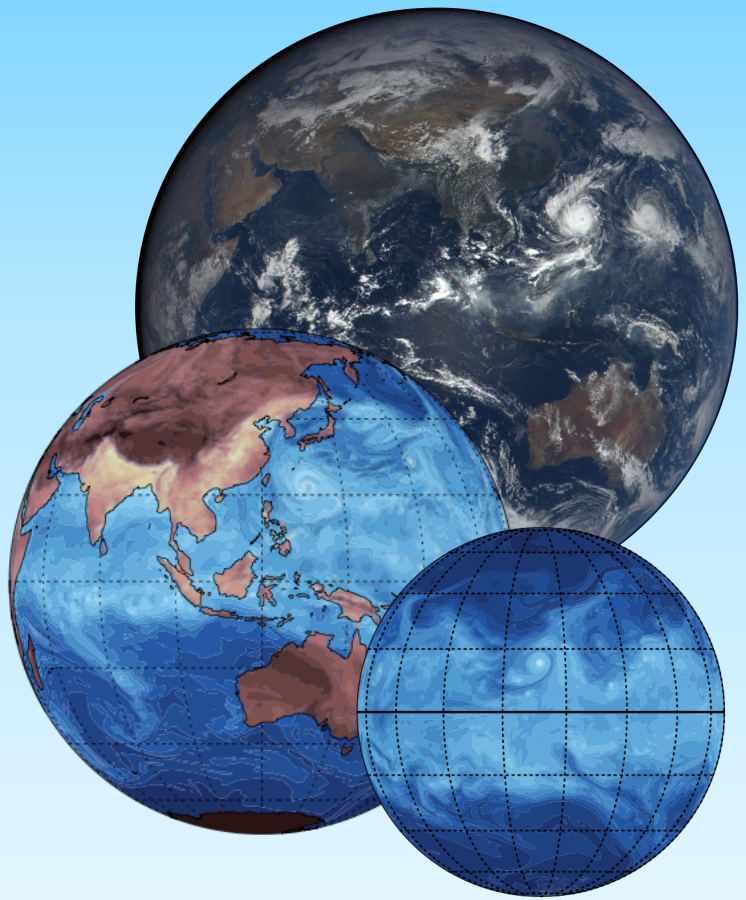

Understanding the Role of Tropical Cyclones in the Climate System with Simplified Climate Models

Xiaoning Wu

IACS Junior Researcher Award, July 25, 2019

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NCAR Host: Scott Bachman (Climate and Global Dynamics Laboratory, Oceanography Section)

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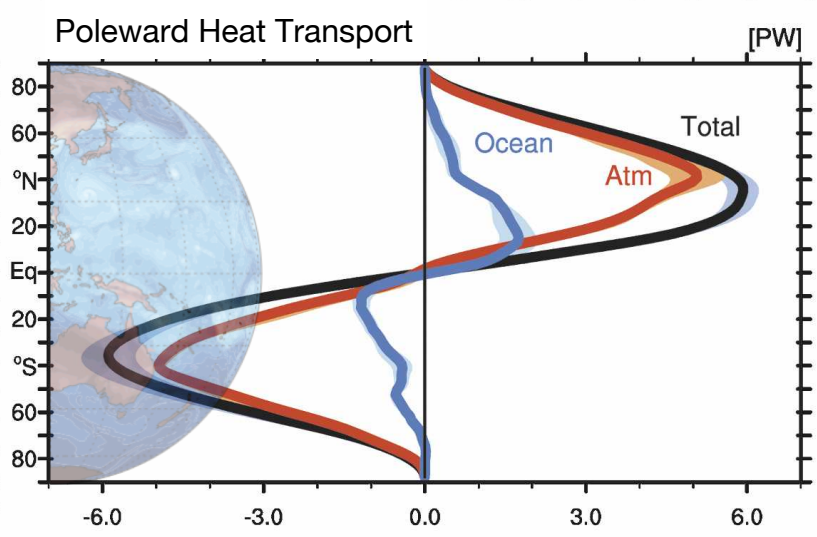
Satellite image: NASA; figure design adapted from B. Medeiros

Motivation: 1 hurricane = millions of atomic bombs

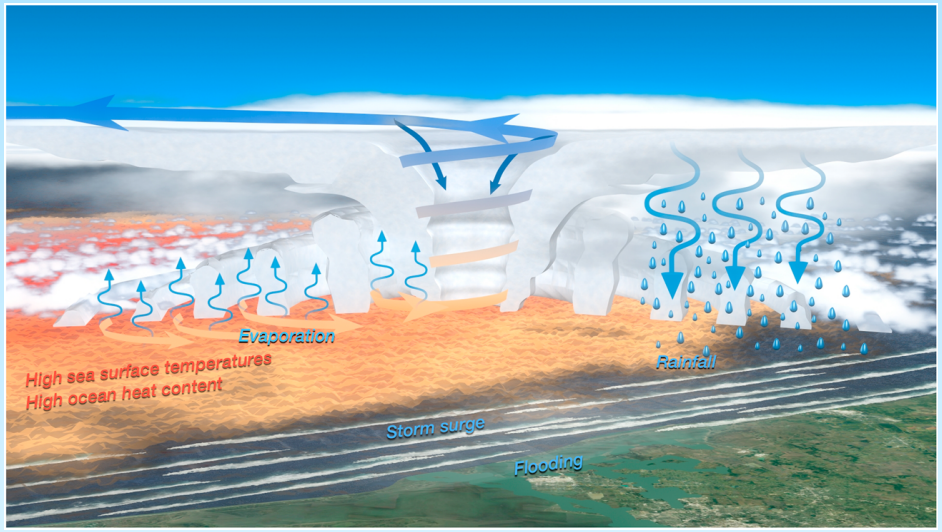
[Source: NOAA]

Coastal communities in Mexico Beach, FL before and after Hurricane Michael (2018)

Question: Do tropical cyclones affect climate system energy transport?



