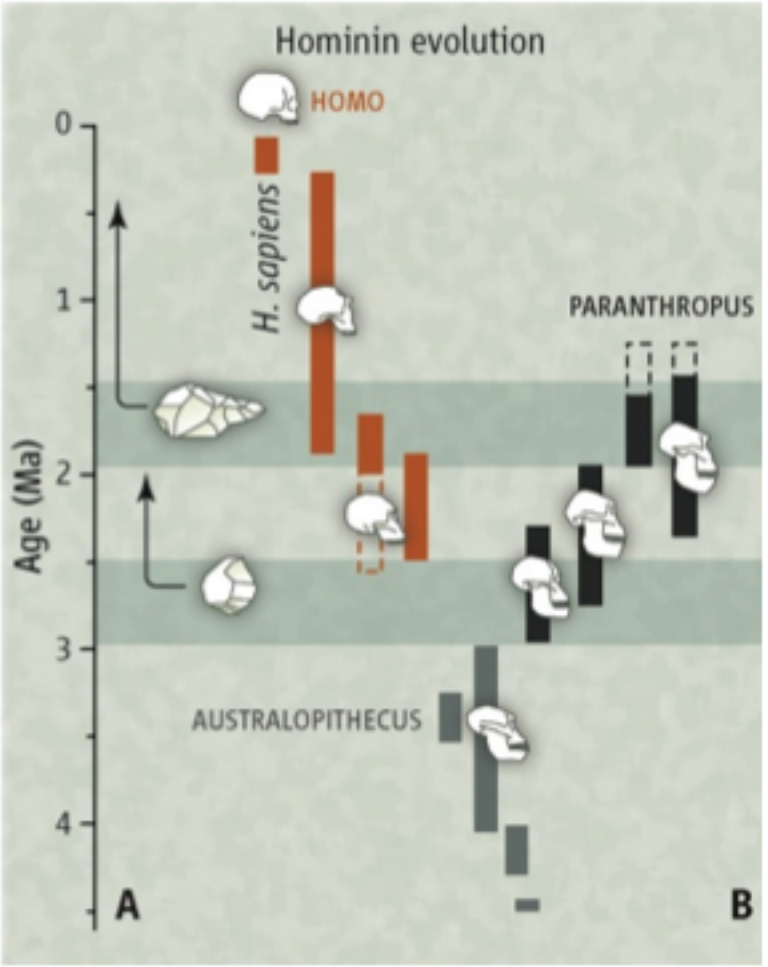
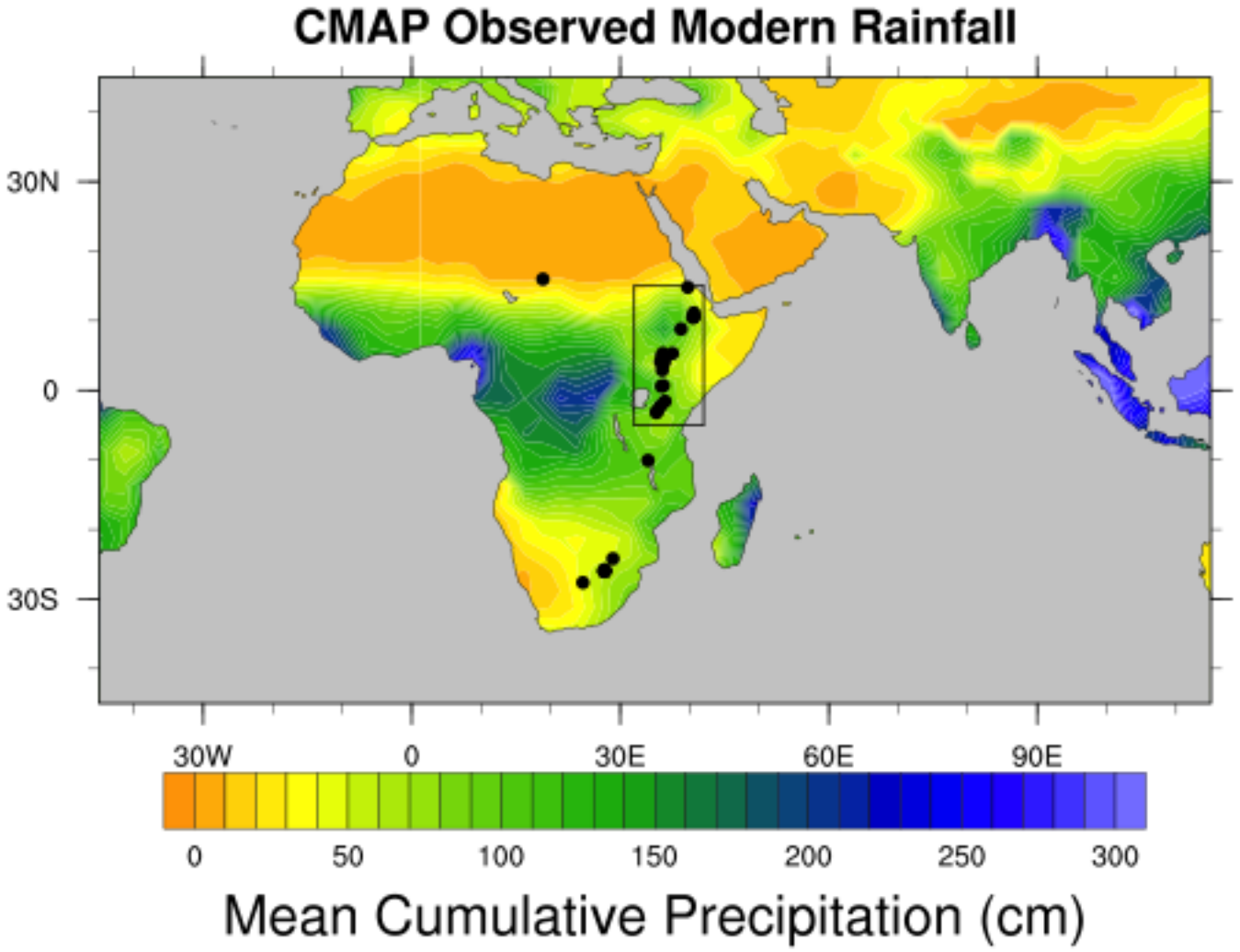
Homonin Evolution

- Several important steps towards the evolution of humans have taken place in past 4 million years
- All occurred in Africa
- Major developments at ~2.6Ma and ~1.9Ma



