Hurricane prediction using initialized high-resolution CESM

Colin M. Zarzycki
National Center for Atmospheric Research
Climate and Global Dynamics (CGD) / Mesoscale and Microscale Meteorology (MMM)

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Initialized Earth System Prediction
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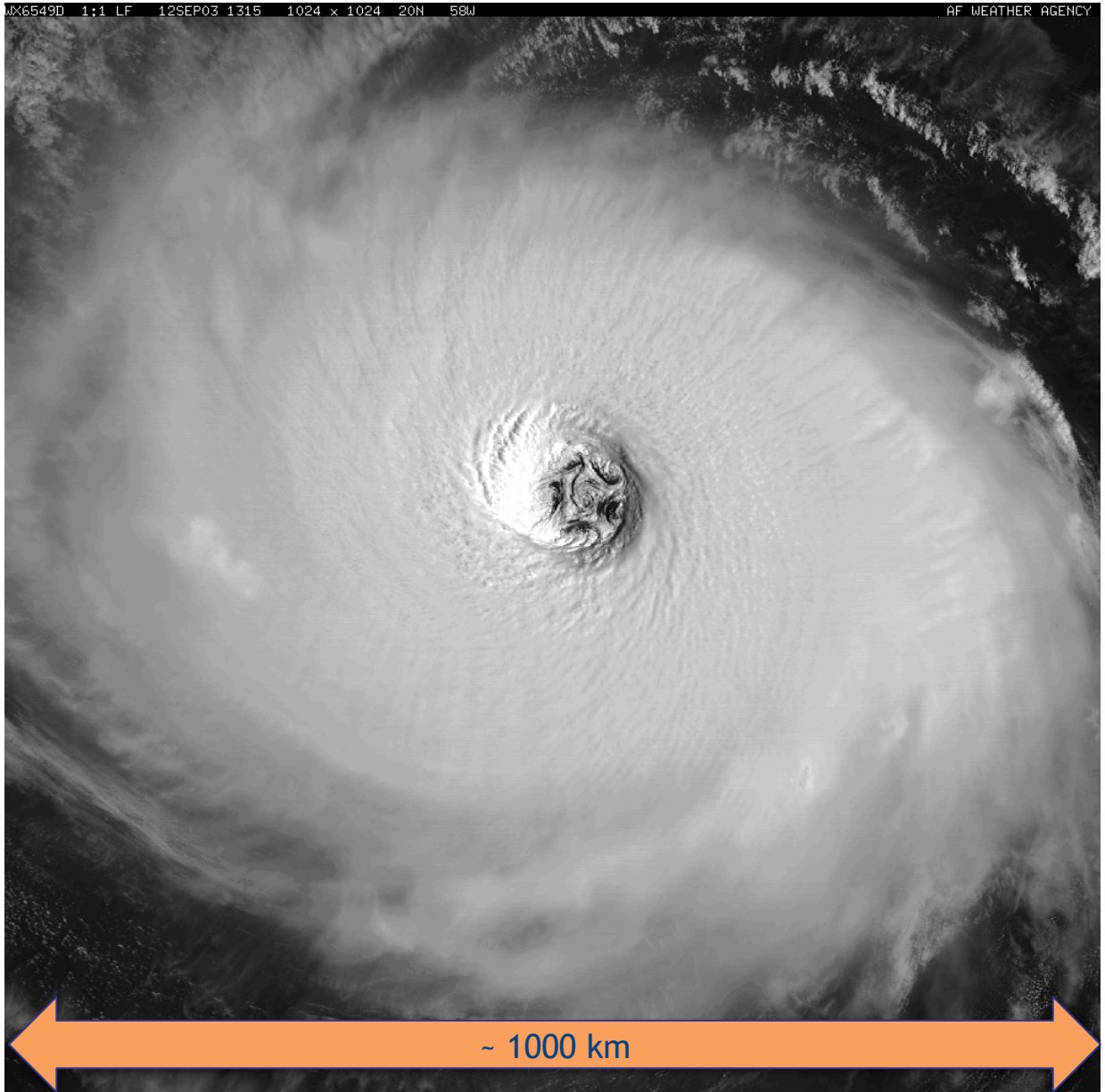
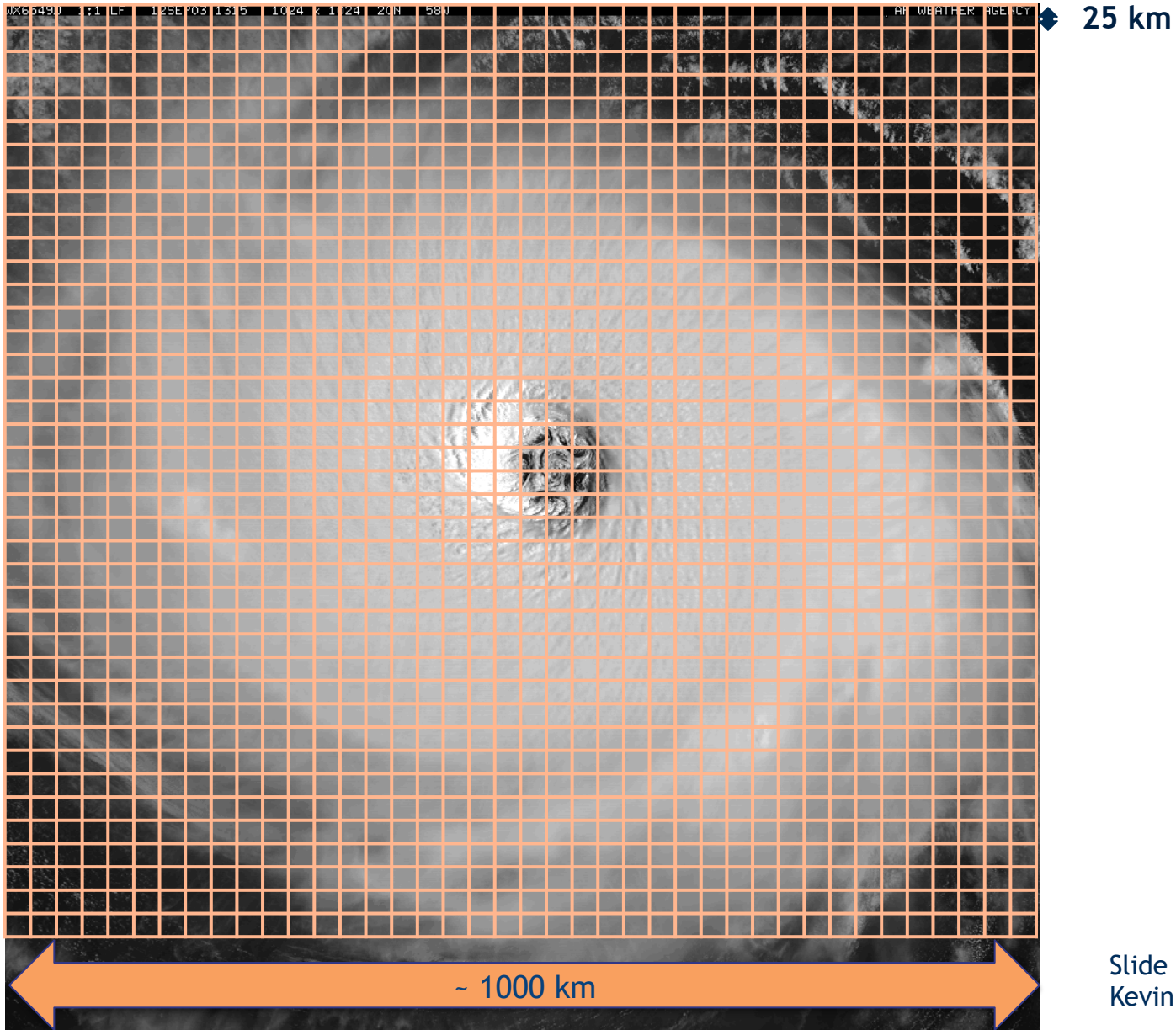
TCs (hurricanes) and resolution



