

Analyzing Tropical Cyclone-Climate Interactions Using the Community Earth System Model (CESM)

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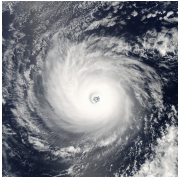
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Blue Waters Annual Symposium



BLUE WATERS
SUSTAINED PETASCALE COMPUTING





Why

- Tropical damage



Photo: Pool/Reuters

OCTOBER 3, 2005

www.time.com AOL Keyword: TIME

POLITICS OF CRONYISM ■ GENERATION JIHAD ■ NEIL YOUNG SINGS

TIME

ARE WE MAKING HURRICANES WORSE?

- THE IMPACT OF GLOBAL WARMING
- THE COST OF COASTAL DEVELOPMENT
- PLUS: CHARTING THE GULF COAST DESTRUCTION



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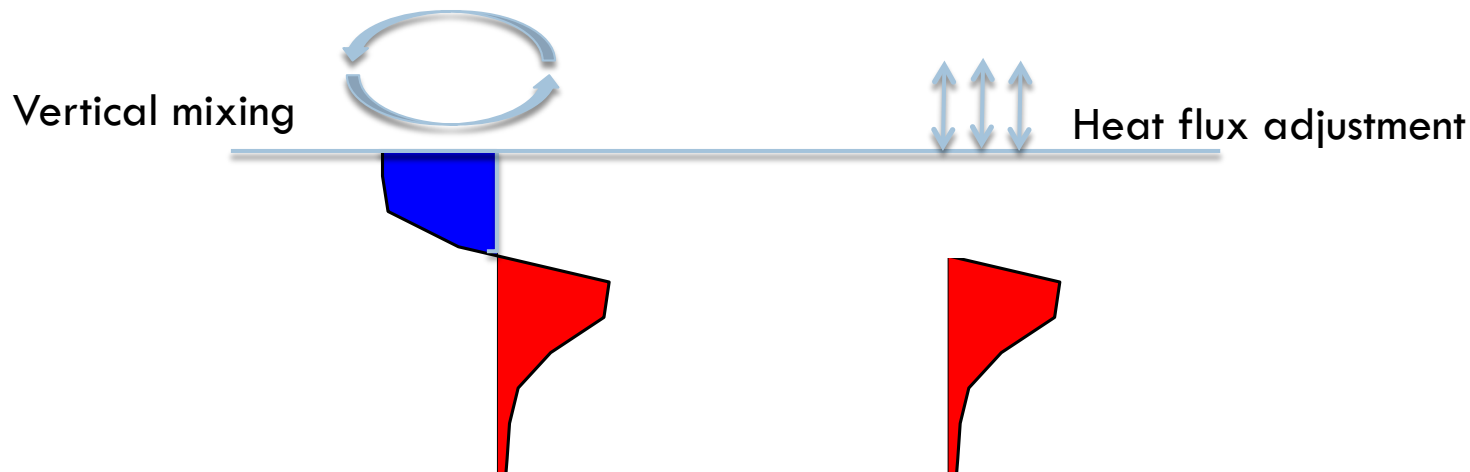
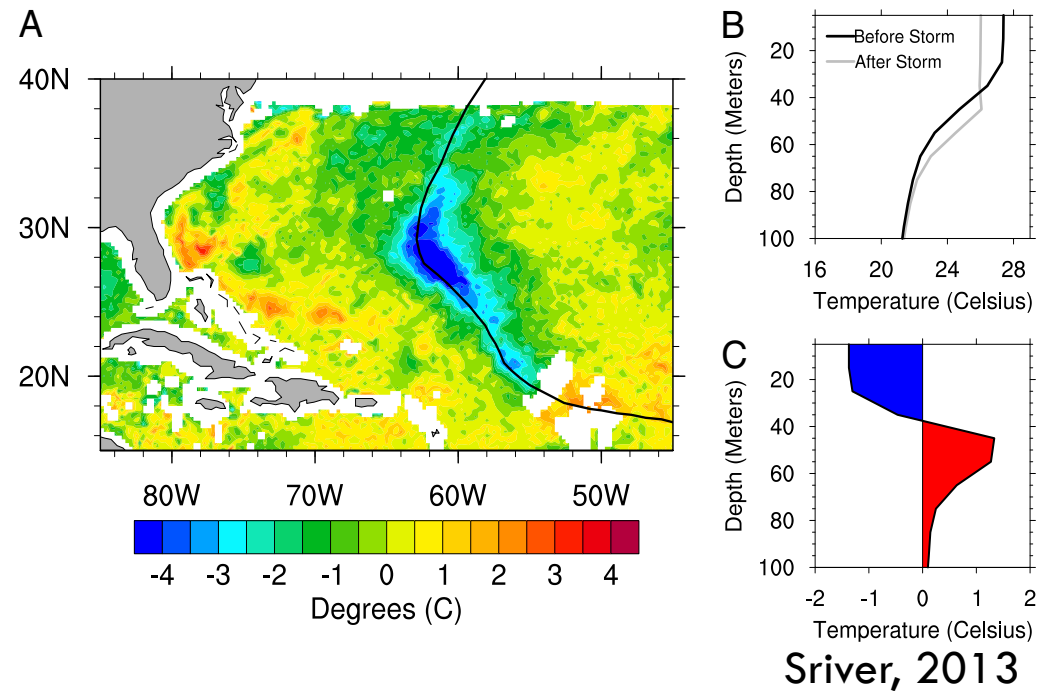


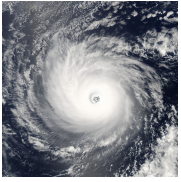
Photo: Mike Groll

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Why do we care: TC-Climate Interactions

- TCs play an active role in the climate system through enhanced ocean mixing associated with extreme TC winds.
- TC induces ocean vertical mixing
- Net heat gain in the ocean

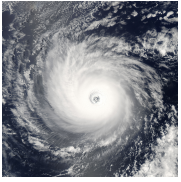




TC's Potential Impacts on Climate



- TCs have the potential to alter the **large scale circulation pattern** and heat **transports** in the coupled atmosphere-ocean system
 - ▣ Ocean heat budget [Emanuel, 2001; Srive and Huber, 2007]
 - ▣ Meridional ocean heat transport [Emanuel, 2001; Fedorov et al., 2010]
 - ▣ Atmosphere circulation pattern [e.g. Sriver and Huber, 2010]
 - ▣ Climate variability (e.g. El Nino) [Fedorov et al., 2010]
- Extreme **weather events** could potentially affect the large scale **climate**
- Understanding the TC-climate connection can advance our understanding about **climate dynamics and variability**
- TCs' contribution to the climate system may have important implications for **anthropogenic global warming through feedbacks** in the coupled system



Key Challenges



- TC-climate interactions are largely **unexplored** in current climate models.

