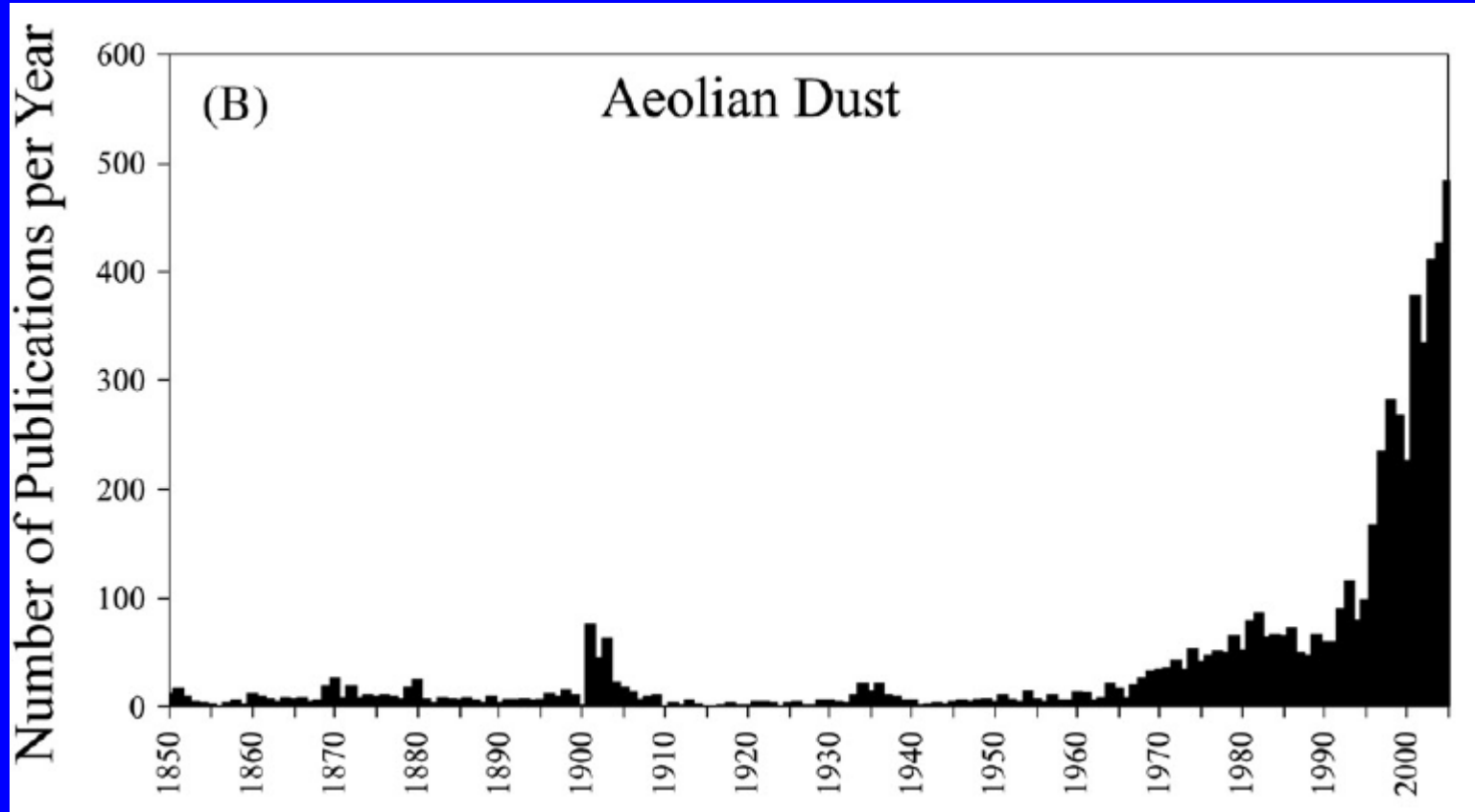


**LONG TERM TRENDS IN AFRICAN DUST TRANSPORT TO
THE CARIBBEAN: AFRICAN SOURCES, CHANGING
CLIMATE, AND FUTURE SCENARIOS**

**NOAA ESRL Global Monitoring Annual Conference
May 15th to 17th, 2012 in Boulder, CO**

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Dust Publication Rates



Stout, Andrew, and Gill. Publication trends in aeolian research: An analysis of the Bibliography of Aeolian Research, *Geomorphology* 105 (2009)

Why the Interest in Arid Region Mineral Dust?

- ❑ Dust, as would any aerosol, can affect climate:
 - > Directly by scattering and absorbing solar radiation
 - > Indirectly by impacting on cloud processes.
- ❑ Dust is different from other aerosol types in that:
 - > The generation of dust is itself affected by climate
Raises concerns about feedback on climate.
 - > Dust-iron is an essential micronutrient in the marine biosphere
Affects primary productivity and Carbon cycle - climate feedback.
- ❑ North Africa emits over half of the total global dust emissions.

Problem

- ❑ In order to forecast future climate - dust relationships we must :
 - > Understand how dust generation is affected by weather and climate
 - > Be able to predict the future climate variables that affect dust generation

Primary Focus of this Presentation

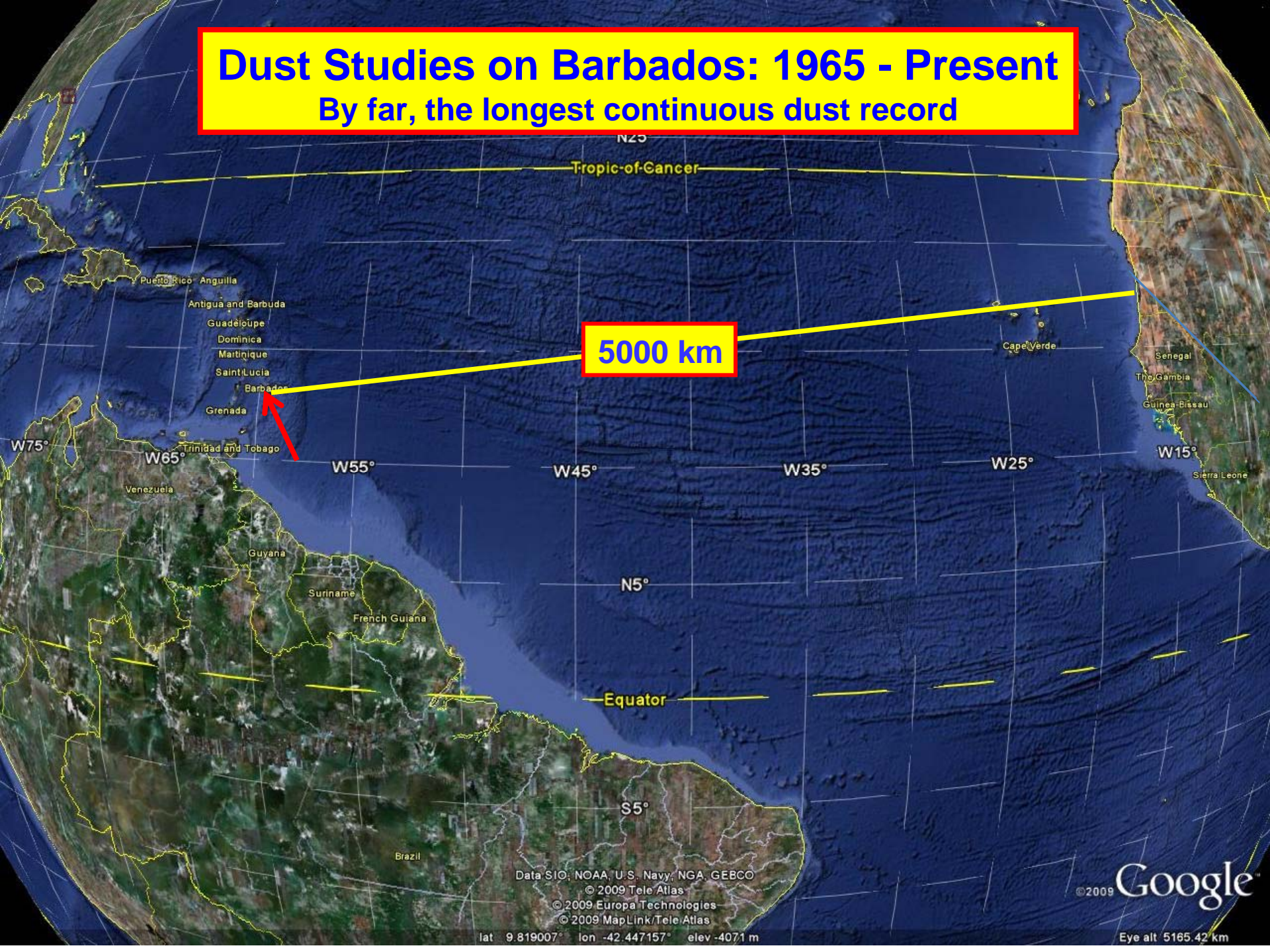
- ❑ Present the long-term record of African dust transport as measured on Barbados from 1965 to 2008.
 - To my knowledge - the longest continuous remote-region aerosol record.

- ❑ Discuss the relationship of dust transport variability in terms of rainfall in North Africa and in terms of other climate metrics.
 - Rainfall used as a proxy for ensemble climate variables and related changes in land surface processes.

