Impact of Desert Dust Radiative Forcing on Sahel Rainfall

IUGG 2007 Perugia

Masaru Yoshioka

School of Geographical Sciences
University of Bristol, UK

This presentation is based on

M. Yoshioka, N. Mahowald, A. Conley, W. Collins, D. Fillmore, C. Zender, and D. Coleman:

Impact of Desert Dust Radiative Forcing on Sahel Precipitation
– Relative importance of dust compared to SST variations, vegetation changes and GHG warming

Journal of Climate, 20 (8), pp. 1445-1467, 2007, DOI: 10.1175/JCLI4056.1

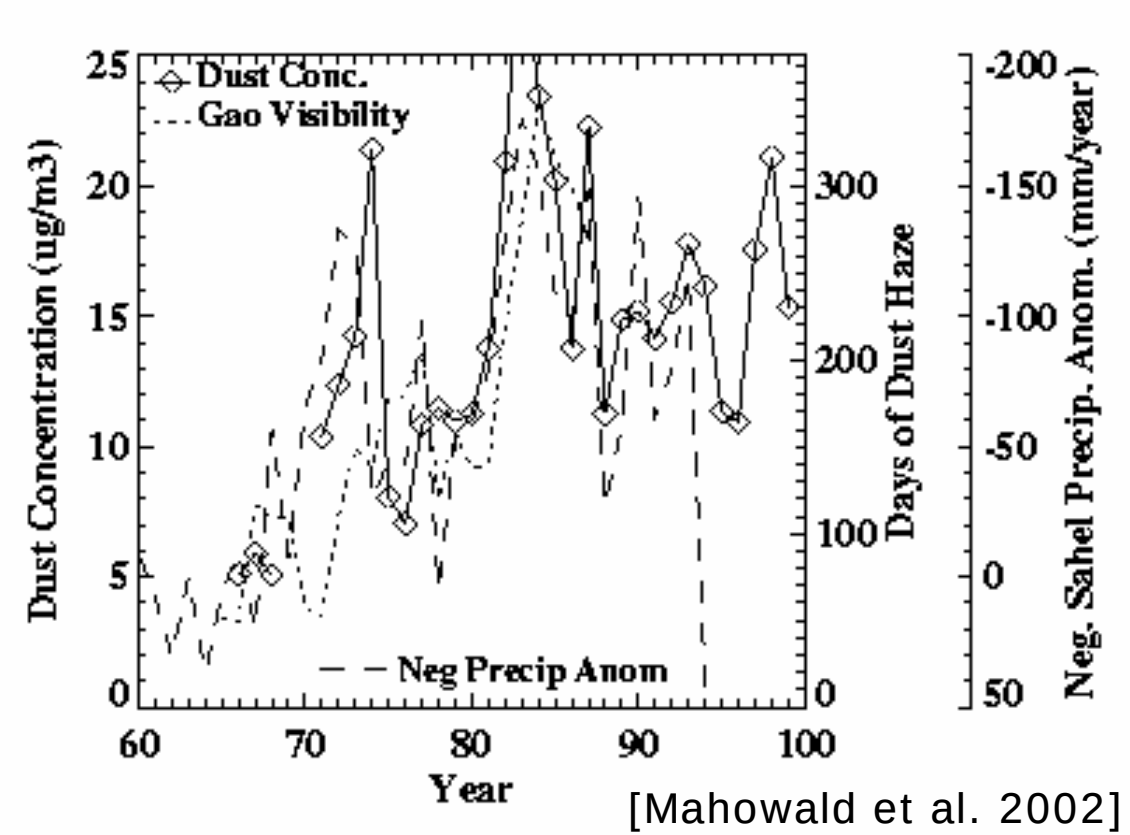
The Drought in the African Sahel

- Most of the annual rainfall in the African Sahel region comes from the West African Monsoon (WAM) associated with the seasonally migrating ITCZ
- Droughts since 1970s are exceptionally severe and spatially and temporally coherent;
  - tend to affect the entire region across the continent at the same time
  - tend to continue for many years or even decades;

    Nearly all years in 1970-90s are anomalously dry

    compared to the 20th century average [Nicholson, 2000]
  - Positive feedback? Multi-year memory?

North African desert dust



[Mahowald et al. 2002]

- A 4-fold increase has been observed in surface concentration in Barbados from 1960s to 80s [Prospero and Nees, 1986, Prospero et al., 1996]
- Negatively correlated with Sahel rainfall

Mechanisms controlling Sahel rainfall

- SST patterns
  [Folland et al., 1986; Lamb and Peppler, 1992; Rowell et al., 1995; Bader and Latif, 2003; Giannini et al., 2003; Hoerling et al., submitted]
  - Contrast in N and S Atlantic Ocean SSTs
  - Indian Ocean SST
- Land-atmosphere interactions
  [Xue and Shukla, 1993; Xue, 1997; Clark et al., 2001; Taylor et al., 2002; Xue et al., 2004]
  - Surface hydrology and vegetation dynamics could provide a multi-year memory and positive feedback
- Dust?
  - can affect SSTs through radiative forcing
  - may provide the positive feedback and multi-year memory since it is controlled by surface hydrology and vegetation dynamics [Nicholson, 2000; Prospero and Lamb, 2003]
  - Reduced rainfall in North Africa have been obtained when dust radiative forcing is included in GCM simulations [Miller and Tegen, 1998; Miller et al., 2004]

Model and some details of study

- GCM simulations with the National Center for Atmospheric Research (**NCAR**) Community Atmosphere Model (**CAM3**)
- Coupled with Community Land Model (**CLM3**)
- Either coupled with the Slab Ocean Model (**SOM runs**) or forced by observed climatological SSTs (**AMIP runs**)
- Dust Entrainment And Deposition model (**DEAD**) [Zender et al. 2003]
- Dust shortwave and longwave effects and feedback (except longwave scattering) are included
- Vegetations in wet and dry periods are prescribed
- Dust optical properties are based on recent estimates [Dubovik et al. 2002; Sinyuk et al. 2003] and less absorbing in SW than typical previous studies
- Dust size distribution is based on recent study [Reid et al. 2003] and dust particles are larger than previous studies

Simulation cases

- SSTs;
  - Forced by observed SST (AMIP) ***OR***
  - Coupled with slab ocean model (SOM)
- Dust effects;
  - No dust radiative effect,
  - Prescribed SW effect,
  - SW effect and feedback, ***OR***
  - SW and LW effects and feedbacks
- Vegetation;
  - Fixed throughout the simulation ***OR***
  - Shifted from wet to dry periods
- GHGs, non-dust aerosols and solar irradiance;
  - Fixed at 1990s levels,
  - CO_2 doubled, ***OR***
  - Followed the historical records

Analyses

- Simulations under different conditions are compared to isolate effect of each factor from others
- Statistical analyses are performed by treating different ensemble members and individual years under same boundary conditions as samples

More details and Results

Come to the poster session and find out!

Final figure;
Radiative (SW+LW) forcing and feedback of dust may explain ~30% of observed rainfall reduction!!!