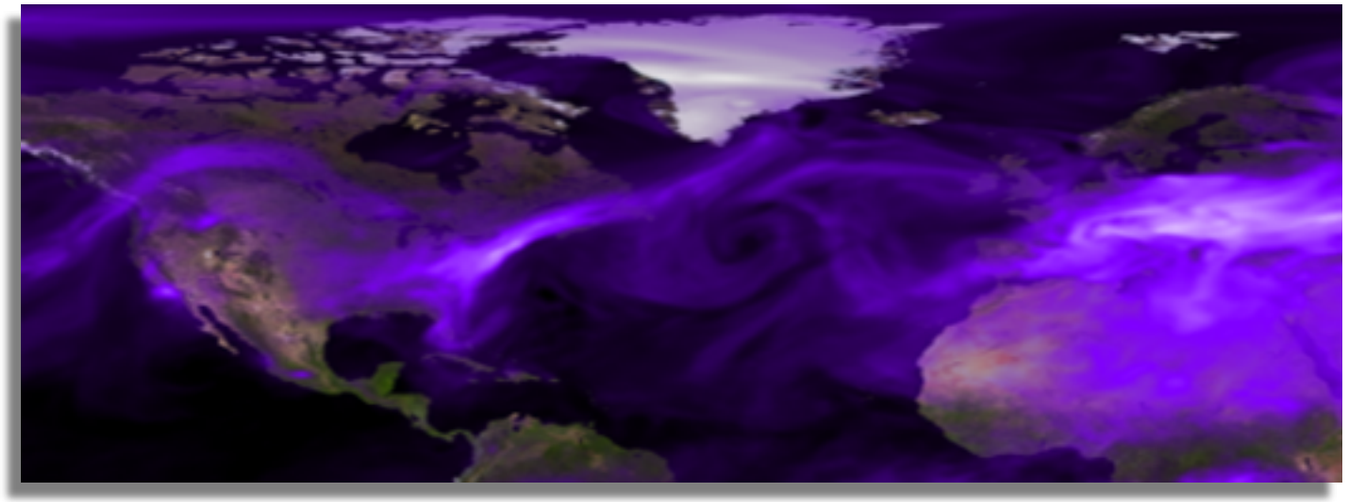
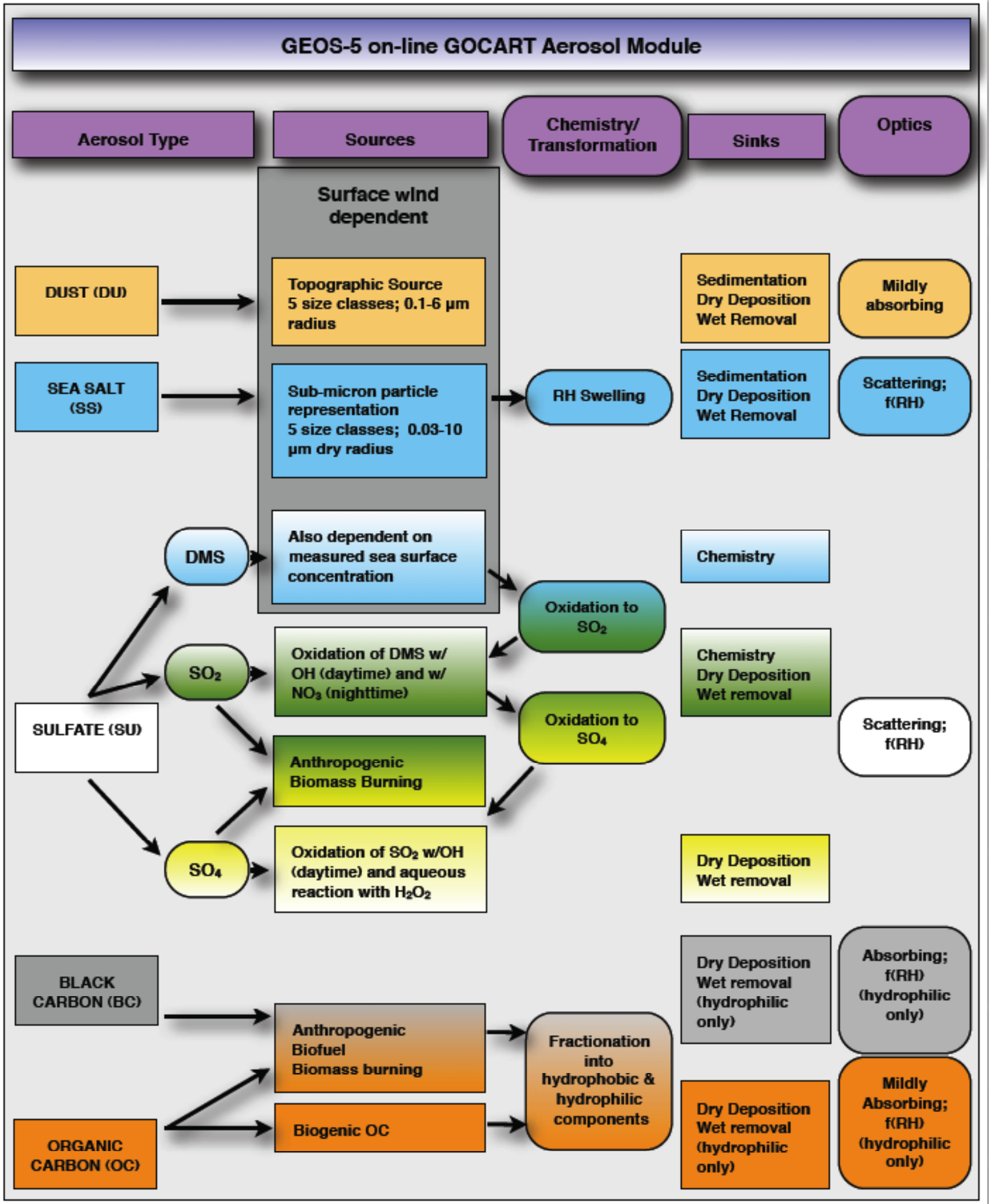


Aerosol Simulation Capabilities in GEOS-5

Cynthia Randles, Peter Colarco, Arlindo da Silva,
Ravi Govindaraju, and Ed Nowottnick

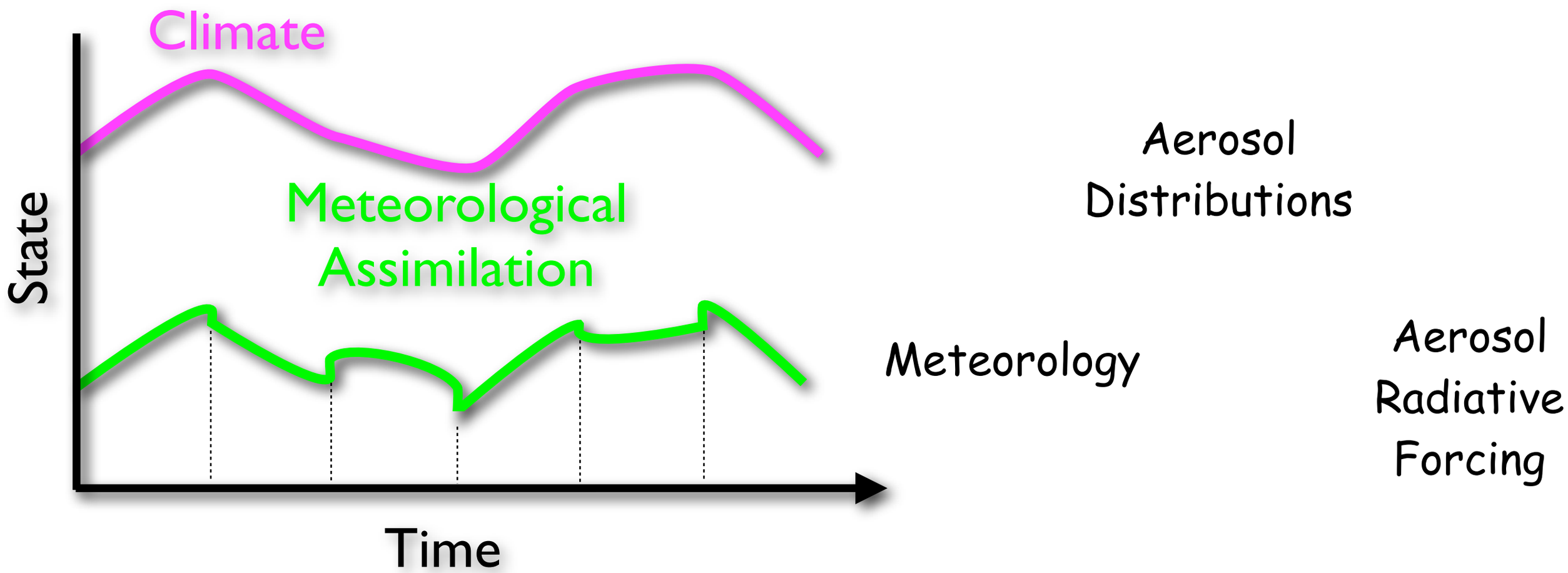
AEROCENTER Aerosol Update
April 29, 2010



GEOS-5 on-line GOCART Aerosol Module

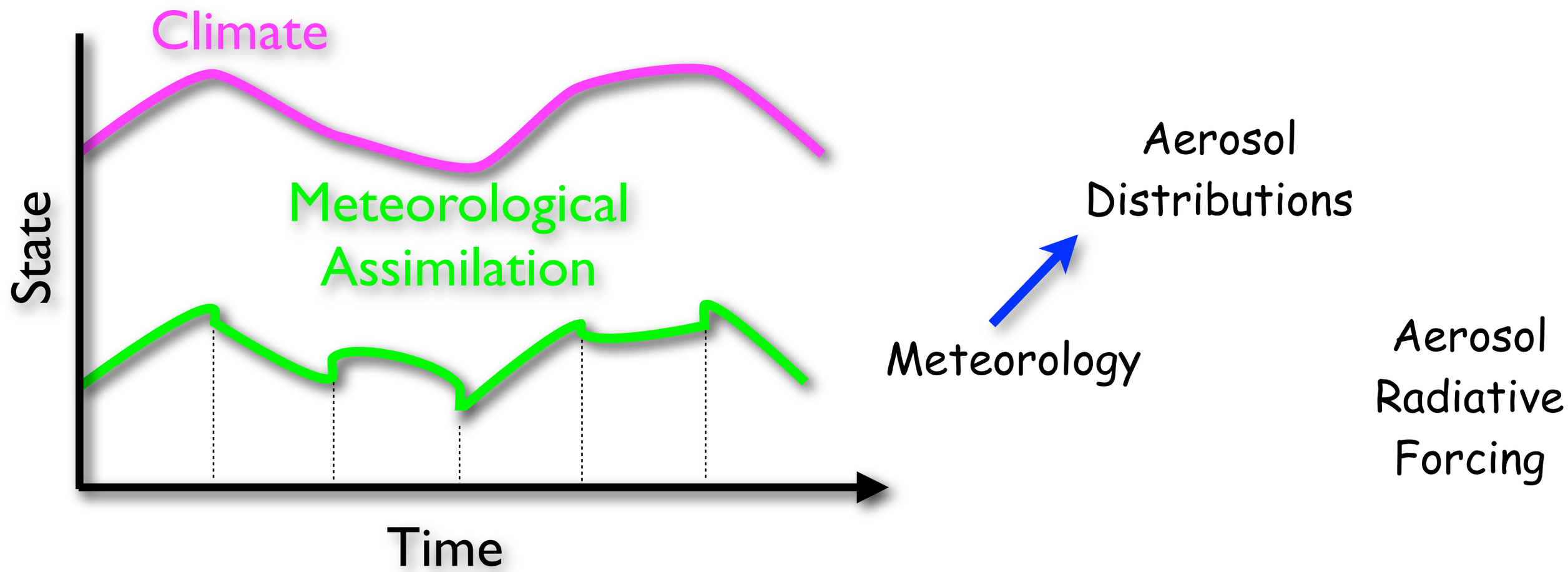
- A version of the Goddard Chemistry, Aerosol, Radiation, and Transport Model (**GOCART**) [Chin et al., 2002] embedded in GEOS AGCM [Colarco et al., 2009].
- **Treatment of major tropospheric aerosols** (dust, sea salt, sulfate, black and organic carbon) **including sources, sinks and chemical transformations.**
- Dust, sea salt, and DMS emissions have a **wind dependency**.
- Sulfate, sea salt, and hydrophyllic carbonaceous aerosols grow with changing model relative humidity.
- Optical properties (with exception of dust) from OPAC; dust uses OPAC except in visible, where optical properties based on AERONET measurements are used.

NASA GEOS-5 Model Modes



Climate "Free-running" AGCM. May respond to, e.g., imposed sea surface temperatures, prescribed aerosol distributions, etc.

NASA GEOS-5 Model Modes



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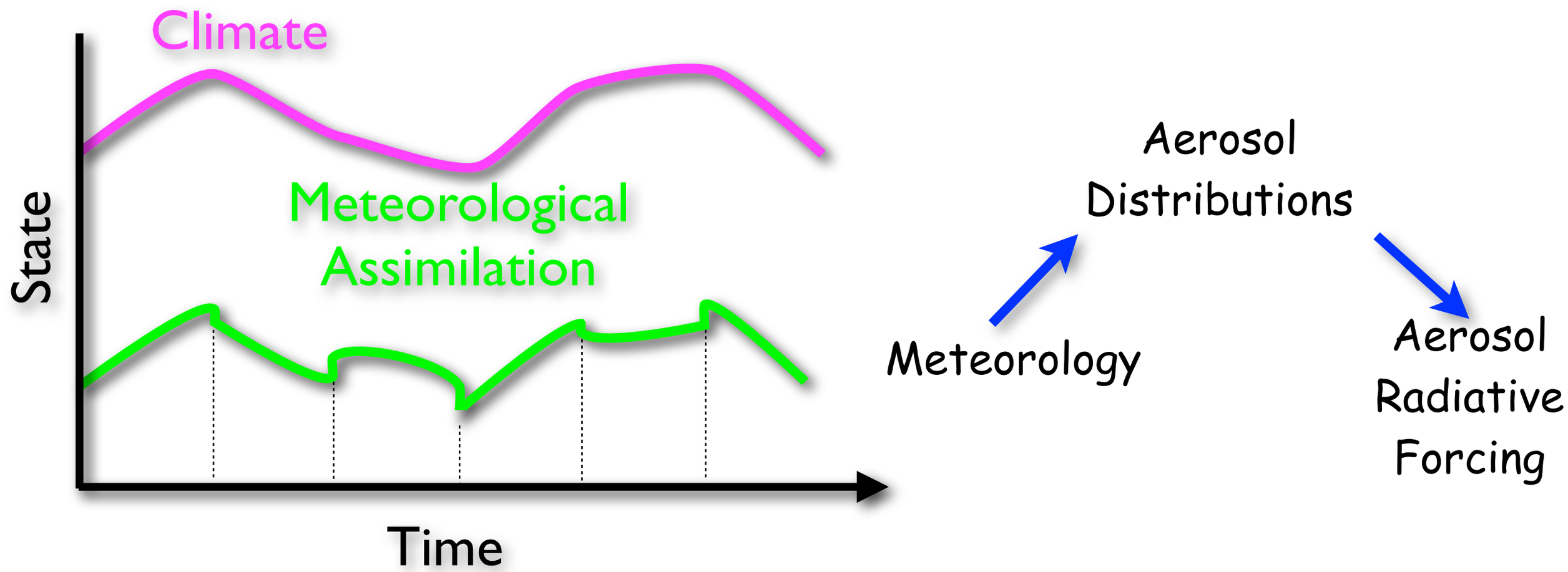

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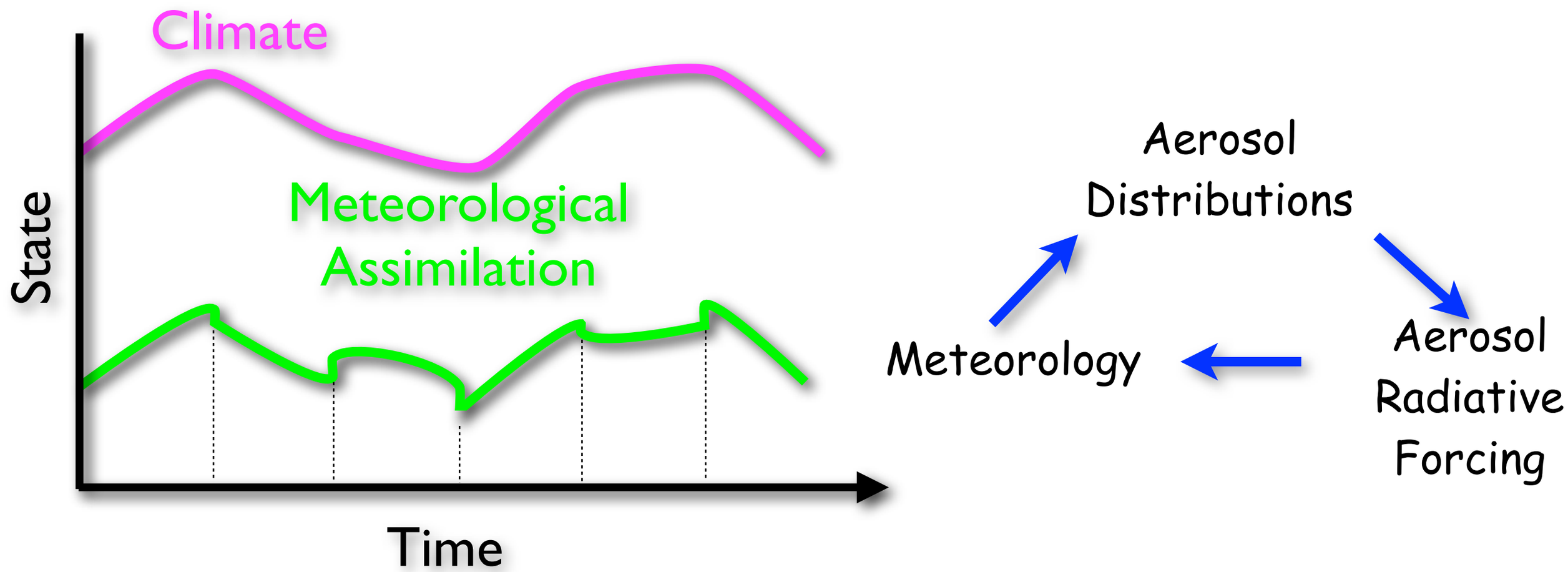

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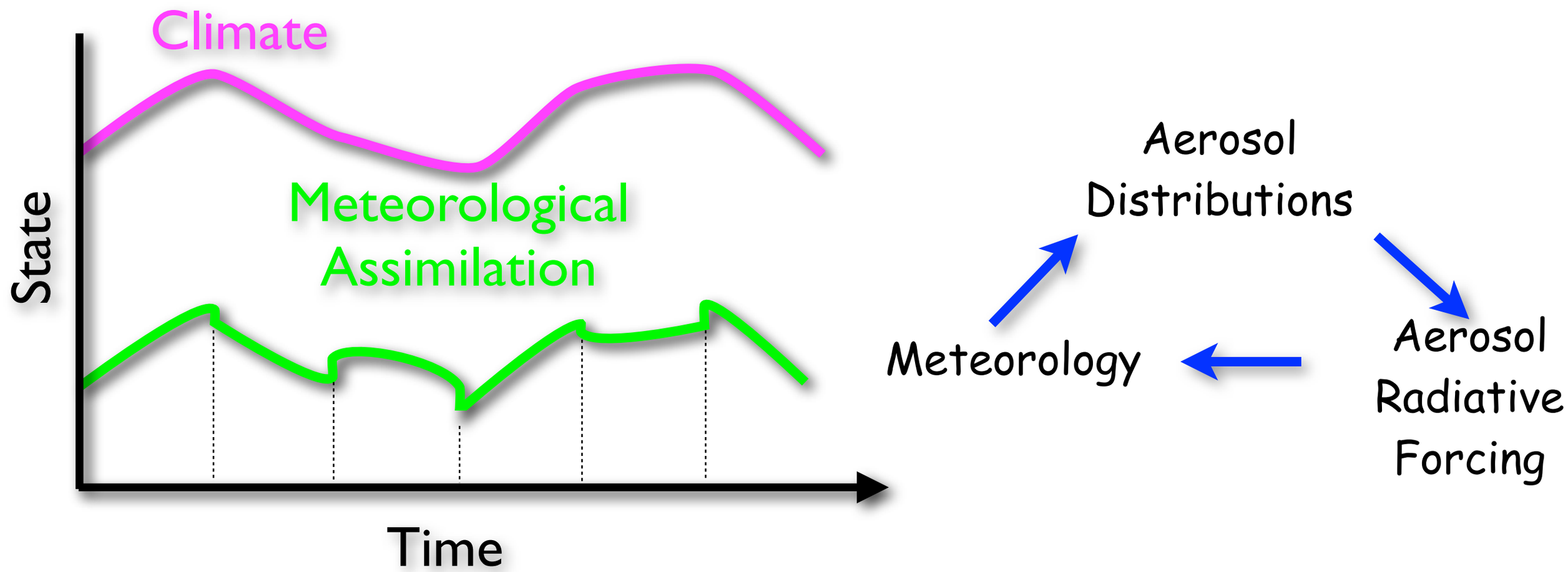
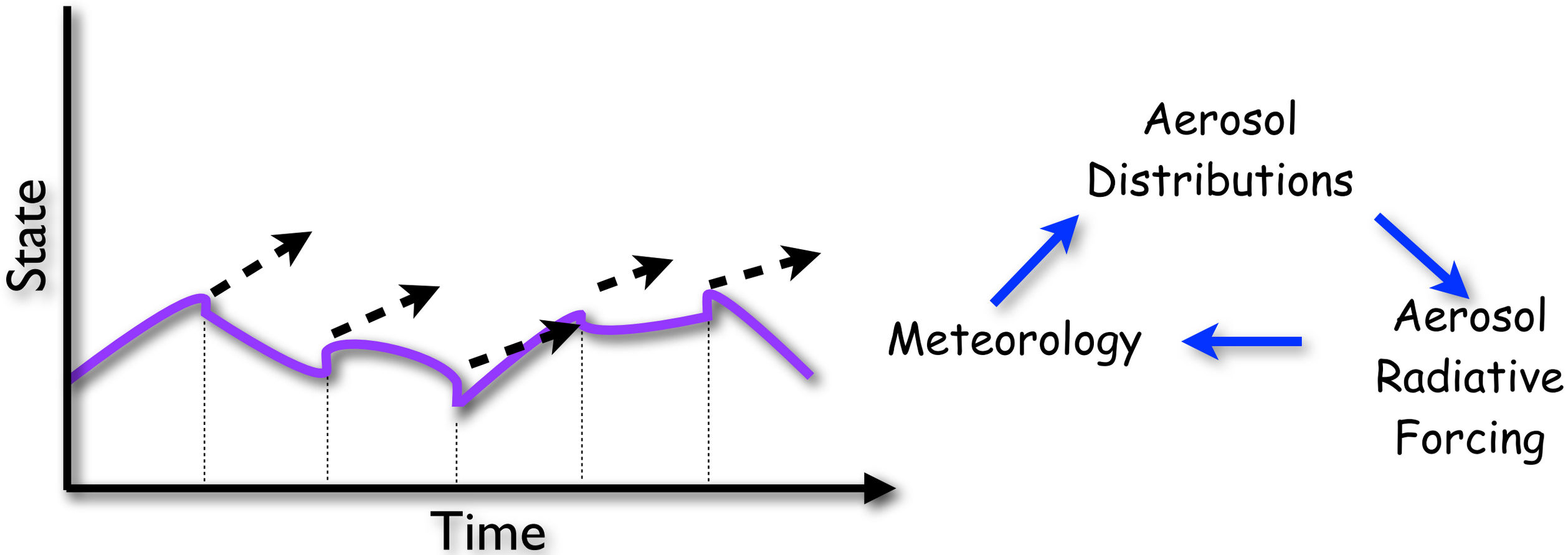


Assimilation As in Climate mode, but with some periodicity an atmospheric assimilation is performed and the atmospheric state is adjusted.

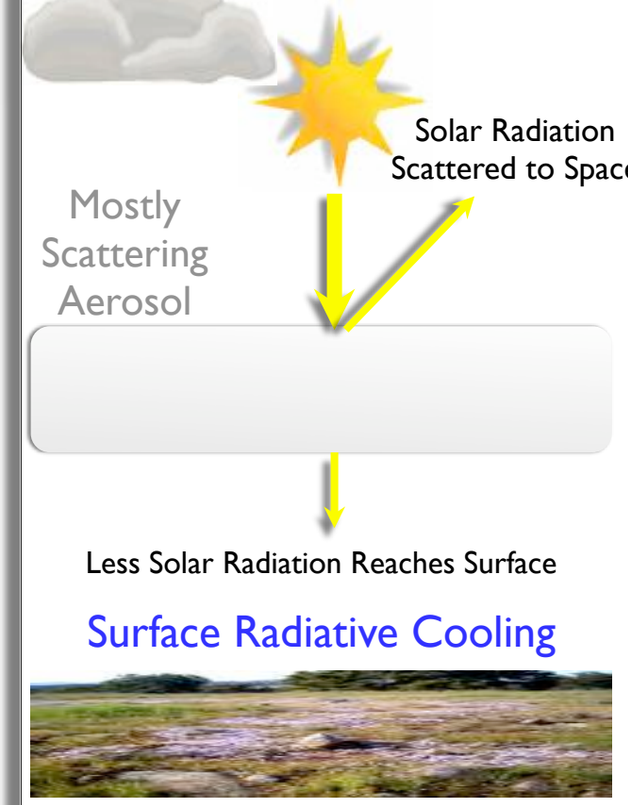
NASA GEOS-5 Model Modes

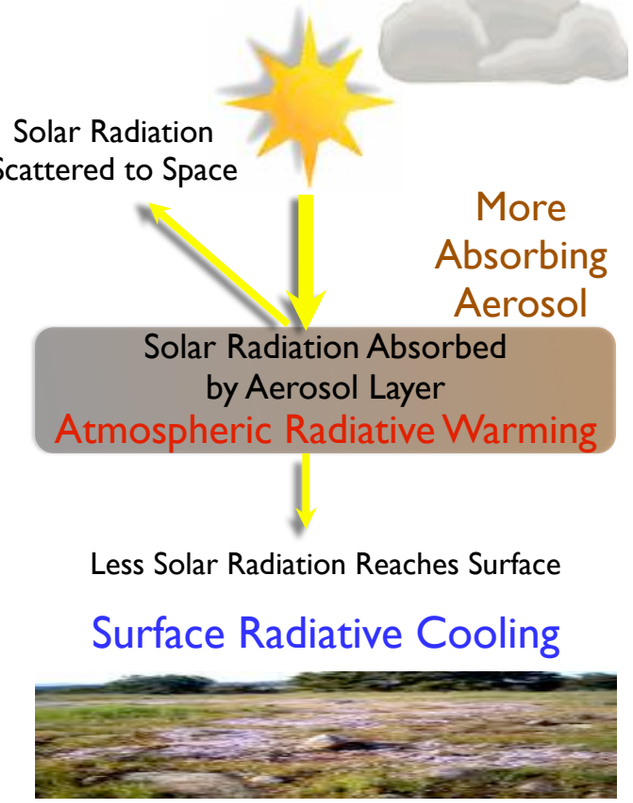


Forecast The model performs an atmospheric assimilation and a forecast of the free-running system is spun off.

