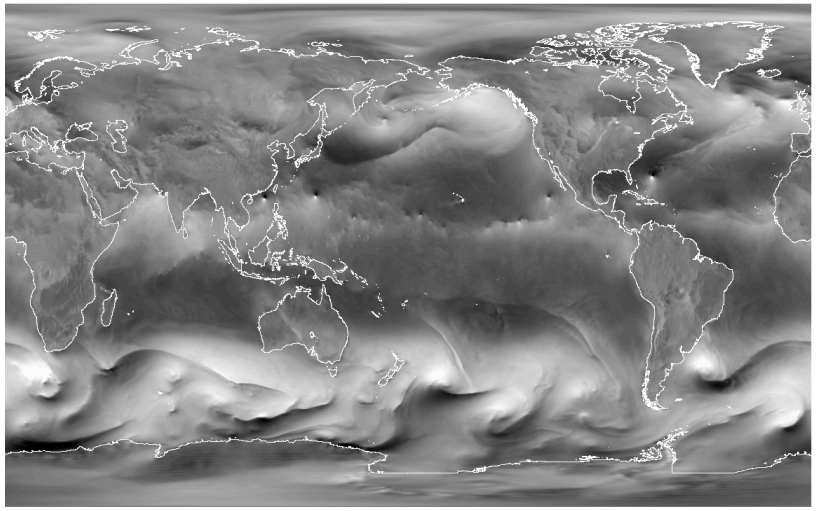
Hierarchy of models for studying the climatology and structure of tropical cyclones

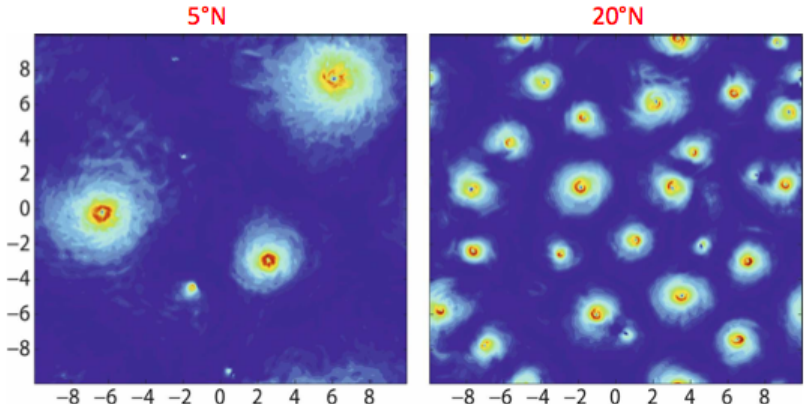
Isaac Held – DOE Climate Modeling PI Meeting, May 2014

Princeton U. researchers supported in part by DOE/Regional and Global Climate Modeling:
Wenyu Zhou, Andrew Ballinger, Tim Merlis (thanks)

[See also poster on tropical upper tropospheric temperature trends
Stephan Fueglistaler, Tom Flannaghan]



Aqua-planet fixed–SST and slab ocean



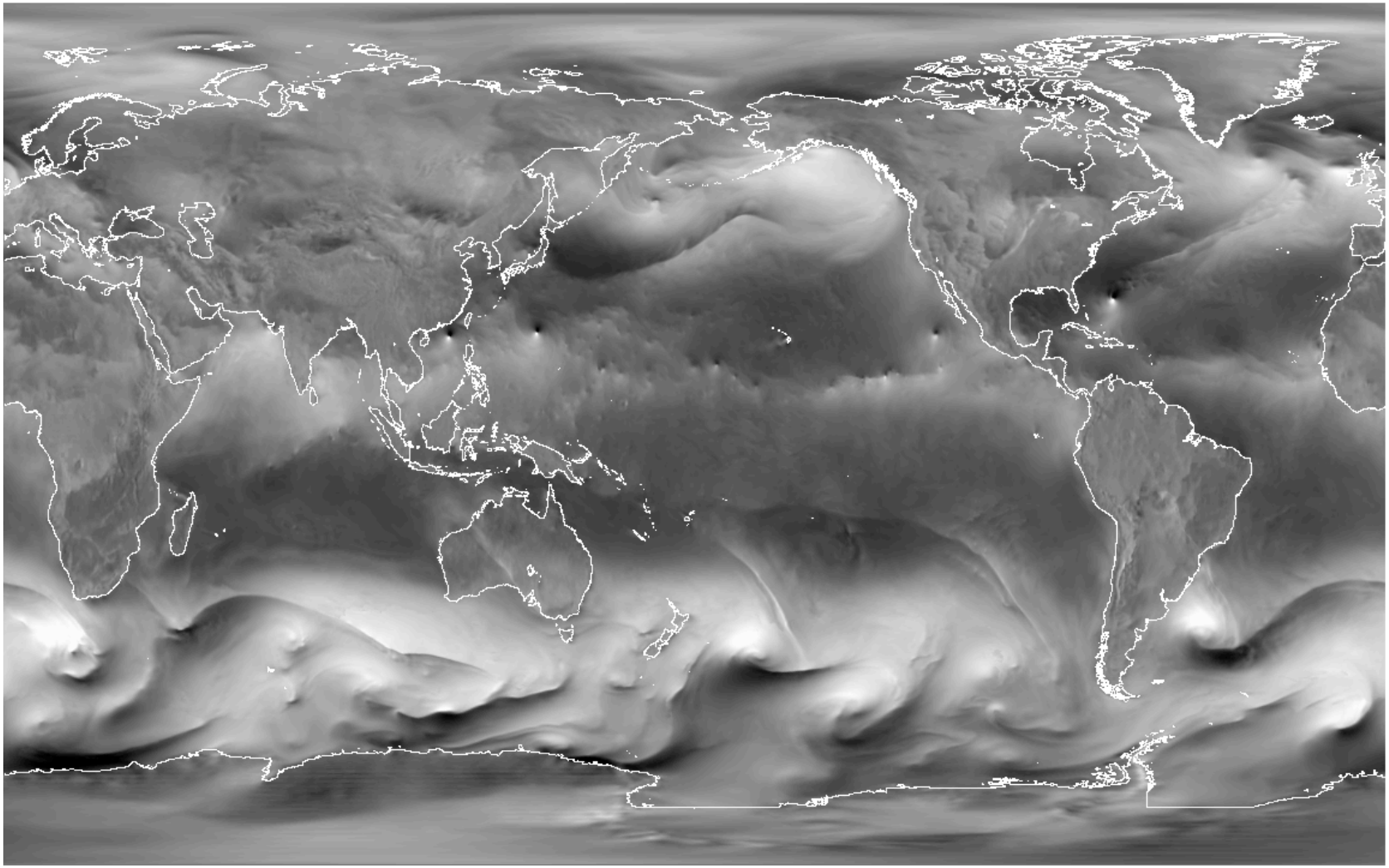
Rotating radiative-convective equilibrium in on doubly-periodic f-plane

