High Resolution Earth System Modeling using Blue Waters Capabilities

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Objectives

- "This project is aimed at better quantifying future regional climate change by running a high-resolution global coupled climate model namely an advanced version of the Community Earth System Model (CESM) … to meet the needs for the next generation assessments of climate change."
  - Medium resolution (~1°lat/lon) basis for previous assessments
  - Next step is to push resolution to better simulate storms and regional atmospheric circulation
- "… modeling studies on Blue Waters that will push the state-of-the-art for such analyses."
- "… specific studies … to further clarify the understanding of the effects of small-scale regional features … "
  - Weather Research and Forcasting (WRF) Model at 12km resolution over the U.S.

Family of High-Resolution Simulations
Community Earth System Model (CESM)

- 0.25° atmos-land / 1.0° ocean-sea ice fully coupled (high res atmos)
  - pre-industrial (PI) control (100 years)
  - 20th Century historical (1850-2005)
  - Future scenarios (2006-2100)
- 0.25° atmos-land / 1.0° ocean-sea ice atmos-only (AMIP, time slices)
  - 4 present day (1979-2012) – perturbed atmos initial conditions
  - 4 future RCP8.5 (2070-2099) – perturbed atmos initial conditions
  - 6 future RCP8.5 (2070-2099) – different SST boundary forcing
- 0.25° atmos-land / 0.1° ocean-sea ice fully coupled (high res ocean)
  - Present Day (year 2000 constant forcing) ~110 years
  - Early Century (2001-2005)
  - Future RCP8.5 scenario (2006-2050)

Why Blue Waters?

- 0.25° atmos-land / 1.0° ocean-sea ice fully coupled (high res atmos)
  - pre-industrial (PI) control (100 years)
  - 20th Century historical (1850-2005)
  - Future scenarios (2006-2100)

~53.5M core-hours
or ~3.3M node-hours

- 0.25° atmos-land / 1.0° ocean-sea ice atmos-only (AMIP, time slices)
  - 3 present day (1979-2012) – perturbed atmos initial conditions
  - 4 future RCP8.5 (2070-2099) – perturbed atmos ICs
  - 6 future RCP8.5 (2070-2099) – different SST boundary forcing

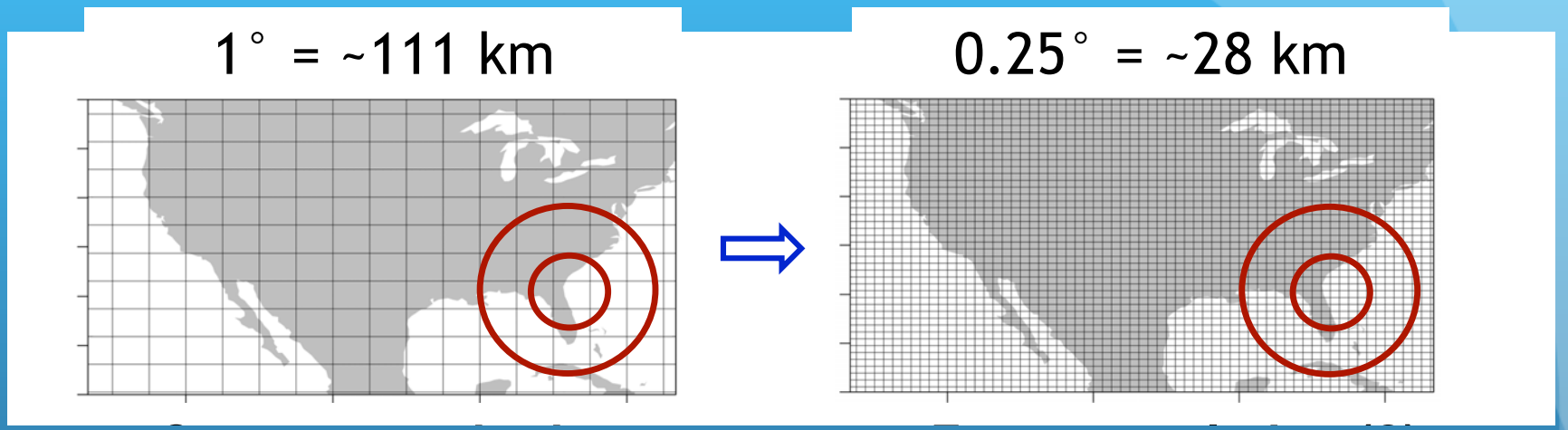
~70M core-hours or
~4.4M node-hours

- 0.25° atmos-land / 0.1° ocean-sea ice fully coupled (high res ocean)
  - Present Day (year 2000 constant forcing) ~110 years
  - Early Century (2001-2005)
  - Future RCP8.5 scenario (2006-2020)

~35M core-hours or
~2.2M node-hours

Medium-resolution model (1°) for all of the above runs
~2.5M core-hours or ~160K node-hours

