Satellite and Ground-Based Remote Sensing of Mineral Dust Using MODIS IR Window Channels, AERI Spectra and ARM Data

Richard Hansell Jr. (rhansell@atmos.ucla.edu) [1], K.N. Liou [1], S.C. Ou [1], S.C. Tsay [2], J. Ji [3] and J. Reid[4]

[1] Department of Atmospheric and Oceanic Sciences, UCLA, [2] Goddard Space Flight Center, NASA, Greenbelt, Maryland
[3] University of Maryland College Park, Maryland, [4] Naval Research Laboratory, Monterey, California

1. Introduction

- The effects of mineral dust on earth's climate system remain highly uncertain (**IPCC 2001**) due in part to a lack of data and an understanding of its key properties.
- We present a satellite and surface-based technique for remotely sensing dust using data collected during the United Arab Emirates Unified Aerosol Experiment (UAE^2 -2004), the NASA African Monsoon Multidisciplinary Analyses (NAMMA – 2006) and at the ARM mobile facility (AMF) Niamey, Niger.
- Following previous approaches, an integrated technique for detecting dust aerosol using MODIS IR channel data at 3.75, 8.6, 11 and 12μm is given (Hansell et al. 2007; submitted – under review).
- A surface-based detection/retrieval approach for dust aerosol using the GSFC NASA SMART Atmospheric Emitted Radiance Interferometer (AERI) in the thermal IR window is also presented.

2. MODIS Dust Detection - method

We combine/modify 3 prior techniques for detecting dust aerosol for daytime and nighttime applications: (integrated dust detection - IDD)

1) Develop *D*-parameter* based on *D-parameter* approach (Roskovensky and Liou, 2005) – (uses only the thermal IR channels)
   a. D* > 1 → dust; D* < 1 → cloud (Fig. 2a)
2) Add dust to brightness temperature difference (*BTD*) slope method (Strabala et al. 1994) – (dust typically exhibits a negative slope) (Fig. 2b)
3) 3.75-11μm *BTD* method for dust AOT classification

