Observational Constraints On the Global Dust Aerosol Cycle

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With Thanks to
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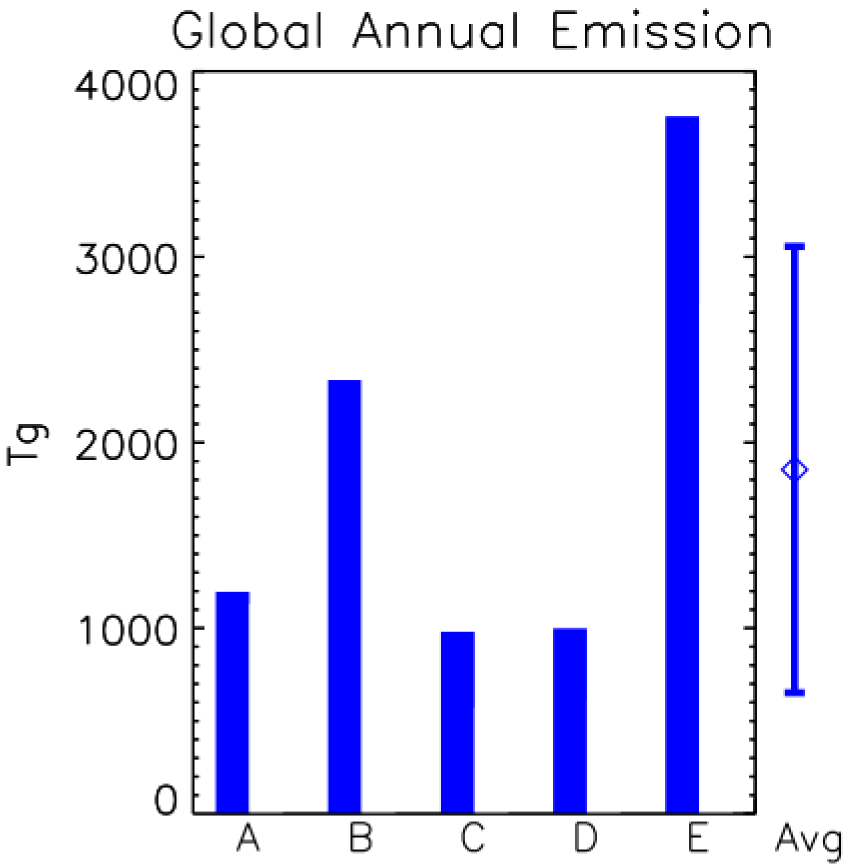
Model Estimates of Global Dust Emission Vary Widely

- AEROCOM Models
  - –GISS
  - –NCAR MATCH
  - –GFDL MOZART
  - –LSCE
  - –KYU
- Multi-year climatology:
  - –Model Mean: 1854 Tg
  - –Std Dev: 1202 Tg



Textor et al, *Atmos. Chem. Phys.* 2006

Modelers want to know the mass of soil particles entering the atmosphere along with its size distribution.

- Strong winds lift soil particles into the atmosphere through saltation and sandblasting.
- We have detailed physical theories of these processes and measurements from wind tunnels. (e.g. Gillette 1978, Marticorena and Bergmetti 1995, Alfaro and Gomes 2001, Grini and Zender 2002)

⇒ Attempts to apply this knowledge to global models are complicated by surface heterogeneity and the models' large resolved spatial scale.

Emission In Global Models

- In practice, emission in global models typically increases with wind speed, and varies spatially according to the presence of dust sources. The total emitted mass and its size distribution is controlled by a factor C(r) that is generally assumed independent of location.

$$\mathcal{E} = f(u, r, \mathbf{x}) \rightarrow C(r) S(\mathbf{x}) f(u)$$

$\Rightarrow$ C(r) is typically tuned to match observations (often unstated).

- Assumption: there is a ‘universal’ value of C(r), such that all source regions emit with the same efficiency and size distribution for a given wind speed.
- Assumption: processes that carry dust to the measurement location are well-constrained compared to emission, so that it is appropriate to tune emission rather the transport and removal processes to match the measurements downwind of the source.

Cakmur et al. *J. Geophys. Res.*, 2006

Experiment

- ⇒ Tune C(r)☐in the AEROCOM models so that each model has a minimum error with respect to a globally distributed set of observations.
- ⇒ If these assumptions are valid, then the range of emission among the AEROCOM models should be substantially reduced. That is, if poor knowledge and inconsistent choices of C(r) are the main reasons for the disagreement among AEROCOM model emission, then tuning of C(r) to match observations should reduce the estimated emission range.