Claim:

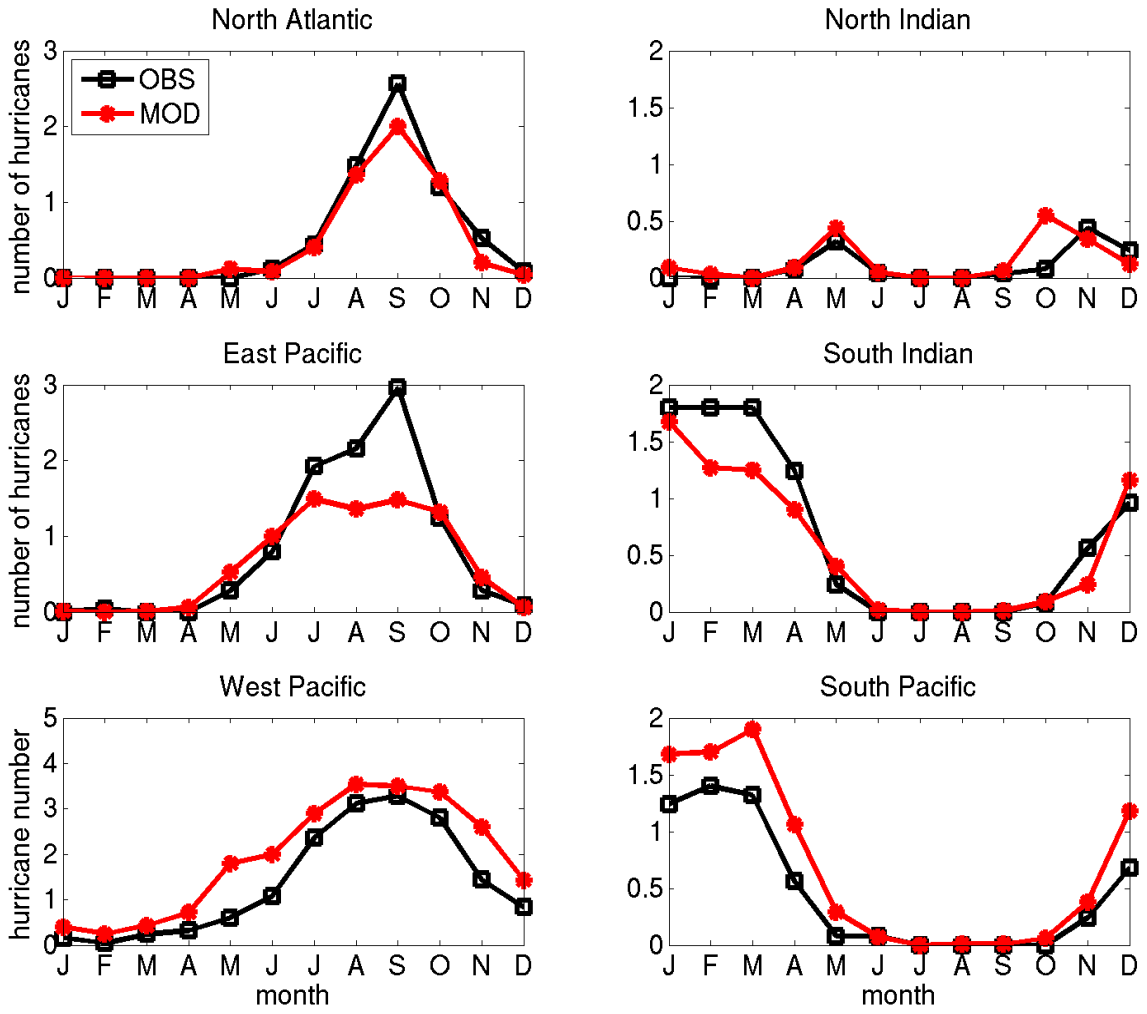
we are entering the golden age
of simulation of tropical cyclones in global models

{analogous to the state of simulation of
baroclinic eddies in the early days
of atmospheric GCMs}

Starting point is 50km (25 km) GFDL HiRAM model with realistic boundary conditions

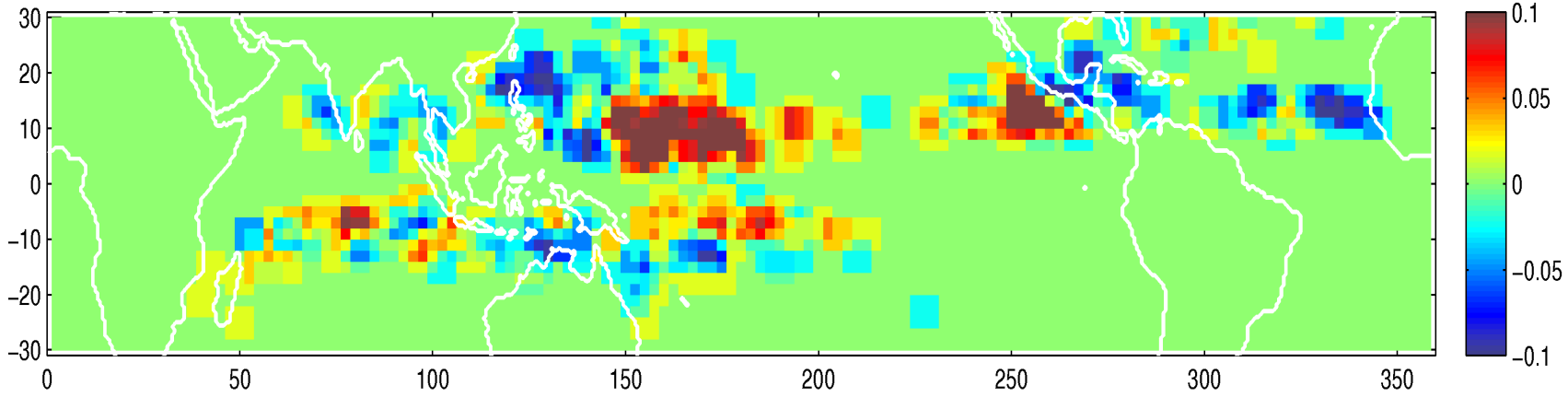


Model captures the seasonal cycle of hurricane frequency over various ocean basins

