Using the NASA GEOS-5 MERRAero Aerosol Reanalysis to Understand the OMI OMAERUV Aerosol Products

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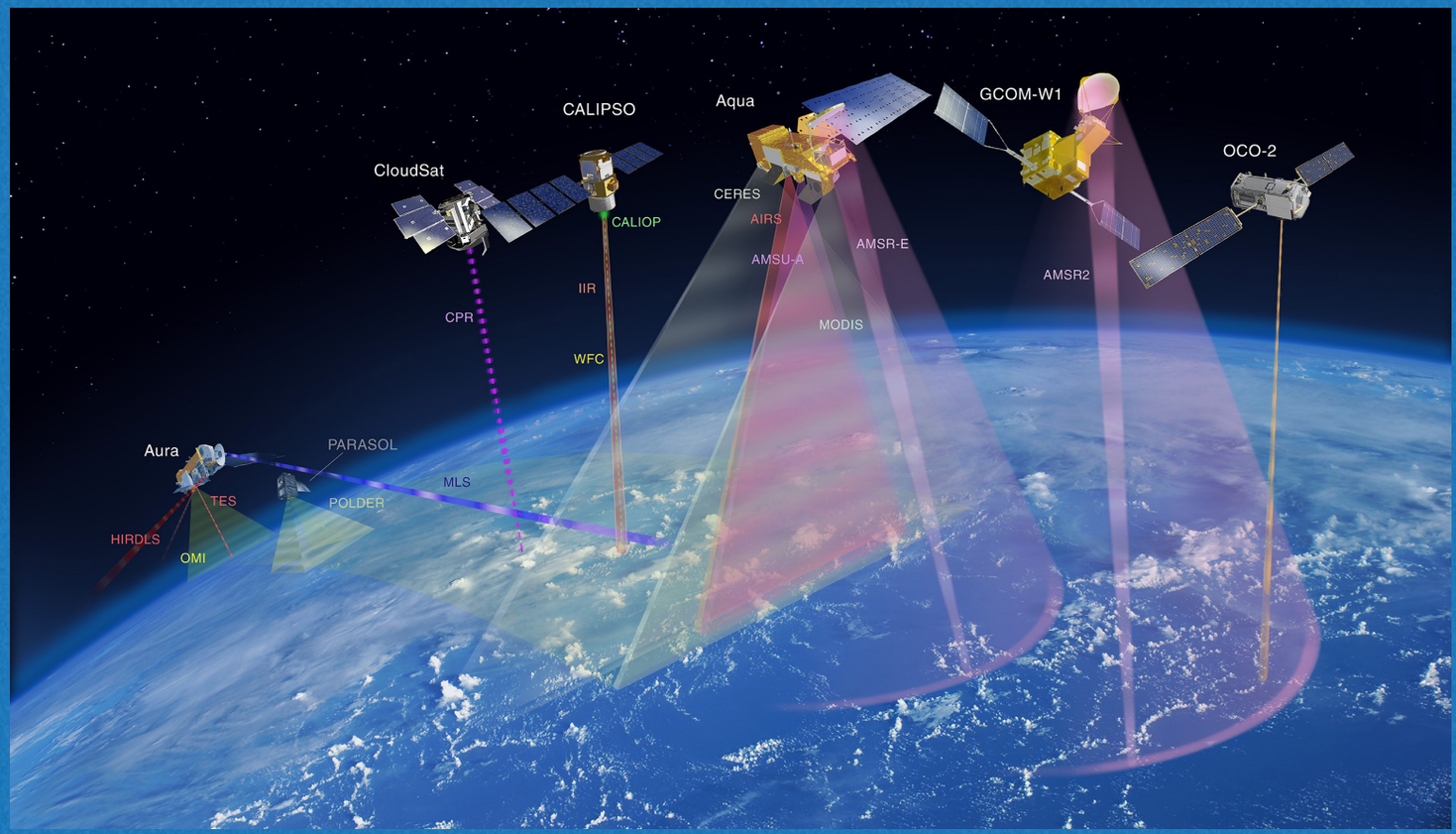
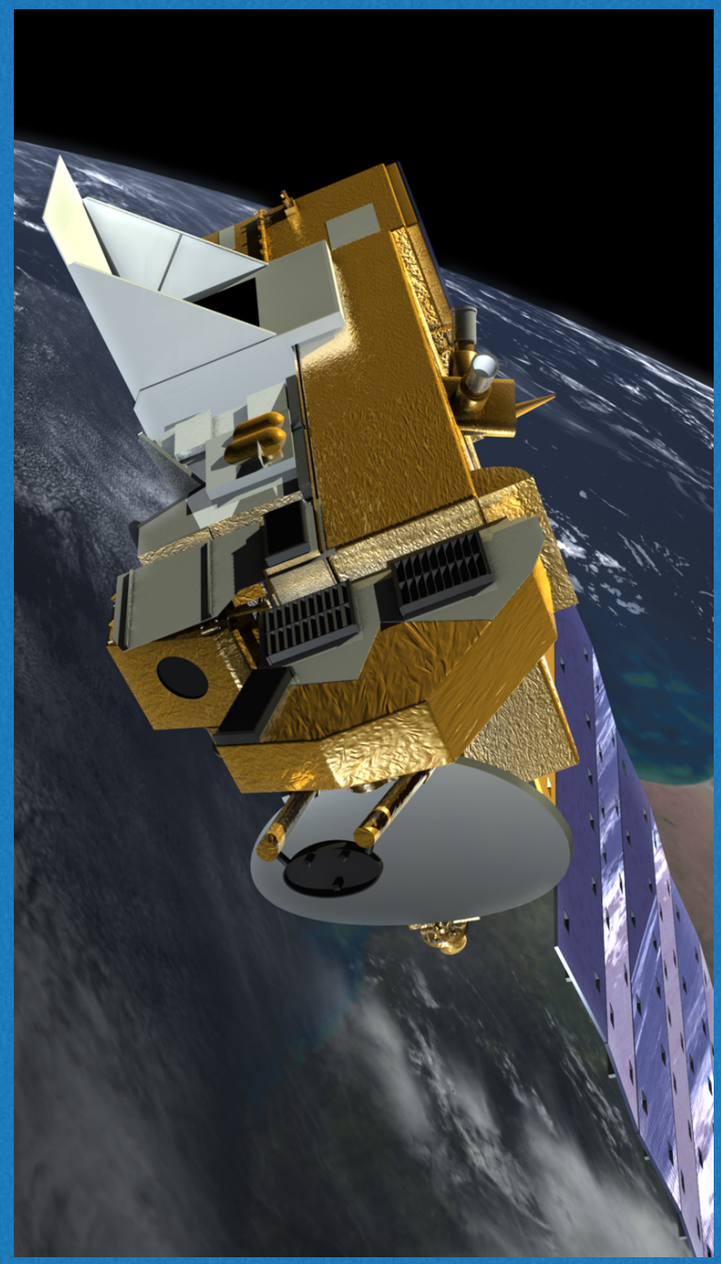


Objective and Approach

- Our objective is to investigate the sensitivity of the **OMI OMAERUV** aerosol retrieval algorithms to various aerosol parameters using synthetic data
- Our approach is to use the GEOS-5 produced **MERRAero aerosol reanalysis** as a proxy for nature
  - simulate the OMI radiance observations
  - provide these as inputs to OMAERUV
  - compare retrieved aerosol products to those directly calculated in model
- This kind of **Observing System Simulation Experiment** is a powerful tool to interrogate the retrieval algorithms we rely on for our science

