Sensitivity of Tropical Climate Variability in CESM1 to Uncertainty in Climate Forcings of the Late Pliocene

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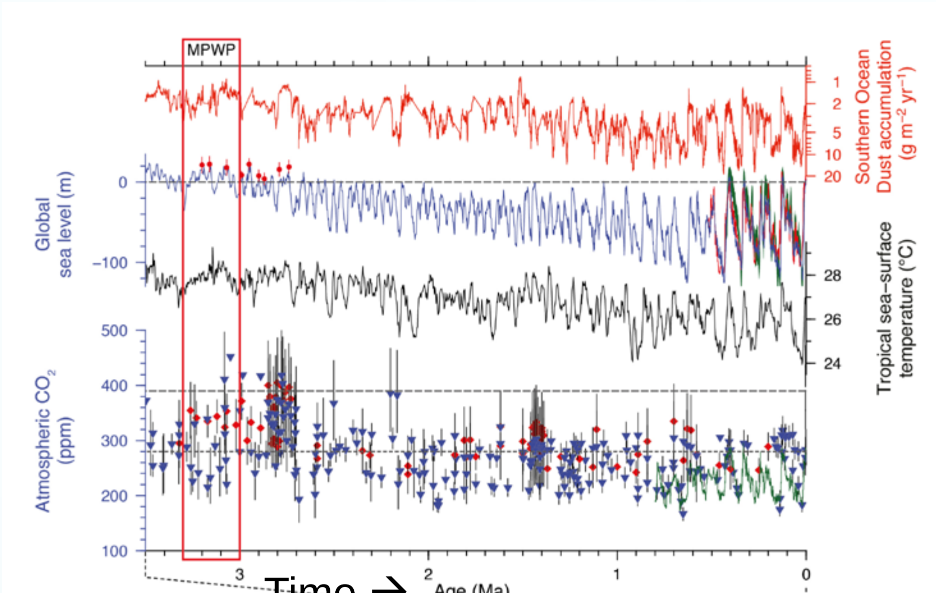
Late-Pliocene (~3.3-3.0 Million Years Ago)



A paleo-analogue for future Climate Change?

- Global MAT ~2-3^{o}C warmer than Preindustrial
- Mean sea level up +20m(+/- 10m)
- Reductions in Ice sheet volume and extents
- CO_2 levels moderately high (vs. Preindustrial)
  - ~365-415ppmv (Pagani et al. 2010)
- Continental configuration close to Modern

(~Fig. from Ch. 5, IPCC AR5 WG1)

How does ENSO respond to Pliocene Climate Forcing?

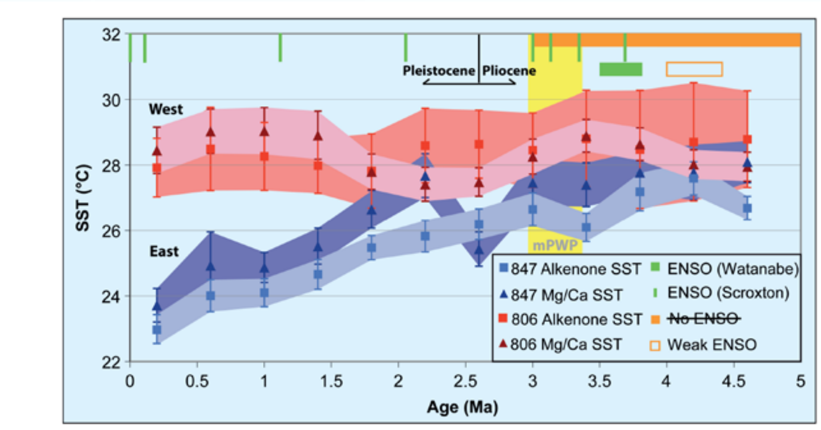


Figure 1: Variation in the Sea Surface Temperature in the Equatorial Pacific over the past five million years. The estimates come from two ocean cores in the West (ODP 806

Brierley, 2013

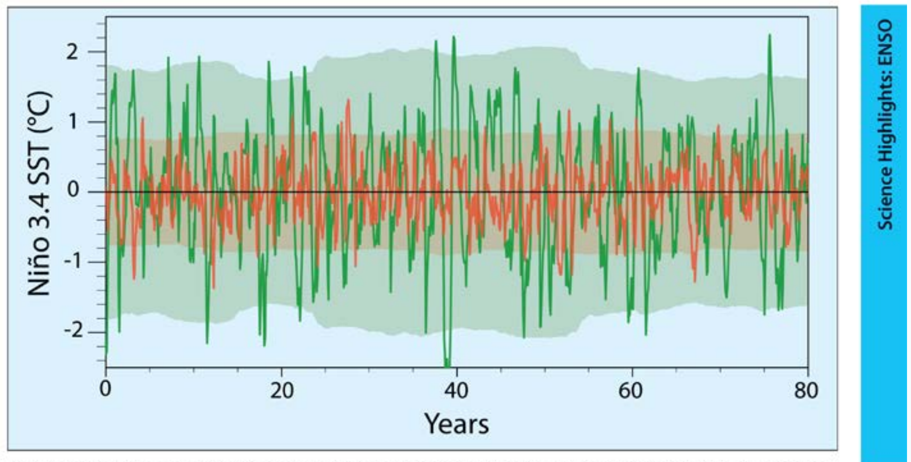
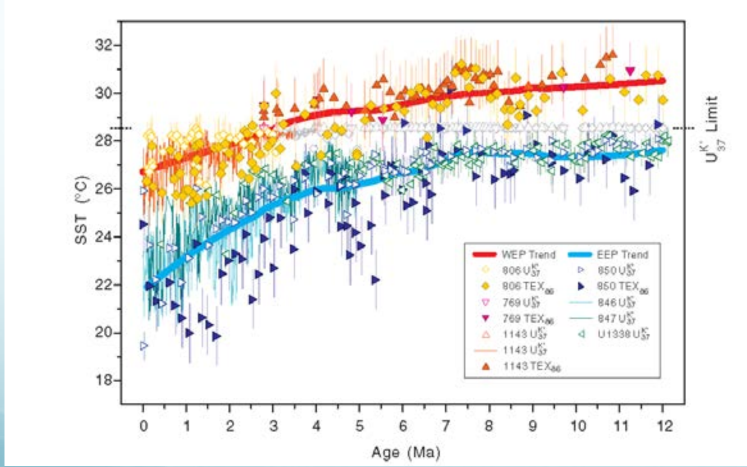
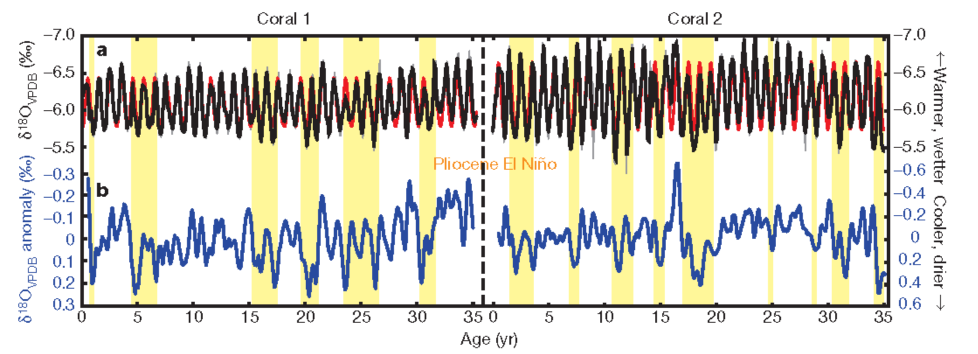


Figure 2: Niño 3.4 SST anomalies in two model simulations; a control (green) and one with an equatorial SST gradient that is approximately halved (red). The shaded area represents four standard deviations from a 30-year running window (Fedorov et al. 2010).