Defense Meteorological Satellite Program (DMSP) image of Hurricane Isabel at 1315 UTC 12 Sep 2003

Slide inspired by Kevin Reed

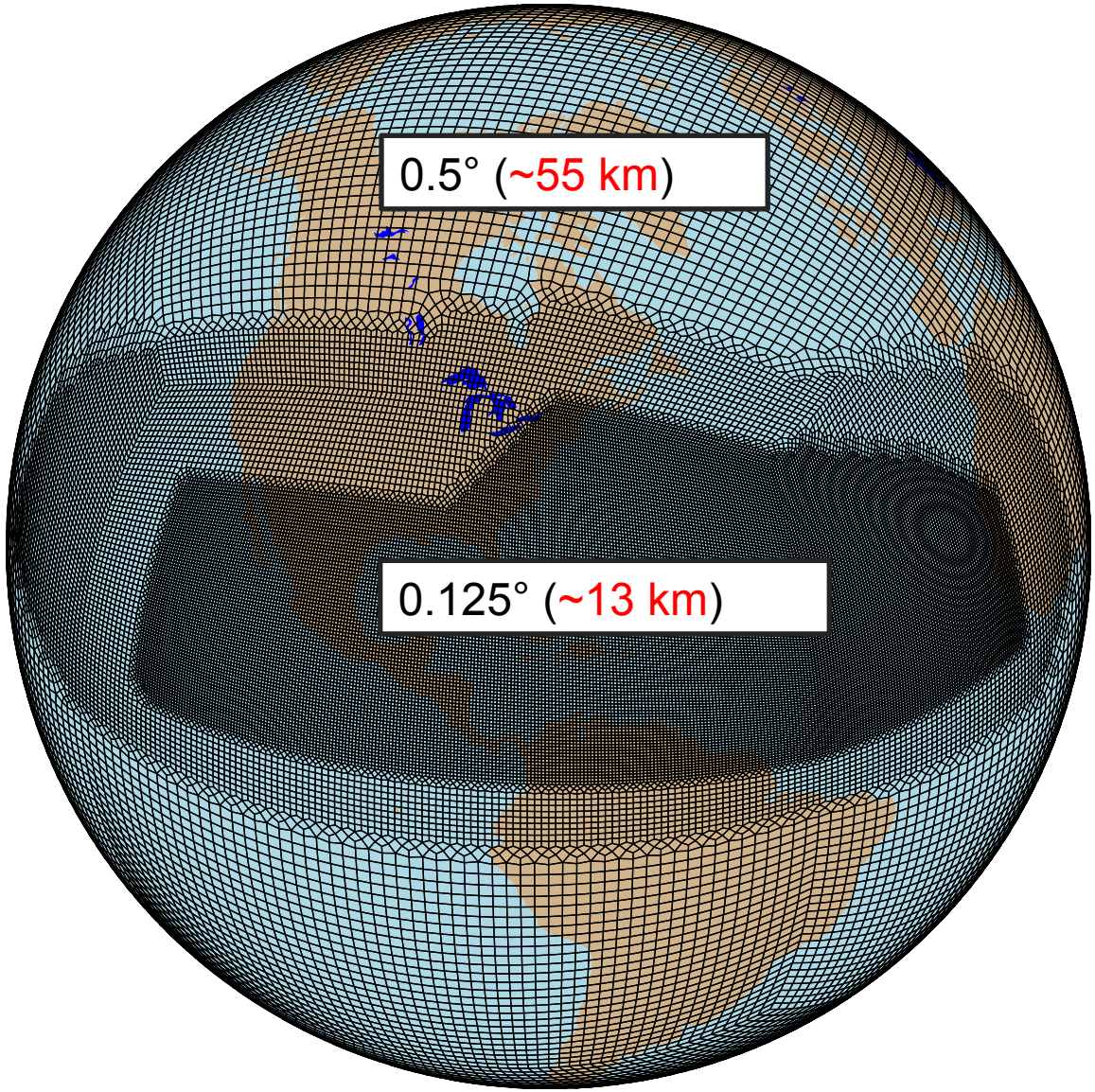
TCs (hurricanes) and resolution



Defense Meteorological Satellite Program (DMSP) image of Hurricane Isabel at 1315 UTC 12 Sep 2003

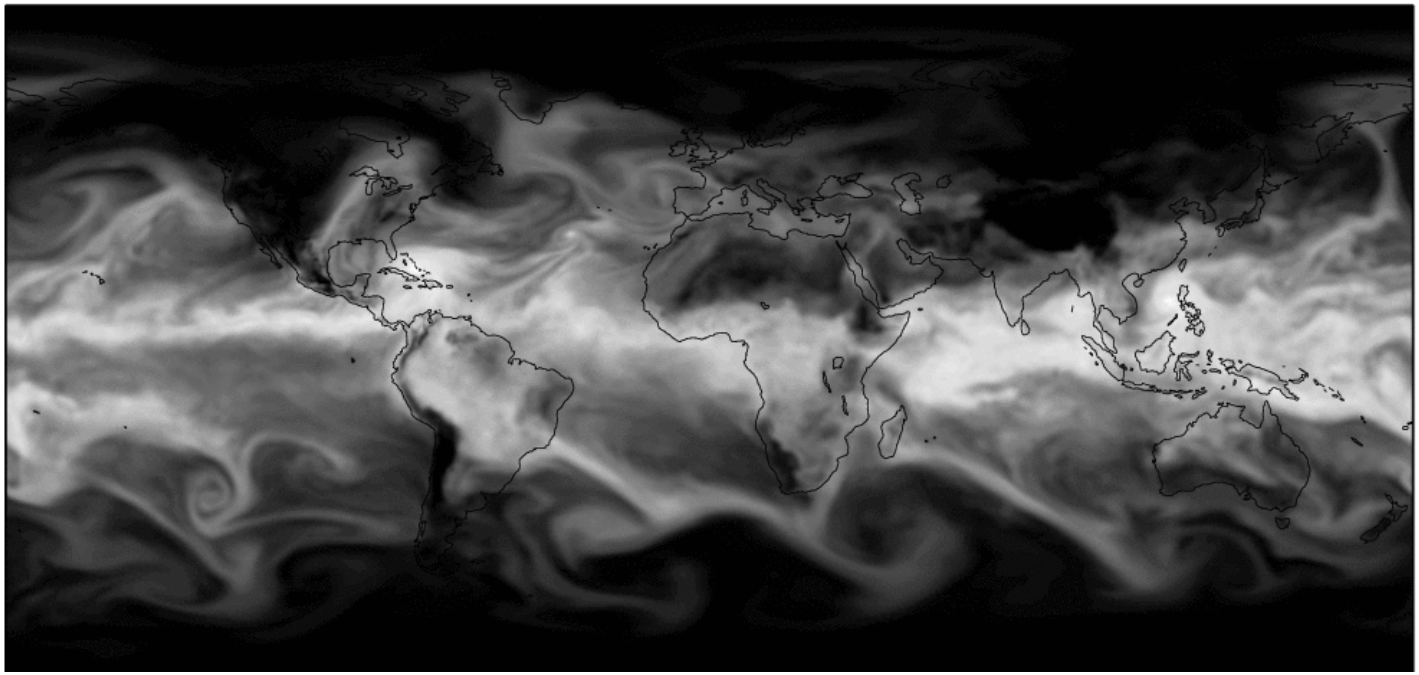
Slide inspired by Kevin Reed

CAM-SE "forecast mode"