Dust Studies on Barbados: 1965 - Present

By far, the longest continuous dust record

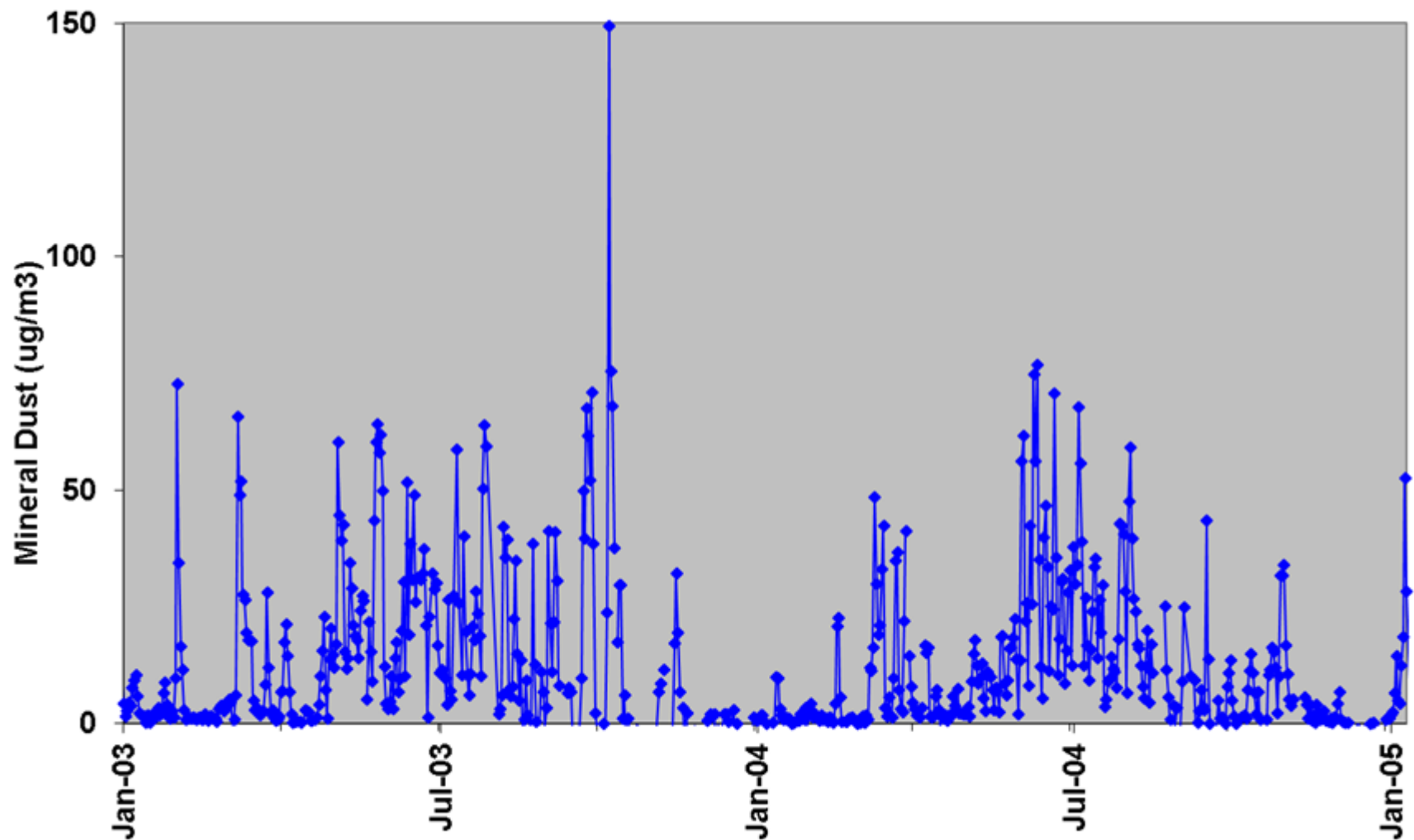
5000 km



U. Miami Aerosol Research Station, Barbados



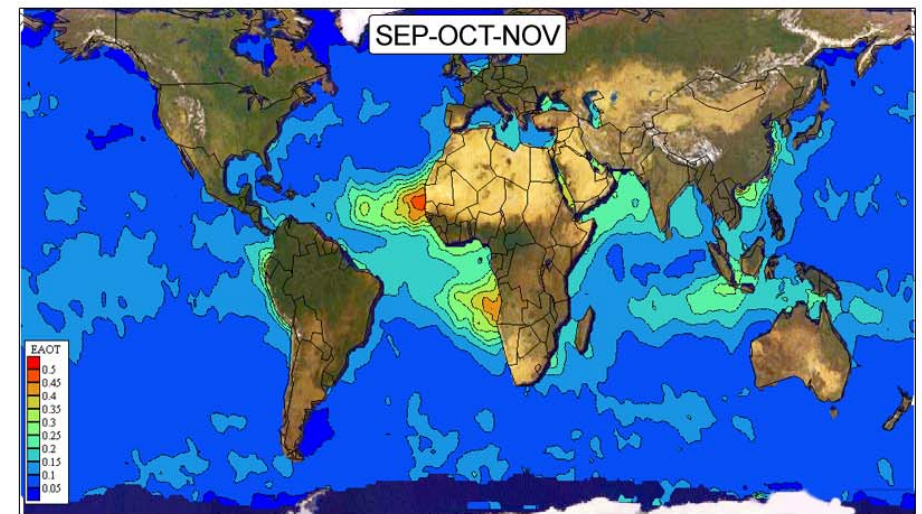
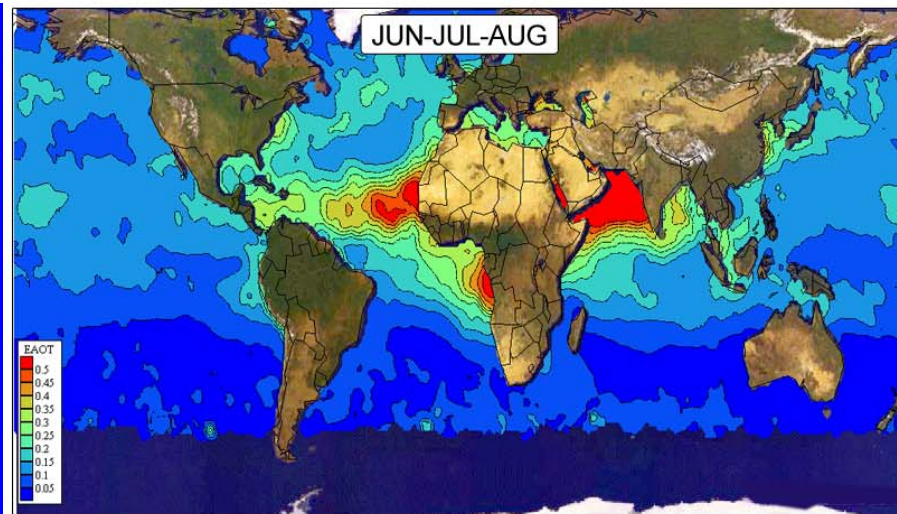
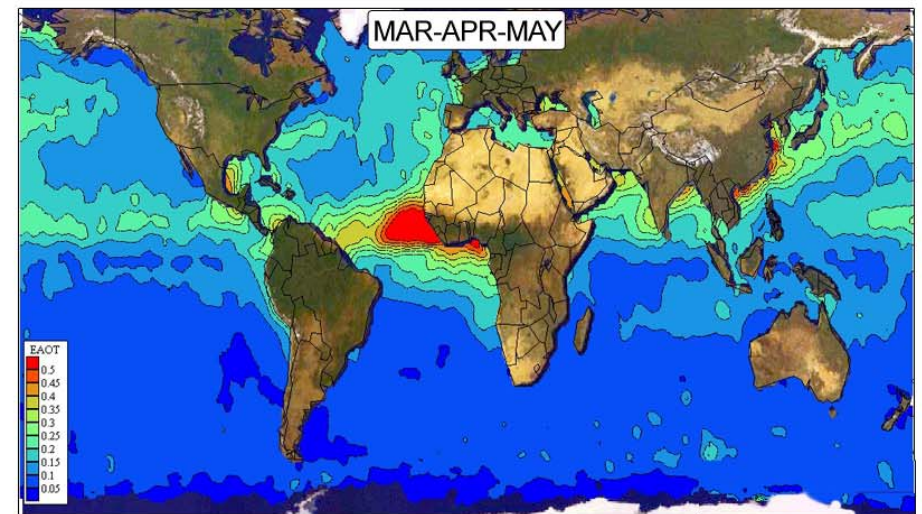
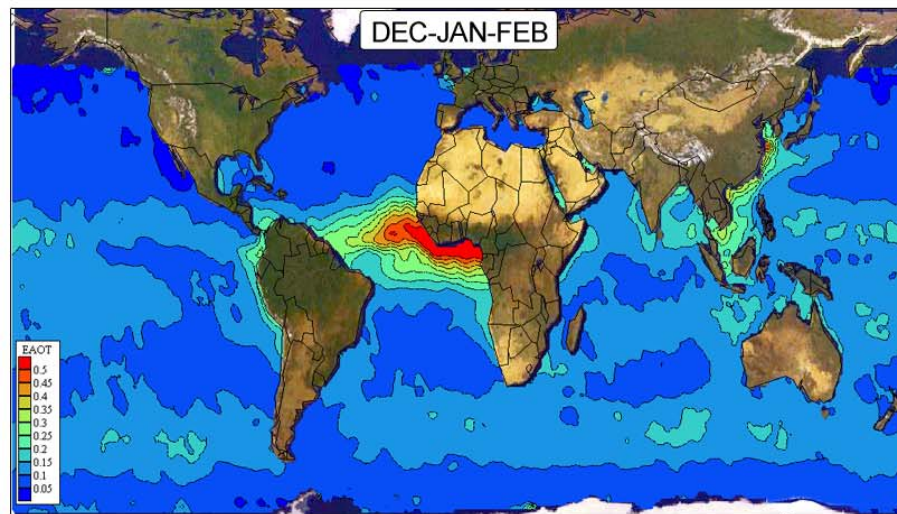
Example: Barbados Daily Dust Conc's: 2003 - 2004



Seasonal changes are linked to changes in source activity and to large-scale changes in wind transport systems.

How do Seasonal Dust Trends Relate to Transport Patterns?