From Federov et al 2010



Zhang et al. Science 2014



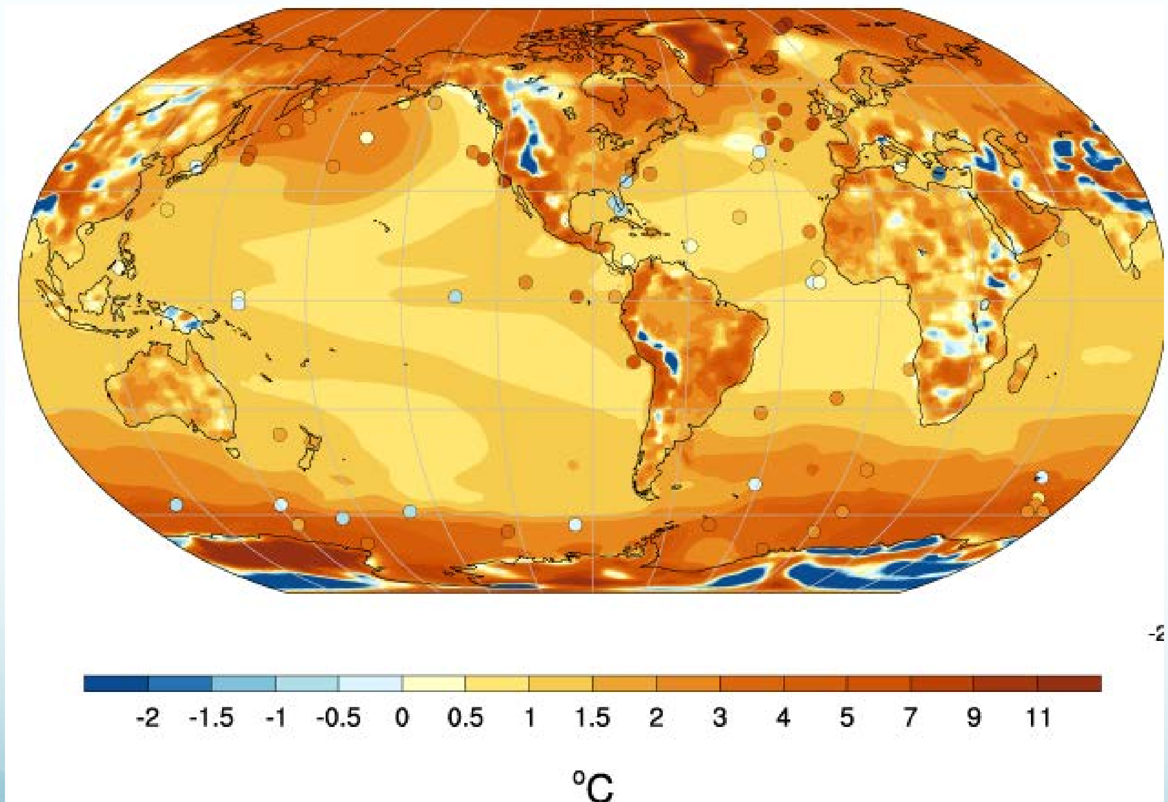
Coral δ18O, Watanabe et al. 2010

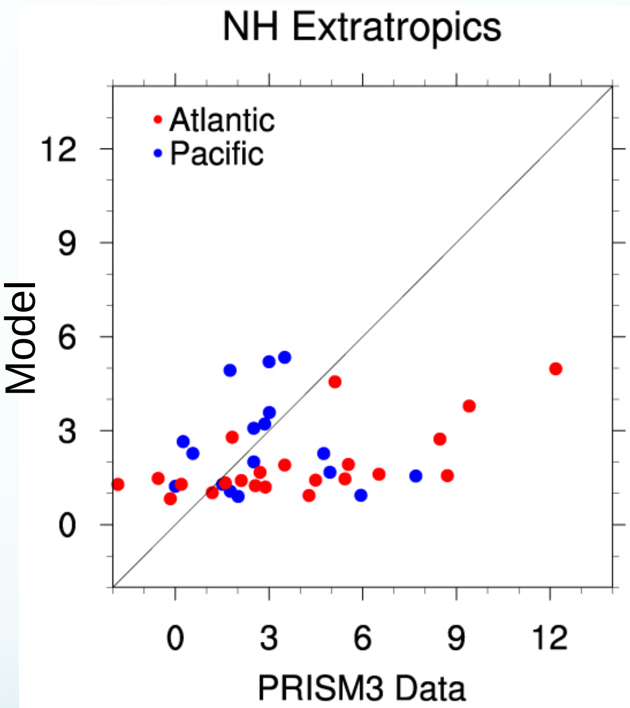
CCSM4 Results from PlioMIP1

MAT ~1.8K higher than Preindustrial Control

PlioMIP1 range: 1.8-3.6°C

Pliocene – Preindustrial MAT

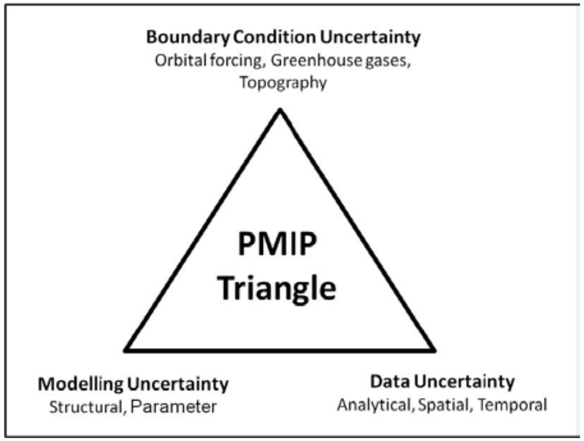




For more results and discussion go to: Rosenbloom et al. GMD 2013

Sensitivity Runs to Pliocene Climate Forcings

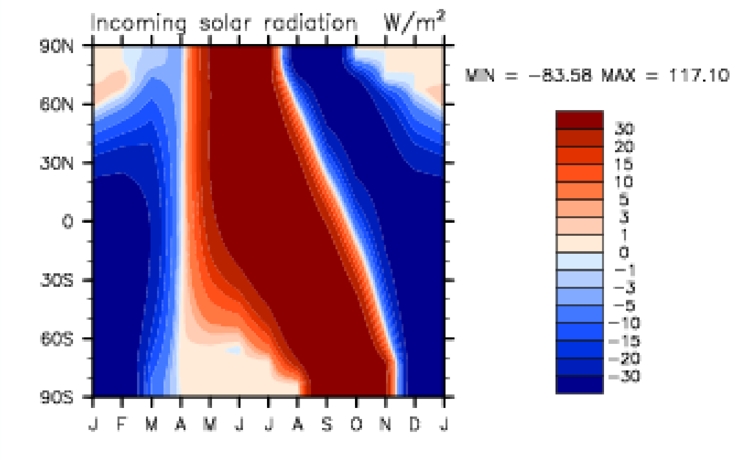
- CESM1-CAM4, FV1_gx1v6,
- 200 years from 451 of PlioMIP1



