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Using AIRS to study dust and cirrus

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AIRS : Atmospheric InfraRed Sounder

- 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 (rms errors $\leq$ 1.25K), water vapor (rms errors 20-40%) and trace gas profiles
- Very stable instrument with well characterized radiances
- Standard products include cloud top heights

Clouds, Dust and AIRS radiances

- 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
- AIRS has sensitivity to silicate-based absorbers and cirrus : radiance spectra exhibit their spectral signatures
- Can potentially use AIRS to study all three over ocean or land eg use AIRS radiances day and night, over ocean and land to
  - detect dust
  - retrieve optical depths
  - obtain quick estimates of OLR forcing

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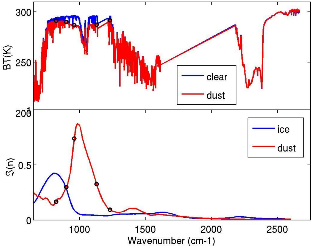
Dust Flag



- 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 (warning : needs improvement)

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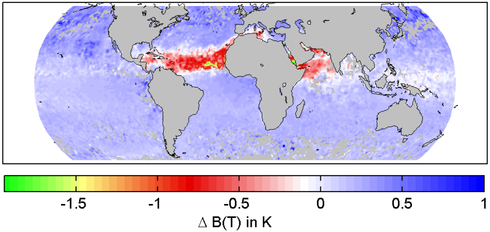
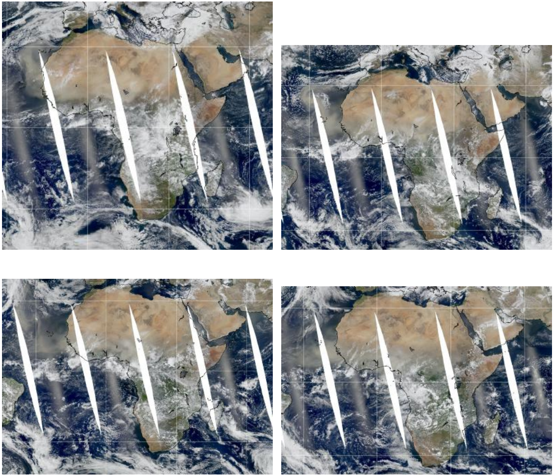
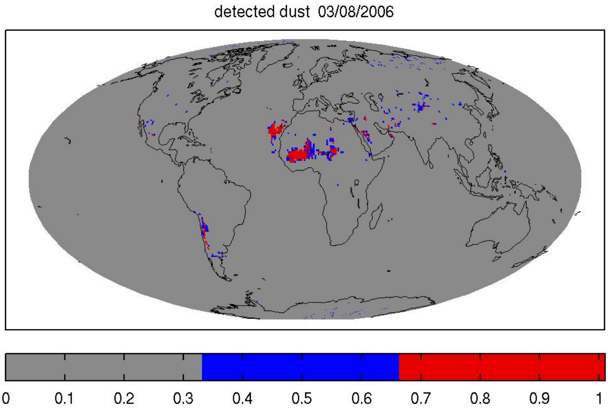
Long Range Transport of Sahara Dust
AIRS data for July 2003



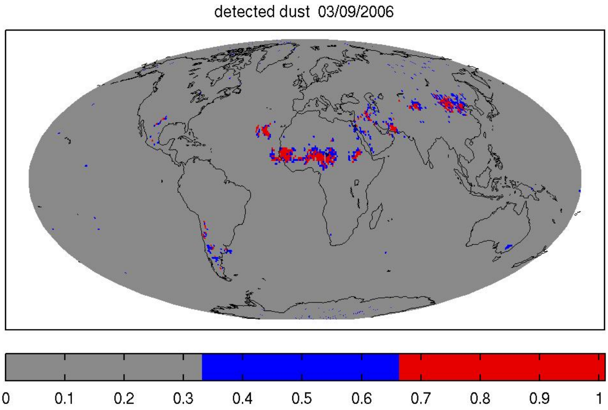
March 08,09,10,11 2006 MODIS-VISIBLE



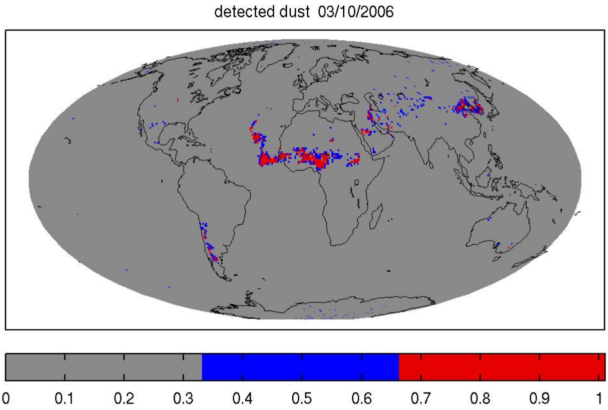
DustFlag applied over Sea and Land March 08, 2006