Aura and OMI

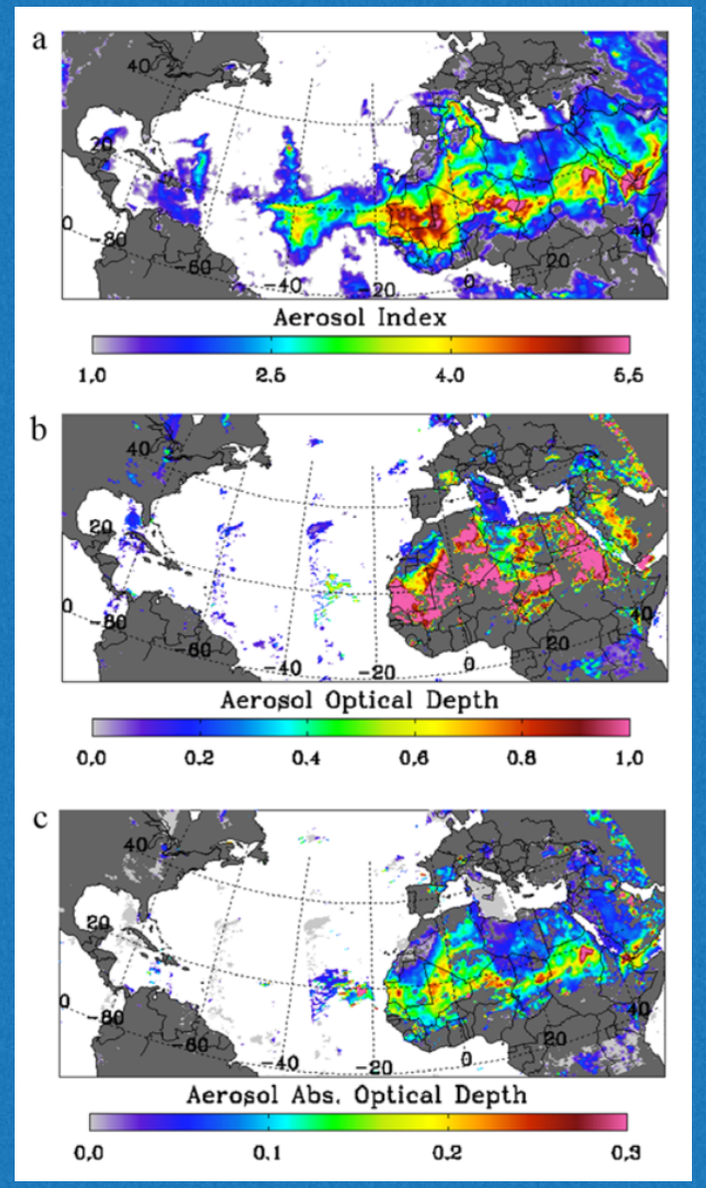
- Aura was launched July 15, 2004
- Positioned into A-Train constellation, about 1:30/13:30 local equator crossing time
- OMI
  - Ozone Monitoring Instrument
  - Joint Dutch-Finnish instrument
  - Wide-swath (~2600 km), hyperspectral (270 - 500 nm) imager (13 x 24 km^2 at nadir)
  - Measures ozone, trace gases, aerosols
  - Heritage with Total Ozone Mapping Spectrometer (TOMS)



OMI Aerosol Products

- There are at least two different aerosol retrieval algorithms in use
  - Multi-channel (19 wavelength) algorithm (Torres et al. 2002; Curier et al. 2008)
  - Two channel (354 and 388 nm) TOMS-like algorithm (OMAERUV, Torres et al. 2007)

- OMAERUV
  - UV measurements show sensitivity to aerosol absorption and altitude
  - Products include the aerosol index (AI), AOD, AAOD/SSA



Torres et al. 2007

The OMI Aerosol Index

Aerosol Index gives semi-quantitative information about the distributions of absorbing aerosols, sensitive to height and single scattering albedo

$$AI = -100 \cdot \log_{10}\left(\frac{I_{354}}{I_{354}^{Ray}\left(LER'_{388}\right)}\right)$$

$$LER_{\lambda} = \frac{I_{\lambda} - I_{\lambda}^{Ray}}{T_{\lambda}^{Ray} + S_{\lambda}^{Ray}\left(I_{\lambda} - I_{\lambda}^{Ray}\right)}$$

$$LER'_{388} = LER_{388} - \left(Alb_{388} - Alb_{354}\right) \cdot cf$$

AI Algorithm

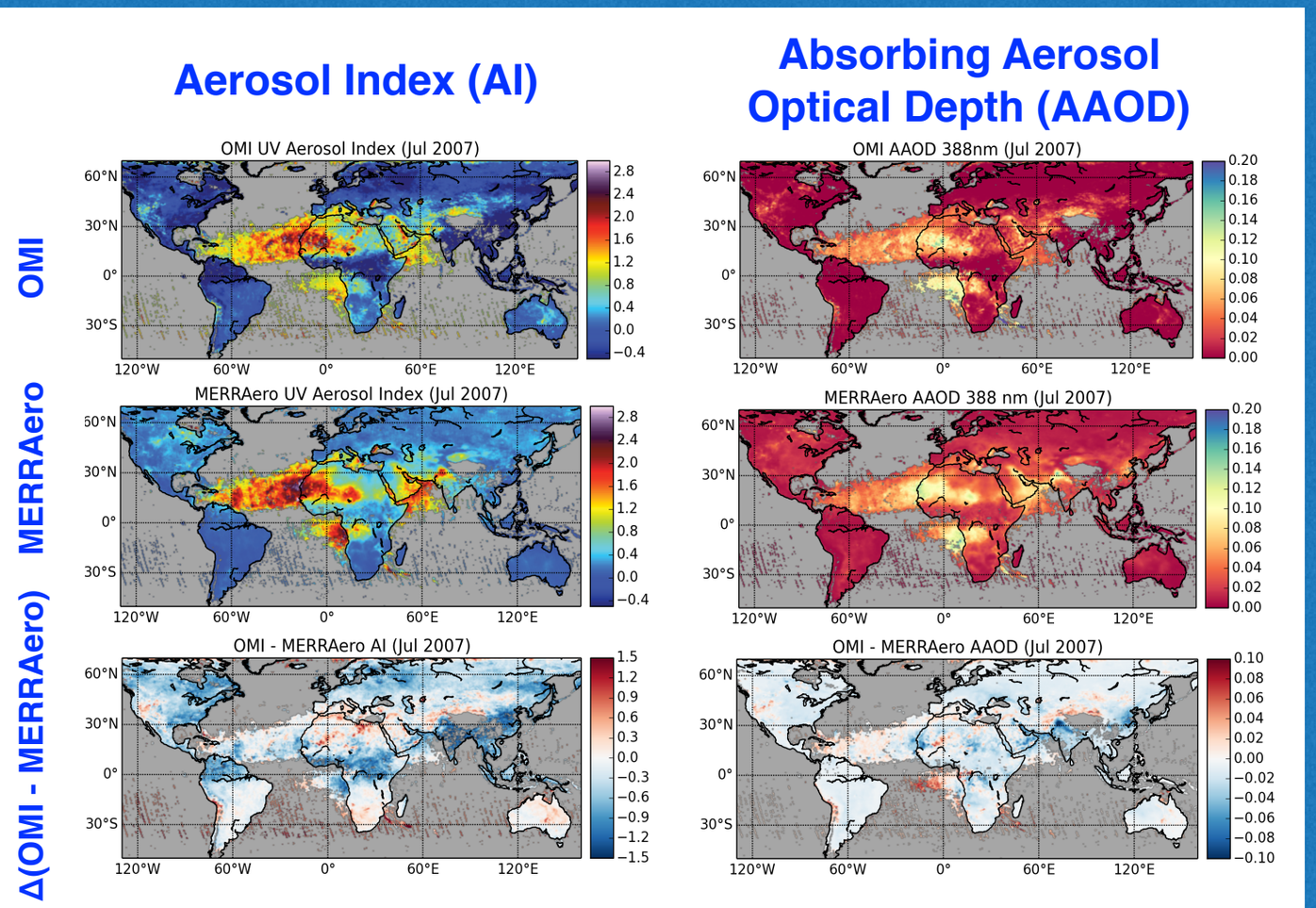
- Formally: the AI is the error in estimating observed 354 nm radiance from the 388 nm radiance assuming a purely molecular atmosphere bounded by a spectrally varying Lambertian surface;
- In other words, it's a measure of how the observed spectral contrast differs from what you'd expect in a molecular atmosphere

Application to MERRAero

- MERRAero is GEOS-5 aerosol reanalysis
  - Replay MERRA meteorology, 0.5°
  - Assimilate MODIS-derived AOD (i.e., AOD is constrained) and adjust model aerosol mass

