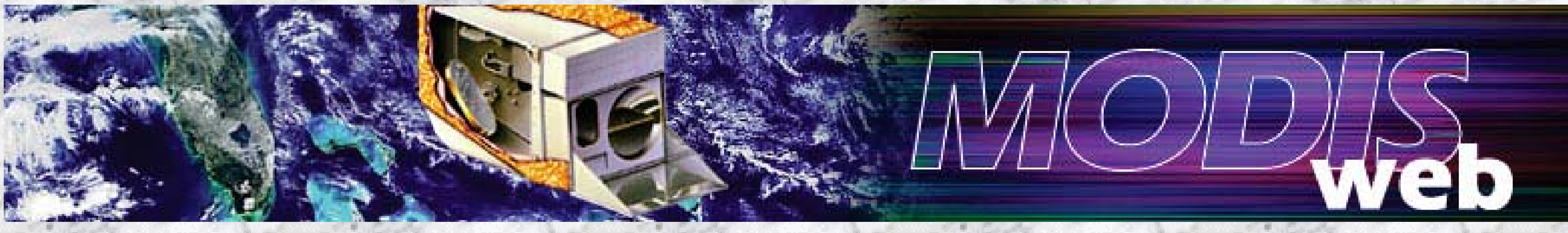

Atmospheric Correction of MODIS Visible and SWIR Bands:

Applications to Cloud Optical Property Retrievals

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TABLE OF CONTENTS:

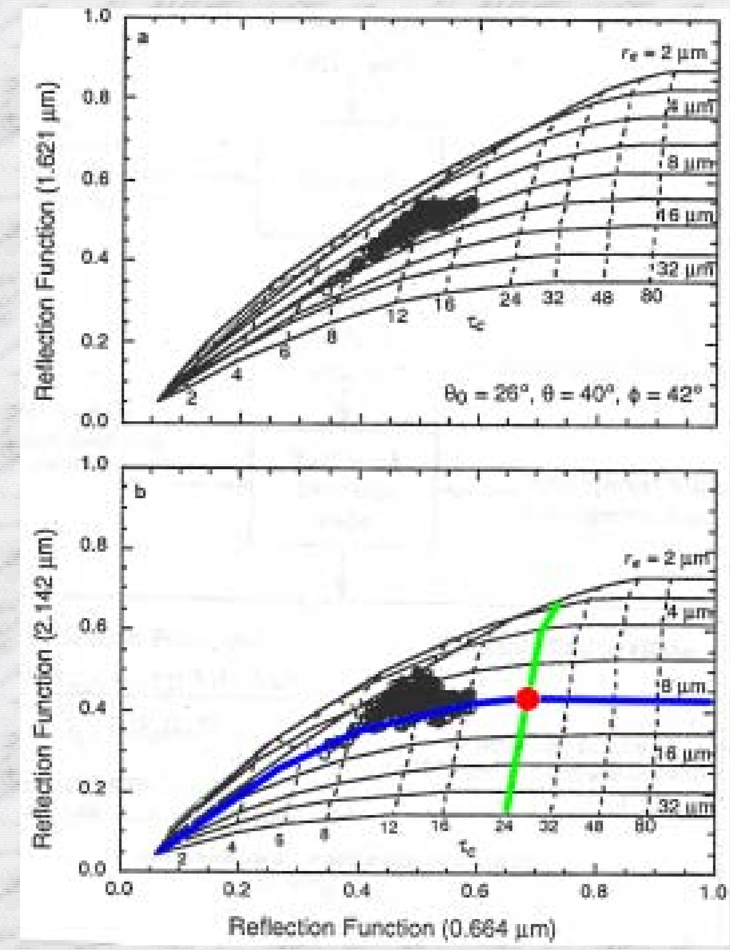
INTRODUCTION:

MOD06OD Algorithm in A Nut Shell

- The determination of optical thickness (τ_c) and effective radius (r_e) is an inverse problem.
- If τ_c and r_e are known, we can forward calculate the cloud reflectance for a given underlying surface and solar-viewing geometry, using the Mie and asymtotic theory.
- Reflectance of a non-absorbing visible band (0.65 μm) is primarily function of τ_c, while Reflectance of water/ice absorbing band (2.1μm) is primarily a function of r_e.

INTRODUCTION:

MOD06OD Algorithm in A Nut Shell (continued)



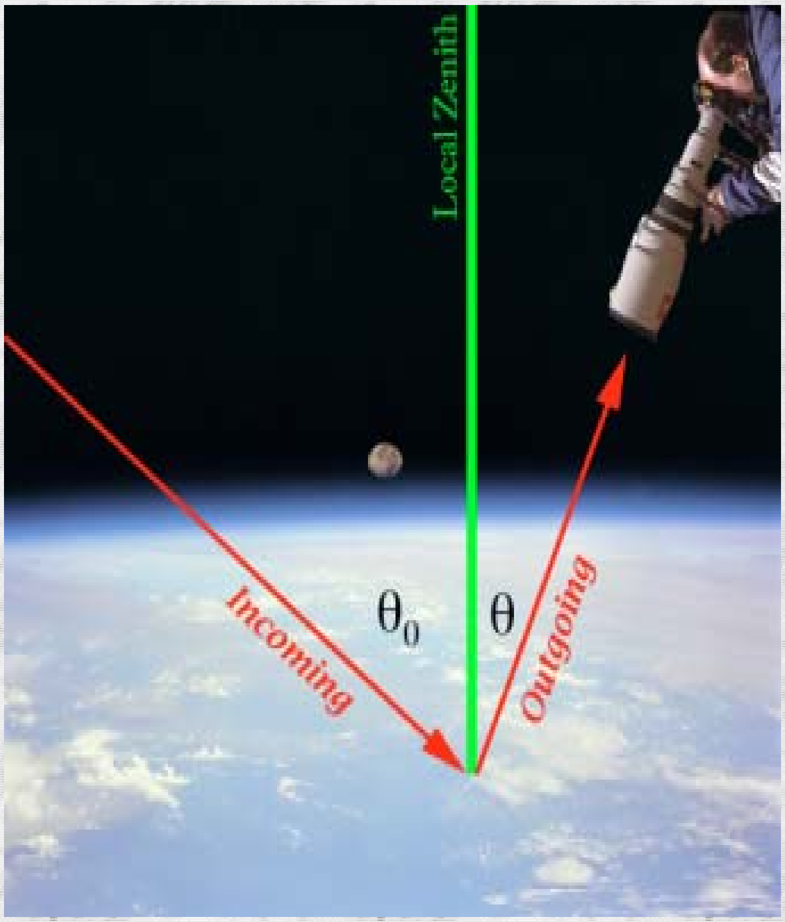
Values of τ_c and r_e are obtained by comparing the R_{obs} with $R_{calculated}$ and searching for the combination of that gives the best fit.

$$R_{obs} = \frac{\pi * I_{obs}}{\mu_0 * F_0}$$

I_{obs}: observed radiance by MODIS
F_0: Solar Irradiance at TOA
μ_0: cosine of solar zenith

Land: 0.65 and 2.1 µm pair
Ocean: 0.86 and 2.1 µm pair

INTRODUCTION:
Define Problem



Monochromatic reflectance of a cloud:

$$= \frac{\pi * I_\lambda^{cloudTop}}{\mu_0 * F_\lambda^{cloudTop}}$$

$$= \frac{\pi * \dfrac{I_\lambda^{obs}}{T_\lambda(\mu)}}{\mu_0 * F_{0\lambda} * T_\lambda(\mu_0)}$$

