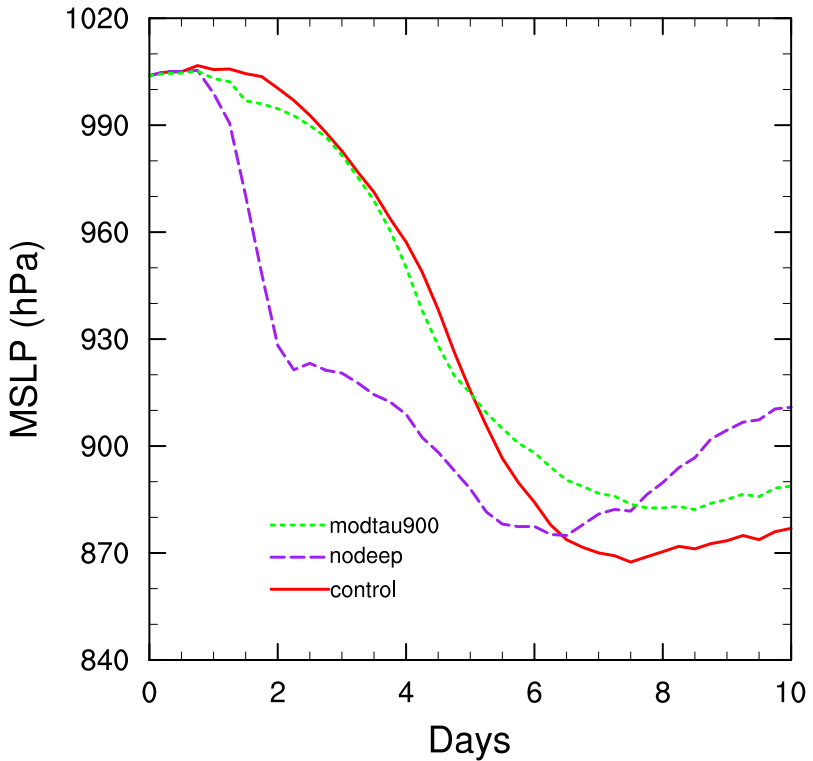


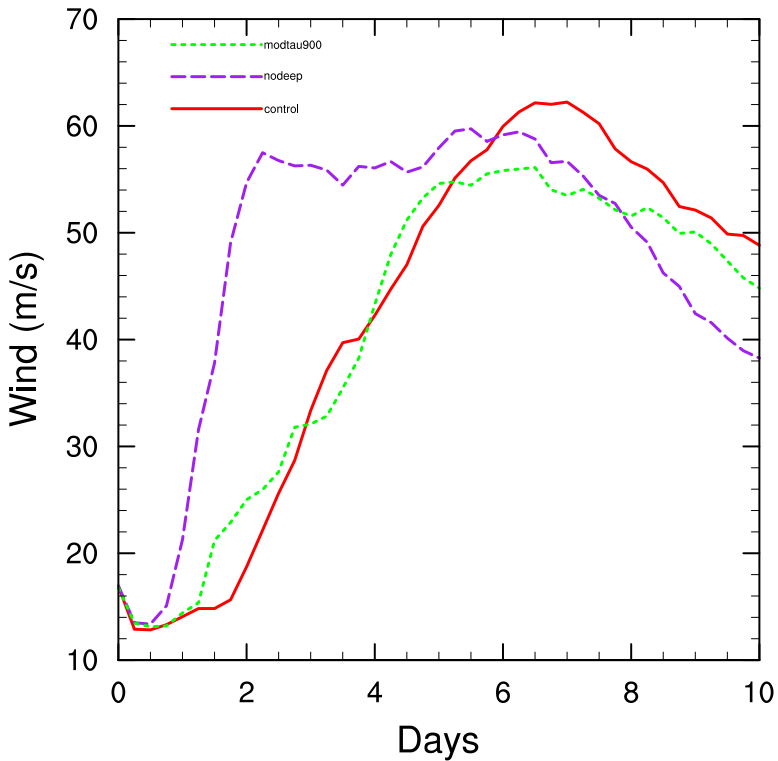


Zarzycki et al., MWR, 2014

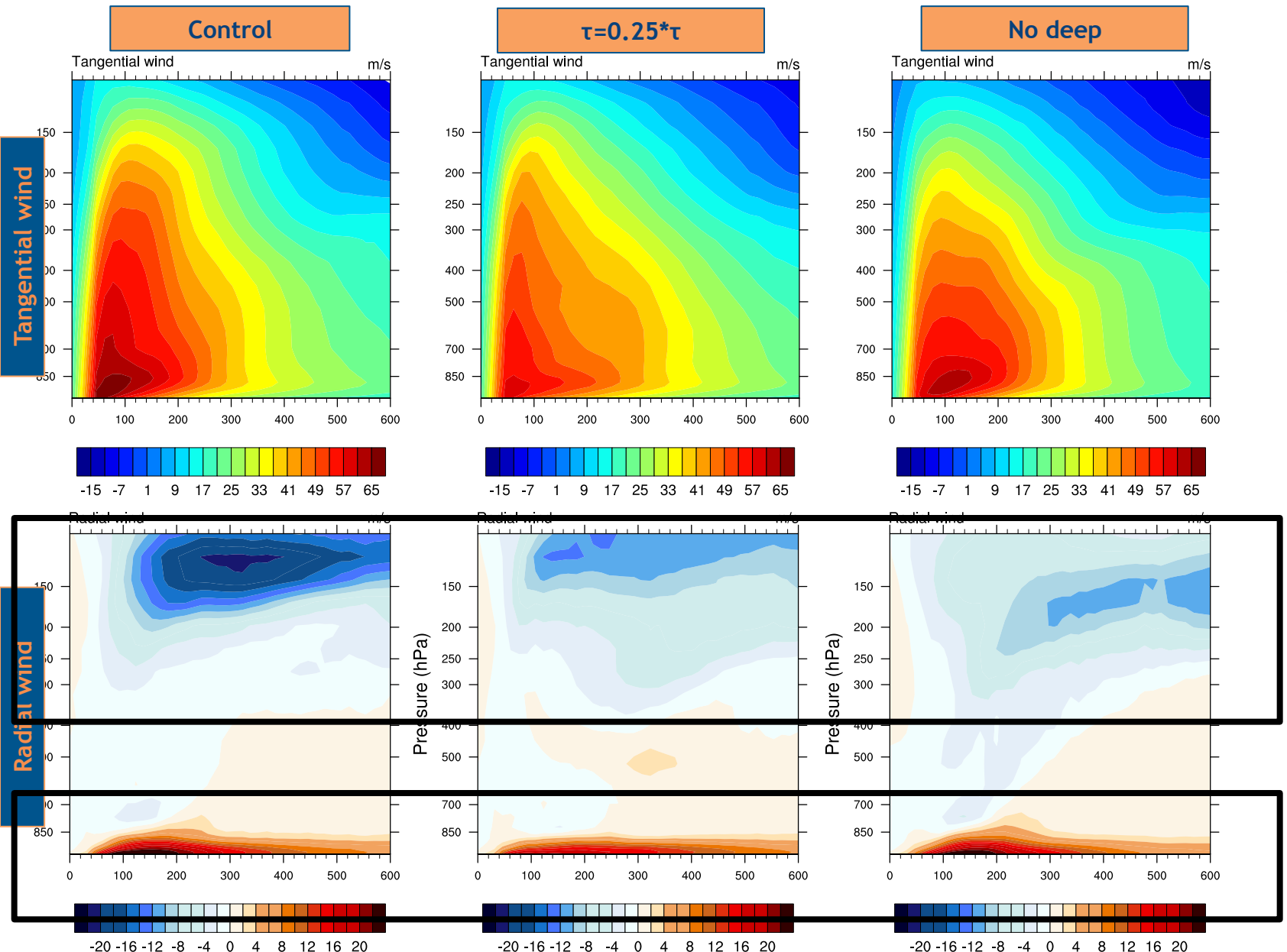
Preliminary sensitivity runs

- **Control**: Default CAM5 physics, (d_{time}=1800s)
- **No deep**: No ZM deep convection (is convection not "turning off" enough)
- **Modified τ**: Decrease convective relaxation from 3600s -> 900s (is convection too "inactive?" e.g., Williamson, QJRMS, 2013)





Storm dynamical structure



Day 8: Storm has generally reached maximum intensity/ steady state

Vertical temperature anomaly

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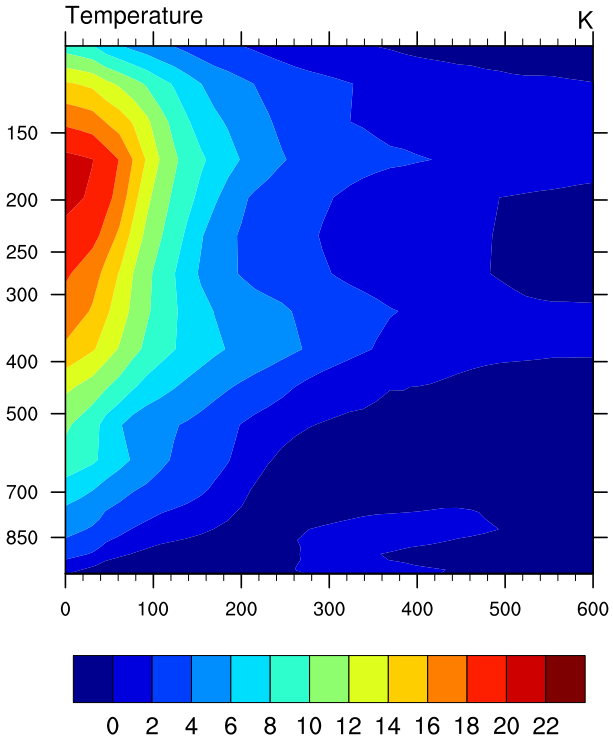
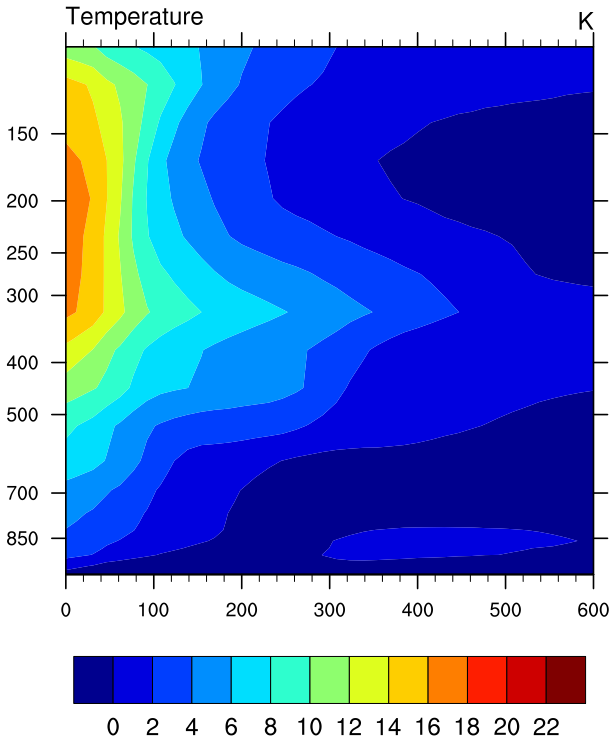
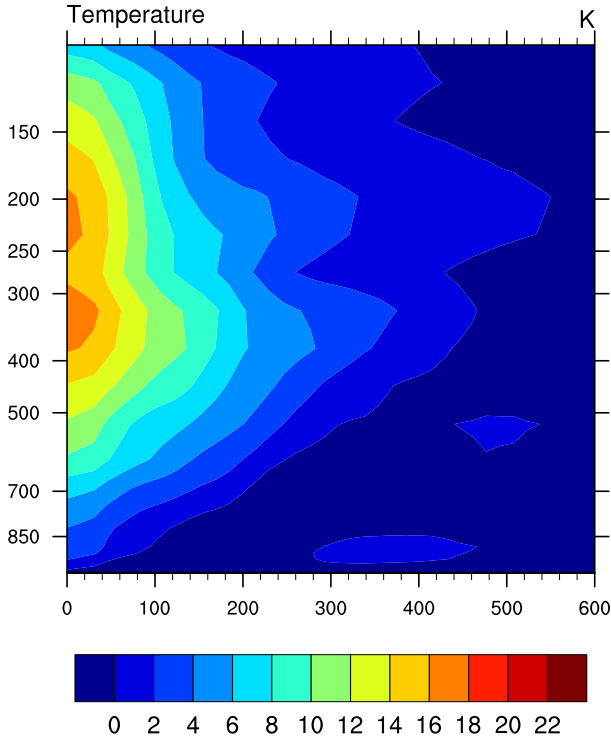
Control