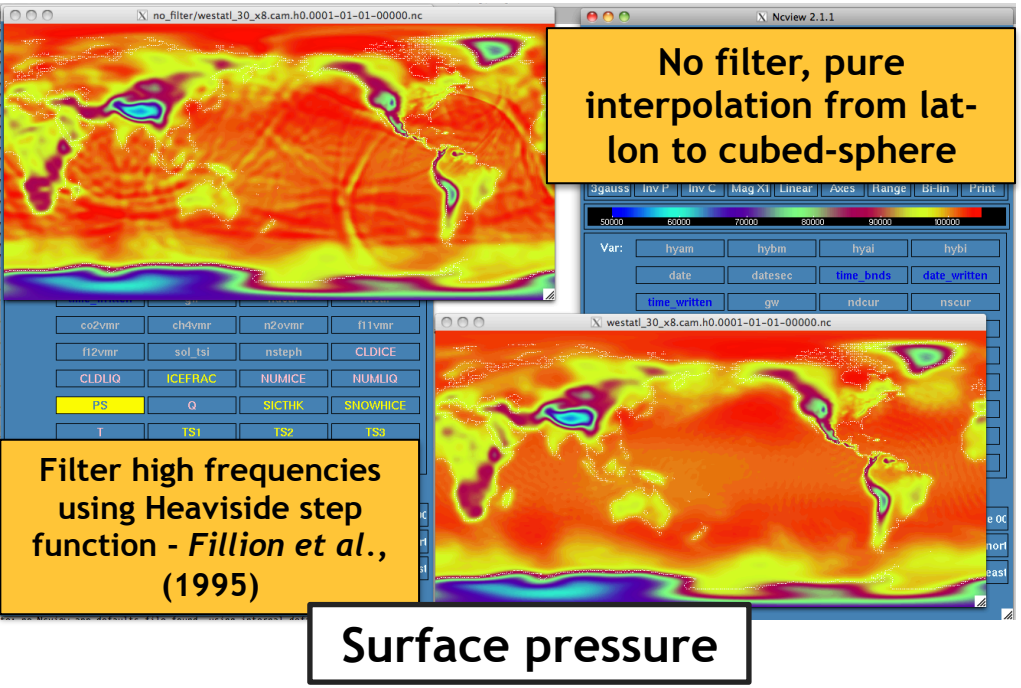
CAM-SE "forecast mode"

- CAM 5.2 (CESM 1.2.0)
- Every 12 hours (00Z and 12Z) from August 1st to November 1st for 2012-2013
- Initialization (psuedo-"cold" start)
  - **Atmosphere**: GFS analysis, forward DFI (Fillion *et al.*, 1995)
  - **Ocean**: Prescribed SSTs/ice (GFS analysis) -> PERSISTENCE
  - **Land**: active (initial cycled spinup, then 12 hourly forecast used for init)
- 8 day forecast = ~1.5 hours of wall clock time on 800 cores (YS)
  - ~10x cheaper than a globally-uniform 13 km forecast



Sandy TPW:
INIT 12Z
10/25/12

Some “cold” start notes…



No filter, pure interpolation from lat-lon to cubed-sphere

Filter high frequencies using Heaviside step function - *Fillion et al.*, (1995)

Surface pressure

- SE dycore -> less implicit diffusion, gravity wave noise from cold starts, need digital filter initialization (DFI)
- Not as big of an issue with dycores with implicit diffusion (FV, MPAS, FV3, etc.)

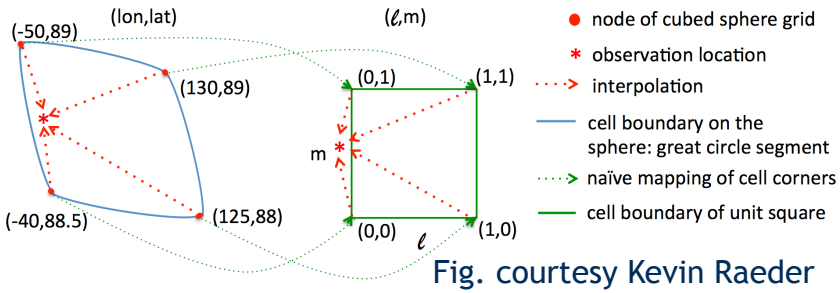
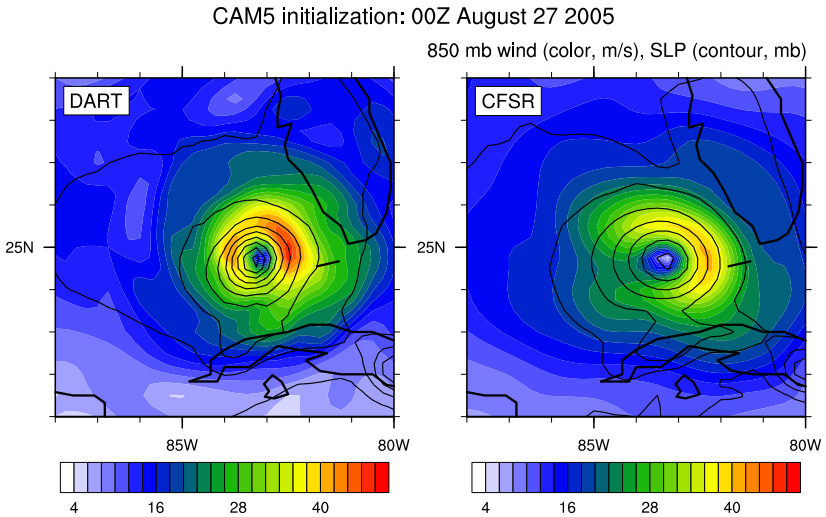