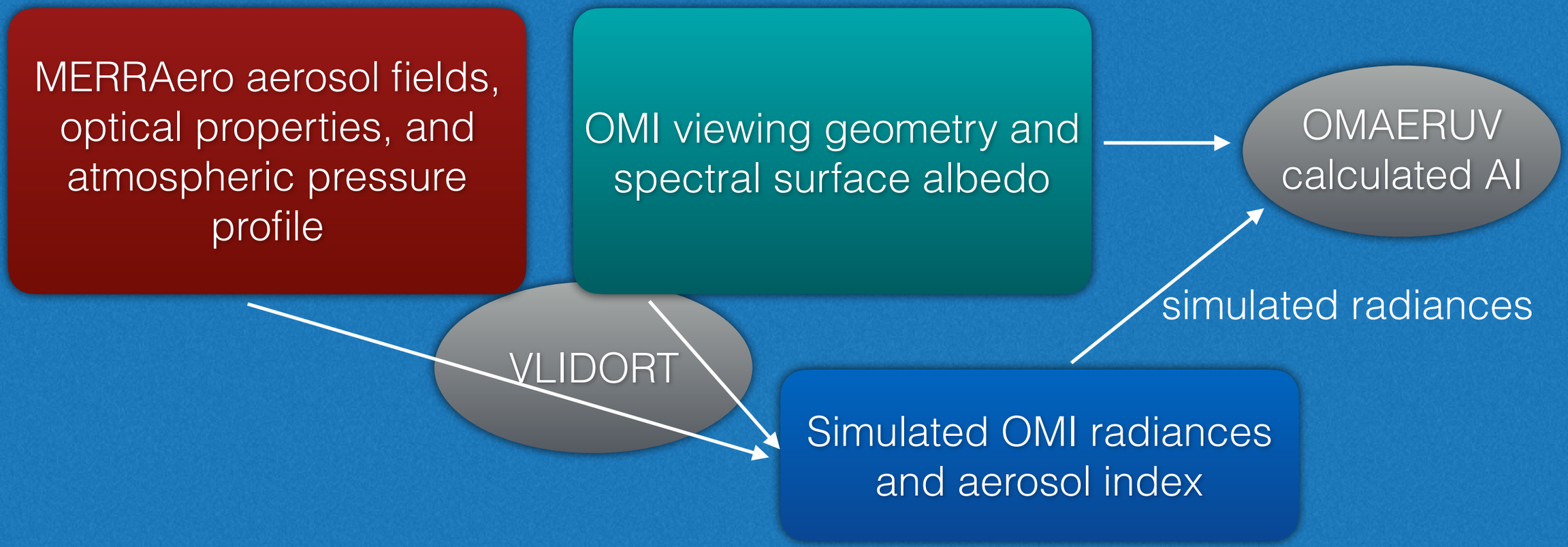
- OMI Observation Simulator
  - VLIDORT interface to model fields to simulate OMI radiances (inputs are OMI viewing geometry and surface reflectances)

- Comparison to OMI AI and retrieval products (AAOD) lets us improve unconstrained optical property assumptions (absorption)



Buchard et al. 2015
See also Hammer et al. ACP 2016 for adjustments to biomass burning aerosols and impact on photolysis rates

Our OMI Simulator

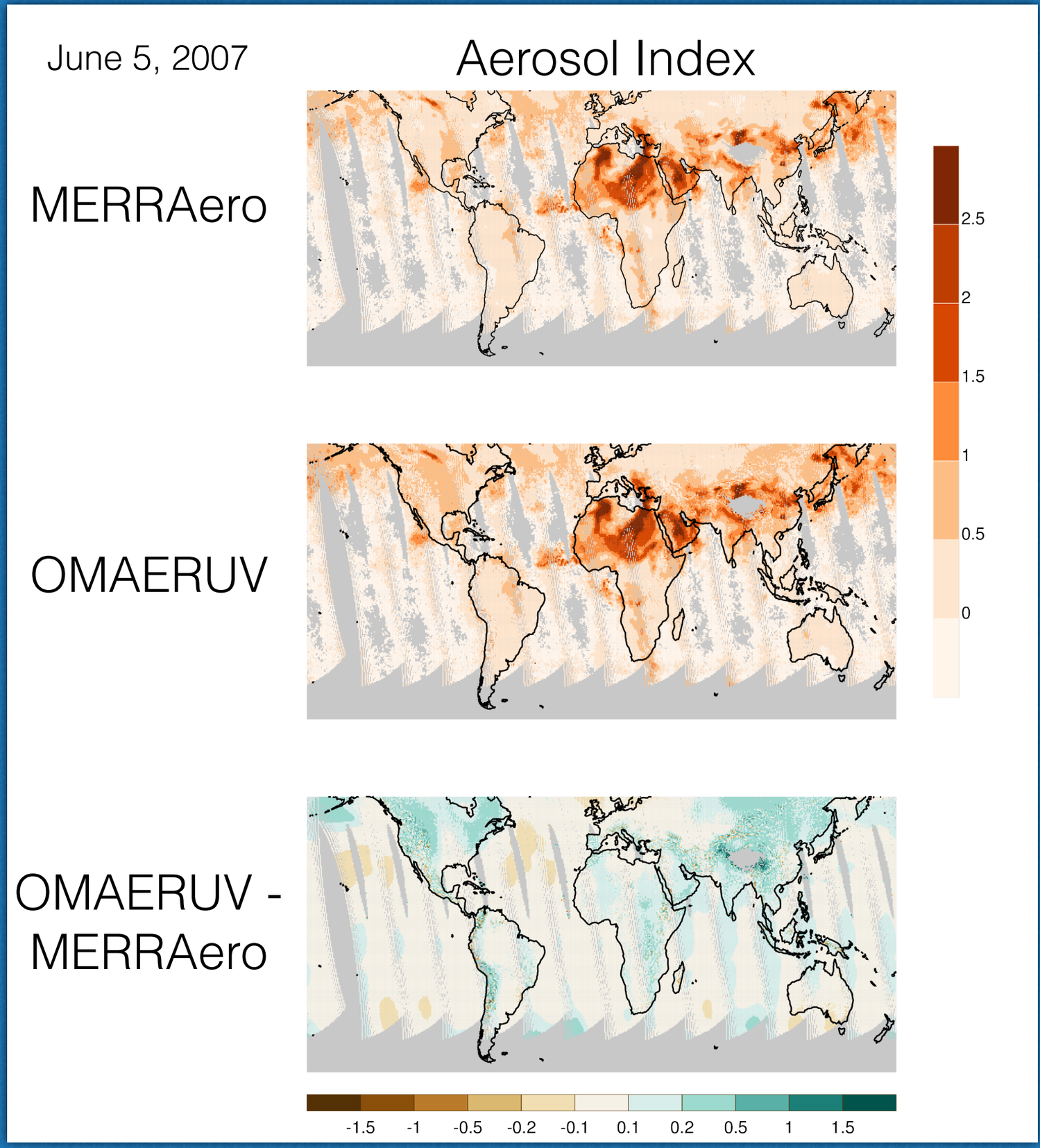


- We assume cloud-free conditions
- Compare simulated to OMAERUV retrieved AI
- *Do they agree?*

Simulation of AI

- Given the same radiances, MERRAero and OMAERUV compute similar but different AI values

- Possible explanations:
  - differences in AI formulation
  - differences in radiative transfer
  - differences in some other critical parameter



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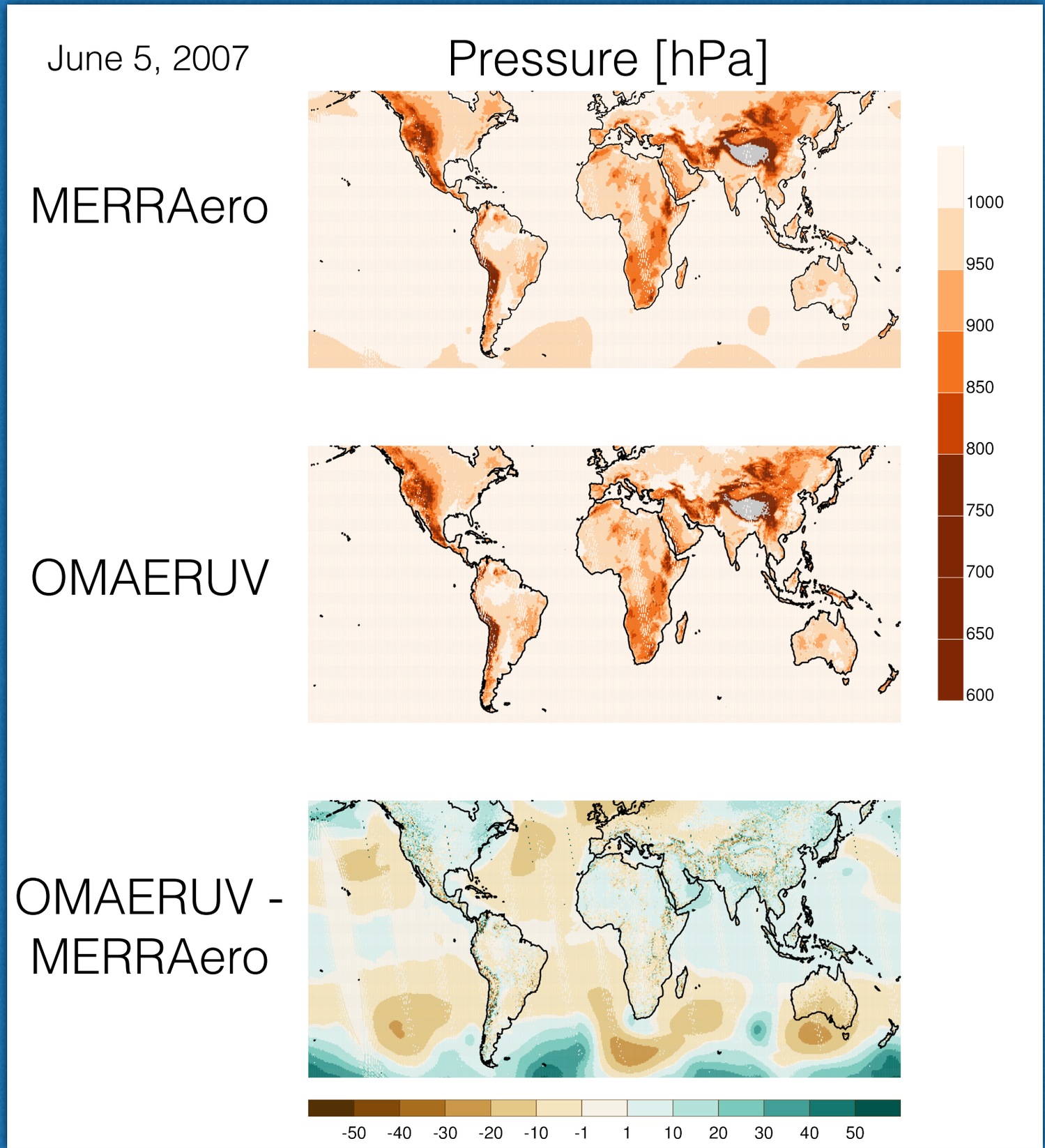
  - GEOS-5 uses model pressure
  - OMAERUV assumes altitude-dependent but time-invariant pressure