NOAA AVHRR Aerosol Optical Depth





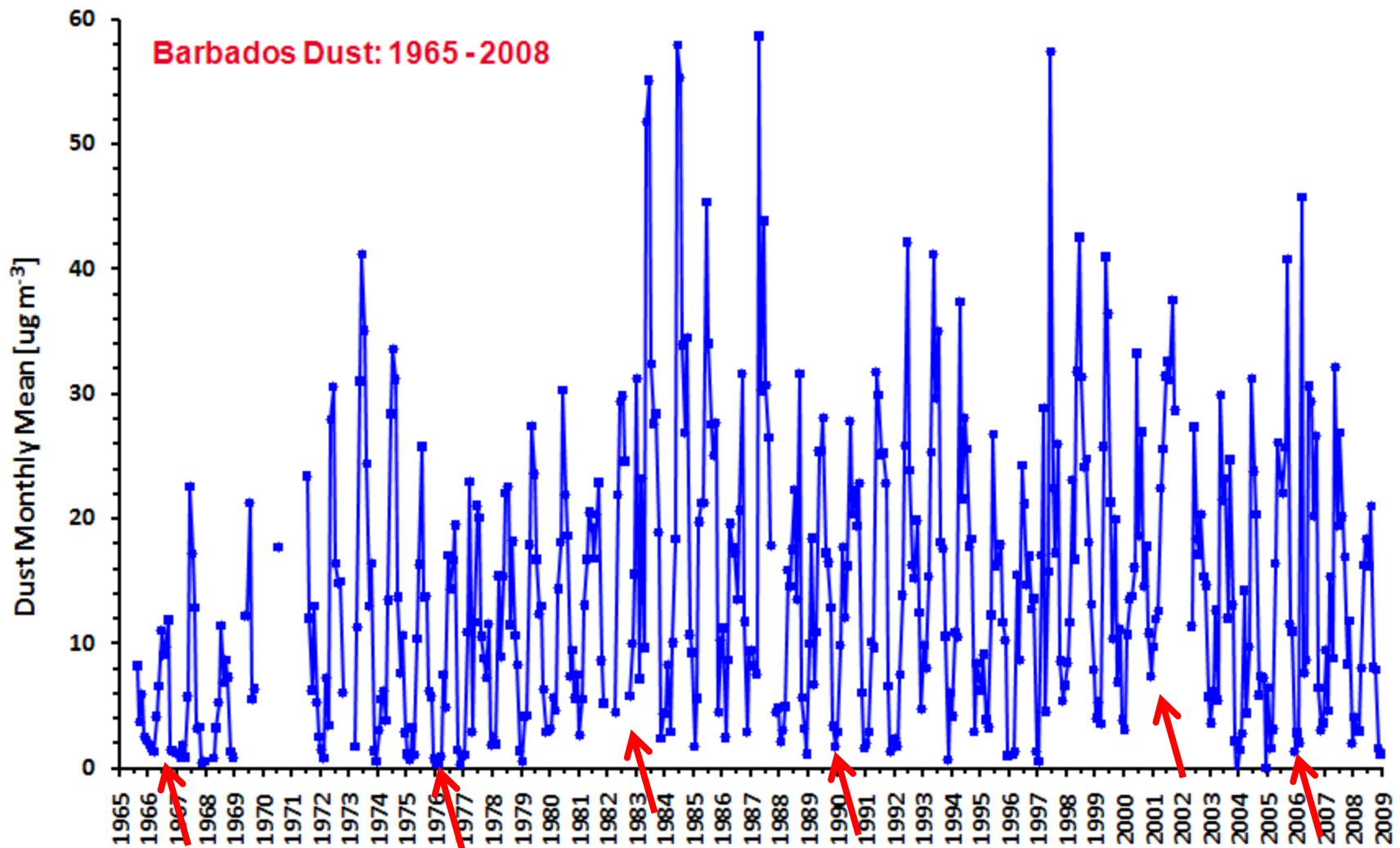
Barbados dust from the air



Barbados summer dust day

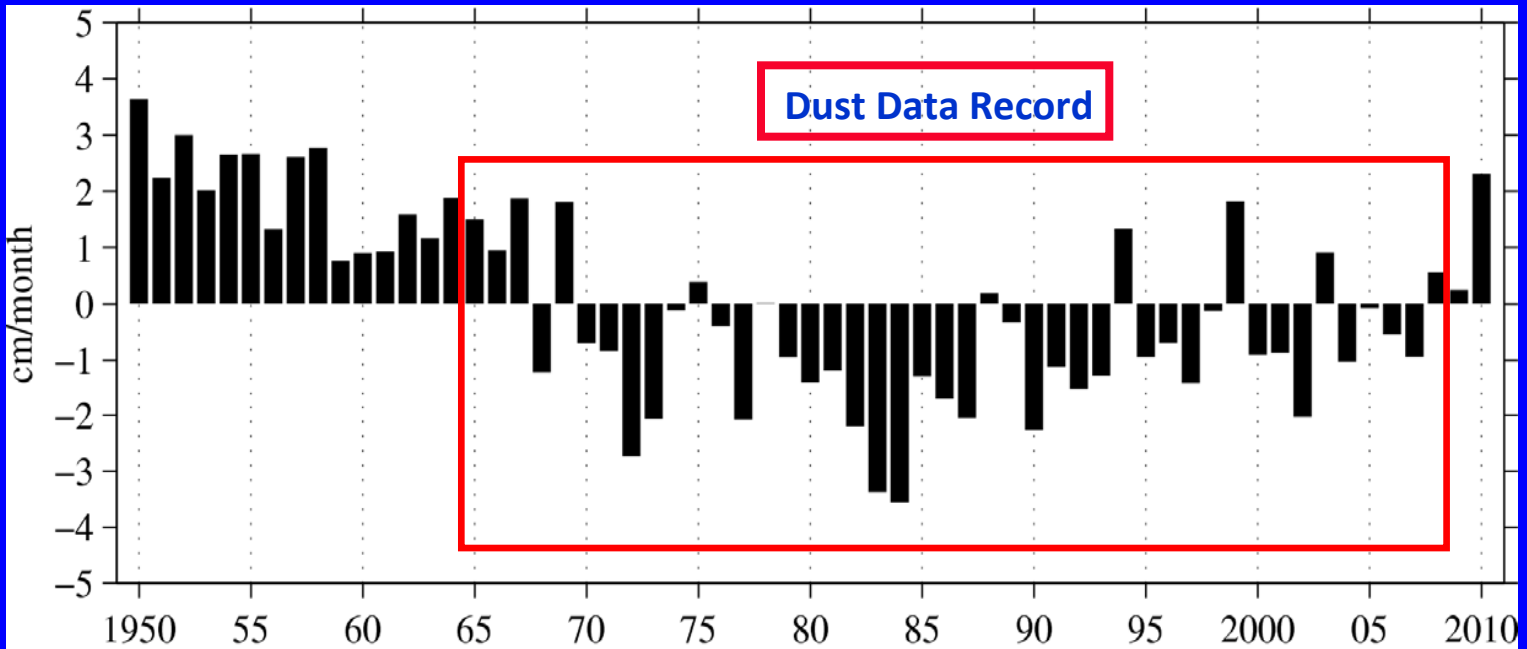
10 km

Long Term Variability of Barbados Dust: Monthly Means 1965 - 2008



Big changes in Summer dust. Note: Winter dust changes also!

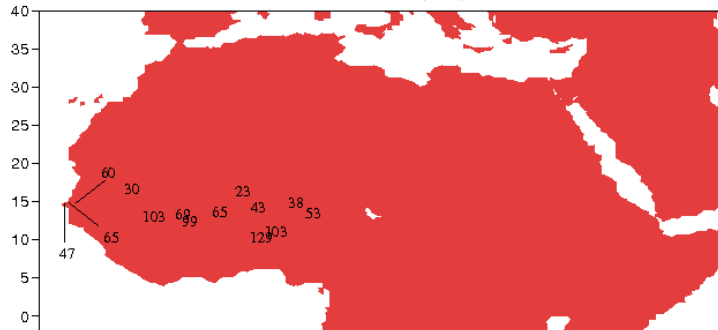
Sahel Mean Precipitation Anomalies: 1950 - 2010 [JISAO]



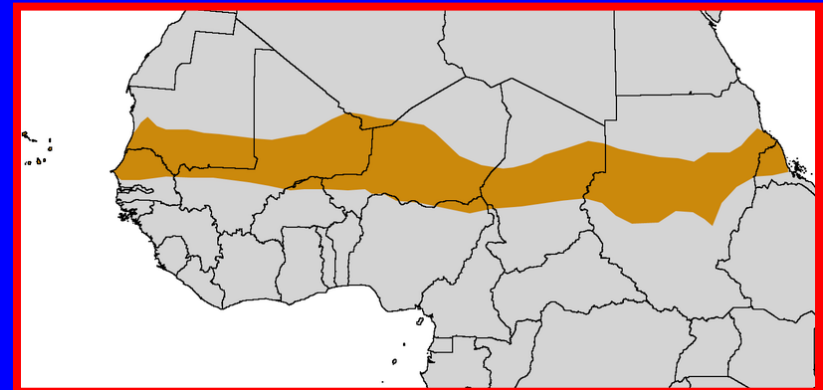
http://www.jisao.washington.edu/data_sets/sahel/

Averages over 20–10N, 20W–10E; 1950–2010 climatology
NOAA NCDC Global Historical Climatology Network data