High Resolution

to resolve small-scale features

Long simulation time

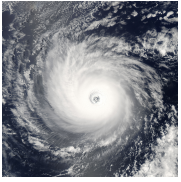
to construct TC climatology

Air-sea coupling

to correctly capture the interactions and feedbacks

WE NEED MORE POWER





Why Blue Waters

BLUE WATERS
SUSTAINED PETASCALE COMPUTING

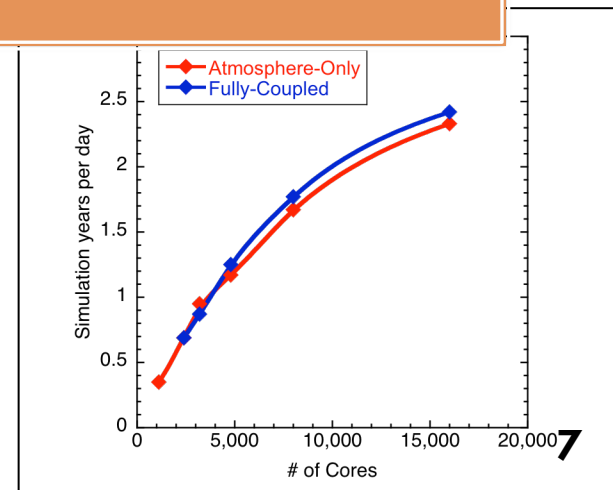


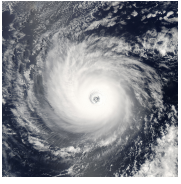
- We investigate the TC-climate connection using the state-of-the-art Earth system model -- Community Earth System Model (CESM). BW is

- Blue Waters provides a unique opportunity to analyze tropical cyclone-climate connections using a state-of-the-art, comprehensive Earth system model.

using 800-1000 nodes

- **Code testing and load balancing** through previous allocations have laid the groundwork for the new simulations.





Results from ocean-only simulations



- TCs have the potential to influence large scale climate dynamics and circulations

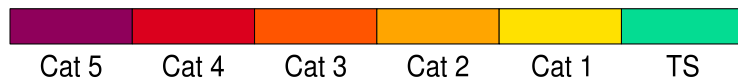
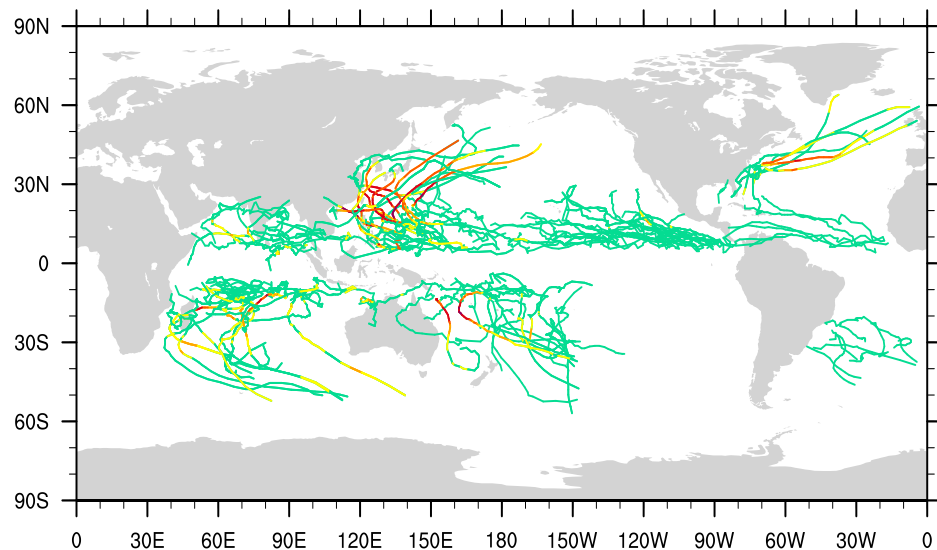


- Are these features captured by the current climate models?

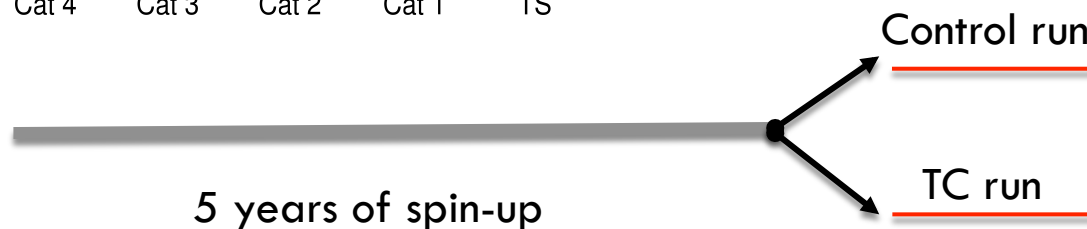


- What is the effect of the **ocean model resolution** on these processes?