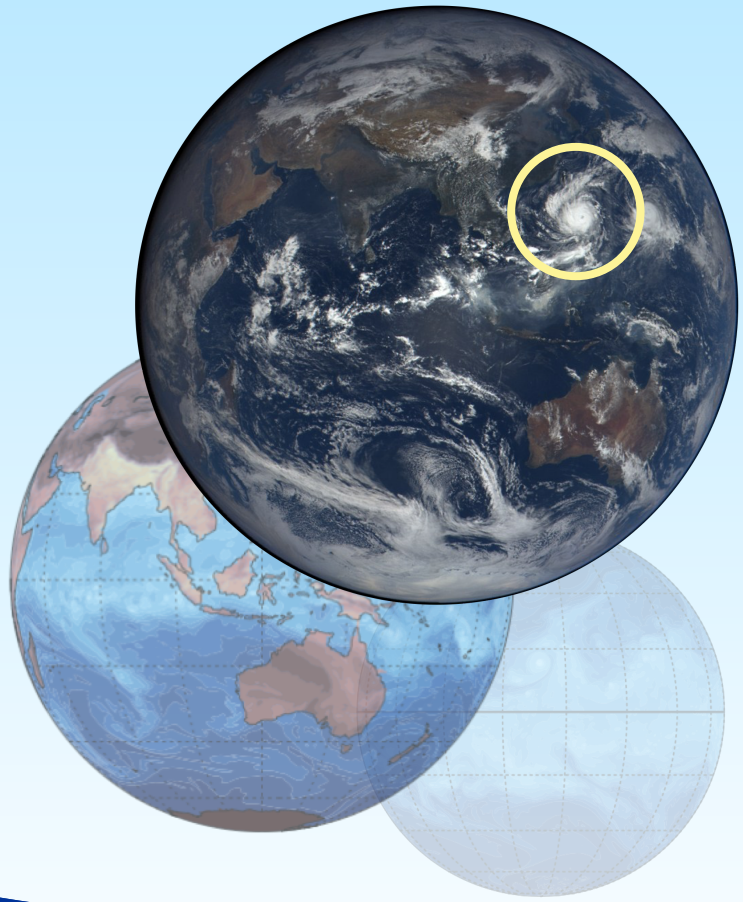
Adapted from Fasullo and Trenberth [2008]

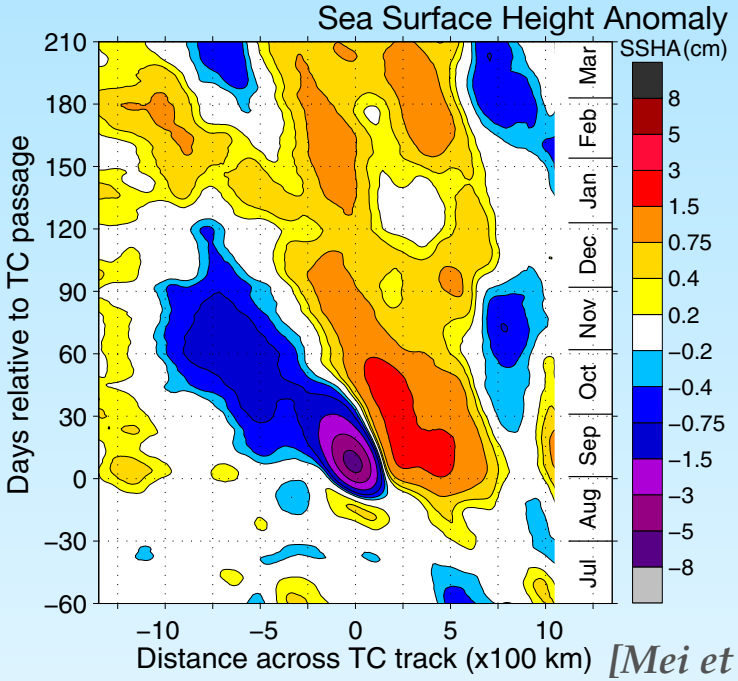


[Steven Deyo, NCAR]

- For the Equable Climates, 146-34 Myr B.P. (Cretaceous - Eocene): tropical cyclones hypothesized to keep the poles warmer by **enhancing ocean heat transport** (Emanuel, 2002; Korty et al., 2008)
- For current and future climates: Can tropical cyclones be a significant agent of energy transport? If so, how?

