Records of dust emission rates from the Sahara-Sahel region of Africa

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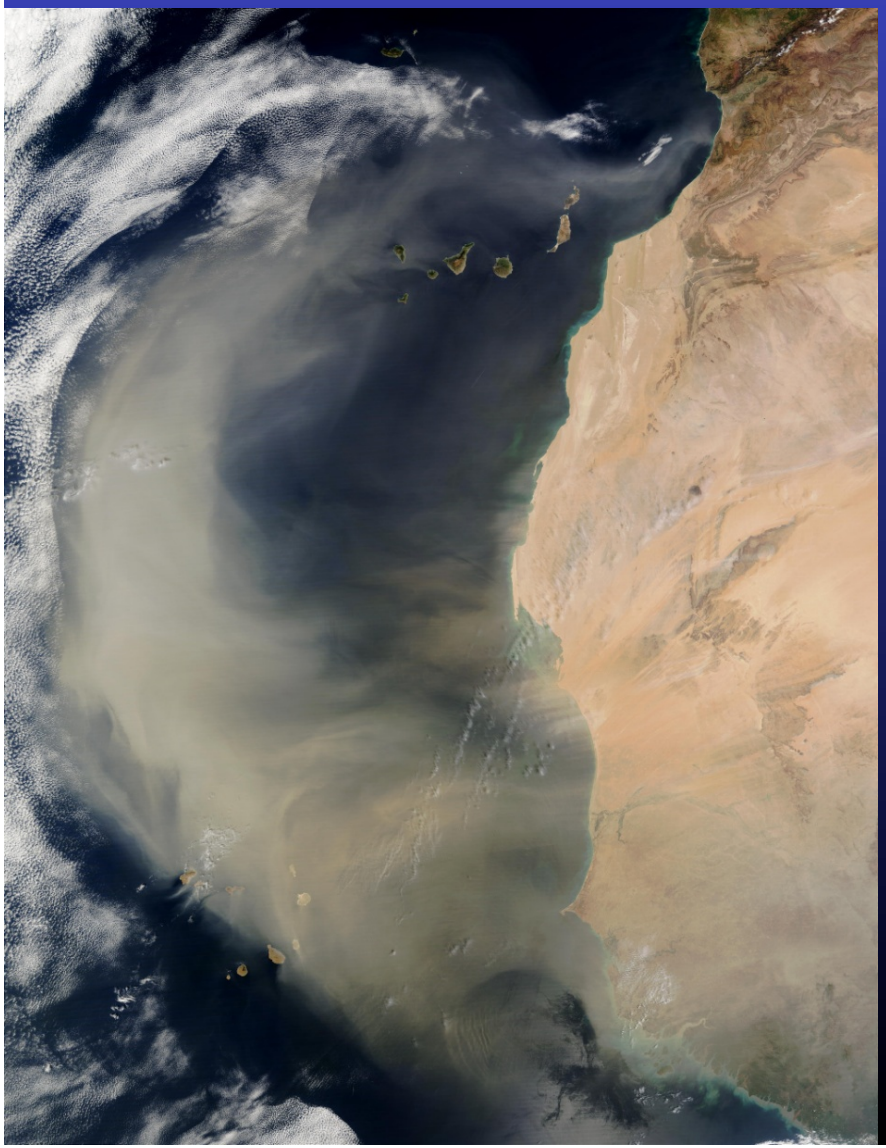
The roadmap

Dust generation from the Sahara-Sahel region

- Mid-late 20th century dust record from a Cape Verde coral.
- 18-20th century dust record from a Red Sea coral.
- A first pass of a 1000-yr record of African dust deposition in the Bahamas.

Introduction *Why the Sahara-Sahel region?*

Accounts for ~50% of global mineral dust emission (Andreae 1995; Cakmur et al. 2006)



- The amount of dust emitted from arid and semi-arid regions may be linked to precipitation (e.g., N'Tchayi Mbourou et al., 1997; Prospero and Lamb, 2003; Chiapello et al., 2005)

- Precipitation itself may be linked to oceanic sea surface temperatures (e.g., Hastenrath and Lamb,1977; Vizy and Cook, 2001; Giannini et al., 2003).

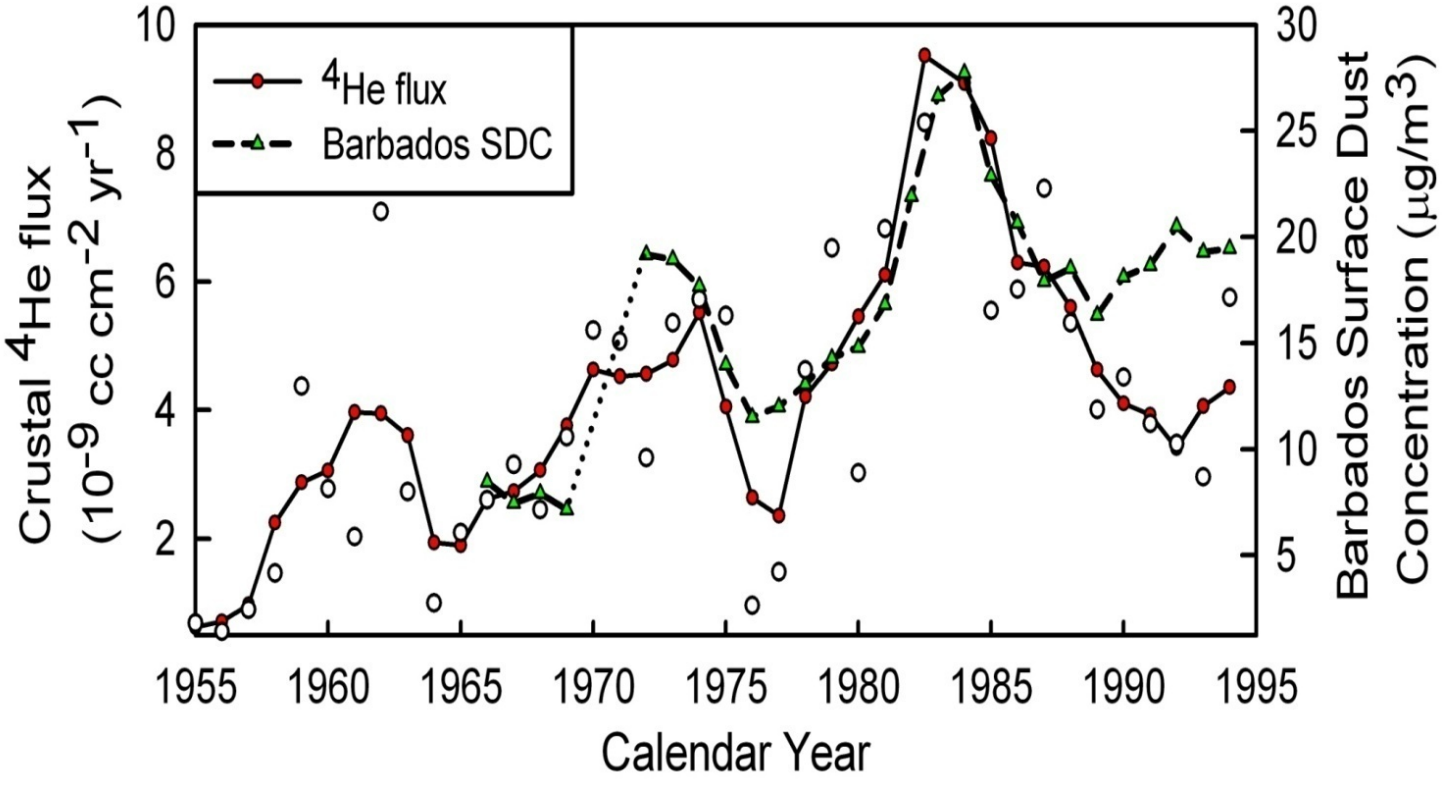
For the Sahara-Sahel region neither the magnitude nor the sign of the dust (precipitation rate) changes are clear.

Using ^{4}He in corals to trace mineral dust

Sample: Coral collected off the coast of Sal, archipelago, in 1996

The dust record from Cape Verde

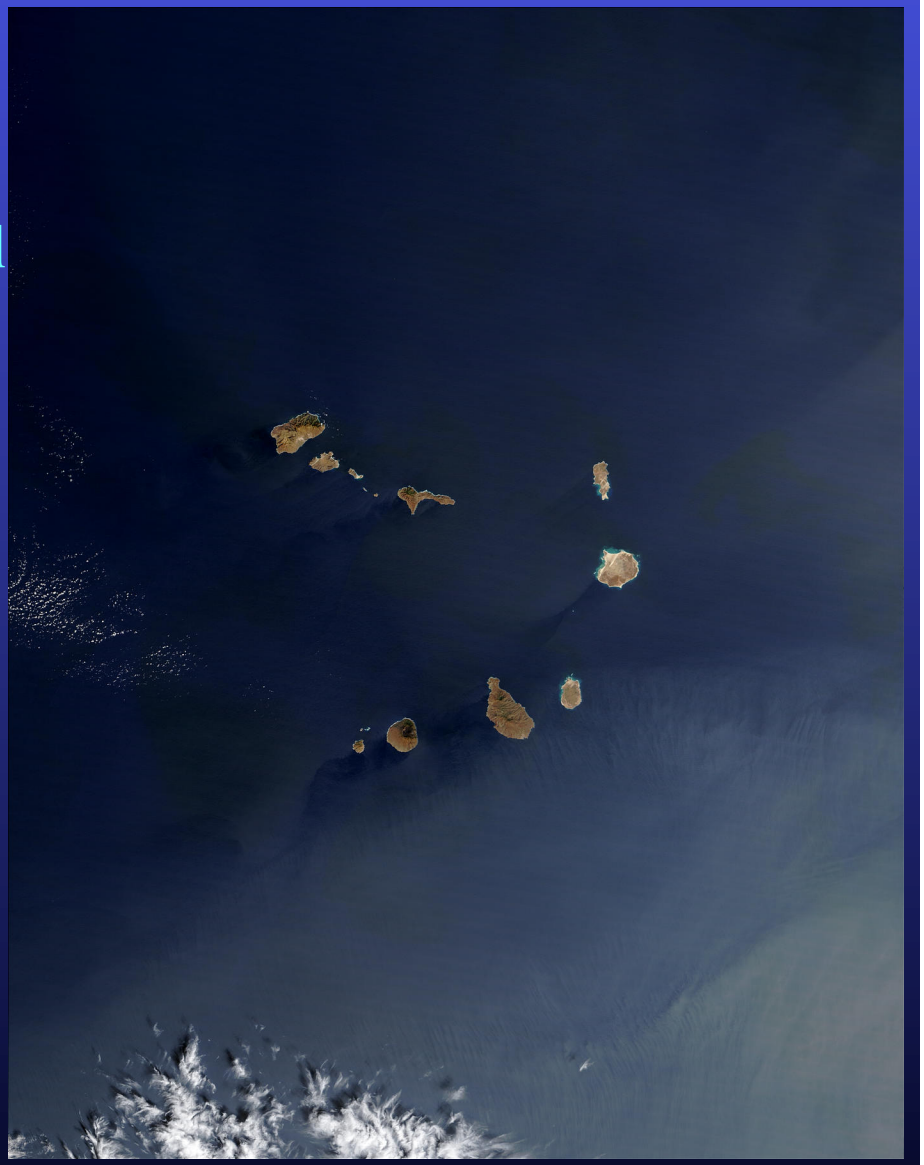
Barbados SDC data from Prospero and Lamb (2003).



Factor of 9 increase in dust emission rates between mid-1950's and early-1980's → 45% increase in global aerosol loads
Similar conclusion as Prospero and Lamb (2003).

(Mukhopadhyay and Kreycik; GRL 2008)

Dust deposition based on sediment trap data (Ratmeyer et al. 1999; Bory and Newton, 2000) **and model reconstructions** (Duce et al., 1991; Prospero 1995; Mahowald et al., 2005)
→ **depositional flux of dust is 3-50 g m^{-2} yr^{-1}**



Use average value of the ^4He depositional flux from the Cape Verde coral and the average ^4He concentration in the terrigenous matter off Cape Blanc.

→**Average annual dust deposition rate of 7.4 g m^{-2} yr^{-1}**
(Mukhopadhyay and Kreycik, GRL, 2008)

Sentences you will probably never read in a published paper:

"We were totally surprised it worked!"

"We just thought it'd be a neat thing to do."

"I'm only doing this to get tenure."