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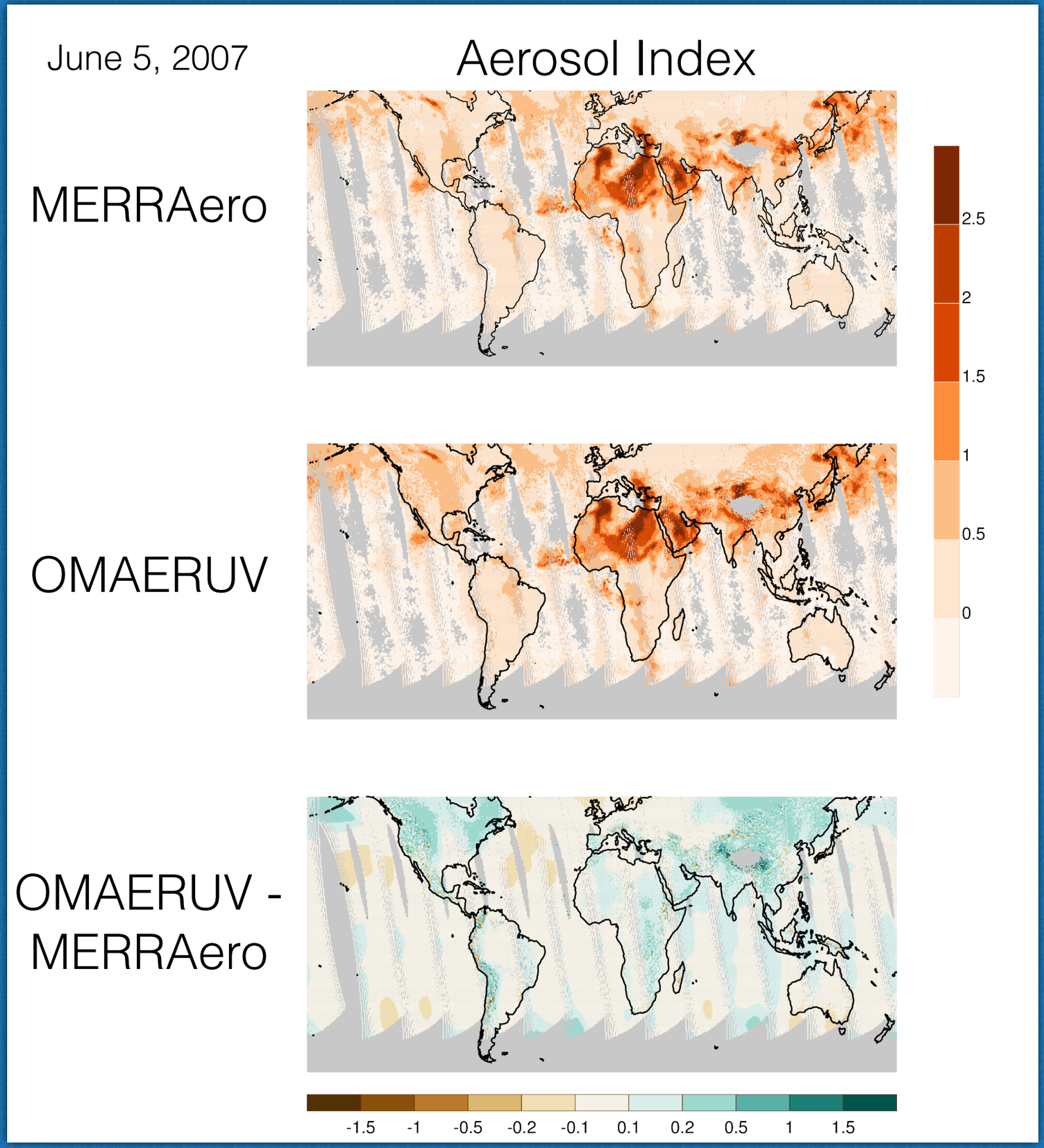