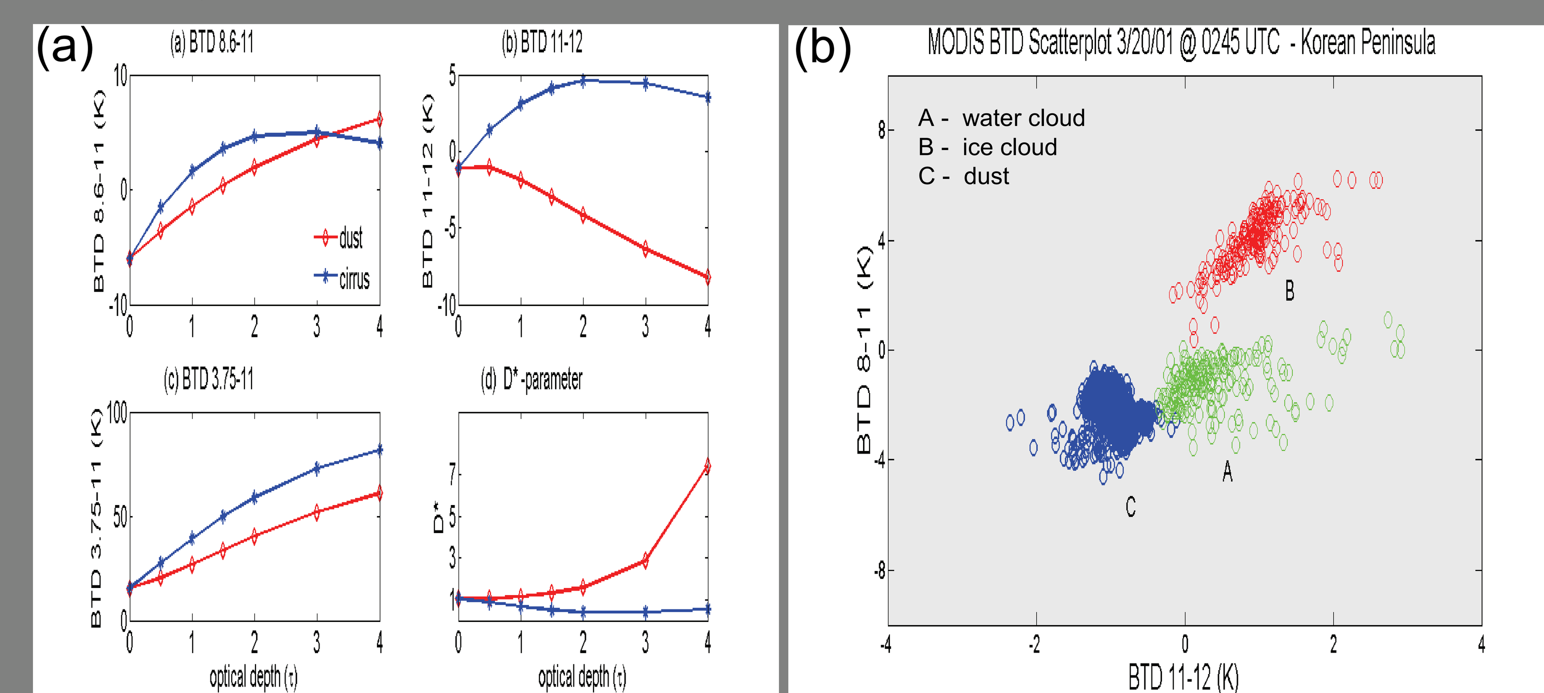


Fig 2. (a) Simulations of *BTD* and *D*-parameter* assuming quartz dust over land (b) Observed MODIS *BTD* of cirrus, low-cloud and dust over Korea on March 20, 2001. Compared to clouds, dust typically displays a negative slope

3. MODIS Dust Detection - results

Persian Gulf (UAE^2) - 9/12/04 and mobile ARM site at Niamey, Niger 3/8/06 are shown. The GSFC NASA 'Deep Blue' solar retrieval algorithm (Hsu et al. 2004) and ARM surface MPL are used for day & night validation respectively. IDD detected dust (Fig.3b) agrees well with Deep Blue AOT's > 1 (Fig. 3c). IDD captures dust & cirrus clouds over Niamey (Fig. 3e) while ARM MPL also observes the cirrus and dust (Fig. 3f).