Observation: Tropical cyclones may contribute ~15% to ocean heat transport

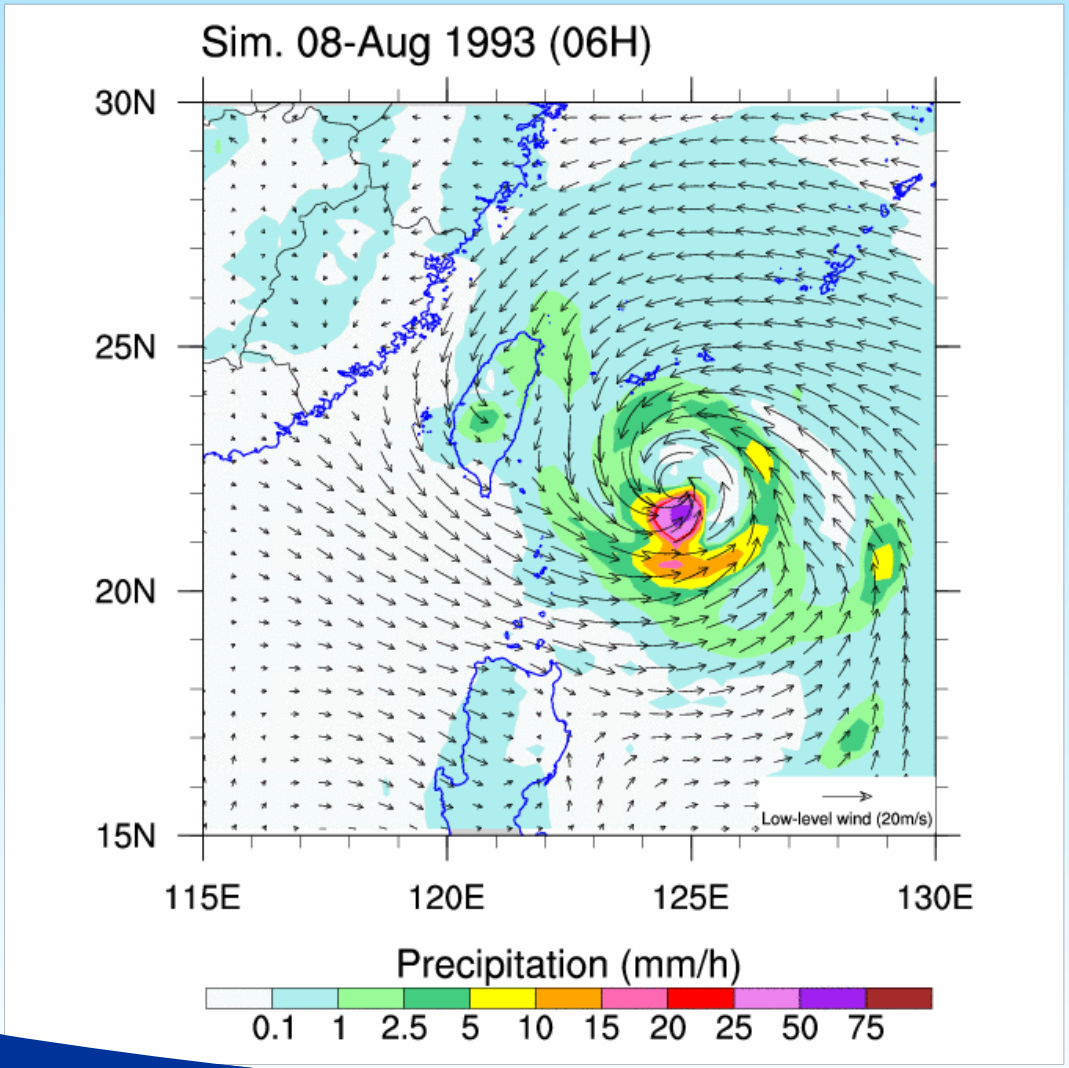




[Mei et al, 2013]

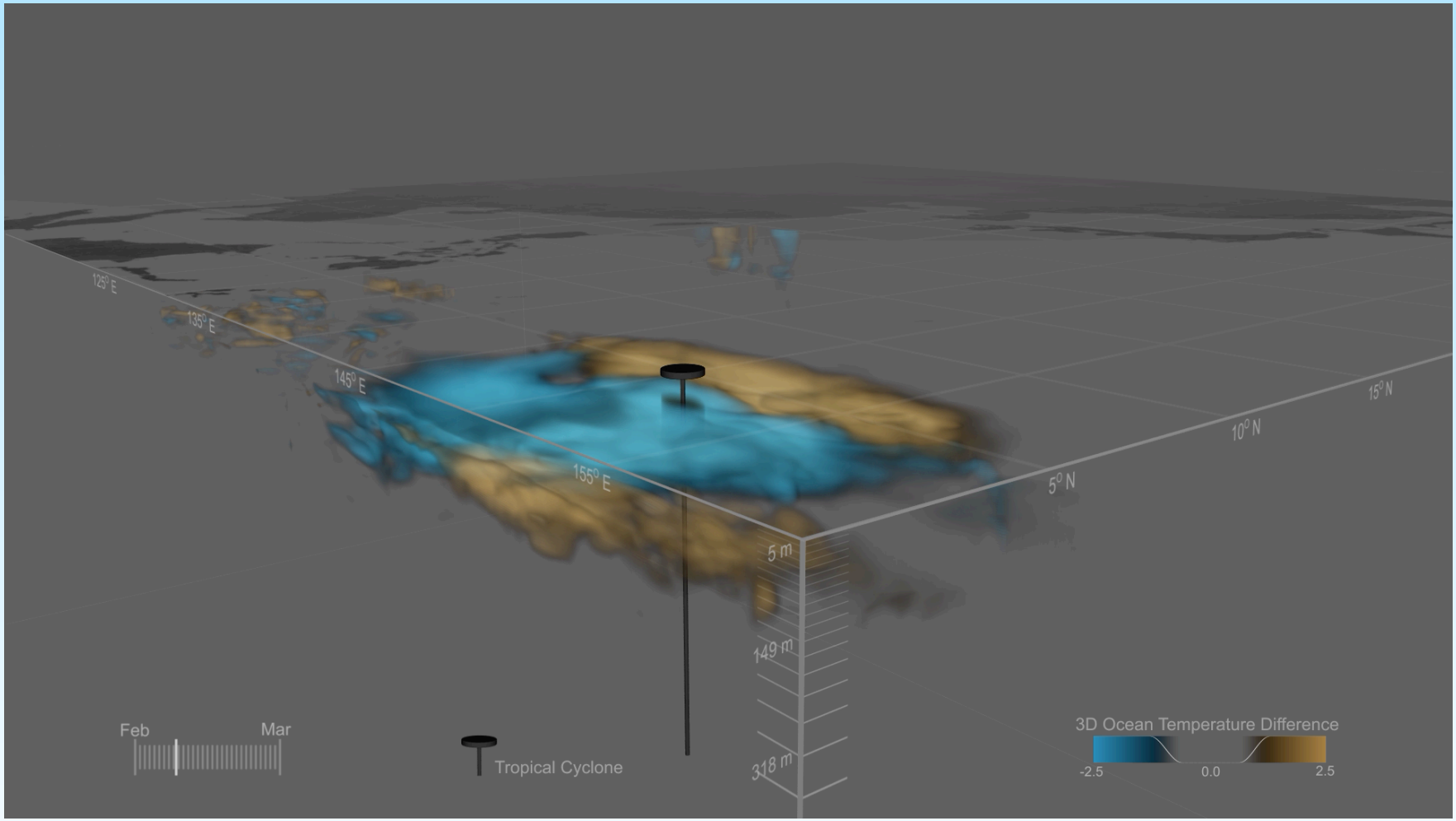
- Earlier estimates: anywhere between 5-50%
- Mei et al. (2013): Northern Hemisphere TCs contribute 0.32 ± 0.15 PW (~15 ± 7%) to poleward ocean heat transport
- BUT global tropical ocean heat transport (2.3 ± 0.4 PW) has a substantial error margin (Ganachaud and Wunsch, 2003)