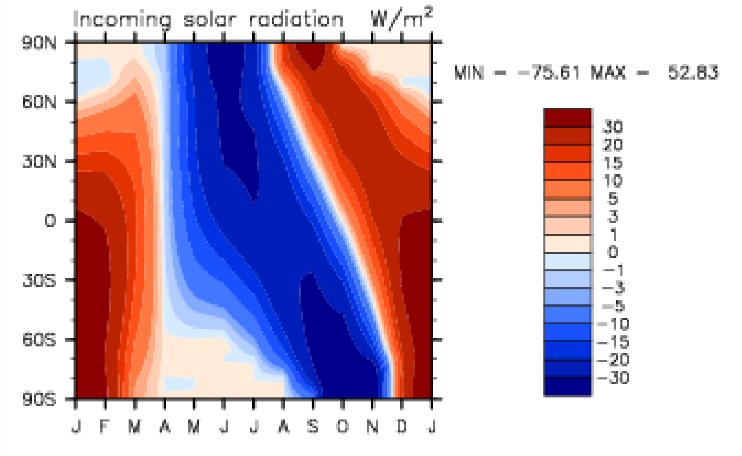
Simulations	CO_2 (ppmv)	Orbital	Paleogeography
Preindustrial Control	284.7	1990	Modern
Pliocene Control	405	"	PlioMIP1
Plio-BSC	"	"	No Bering St.
Plio-CA	"	"	No Canadian Archipelago
Plio-CA+BSC	"	"	No BS or CA
Plio-WAIS	"	"	No WAIS (+ocean)
NH Summer Max	"	3.037 Ma	PlioMIP1
NH Summer Min	"	3.049 Ma	"
High CO2	450	1990	"
Low CO2	350	1990	"