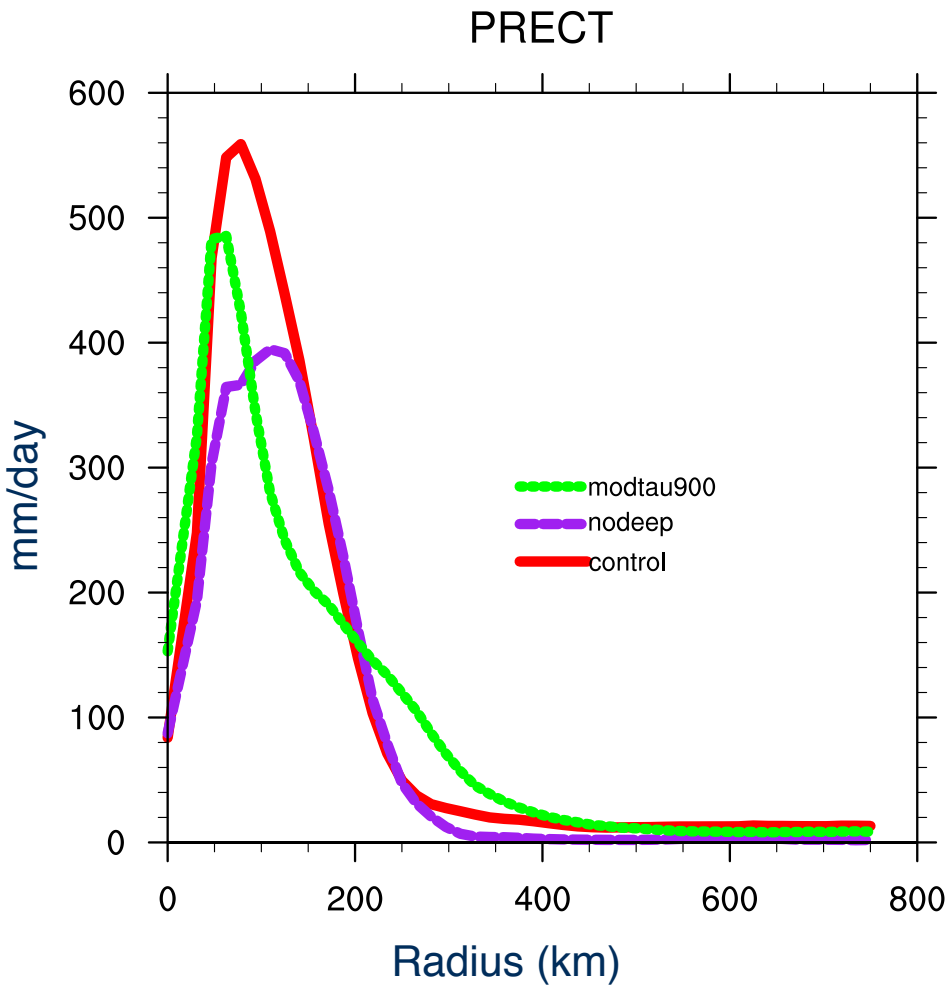
τ=0.25*τ

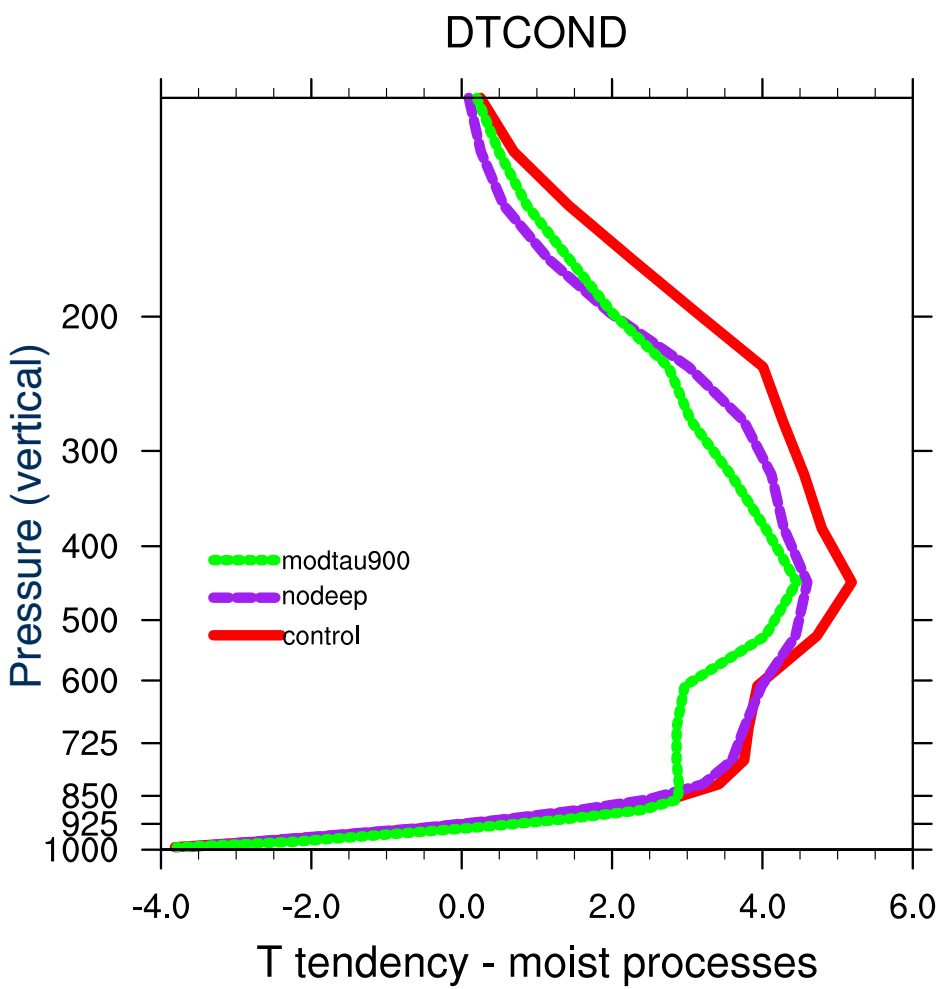


No deep



Moisture profiles

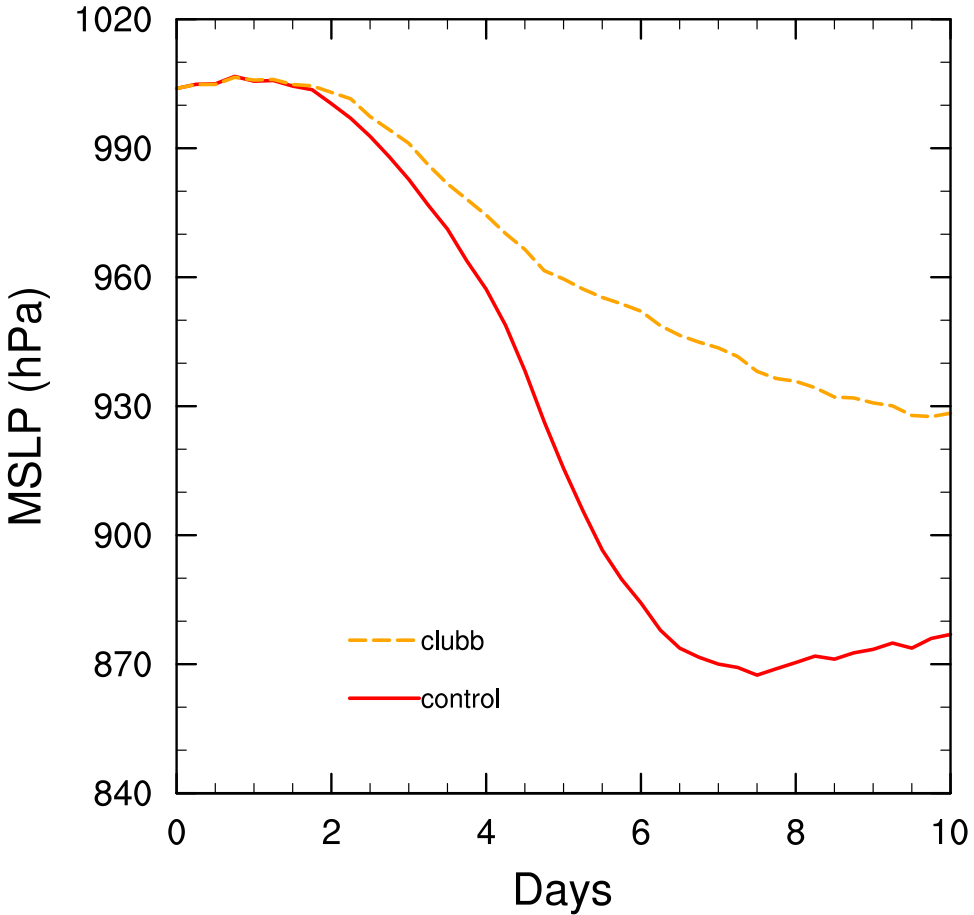