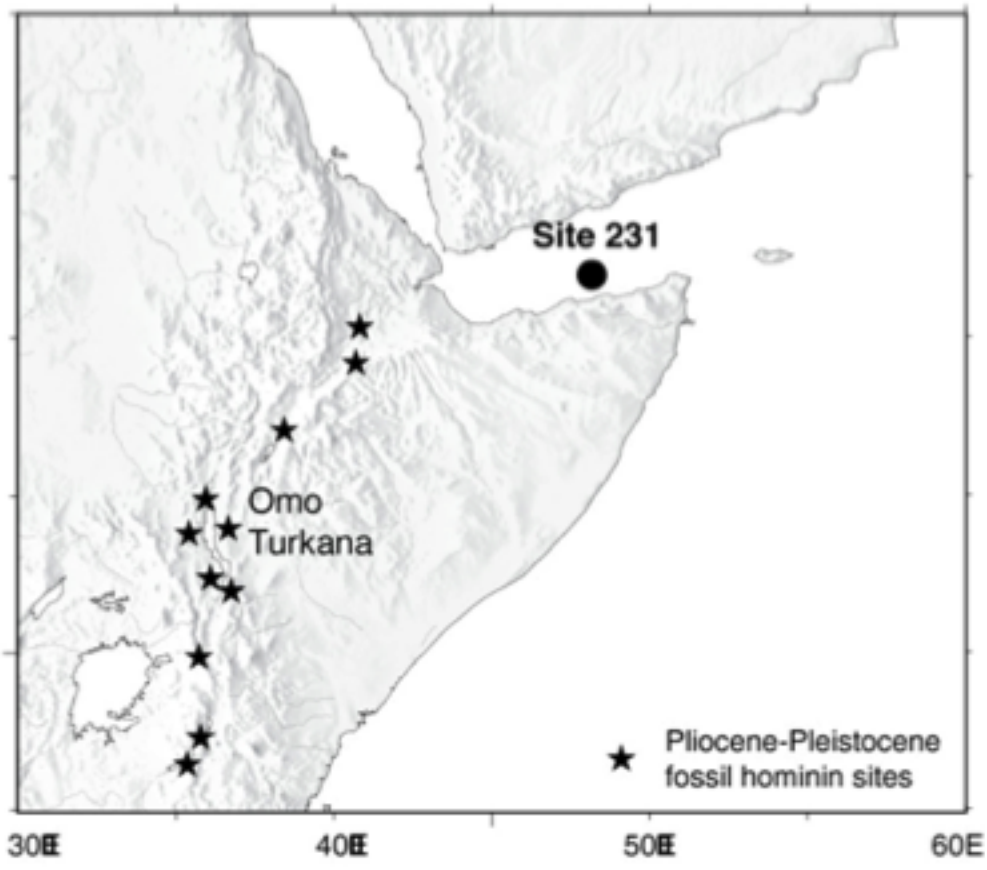
deMenocal, 2011

Fossil Locations



Focus on East Africa & Rift Valley

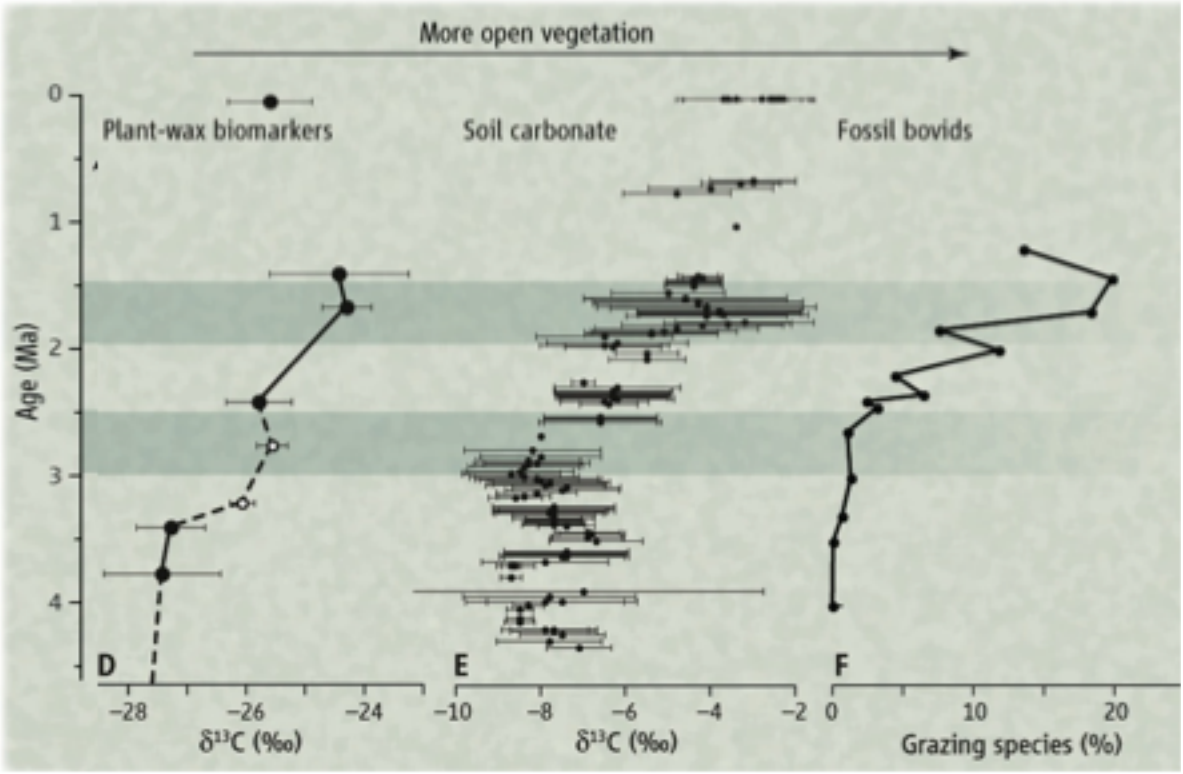
- Distinct concentration of hominin remains in East Africa
- Suggest this region especially important of human evolution
- High orography surrounding the rift valley



Feakins, deMenocal, Eglinton (*Geology,* 2005)

Climate Theory

- Important global climate changes over 3Ma
- Evidence of a drying of East Africa
  - esp. at ~1.9Ma
- Suggested that climate drove human evolution

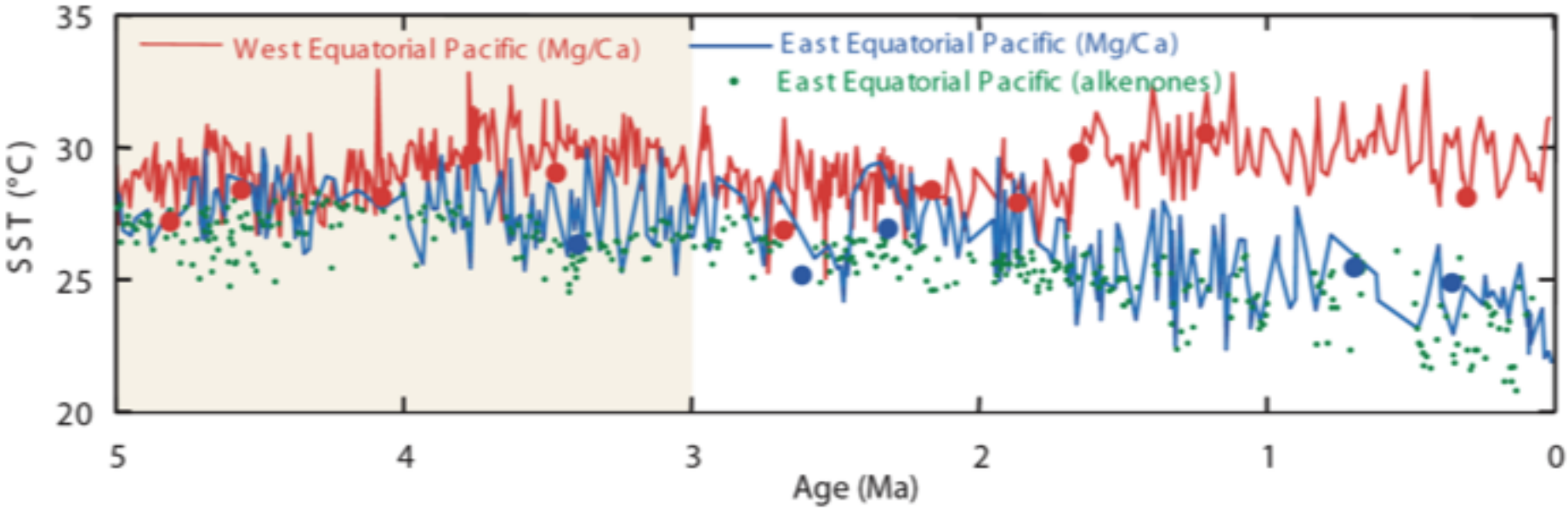


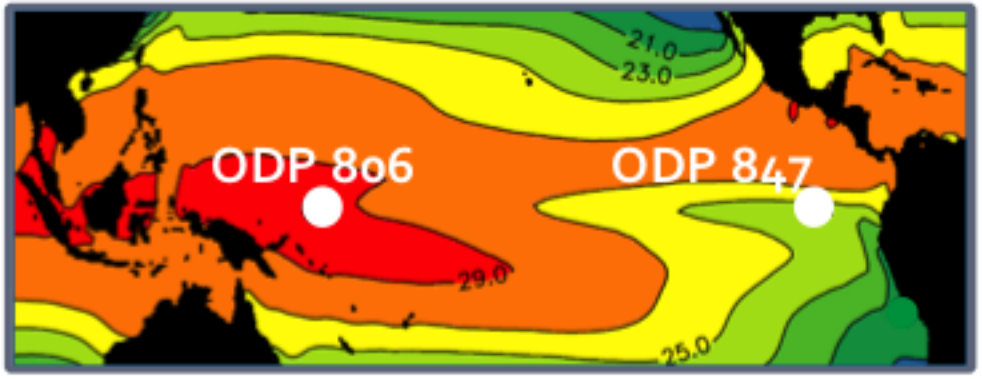
deMenocal, 2011

Equatorial Temperature Gradients

Paleobservations from the Indian and Pacific Oceans

Permanent El Niño (No Zonal SST Grad.)