Extremes in Orbitally-driven Insolation Anomalies

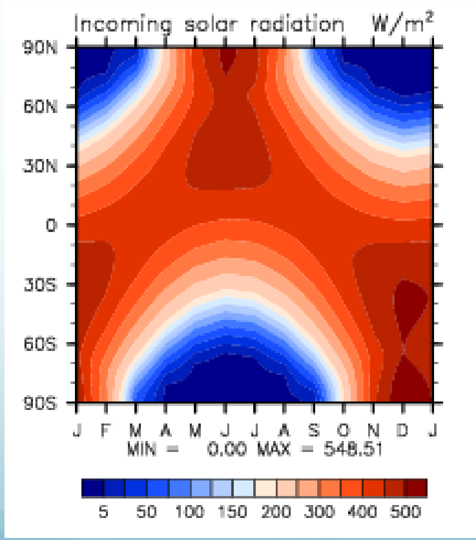
NHMax



NHMin



Pliocene

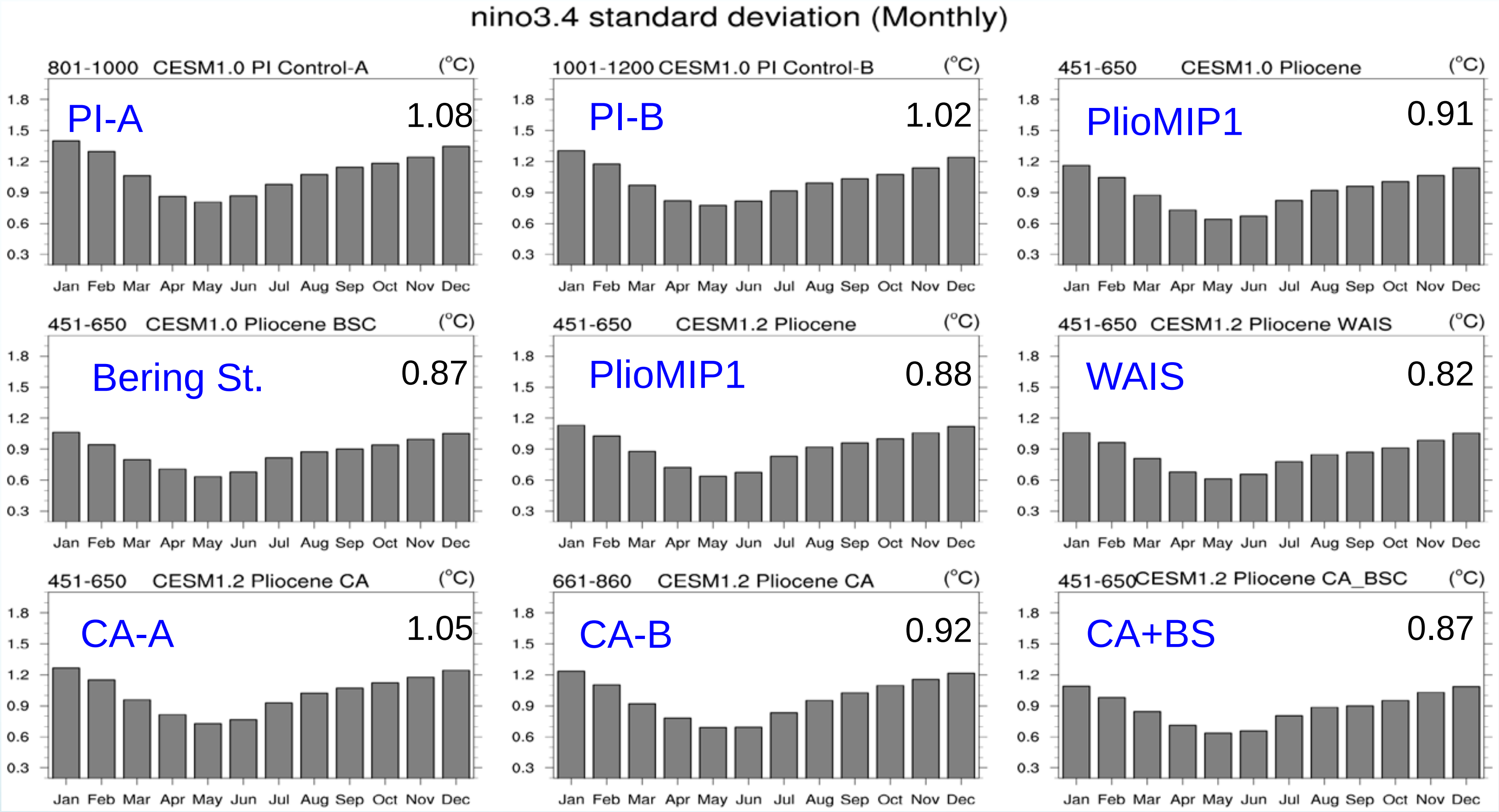


Increased NH seasonality

Decreased NH seasonality

Greater anomalies than in mid-Holocene due to Larger eccentricity

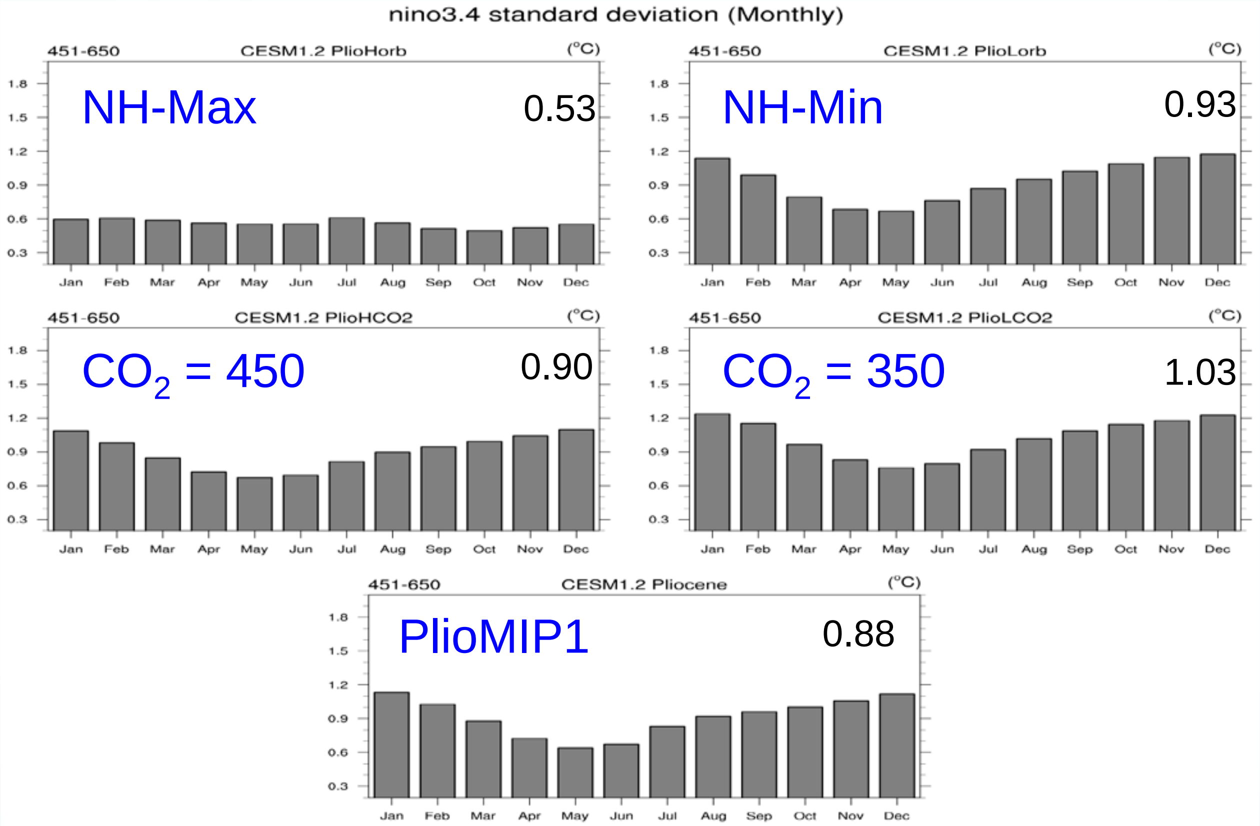
ENSO Sensitivity to Pliocene Gateway closures



Monthly Nino3.4 Standard Deviations

~from CAS Climate Variability Diagnostics Package (Phillips et al. 2014)