GISS Model Surface Concentration at Barbados

Ratio of model to observation standard deviation S=1.10,

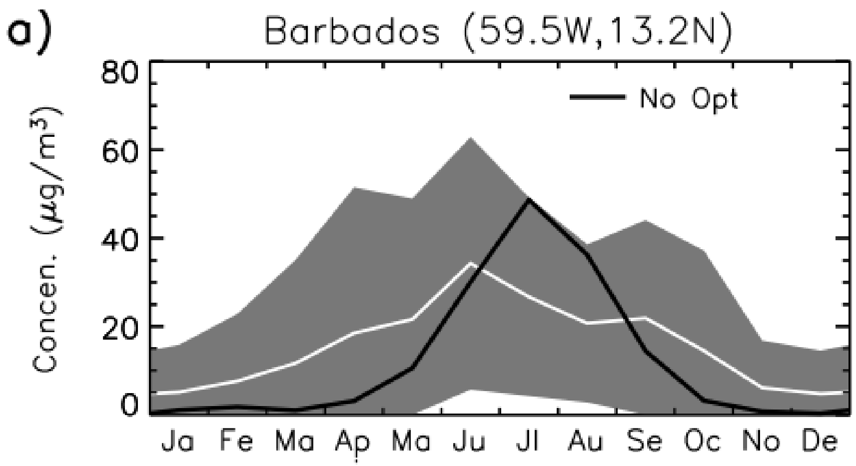
$$S^2 \equiv \sum_i m_i^2 / \sum o_i^2$$

Correlation r=0.84,

$$r = \sum_i m_i o_i / \sqrt{(\sum_i m_i^2 \sum_i o_i^2)}$$

Root mean square error E=0.60,

$$E^2 = \sum_i (m_i - o_i)^2 / \sum_i o_i^2$$



⇒ Optimize: multiply total emission by a factor α that minimizes the root mean square error E: $C(r) \rightarrow \alpha C(r),\ m_i \rightarrow \alpha m_i.$

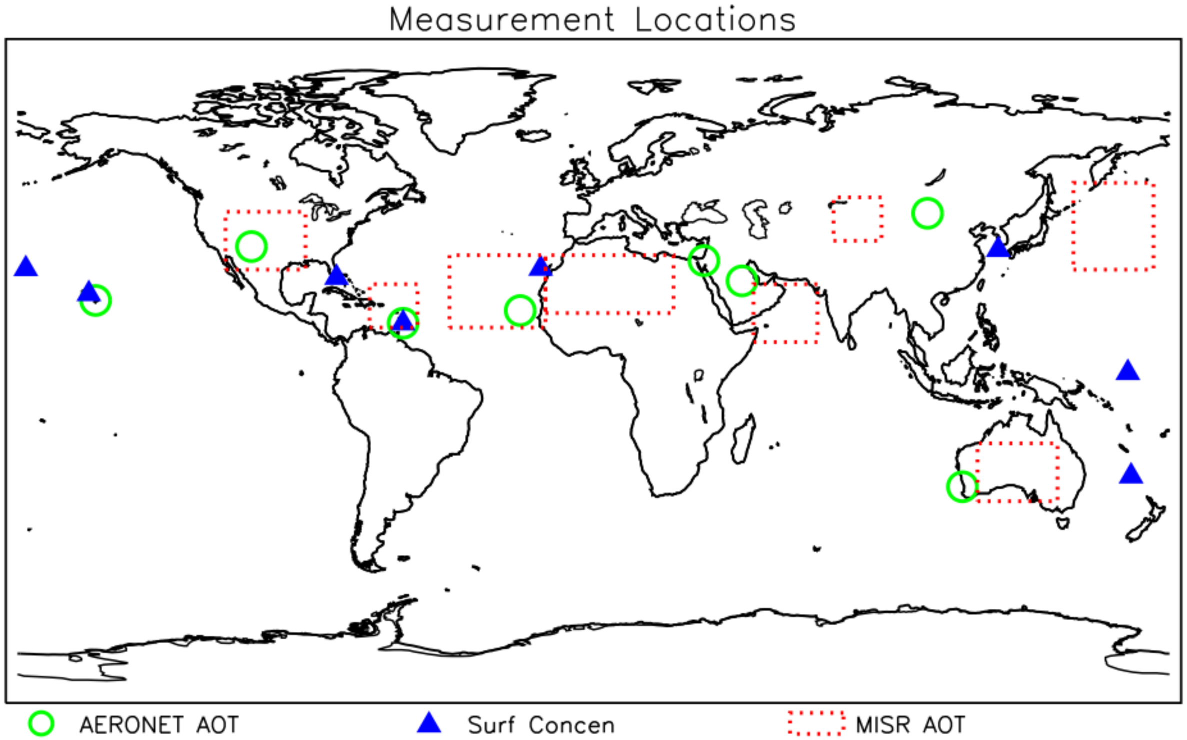
E = 0.54 (S=0.84, r=0.84)

