Deglacial ITCZ shifts and Human Population Responses

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Overview

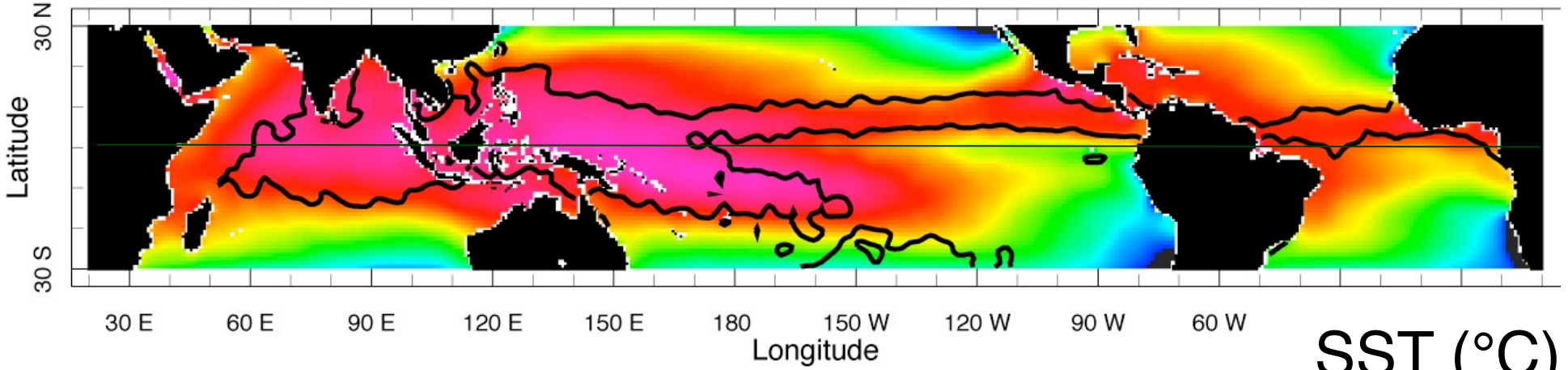
Part 1

- Signature of and controls on marine ITCZ
- Atlantic and Pacific ITCZ shifts since 20 ka

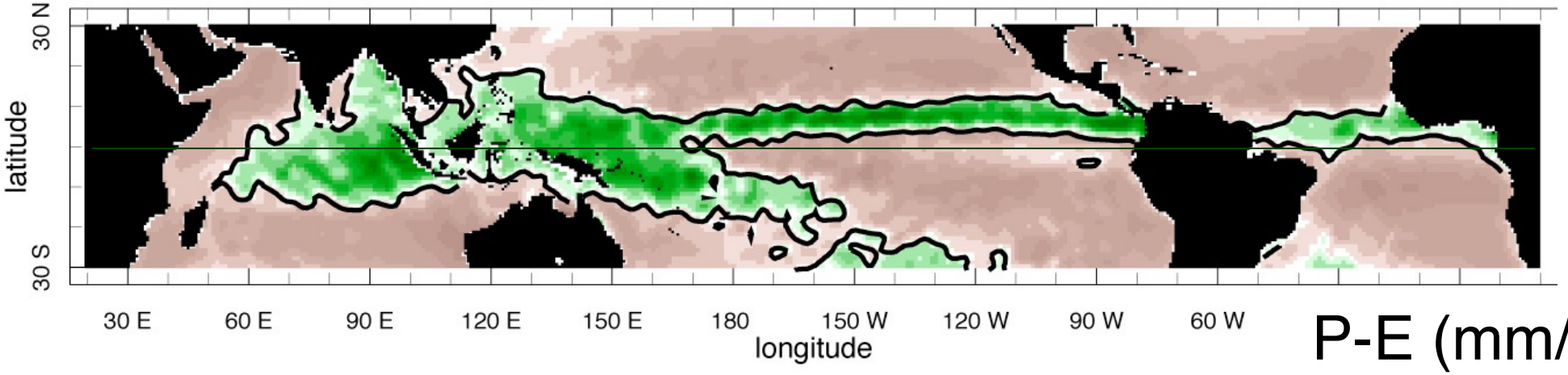
Part 2

- North African climate and vegetation
- Human population dynamics

Tropical ocean temperatures and rainfall

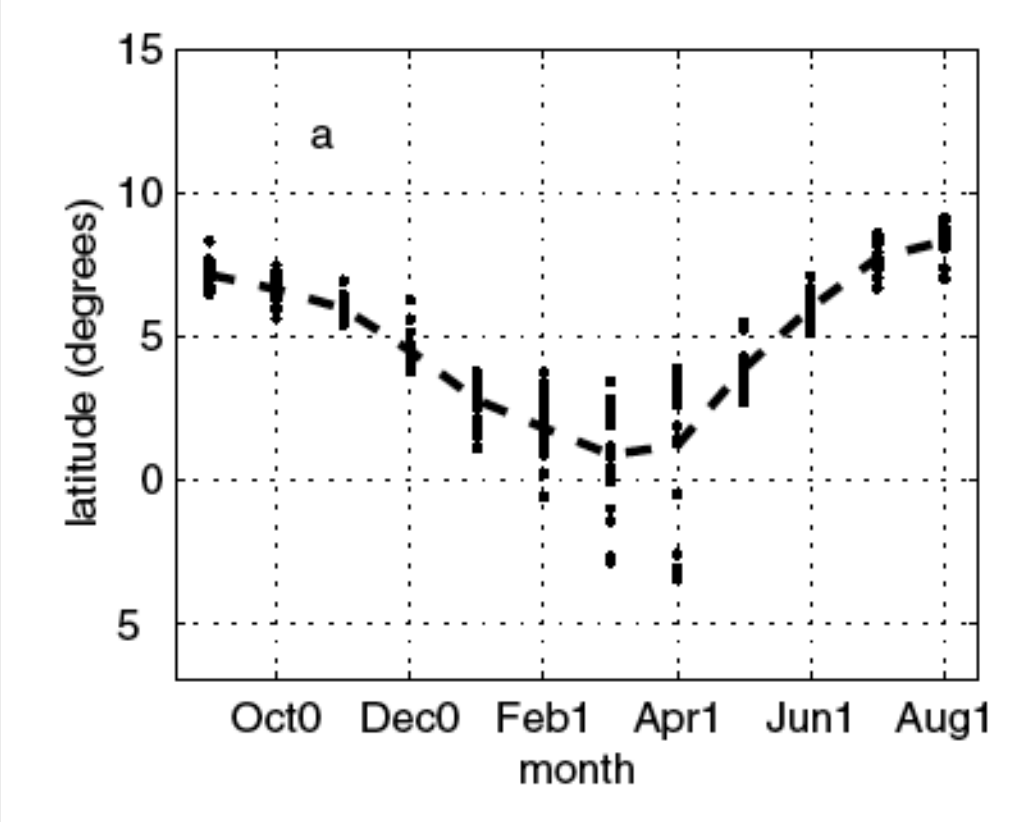


SST (°C)



P-E (mm/d)

Historical Atlantic ITCZ variability



Base period
1979-1999

Interannual-decadal variability: **± 2° latitude**

Chiang, 2002

Part 1: What controls the mean ITCZ position

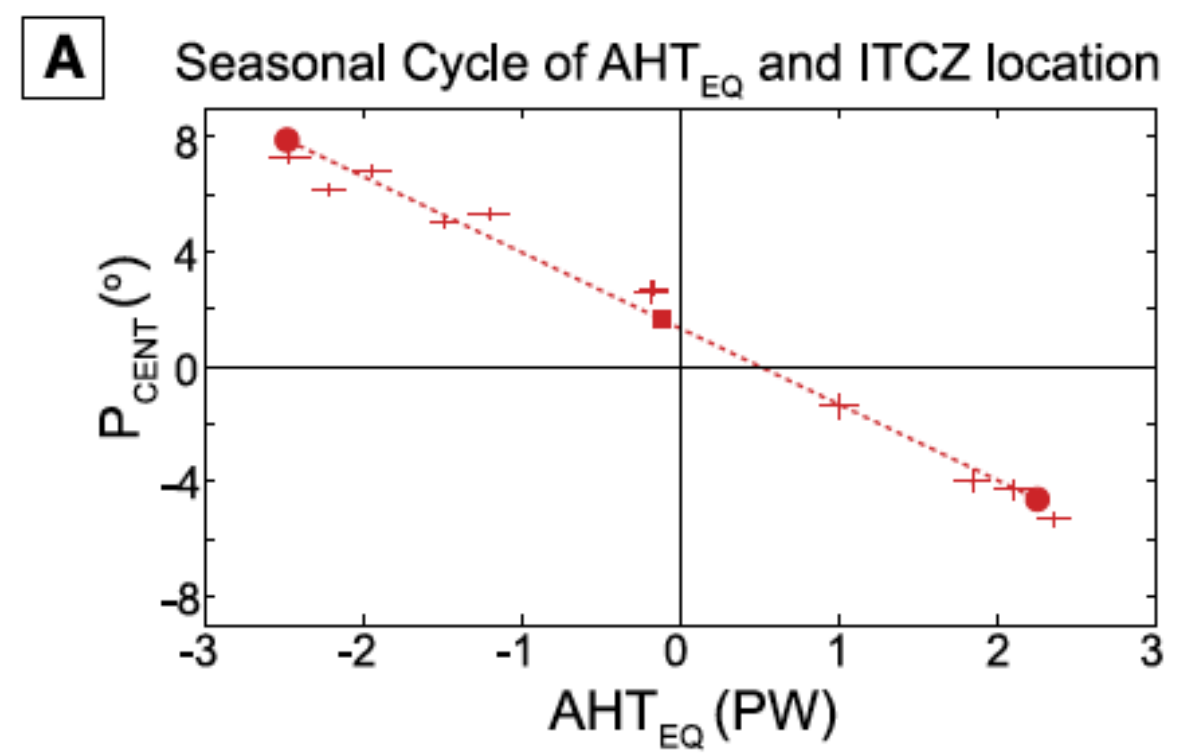
1) **Interhemispheric T difference (global)**

- ITCZ shifts away from colder hemisphere.
- Hadley circulation transports heat to winter hemi.