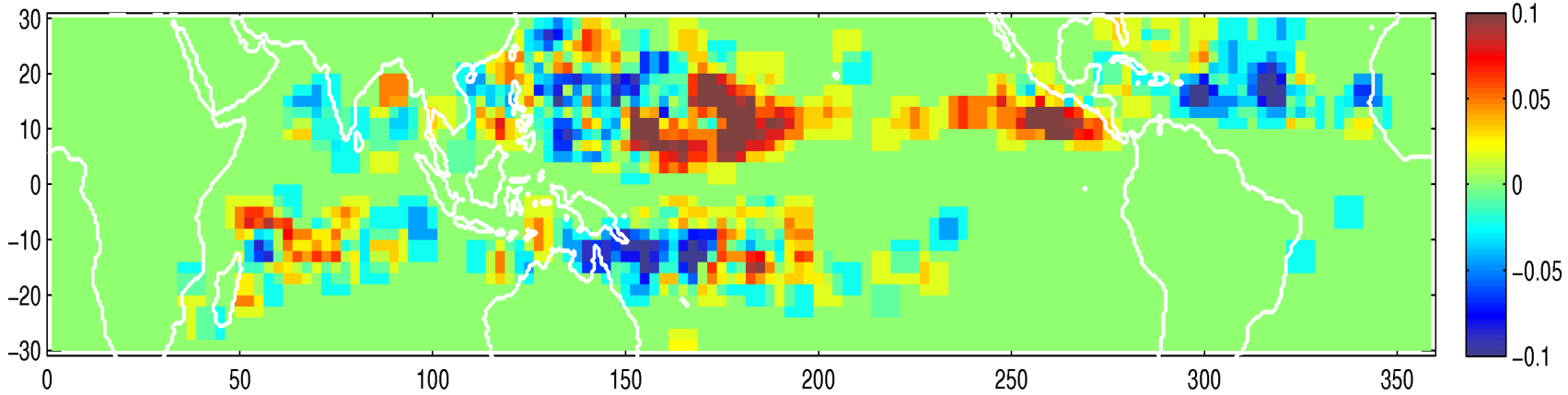


Model captures ENSO effect on hurricane genesis frequency

El-Nino years minus La-Nina years (observation)



El-Nino years minus La-Nina years (C180HiRAM)



3-member ensemble
CMIP5 50km time-slice model
Using observed ocean temperatures and sea ice

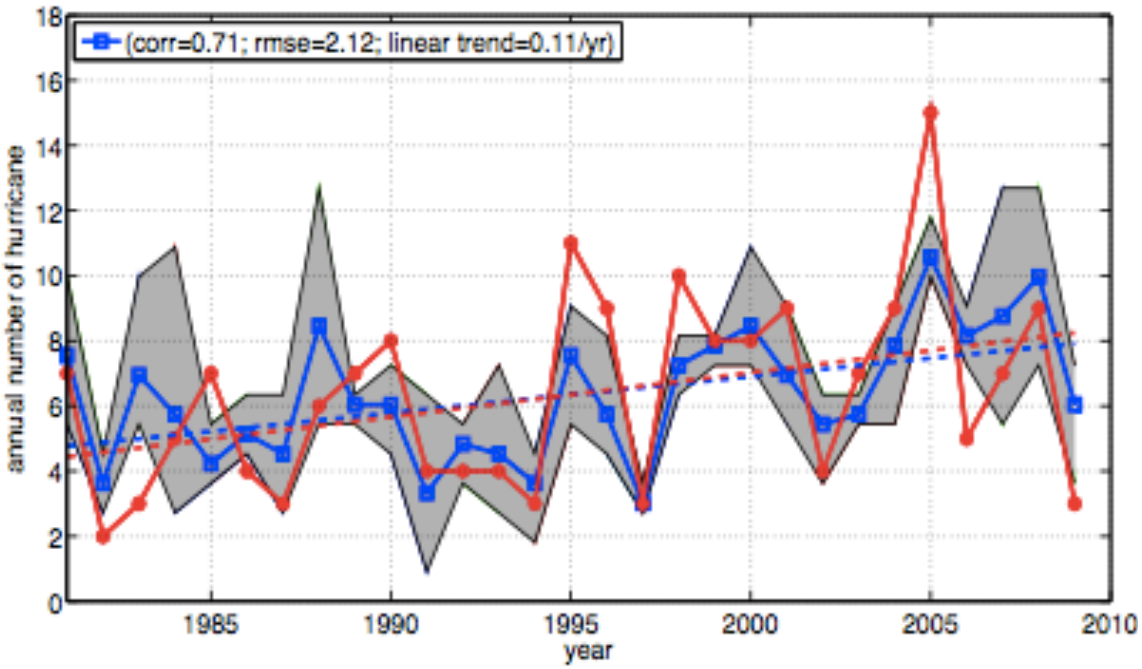
Model simulates interannual variability
and recent trends in frequency of Atlantic tropical cyclones