DustFlag applied over Sea and Land March 09, 2006



DustFlag applied over Sea and Land March 10, 2006



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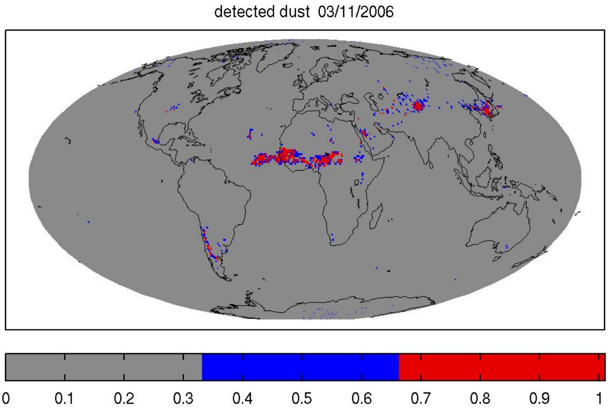
DustFlag applied over Sea and Land March 11, 2006



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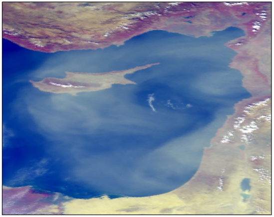
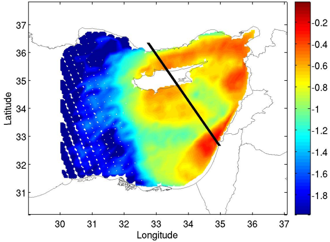
Retrieval of Dust Optical Depths Over Ocean and Land

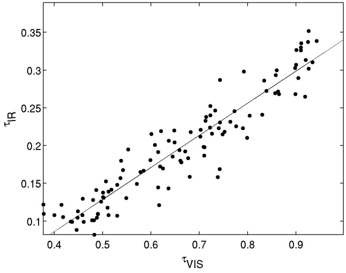
- use SARTA (PCLSAM : Chou et al, AMS Jan 1999 pg 159)
- uses Masuda emissivity for ocean
- uses Global Infrared Land Surface Emissivity Database (SSEC/U.Wisc) (E. Borbas, S. Wetzel-Seemann, R. O. Knuteson, P. Antonelli, J. Li and H.-L. Huang)
- uses ECMWF (or AIRS retrievals) for T(z),Q(z) fields, with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

AIRS Retrieval October 19, 2002 over E. Mediterranean



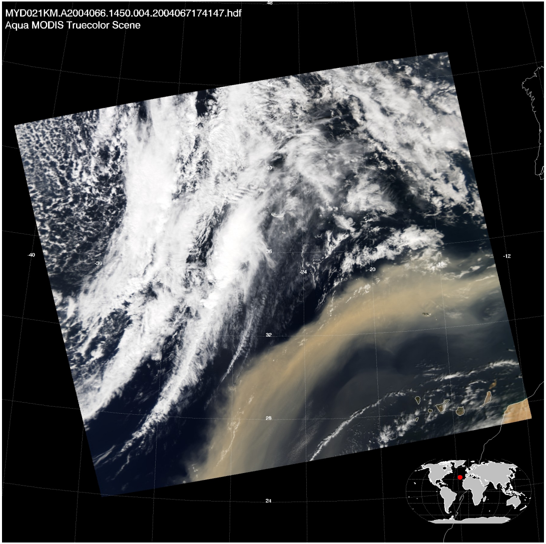


Comparing MODIS to AIRS

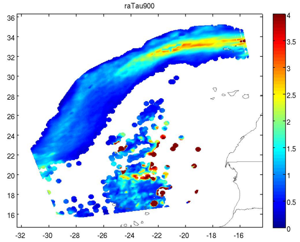


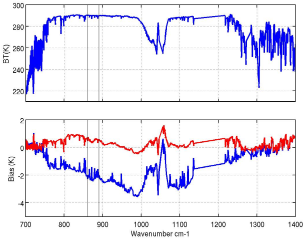
MODIS channel 2 (0.55 um) compared to AIRS 900 cm-1
$\tau_{IR} = 0.425\tau_{VIS} - 0.084$, with a correlation of 0.935 **GRL Paper with Sergio DeSouzaMachado, Larrabee Strow, Scott Hannon and Howard Motteler**

