Extratropical Hurricane Mixing and the Equatorial Cold Tongue

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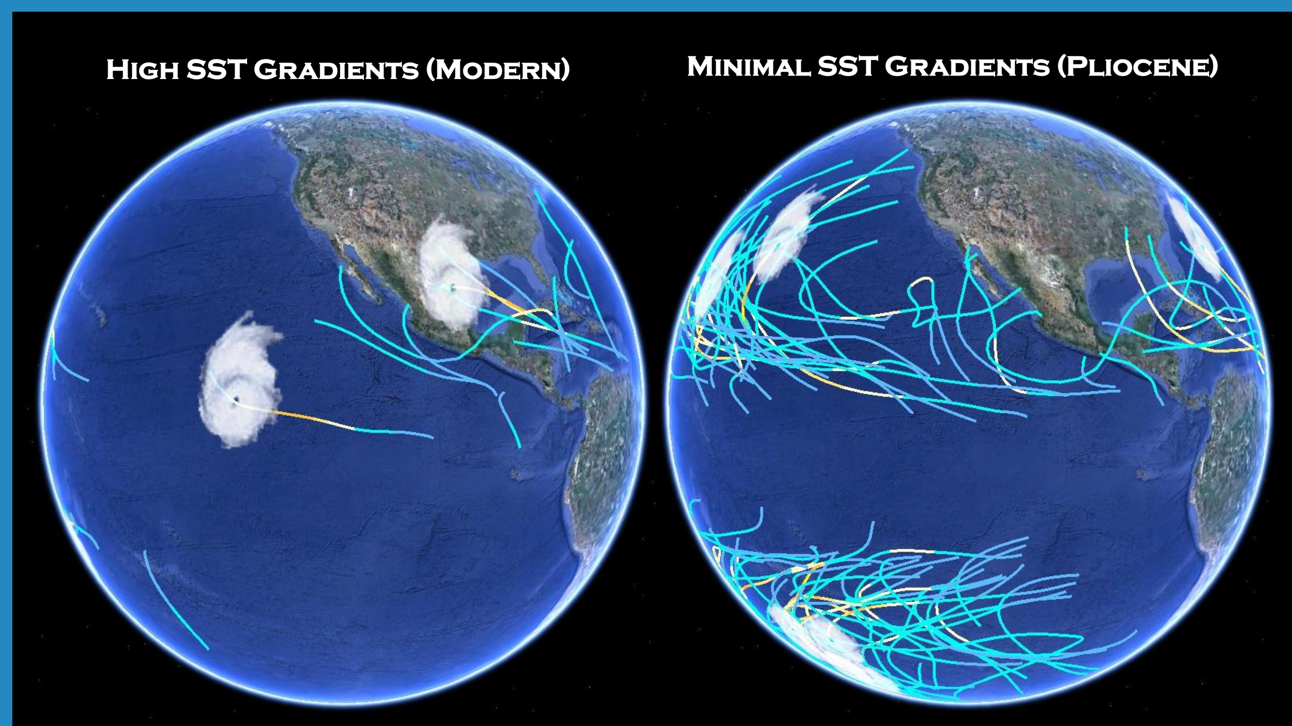
Introduction

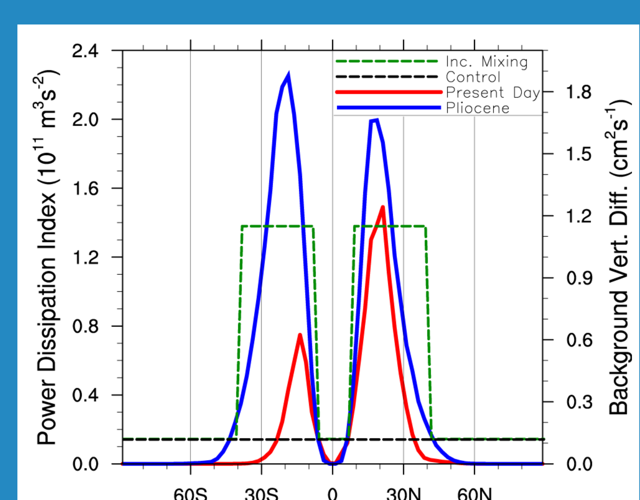


1: A sample year of simulated tropical cyclone tracks for conditions with various tropical gradients (Fedorov et al. 2010). *Both simulations are created using a statistical downscaling model (Emanuel et al. 2008) forced with atmosphere-only GCM simulations using modern SST observations and reconstructed early Pliocene SST (Brierley et al. 2009).*