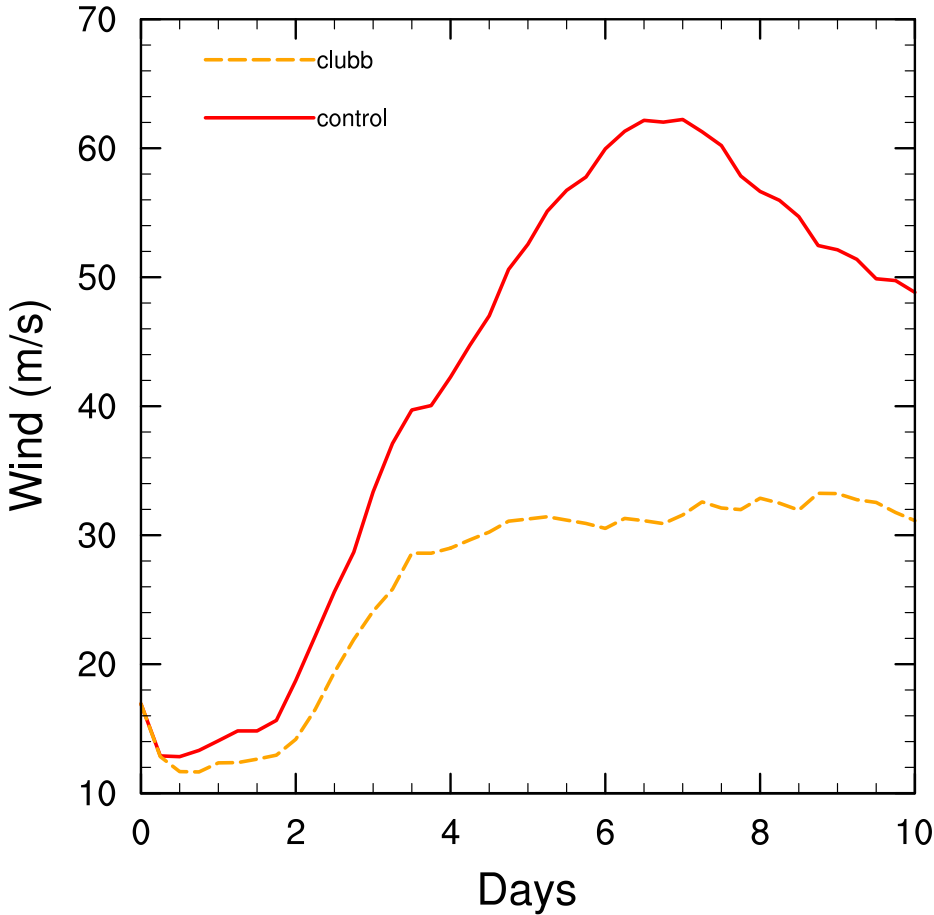


Radially-integrated within 300 km

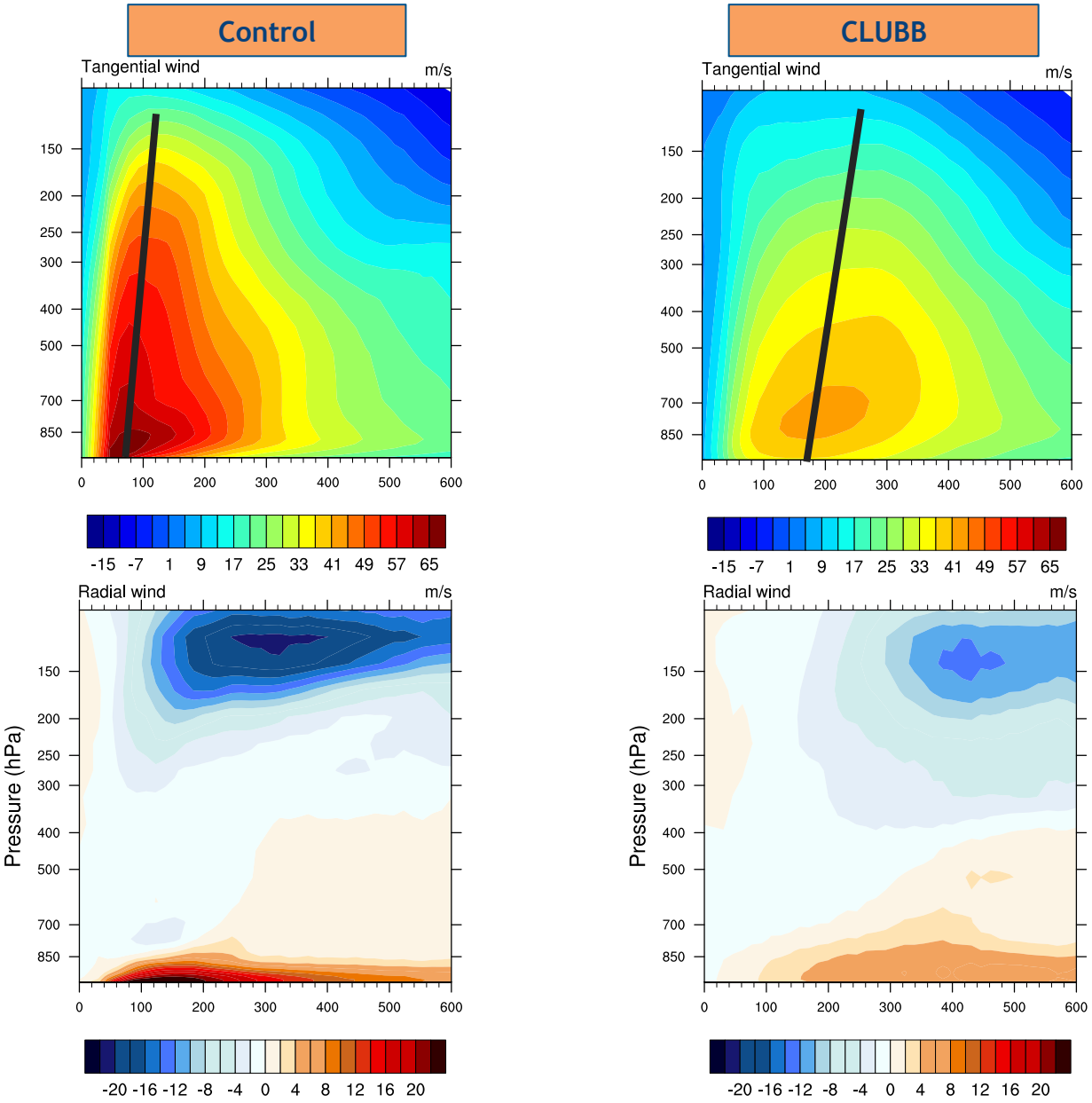
CLUBB sensitivity runs