ENSO Sensitivity to Radiative Forcing

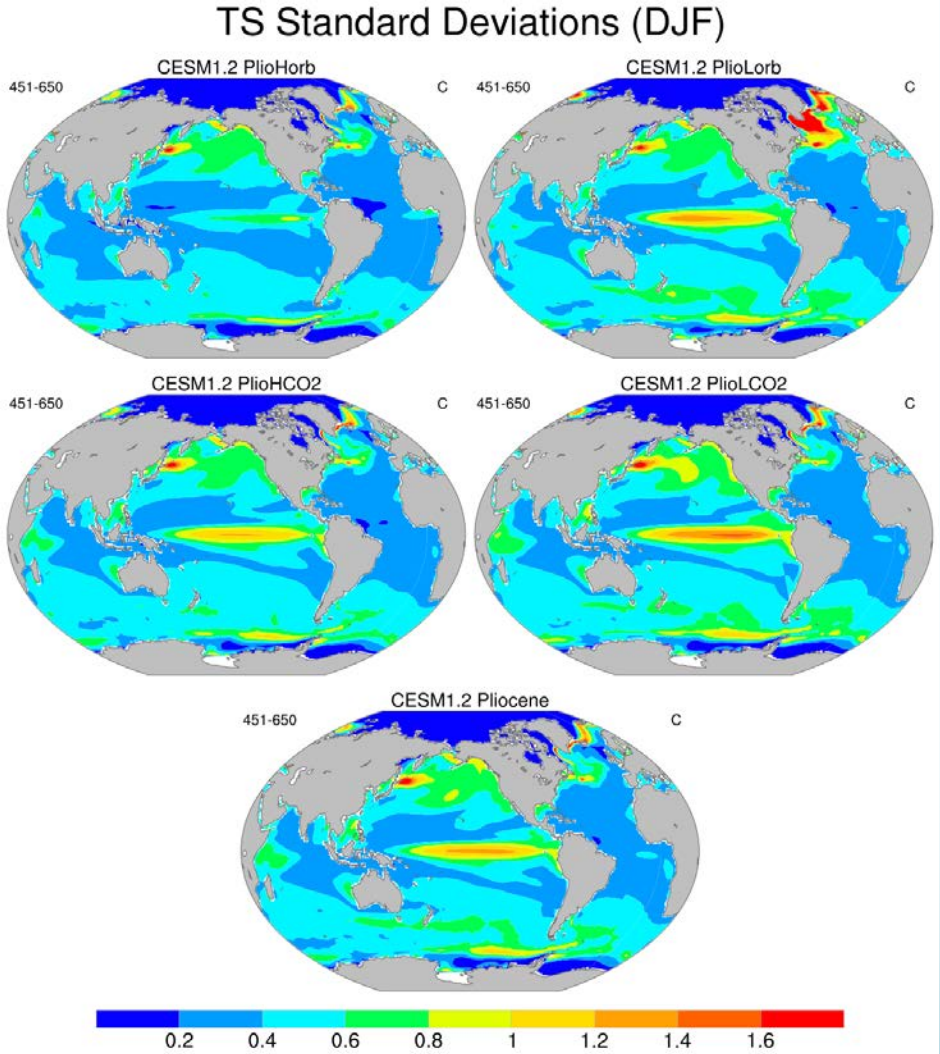


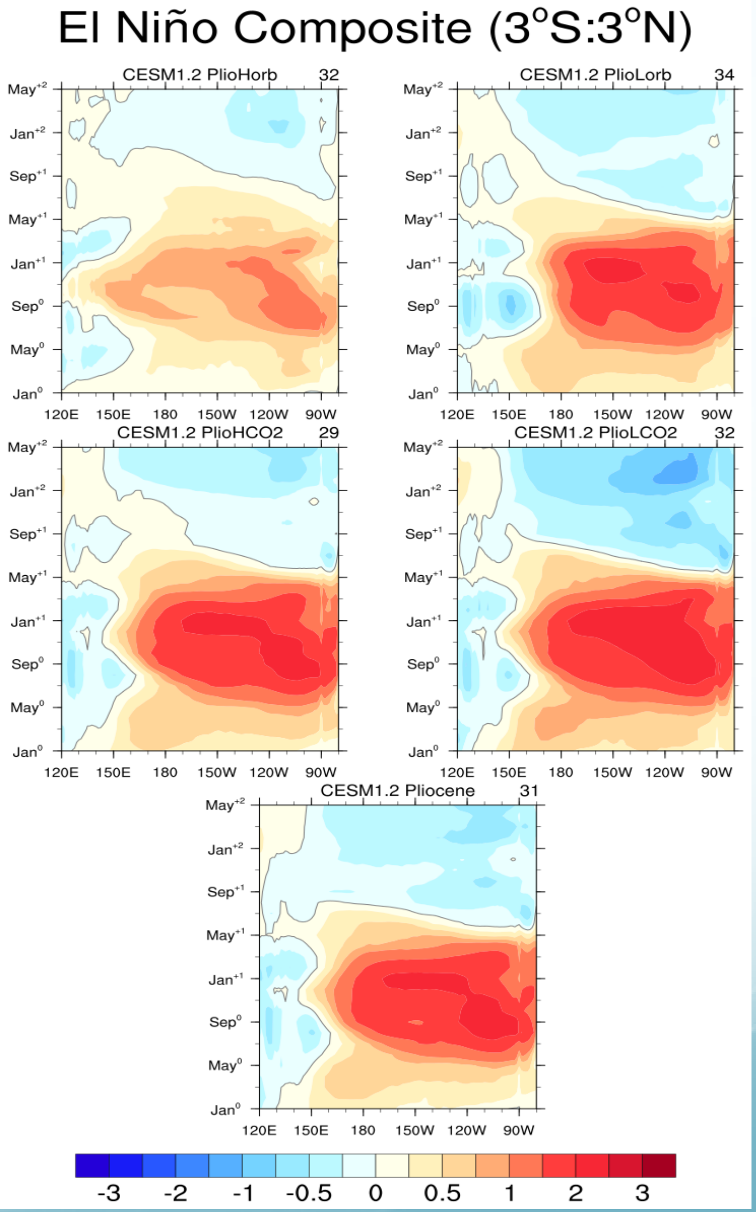
Monthly Nino3.4 Standard Deviations

~from CAS Climate Variability Diagnostics Package (Phillips et al. 2014)

Spatial Patterns

Warm Event Hovmueller





~from CAS CVDP (Phillips et al. 2014)

ENSO Suppression by Orbital Forcing

Clement et al. (1999; 2000; 2001) *Orbitally driven seasonal cycle changes dominate extratropical influences through dynamical ocean responses (CZ Model).*

Bjerknes-Jin Feedback analysis

Changes in background state and/or air-sea coupling intensity/efficiency lead to weaker positive feedbacks, and/or stronger negative feedbacks

Frequency Entrainment

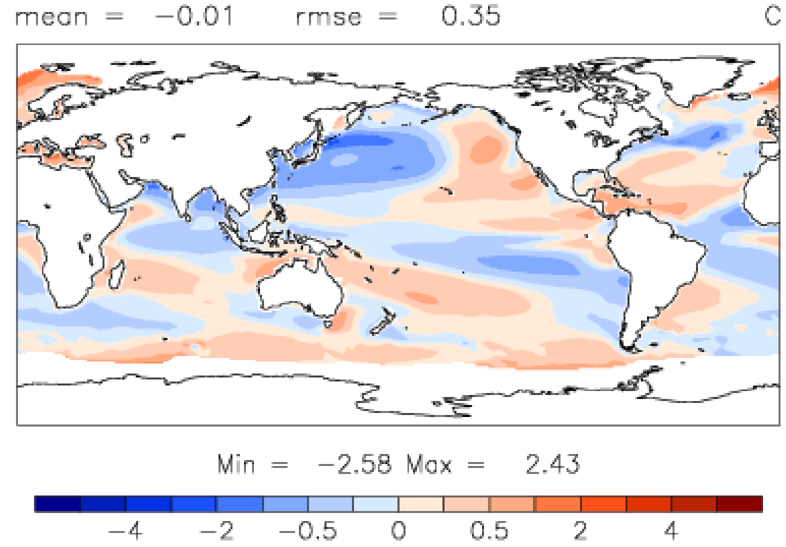
Non Linear process by which ***s****elf-excited oscillating mode is damped by a periodic mode forced externally, acquiring the frequency of forcing.*

ENSO → Annual Cycle (Chang et al. 1994; Liu 2002; others)

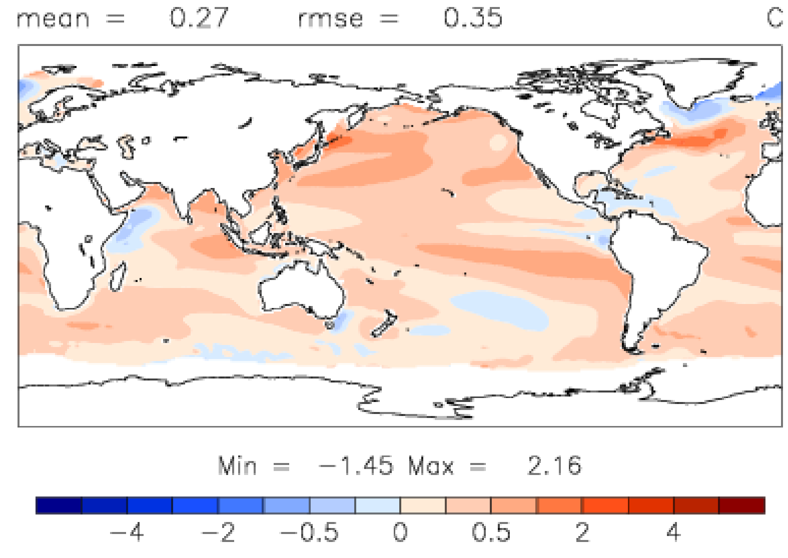
Extra-tropical influences (Monsoon strengthening, Meridional assymmetries) (Timmermann, et al. 2007)