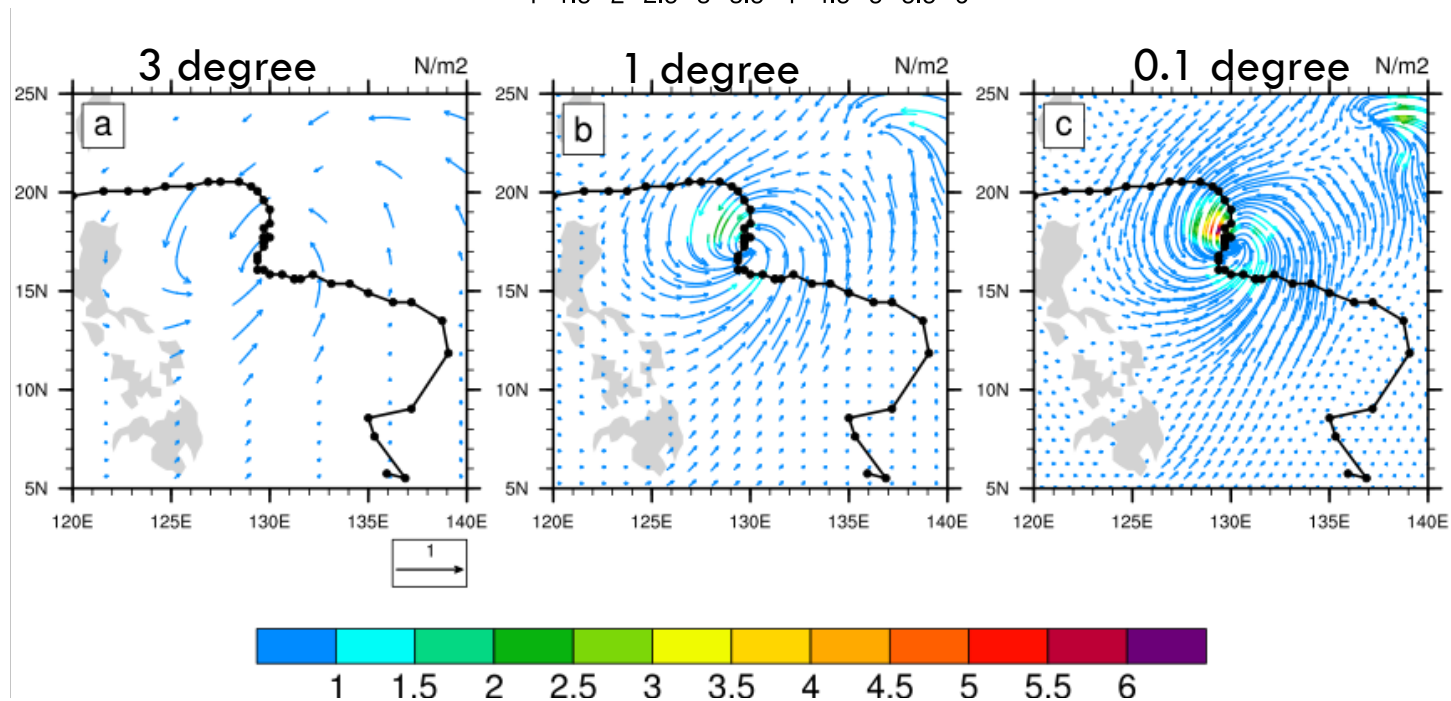
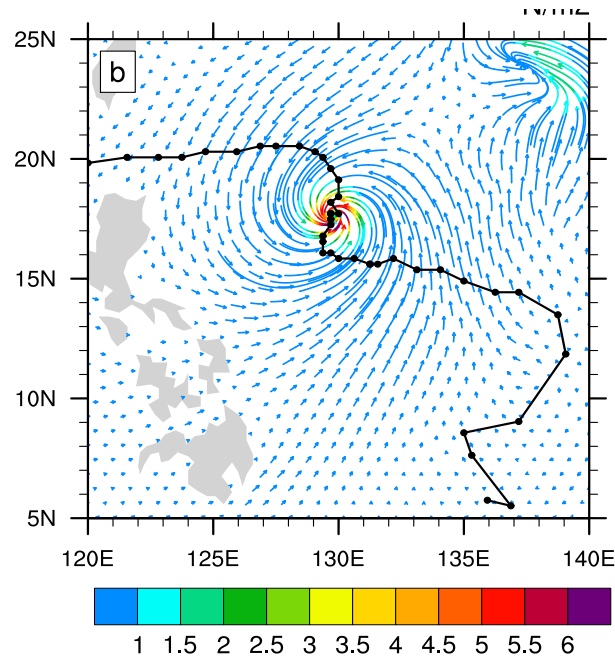
Use TC winds to force the ocean model