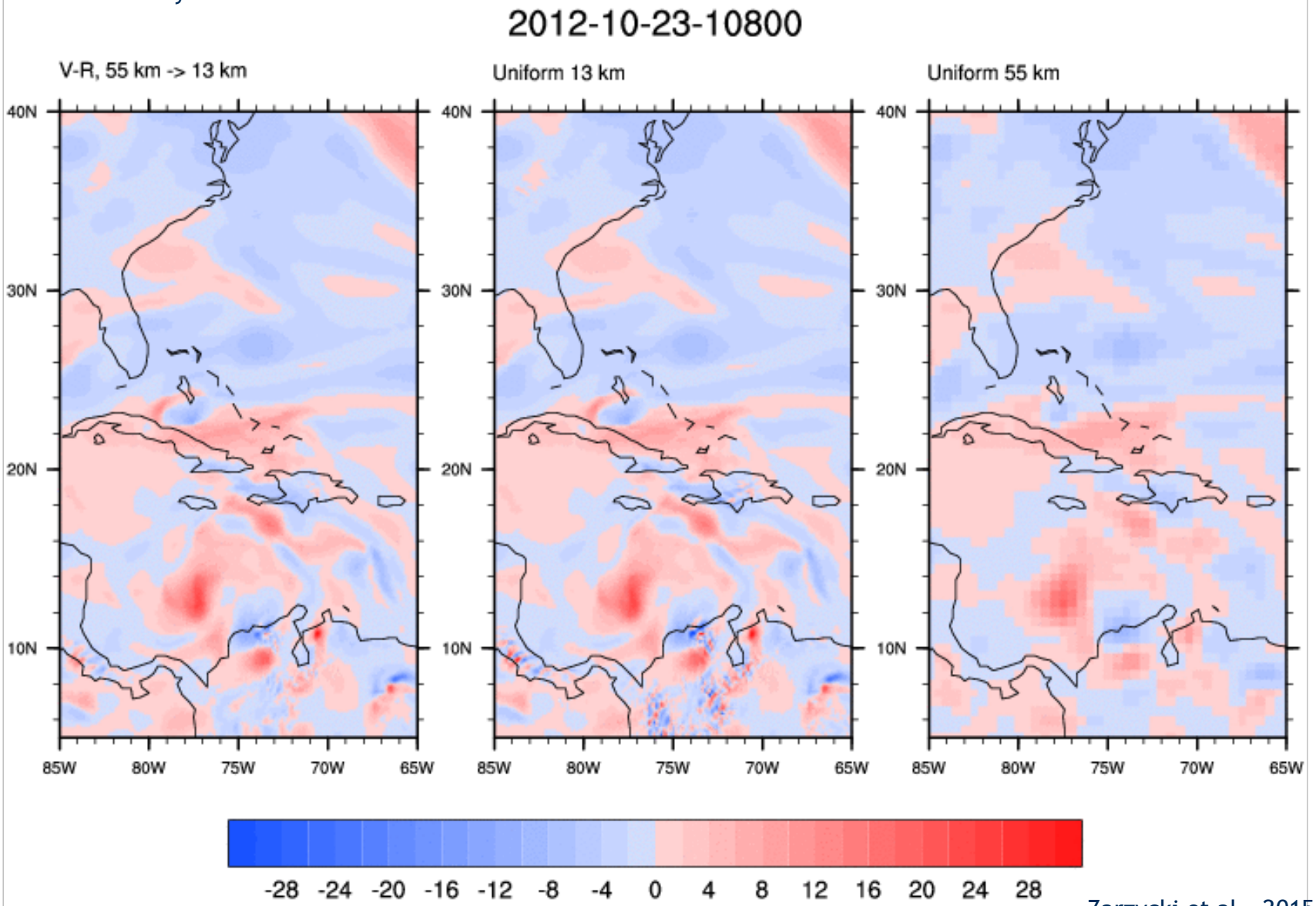
Fig. courtesy Kevin Raeder



- DART in CESM -> more faithful representation of TC on native grid?
- Talk to Kevin Raeder!