Note that total (root mean square) error is reduced, but correlation is not improved. Rescaling total emission doesn't change the timing of the seasonal peak.

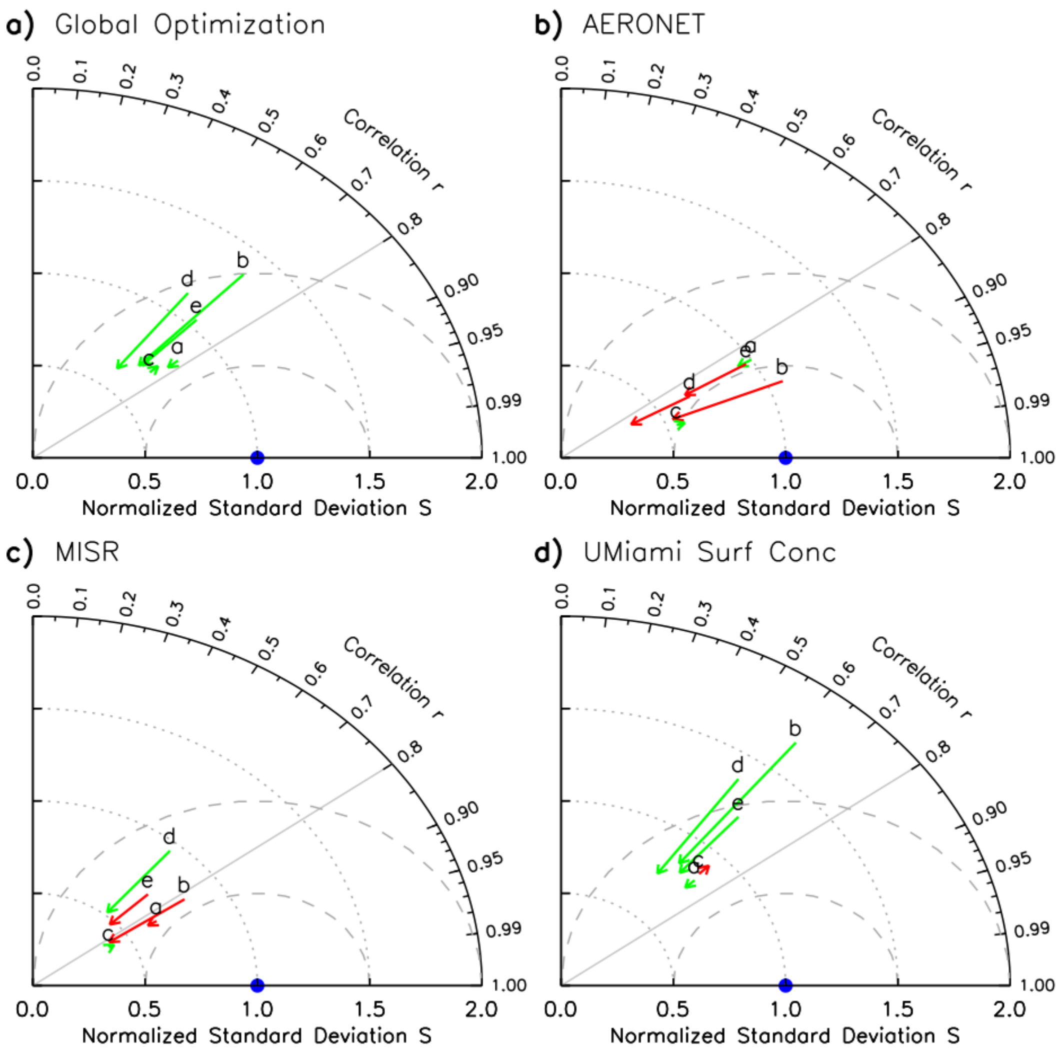
⇒ Rescale clay and silt emission separately (requires separate archival of clay and silt in model intercomparisons like AEROCOM).