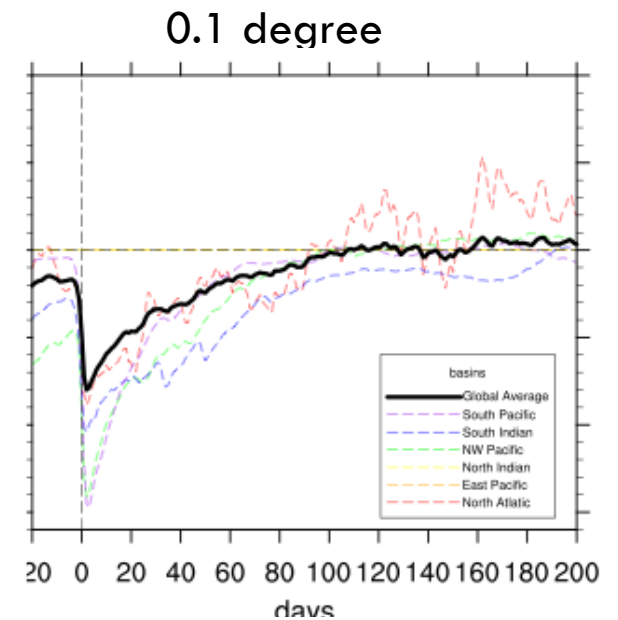
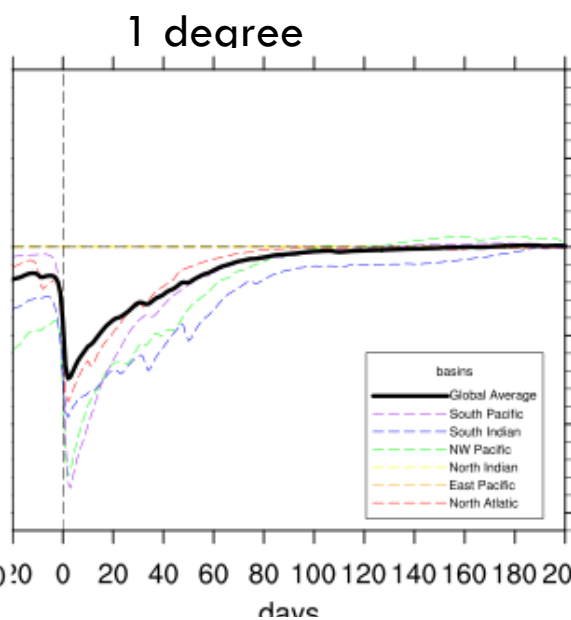
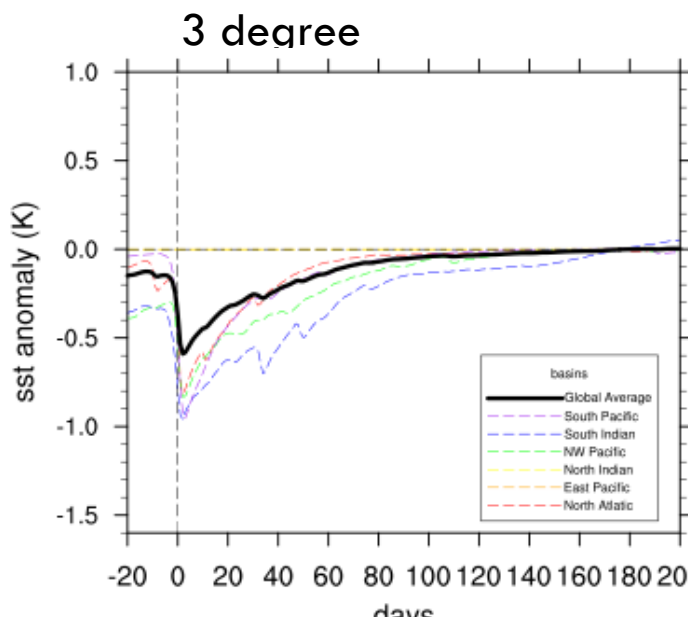
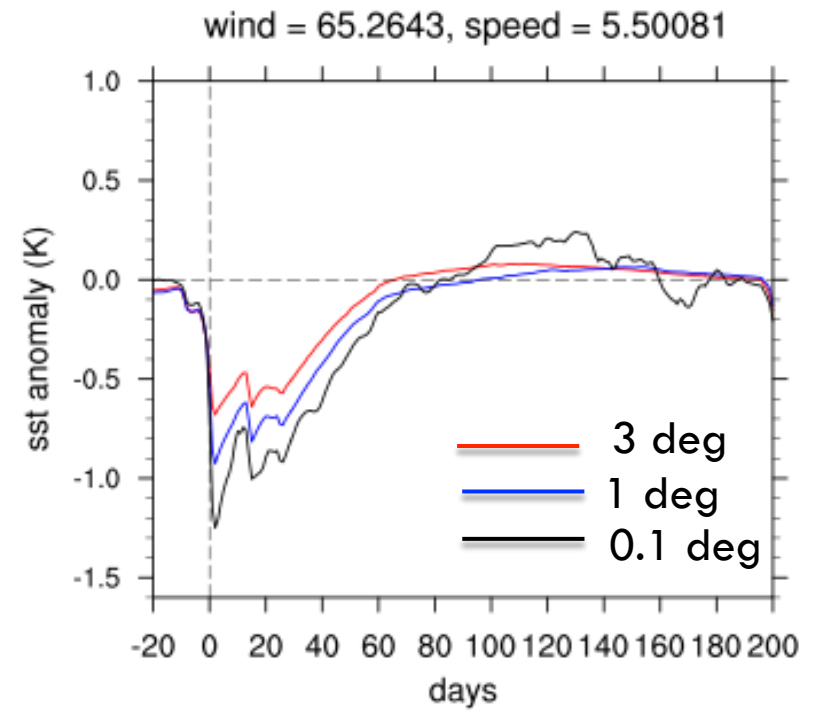
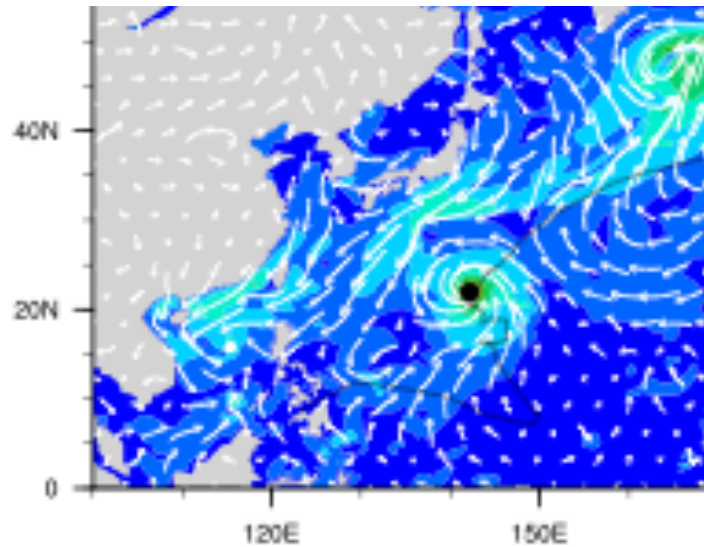
- Ocean model:
 - ▣ CESM POP2
 - Horizontal grid spacing:
 - 3 degree
 - 1 degree
 - 0.1 degree
- *P.S. 1° is about 110 km