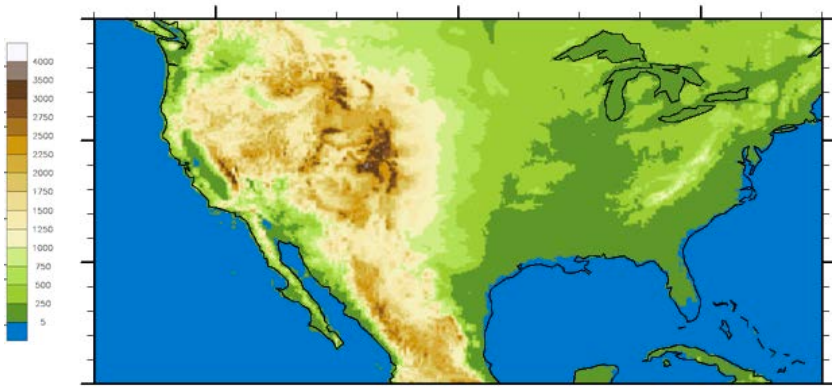
What does high resolution buy us?



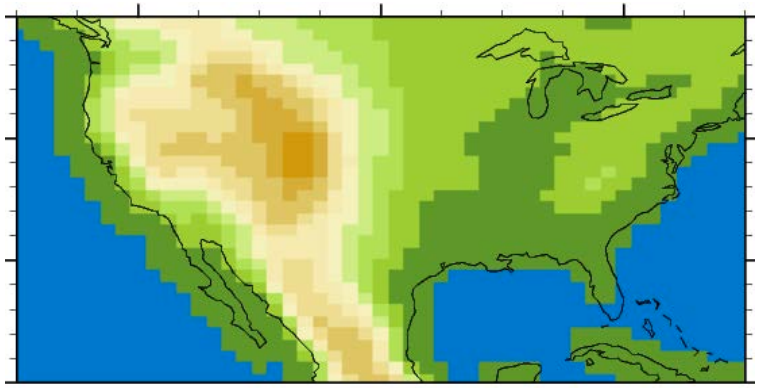
Courtesy Cecile Hannay

U.S. Topography

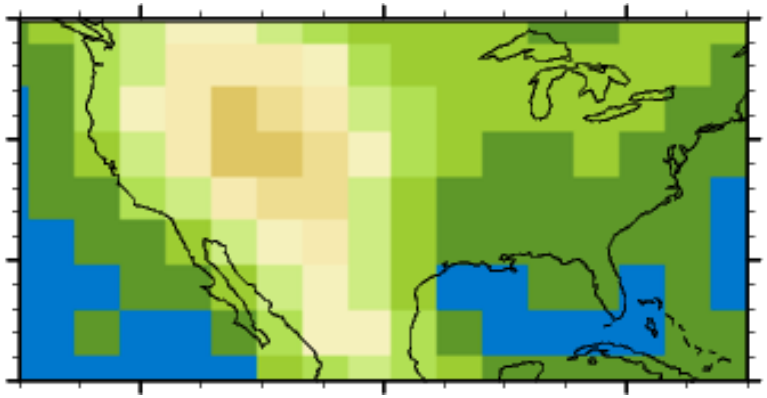
Observation



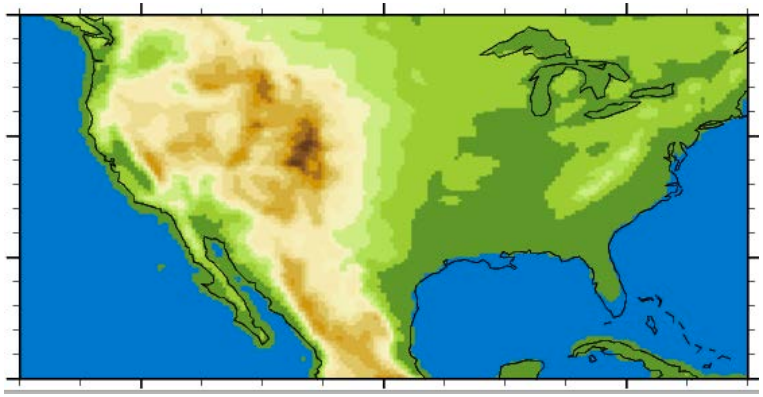
CAM at 1 degree (standard resolution)



CAM at T31



CAM at 0.25 degree (high resolution)

