#### **Chris Brierley**

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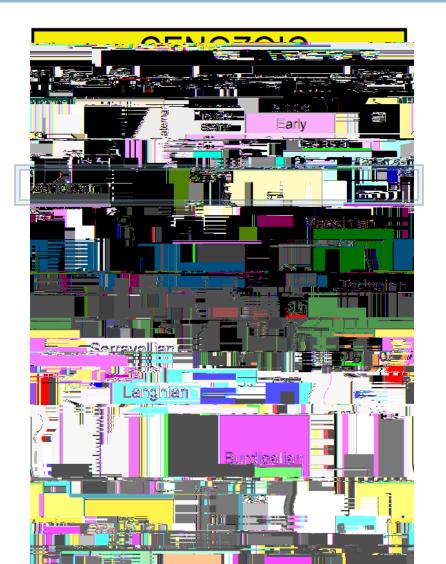


Introduction to the early Pliocene dimate When & why should we care? Tropical SST differences & comparisons to the future **Tropical Cydones** Future predictions uncertain Modeling Pliocene tropical cydones A tropical cydone feedback? The subtropical ocean circulation Warming of the cold tongue Does this feedback explain the Pliocene warmpool?

# When is the early Pliocene

Time period spanning 5.3~3.6 million years ago.

A relatively-short and recent period in the geological past. Deep time in view of most dimate scientists



#### Why care about the early Pliocene?

Natural global warming stabilization experiment Pliocene  $CO_2$  was 300 – 400 ppm Present-Day is roughly 390 ppm



# What else do we know about the early Pliocene?

Landmasses approximately same as today New Guinea and Halmahera moving North (c. 5Ma) Isthmus of Panama Closing (c. 5Ma)

- Ice Volume/Sea level
  - Sea Level roughly 25m higher
  - Reduced Greenland ice sheet
  - Reductions in Ice on Antarctica

Vegetation

- Forests on coast of Greenland
- Reduced amount of Tundra
- Sea Surface Temperature data