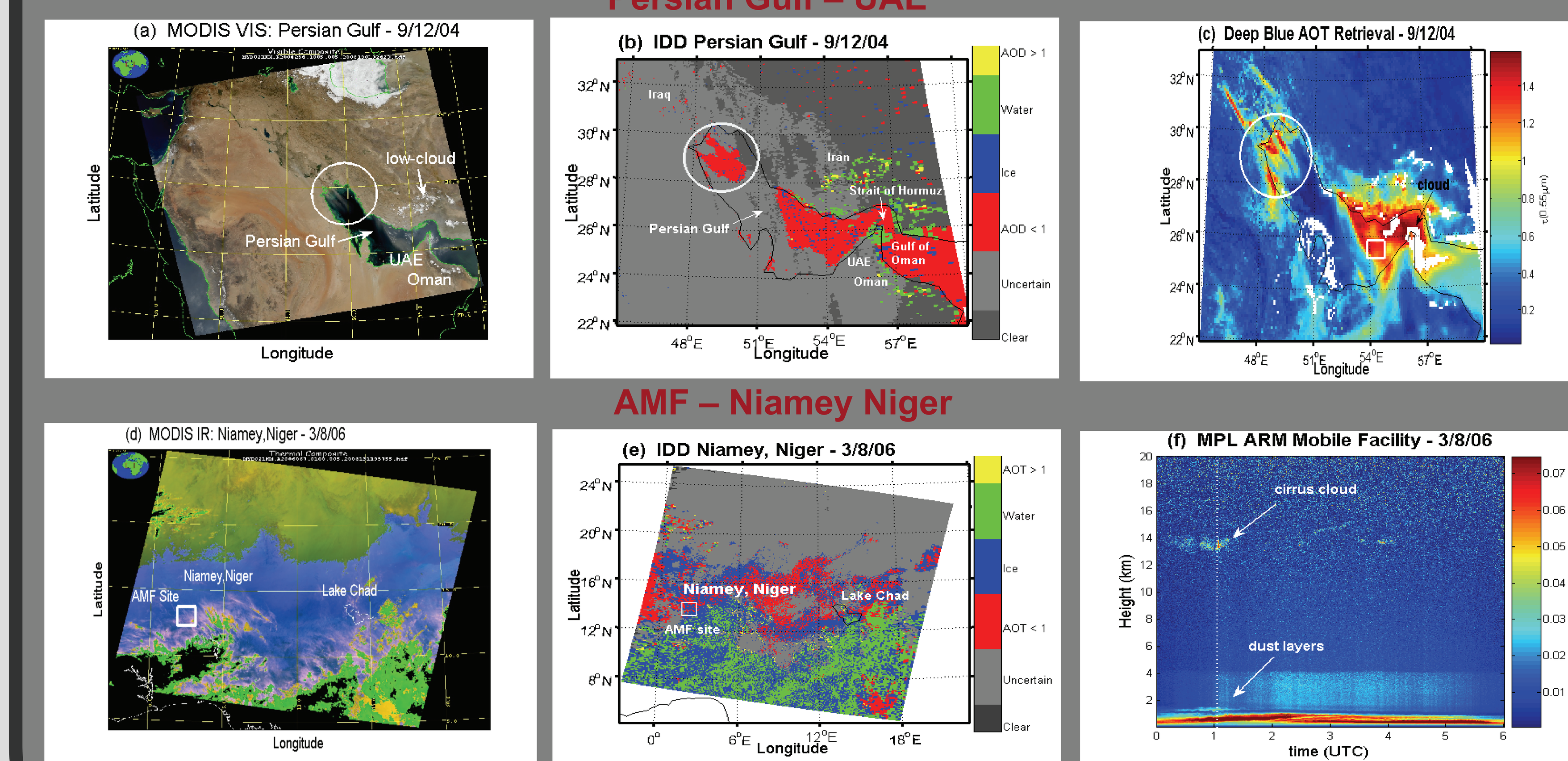


Fig 3. (a). MODIS visible over Persian Gulf (b) Daytime Persian Gulf IDD results. (c) Deep Blue AOT over Persian Gulf (d) MODIS IR over Niamey (e) Nighttime Niamey IDD results (f) ARM surface MPL at Niamey

