

MERRA-2 Aerosols: Monthly Mean Aerosol Optical Depth (AOD)

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3. NASA Atmospheric Chemistry and Dynamics Laboratory
4. GESTAR/USRA
5. GESTAR/Johns Hopkins University
6. SSAI

MERRA-2: Meteorological and Aerosol Reanalysis (1979 - Present)

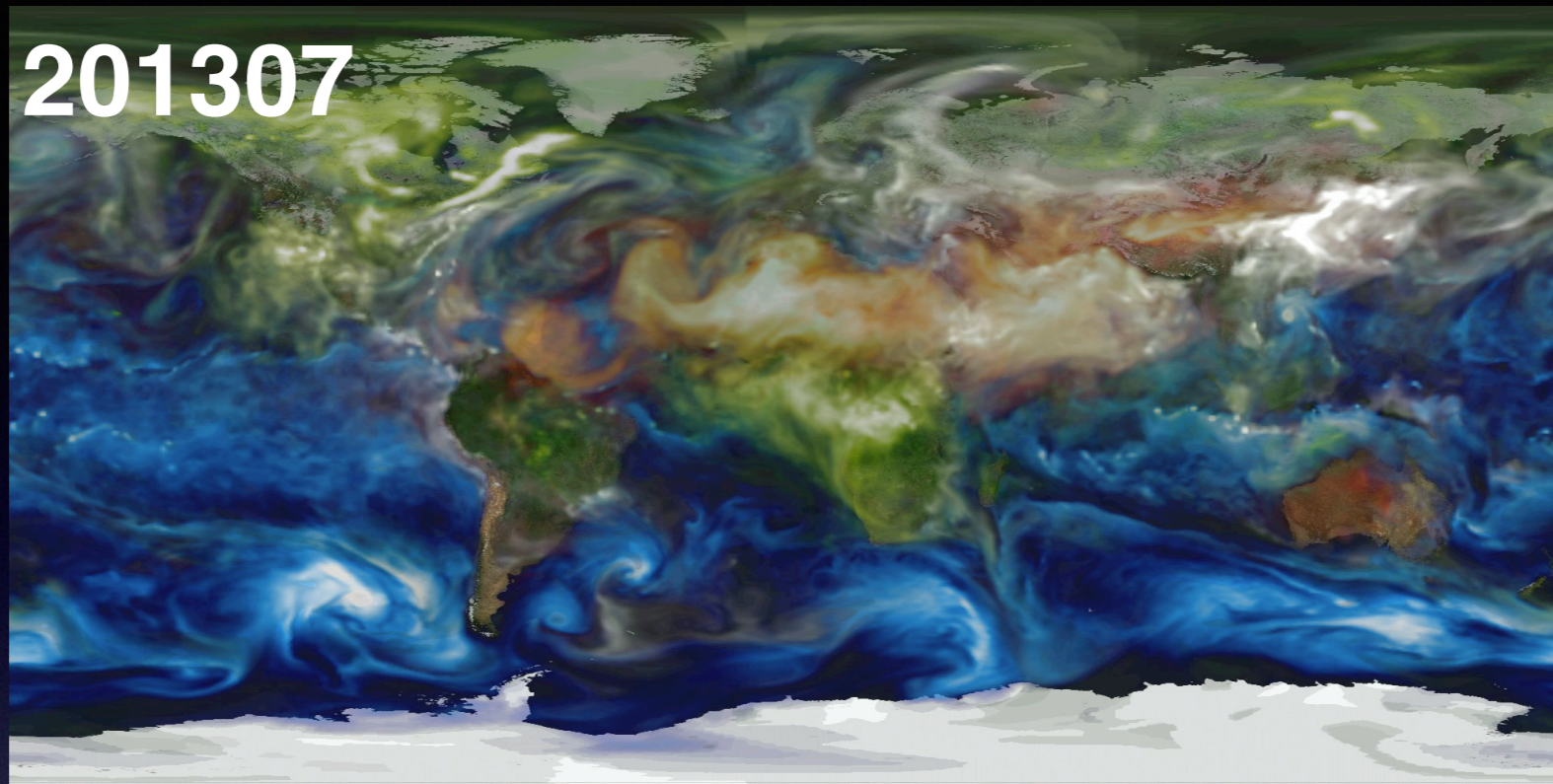
SO₄

201307

Carbon

Sea Salt

Dust



Feature	Description
Model	GEOS-5 Earth Modeling System with GOCART aerosols coupled to radiation parameterization
Fire Emissions	RETRO, GFED, and QFED: Daily, NRT, MODIS FRP based
Met. Data	MERRA-2 (run simultaneously with met. reanalysis)
Aerosol Observing System	MODIS: Aqua & Terra Neural Net Retrievals (NNR) of 550 nm AOD, AERONET, MISR (surface albedo > 0.15), AVHRR.
Resolution	~50 km (0.5° × 0.625° latitude × longitude), 72 layers, top ~85 km
Aerosol Species	Dust (DU), sea-salt (SS), sulfates (SO ₄), organic and black carbon

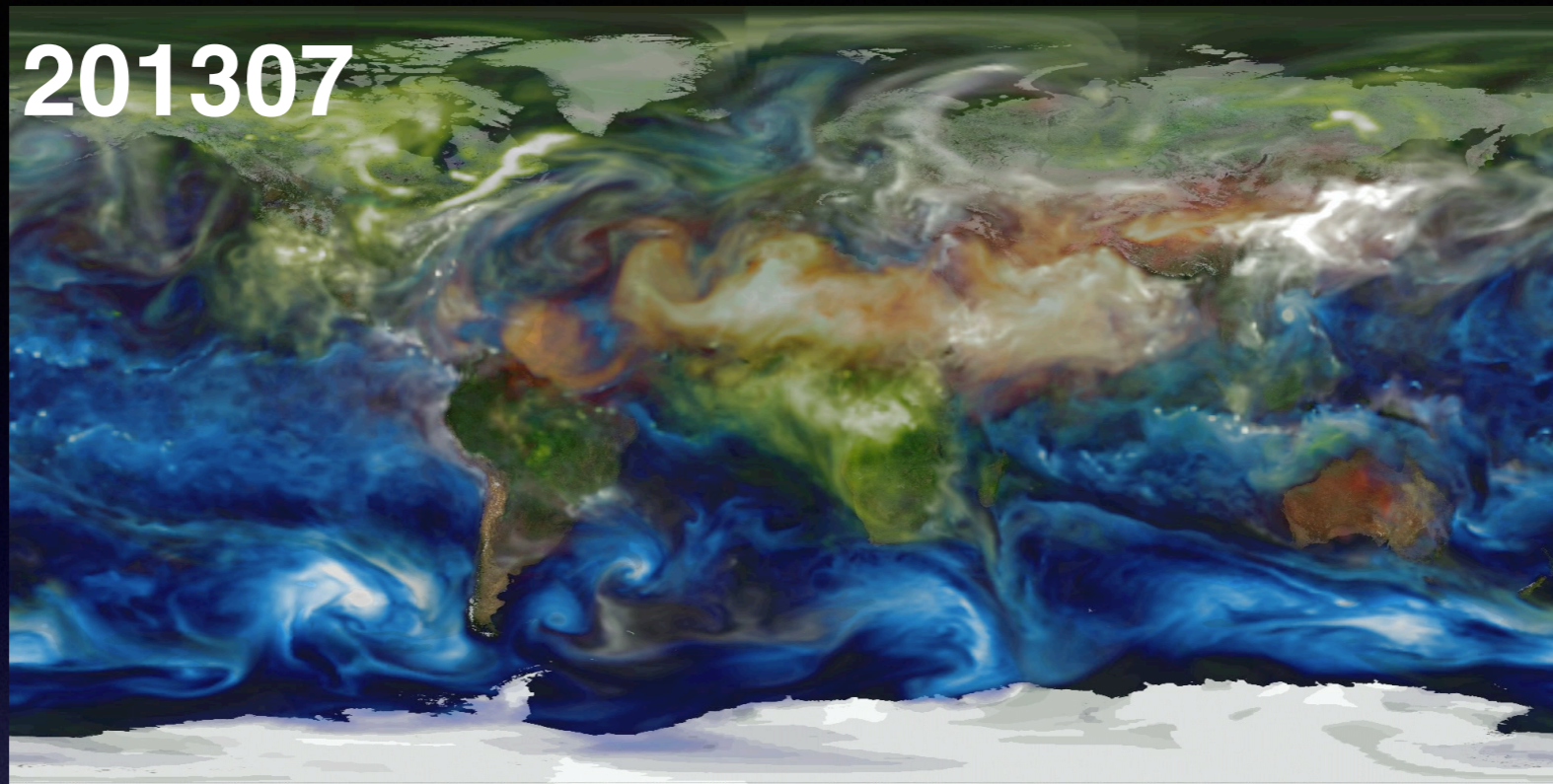
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Aerosol Assimilation: Forecast and Updates