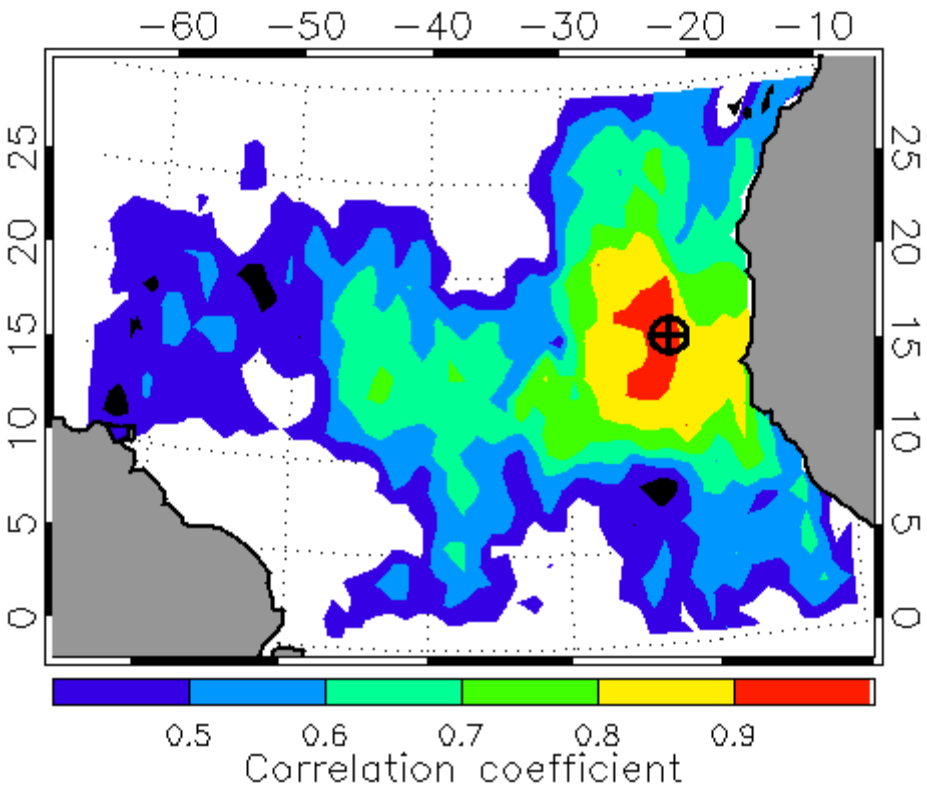
"Oops."

"Previous work by XXX et al. is actually pretty good!"

"To be honest, we came up with the hypothesis *after* doing the experiment."

"The results are just 'OK'."

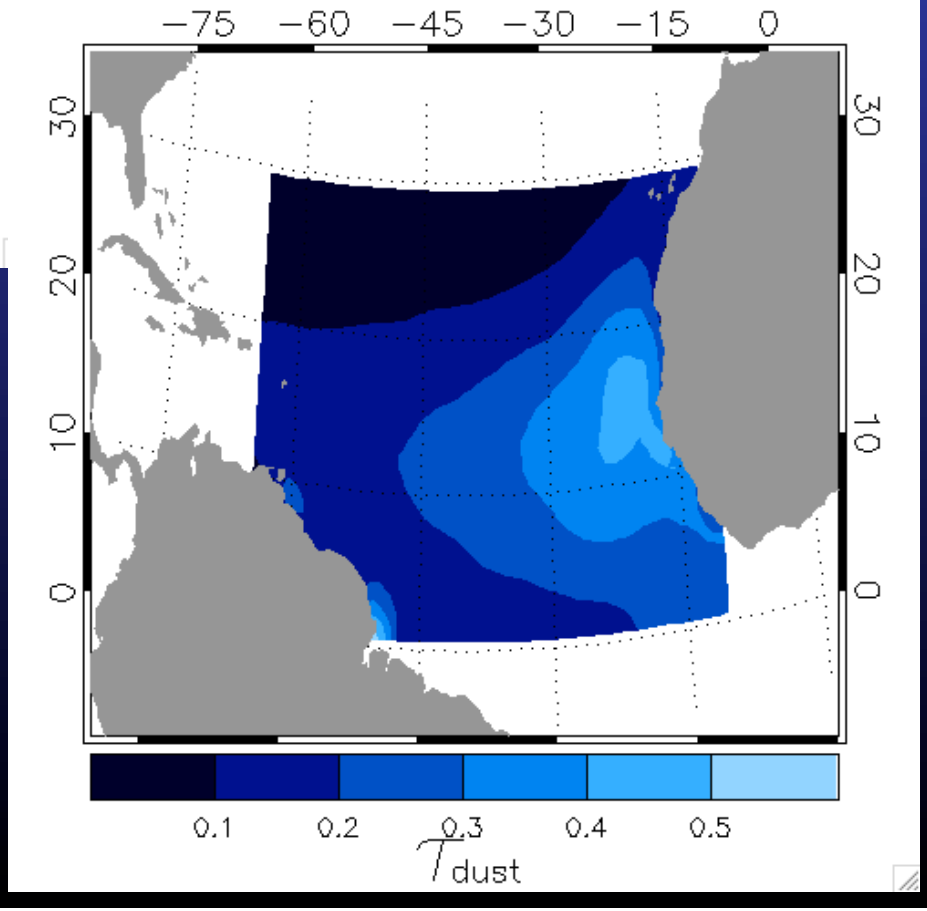
"Future work will... ah, who are we kidding? We won't get more funding to do this."



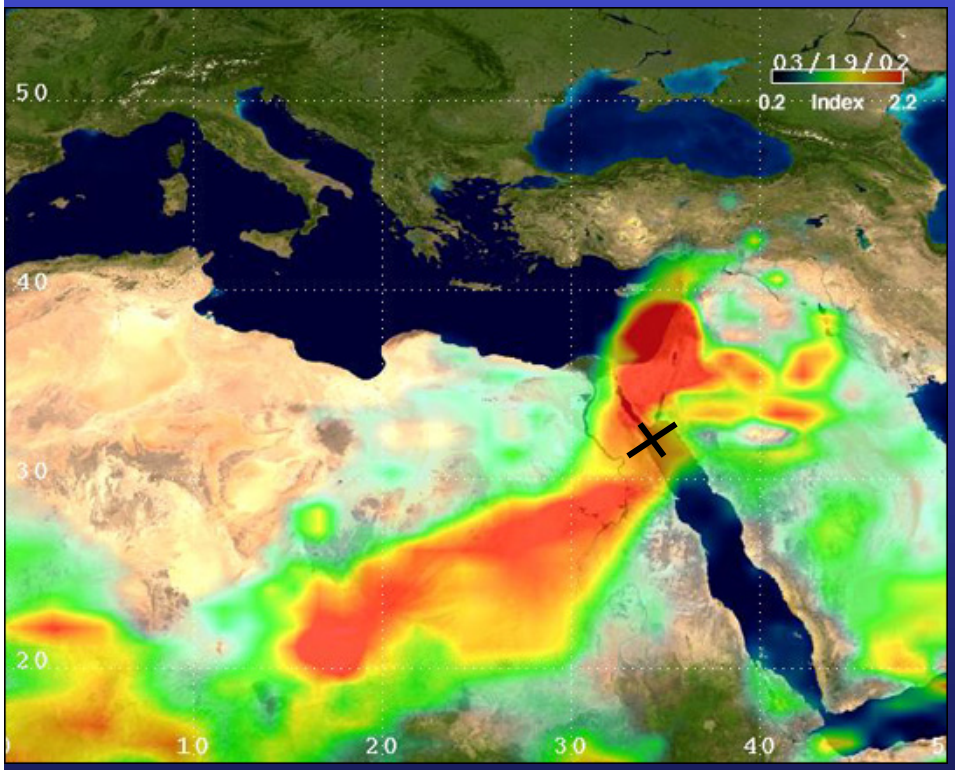
← **Correlation map of NOAA's AVHRR dust optical thickness and Cape Verde ^{4}He record**

Map of long term mean dust optical depth for the period 1955-2008. →

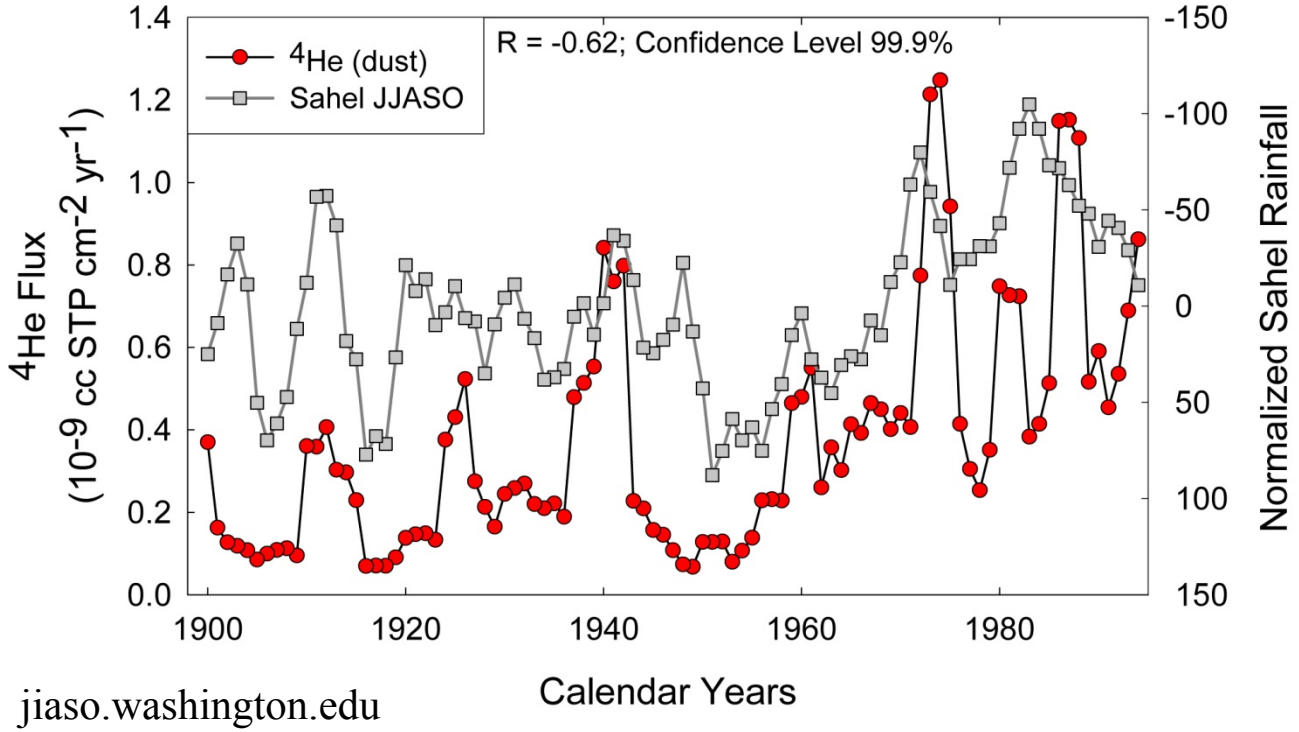
Evan and Mukhopadhyay, (2010 in rev)