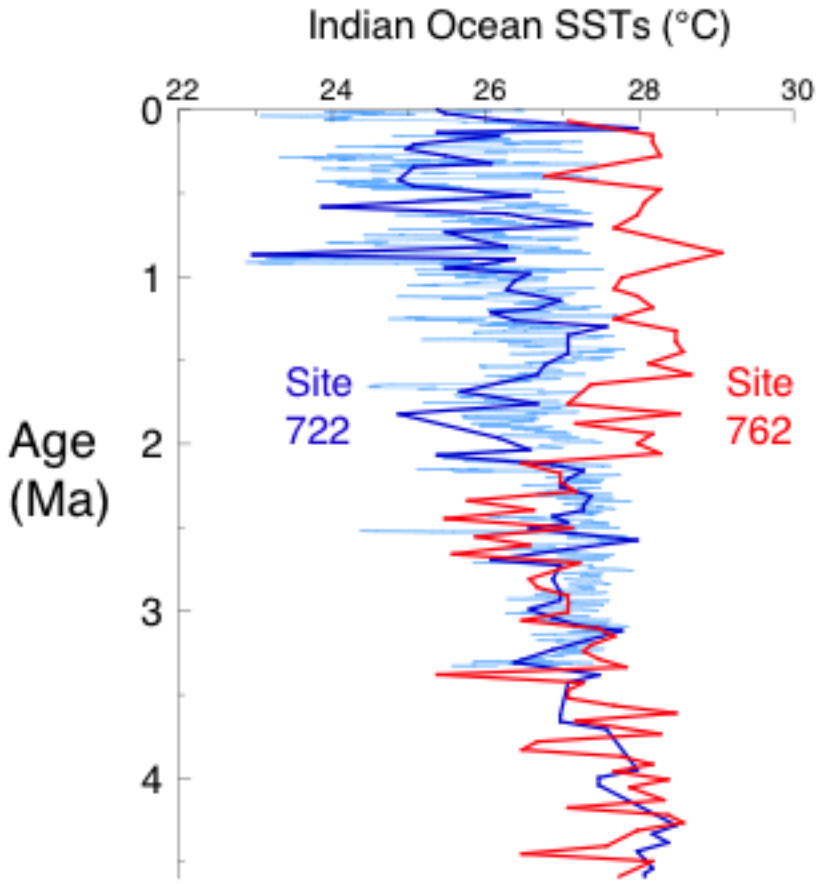




Fedorov *et al.* 2006.
The Pliocene Paradox (Mechanisms for a permanent El Niño)

Indian ocean gradient

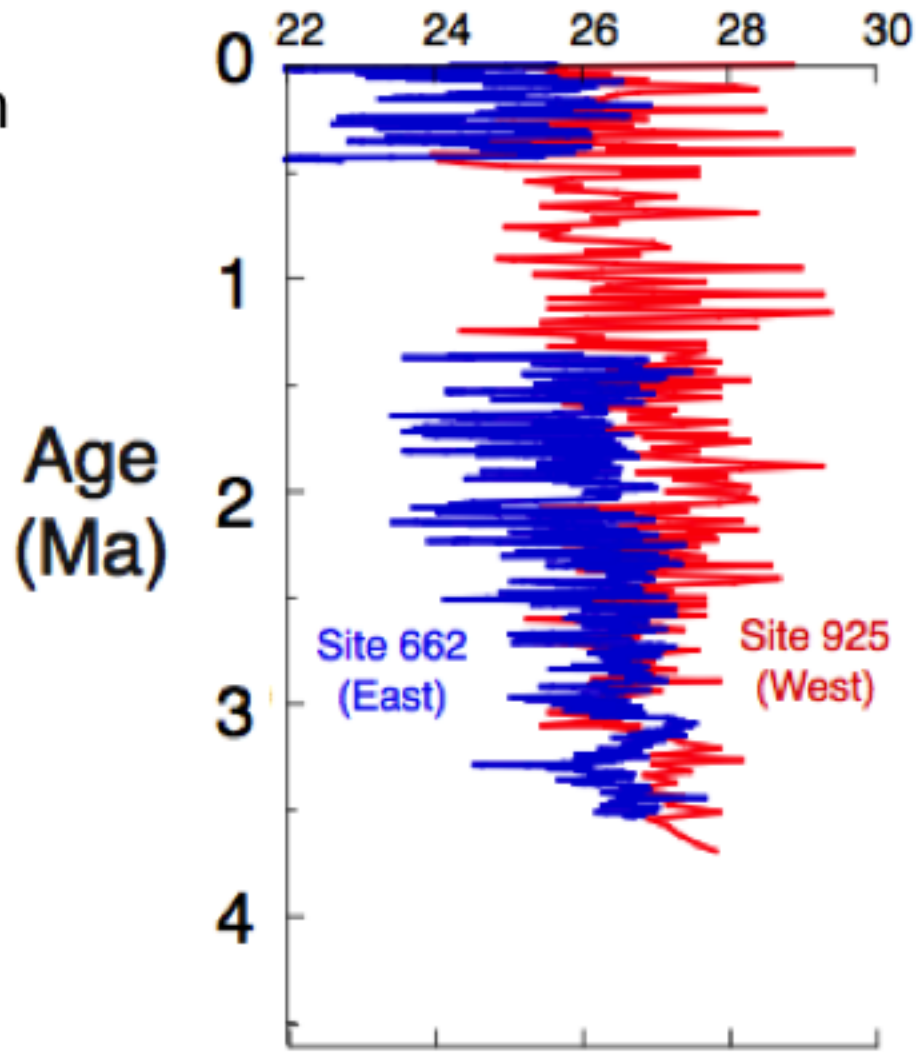
- Alkenone SSTs from Arabian Sea and off West Australia
- Zonal SST gradient in the Indian Ocean also develops at ~1.9Ma



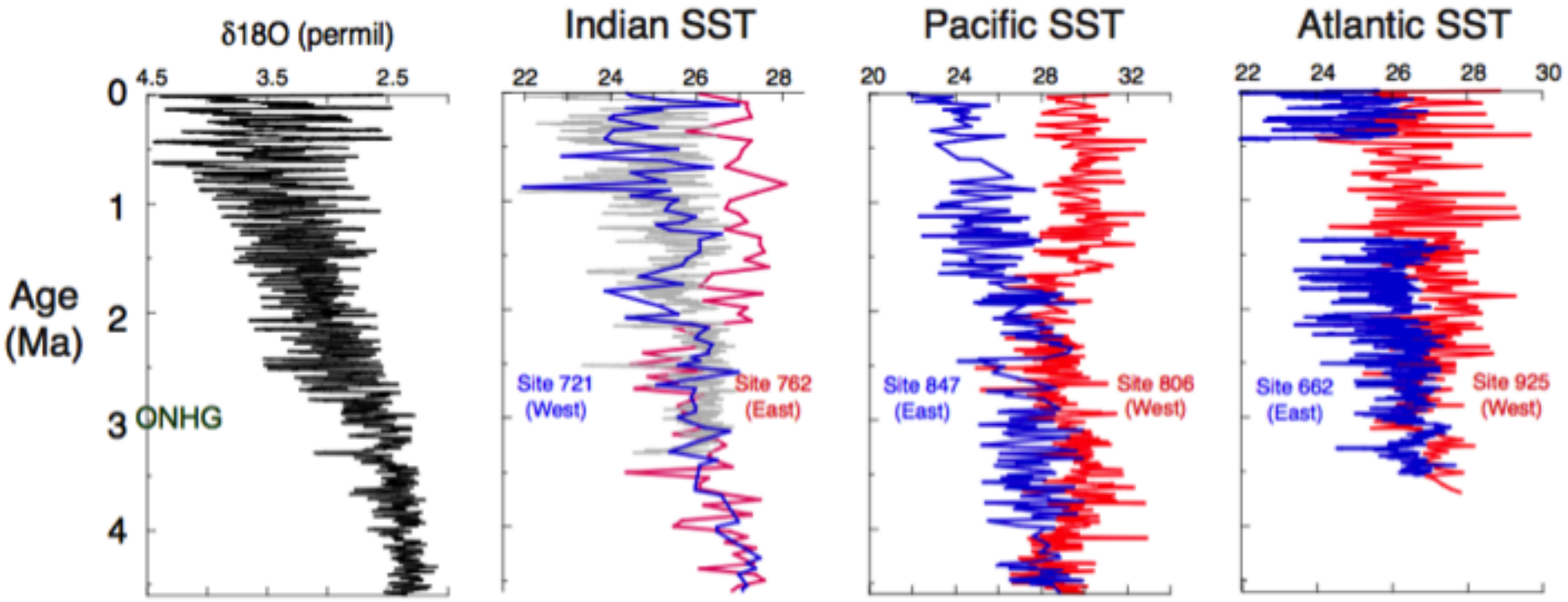
Huang et al., 2007 (722)
deMenocal et al., in prep (762)