Annual total rainfall (cm), 1950–93

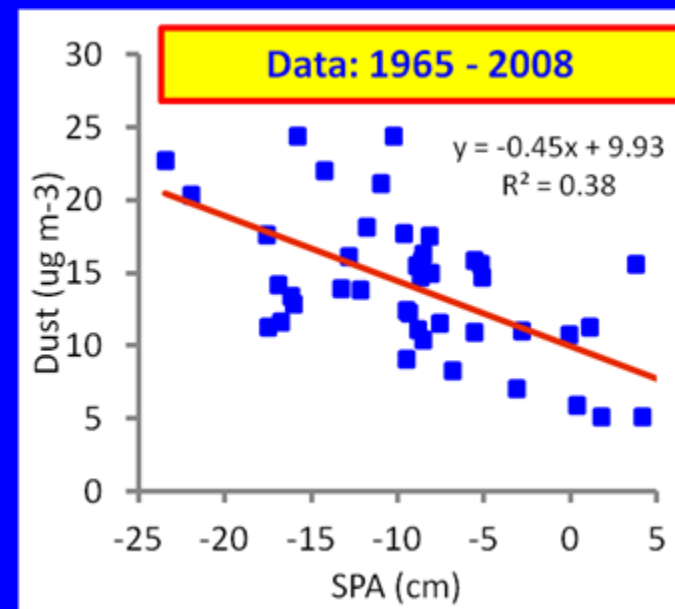
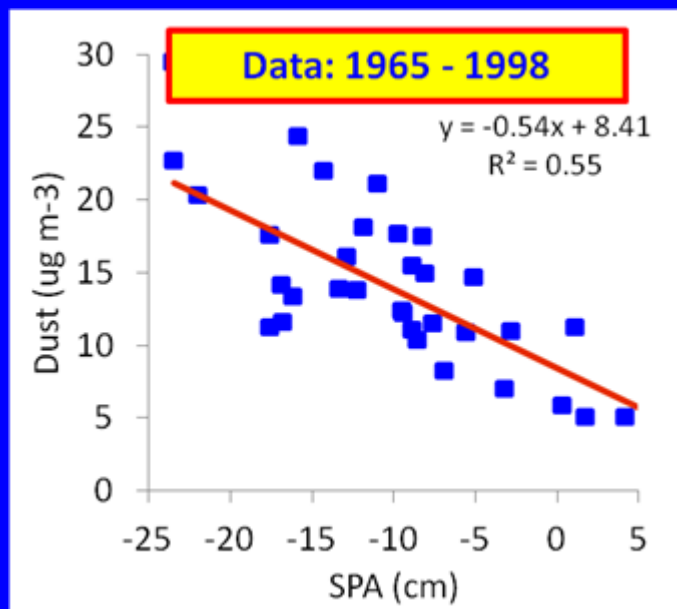
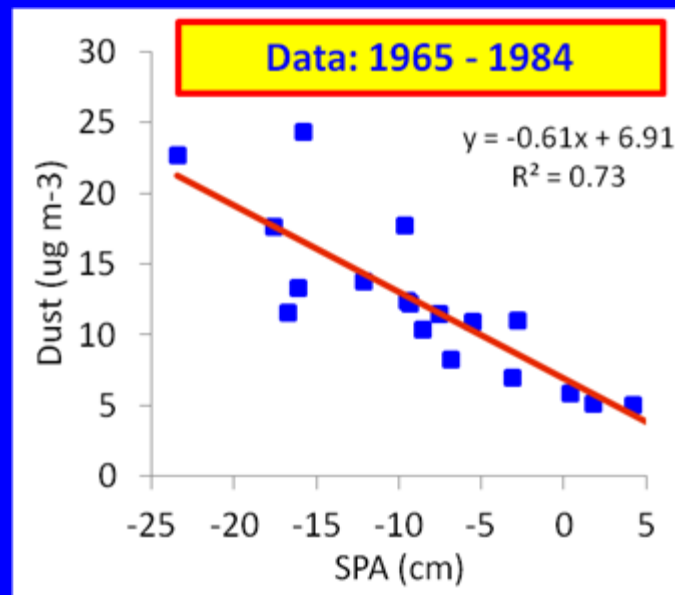
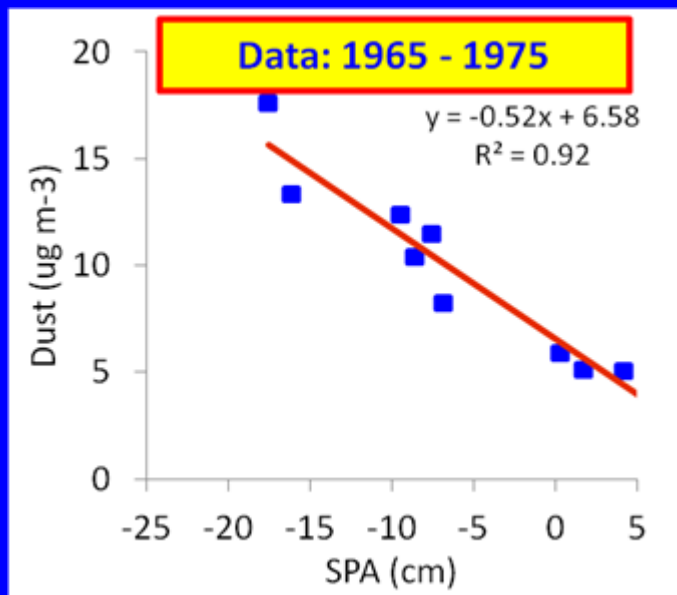


JISAO: Sahel Stations Used in Creating Index



Sahel: land area between isohyet lines 200mm and 600mm mean 20th century annual rainfall.

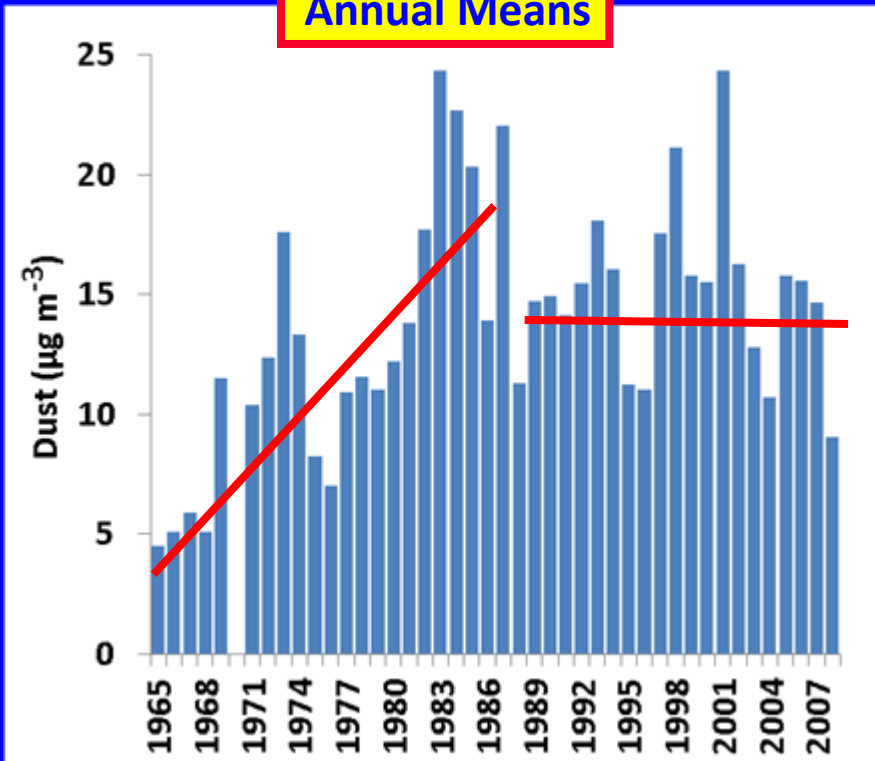
Dust – Sahel Precipitation Relationship: It's Evolution over Time



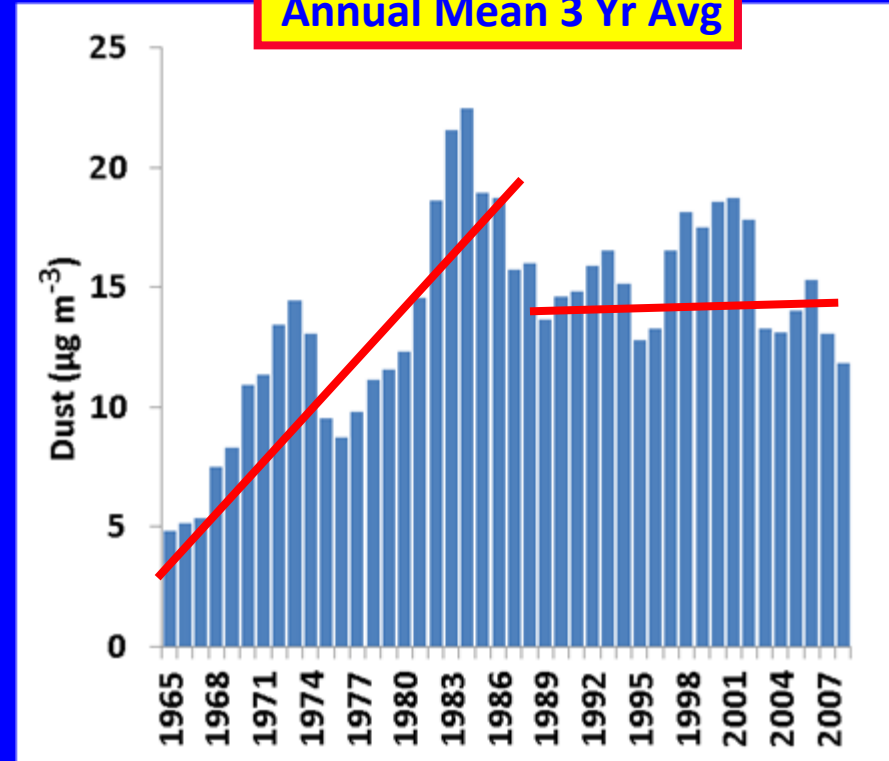
SPA: Sahel Precipitation Anomaly cm/year