Constrain C(r) With Global Measurements

- Aerosol Optical Thickness (AOT): AERONET and MISR.
- Surface concentration from Univ. of Miami.



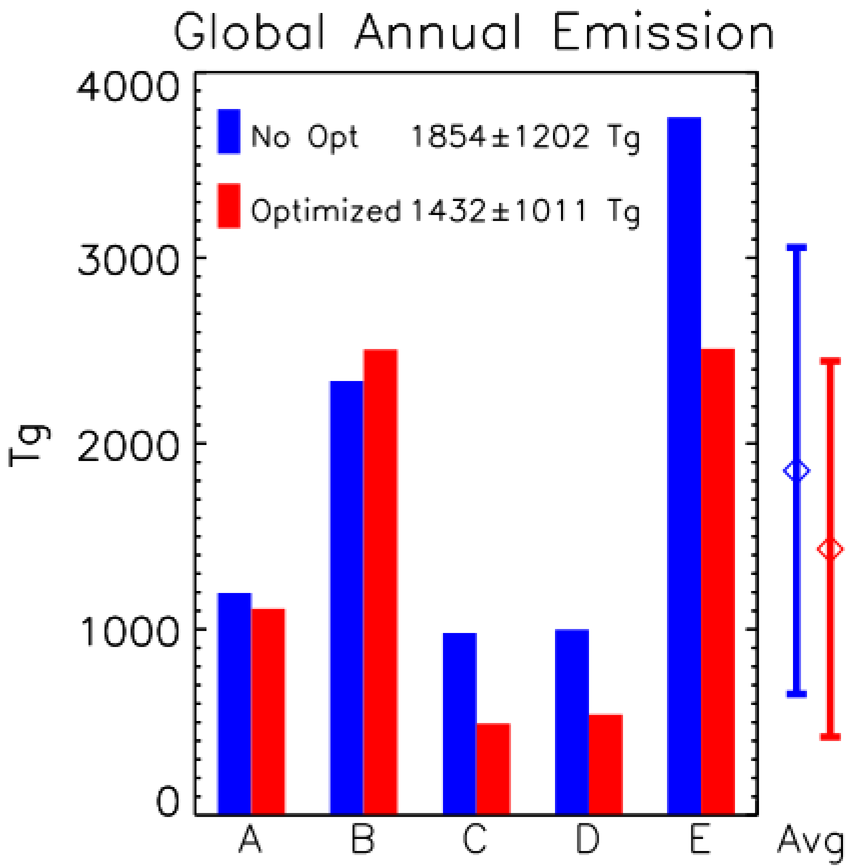
Global Optimization



- In a Taylor diagram, the ratio of the model and observed standard deviation is plotted on the radial axis, and the angle depends upon the correlation (Taylor, *J. Geophys. Res.*, 2001).
- The rms error increases with distance from the blue circle on the horizontal axis.
- For each model, an arrow connects the unoptimized optimized values.
- The arrow points toward the optimized value.
- A green arrow indicates a smaller rms error after optimization; red indicates a larger rms error.

Model	RMS (No Opt)	RMS (Optimized)
A	0.63	0.63
B	1.00	0.73
C	0.67	0.67
D	0.94	0.79
E	0.80	0.72

- Optimization increases the agreement of each model with the observations (by reducing the RMS error).
- But the range of emission among the AEROCOM models is not reduced.



Conclusions

- Tuning emission through C(r) brings the AEROCOM models into better agreement with observations of aerosol optical thickness and surface concentration, but the range of model emission is not reduced.
- Errors and uncertainties in other processes (e.g. transport and removal) have a comparable effect upon the model dust cycle.
- Caveats:
  - Surface wind speed may vary widely among the models, creating differences in emission that can't be corrected by adjusting C(r).
  - Clay and silt emission may need to be tuned individually rather than total emission. Future intercomparison experiments should archive separate silt and clay contributions to load and AOT.
- The global rms error is a 'skill score' that is useful for assessing model development even in the absence of tuning.
- Soon to be publicly available as a fortran (and IDL) program.