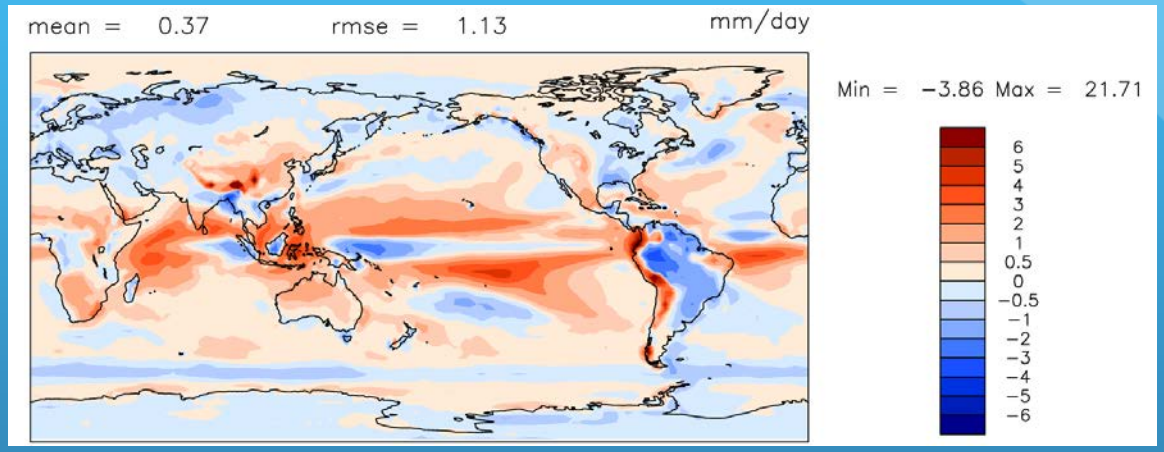


Courtesy Cecile Hannay

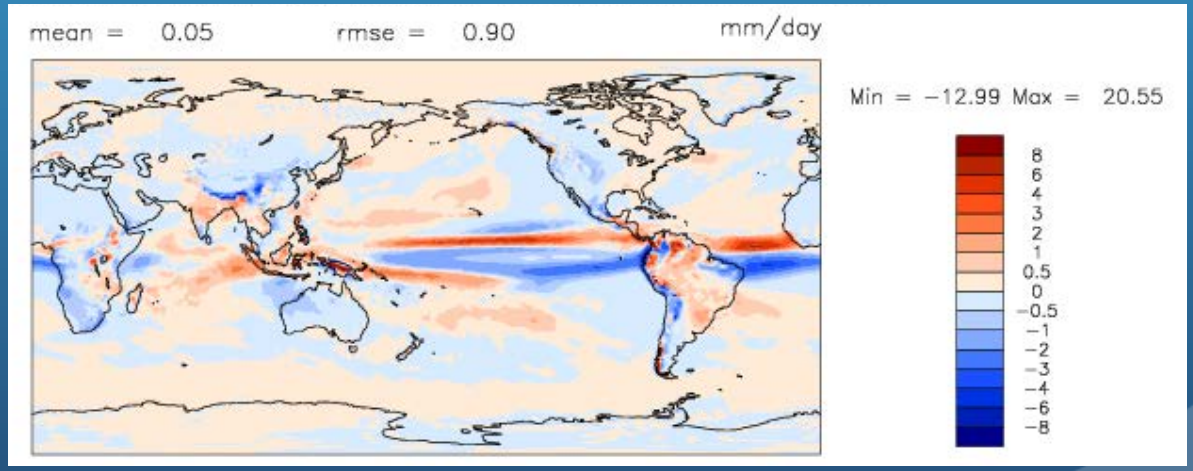
Mean Precipitation (large scale)

(1°atmosphere to 0.25°)