Conventional climate modeling: Tropical cyclones represented at high resolution



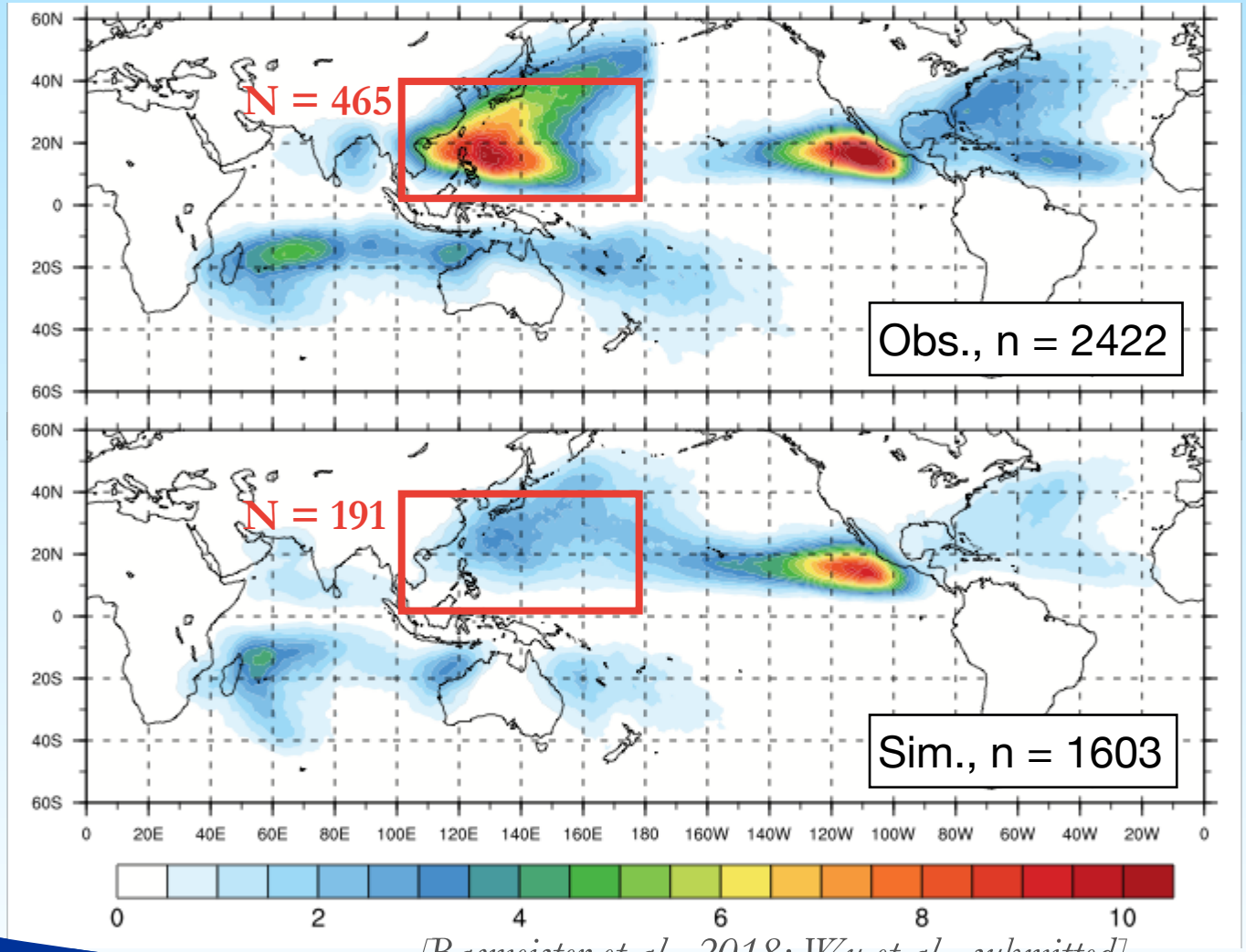
- NCAR's Community Atmosphere Model at ~28 km horizontal resolution
- Tropical cyclone (TC) precipitation and wind field capturing the interaction with mountainous island
- Biases in simulated TC statistics, especially for the Western North Pacific (Bacmeister et al., 2018; Wu et al., submitted)

Conventional climate modeling: Ocean response to TC captured



[Li and Sriver, 2018; Bock, 2017]

Conventional climate modeling: Biases in TC climatology

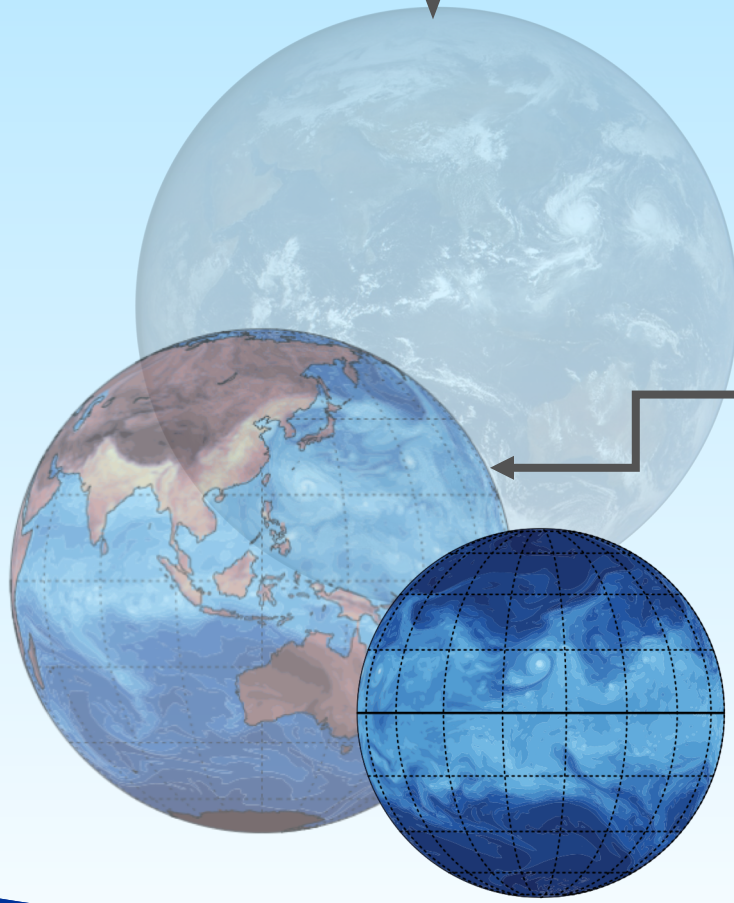


[Bacmeister et al., 2018; Wu et al., submitted]

CAM5-only decadal (1980-2005) climatology:

- Global TC frequency: ~70% of observation
- Western North Pacific: ~40% of observation