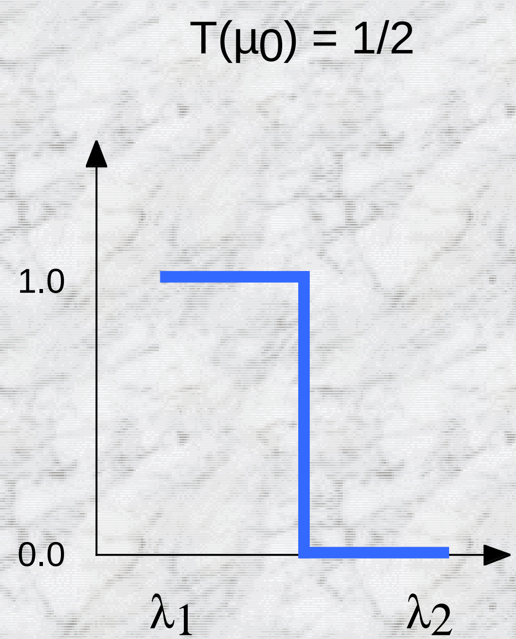
$$= \frac{\pi * I_\lambda^{obs}}{\mu_0 * F_{0\lambda}} * \frac{1}{T_\lambda(\mu) * T_\lambda(\mu_0)}$$

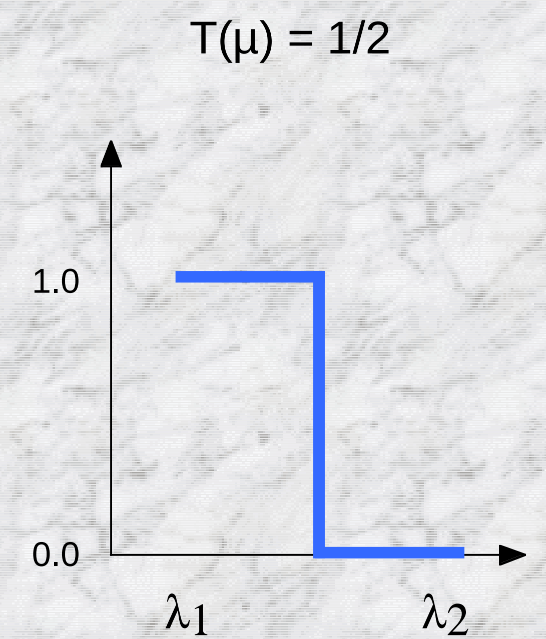
INTRODUCTION:

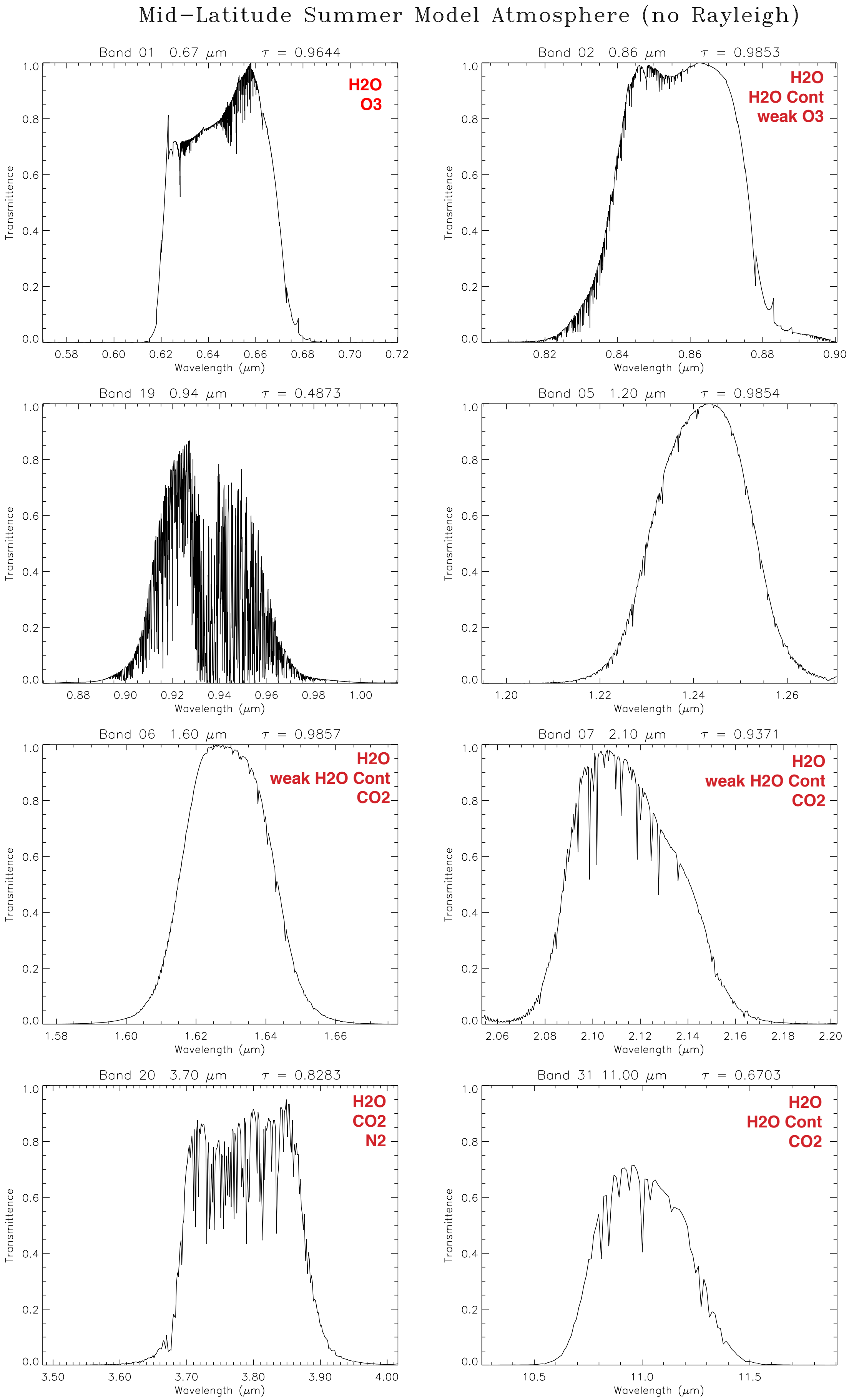
Define Problem

Two-way transmittance for a MODIS Band:

$$[T(\mu_0)*T(\mu)]_{band} = \frac{1}{2} \neq [T(\mu_0)]_{band} * [T(\mu)]_{band}$$






Mid–Latitude Summer Model Atmosphere (no Rayleigh)
Band 01 0.67 μm τ = 0.9644
H2O
O3
Band 02 0.86 μm τ = 0.9853
H2O
H2O Cont
weak O3
Band 19 0.94 μm τ = 0.4873
Band 05 1.20 μm τ = 0.9854
Band 06 1.60 μm τ = 0.9857
H2O
weak H2O Cont
CO2
Band 07 2.10 μm τ = 0.9371
H2O
weak H2O Cont
CO2
Band 20 3.70 μm τ = 0.8283
H2O
CO2
N2
Band 31 11.00 μm τ = 0.6703
H2O
H2O Cont
CO2
Transmittence
Wavelength (μm)

CORRECTION METHOD:

Parameterization

- Column integrated precipitable water from cloud top to TOA. Other common gases included, although not parameterized.