Annual Mean SST Anomalies

SSTa NHMax - Pliocene



SSTa NHMin - Pliocene

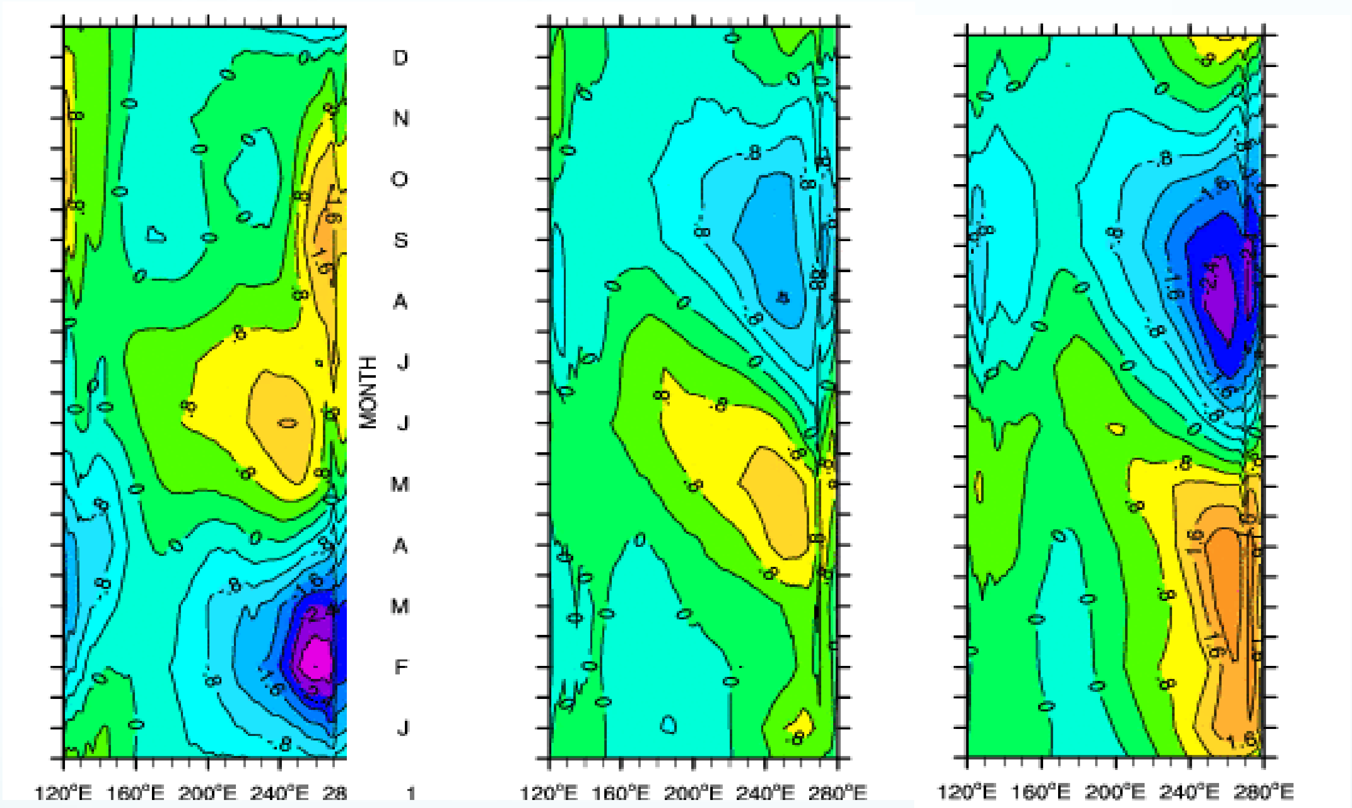


Weaker Mean zonal SST gradient
Stronger Meridional SST gradient

Slightly stronger zonal gradient
Weaker Meridional gradient

Annual Cycle of Equatorial SST

Weaker Zonal gradient



NH-Max **Pliocene** **NH-Min**

Stronger Zonal gradient

NH-Max Phase shifts: E. Pac. Cooling in NH Winter to Spring
E. Pac. Warming in NH Summer to Fall
NH-Min Enhanced Seasonal Cycle Amplitude

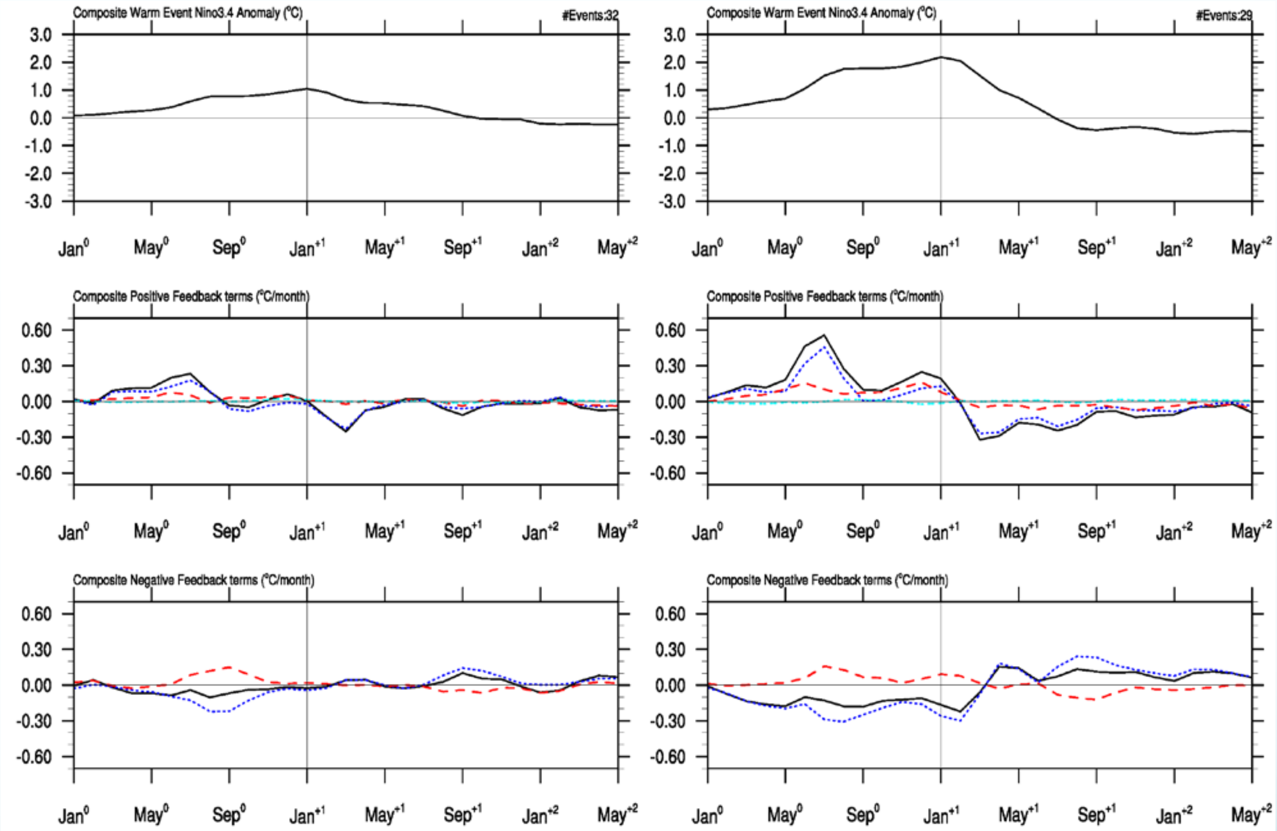
Composite Nino3.4 Warm Event (NDJ Nino3.4 SSTa ≥ 1σ)