1° model - observations

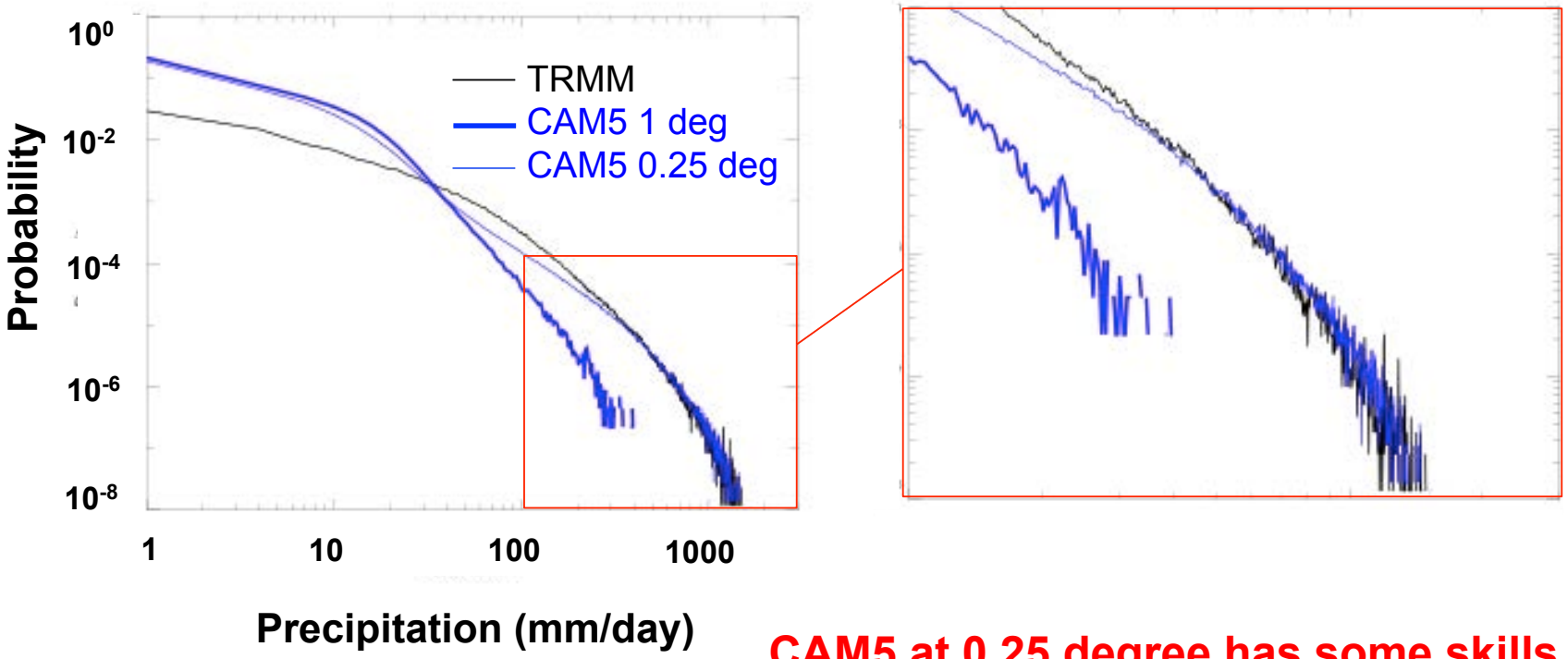


0.25° model - 1° model



Extreme Precipitation

(1°atmosphere to 0.25°)

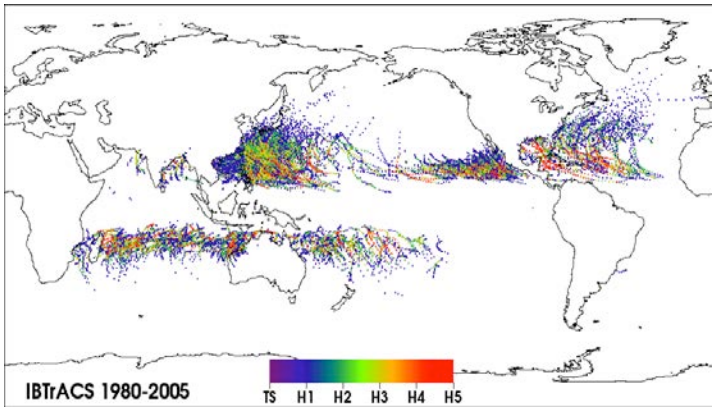


CAM5 at 0.25 degree has some skills to simulate extreme precipitation

Courtesy Julio Bacmeister

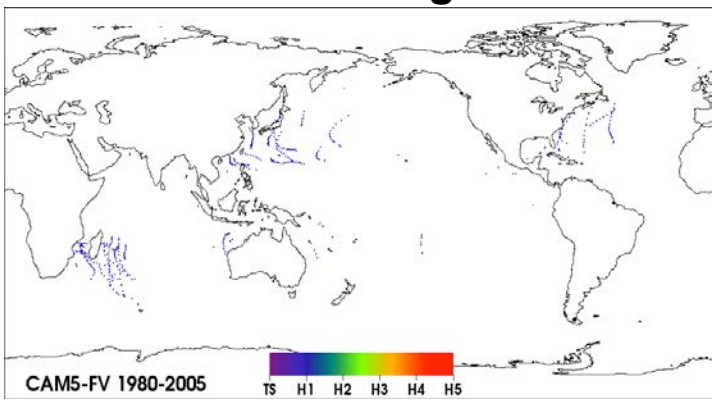
Resolving Tropical Cyclones

Observations: IBTrACS

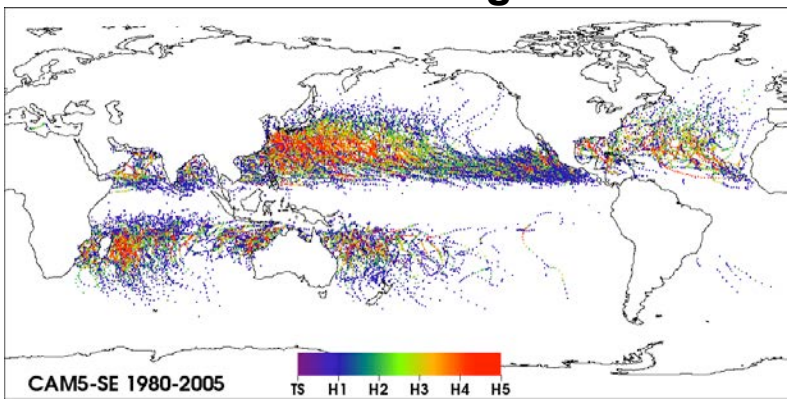


- **Tropical cyclone tracks identified by GFDL tracking algorithm**
- **CAM5 at 0.25 degree has some skills to simulate tropical cyclones**