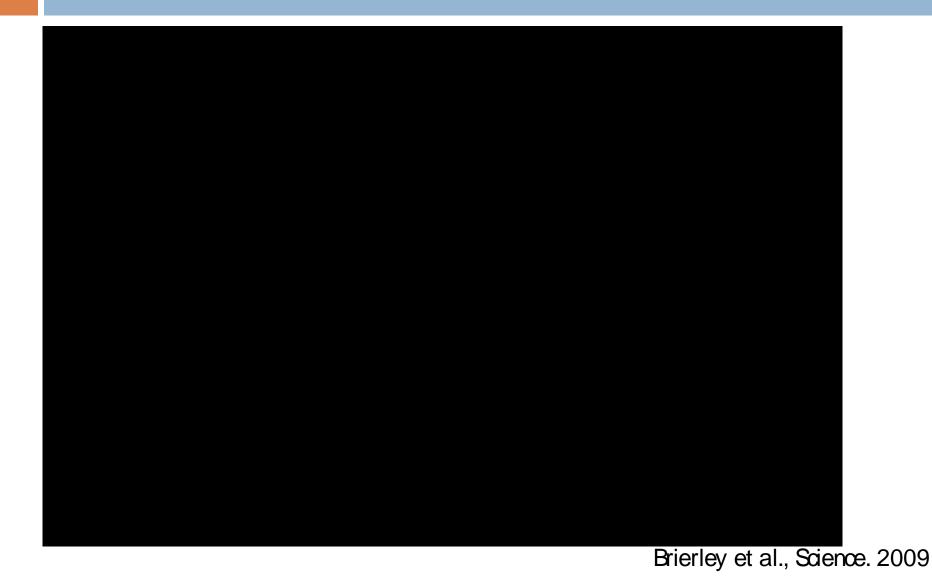


#### Waras Permanent El Niño



Wara et al., Science. 2005

### California Margin



#### A vast warmpool?

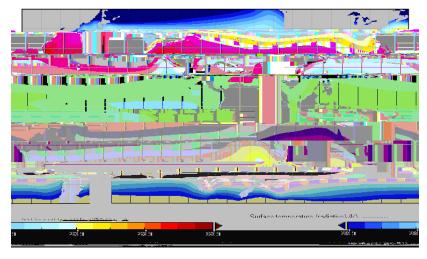


# Could this just be Global Warming?

#### Present Day with Pliocene Obs.

#### Simulation with Quadrupled CO<sub>2</sub>





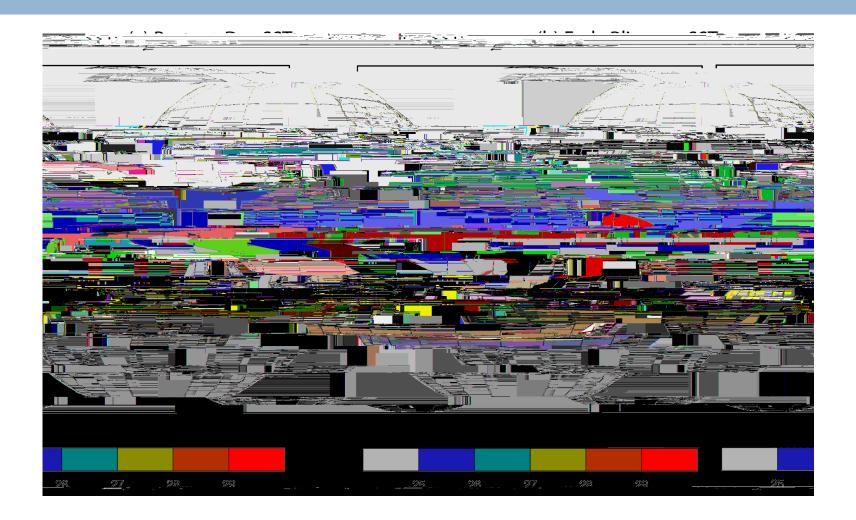
#### Climate impacts of Vast Warmpool

Use atmosphere model to simulate response to SST pattern

#### AGCM requires more than 3 SSTs

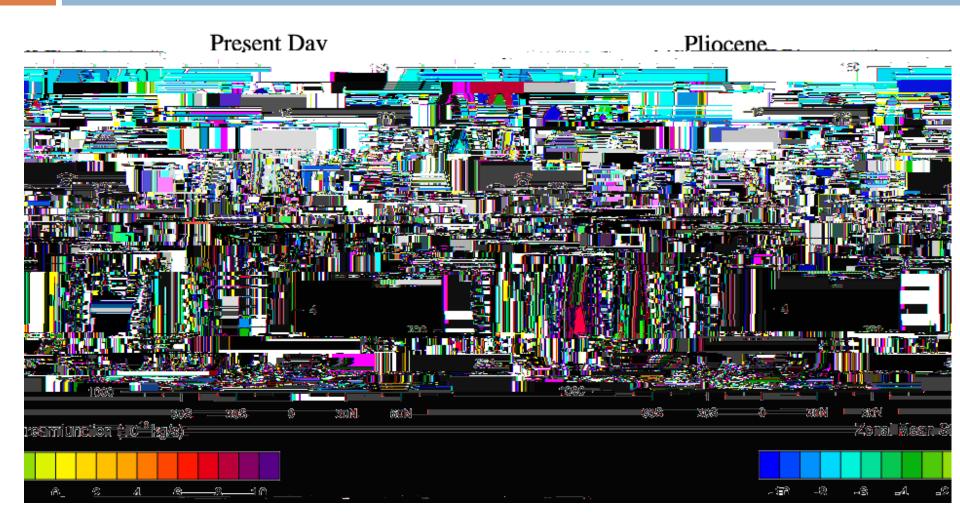
Compile PaleoSST observations to get SST profile