Atlantic Ocean

- Zonal SST gradient in Atlantic does not show a distinct development
- Possibly something happens at 2Ma, but it is relatively weak

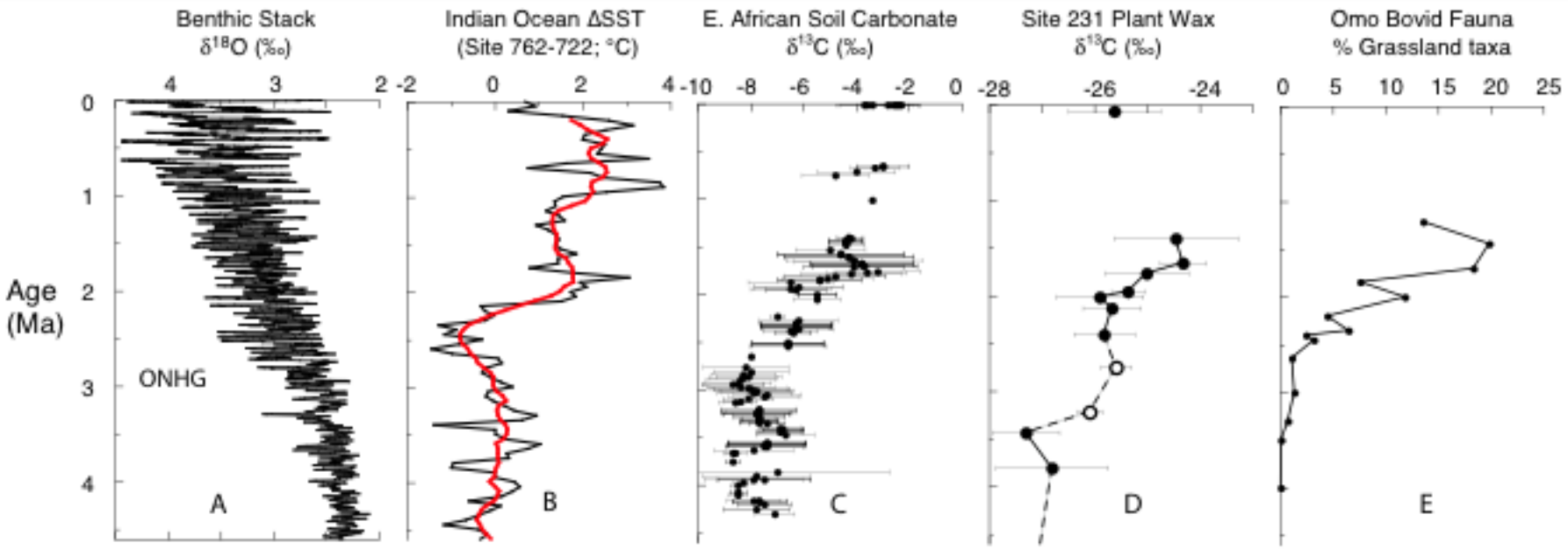


Combined plot of SST gradients



- Indian and Pacific SST gradients develop at roughly similar time at 2Ma

Summary of Paleobservations

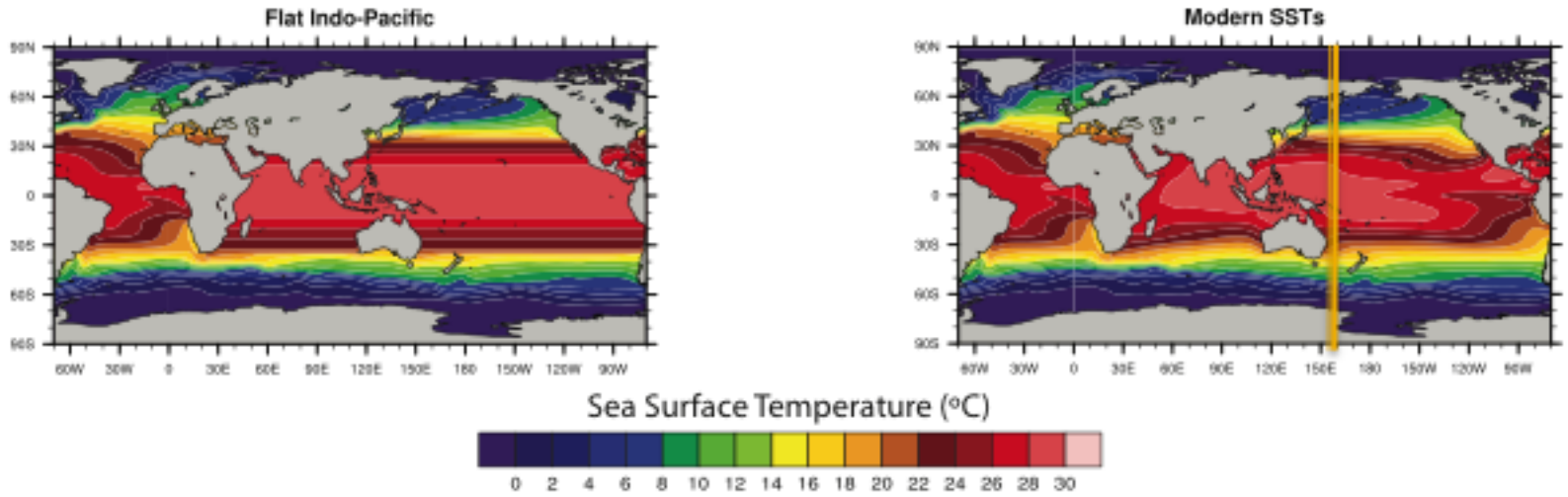


- East African becomes more arid, possibly impacting human evolution
- Zonal temperature gradients develop in both the Indian and Pacific Oceans

Are the two connected?

A Climate Model Experiment

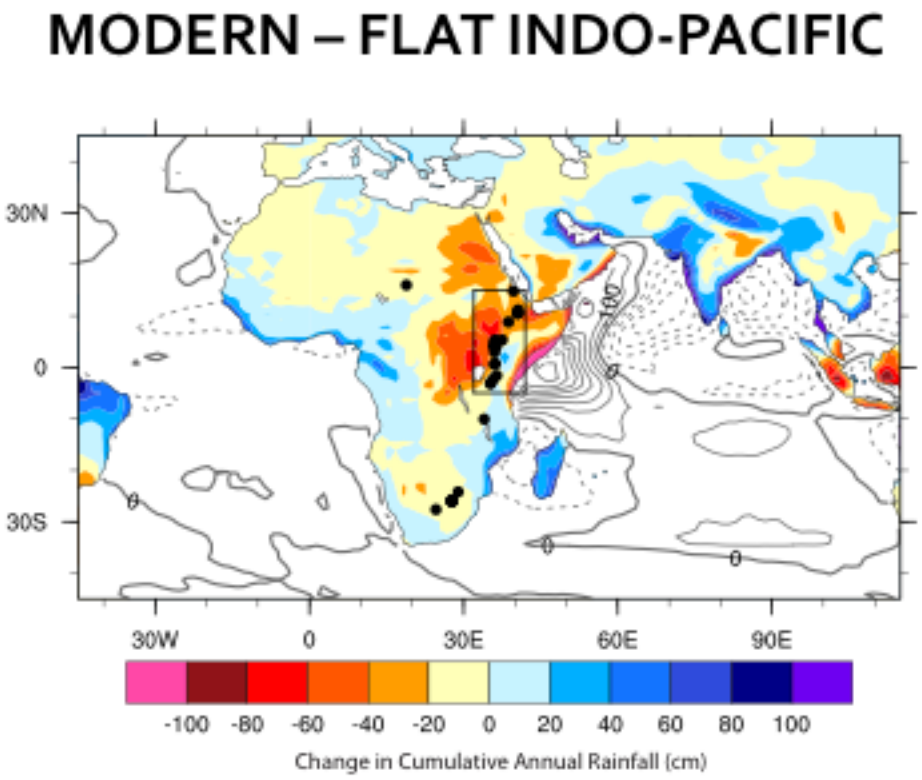
Creating the SST field



- Follow same methodology as prior work:
  - Impose SSTs underneath atmosphere model
- Create SST field by extending conditions from 155°E across Indo-Pacific, between 35° N/S