2) **Orbital monsoon forcing (regional)**

- Stronger monsoonal circulation from orbital precession draws 'rain belt' away from equator.

Seasonal ITCZ amplitude and heat transport

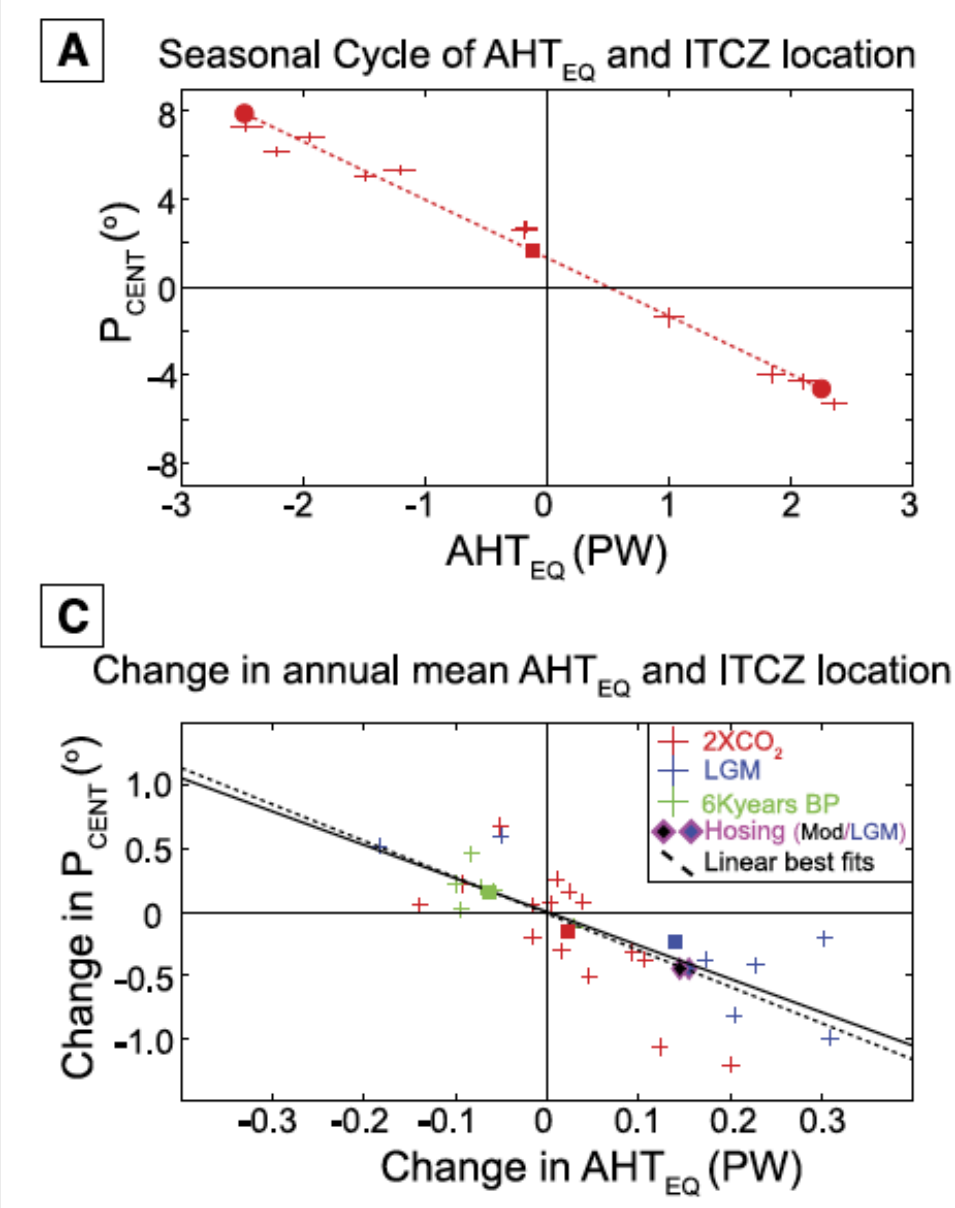


Slope:
1PW per 3° shift

ITCZ seasonal range of ±6° is associated with ±2.5 PW atmospheric heat transport toward winter hemisphere

McGee et al., 2014
Donahoe et al., 2013

How large were past global ITCZ shifts ?



Slope is remarkably constant for 2xCO2, LGM, 6K, Hosing experiments,

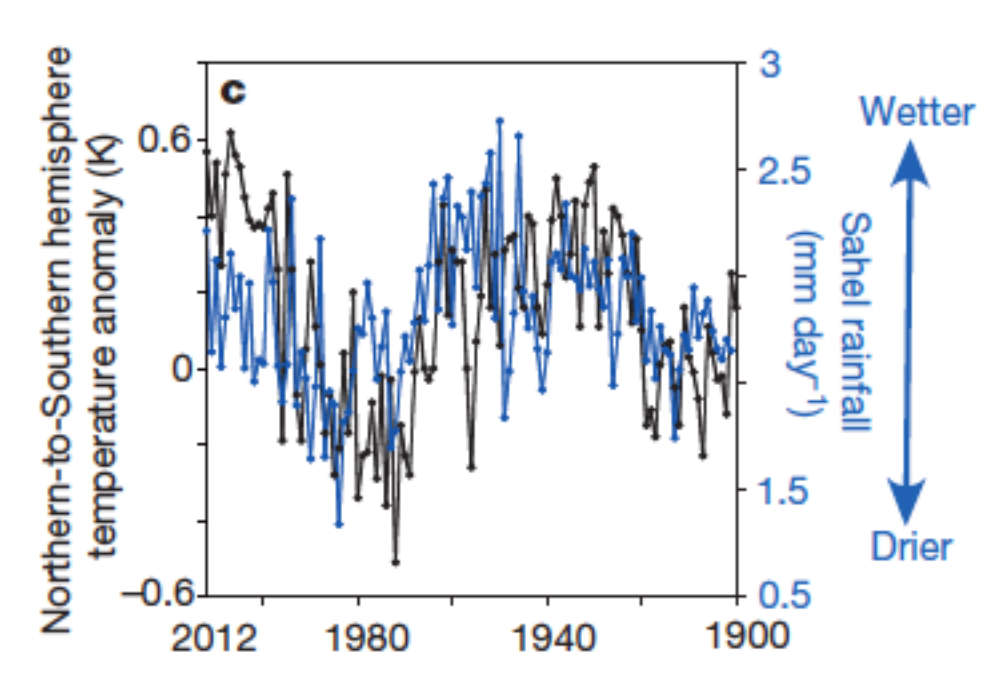
approx. 3° shift per 1PW

Places fundamental limits on magnitude of global mean ITCZ shifts.