Barbados Dust Annual Means Time Trends

Annual Means



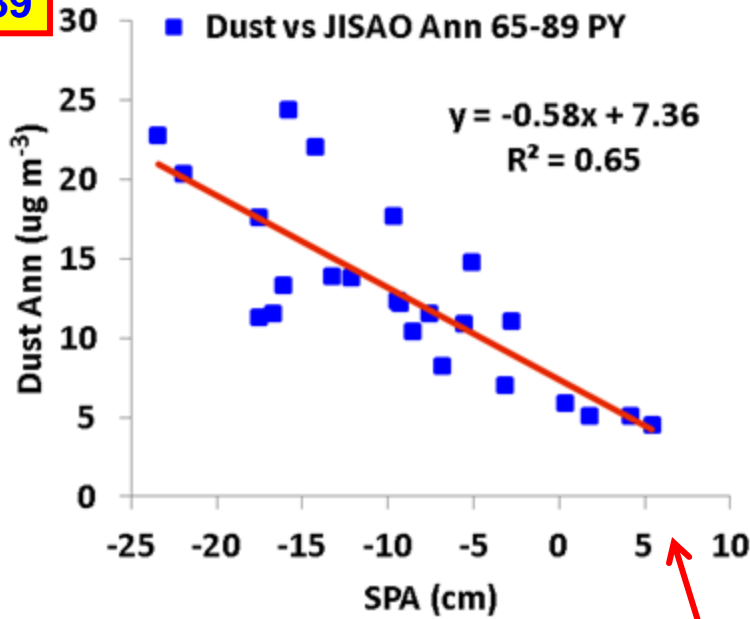
Annual Mean 3 Yr Avg



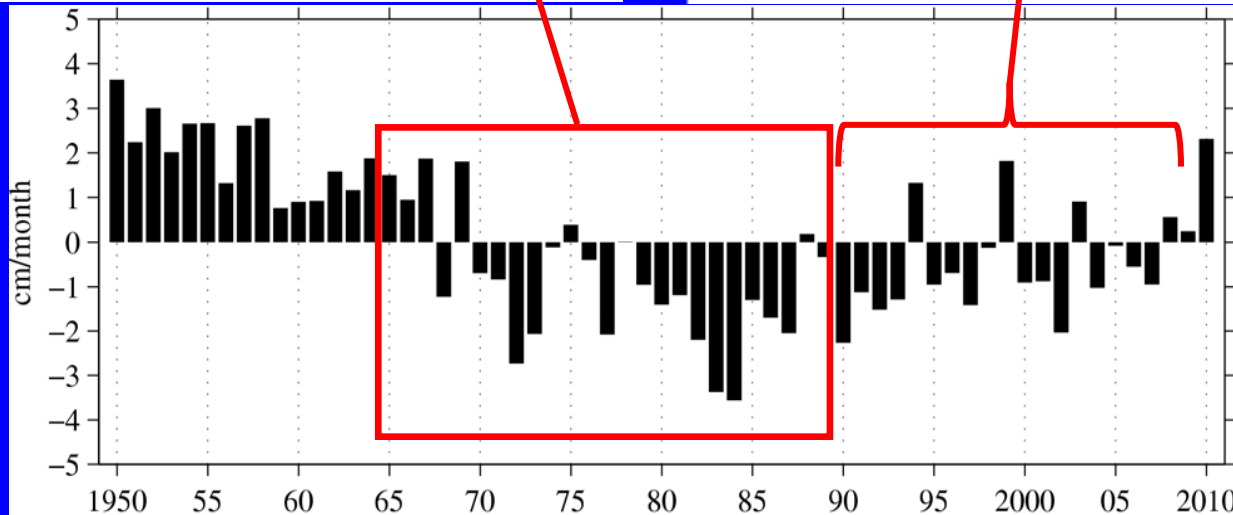
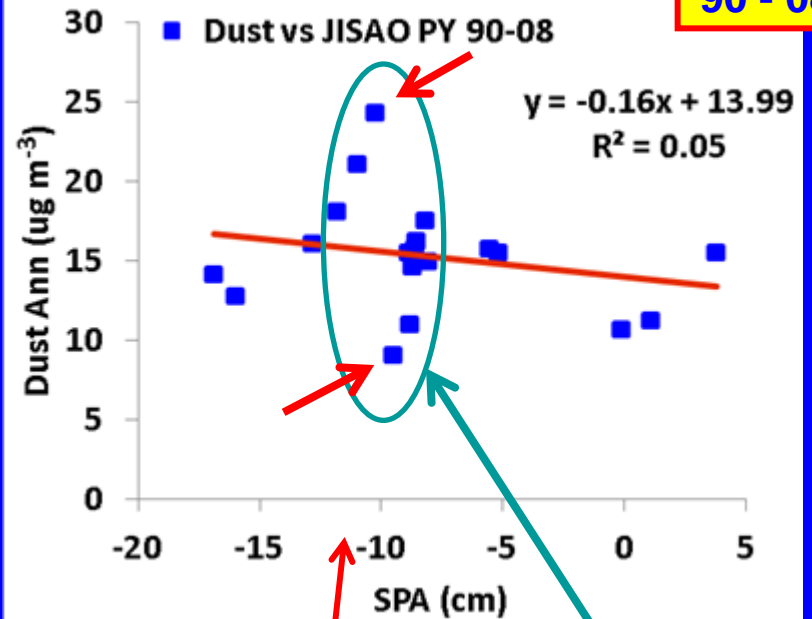
Conclusion: dust transport has stabilized at a moderately high level since late 1980s

Splitting the Record: Two Dust Regimes - one not related to "rainfall"

65-89



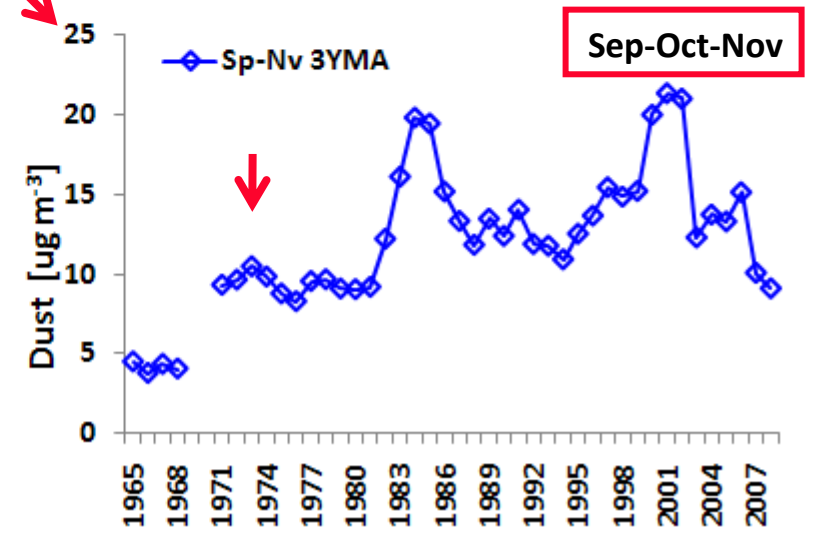
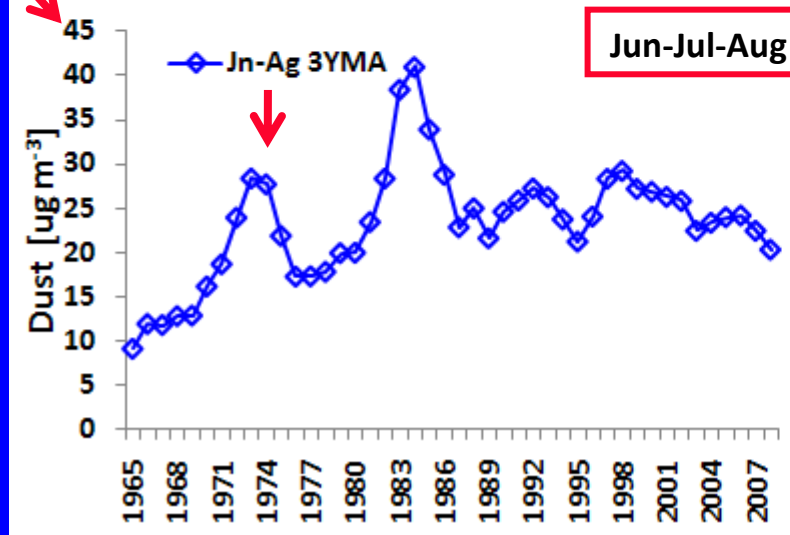
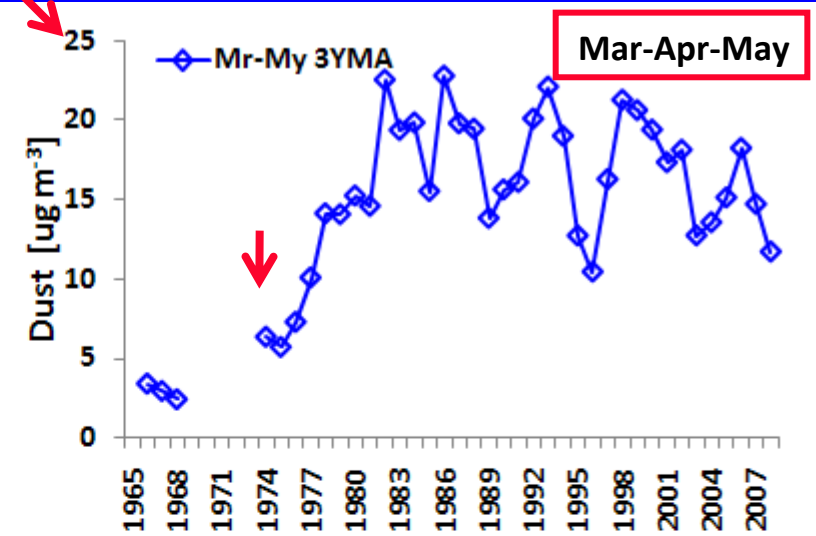
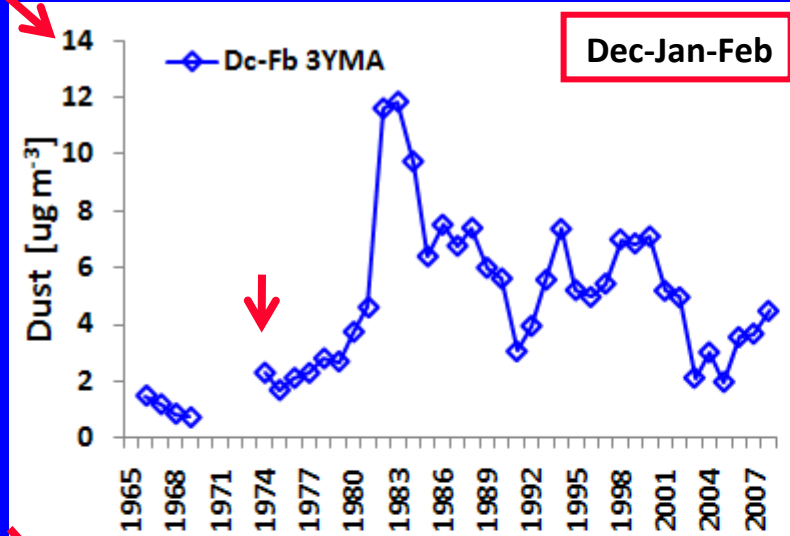
90 - 08



Note the wide range of dust concentrations for a relatively narrow range of rainfall deficits.