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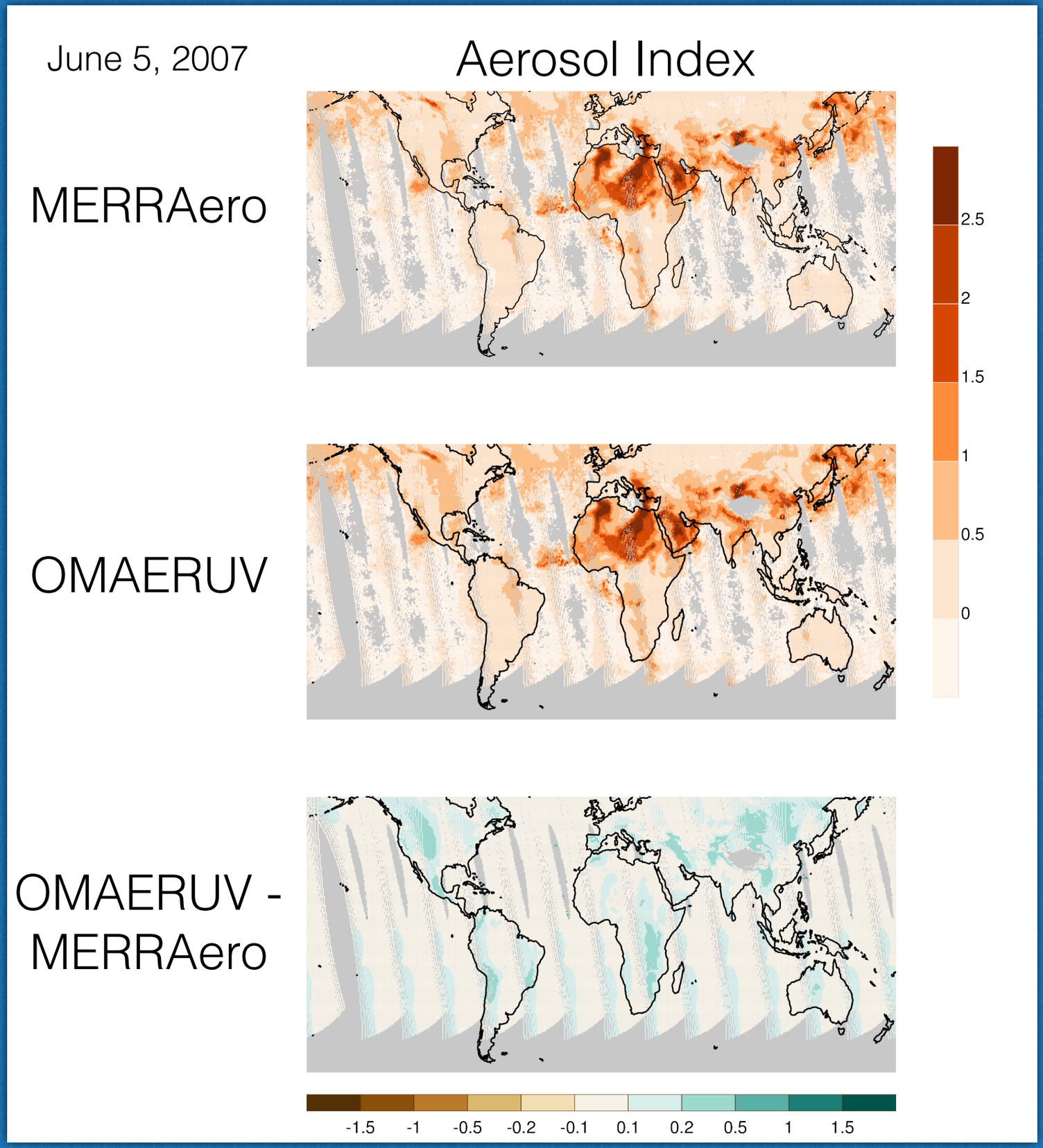
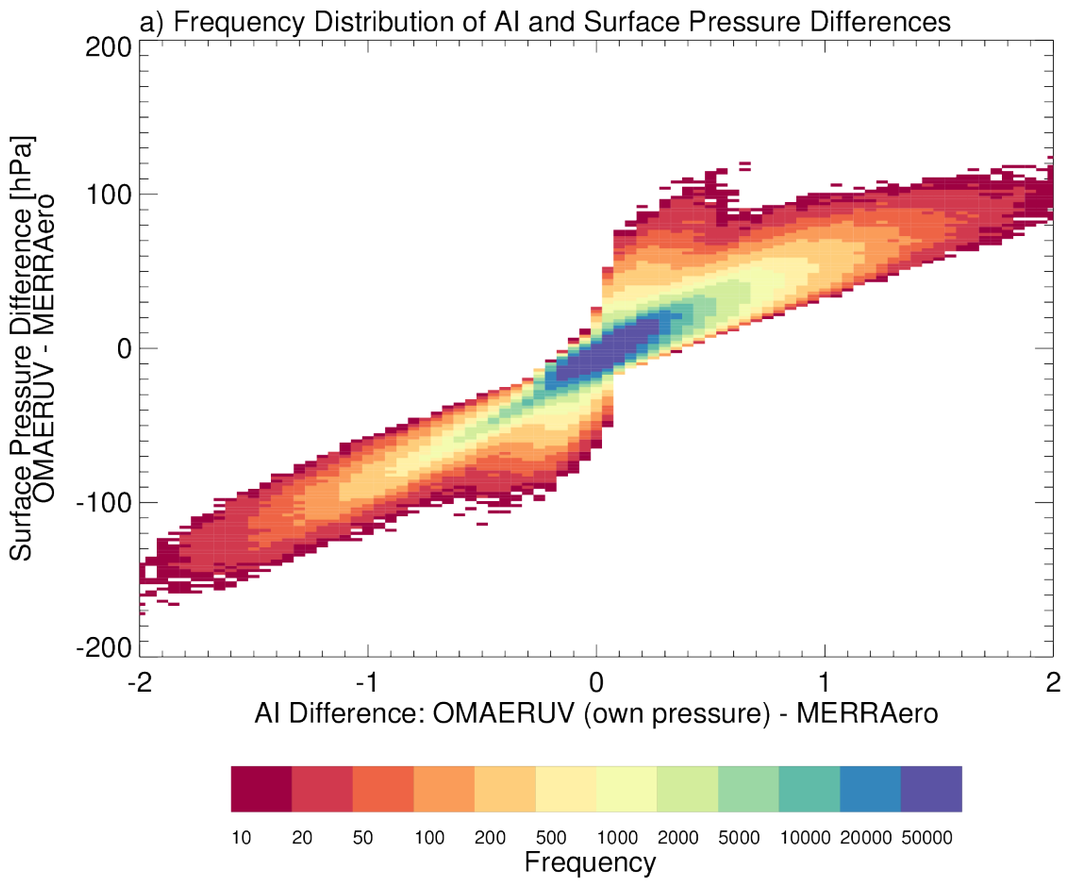
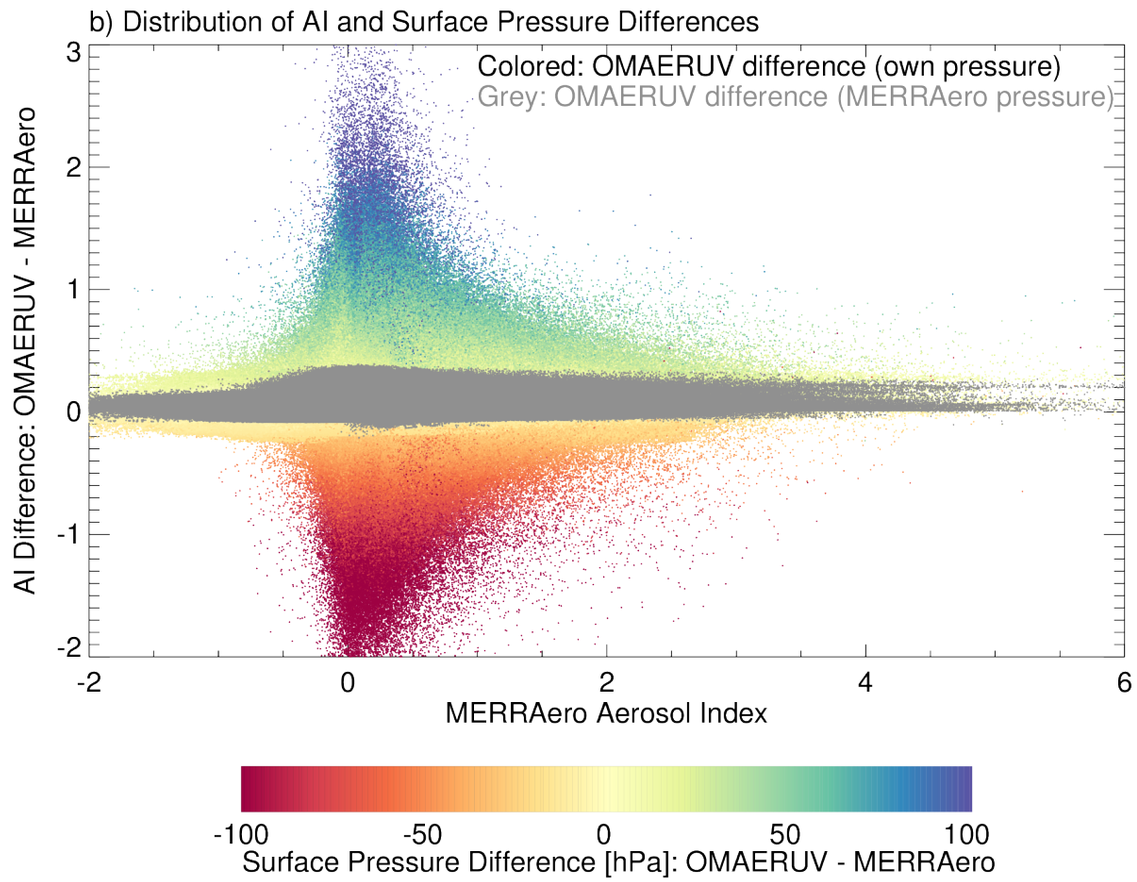


Sensitivity of AI to Pressure





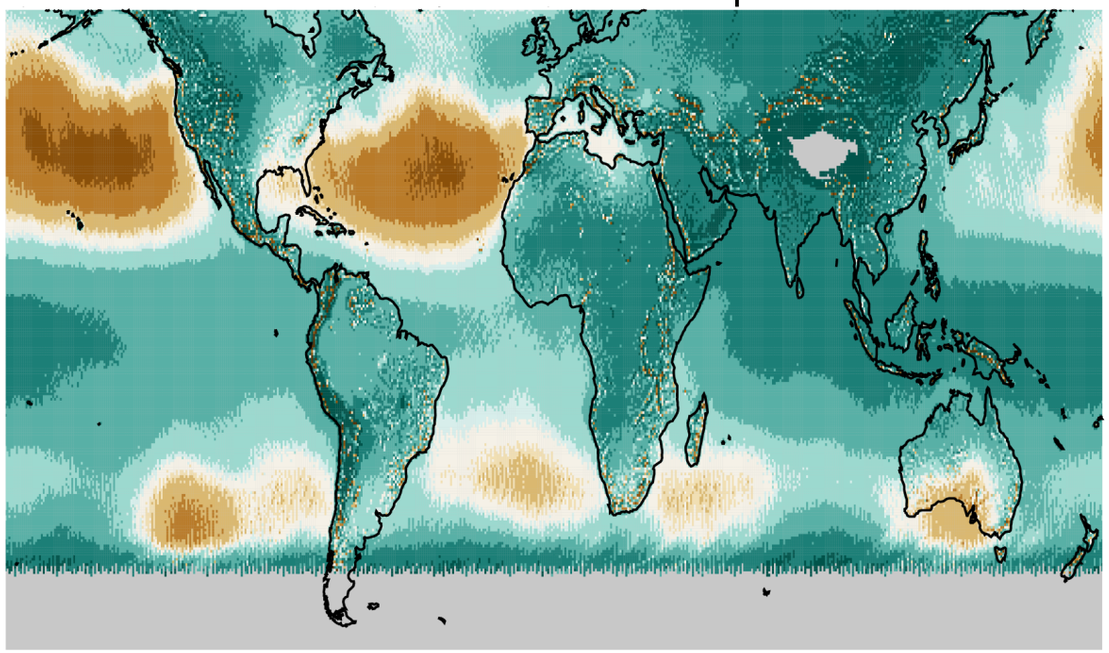
All OMI pixels for June 2007 (n = 26.3M)

