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Using AIRS to study duststorms

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The low-down dirt about dust ...

- Dust storms occur all over the world
- Dust storms are now more frequent, because of climatic variability and land change use such as overgrazing or deforestation
- Diseases associated with duststorm outbreaks in Africa?
- Micronutrients transported across oceans (Africa to Amazon, Gobi Desert to Japan ...)
- Bacteria in dust can kill coral
- Atmospheric forcing due to dust storms can be significant

DeSouza-Machado, Strow, Motteler, Hannon, "Infrared dust spectral signatures from AIRS", GRL v33 (2006)

Jickells, T., et al. (2005), Global iron connections between desert dust, ocean biogeochemistry and climate, Science, 308, 67

Kaufmann Review Article: 2006

Atmos. Chem. Phys., 6, 613–666, 2006
www.atmos-chem-phys.net/6/613/2006/

Atmospheric Chemistry and Physics

A review of measurement-based assessments of the aerosol direct radiative effect and forcing

H. Yu[1,2], Y. J. Kaufman[2], M. Chin[2], G. Feingold[3], L. A. Remer[2], T. L. Anderson[4], Y. Balkanski[5], N. Bellouin[6], O. Boucher[7,6], S. Christopher[8], P. DeCola[9], R. Kahn[10], D. Koch[11], N. Loeb[12], M. S. Reddy[7,13], M. Schulz[5], T. Takemura[14], and M. Zhou[15]

increases with wind speed. Nevertheless, current estimates of aerosol warming effects in the thermal infrared remain highly uncertain, because assessment of the effects requires vertical distributions of aerosol extinction and atmospheric temperature that are not well characterized by either observations or simulations (Sokolik et al., 2001; Lubin et al., 2002). Aerosol optical properties in the thermal infrared range are rarely measured directly, hence the estimates of the thermal infrared effect depend largely on assumed aerosol models. In addition, the scattering effect in the thermal infrared domain is generally neglected in most GCMs, which may lead to an underestimate of the thermal infrared aerosol effect (Dufresne et al., 2002).

AIRS : Atmospheric InfraRed Sounder

Introduction
DustFlag
DustStorms
Dust Retrievals
OLR Calculations
Conclusions

- AIRS launched in May 2002 on board NASA-Aqua (A-train); operational since Sept 2002
- AIRS is a hyperspectral infrared sounder
- AIRS has low noise, high resolution thermal IR channels (650 - 2800 cm^{-1} with $\nu/\delta\nu \simeq 1200$) (3.7 to 15.4 μm)
- 13.5 km footprint, scans $\pm 45 deg$ from nadir, twice daily global coverage
- Produces temperature profiles with 1K/km accuracy, water vapor and trace gas profiles.

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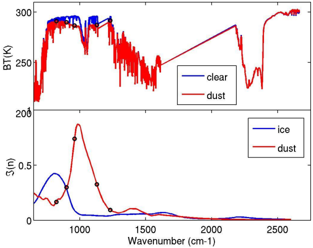
Dust and AIRS radiances

- AIRS has sensitivity to dust spectral signatures
- Can use AIRS radiances day and night, over sea and land to
  - detect dust
  - retrieve optical depths
  - obtain quick estimates of OLR forcing

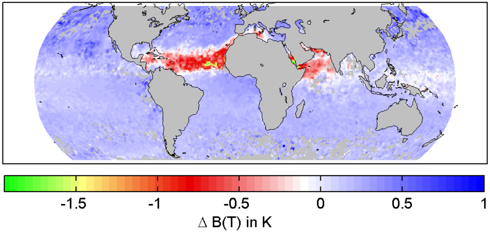
Most of the slides are daily sequences of plots, so should go by quickly! ....