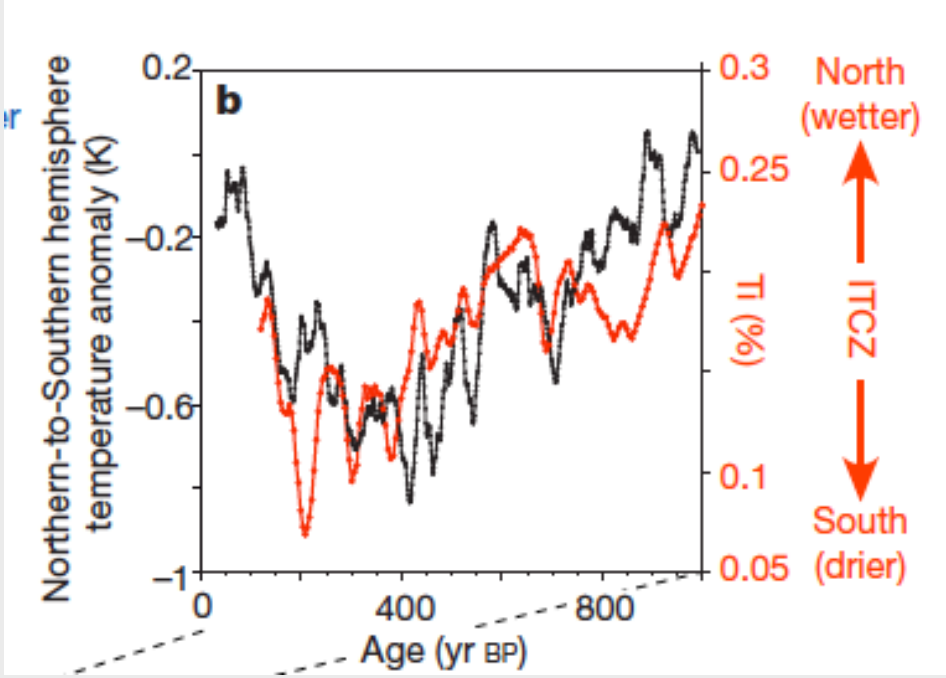
McGee et al., 2014
Donahoe et al., 2013

ITCZ - Historical and last millennium

Last Century



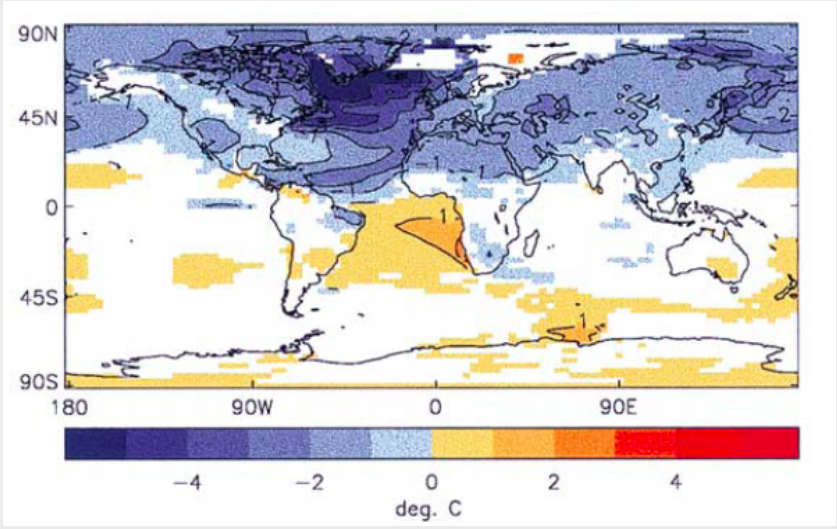
Last Millennium



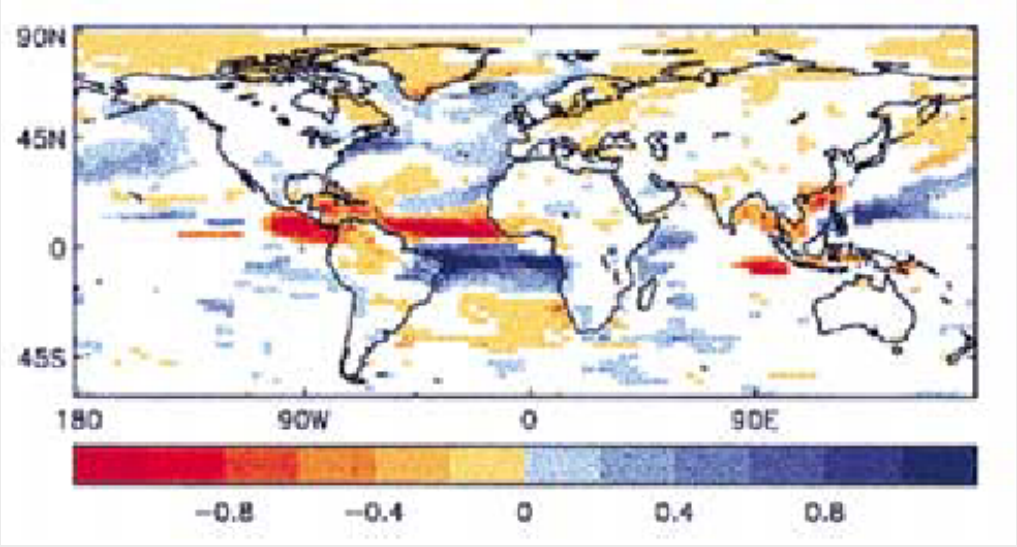
Importance of the interhemispheric T-gradient

Schneider, Bischoff, Haug, 2014

Atlantic ITCZ shift in hosing experiment



Δ temperature (°C)

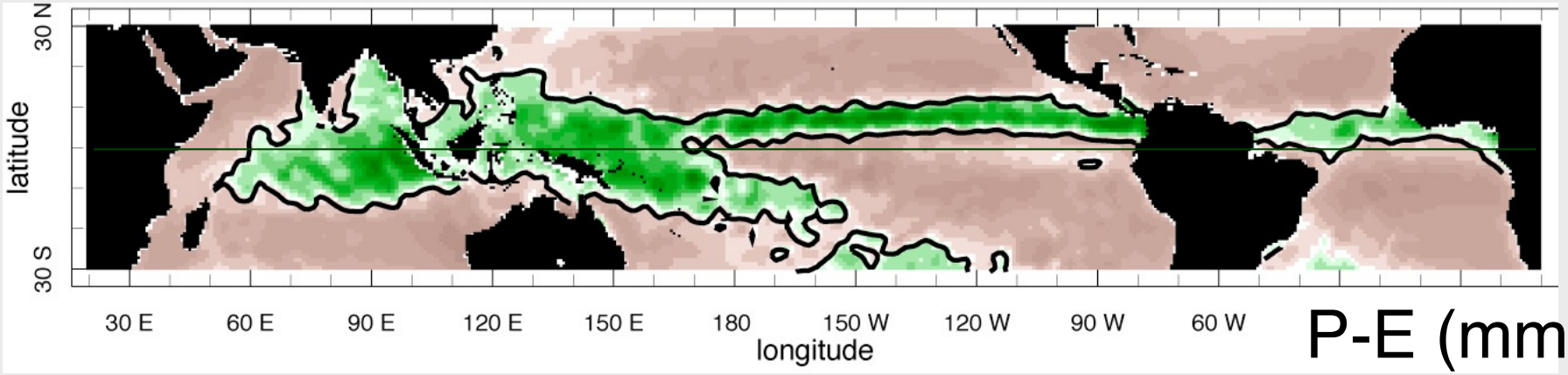


Δ precipitation (m/y)

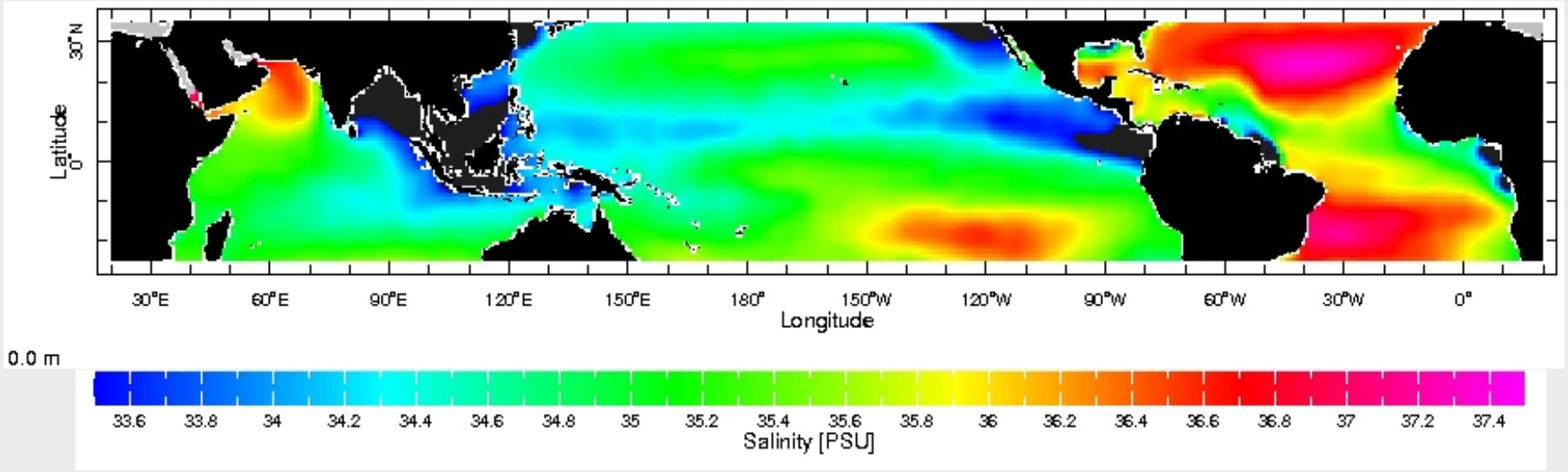
10° southward ITCZ shift

Vellinga and Wood, 2002

ITCZ imprints ocean salinity field

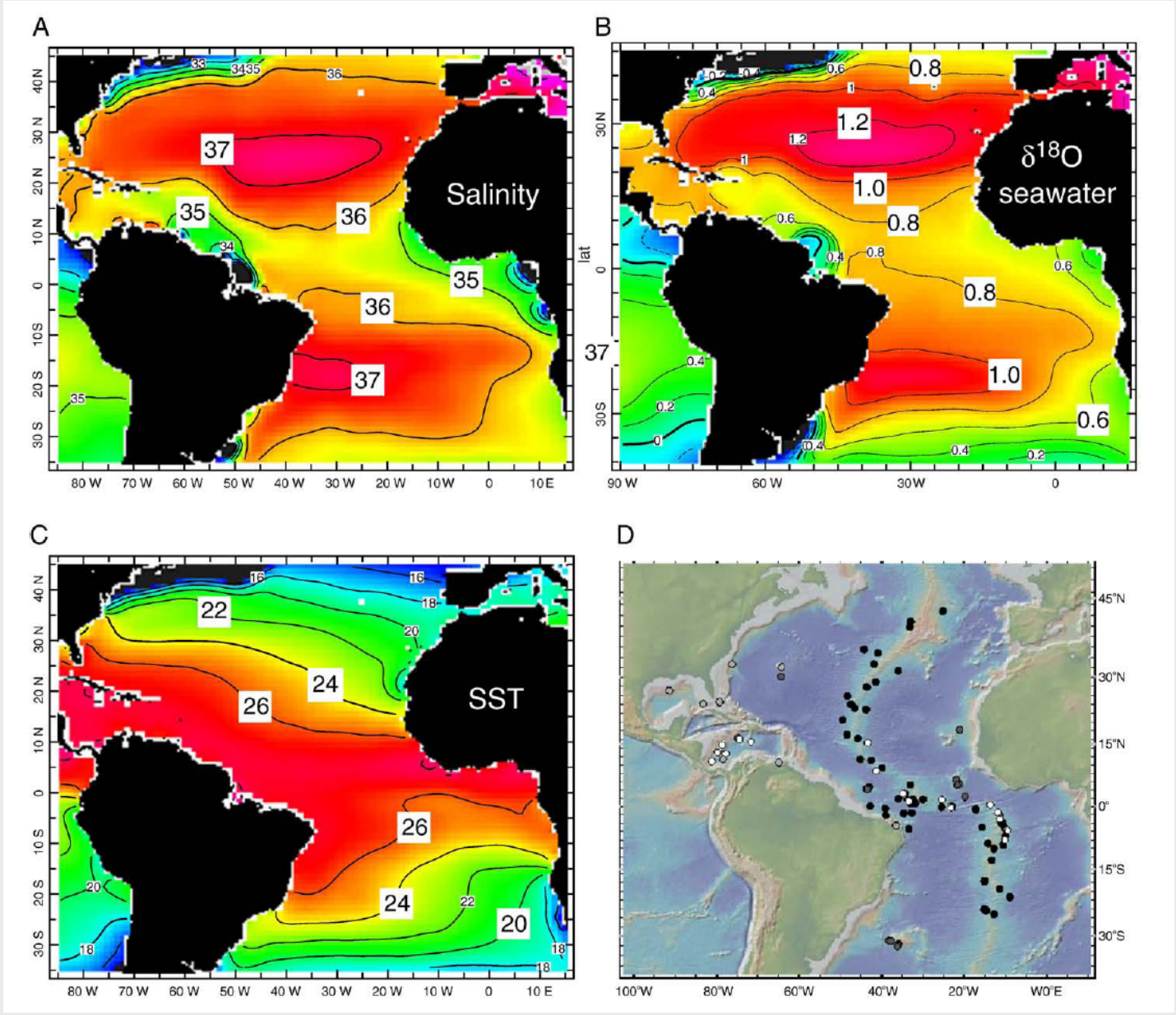


P-E (mm/d)



