RELATIVE IMPORTANCE OF MERIDIONAL AND ZONAL SEA SURFACE TEMPERATURE GRADIENTS FOR THE ONSET OF THE ICE AGES AND PLIOCENE-PLEISTOCENE CLIMATE EVOLUTION

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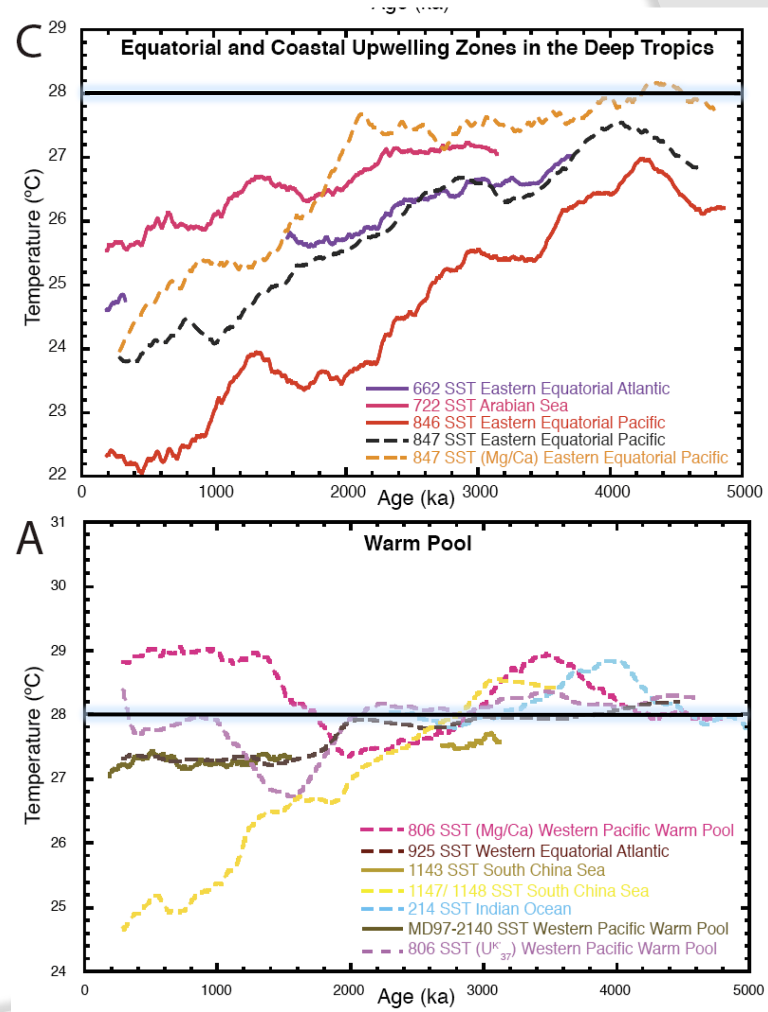
Outline

- Pliocene SST gradients
- Experiment design
- Relative impacts on hydrological cycle
- Relevance to glacial cycles
- Conclusions

Zonal SST gradient

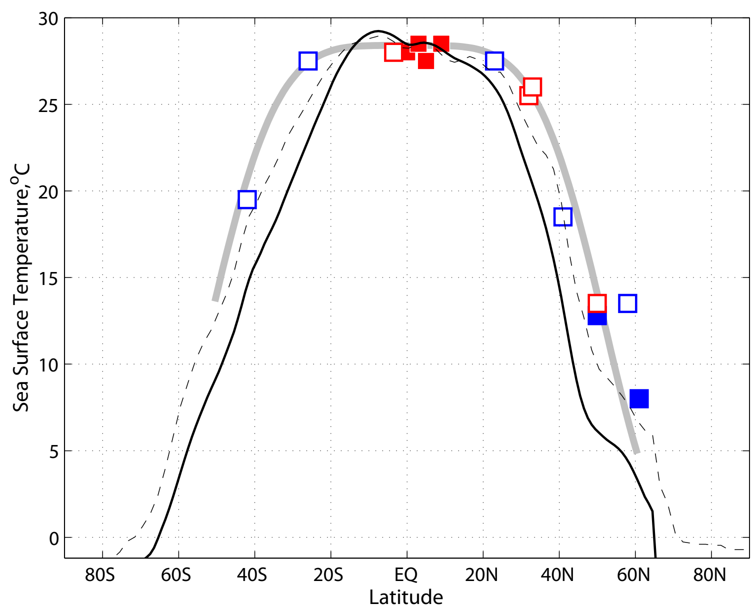
- Equatorial SSTs were much more uniform in Early Pliocene
- Zonal SST gradient was weaker, with some records suggesting non-existent
- “Permanent El Niño”



