Observed 20th Century dust variability: implications for climate and biogeochemistry

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Motivation

- Dust is important ‘natural’ aerosol (50% of mass)
- Important for radiative forcing, and indirect interactions with clouds (water and ice) (e.g. Tegen and Miller 1998; Rosenfeld et al., 1996; DeMott et al., 2001)
- Important for ocean biogeochemistry because of iron inputs to oceans (e.g. Martin et al., 1991; Moore et al., 2006)
- Important for land biogeochemistry on long time scales due to P (e.g. Swap et al., 1992)
- Climate forcing important: leads to shift in ITCZ to southern hemisphere (e.g. Perlwitz et al., 2001; Yoshioka et al., 2007)
- Trends in dust from humans not known (e.g. Mahowald et al., 2009)
  - Climate change (e.g. Mahowald and Luo, 2003)
  - CO2 fertilization (e.g. Mahowald et al., 1999; Kohfeld and Harrison, 2000)
  - Land use impacts on dust sources (e.g. Tegen et al., 2004; Mahowald et al., 2004; Moulin and Chiapello, 2006; Ginoux et al., submtited)
  - Water use impacts on dust sources (e.g. Mahowald et al., 2007)

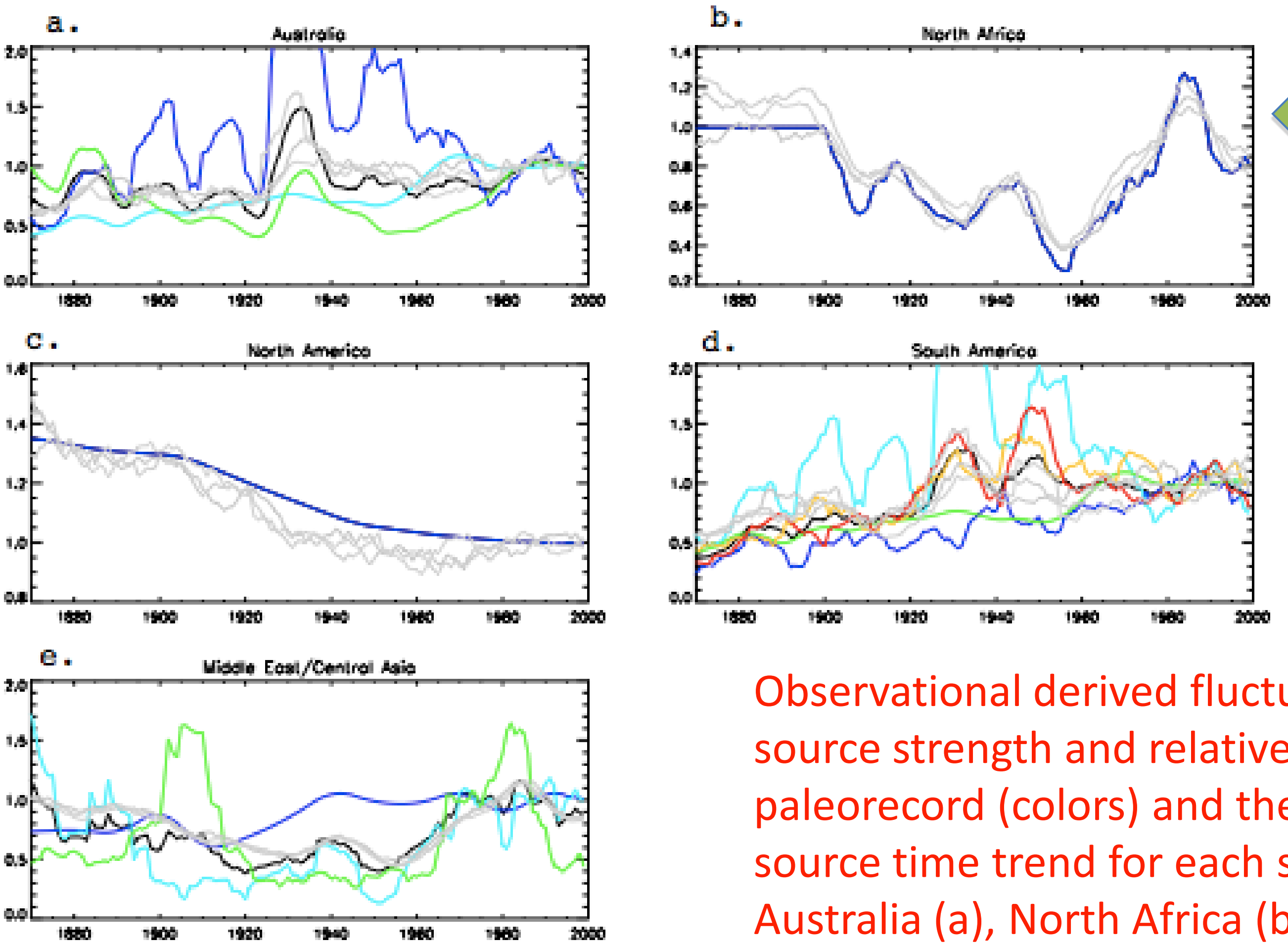
Methodology for dust variability

- Use paleodata from 1870 to 2000
  - Ice cores, lake cores, coral cores of dust fluxes
- Relate each core to dominant sources (7 areas)
  - Use model and geochemistry data
- Create average source area evolution
  - Assume most of variability is source strength
- Use model predictions of source apportionment to obtain time series at every grid point of deposition flux

Methodology for determining impacts

- CCSM3/4 model components were run asynchronously
- Climate impacts
  - Use CAM/CLM with SNICAR to calculate dust radiative forcing and climate response (need to force sources to change to get observed change).
  - Use ensembles, SOM and look at with and without dust variability (3 and 4 ensemble members, respectively)
  - Estimate radiative forcing from indirect effects assuming proportional to AOD (Rosenfeld et al, 2008).
- Biogeochemistry:
  - Land: Use CAM/CLM output (change in T and P) to drive 2 simulations of CLM-CN to get land carbon flux changes (only considers physical climate response)
  - Ocean Use POP/BEC to obtain ocean biogeochemistry response with and without dust changes (only considers soluble iron fluctuations)

Time evolution of sources (from obs)

