

Uncertainty in modeling dust mass balance and radiative forcing from size parameterization

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Dust is important!

- Dust is one of the most abundant aerosol species in the atmosphere in terms of mass.
- Dust has significant impacts on earth ecosystems, climate, and air quality
 - Interact with the solar radiation through absorption and scattering and to a lesser extent with the terrestrial radiation, and also serve as cloud condensation nuclei (CCN) and/or ice nuclei (IN) to influence cloud albedo and lifetime.
 - Impact visibility and human health
 - influence the ecosystems of oceans and rain forests and surface albedo of land covered by snow through deposition
- Modeling dust and its impact is uncertain (e.g., emission, **size distribution**, optical properties)

WRF-Chem (v3.3.1)

- MADE/SORGAM and MOSAIC aerosol mechanisms
- GOCART dust emission scheme with Kok's dust size distribution (Zhao et al., 2010; Kok 2011)
- RRTMG SW and LW radiation scheme interacted with aerosols (Zhao et al., 2011); Dust AOD and radiative forcing are diagnosed as Zhao et al. (2013).
- Morrison 2-moment microphysics and Kain-Fritsch cumulus parameterizations for aerosol transport and wet-scavenging.
- Quasi-global channel configuration, i.e., using periodic boundary conditions in the zonal direction, with 360×130 grid cells (180°W - 180°E , 60°S - 70°N) at 1 degree horizontal resolution; Meteorology nudged to GFS reanalysis



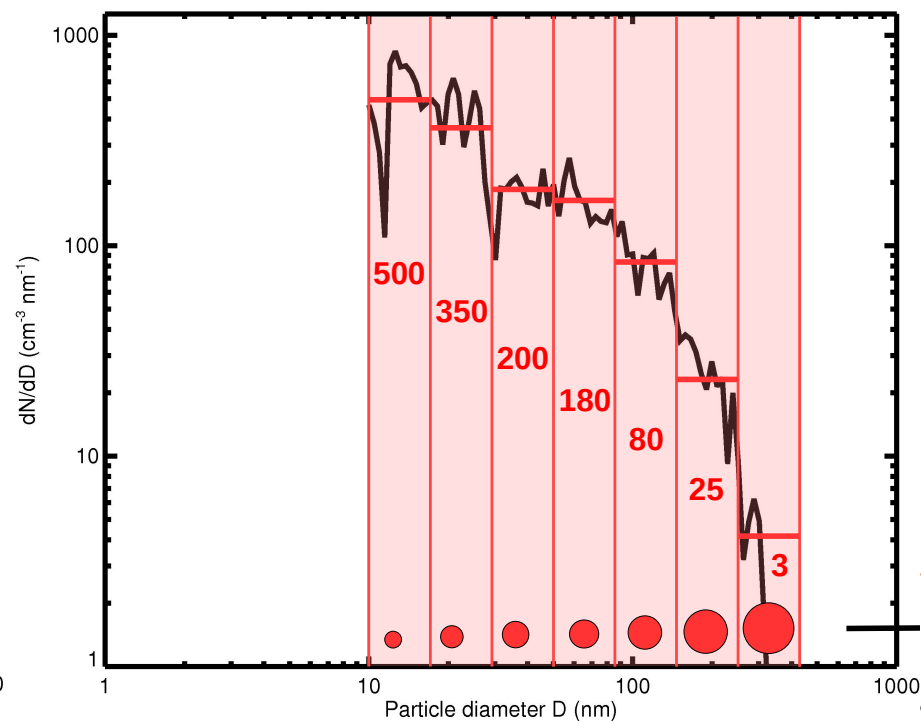
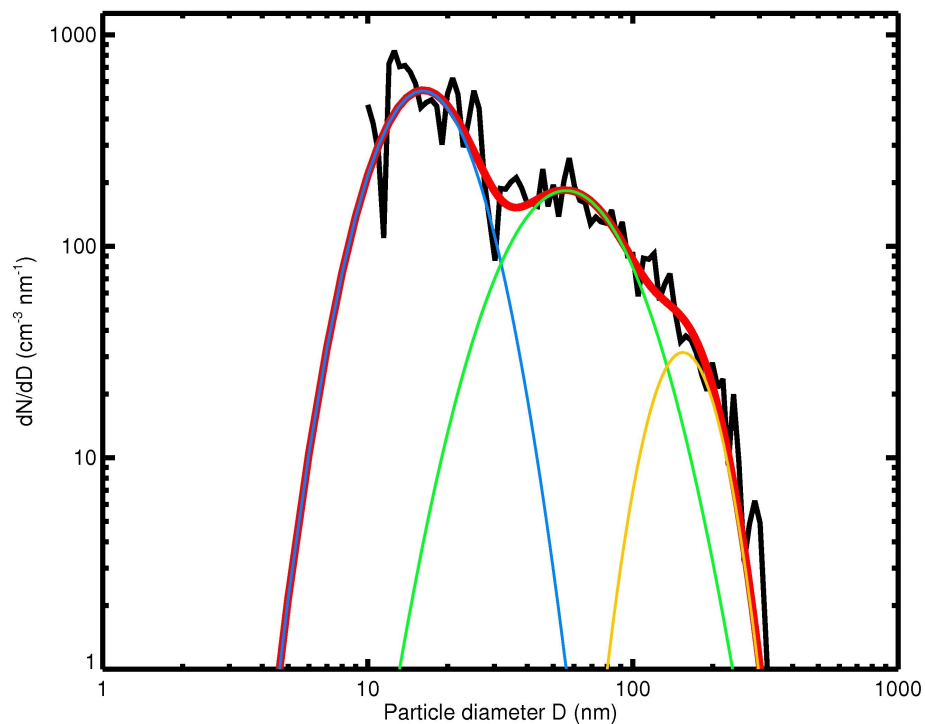
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Aerosol Size Parameterization

- 3-mode in MADE/SORGAM (MOD3)
- 4-bin in MOSAIC (BIN4)
- 8-bin in MOSAIC (BIN8)