Dust Flag

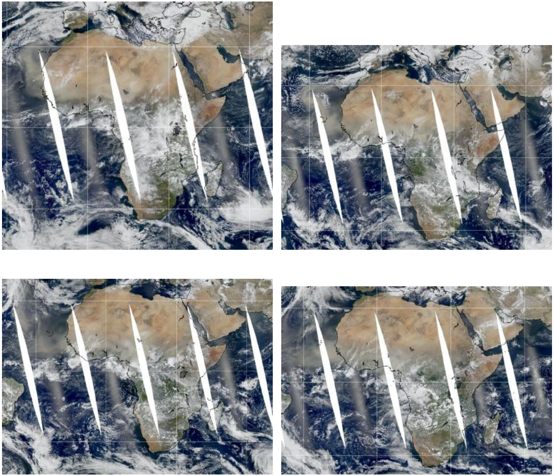


- Set up a sequence of "threshold dust cloud tests"
- 5 channels chosen are [822.4 900.3 961.1 1129.03 1231.3] cm^{-1}
- Tests involve split window brightness temperature differences
- Use t=380 over water; t=360 over land

Long Range Transport of Sahara Dust
AIRS data for July 2003



March 08,09,10,11 2006 MODIS-VISIBLE



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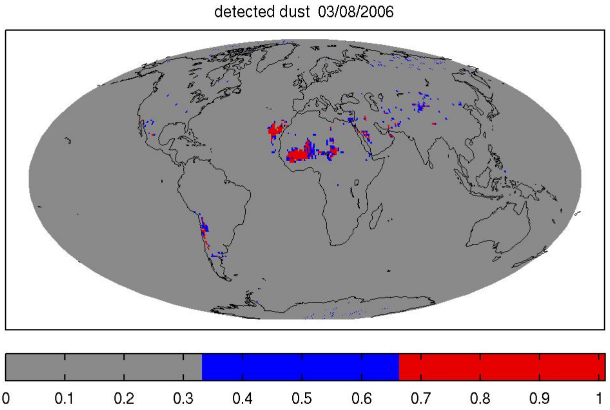
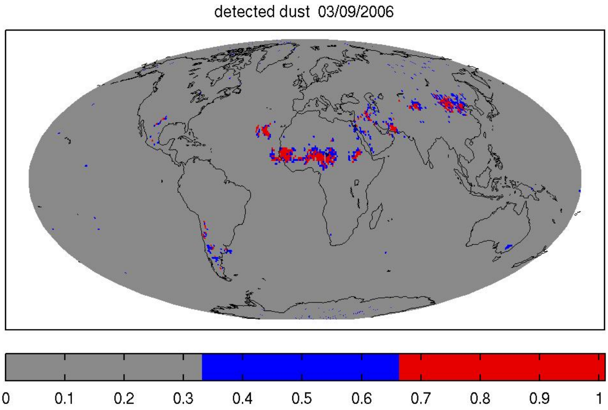
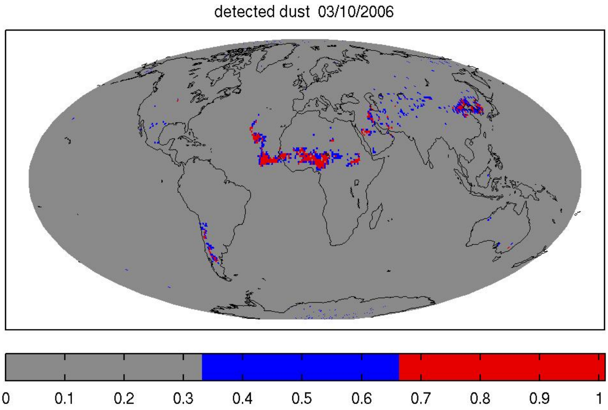
DustFlag applied over Sea and Land March 08, 2006



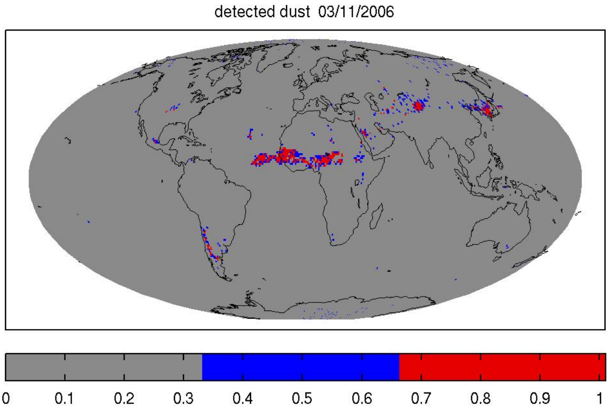
DustFlag applied over Sea and Land March 09, 2006



