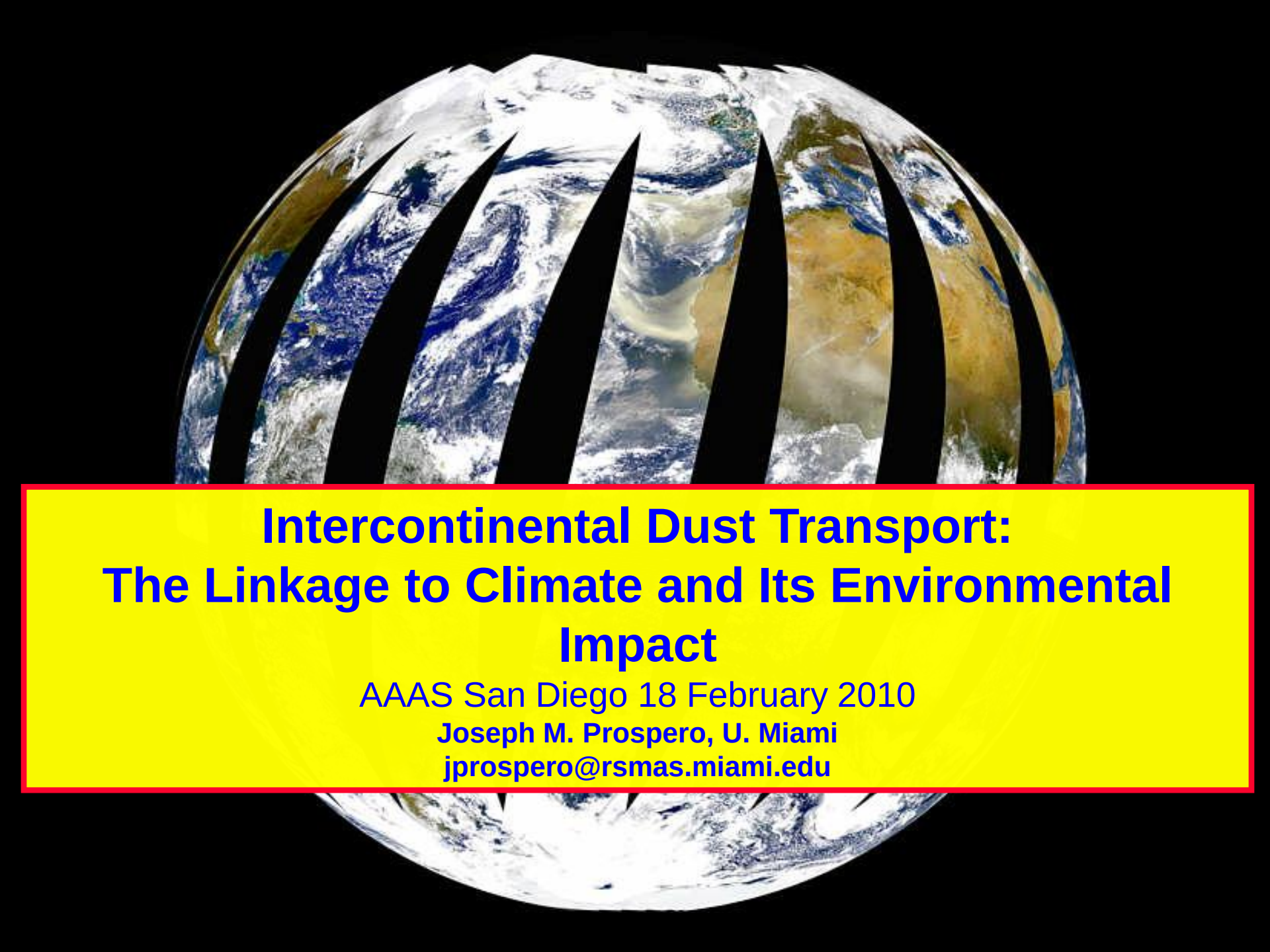


Intercontinental Dust Transport: The Linkage to Climate and Its Environmental Impact

AAAS San Diego 18 February 2010

Joseph M. Prospero, U. Miami
jprospero@rsmas.miami.edu

Conclusions: AAAS 2004

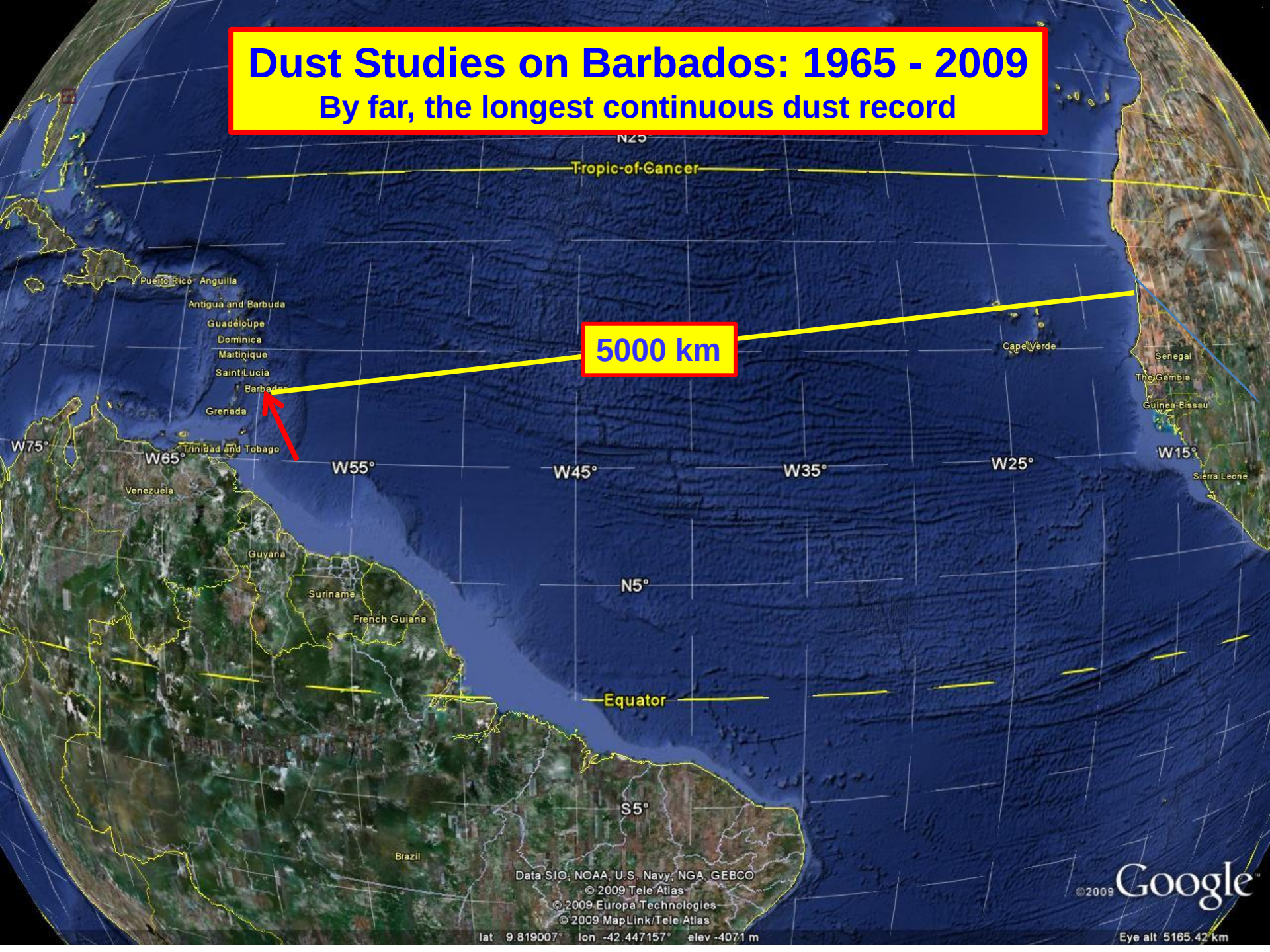
- Dust mobilization over Africa and transport over the Atlantic was linked to rainfall deficits in North Africa (e.g., Sahel - Sudan region) in a clear way.

- Major spikes in dust transport seemed to follow strong El Niño events.

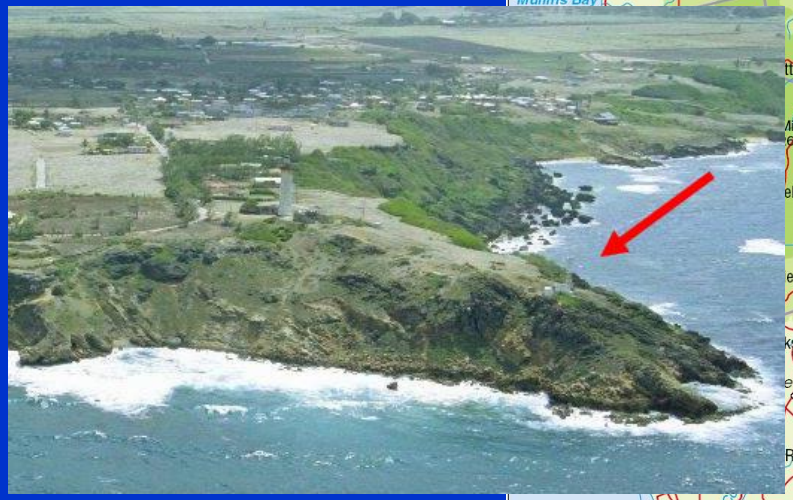
Question: AAAS 2010

With ten more years of data and more El Niño variability - how do these conclusions stand up?

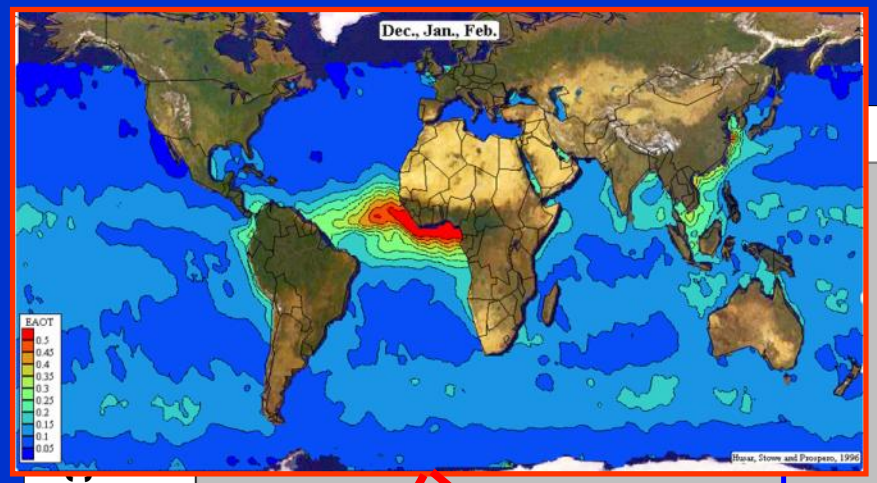
Short answer: NOT WELL!

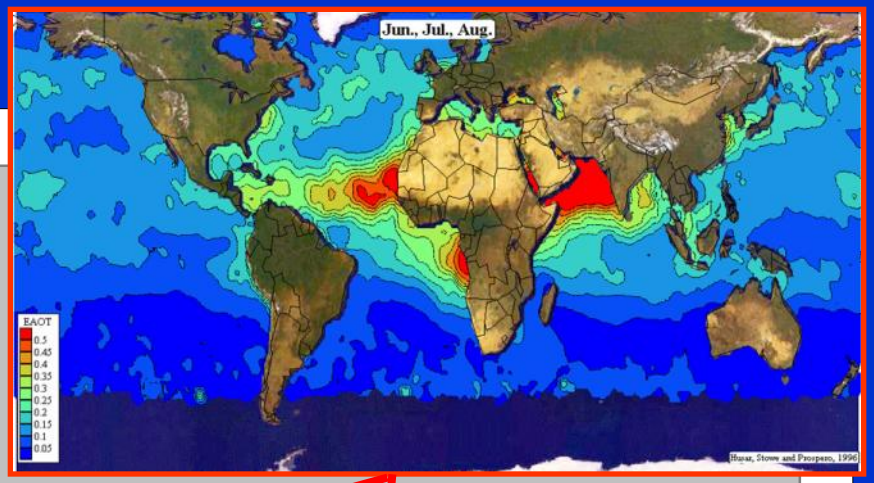

Dust Studies on Barbados: 1965 - 2009
By far, the longest continuous dust record
N25°
Tropic of Cancer
Puerto Rico
Anguilla
Antigua and Barbuda
Guadeloupe
Dominica
Martinique
Saint Lucia
Barbados
Grenada
Trinidad and Tobago
5000 km
Cape Verde
Senegal
The Gambia
Guinea-Bissau
Sierra Leone
W75°
W65°
W55°
W45°
W35°
W25°
W15°
Venezuela
Guyana
Suriname
French Guiana
N5°
Equator
S5°
Brazil
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2009 Tele Atlas
© 2009 Europa Technologies
© 2009 MapLink/Tele Atlas
lat 9.819007° lon -42.447157° elev -4071 m
©2009 Google
Eye alt 5165.42 km

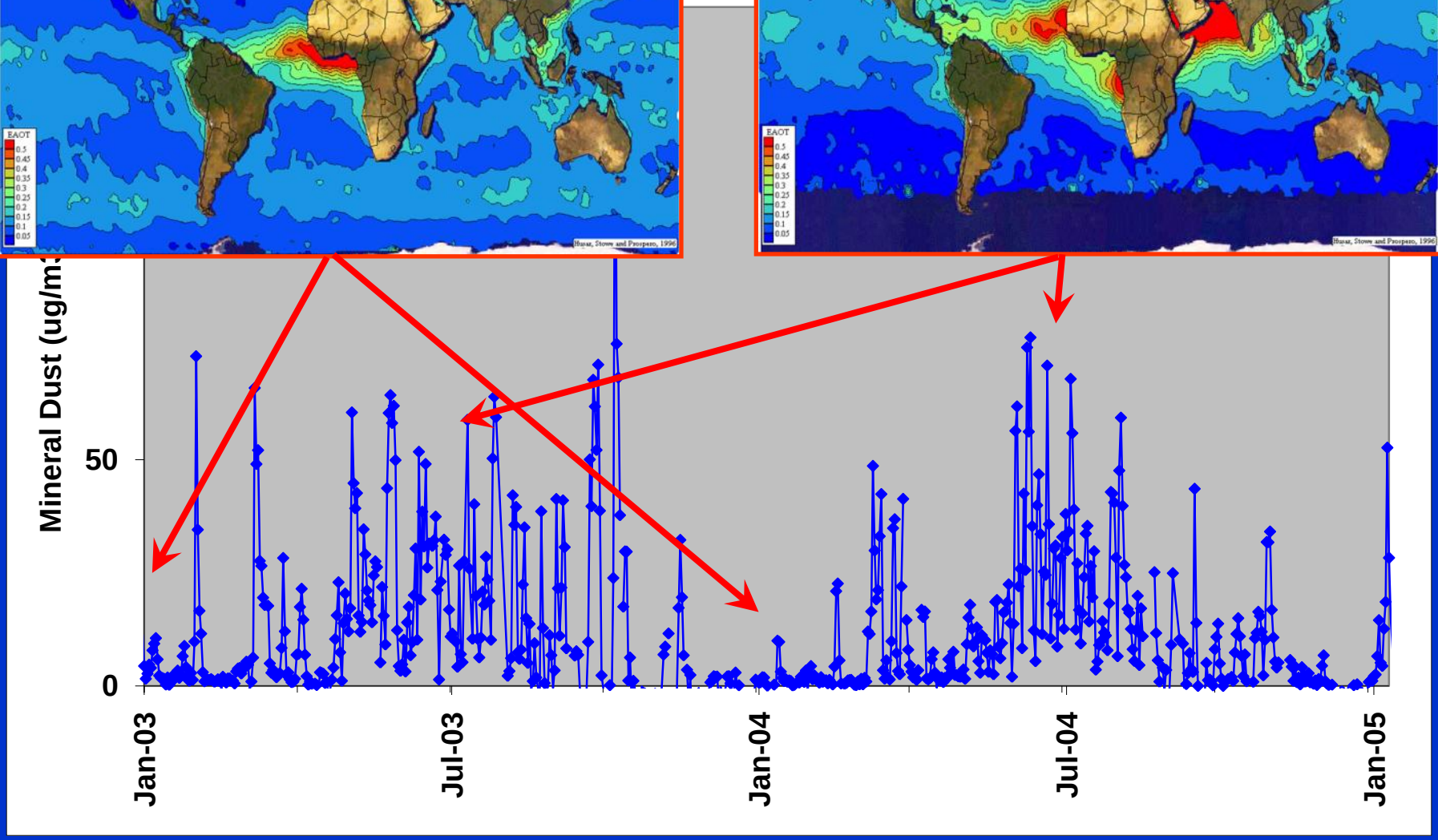
U. Miami Aerosol Research Station, Barbados