From Jan Kazil in CIRES



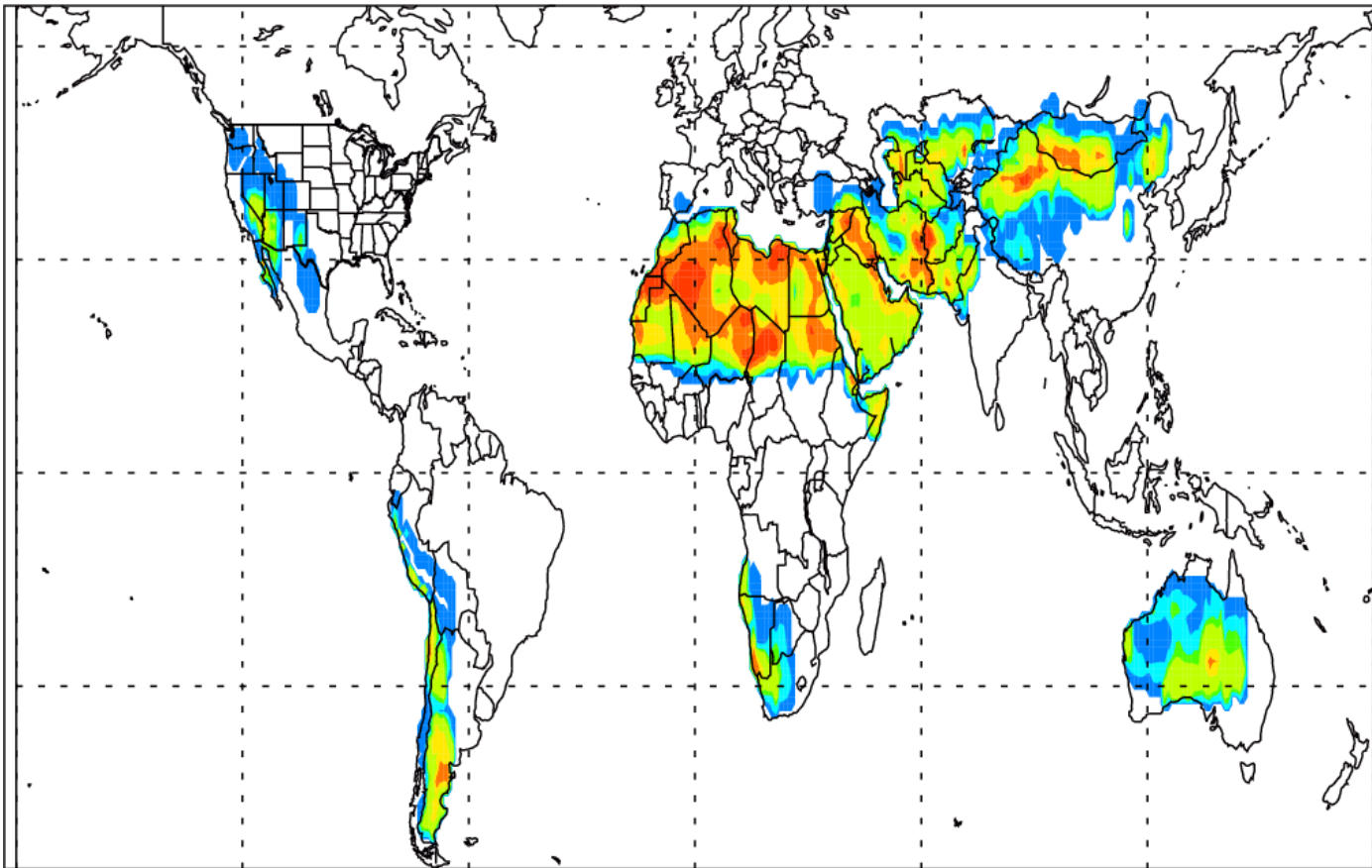
6012 Tg/year

**WRF-Chem
simulations**

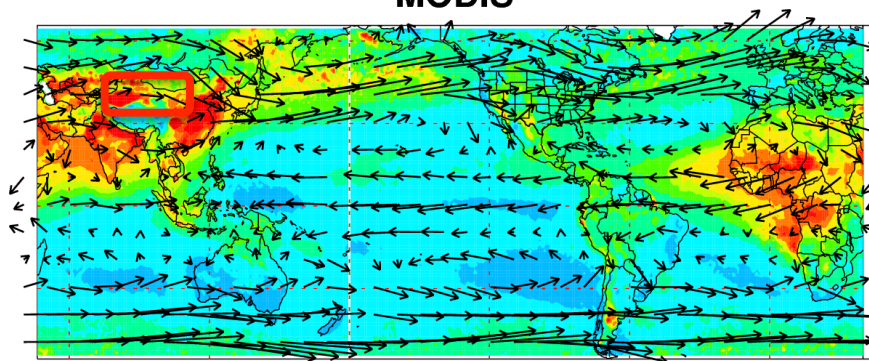
- BIN8
- BIN4
- MOD3
- MOD3_tuned
(3006 Tg/year)

0.1 0.5 1 5 10 20 50

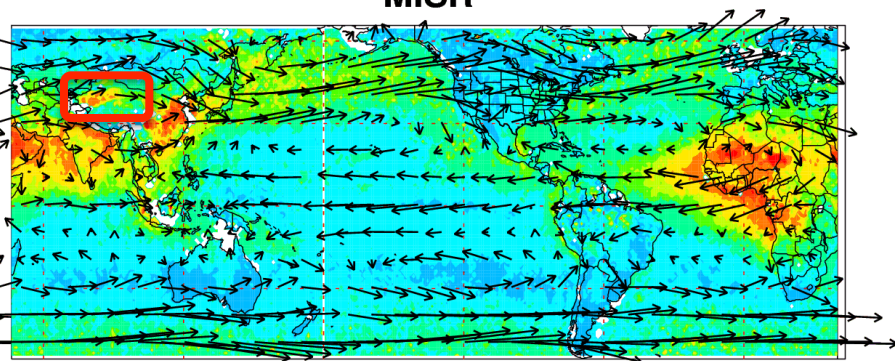
Dust emission [$\mu\text{g}/\text{m}^2/\text{s}$]