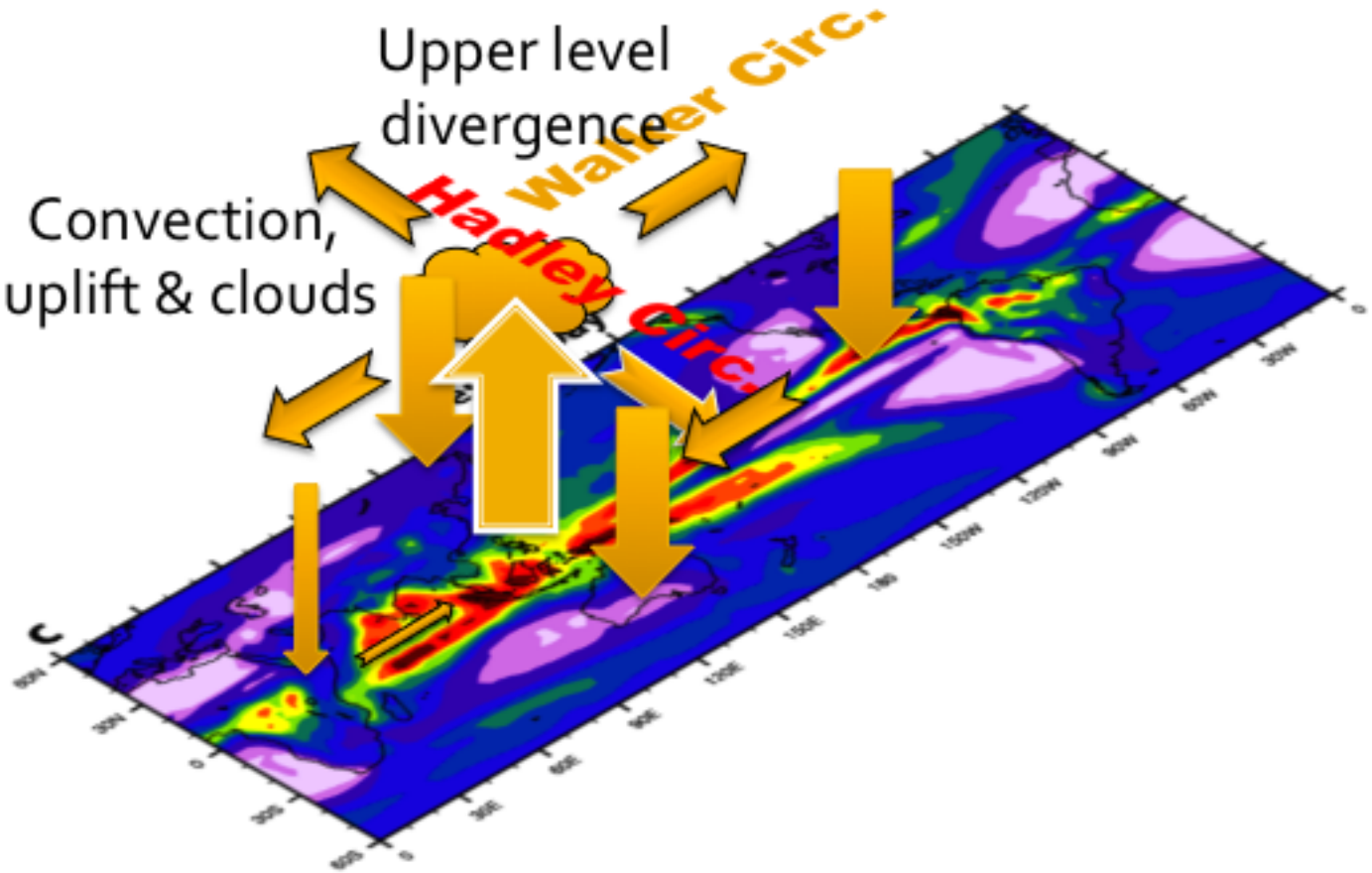
Rainfall Impacts

- A world without zonal temperature gradients in the Indo-Pacific has wetter conditions over East Africa
- The observed development of SST gradients would have caused a large-scale drying of East Africa
- Why does this happen?



How does developing zonal gradients cause African drying?

Review of the tropical circulation

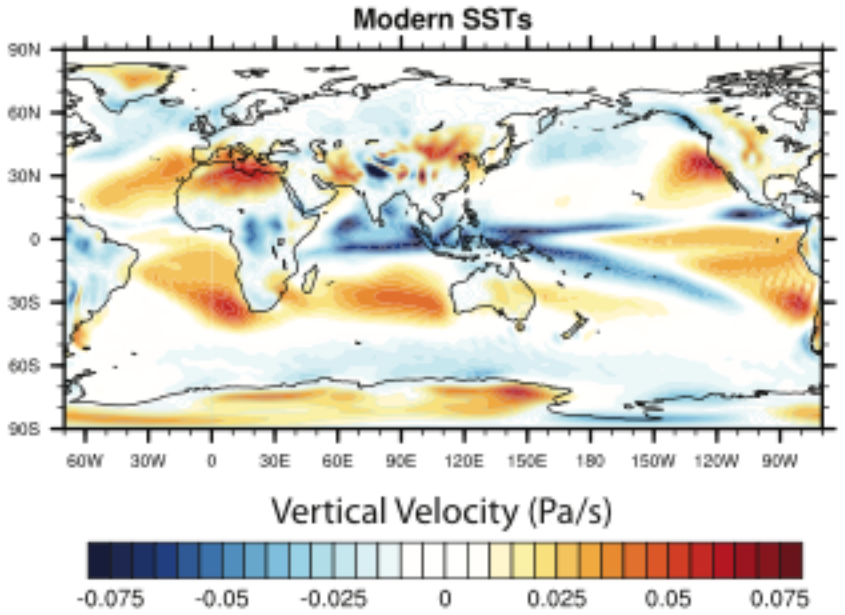


Vertical Pressure Velocity

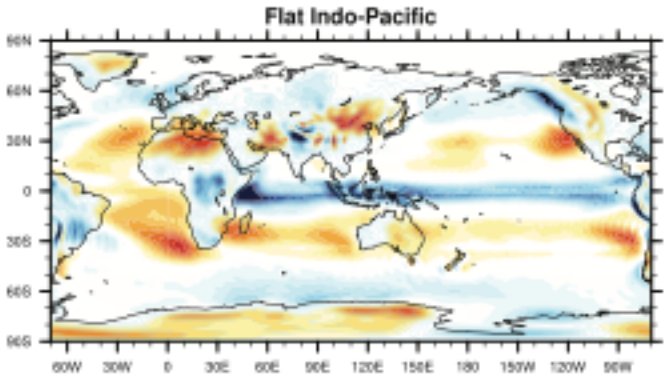
- Blue is uplift of air
- Red is sinking

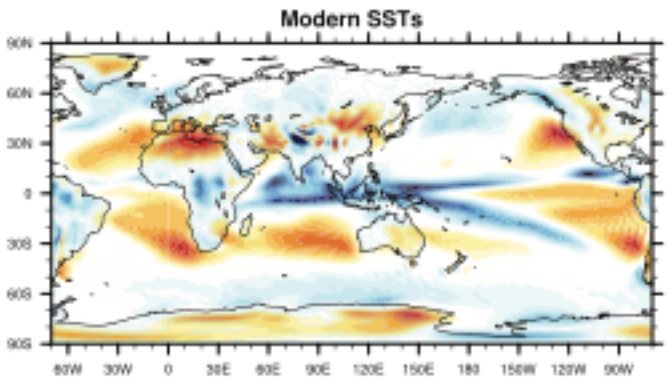
- Convection over warm pool & ITCZ

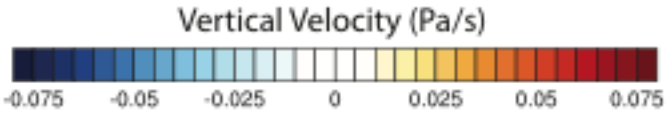
- Sinking under Hadley cell and in East Pacific