4. AERI Dust Detection & Retrieval: method/results

(4A). AERI Radiance measurements during NAMMA and UAE^2

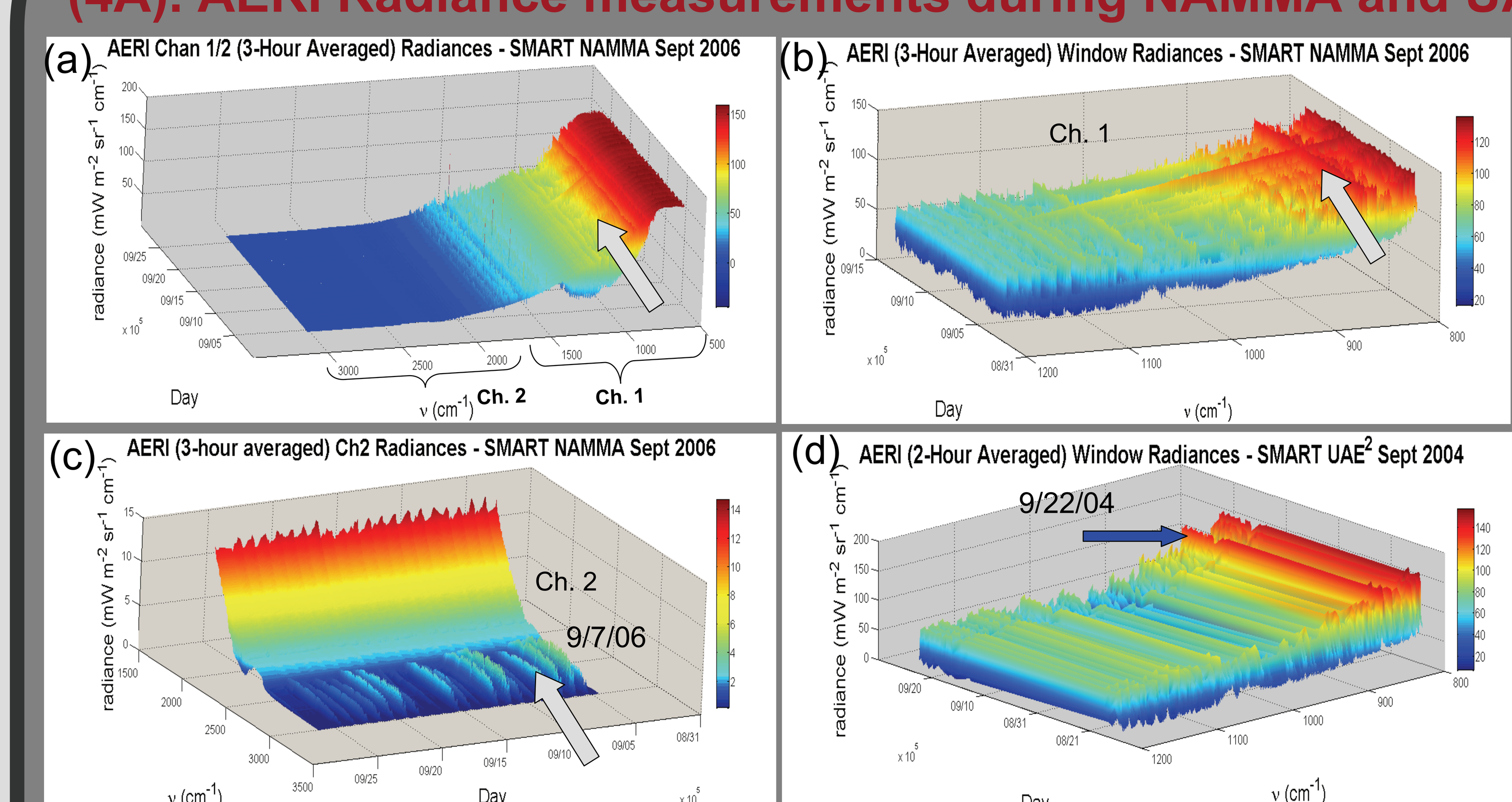


Fig 4A. AERI Ch. 1/2 spectral radiances. (a) NAMMA 3-hr averaged Ch. 1/2 data. (b) NAMMA IR window (Ch.1) 3-hr averaged data. (c) NAMMA 3-hr averaged Ch.2 data. (d) UAE^2 2-hr averaged IR window Ch. 1 data.

Note the clear variability in dust during NAMMA [Figs. 4 (a-c)] as Indicated by the grey arrows