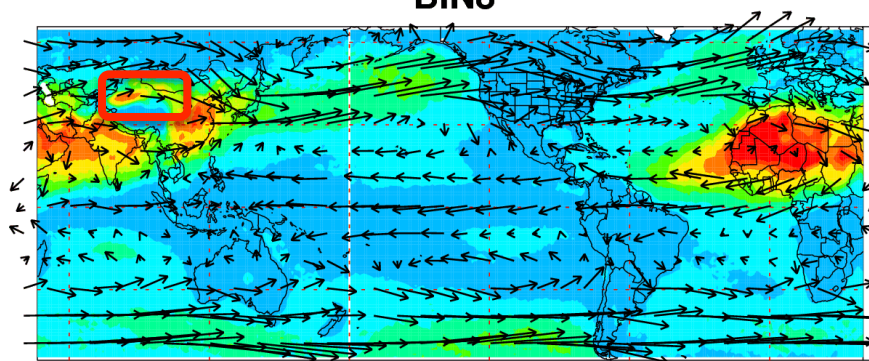
MODIS



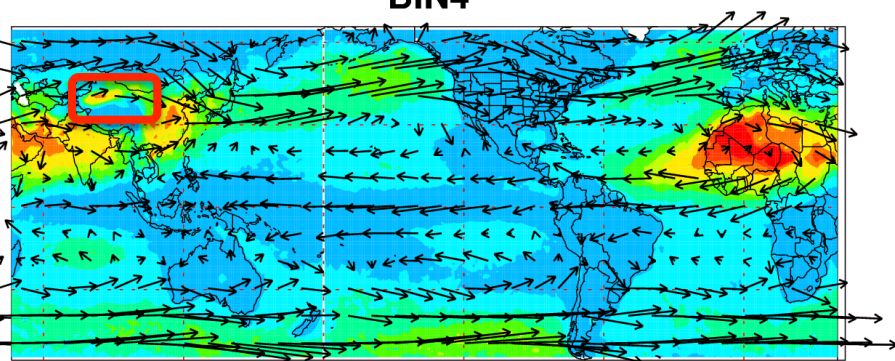
MISR



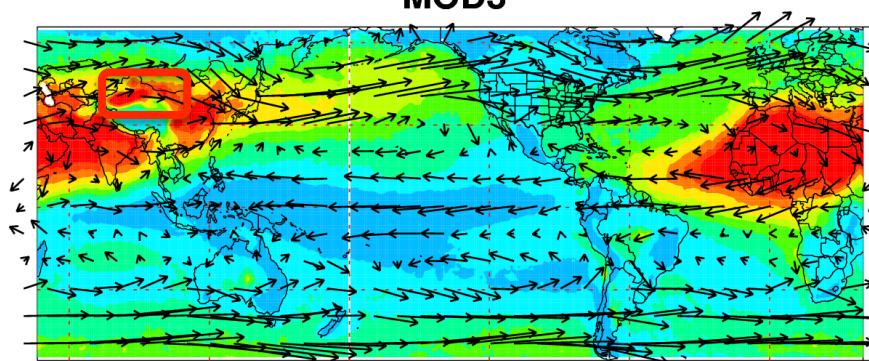
BIN8



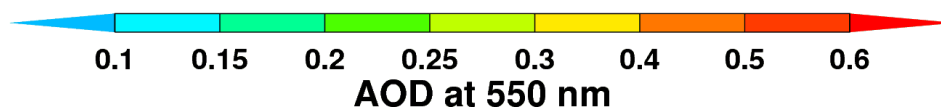
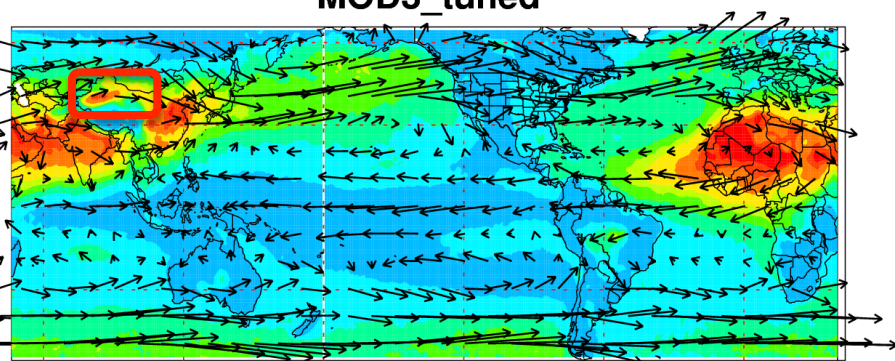
BIN4