Salinity

Coretop Calibration



Arbuszewski et al., 2010

Estimating $\delta^{18}O_{seawater}$ with Foram Chemistry

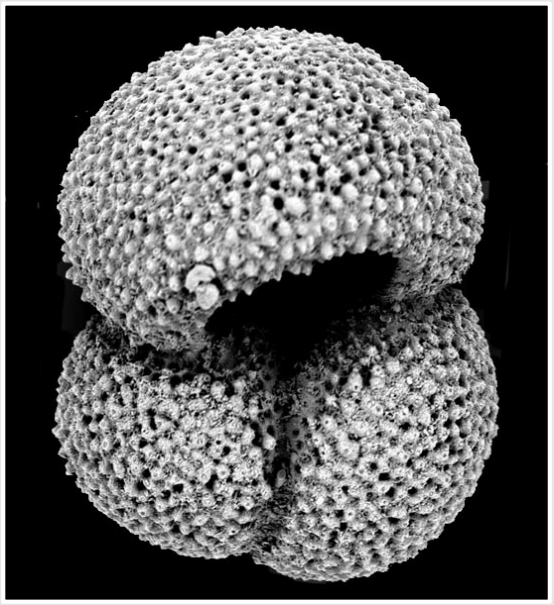
Isotope temperature equation (Bemis et al., 1998):

$T\ (°C) = 16.5 - 4.80\ (\delta^{18}O_{shell} - \delta^{18}O_{seawater})$

Mg/Ca temperature equation (Dekens et al., 2002):

$T\ (°C) = \ln (Mg/Ca / 0.38) / 0.09 + 0.61 * \text{core depth(km)}$

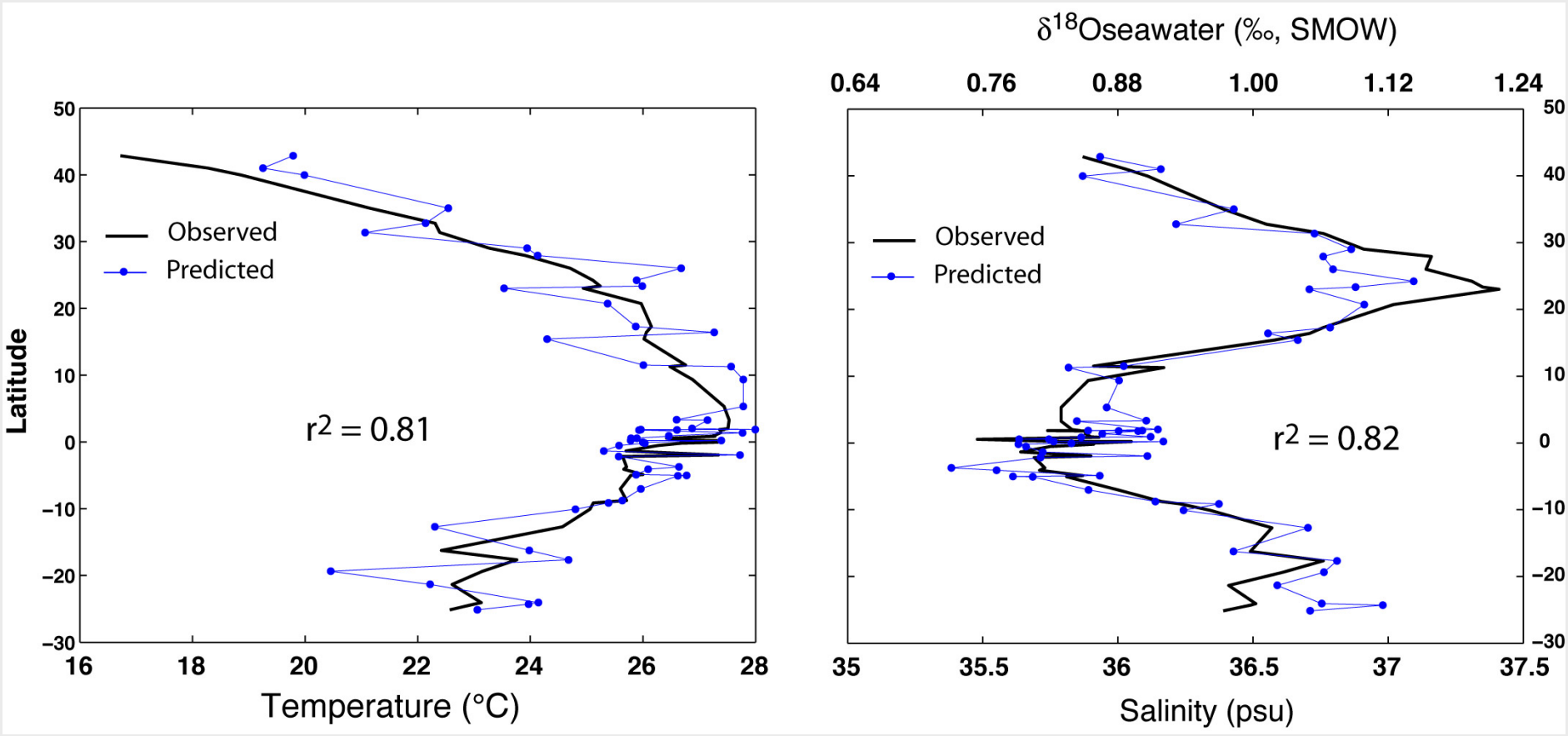
$$\text{Shell } \delta^{18}O_{seawater} = \delta^{18}O_{shell} + (T_{Mg/Ca} - 16.5)/4.8) + 0.27$$