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



Optical Depth and Bias





Optimum particle diameter $\simeq$ 2 um; optimum height $\simeq$ 1 km

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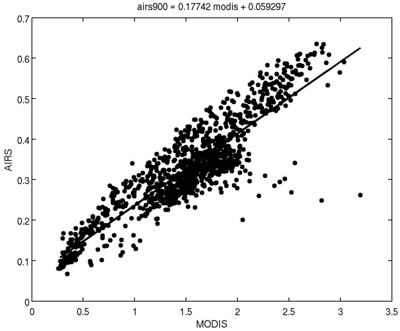
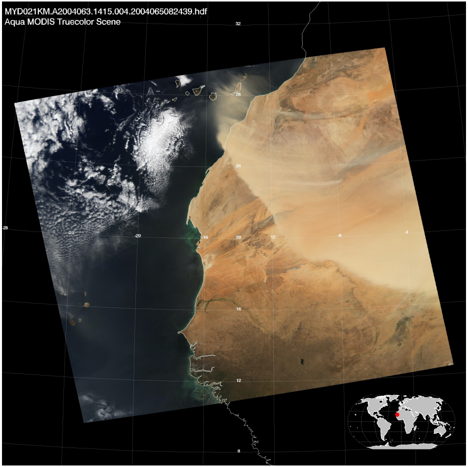
AIRS vs MODIS regression at 600 mb

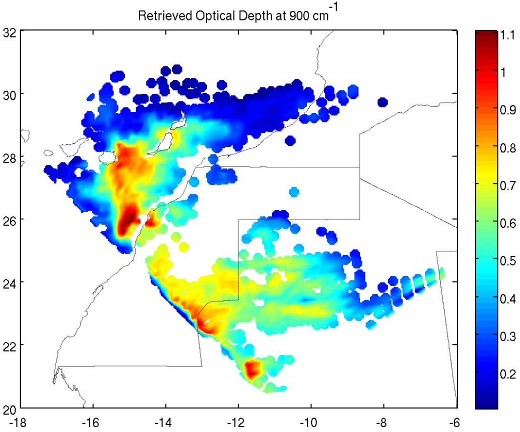


AIRS infrared optical depths at 900 cm^{-1} plotted against MODIS Ch 2 (550 nm) visible optical depths, for dusttop at 600 mb. At 900 mb (1.0 km), $\frac{\tau_{AIRS}}{\tau_{MODIS}} \simeq 0.5$

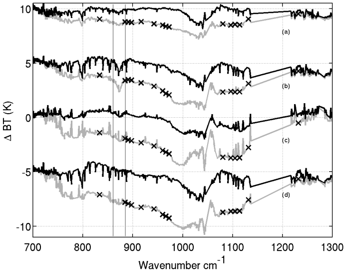
MODIS image of duststorm on March 3, 2004 over N.W.Africa



Retrieved infrared optical depths using AIRS IR data



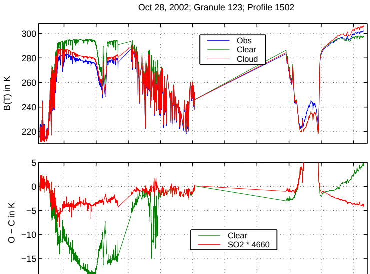
Infrared Retrievals from many global duststorms (over ocean)



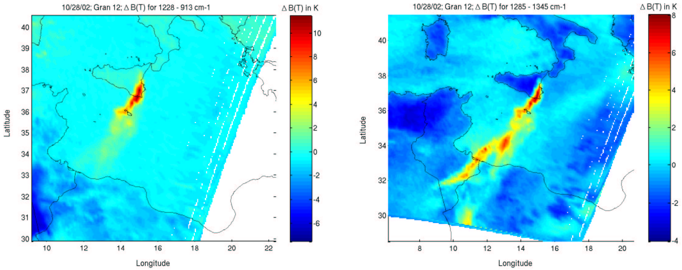
(a) Libyan/Egyptian coast (02/28/2005)
(b) Eastern Mediteranean (10/19/2005)
(c) China Sea (11/12/2002)
(d) W. African coast (07/25/2004)

- 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*

Mt. Etna Eruption, Oct 2002

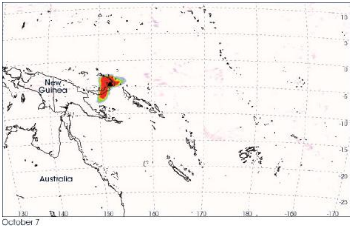


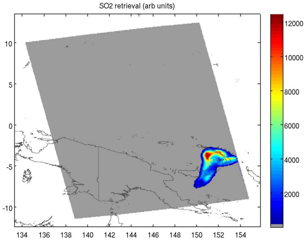
Tracking the Ash and SO2



GRL Paper with Simon Carn, Yvonne Edmonds, Larrabee Strow, Sergio DeSouzaMachado, Scott Hannon and Howard Motteler