Resolution comparison

Sandy 500 hPa vorticity: INIT 00Z 10/23/12

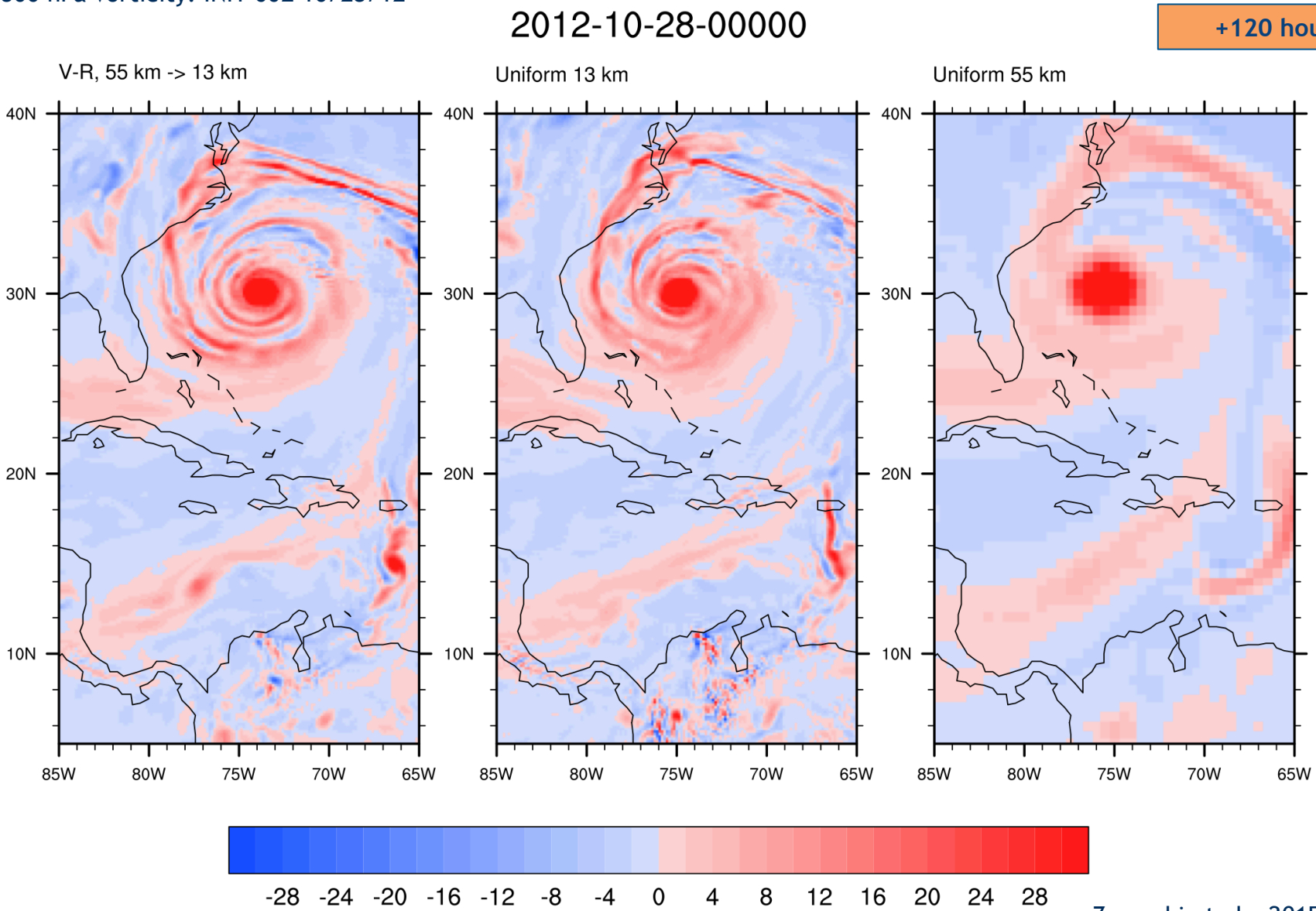


Zarzycki et al., 2015, MWR

Resolution comparison

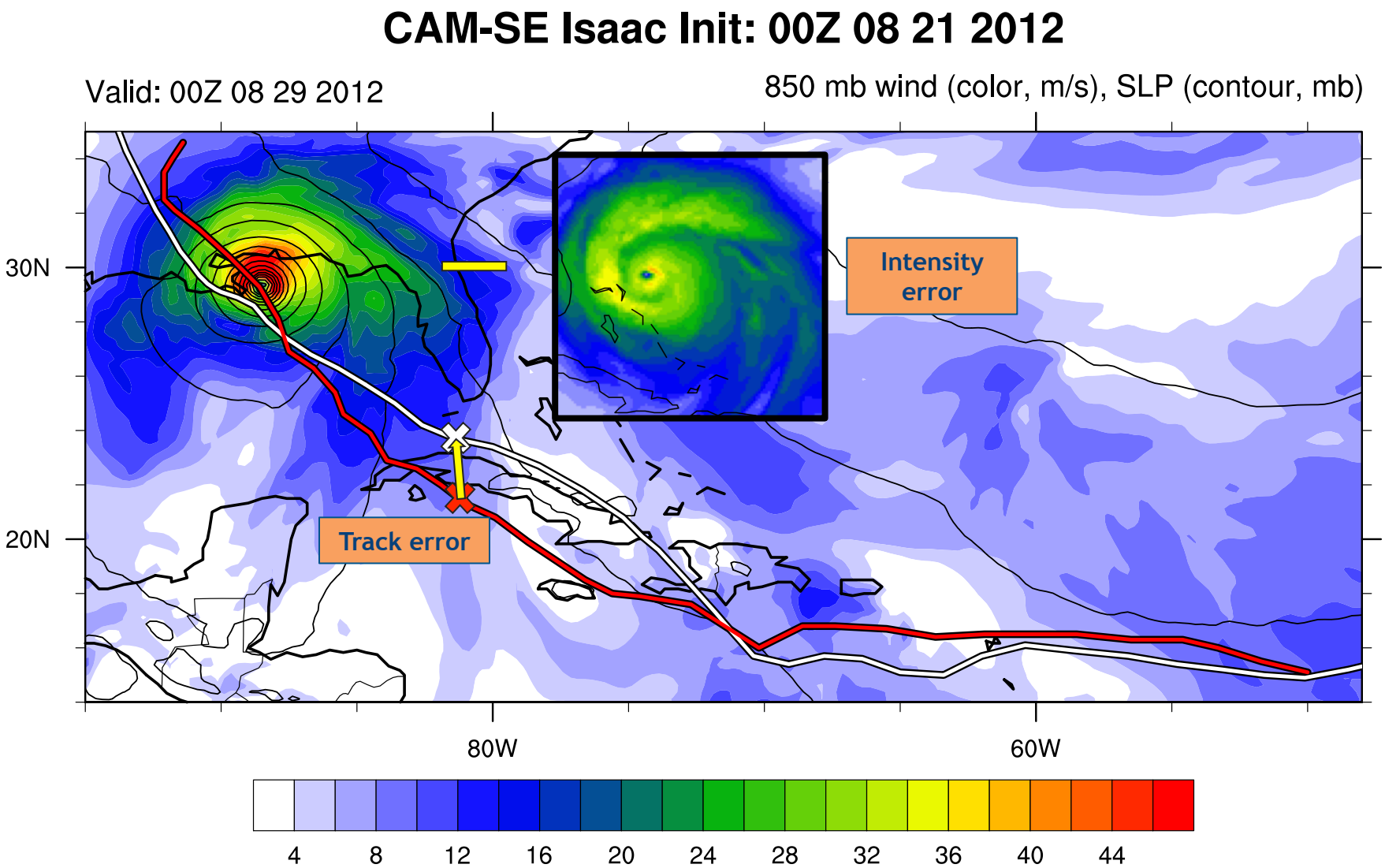
Sandy 500 hPa vorticity: INIT 00Z 10/23/12