Number of North Atlantic tropical cyclones in each year

Red: observations

Blue: model ensemble mean

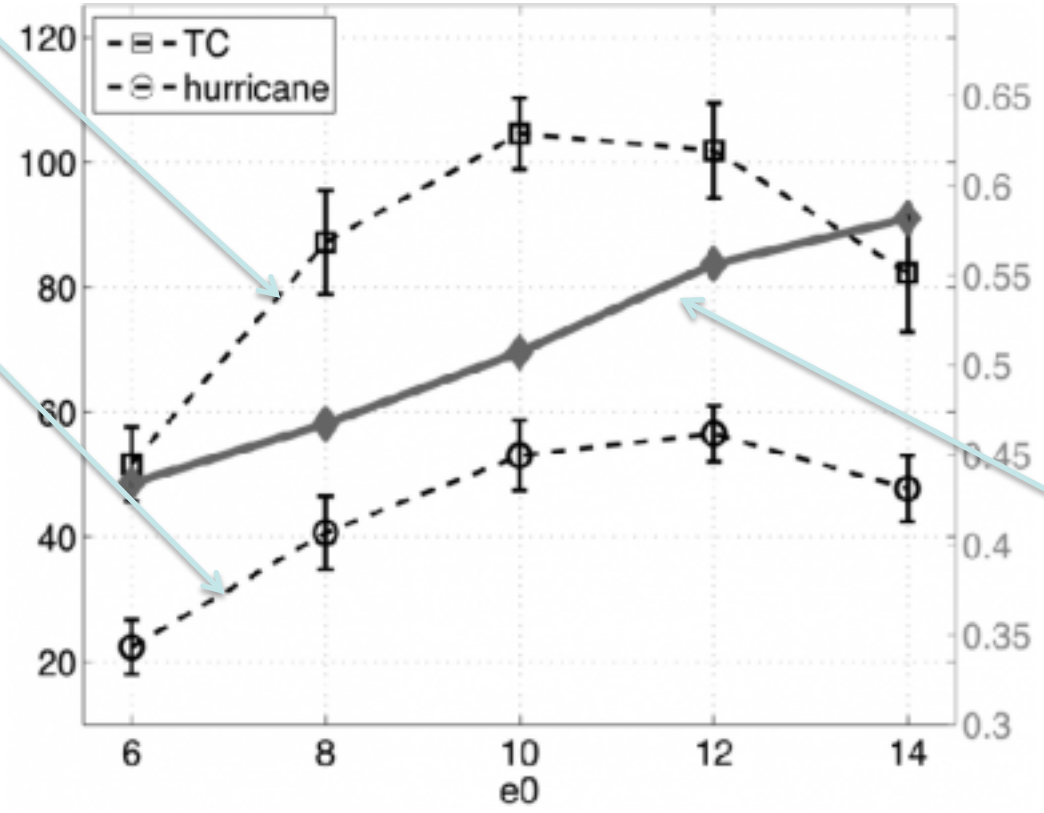
Shading: model spread



Effect of change in convection scheme on TCs in HiRAM

TCs

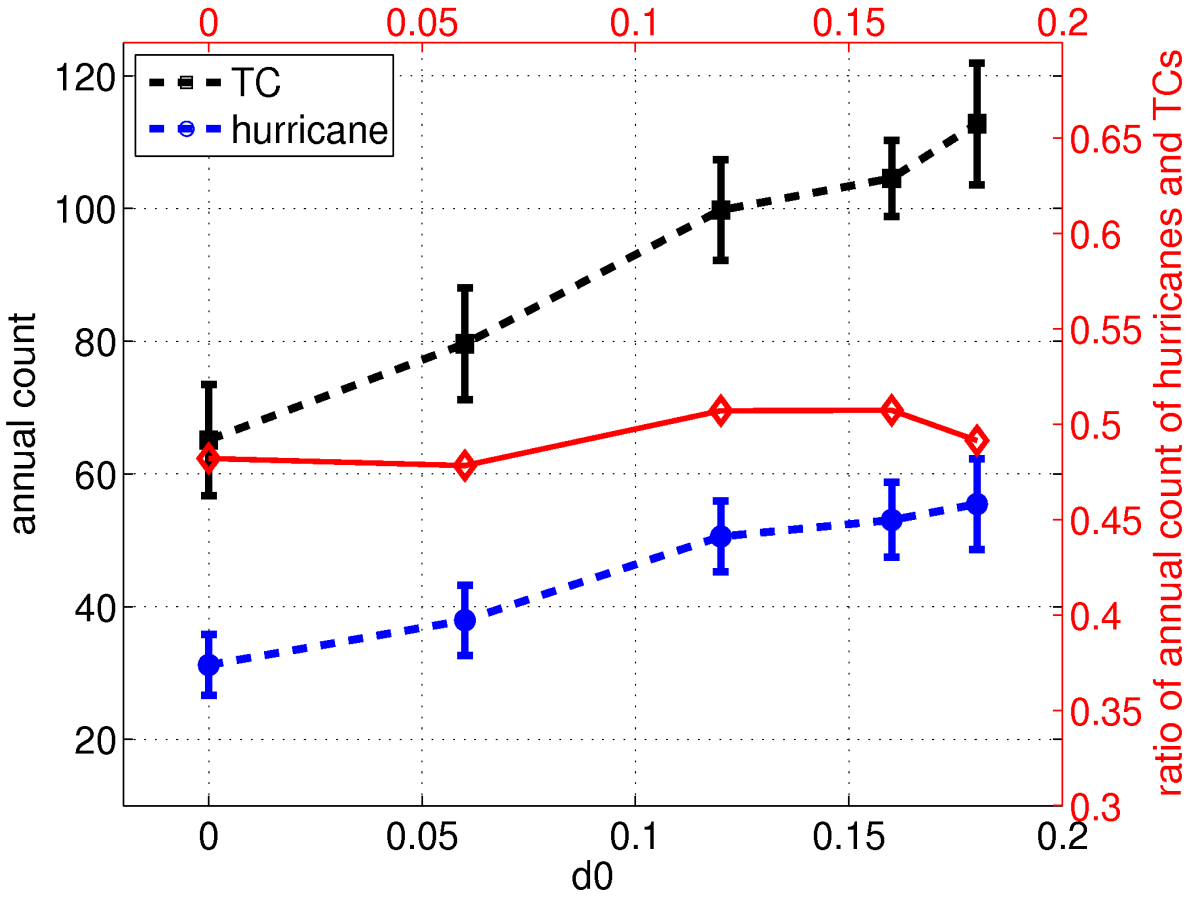
Hurricanes

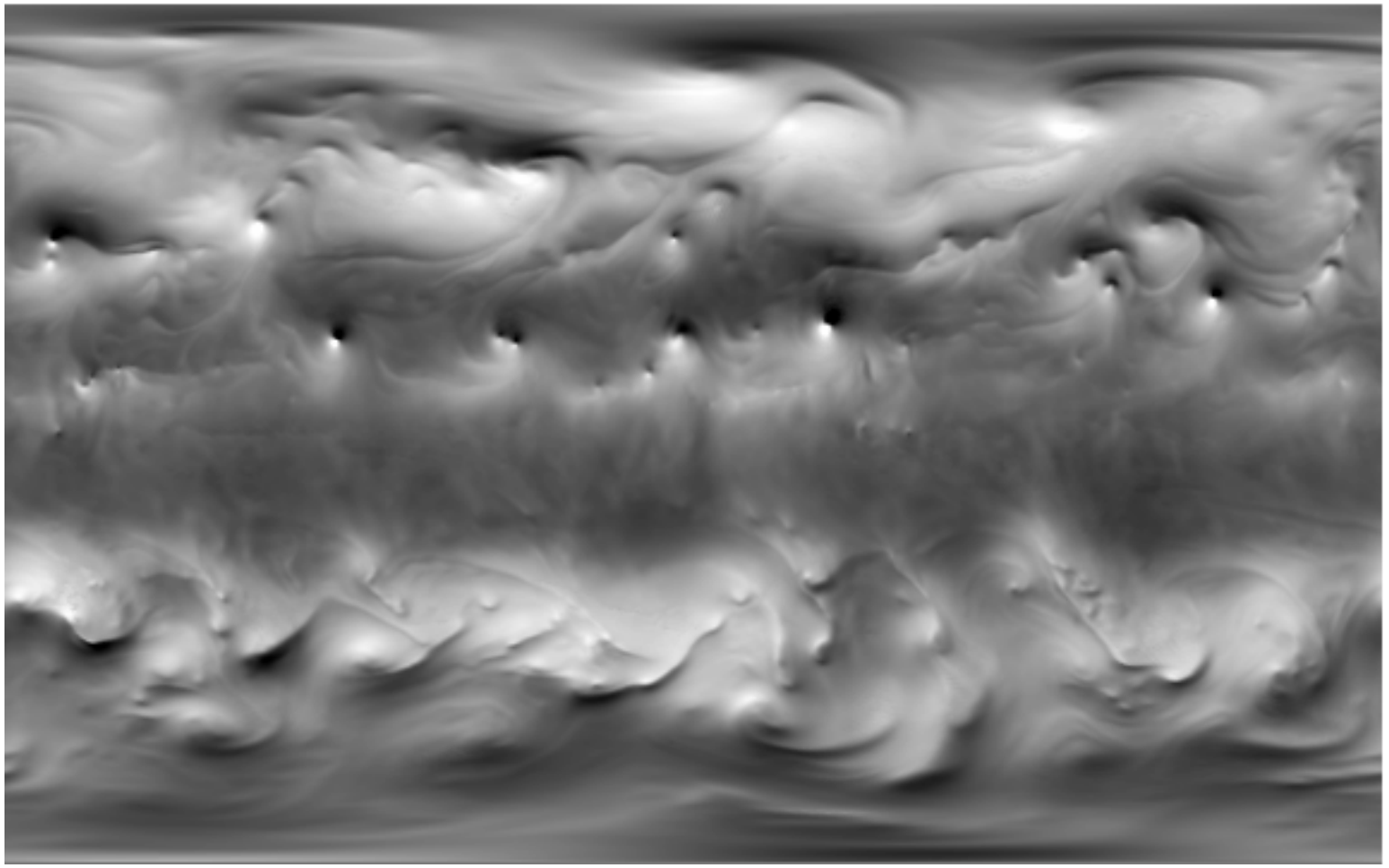