Barbados Daily Dust Concentrations: 2003 - 2004







Barbados dust from 8 km

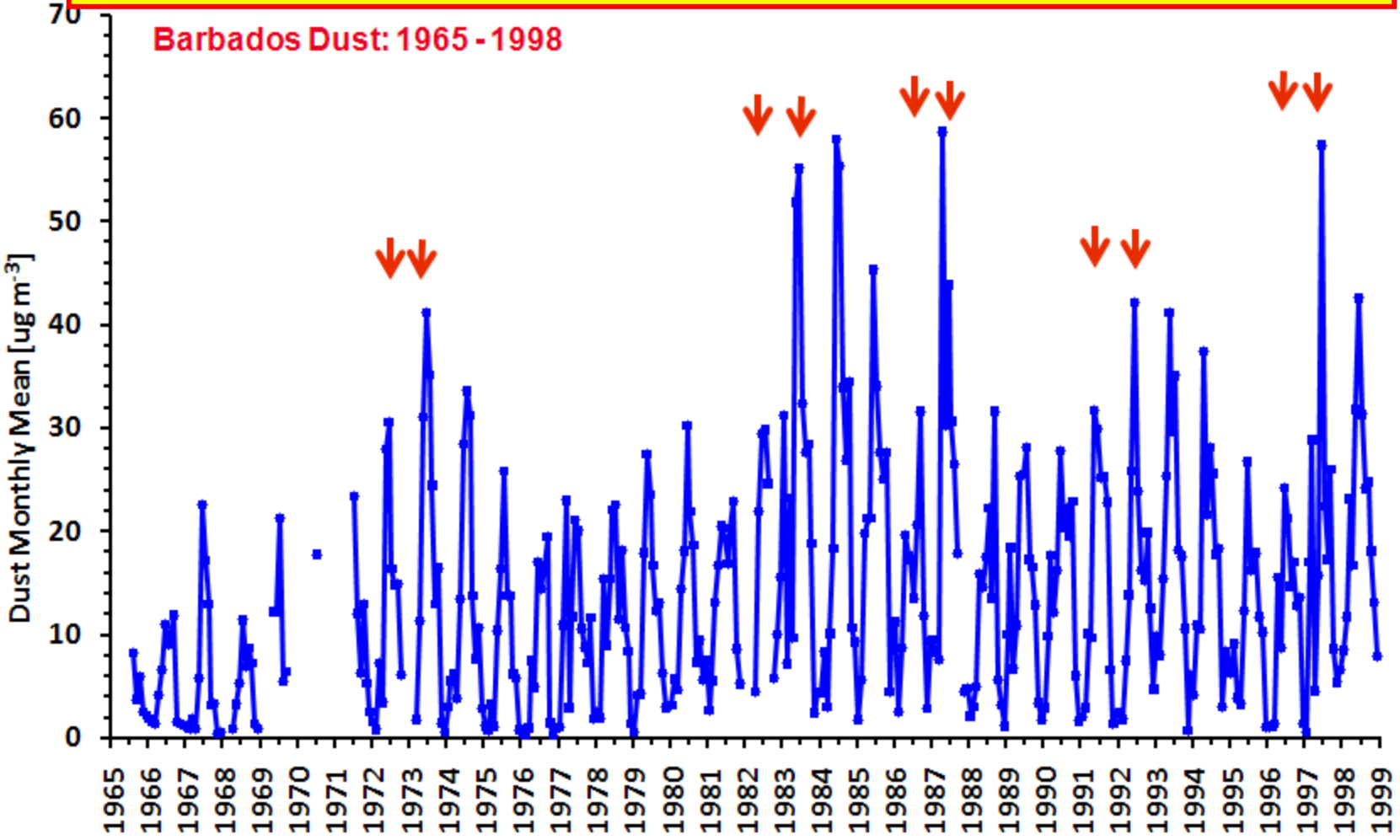
Typical summer dust day

African Dust: A Geologically Significant Contributor to Soils

Dustfall – Rain: Miami 19 July 2009

2004 AAAS - Dust and Climate

Long Term Variability of Barbados Dust: The Link to Climate - ENSO

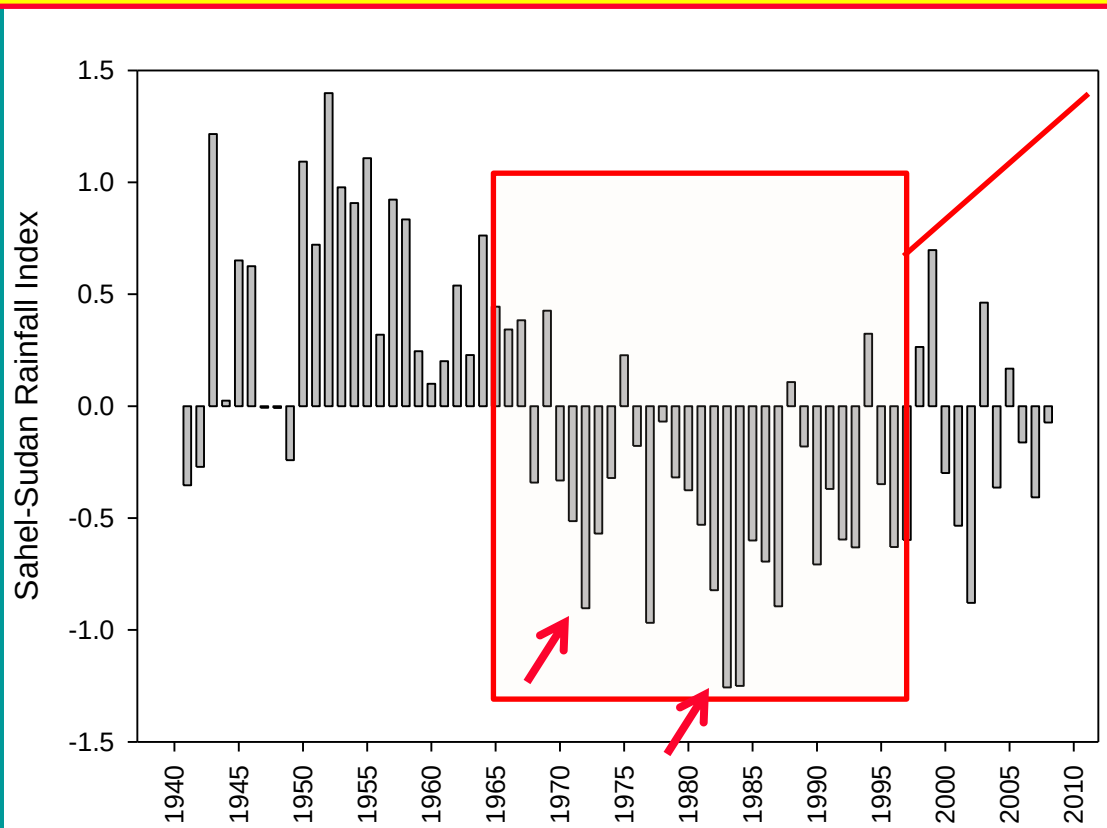


Major El Niño events: 1972-73, 1982-83, 1986-87, 1991-92, 1997-98

NOAA-CIRES Climate Diagnostics Center Multivariate ENSO Index web site: http://www.cdc.noaa.gov/~kew/MEI/mei.html].

2004 AAAS - Dust and Climate

Previous data coverage was associated with extended and often severe drought conditions.

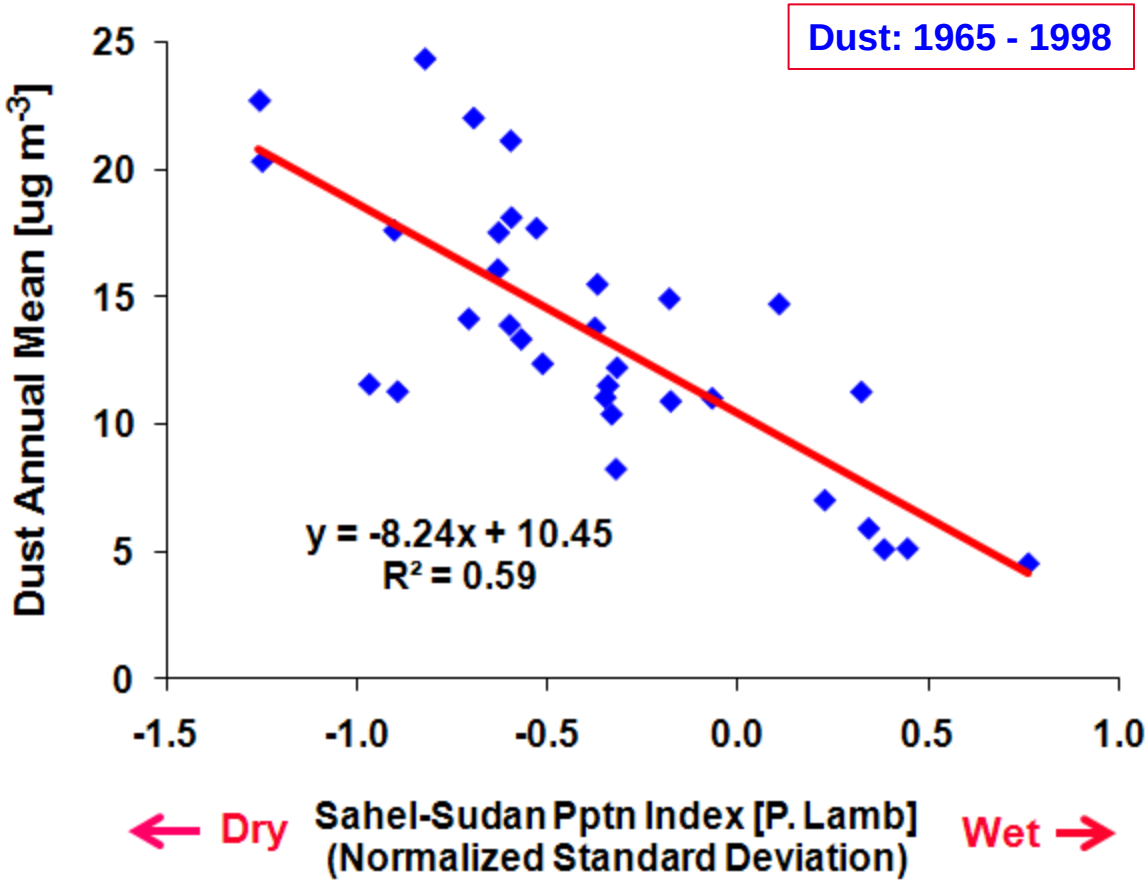


Sahel - Sudan Precipitation Index
Normalized Departures - Standard Deviations
(P. Lamb, Univ. Oklahoma)

Prospero, J. M., and P. J. Lamb (2003), African droughts and dust transport to the Caribbean: Climate change implications, *Science, 302, 1024-1027,*

2004 AAAS - Dust and Climate

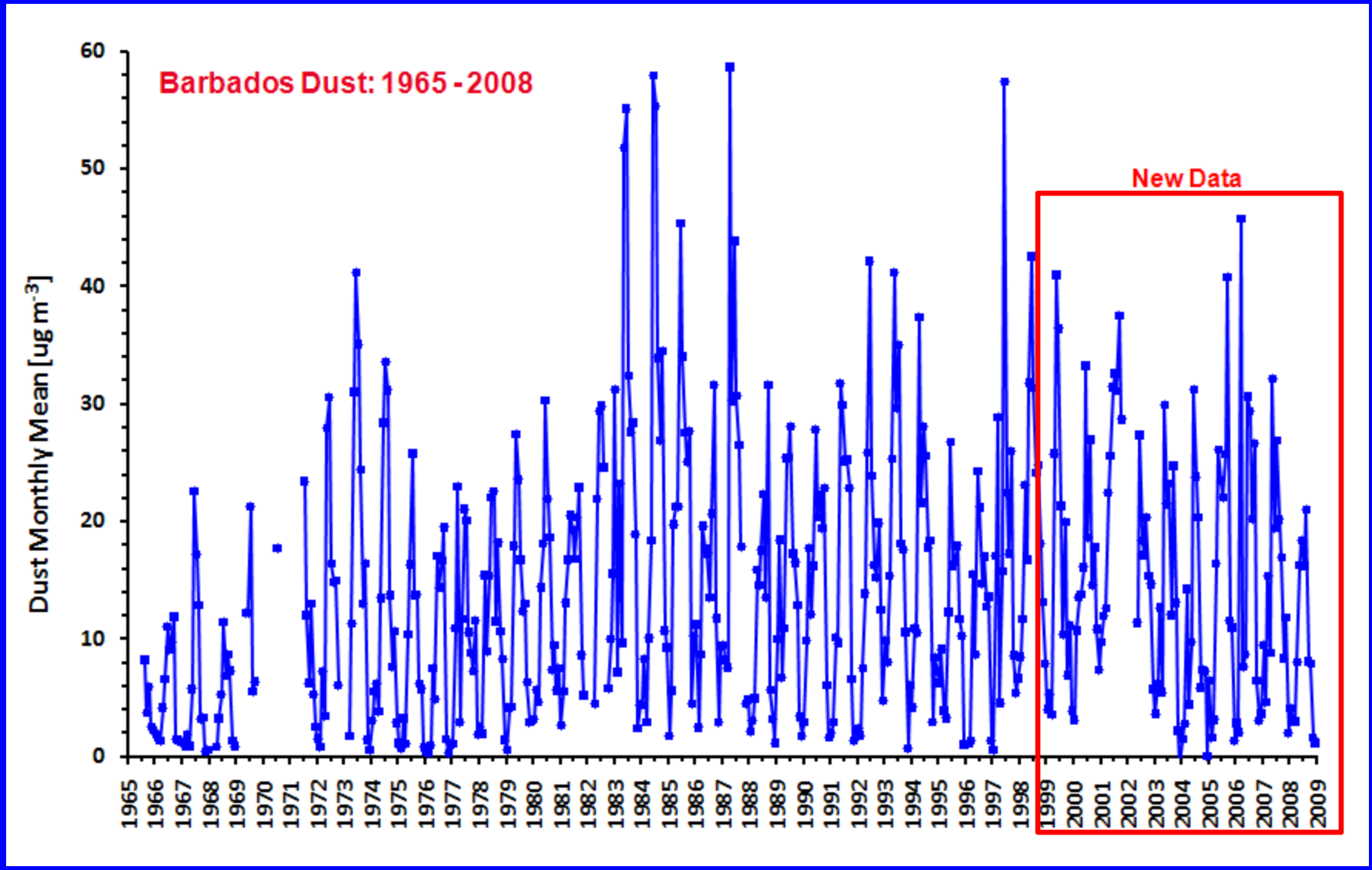
Barbados Dust & Sahel Rainfall: 1965 - 1998