+120 hours



Zarzycki et al., 2015, MWR

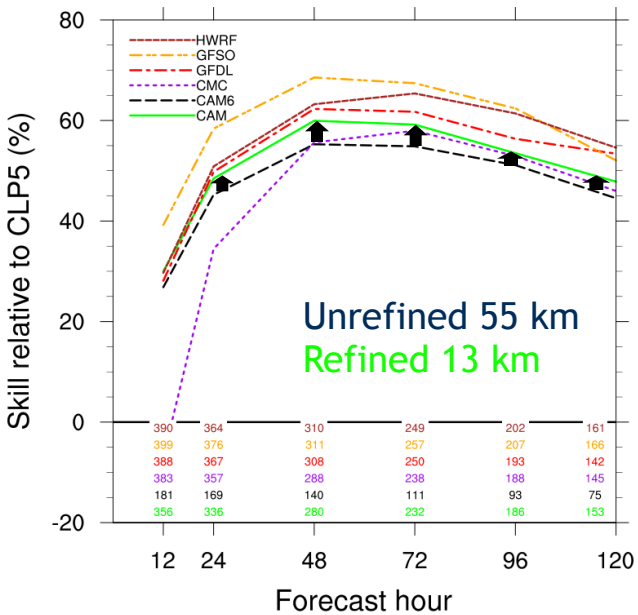
Measuring forecast skill



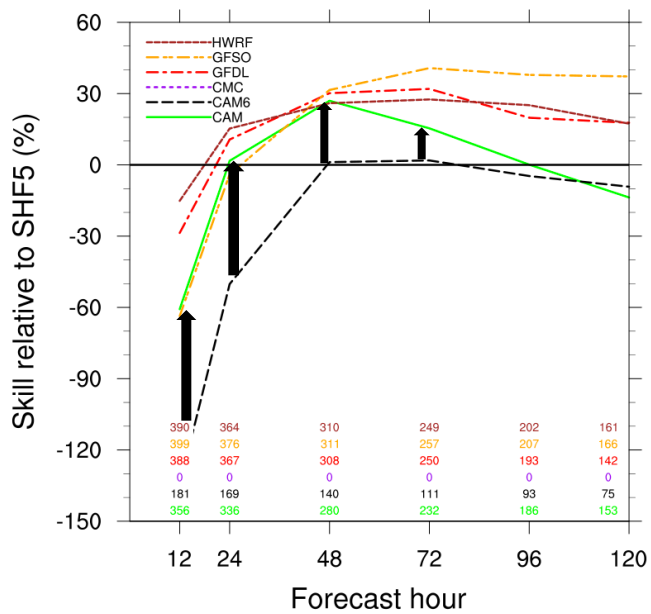
CAM-SE "forecast mode" control

Zarzycki et al., 2015, MWR

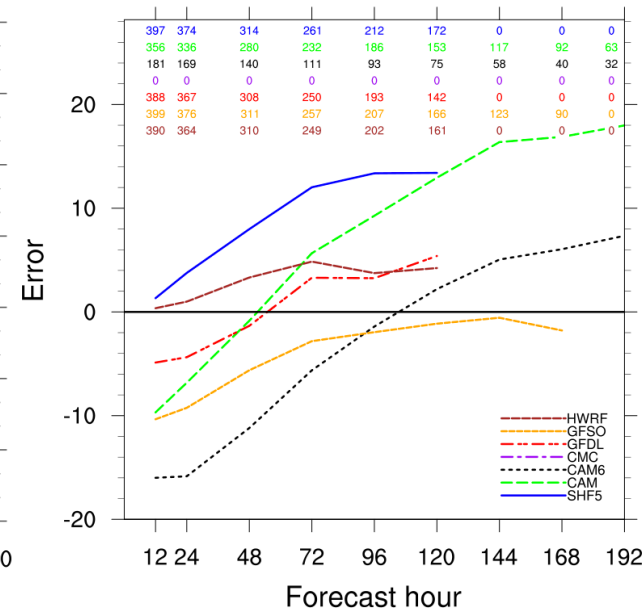
Track error



Absolute wind error



Wind bias



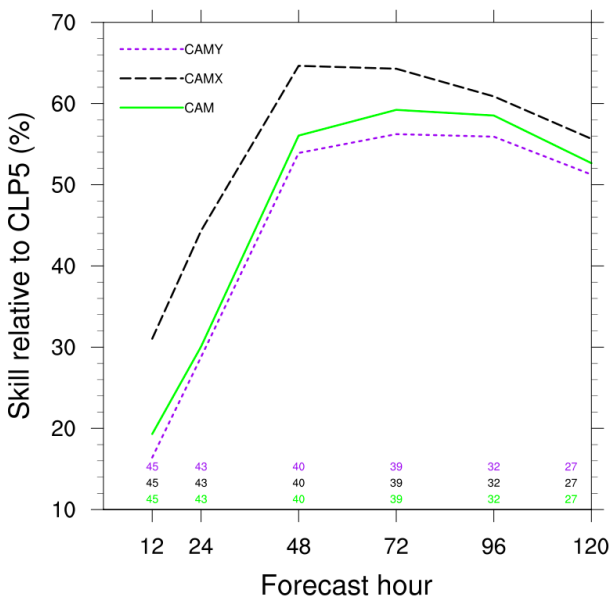
- Refinement improves both track, intensity skill
- Track behavior of TCs looks good…
  - Within envelope of operational NWP models!
- … CAM exhibits a high bias in TC intensity, especially as the solution moves away from initial state

CAM-SE "forecast mode" sensitivity

Zarzycki et al., 2015, MWR

- Sensitivity simulations
  - Choose 20 *worst* CAM forecasts (high wind bias)
    1. Turn off deep convection (**CAMY**)
    2. Decrease dtime (and deep convective relaxation time) by 4x (**CAMX**)

Track error



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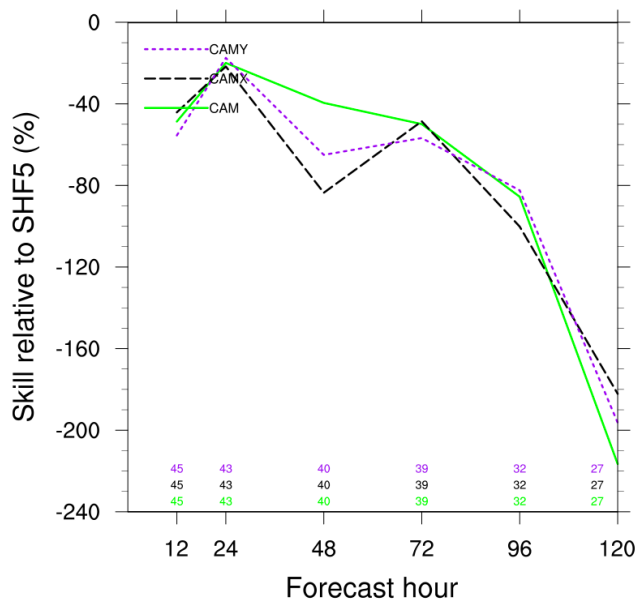
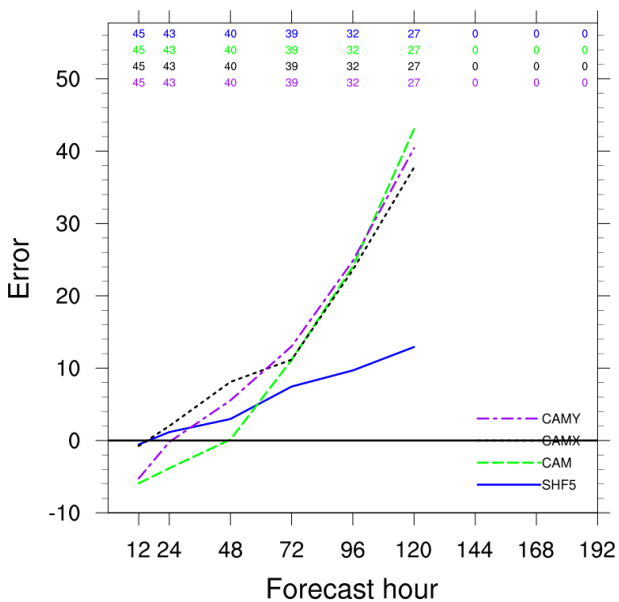


Wind bias



Hurricane Sandy forecasts

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hat closely predicted Hurricane
ys ahead of U.S. and other

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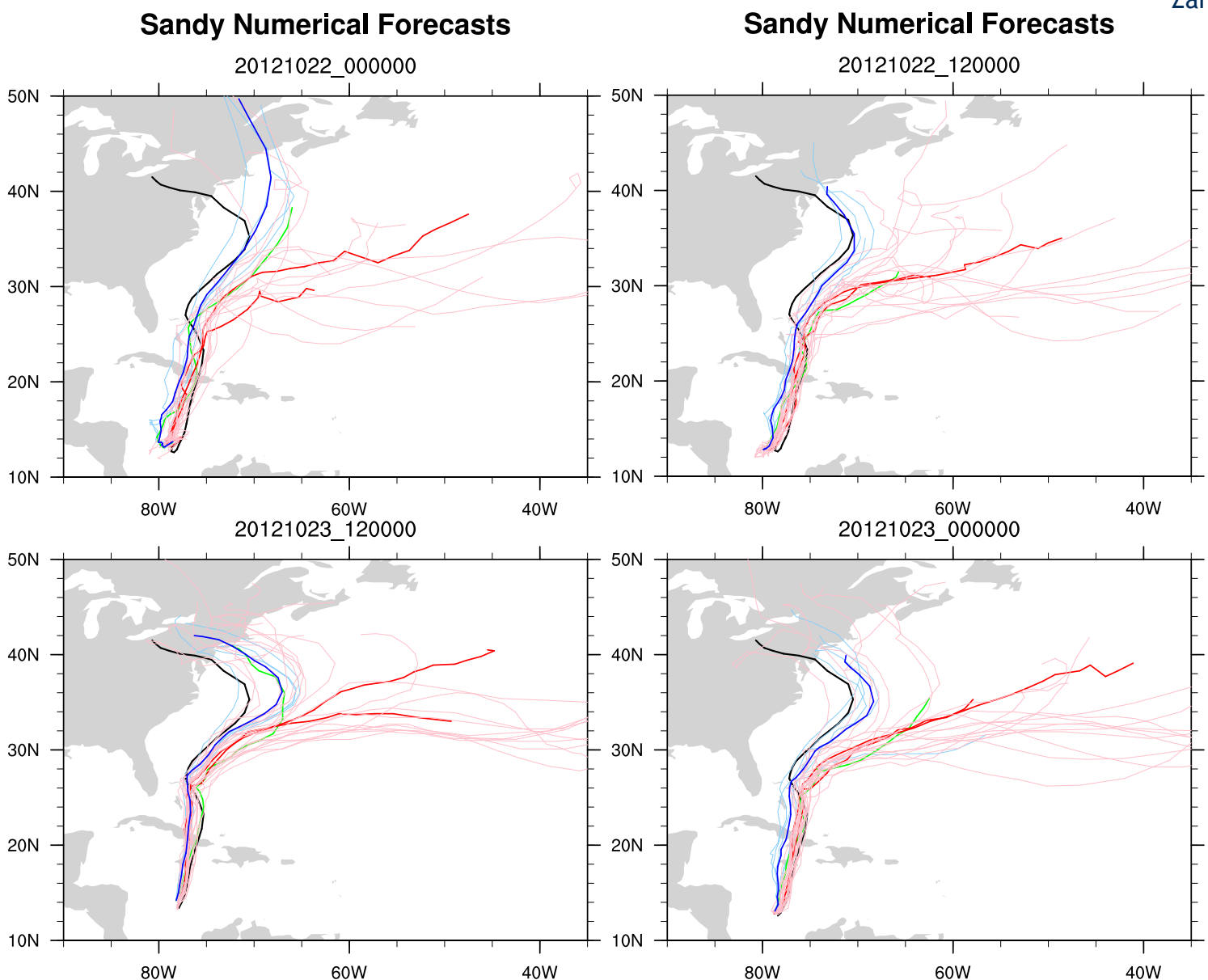
Hurricane Sandy forecasts