- *Moisture weighted mean column air temperature from cloud top to TOA.*

- *Surface temperature.*

CORRECTION METHOD:
Parameterization (continued)

Transmittance(Pc, PW, $\mu_{effective}$, λ):

- Pc = cloud top height
- PW = precipitable water from cloud top to TOA
- $\mu_{effective}$ is defined as: $$\frac{1}{\mu_{effective}} = \frac{1}{\mu_0} + \frac{1}{\mu}$$
- λ: wavelength

CORRECTION METHOD:
MODTRAN 4

- For each model atmosphere, compute one-way transmittances for various combinations of Pc, PW, $\mu_{effective}$. The result is a 3D table: $\mathbf{T}$(Pc, PW, $\mu_{effective}$).

- Repeat the same procedure for all available model atmospheres, plus several real-world atmospheric profiles to increase sampling space. Now you have a 4D table: $\mathbf{T}$(Pc, PW, $\mu_{effective}$, N_Profiles)

- Collapse 4th dimension by taking averages, also store standard deviations: $\mathbf{T}_{ave}$(Pc, PW, $\mu_{effective}$).

CORRECTION METHOD:
MODTRAN 4 (continued)

- The linkage between one-way and two-way transmittance is in $\frac{1}{\mu_{effective}}$, the path (i.e. absorbing amount scaling factor)

$$\frac{1}{\mu_{effective}} = \frac{1}{\cos\theta_{effective}} = \frac{1}{\cos\theta_0} + \frac{1}{\cos\theta}$$

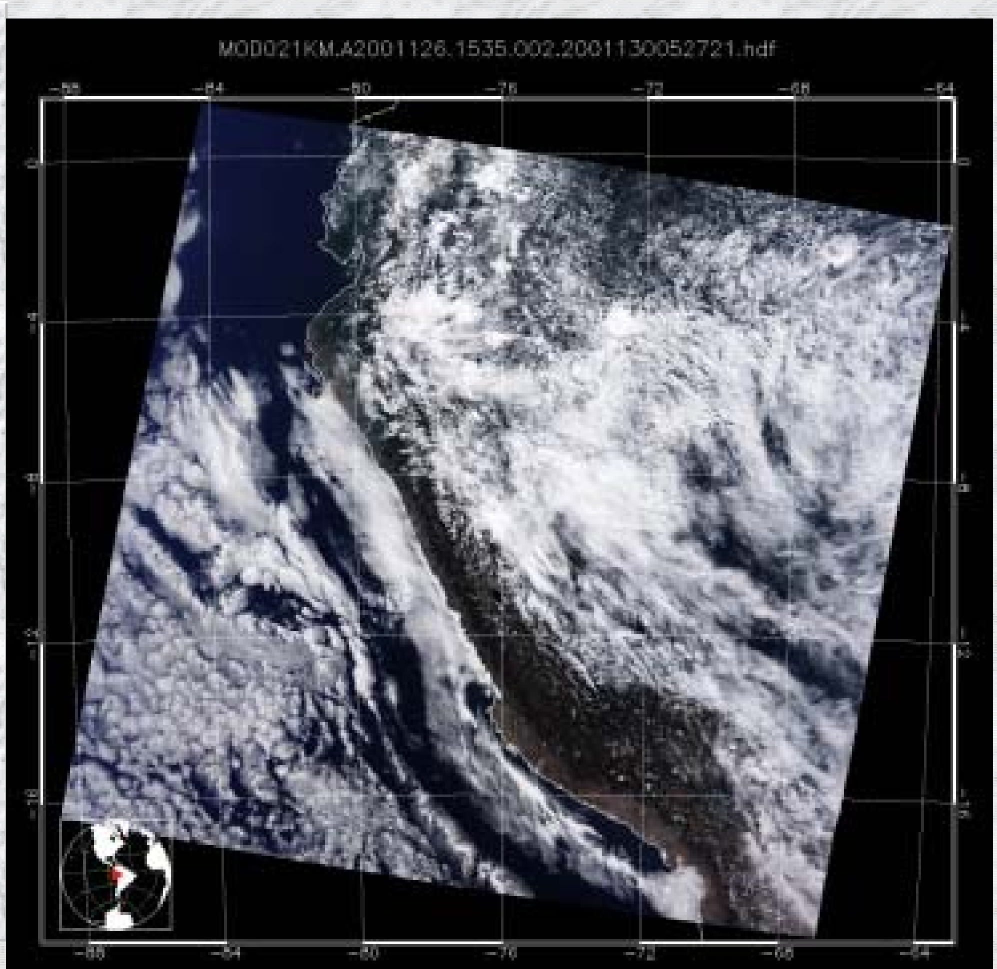
- If it is a two-way path, $\mu_{effective} \leq 0.5$ (or $\theta_{effective} \geq 60^\circ$).

- A MODIS granual: $\theta_0 = 33.32^\circ$, $\theta = 46.16^\circ$ (edge pixel), then $\theta_{effective} = 67.75^\circ$.

CORRECTION METHOD:
Sources of Uncertainties

- Refraction is not properly accounted for.
- Not a 3-D geometry.
- Variations in the structures of moisture profiles.

CASE STUDY:
RGB Composite



Date:

May 6th, 2001
126th day

Time:

15:35 UTC
10:35 Local

Ecosystems:

Ocean, narrow strip of grass land, evergreen forest.