- 12% of points have |Δ(OMAERUV - MERRAero)AI |> 0.2 when OMAERUV uses own pressure
- 3% of points have |Δ(OMAERUV - MERRAero)AI |> 0.2 when OMAERUV uses MERRAero pressure

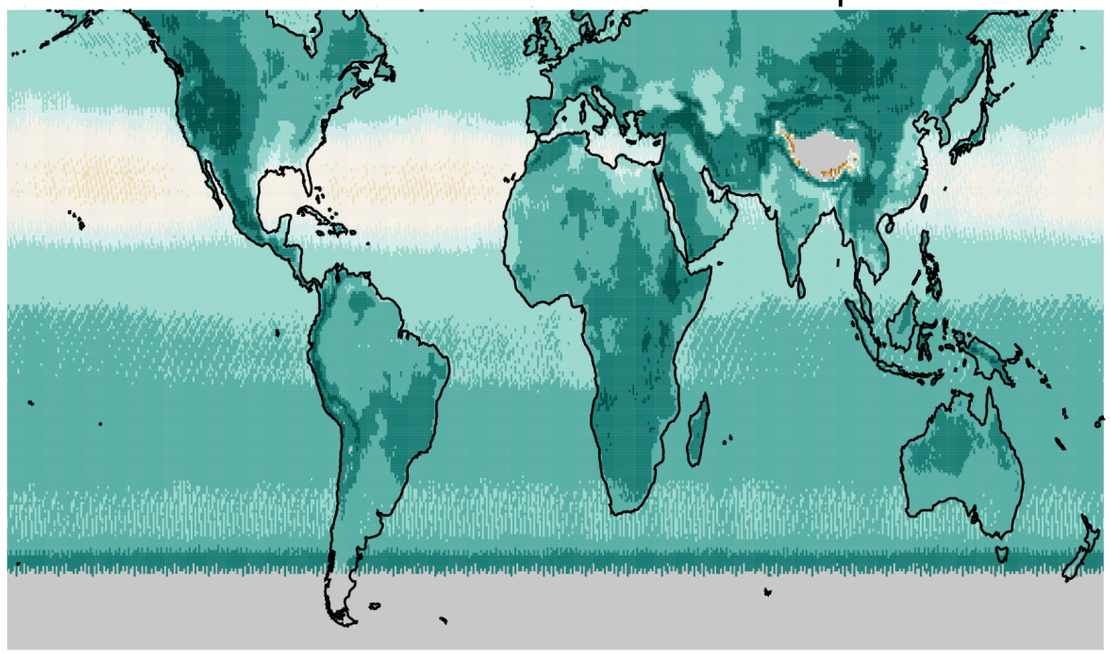
Difference in Monthly Mean AI

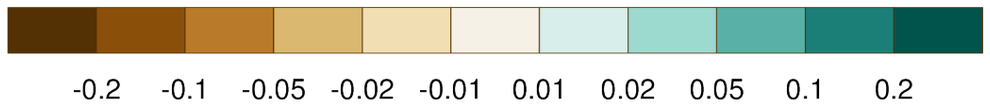
ΔAI OMAERUV - MERRAero

OMAERUV uses own pressure



OMAERUV uses MERRAero pressure





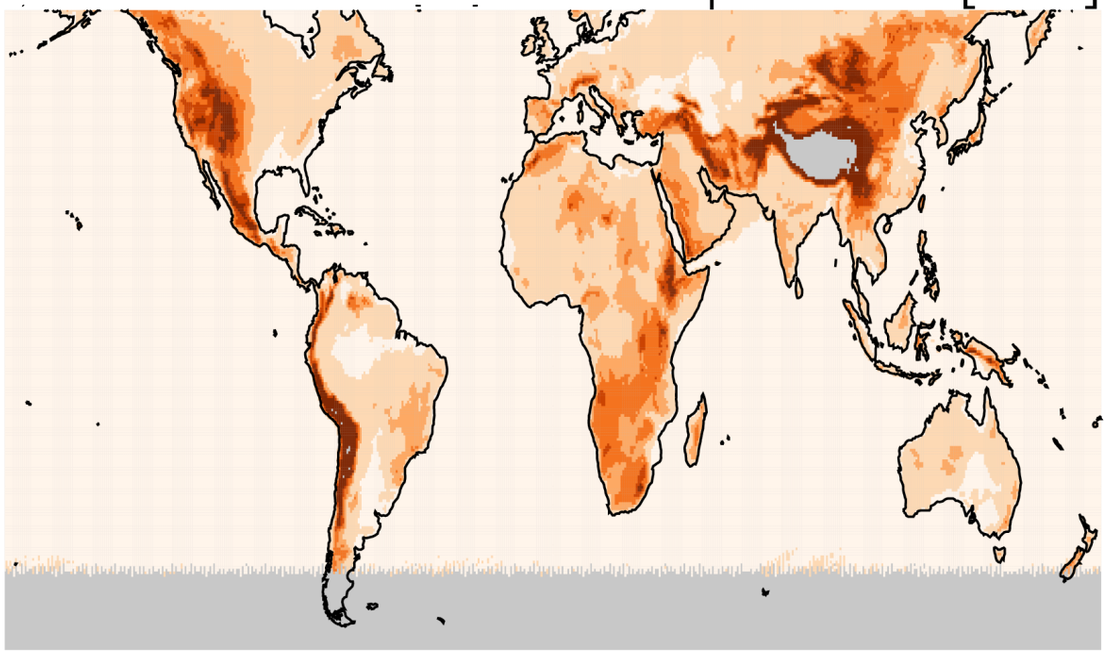
Monthly mean ΔAI comparison for June 2007

- Using MERRAero pressures, residual very small over ocean, with a seasonally varying latitude dependence
- Relatively larger but temporally stationary residual over land

Difference in Monthly Mean AI

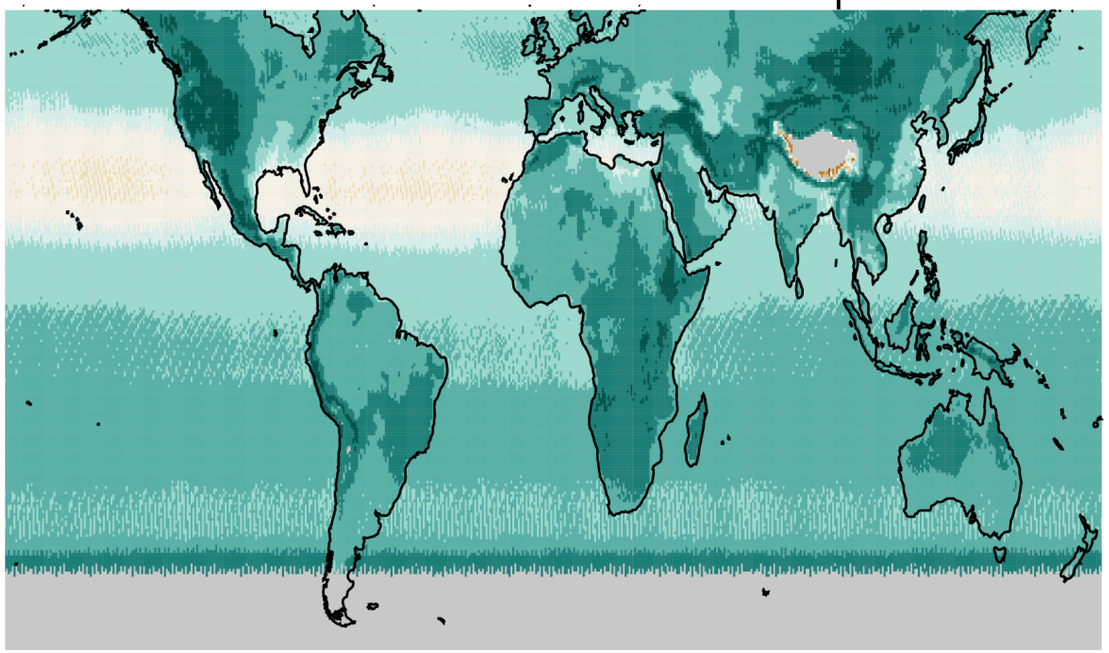
ΔAI OMAERUV - MERRAero

MERRAero mean surface pressure [hPa]