Short-term
forecast

Obs. - Forecast AOD

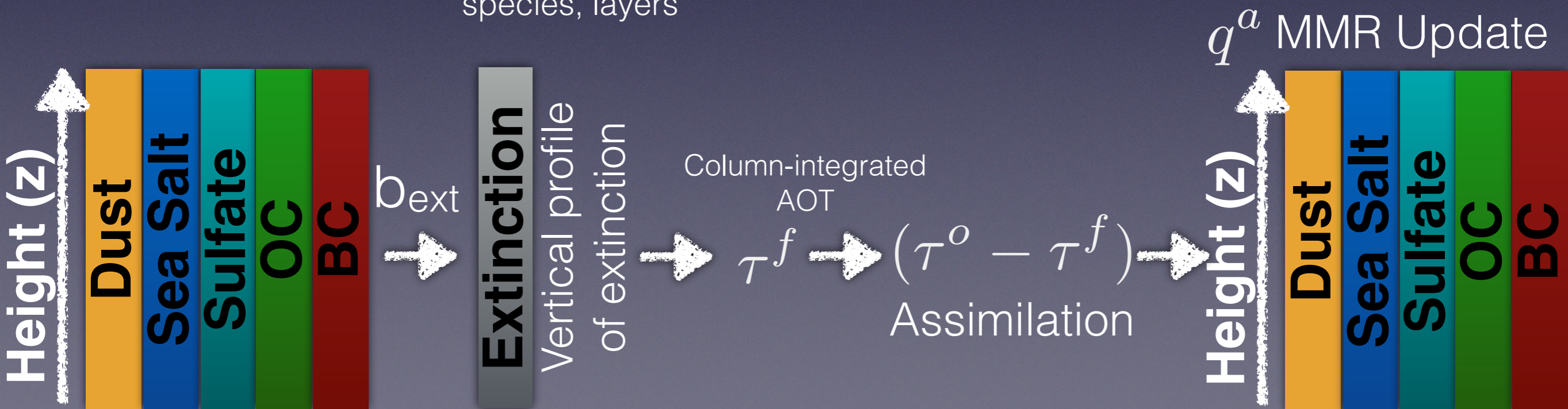
$$q^a = q^f + K \times (\tau^o - \tau^f)$$

Mass-mixing
ratio updated

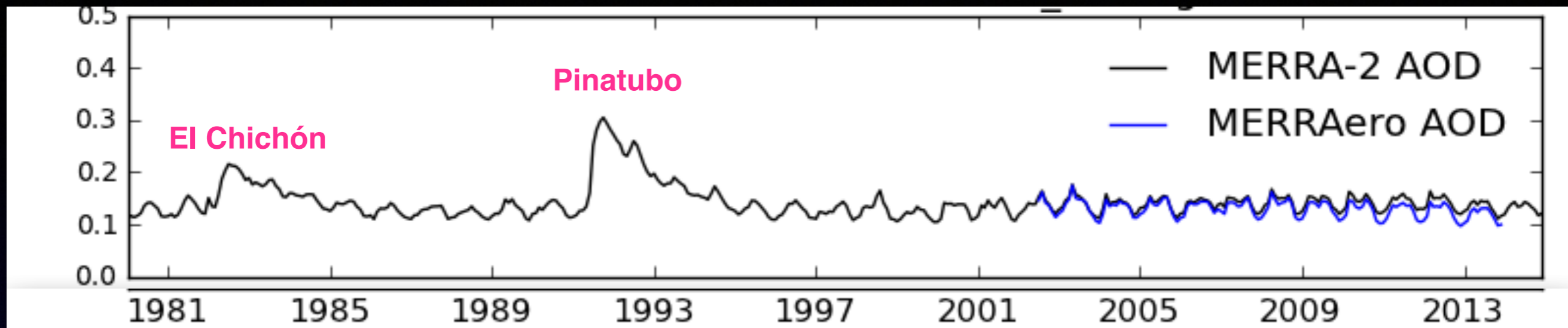
Operator

$$\tau^f = \sum_{\text{species, layers}} q^f \times \rho \times b_{ext}$$

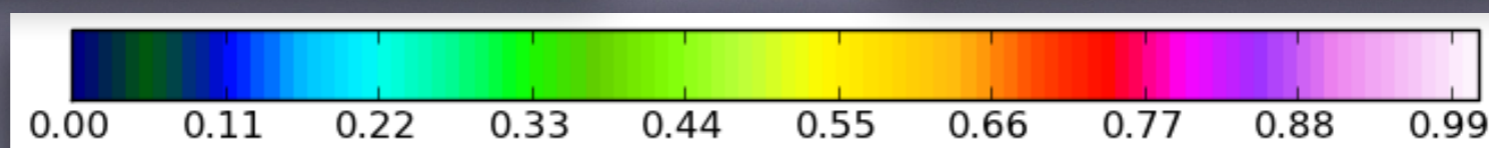
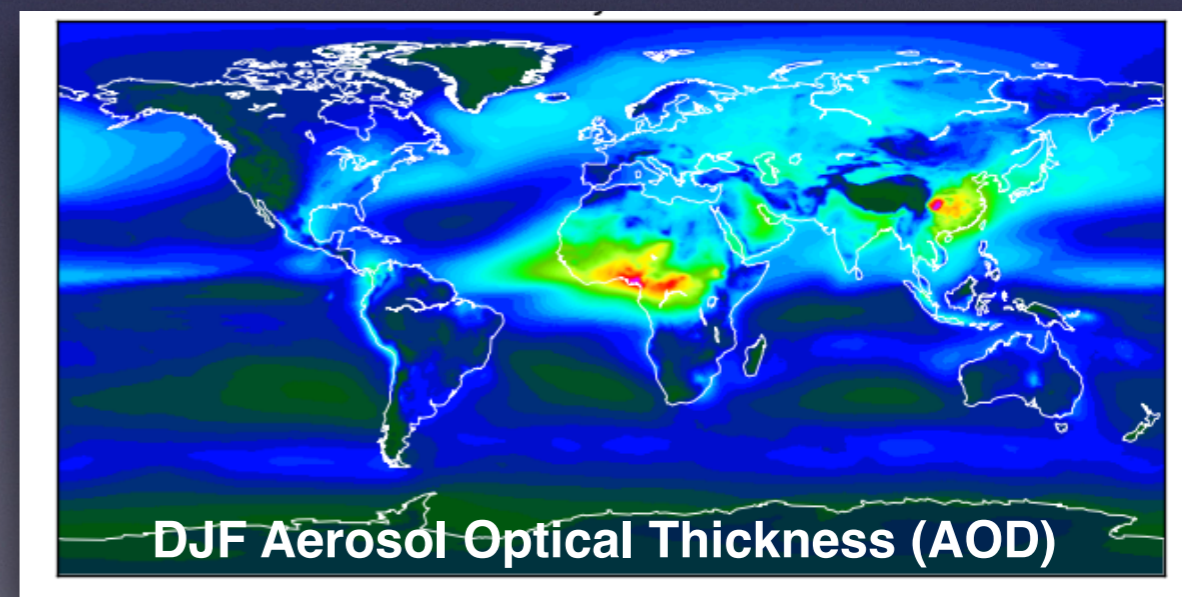
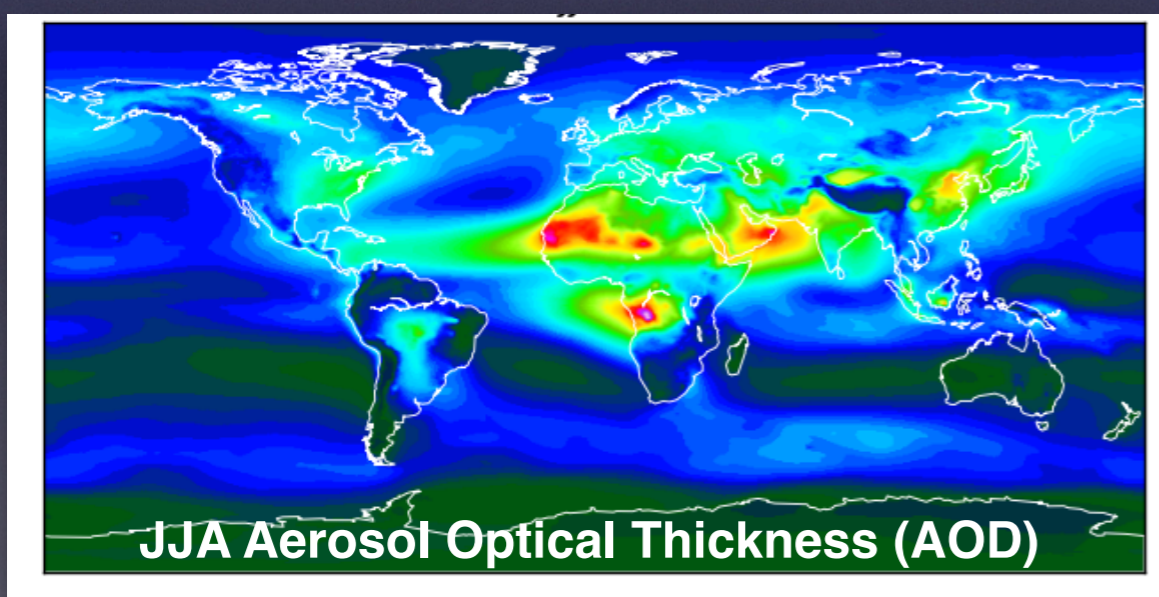
Optics Assumptions