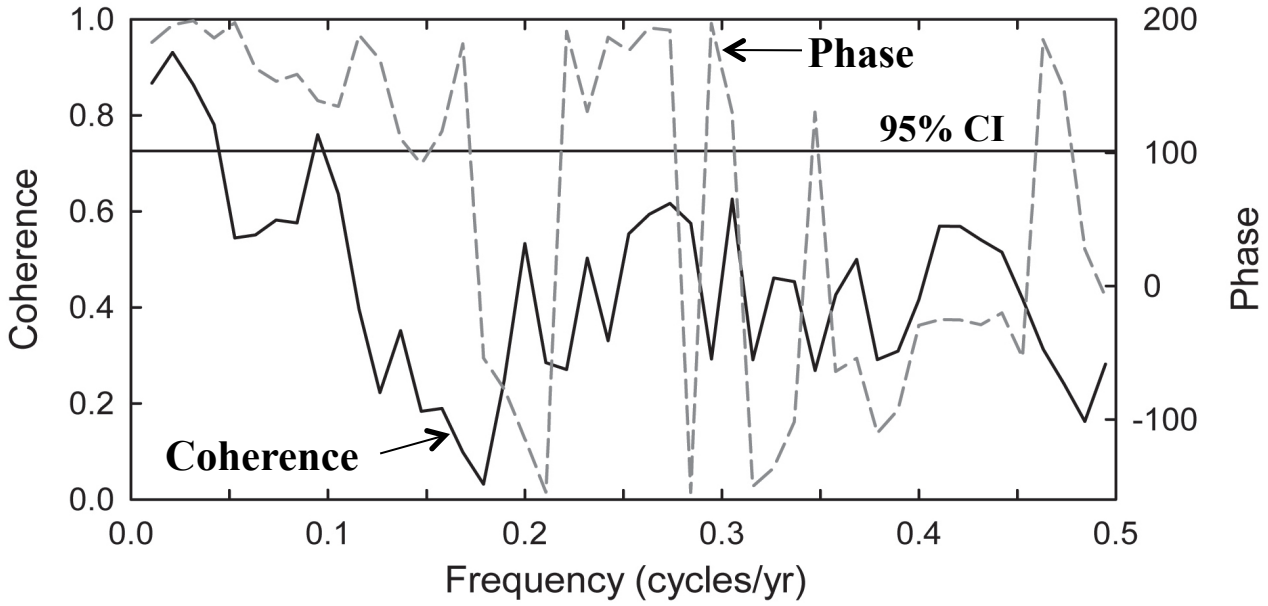


^{4}*He record from a Porites in the Red Sea*



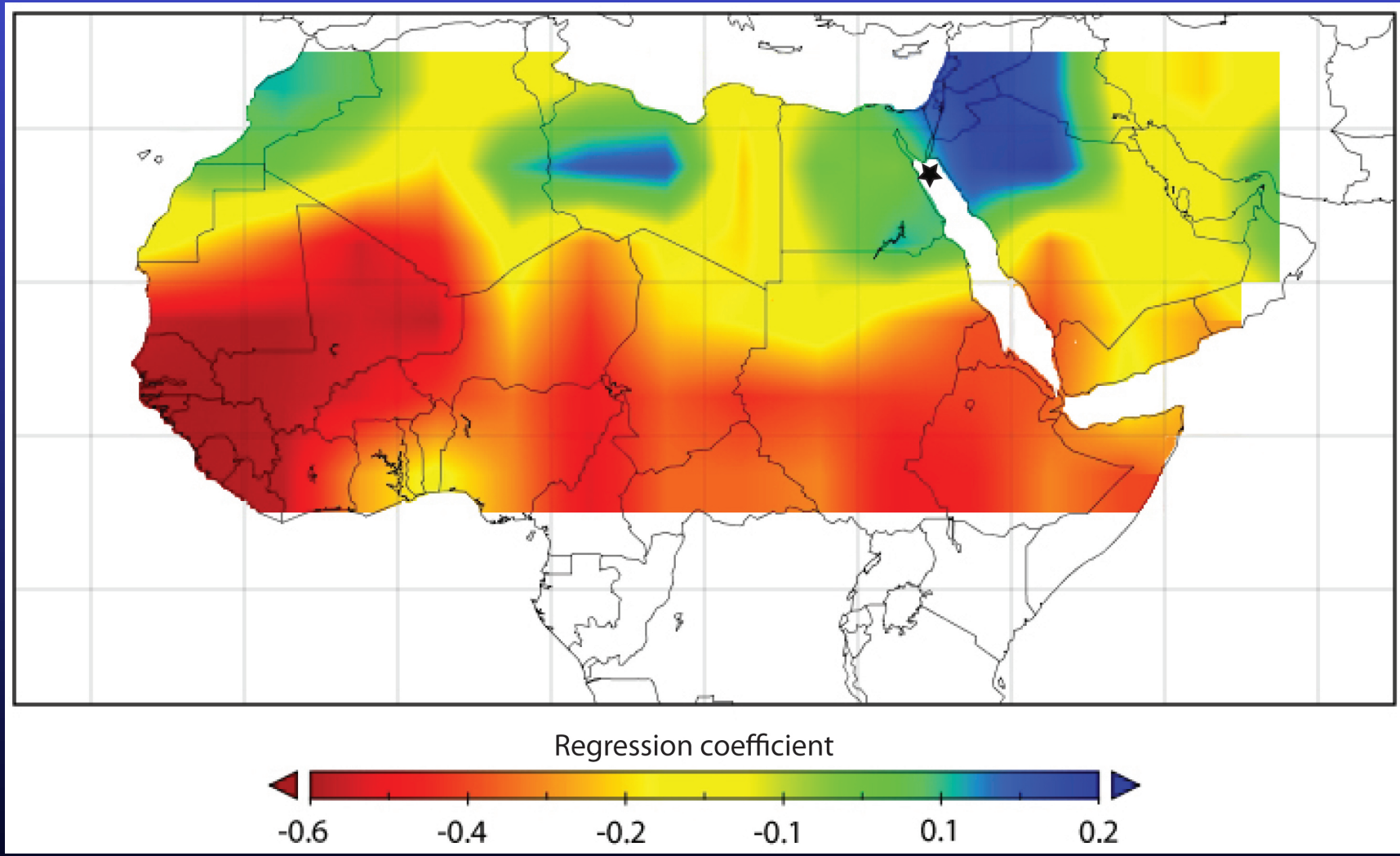
Annual bands in the *Porites* coral from the Red Sea.
Provides ~262 year long record.





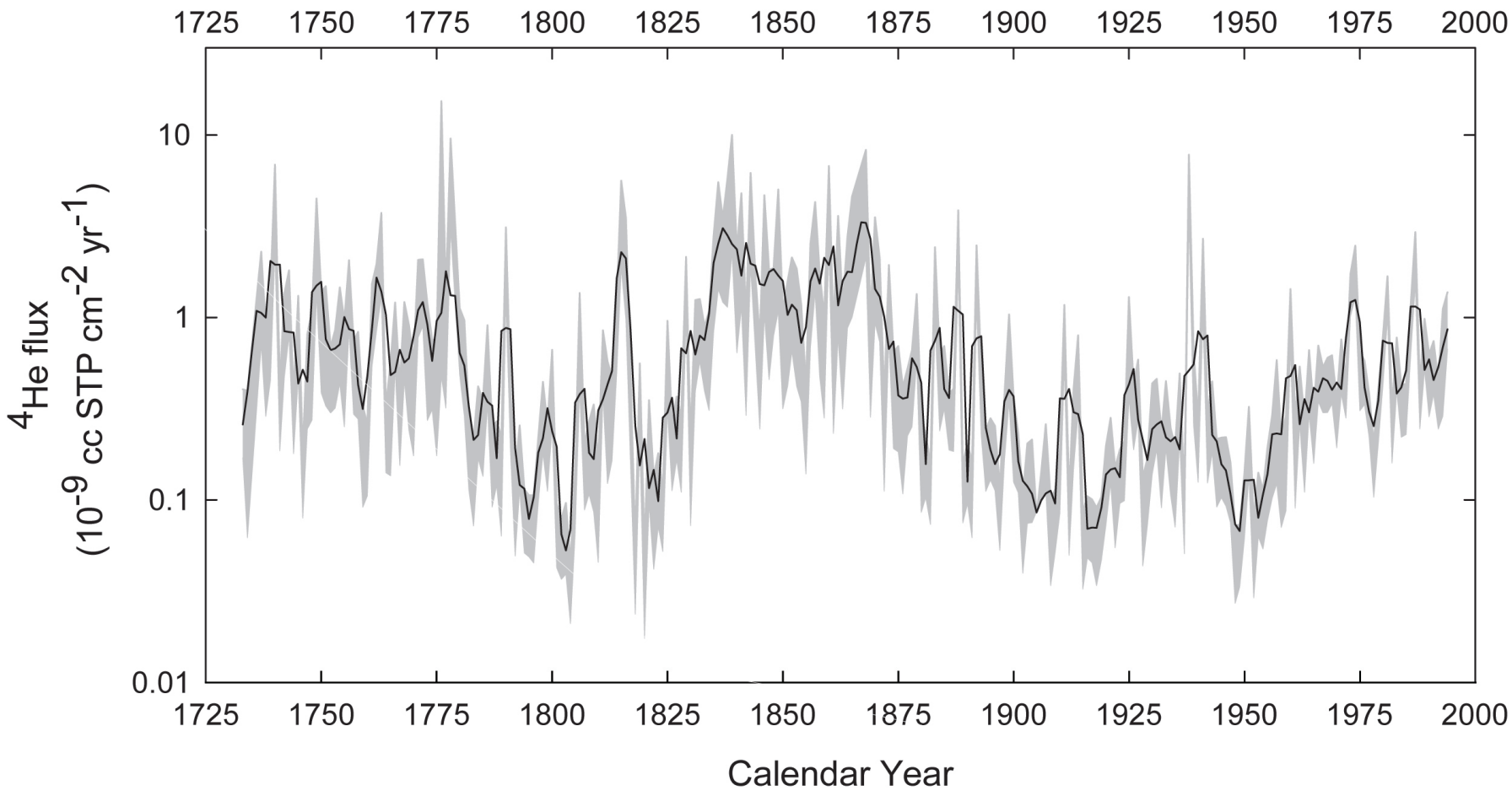
Correlation between He flux in the Red Sea coral and precipitation in the Sudano-Sahel region

Spatial correlation between ^{4}He flux record and previous year's precipitations