Prospero, J. M., and P. J. Lamb (2003)*Science, 302*

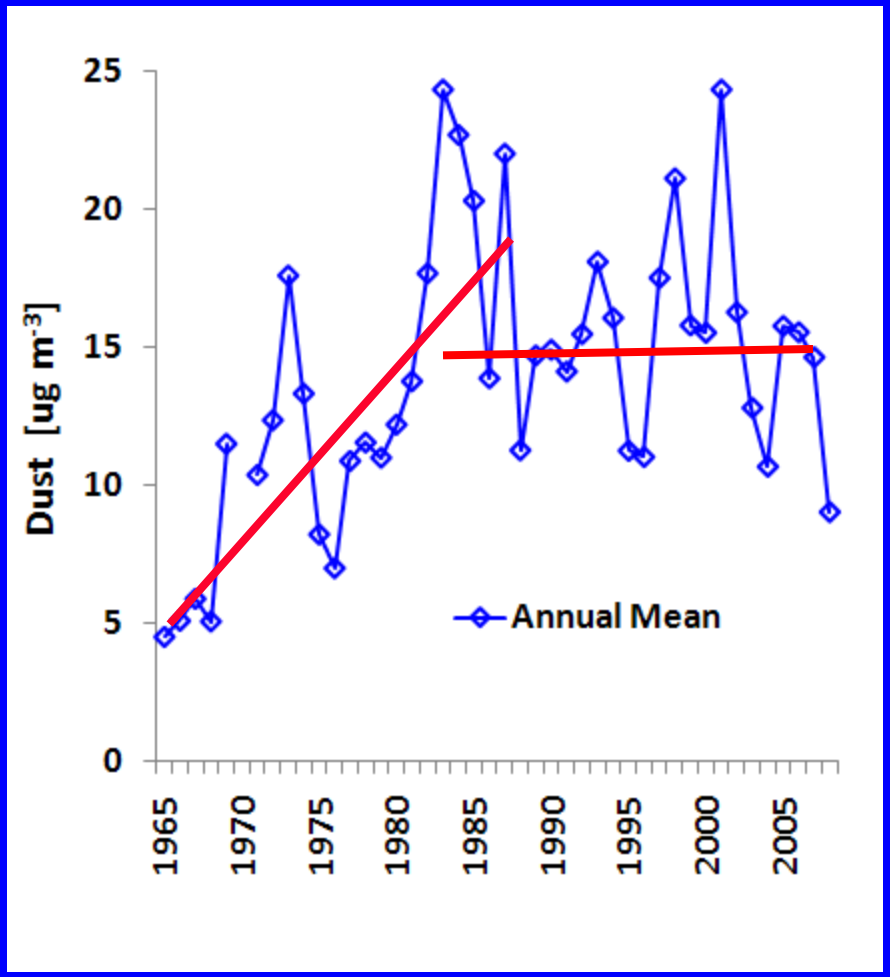
AAAS 2010 - Dust and Climate

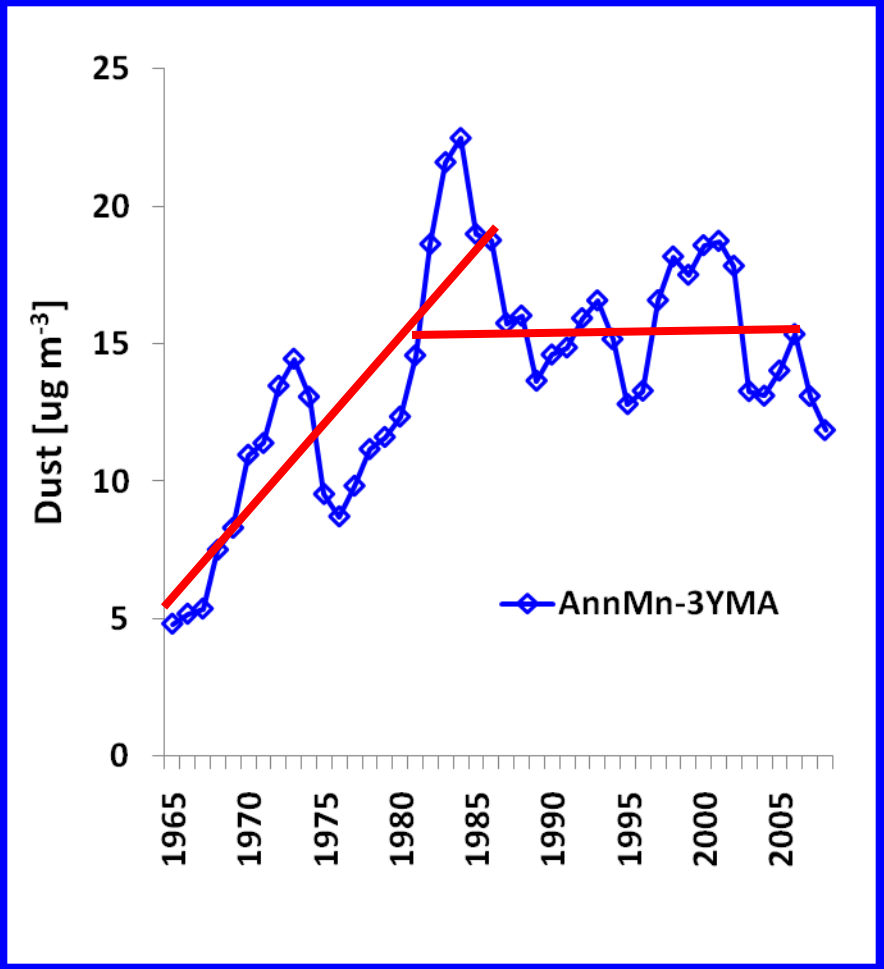
Long Term Variability of Barbados Dust: The Link to Climate



AAAS 2010 - Dust and Climate

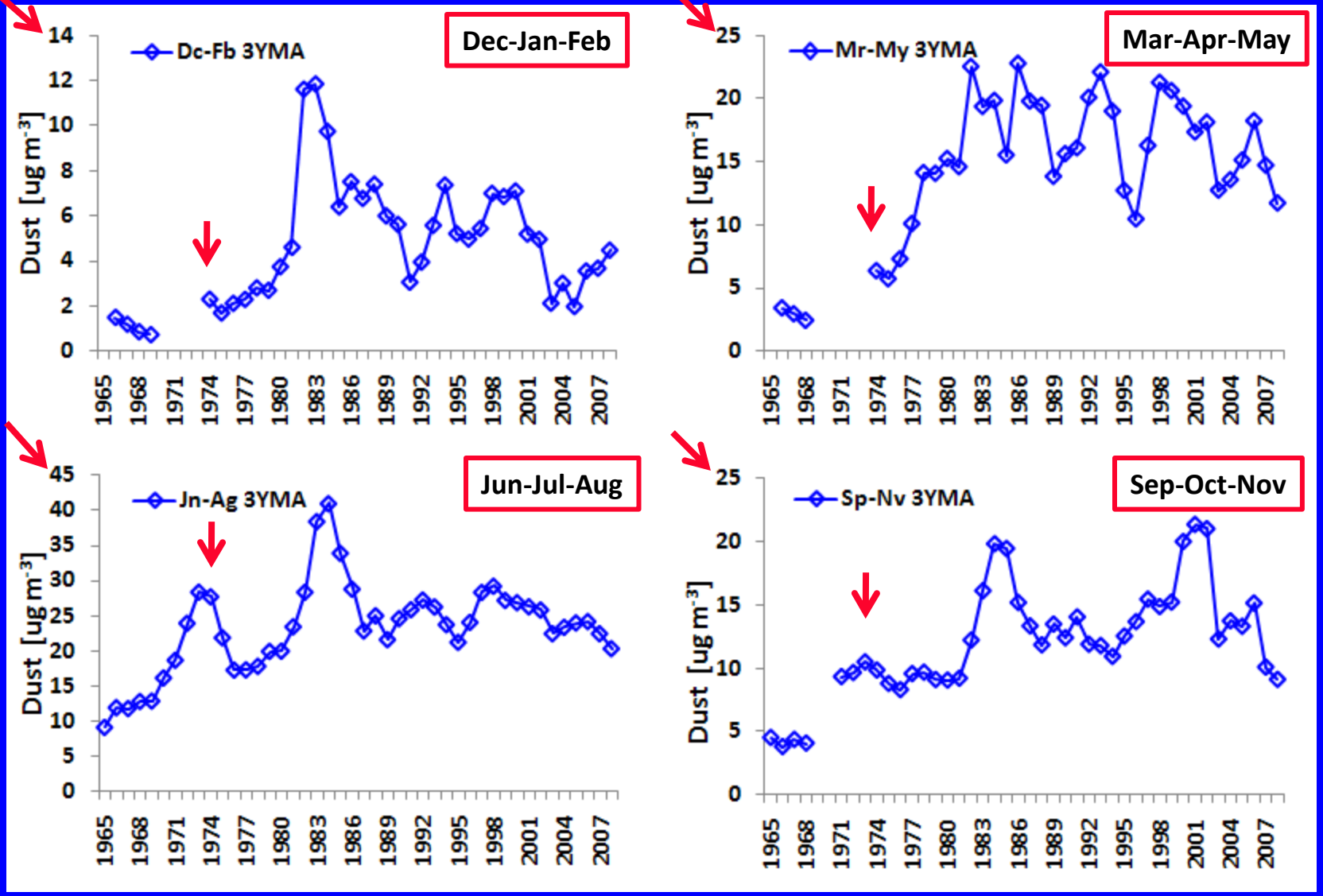
Barbados Dust Annual Means & Three-Year Moving Average





Conclusion: dust transport has stabilized at a moderately high level since late 1980s

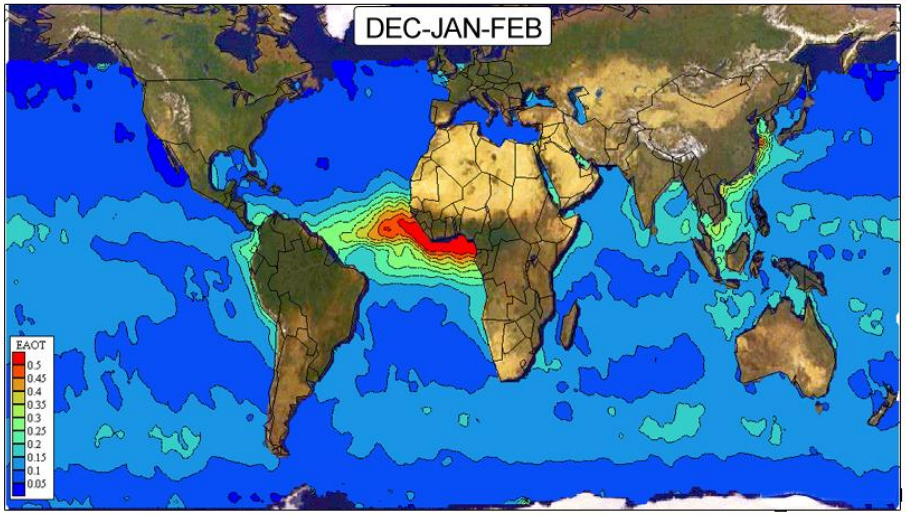
Barbados: Seasonal Dust Trends - Three Year Moving Averages

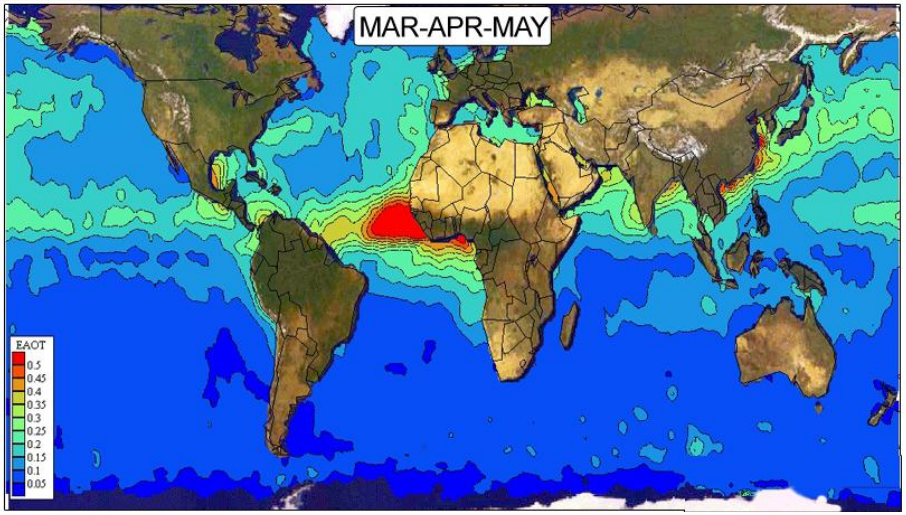


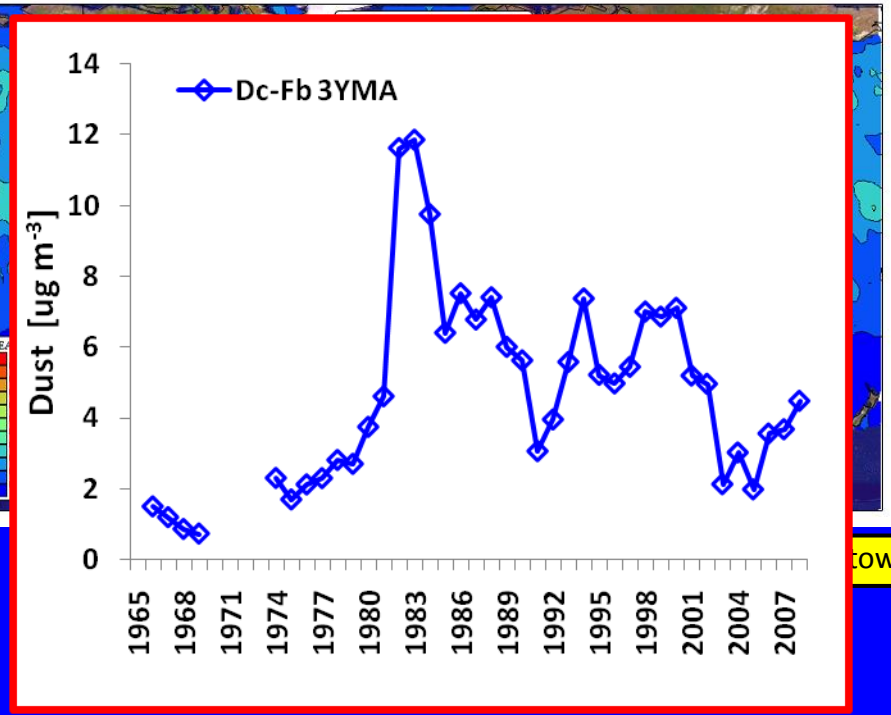
The greatest changes in dust transport occurred in the Winter and Spring periods!
Also minimal impact of the drought in early 1970s except in Jun-Jul-Aug.