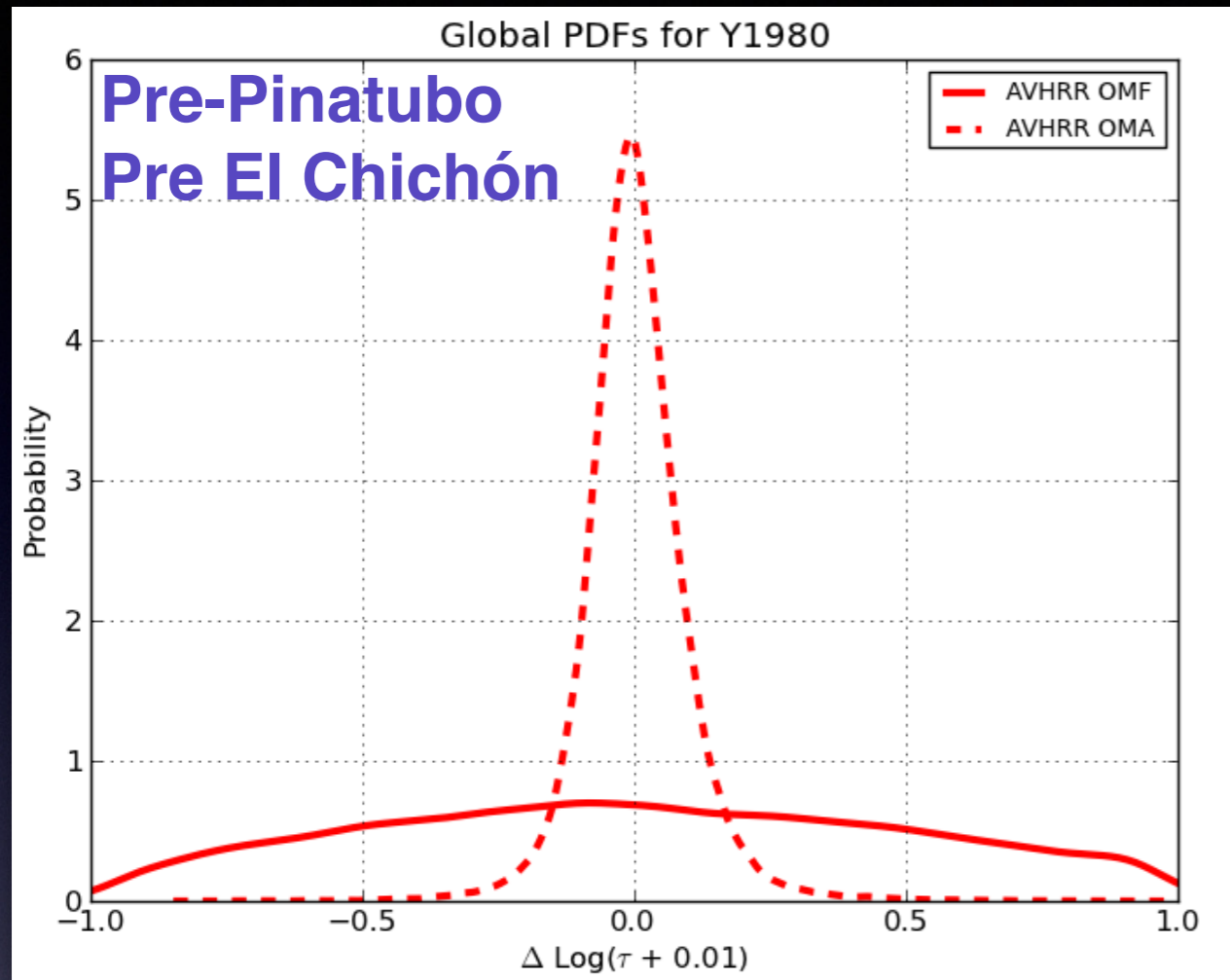
AOD Climatology and Time Series



- Monthly-mean time series dominated by major volcanic eruptions.
- MERRA-2 and previous aerosol assimilation (MERRAero; used MERRA-1 met and assimilated MODIS only) show good agreement in EOS period.