(4B). AERI dust/cloud separation

Dust/cloud mask is applied to data across 17 clean sub bands of the IR window based on:

1. Spectral differences between ice and mineral dust at 8-10μm (1000-1250 cm^{-1})
2. A low-cloud filter which rejects sub band brightness temperatures > average + 1-σ

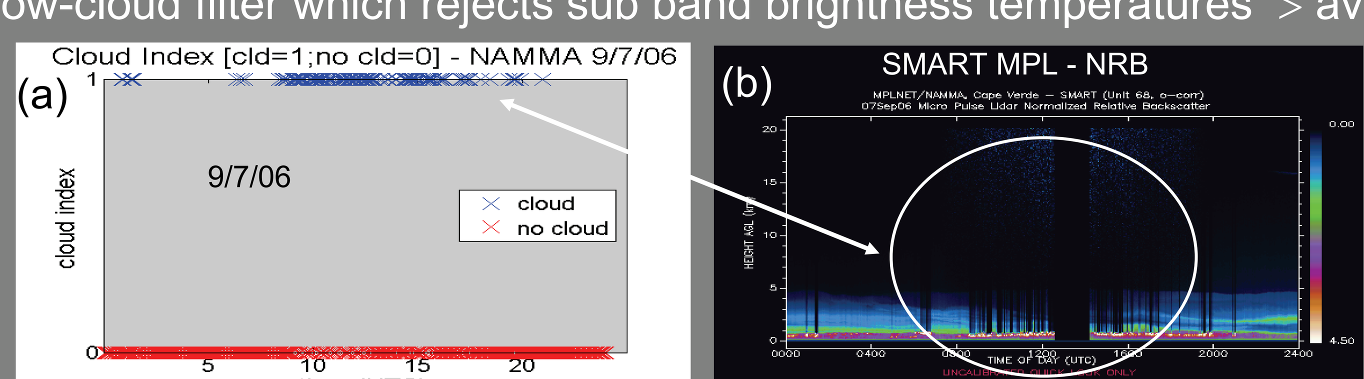
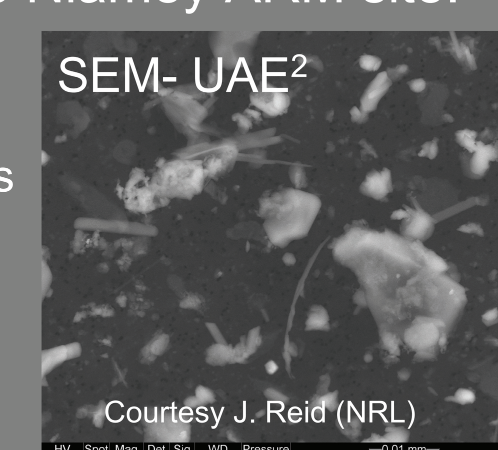