Hurricanes/TCs

Inhibiting parameterized convection =>

Sensitivity of global mean frequency to "divergence damping" in dynamical core

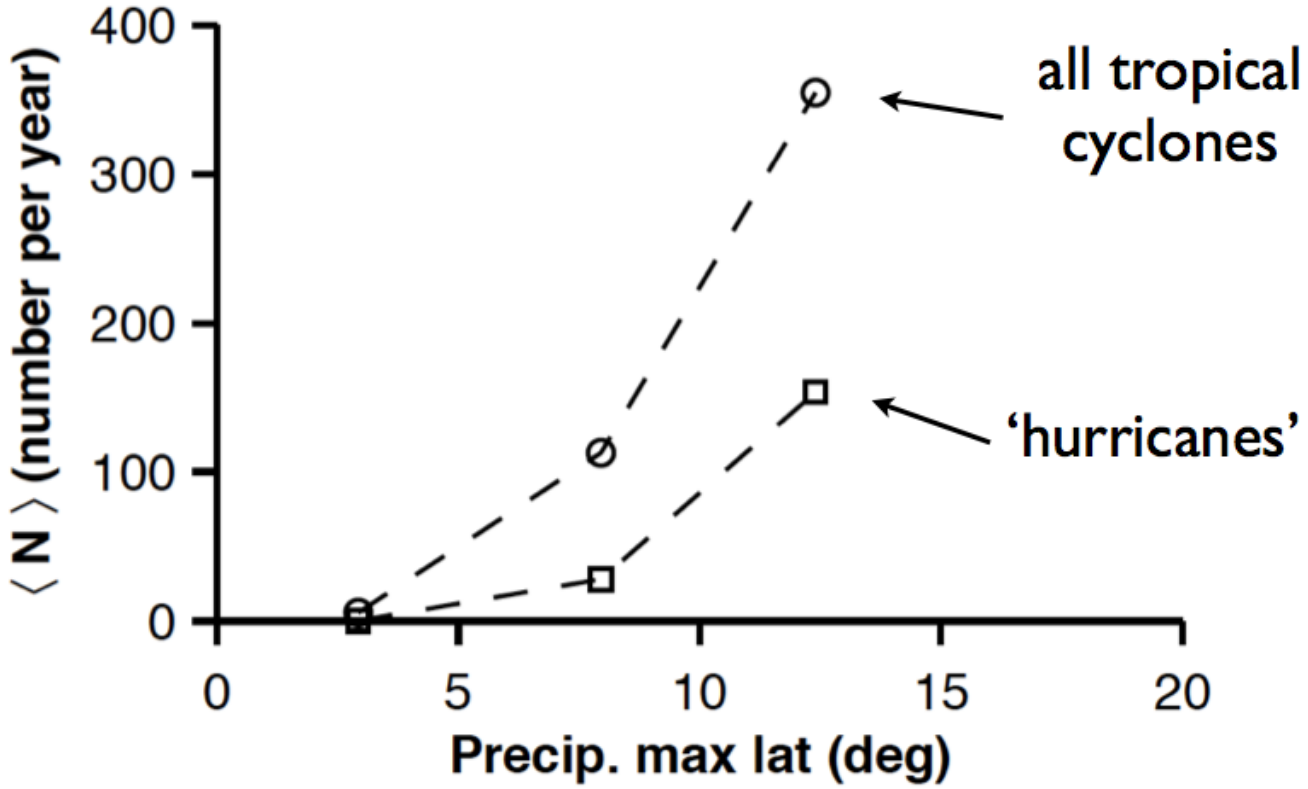




Aqua-planet with zonally symmetric climate and imposed fluxes that move ITCZ into Northern Hemisphere – Tim Merlis

