CERES Derived Narrowband Fluxes for Correcting 3D Radiative Effects in MODIS Aerosol Retrieval Near Clouds

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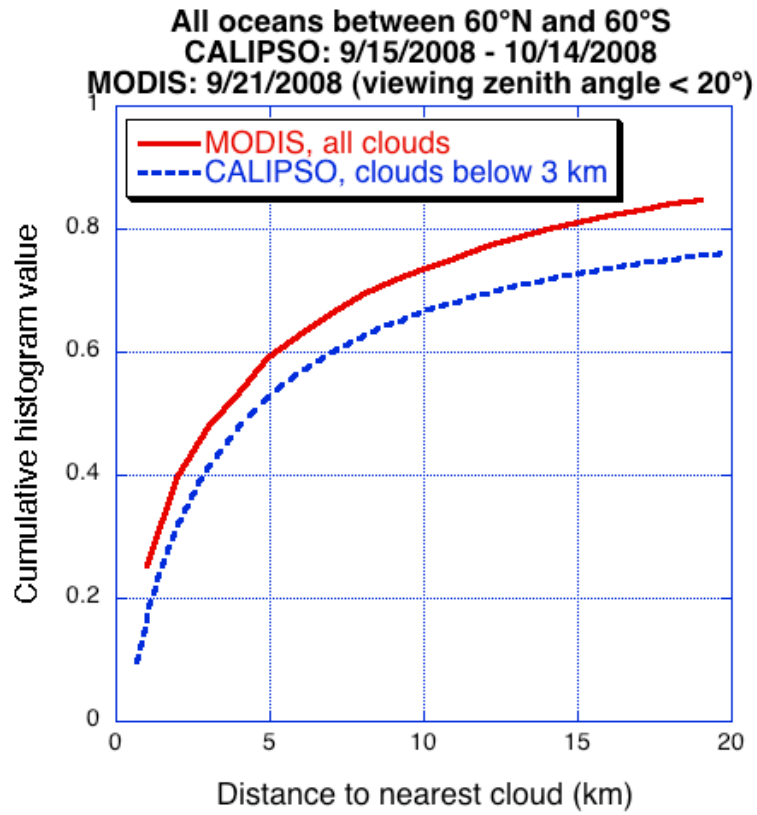
Tamas Varnai, Robert Cahalan

Clear areas near clouds



Motivation:

- Help satellite studies of aerosol-cloud interactions
- Aerosol remote sensing near clouds is challenging
- Excluding areas near-cloud risks biases in aerosol data

from **MODIS**: 60% of all clear sky pixels are located 5 km or less from all clouds

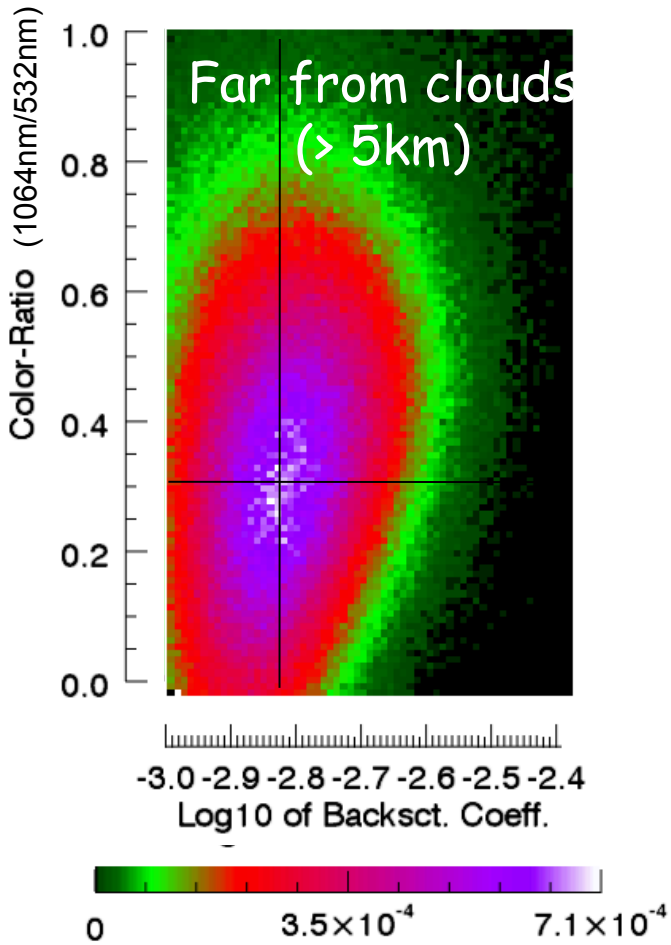
from **CALIPSO**: 50% of all clear sky pixels are located 5 km or less from low clouds

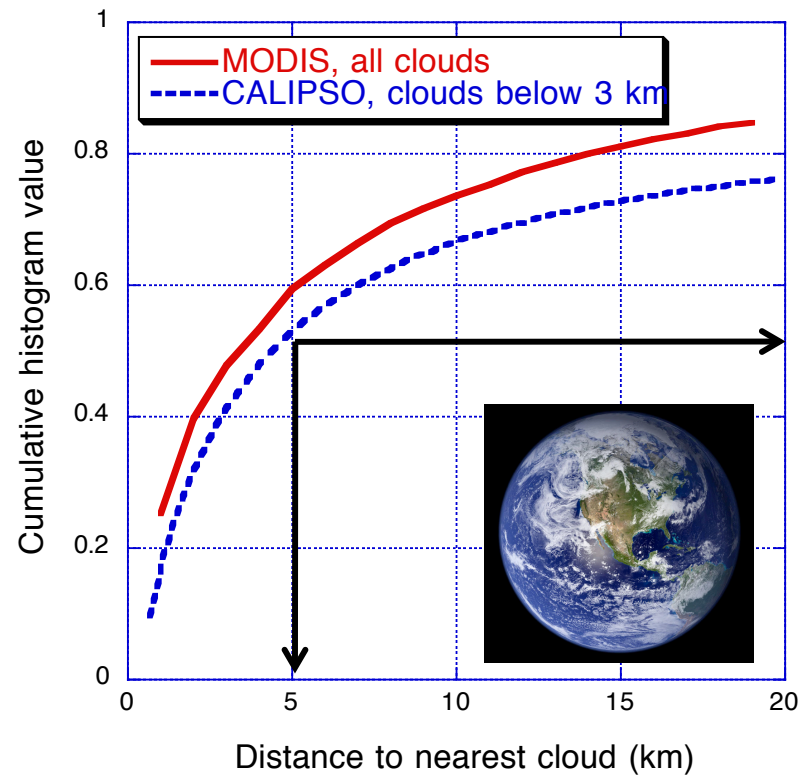
(Varnai and Marshak)

CALIPSO

(ColorRatio vs. Backscat close to and far from clouds)

Global night data over ocean



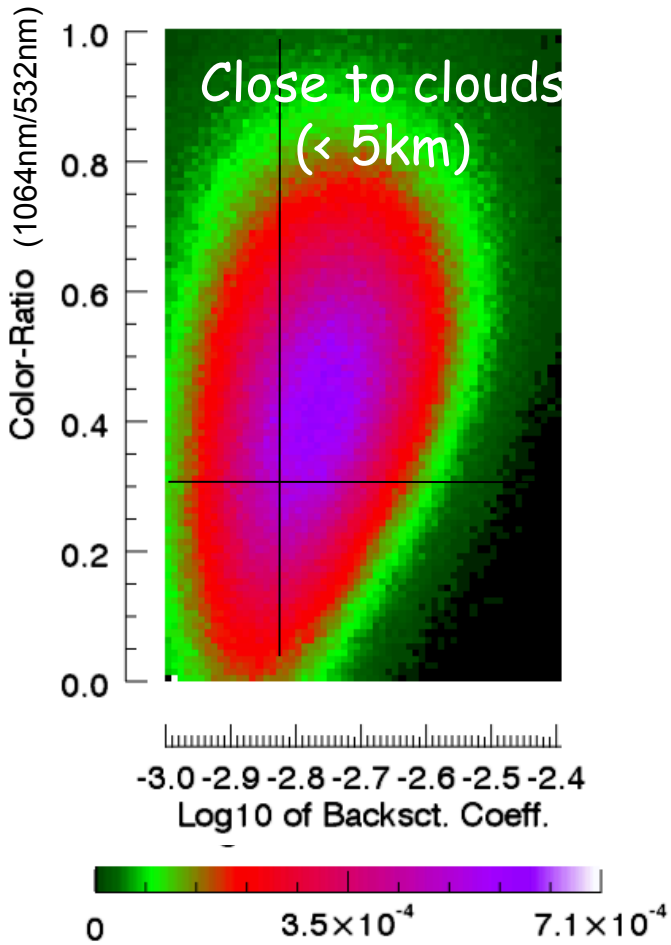


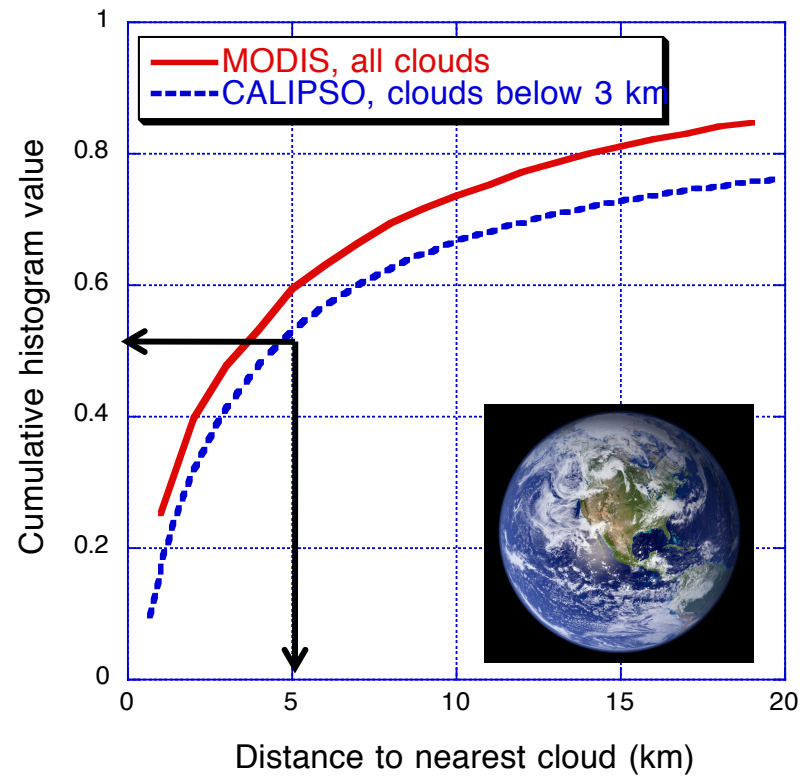
Fraction of cloud-free vertical profiles

CALIPSO

(ColorRatio vs. Backscat close to and far from clouds)

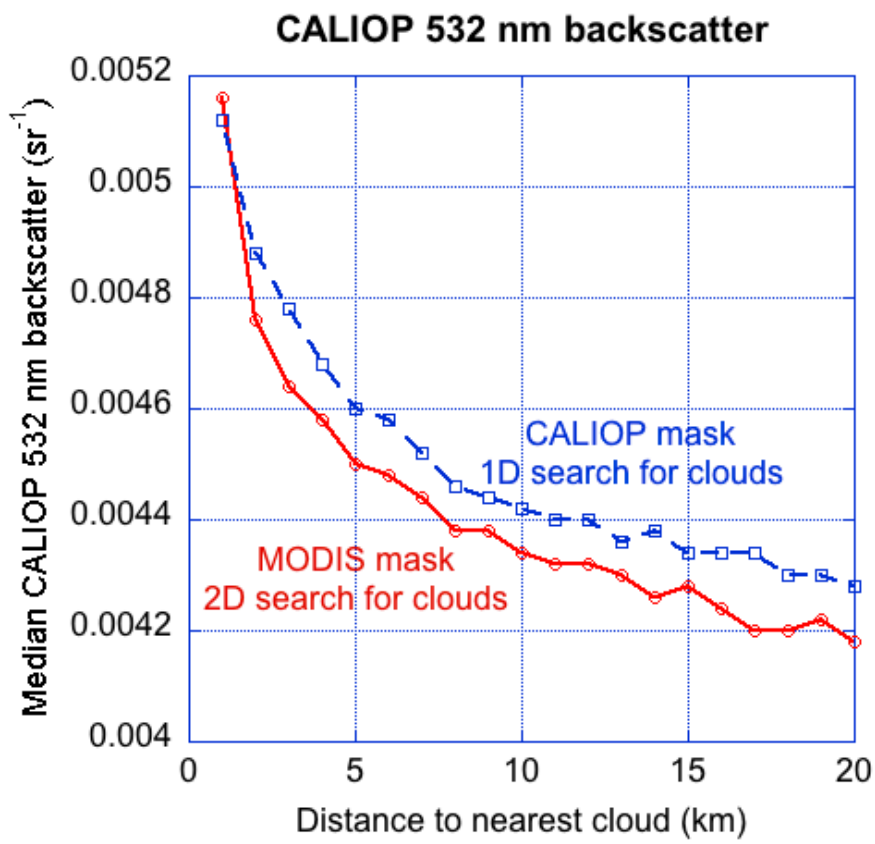
Global night data over ocean

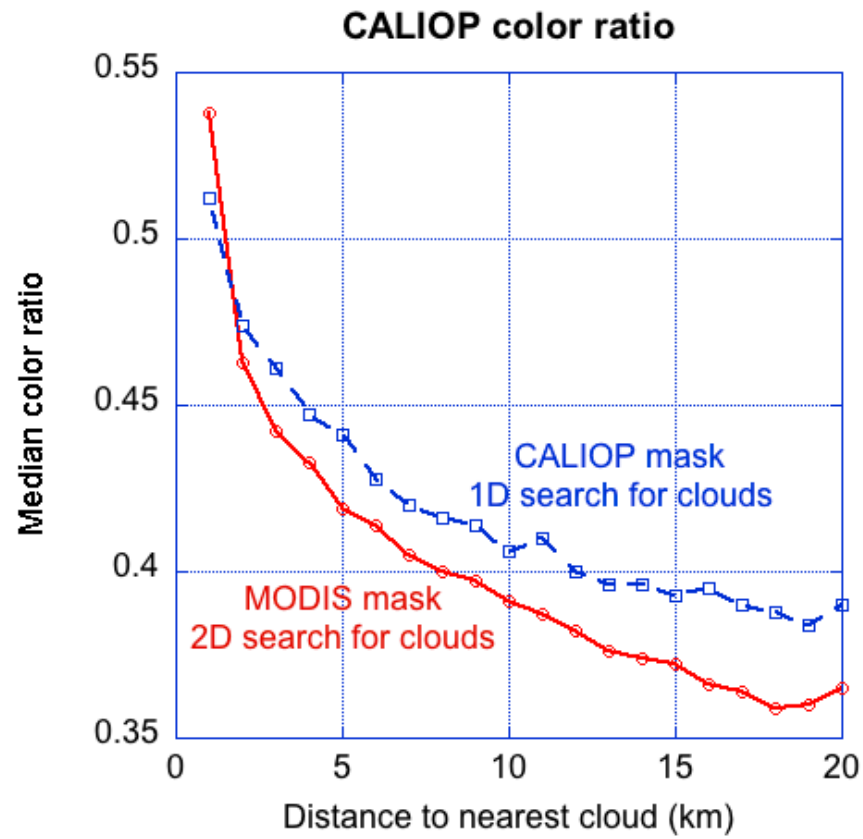




Fraction of cloud-free vertical profiles

CALIOP vs. MODIS cloud mask

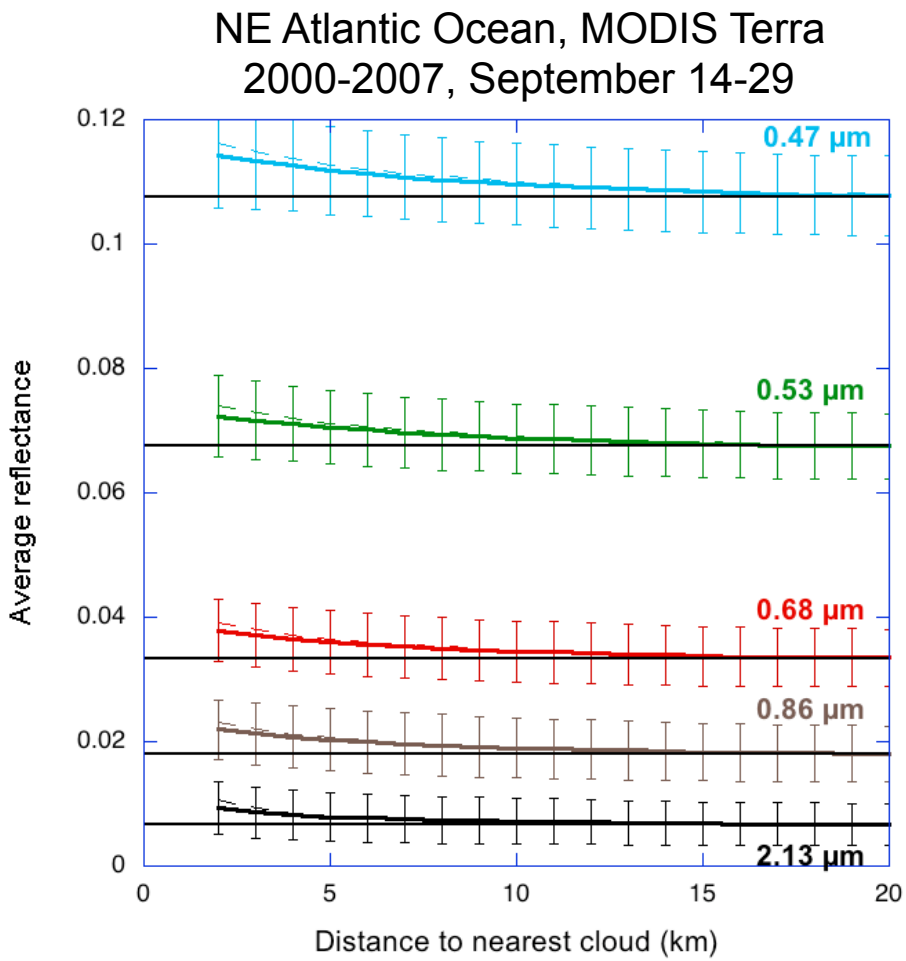




Behavior is similar using either cloud mask
Daytime data over oceans during April 2007