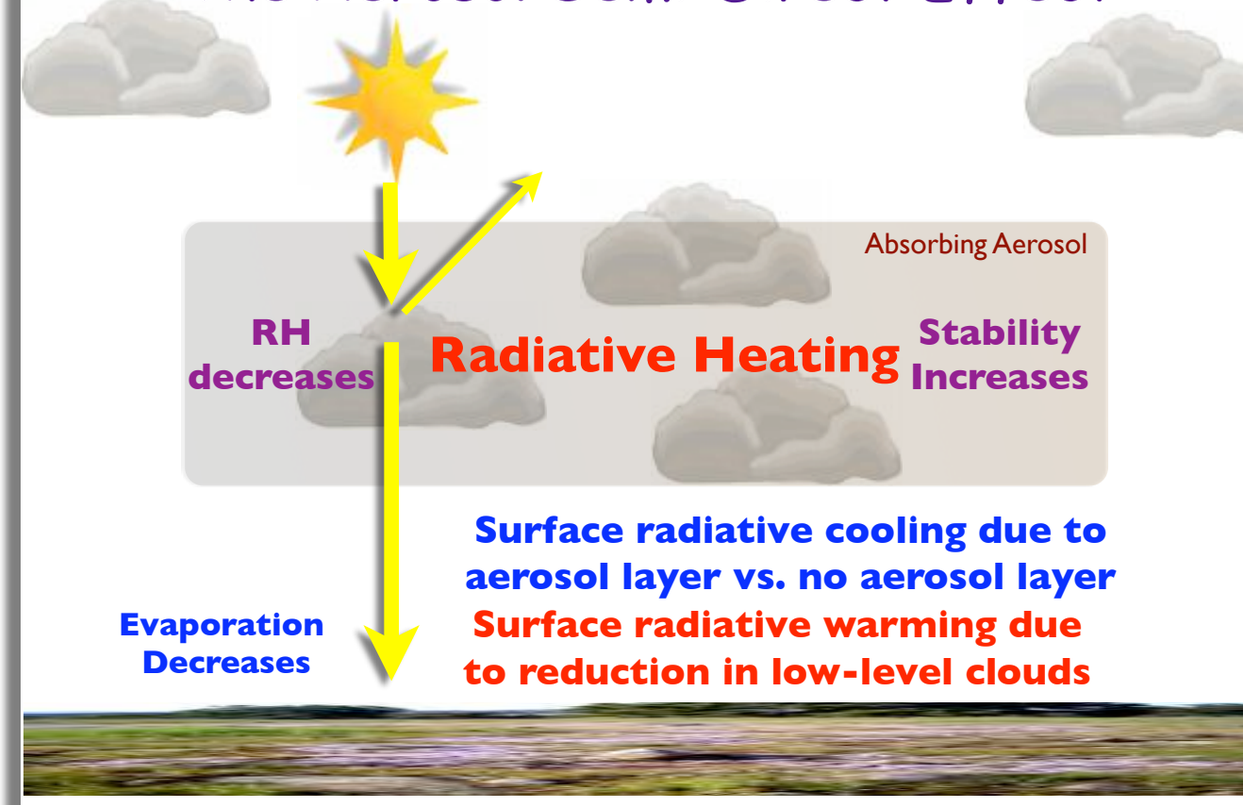
Aerosol Effects in GEOS-5

The Aerosol Direct Effect

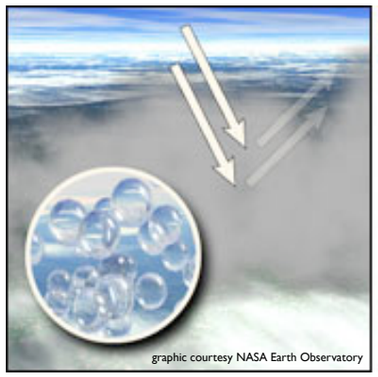


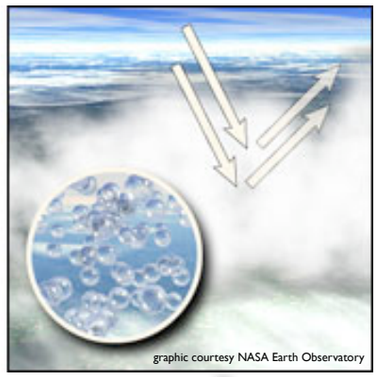


The Aerosol Semi-Direct Effect



The Aerosol Indirect Effect





Larger cloud droplets, less reflective cloud. → **Twomey Effect** → Smaller cloud droplets, more reflective cloud.

Less Aerosols — More Aerosols

Larger cloud droplets, droplets rain out easier, clouds dissipate quicker. → **Albrecht Effect** → Smaller cloud droplets, droplets rain out less, longer-lived clouds.

Aerosol Effects in GEOS-5

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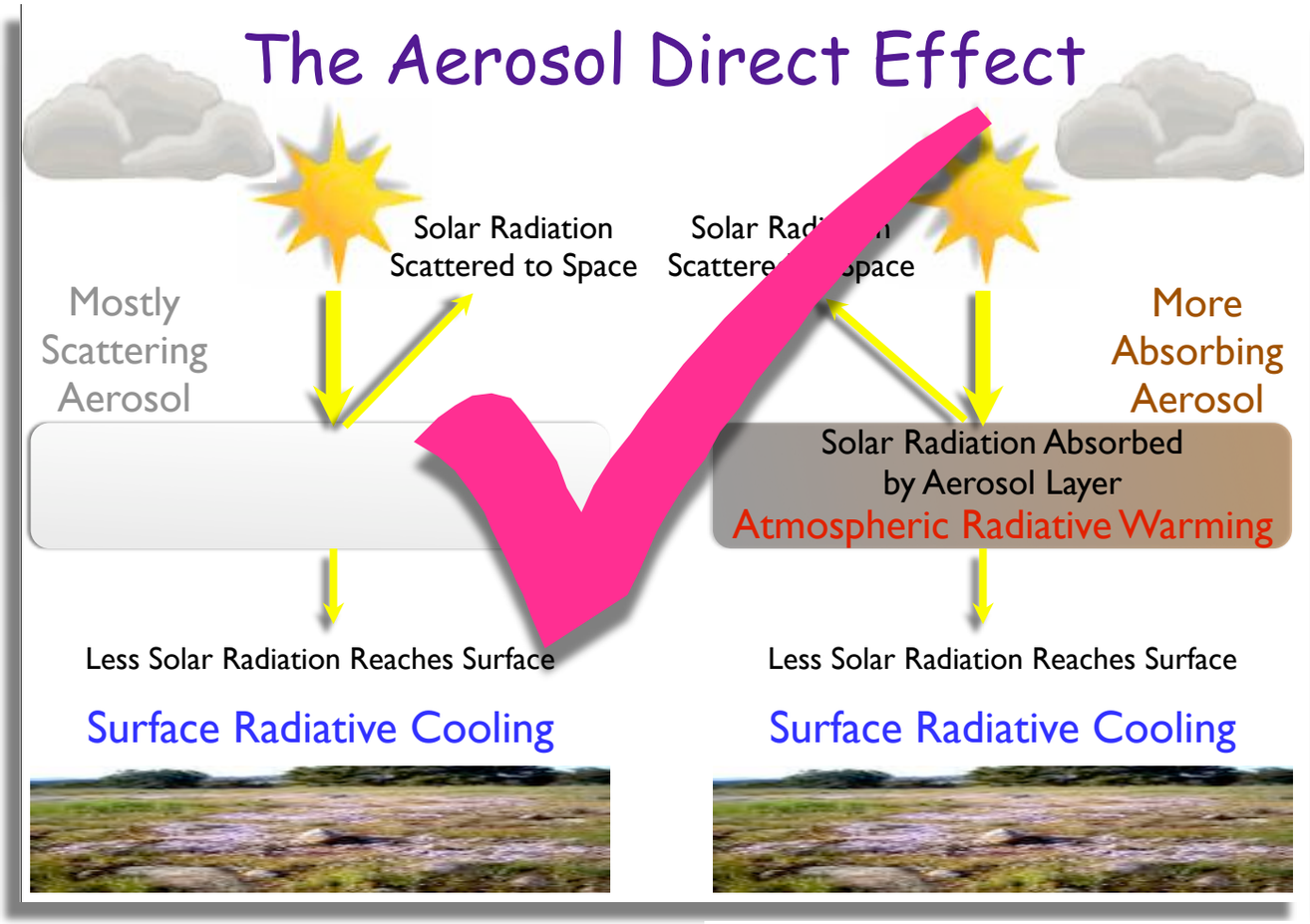

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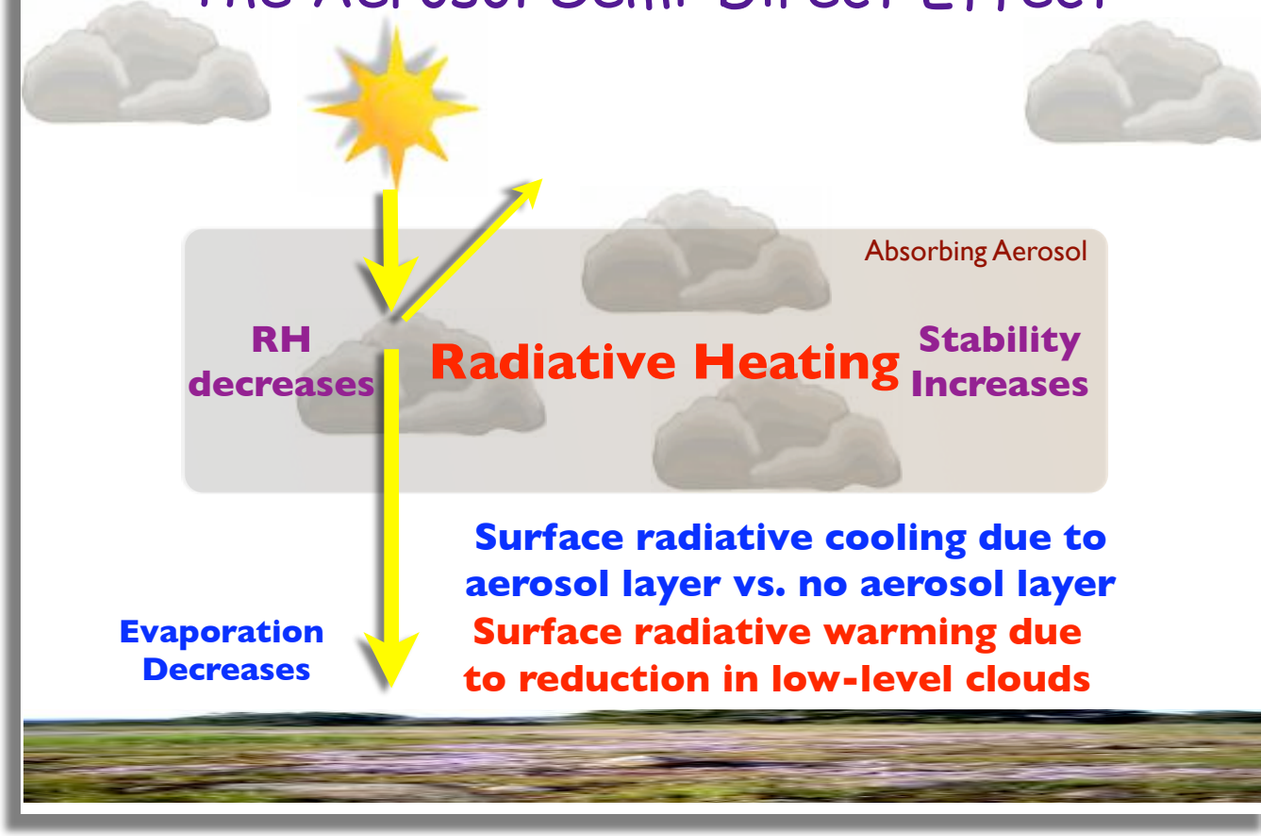

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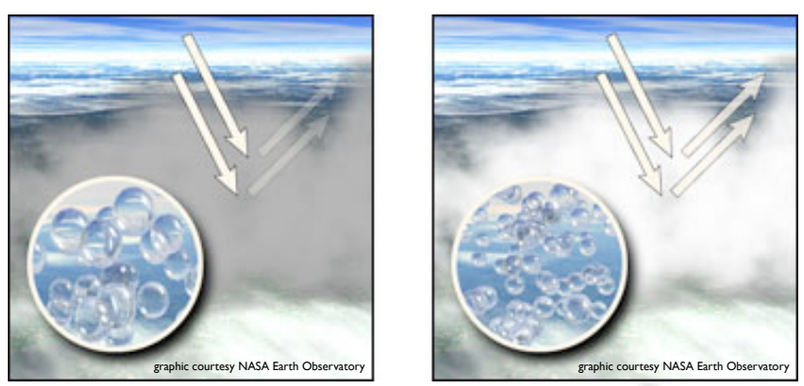

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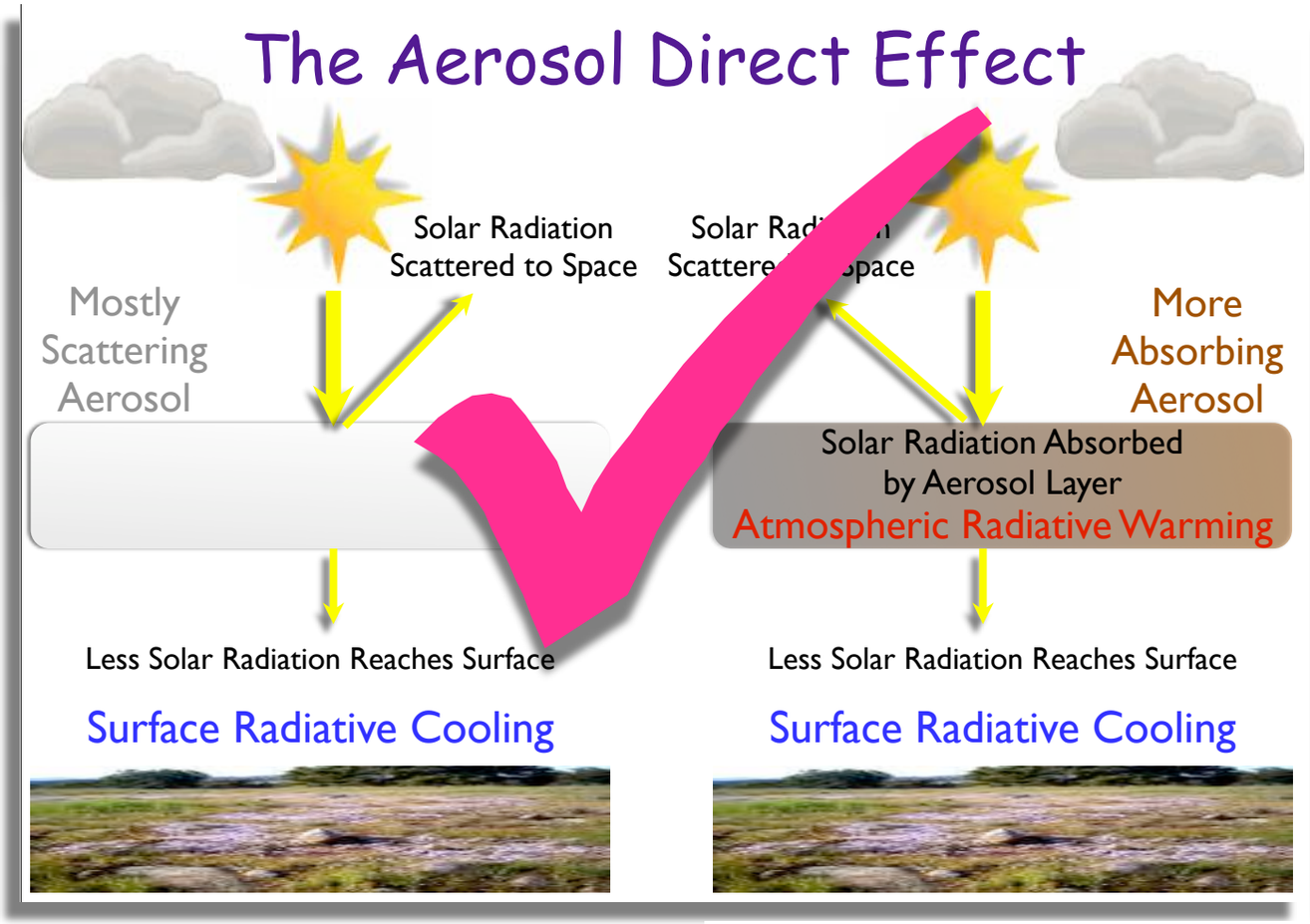

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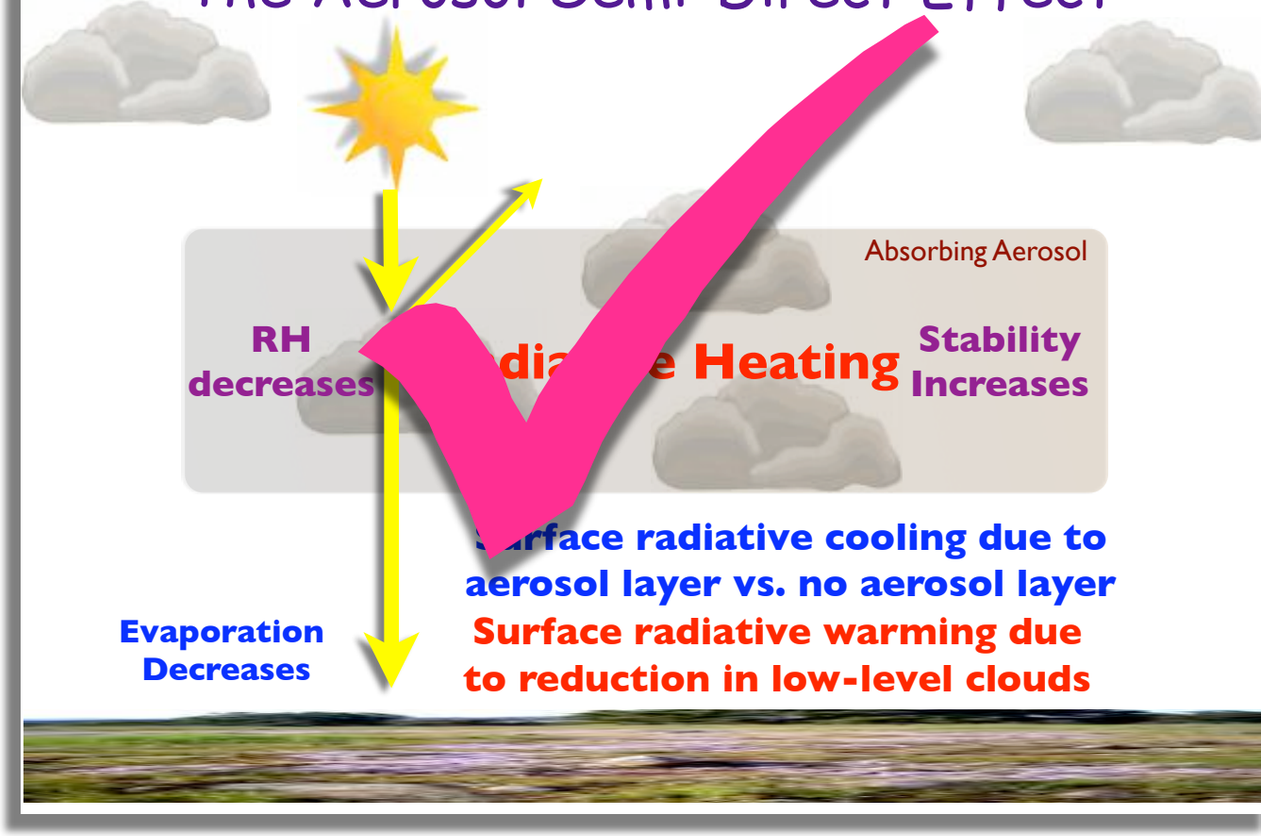

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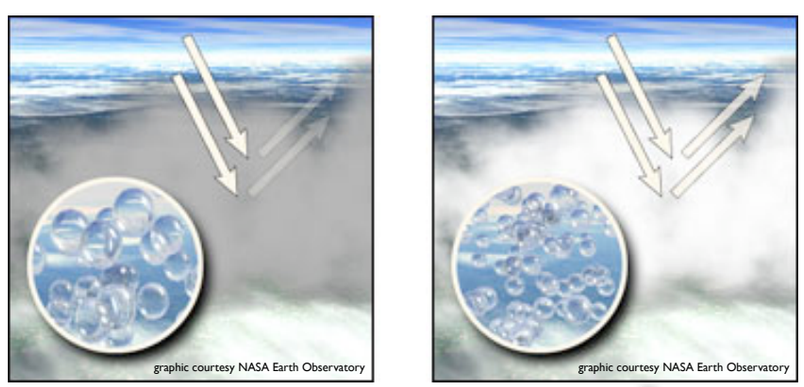

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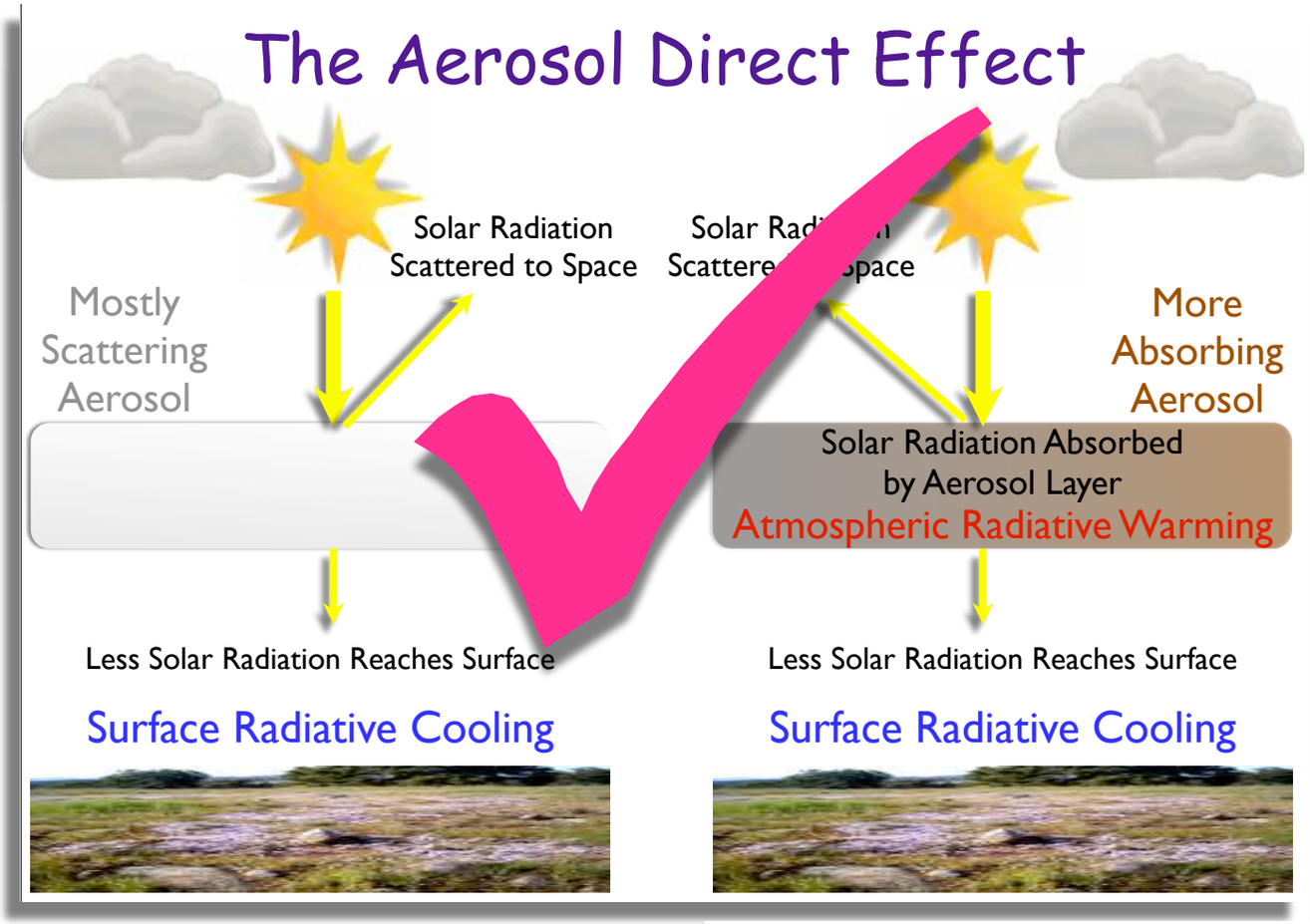

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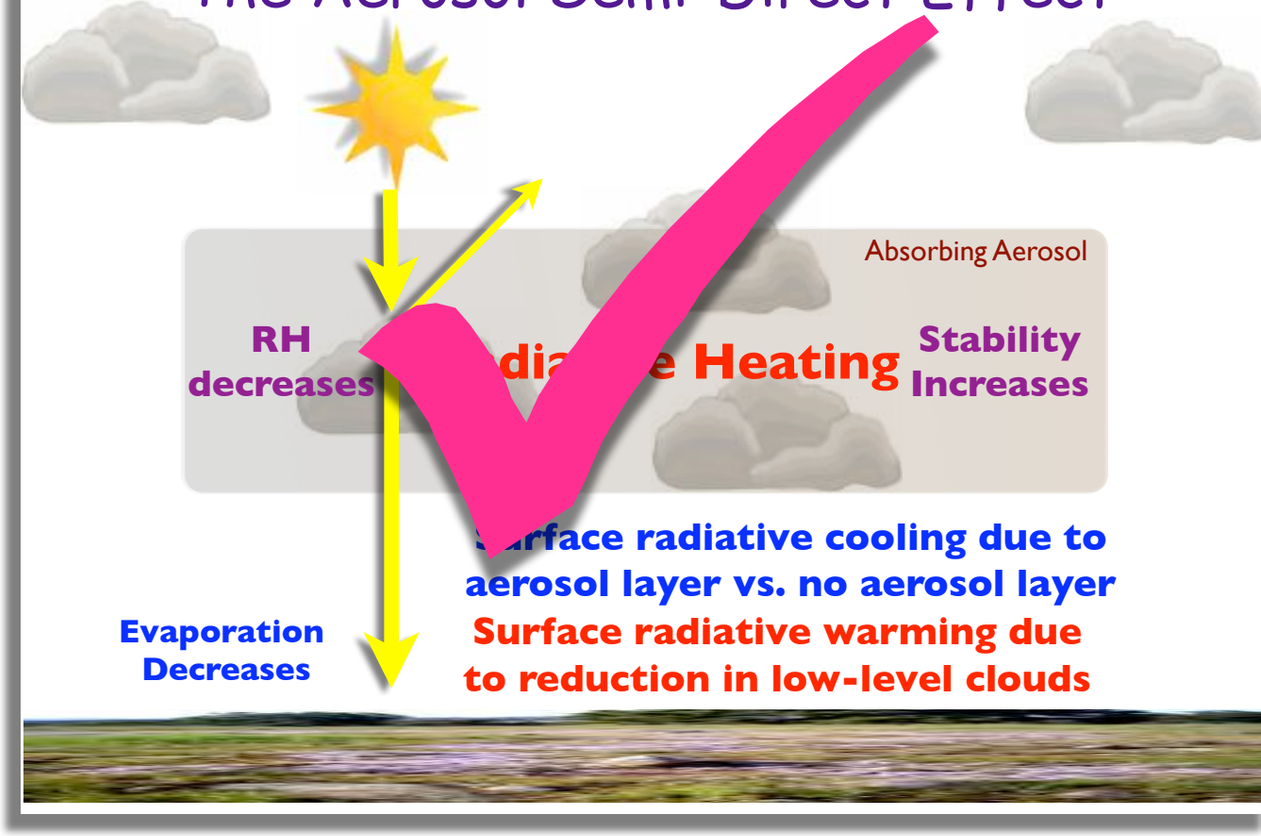