Fig 4B. Example of AERI dust/cloud mask (NAMMA 9/7/06) (a) AERI cloud index (b) SMART MPL NRB

(4C). Retrieval methodology

A statistical optimization approach across the sub-bands is employed to retrieve dust optical depth at 10μm. A collocated AERONET sun-photometer is used for comparison. 2 retrieval cases are given from UAE^2 and the Niamey ARM site.

❖Dust model parameters:
- Shape: spheres, spheroids and compact hexagons
- Size: *in-situ* aero dynamical particle size (APS 3321) parameters
- Composition: pure silicates, carbonates, and bulk dust models



❖Minimize difference of ΔBT (model – observed)

$$\chi^2 = \sum_{i=1}^{17}[\ln(\Delta BT^i_{calc}) - \ln(\Delta BT^i_{aeri})]^2 \quad (1) \qquad \Delta BT = BT_{calc/aeri} - BT_{clear} \quad (2)$$

(4D). Retrieval results / AERONET comparison

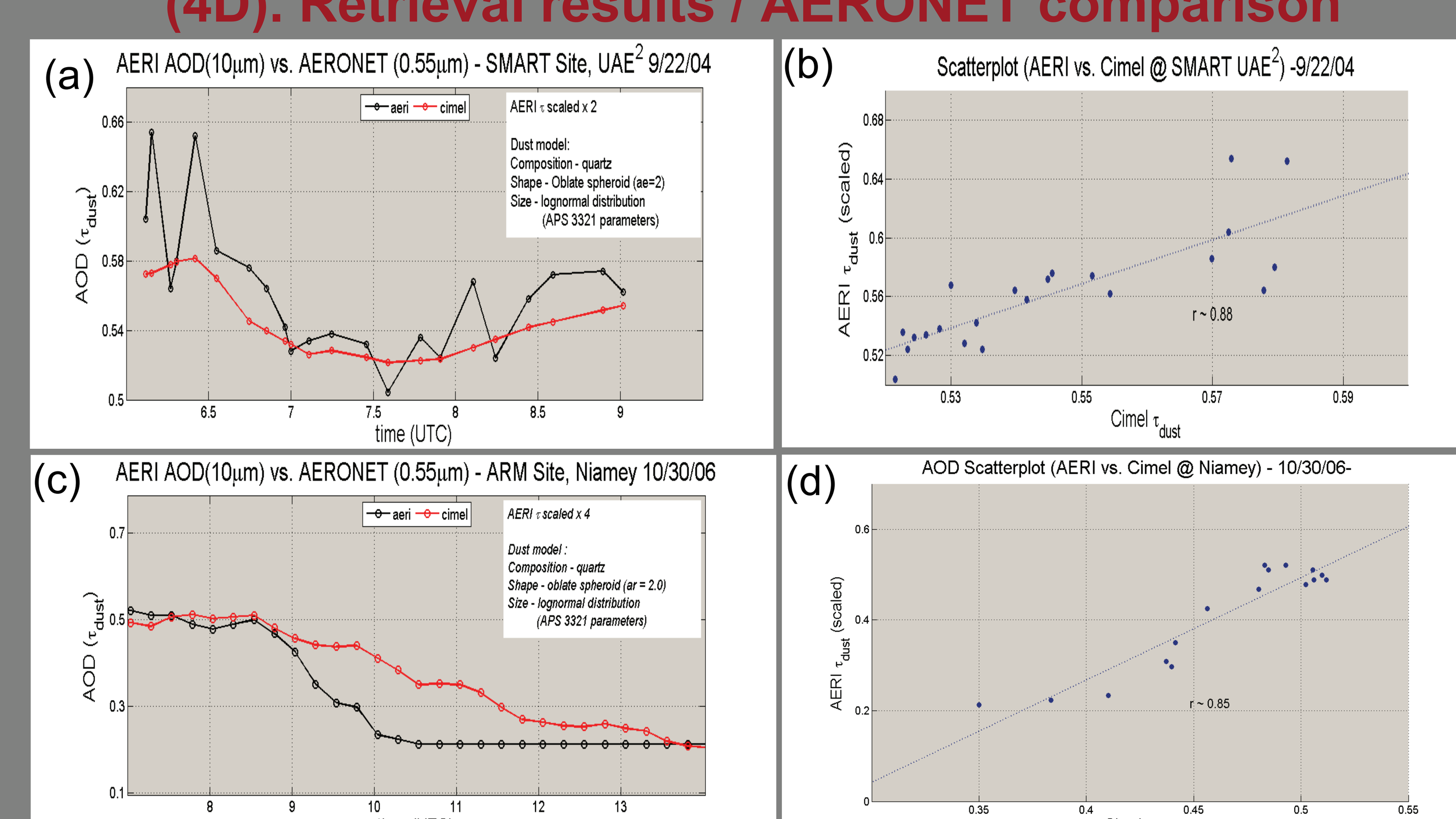


Fig 4D. (2) AERI retrieval cases (a) UAE^2 9/22/2004. AERI τ is scaled x 2 for comparison. (Scaling ∝ particle size – under Investigation) (b) AOD scatter plot (AERI vs. Cimel). AOT's correlate well with r~ 0.88. In the optimized best fit:

Mean (AERI – Model) ~ 1.30K
Standard Dev ~ 4.52K

(c) Niamey 10/30/06 retrieval. AERI τ scaled x 4 for comparison. (d) AOD scatter plot for Niamey 10/30/2006. AOT's correlate well with r~0.85. In the optimized best fit:

Mean (AERI – Model) ~ 2.13K
Standard Dev ~ 4.77K

5. Summary/References

- Remote sensing of dust aerosol using MODIS and AERI thermal IR window data from recent field studies was presented
- MODIS integrated dust detection results compare favorably with NASA's 'Deep Blue' AOT retrieval (τ > 1) for the Persian Gulf and with the ARM site's MPL detected cirrus/dust over Niamey
- AERI dust/cloud detection results compare well with the NASA SMART MPL
- Variability in AERI retrieved dust AOT compares reasonably well with the AERONET sun-photometer AOT. Magnitude differences are related to the particle size parameter.

Hansell R.A., S.C. Ou, K.N. Liou, J.K. Roskovensky, S.C. Tsay, C. Hsu, and Q. Ji (2007) , Simultaneous Detection/Separation of Mineral Dust and Cirrus Clouds Using MODIS Thermal Infrared Window Data, *Geophys. Res. Lett, submitted – under review*

Hsu, N. C., S. C. Tsay, M.D. King, and J. R. Herman (2004), Aerosol properties over bright-reflecting source regions, *IEEE Trans. Geosci. Remote Sensing*, **42**, 557-569.

Roskovensky, J. K., and K. N. Liou (2005), Differentiating airborne dust from cirrus clouds using MODIS data, *Geophys. Res. Lett.* **32**, L12809, doi: 10.1029/2005GLO022798

Strabala K. I., S. A. Ackerman, and W. P. Menzel (1994), Cloud properties inferred from 8-12μm data, *J. Appl. Meteor.*, **33**, 212-229