Gap: Uncertainty and complexity



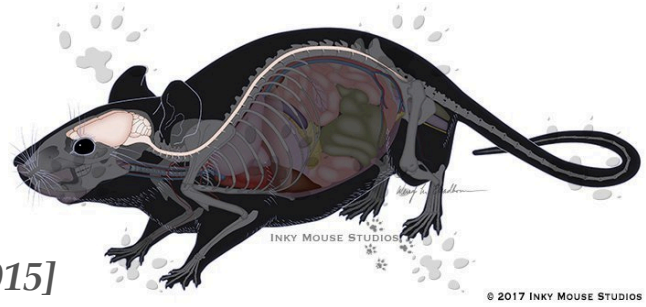
- Observation:
  - Limited records of TCs, especially of the ocean
  - Large error margin in ocean heat transport
- Conventional climate modeling:
  - Uncertainty from limited skills (atmosphere and ocean)
  - Computationally expensive due to complex components

Approach: A hierarchy of simpler models

Human

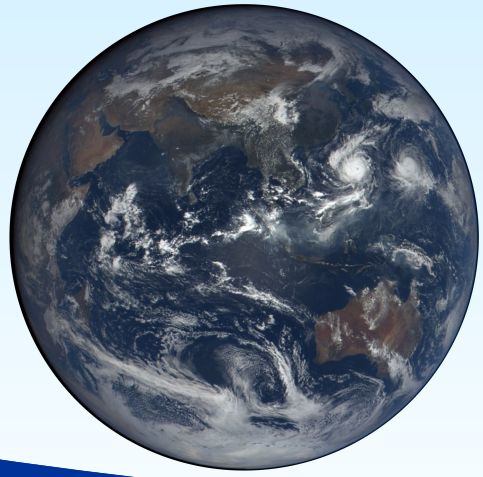
[Prokop, 2015]