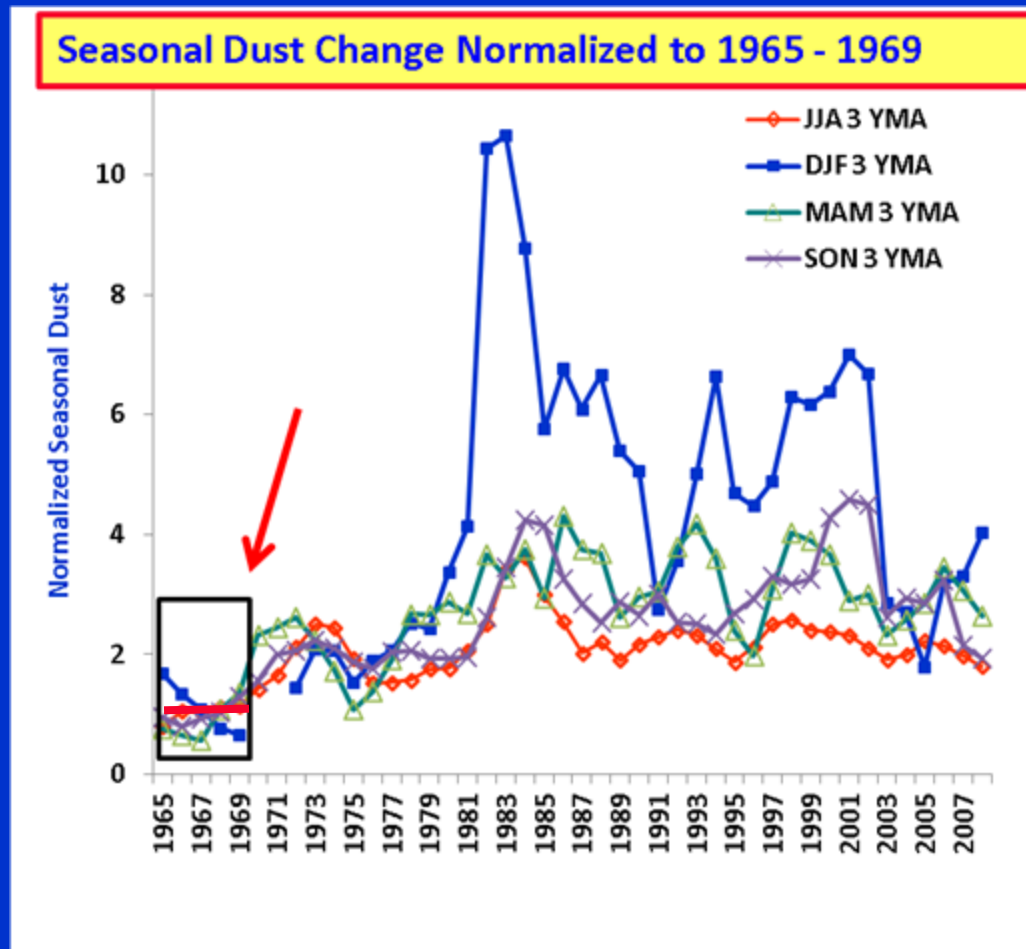
Averages over 20-10N, 20W-10E; 1950-2010 climatology
NOAA NCDC Global Historical Climatology Network data

Barbados: Seasonal Dust Trends - Varying Response to Drought(?)



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.

Barbados: Seasonal Dust Trends - Varying Response to Drought

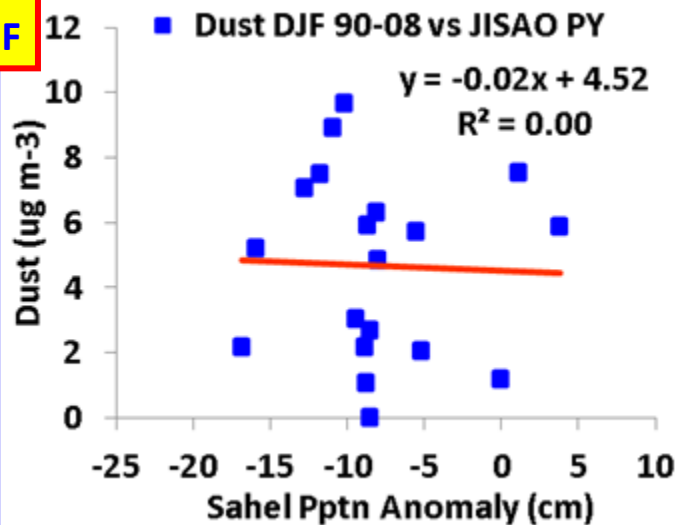


Early 70's drought strongly impacted Summer dust; minimally impacted Winter dust .

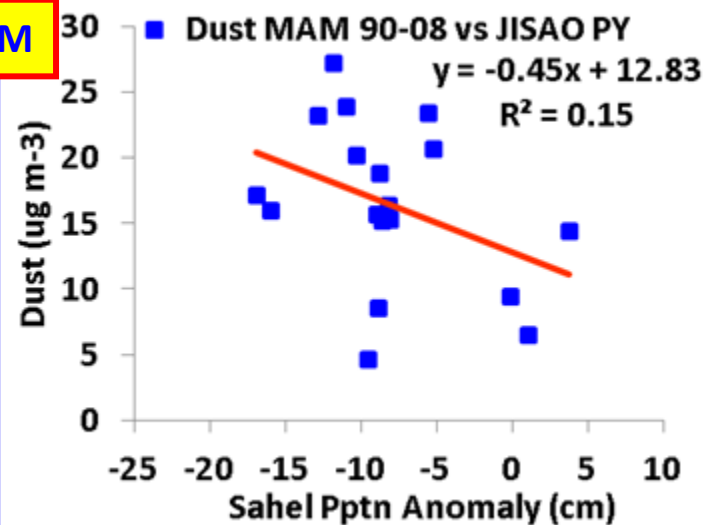
Early 80's drought impacted all Seasons; Spring dust never returns to "normal".

Seasonal Dust vs Sahel Pptn Anomaly: 1990 - 2008

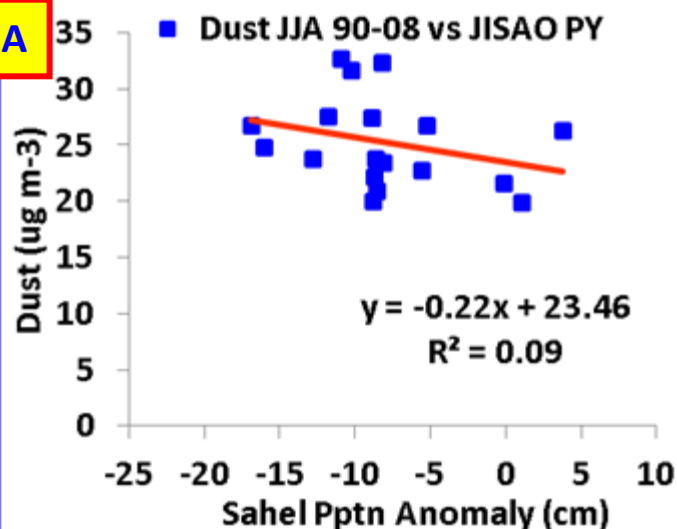
DJF



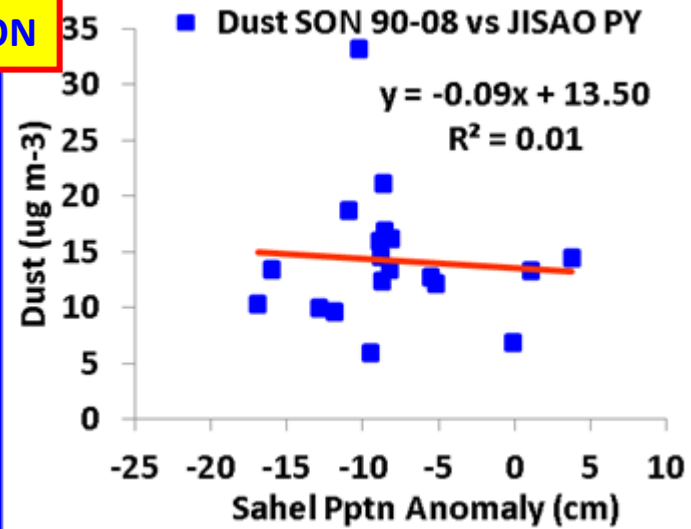
MAM



JJA

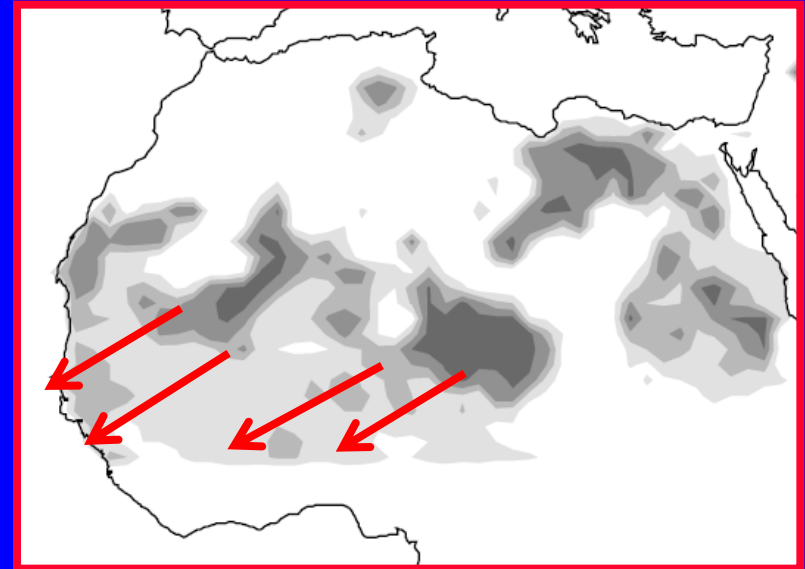
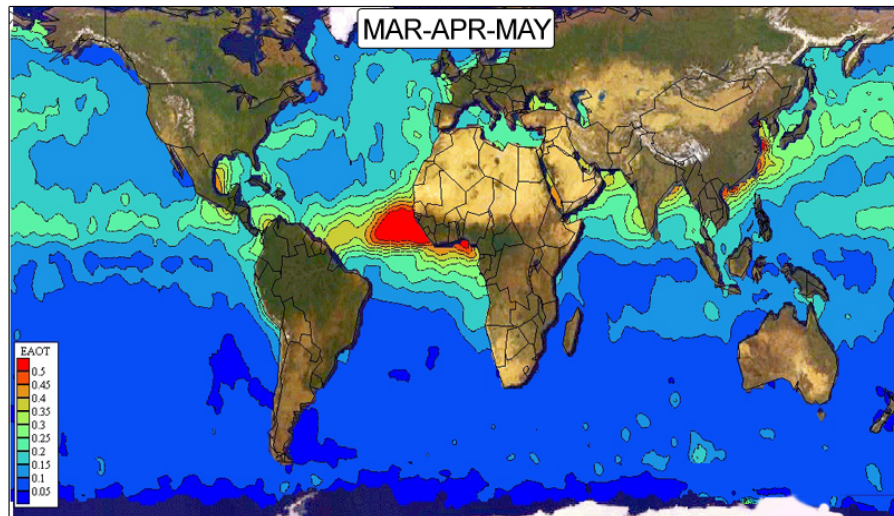
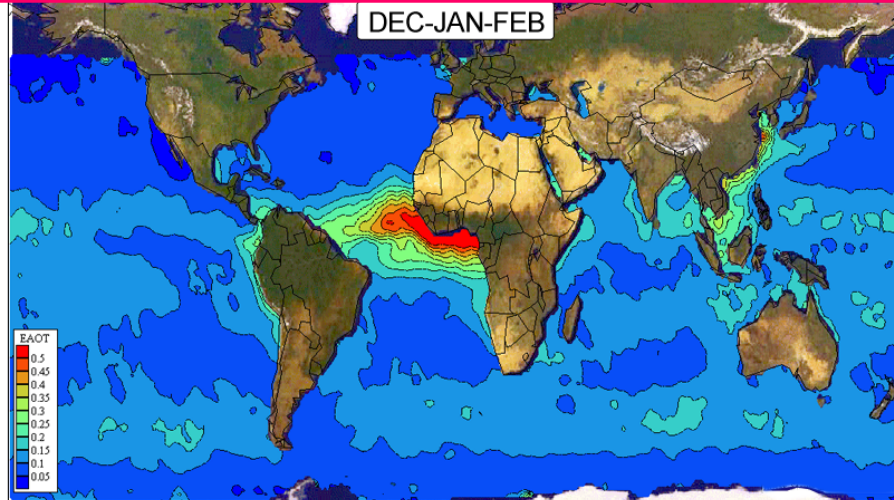