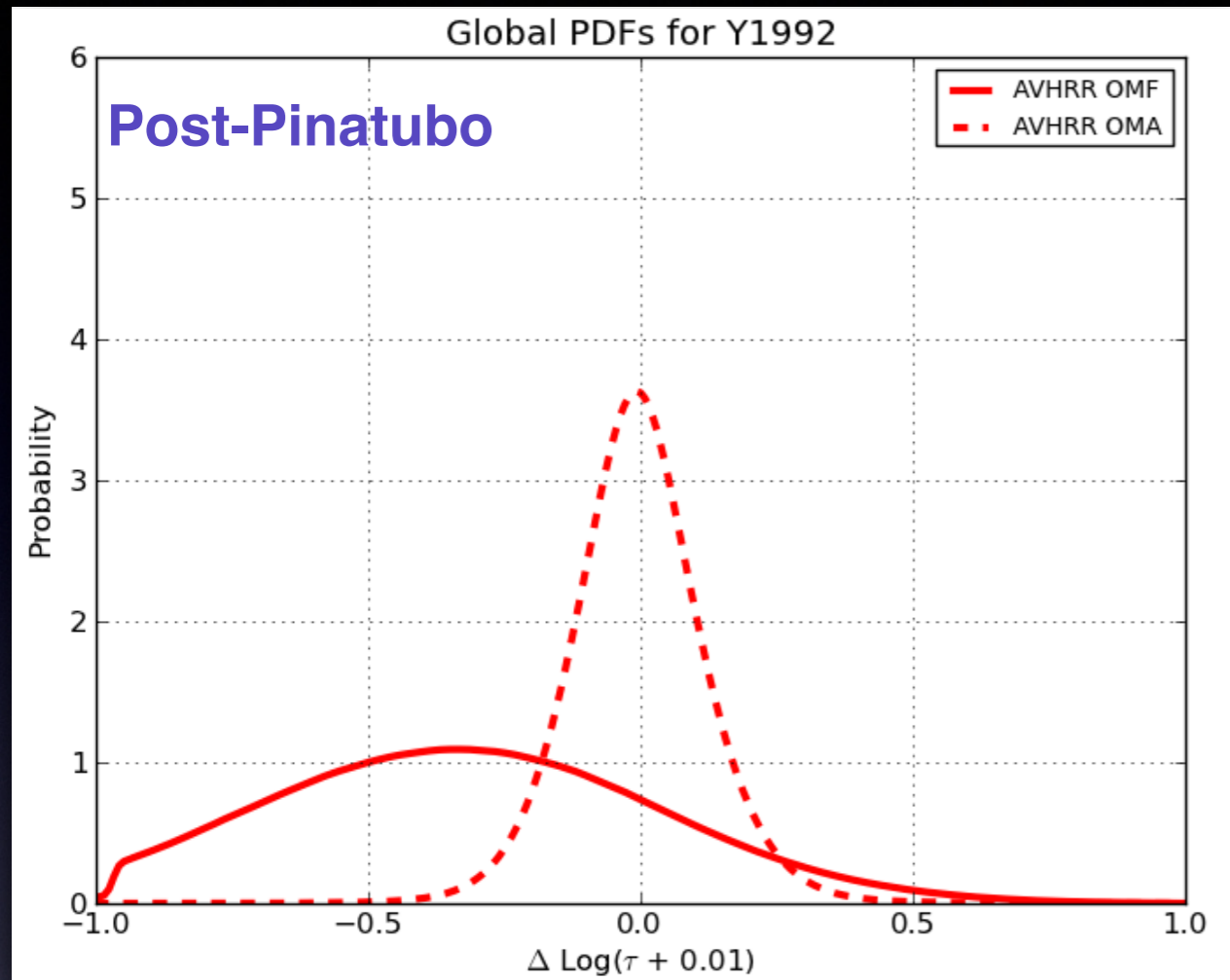


MERRA-2 AOD: O-F and O-A



Observation	Period	Coverage
AVHRR	January 1979 - August 2002	Ocean Only
AERONET	January 1999 - December 2013	Land Surface Stations
MODIS Terra NNR	March 2000 - December 2013	Dark Target
MISR	March 2000 - December 2013	Bright Surface (albedo > 0.15)
MODIS Aqua NNR	August 2002 - December 2013	Dark Target

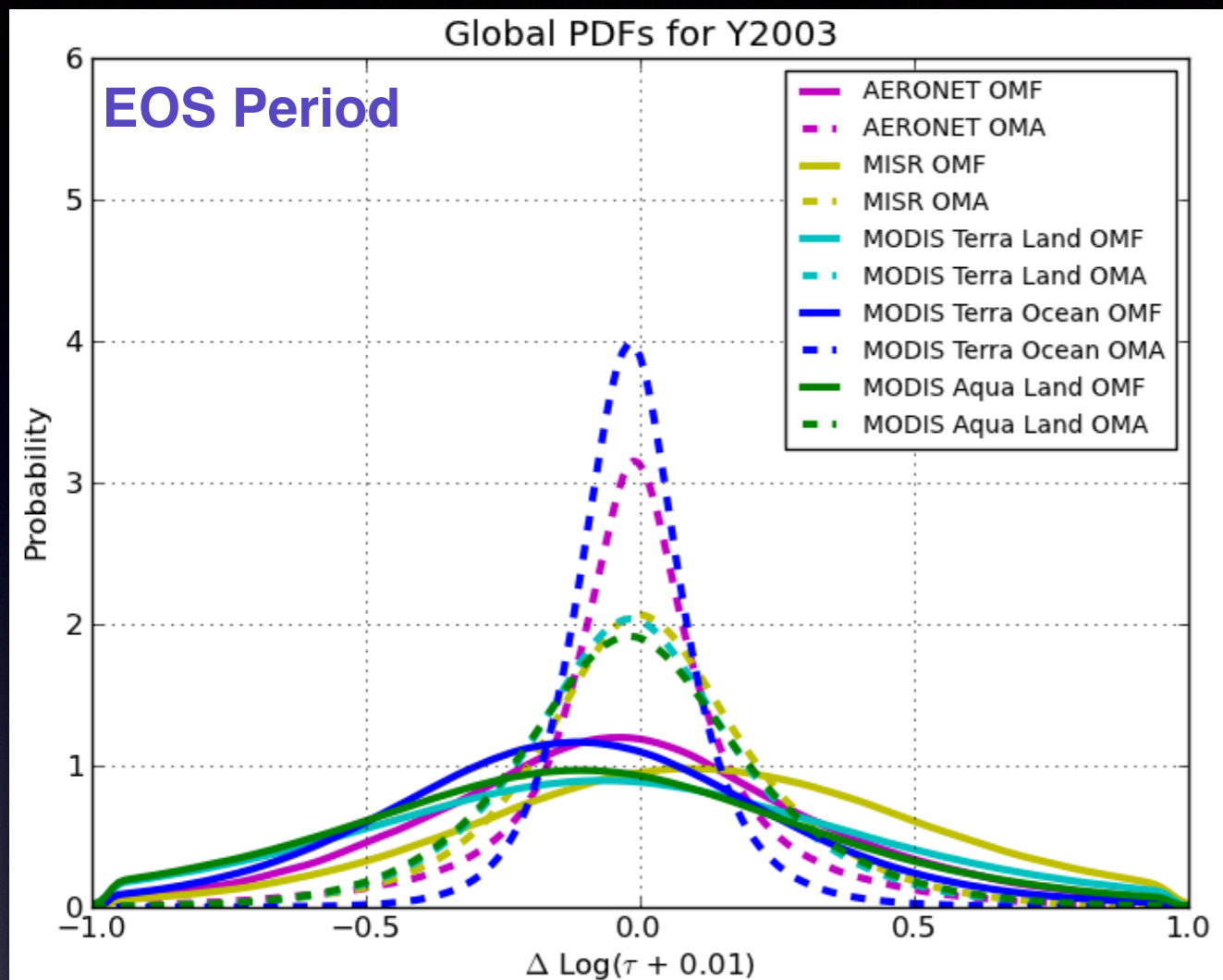
MERRA-2 AOD: O-F and O-A



- **O - F Post-Pinatubo indicates forecast AOD too high.**
 - In M2 stratospheric sulfate/volcanic aerosol size = tropospheric sulfate size.
 - For Pinatubo emissions used, volcanic/stratospheric size should be larger than tropospheric [Aquila *et al.* 2012].