Uplift in Flat Indo-Pacific

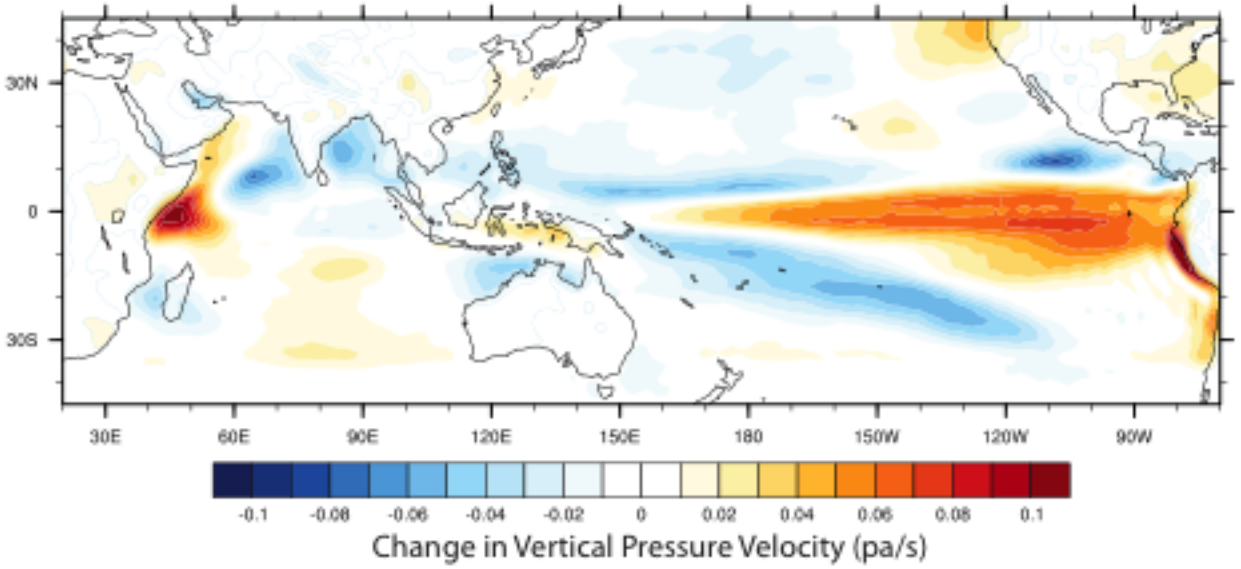






- In the simulation with warm waters stretching along the Equator
- Uplift right the way along Equator
- Strongest uplift off East Africa

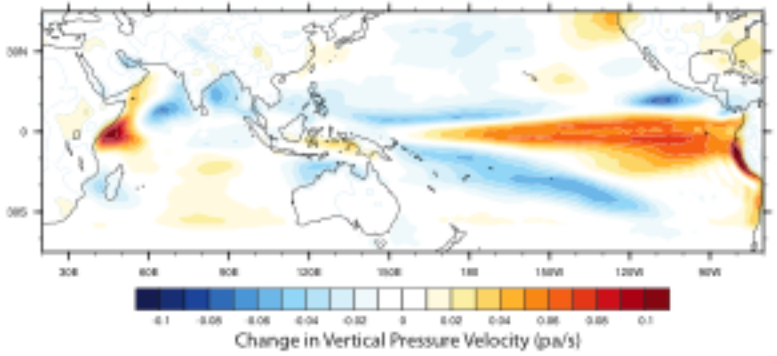
Difference in vertical velocity

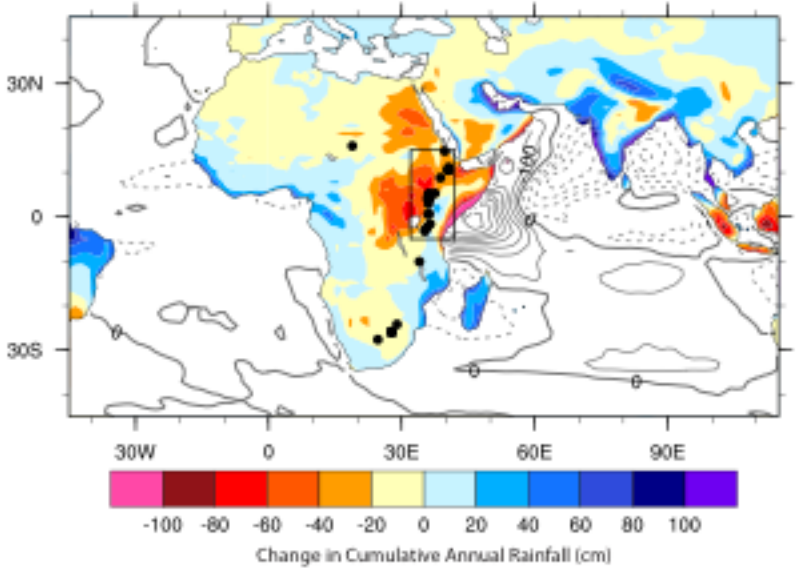


- Modern SSTs – Flat Indo-Pacific
- So as develop SST gradients, we lose the uplift off East Africa
- Much less convection off East Africa

Reduced Uplift and Precip

- Reduced convection means less rainfall
- Reduction in rainfall strongest over ocean
- Some impacts on land, which the signal discussed earlier

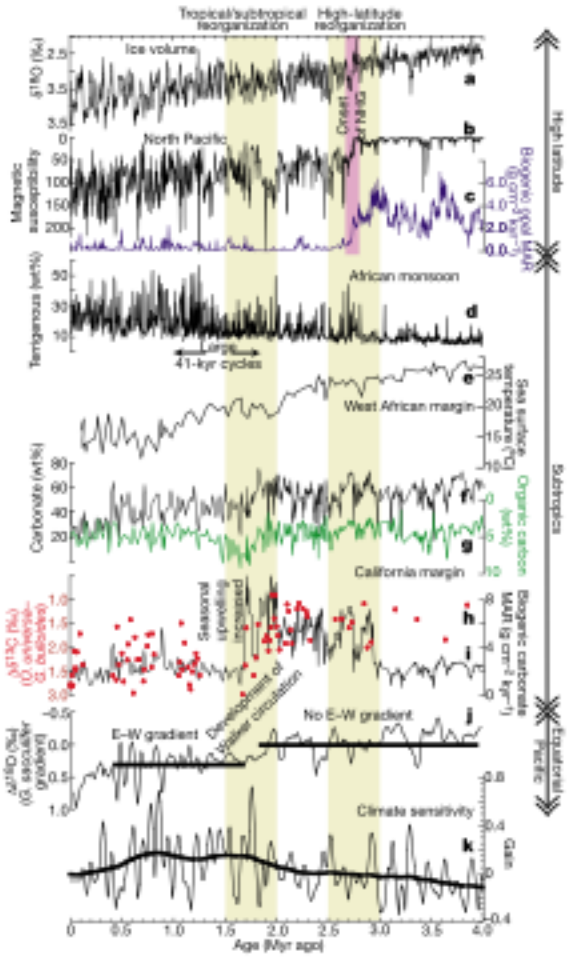




Is this new?