Fedorov, Lawrence, Brierley, Liu & Dekens: Review in prep

Meridional SST gradient

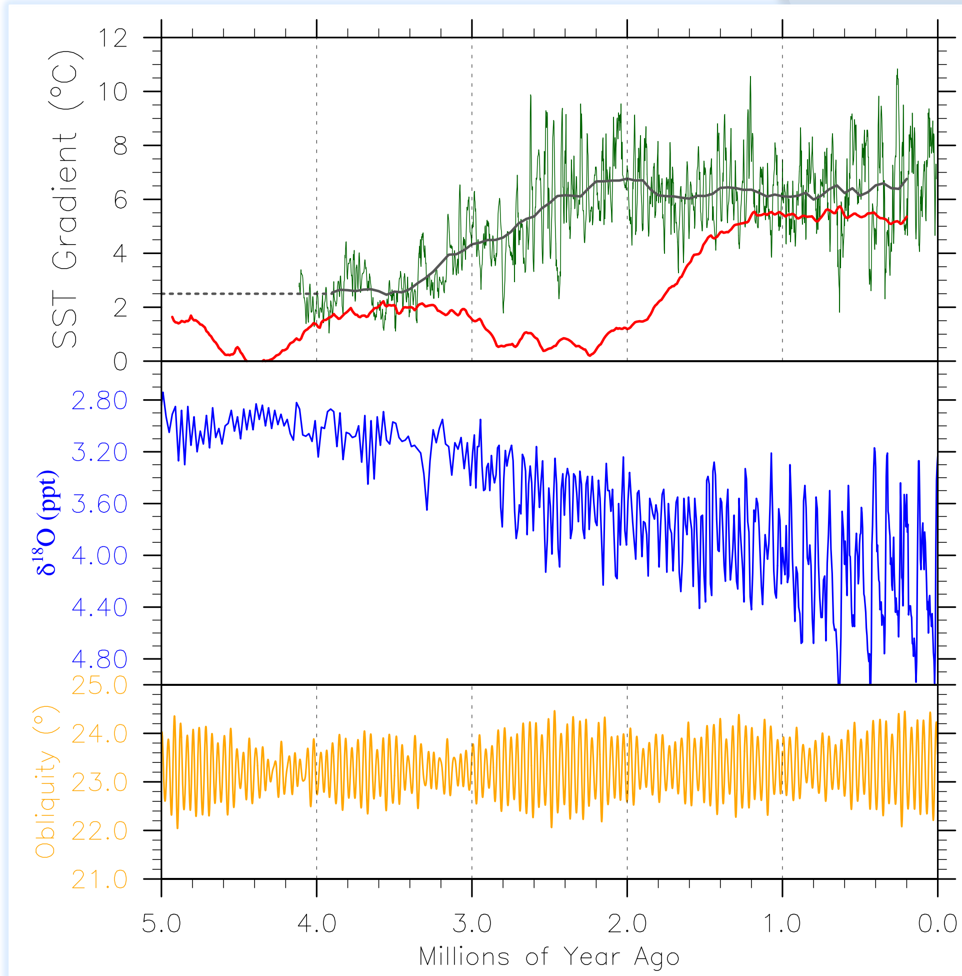
- Warm coastal upwelling regions at ~30°N
- Very weak meridional SST gradient in tropics
- Polar Amplification: high latitudes warm more than tropics