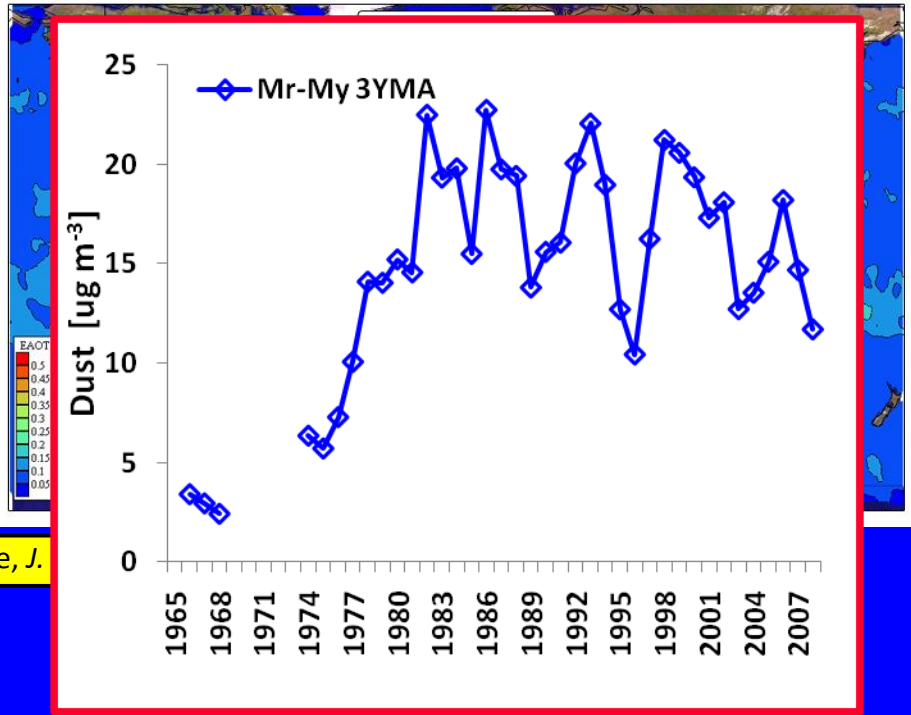
How do Long-Term Dust Trends Relate to Seasonal Transport Patterns?

NOAA AVHRR Aerosol Optical Depth



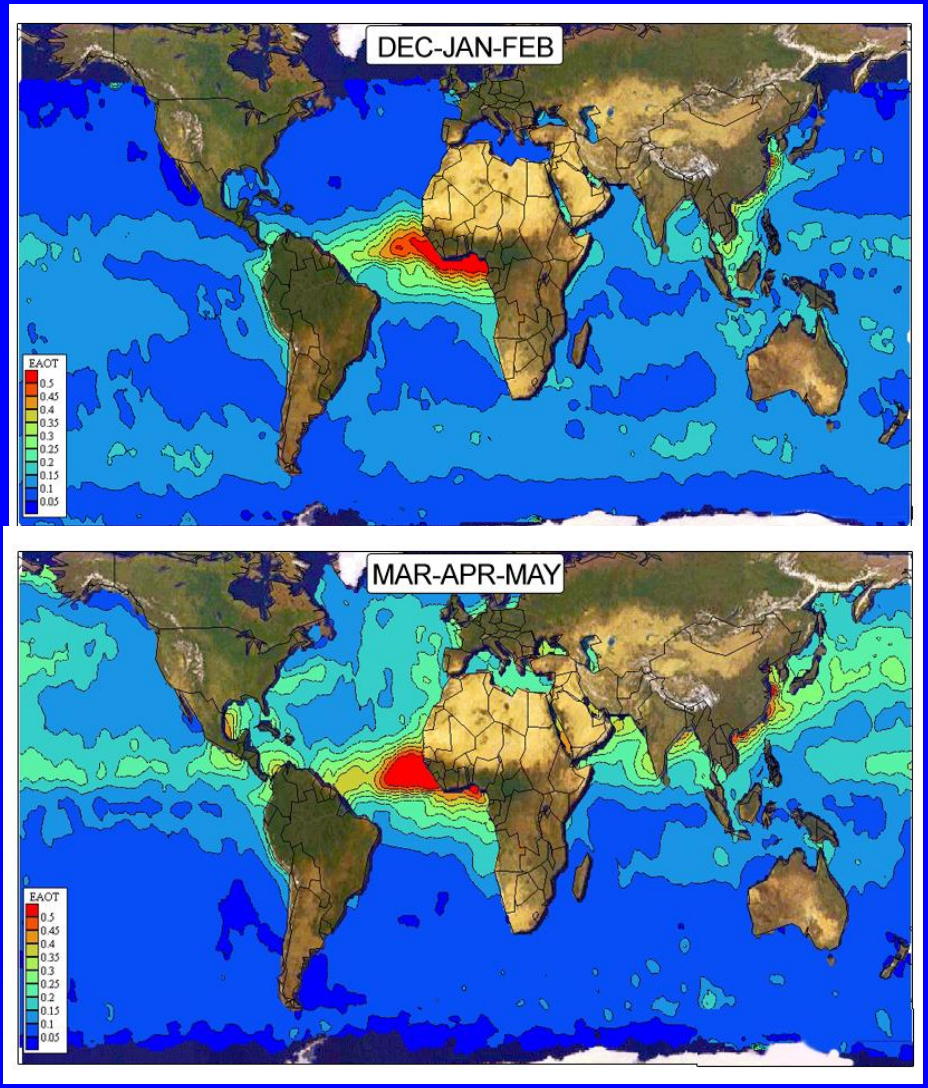


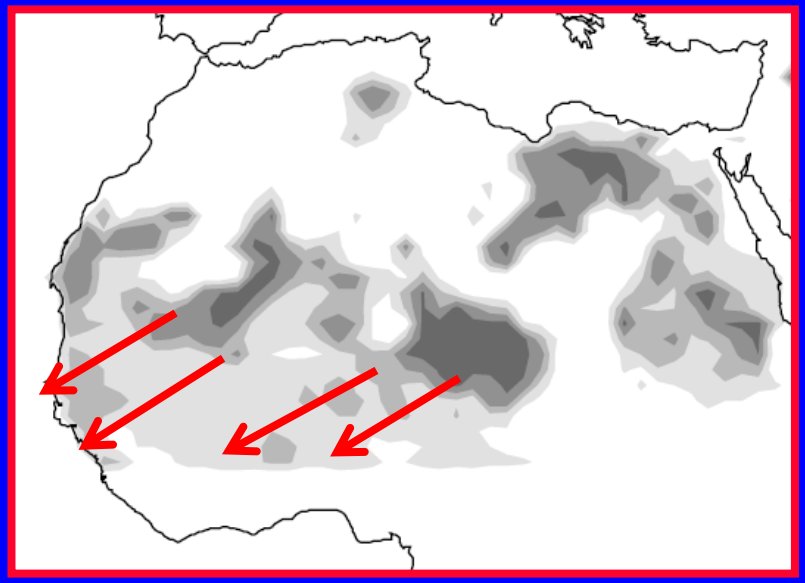




owe, *J.*

The strong increase in dust transport during the Winter and Spring months seems to be strongly associated with sources in the Sahel - Sudan region.

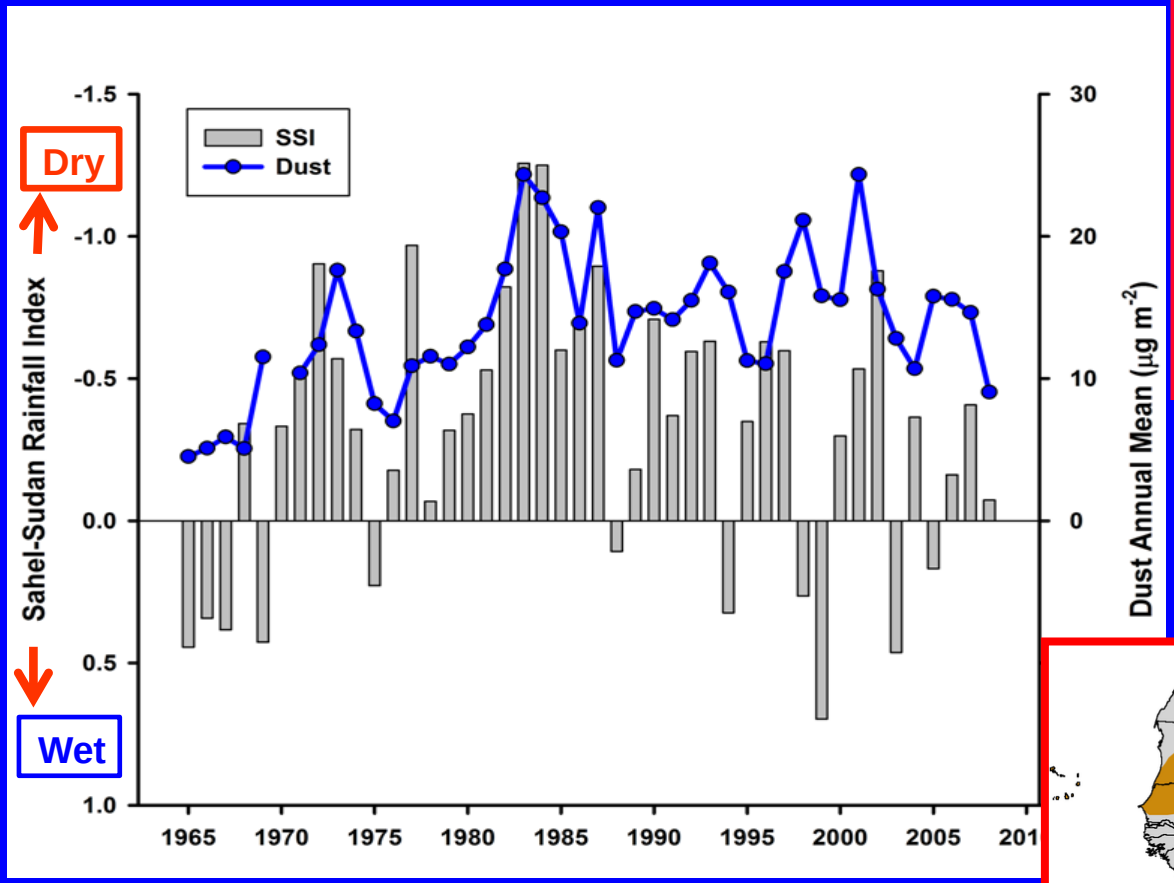




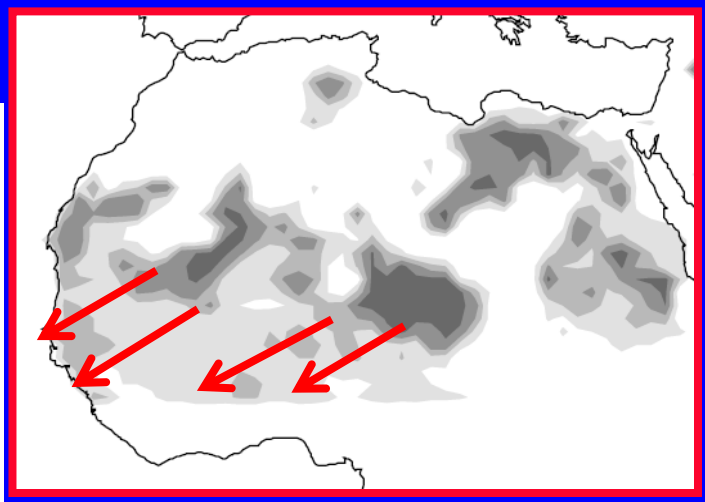
TOMS Dust Sources: Prospero et al.,(2002), Environmental characterization of global sources of atmospheric soil dust identified with the TOMS absorbing aerosol product, *Rev. Geophys, 40*

Bodele Depression, Chad

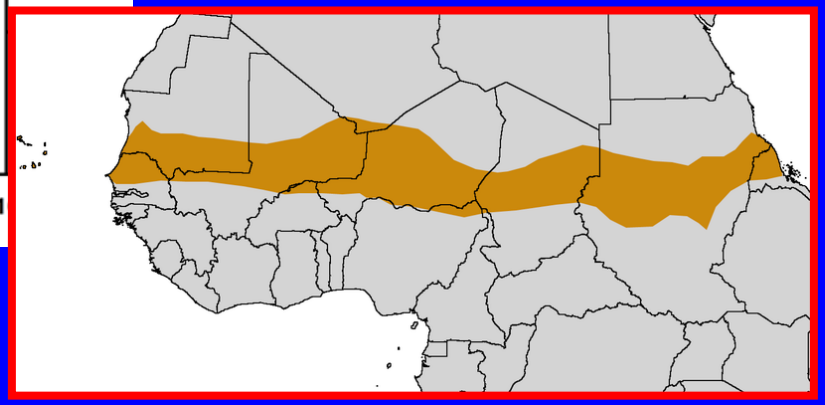
Barbados Dust & Sahel-Sudan Rainfall



Annual Barbados dust concentration tracks Sahel-Sudan Rainfall Index until the late 1980s. (Note the inverted Rainfall Index scale.)



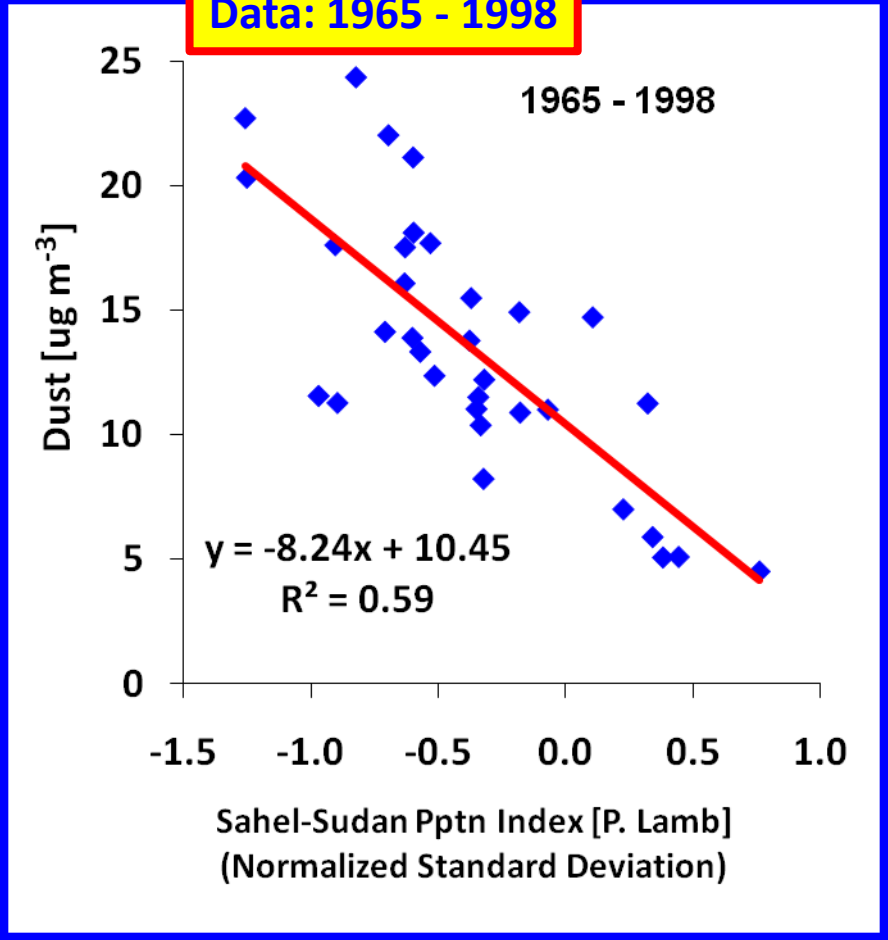
Major dust source areas in North Africa identified by TOMS aerosol index. Prospero et al.,(2002), *Rev. Geophys, 40*