### Expansion of Warmpool



#### Walker Circulation Collapses

### Hadley Circulation Weakens

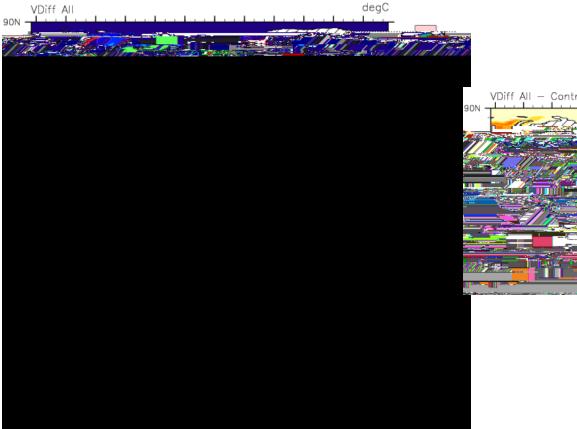


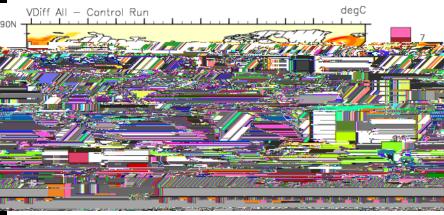
Brierley et al., Science. 2009

# Coupled Modeling of Pliocene

#### Sea Surface Temperature (10x, ctl)

#### Difference



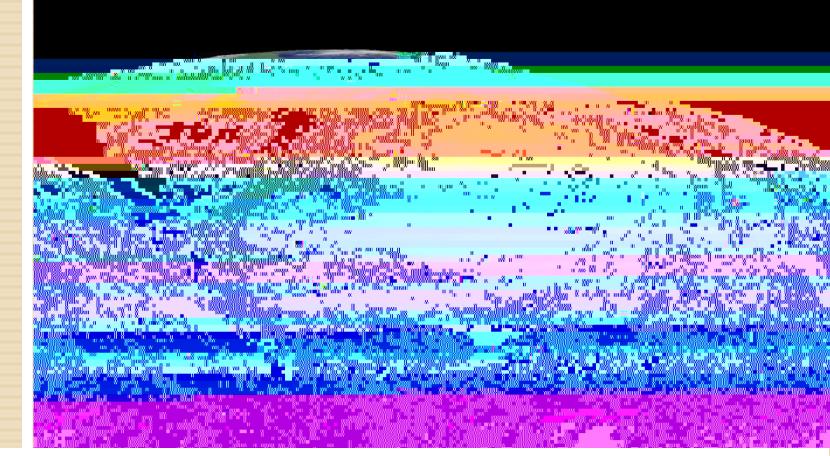


# Early Pliocene Summary

Early Pliocene boundary conditions similar to anthropocene.

Observations of tropical dimate differ from projections, with a vast warmpool across the Pacific Suggish atmospheric circulation.

Models do not simulate vast warmpool, yet the dimate state appears to have existed for ~1Ma Additional mixing may help sustain a Pliocene state

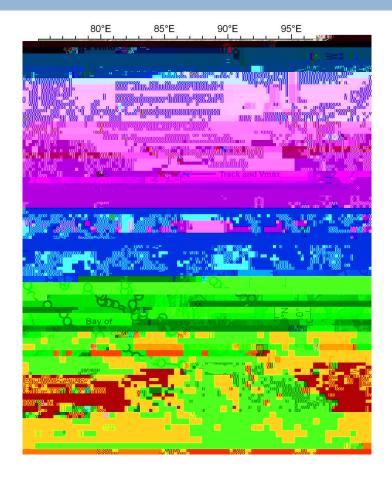


#### **Tropical Cydones**

What would the tropical cyclone distribution have looked like in the Early Pliocene?