Brierley et al., Science, 2009

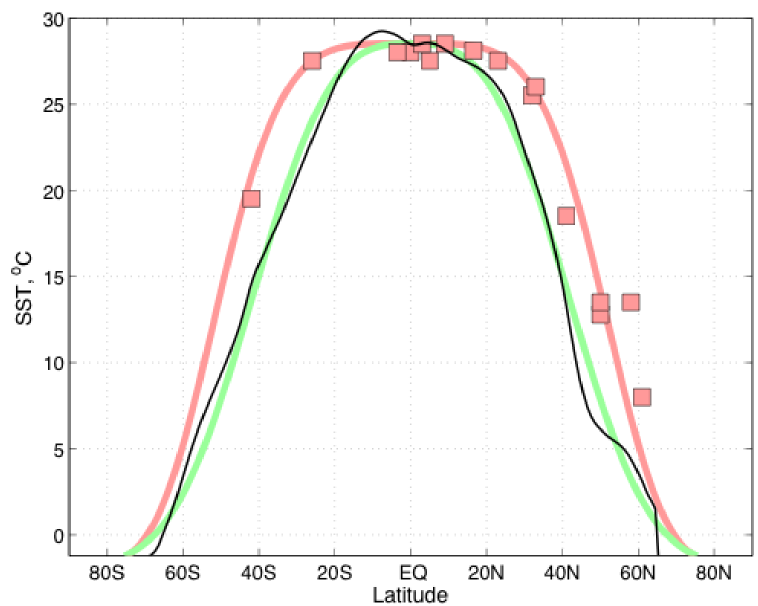
Temporal Evolution

- Indices of Meridional and Zonal SST gradient using ODP sites
- Neither follow trends of $\delta^{18}O$ or obliquity
- As SST gradient appear loosely independent what are their impacts?