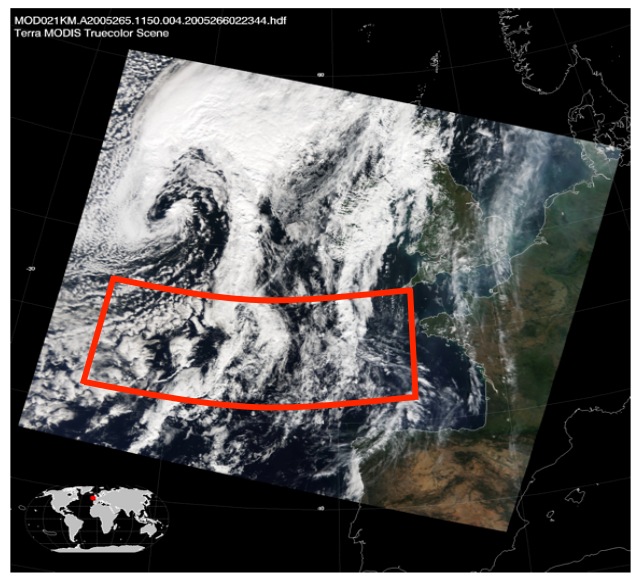
(Varnai and Marshak)

MODIS reflectances increase near clouds



Reflectance increase may come from:

- Aerosol changes (e.g., swelling in humid air)
- Undetected cloud particles
- Instrument imperfections
- 3D radiative effects

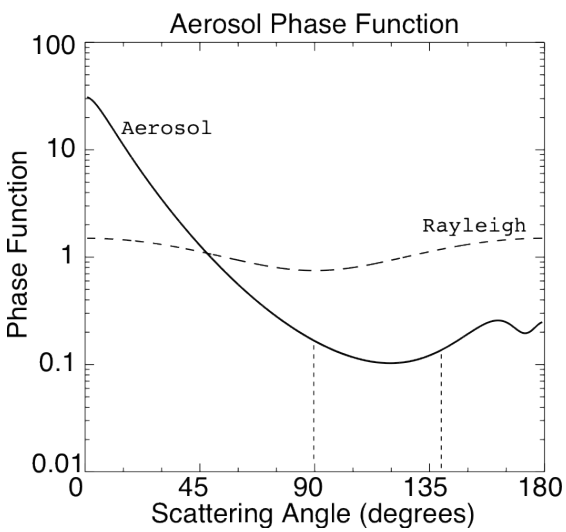


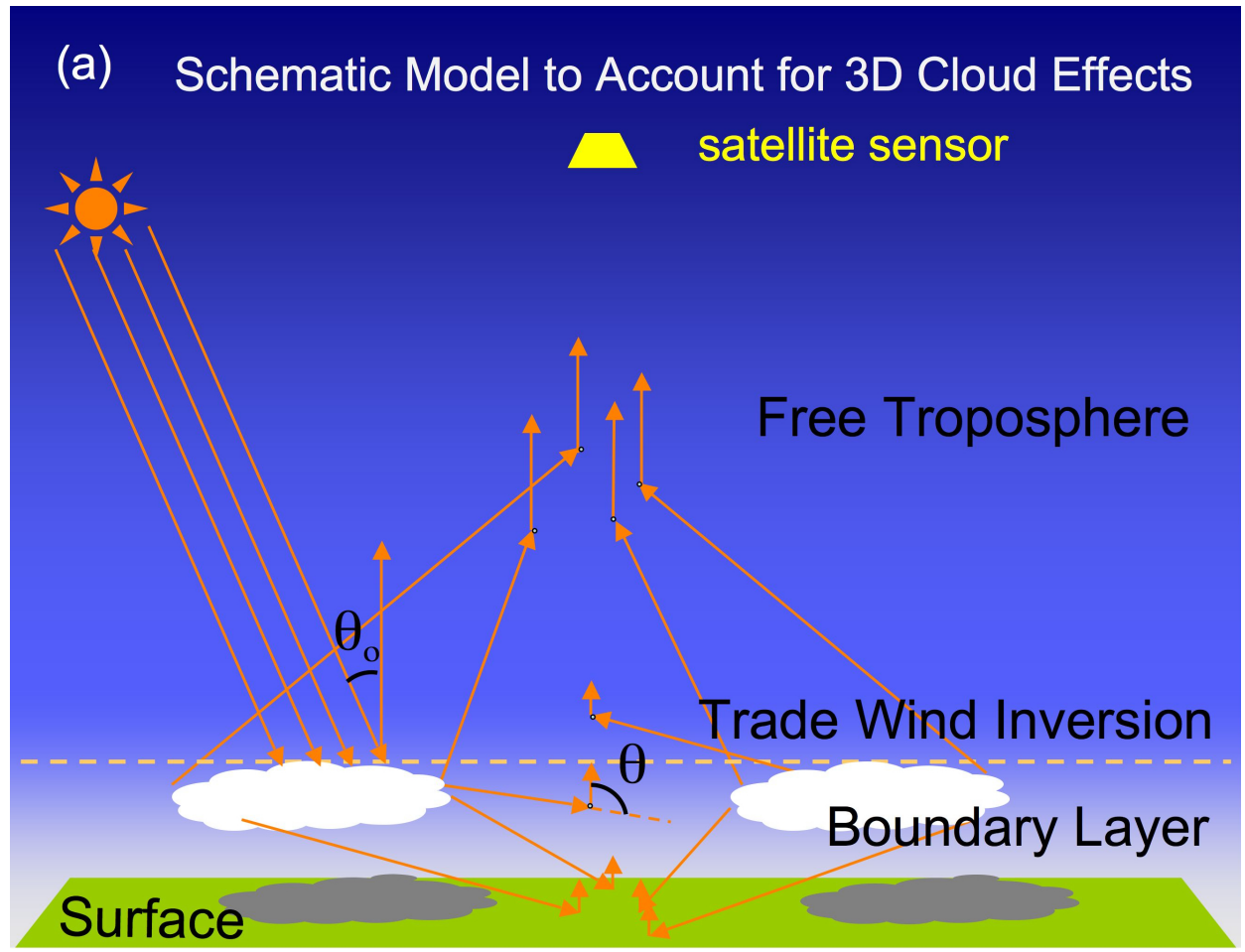
Várnai and Marshak (2009)

Contribution to the Enhancement

$$\Delta I = \sum_i \left(\Delta I_a(z_i) + \Delta I_m(z_i) \right) + \Delta I_s$$

Contribution from Radiative interaction Between cloud and molecular layer above is the major mechanism for low clouds over dark surface.





(e.g., Wen et al., 2008; Dave 1967; Platnick 2000)

Approach

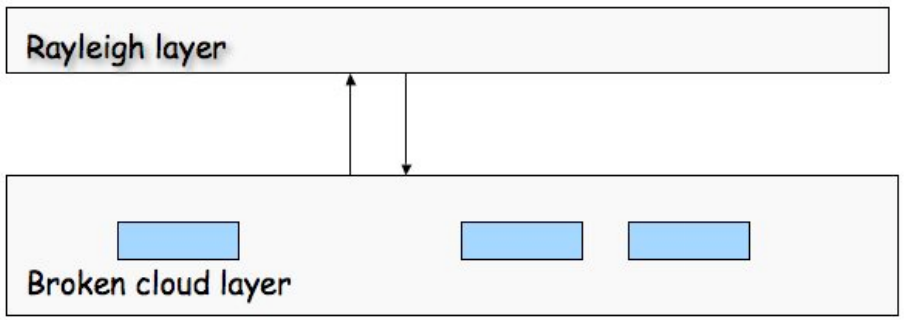
- Estimate 3D cloud-induced radiance enhancement using the two-layer model
- Retrieve aerosol optical thickness using MODIS algorithm

✧Model: the Two-Layer Model (Marshak et al., 2008)
✧Inputs: 1. Rayleigh scattering optical depth
2. Upward flux or albedo
✧Challenge: estimate narrowband flux

$$\Delta R = \frac{\alpha_c T_m(\tau_m, \Omega_0)}{1 - \alpha_c R_{m,diff}(\tau_m, \Omega)} [t_{m,diff}(\tau_m, \Omega) - e^{-\frac{\tau_m}{\mu}}]$$

$$R_{corr} = R_{MODIS} - \Delta R$$

Two-layer model



Derive Narrowband Flux
CERES Comes to Help

Assume that the **ratio** between the *observed* NB and BB fluxes is equal to that from *theoretical* computation.

$$F^{nb} \approx F^{bb}_{obs} \cdot \frac{F_t^{nb}}{F_t^{bb}}$$

For partly cloudy CERES footprint with cloud cover of f, reflected BB and NB fluxes are:

$$F_t^{nb} \approx f \cdot F^{nb}_{cloud} + (1-f) \cdot F^{nb}_{clear}$$

$$F_t^{bb} \approx f \cdot F^{bb}_{cloud} + (1-f) \cdot F^{bb}_{clear}$$

To compute cloud fluxes the logarithm of cloud optical depth weighted by cloud fraction is applied

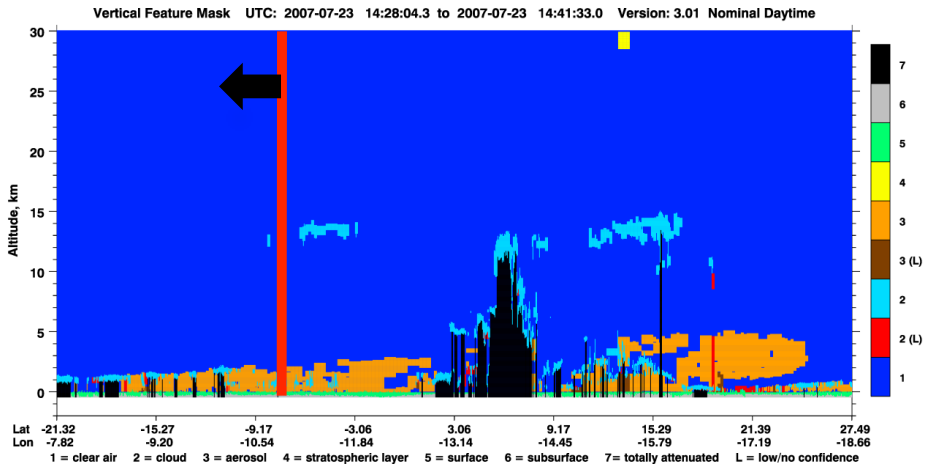
$$\ln(\bar{\tau}) = \ln(f\tilde{\tau}), \quad \tilde{\tau} = \exp(\overline{\ln \tau_i})$$

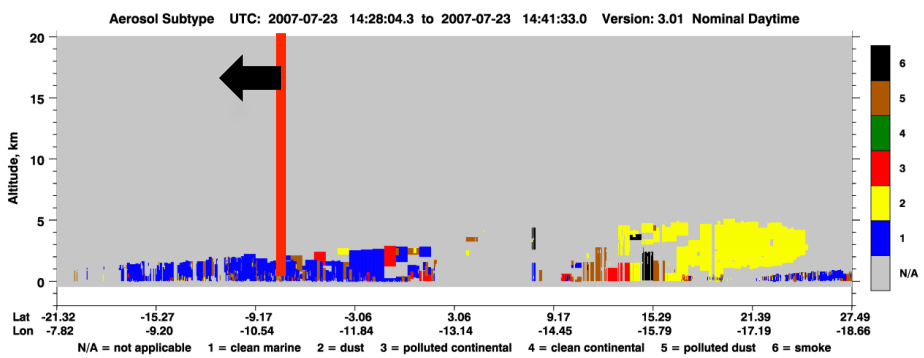
RT model (τ, f, r_e)
Correlated-k for BB
Ocean BRDF
Input from CERES

Steps in Aerosol Correction Scheme

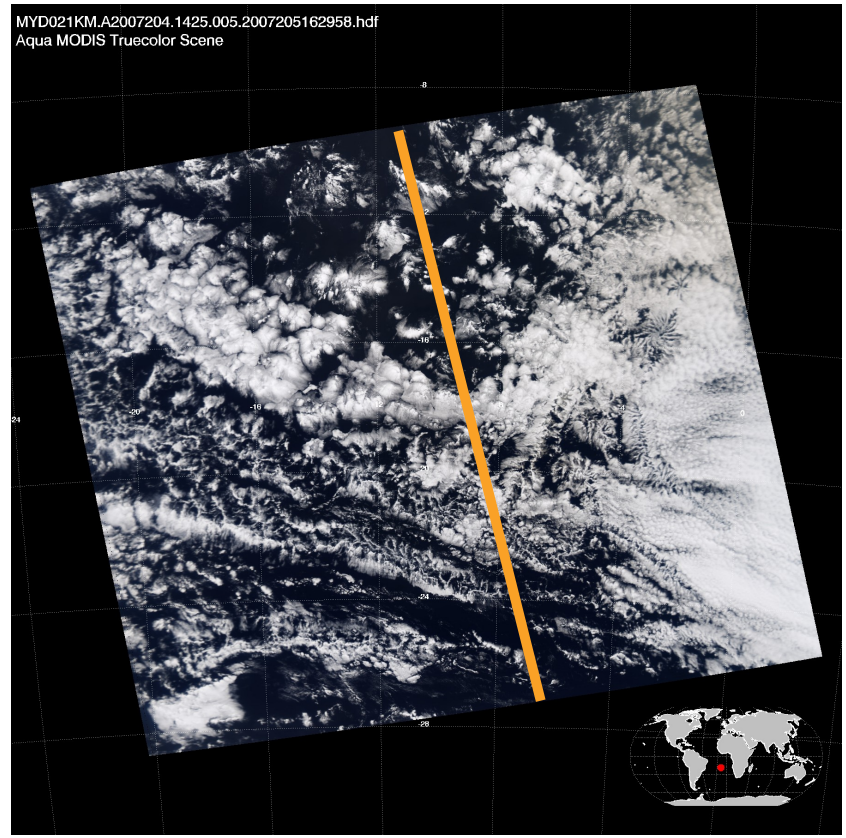
1. Estimate narrowband flux from CERES broadband flux
2. Compute the radiance enhancement due to the interaction between cloud and molecular layer above using the Two-Layer Model
3. Input a set of corrected radiance to MODIS Offline Model to retrieve aerosol optical thickness