Zarzycki et al., 2015, MWR



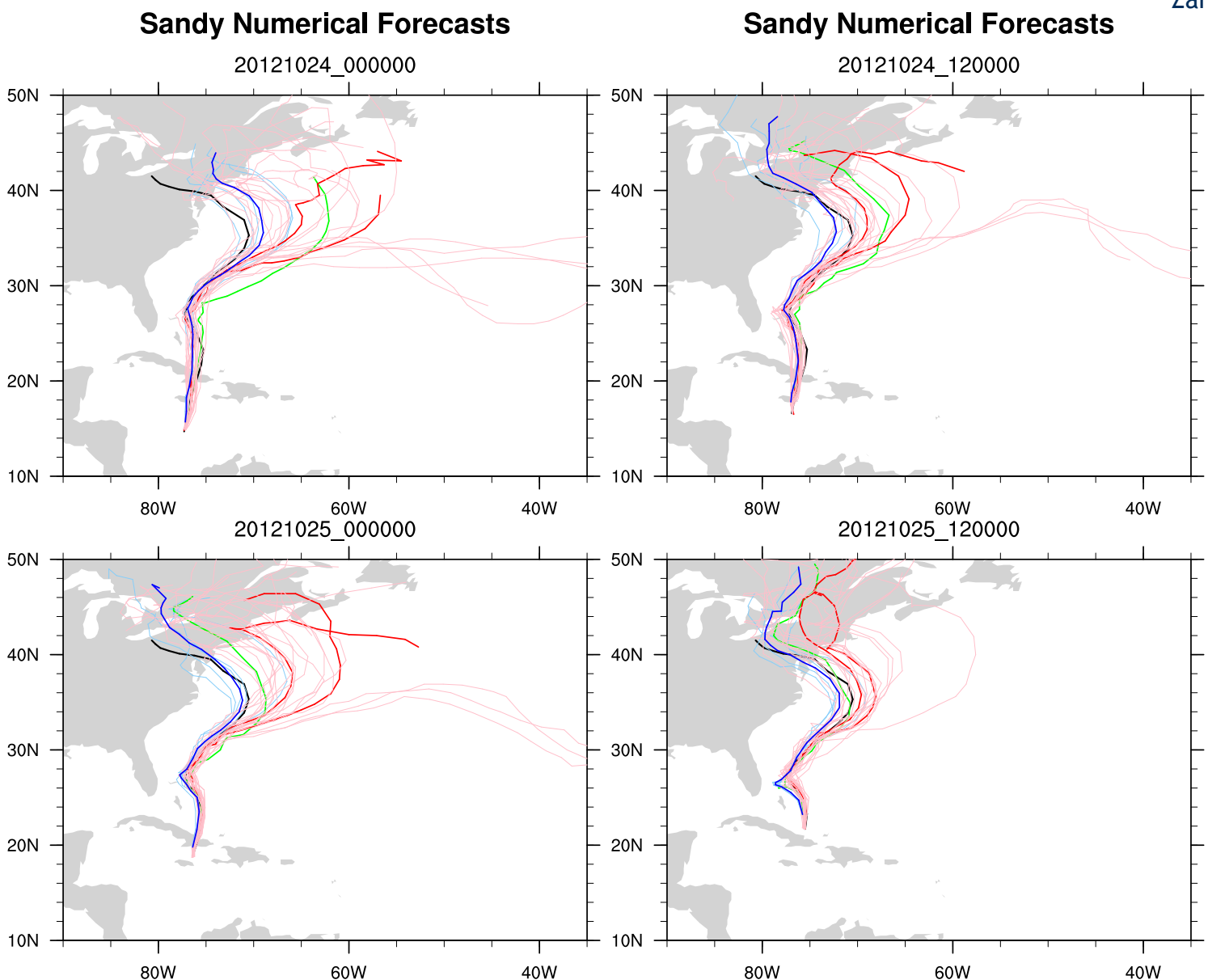
Observations

CAM members
CAM ens. mean
CAM-CLUBB

GFS (oper.)
GEFS members
GEFS ens. mean

Hurricane Sandy forecasts

Zarzycki et al., 2015, MWR



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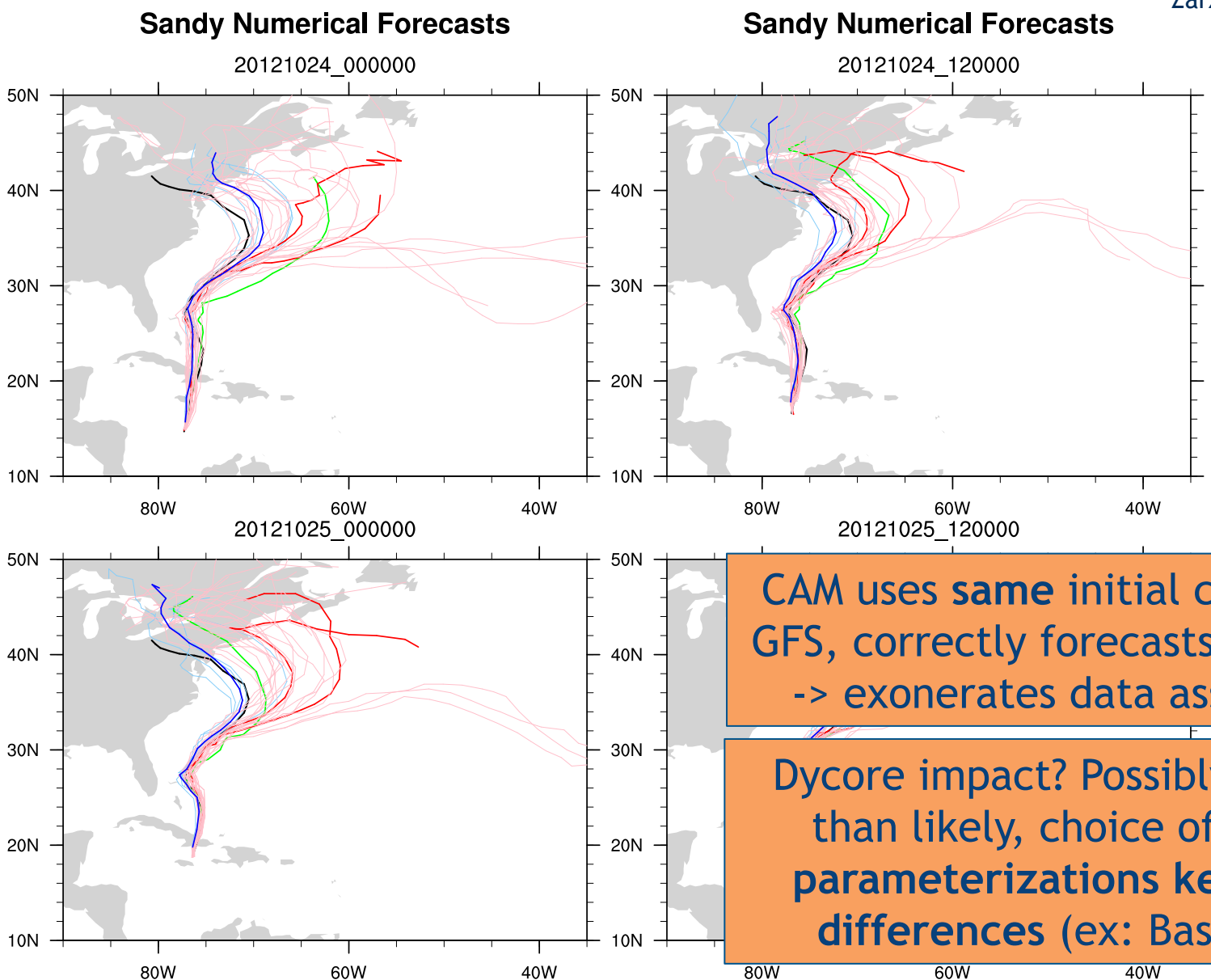