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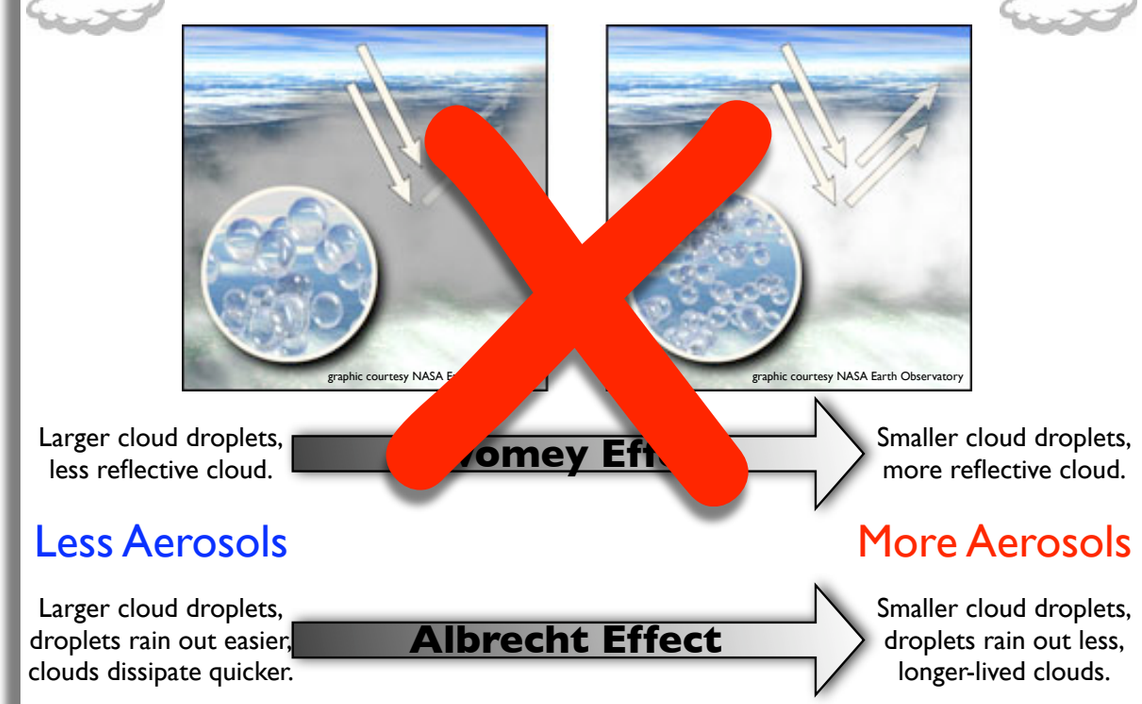


PIESA Experiments

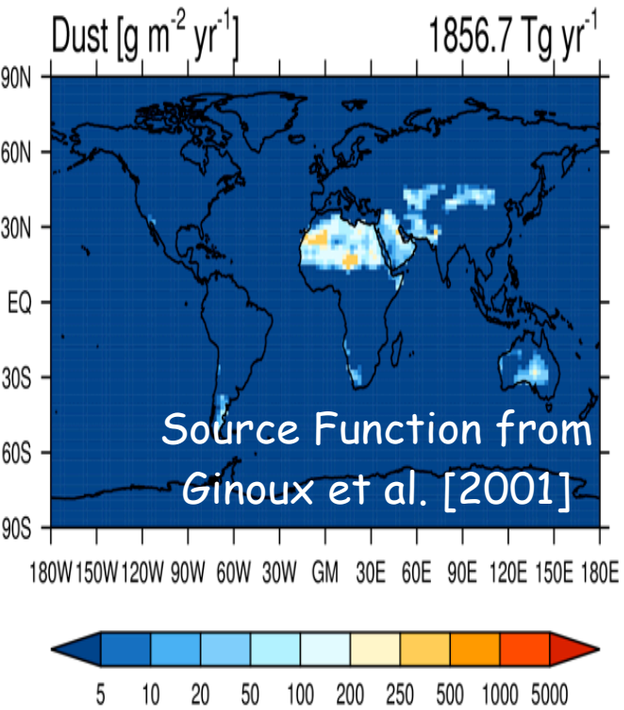
(Preliminary Integrated Earth System Analysis)

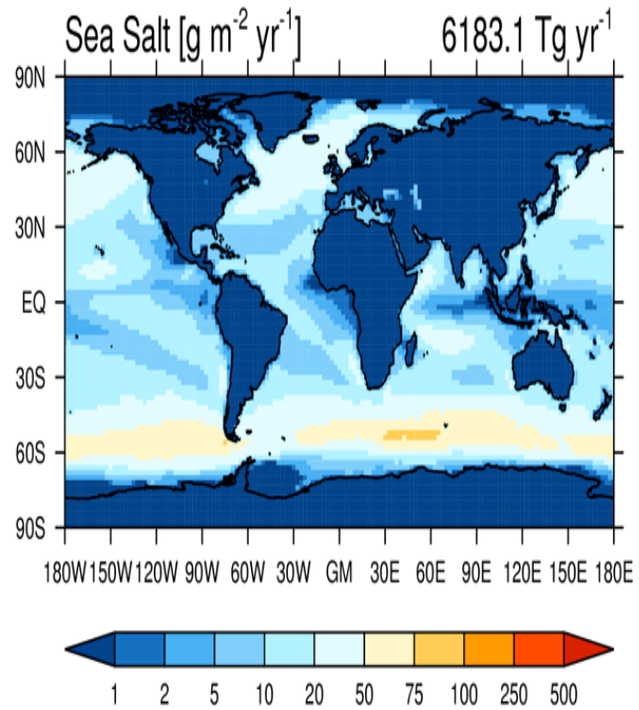
http://www.geos5.org/wiki/index.php?title=GEOS-5_Configuration_for_PIESA

Experiment [2.5°×2.0°]	Description	Purpose
No Aerosol Forcing (Base Case)	No aerosol radiative forcing.	Use this simulation to ascertain aerosol climate impact by comparing to next two simulations.
Interactive Aerosol Forcing	GOCART aerosols run interactively, impacting the model dynamics	What do the climate and aerosol distributions look like if they are internally consistent? How different is the climate response relative to being forced by climatological aerosols?
Climatology	Aerosol climatology prescribed from interactive run (above).	Monthly-mean aerosol climatology from a consistent on-line aerosol version of the model (interactive run). What is the climate effect of removing the influence of meteorology on aerosol distributions?

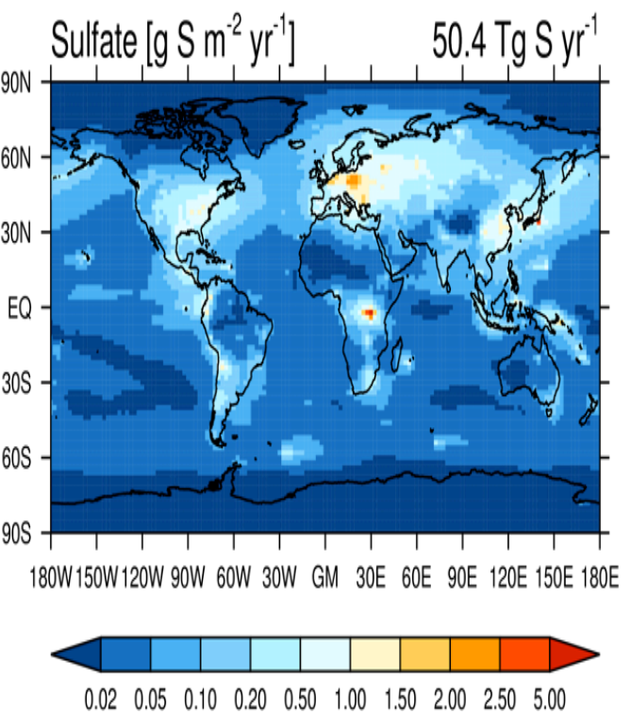
Fully Interactive GOCART Aerosols Y2003

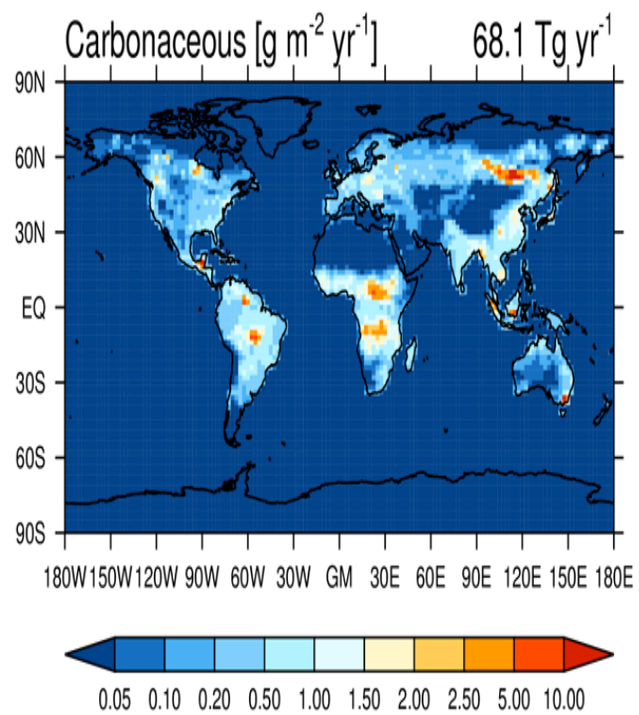
Emissions Driven by AGCM Winds



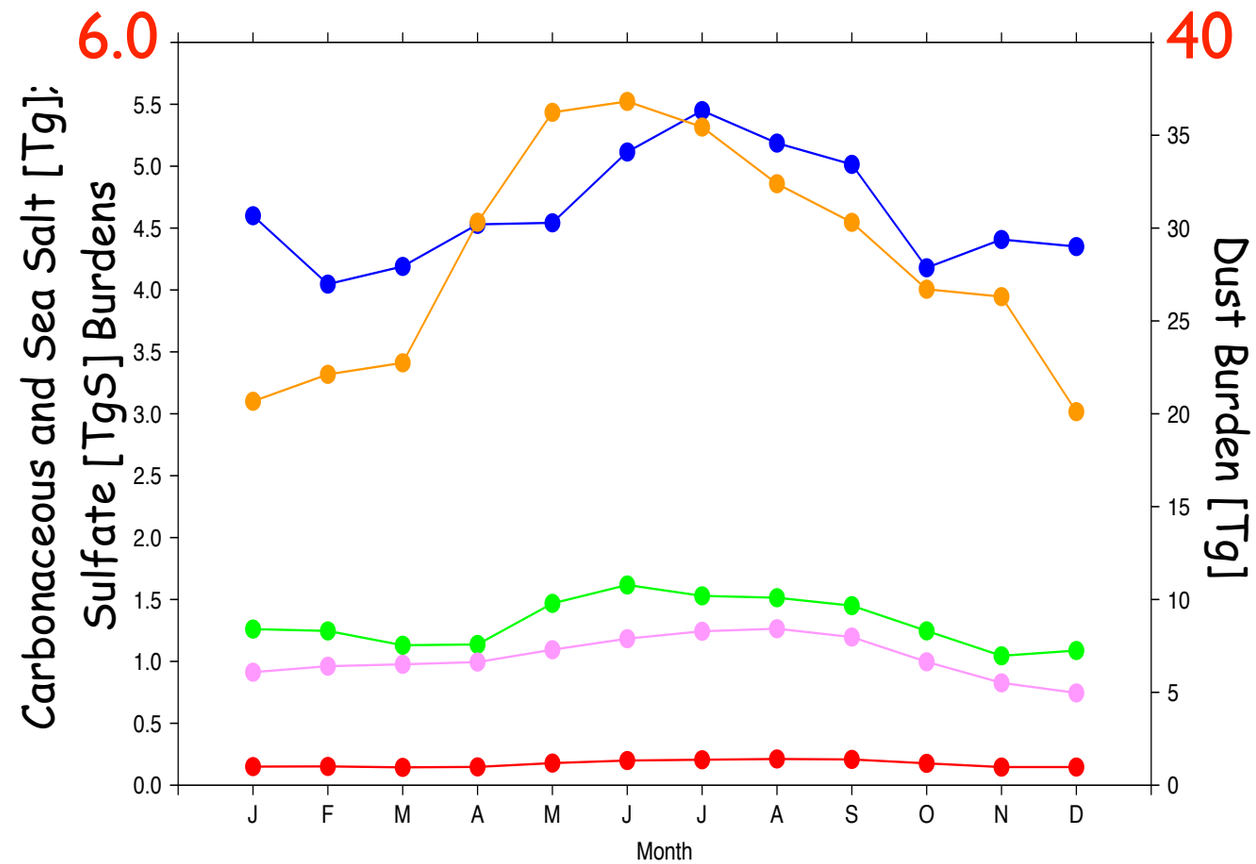


Annual Emissions from AeroCom





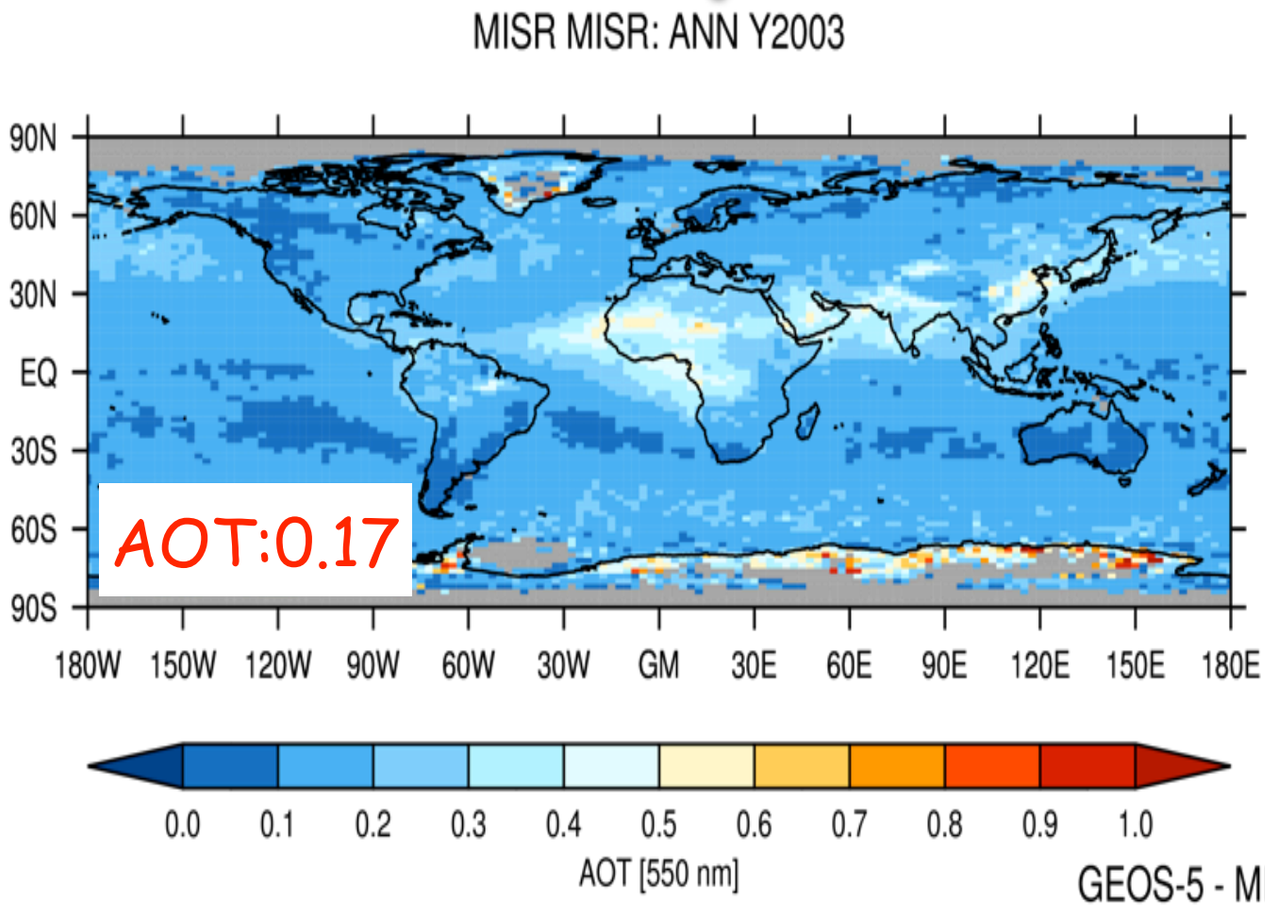
GEOS-5 Aerosol Burdens Y2003

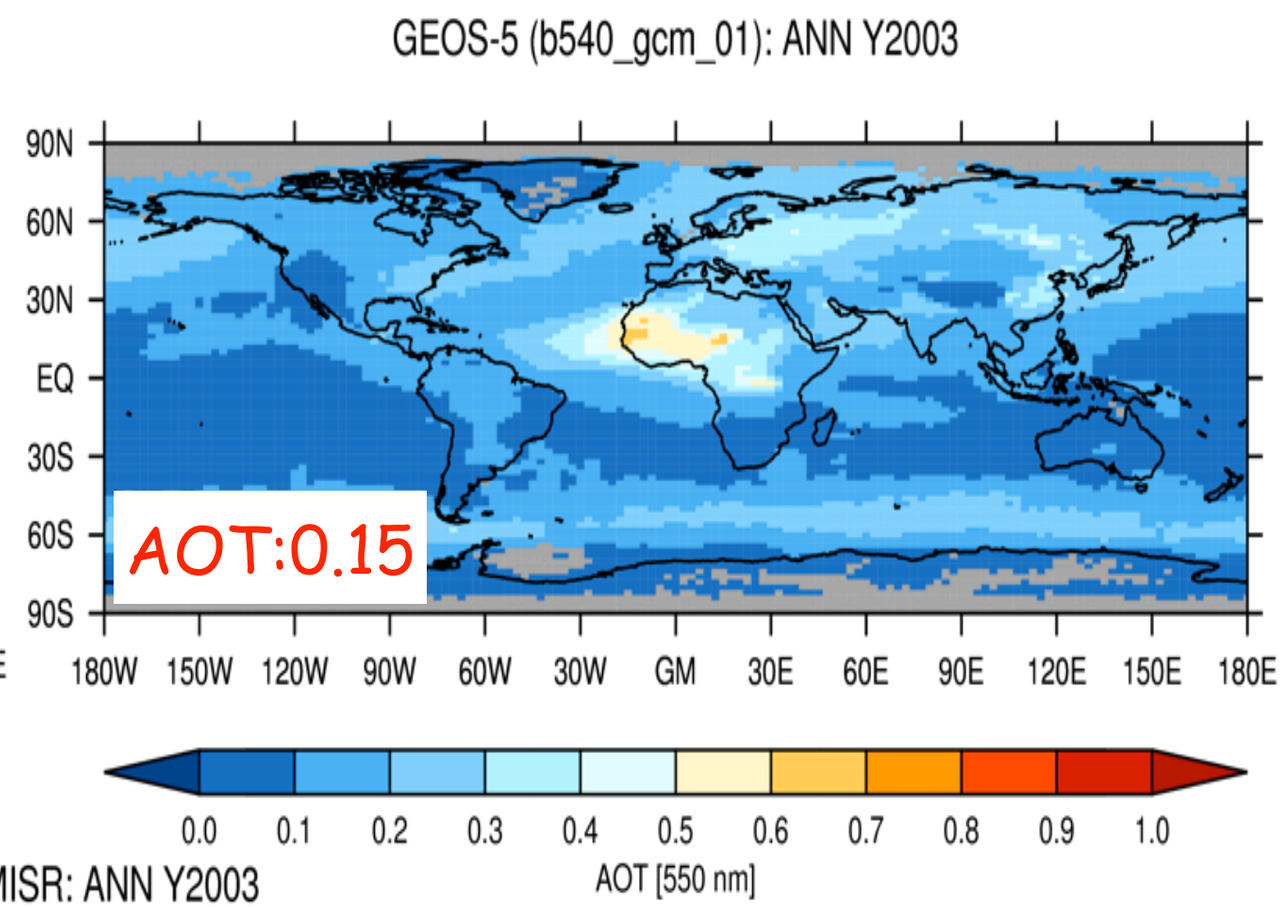


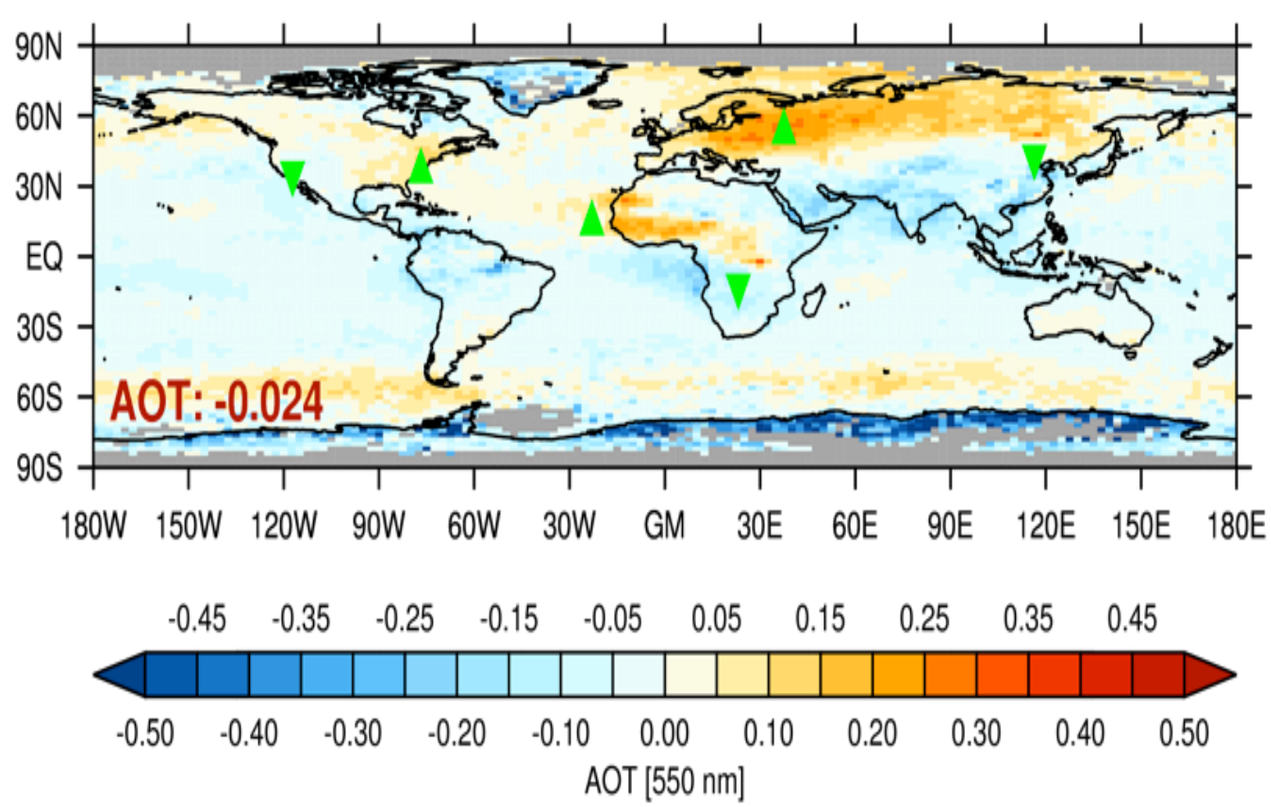
- Particulate Organic Matter; Lifetime = 7.9 days
- Black Carbon; Lifetime = 8.4 days
- Sulfate; Lifetime = 7.5 days
- Sea Salt; Lifetime = 0.3 days
- Dust (right axis); Lifetime = 5.6 days

- Biomass burning emissions from GFEDv2 [van der Werf et al., 2006].
- Fossil fuel/biofuel: carbonaceous emissions Bond et al. [2004] and Streets et al. [2008]; EDGAR database and Streets et al. [2008] for SO_2 emissions.