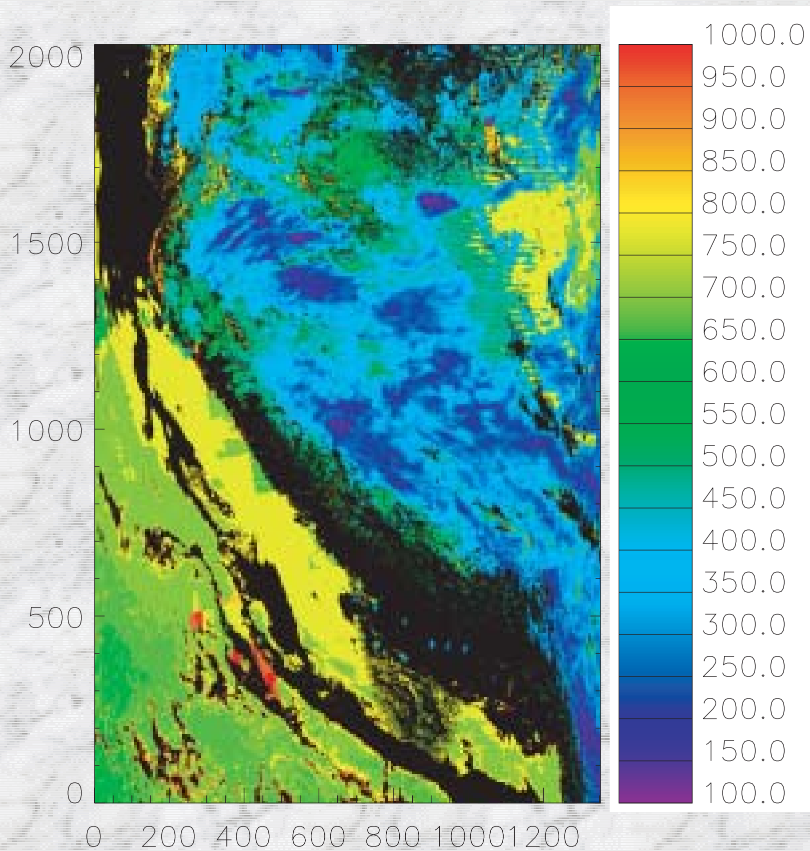
SOUTH AMERICA

802636AI (R02108) 6-99

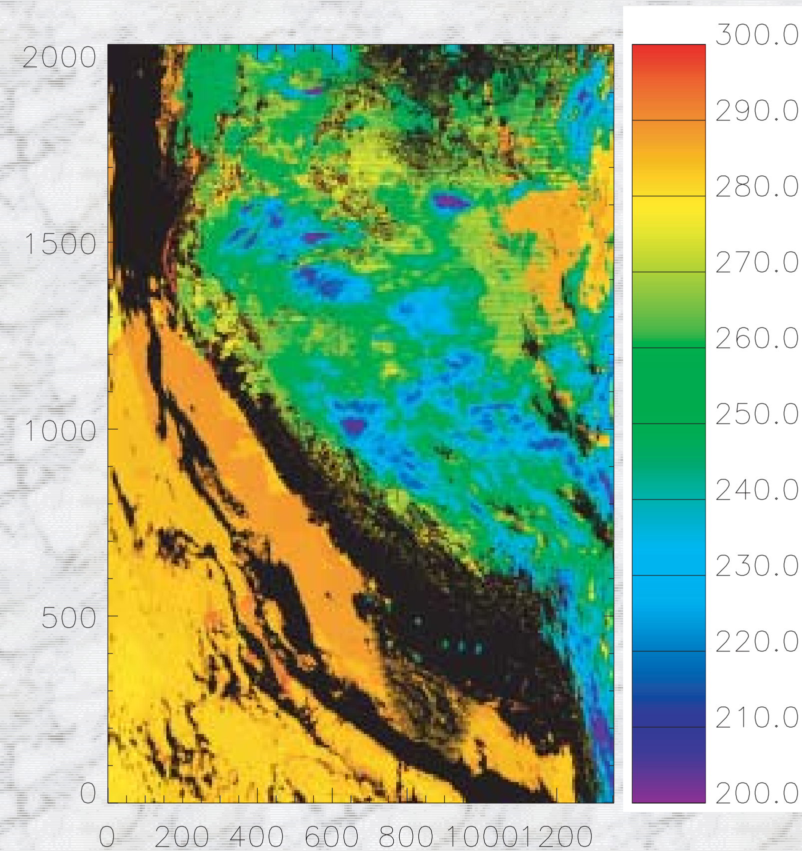
Case Study:

Cloud Top Pressure and Temperature

Cloud Top Pressure (mb)

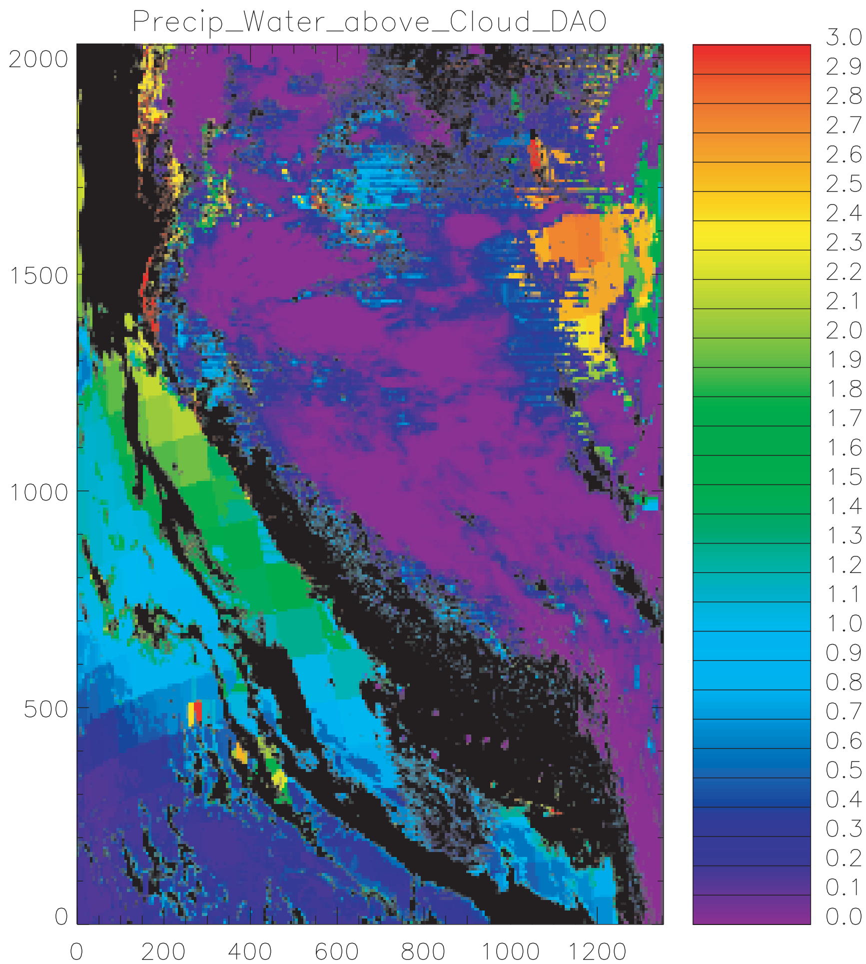


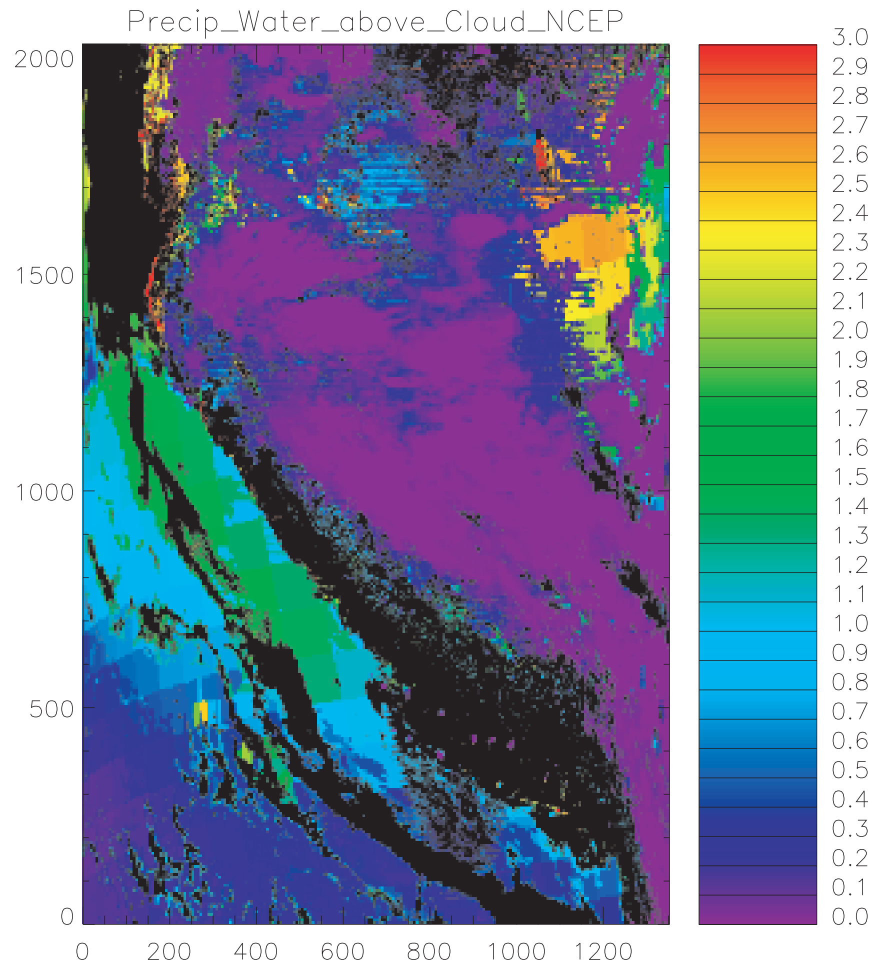
Cloud Top Temperature (K)