DustFlag applied over Sea and Land March 10, 2006



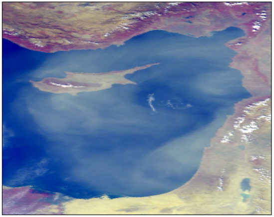
DustFlag applied over Sea and Land March 11, 2006

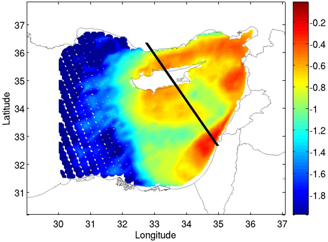


Retrieval of Dust Optical Depths Over Ocean and Land

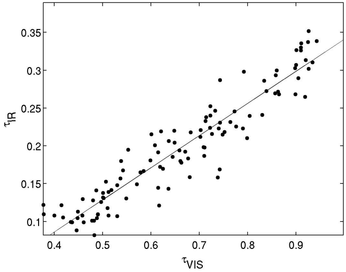
- use SARTA (PCLSAM : Chou et al, AMS Jan 1999 pg 159)
- uses Masuda emissivity for ocean
- uses Global Infrared Land Surface Emissivity Database (SSEC/U.Wisc) (E. Borbas, S. Wetzel-Seemann, R. O. Knuteson, P. Antonelli, J. Li and H.-L. Huang)
- uses ECMWF (or AIRS retrievals) for T(z),Q(z) fields, with adjusted surface temperature (George Aumann) for sea and land
- very fast ≤ 1 second per profile (even if looping over *ptop*, *dme*)

AIRS Retrieval October 19, 2002 over E. Mediterranean





Comparing MODIS to AIRS



MODIS channel 2 (0.55 um) compared to AIRS 900 cm-1
$\tau_{IR} = 0.425\tau_{VIS} - 0.084$, with a correlation of 0.935

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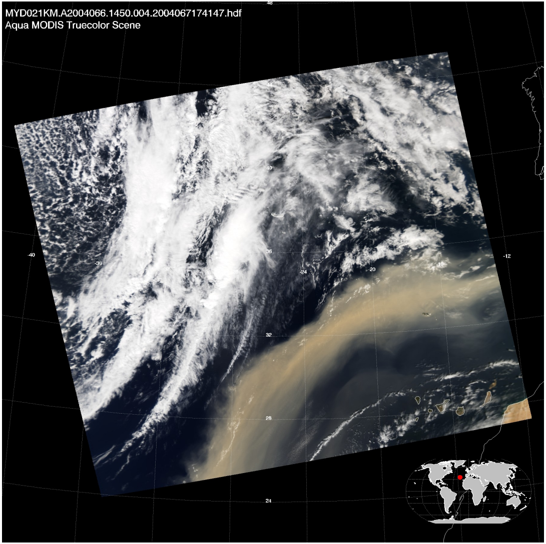
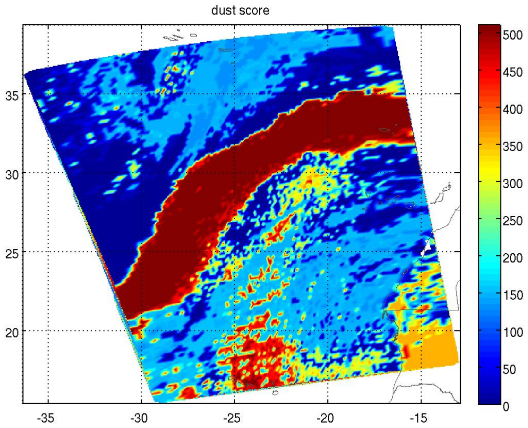
True color image made from MODIS data, for March 6, 2004 at approximately 1430 UTC