Comparison to MISR AOT







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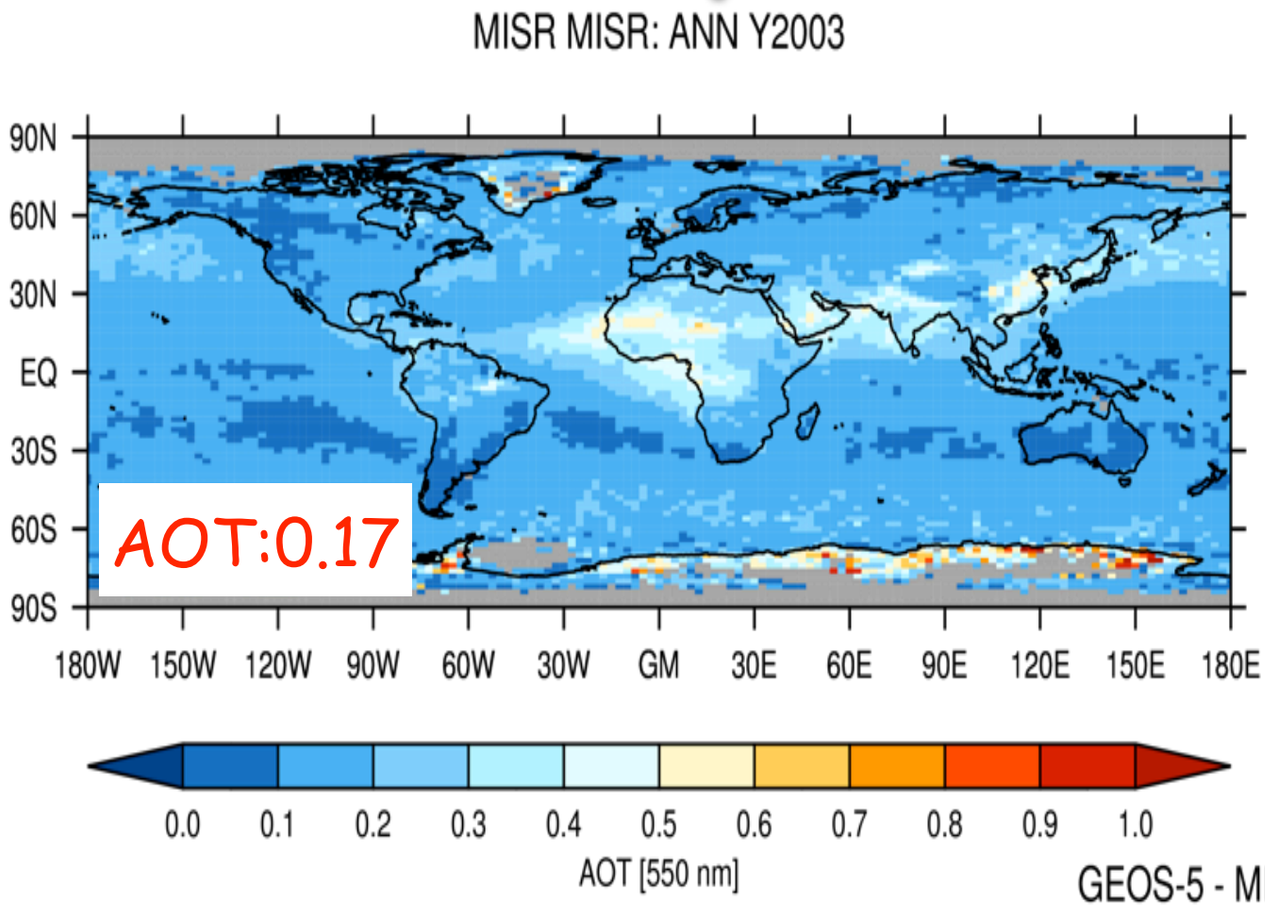

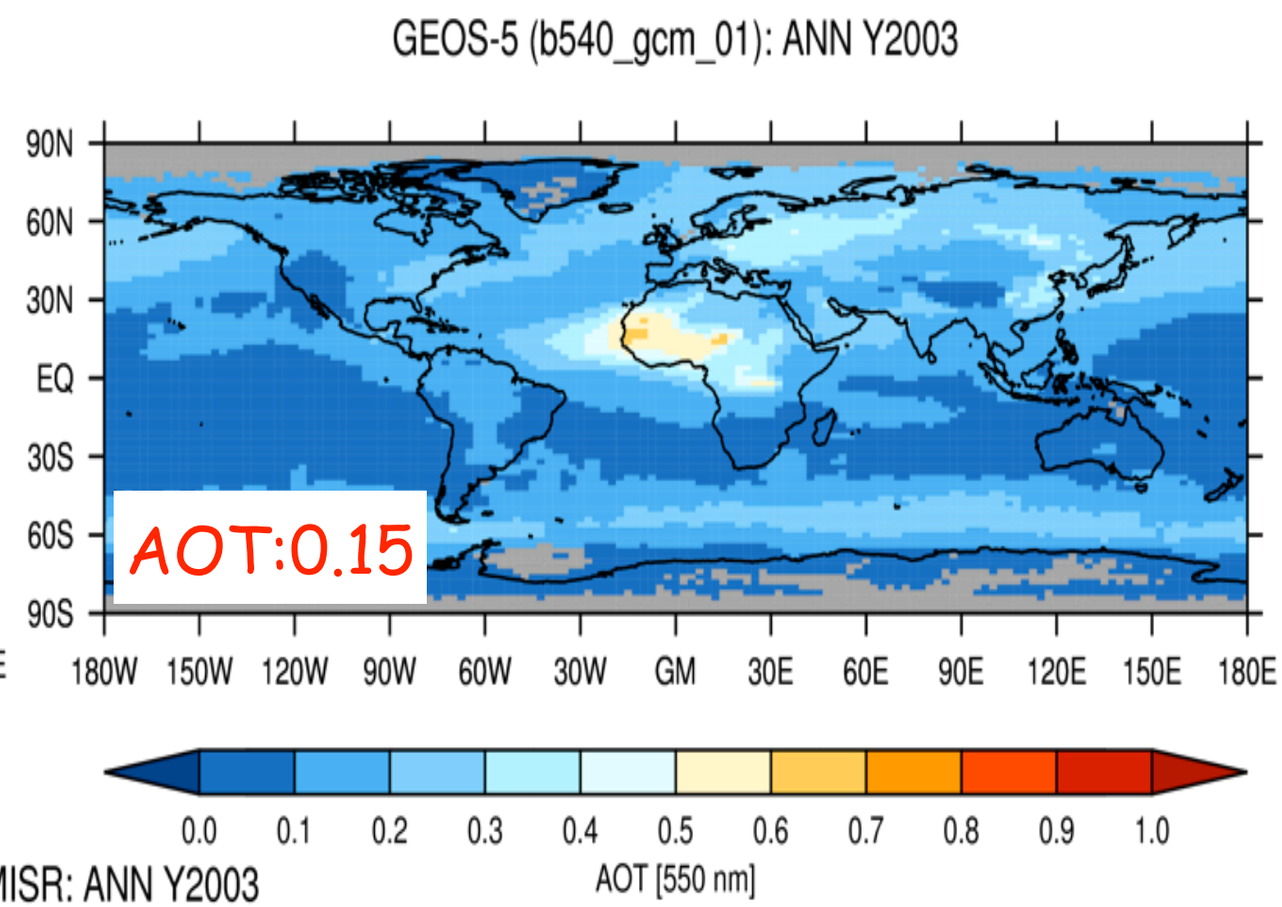

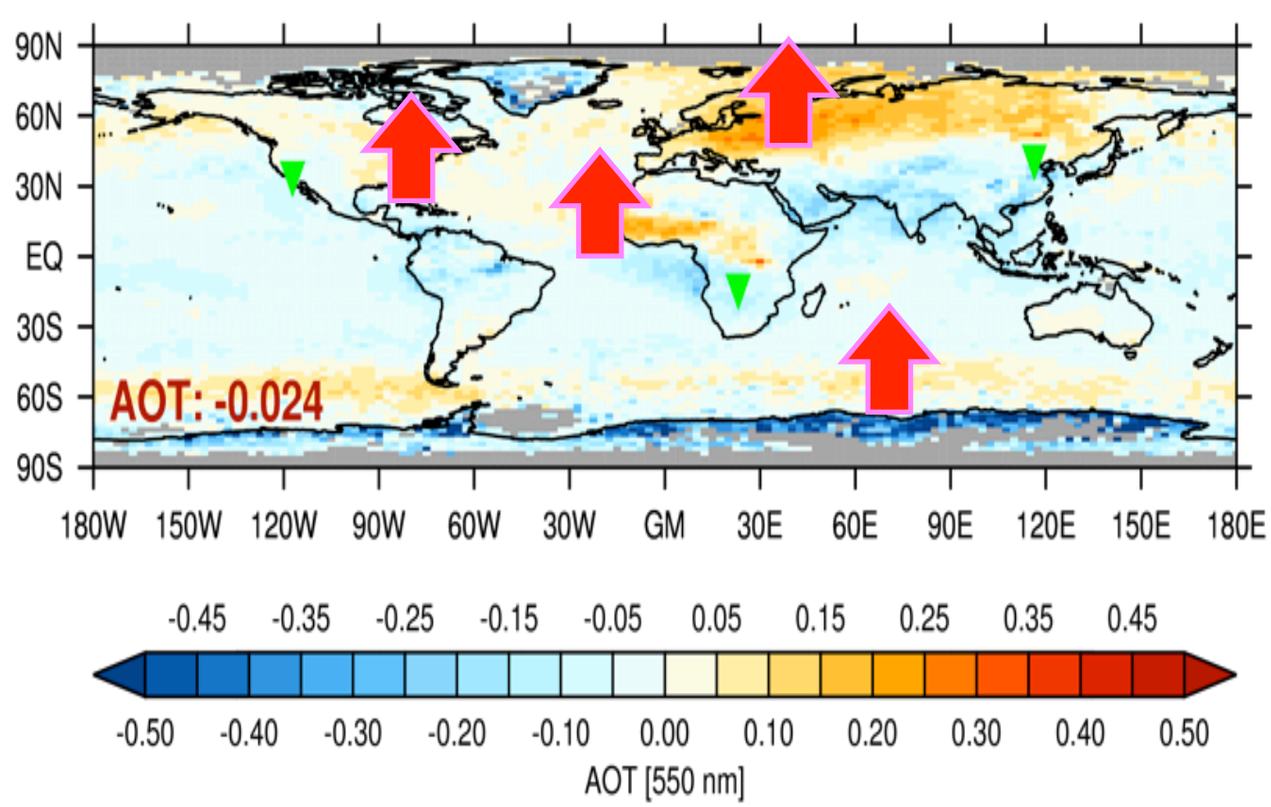

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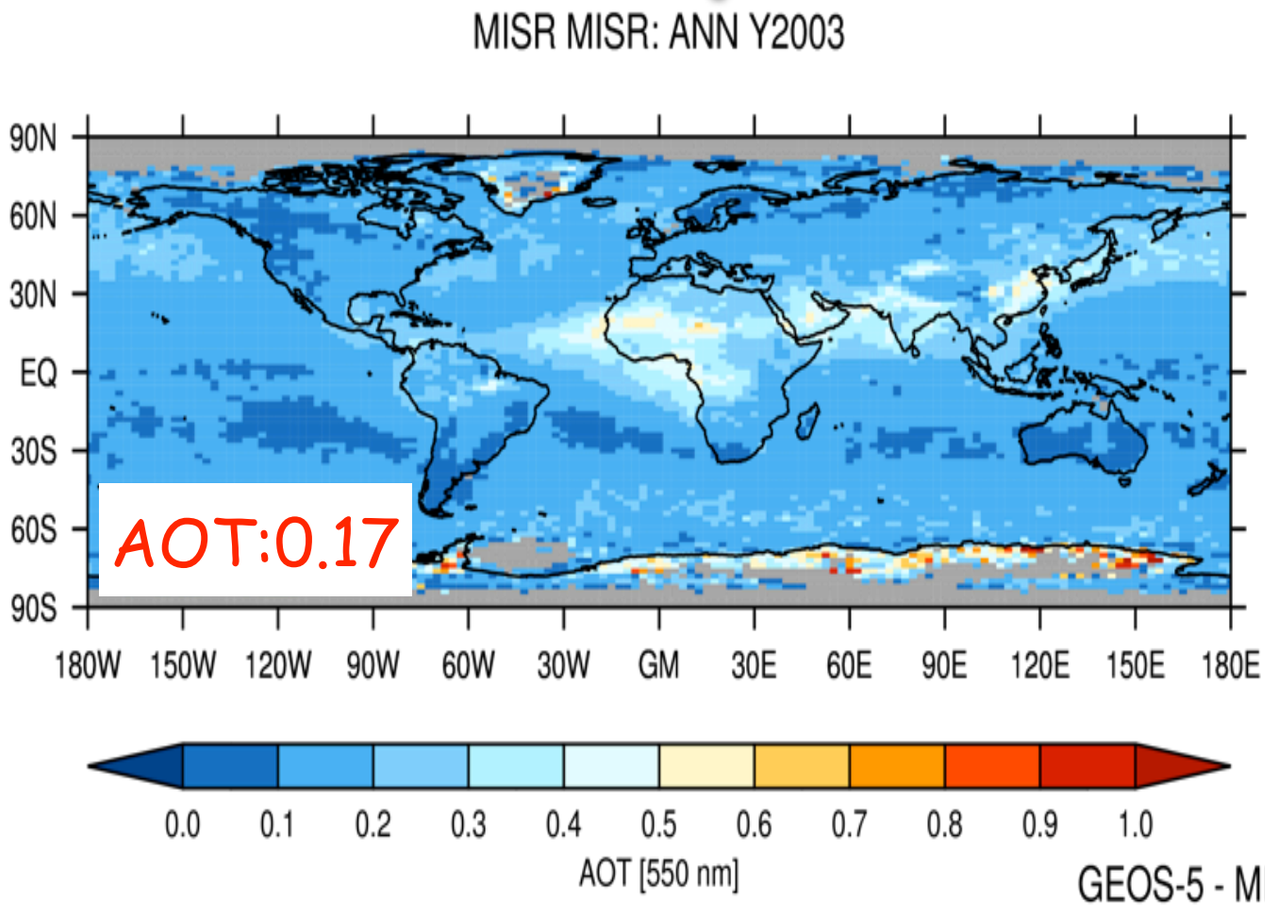

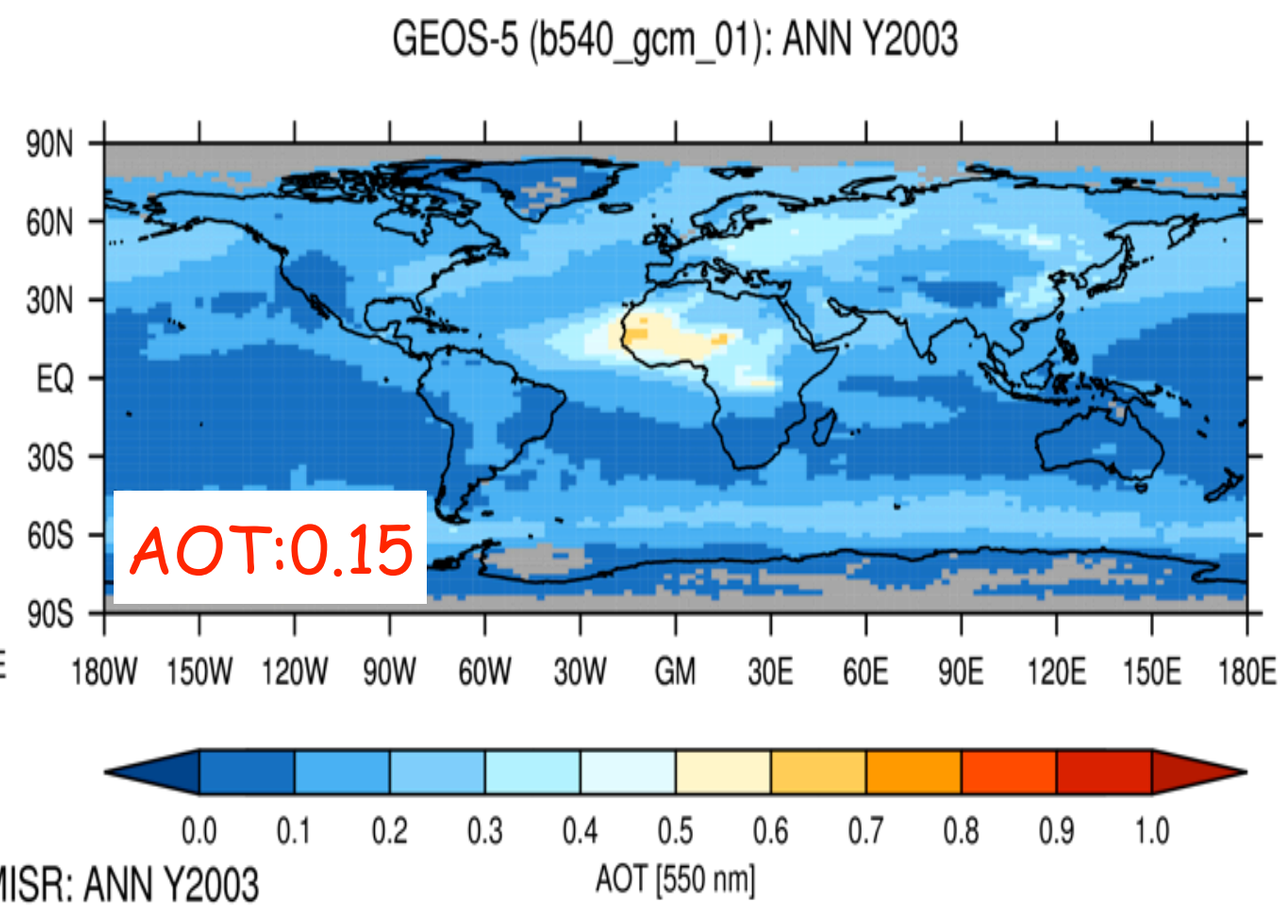

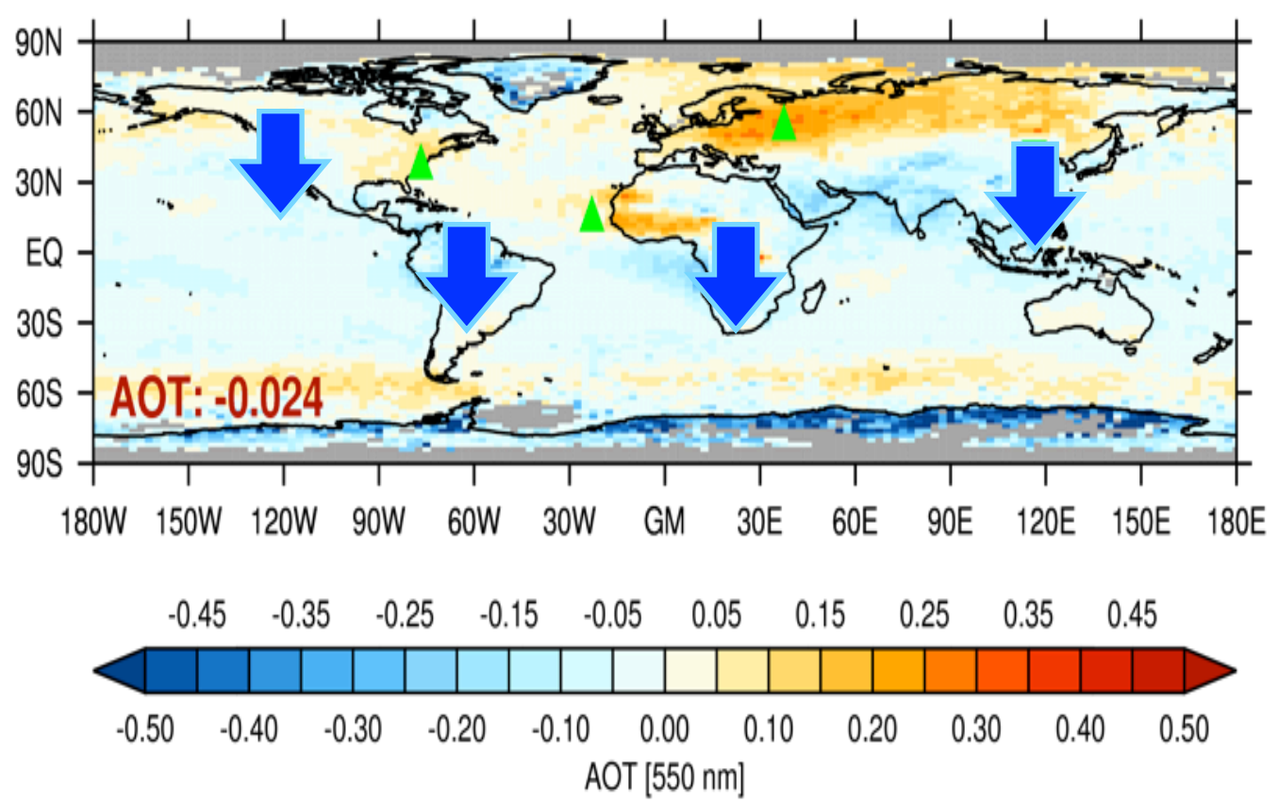

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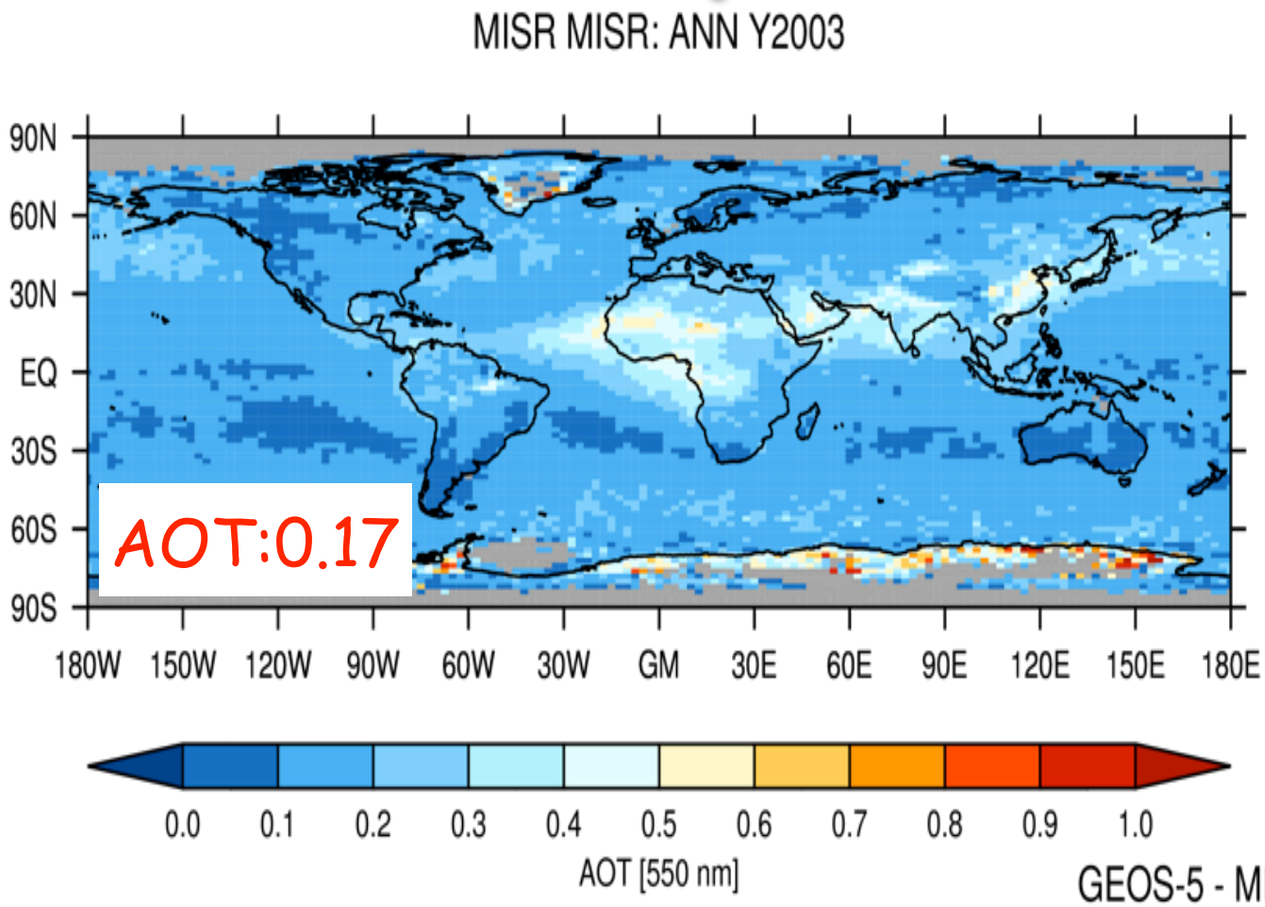

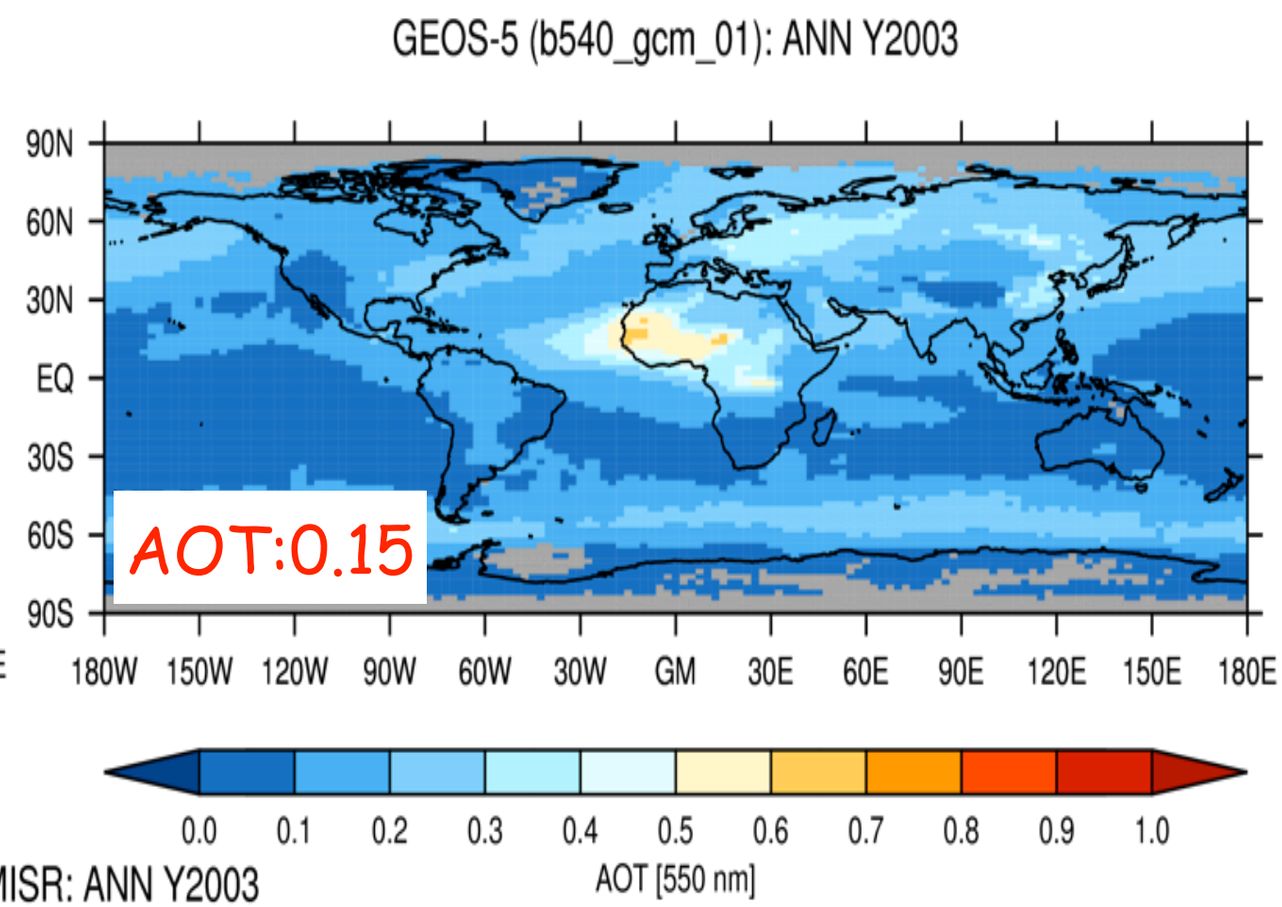

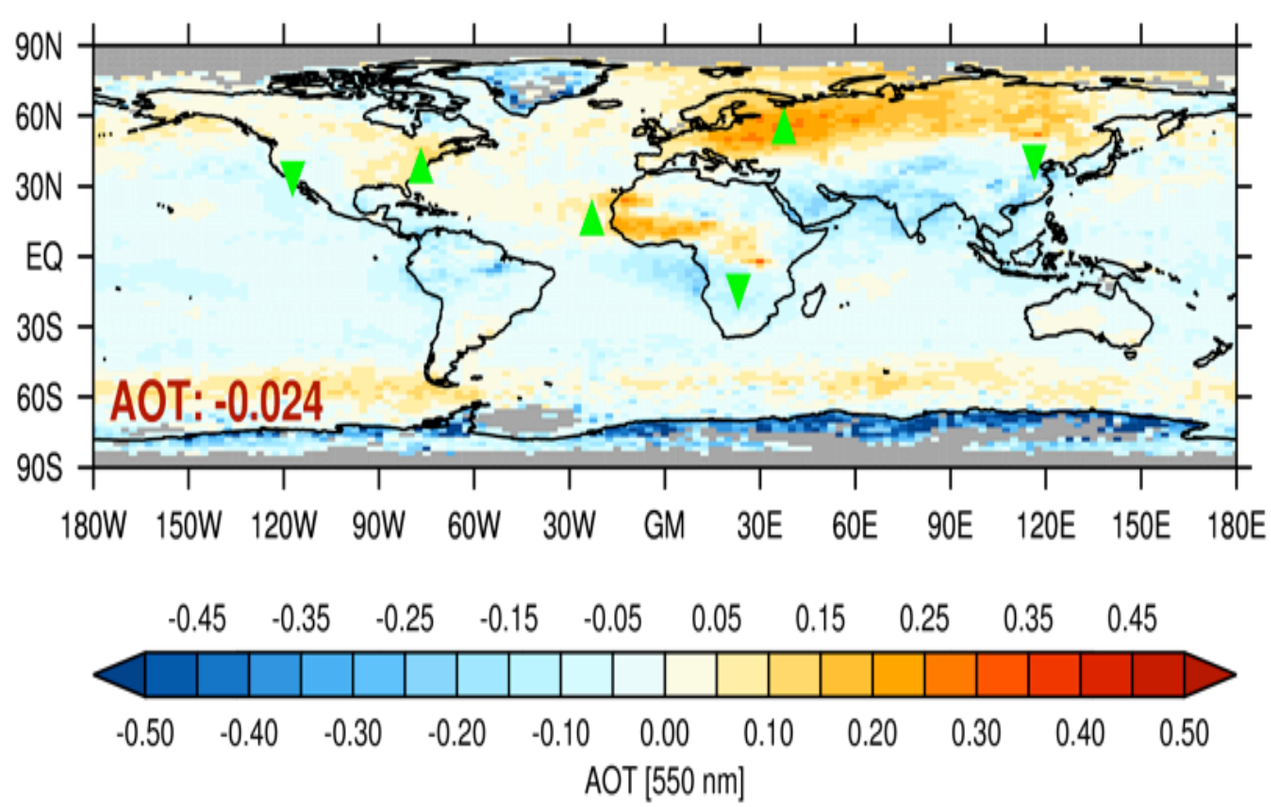

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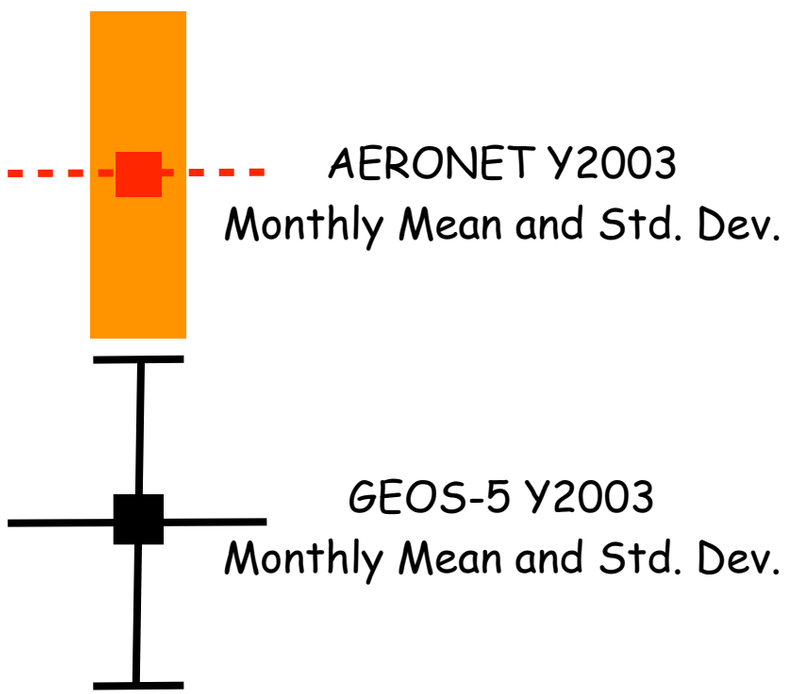