Rainfall data from GHCN 2

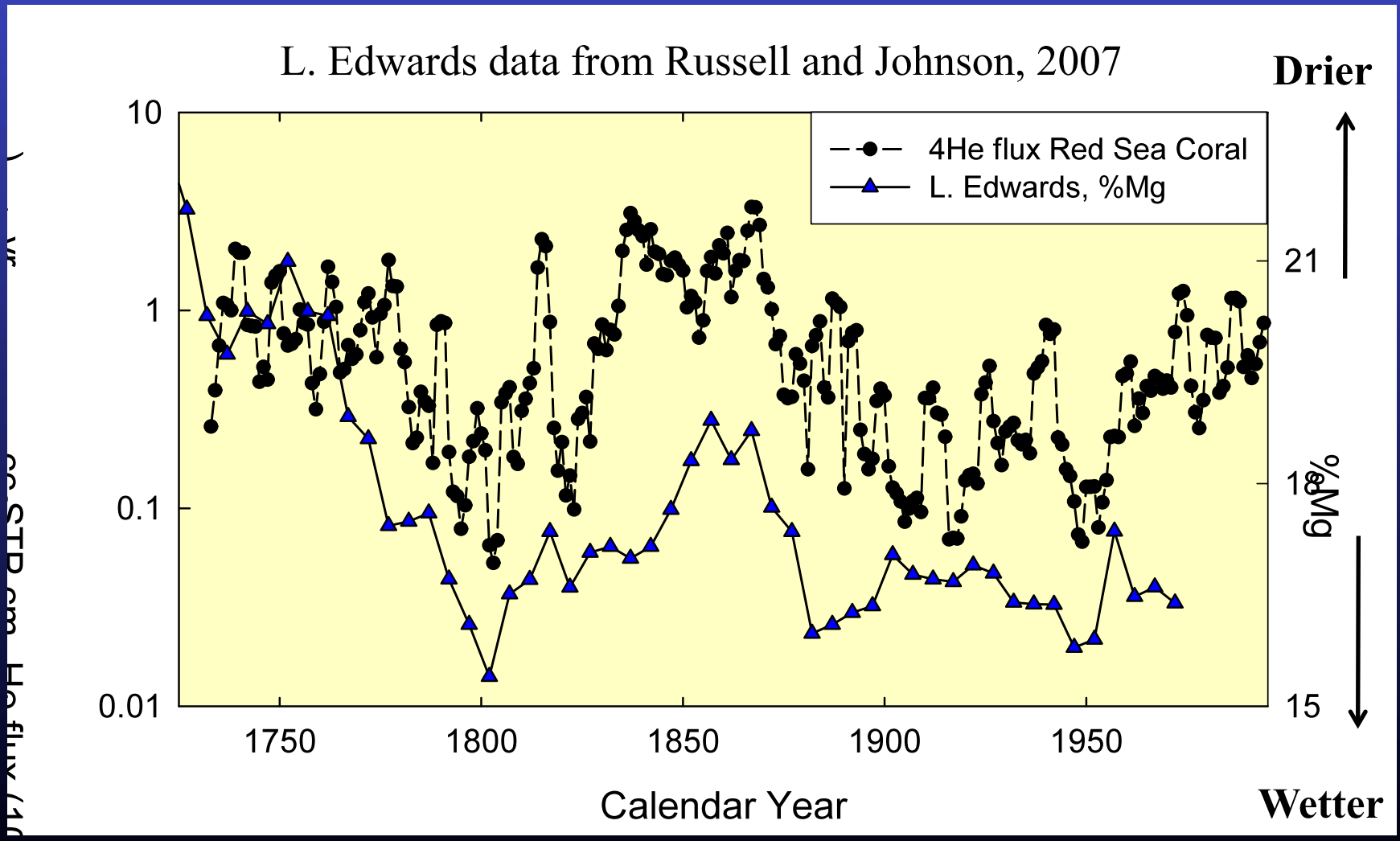
A 260 year dust record from the Red Sea



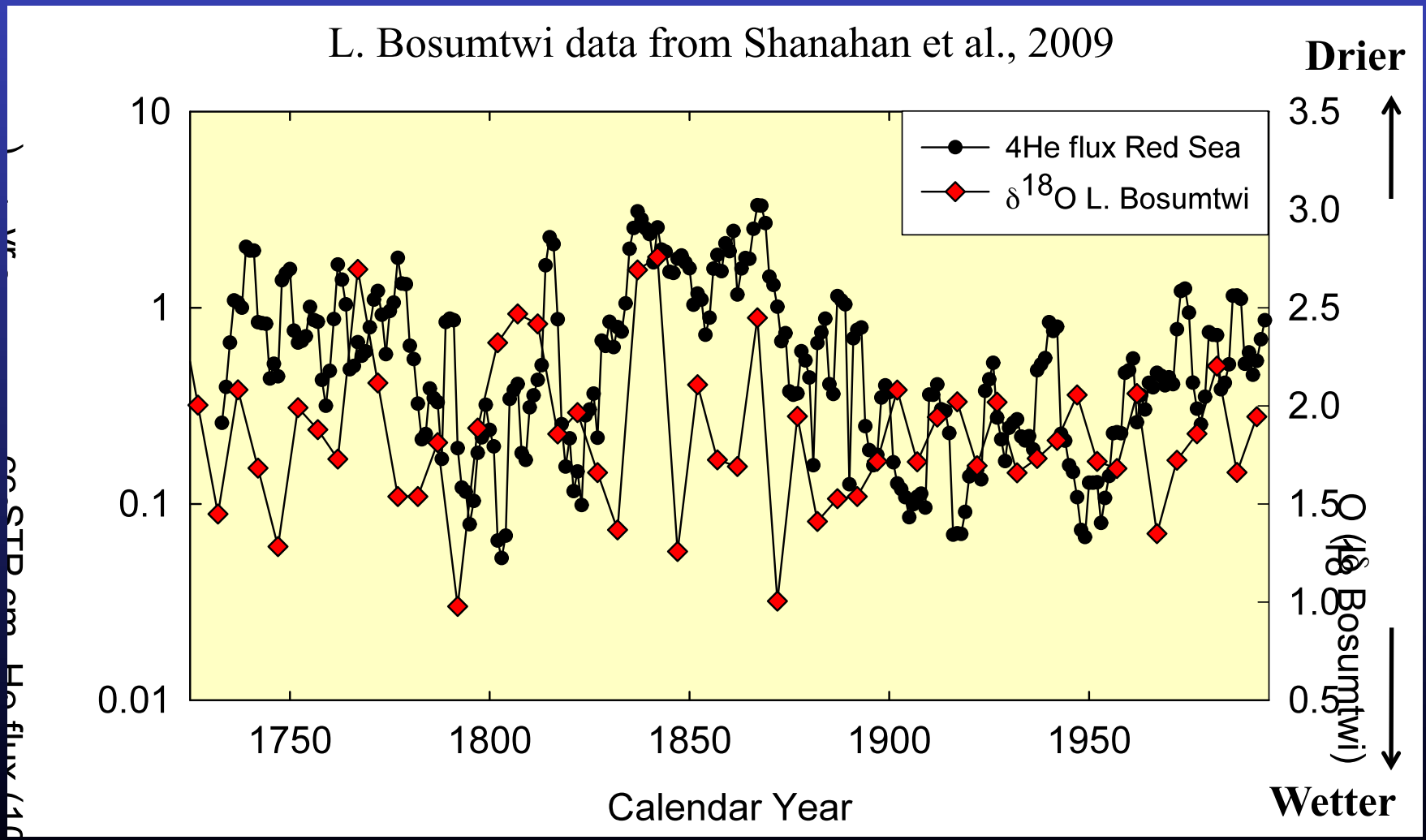
Dust fluxes in the 18-19th century were on average a factor of 2-4 higher than in the 20th century.

The 20th century droughts appear to have been much less severe than 19th and 18th century droughts.

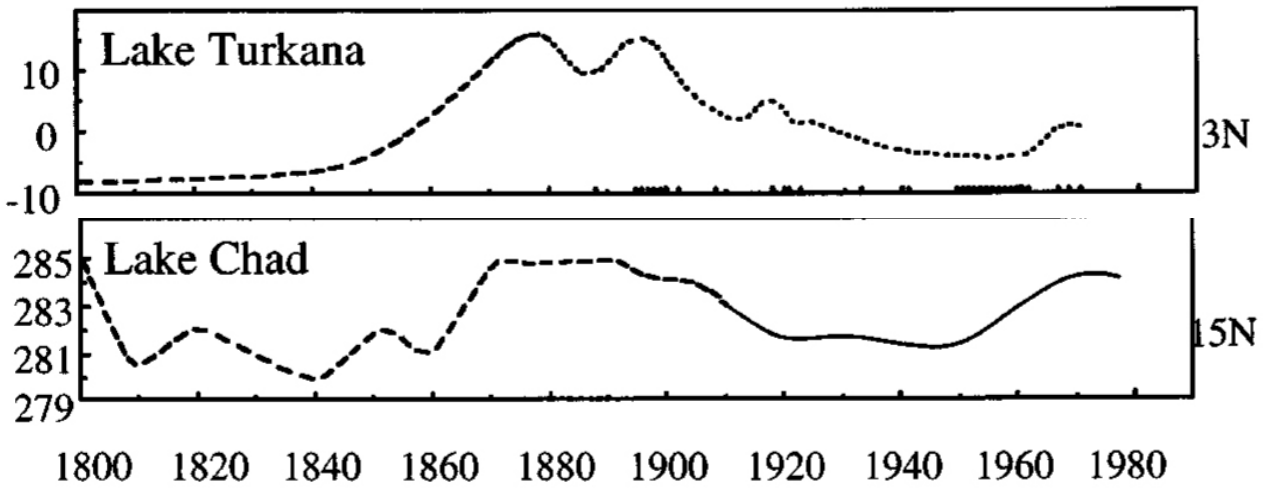
Comparison of our dust record with lake levels in Lake Edwards, Equatorial Central Africa.



Comparison of our dust record with lake levels in Lake Bosumtwi, Tropical West Africa.