SON



All regressions are very bad!

The source of the strong increase in dust transport during the Winter and Spring months seems to be strongly associated with sources in the Sahel - Soudano 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

Sahel Rainfall, African Dust & AMO , ENSO, NAO, AWP, SST, TCs, etc.

There is a considerable literature on these various climate metrics and African/Sahel rainfall.

- Atlantic Multi-decadal Oscillation – AMO
- North Atlantic Oscillation – NAO
- Arctic Oscillation – AO
- Sea Surface Temperature – SST
- Tropical Cyclone statistics – TCs
- El Nino – Southern Oscillation
- Atlantic Warm Pool - AWP

Question: can we relate the change in dust transport that took place in the late 1980s – early 1990s to any specific climate metric?

Some TC- Climate Variables in the North Atlantic Ocean

There have been substantial changes in many metrics starting ca. 1990.

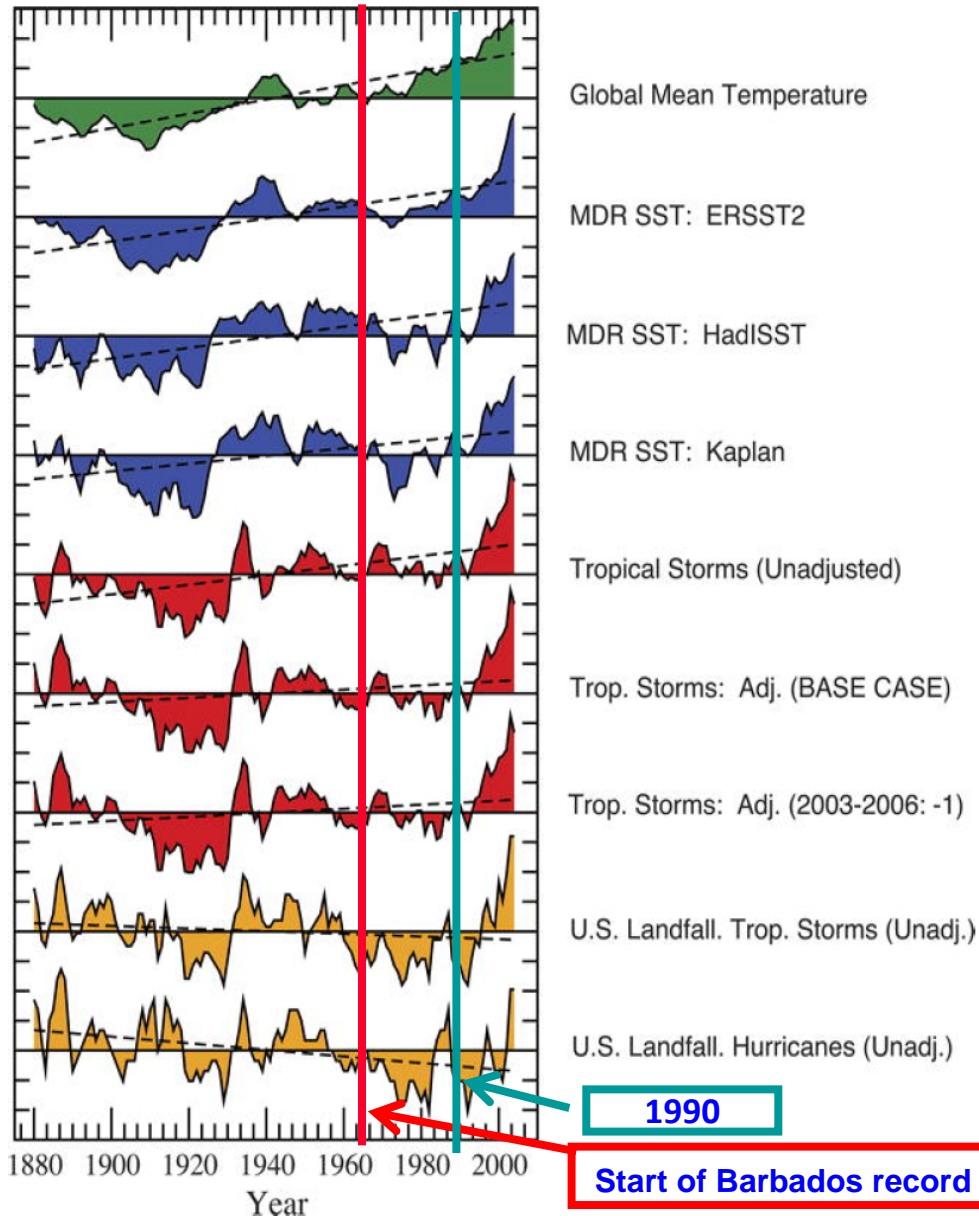
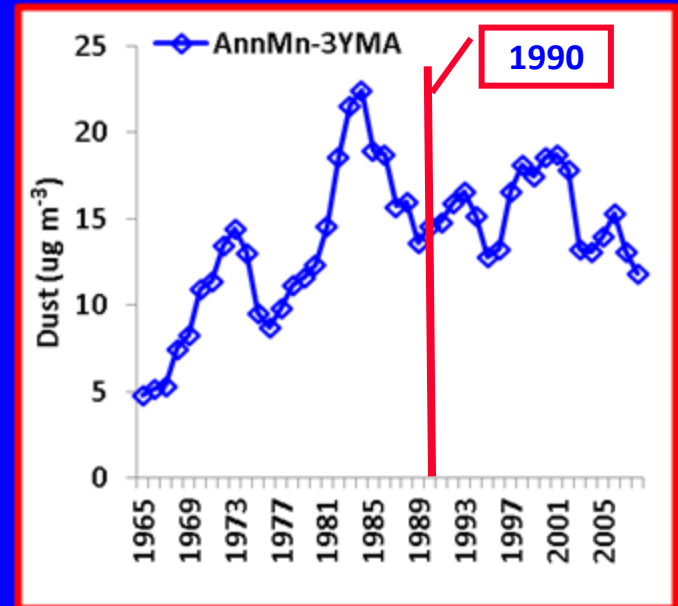
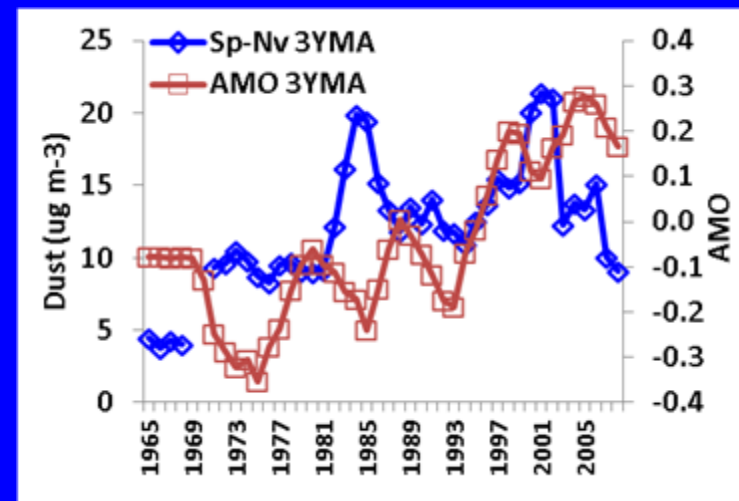
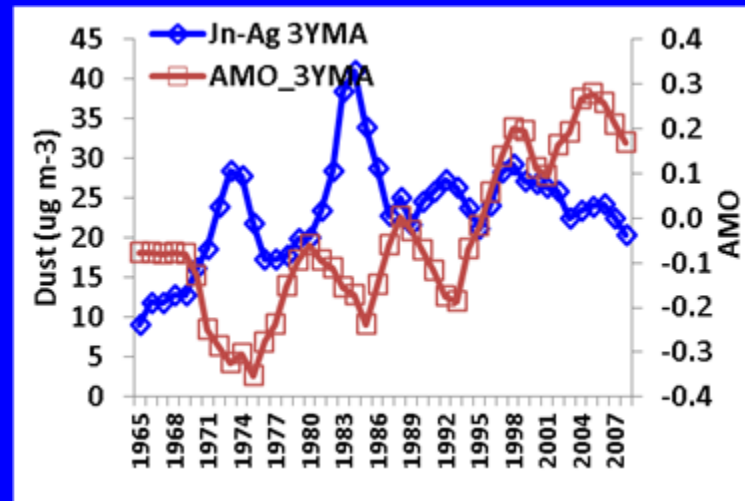
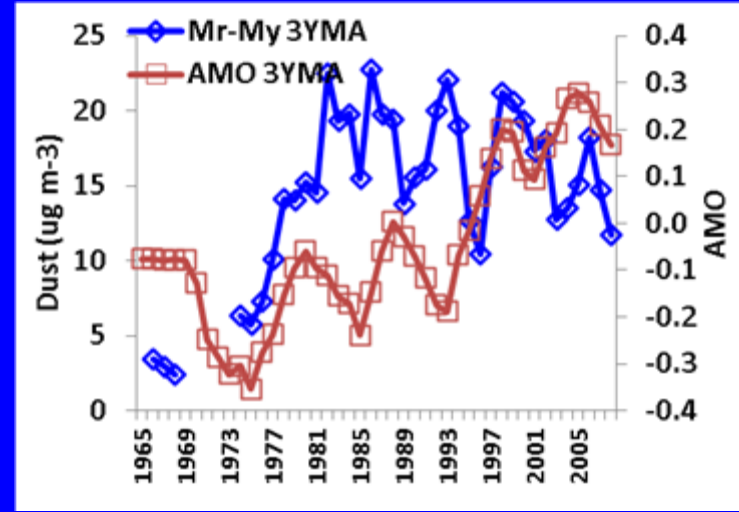
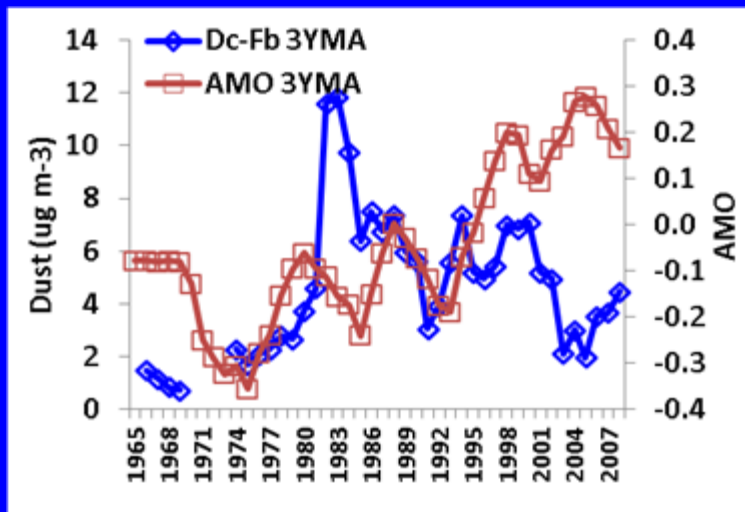