CAM5: 1 degree

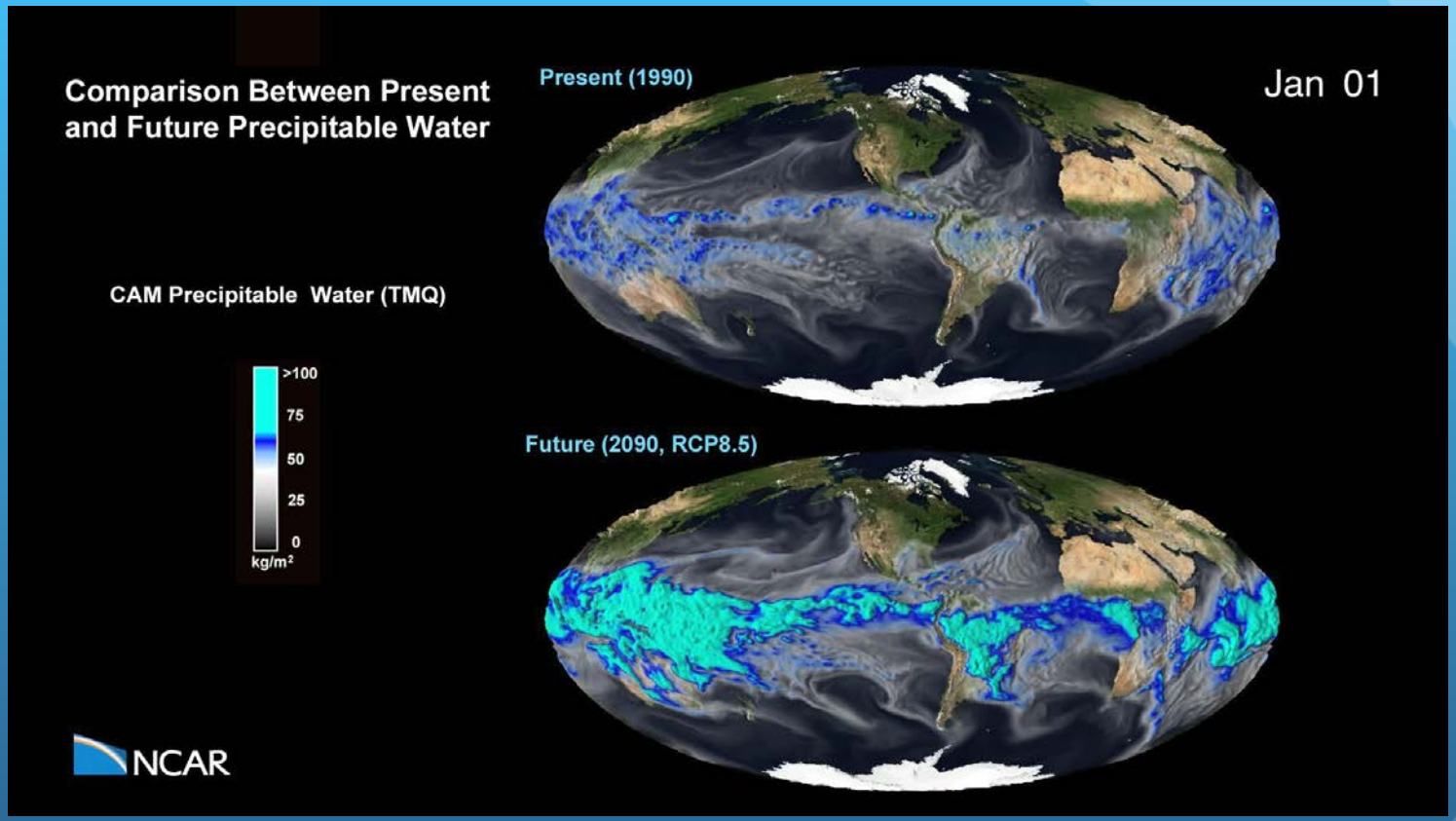


CAM5: 0.25 degree



Courtesy: Kevin Reed [See also: Wehner et al. 2014, JAMES]

Present Day and Future Precipitable Water



Scheitlan, T. and M. Rehme, 2015: Climate Change: A high-resolution atmospheric model (0.25 degree) with specified ocean temperatures and sea ice. May 2015, *You Tube*. https://youtu.be/tm1w_FPosT4