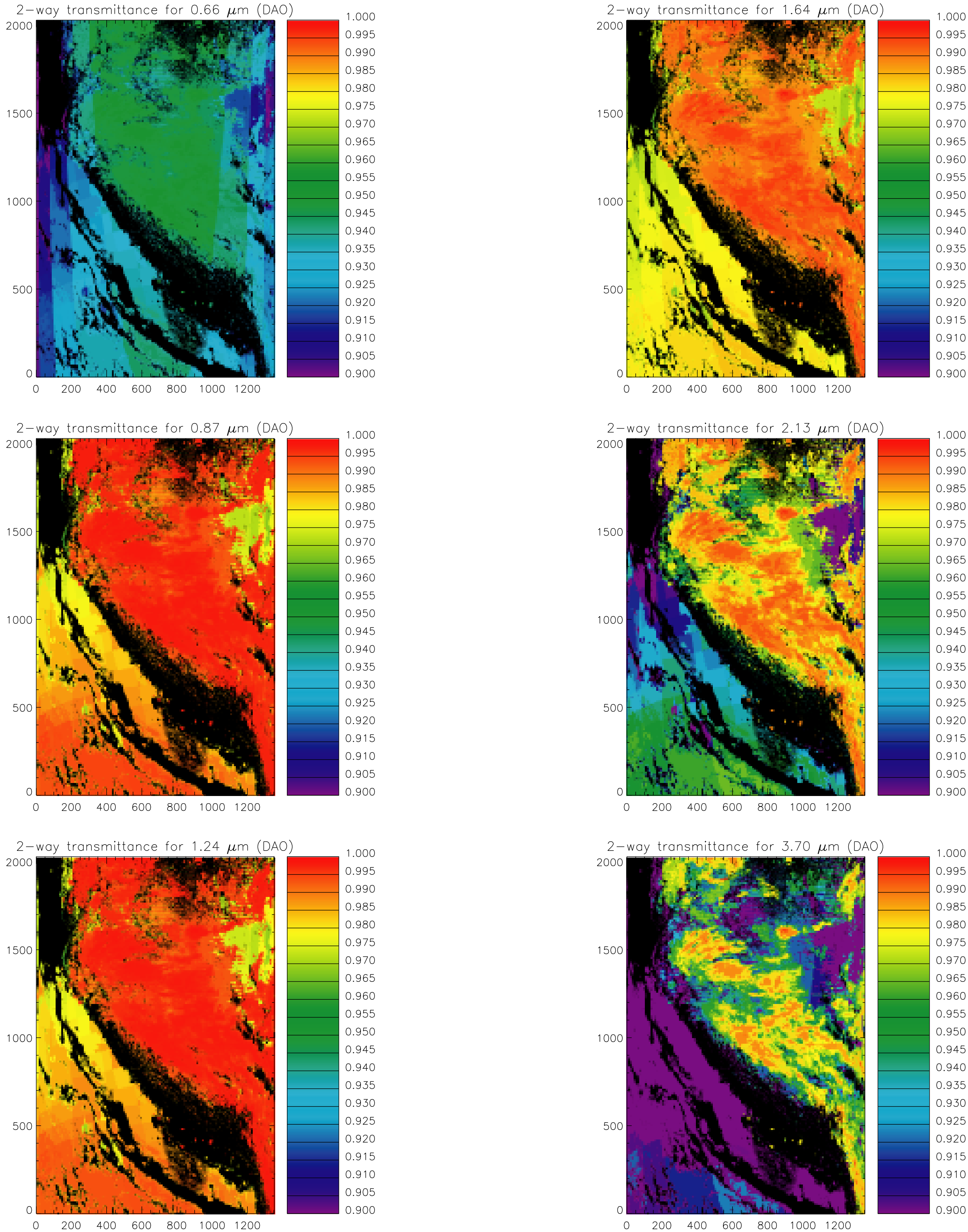
Case Study

Integrated Precipitable Water Above Cloud





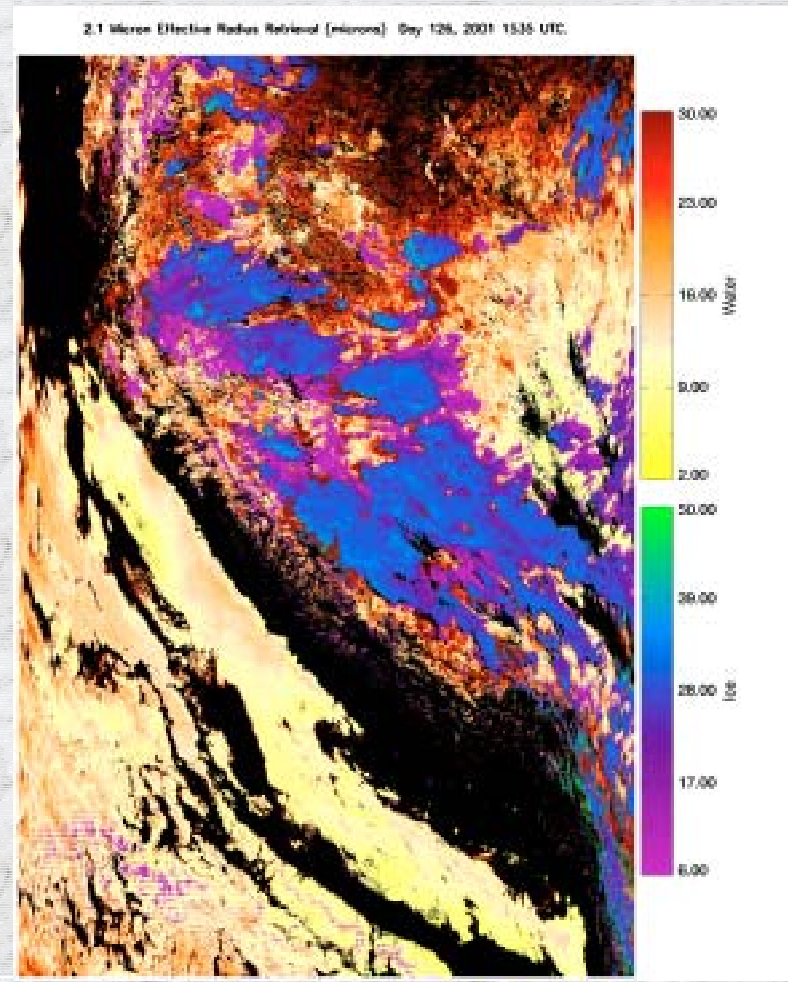
Two-Way Transmittance (DAO)