The impact of tropical cyclones (TC) on global climate is still debated. They rapidly mix the water column beneath them, bringing cold water to the surface. One way to parameterise this process in a climate model is to introduce an additional vertical diffusivity term, that can either be constant (Jansen & Ferrari, 2009) or dependent on the atmospheric state (Korty et al., 2008). Past greenhouse climates suggest weak meridional and zonal temperature gradients in the Tropics (Brierley et al., 2009), and therefore altered tropical cyclone distributions (Fedorov, 2010). Could this have had climate consequences?

Method

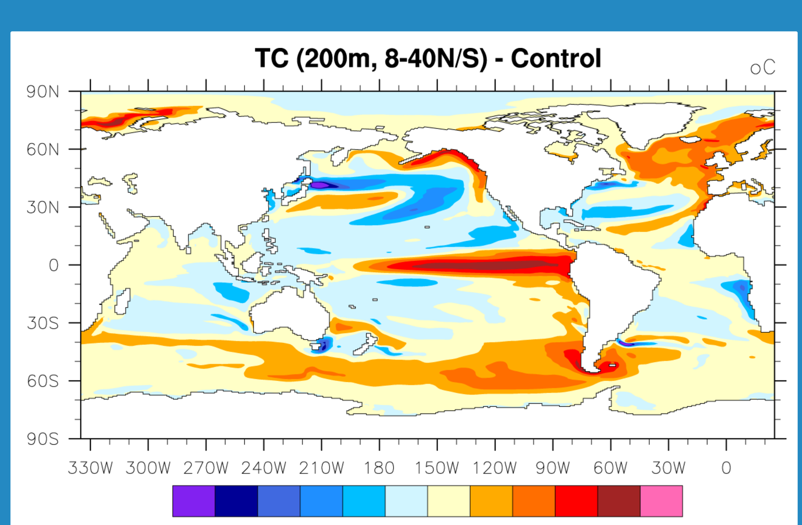
To determine the impact of a broad swath of TC mixing in the Pacific, we add increased ocean mixing to a coupled climate model (CCSM3). The background vertical diffusivity is increased tenfold to 1.1 cm^2s^{-1} (2). This additional mixing occurs in the top 200m and between 8º-40º N/S in all oceans (Fedorov et al., 2010).



2: Mixing related to tropical cyclones. *The zonally integrated, annual average power dissipation index (a measure of ocean mixing), as derived from the modeled climate, for the present day (red line) and the early Pliocene (blue line, Fedorov et al., 2010). The background vertical diffusivity in the two coupled model runs (dashed lines).*

Warming of the Cold Tongue

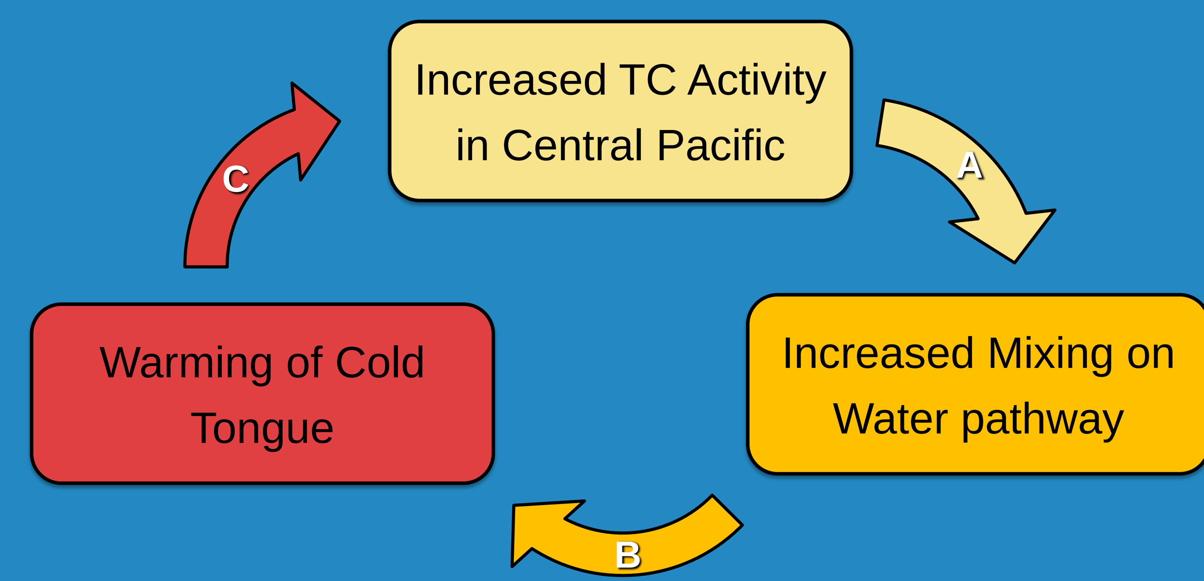
The additional TC mixing leads to a dramatic warming of the eastern equatorial Pacific (3), somewhat like a persistent El Niño-like state (Brierley et al. 2009).