Off West Coast of Africa





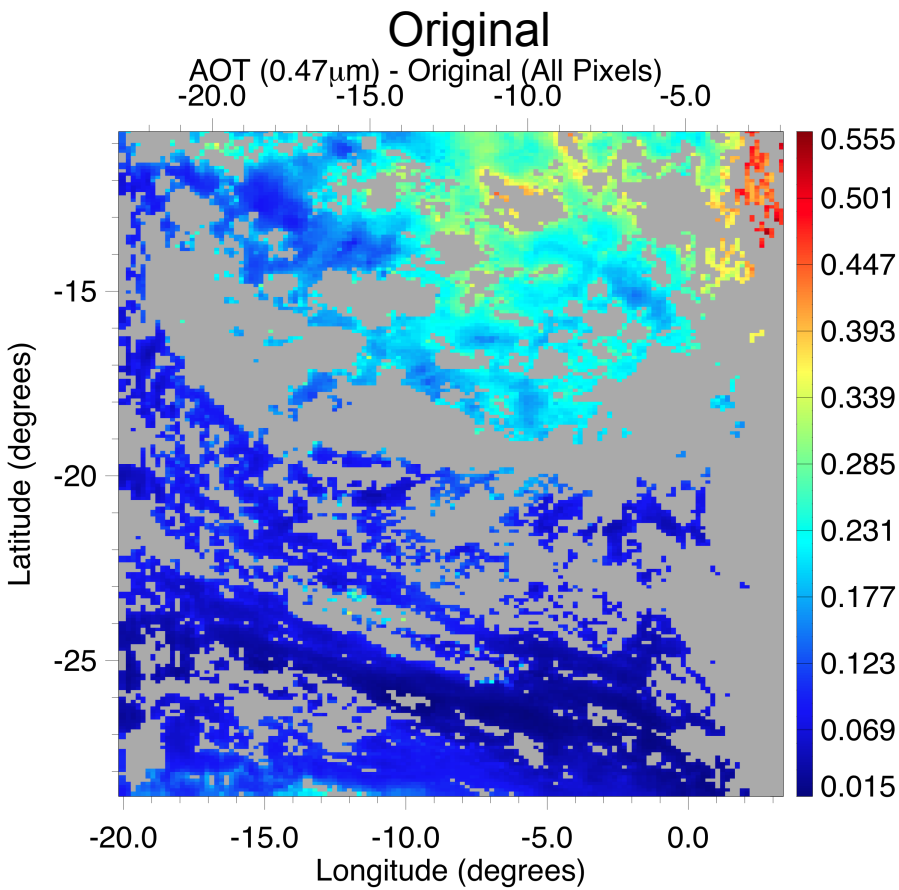
July 23, 2007

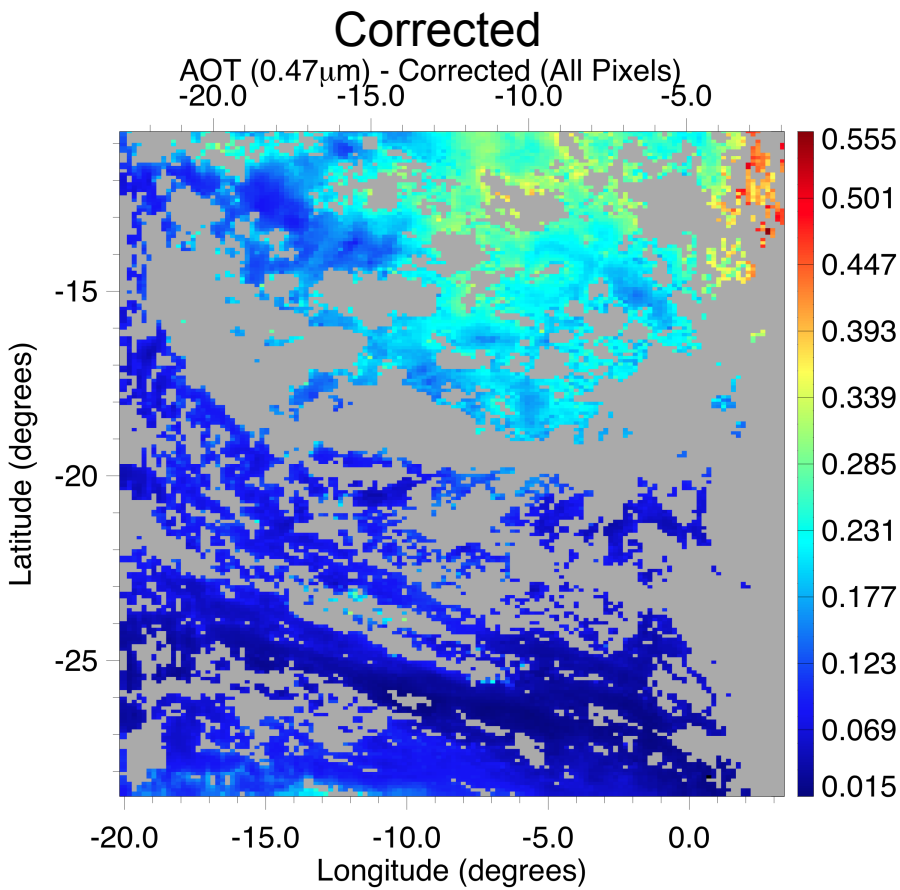


Aerosol Optical Thickne

Original vs Corrected

All Pixels at 0.47 μm

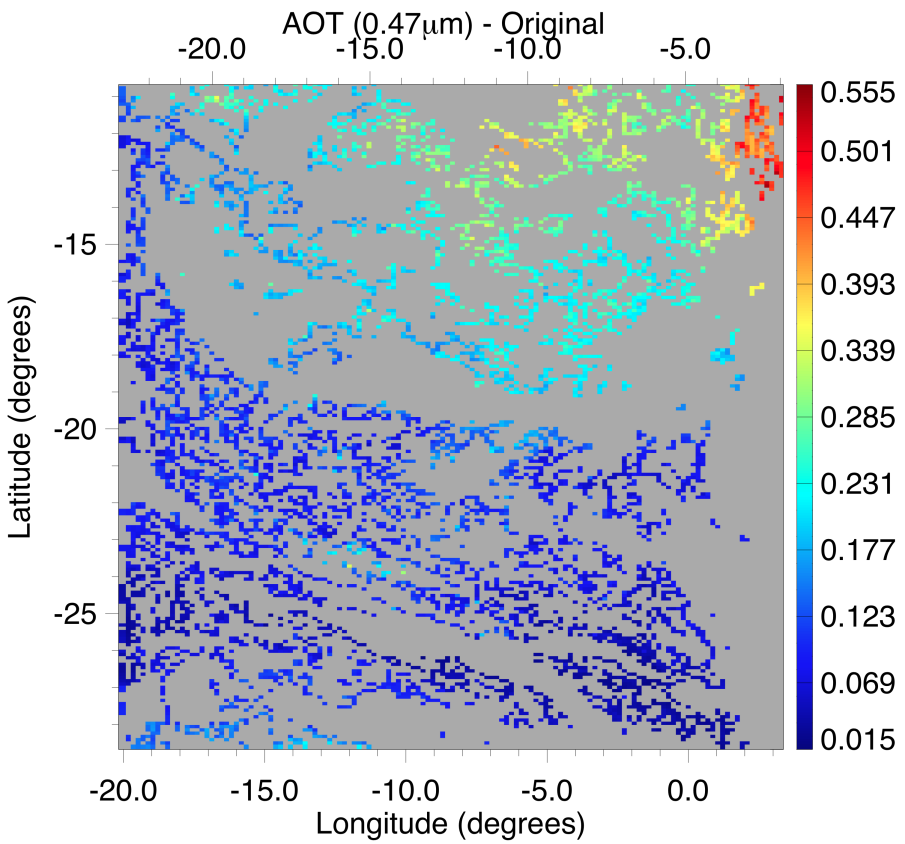




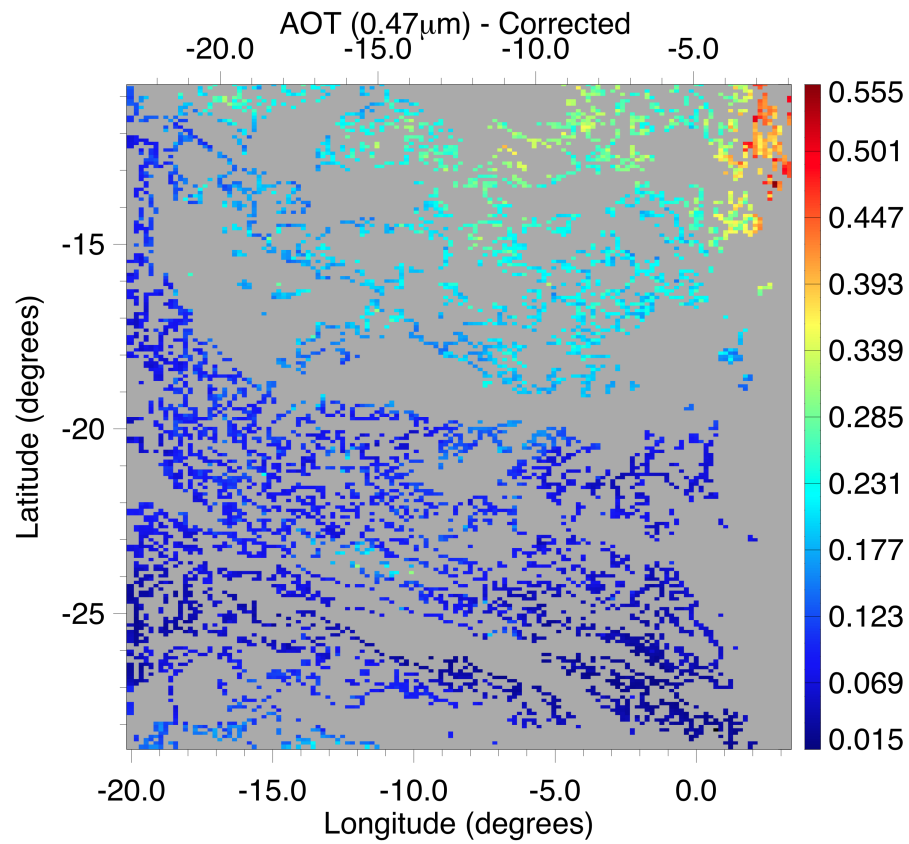
Aerosol Optical Thickness
Original vs Corrected

