Variability of Mineral Aerosols in the Atmosphere

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Introduction

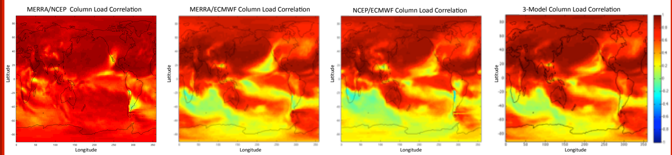
- Mineral aerosols are important for their climate and biogeochemical impacts (Tegen et al., 1996), but there are gaps in our understanding of both their distribution and their effects.
- Here we examine the monthly variability in desert dust using the Community Atmospheric Model (CAM) driven by three different reanalysis datasets. Our goals are:
  1. to understand if the current generation of models can capture observed variability in aerosol optical depth and
  2. to see which aspects of interannual variability are simulating similarly across the different reanalysis models.
- This will help us understand how much we can trust the simulated variability. Since we are evaluating monthly mean values, we are including seasonal variability as well as interannual variability in this set of comparisons.

Methodology

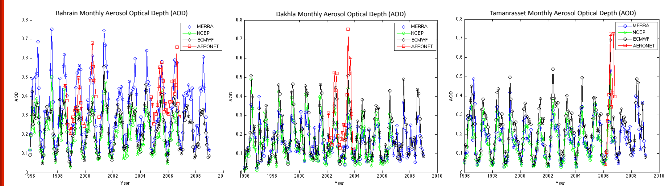
- This study attempts to examine large-scale spatial and temporal variability of dust in the atmosphere by using NCAR's Community Atmospheric Model (CAM) to simulate monthly average dust dispersal across the globe.
- In order to ensure accurate results, three different reanalyzed meteorological datasets were used to drive the dispersal of atmospheric dust:
  - MERRA (Modern Era-Retrospective Analysis for Research and Applications)—simulated from 1980 to 2010.
  - NCEP (National Centers for Environmental Prediction) —simulated from 1989 to 2006.
  - ECMWF (European Center for Medium-Range Weather Forecasts) —simulated from 1990 to 2009.
- The results of these simulations were compared to aerosol observations from the AERONET (Aerosol Robotic Network) database and to each other, in order to determine which of the reanalyzed datasets produced output most consistent with reality.
- The global variability for dust concentration in each simulation was then calculated and plotted. Variability is defined here as the standard deviation of the data over the mean value.
- Finally, the variability for other dust parameters (such as mobilization and deposition) were calculated, in order to determine which of them was driving the variability observed in the concentration.
- On this poster, concentrations are compared in units of kg/kg, while the units for deposition are kg/m²/s, and aerosol optical depth units are fractions.

Results

- Overall, the MERRA and NCEP simulations (seasonal cycle included) correlate very strongly with one another, and less strongly with the ECMWF, especially in the southern hemisphere. Correlation between all three models follows a similar pattern.



- None of the three reanalysis-driven simulations were significantly better then the others at matching AERONET observations for specific locations.



Bahrain Model/Observation Correlation Coefficients

MERRA/AERONET	r = 0.74
NCEP/AERONET	r = 0.76
ECMWF/AERONET	r = 0.72

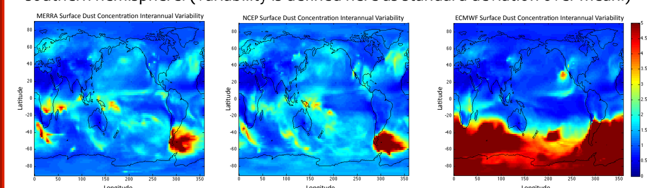
Dakhla Model/Observation Correlation Coefficients

MERRA/AERONET	r = 0.91
NCEP/AERONET	r = 0.90
ECMWF/AERONET	r = 0.92

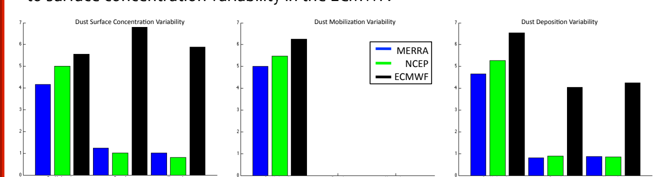
Tamanrasset Model/Observation Correlation Coefficients

MERRA/AERONET	r = 0.73
NCEP/AERONET	r = 0.71
ECMWF/AERONET	r = 0.75

- Interannual variability of dust concentration (seasonal cycle included) was greatest near the equatorial Indian Ocean, the southwestern United States, the North Atlantic, and South America. The ECMWF simulation produced huge variability for almost the entire southern hemisphere. (Variability is defined here as standard deviation over mean.)



- Dust mobilization variability in South America was very large, and drove large variability in both dust deposition locally, as well as surface concentration. This variability was seen in the surface concentrations as far downwind as Crozet and Kerguelen, in the ECWMF-driven reanalysis, but was much more muted in other reanalysis-driven model runs. Surface concentration variability at Crozet was actually larger than in the source regions in the ECMWF driven runs, suggesting that transport variability enhanced the overall variability. Deposition variability at Crozet and Kerguelen was muted compared to surface concentration variability in the ECMWF.



Conclusions

- The MERRA, NCEP, and ECMWF reanalysis –driven model runs agree quite well for comparison of monthly mean simulations in the northern hemisphere, but differ considerably in the southern hemisphere. These differences are consistent with fewer high quality meteorological observations in the southern hemisphere, especially over ocean regions, driving larger differences in the reanalyses.
- All the model simulations did fairly well at matching observed aerosol optical depth in the AERONET data.
- All the model simulations show South America as the location with the greatest interannual variability of atmospheric mineral aerosols (seasonal cycle included), although the ECMWF output extended the region of greatest variability to most of the southern hemisphere.
- Interannual variability of dust mobilization in South America (seasonal cycle included) appears to be the driver behind the large amount of variability observed in the southern hemisphere, although transport and deposition do play a part. For example, at Kerguelen, the variability in surface concentration is greater than the variability in deposition, suggesting that the variability in surface concentration is more closely tied to the variability in dust that mobilized elsewhere and was transported in.
- A variable dust surface emission flux could perhaps be due to a few anomalously large mobilization events, and a variable deposition rate could be due to sporadic desert rainfall.

Future Research

- In the future we will evaluate the mean seasonal cycle separately from the simulated interannual variability.
- More data from the southern hemisphere is needed to see if the huge interannual variability displayed by the ECMWF simulation is actually occurring, and if it is, how closely its magnitude matches what is shown in the model output.
- The exact cause of the large South American variability should be determined by looking at factors such as wind speed, temperature, soil moisture, and precipitation.
- Ground observations of surface dust concentration could help to determine which model is the most accurate overall.
- In addition, we will use the model results to consider how long observations need be taken at each location in order to obtain a mean value similar to the long term mean, at least according to the model.