FIG. 9. Normalized tropical Atlantic indices (5-yr running means of time series from 1878 to 2006, solid black) and their linear trends (dashed black). Vecchi, G.A., and T.R. Knutson, 2008 *J. Climate*, 21, 3580–3600.



Seasonal Dust Trends: Atlantic Multi-decadal Oscillation



NOAA Atlantic Multidecadal Oscillation Data <http://www.esrl.noaa.gov/psd/data/correlation/amon.us.data>

The relationship is excellent for Summer dust during the first two drought phases and possibly the early 90s peak. No clear relationship for other seasons.

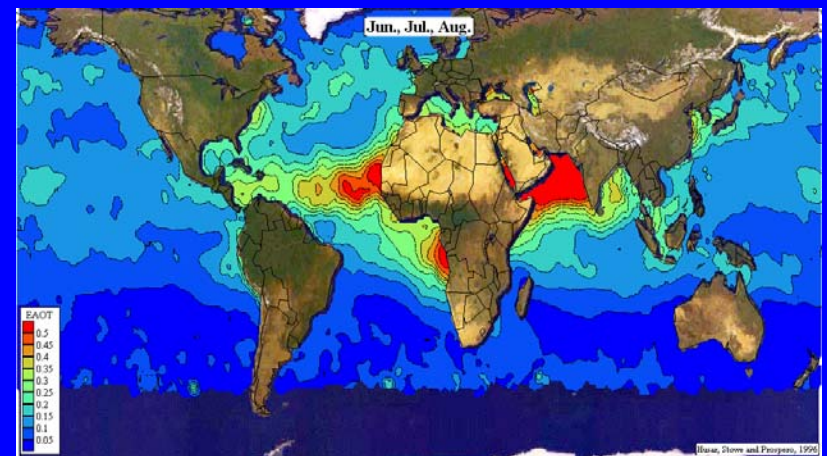
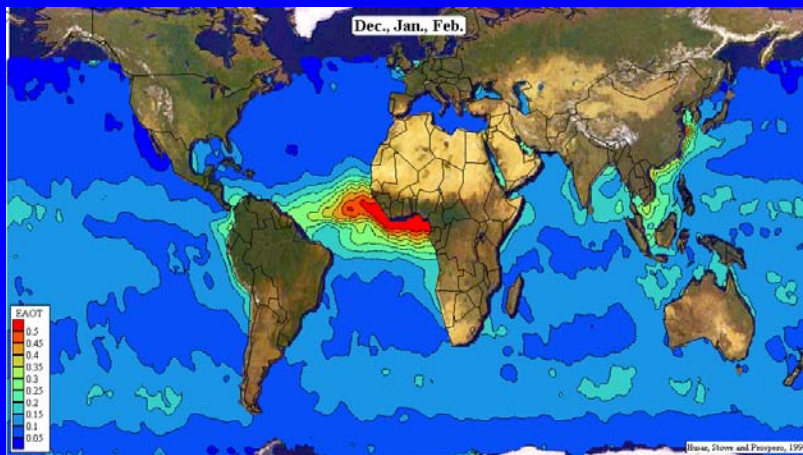
Climate-Dust Forecasts: Models Do a Poor Job with Dust Today

Huneus, N., et al. (2011), Global dust model intercomparison in AeroCom Phase I, *Atmos. Chem. Phys.*, 11(15), 7781-7816, doi: 10.5194/acp-11-7781-2011.

... a broad intercomparison of a total of 15 global aerosol models within the AeroCom project. Each model is compared to observations related to desert dust aerosols, their direct radiative effect, and their impact on the biogeochemical cycle, i.e., aerosol optical depth (AOD) and dust deposition.

... The models ... simulate the offshore transport of West Africa throughout the year but they overestimate the AOD and they transport too fine particles.

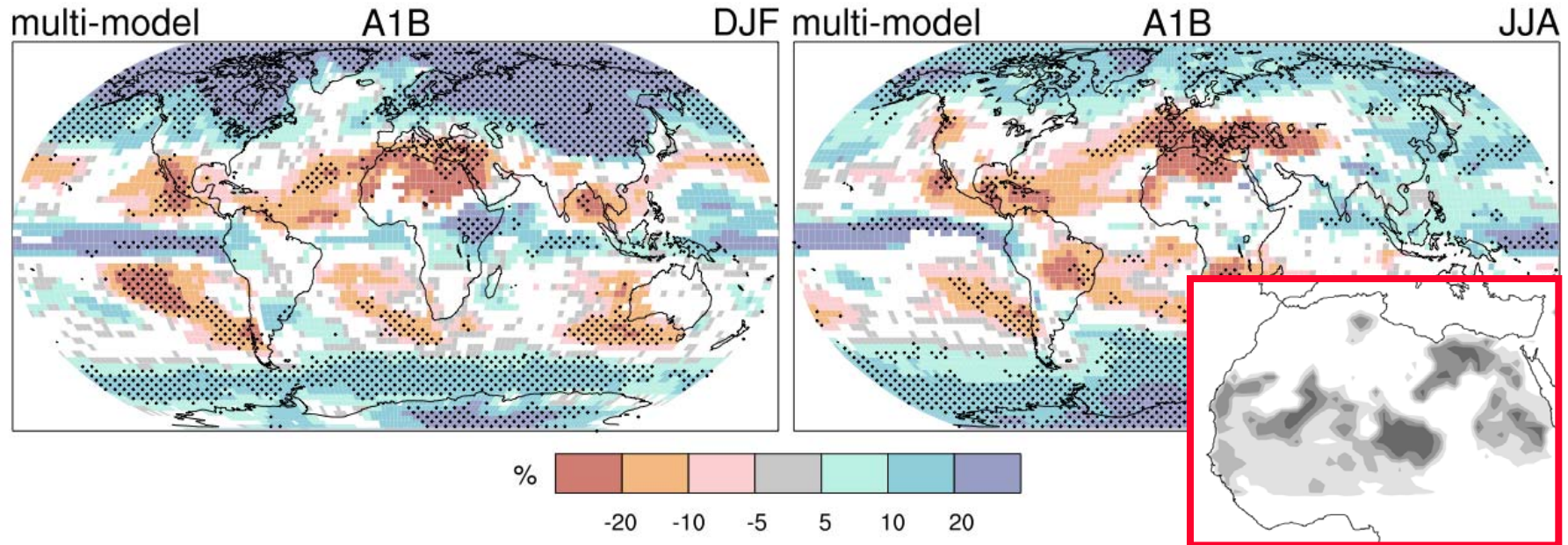
... However, most models do not reproduce the trans-Atlantic dust transport in Winter-Spring nor the southward displacement of the dust cloud that is responsible for the transport of dust into South America.



Projections of Future Changes in Climate

What does it mean for Atlantic & Americas dust?

Projected Patterns of Precipitation Changes



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 among the most important sources relative to trans-Atlantic dust transport.

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 Sahel rainfall and various climate metrics.
- ❑ The seasonal pattern of dust transport has changed with time.
 - The greatest changes were in Winter and Spring which have increased sharply and remain high today
 - Changes in seasonal pattern suggests that greatest impact on drought-dust (on seasonal basis) was in the Sahel-Soudano region.
- ❑ The impact of land use on dust mobilization remains highly uncertain and much debated.
- ❑ Dust models require much work. Dust mobilization and impacts are highly model specific.

- ❑ Because of these uncertainties, the uncertainty in future rainfall/climate/population in the Sahel-Soudano region, and the variability of dust output in Saharan sources, at present it is impossible to anticipate future trends in dust transport across the Atlantic.

A satellite image showing a coastal region, likely the Gulf of Mexico. The image is dominated by a large, light-brown, hazy area that appears to be a dust plume or a large-scale atmospheric phenomenon. The coastline is visible on the left side, with some islands and a large body of water. A black outline is drawn on the image, defining a specific rectangular area within the hazy region. The background of the slide is a solid blue color.

Thank You

MODIS Aqua 3 March 2004 1415 UT

XX