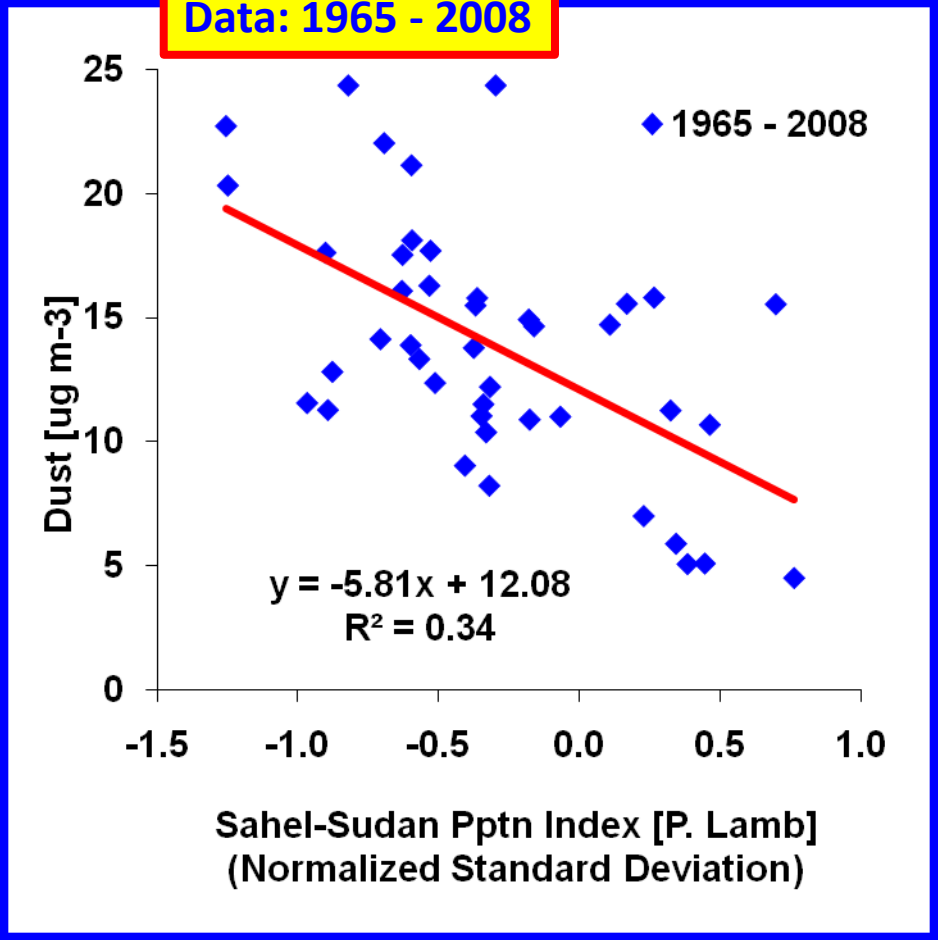
Sahel: African land area between the lines of 200mm and 600mm mean 20th century annual rainfall. (Wikipedia)

Are Barbados Dust Concentrations Linked to Rainfall in the Sahel-Sudan of North Africa?

Data: 1965 - 1998



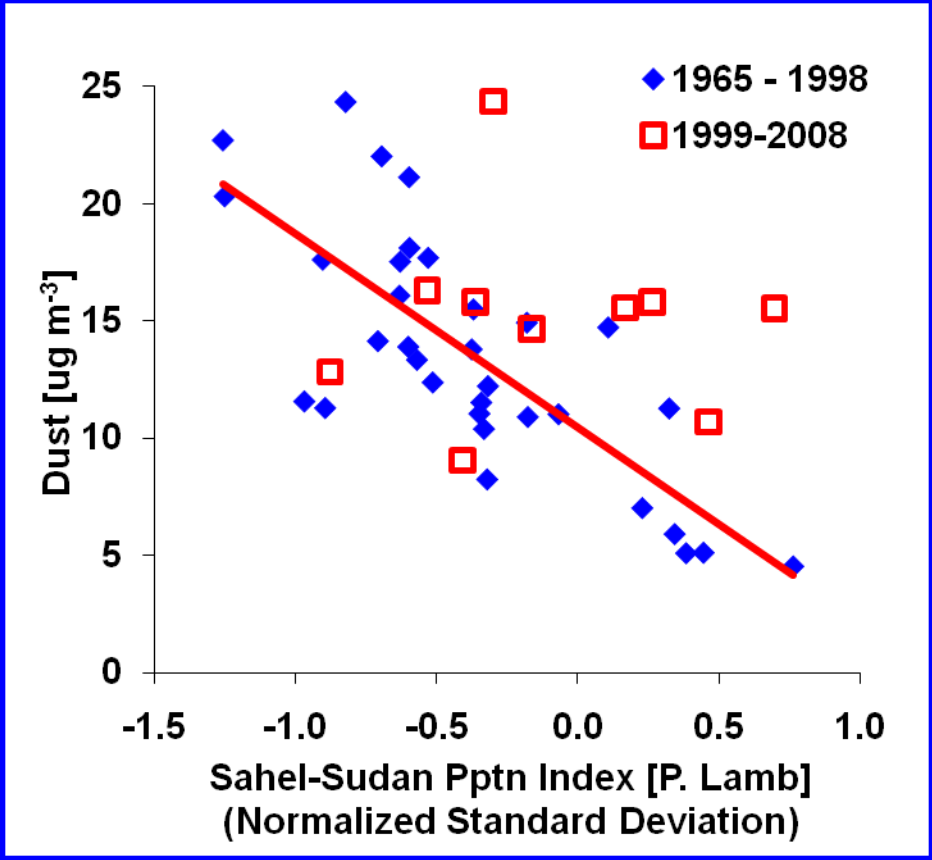
Data: 1965 - 2008

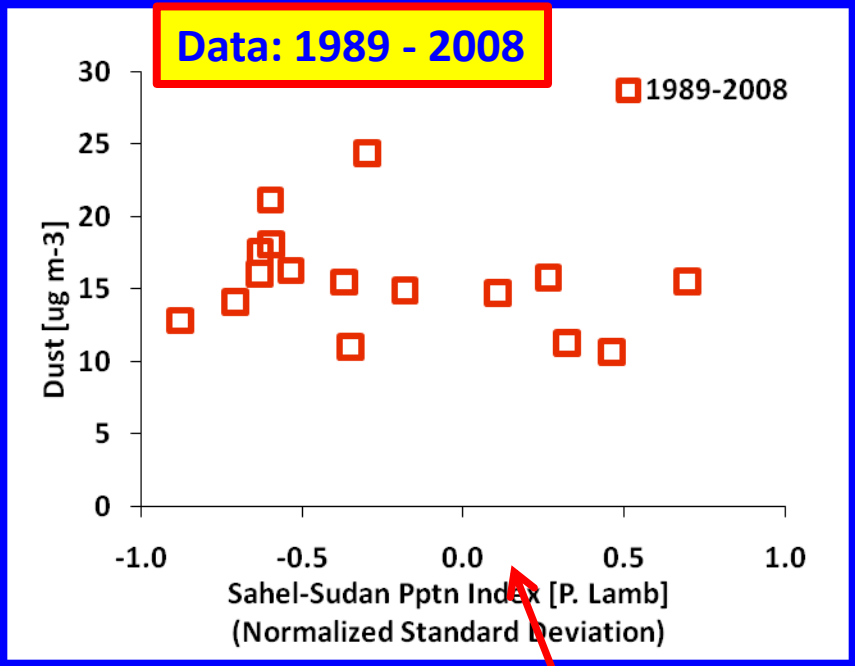


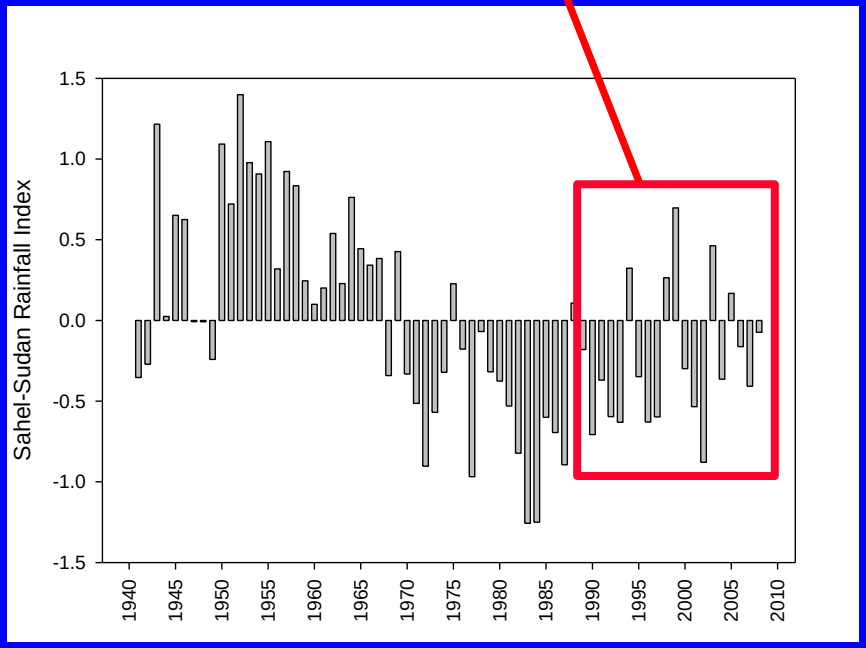
Prospero and Lamb (2003)*Science, 302*

The apparent relationship between Barbados annual mean dust concentrations and SSPI appears to hold up - but the relationship is degraded.

Plotting the data from 1999 to 2008 separately - dust concentrations are completely unrelated to SSPI. Even over the last 20 years!







Other Climate Variables in the North Atlantic Ocean

There have been substantial changes in many metrics starting in early 1990s.

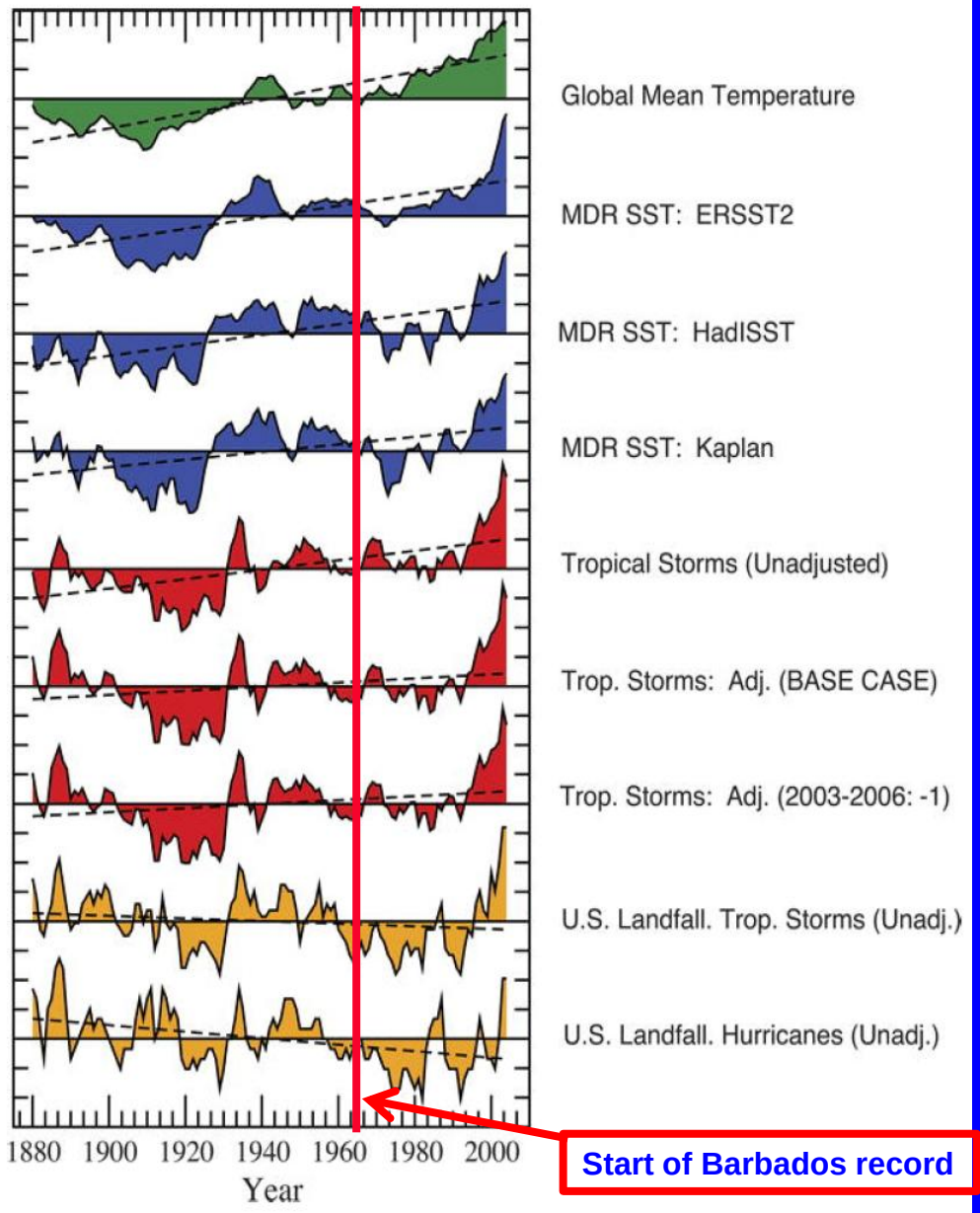
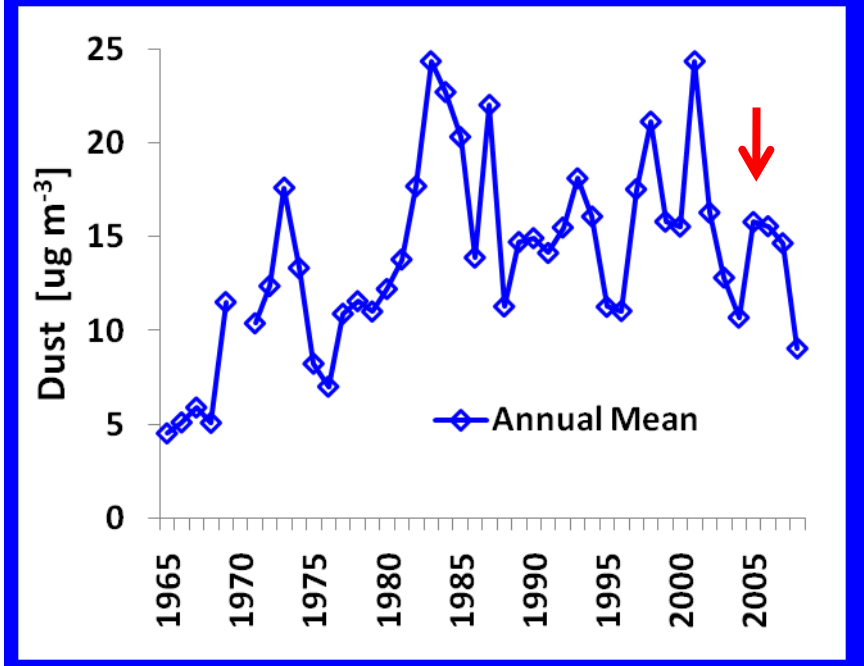


FIG. 9. Normalized tropical Atlantic indices (5-yr running means of time series from 1878 to 2006, solid black) and their linear trends (dashed black). Vecchi, G.A., and T.R. Knutson, 2008 *J. Climate*, 21, 3580–3600.