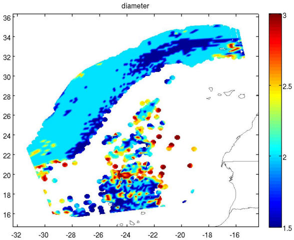


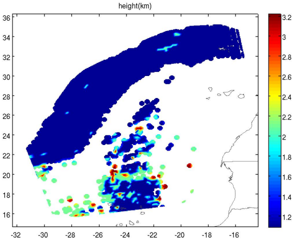
Dustflag applied to AIRS radiance spectra, for same duststorm



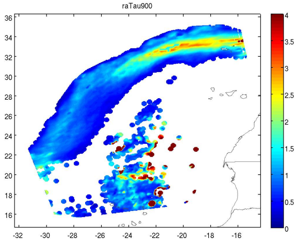
Pixels with a score above 380 are flagged as dust contaminated.

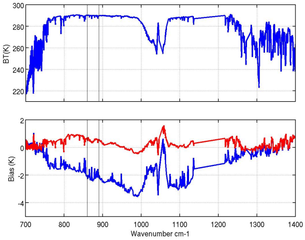
Diameter and Height retrieval





Optical Depth and Bias





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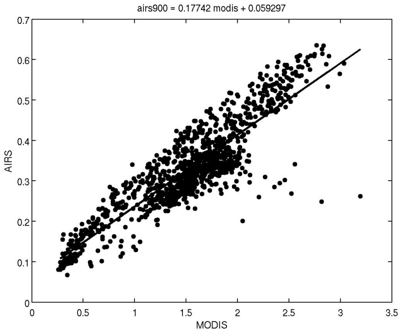
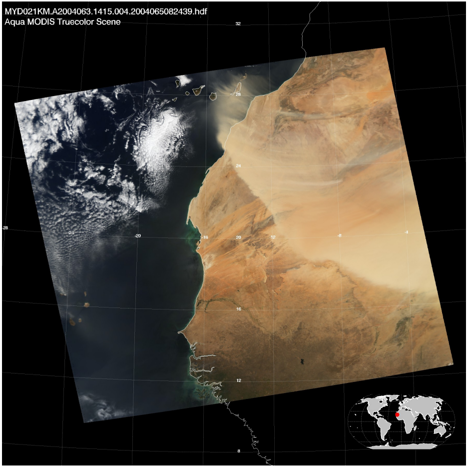
AIRS vs MODIS regression at 600 mb

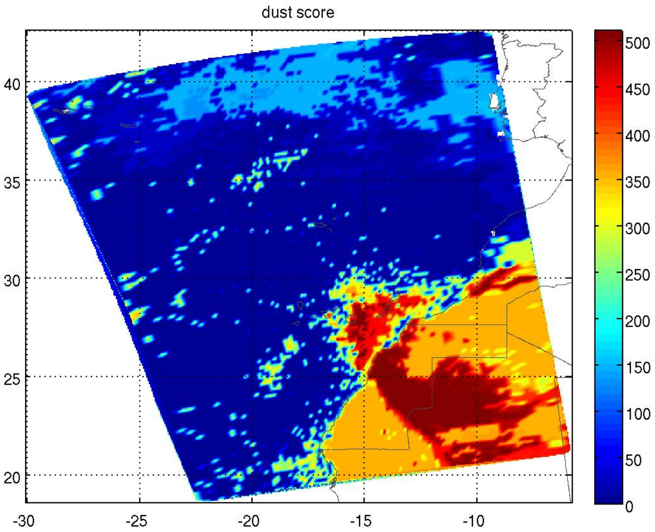


AIRS infrared optical depths at 900 cm^{-1} plotted against MODIS Ch 2 (550 nm) visible optical depths, for dusttop at 600 mb. At 900 mb (1.0 km), $\frac{\tau_{AIRS}}{\tau_{MODIS}} \simeq 0.5$

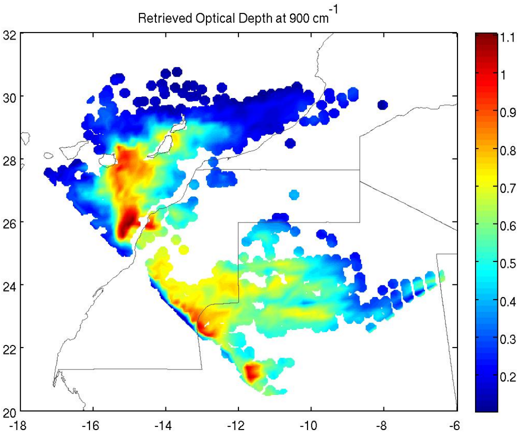
MODIS image of duststorm on March 3, 2004 over N.W.Africa