MOD3



MOD3_tuned



→ 10 m/s

Dust

Other

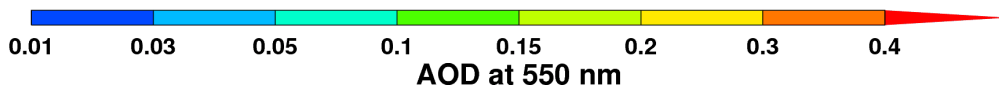
BIN8

BIN4

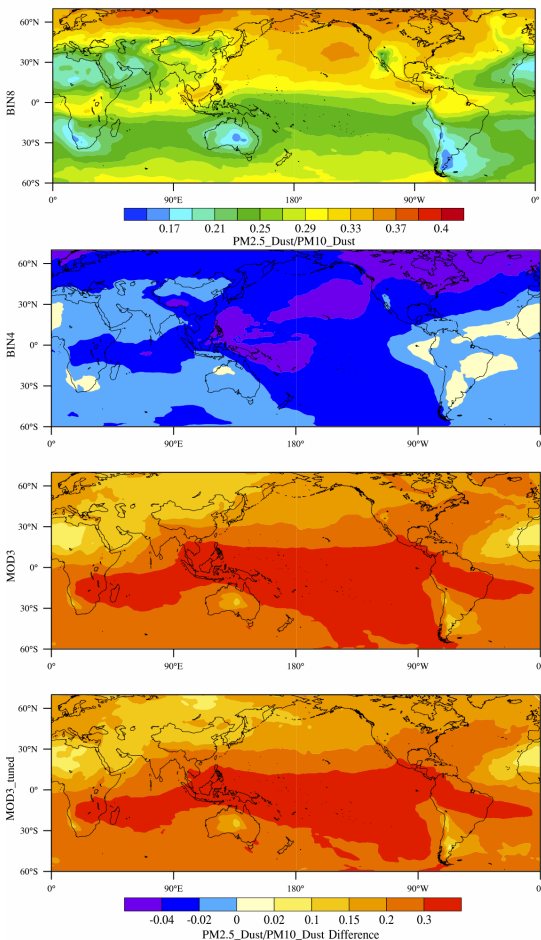
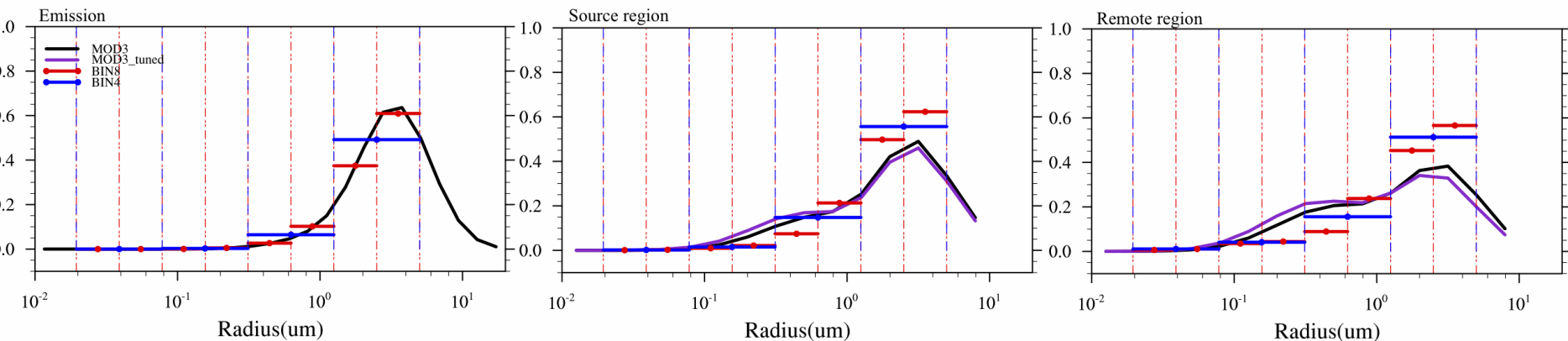
MOD3

MOD3
(tuned)

- Dust contributes to >90% of total AOD over the desert regions.
- Large difference in dust AOD among the four cases
- Difference in AOD contributed by other aerosols among the four cases is relatively small and not investigated

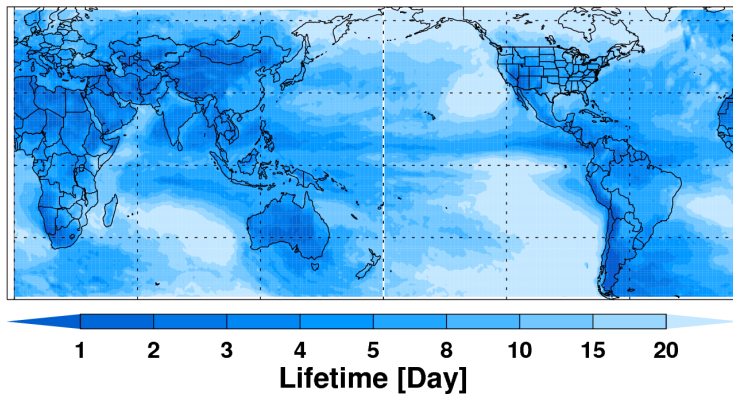


Normalized $dV/d\ln(r)$ of dust



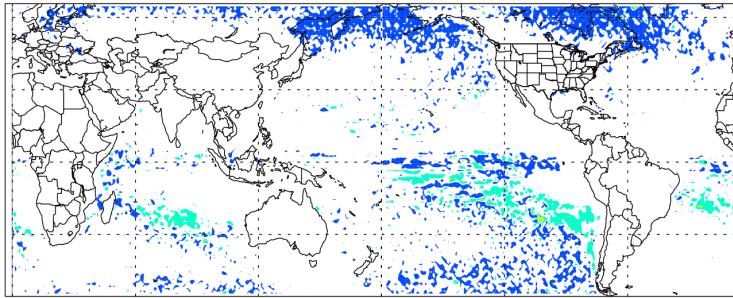
- BIN4 follows BIN8, but has coarser size resolution; This results in fewer fine dust particles in BIN4 than BIN8
- MOD3 and MOD3_tuned retains more fine dust particles but fewer coarse dust particles versus BIN8; The prescribed σ is the main contributor to the bias of 3-mode approach (Zhao et al., 2010)

BIN8



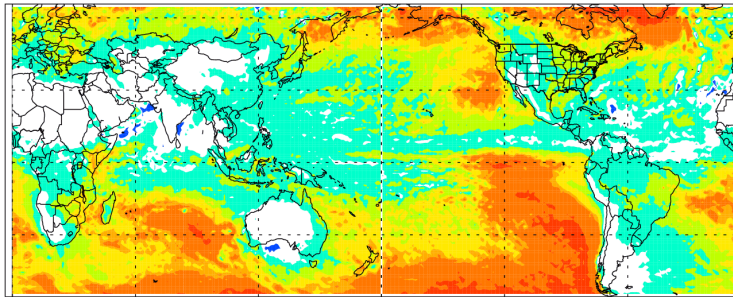
- BIN8 simulates a shorter lifetime (~ 1 day) nearby the dust source regions and a longer lifetime (> 10 days) over the remote oceans