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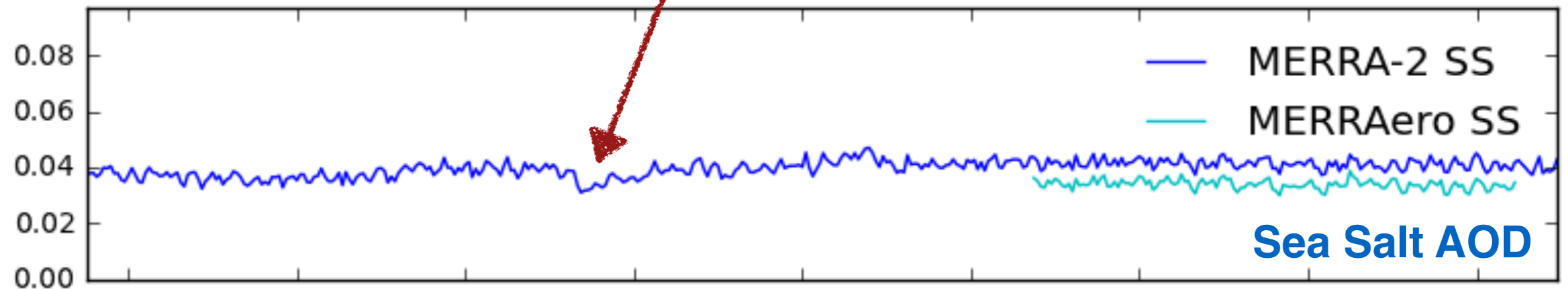
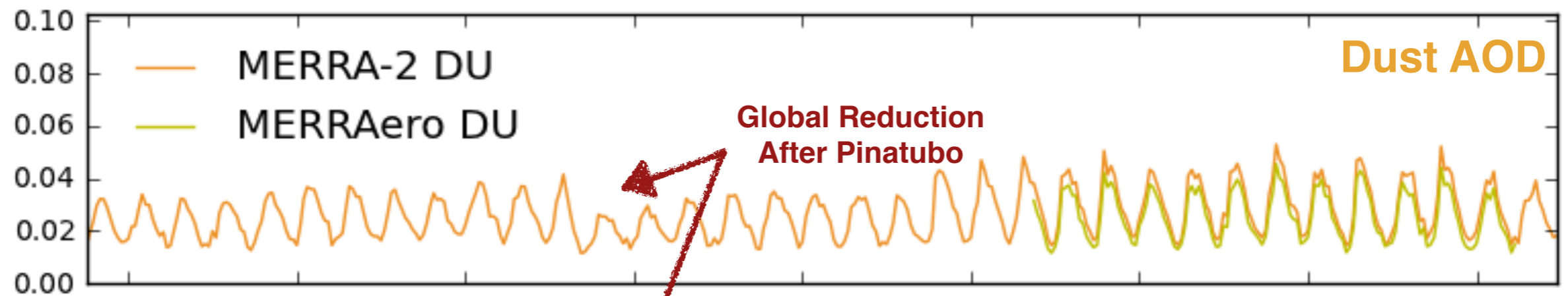
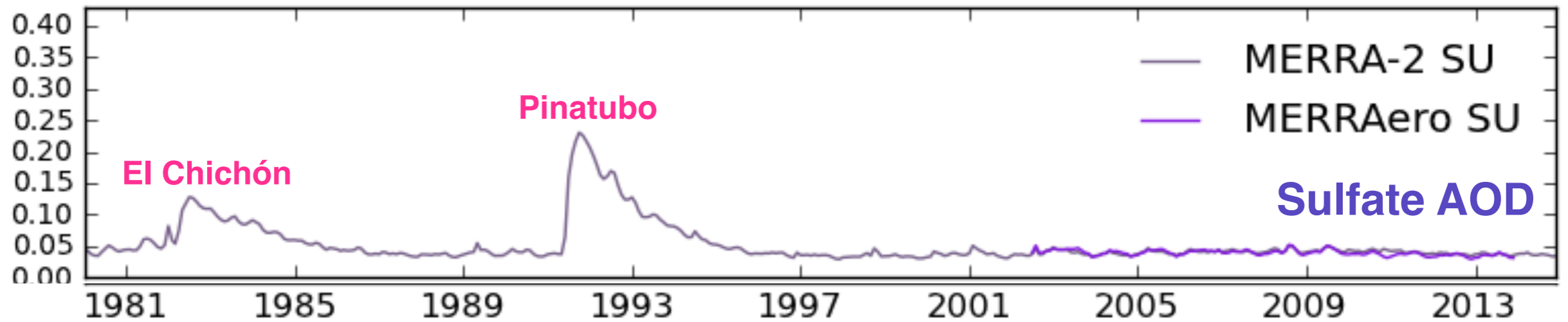
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- **EOS-period forecast AOD over bright surfaces too low (MISR).**

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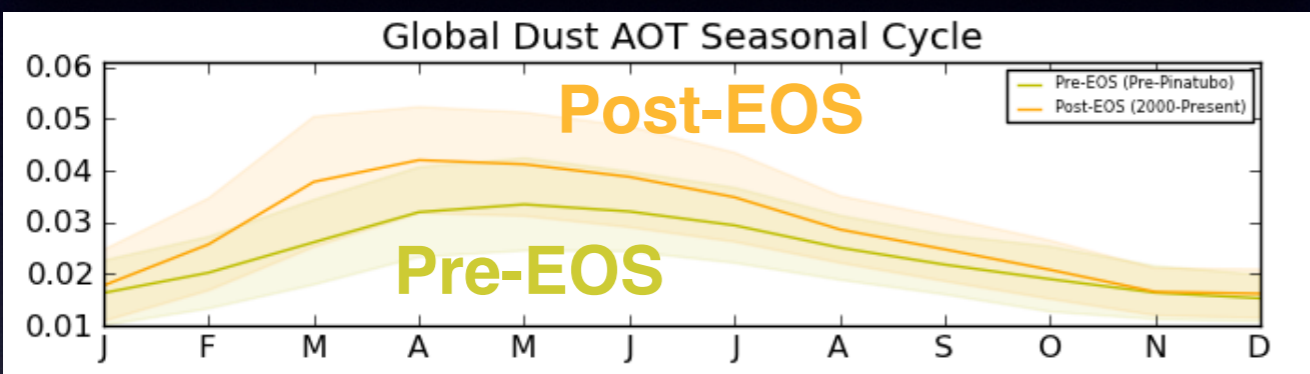
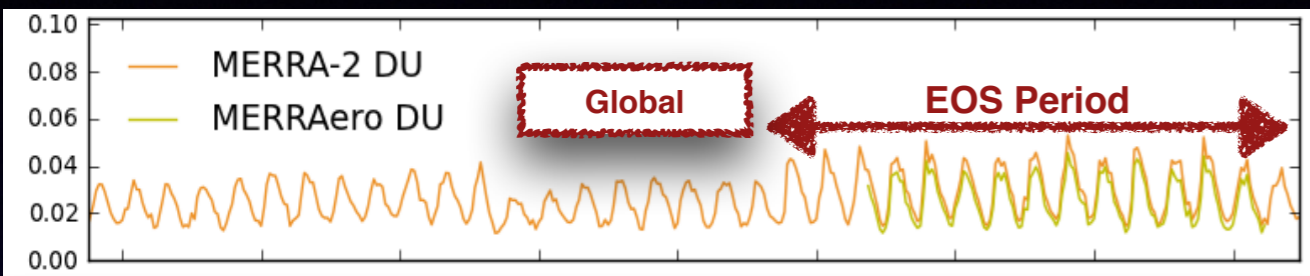
Impact of Large Volcanic Eruptions on Non-Volcanic Species



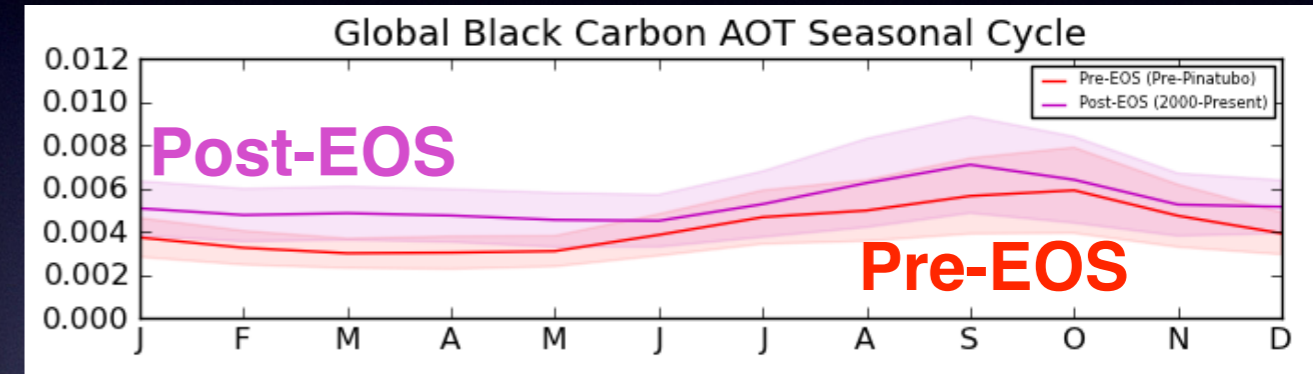
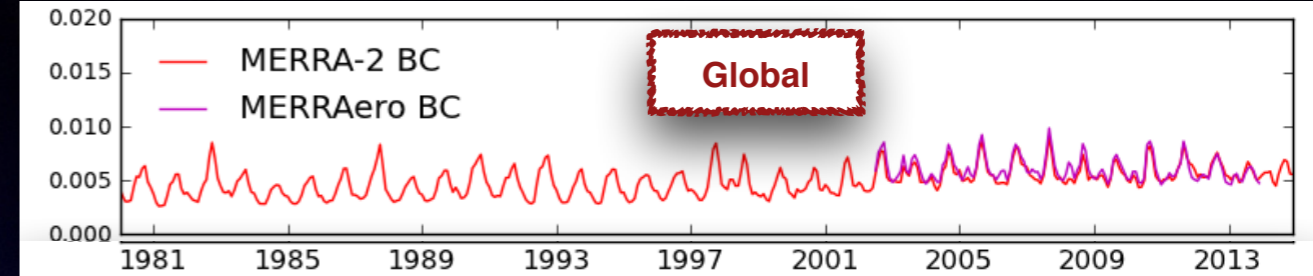
- During/after Pinatubo, AOD analysis increments were applied to all species, not only sulfate aerosols.
- Artificial decrease in other species results.