Tim Merlis, Princeton 2012

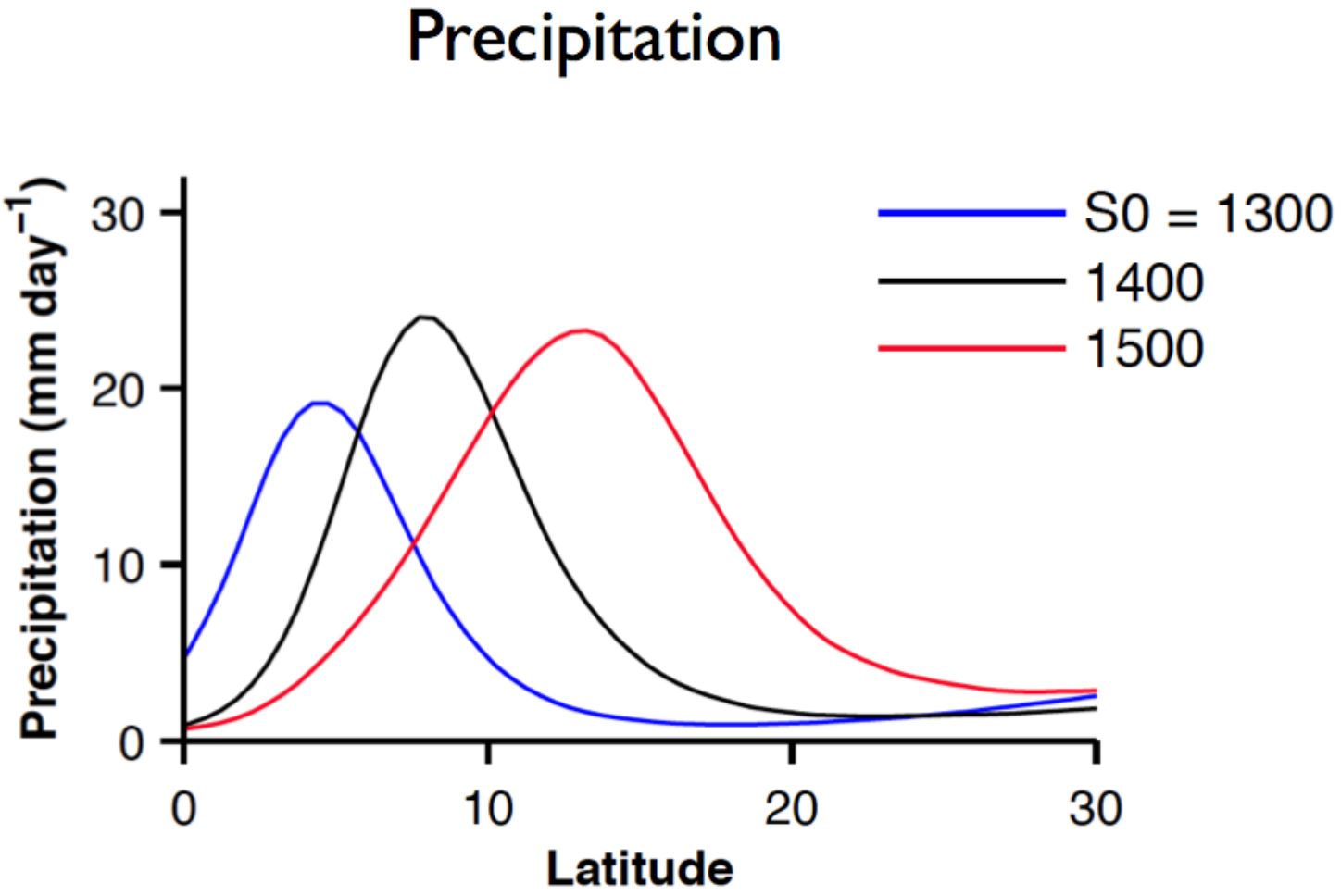
Varying ITCZ position with reference S0



Poleward ITCZ more favorable for cyclogenesis.

Consistent with genesis indices that depend on absolute vorticity e.g., Emanuel & Nolan (2004)

Tim Merlis, Princeton 2012



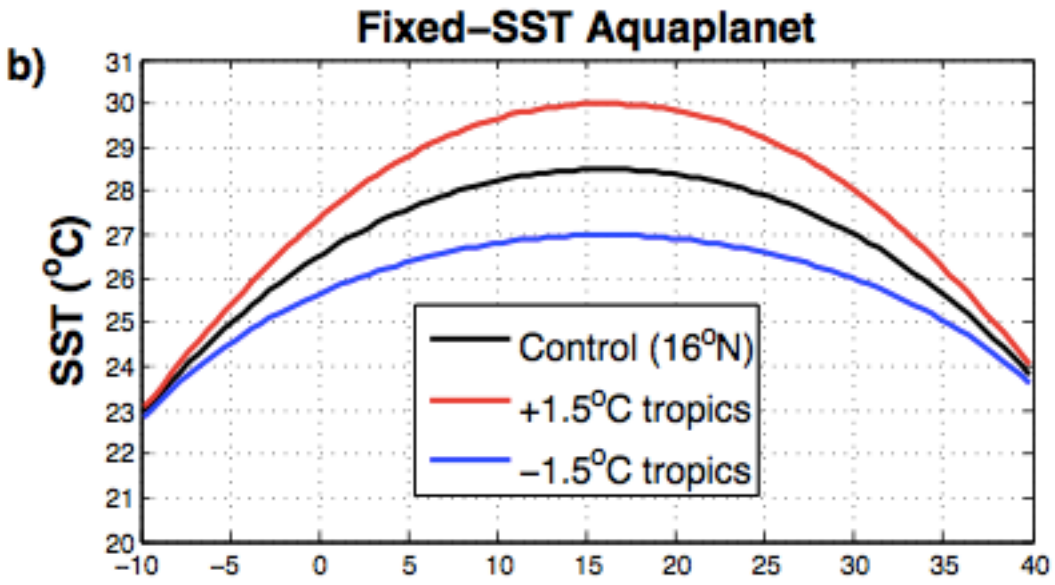
ITCZ & TC genesis shifts poleward with warming!