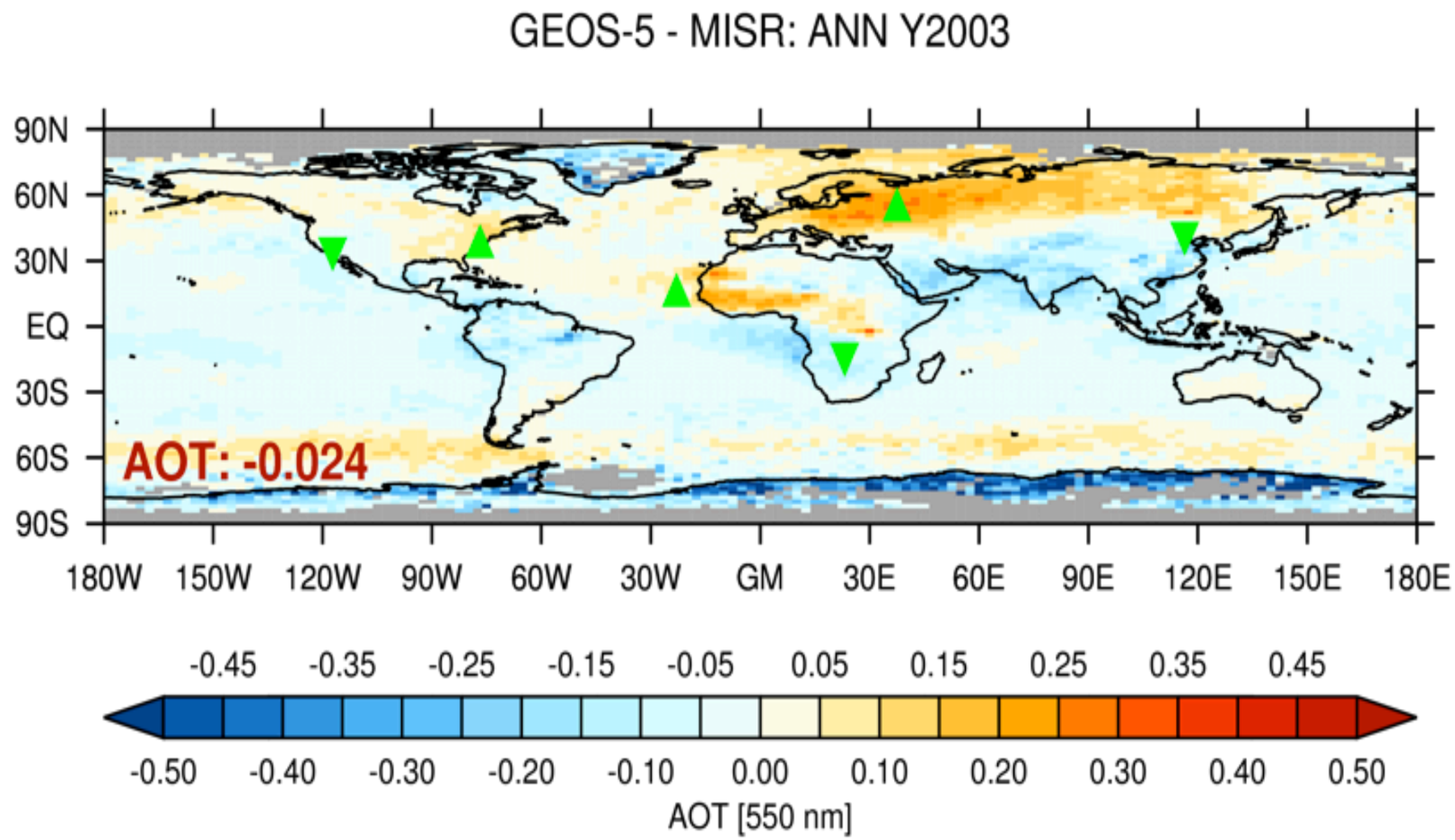

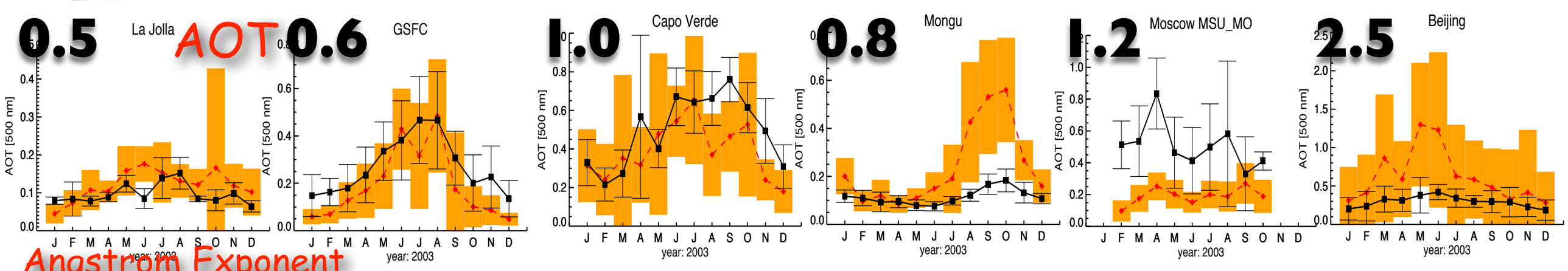

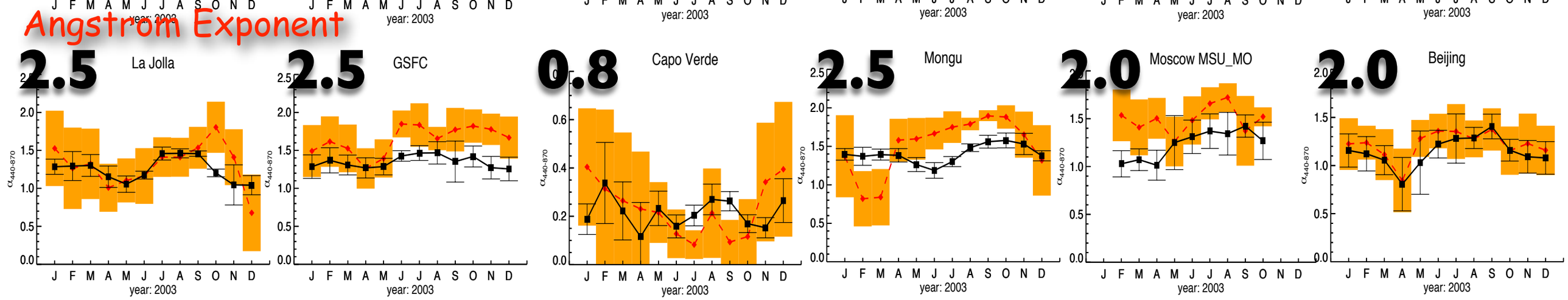

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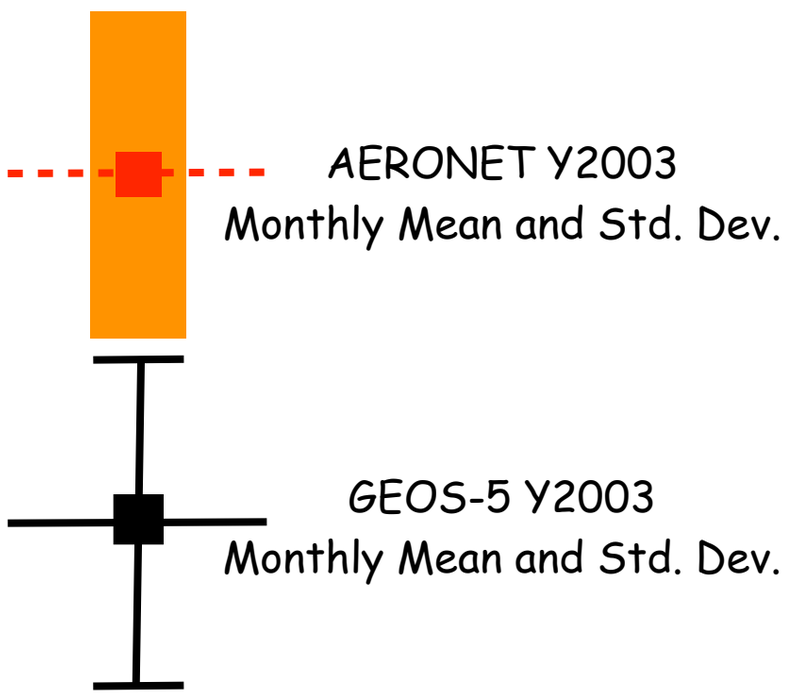

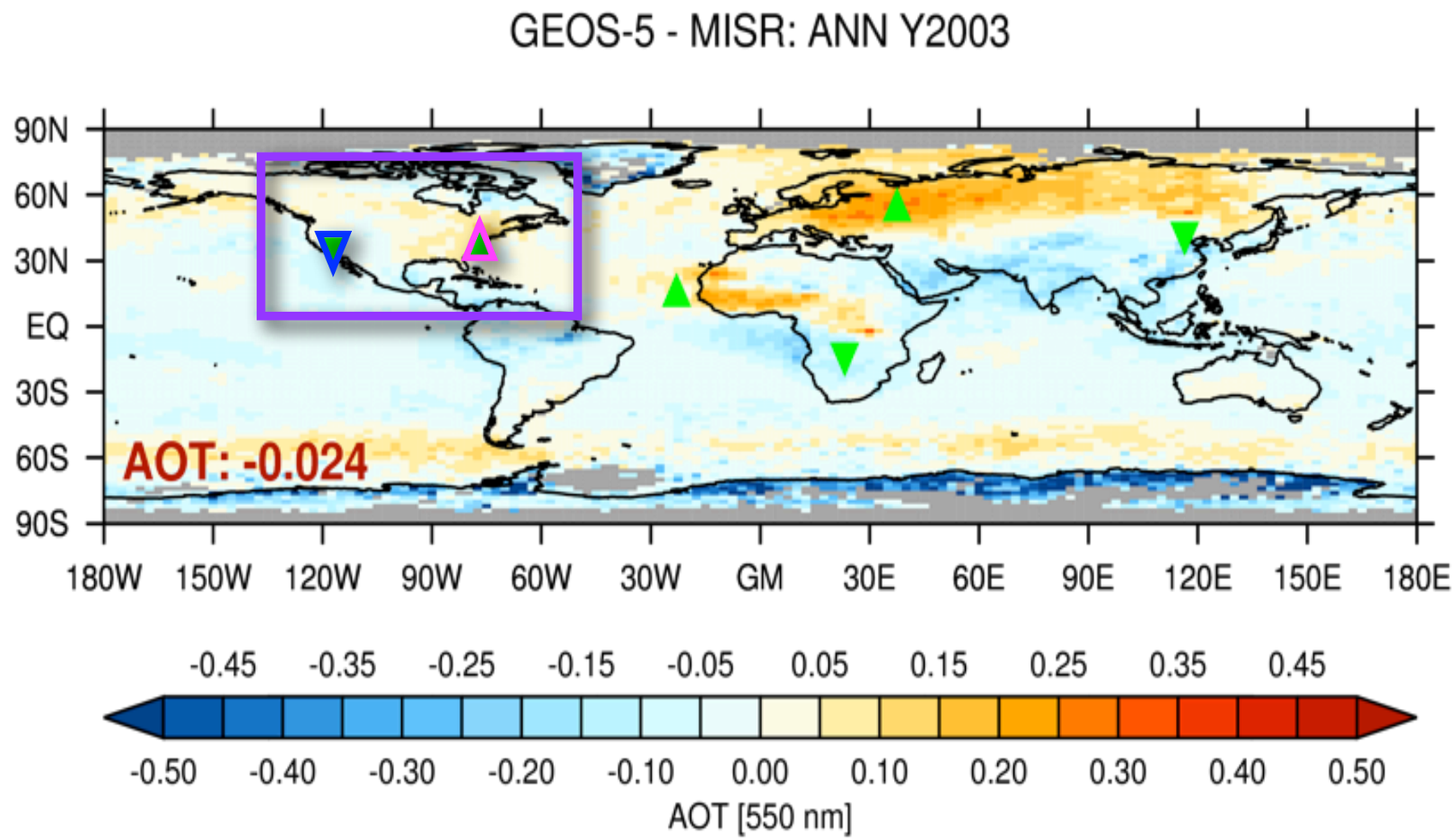

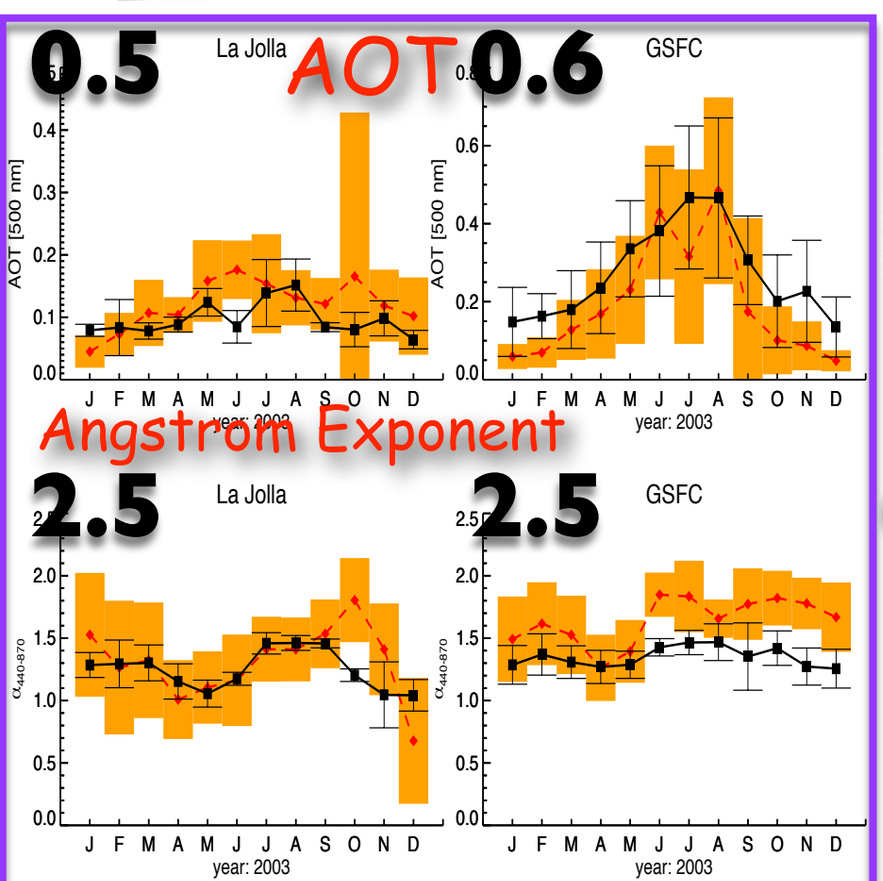

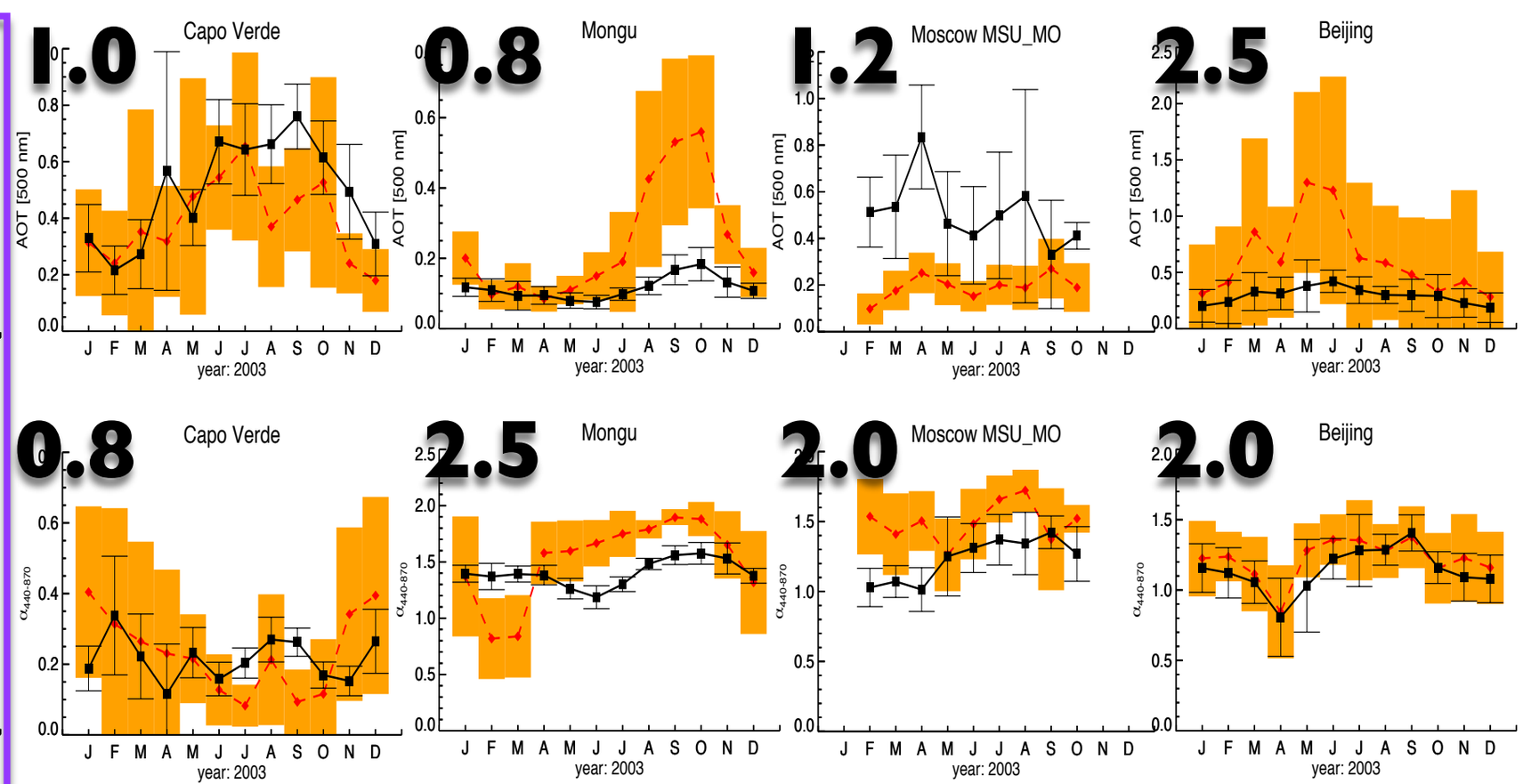

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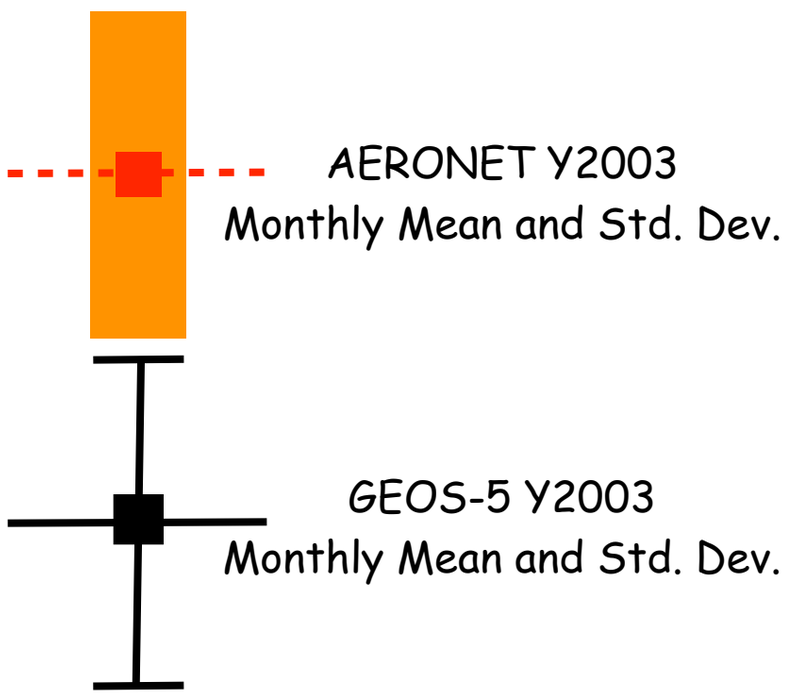