- Control: Default CAM5 physics, d_{time} = 1800s
- CLUBB: CLUBB with MG1.0, ZM



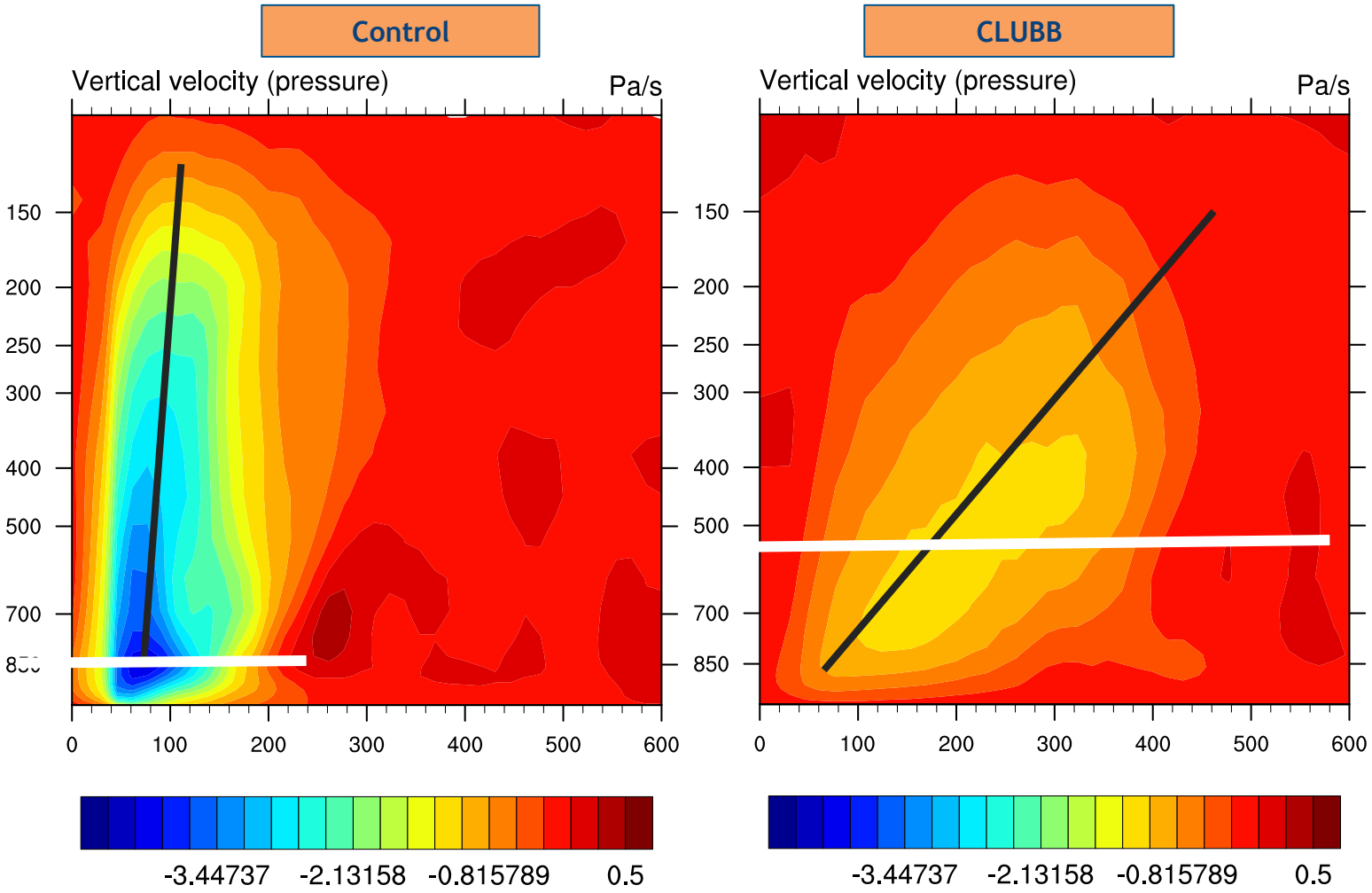