Mouse

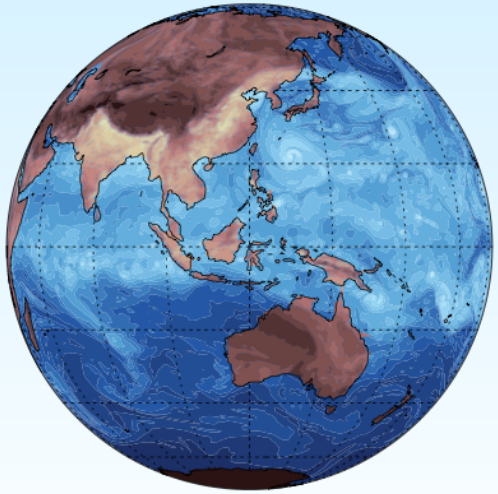


Fruit fly

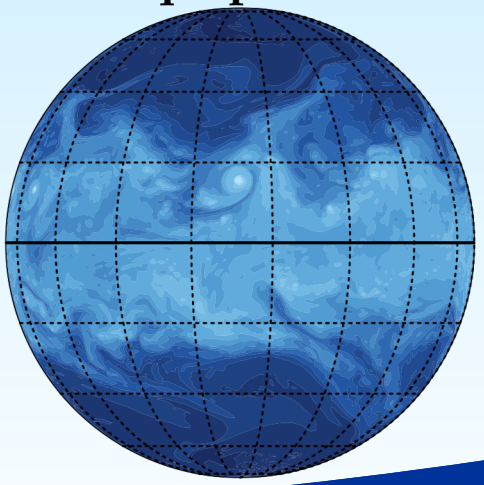
Earth's Climate



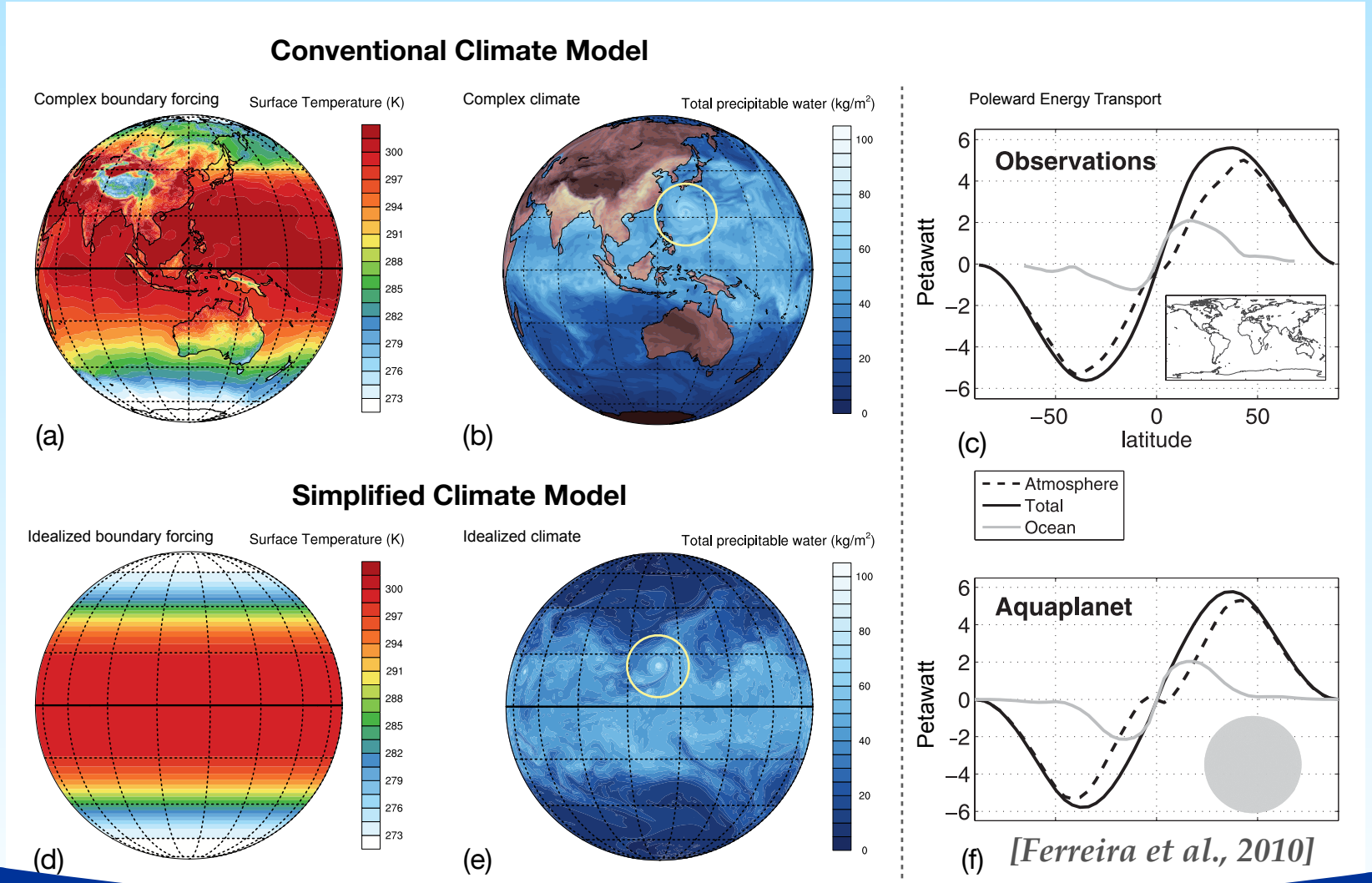
Conventional Model



Simplified Model (Aquaplanet)

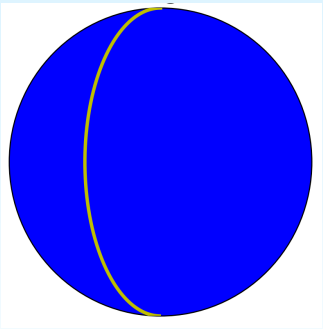


Approach: A hierarchy of simpler models

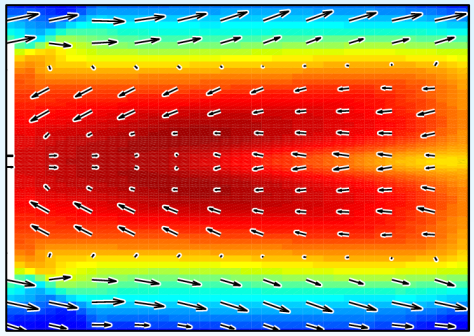


Proposed Hypotheses

- H1: TCs contribute a significant fraction (>10%) to ocean heat transport (cf. Mei et al. 2013).
- H2: TCs contribute a significant fraction (>10%) to oceanic overturning circulation in the tropics (cf. Shi and Bretherton 2014).
- H3: The impact of TCs is enhanced in the presence of western boundary currents (cf. Li and Sriver 2018a).



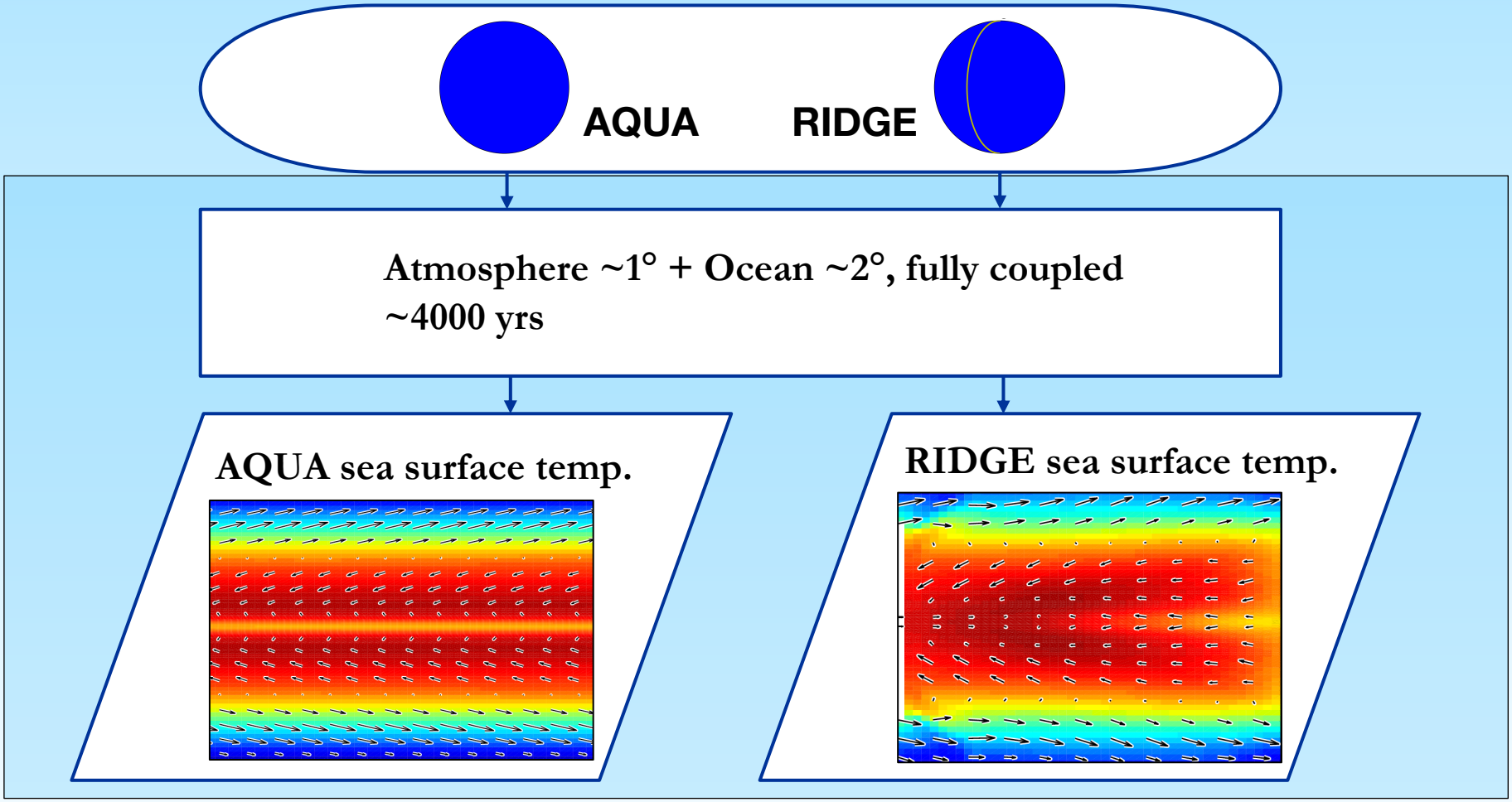
RIDGE: aquaplanet with a strip of pole-to-pole continent