- The development of the Walker circ. has been noted before
- Consequences for Africa discussed
- But not shown explicitly

- However, in model world we can dig deeper…



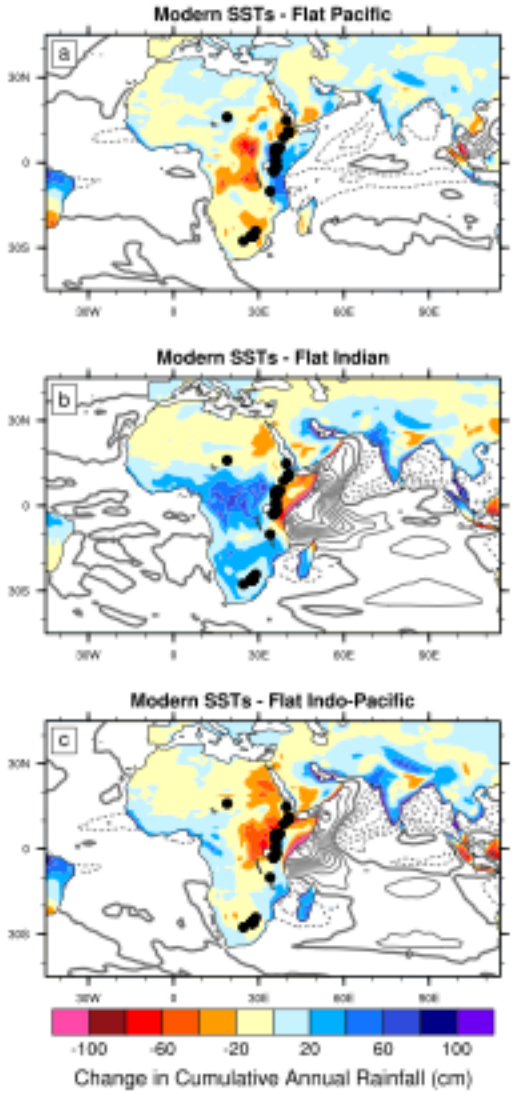
Ravelo et al. 2004

Indian or Pacific?

The zonal SST gradient develops at a similar time, but which ocean dominates the signal over East Africa?

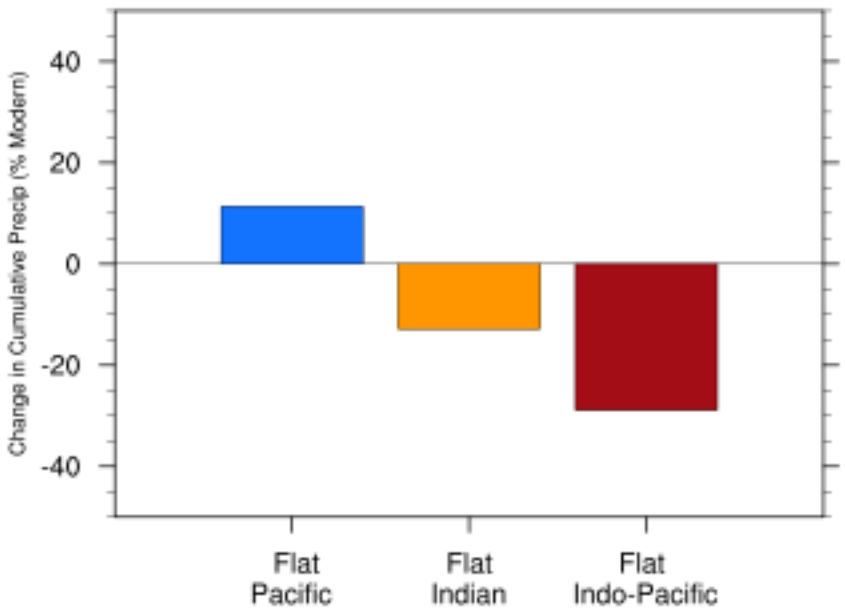
Developing the gradients alone

- Simulations with flat SSTs in either Indian or Pacific ocean alone
- Have roughly reversed dipole patterns, unlike combined
- Boundary lies roughly along Rift Valley



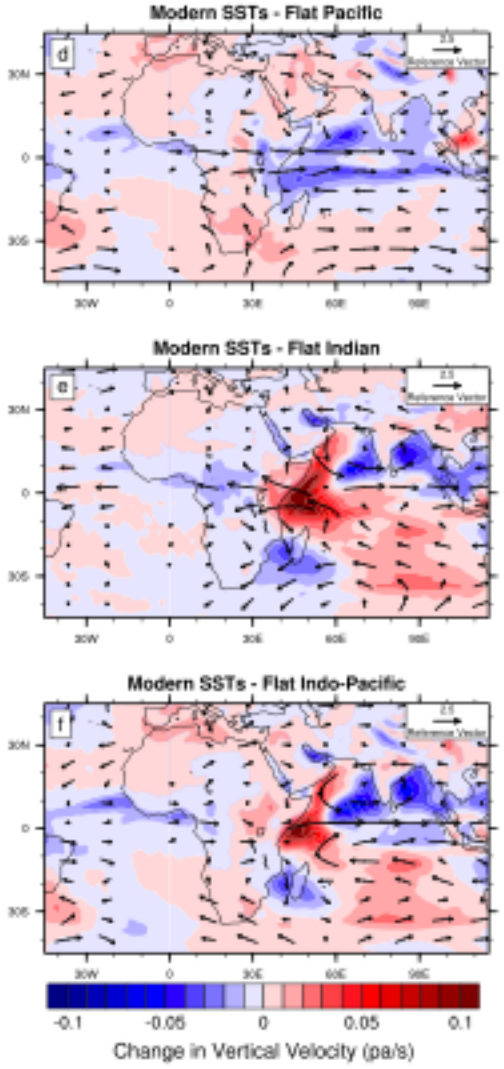
Non-Linearity

- Combined response is not a simple sum of its parts
- Take area average over Rift Valley (only land)
- Non-linearity with most choices of region, but amounts change



Reasons for Non-linearity

- Developing Pacific gradient only has increased uplift, but winds coming more from interior
- Developing Indian only has much less uplift, but winds from ocean
- Combine uplift and wind direction impacts



Summary of Results

- Paleobservations show that the SST gradient along the Equator in both the Pacific and Indian develops around 1.9Ma
- Developing such gradients can cause aridification of East Africa, as is observed
- This drying of East Africa influenced human evolution
- The fact that both SST gradients developed at the same time is essential

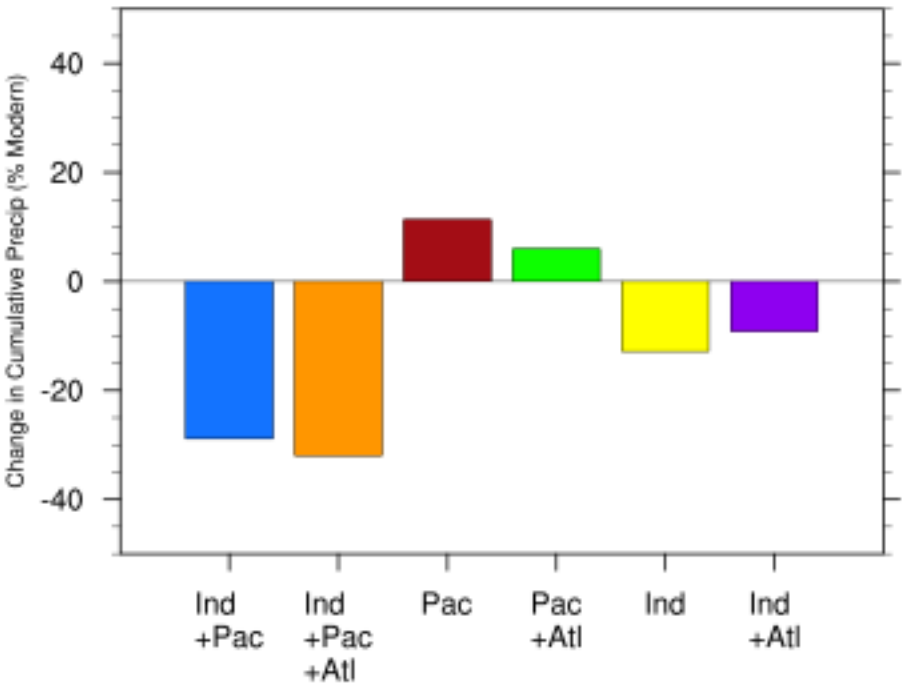
Where do we go from here?