600 650 700 750 800 850 900 950 1000

OMAERUV uses MERRAero pressure



-0.2 -0.1 -0.05 -0.02 -0.01 0.01 0.02 0.05 0.1 0.2

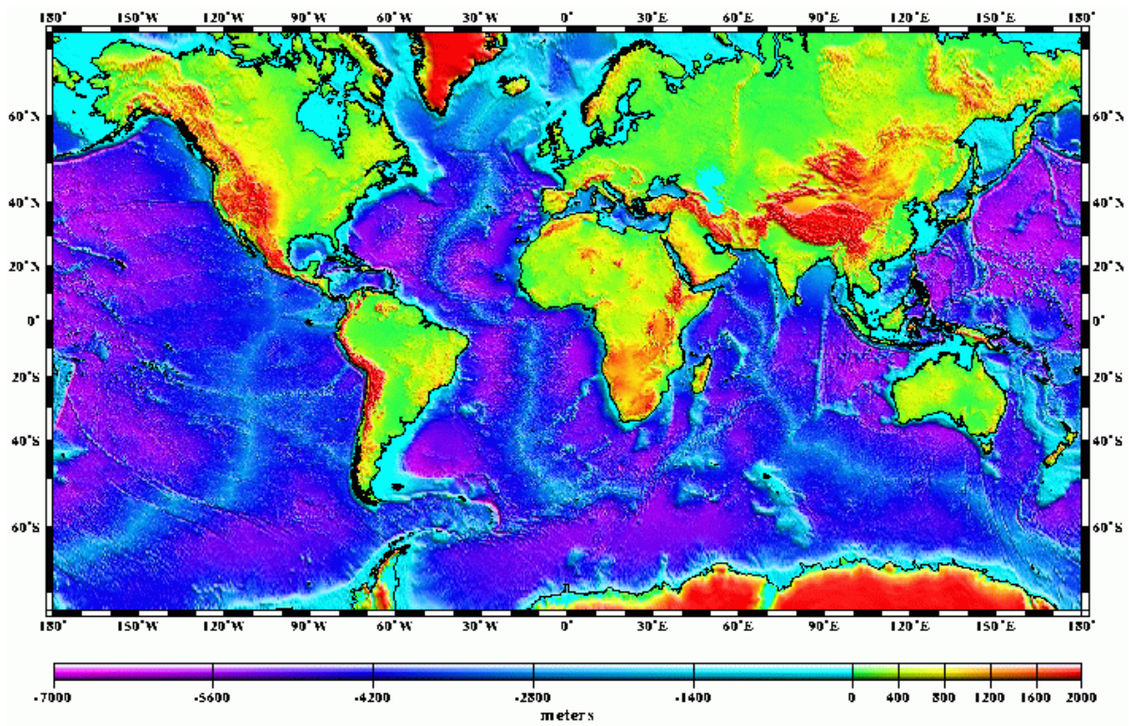
Monthly mean ΔAI comparison for June 2007

- Using MERRAero pressures, residual very small over ocean, with a seasonally varying latitude dependence
- Relatively larger but temporally stationary residual over land
- Residuals correlate with mean surface pressure fields

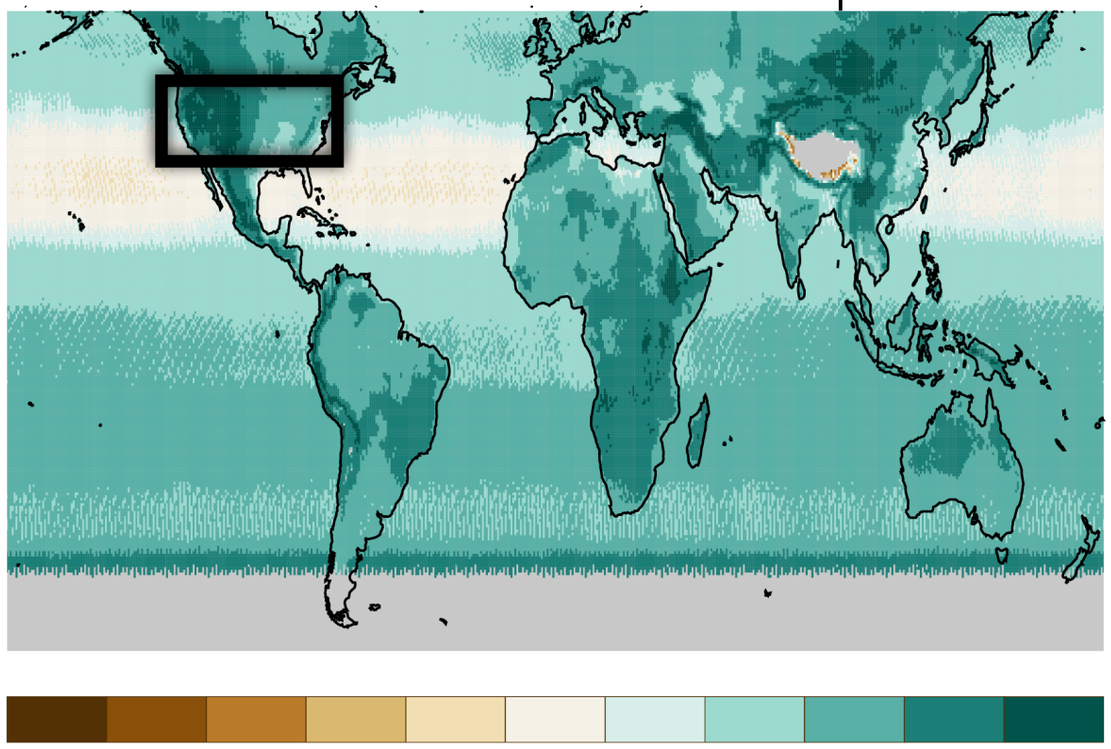
Difference in Monthly Mean AI

ΔAI OMAERUV - MERRAero

Altitude [m]