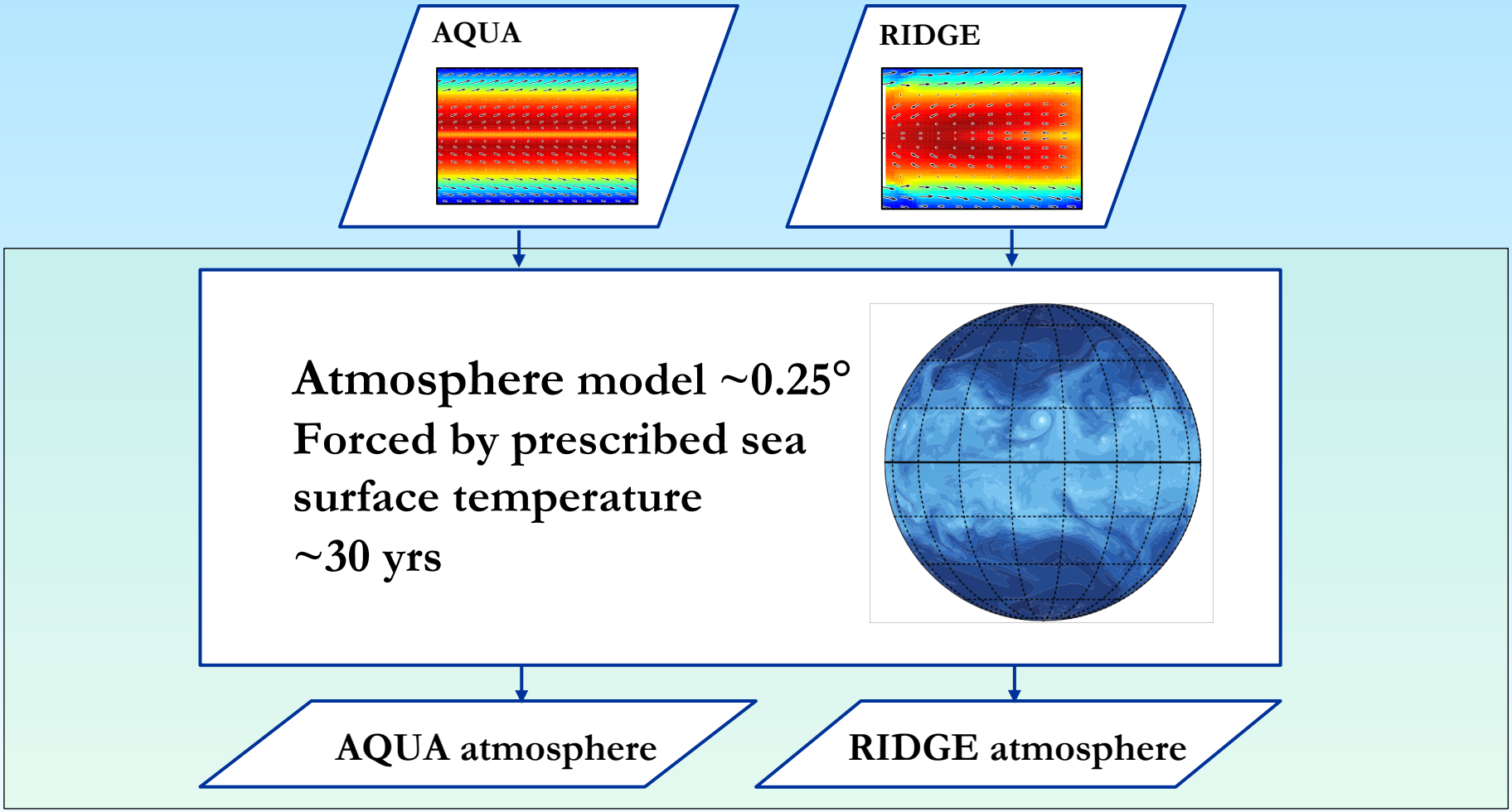
[DiNezio, 2019]

Ocean dynamics leads to western boundary currents, like the Atlantic Gulf Stream or Pacific Kuroshio

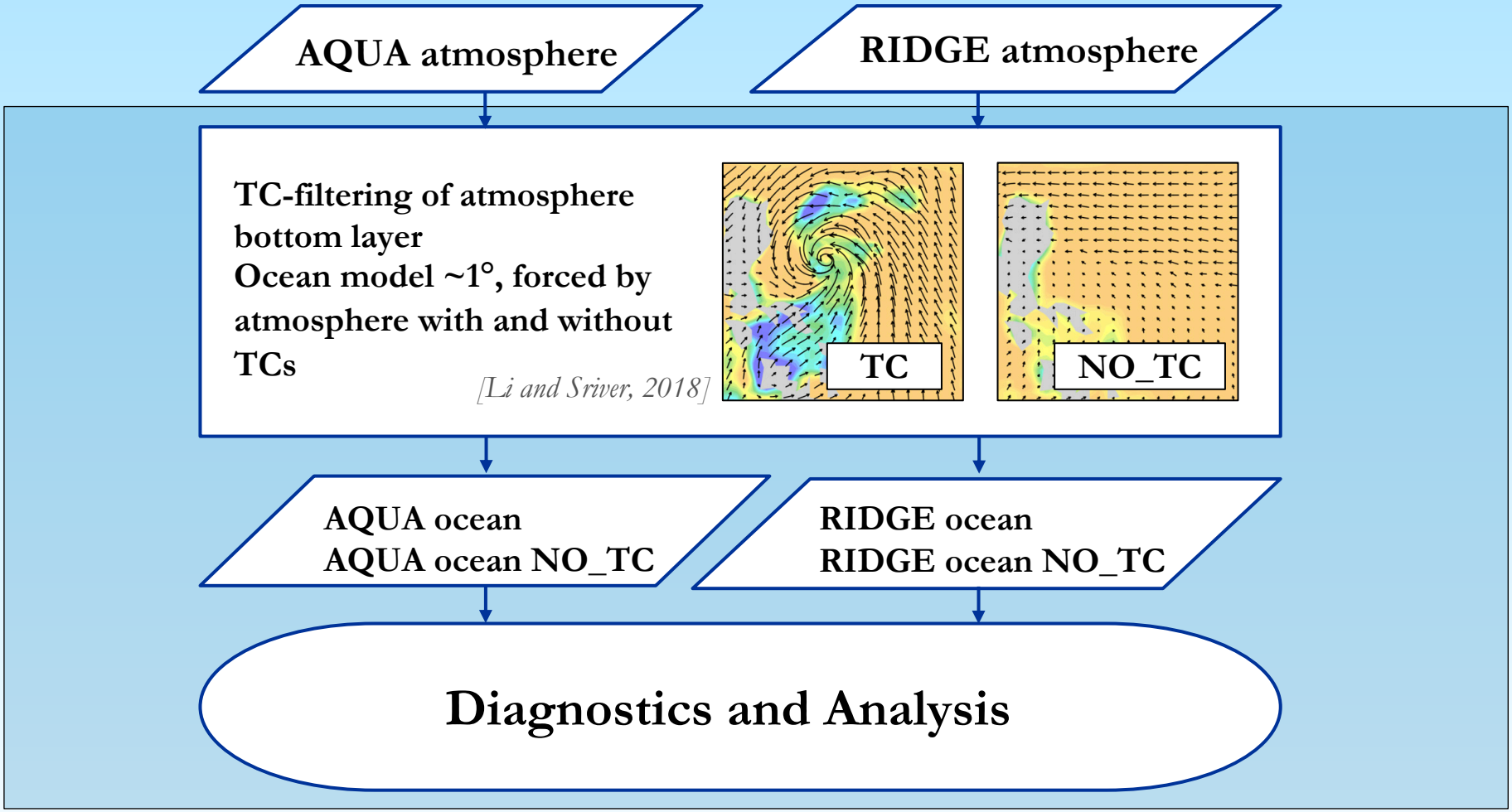
Experiment 1: Low-resolution coupled simulation