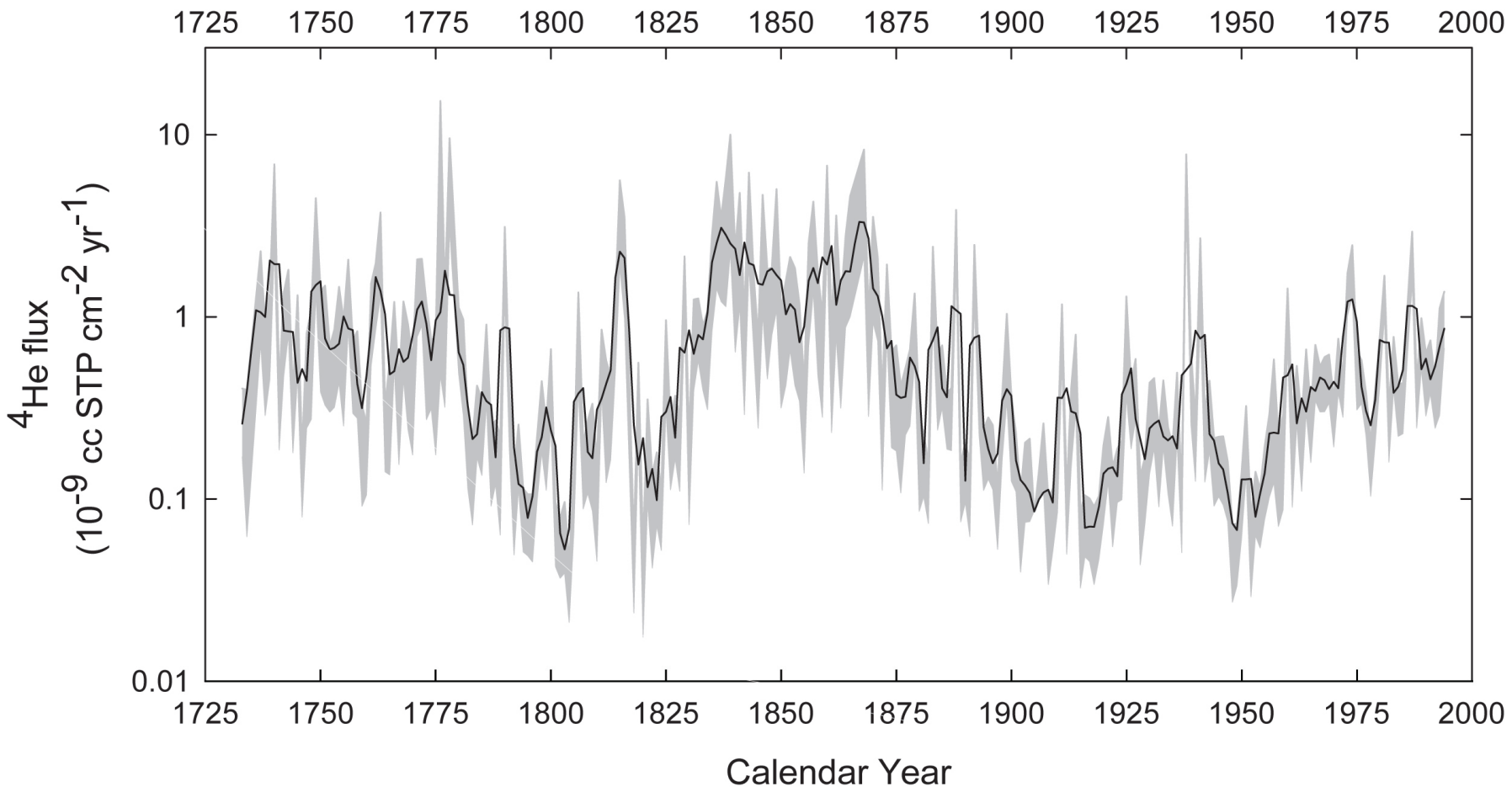


Lake levels from Tropical and Equatorial Africa



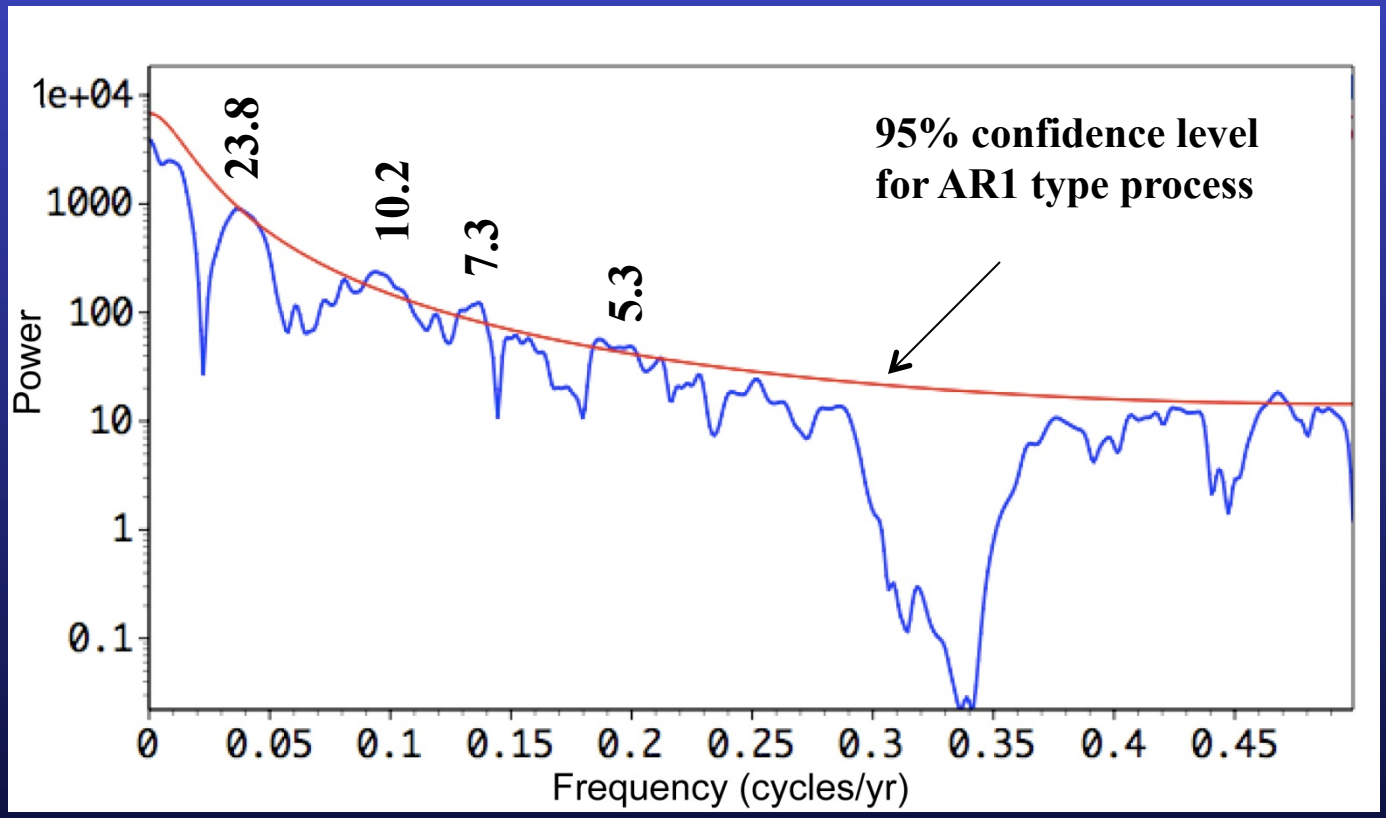
Nicholson and Yin, 2001

A 260 year dust record from the Red Sea

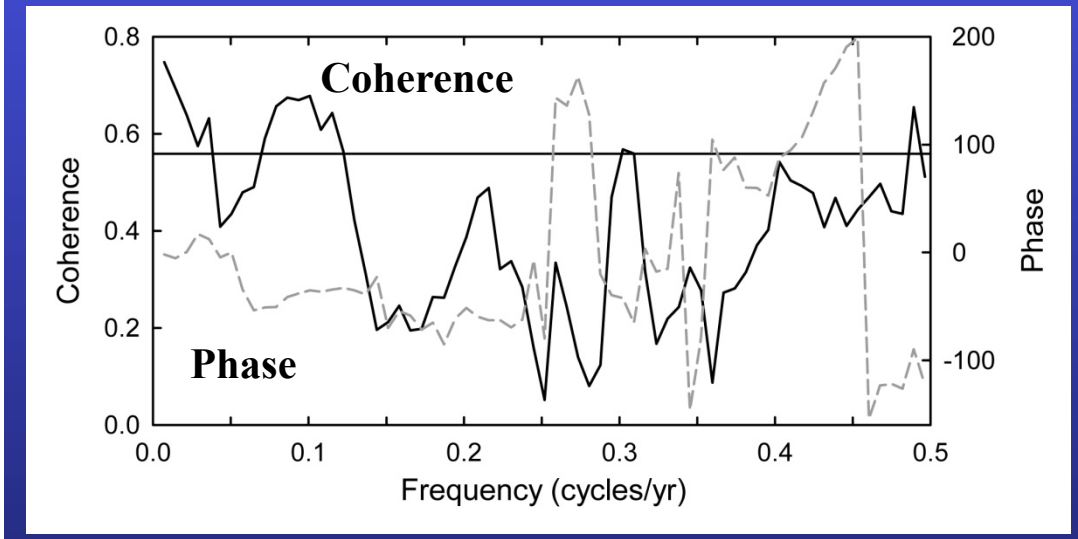


Dust peaks in the 1840-1860's associated with severe droughts

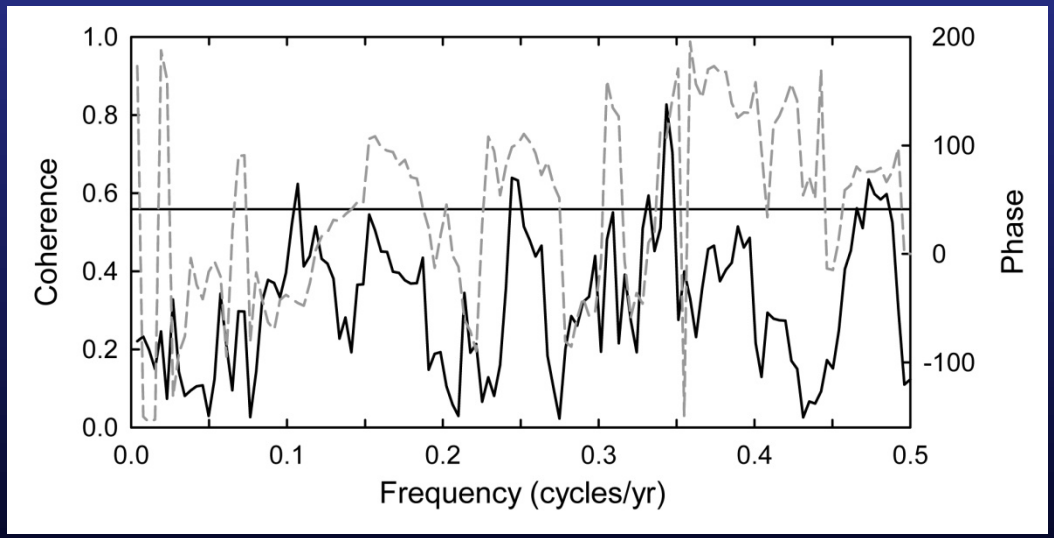
Power spectra of the Red Sea dust record



Multi taper spectral analyses reveals powers at sub-decadal, decadal and multi-decadal bands.



Dust & Tropical Indian Ocean 1994-1856; Kaplan extended SSTA (Kaplan et al., 1998)

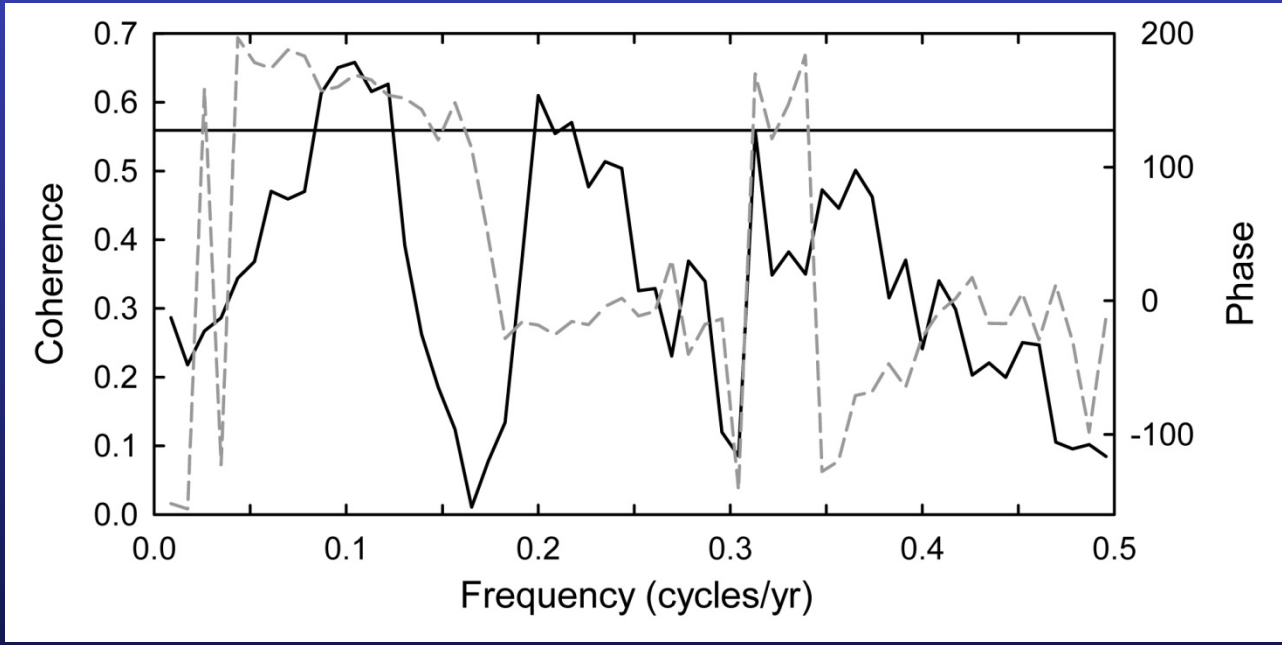


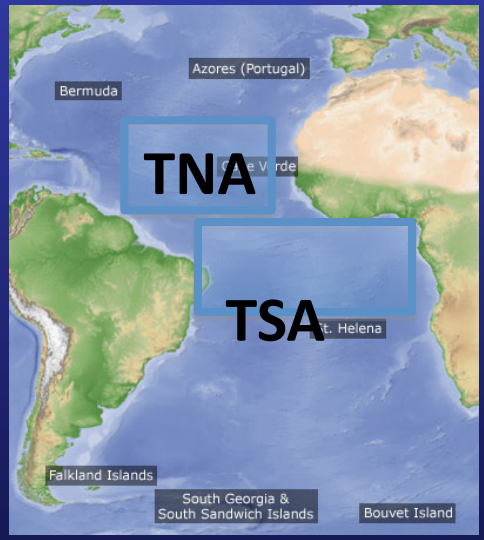
Dust & NINO 3.4 SSTA: 1994-1732
(Cook et al., 2008)

Warming in tropical Indian and Pacific ocean → more dust from Africa

Dust and Tropical Atlantic Meridional Gradient: 1994-1880

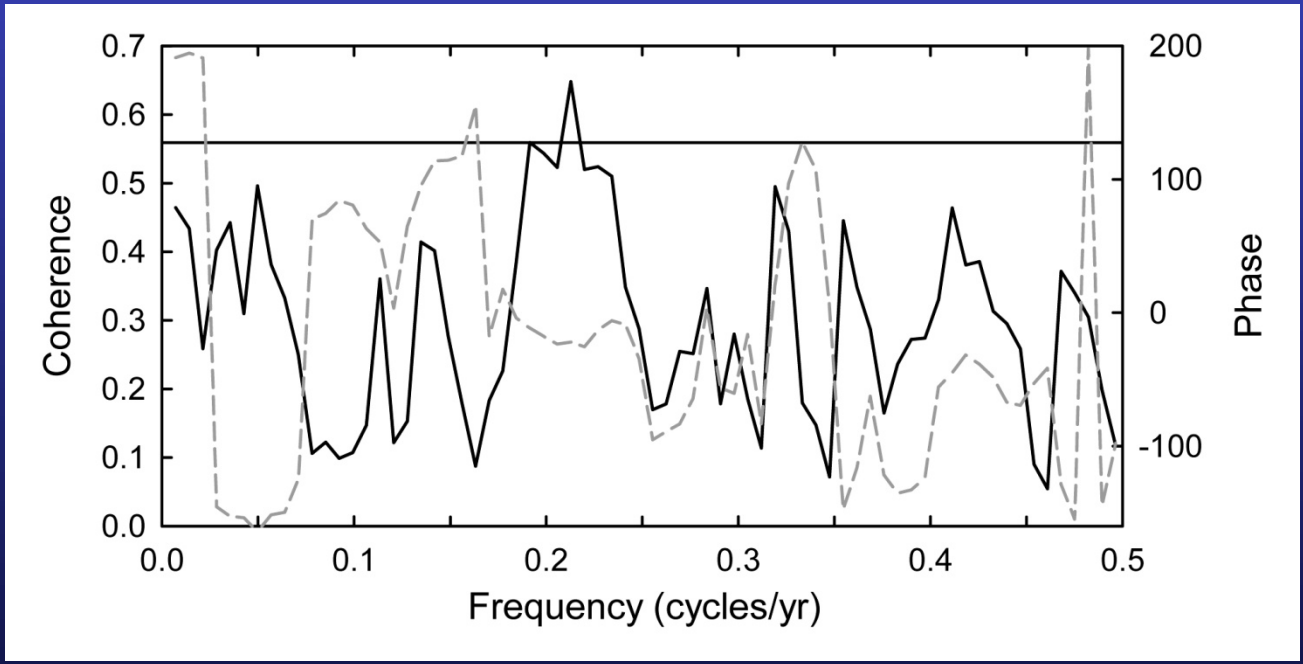
(e.g., Servain et al, 1991, Melice et al, 2003)