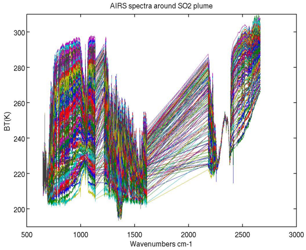
Rabaul Volcano, Oct 7, 2006 (seen by OMI)

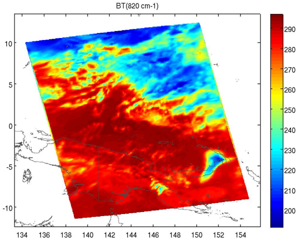




LHS : http://earthobservatory.nasa.gov/Newsroom/NewImages/
RHS : Thanks to Scott Hannon! SO2 multiplier ($\times$ standard SO2 profile)

Tracking the Cirrus and SO2





Thanks to Scott Hannon!
LHS shows AIRS spectra in the SO2 plume region; notice strong SO2 signal and cirrus contamination
RHS shows BT(820 cm-1) and shows cirrus cloud in vicinity of SO2 plume

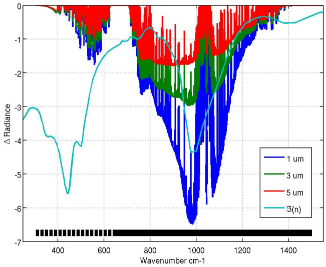
Using the PCLSAM model (Chou at al, AMS Jan 1999 pg 159) can reparameterize optical depth τ with atm gases only to $\tau \rightarrow \tau(atm) + \tau(scatter, E, \omega, g)$

Radiance at the top of a cloudy sky atmosphere

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

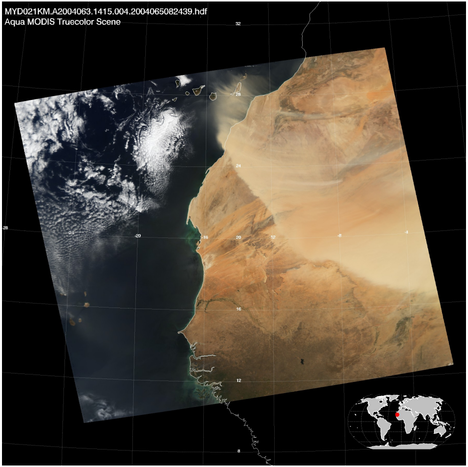
This is same as clear sky OLR equation, and so can compute estimates of OLR forcing

Outgoing Longwave Radiation and Clouds/Aerosols



Simulated thermal IR and Far IR changes in TOA radiance, for realistic dust cloud of particle diameters 1,3,5 μm, with the refractive index (scaled) shown in cyan. 90% of the OLR forcing comes from the region covered by the AIRS thermal IR channels (shown in solid black). Vertical units are in $mWm^{-2}sr^{-1}/cm^{-1}$.

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



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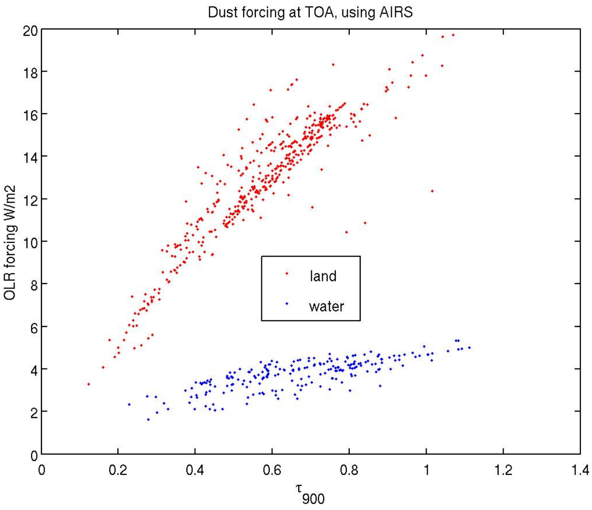
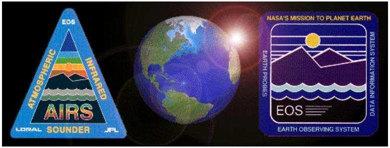
Dust forcing over land and water



Conclusion

Ability of hyperspectral IR sounders to detect dust, retrieve optical depths and compute lower bound estimates of OLR forcing



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