Corrected Pixels 0.47 µm

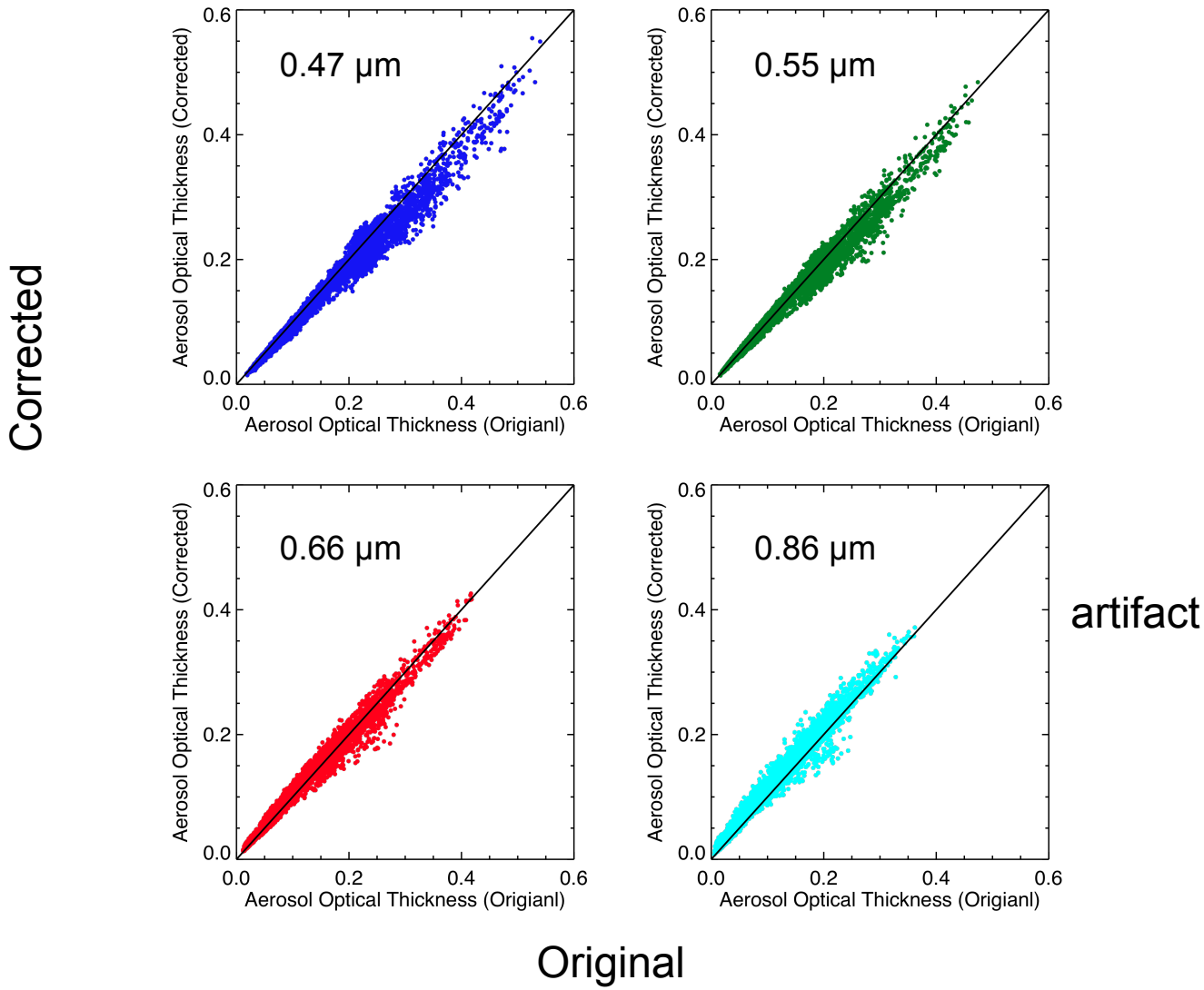
Original



Corrected

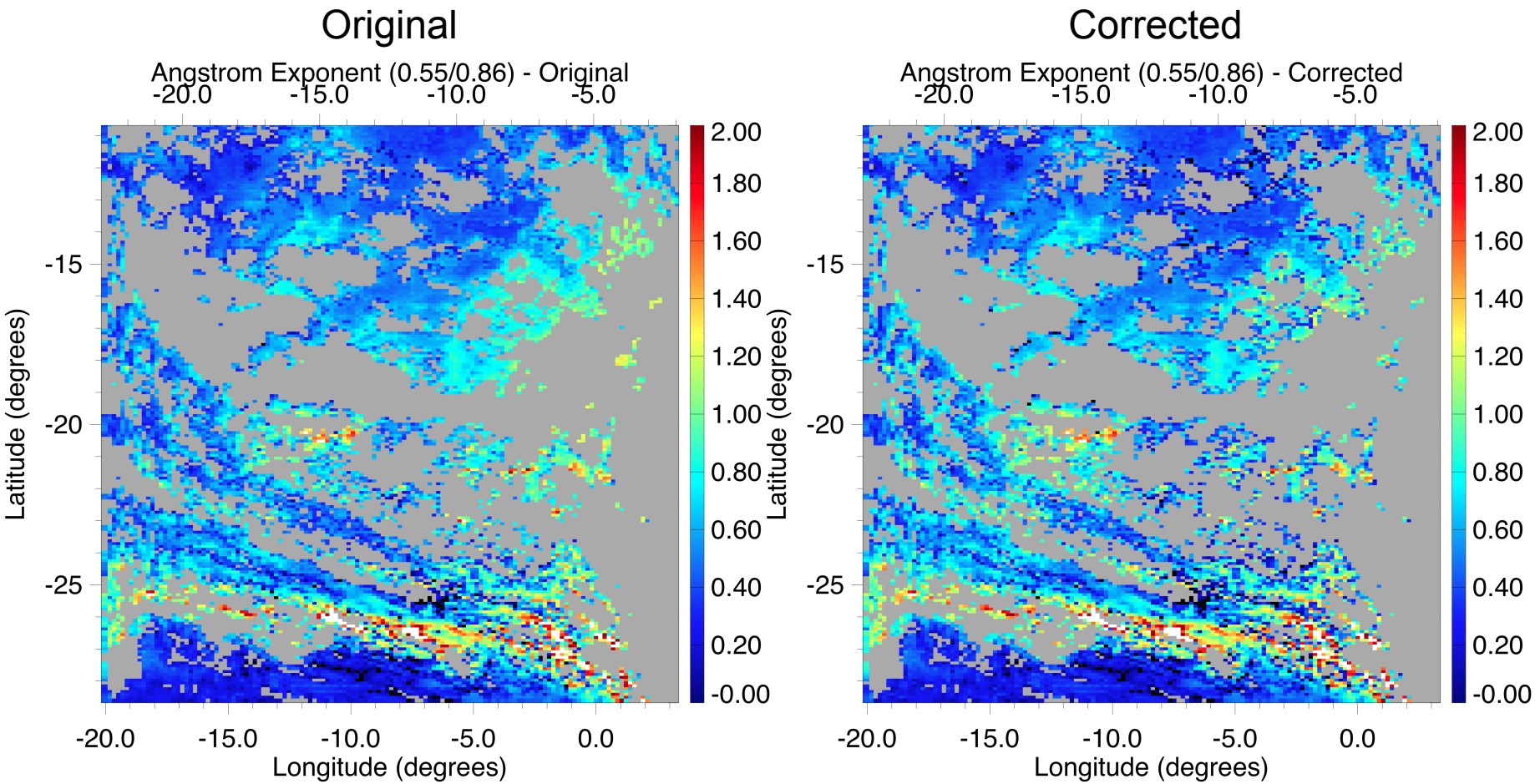


Aerosol Optical Thickness
Original vs Corrected



Angstrom Exponent
Original vs Corrected

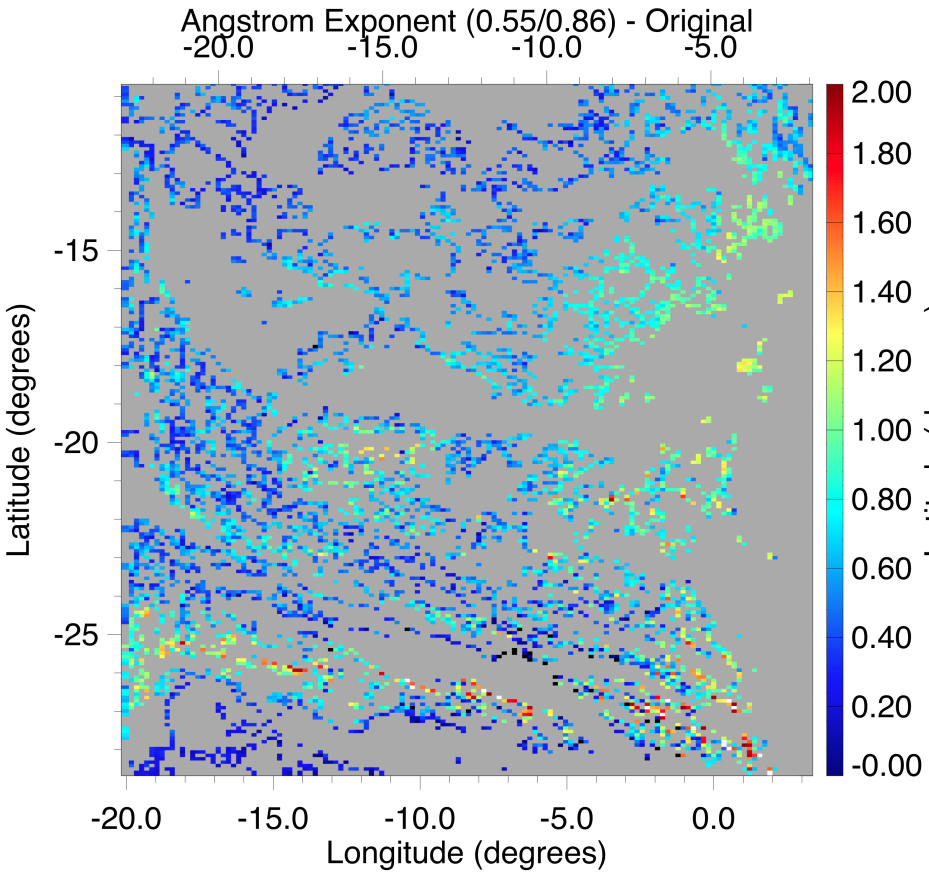
All Pixels



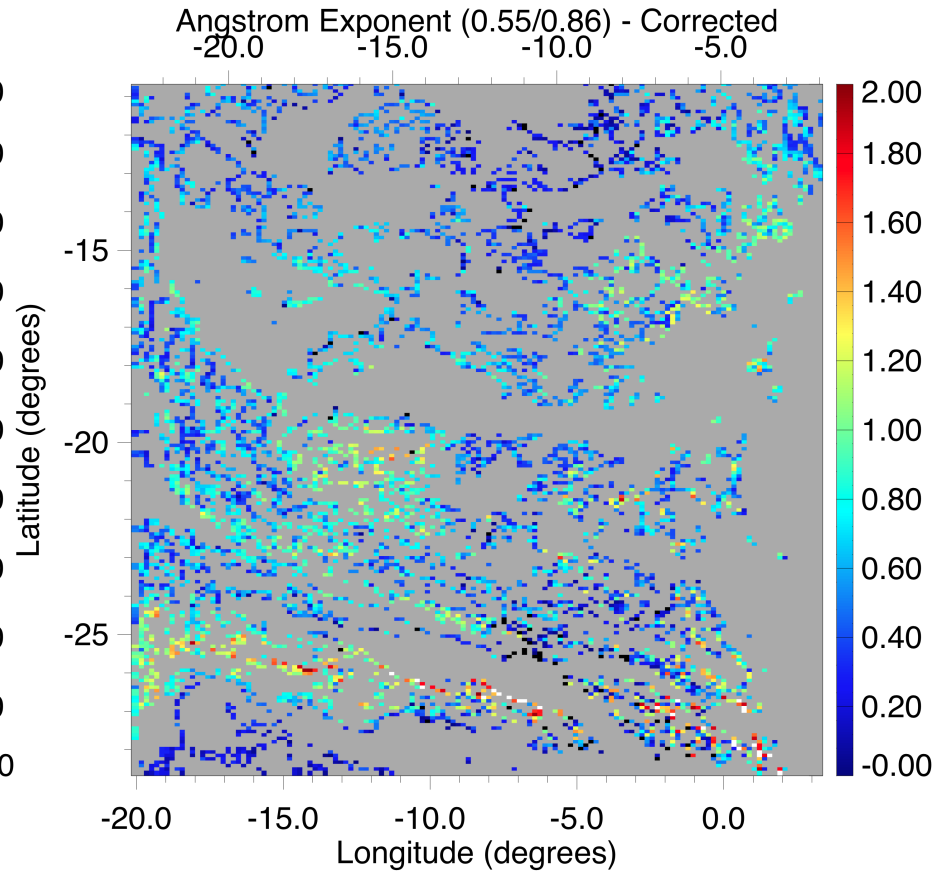
Angstrom Exponent
Original vs Corrected

Corrected Pixels

Original

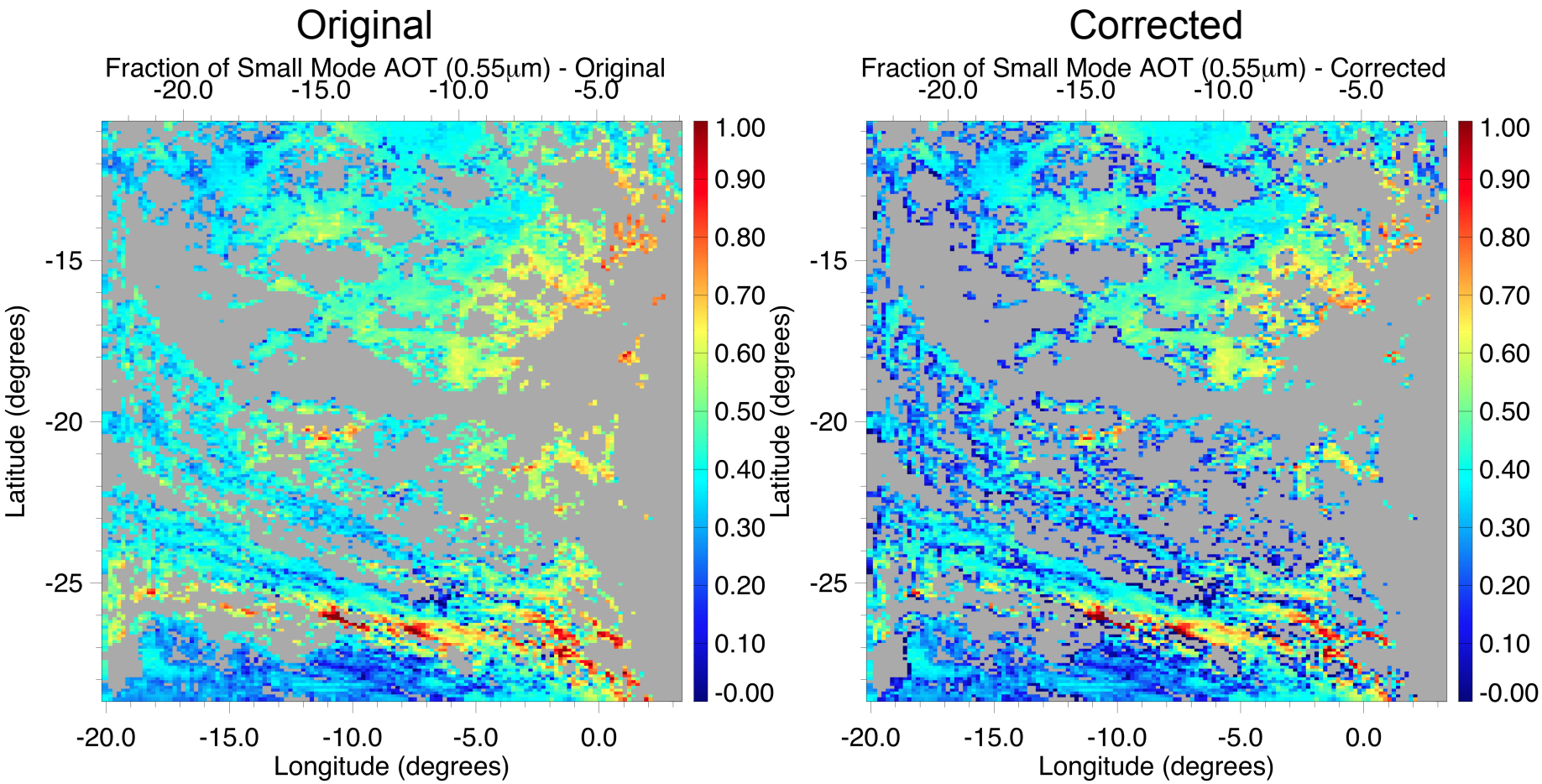


Corrected



Fraction of Small Mode AOT
Original vs Corrected

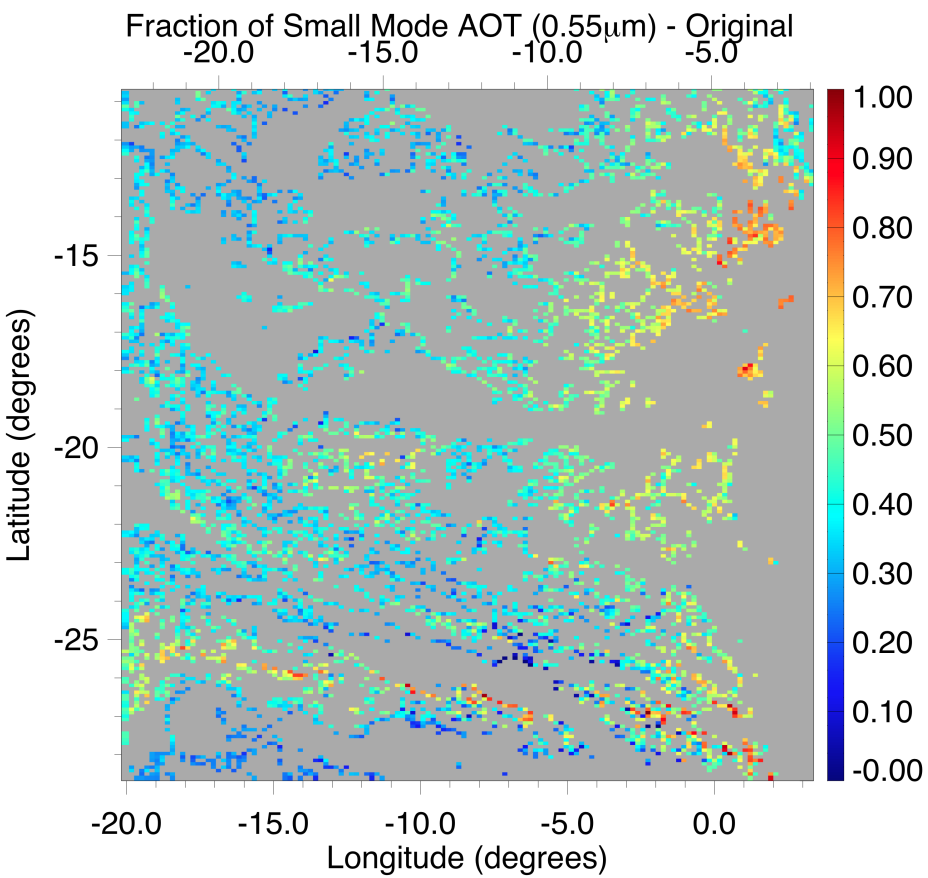
All Pixels



Fraction of Small Mode AOT
Original vs Corrected

Corrected Pixels

Original



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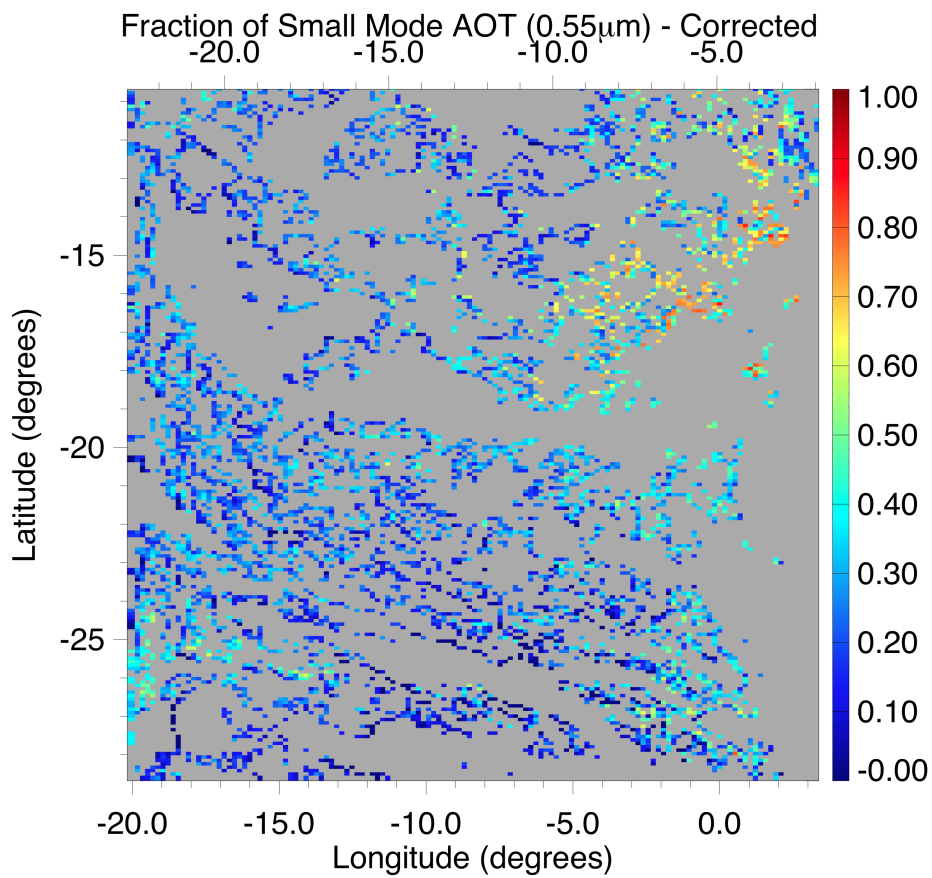
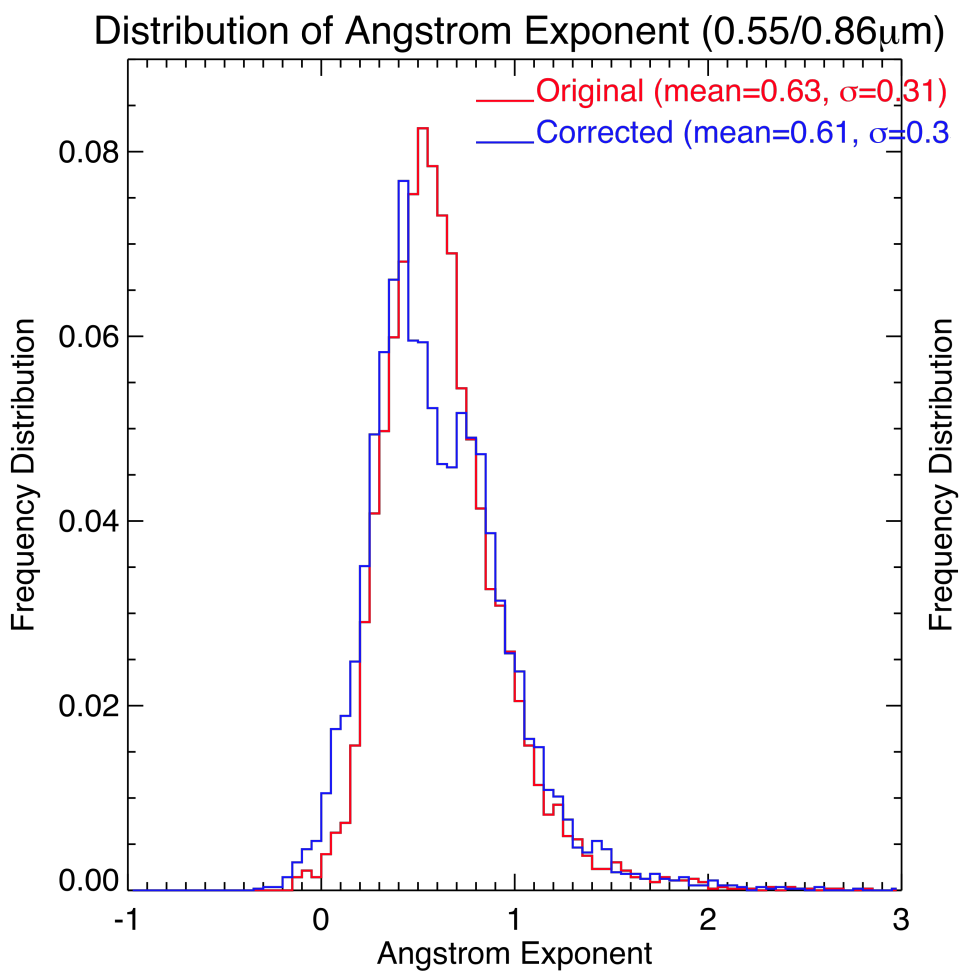