BIN4



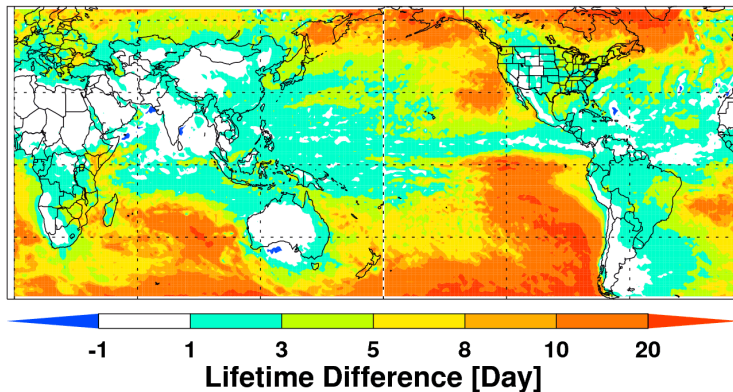
- Dust lifetime in BIN4 is a little longer than that in BIN8 globally with small difference less than one day

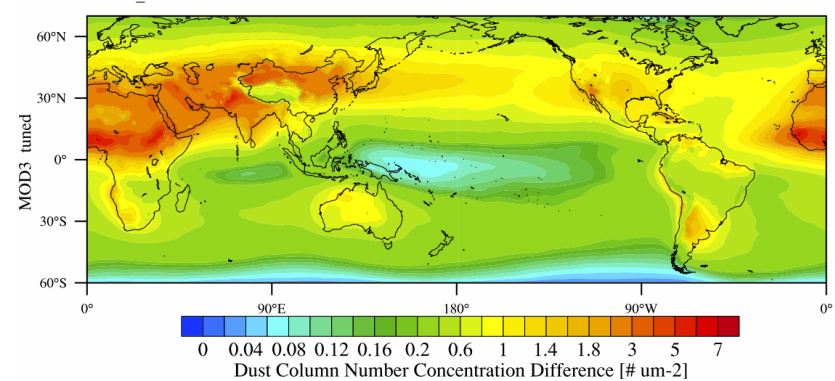
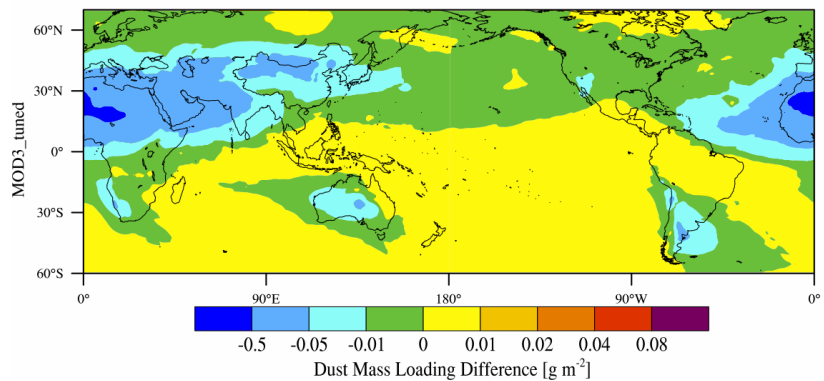
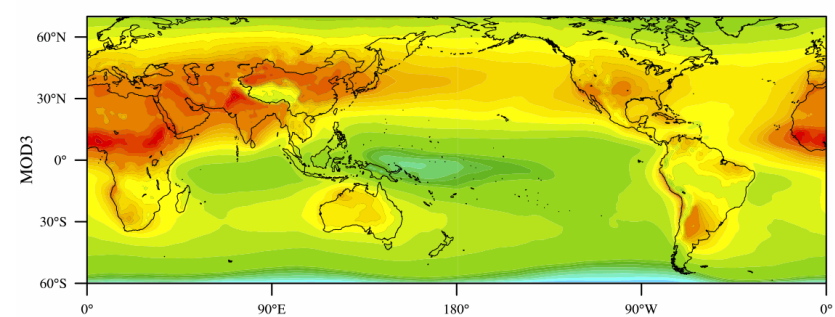
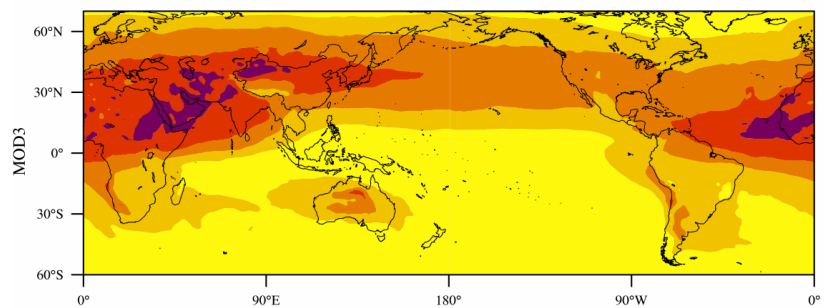
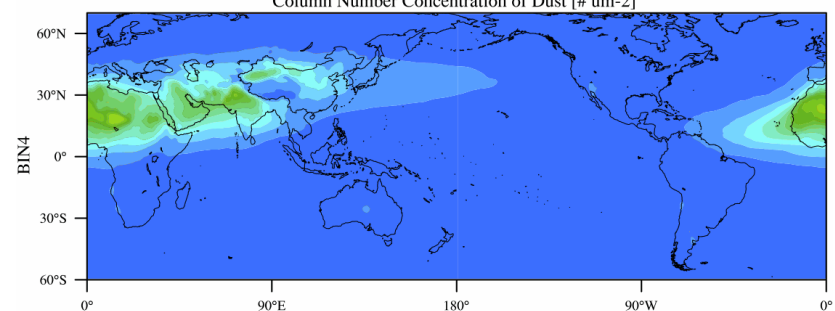
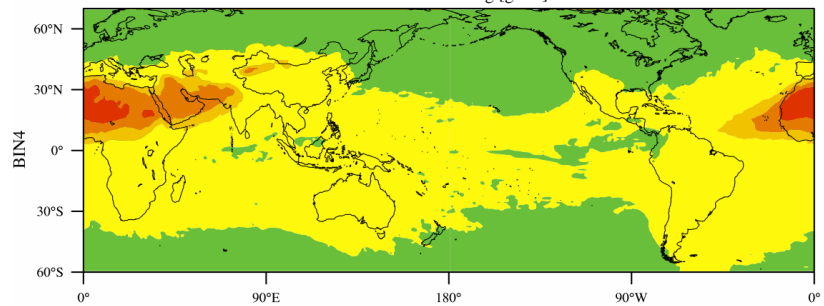
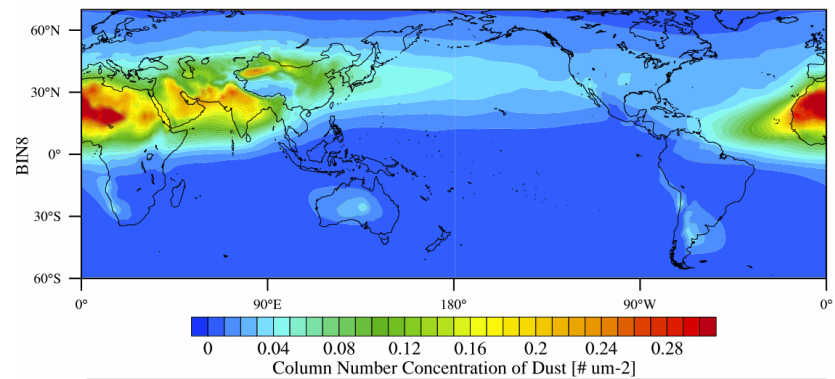
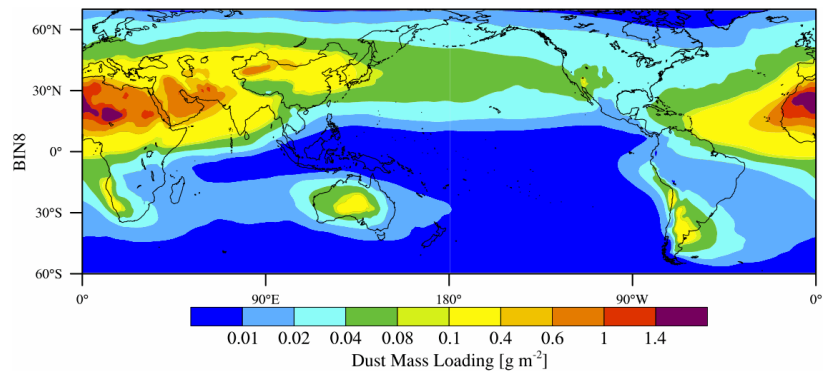
MOD3