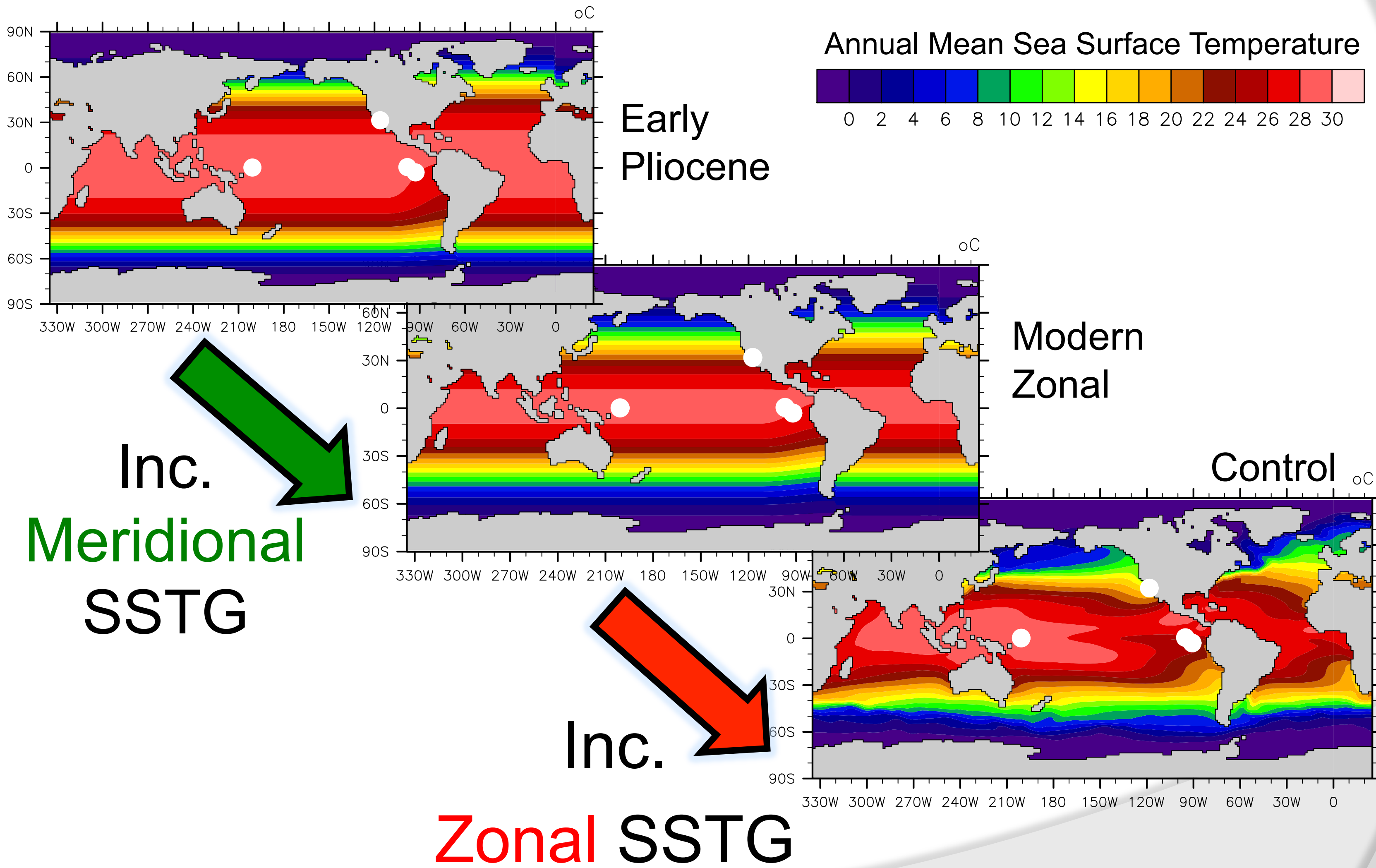


Sensitivity Experiment Design

- Use atmosphere-only GCM (CAM3 T85)
- Keep CO2, insolation and topography at 1990 conditions
- Prescribe global SSTs using different profiles
- 3 Simulations: Early Pliocene, Modern Zonal, Control



Isolating the SST gradients

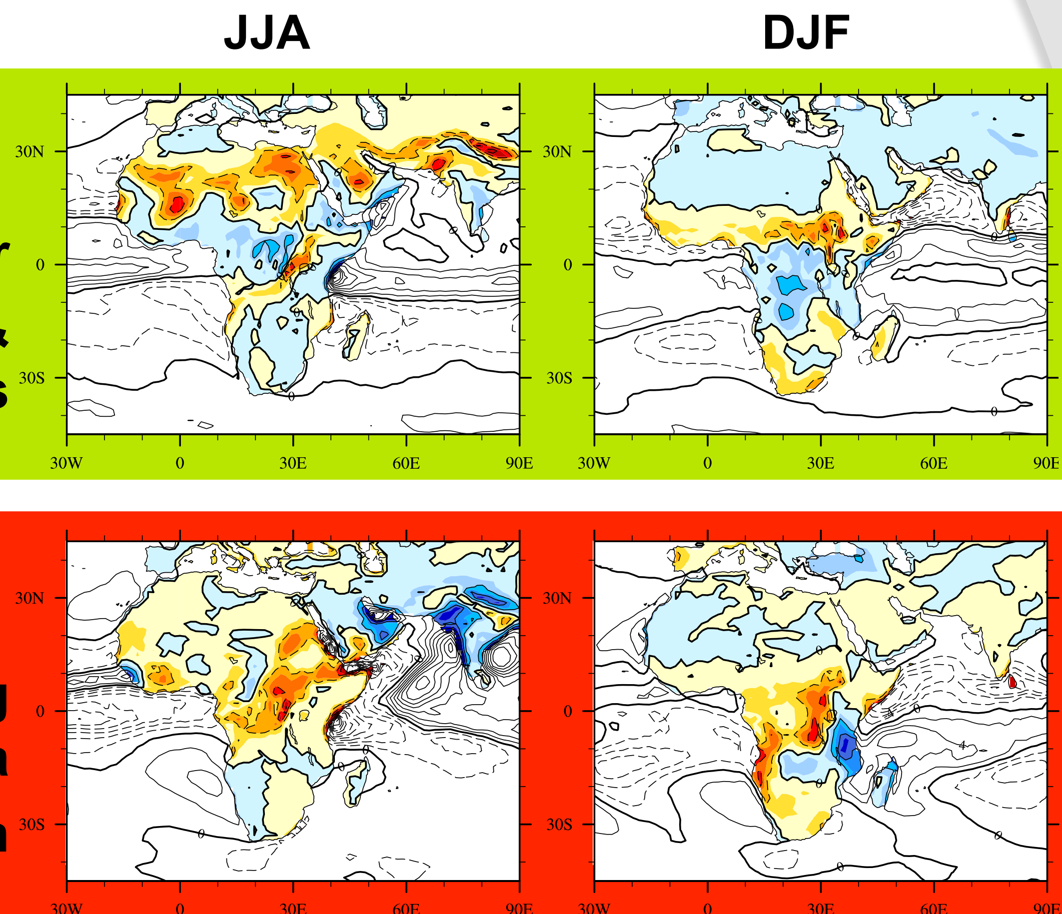


Global Impacts

	Increasing Meridional SST Gradient	Increasing Zonal SST Gradient
Surface Air Temperature	-3.2 ^oC	-0.6 ^oC
Water Vapor/Lapse Rate	-10.8 W/m^2	-2.6 W/m^2
Clouds	-3.1 W/m^2	-2.7 W/m^2
Surface Albedo	-1.8 W/m^2	-2.7 W/m^2