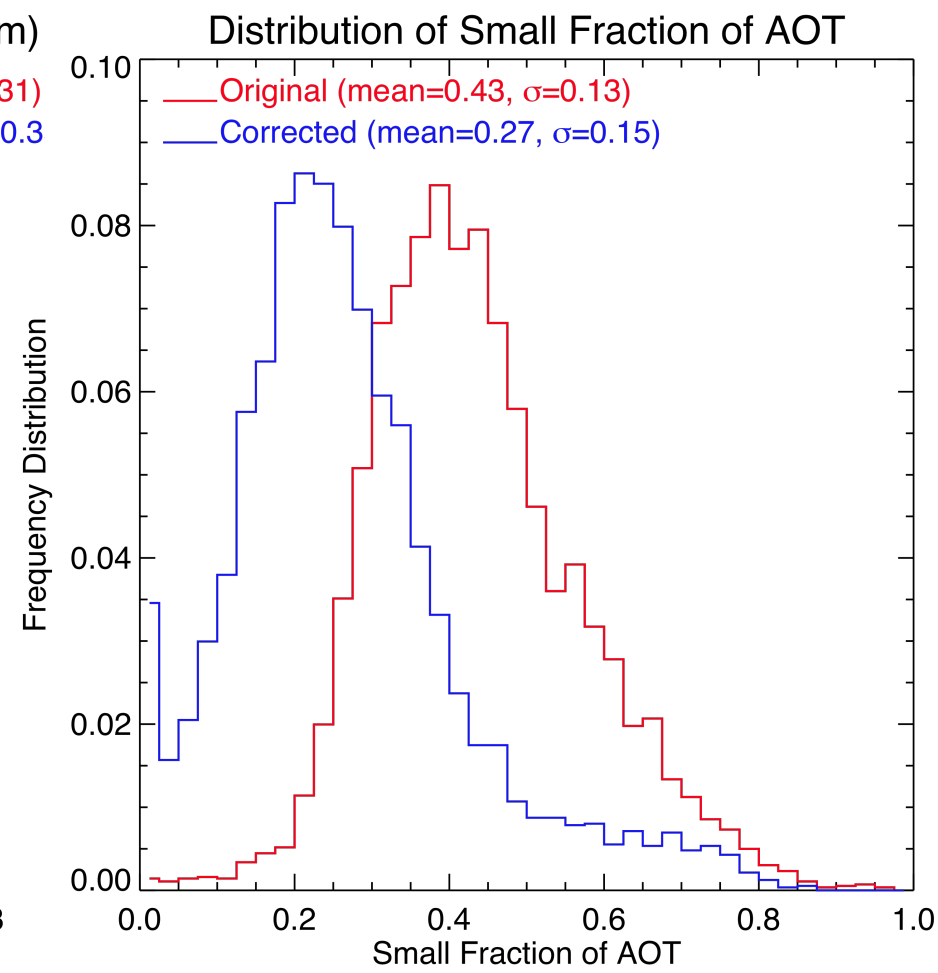


Original vs Corrected

Angstrom Exponent



Small Fraction of AOT



Summary

1. CERES observed SW flux are used to derive narrowband flux;

2. Apply the Two-Layer Model to estimate 3D cloud induced radiance enhancement;

3. We are able to make corrections to the cloud adjacency effects due to the molecular layer above;

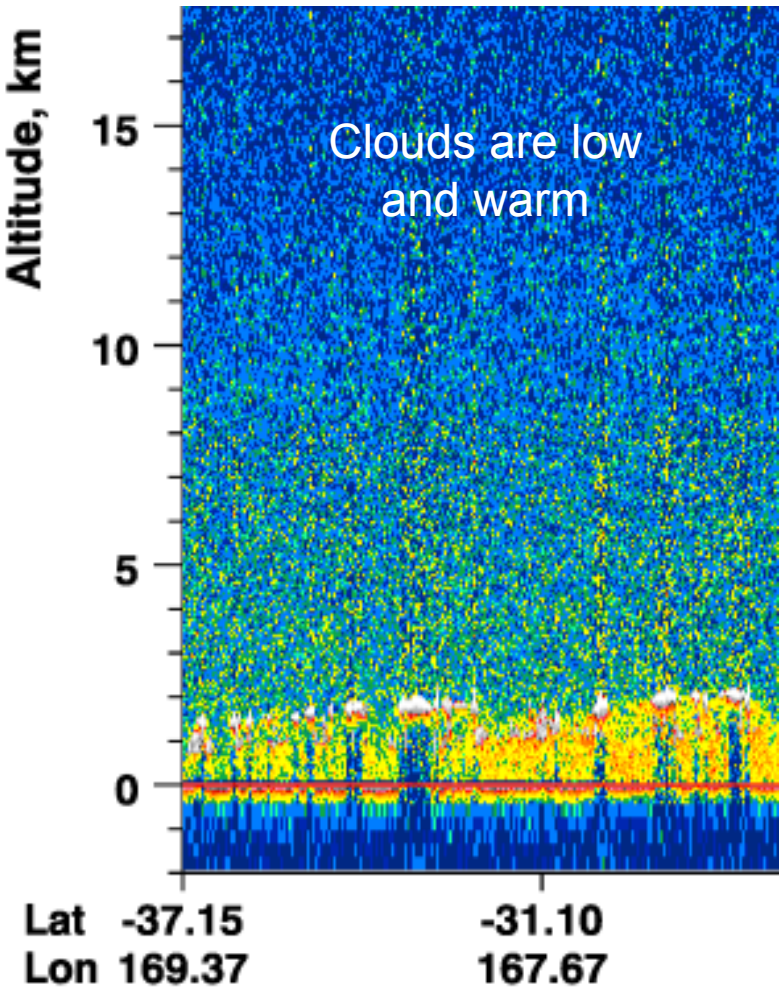
4. Correction for cloud adjacency effects leads to smaller Angstrom exponent and smaller fine mode fraction of aerosol optical thickness.

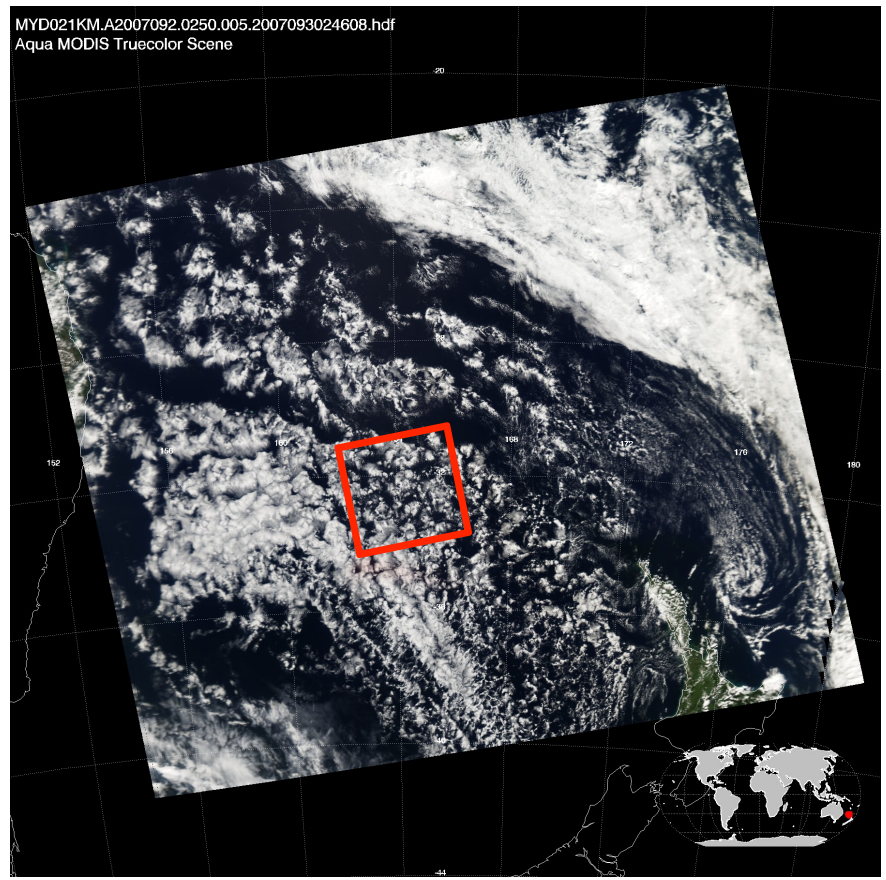
5. We are not able yet to correct for the surface effects.

Challenegs

- How to correct surface effects?
- Generalization over land?
- Validation?