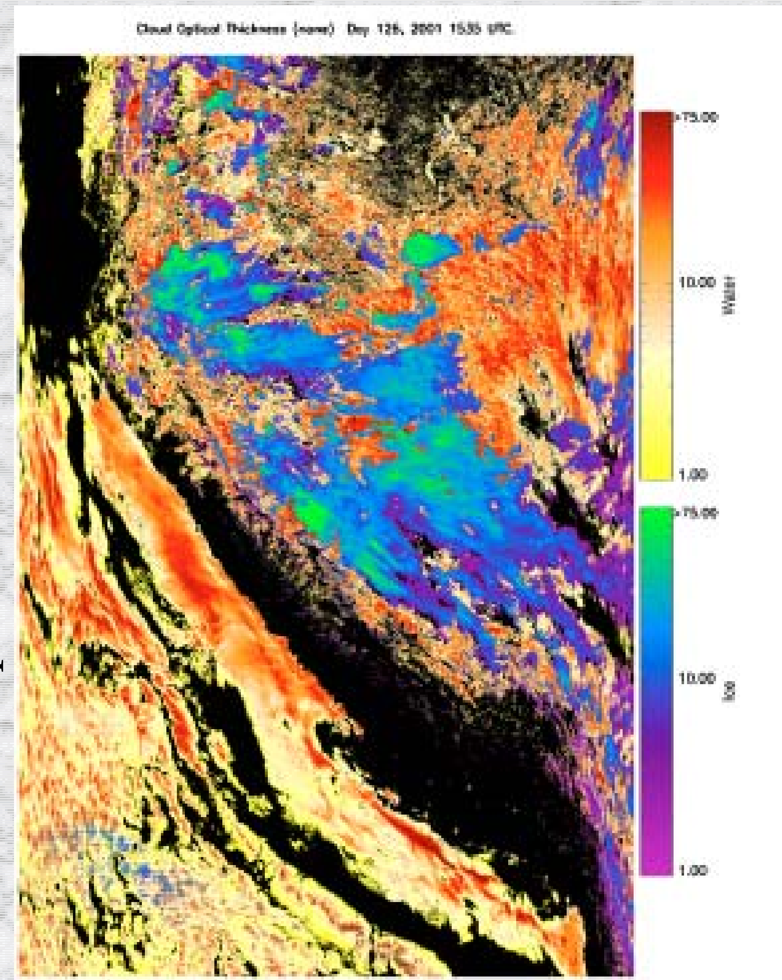
Case Study:

Retrieval Results (atmospheric corrected)

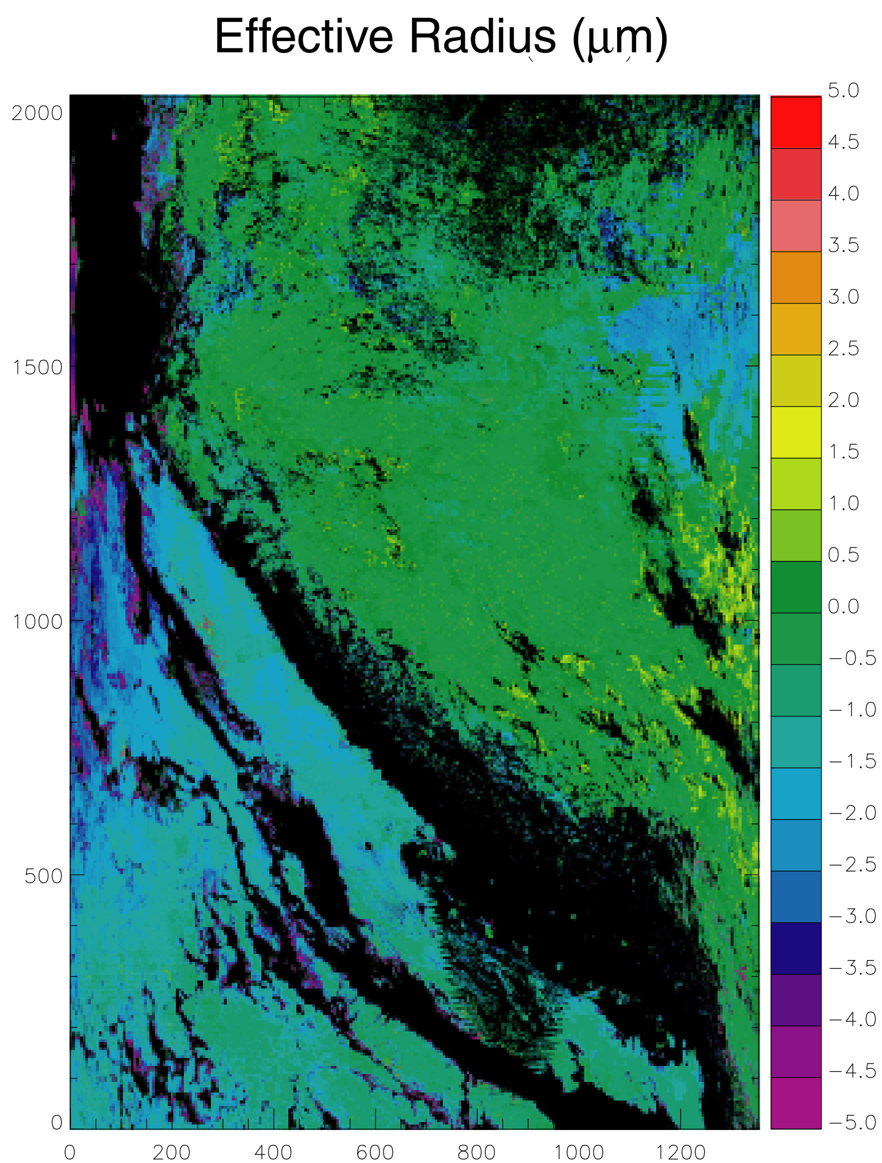
Effective Radius (μm)

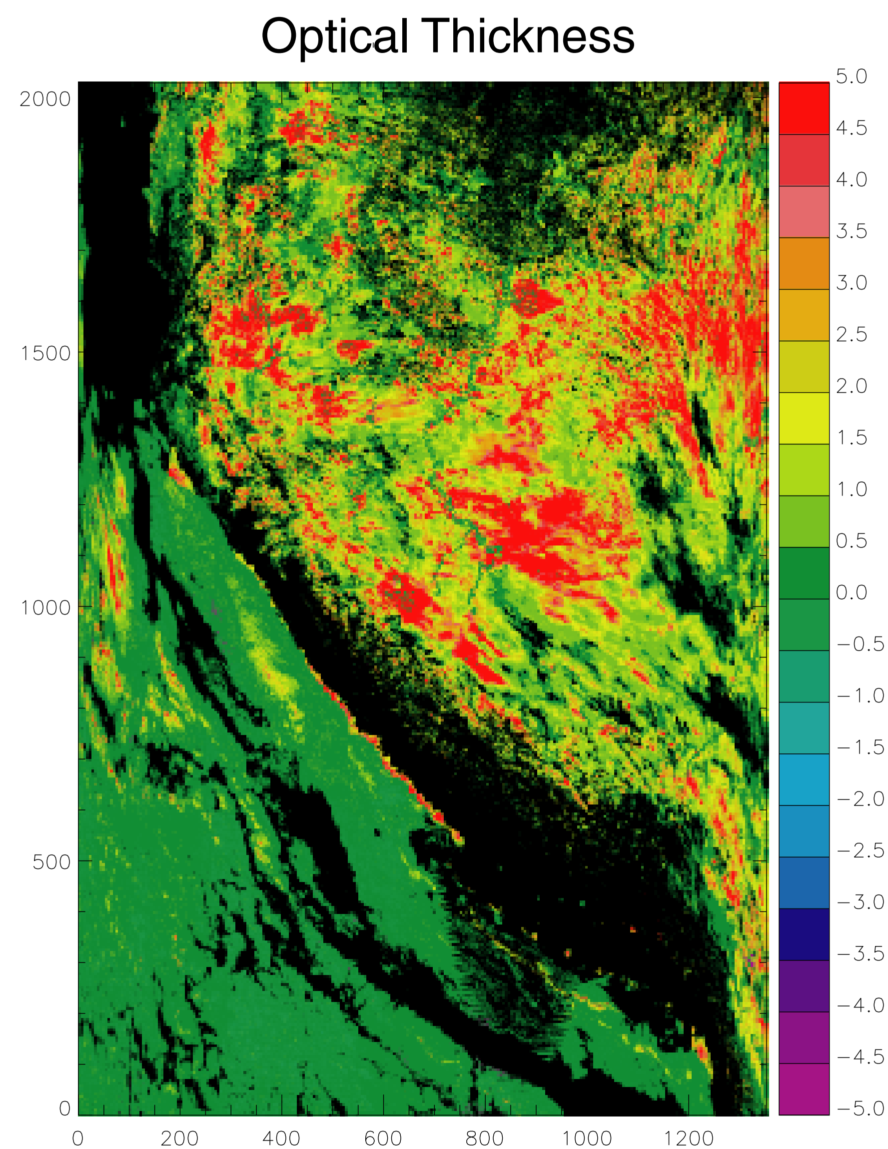


Optical Thickness



Differences (atmospheric corrected - uncorrected)