The impact of dust on SST?! And hurricanes?!

Dust Mobilization & Human Impacts

It is difficult to separate the effects of climate change on dust mobilization from those resulting from human activity.

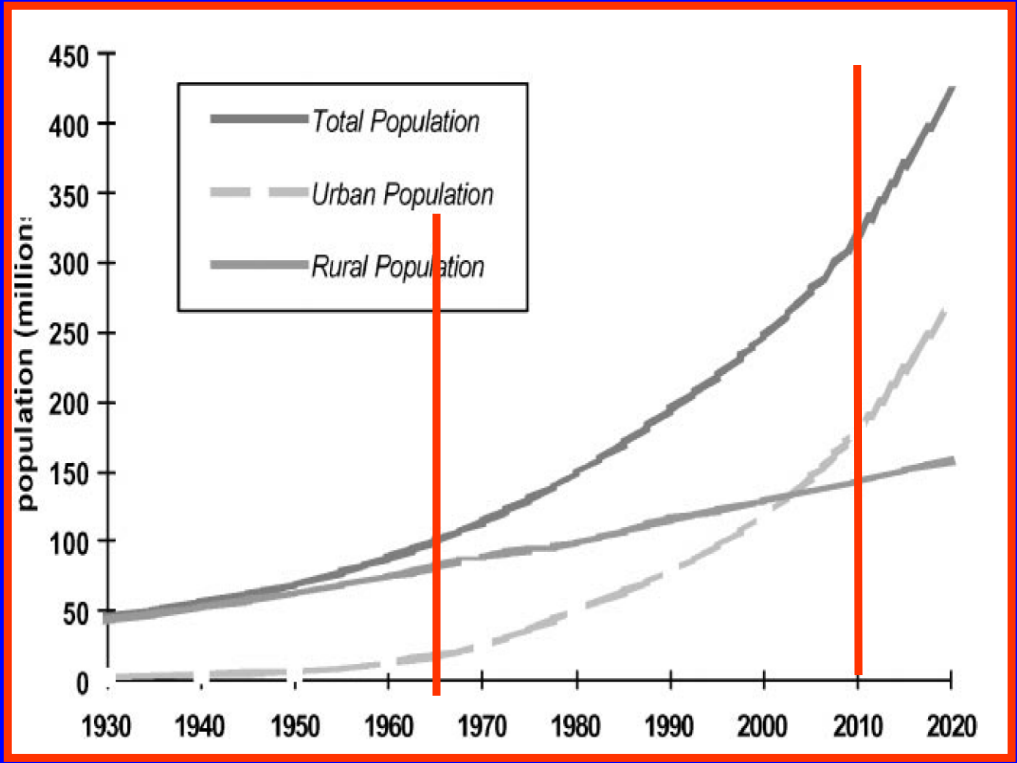


Fig. 1. Past and projected urban, rural and total population of West Africa. Cour, *Global Environmental Change* 11 (2001).

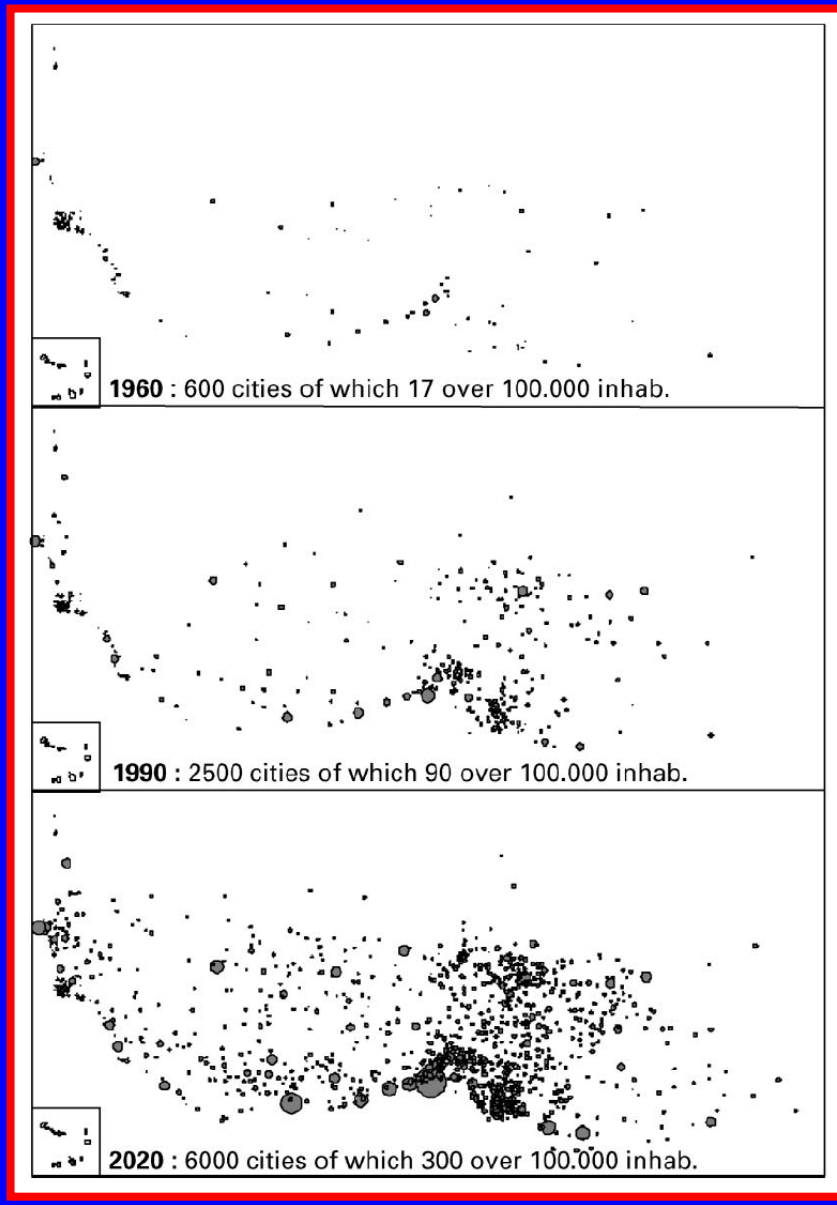
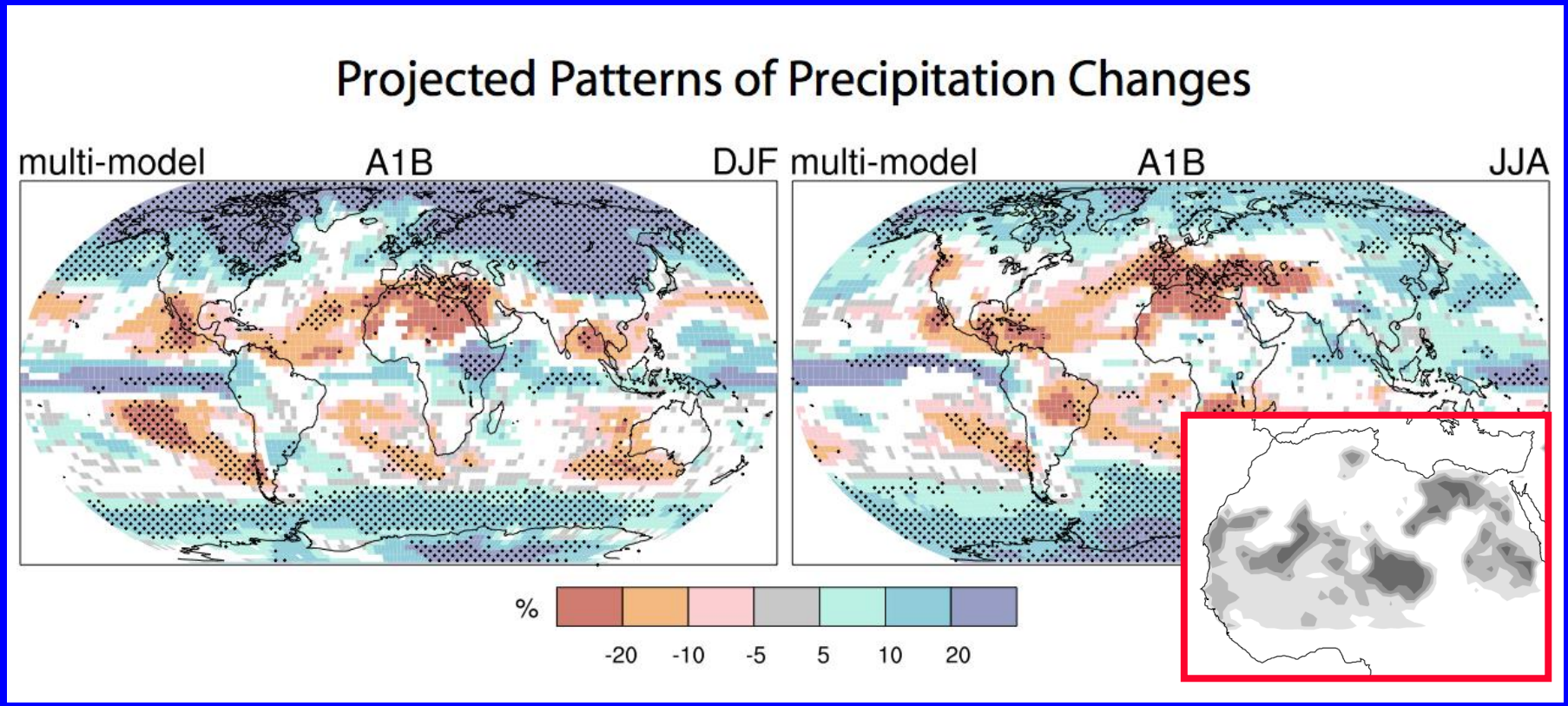


Fig. 2. Network of Cities over 50,000 inhabitants in West Africa: Evolution between 1960 and 1990, and projection for 2020. Cour, 2001.

Projections of Future Changes in Climate
What does it mean for Atlantic dust?



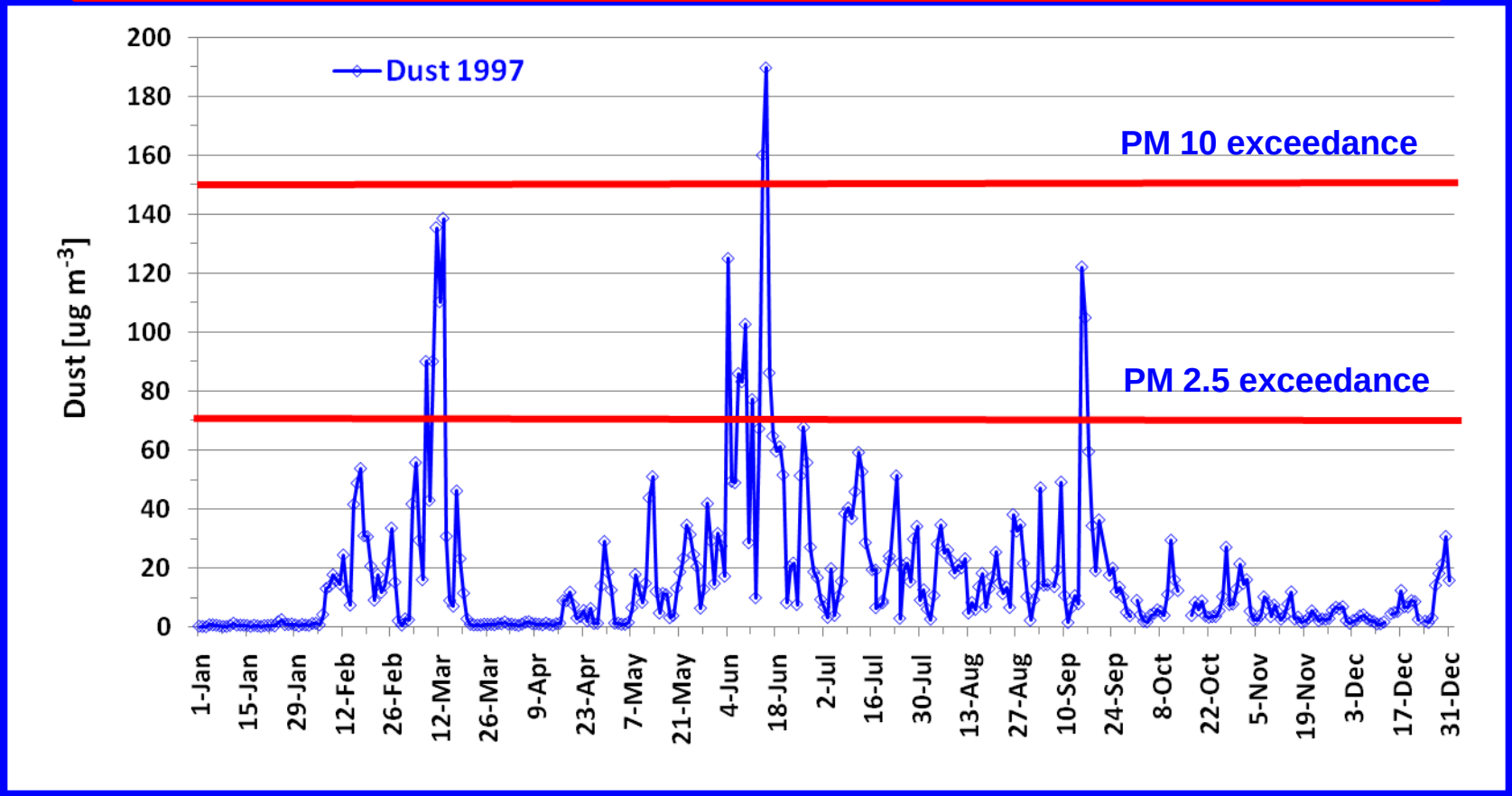
New in IPCC 2007: Drying in much of the subtropics, more rain in higher latitudes, continuing the broad pattern of rainfall changes already observed.

Note: in white areas, no predictions - fewer than 66% of the models agree on the sign of the change. These areas are the most important sources relative to trans-Atlantic dust transport.

African Dust and Air Quality in the Caribbean

US EPA National Ambient Air Quality Standards (24 hour)
PM 2.5: 35 ug m^{-3}
PM 10: 150 ug m^{-3}

About half of the dust mass in Barbados Trade Winds is PM 2.5, over 90% is PM 10.



During dusty years, the 24-hour PM 2.5 standard is exceeded 10 - 20 times.

Conclusions: African Dust and Climate (based on Barbados Record)

- Over the past 20 years dust concentrations seemed to have settled into relatively narrow range that is substantially higher than pre-drought levels.