G. ruber (white)

Arbuszewski et al., 2010

Proxy Calibration



RMSE ± 1.1°C

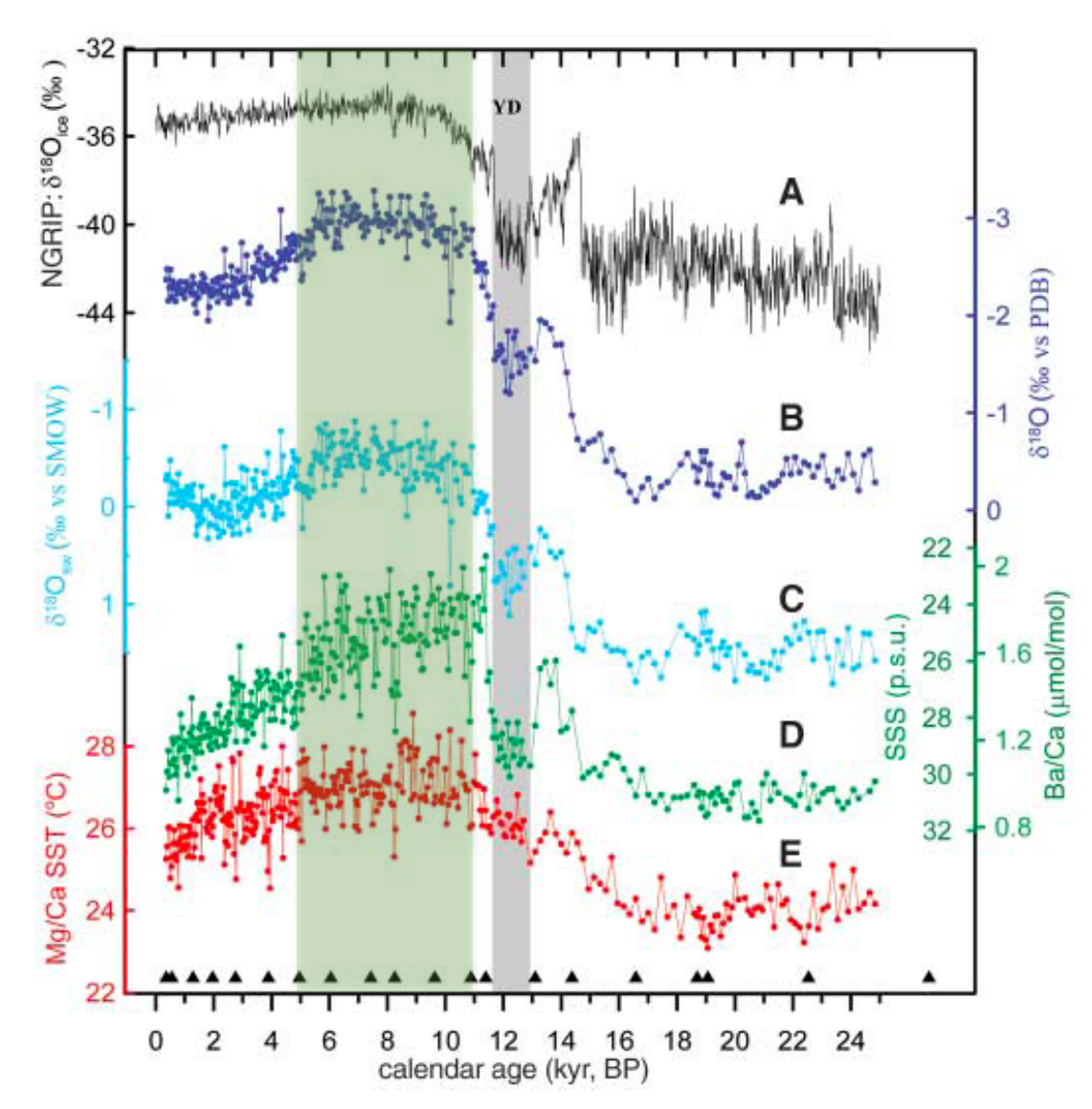
RMSE ± 0.20 PSU, or ± 0.05‰ SMOW

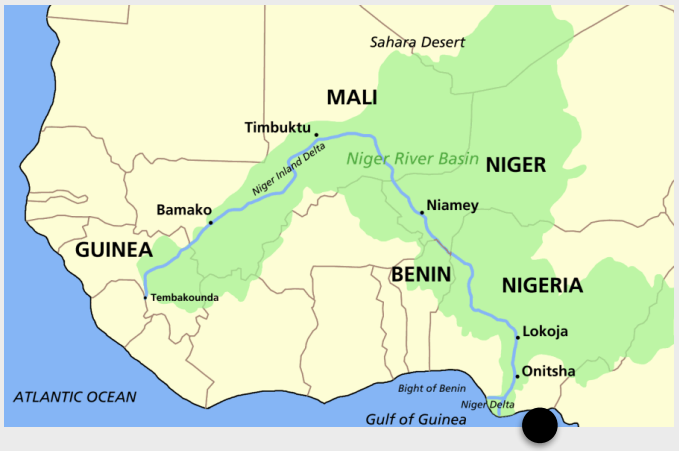
Arbuszewski et al., 2010

Enhanced Niger River runoff - early Holocene

fresh

salty



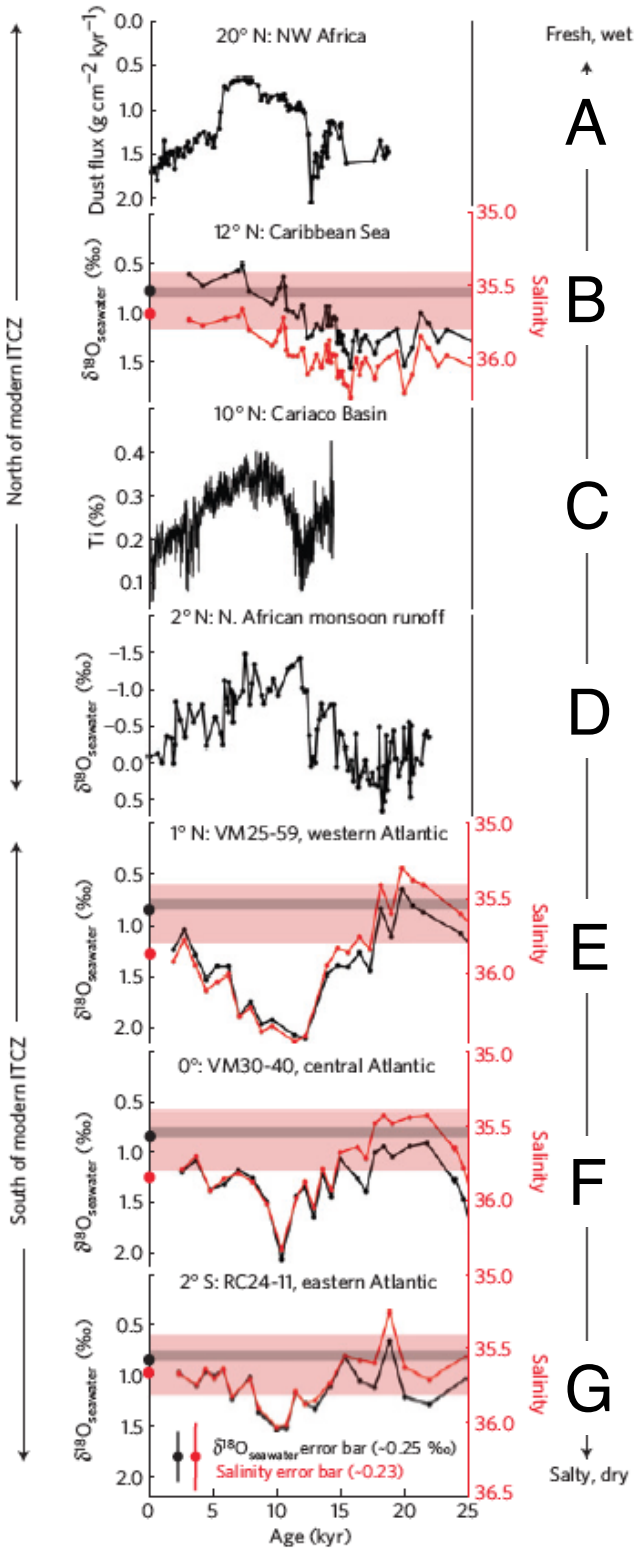


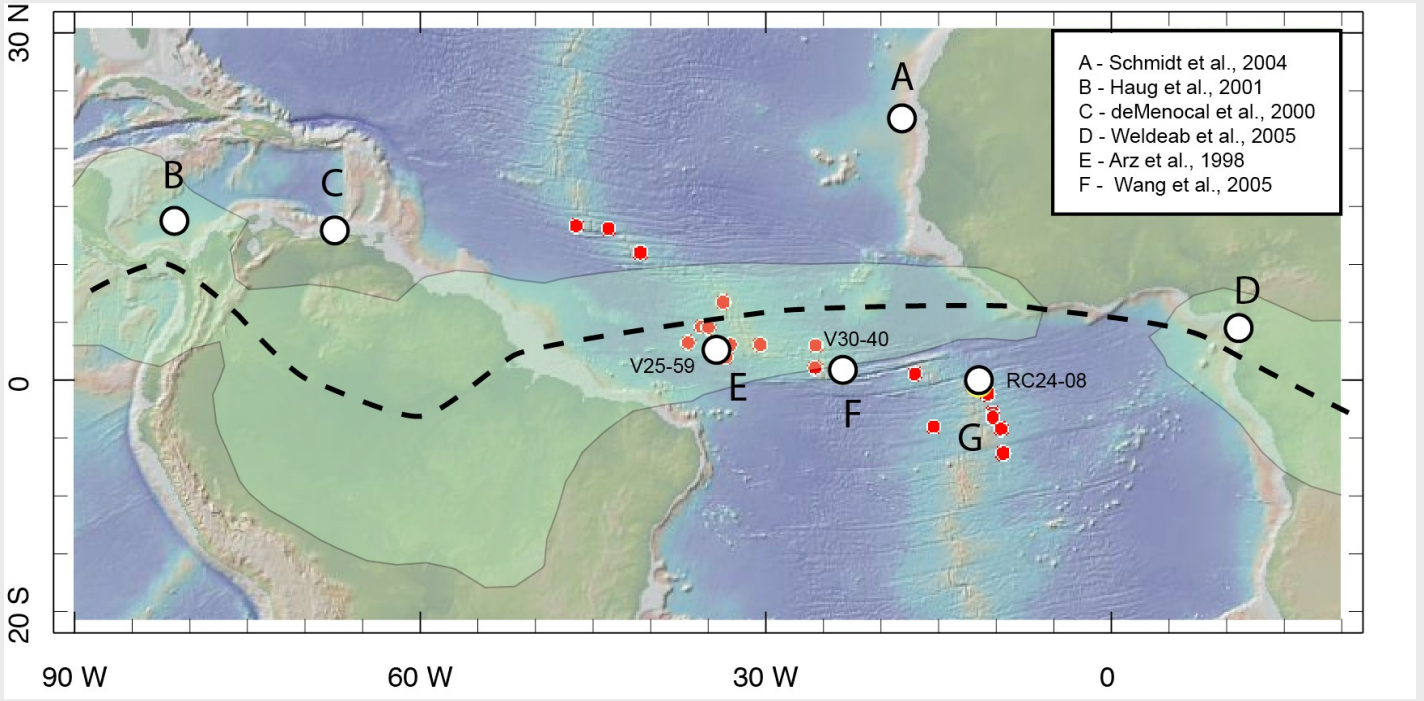
AHP

Weldeab et al, 2009

Deglacial Atlantic ITCZ shifts

S'ward shift during stadials due to N. Atl. cooling
N'ward shift follows early Holocene insolation