- Increasing the Meridional SST gradient cools the planet much more than increasing the zonal gradient
- This is dominated by the greenhouse effect of water vapor in the atmosphere
- Changes in the gradients also alter hydrological cycle

African Impacts



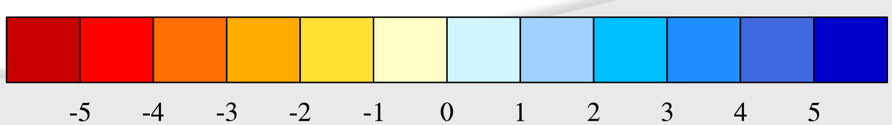
Inc. Meridional

- Sahara much drier
- Hadley Cell contracts & strengthens

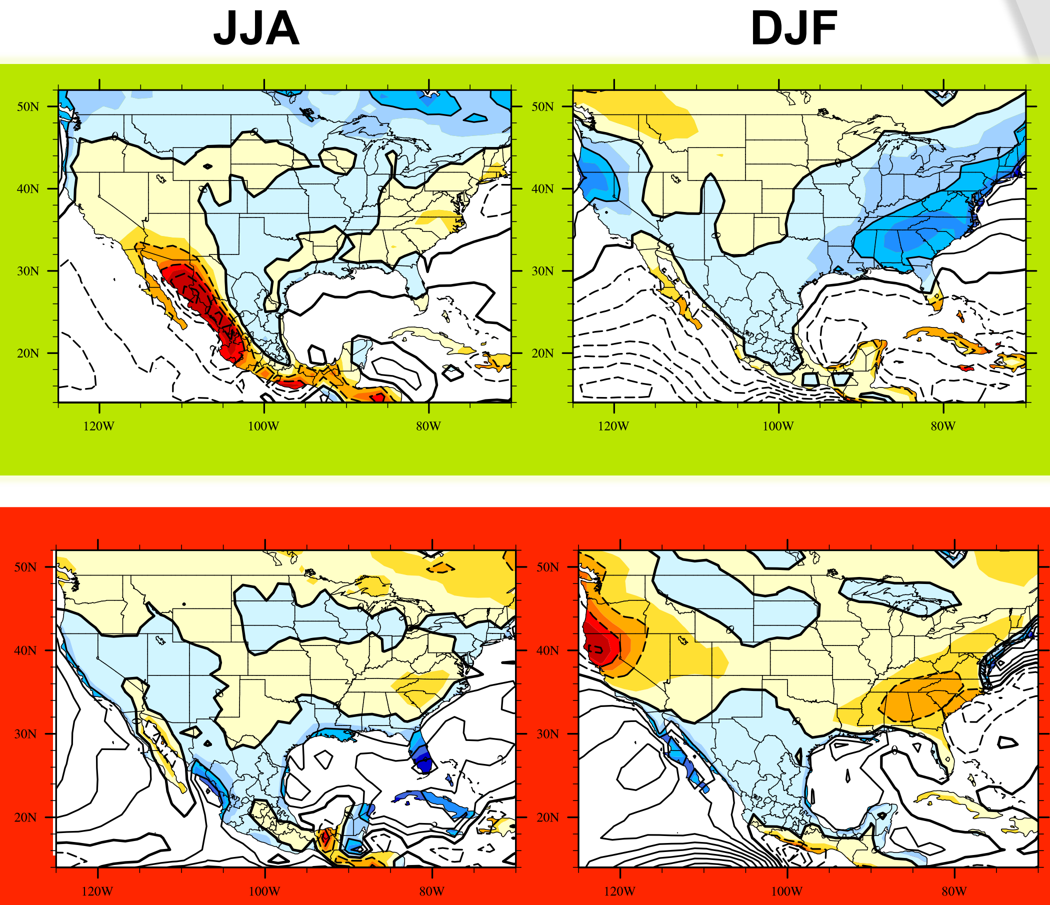
Inc. Zonal

- Substantial Drying throughout Africa
- Stronger Monsoon

Impact of SST Gradients on Precipitation - Evaporation (Lines, c.i. = 2 mm/day)