Dust flag using AIRS IR data



Retrieved infrared optical depths using AIRS IR data



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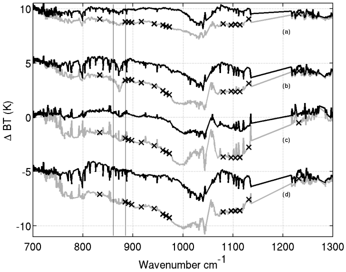
Infrared Retrievals from many global duststorms (over ocean)



(a) Libyan/Egyptian coast (02/28/2005)
(b) Eastern Mediteranean (10/19/2005)
(c) China Sea (11/12/2002)
(d) W. African coast (07/25/2004)

- All show the “V” shape in 800-1200 cm^{-1} (silicate absorber)
- Notch feature between 860 and 880 cm^{-1} is strongest in *b*, *c*

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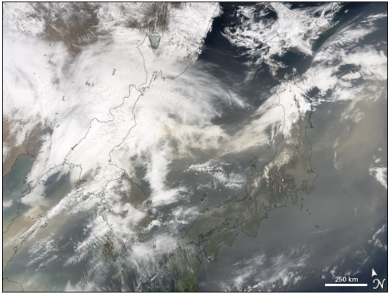
Gobi Desert Dust Storm April 2006

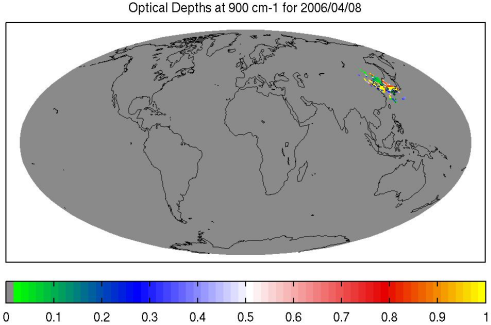
http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards_v2.php3?img_id13505



April 8, large dust storm originated in inner Mongolia, and started travelling east, across the Pacific Ocean and reaches west coast of USA 6 days later.

Sergio DeSouza-Machado (UMBC), Sung-Yung Lee, Eric Fetzer, Brian Kahn, Bjorn Lambrigtsen, Sharon Ray (Jet Propulsion Laboratory)

8 April 2006, AIRS retrievals



Optical depth at 900 cm^{-1}

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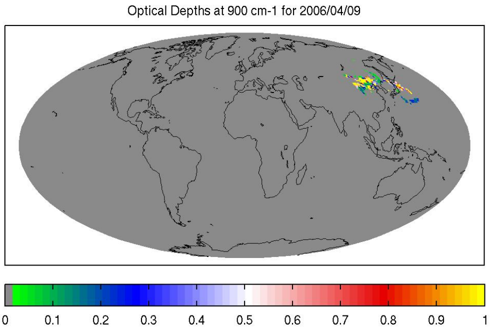
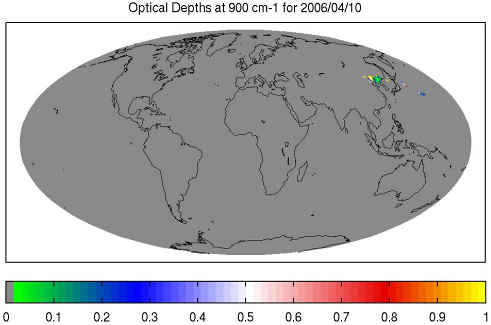
9 April 2006, AIRS retrievals