CLUBB structural differences

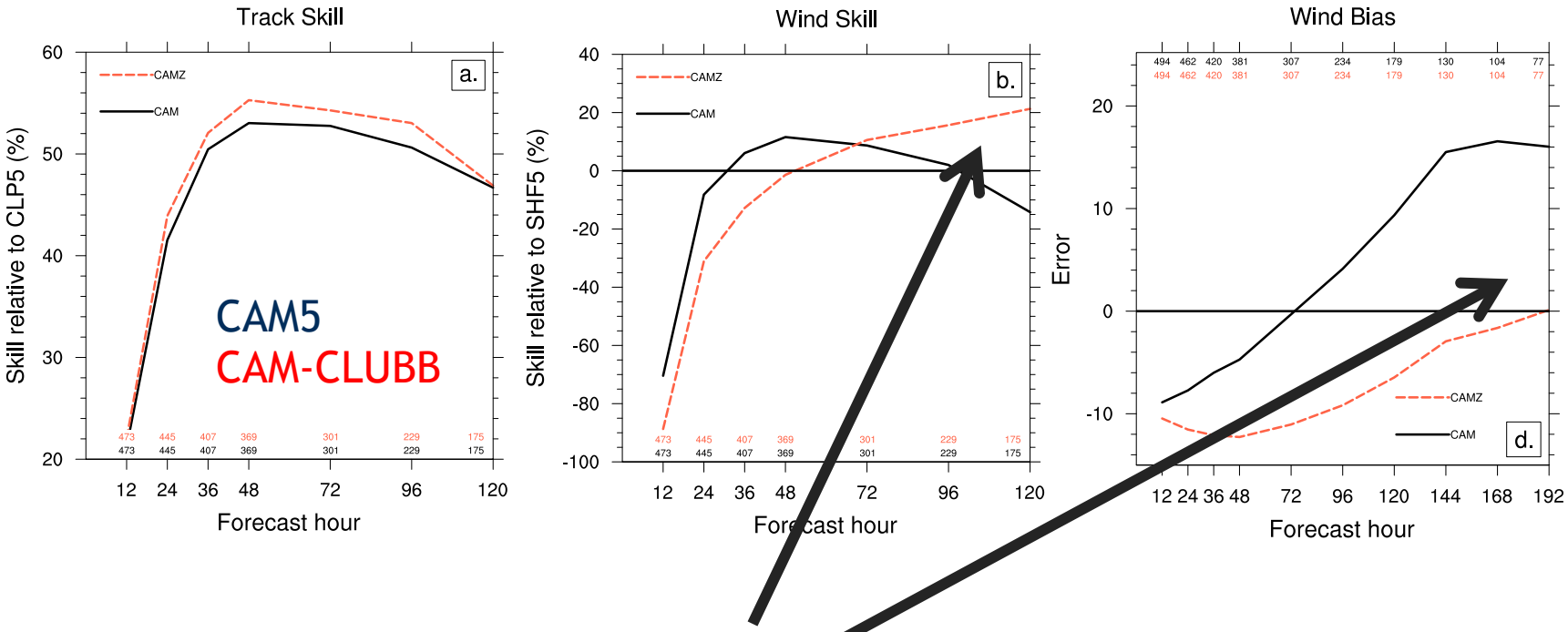


- CLUBB - weaker, shallower storm
- Broader inflow/ outflow
- RMW moves from ~5Δx to ~13Δx