OMAERUV uses MERRAero pressure



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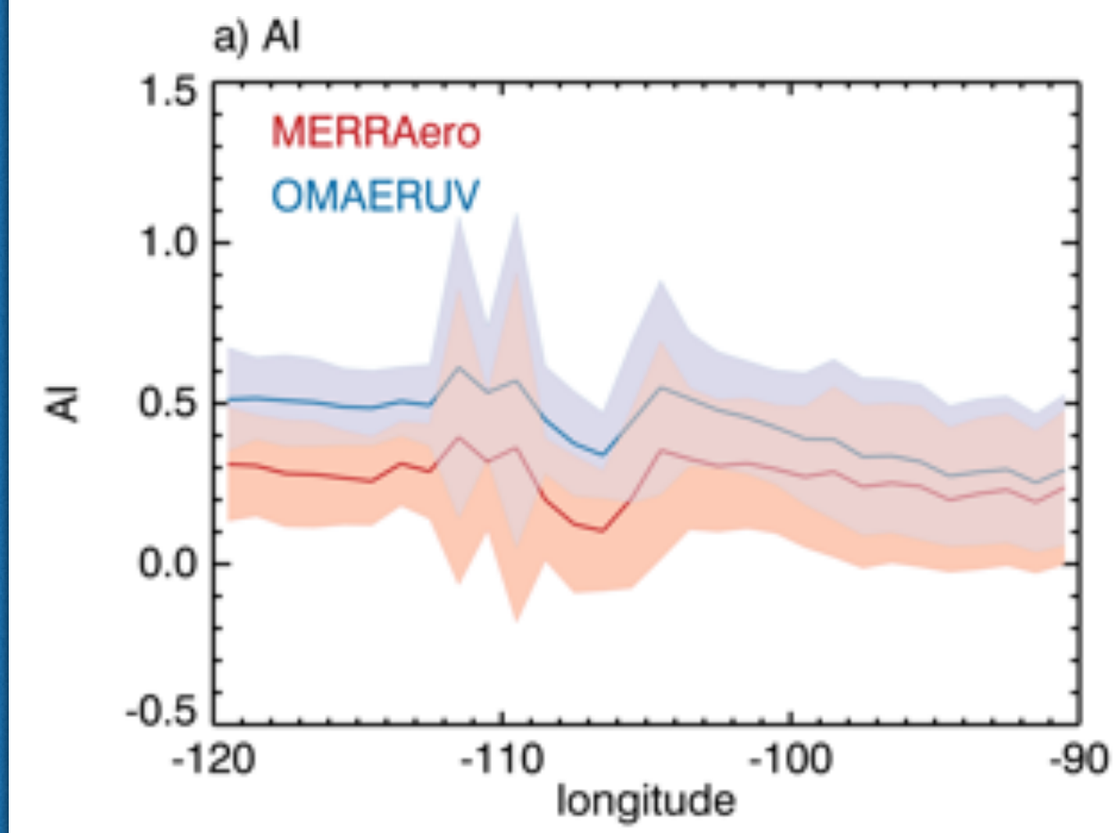
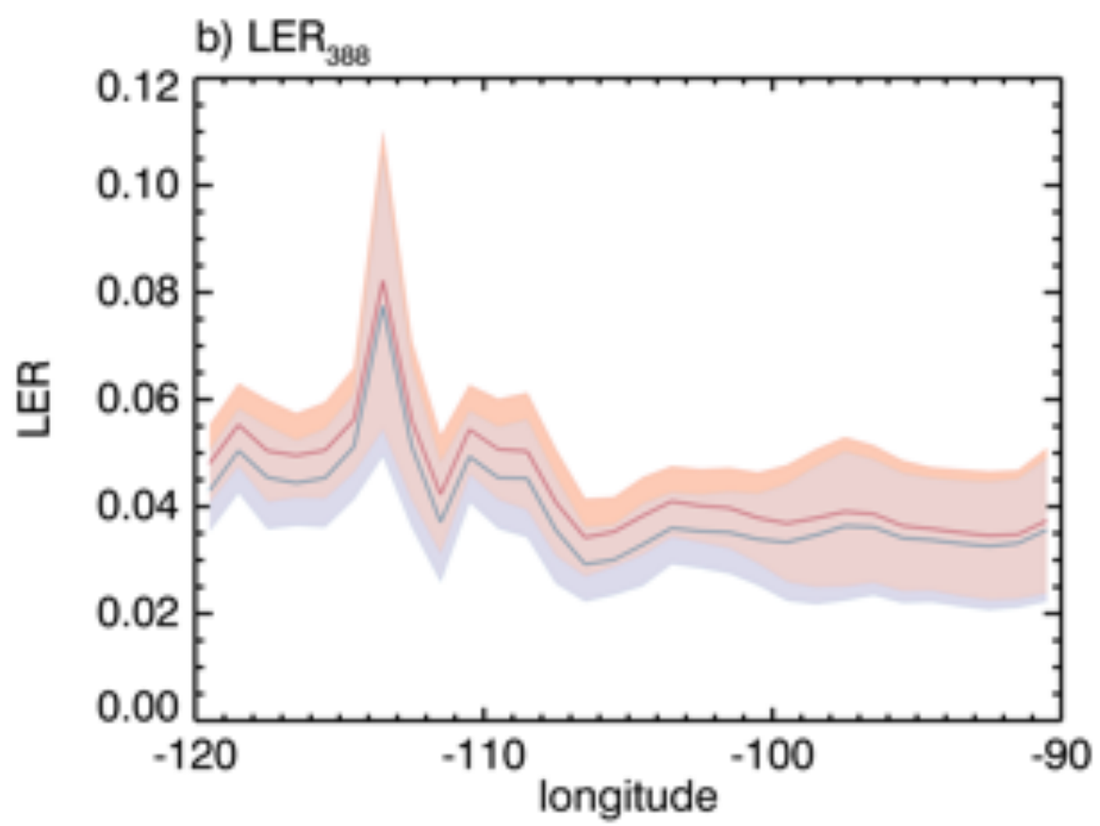
- Relatively larger but temporally stationary residual over land
- Residuals correlate with mean surface pressure fields
- Mean pressure correlates with topography

Sensitivity to Radiative Transfer



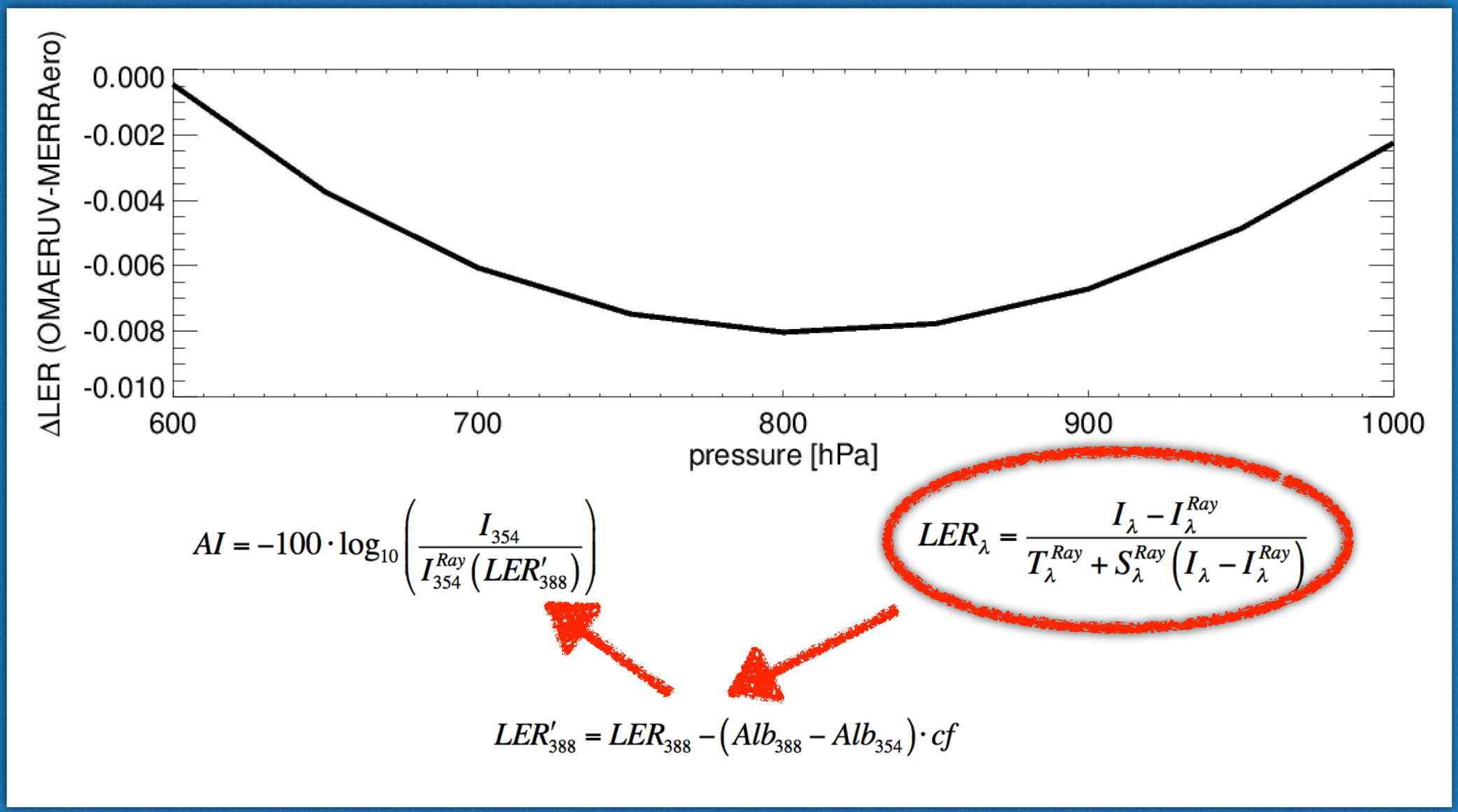


Marching east to west across this region, AI and LER differences grow larger as terrain altitude increases

We found possibly significant difference between MERRAero and OMAERUV:

- MERRAero uses exact pressure profile to compute Rayleigh part of AI calculation
- OMAERUV uses precomputed values of Rayleigh calculation at two pressures (600 and 1000 hPa) and interpolates to actual pressure

Sensitivity to Radiative Transfer



Sensitivity analysis comparing MERRAero calculations versus OMAERUV shows implication of pressure interpolation

Conclusions

- Demonstrated OMAERUV AI has imprint of assumed surface pressure on it; forcing to MERRAero surface pressure mostly resolves this, especially over water
- Over land there is remaining AI residual which we think is related to topography indirectly by assumptions in OMAERUV Rayleigh lookup tables
- Really just scratching the surface here: next step is to investigate the OMAERUV retrievals of AOD and SSA