3: Impact of TC Mixing on SST. *The difference between the simulation with two bands of additional vertical mixing and a control simulation. There is a warming at high latitudes and the eastern tropical Pacific, but cooling elsewhere.*

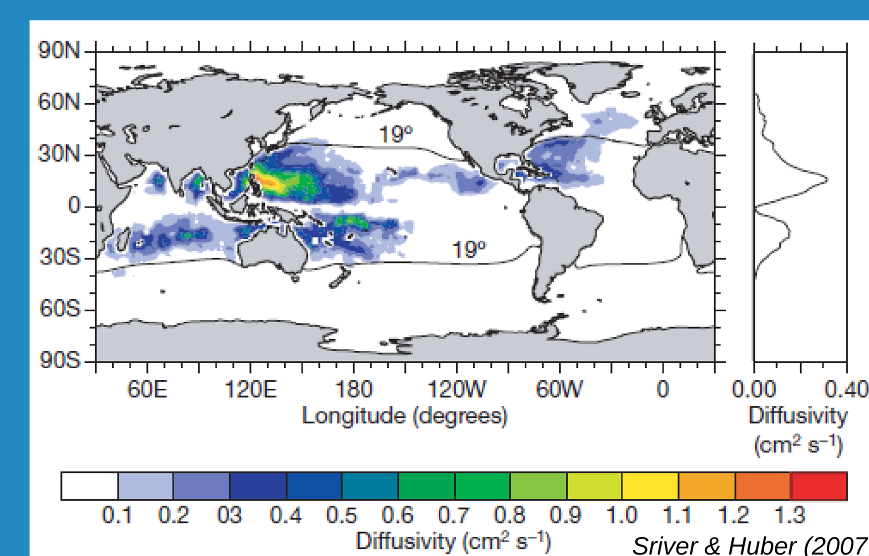
Hurricane - Climate Feedback

The addition of hurricane mixing leading to a warming of the cold tongue implies a positive feedback between tropical cyclones and the ocean. If the strength of the positive feedback is sufficiently large, then it may explain the persistent El Niño-like state seen in the early Pliocene, by allowing multiple climate states to exist in the tropical Pacific. The proposed feedback between hurricanes and the ocean circulation involves three processes, as shown below.

