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Using AIRS to study duststorms

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The low-down dirt about dust \dots

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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

\overline{ASL} Kaufmann Review Article: 2006 **HULL** Isaannan H is 2000 H _i 2000 (Hsu et al., 3000) of the 30% (Hsu H su et al., 2000) of the H

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70% at high winds (>10 ms−¹

), because sea-salt production \mathbf{r}

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

H. Yu^{1,2}, Y. J. Kaufman², M. Chin², G. Feingold³, L. A. Remer², T. L. Anderson⁴, Y. Balkanski⁵, N. Bellouin⁶, H. Yu^{1,2}, Y. J. Kaufman², M. Chin², G. Feingold³, L. A. Remer², T. L. Anderson⁴, Y. Balkanski⁵, N. Bellouin⁶, O. Boucher^{7,6}, S. Christopher⁸, P. DeCola⁰, R. Kahn¹⁰, D. Koch¹¹, N. Loeb¹², M. S. **T. Takemura¹⁴**, and M. Zhou¹⁵

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).

\blacksquare Introduction DustFlag the DCF estimate, with individual shares ranging from 13– namely f^f and faf over both land and ocean, and τ over

the global clear-sky DCF is estimated to be −1.3 W/m2 with the -1.3 an uncertainty of 62%. The uncertainty partitions to the land and ocean more or less evenly. The parameter uncertainty contribution to DCF further suggests that five parameters,

DustStorms $20 \times 20 \times 10^{-10}$ s_{max} point out that the these uncertainties presumably representations p

Dust Retrievals $s_{\rm max}$ bound because the sources of error are assumed b \mathcal{L} . Uncertainties associated with several particles associated with several particles associated with several particles \mathcal{L}

OLR ULK
Calculations and documents advance of \overline{c} and \overline{c} and \overline{c} and \overline{c} rameters are also not well defined. Nevertheless, such uncer-

Dusty sky

More work MAERI data

Conclusions in the absolution of the absolution of the assessment of the absolution of the absolution of the a direct effect as summarized above, several important issues remain, and significant efforts are required to address them.

As discussed earlier, most measurement-based studies so far have concentrated on the influences by the sum of natural and anthropogenic aerosols on solar radiation in clear sky conditions. Current DCF estimates are poorly constrained by observations. Because of a lack of measurements of aerosol absorption and difficulty in characterizing land surface reflection, estimates of DRE over land and at the ocean sur-

ASL AIRS : Atmospheric InfraRed Sounder

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OLR [Calculations](#page-40-0) [Conclusions](#page-45-0) 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 μ m)
- \bullet 13.5 km footprint, scans ± 45 deg from nadir, twice daily global coverage
- Produces temperature profiles with $1K/km$ accuracy, water vapor and trace gas profiles.

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
	- o obtain quick estimates of OLR forcing

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

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\overline{A} S/ Dust Flag

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- 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
- \bullet Use $t=380$ over water; $t=360$ over land

ASL Long Range Transport of Sahara Dust
ASL AIRS data for July 2003 AIRS data for July 2003

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 -1.5 -0.5 0.5 -1 0 1 Δ B(T) in K

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

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ASL | DustFlag applied over Sea and Land March 08, 2006

ASL | DustFlag applied over Sea and Land March 09, 2006

ASL | DustFlag applied over Sea and Land March 10, 2006

ASL | DustFlag applied over Sea and Land March 11, 2006

$\begin{array}{|c|c|c|}\nA\,S\end{array}$ Retrieval of Dust Optical Depths Over Ocean and Land

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- 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)

ASL AIRS Retrieval October 19, 2002 over E.
Mediterranean Mediterranean

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ASI Comparing MODIS to AIRS

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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

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

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ASL Dustflag applied to AIRS radiance spectra, for same duststorm

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

ASL Diameter and Height retrieval

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ASL Optical Depth and Bias

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\vert \vert AIRS vs MODIS regression at 600 mb

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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), $\frac{\tau_{AIRS}}{\tau_{MODIS}} \simeq 0.5$

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

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ASL Dust flag using AIRS IR data

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ASL Retrieved infrared optical depths using AIRS IR data

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ASL Infrared Retrievals from many global duststorms (over ocean)

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- (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

ASI Gobi Desert Dust Storm April 2006

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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)

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ASL 8 April 2006, AIRS retrievals

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ASL 9 April 2006, AIRS retrievals

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ASL 10 April 2006, AIRS retrievals

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ASL 11 April 2006, AIRS retrievals

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ASL 12 April 2006, AIRS retrievals

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ASL 13 April 2006, AIRS retrievals

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ASL 14 April 2006, AIRS retrievals

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ASL 15 April 2006, AIRS retrievals

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ASL 16 April 2006, AIRS retrievals

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ASL 17 April 2006, AIRS retrievals

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ASL 18 April 2006, AIRS retrievals

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ASI Elastic Lidar Facility at UMBC

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Courtesy of Ray Rogers and Ray Hoff (UMBC)

ASL Gobi April 2006, AIRS retrievals : optdepth

ASL Gobi April 2006, AIRS retrievals : effective diameter

Effective diameter

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

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Dusttop height (km)

ASI Outgoing Longwave Radiation and Clouds/Aerosols

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

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$|\overline{A}\overline{S}|$ 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

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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

ASL Outgoing Longwave Radiation and Clouds/Aerosols

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

Radiance at the top of a cloudy sky atmosphere

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

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

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

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ASL Dust forcing over land and water

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- **•** 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/ http://www-airs.jpl.nasa.gov/ http://asl.umbc.edu/ sergio@umbc.edu