How the ocean sees the TC

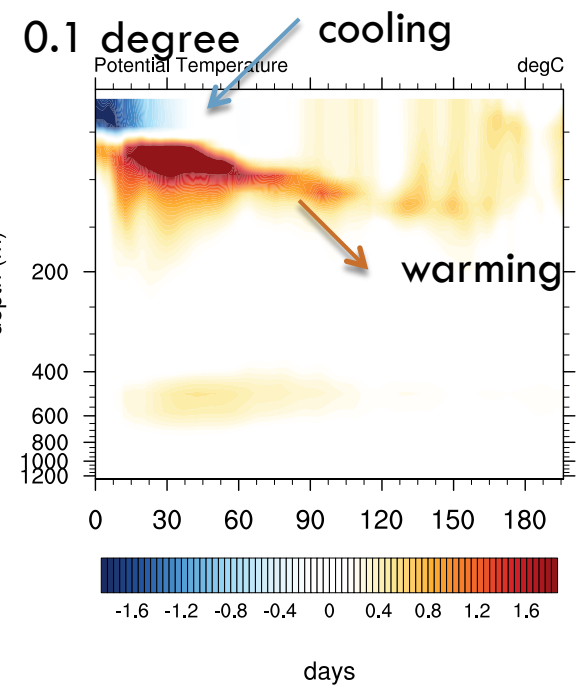
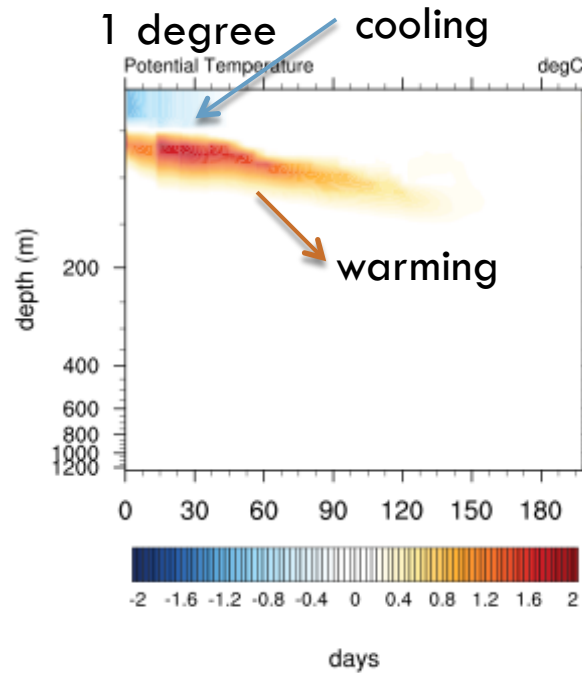
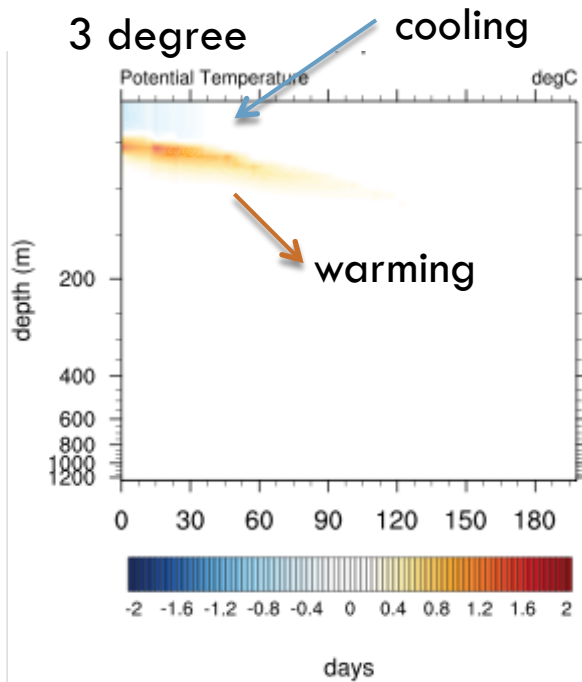
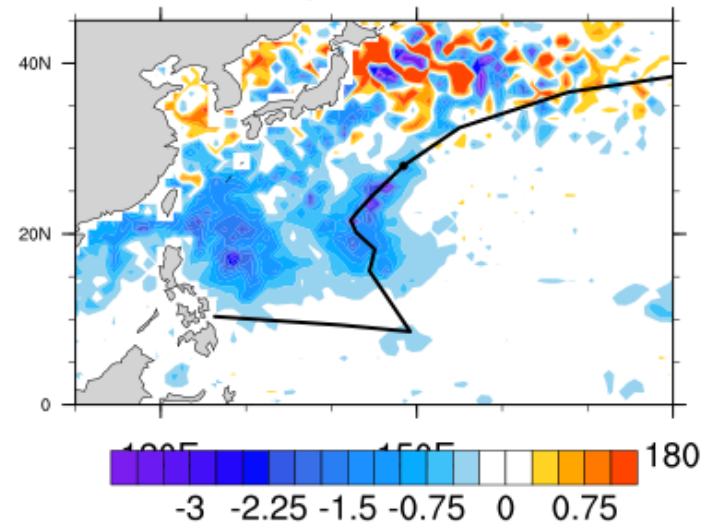