Experiment 2: High-resolution atmosphere-only simulation



Experiment 3: High-resolution ocean-only simulation



Computational highlights

Climate model development

- Bringing together idealized atmosphere and ocean
- Collaboration and community

High-performance computing

- Order of 1,000,000 core hours on supercomputer Cheyenne
- Innovation for potentially high-resolution coupling

Data analysis

- Output order of 10 TB
- Parallel processing for TC-tracking
- Interactive diagnostics and visualization in development

Timeline: 1.5 – 2 years

- Summer 2019: Low-res. coupled simulation
  - Fall 2019: High-res. atmosphere-only simulation
    - Fall-Winter 2019: High-res. ocean-only simulation
      - Spring 2020 and beyond:
        - Data analysis and interpretation
        - Additional experiment: High-res. coupled simulation
        - Presentations and publications

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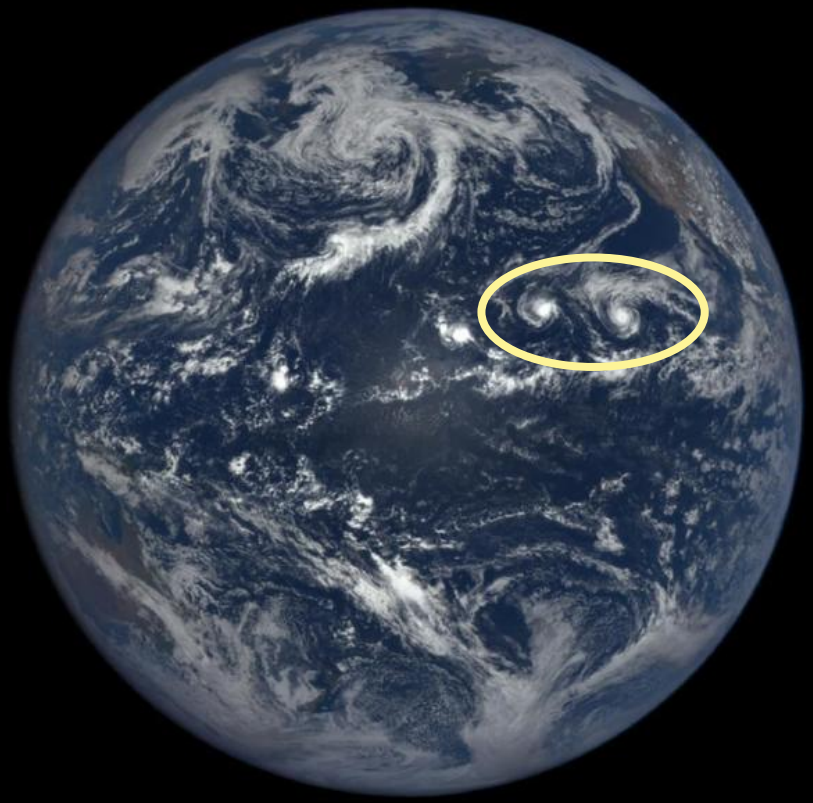
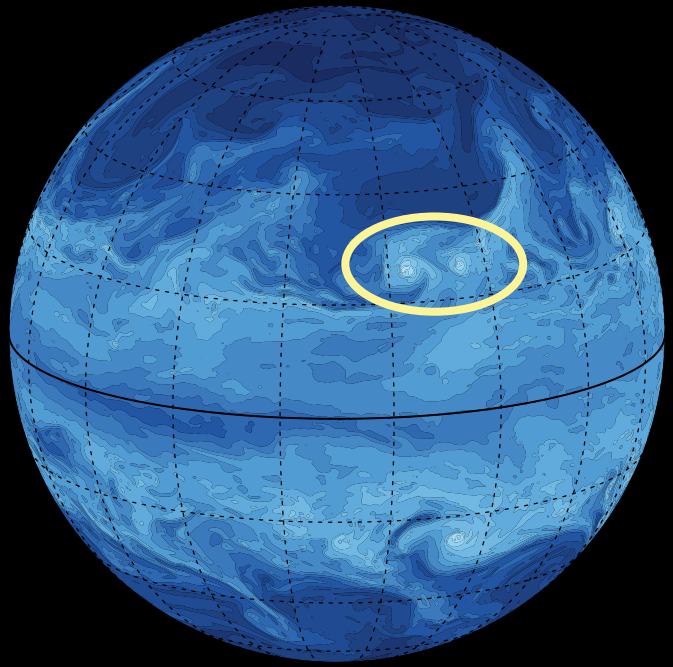
School *of* Marine and Atmospheric Sciences

Broader Impacts: Advancing Climate Science and Modeling

$1 investment in natural hazard mitigation = $11 in national benefit
[the National Institute of Building Sciences, 2019]





[Satellite image: NASA]