# **Tropical Cydone Basics**

Some of most deadly natural disasters Roughly 90 storms occur every year. Strong winds on scales smaller than GCMs Feed on energy extracted from the oœan



Fatalities from the 7 major cyclone events (> 10,000 deaths) from 1584 up to Cyclone Nargis compiled from the Emergency Events Database (EM-DAT) and other sources with storm track and wind speed compared against 2004 Indian Ocean tsunami deaths. Additional cyclone track: 2006 Cyclone Mala with 22 deaths in Myanmar. *Fritz et al. Nature Geosci. (2009)* 

# Future behavior of tropical cydones

Known to be controlled by SSTs and vertical wind shear among other things

Future behavior still uncertain as residual between SST and wind shear increases (at least over N. Atl.) IPCC AR4 says

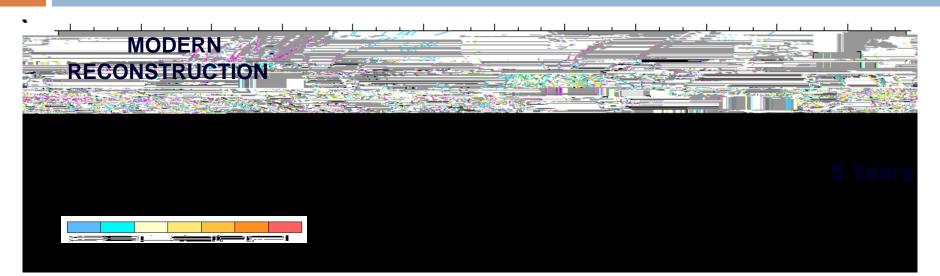
>66% chance increase in peak wind and rain intensity
~50% chance decrease in frequency, with regional variations

Pliocene was both warmer with weaker wind shear

# Statistical Downscaling Model

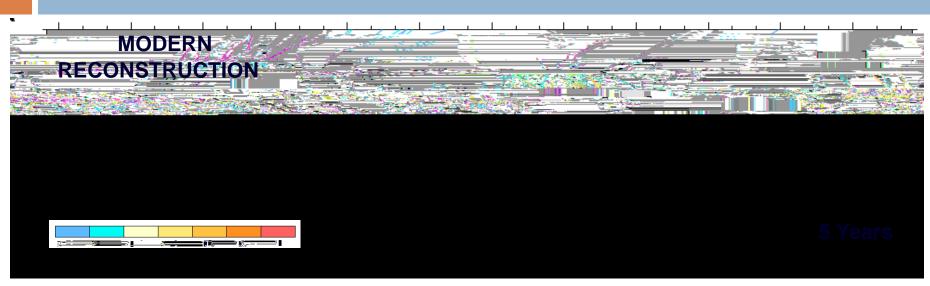
- Create realization of large scale atmospheric flow Embed weak vortex and use hurricane track prediction model to work out where it would go Use 2D CHIPS model to determine intensity along track
- Repeat until have at least 10,000 synthetic tropical cydones.