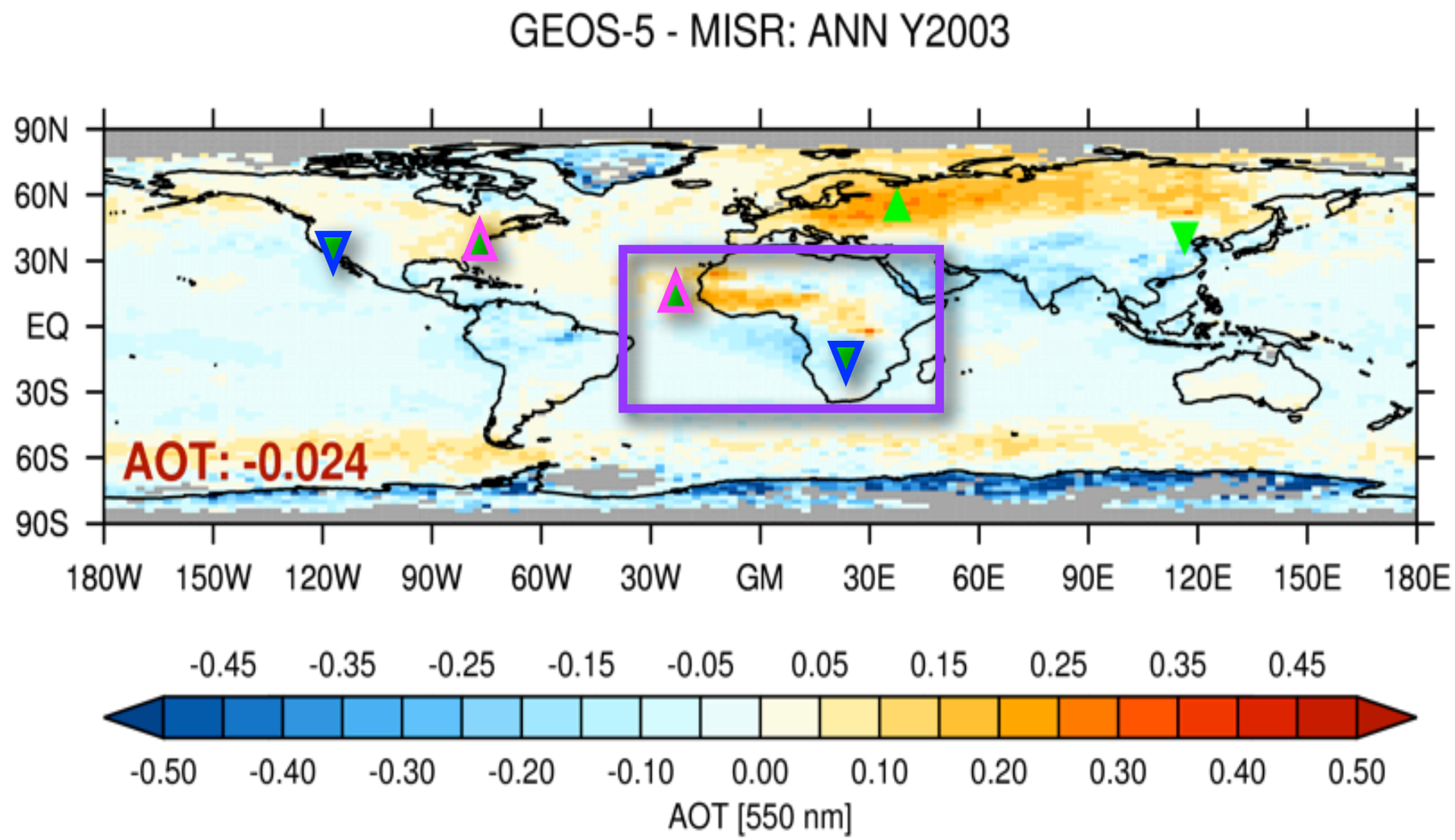

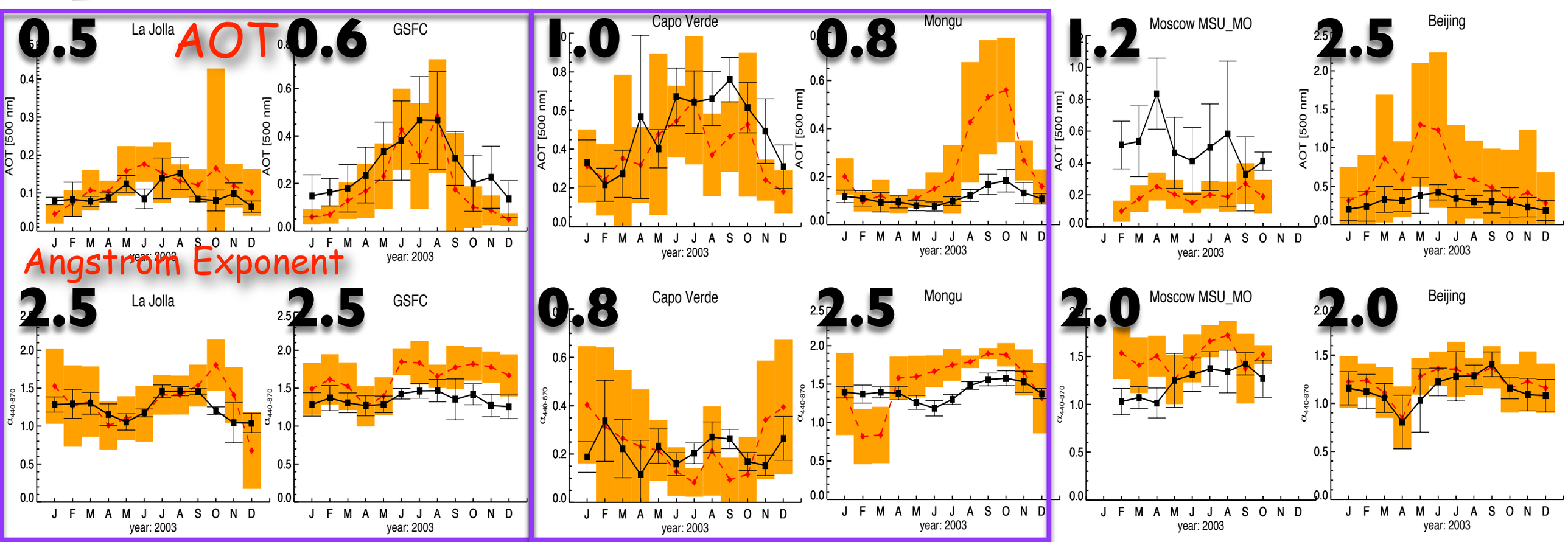

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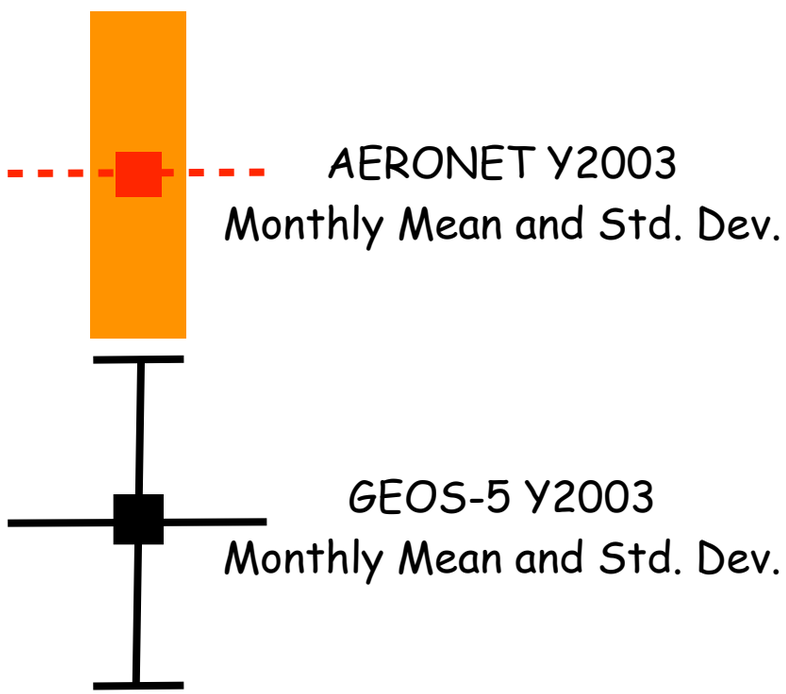
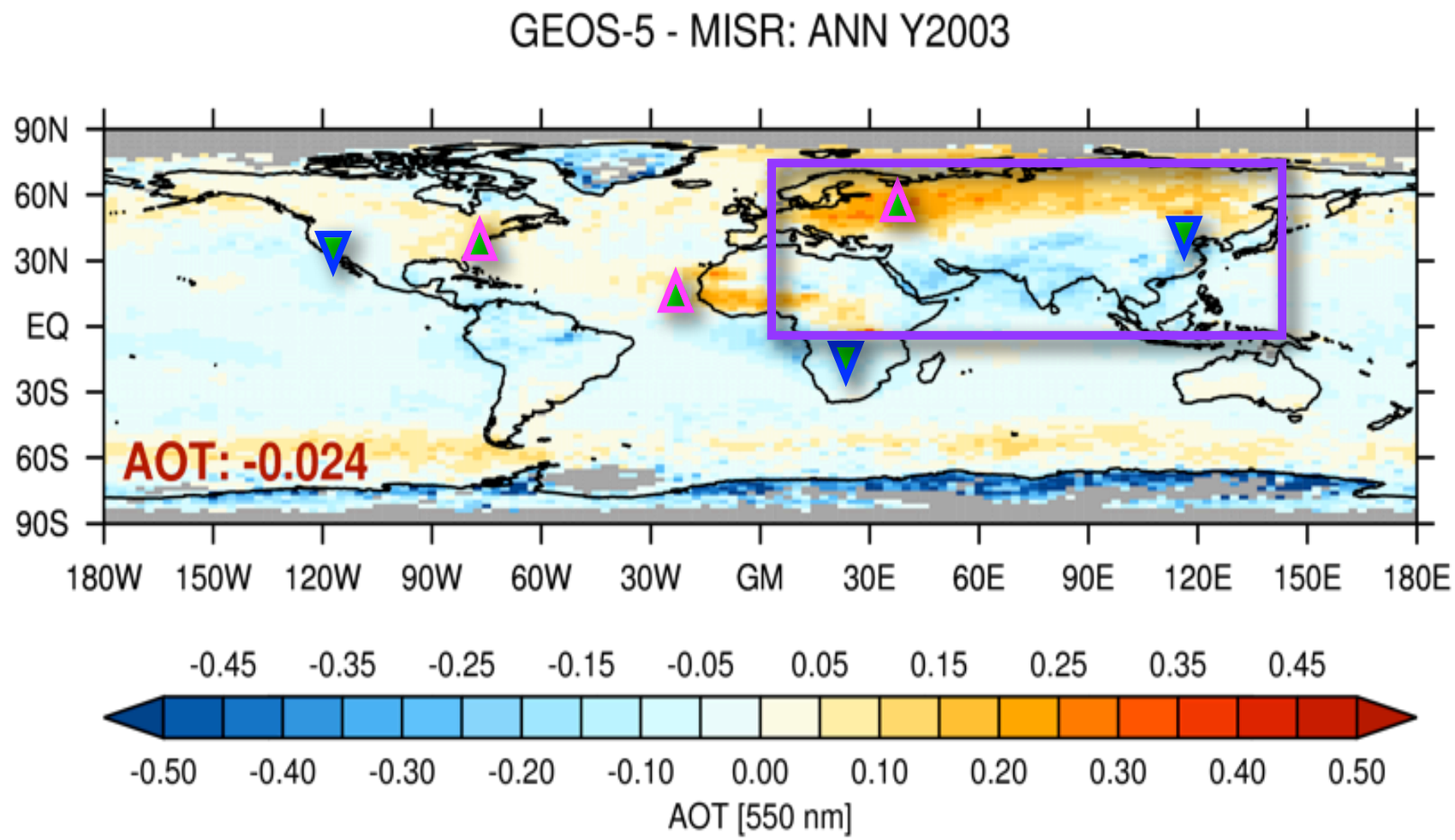
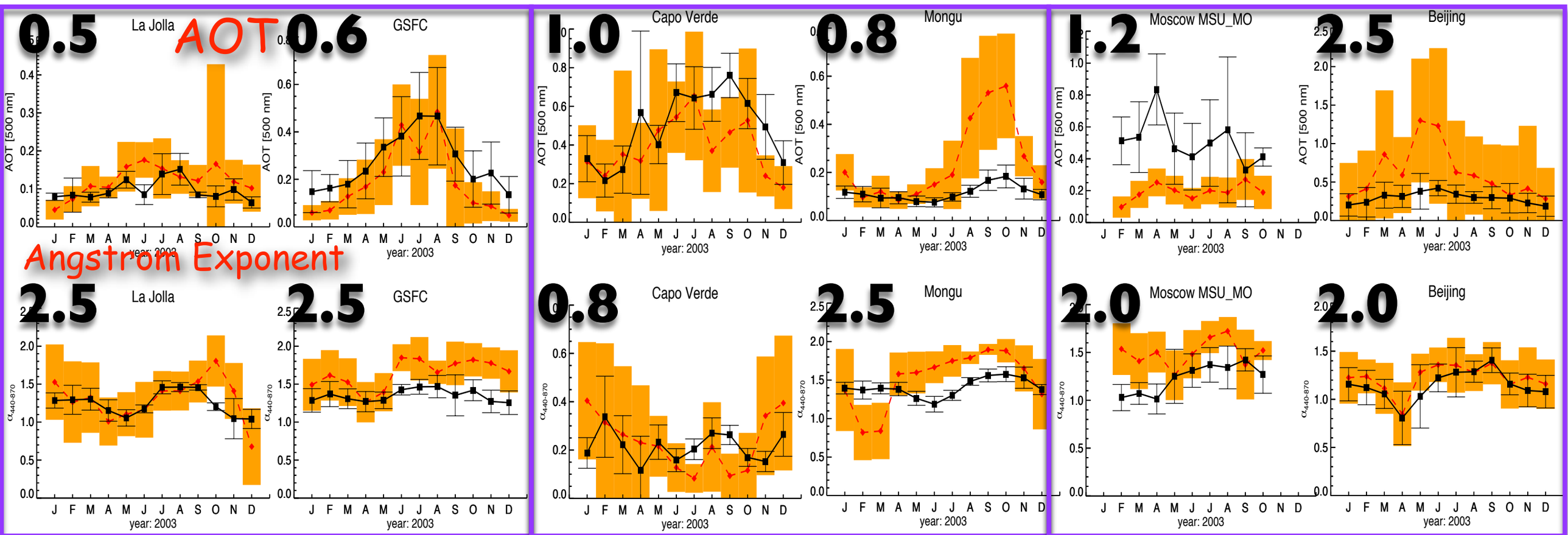
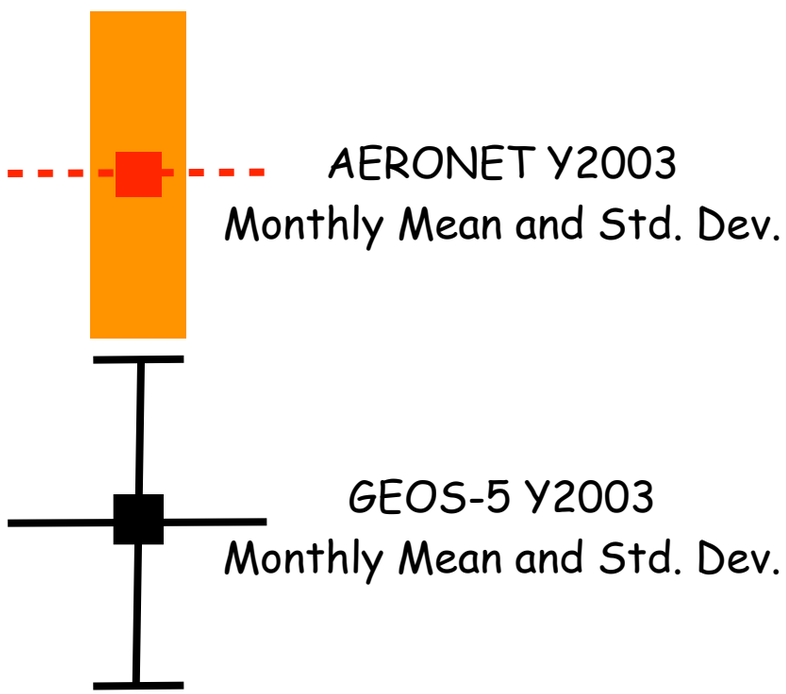
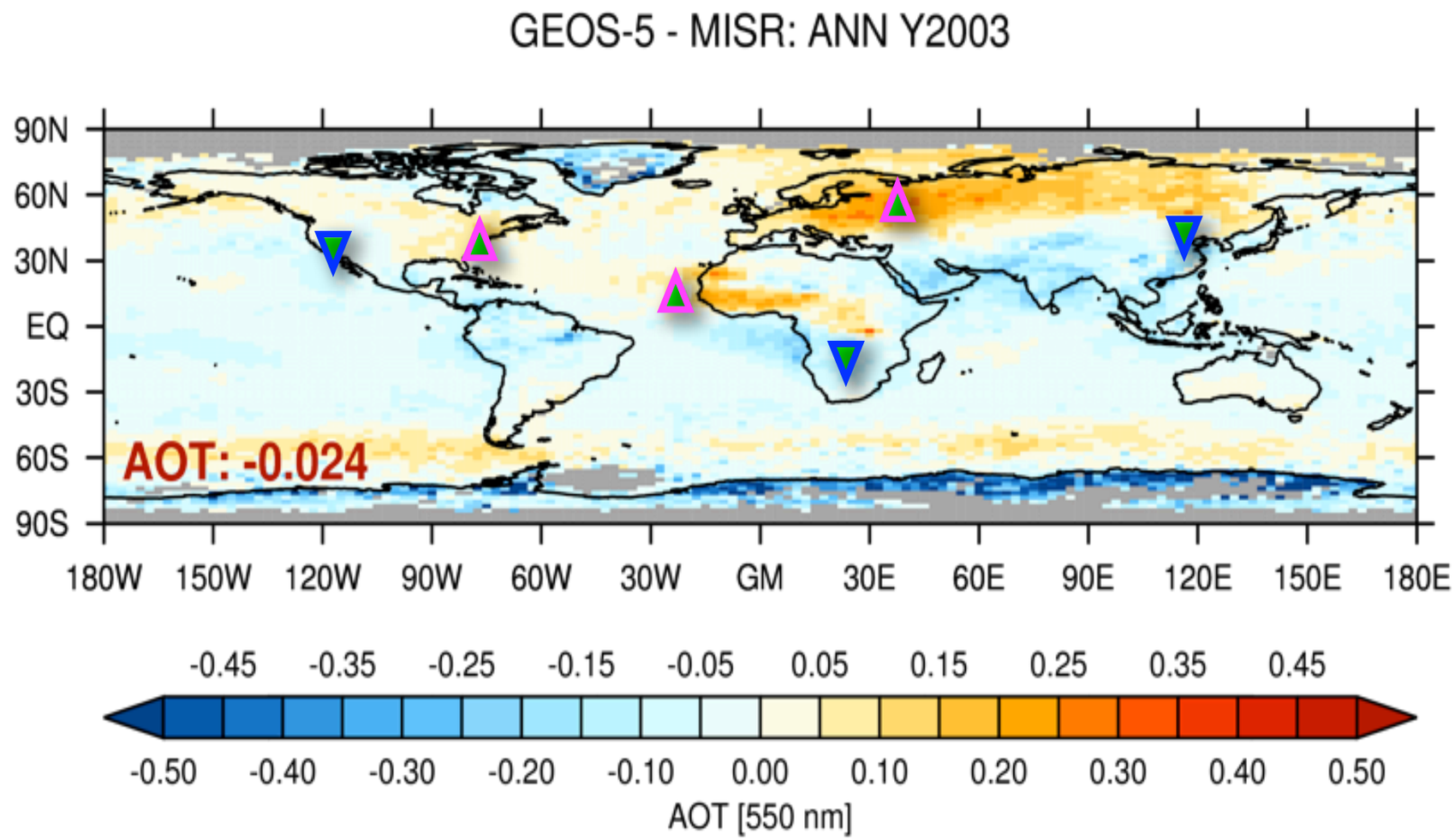


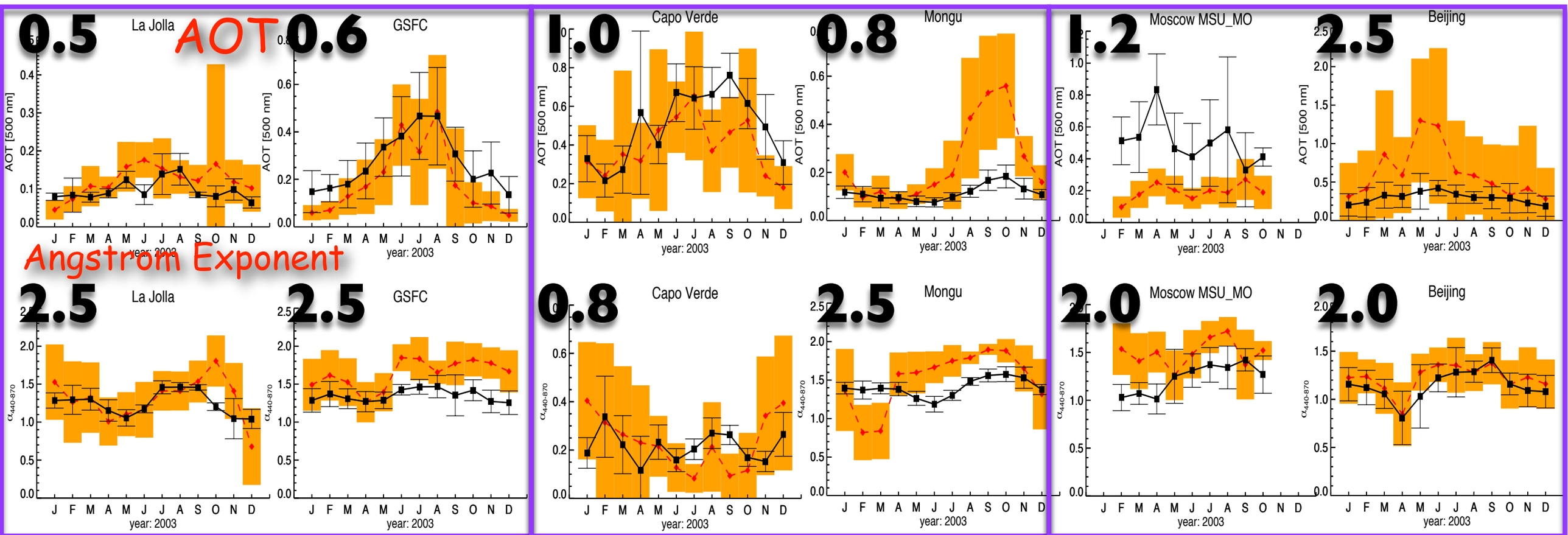




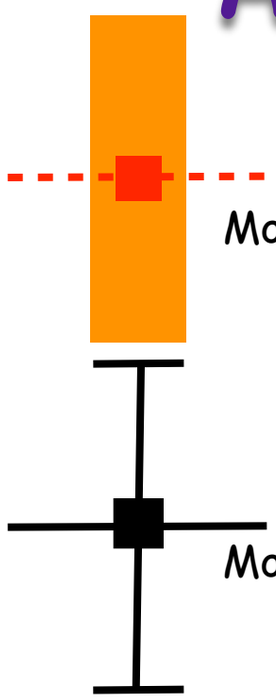
Comparison to AERONET





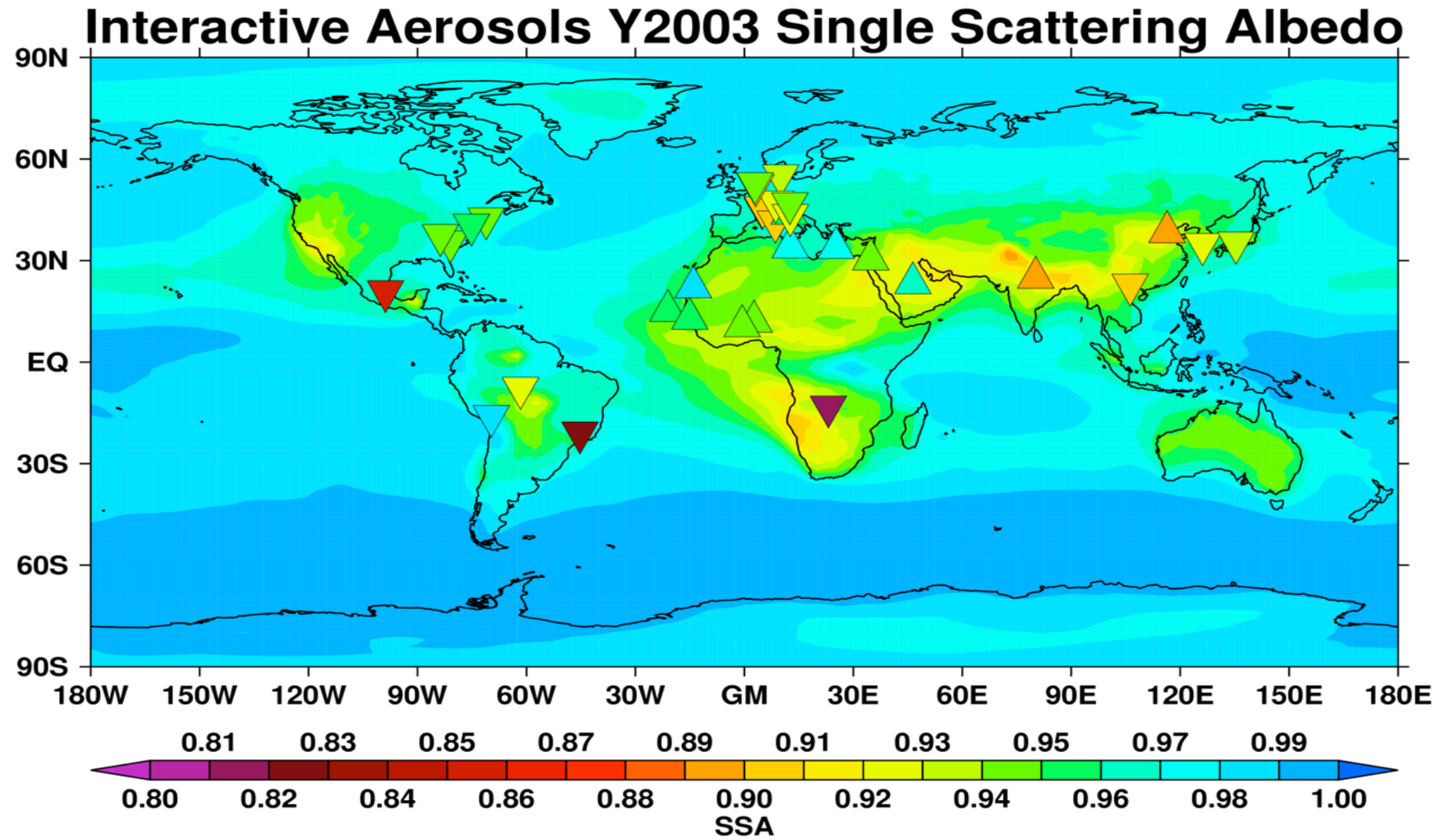


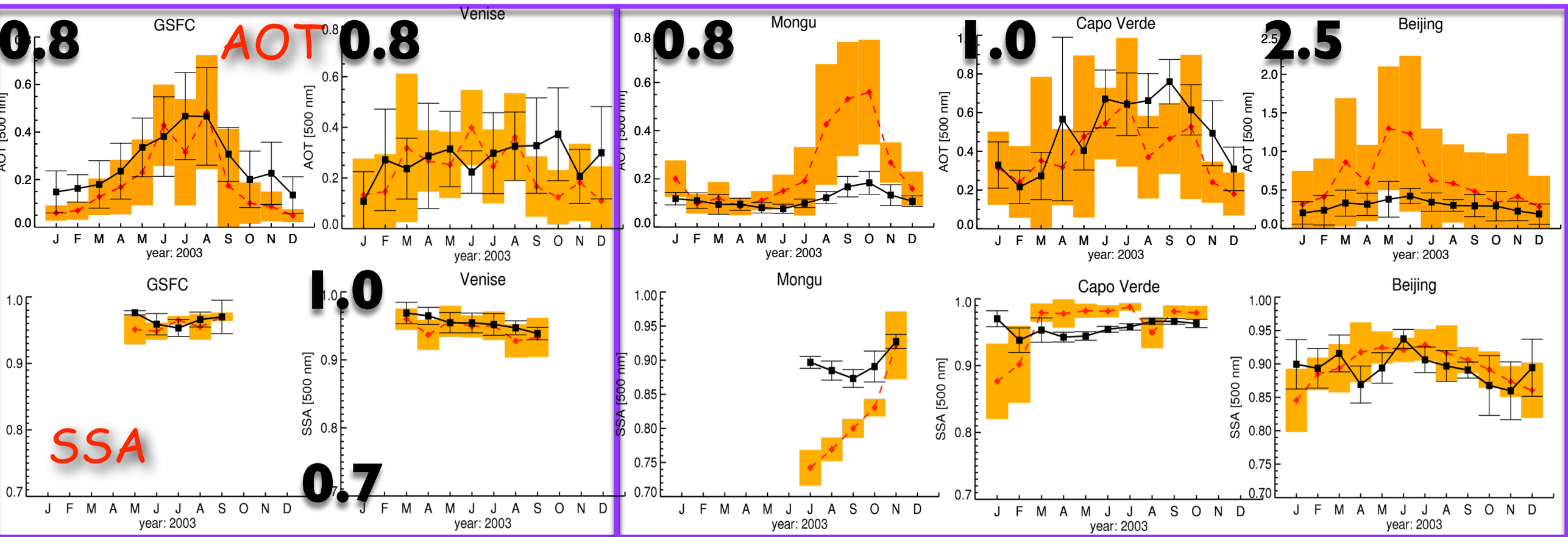
Aerosol Single Scattering Albedo



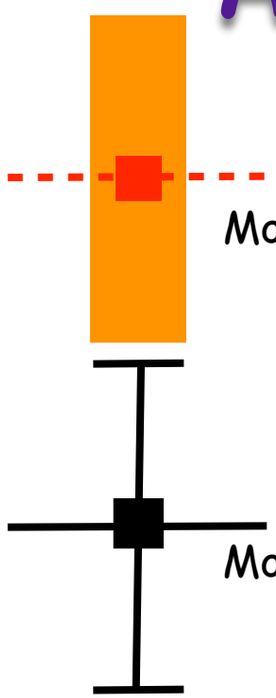
AERONET Y2003
Monthly Mean and Std. Dev.

GEOS-5 Y2003
Monthly Mean and Std. Dev.