Optical depth at 900 cm^{-1}

10 April 2006, AIRS retrievals



Optical depth at 900 cm^{-1}

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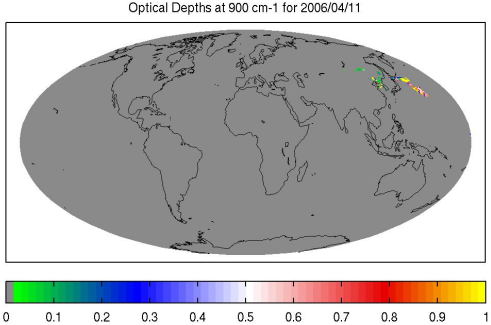
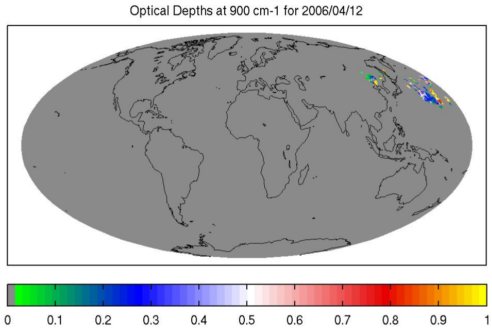
11 April 2006, AIRS retrievals



Optical depth at 900 cm^{-1}

12 April 2006, AIRS retrievals



Optical depth at 900 cm^{-1}

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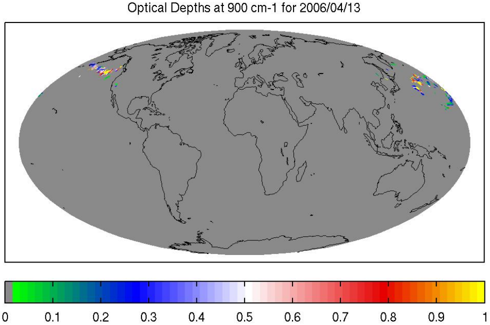
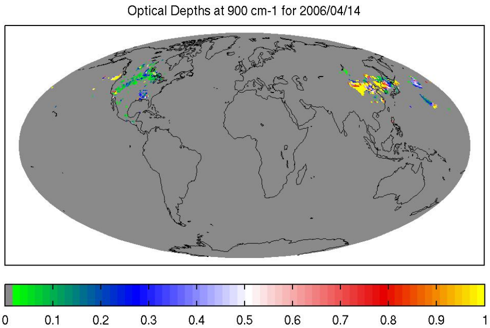
13 April 2006, AIRS retrievals



Optical depth at 900 cm^{-1}

14 April 2006, AIRS retrievals



Optical depth at 900 cm^{-1}

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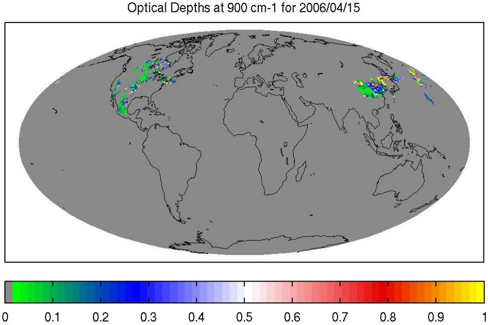
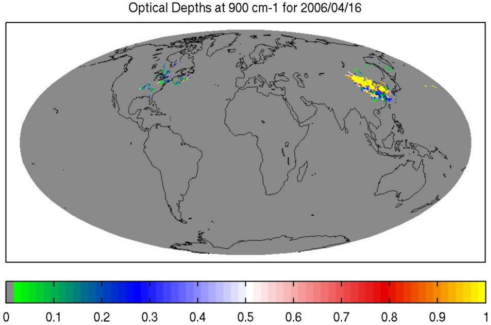
15 April 2006, AIRS retrievals