CLUBB structural differences



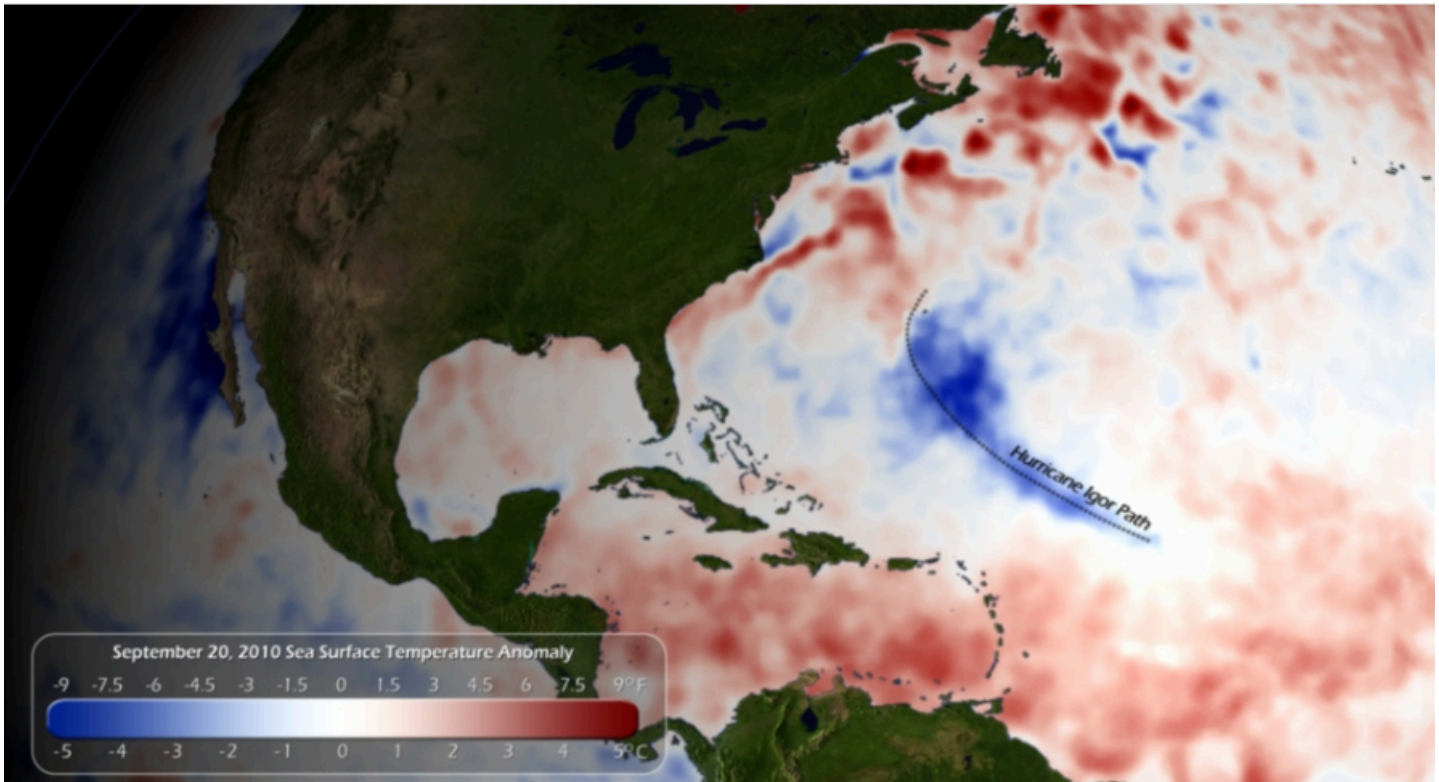
CLUBB forecasts



- CAM-CLUBB outperforms CAM5 with respect to intensity at lead times > 72 hours in 14 km forecast simulations

Interactive ocean?

- Generally, AMIP-style GCM/NWP models run with prescribed SSTs (unlimited heat, no energy closure)
- Strong TCs induce cold wake, negative feedback on intensity



Hurricane Igor (2010) SST anomaly (NOAA)

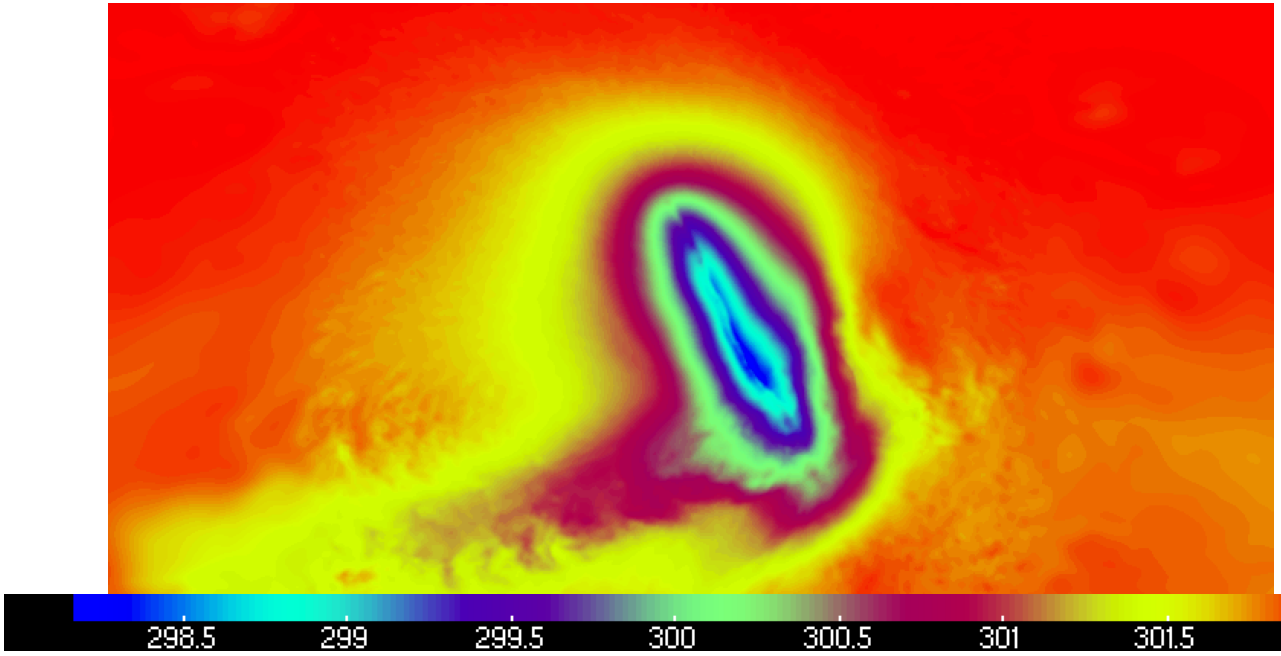
Slab ocean with simplified turbulence

$$SST_{t+\Delta t} = SST_t - \left(\frac{(LHF + SHF)}{C_s} - C_x (u^2 + v^2)^{\frac{1}{2}} \right) \Delta t$$