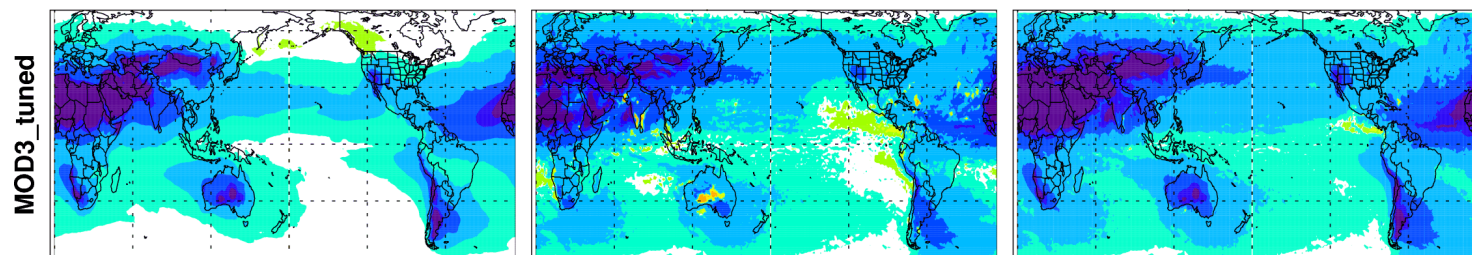
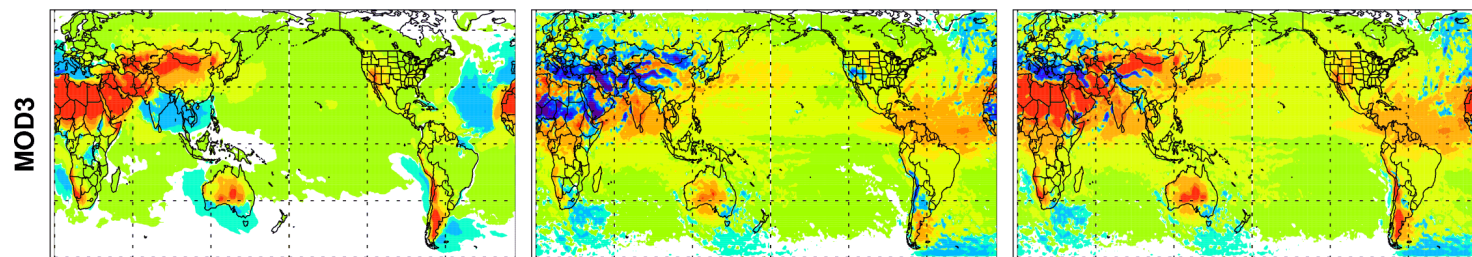
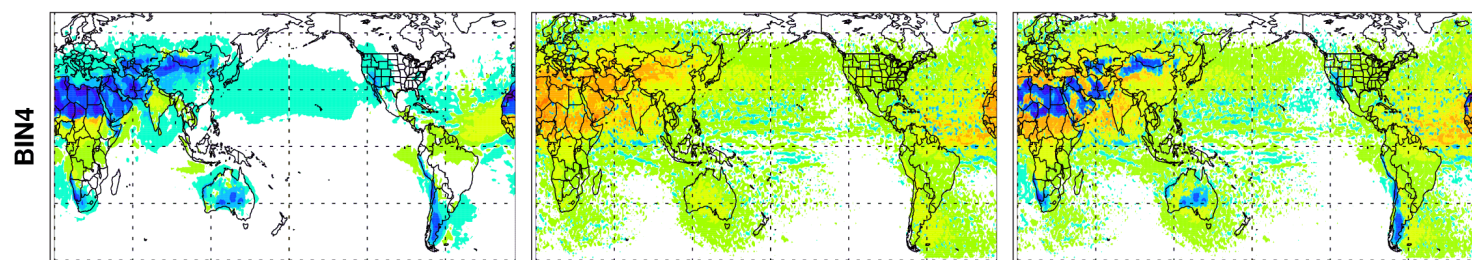
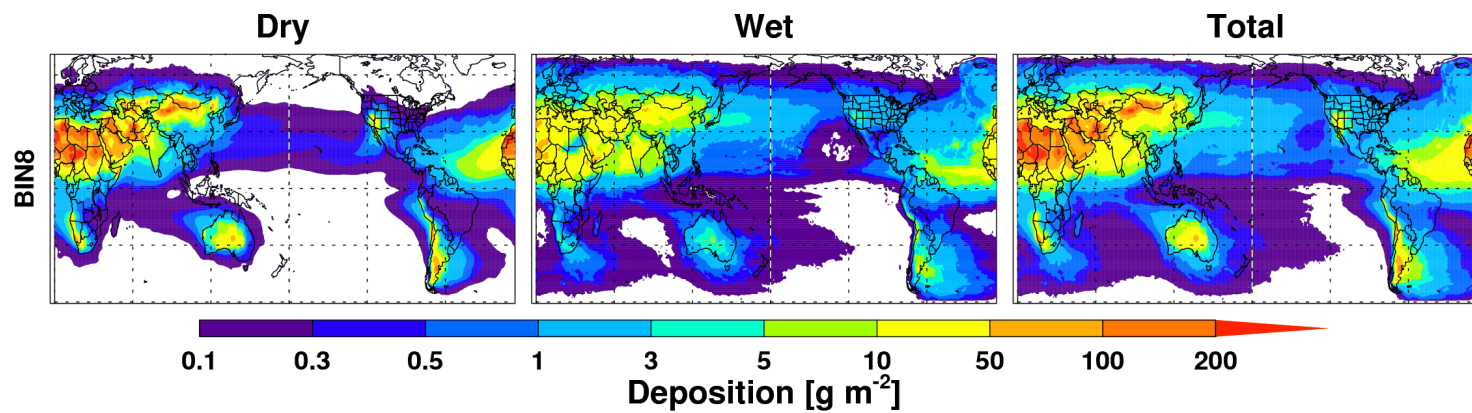