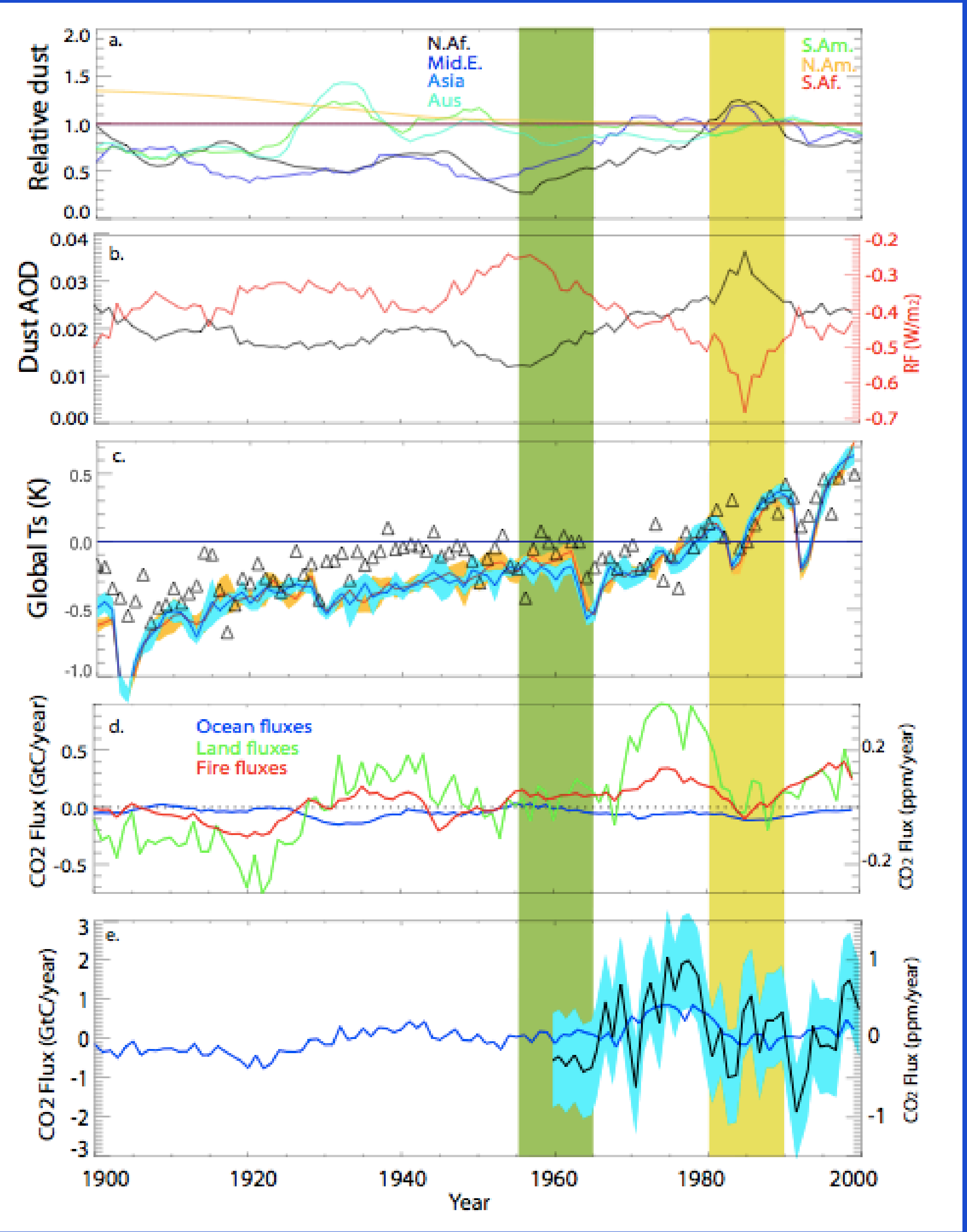


North Africa is 50% of dust and we have only 1 record (to 1955), and we extrapolate back to 1905.

Observational derived fluctuations in relative source strength and relative deposition for each paleorecord (colors) and the mean estimated source time trend for each source area (black) for Australia (a), North Africa (b), N. America (c), South America (d), and Middle East/Central Asia (e). Each line is one paleo record.

Need more obs to constrain better.