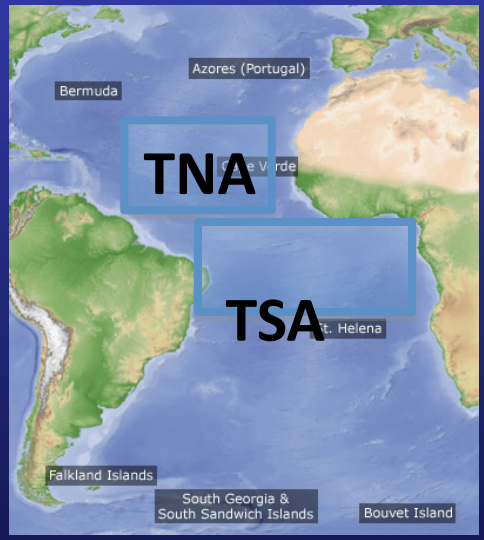




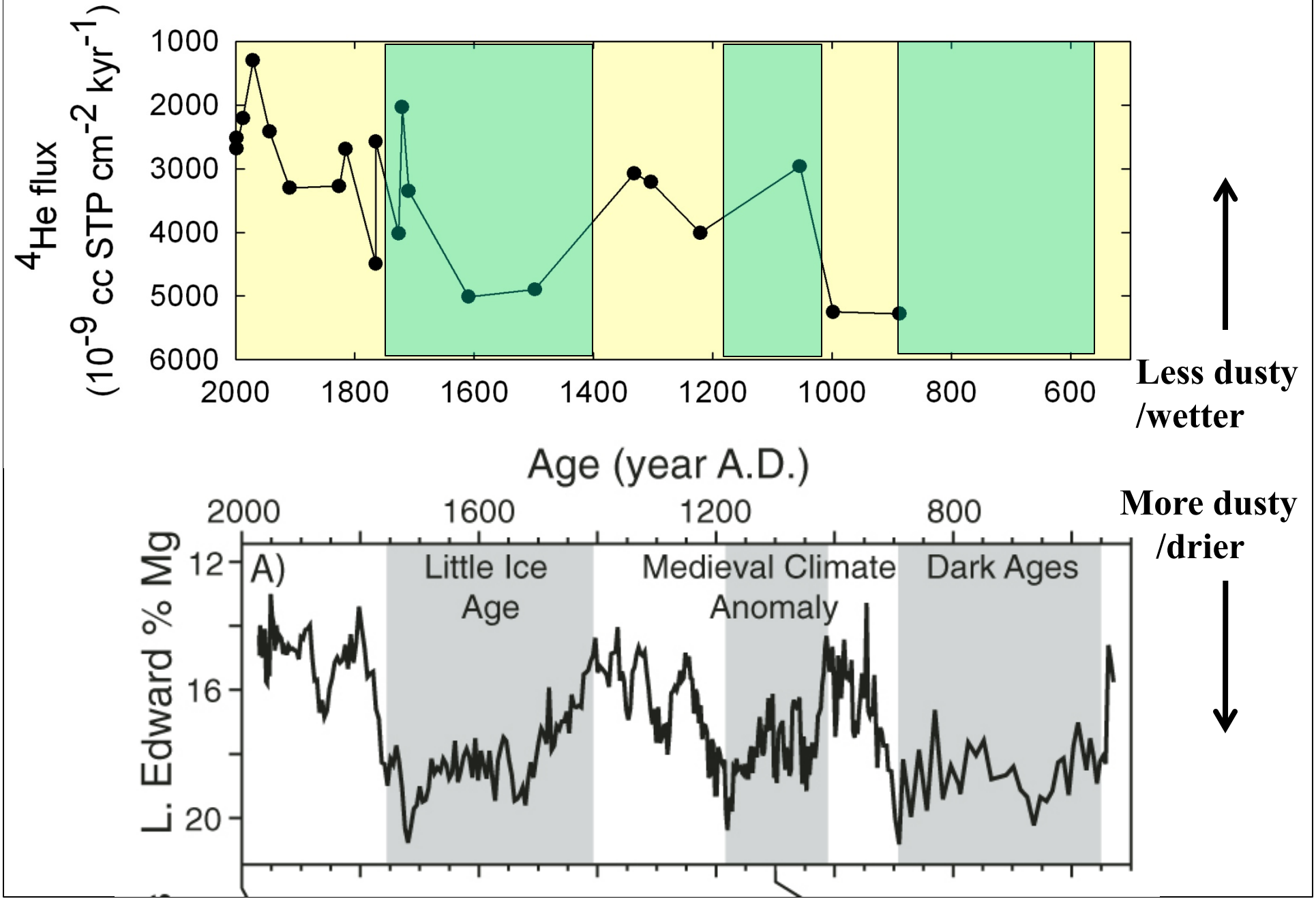
Dust and Tropical Atlantic Meridional Gradient: 1994-1854

(e.g., Servain et al, 1991, Melice et al, 2003)





A 1000 year record of African dust deposition from Bahamas



Sources of uncertainty and future targets

Slow(er) growing Cape Verde coral (0.5 cm/yr):

1g aliquot -> ^{4}He uncertainty of 28%

Fast(er) growing Red Sea coral (1 cm/yr):

1g aliquot -> ^{4}He uncertainty of 51%

Under-sampling of rare large particles

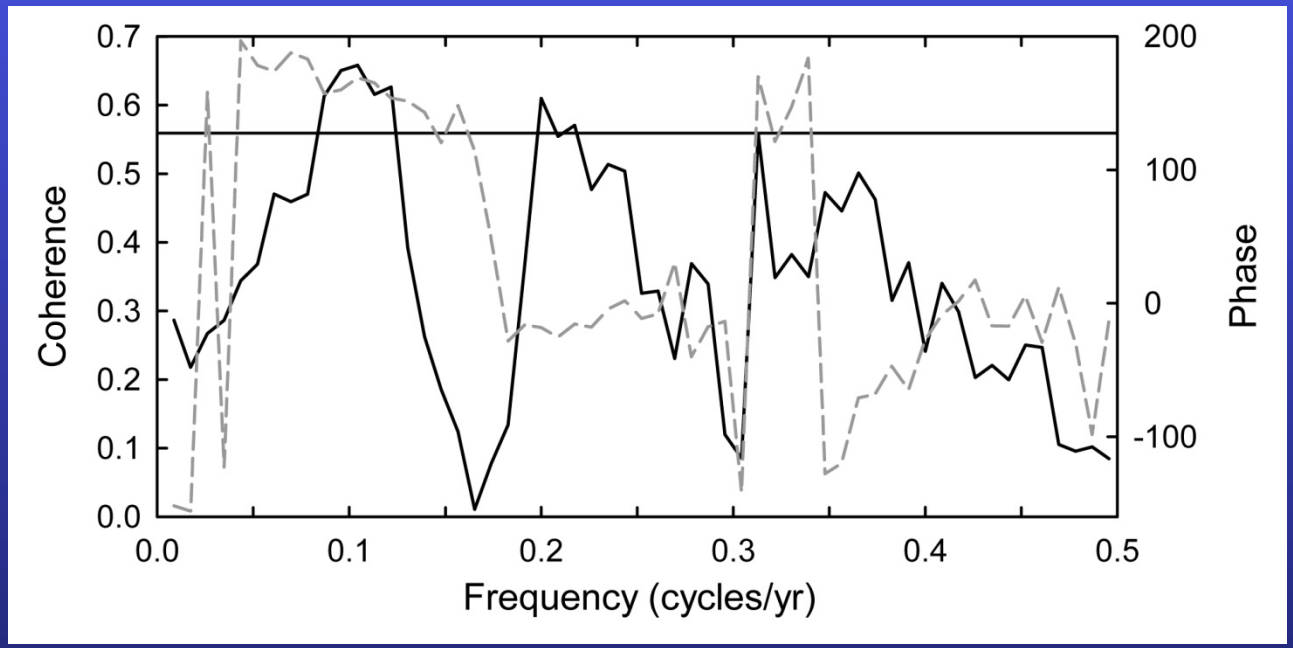
→Need to work with large volume of samples

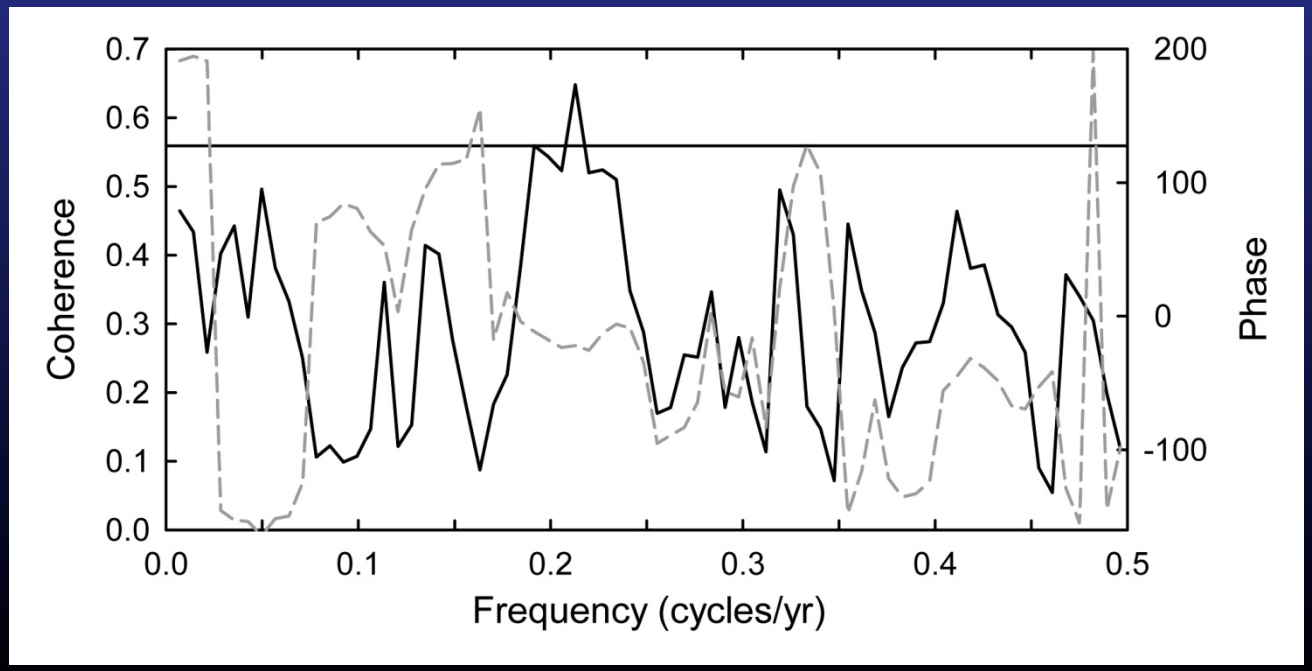
Future targets → coral records off Mozambique, Barbados, Cape Verde carbonate muds in the Bahamas.

Summary and Conclusion

- The ^{4}He record in the *Porites* corals from Cape Verde and Red Sea, and in the carbonate muds from the Bahamas give a robust record of dust emission/precipitation patterns in Northern Africa.
- Dust emission in N. Africa in the 18 and 19th century was a factor of 2-4 higher than in the century 20th → 20th century droughts in Africa were milder compared to droughts over the past 3 centuries.
- The Red Sea dust record shows topical ocean ssta pace the dust→ sub-decadal periods coherent with tropical Pacific ssta; decadal period coherent with the Atlantic meridional gradient and tropical ocean ssta; multidecadal period coherent with tropical Indian ssta.
- Historically, larger dust amplitudes (stronger droughts) during cooler climatic regimes.

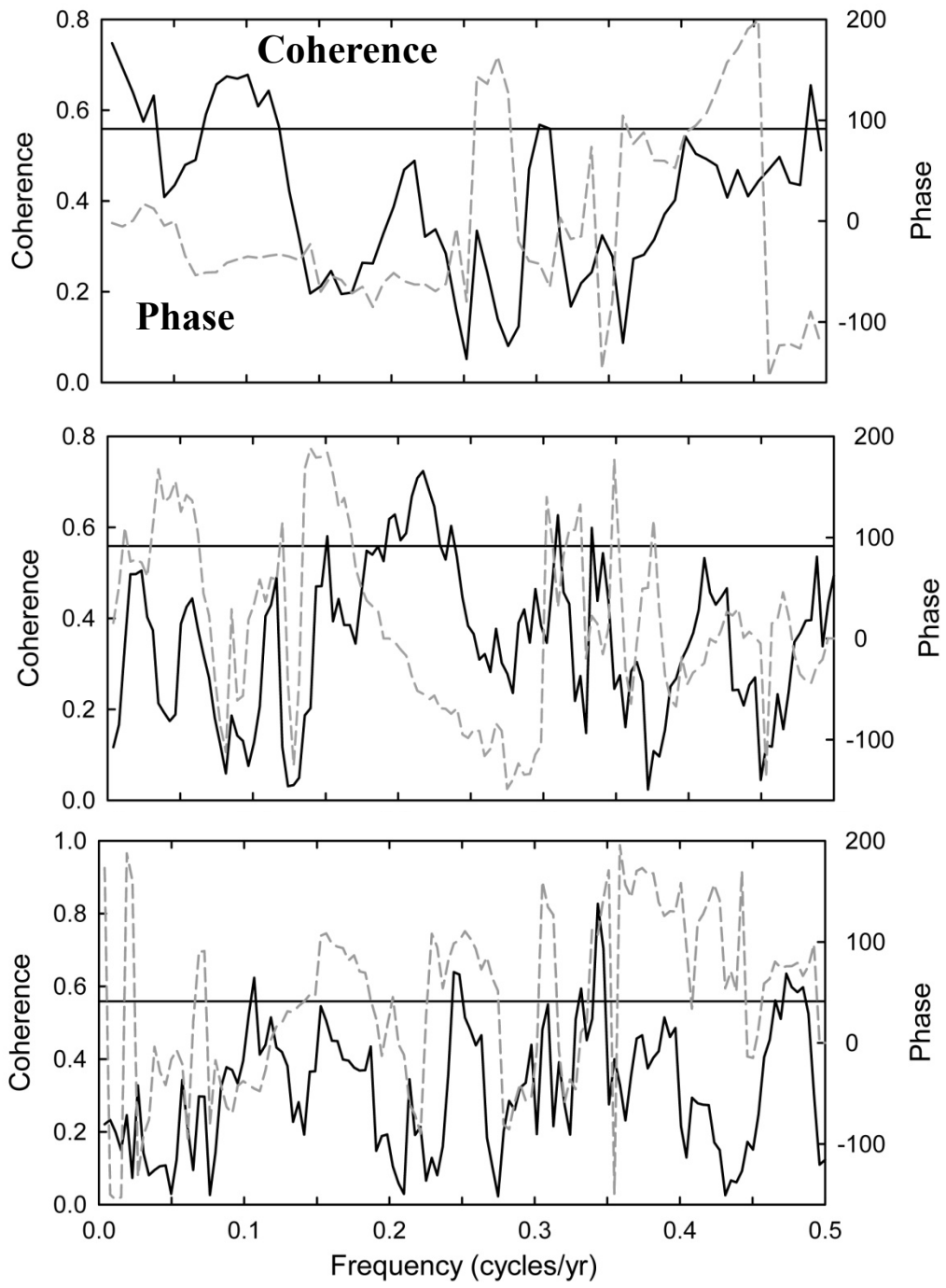
Future targets → coral records off Mozambique, Barbados, Cape Verde carbonate muds in the Bahamas.