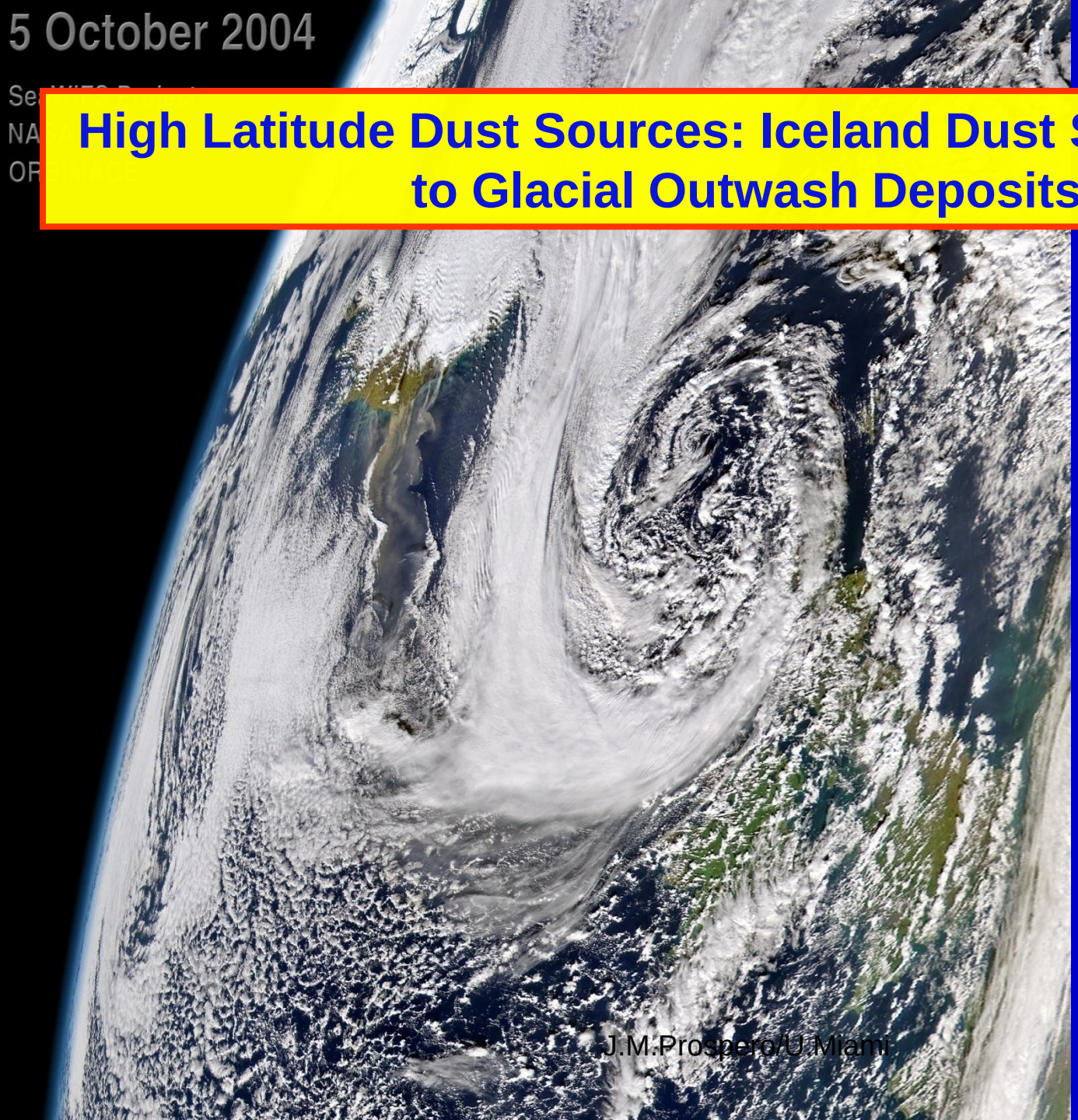
- In contrast to the first 25 years of record, there is now no clear relationship between dust transport and rainfall.

- The seasonal pattern of dust transport has changed with time.
  - Summer transport dominates - increased following the onset of drought
  - Output during Winter and Spring at first lagged and then increased much more sharply and it remains high today
  - The change in seasonal pattern suggests that the greatest impact of the drought-dust was in the Sahel-Sudan.

- Because of these uncertainties and the uncertainty in future rainfall/climate/population in the Sahel-Sudan region, it is difficult to anticipate future trends in transport.

- Dust concentrations in the Caribbean often exceed US EPA standards for PM 2.5, a possible health concern. Given the uncertainty in future dust trends, we cannot anticipate future health impacts.

High Latitude Dust Sources



High Latitude Dust Sources: Iceland Dust Storms Linked to Glacial Outwash Deposits

J.M.Prospero/U.Miami

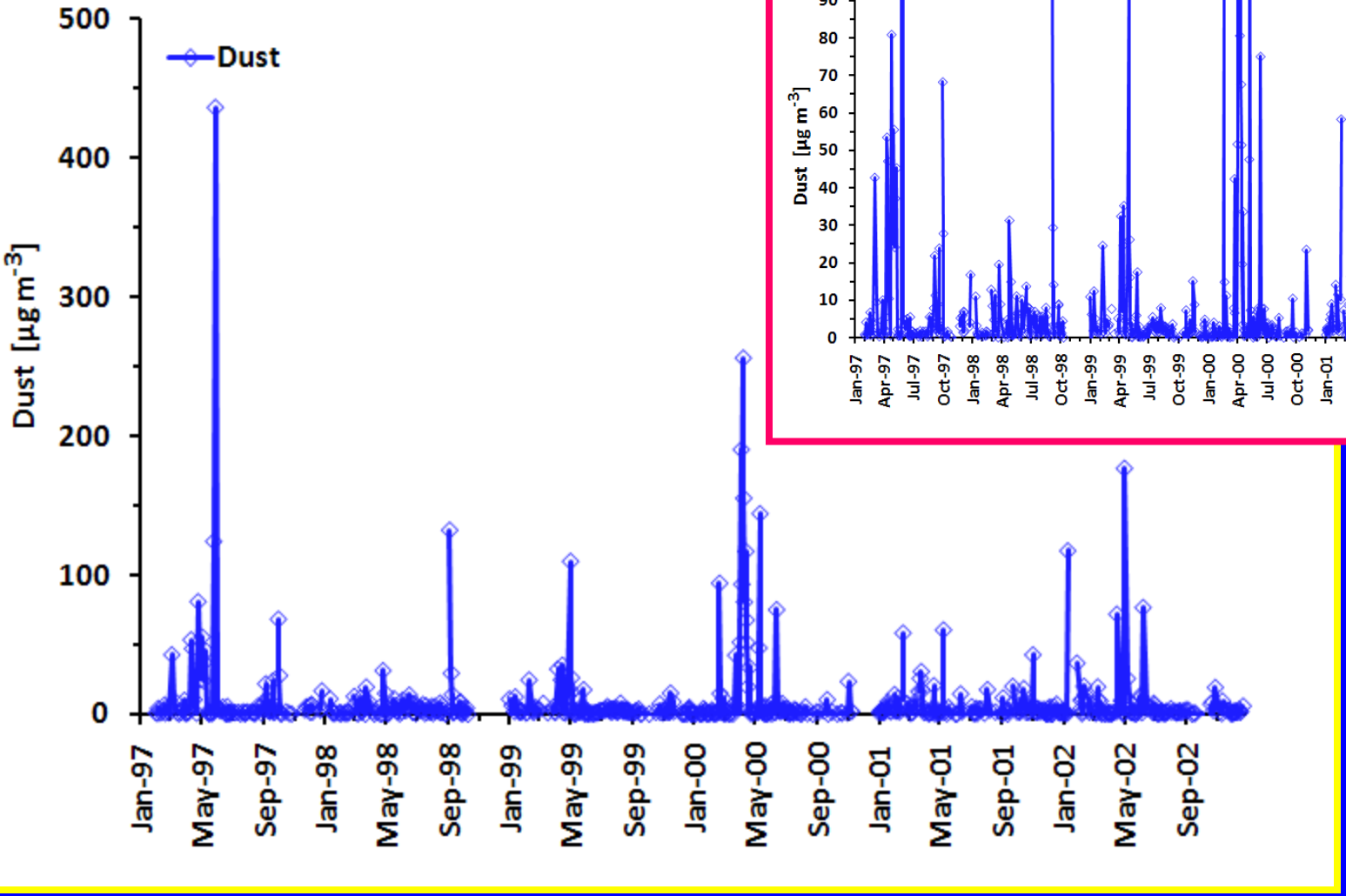
Joseph M. Prospero
RSMAS, Univ. of Miami

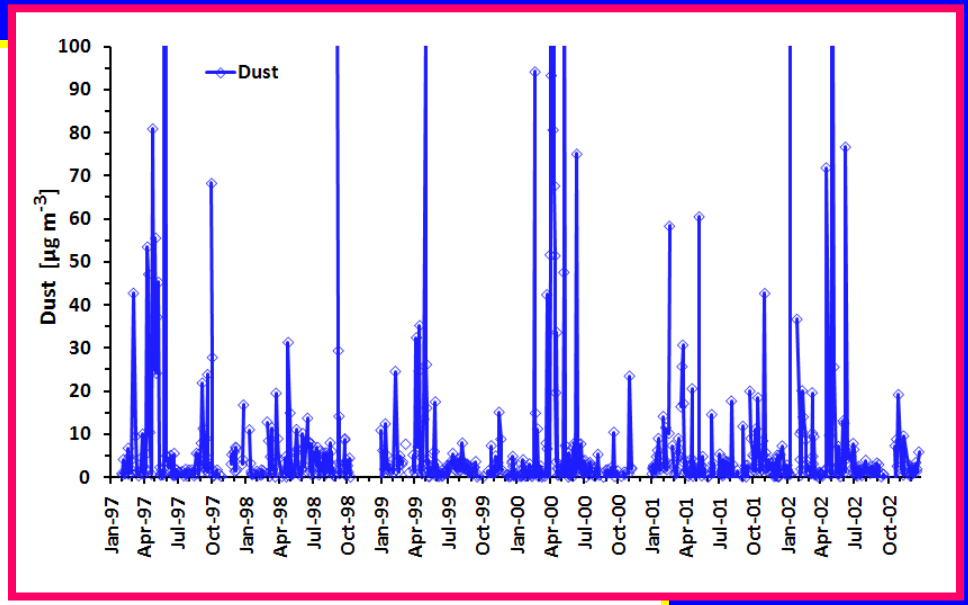
U Miami Station located on Island of Heimaey since 1991

Map of Iceland

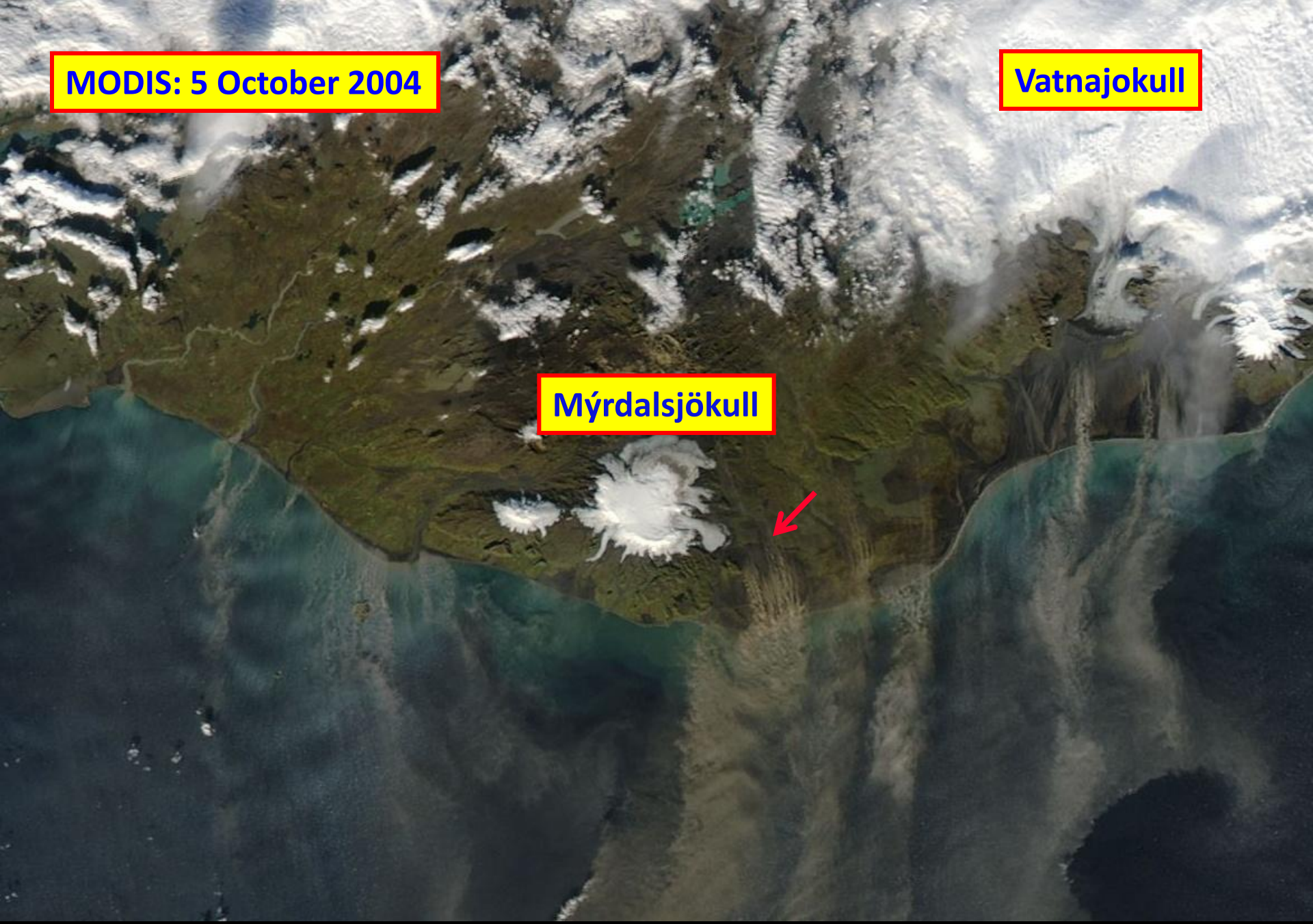
Heimaey

Dust Concentrations on Heimaey, Iceland: 1997 - 2002





Major dust peaks are associated with dust storms that are often visible in satellite images. (Note: the aerosol sampler is sectored to only sample winds from the southerly direction.)

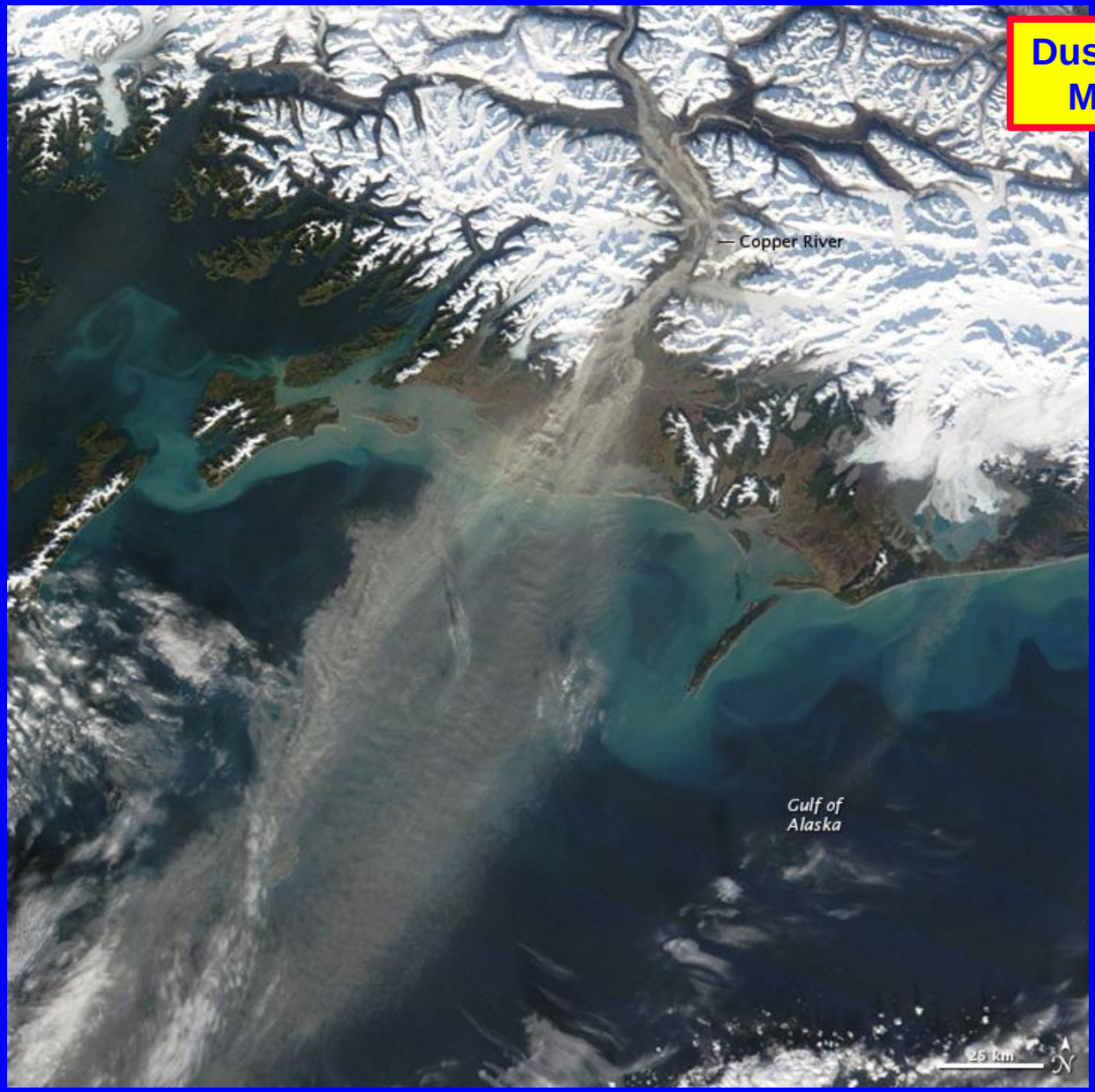


Major dust plumes are linked to "point" sources in periglacial deposits.