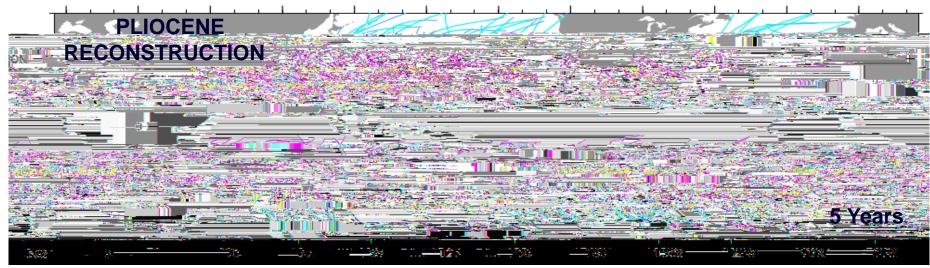
### Synthetic Tracks for Present-day





#### Synthetic Tracks for Pliocene

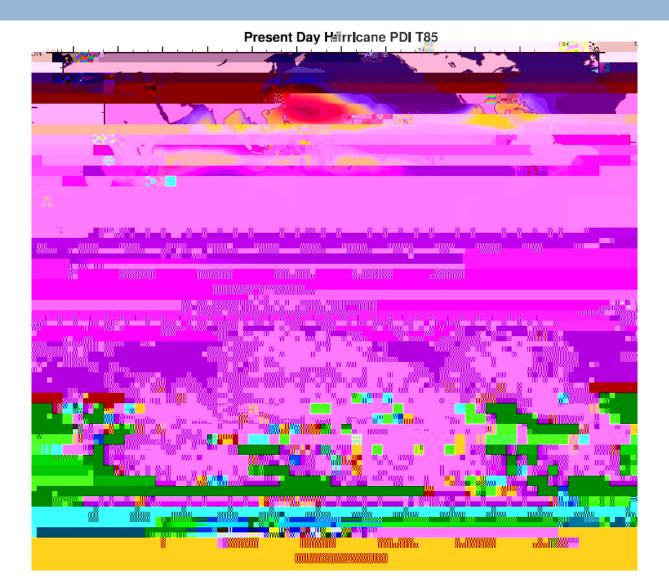




#### **Power Dissipation Index**

Defined by Emanuel (2005) as

#### **PDI** Patterns



#### A dimate feedback

Could the changes in the tropical cyclone in the Pliocene have provided a feedback to keep the dimate in an alternative, warm state?