This study has possibly asked more questions that it has answered

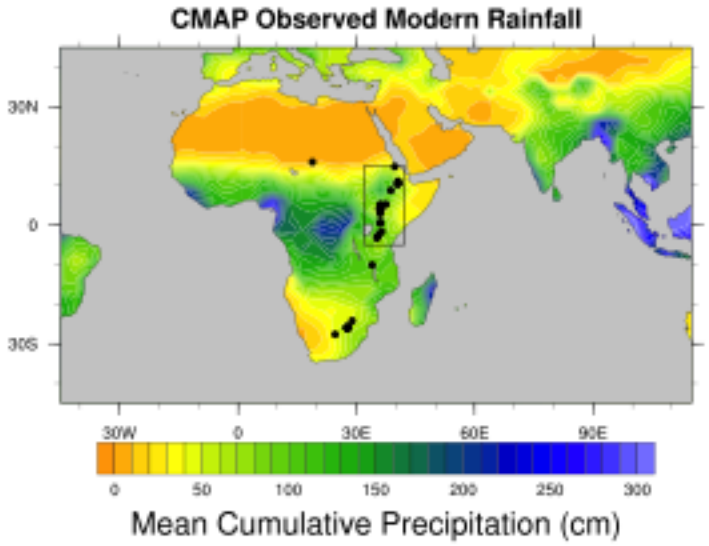
A). Questions arising about the methodology
B). Questions arising from my interpretation of the paleobs.
C). The ultimate cause of the changes

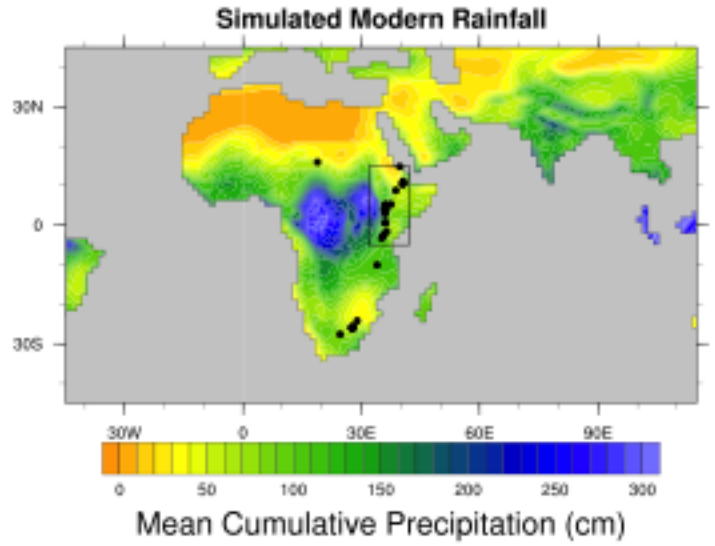
Role of the Atlantic

- Paleobs possibly show development of the Atlantic gradient
- Performed additional simulations with flat SSTs in the Atlantic
- Little change to story: IndoPacific dominates

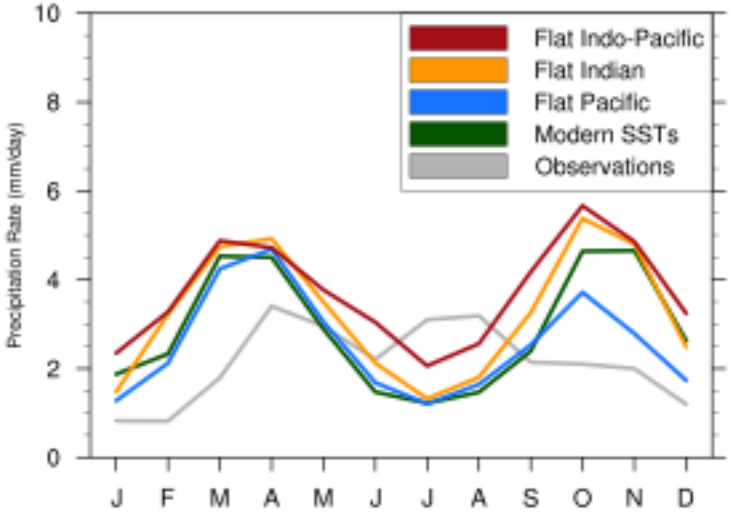


Model Biases

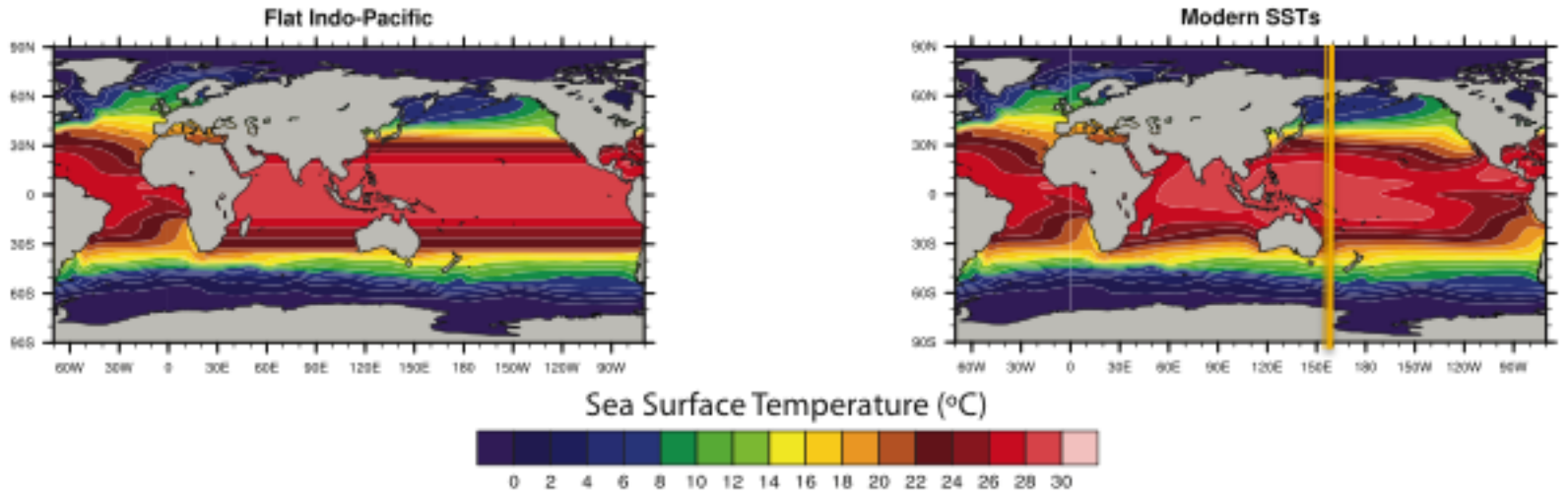




- CAM3 is not brilliant over East Africa
- Issues with both spatial and temporal pattern



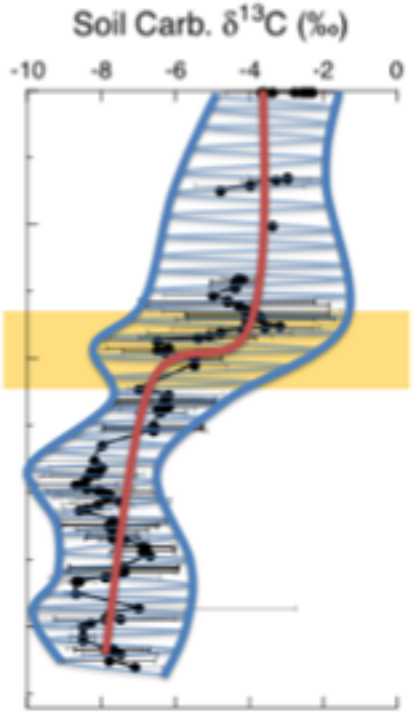
Realism of no zonal gradients



- This study removed all coastal upwelling
  - Removes monsoon
- Convection will occur over the warmest waters
- Would even a very weak SST gradient lead to concentration of convection over the warm pool?

Variability / Pulsed Variability

- I suggested data showed secular trend
- It may also show changes in variability
  - may be the climate driver of human evolution
- Paleolake data shows pulses of strong orbital activity, one coinciding with SST gradients



Interaction with orbital variability

- East Africa not been a focus of simulations of orbital variability
- Regional model probably needed

- Interesting to see how SST gradients and local orography modify orbital impacts

- Should also include vegetation changes: either prescribed or interactively

Reasons for SST gradient changes

- So East African climate change was caused by the development of zonal SST gradients…
- But, why did zonal SST gradients develop?
- Needs further research
  - Part of a gradual shoaling of thermocline?
  - Changes in vertical mixing?
  - Somehow tied to a high-latitude tipping point?

Summary

- Zonal SST gradients developed ~1.9Ma in both Pacific and Indian
- Model study shows this would cause a drying of East Africa, as shown in observations
- Drying of East Africa influenced human evolution
- Therefore:

Development of zonal SST gradients in Indo-Pacific influenced human evolution

- Story is more complex and deserves further research
- Outlined some questions that need to be addressed

Chris Brierley

With Peter deMenocal (Columbia), Alexey Fedorov (Yale)

Equatorial Temperature Gradients and Human Evolution