Tropical Atlantic Meridional Gradient

(e.g., Servain et al, 1991, Melice et al, 2003)

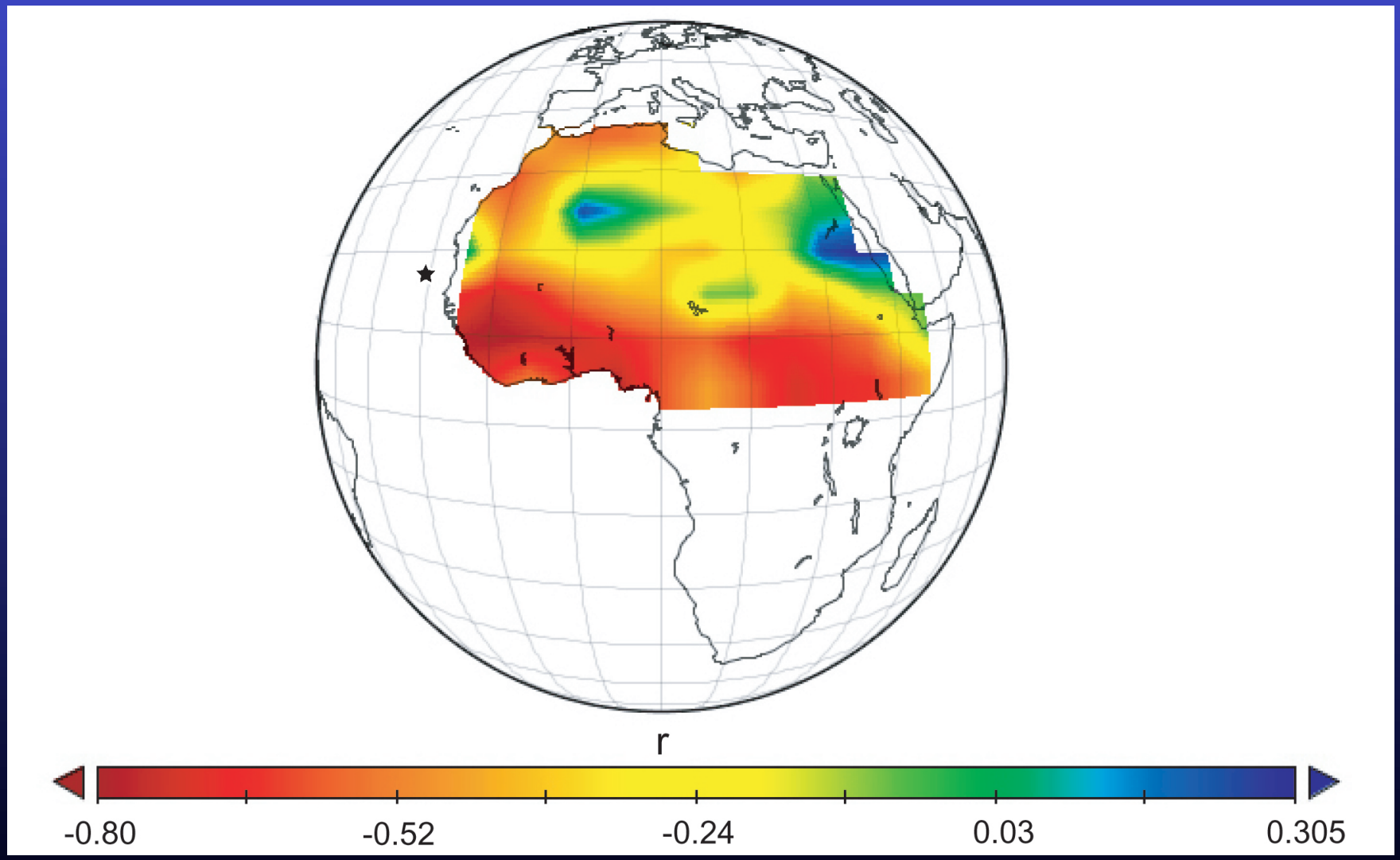


Dust & Tropical Indian Ocean 1994-1856; Kaplan extended SSTA (Kaplan et al., 1998)

Dust & N. Atlantic SSTA: 1994-1732 (Gray et al 2004)

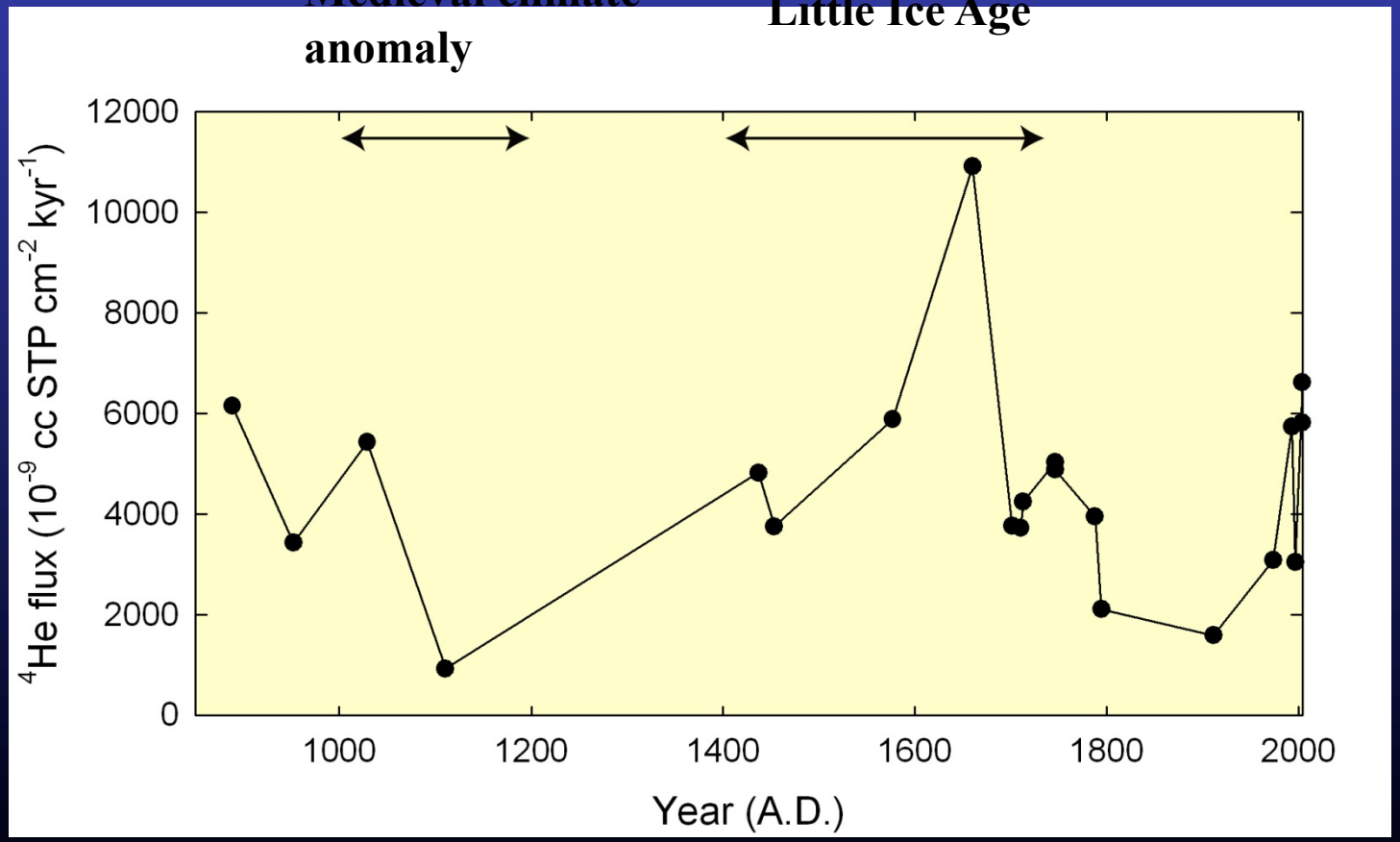
Dust & NINO 3.4 SSTA: 1994-1732 (Cook et al., 2008)

Spatial correlation between ^{4}He flux record and previous year's precipitations

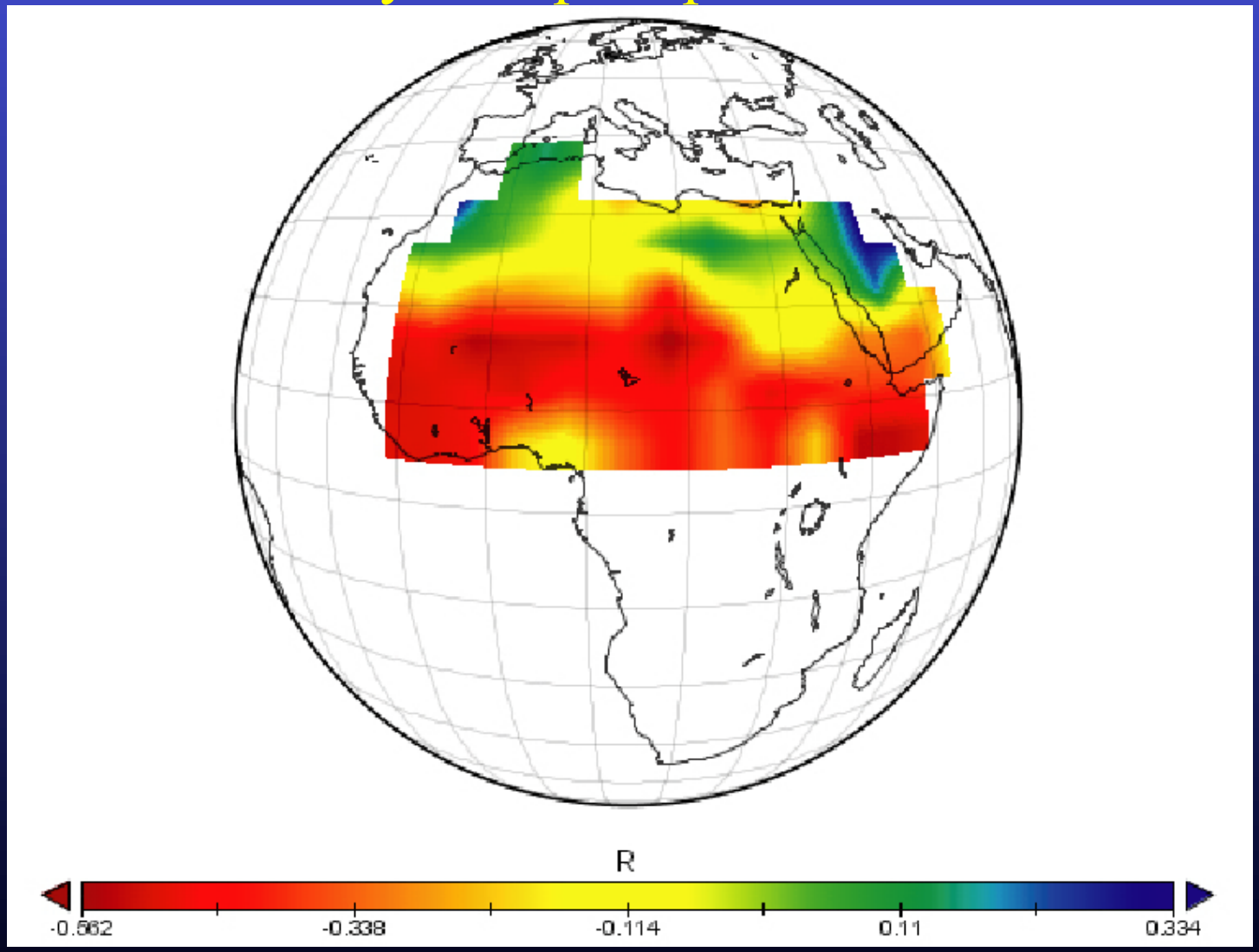


Highest correlations in the Sahel and western Africa

(Mukhopadhyay and Kreycik; GRL 2008)