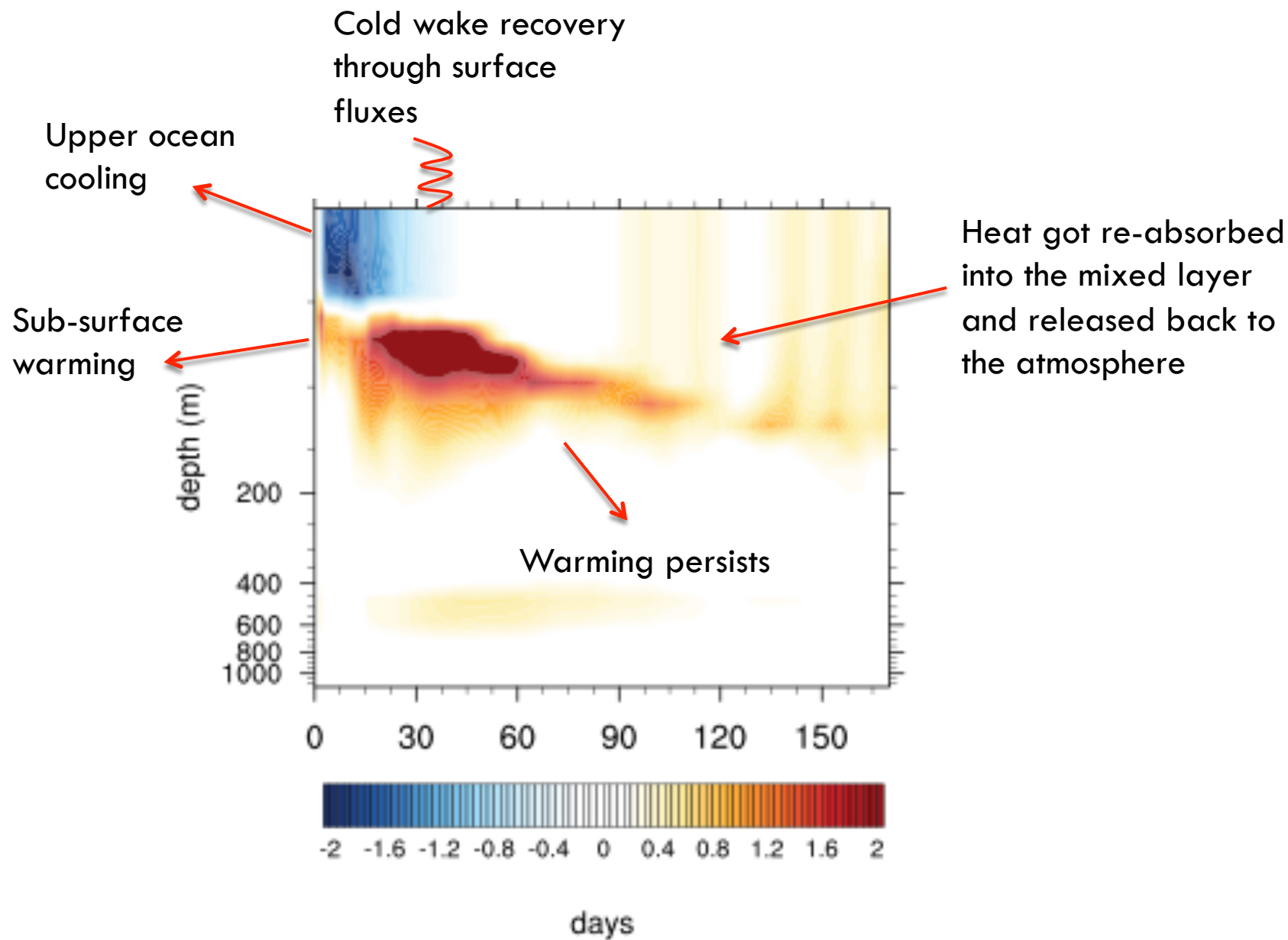
SST responses



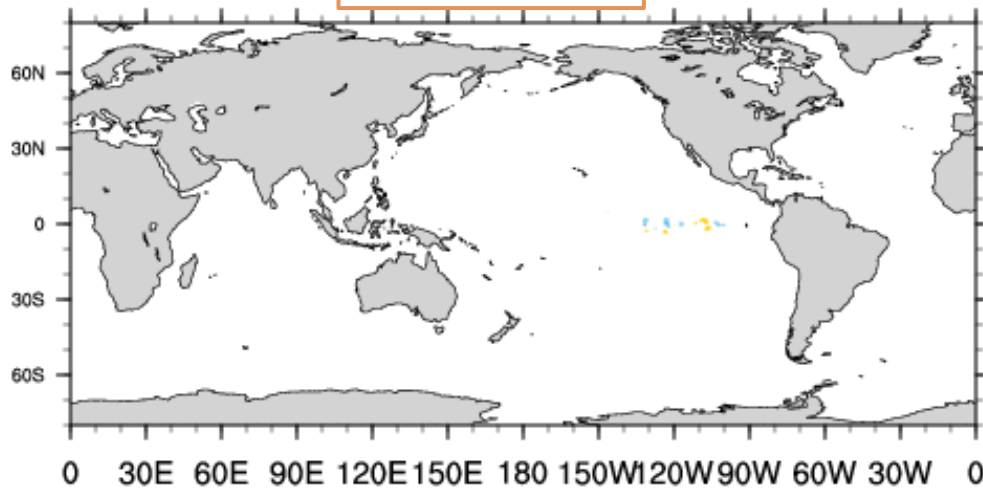
Ocean Sub-surface Responses

wind = 68.4427, speed = 8.09875 time = 287

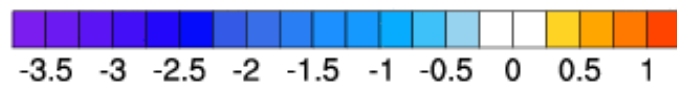
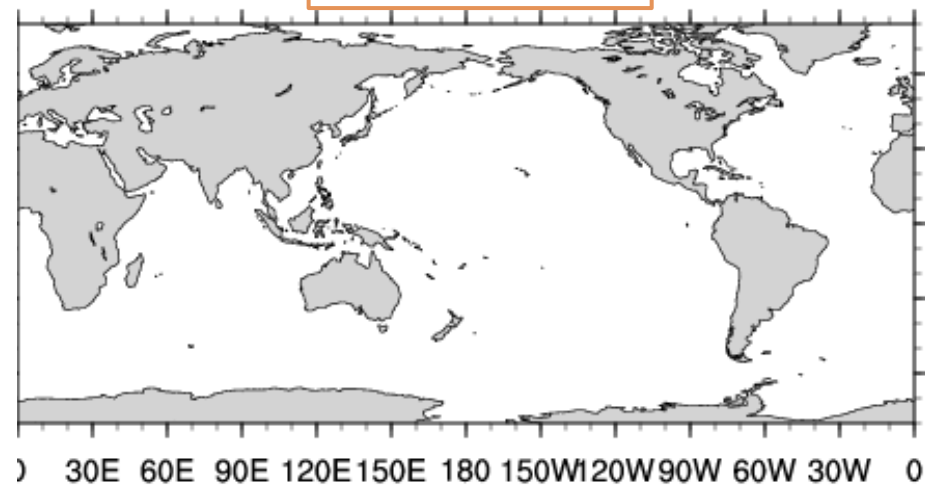