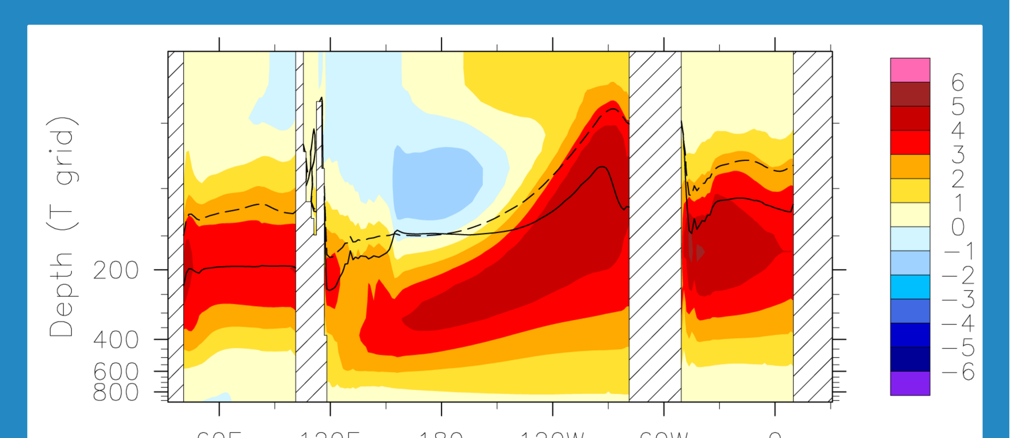


4: Schematic of a positive feedback between hurricanes and climate.

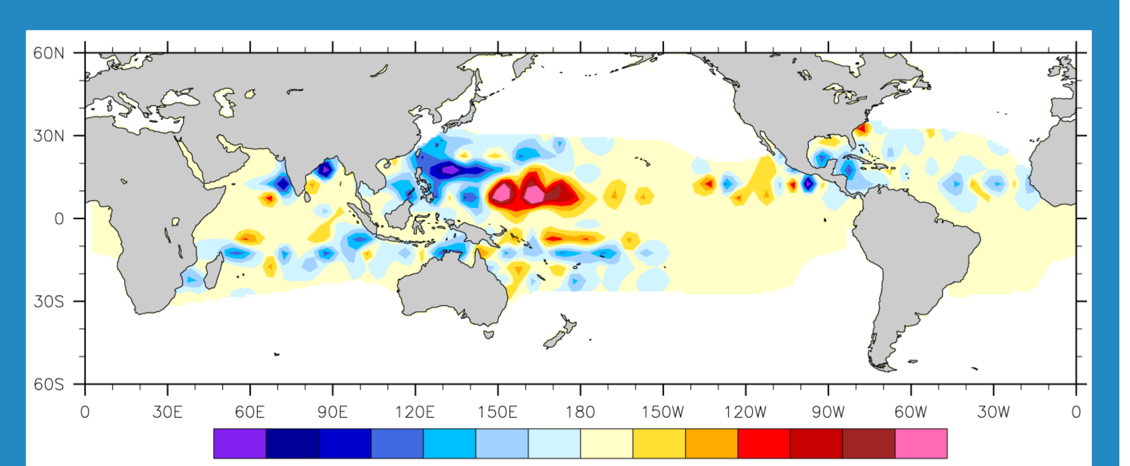
A: Tropical Cyclone Vertical Mixing in the Upper Ocean. *The very strong winds of hurricanes cause intense mixing, bringing colder water up to the surface. The strongest winds can mix the upper 200m. The mixing from individual storms can be compiled to create an annual mean climatology (Sriver & Huber, 2007).*



B: The Impact of Additional Mixing on the Equatorial Thermocline. *The potential temperature difference between the model simulations (averaged 5ºN-5ºS). The lines show the 20ºC isotherm in both runs.*