Mahowald et al., 2010



Time evolution of sources

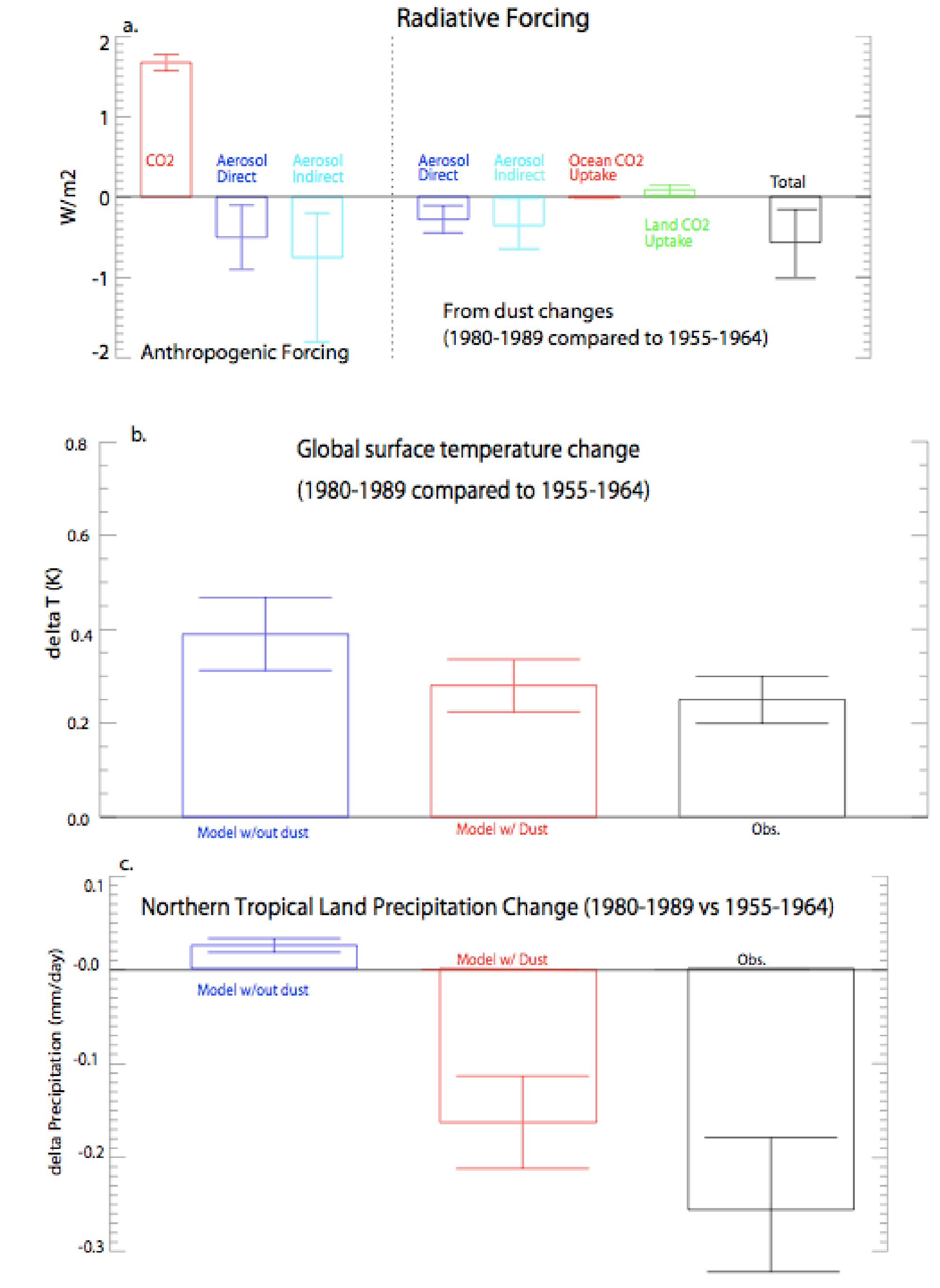
Time evolution of AOD/RF

Time evolution of Ts with dust(yellow) and without (blue) and obs (triangle)

Carbon flux changes with including dust variability

Carbon flux changes from including dust variability (blue) compared to residual carbon from LeQuere et al., 2010

Mahowald et al., 2010



Estimates of net radiative forcing from 1990-1980 (dusty time period) vs. 1955-1965 (non dusty time period) of including dust in simlations: significant compared to anthropogenic radiative forcing.

Global surface temperature increase between dusty and non-dusty time periods (1980-1990 vs. 1955-1965) better matched with dust included in model.

Regional changes in Precip are better simulated with dust included.

Summary/Conclusions

- Over the 20th century, dust has varied by ~2x
  - later time period tends to be more dusty
  - More observations would decrease uncertainty
- Has important implications for climate and biogeochemistry
  - -0.14 W/m2 over 20th century
  - -0.57 +/0.46 W/m2 between dusty and non-dusty time period (1980-1990 vs 1955-1965)
  - Dominant changes are from direct radiative forcing
  - For CO2: Land response from physical climate response is (6ppm) larger than ocean response from additional iron in dust (4ppm).
  - For ocean, 6% increase in productivity