Glacier runoff region, SE of Mýrdalsjökull

Mýrdalsjökull

Satellites often show plumes from periglacial deposits in other Arctic regions.



Dust Storm - Copper River, Alaska
MODIS Terra, 30 October 2009

The Copper River is fed by the Copper Glacier. It flows through a glacier-carved landscape of steep mountains and fields of sand dunes before emptying into the Gulf of Alaska.

Conclusions: Glacial Dust Sources

The most active dust sources seem to be periglacial deposits - glacial outwash soils.

Given the very dynamic meteorological environment, this dust could be carried over great distances.

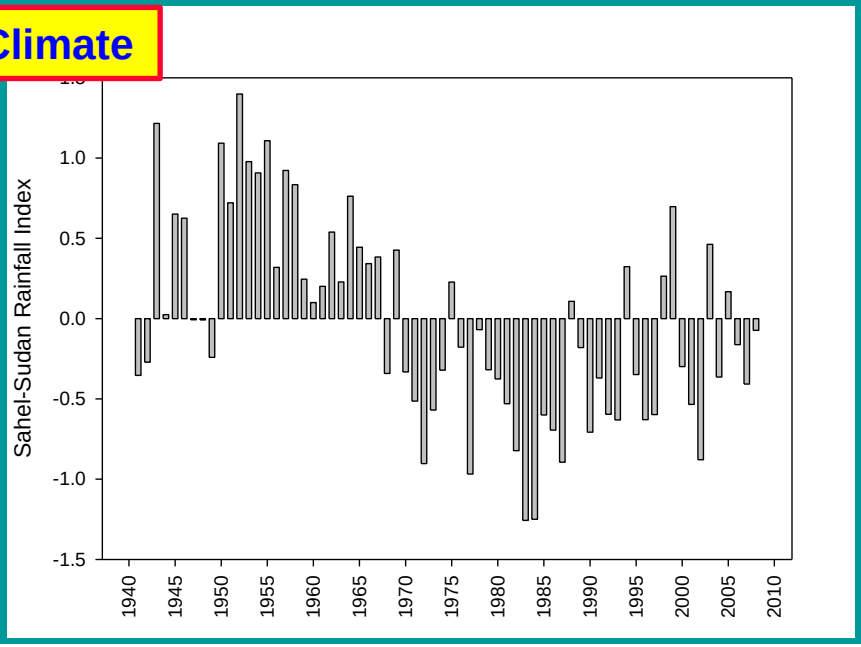
- Impact on air quality impacts in Europe?

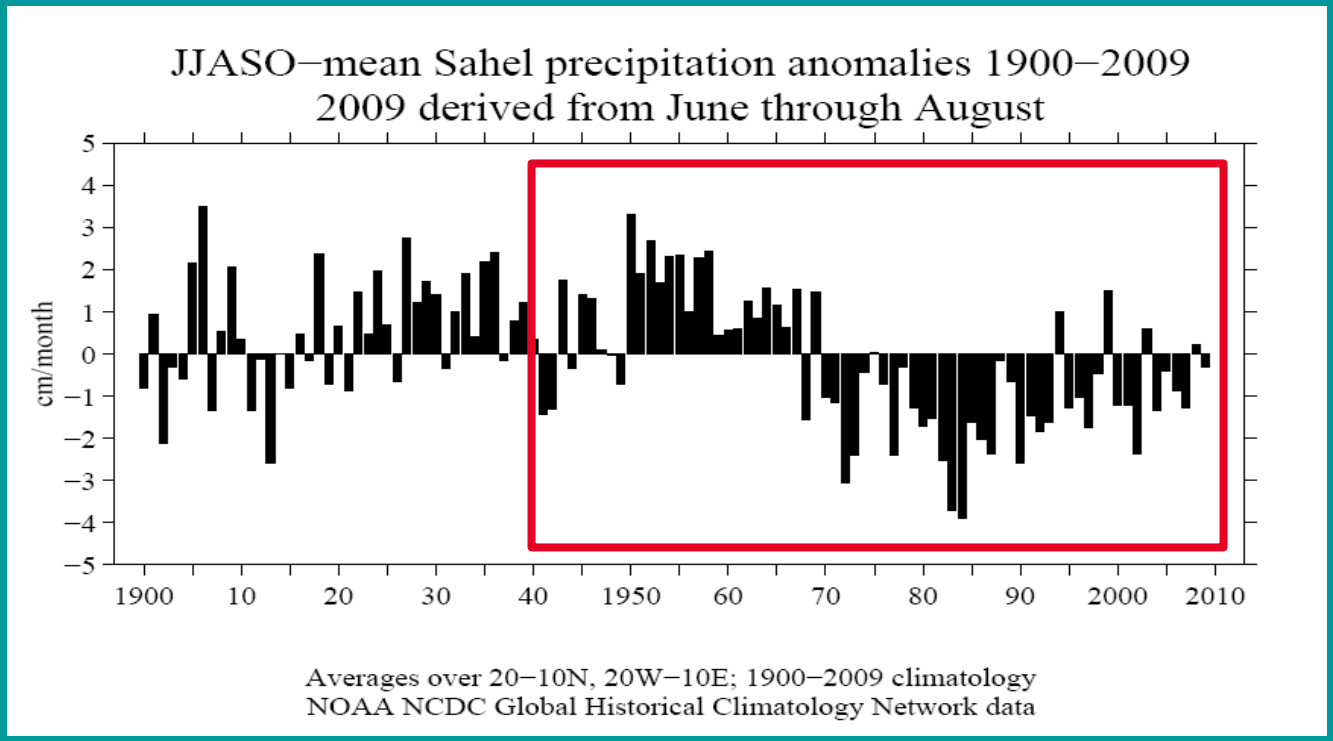
- Are polar deserts and periglacial deposits significant sources of dust?

- Glaciers will continue to retreat because of global warming – what will be the impact on dust mobilization in the high latitudes?

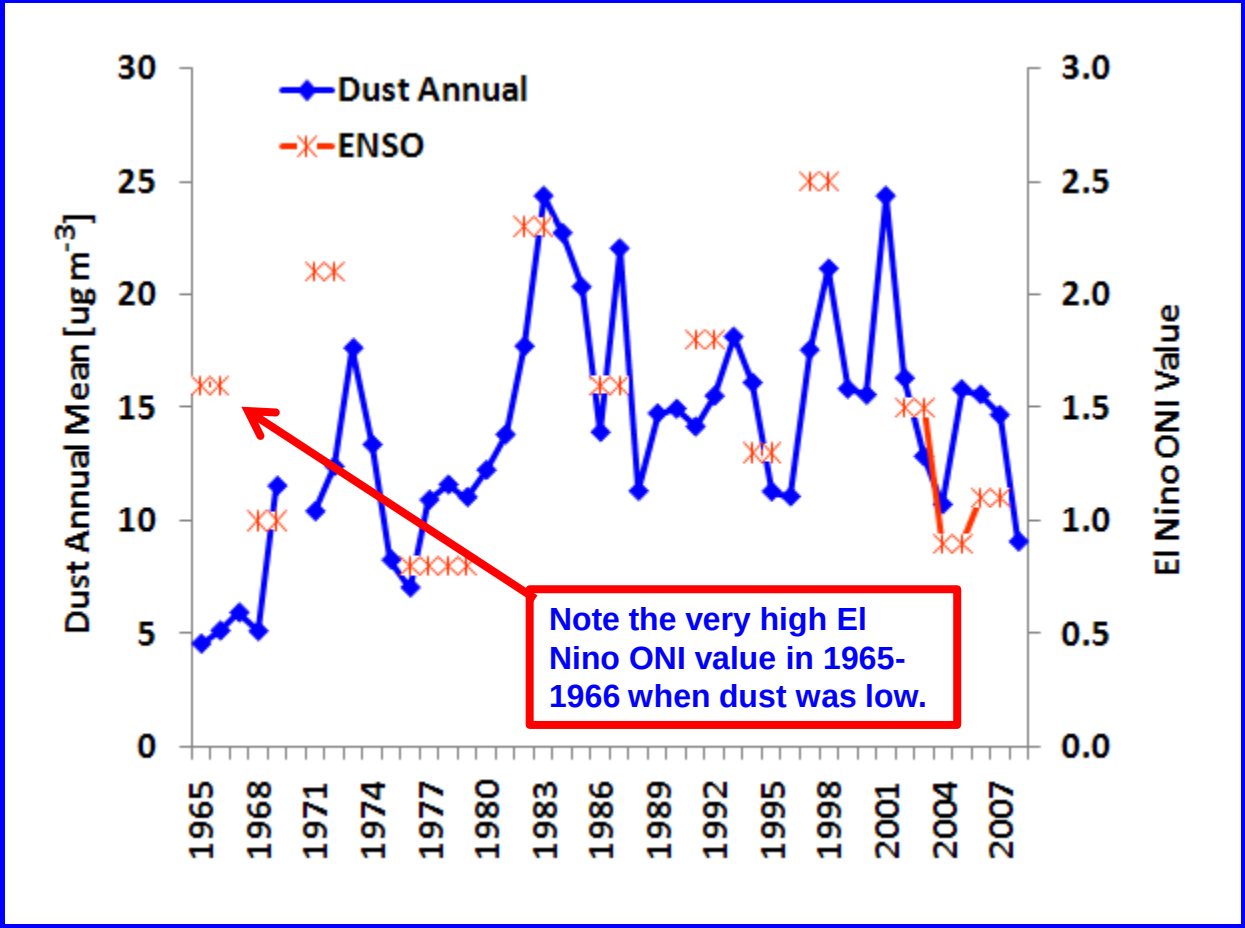
28 January 2004

2004 AAAS - Dust and Climate





Long Term Variability of Barbados Dust: No clear link to ENSO.



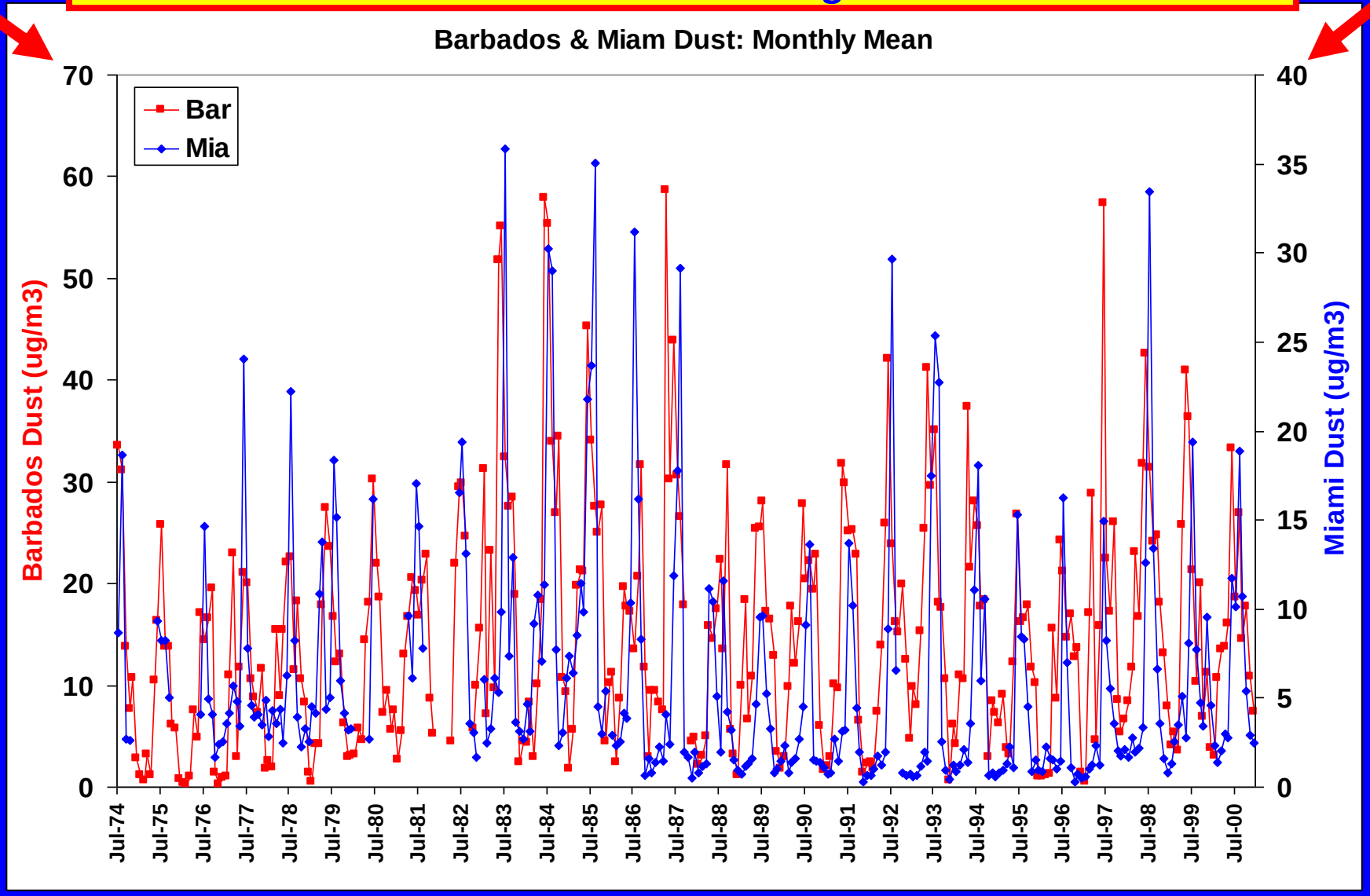
Historical El Niño and ENSO Cycle:

Recent Evolution, Current Status and Predictions

Update prepared by Climate Prediction Center / NCEP 08-Feb-10

http://www.cpc.noaa.gov/products/precip/CWlink/MJO/enso.shtml#history

African Dust: the dominant aerosol constituent over the Caribbean and the southeastern US during the summer.



- MIA74-01m_Ginoux_21Aug01_8Dec06.xls

J.M.Prospero/U.Miami