Present Day and Future Tropical Cyclones

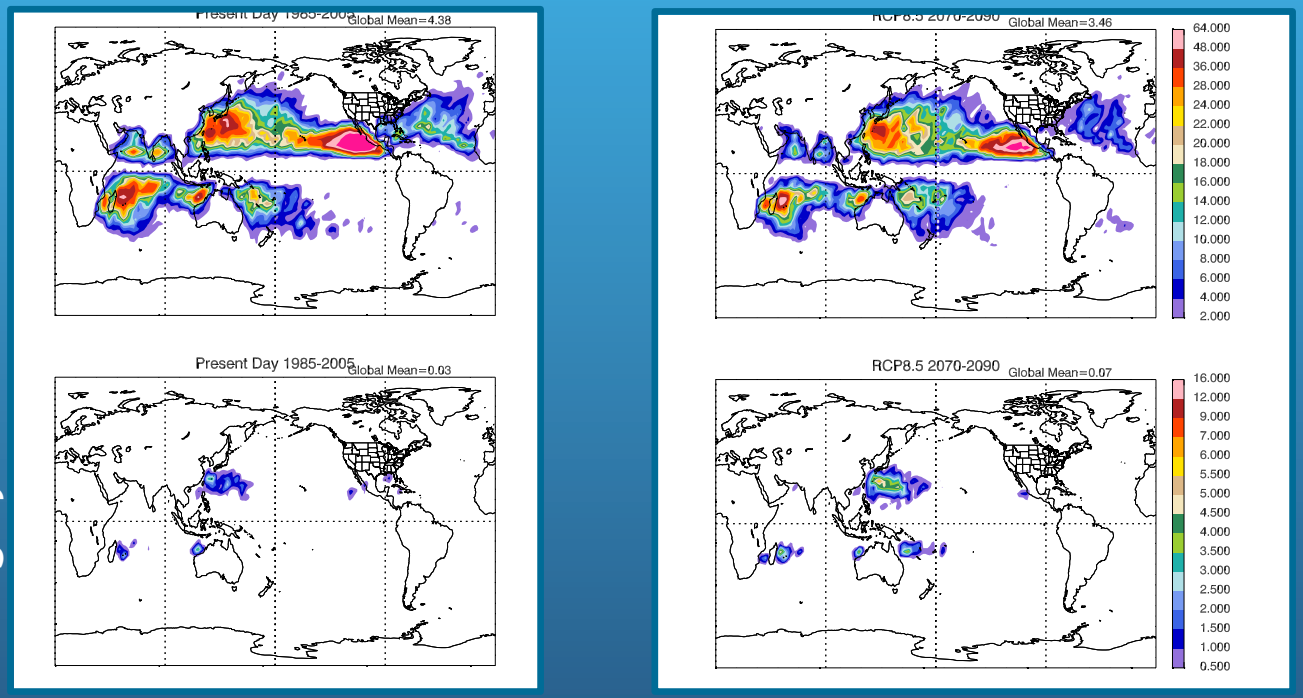
(0.25° atmosphere-only time slice simulations)

Present Day (1985-2005)

Future RCP8.5 (2070-2090)

All Storms

Category 4-5

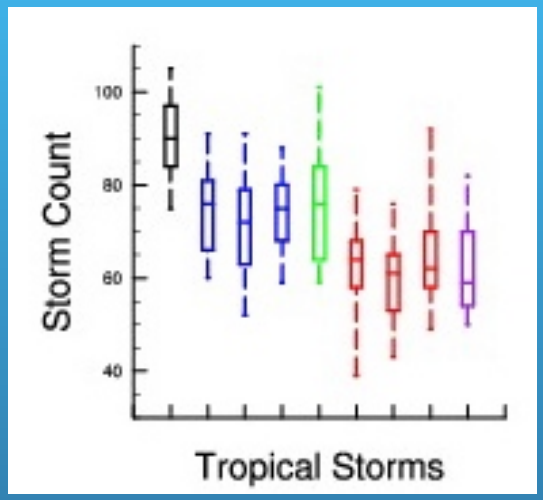


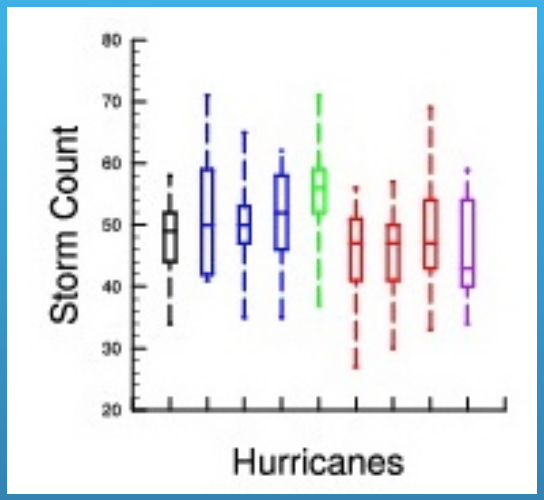
Units are average hours per year in which a storm is found within a 4° x 4° gridbox