low salinity

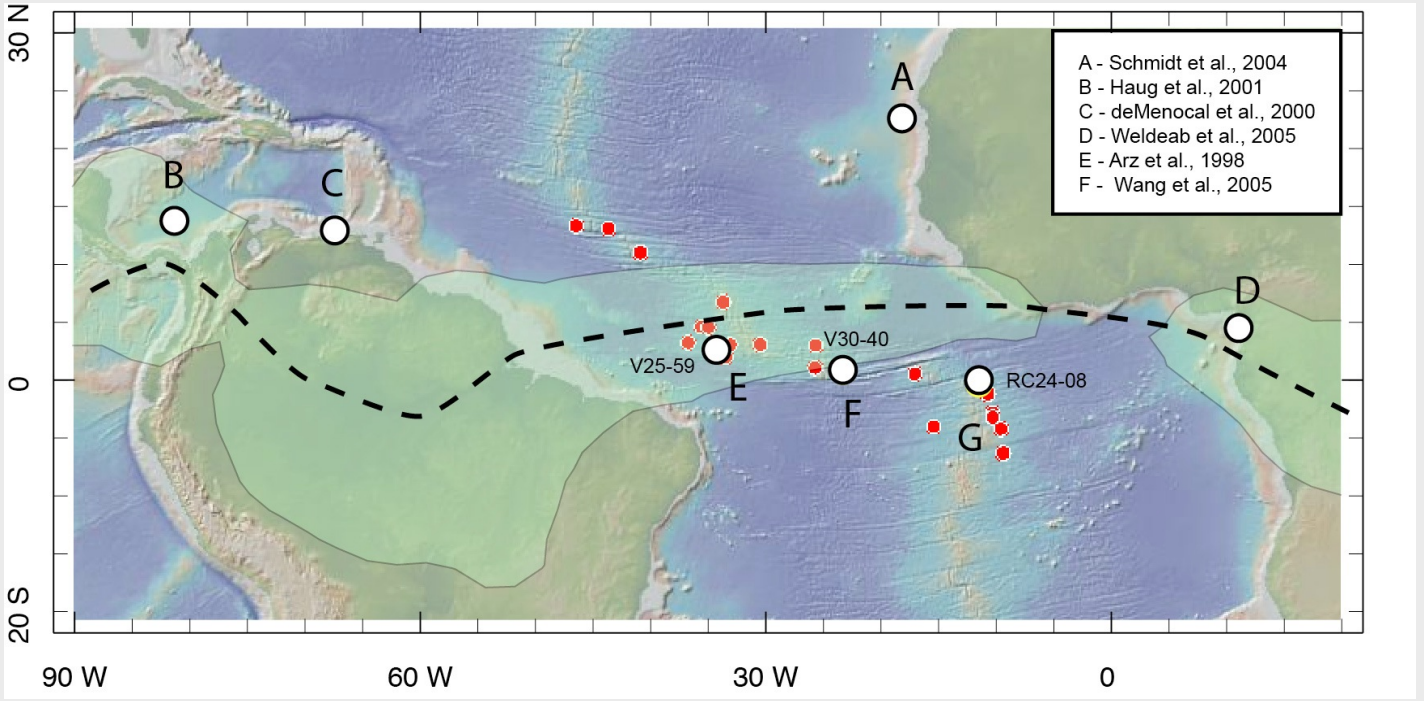
high salinity

Arbuszewski et al., 2013

Deglacial marine ITCZ amplitude

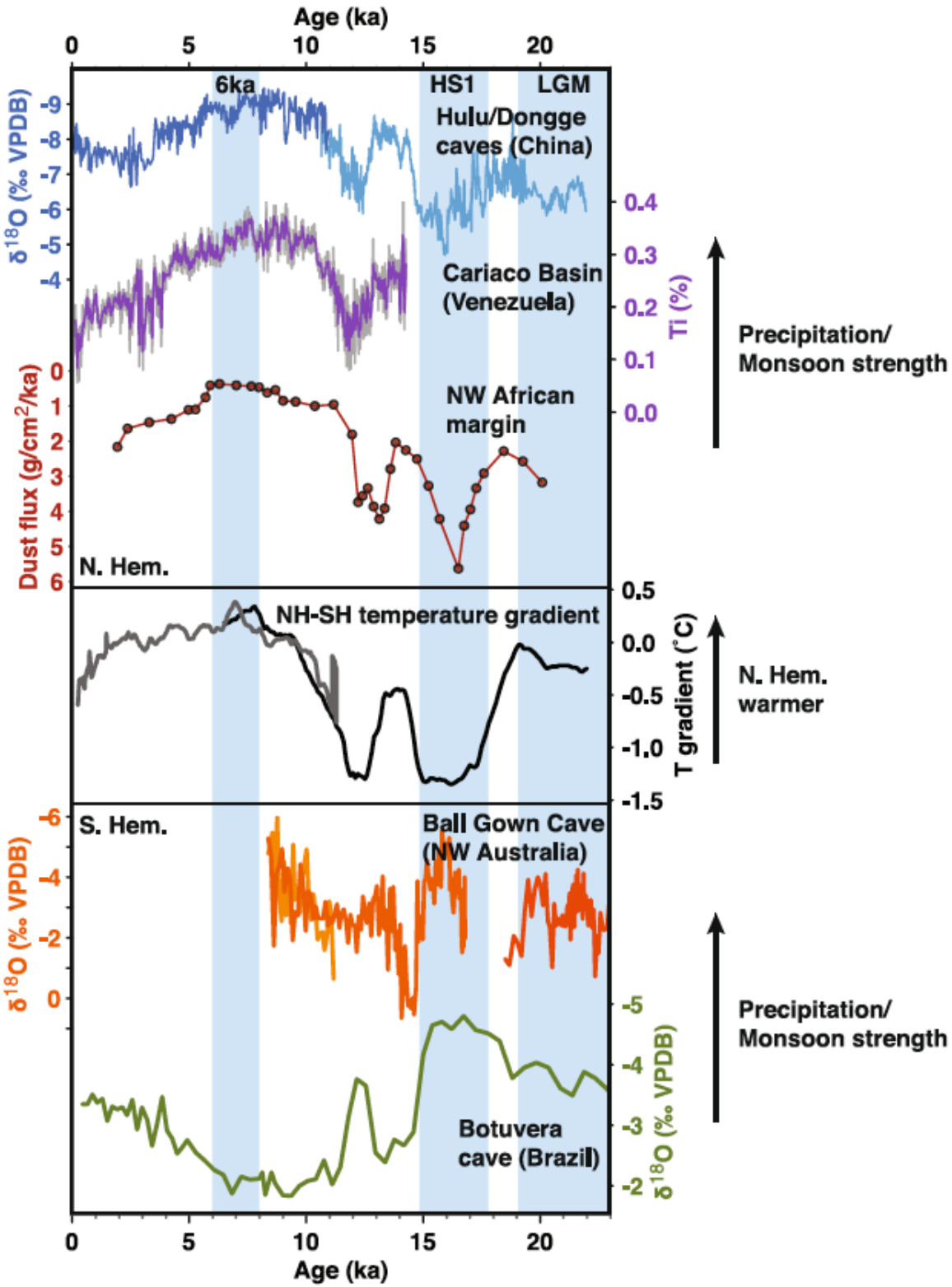
Deglacial ITCZ ranges from Atlantic $\delta^{18}O_{SW}$

5°N - Modern
12°N - E. Holocene
2°S - Heinrich 1



Deglacial Atlantic ITCZ shifts: ±7 ° latitude ?

Arbuszewski et al., 2013



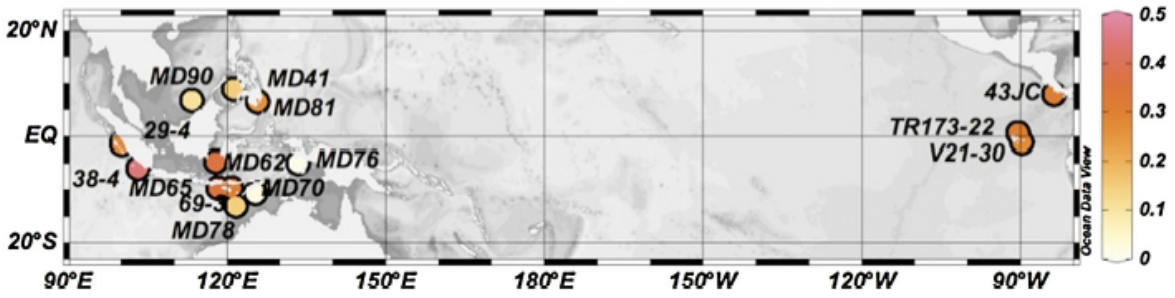
Antiphasing of tropical *precipitation* records.