Plio-NHMax | **Pliocene**

Nino 3.4 SSTa

Positive FB:
-u'dT/dx (Zonal Adv. FB)
-w'dT/dz (Ekman FB)
-WdT'/dz (TC FB)

Negative FB:
Q' (Thermal Damping)
(Mean Horiz. Adv.)



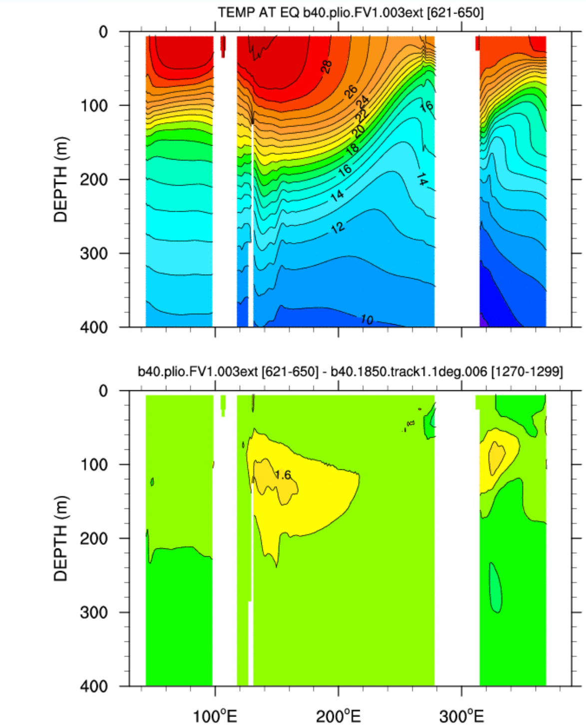
Suggests that weaker growth during Boreal Summer to Fall due to weakened seasonal Zonal SST Gradient

ML Heat Budget methodology of S. Stevenson et al. 2016, in prep

Preliminary Results so Far…

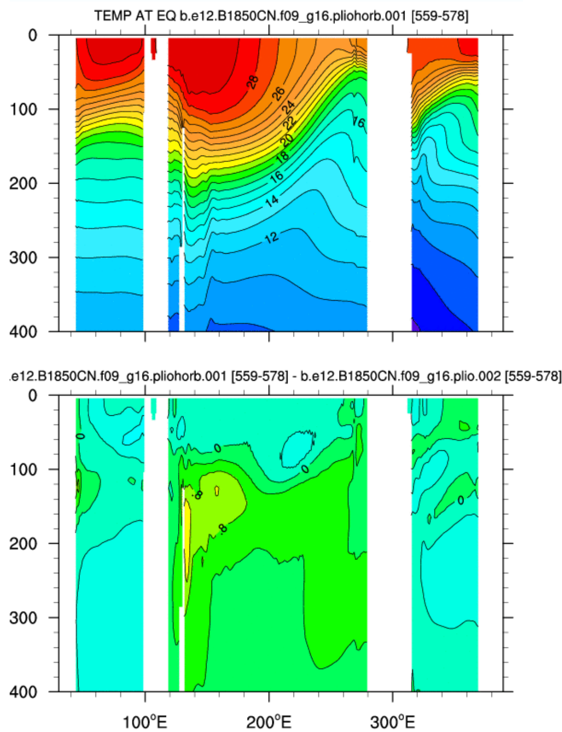
- Very Weak sensitivity of ENSO to gateways
- ENSO is weakly sensitive to Pliocene CO_2 extremes, with greater (weaker) amplitude with low (high) CO_2
- ENSO is strongly damped with Maximum NH Orbitally forced summer insolation forcing and loses phase-locking to annual cycle.
- Damping of ENSO appears to be related to weaker positive zonal advection feedback owing to weaker seasonally mean zonal temperature gradient in boreal summer to fall seasons.
- Further work will probe deeper

Pliocene vs. PI



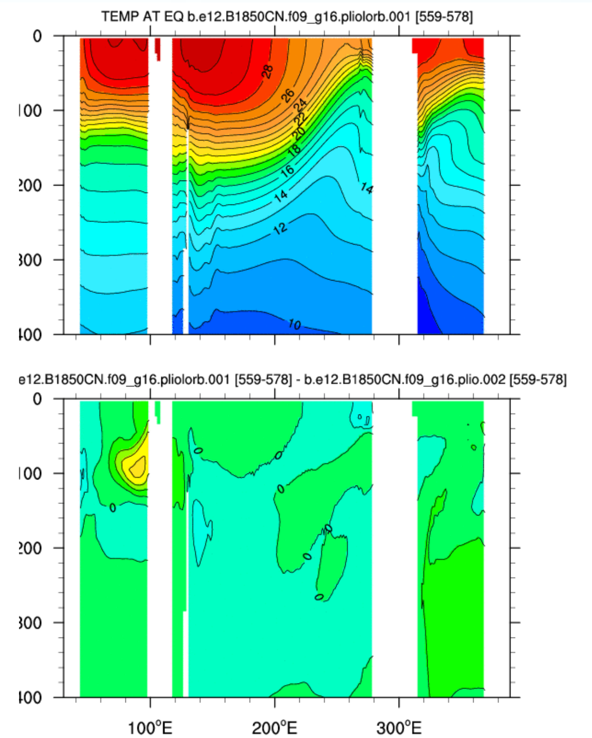
Warmer vs. PI;
Deeper Thermocline in Wpac.
Weaker vertical gradient

NHMax vs. Plio.