N. American Impacts



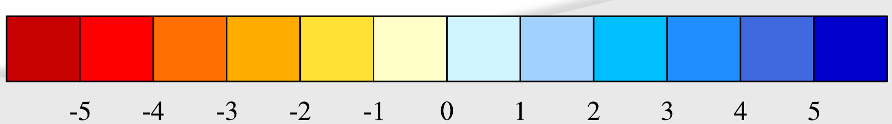
Inc. Meridional

- **West Coast much drier in summer**
- **US wetter in winter**

Inc. Zonal

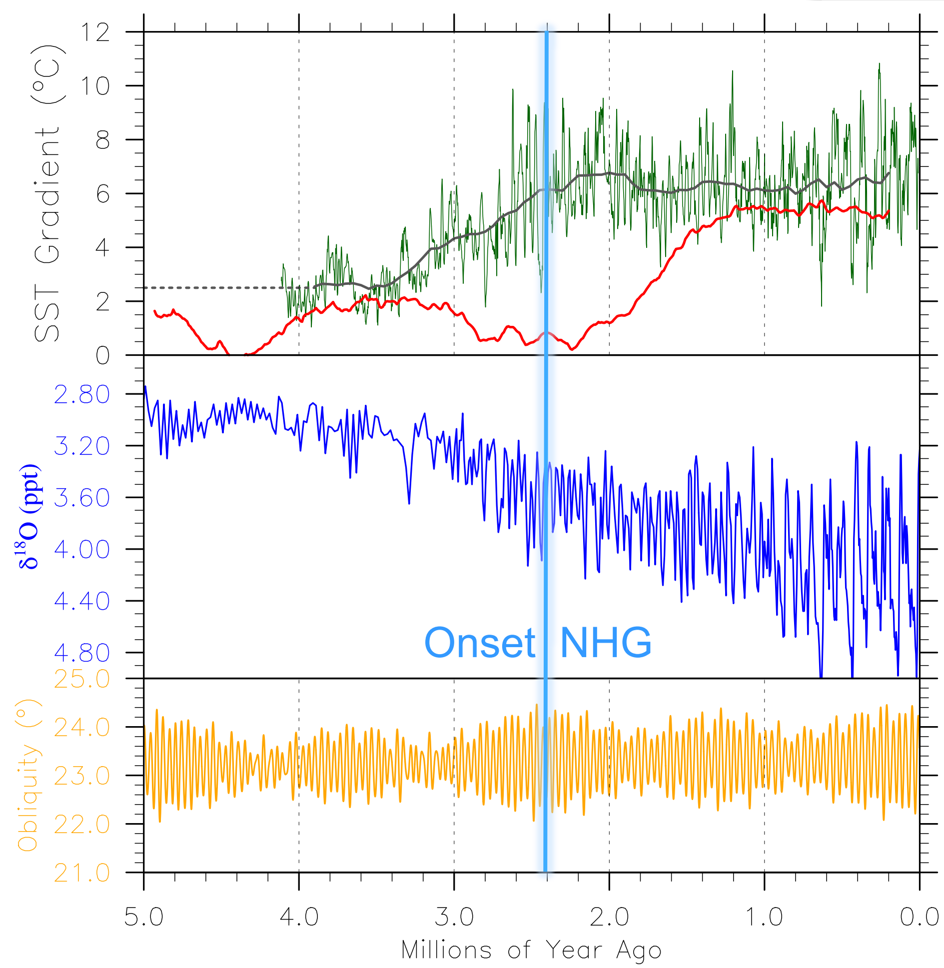
- **Wet Gulf of Mexico**
- **US drier in winter**

Impact of SST Gradients on Precipitation - Evaporation (Lines, c.i. = 2 mm/day)