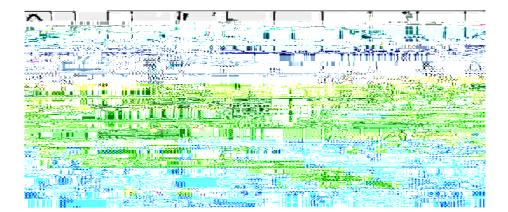
# Trajectories within Subtropical Cell

Water is subducted in subtropical East Pacific

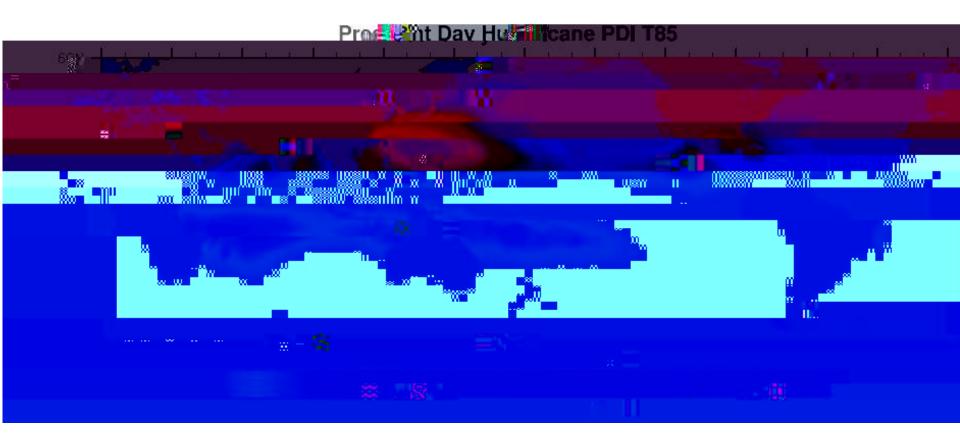
Travels west towards warm pool

Catches EUC and upwells in cold tongue

From Gu & Philander "97

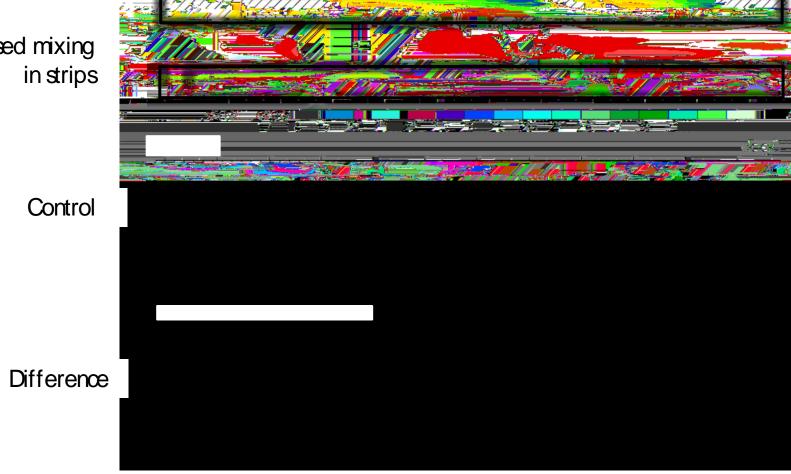


### Present-Day Subduction Pathways



# Including "tropical cyclone" mixing

Increased mixing

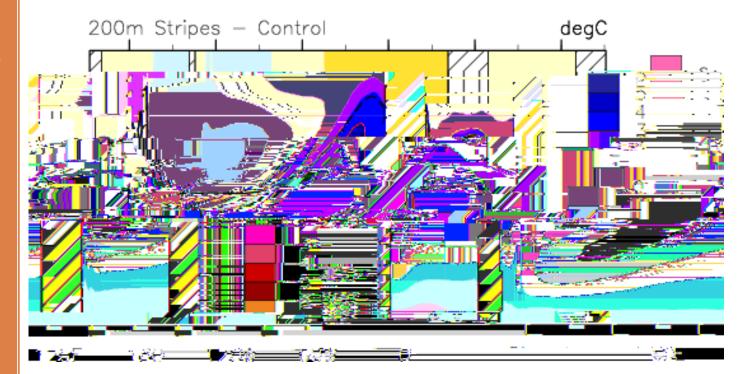


### Impact on the thermodine

Warming of subsurface eq. ocean.

Deepening of thermodine.

Suppresion of interannual variability.



Solid line: 20°C isotherm in mixing run Dashed line: 20°C isotherm in control run

### Impact of E Niño on Cydones

Average change in PDI (in  $10^8 \text{ m}^3\text{s}^1$ ) between an  $\blacksquare$  Niño y(n39(r)8(ain)-2d)8(a neuet)4(er)6(ln)/(y(n39(r)65(, )8(cha

# E Eq. Pac. Warming on Cydones

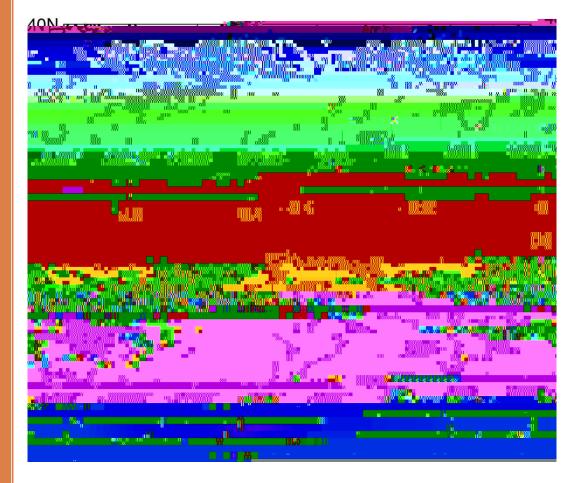
Warming of the cold tongue leads to:

Formation of more storms in central and eastern Pacific

More storms passing over subtropical overturning cell

∃ Nino (~1yr) is much shorter than STC
(~20yrs) so not expect impact on ⊞

Permanent change may feedback on EEP



# Tropical Cydone Feedback





This feedback should exist in theory Need a magnitude to determine if important in practice

### Condusions

The Tropical Pacific had a different SST distribution in the early Pliocene than at Present.

One vast warmpool stretching from Indonesia towards California

This vast warmpool created a sluggish atmospheric dirculation.

Sustaining the warmpool needs an additional physical process included in dimate models Tropical cyclone feedbacks could be that process This feedback could be important in future projections