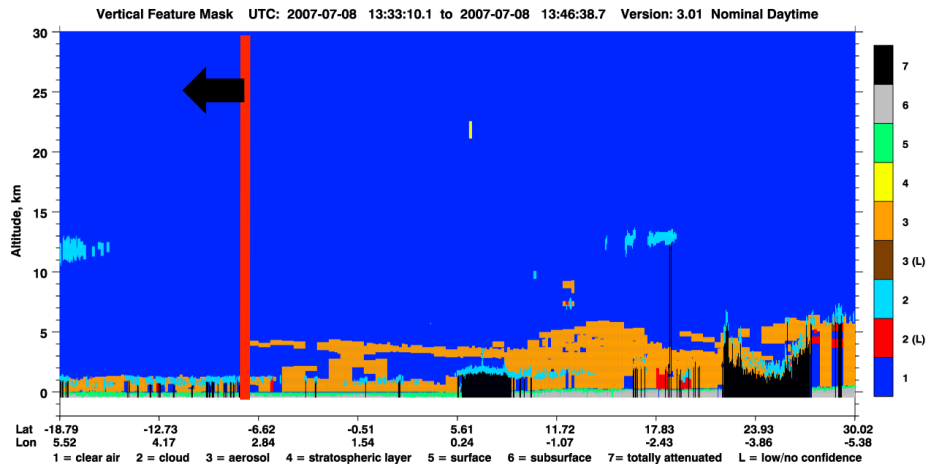
Application to Aqua MODIS

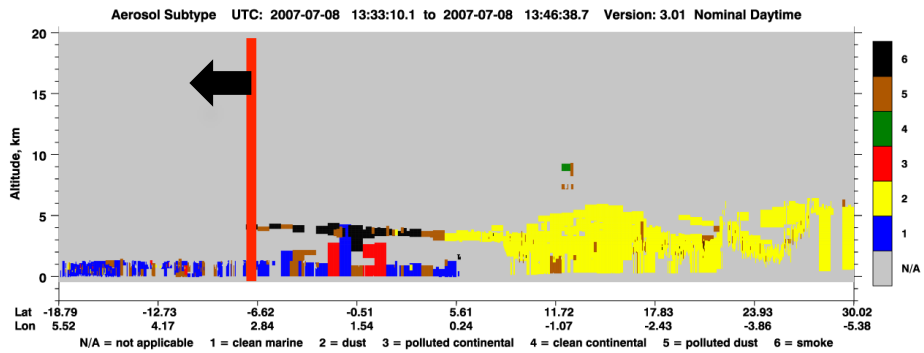


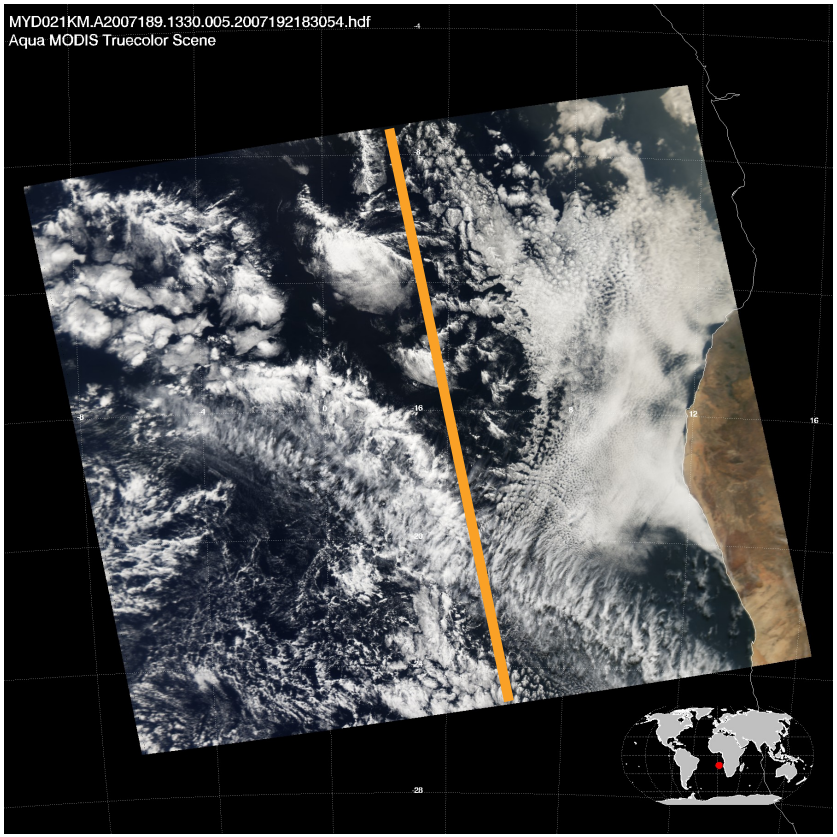


Off West Coast of Africa

July 8, 2007



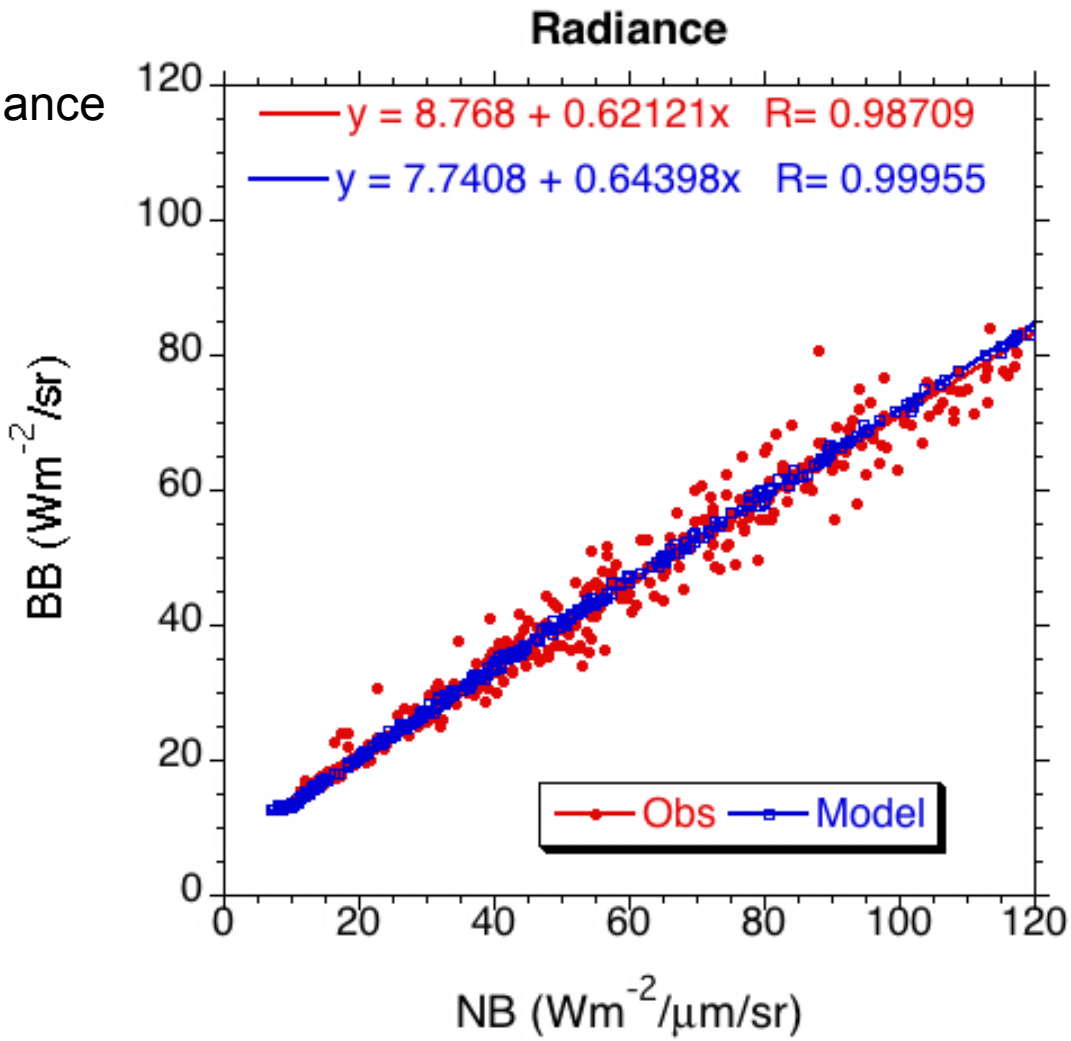




Consistency Check

Check the assumption for radiance

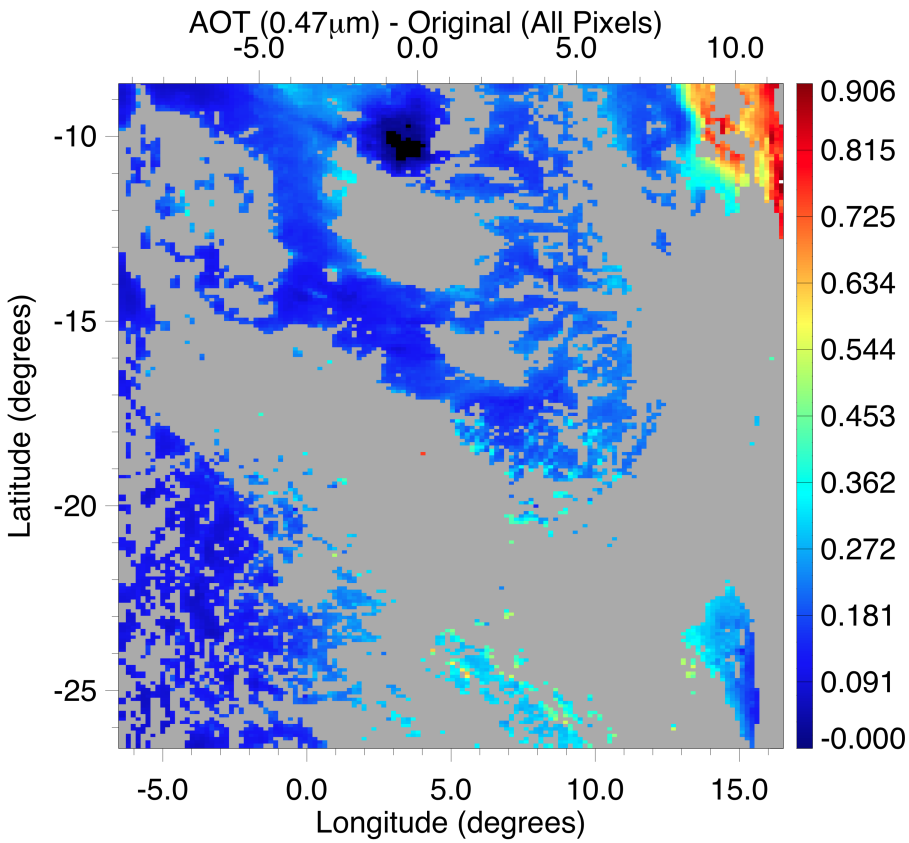
$$\frac{F_{obs}^{NB}}{F_{obs}^{BB}} \approx \frac{F_{mod}^{NB}}{F_{mod}^{BB}}$$



Aerosol Optical Thickness
Original vs Corrected

All Pixels

Original



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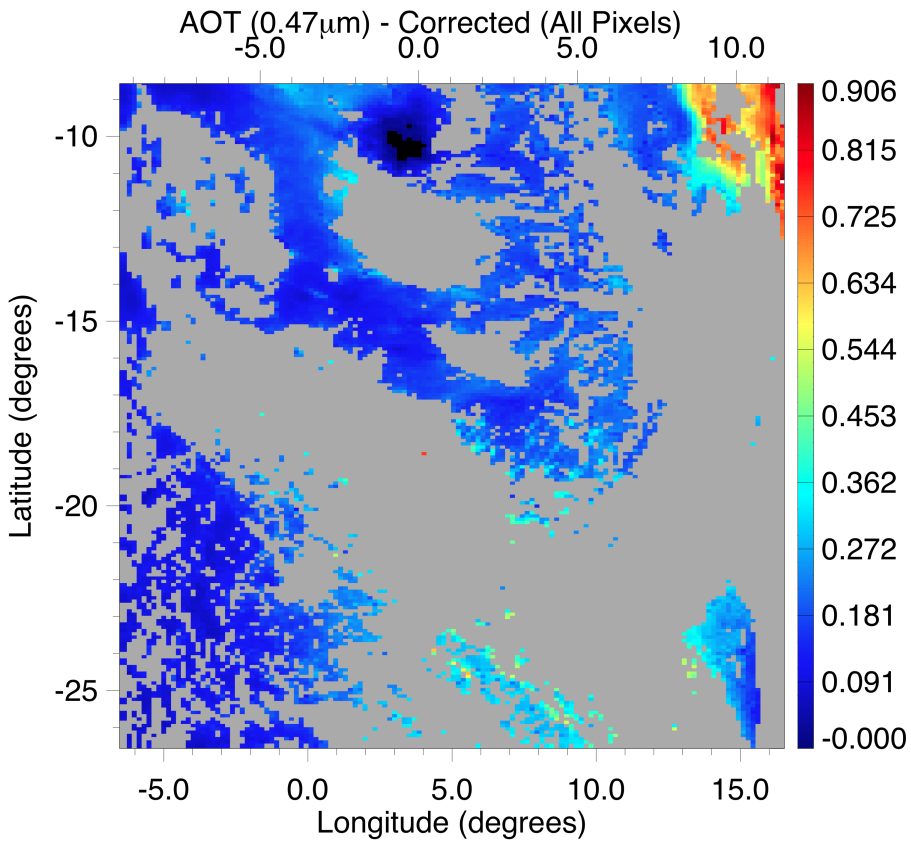
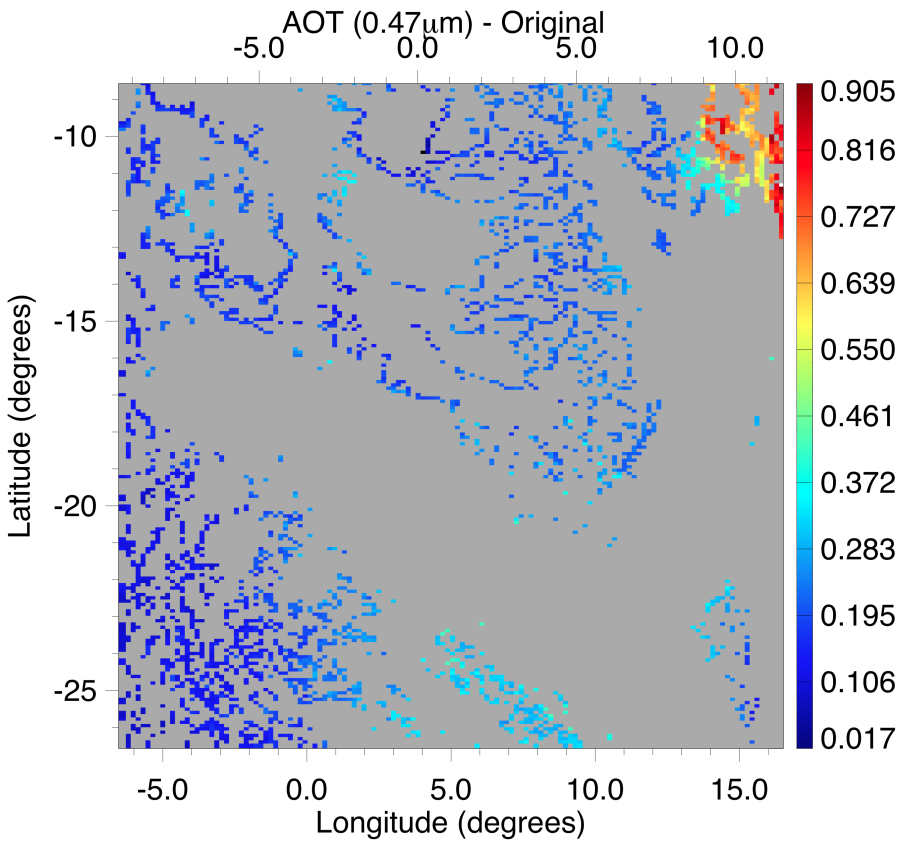