Aerosol Single Scattering Albedo



AERONET Y2003
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GEOS-5 Y2003
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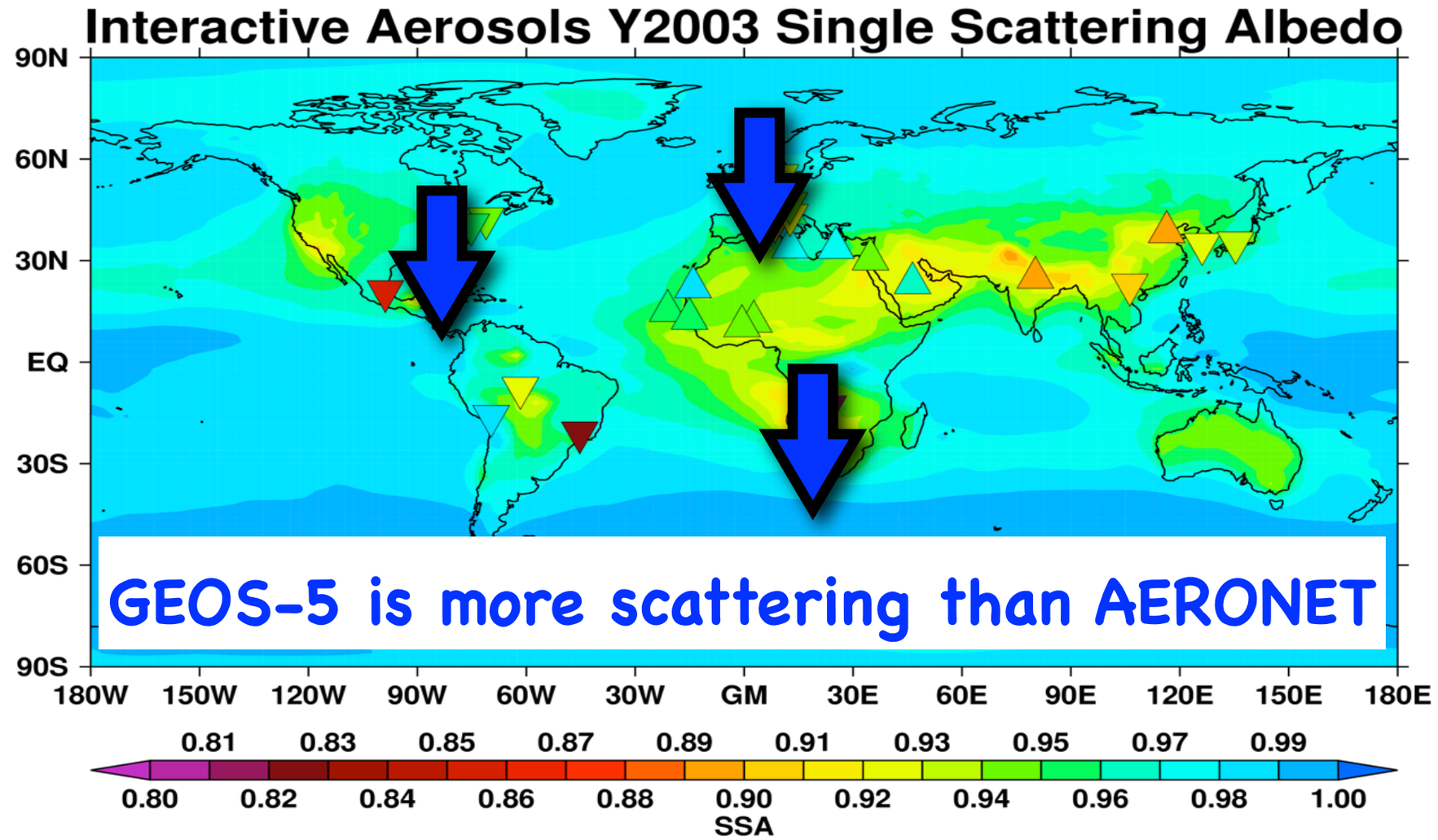
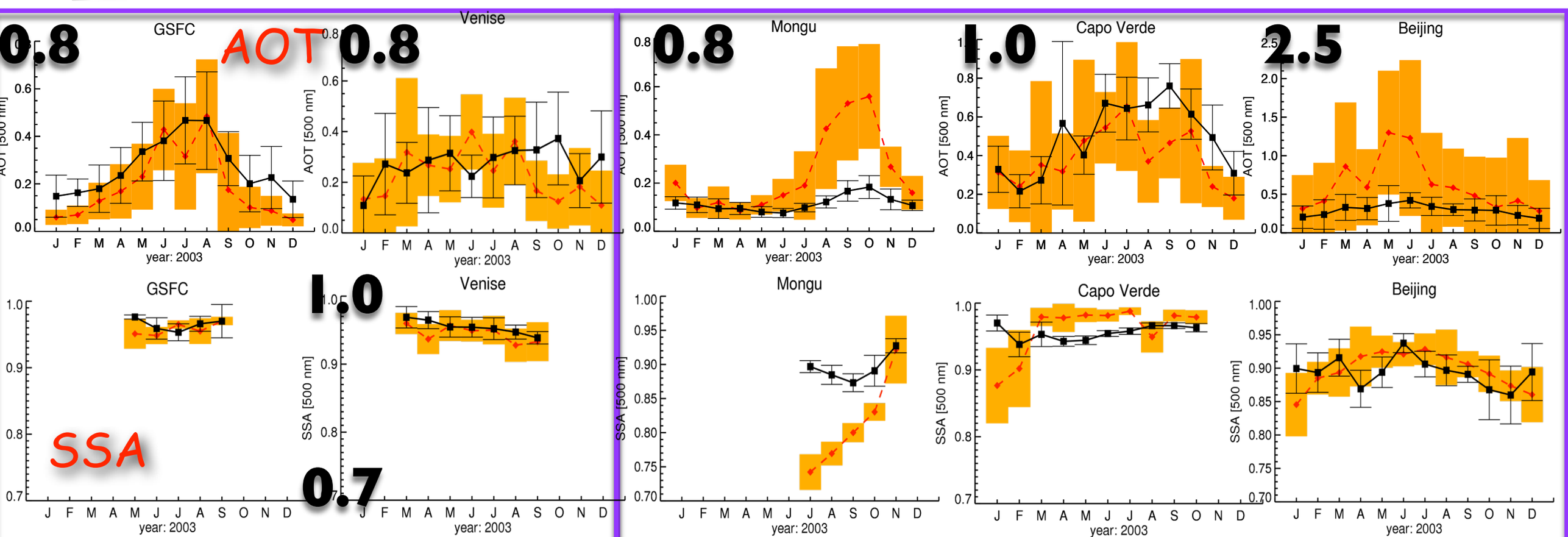
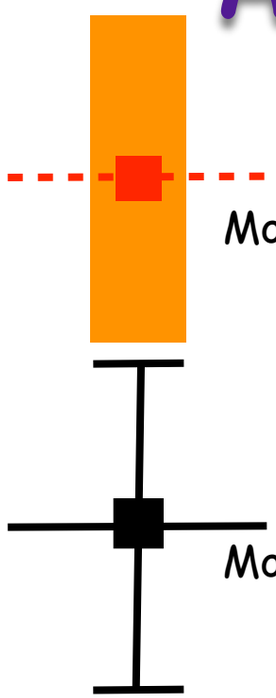


GEOS-5 is more scattering than AERONET

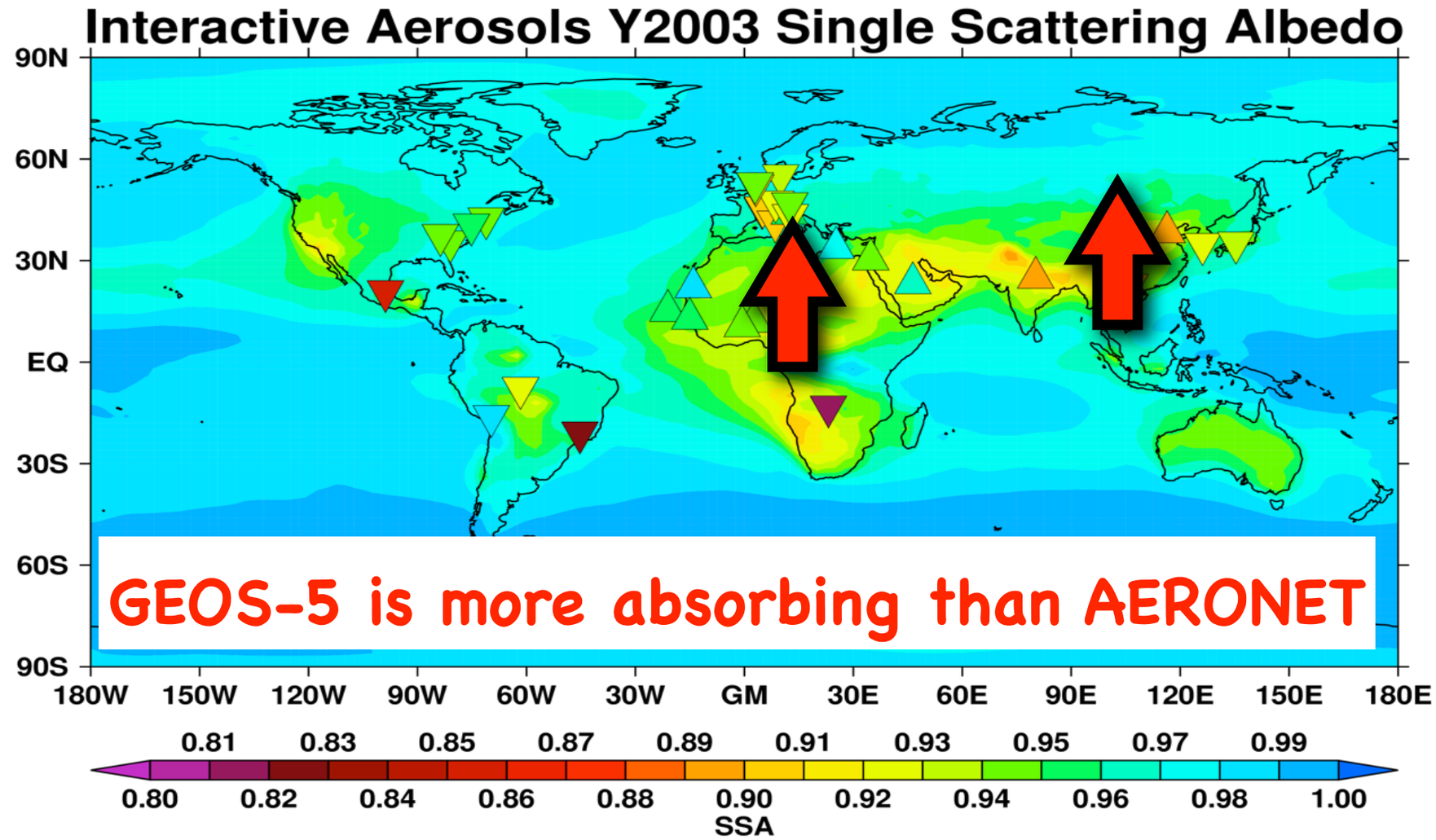


Aerosol Single Scattering Albedo

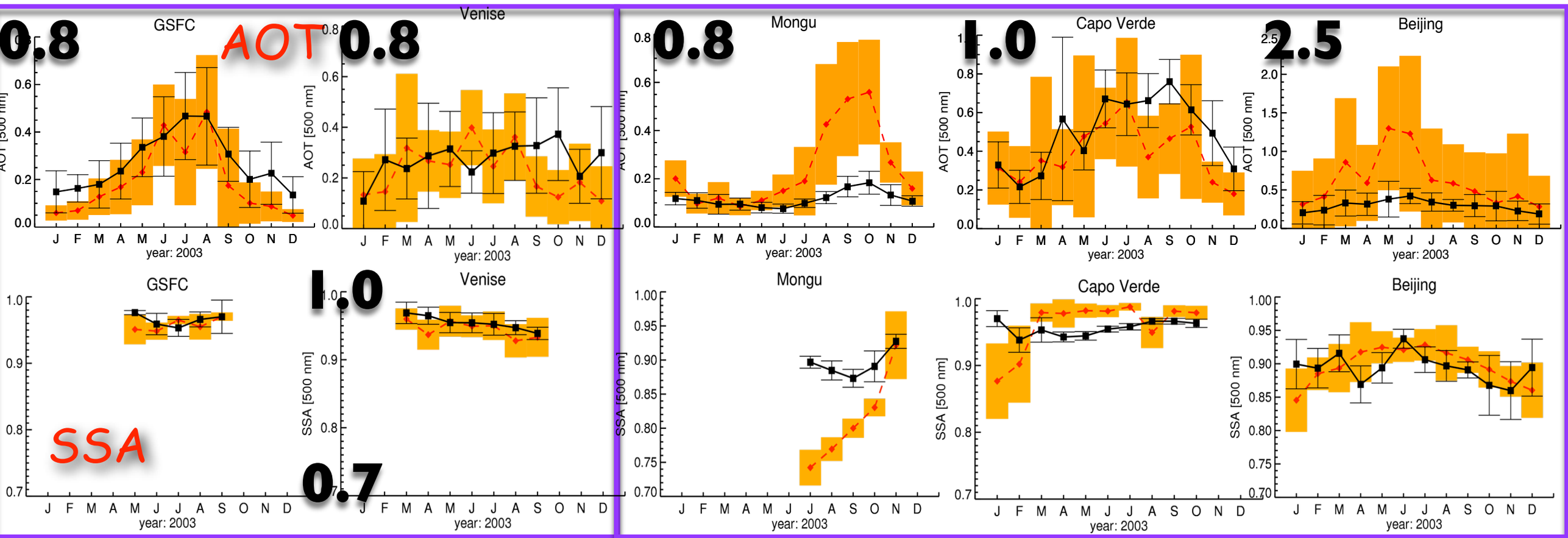


AERONET Y2003
Monthly Mean and Std. Dev.

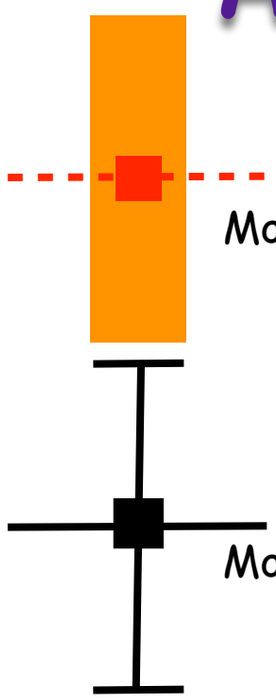
GEOS-5 Y2003
Monthly Mean and Std. Dev.



GEOS-5 is more absorbing than AERONET



Aerosol Single Scattering Albedo



AERONET Y2003
Monthly Mean and Std. Dev.

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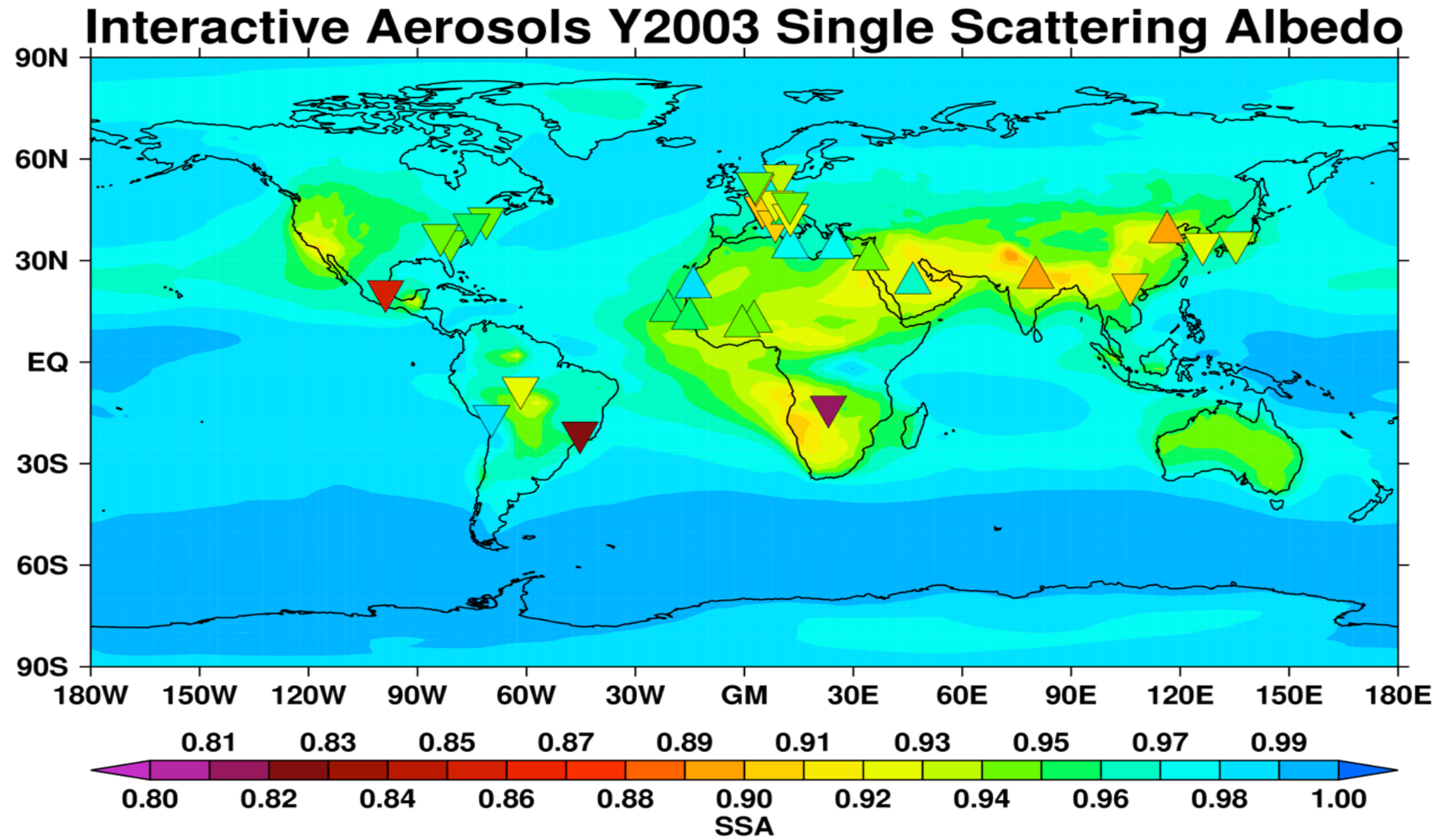
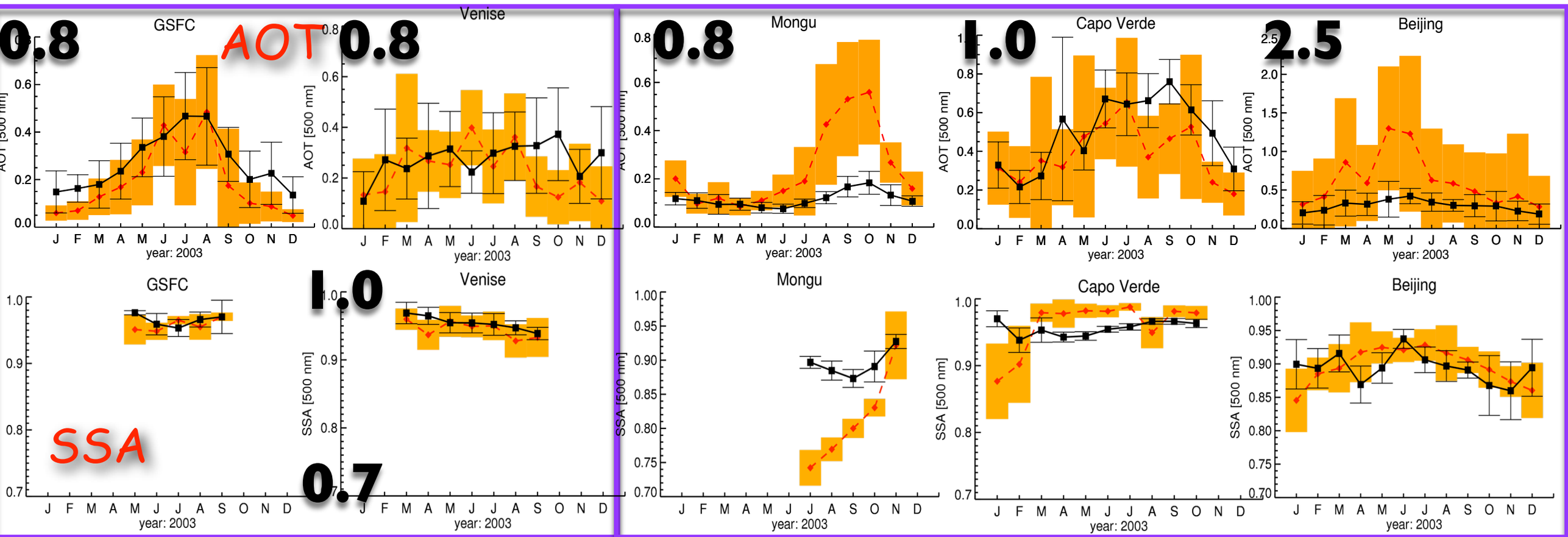


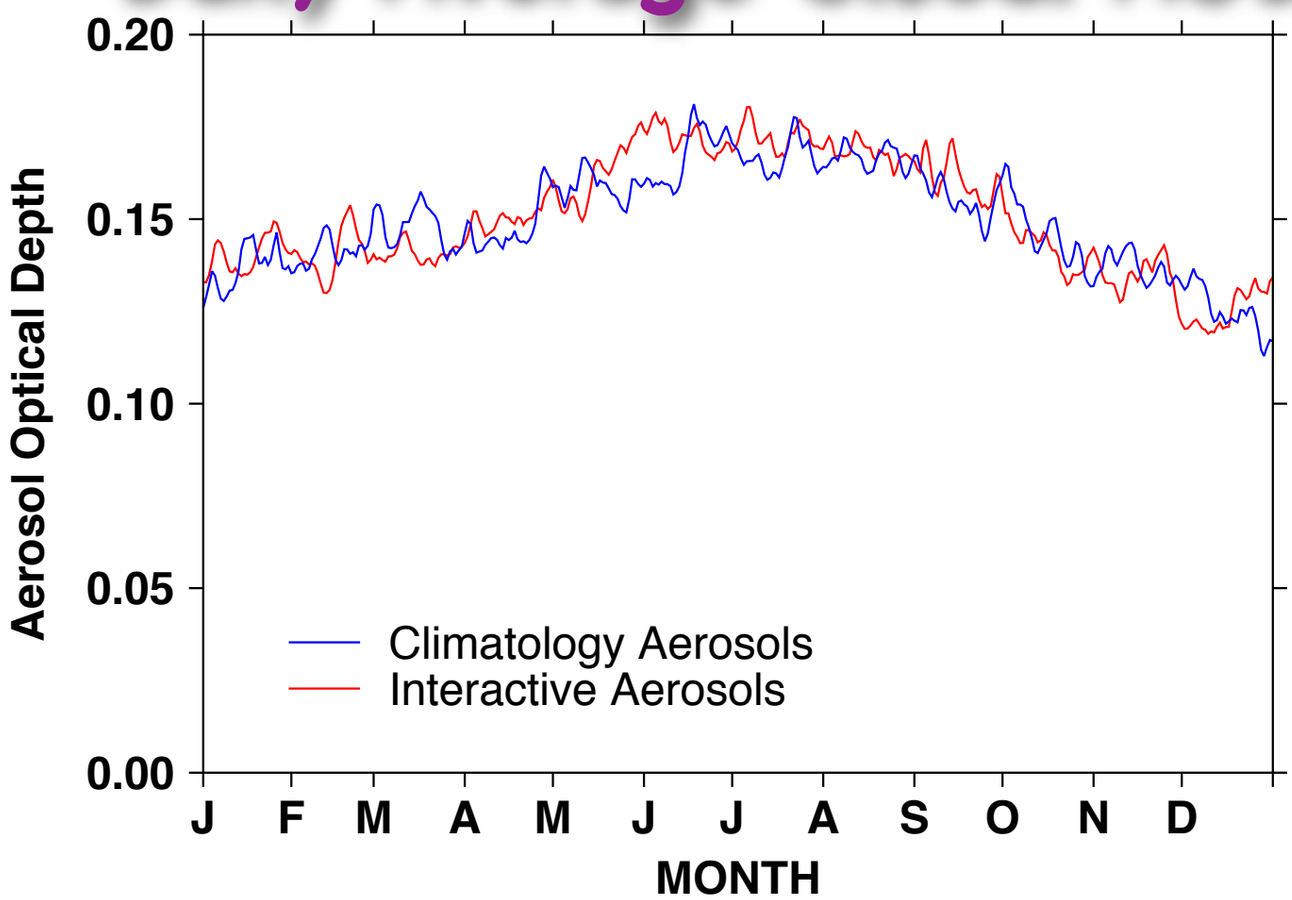


Aerosol - Climate Interactions

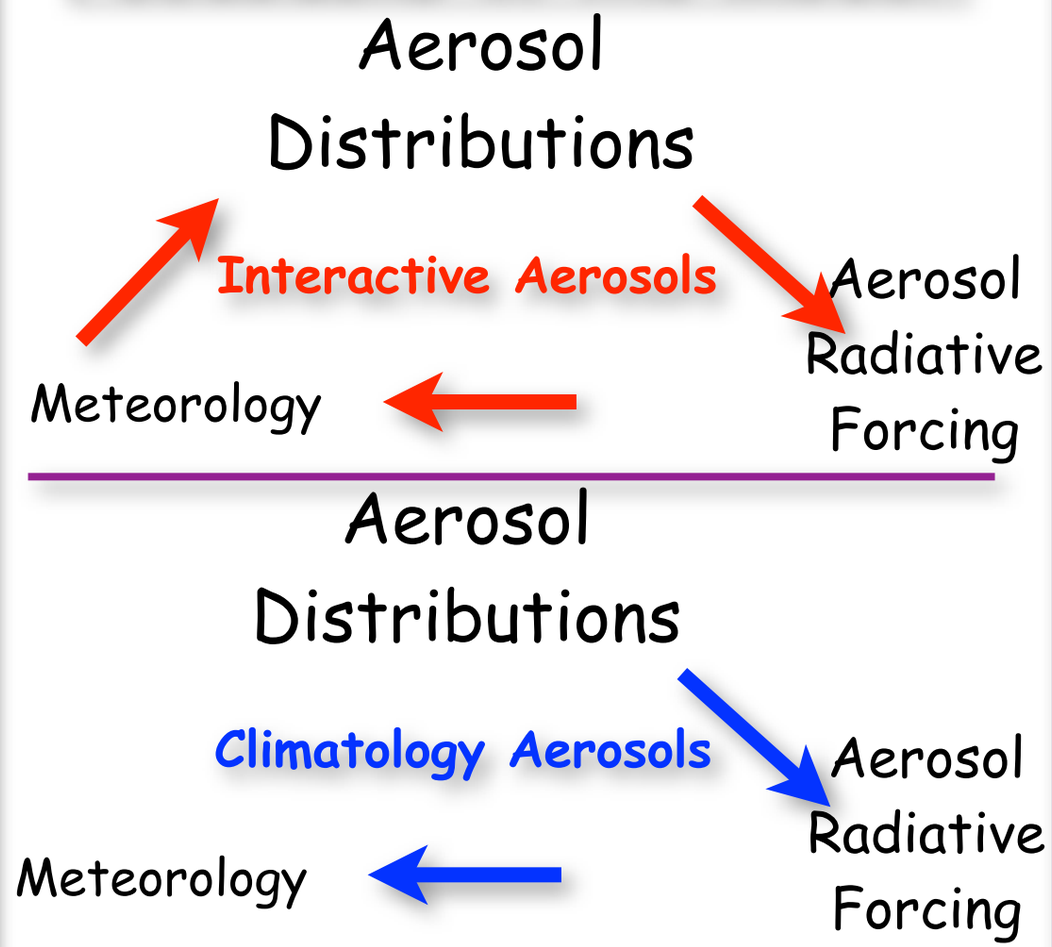
- Climatology Aerosol mass distributions are linearly interpolated between monthly mean values (calculated from Interactive Aerosol experiment), but model relative humidity can modulate aerosol optical depth

- In addition, Interactive Aerosol mass distributions change at every time step and respond to model meteorology (e.g. through wet deposition)