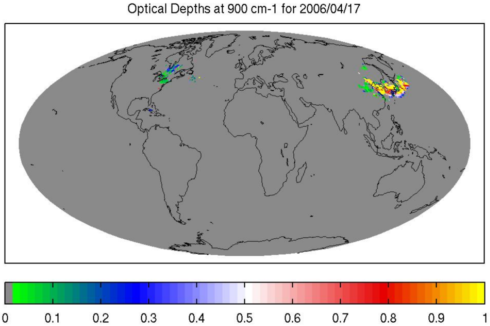
Optical depth at 900 cm^{-1}

16 April 2006, AIRS retrievals



Optical depth at 900 cm^{-1}

17 April 2006, AIRS retrievals



Optical depth at 900 cm^{-1}

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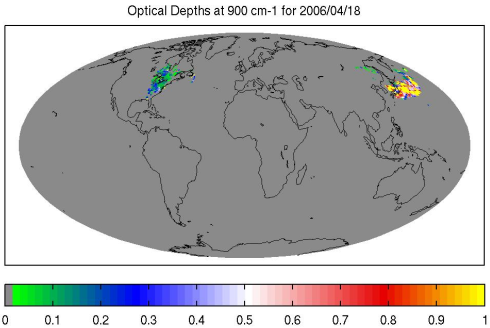
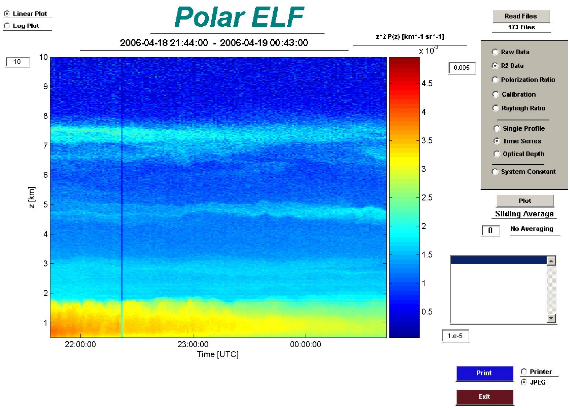
18 April 2006, AIRS retrievals



Optical depth at 900 cm^{-1}

Elastic Lidar Facility at UMBC



Courtesy of Ray Rogers and Ray Hoff (UMBC)

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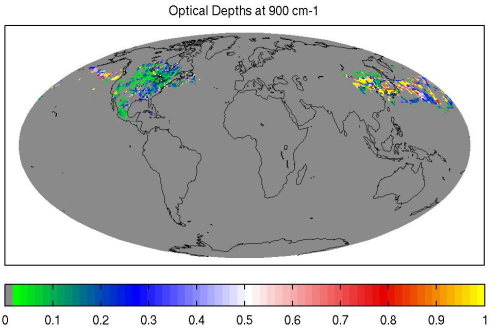
Gobi April 2006, AIRS retrievals : optdepth

- Introduction
- DustFlag
- DustStorms
- **Dust Retrievals**
- OLR Calculations
- Conclusions



Optical depth at 900 cm^{-1}

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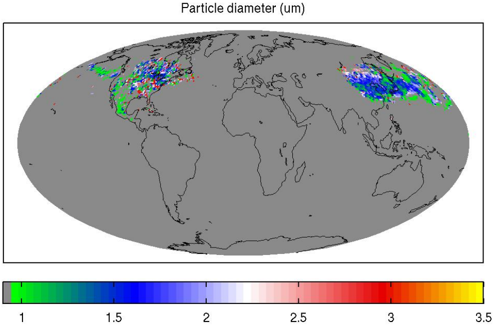
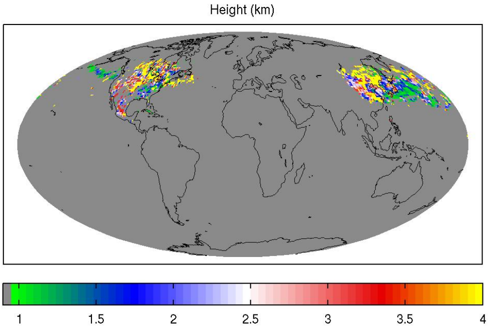
Gobi April 2006, AIRS retrievals : effective diameter

- Introduction
- DustFlag
- DustStorms
- **Dust Retrievals**
- OLR Calculations
- Conclusions



Effective diameter

Gobi April 2006, AIRS retrievals : dusttop height (km)



Dusttop height (km)