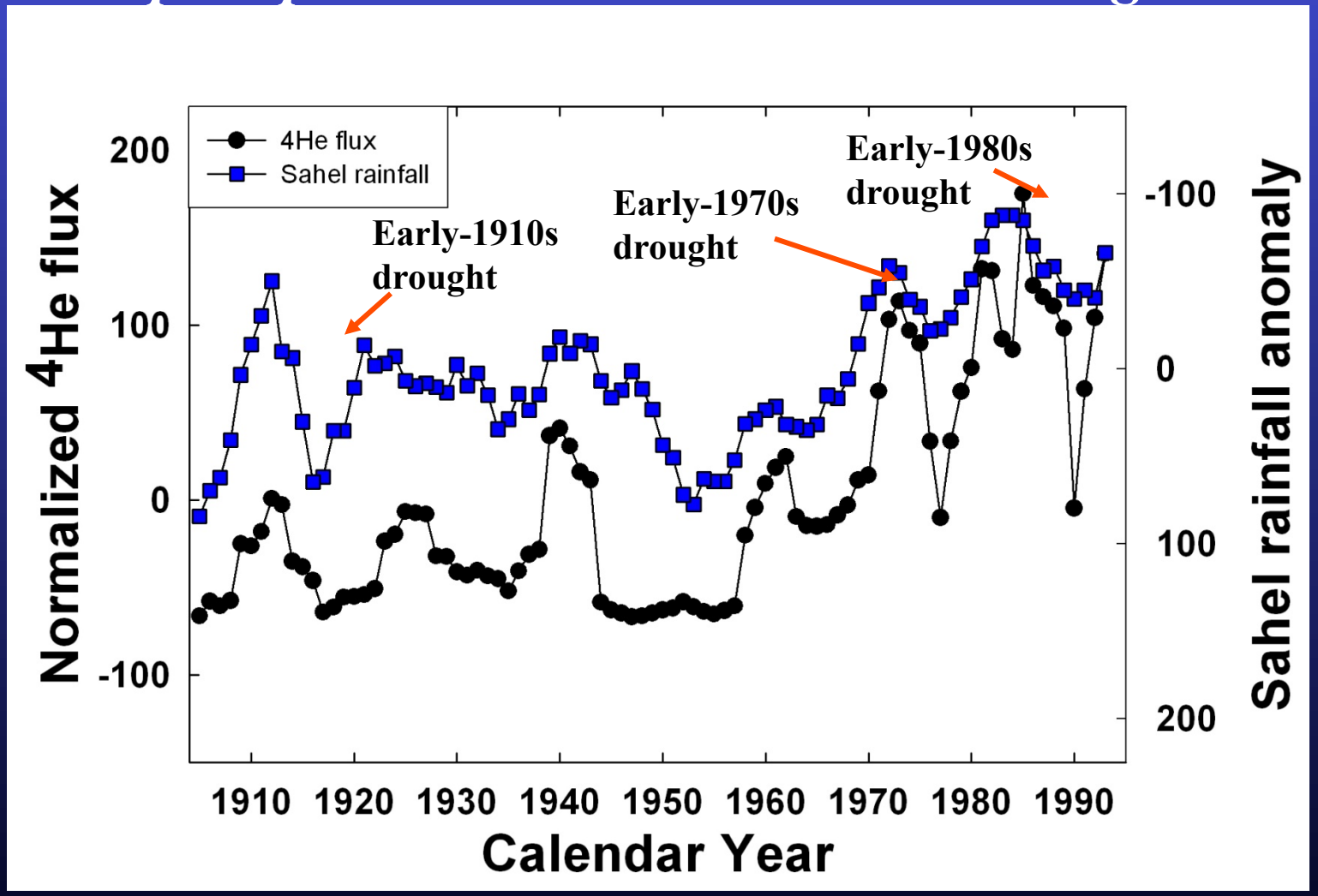

Medieval climate anomaly
Little Ice Age
12000
10000
8000
6000
4000
2000
0
^{4}He flux (10^{-9} cc STP cm^{-2} kyr^{-1})
1000
1200
1400
1600
1800
2000
Year (A.D.)

Spatial correlation between ^{4}He flux record and precious year's precipitation



Highest correlations in Tropical N. Africa→ correlation does not necessarily imply dust is derived from these regions .

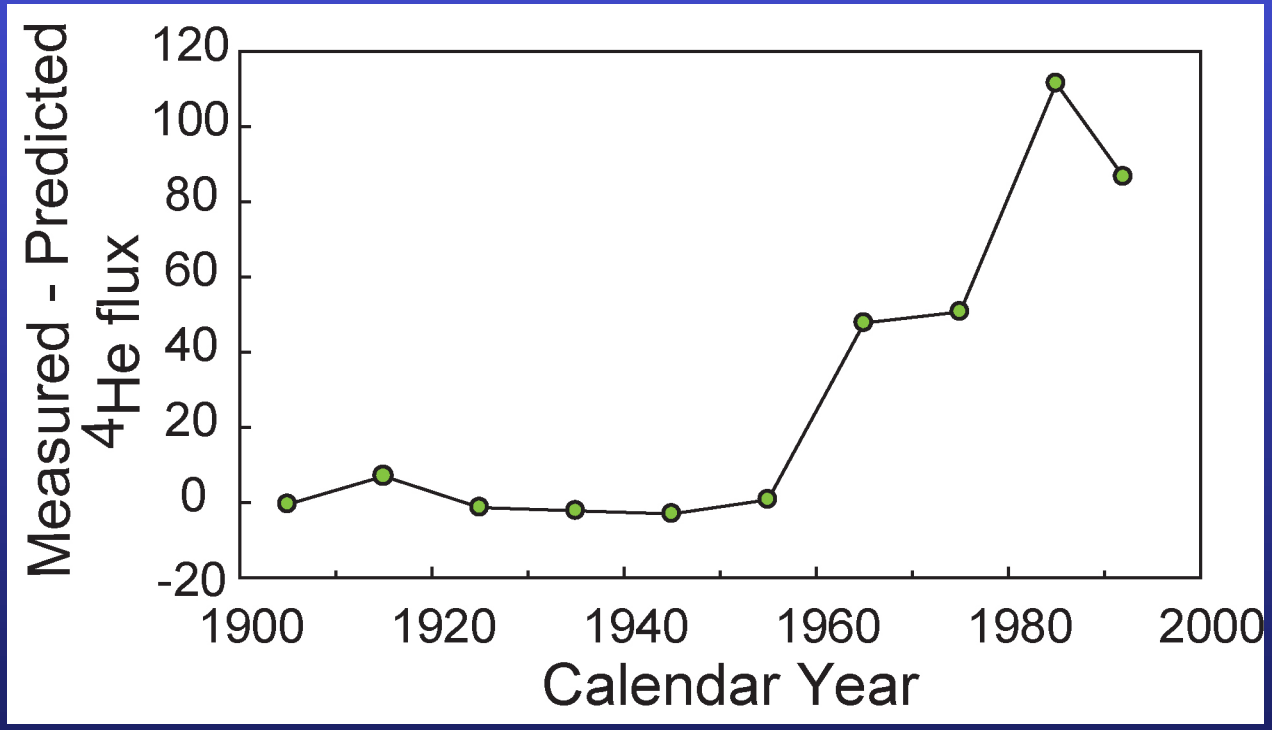
Correlation between He flux in the Red Sea coral and precipitation in the Sudano-Sahel region



Data smoothed with a 5-year filter

(Bhattacharya and Mukhopadhyay, 2009, in prep)

Evidence of change in dust emission for a given rainfall forcing?



- After the wettest decade of the 1950's, dust emission rates from Africa increased significantly more than would be expected from only a reduction in precipitation rates.
- Dust emission rates depends non-linearly on precipitation.
- Dust emission increased as a result of land- management practices and population pressure.
- New sources.

Introduction-II

Objective: Reconstruct dust flux from Sahara-Sahel region of Africa using ^{4}He.

^{4}He as an excellent tracer of mineral dust (Patterson et al., 1999; Marcantonio et al., 2000; Marcantonio et al., 2009 submitted Mukhopadhyay et al., 2001; Mukhopadhyay and Kreycik, 2008, Winckler et al., 2005, 2007).

He is inert; not particle reactive (unlike Ti and Al) and not affected by scavenging.

Very little He in the seawater.

Volcanic dust does not contribute to the Helium budget.

Introduction-I

- The amount of dust emitted from arid and semi-arid regions is intimately linked to precipitation (e.g., N'Tchayi Mbourou et al., 1997; Prospero and Lamb, 2003; Chiapello et al., 2005)

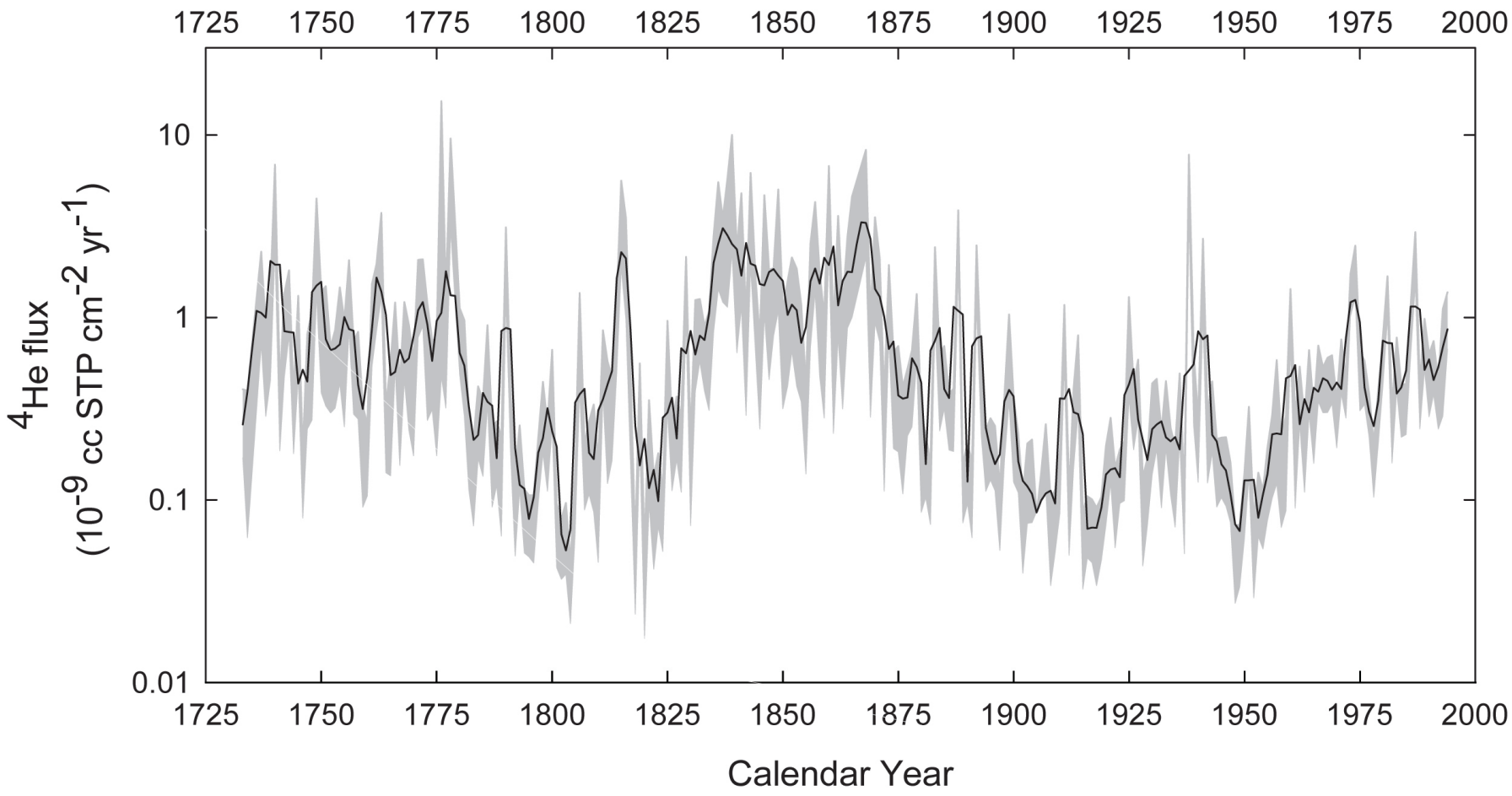
- Precipitation itself may be linked to oceanic sea surface temperatures (e.g., Hastenrath and Lamb,1977; Vizy and Cook, 2001; Giannini et al., 2003).

- Mineral dust can affect the radiative energy balance in the atmosphere (e.g., Alpert et al. 1998).

- North African dust affects nutrient cycling in the Amazon (Swap et al., 1992) and affects air quality in the Caribbean and Southeast US (Prospero and Lamb, 2003).

→ Dust is an important component of the climate system but its impact on the climate system not as well understood as the greenhouse gases.

A 260 year dust record from the Red Sea



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