Observations

CAM members

CAM ens. mean

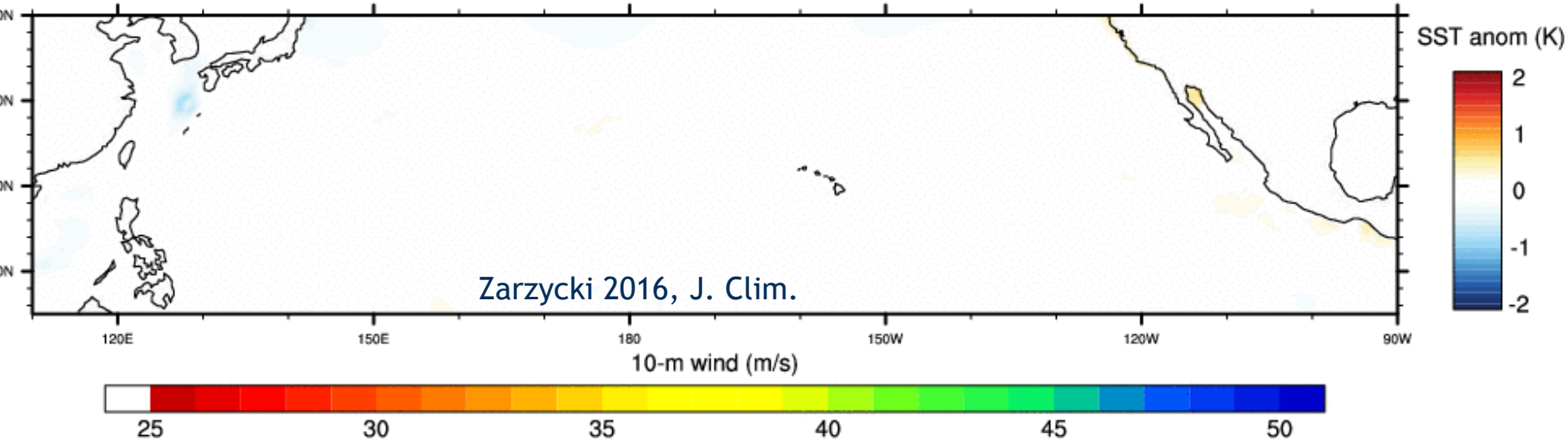
CAM-CLUBB

CAM uses **same** initial conditions as GFS, correctly forecasts recurvature -> exonerates data assimilation?

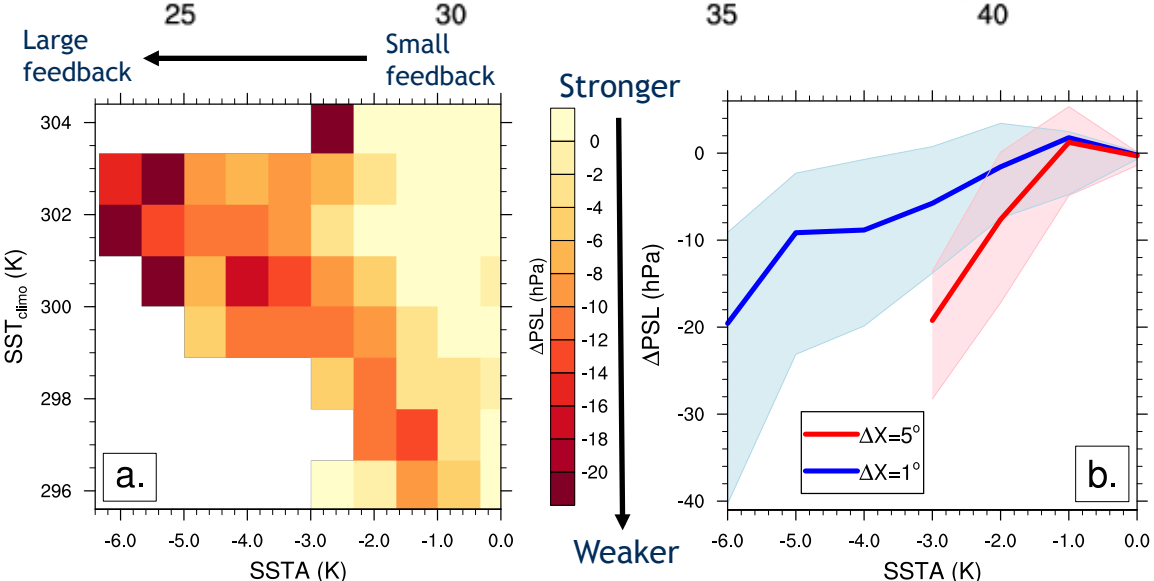
Dycore impact? Possibly, but more than likely, choice of **physical parameterizations key in track differences** (ex: Bassill 2014)

Surface energy biases

~6 week movie Sept.-Oct.
SLAB ensemble member #3
10-m wind contoured rainbow (bottom), SST anomaly red/blue (left)



Zarzycki 2016, J. Clim.



- Part of "high bias" in initialized CAM TCs **due to non-interactive ocean**
- New "slab ocean" with turbulence param.
- Issue? <u>TCs sensitive to biases in mean SST</u>

Summary

- Using initialized CAM/CESM with variable-resolution…
  - Verifies V-R dynamics
  - Allows for understanding/verifying/tuning very-high resolution configurations
- Future directions:
  - Continued initialized experiments with CAM6/CESM2 to explore high-res behavior
  - Couple to slab ocean w/ mixing and/or address ocean biases
  - Seasonal-to-subseasonal (S2S) prediction
    - Unique niche for CESM to exploit?