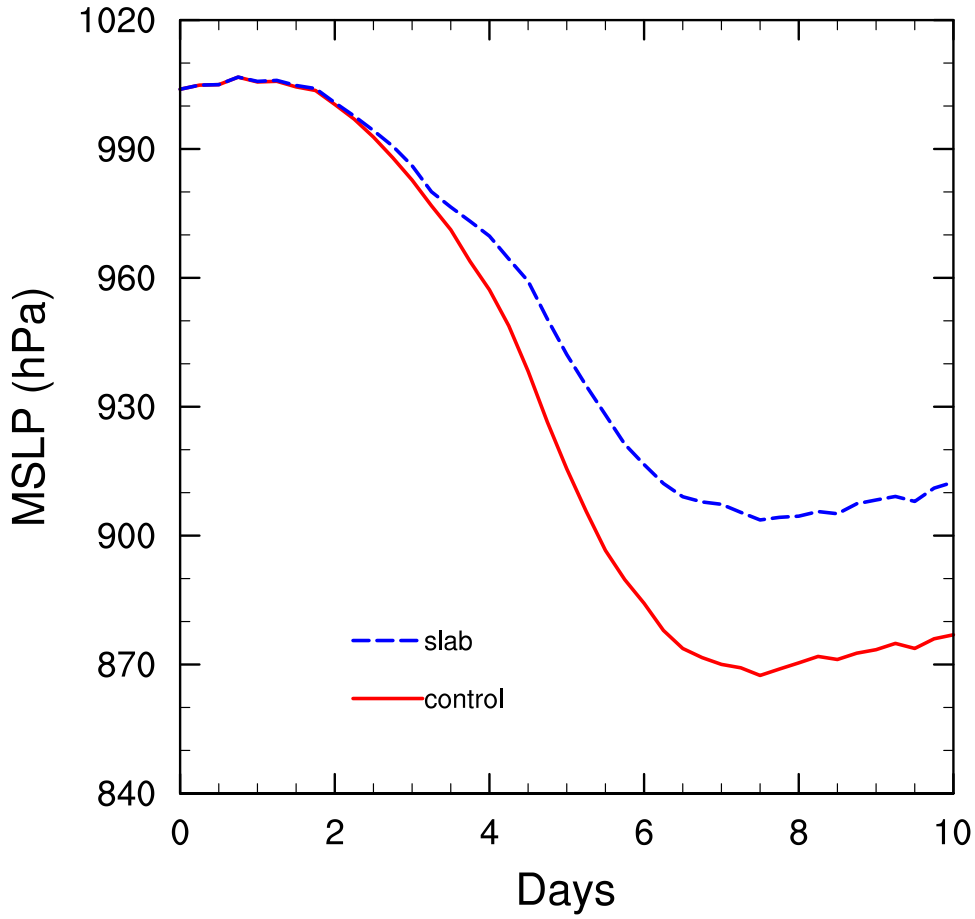
Surface fluxes

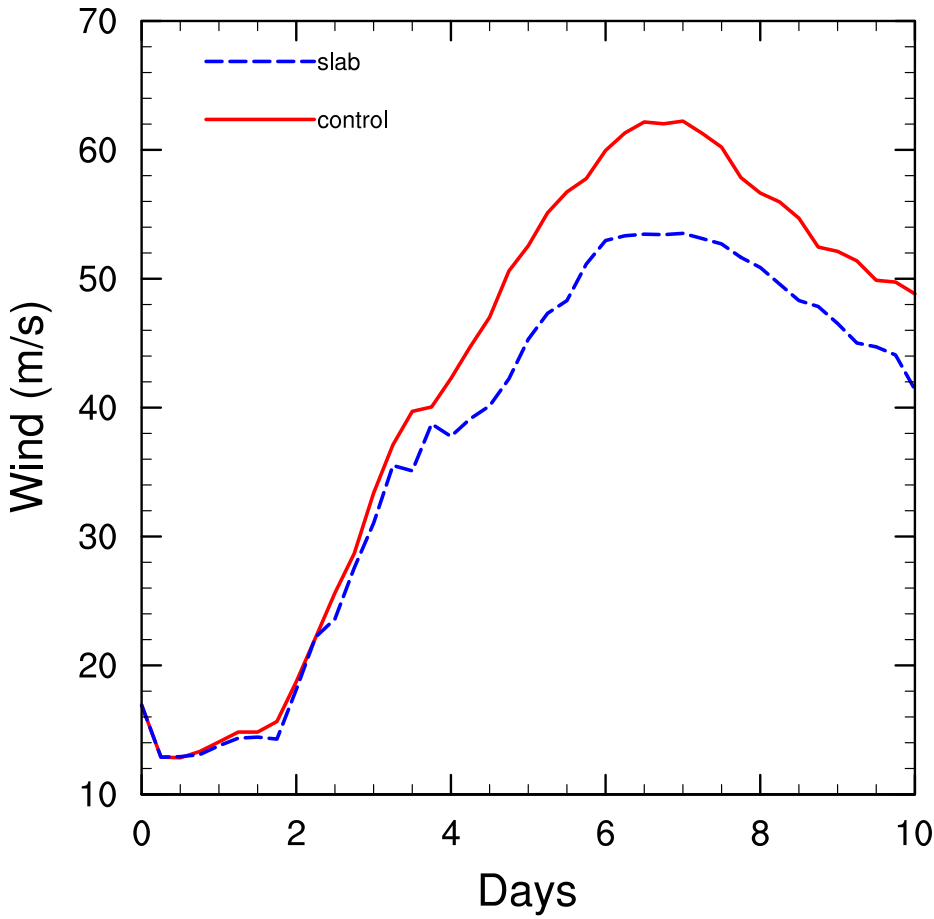
Crude turbulence formulation

- 15-25% of cold wake due to fluxes
- 75-85% to upwelling/ mixing/ Ekman



Slab ocean results





Summary

- **At high resolution (<Δx ~25km) CAM5 appears to produce TCs stronger than observed**
- Sensitivities
  - Turning "up" or "down" CAM5 deep convection (ZM) results in weaker cyclone, structural differences
  - CLUBB/MG1 produces weaker storms, better "skill" but less structurally consistent with observations
  - Realistic SST forcing implies ocn-atm interaction becoming **non-negligible at higher resolutions**
- Next steps?
  - Understand dynamical behavior
  - Condensate loading? Surface drag? CLUBB-MG2? UNICON?
  - Increase vertical resolution?
  - Comparison with LES (CM1?) (Δx~o(100m))
  - Non-hydrostatic CAM-SE? (see next talk?)