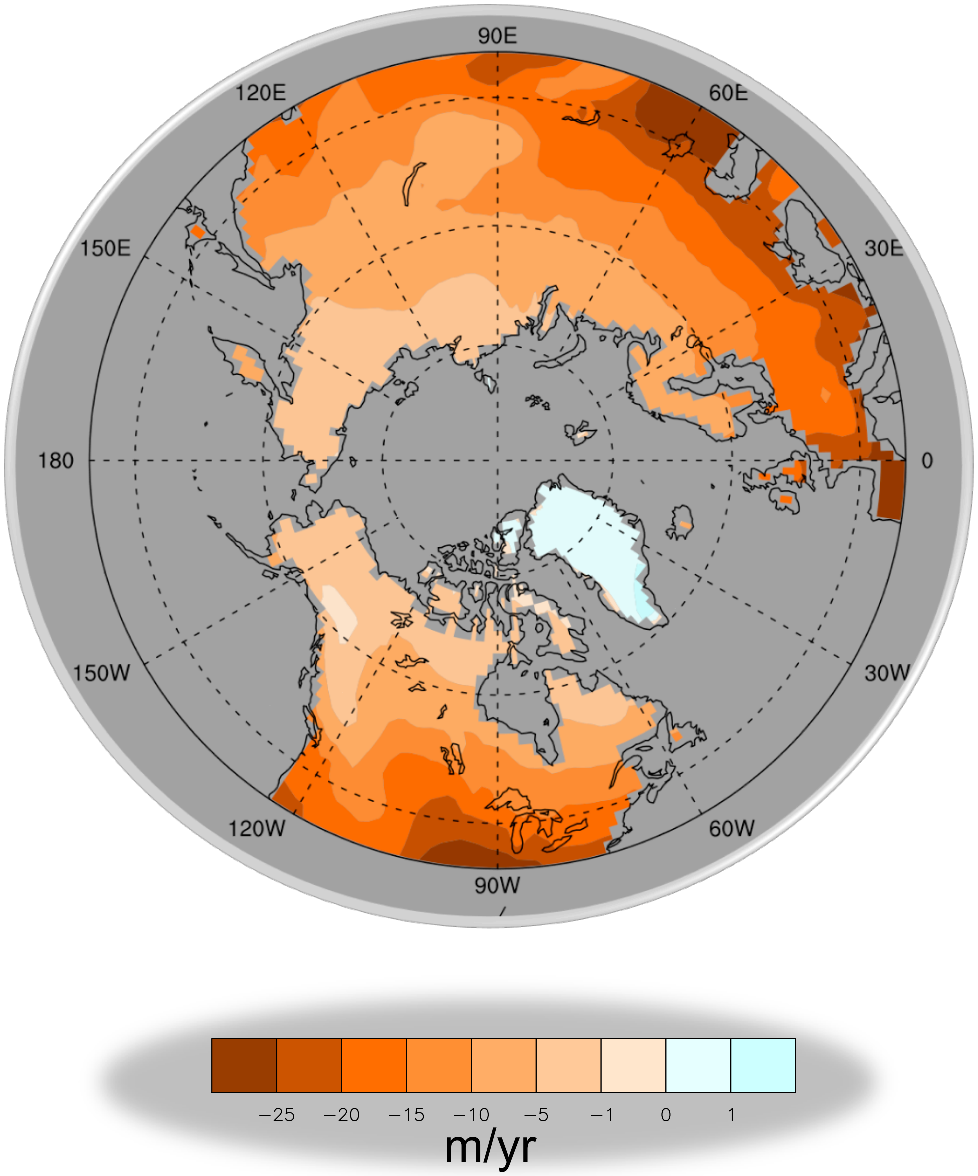


Relationship to NH Glaciations

- Meridional SST gradient starts changing before $\delta^{18}O$ NH glaciations
- Could its changes precondition the ice changes?