Daily Average Global AOD

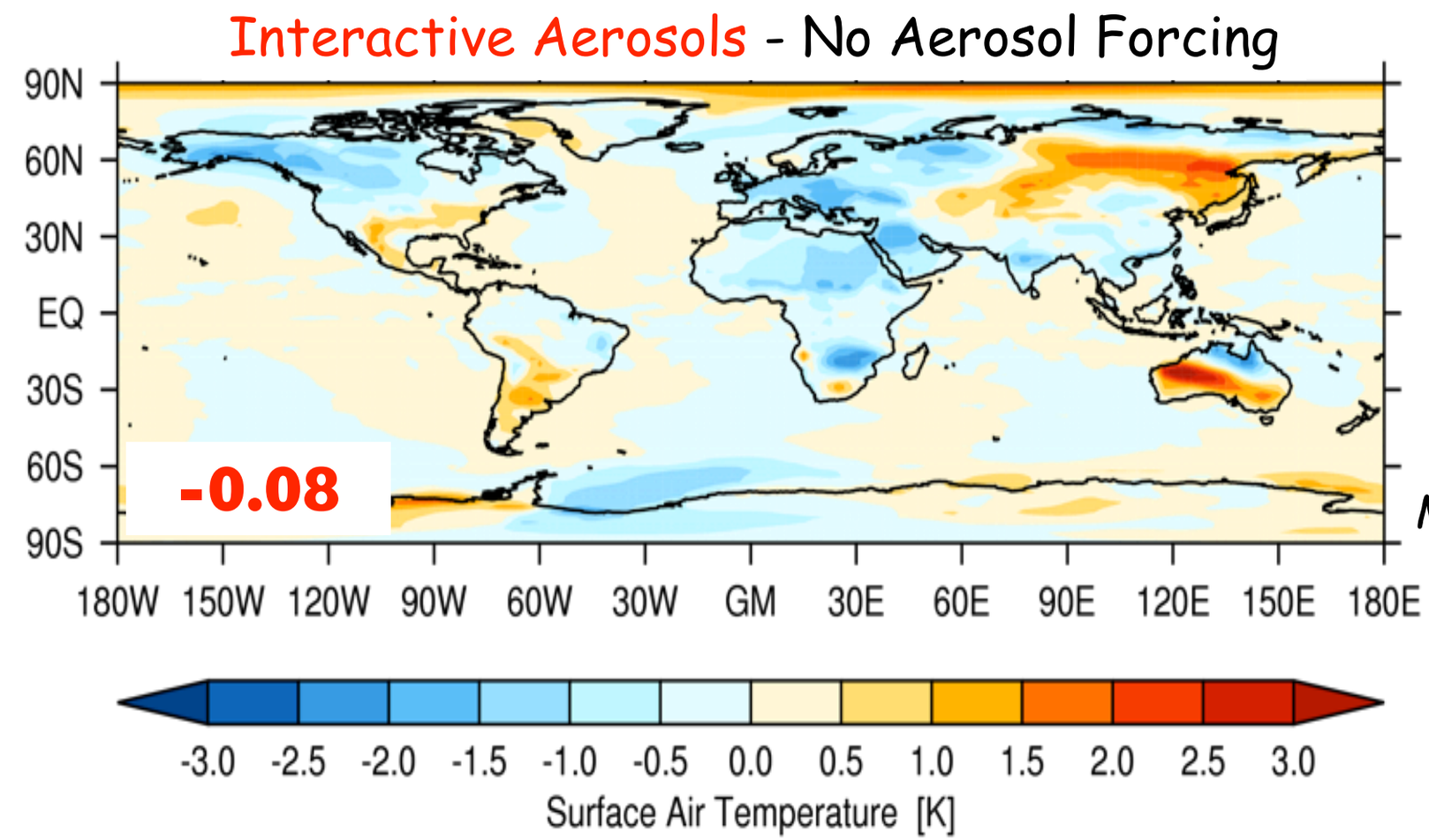


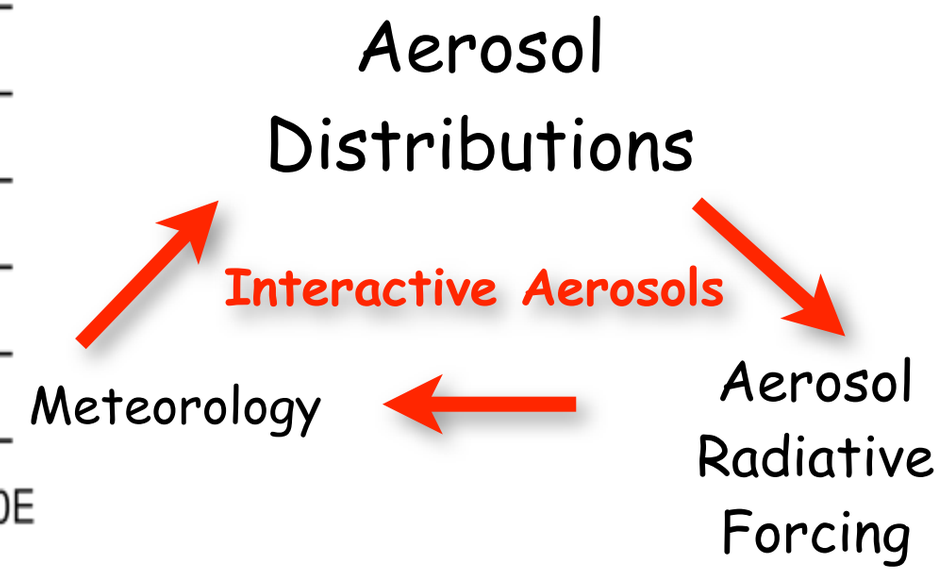
Feedbacks in the Model:

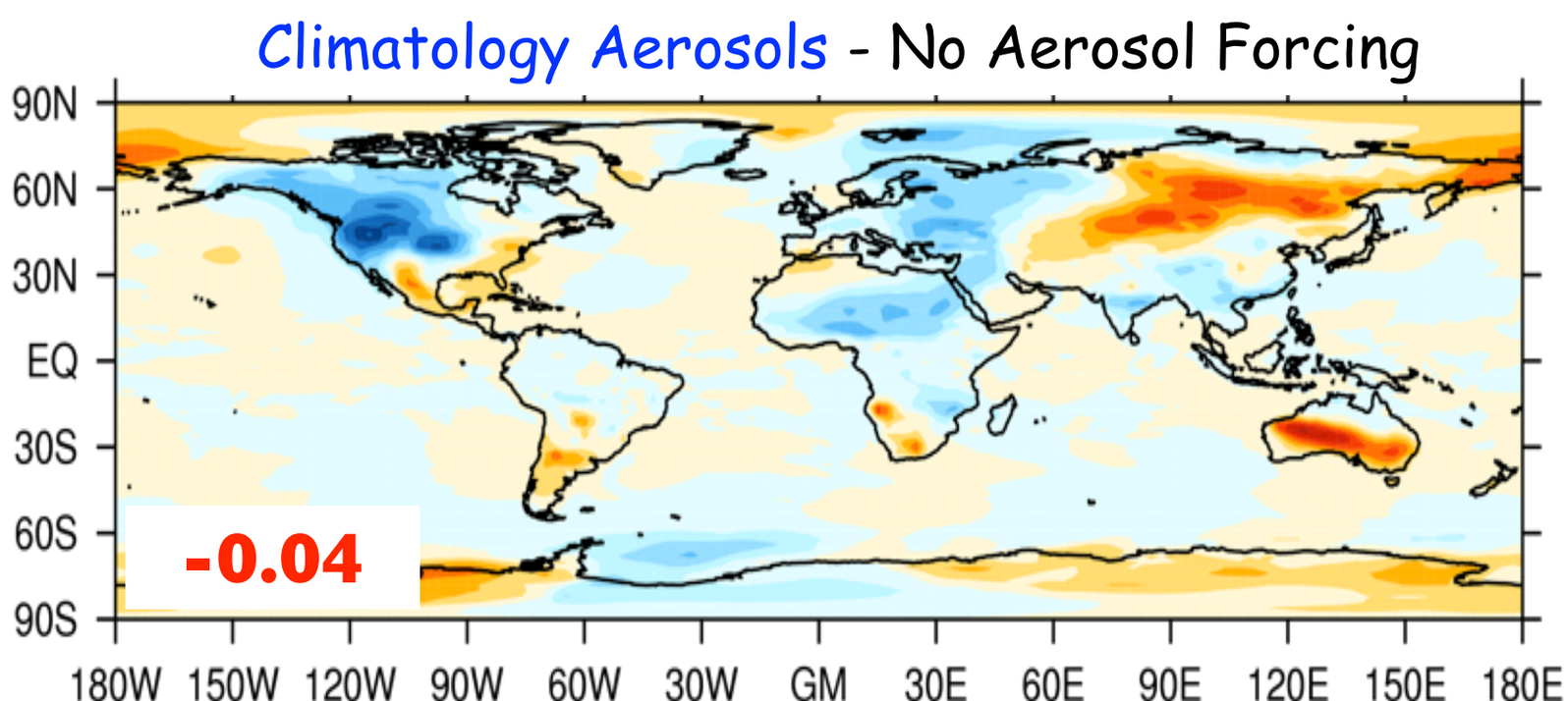


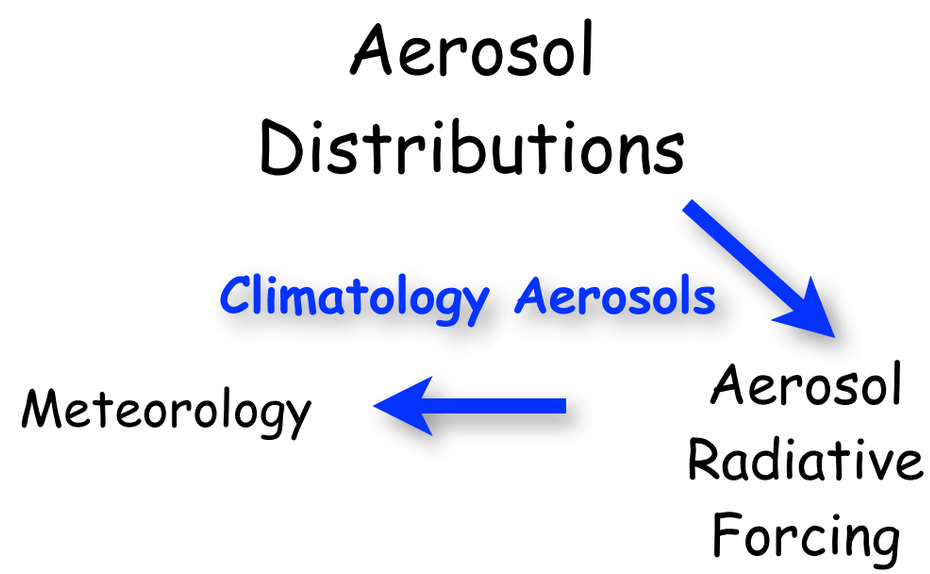
What are the effects of aerosols on climate?

Surface Air Temperature Change





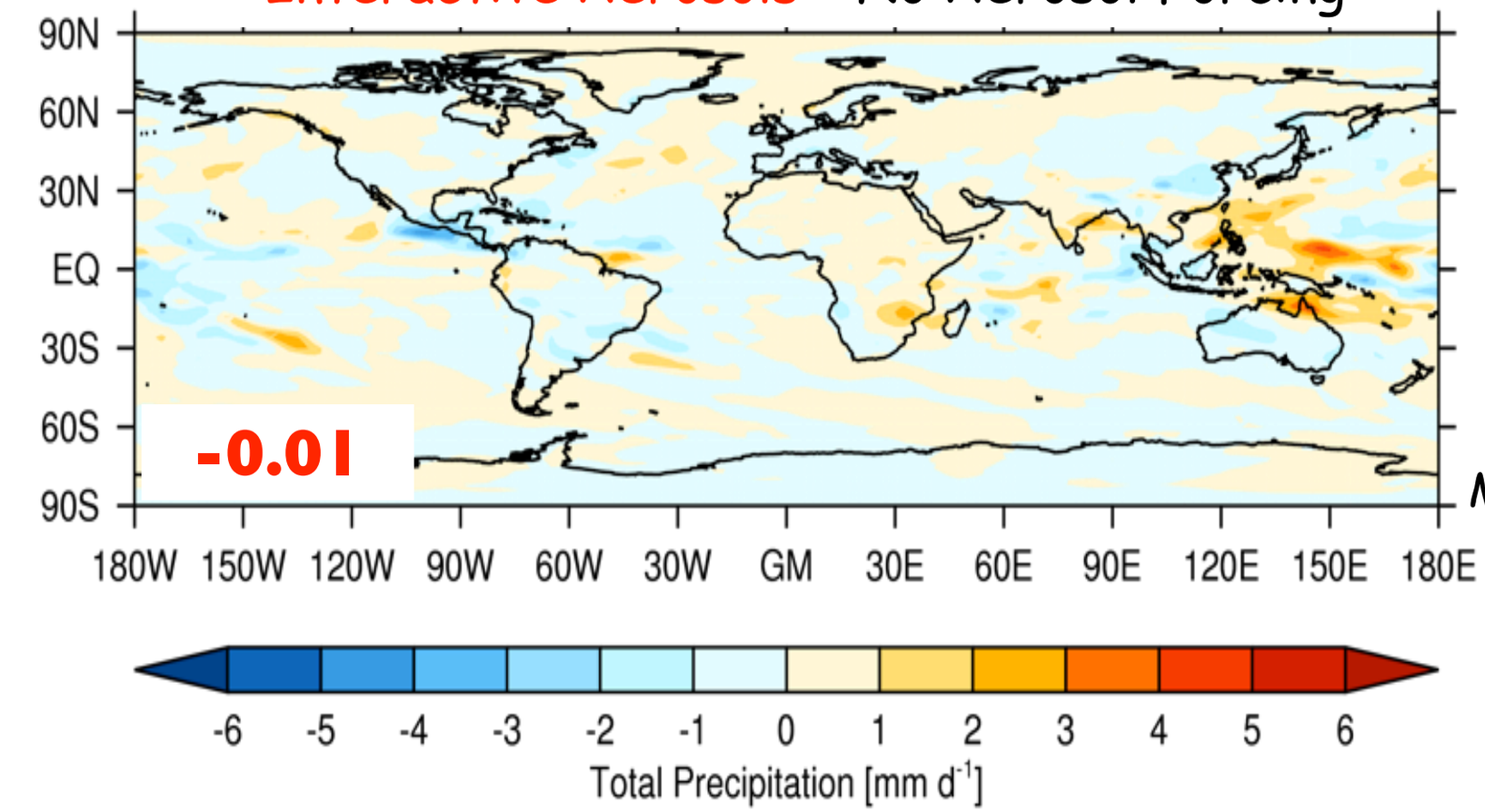




What are the effects of aerosols on climate?

Precipitation Change

Interactive Aerosols - No Aerosol Forcing



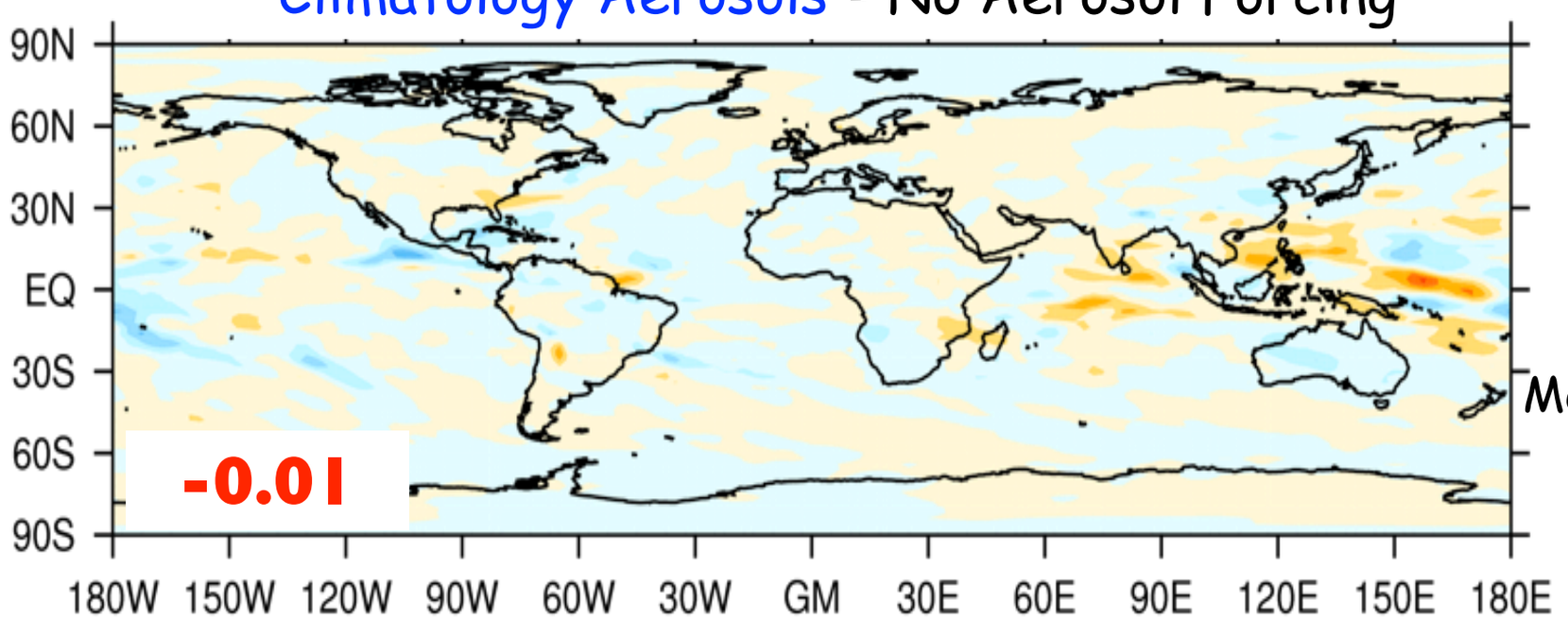
Aerosol Distributions

Interactive Aerosols

Meteorology

Aerosol Radiative Forcing

Climatology Aerosols - No Aerosol Forcing



Aerosol Distributions

Climatology Aerosols

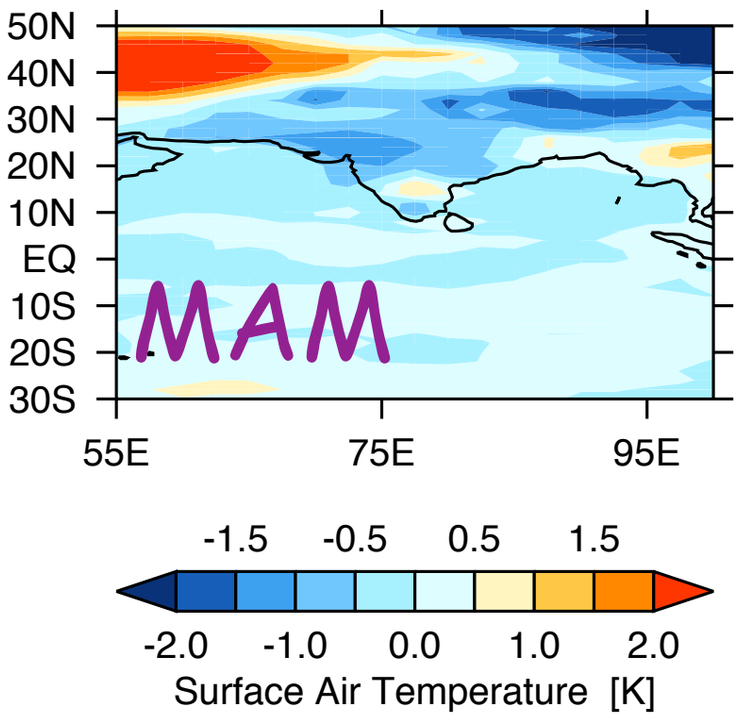
Meteorology

Aerosol Radiative Forcing

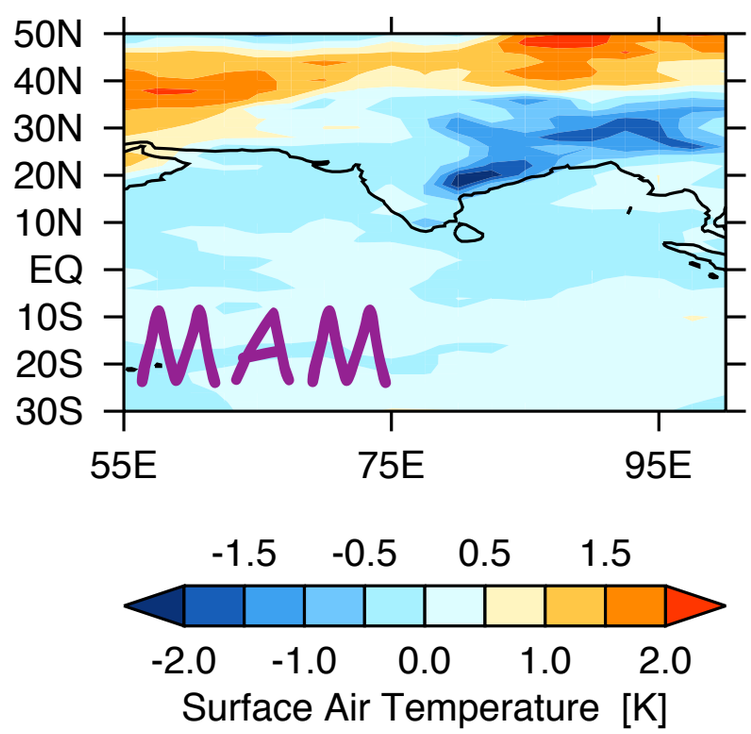
Regional and Shorter Time-Scale Changes

Surface Air Temperature Change

Interactive - No aerosols

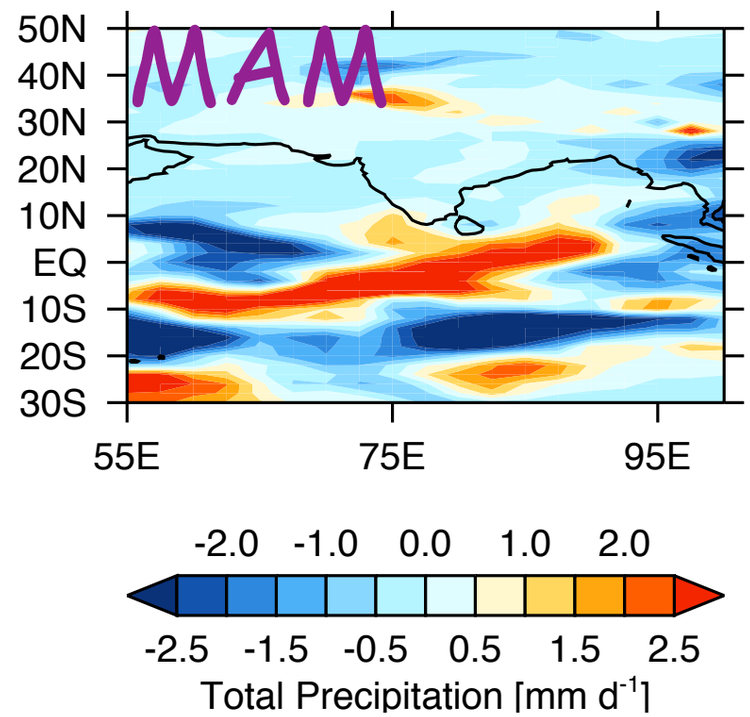


Climatology - No aerosols

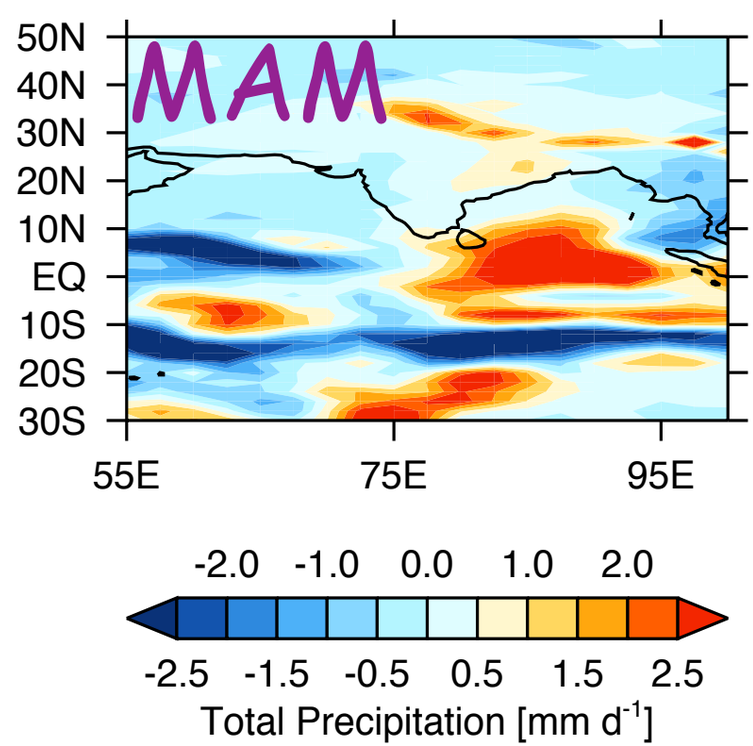


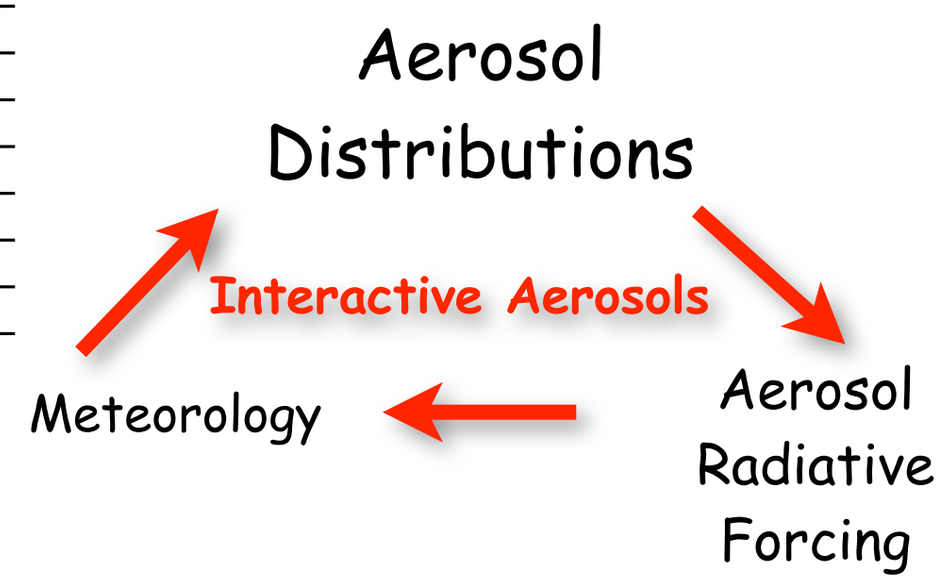
Precipitation Change

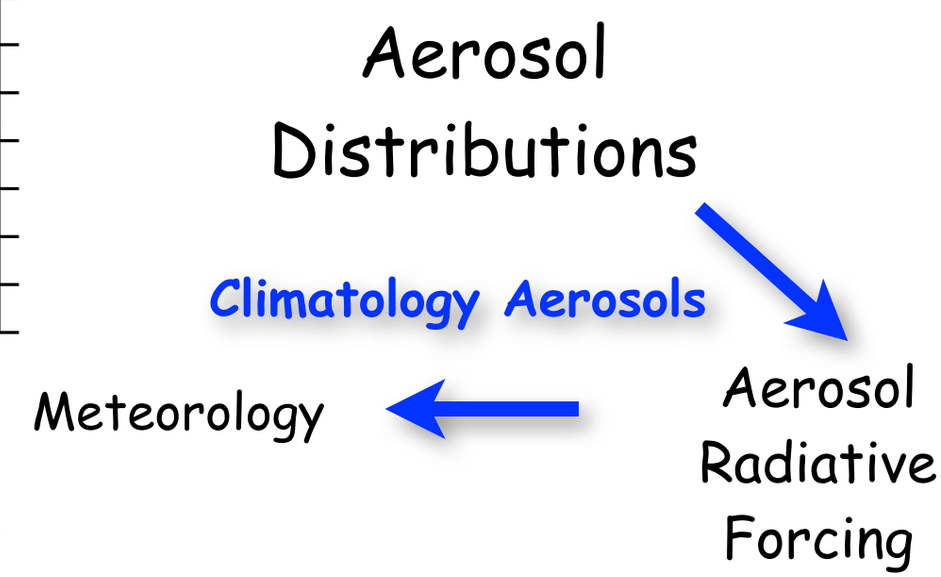
Interactive - No aerosols



Climatology - No aerosols







Take Home Message and Future Directions …

- On-line aerosols can impact model climate differently than off-line aerosol climatologies.
- Multi-year PIESA simulations (2000-2006) with multiple ensembles
  - Fully characterize GEOS-5 aerosol properties and compare to available observations
  - Examine global and regional climate response.
  - Determine statistical significance of response.
  - Eventually, repeat with coupled ocean-atmosphere model.
- Examples of ongoing refinements to aerosols in GEOS-5:
  - Diurnal biomass burning emissions
  - Sub-grid RH variability impacts on aerosol optical properties.