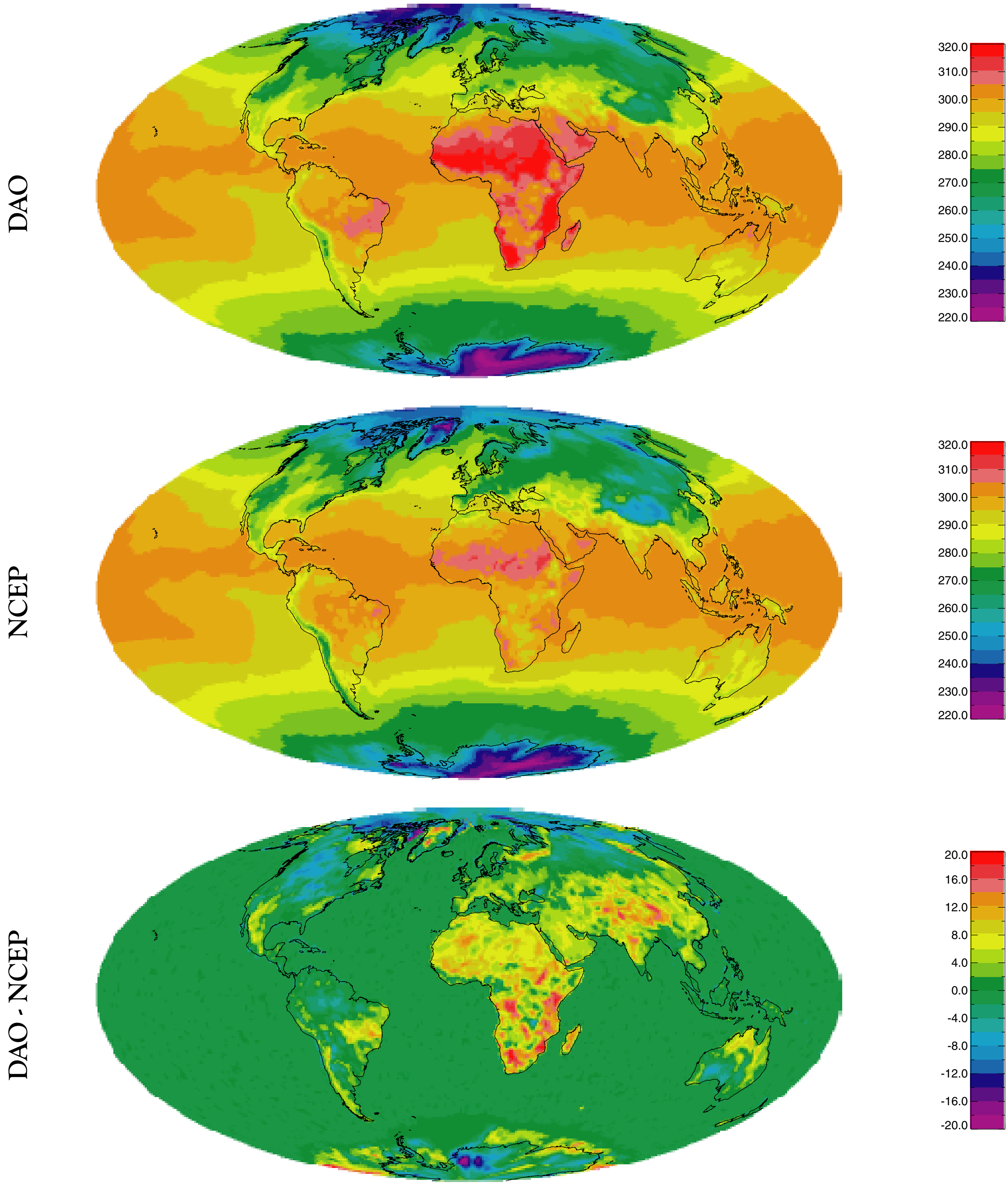




Ancillary Data Comparison

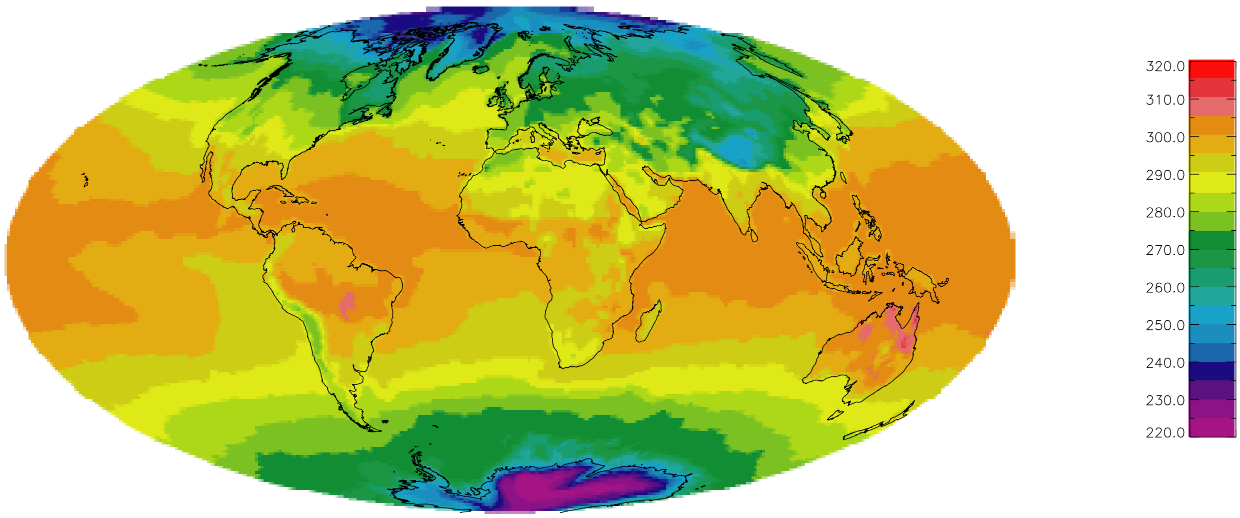
DAO versus NCEP

DAO and NCEP Surface Temperature Comparisons
November 14, 2001   12:00 UTC

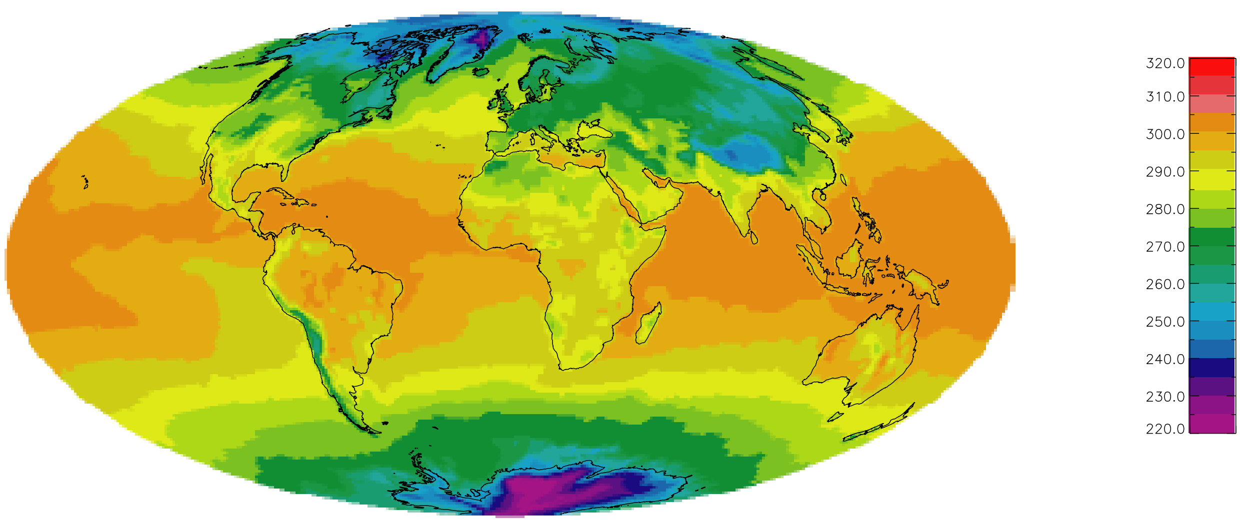


DAO and NCEP Surface Temperature Comparisons
November 14, 2001 00:00 UTC