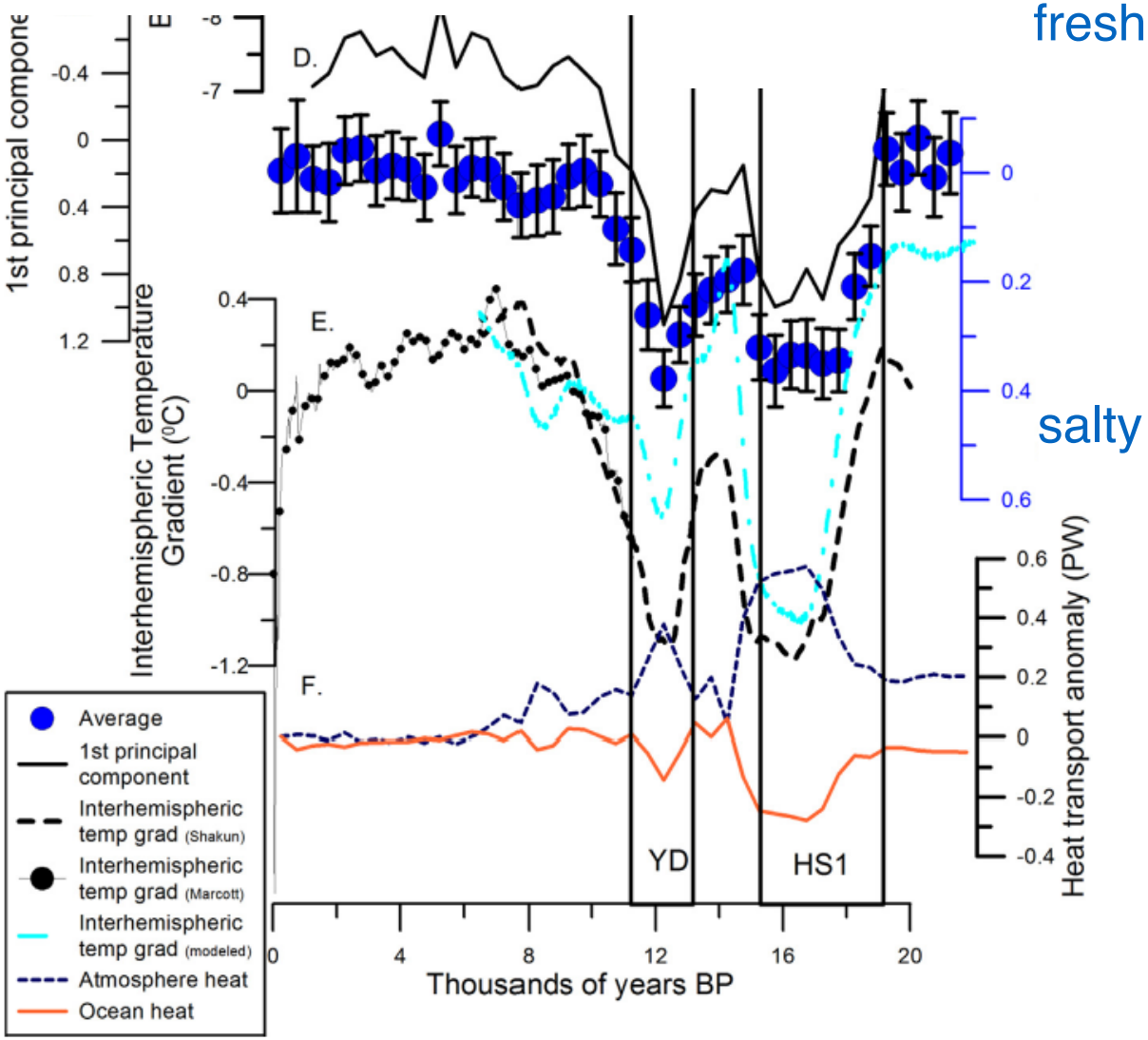
Paced by cross-equatorial T-gradients

Ultimately linked to orbital and high-latitude forcing

McGee et al., 2013

Pacific ITCZ





ITCZ shifted south during stadials…

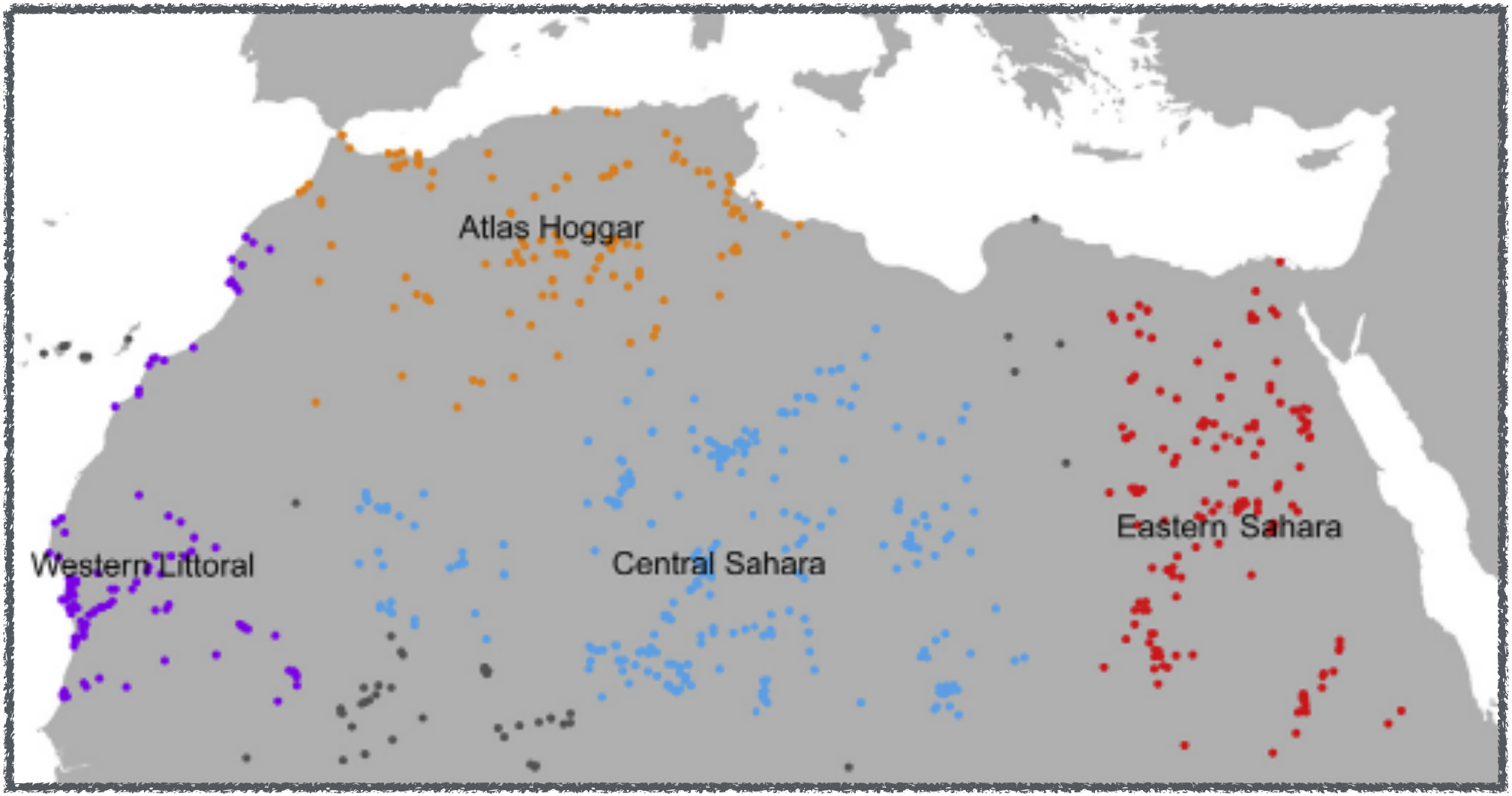
… but no northward shift during Holocene ?

Gibbons et al., 2014 EPSL

Part 1 Summary

- Observations and models suggest global ITCZ position restricted to <1° departures from mean.
- Atlantic marine ITCZ appears to have shifted ±7° over the last 25 ka. Pacific ITCZ shifts were large too.
- Paleo-data may have seasonal bias, certainly regional biases.

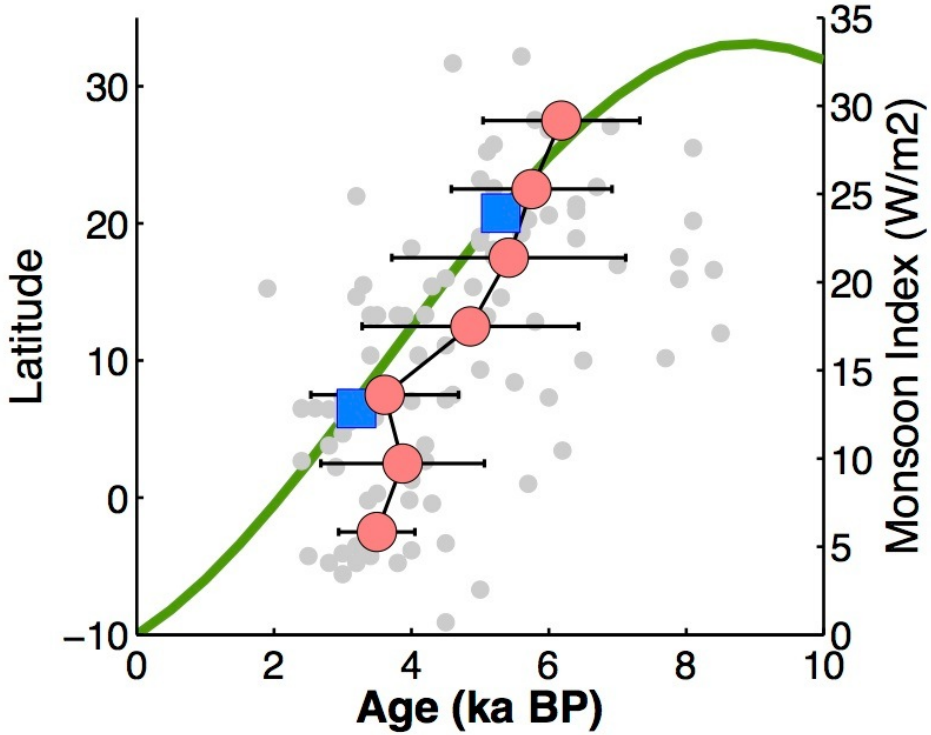
Part 2: Holocene population dynamics



Manning and Timpson, 2014

Time-transgressive end to the AHP

AHP ended first in north, later in the south - tracking insolation.