MERRA-2 AOD: Global Seasonal Cycle

DUST AOD

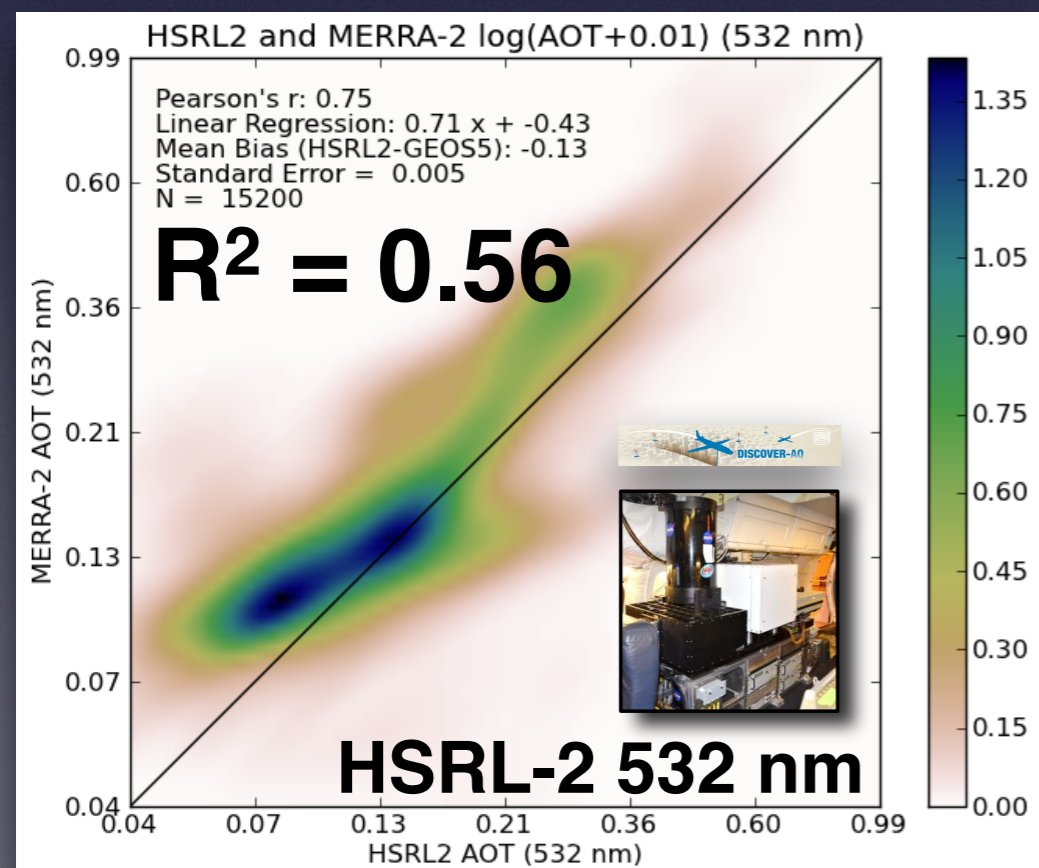
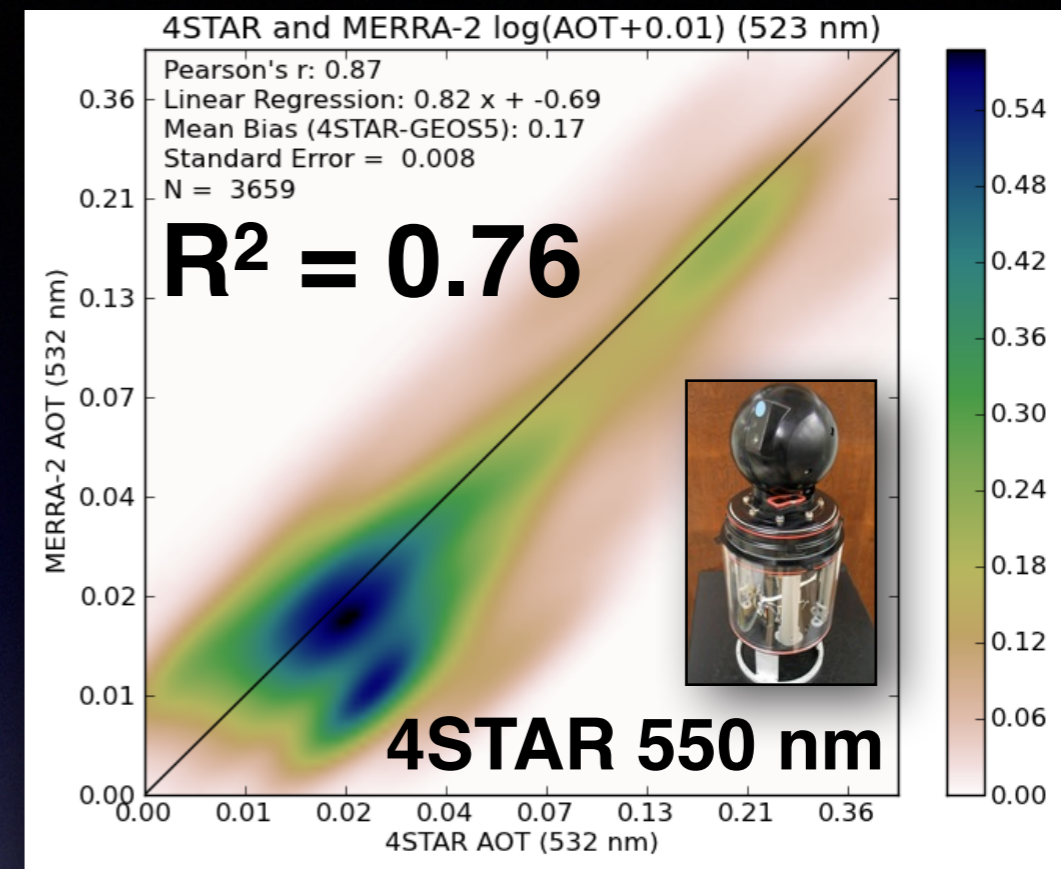
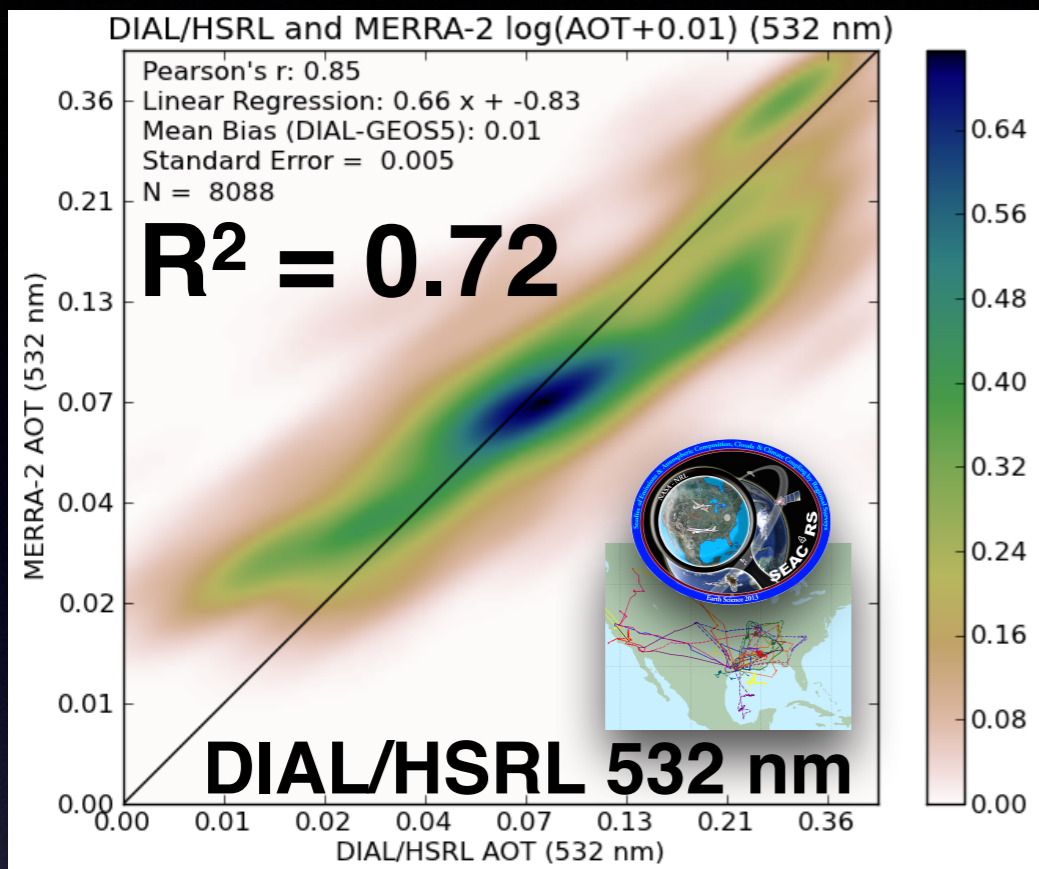