- The MOD3 and MOD3_tuned simulate relatively small difference in dust lifetime (~ 1 day longer) from BIN8 nearby the dust source regions, but the difference increases significantly to 3 days (up to 10 days) longer lifetime over the remote regions.

MOD3_tuned



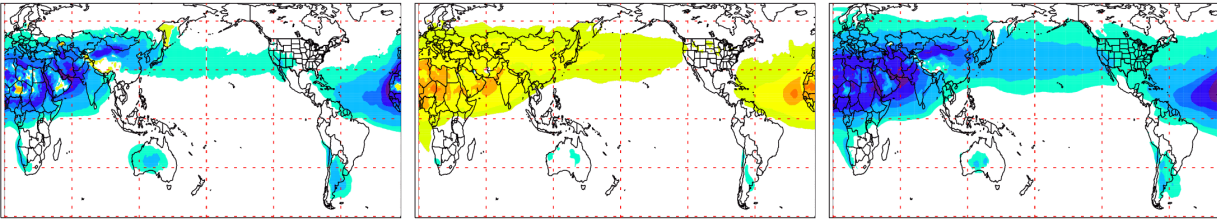




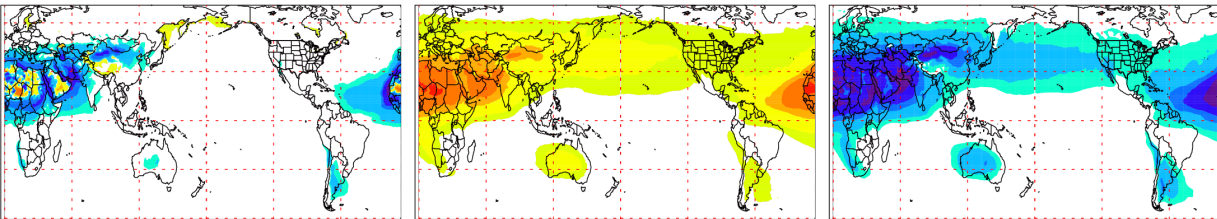
TOA

ATM
BIN8

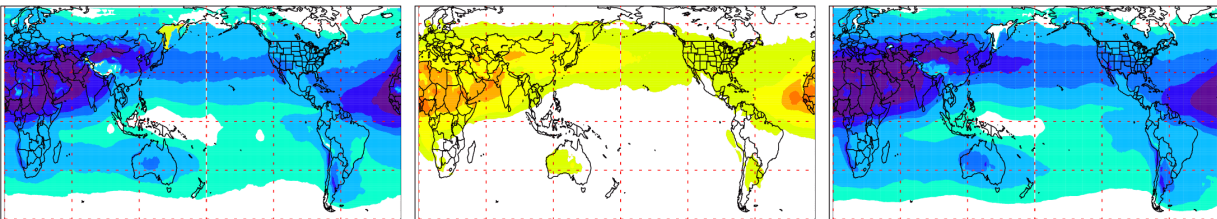
BOT



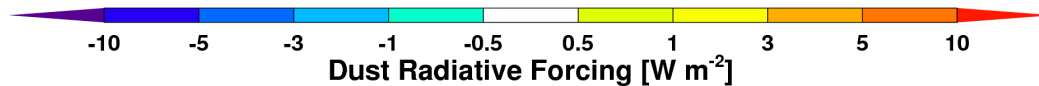
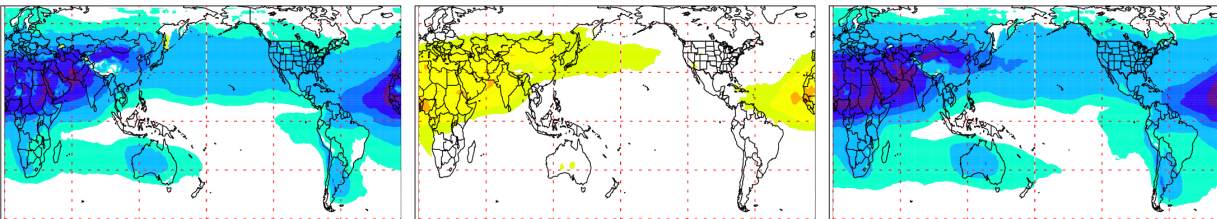
BIN4