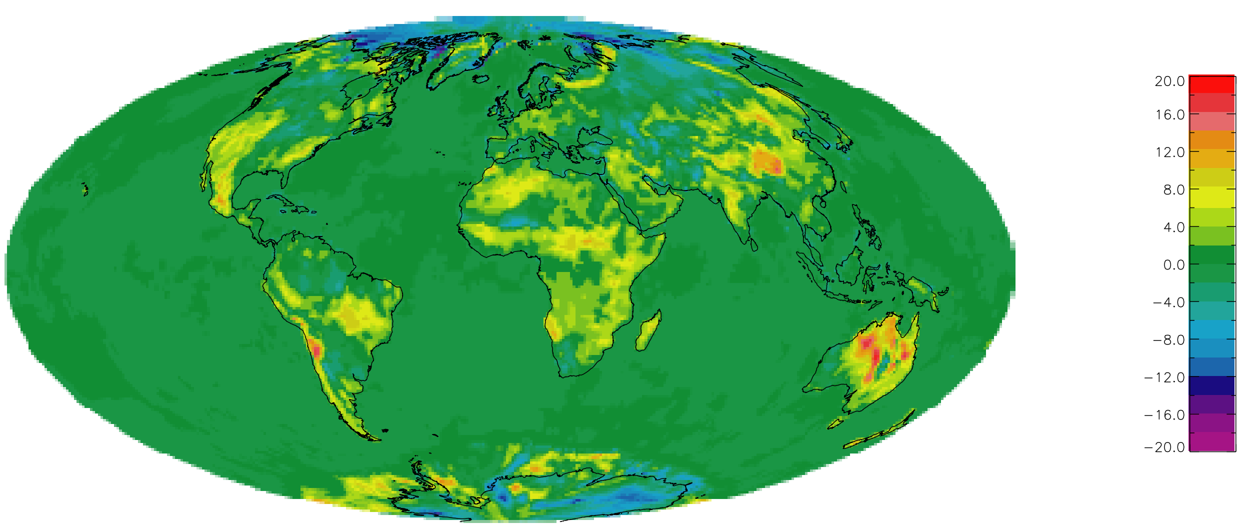
DAO



NCEP

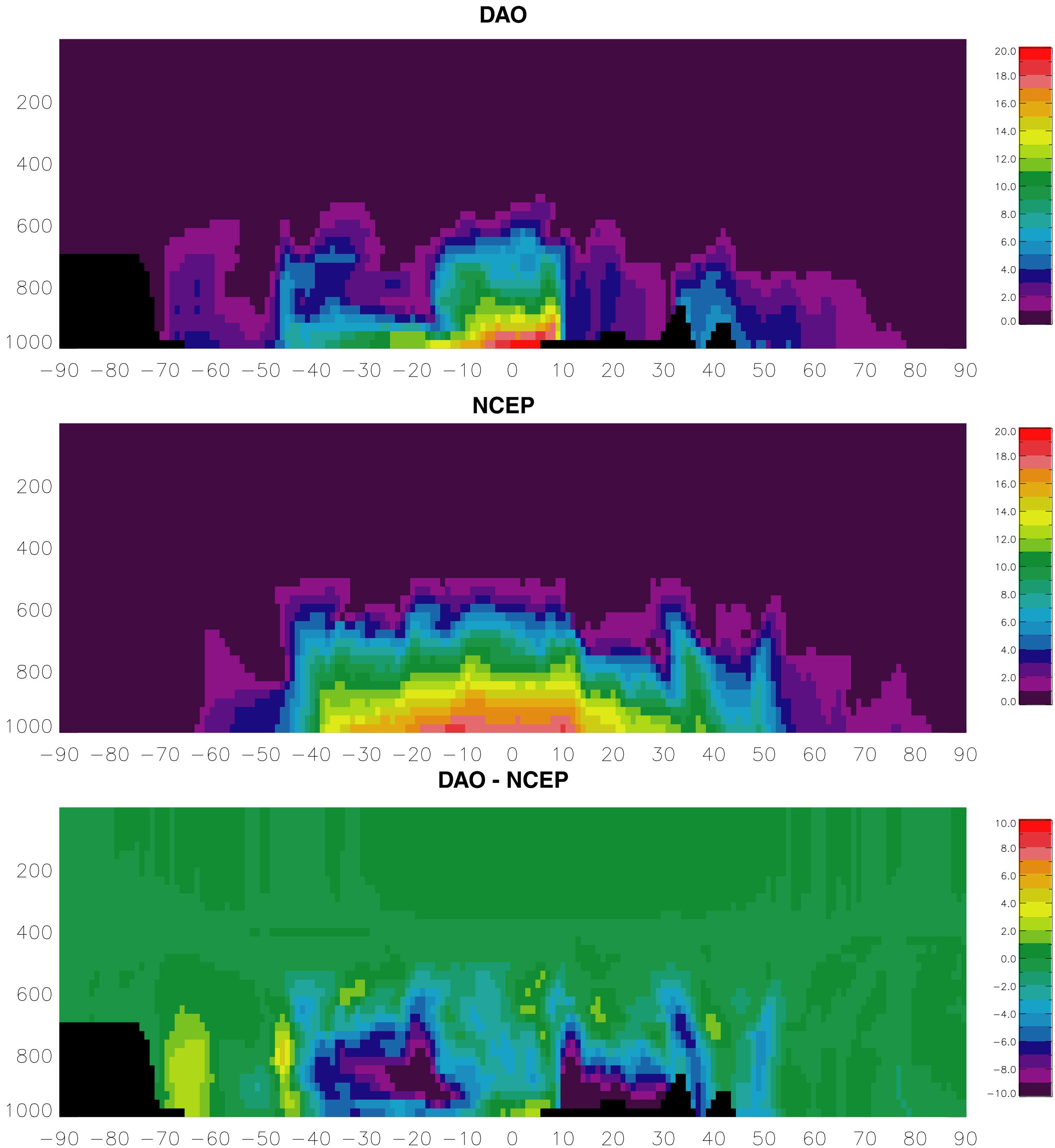


DAO - NCEP



Latitude-Height Cross Section of Specific Humidity (g/kg)

Longitude = 0 degree, November 14, 2001, 00:00UTC



Latitude-Height Cross Section of Specific Humidity (g/kg)

Longitude = 0 degree, November 14, 2001, 12:00UTC