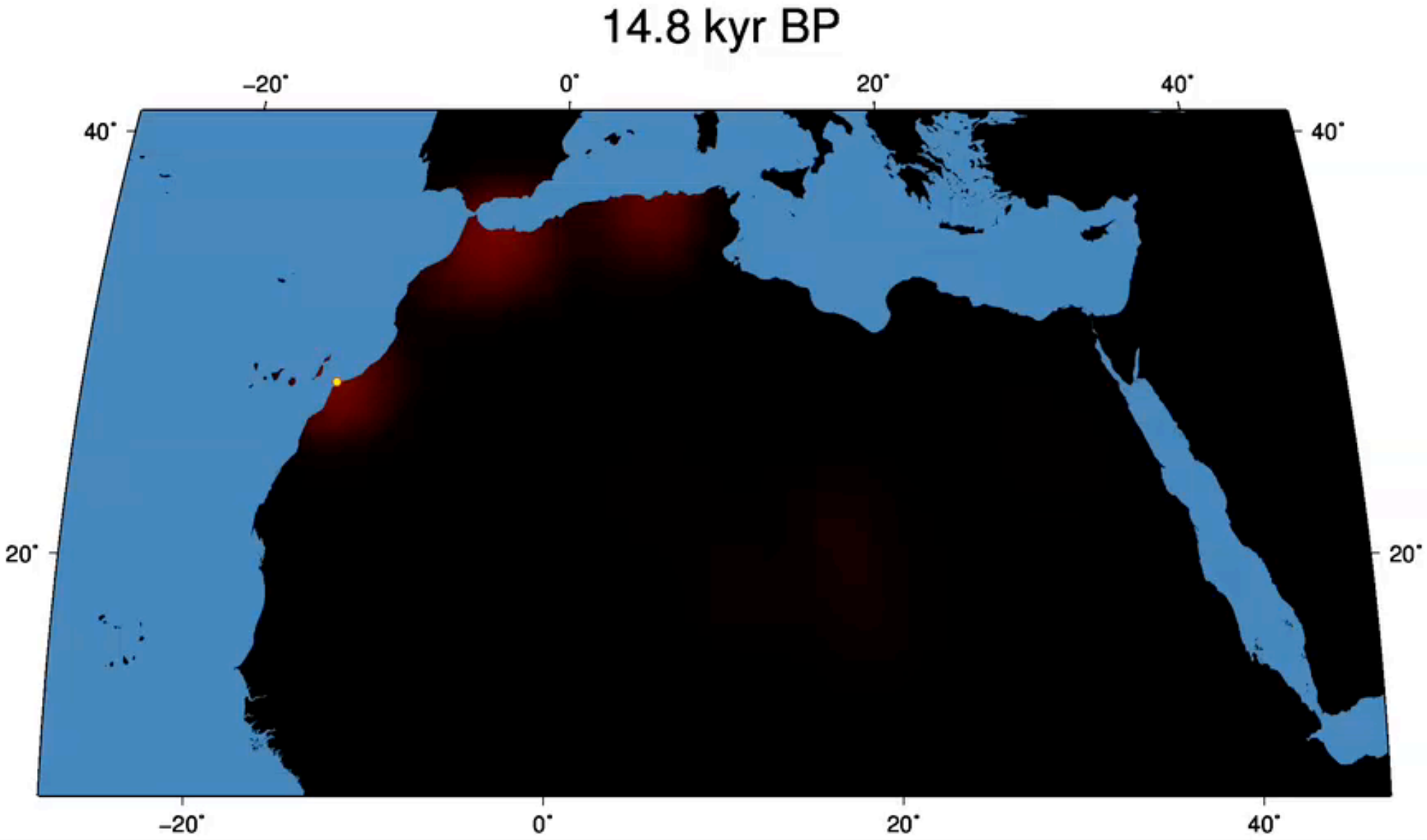


Shanahan et al., 2015
deMenocal, 2015

Stone art & engravings

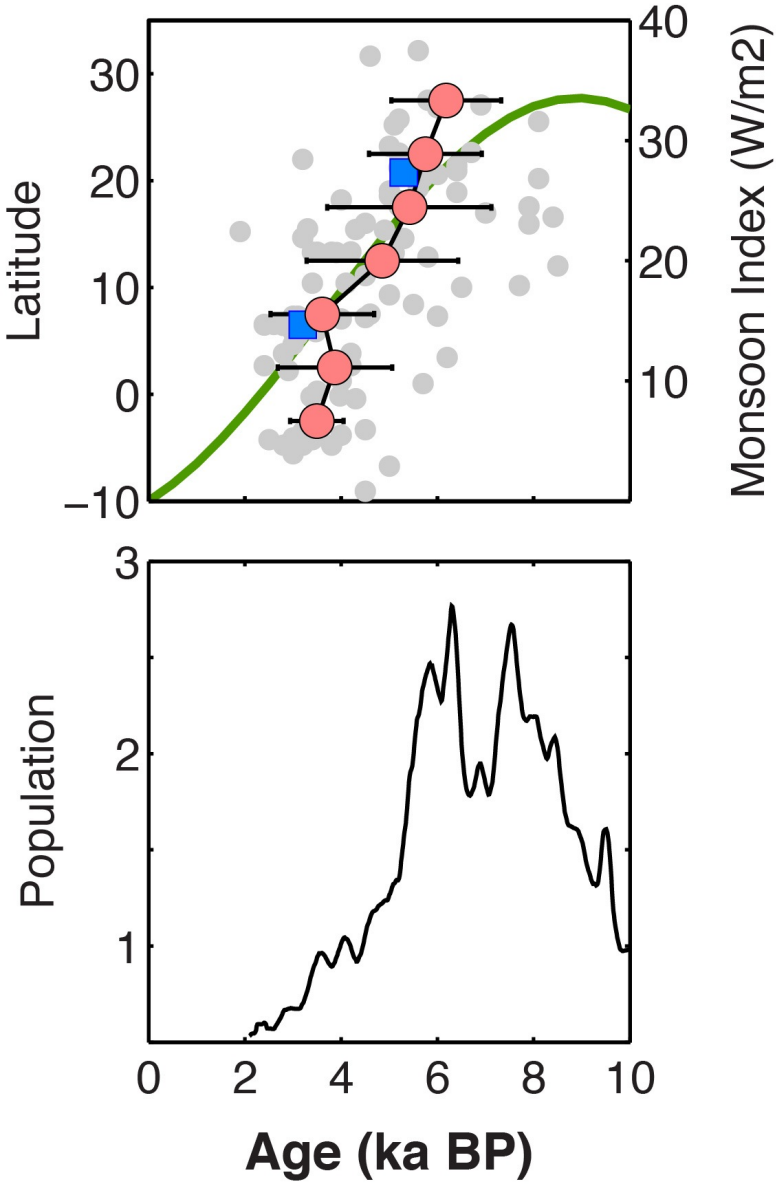
impressive tools and craft

Holocene population dynamics



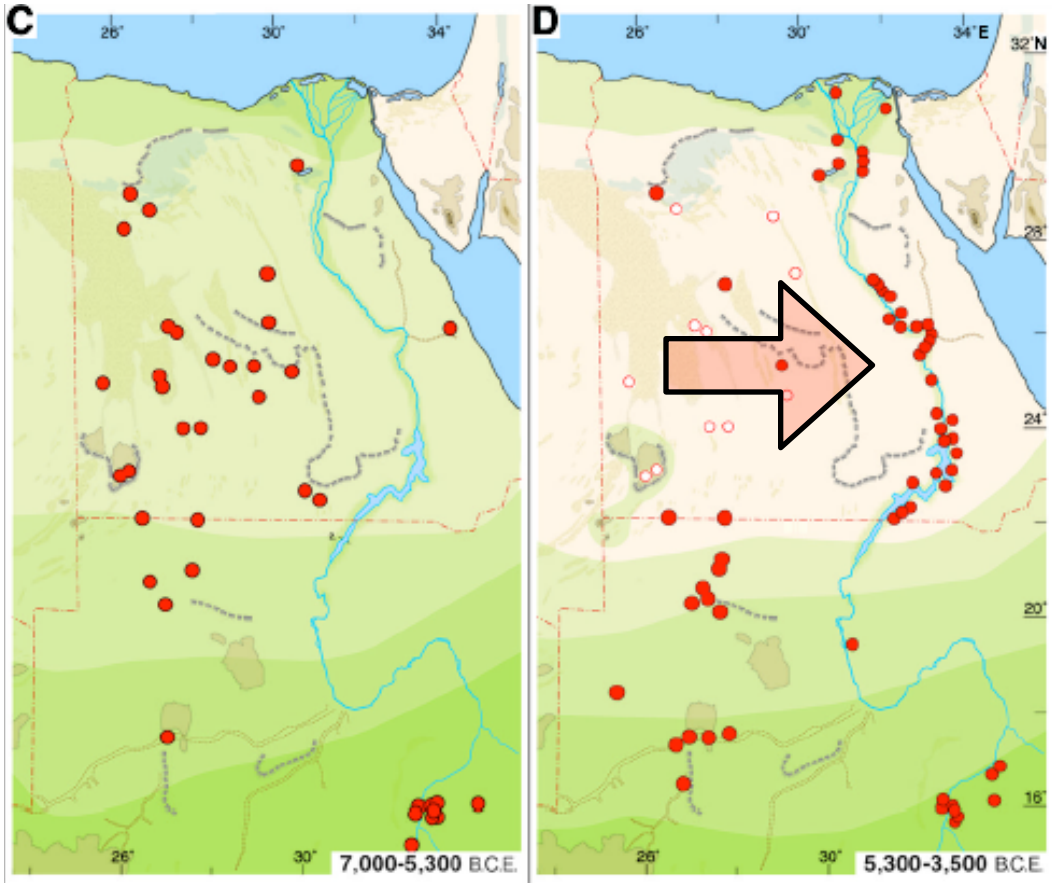
Manning and Timpson, 2014

Depopulation of the Sahara (5 ka BP)



deMenocal, 2014

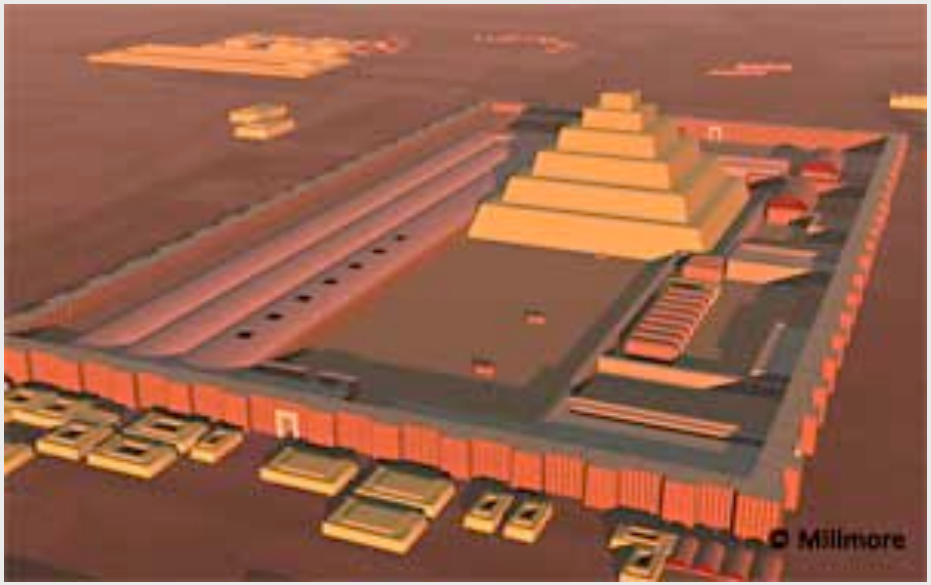
Eastern Sahara



9 ka BP 5 ka BP

Kuper and Kroepelin, 2006

The first Pyramids (4700 yr BP)



Necropolis complex at Saqqara

Protodynastic Egypt (Naqada III period)

Named Kings, State formation.
Political unification along Nile.
Many notable "firsts"

about 5000 yr BP

Narmer Palette

Serekh of Pharaoh Djet