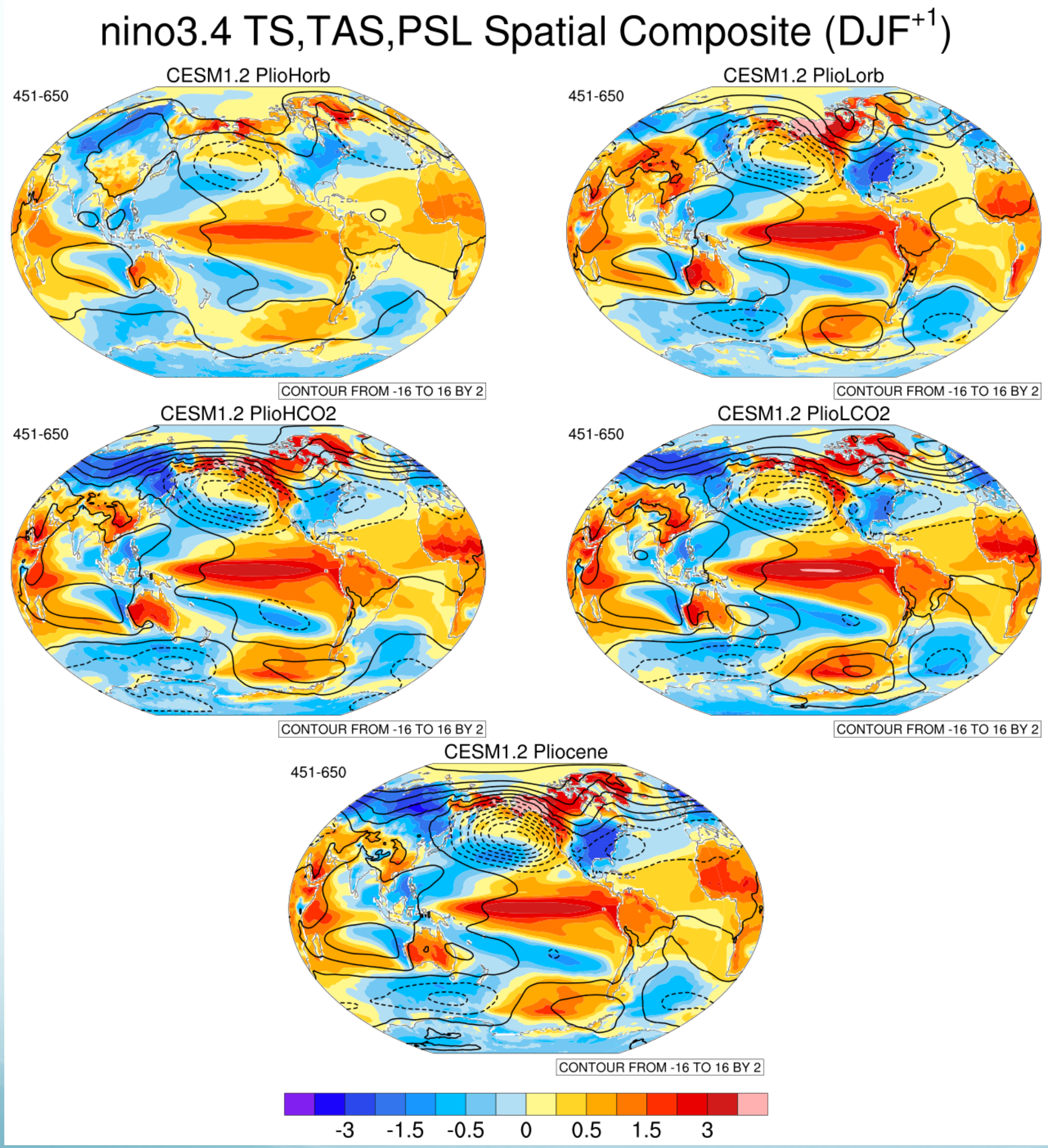


Weak cooling along EQ.
Deeper Thermocline
Weaker d<T>/dz

NHMin vs. Plio.

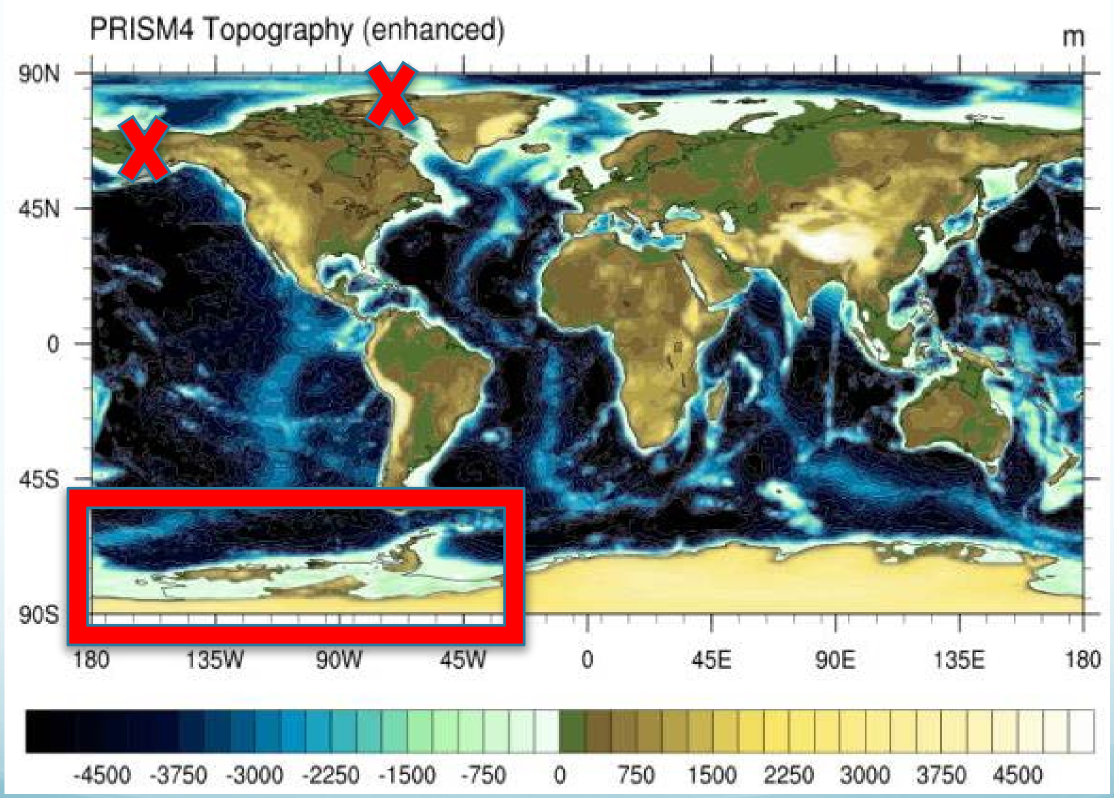


Enhanced zonal SST gradient
Enhanced vertical T gradient


nino3.4 TS,TAS,PSL Spatial Composite (DJF+1)
CESM1.2 PlioHorb
451-650
CONTOUR FROM -16 TO 16 BY 2
CESM1.2 PlioLorb
451-650
CONTOUR FROM -16 TO 16 BY 2
CESM1.2 PlioHCO2
451-650
CONTOUR FROM -16 TO 16 BY 2
CESM1.2 PlioLCO2
451-650
CONTOUR FROM -16 TO 16 BY 2
CESM1.2 Pliocene
451-650
CONTOUR FROM -16 TO 16 BY 2
-3 -1.5 -0.5 0 0.5 1.5 3

Towards PlioMIP2: Paleogeography

- West Antarctic Seaway Open (WAIS removed)
- Closed Bering Strait,
- Closed Canadian Archipelago



http://geology.er.usgs.gov/egpsc/prism/7_pliomip2.html