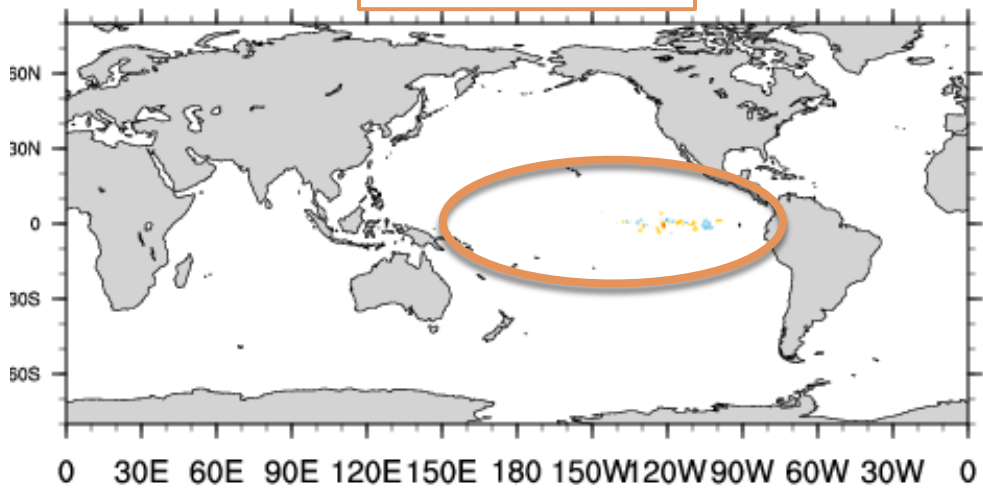
1 degree SST



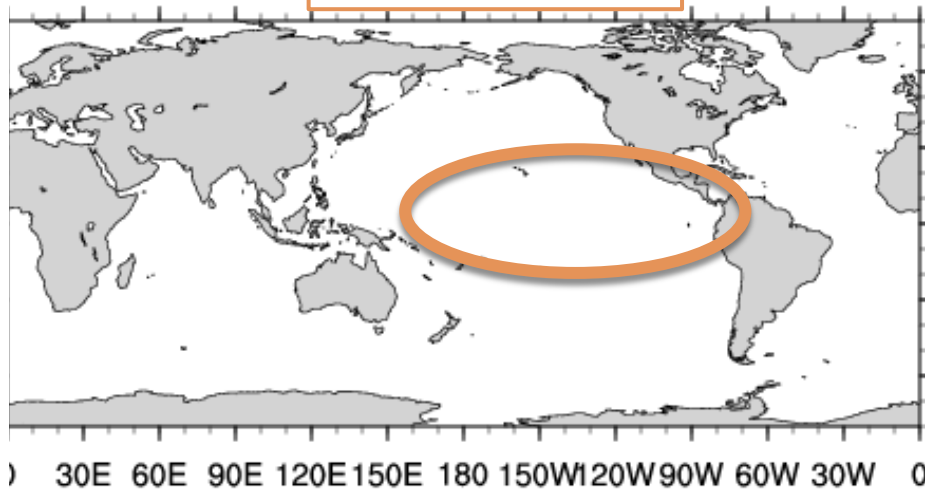
0.1 degree SST



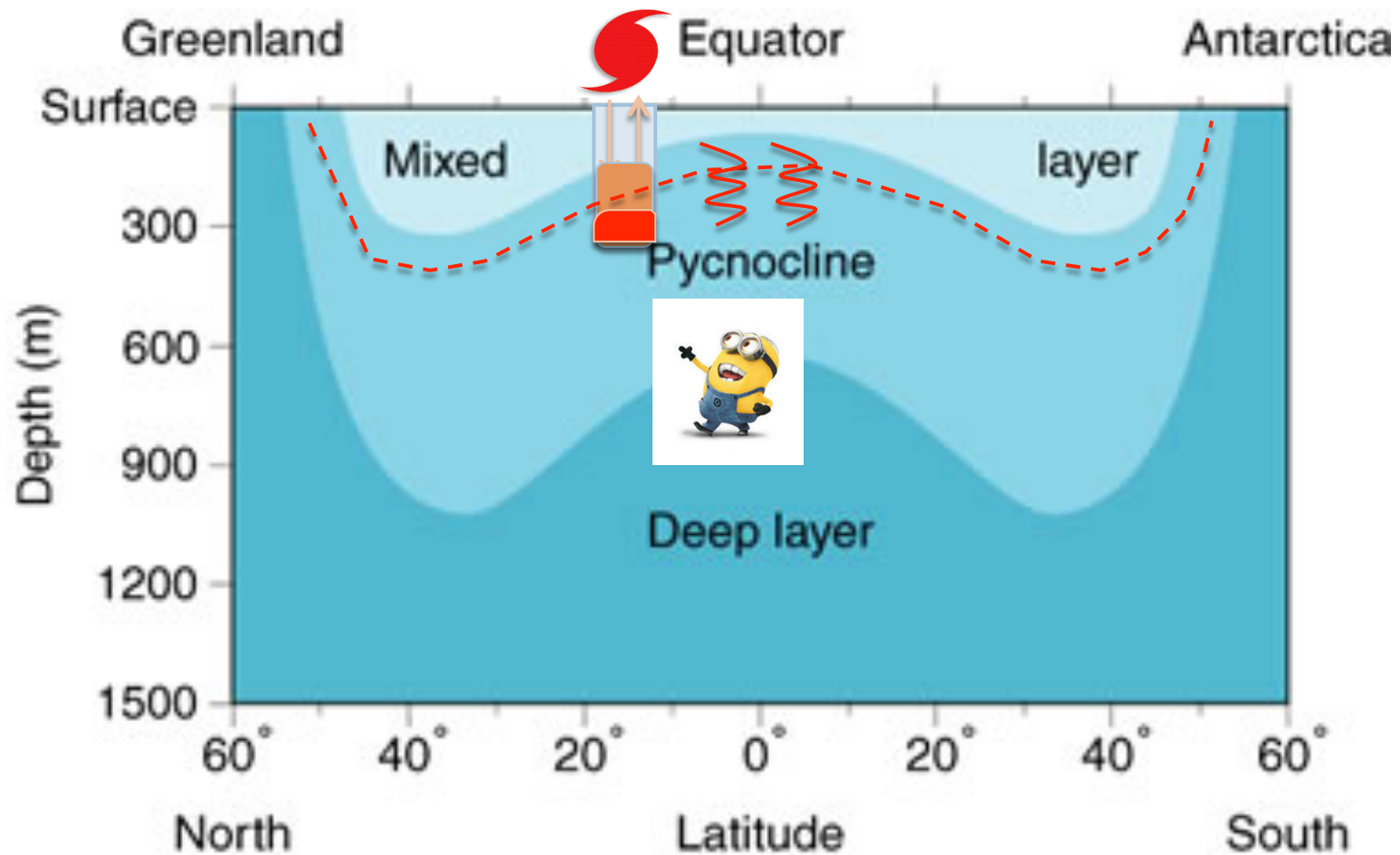
1 degree T100



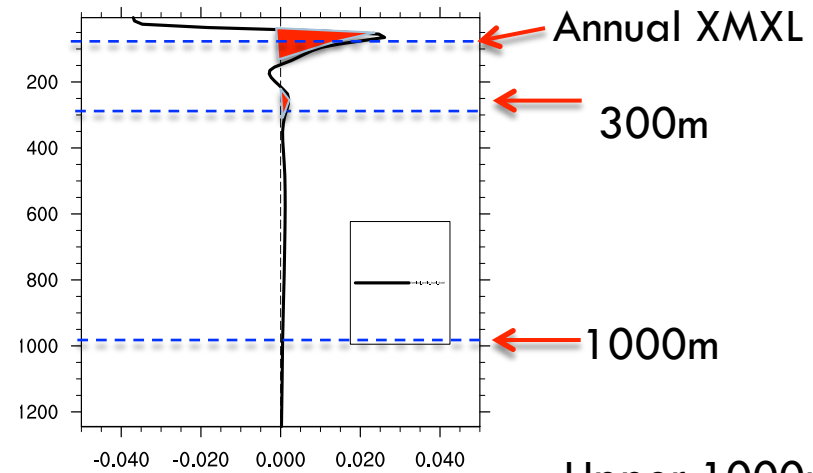
0.1 degree T100



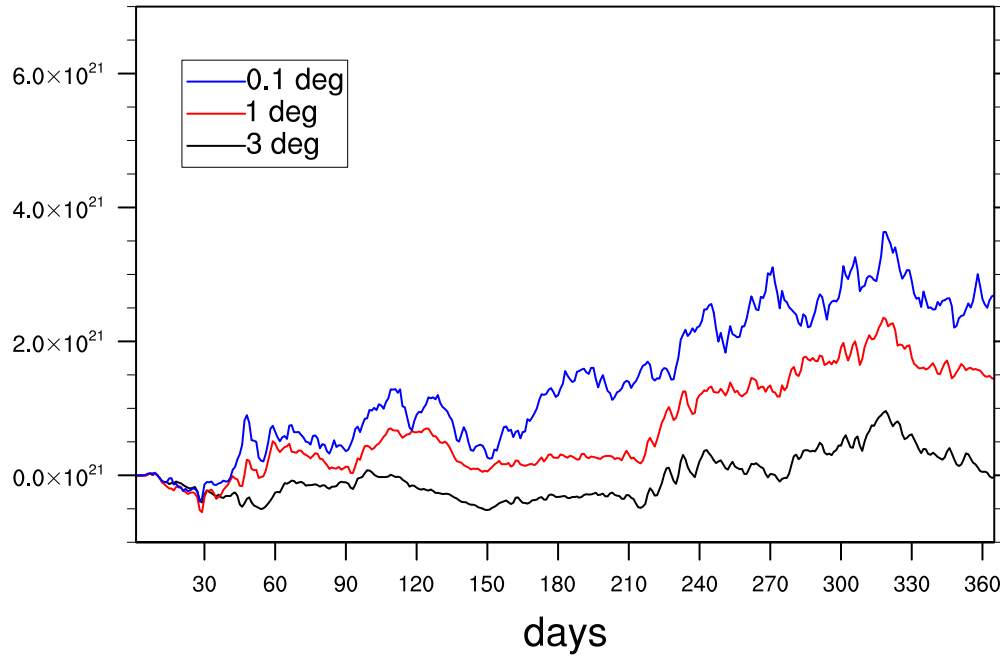
Ocean Heat Uptake



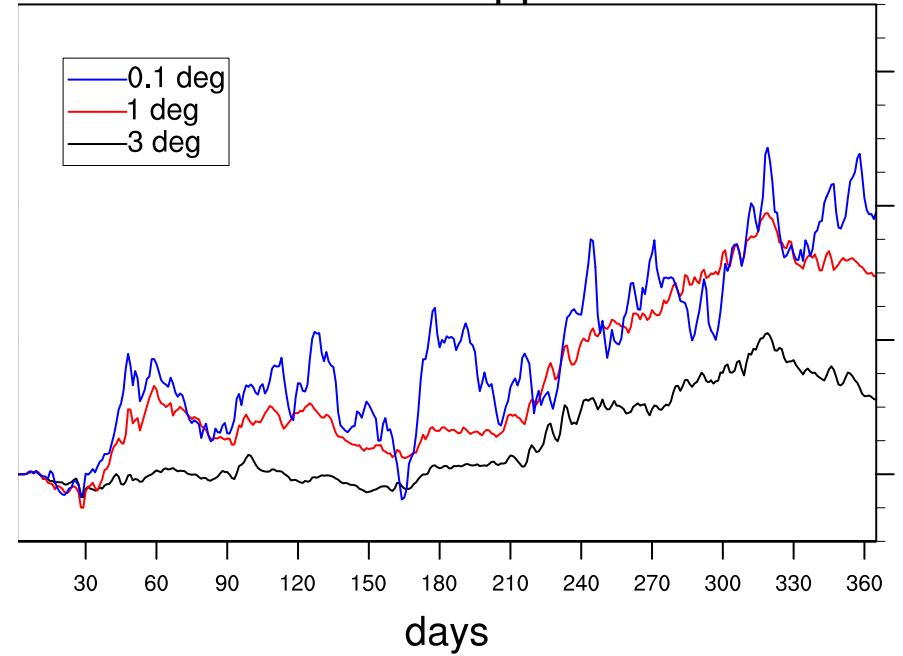
$$OHC = \iiint F \rho C \Delta T dh dW dL$$



Upper 300m

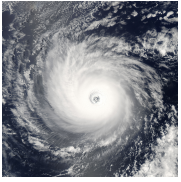


Upper 1000m



3 degree	1 degree	0.1 degree
0.1e+21 J	1.5e+21 J	2.5 e+21 J

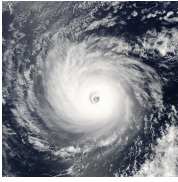
3 degree	1 degree	0.1 degree
1.1e+21 J	3e+21 J	4 e+21 J



Summary



- We examine the effect of ocean model resolution on TC-ocean interactions using an ocean general circulation model.
- The model simulates **key characteristics of transient ocean responses to TCs**, and these responses are sensitive to ocean grid resolution.
- Findings indicate that TCs **significantly contribute to global ocean heat budgets**, pointing to important connections between TCs and ocean dynamics.
- TCs have the potential to influence ocean diapycnal mixing budget, seasonal to interannual **climate variability** (such as ENSO), and **large-scale circulation patterns** in the atmosphere and ocean (such as Hadley Circulation and Meridional Overturning Circulation)



Ongoing and future work

- Decadal-scale high-resolution fully-coupled CESM simulation (with 0.25° atmosphere and 1° ocean) under present-day climate & future climate.
- This research will address the following fundamental science questions:
 - ▣ What is the **impact of tropical cyclones** on regional-to-global scale ocean and atmosphere **circulation patterns**?
 - ▣ Are there dynamical interactions between tropical cyclones and the ocean-atmosphere system that could affect global **climate variability and trends**?
- Results of this work will improve our understanding about the nature of atmosphere-ocean interactions within coupled models, which in turn will **improve predictability** of tropical cyclones, **reduce uncertainty** in climate change projections.

THANK YOU!!!



Why parameterizations for surface processes are important?

- ❑ Biases occur at high wind regimes.
- ❑ Appropriate parameterizations are necessary to reduce uncertainties in climate projections.