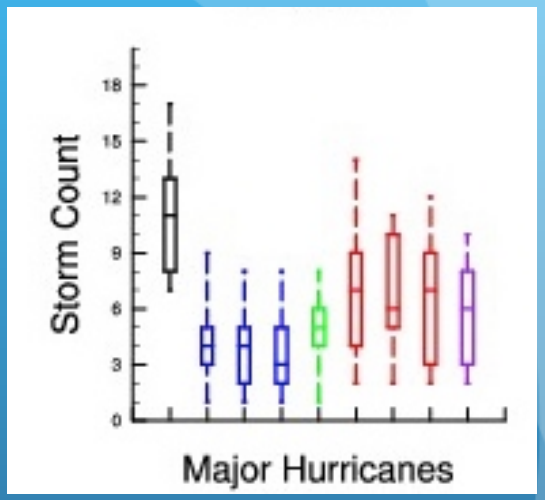
(Bacmeister, et al,. submitted 2016)

Present Day and Future Tropical Cyclones

(0.25° atmosphere-only time slice simulations)







IBTrACS 1985-2005
Present Day 1985-2005
Present Day 1985-2005 (modified dust)
Future RCP8.5 2070-2090
Future RCP8.5 2070-2090 (modified SST)

IBTrACS = International Best Track Archive for Climate Stewardship

Evaluations of high-resolution dynamically downscaled ensembles over the contiguous United States

Zach Zobel; Jiali Wang; Donald Wuebbles; Rao Kotamarthi

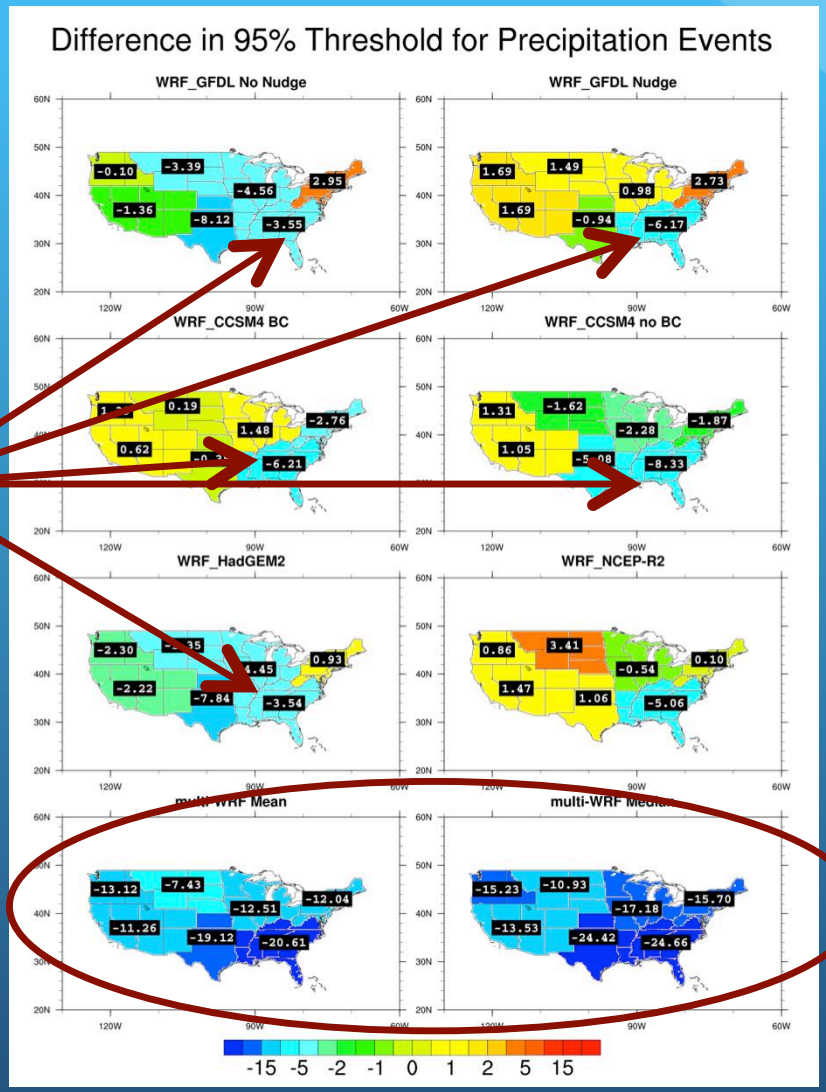
	Lateral boundary conditions	WRF Simulation	Microphysics	Spin-up time	Spectral nudging (strength)	Bias correction
1	NCEP-R2	WRF_NCEP	WSM6	1 day	Yes (3×10^{-4} s^{-1})	No
2	CCSM4	WRF_CCSM_nBC	Morrison	1 year	Yes (3×10^{-5} s^{-1})	No
3	CCSM4	WRF_CCSM_BC	Morrison	1 year	Yes (3×10^{-5} s^{-1})	Yes
4	GFDL-ESM2G	WRF_GFDLNN	Morrison	1 year	No	Yes
5	GFDL-ESM2G	WRF_GFDLN	Morrison	1 year	Yes (3×10^{-5} s^{-1})	Yes
6	HadGEM2-ES	WRF_HadGEM	Morrison	1 year	No	No

- inform researchers why there are regional differences in the near surface climate extremes and better inform prediction methods
- provide stakeholders and the public with knowledge of the uncertainties on how climate change will affect local hydrology processes and the heat stress on humans in a warmer climate

(Zobel et al., submitted 2016)

Extreme precipitation events

Many variables have the highest errors in the wettest and driest regions of the continental U.S., regions where small-scale processes are common.



millimeters

The accuracy of extreme values are highly dependent on region and boundary conditions.