Typically, number of TCs decreases with global warming with realistic boundary conditions

But in the aqua-planet configuration, the number increases because ITCZ moves poleward

Understanding this result has 3 distinct parts
-- how does the ITCZ move with warming
-- how does the TC number change with ITCZ latitude
-- how does the TC number change with warming with fixed ITCZ latitude

Tim Merlis, et al – GRL 2013



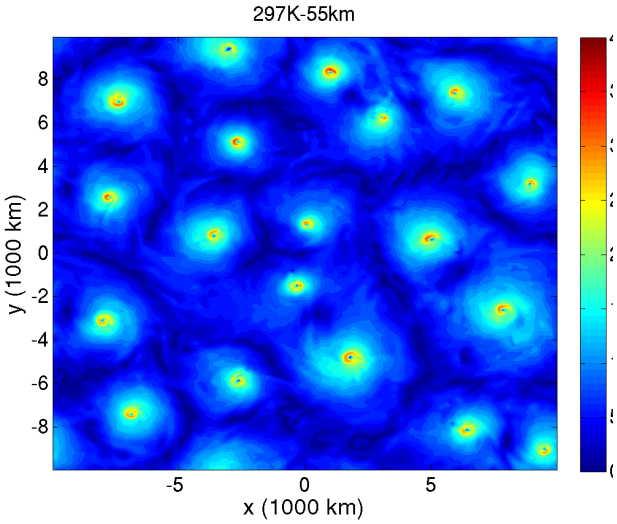
As tropical SST distribution is flattened, number of TCs decreases but intensity increases (ACE increases)

Why?

Andrew Ballinger et al, to be submitted

Rotating radiative convective equilibrium on doubly-periodic f-plane

297K



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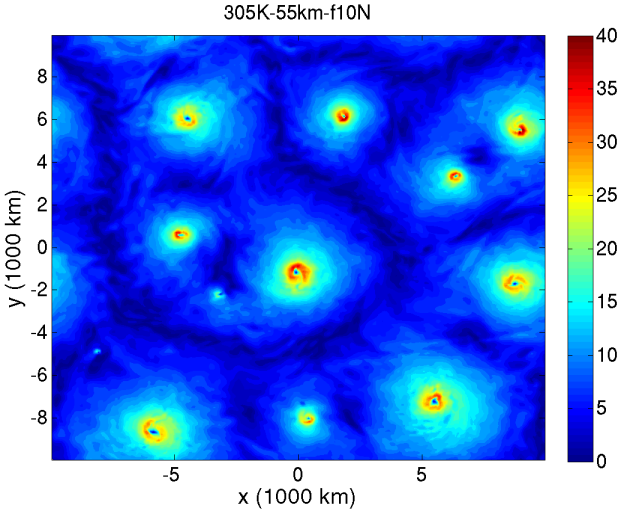