Black Carbon AOD



- Pre- and Post-EOS differences in AOD seasonal cycle.
 - Depending on aerosol species, results from a combination of differences in observing system and emissions.
- ➔ Prior to EOS-period AVHRR over Ocean Only!

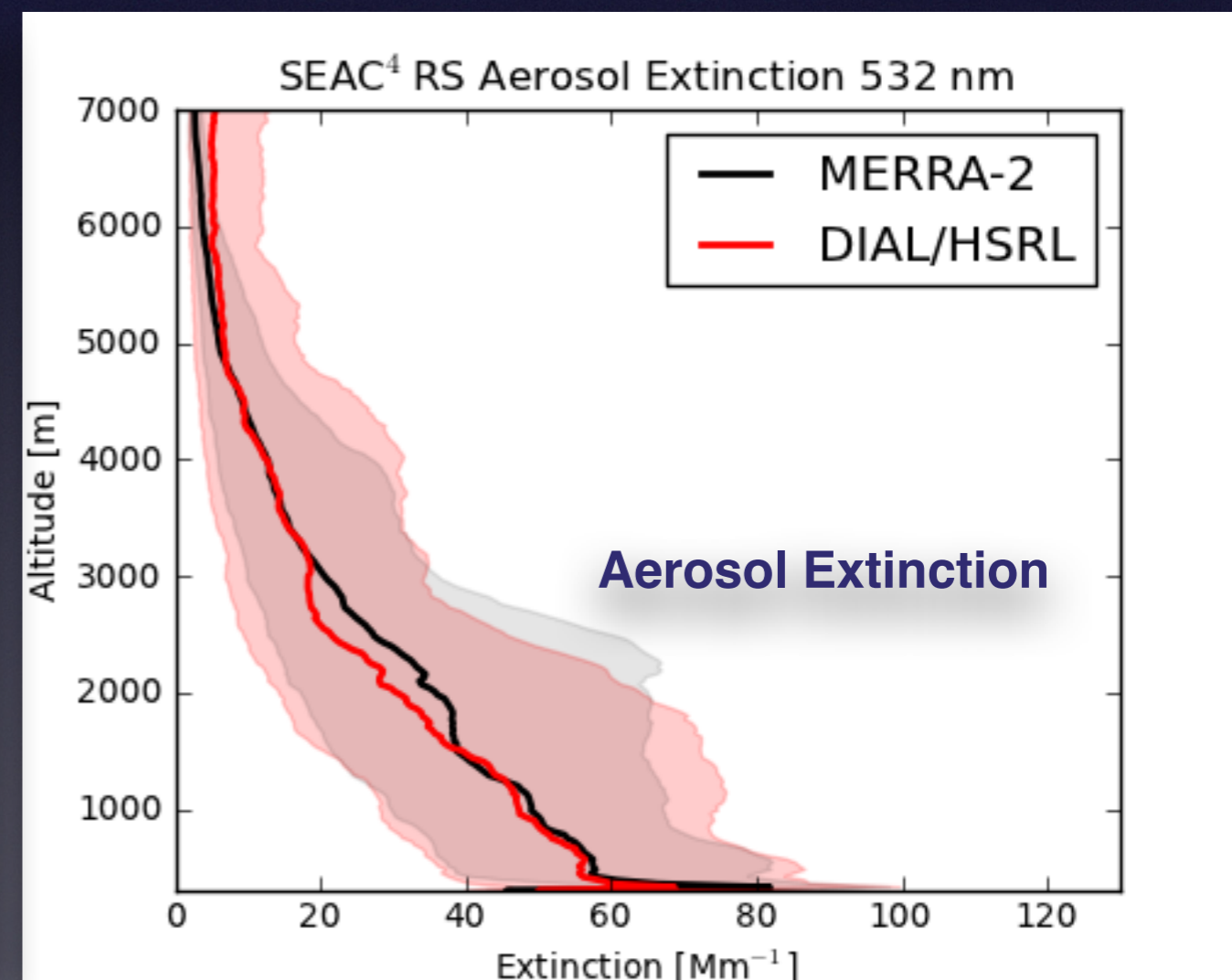
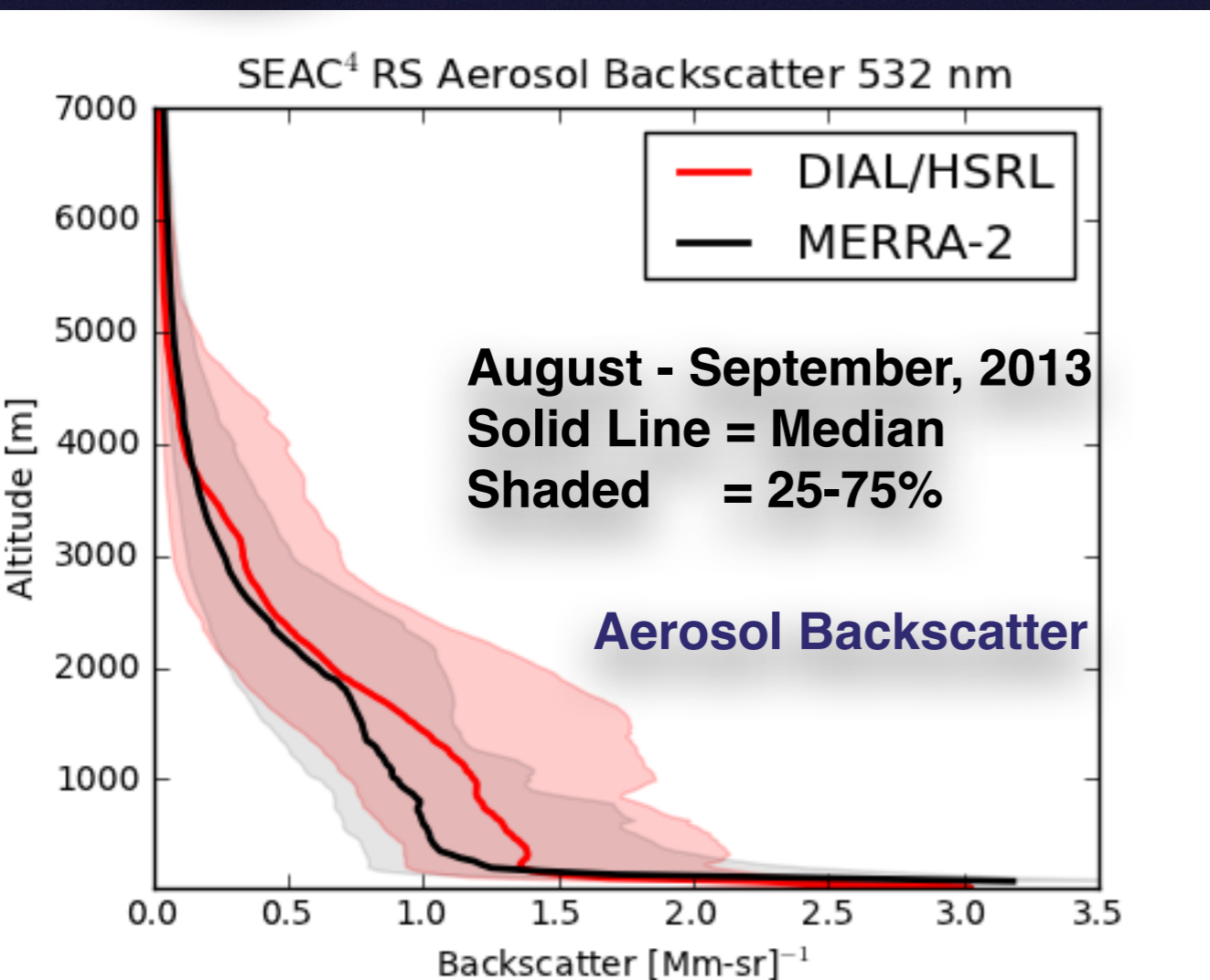
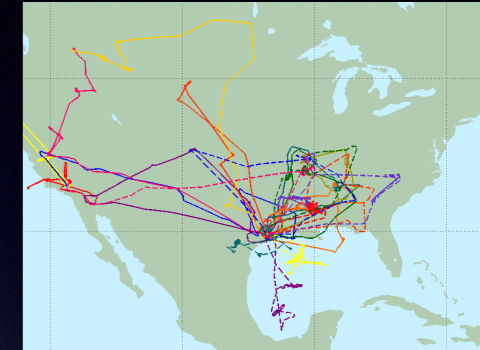
Independent Validation: SEAC⁴RS/DAQ DIAL/HSRL/HSRL-2 and 4STAR AOD