Mean and median diminish variability.

(Zobel et al., submitted 2016)

Publications

Bacmeister, J. T., K. A. Reed, C. Hannay, P. Lawrence, S. Bates, J. E. Truesdale, N. Rosenbloom, and M. Levy, Projected changes in tropical cyclone activity under future warming scenarios using a high-resolution climate model. Submitted to *Climatic Change* (2016).

Zarzycki, C. M., Reed, K. A., Bacmeister, J. T., Craig, A. P., Bates, S. C., and N. A. Rosenbloom, Impact of surface coupling grids on tropical cyclone extremes in high-resolution atmospheric simulations. *Geoscientific Model Development*, 9:2 (2016), pp. 779-788.

Zobel, Z., J. Wang, D. J. Wuebbles, and V. R. Kotamarthi, Evaluations of high-resolution dynamically downscaled ensembles over the contiguous United States. Submitted to *Climate Dynamics* (2016).

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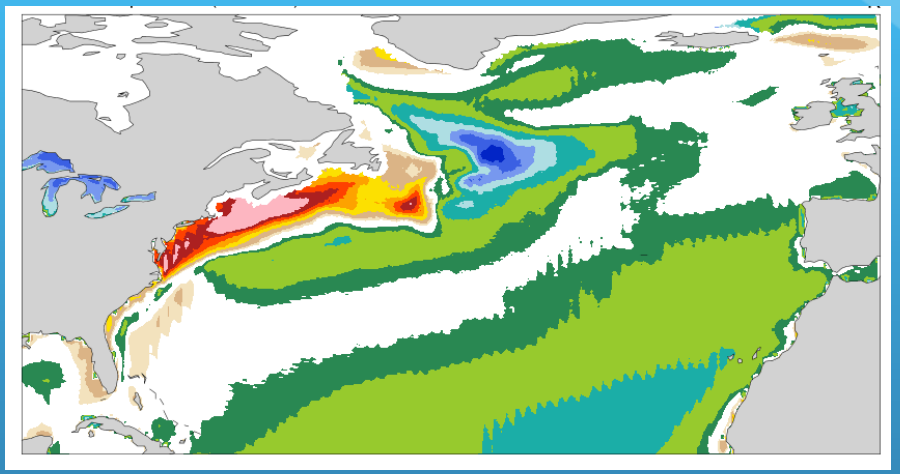
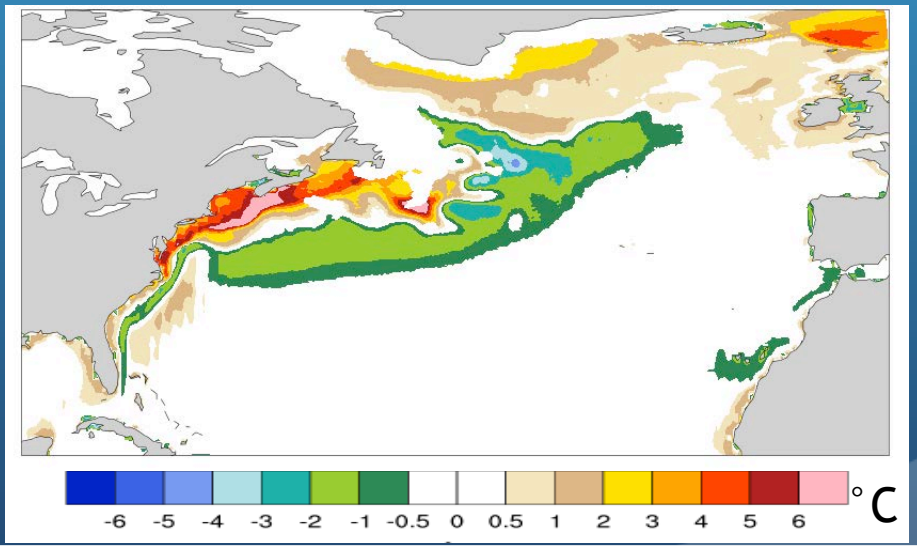
High Resolution Ocean – from 1° to 0.1°
Atlantic Sea Surface Temperature

Medium resolution ocean bias
OBS = Reynolds (2007)

MODEL - OBS



MEDIUM RES – HIGH RES OCEAN



Improvement due to high resolution.

Sign convention – matching colors (top and bottom) implies improvement with resolution.

Courtesy Justin Small