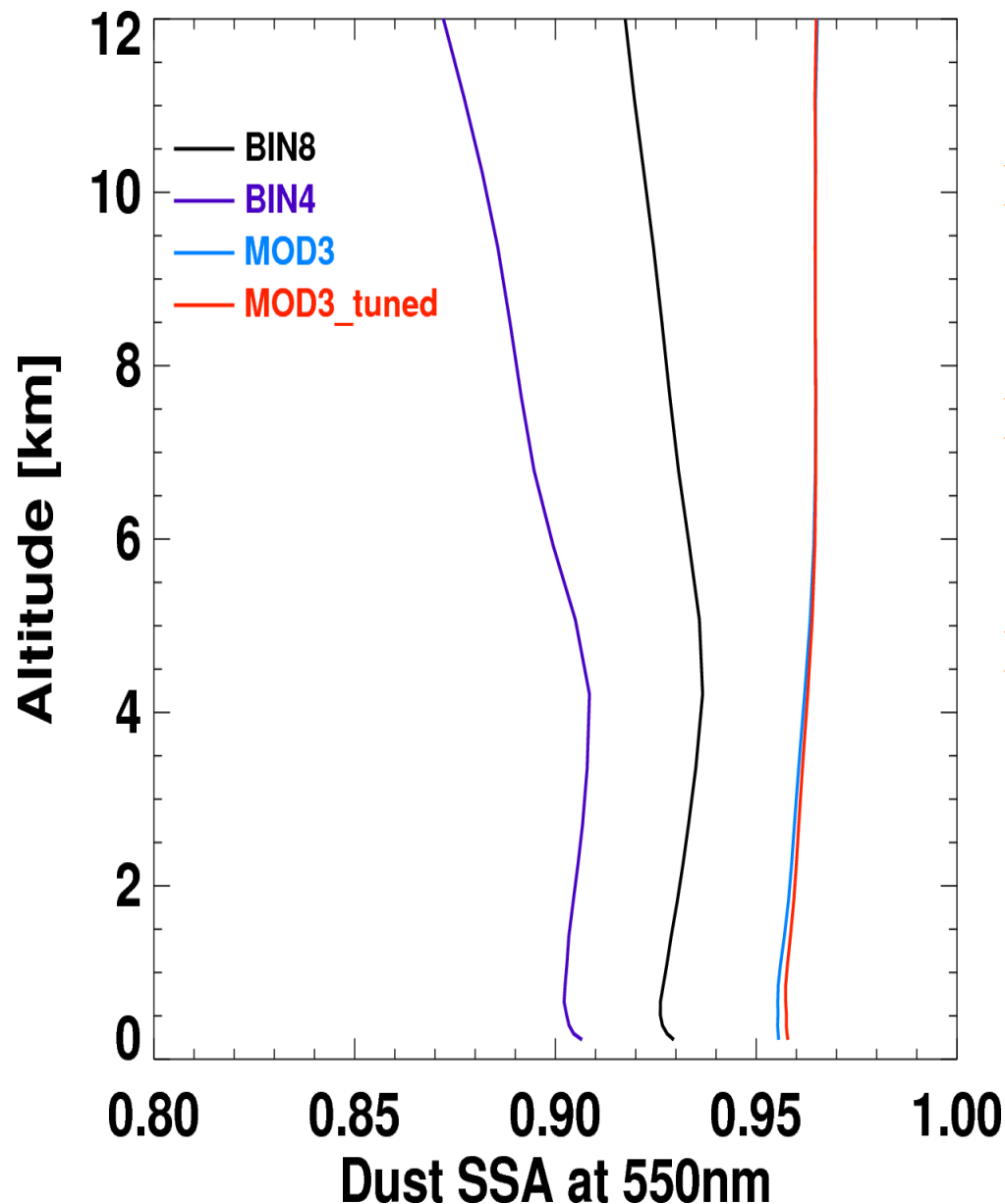
MOD3



MOD3_tuned



- Surface cooling effect of $-1.02 \sim -2.87 \text{ W m}^{-2}$
- Atmospheric warming effect of $0.39 \sim 0.96 \text{ W m}^{-2}$
- Dust TOA cooling effect of $-0.24 \sim -2.20 \text{ W m}^{-2}$



- BIN4 simulates the smallest dust SSA indicating the strongest dust absorbing
- BIN8 simulates a larger value of dust SSA indicating weaker dust absorbing
- MOD3 and MOD3_tuned simulate very similar and the largest dust SSA indicating the weakest dust absorbing

Summary

- Three size parameterizations lead to different size distributions of dust, which significantly affects the dust lifetime. However, the global dust lifetime is mainly determined by the dust lifetime nearby the dust source regions.
- Three size parameterizations result in uncertainties of dust mass loading of up to 25% and dust number loading of up to a factor of 100. In addition, they also result in significantly different dry and wet deposition fluxes.
- Three size parameterizations cause a significant difference of a factor of 2~3 in dust surface cooling effect ($-1.02 \sim -2.87 \text{ W m}^{-2}$) and atmospheric warming effect ($0.39 \sim 0.96 \text{ W m}^{-2}$) and in a tremendous difference of a factor of ~10 in dust TOA cooling effect ($-0.24 \sim -2.20 \text{ W m}^{-2}$).
- An uncertainty of a factor of 2 in dust emission derived by the top-down method solely due to the size parameterizations in models (3-mode versus 8-bin here).
- Uncertainties in simulating dust impact on climate and oceanic ecosystem due to size parameterizations are worthy of further investigation.

Extra



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Zhao et al., 2010, ACP