Outgoing Longwave Radiation and Clouds/Aerosols

Introduction
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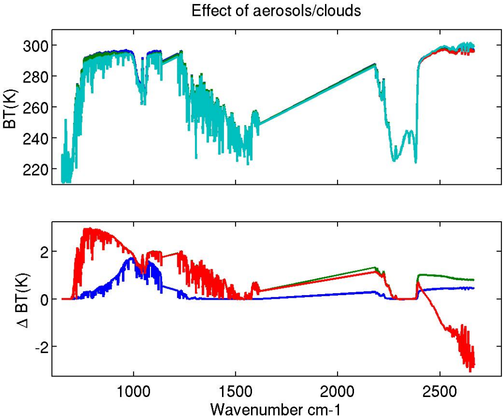
Aerosols and clouds affect outgoing radiation
eg look at Tropical Profile with dust and cirrus



Climate Forcing by clouds/aerosols/dust

Literature eg J.Zhang/S. Christopher and H. Yu, Y. Kaufman *et.al*.
Atmospheric Chem and Physics : John Seinfeld, Spyros Pandis

- Magnitude of climate forcing by clouds/aerosols is uncertain, especially in the longwave
- Can use MODIS to identify dusty scenes, MISR to obtain optical depths and CERES to obtain broadband TOA LW flux, or have potential to use AIRS to study all three over ocean or land

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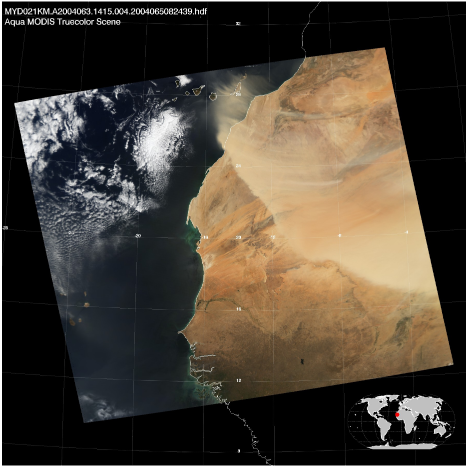
Outgoing Longwave Radiation and Clouds/Aerosols

Using the PCLSAM model (Chou at al, AMS Jan 1999 pg 159) can reparameterize optical depth τ with atm gases only to
$\tau \rightarrow \tau(atm) + \tau(scatter, E, \omega, g)$
Radiance at the top of a cloudy sky atmosphere

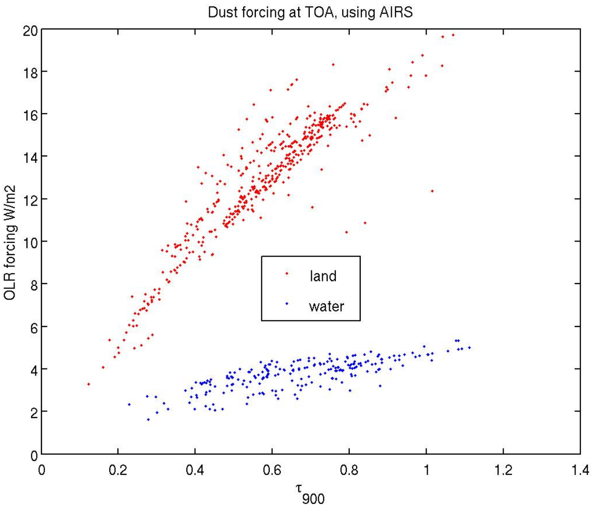
$$R(\nu) = \epsilon_s B(\nu, T_s)\tau_{1\rightarrow N}(\nu,\theta) + \sum_{i=1}^{i=N} B(\nu, T_i)(\tau_{i+1\rightarrow N}(\nu,\theta) - \tau_{i\rightarrow N}(\nu,\theta))$$

This is same as clear sky OLR equation, and so can compute estimates of OLR forcing

MODIS image of duststorm on March 3, 2004 over N.W.Africa

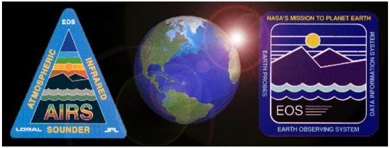


Dust forcing over land and water



Conclusion

- Dust Flag works over ocean and land
- Rapid dust retrievals over ocean and land
- Rapid estimates of OLR forcing by dust



http://earthobservatory.nasa.gov/
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http://asl.umbc.edu/
sergio@umbc.edu