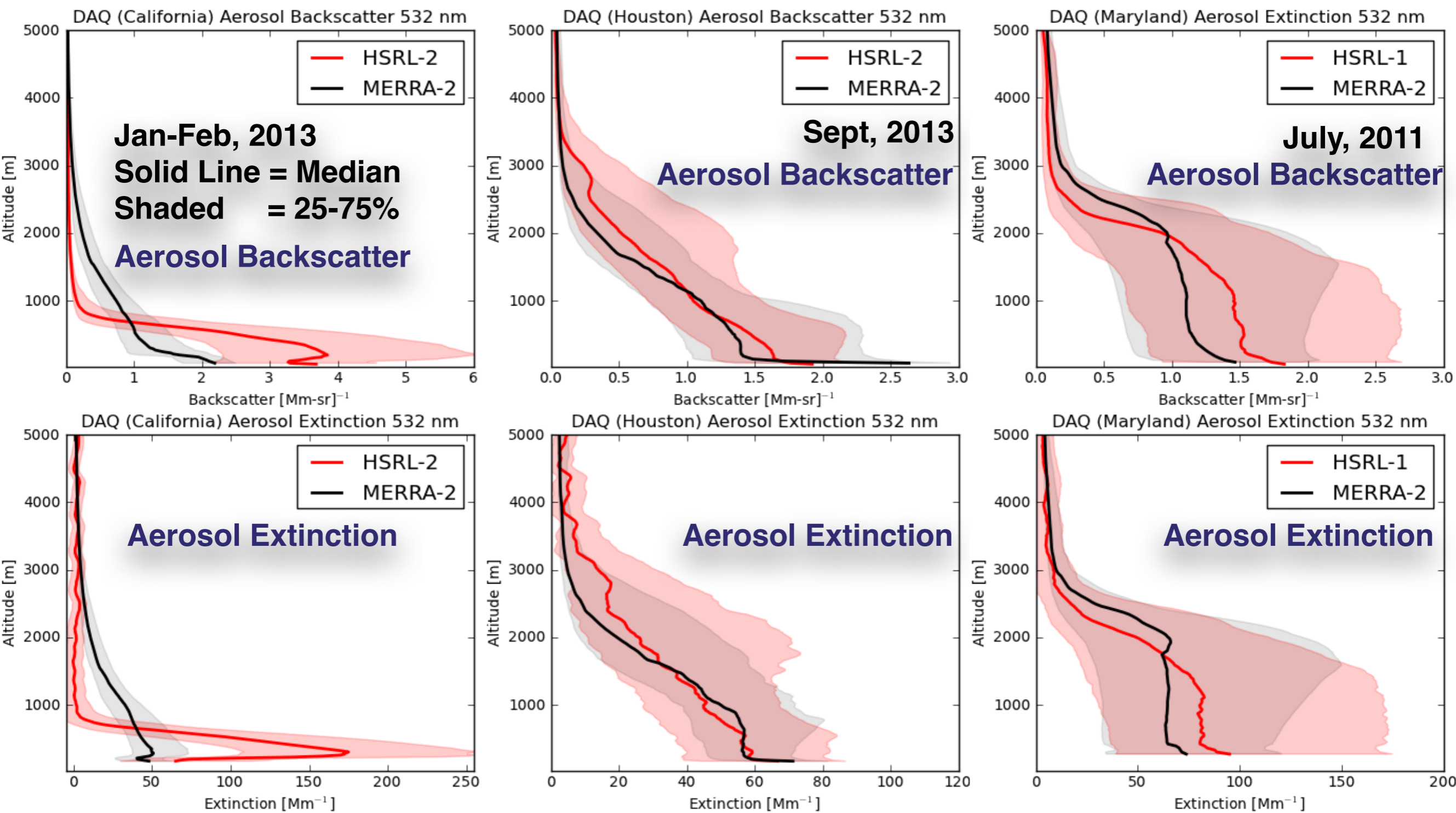
- MERRA-2 sampled along-track and between DIAL/HSRL/HSRL-2 specified minimum and maximum levels for AOD calculation.
- Model sampled along-track and *above* DC8 for 4STAR comparison.
- **N.B.:** AOT Assimilation constrains the total column AOD at 550 nm; the vertical distribution of aerosols remains ~ the same as in the forecast model (GEOS-5/GOCART).

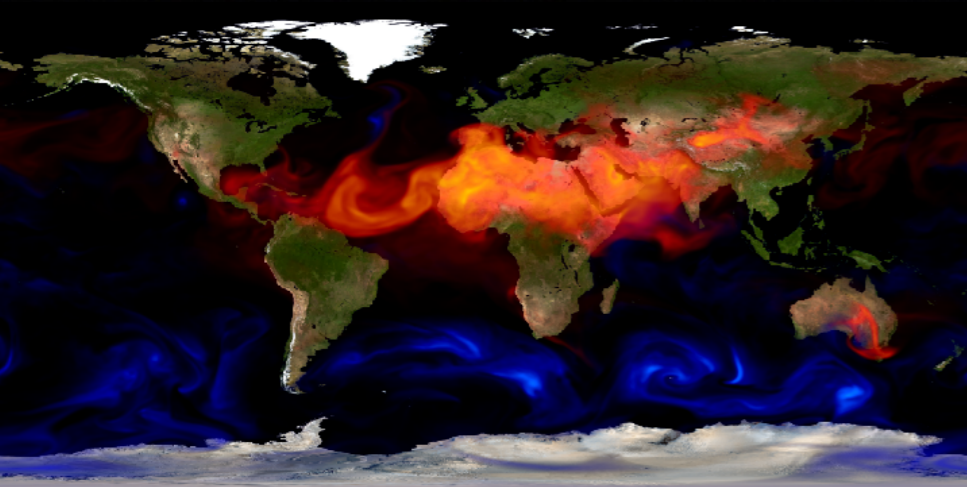
Independent Validation: MERRA-2 and DIAL/HSRL

- Assimilation only constrains (column) optical depth.
- Reasonable agreement of aerosol backscatter profiles over North America with observations.



Independent Validation: MERRA-2 and HSRL-1/HSRL-2





Summary

- Global Mean AOD time series is reasonable and agrees with previous aerosol assimilation (MERRAero).
- Strong volcanic influence on time series of individual aerosol species AOD.
- Pre- and Post-EOS periods show differences in individual aerosol species, particularly seasonally and regionally.
- Good agreement with independent AOD observations from field campaigns over United States (SEAC⁴RS, DISCOVER-AQ).

END

Impact of Large Volcanic Eruptions