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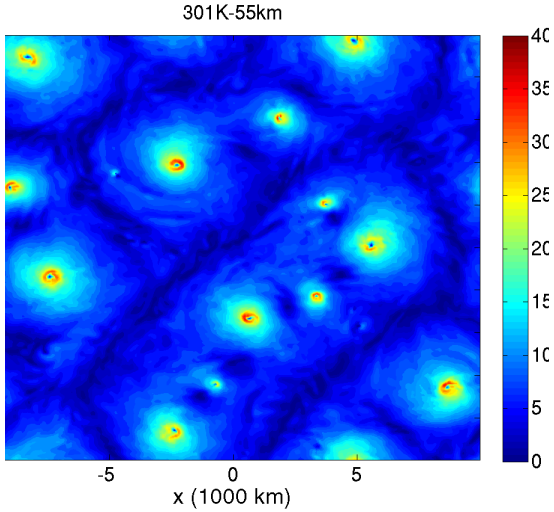
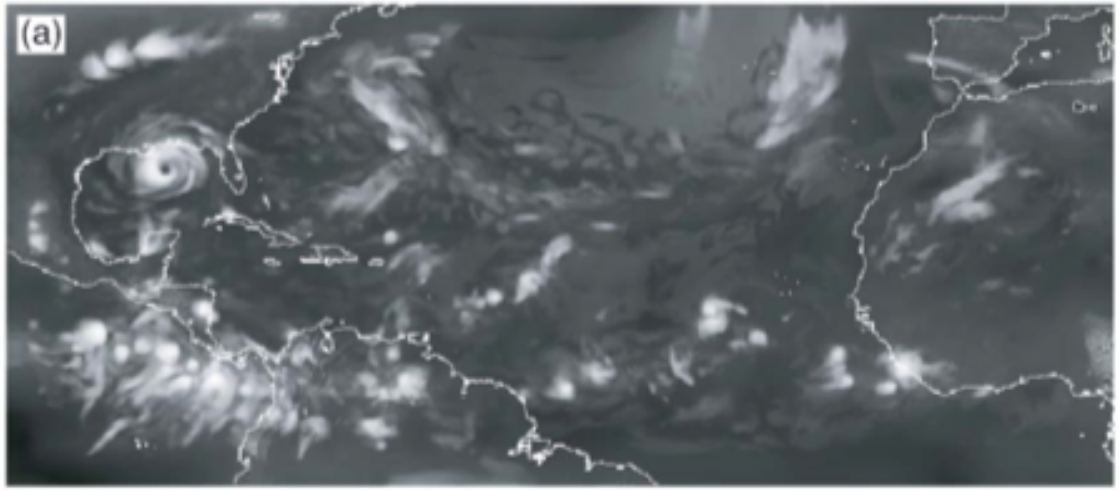
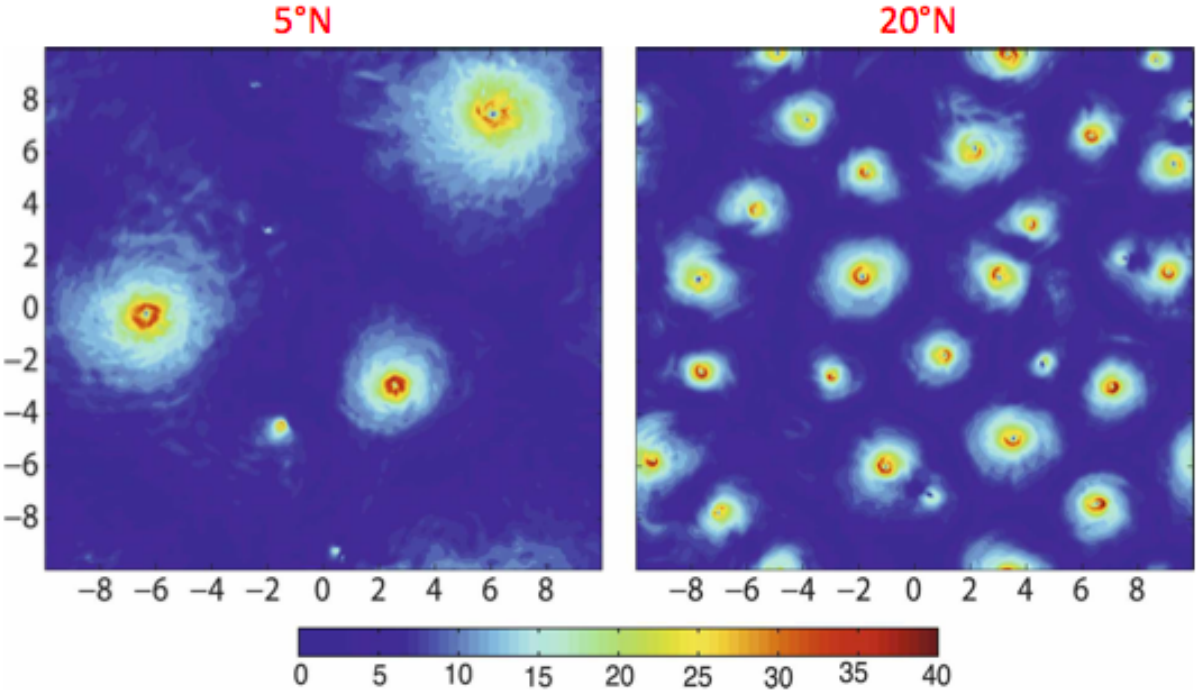


Near surface wind speed

End state of homogeneous model of tropics is closely-packed hurricanes!



Lots of interesting parameter dependencies



Snapshots of surface wind speed (m/s) for ambient rotation rates

Example:

Radius of maximum winds increases with increase in environmental rotation rate

despite decrease in the size of storms

Wenyu Zhou et al, J. Atmos. Sci 2014

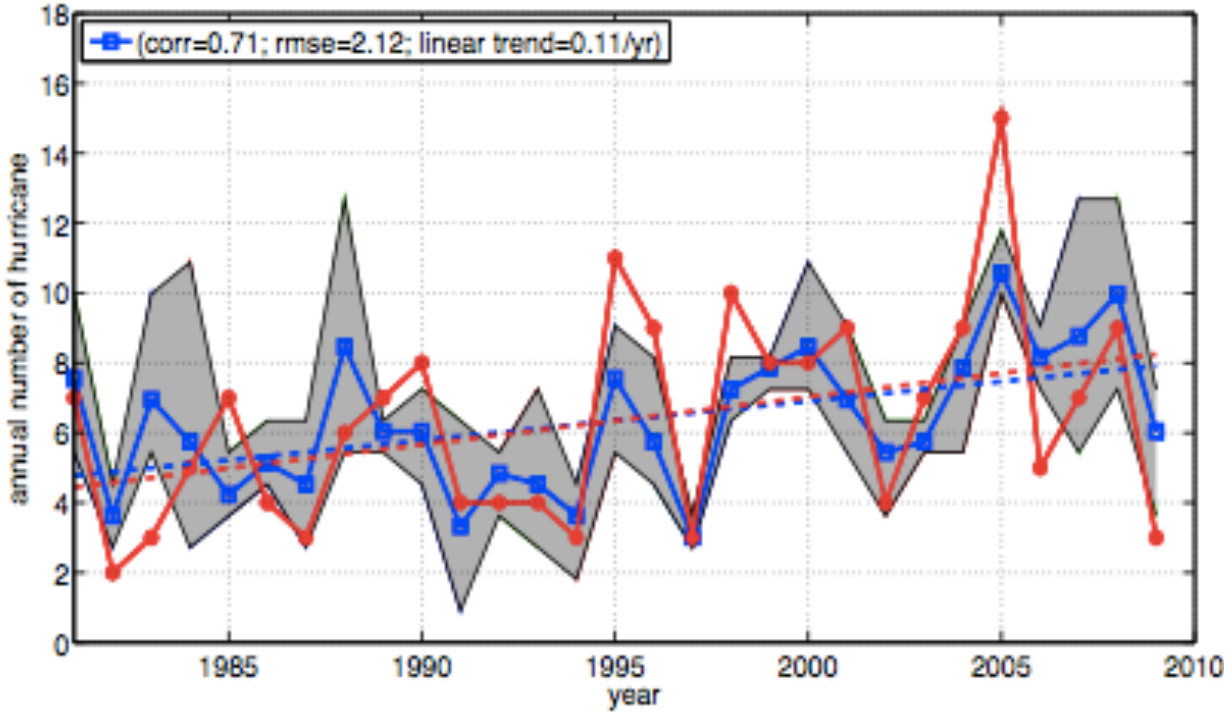
Plausibly realistic TC statistics in global models
just the starting point

Idealized models retaining GCM physics/numerics
but with simplified boundary conditions/geometry
are valuable for

1) *developing an understanding of tropical storm statistics, and*

2) *understanding differences between global models*

HadISST



Hurrell/CMIP5