Aerosol Optical Thickness
Original vs Corrected

Corrected Pixels

Original



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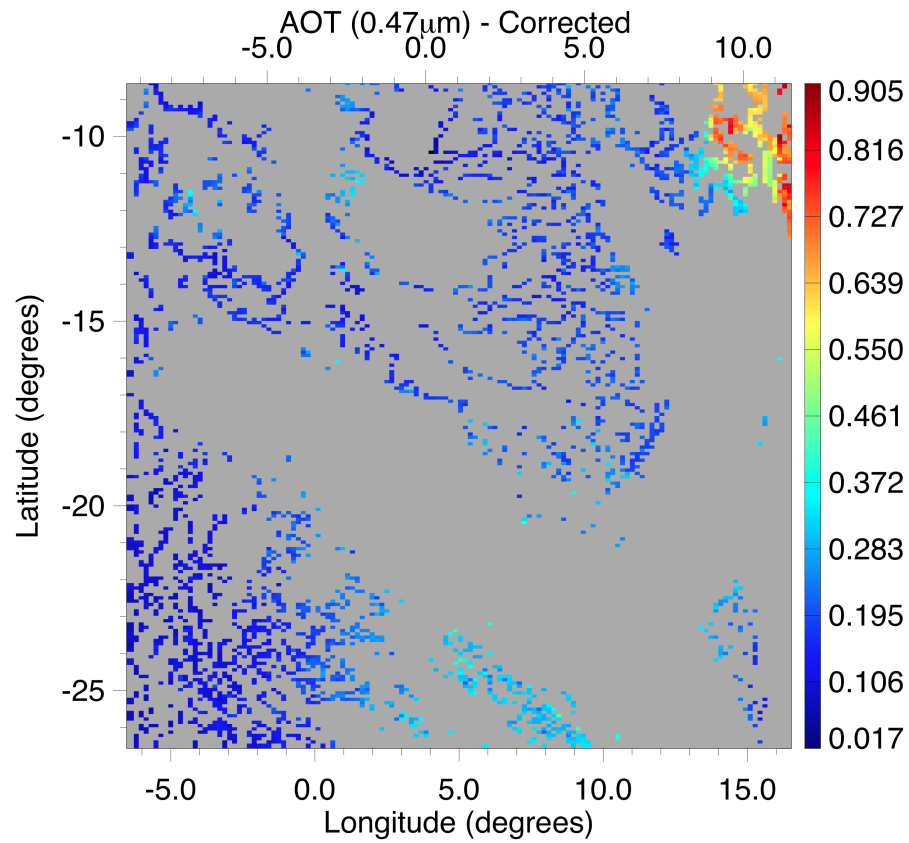
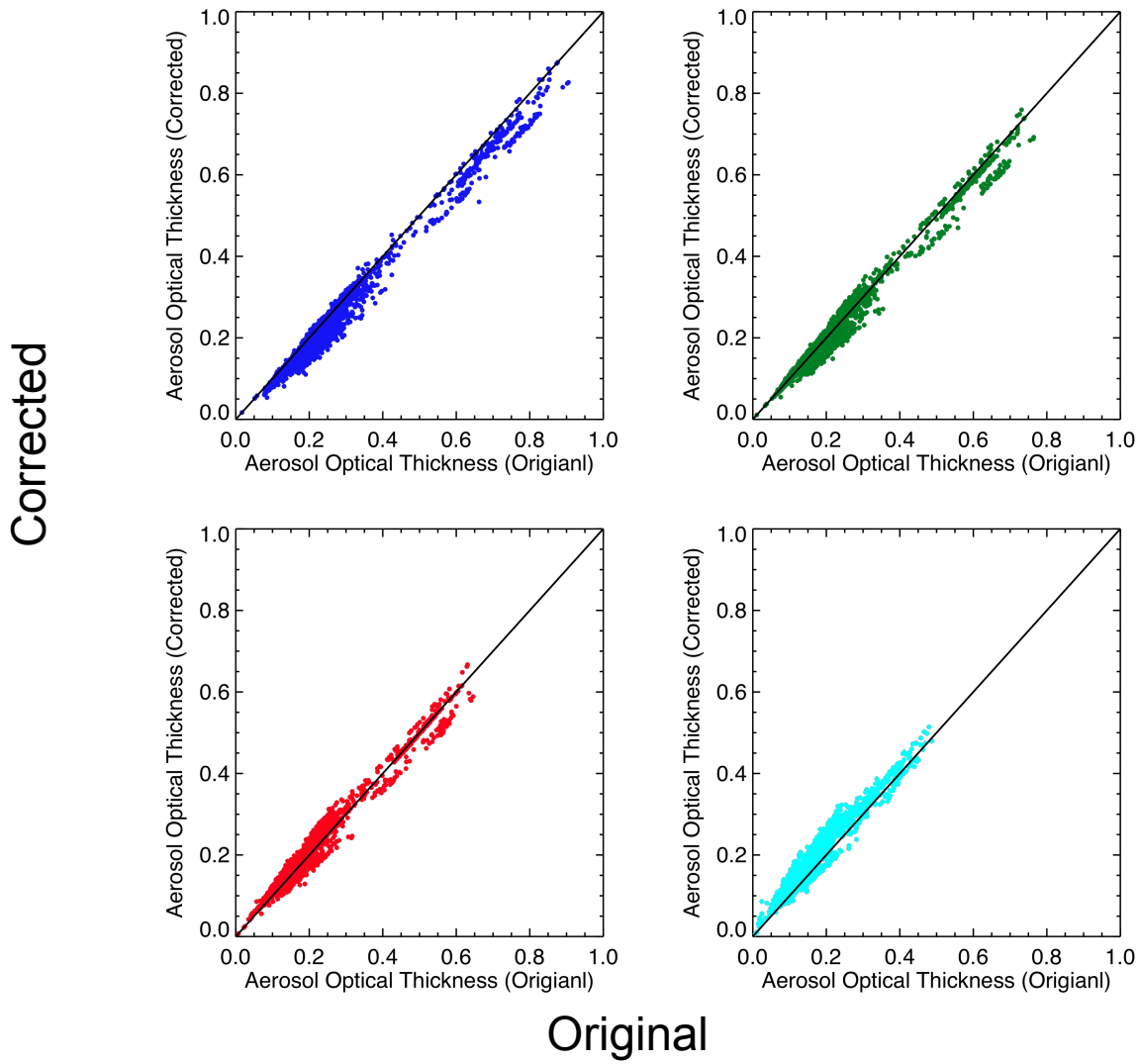
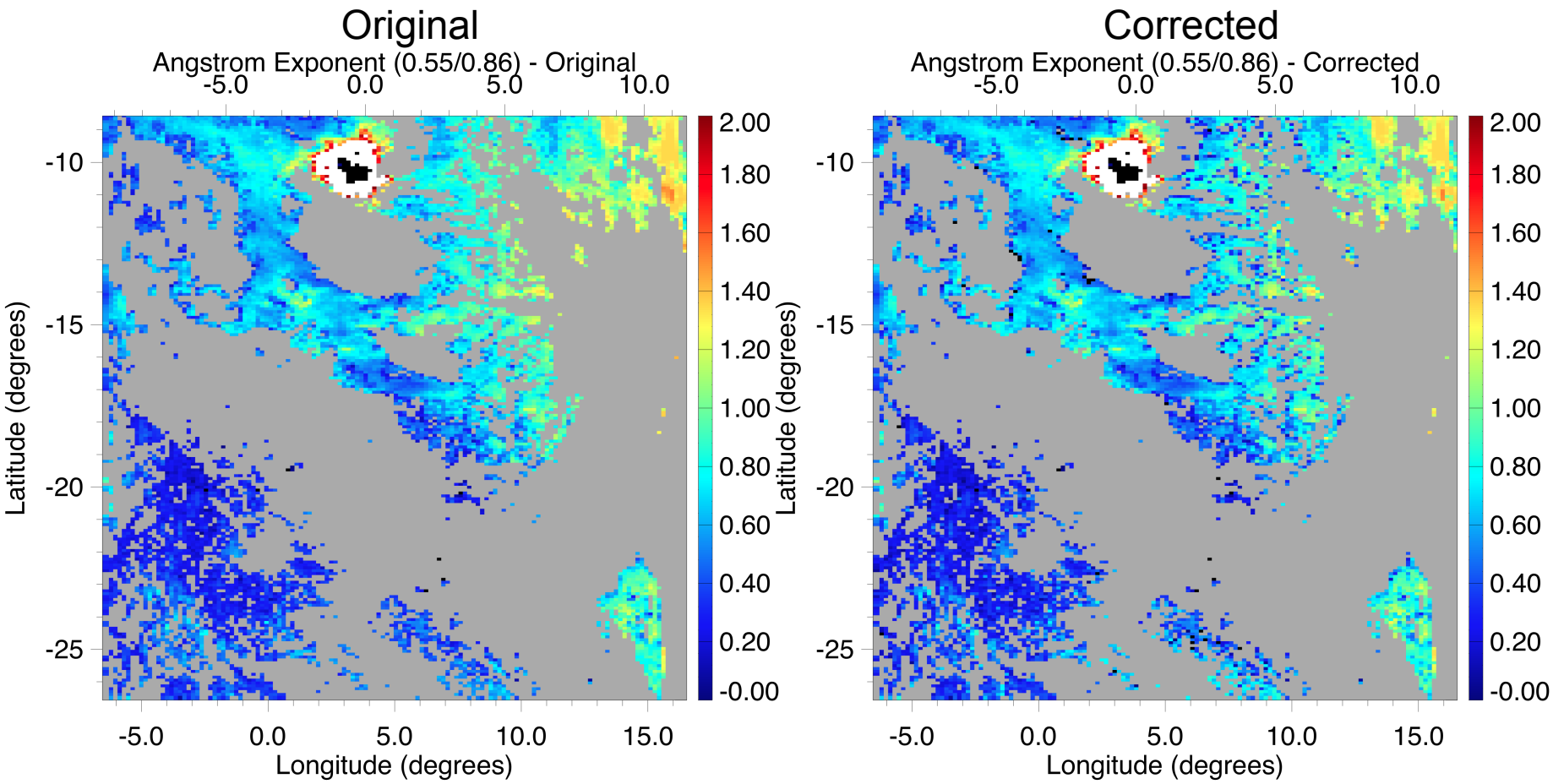


Aerosol Optical Thickness
Original vs Corrected



Angstrom Exponent
Original vs Corrected

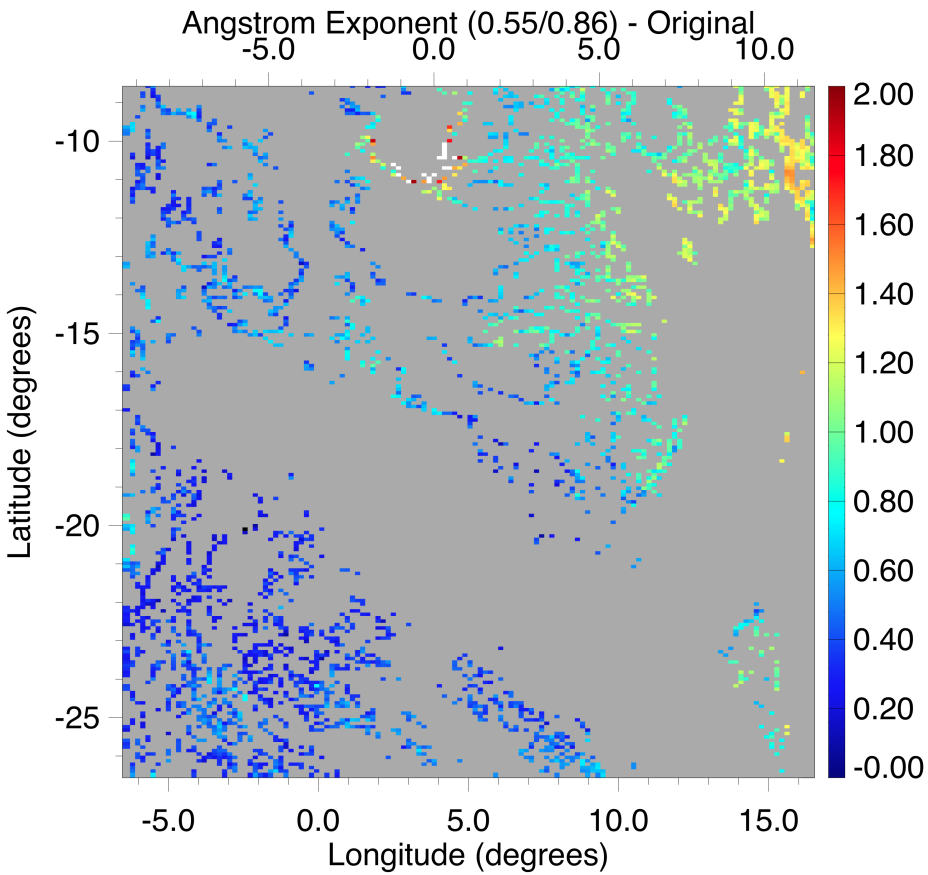
All Pixels



Angstrom Exponent
Original vs Corrected

Pixels got corrected

Original



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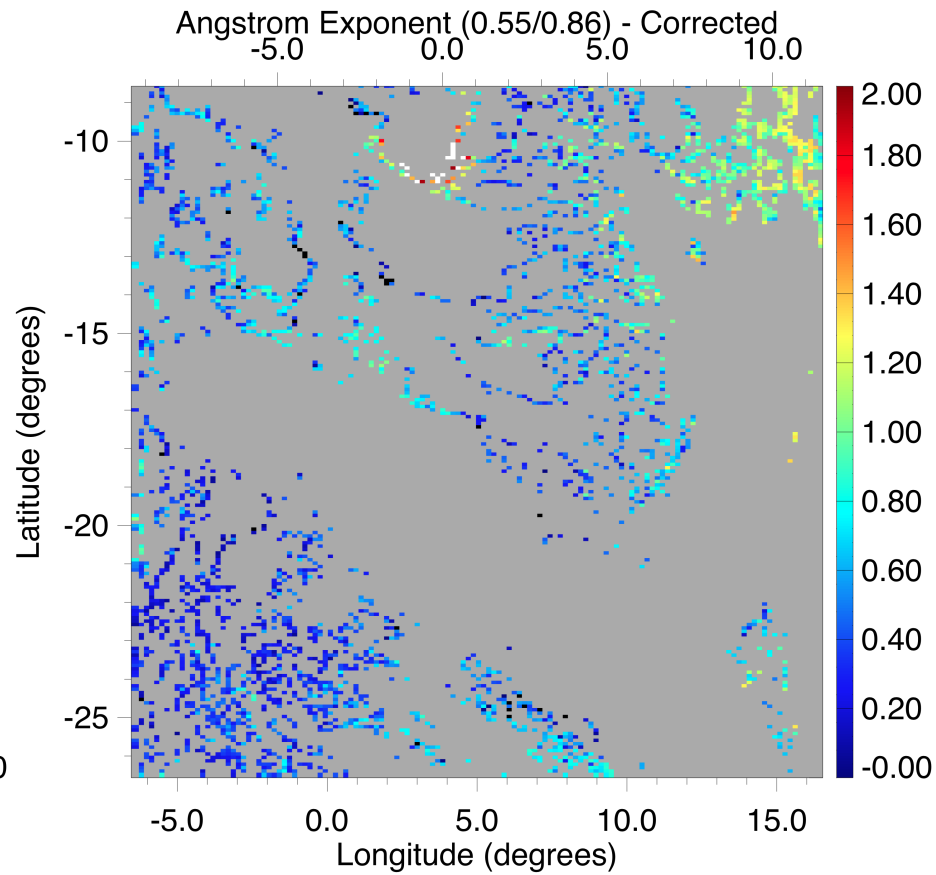
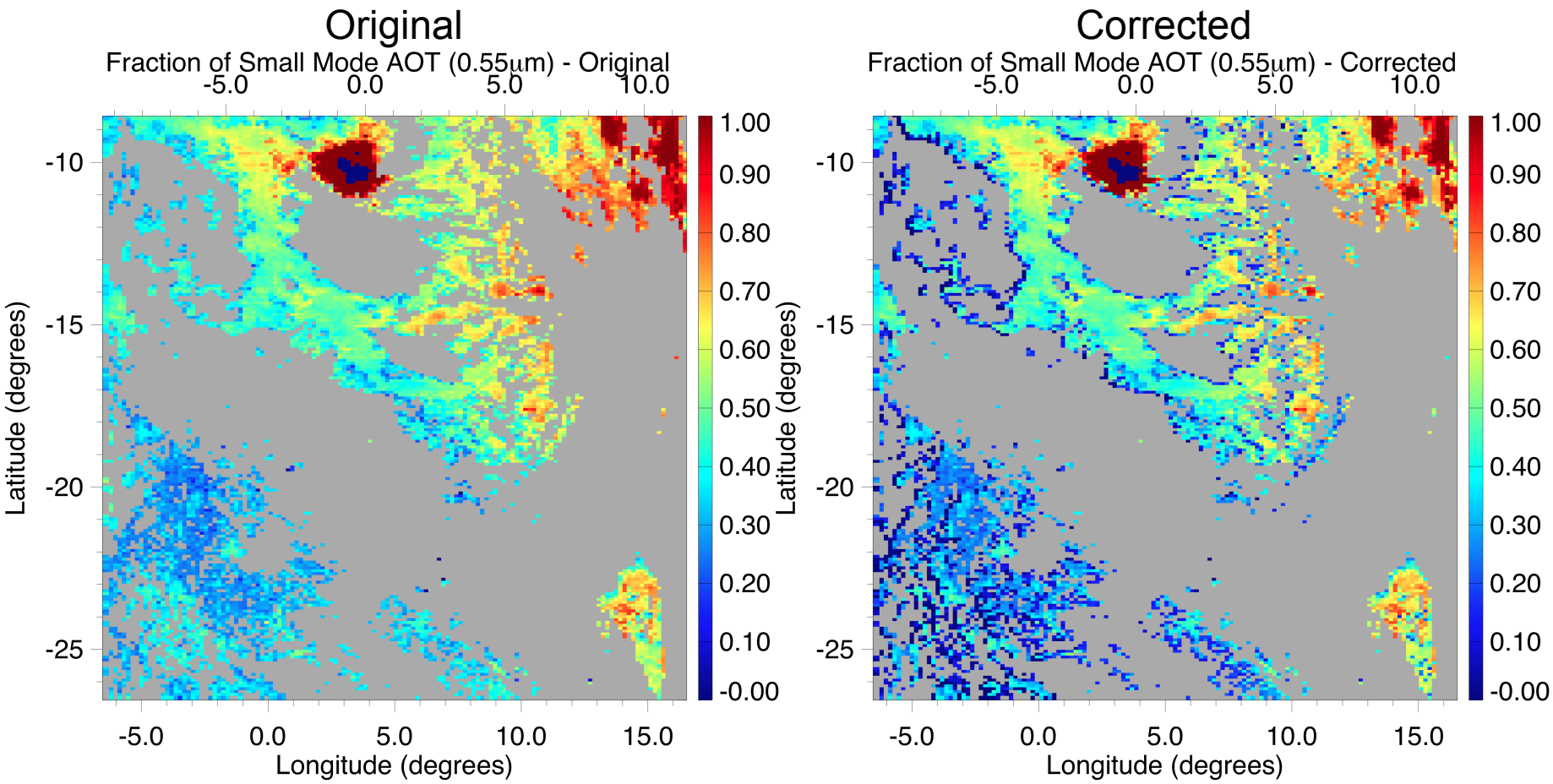