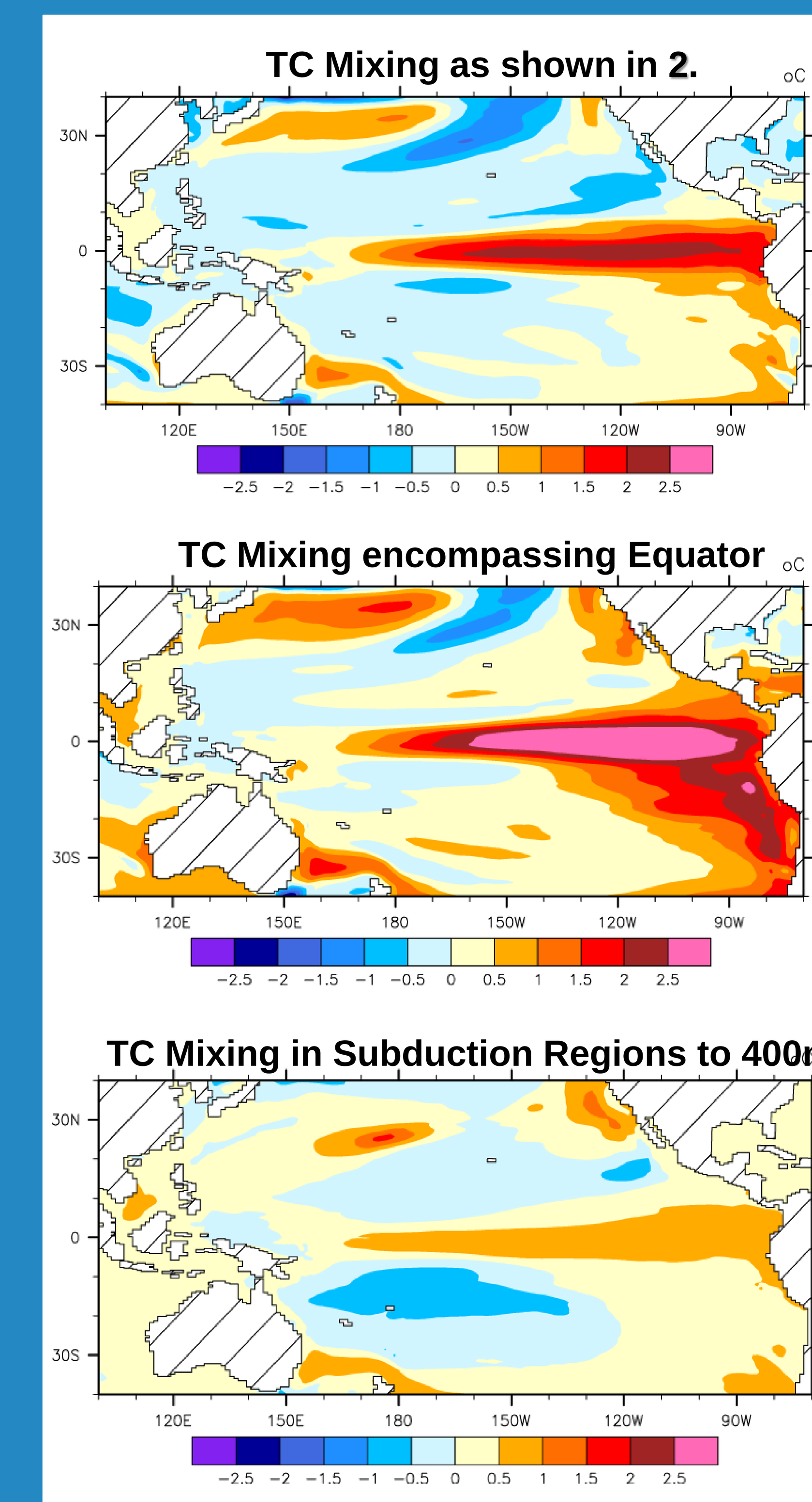
C: Effect of warm cold tongue on Hurricane Distribution. *A warming in the eastern tropical Pacific causes the main region of storm genesis to move eastwards. The panel shows the difference in tropical cyclogenesis (from 50 years of Best Track observations) between the 8 strongest El Niño years and the 8 strongest La Niña years (storms generated per 5º gridbox per year). A preference for central Pacific cyclogenesis correlates well with the warming of the cold tongue.*



Robustness of Feedback

The strength of the feedback depends on several uncertain parameters, such as the location of the tropical cyclones and the magnitude of their mixing and the crucially dependent on the of tropical cyclone mixing.

Sensitivity to cold tongue response to location increased mixing. Several climate model experiments have been performed with changes. Here we the warming of the east Tropical Pacific arising in three different cases. The upper panel shows the warming the case described previously: there is a warming of 2ºC. In the extreme case (middle), where there is no gap between the bands of hurricane mixing, there is a significant increase in amount of warming to over 3ºC. However, if the mixing is applied only to the subduction and down to the depth of 400m, then the response is only weak (lower panel).



The amount of mixing caused by individual hurricanes. This is still an active area of research, and it is still unclear how to progress from transient features to annual climate response. We have taken a simple approach to the issue here, but are performing a more comprehensive study into the issue, and hope to inspire other research in the area.

Conclusions

- Tropical Cyclones are a source of vertical mixing in the ocean
- This mixing can warm the cold tongue in the Pacific.
- We propose a feedback between tropical cyclones and the ocean that can sustain a warm tongue.
- The amount and nature of these changes in heat transport are strongly dependent on the location of the mixing.

References

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