Control Potential Ice Mass Balance



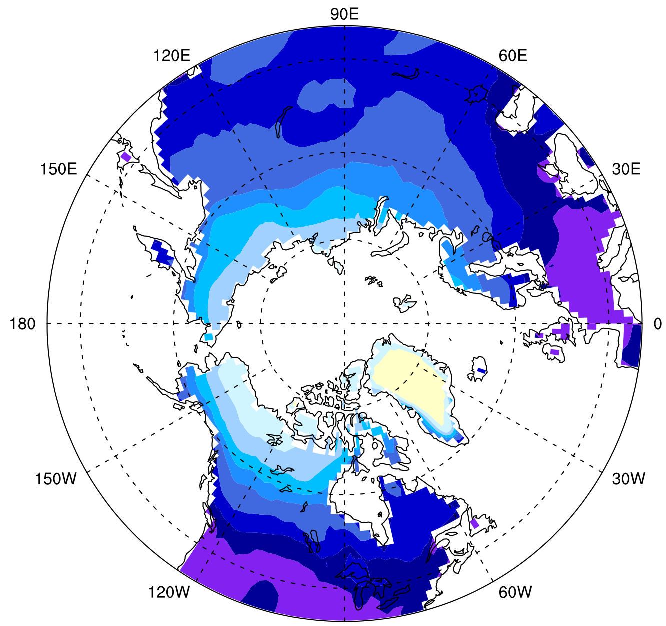
A measure of expected ice accumulation, calculated as:

Snowfall – β * PDD

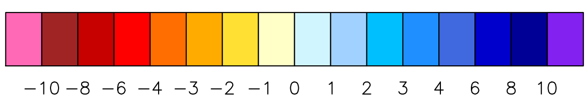
Snowfall in m/yr l.w.e; PDD is positive degree days, and is the sum of the surface air temperature whenever it is above freezing; β is 0.005.

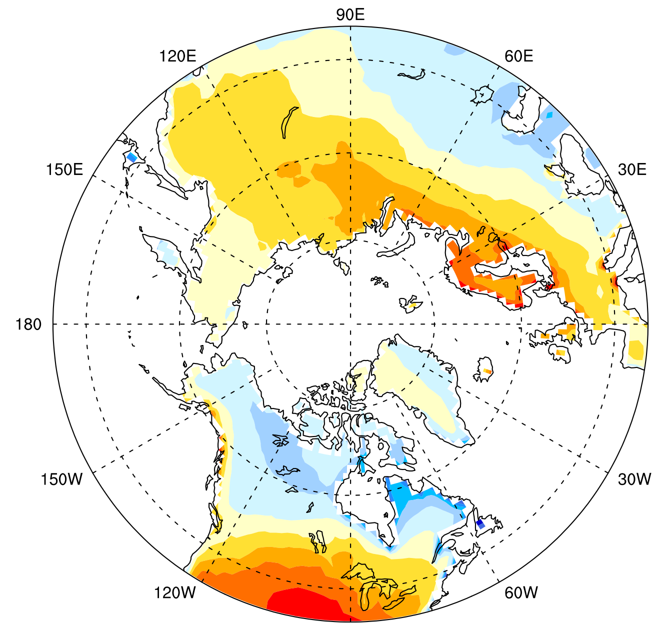
- In the Control run, ice grows only on Greenland (coldest of the 3 runs)

Impacts on Ice Growth

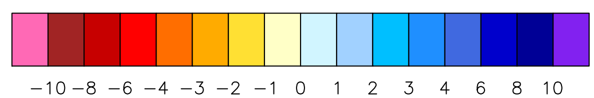


Inc. Meridional SSTG





Inc. Zonal SSTG



- Both facilitate ice-growth in Canadian Arctic
- Meridional SST changes dominate the signal (but zonal changes still important)

Conclusions

- Both meridional and zonal SST gradients have increased since the Early Pliocene
- A sensitivity study with atmospheric GCM indicates:
  - Meridional SST changes were more important than zonal for global climate (3.2°C vs 0.6°C on global mean temp)
  - Changes in both gradients alter regional hydrological cycle
    - Meridional: N. Africa and West coast of N. America
    - Zonal: the Asian monsoon and E. Africa
  - An increase in meridional and, to a lesser extent, zonal SST gradient are favorable for the onset of NH glaciation
- To simulate the Pliocene-Pleistocene transition climate models need to reproduce accurately changes in both gradients

Further Discussion

- This is only a sensitivity study and not complete climate reconstructions
  - Both meridional and zonal changes were probably not independent of each other
  - The zonal conditions assume no zonal gradients throughout the globe; certainly excessive

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Relative importance of meridional and zonal sea surface temperature gradients for the onset of the ice ages and Pliocene-Pleistocene climate evolution

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