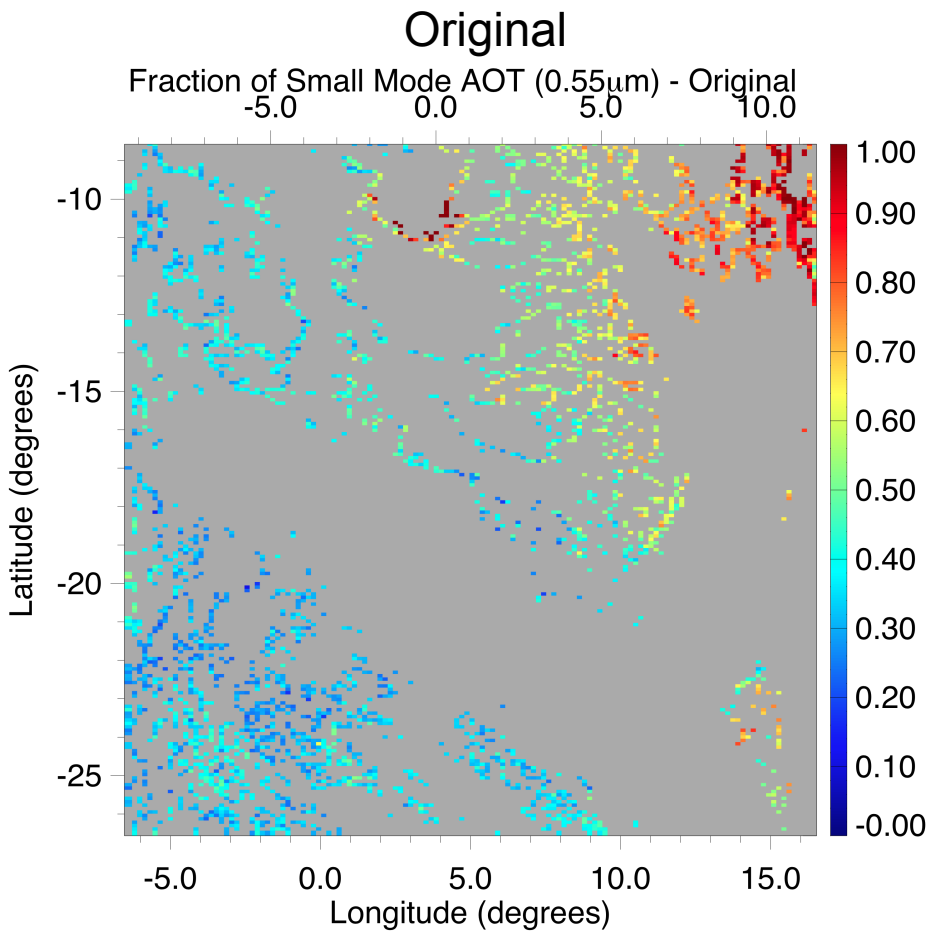
Fraction of Small Mode AOT
Original vs Corrected

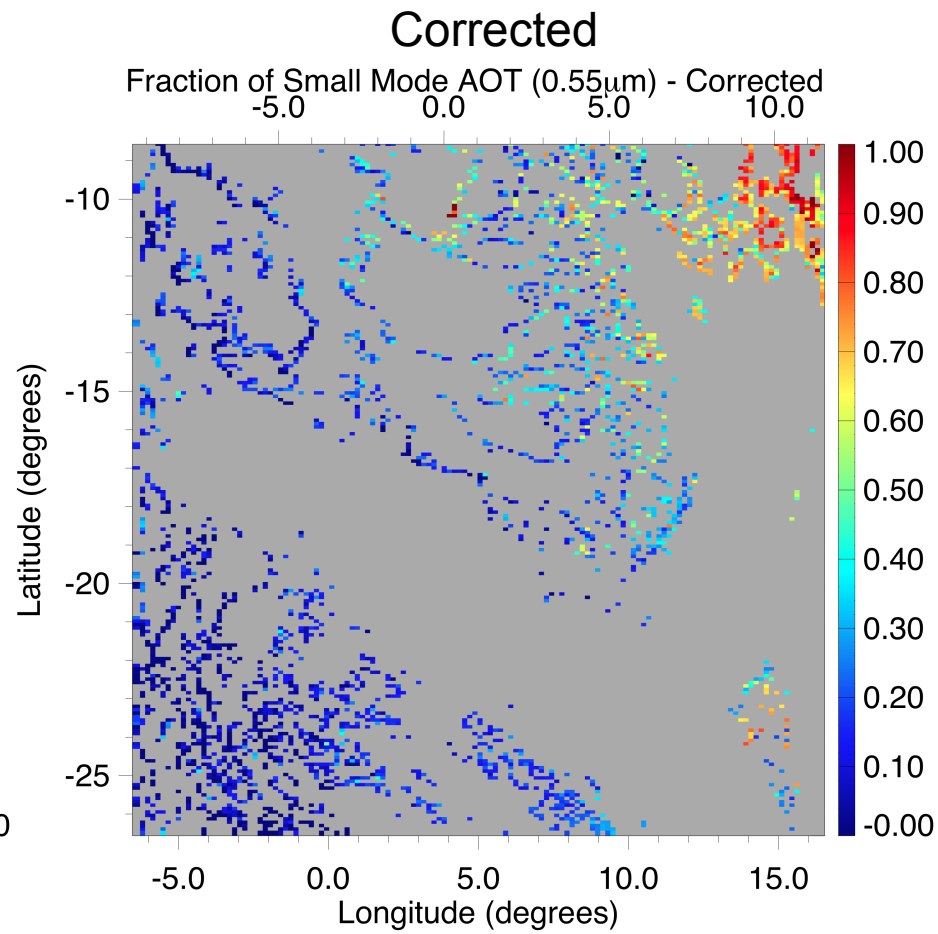
All Pixels



Fraction of Small Mode AOT
Original vs Corrected

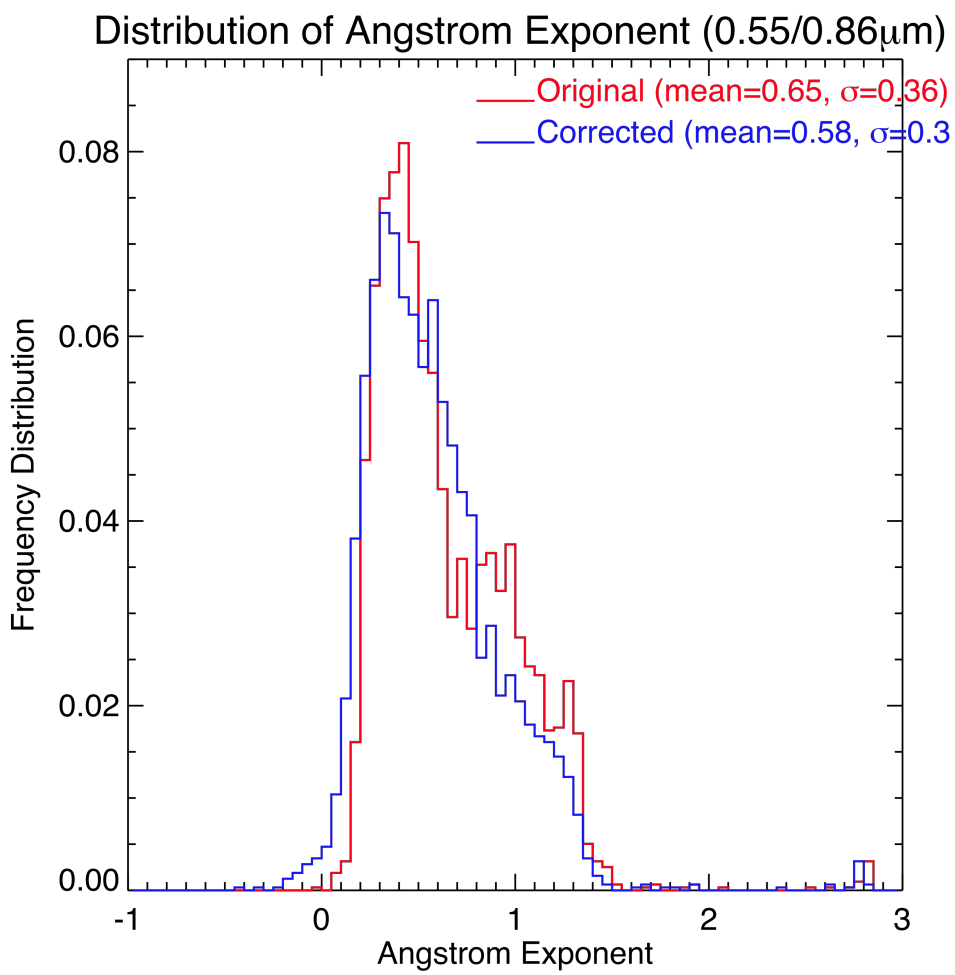
Pixels got corrected



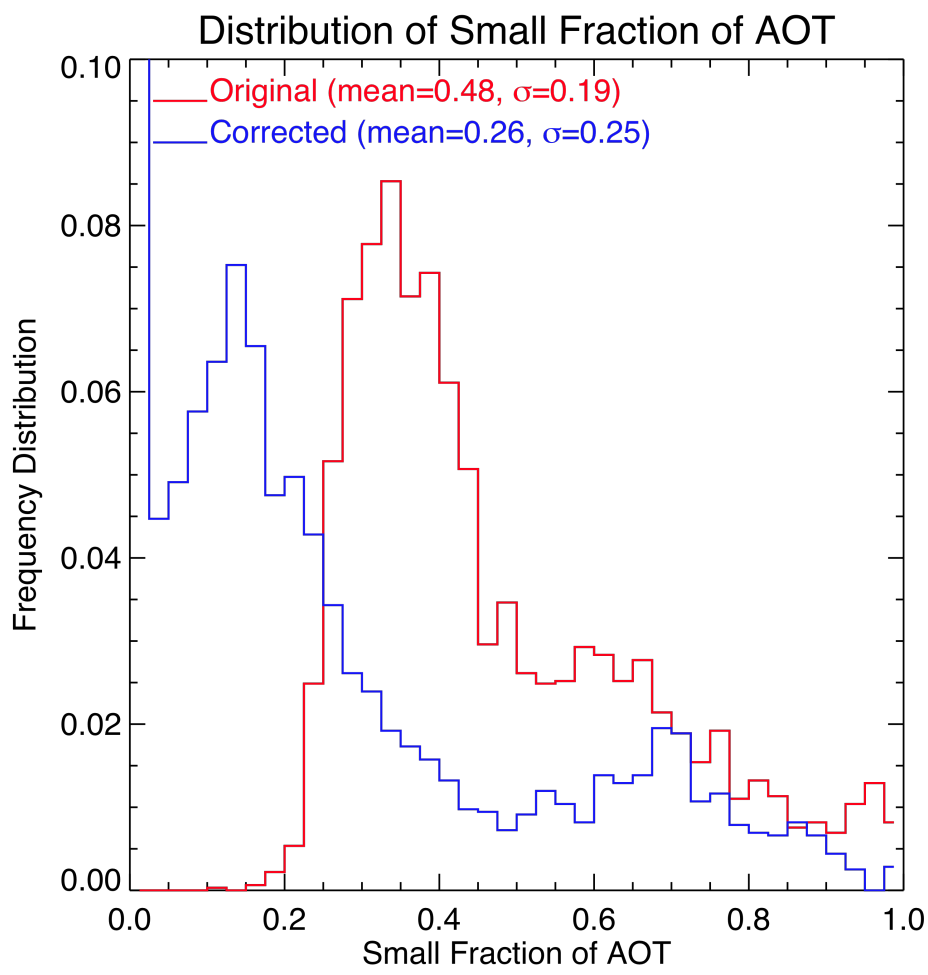


Original vs Corrected

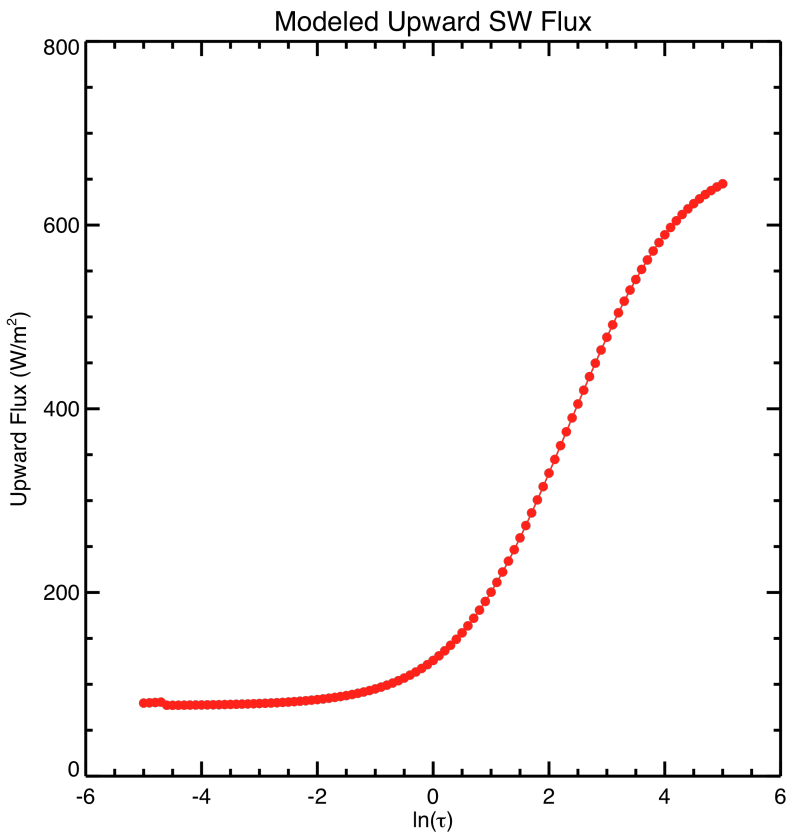
Angstrom Exponent



Fraction of Fine Mode AOT



Modeled SW TOA Radiance



Modeled upward SW flux for water clouds θ_0=45°

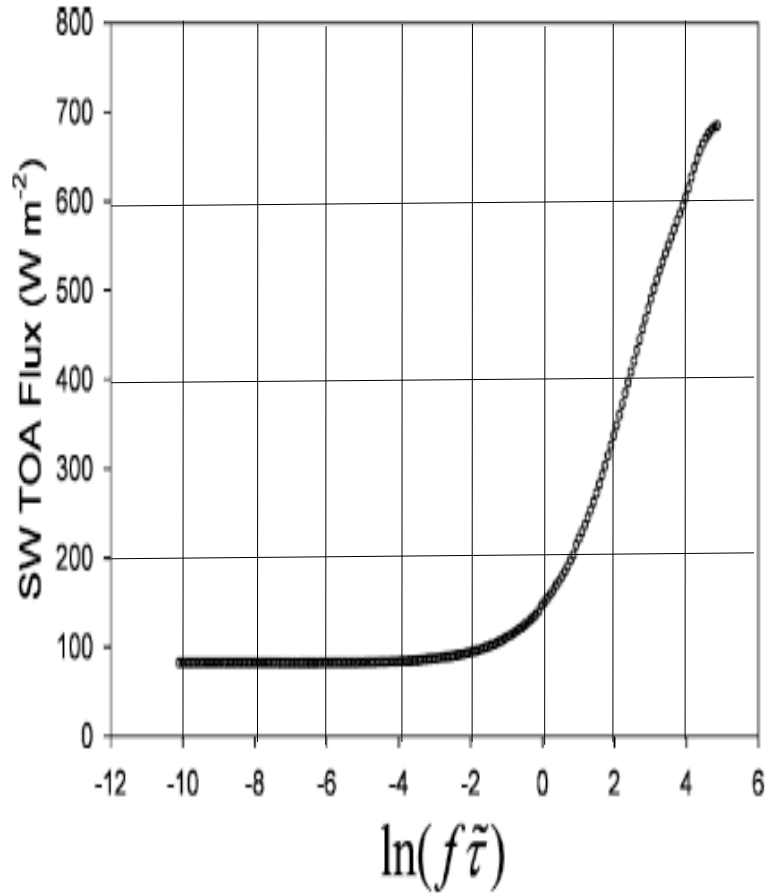


FIG. 2. TOA flux against $\ln(f\tilde{\tau})$ for liquid water clouds at θ_o = 44°–46°.

Loeb et al, 2005

Linearity between NB and BB