Detecting Dust with IASI

Sergio DeSouza-Machado, L. Larrabee Strow, Scott Hannon, Breno Imbiriba, and Howard Motteler

Atmospheric Spectroscopy Laboratory (ASL)
The Joint Center for Earth Systems Technology
University of Maryland Baltimore County (UMBC)

1st IASI Conference, Anglet, France

November 14, 2007
Outline

- Learning how to detect and retrieve dust with AIRS
- Hope to incorporate dust retrievals into AIRS $T(z), Q(z)$ retrievals
- Currently use CALIPSO or climatology for dust altitude (problem in IR)
- With IASI we now have 4 daily views of dust events (if cloud-free)
- Science topics: Dust Transport
  - Need optical depths and particle sizes
- Science topics: OLR forcing for climate
  - AIRS and IASI are excellent instruments for longwave OLR dust forcing
  - Dust could be an important climate change variable
IASI and AIRS have sensitivity to dust spectral signatures

IASI and AIRS radiances can provide **day and night**:
- Dust detection **over ocean and land**
- Retrieval of optical depths
- Dust OLR forcing
- Can retrieve dust over **sunglint regions** (MODIS has problems)

Significant fraction (5%?) of IR observations dust contaminated, especially Atlantic during hurricane season

Examination of AIRS L2 products shows retrievals avoid dust regions, or produce erroneous results.
Retrieval of Dust Optical Depths Over Ocean and Land

- RTA is SARTA-scattering (PCLSAM : Chou et al, 1999)
- Masuda emissivity for ocean
- Retrieve only for FOVs tagged as “dust contaminated” (very important for avoiding clouds)
UMBC Dust Retrieval Methods

- **FASTER method**
  - Use ECMWF (or AIRS retrievals) for $T(z), Q(z)$ fields
  - Climatology or CALIPSO guess for $p_{top}$, use 2 um radius
  - Minimize weighted average of $BT^i_{obs} - BT^i_{calc}$, and $(BT^i_{obs} - BT^j_{obs}) - (BT^i_{calc} - BT^j_{calc})$ for selected set of thermal IR channels
  - Linear fit with SARTA CLOUDY to estimate cloud loading $n$
  - $BT^i_{obs} = BT^i_{calc} (n) + \delta BT^i_{errors}$
  - Very fast $\leq 1$ second per profile

- **SLOWER method**
  - Climatology or CALIPSO guess for $p_{top}$, use 2 um radius
  - Use ECMWF (or AIRS retrievals) for first guess $T(z), Q(z)$ fields
  - 1d VAR method for $T(z), Q(z), SST, dust parameters$
  - Slow, $\simeq 1$ minute per profile
  - Motivation: persuade “retrievers” they need to include dust.
Optical Depths for Feb 24, 2007 Dust Storm

Calipso track overlaid on crosses
Left side: AIRS at 900 cm⁻¹; Right side: MODIS at 0.55 um
3 instruments on the A-Train (Feb 24, 2007 duststorm)

**AIRS 10 um (x3), Calipso 0.55 um and MODIS 0.55 um optical depths retrieved along Calipso track**
March 6, 2004 Dust Storm

Left: True color MODIS image
Right: AIRS Dust flag
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), \( \frac{\tau_{\text{AIRS}}}{\tau_{\text{MODIS}}} \approx 0.5 \)
Retrievals Over Sahara: May 9, 2007

Left: MODIS
Right: AIRS
CALIPSO track shown as crosses
Comparisons along CALIPSO tracks to MODIS Deep Blue for Saharan Dust Storms in May 2007 (AIRS 10 um OD ≈ × 2 less than MODIS 0.55 um)
Can do all of the above with IASI

- Starting to implement IASI dust algorithm
- Same dust detection algorithm; (channels need to be optimized for IASI)
- Same dust retrieval algorithm(s)
- Daytime, compare AIRS and MODIS on Aqua, and IASI on Metop and MODIS on Terra
- First preliminary study: the 2007/07/28 Saharan Dust Storm
Dust storm near NW Africa: Daytime MODIS visible views

July 28, 2007 off NW Africa
Left: Terra MODIS at (daytime descending)
Right: Aqua MODIS at (daytime ascending)
July 28, 2007 off NW Africa
Left : IASI at (two granules, daytime descending)
Right : AIRS at (one granule, daytime ascending)
Dust storm near NW Africa: Nighttime IR views

July 28/29, 2007 off NW Africa
Left: IASI (one granule, nighttime ascending)
Right: AIRS (two granules, nighttime descending)
Dust storm near NW Africa: Terra MODIS vs IASI

July 28, 2007 off NW Africa
Left: Terra MODIS (daytime descending) 0.55 um optical depths
Right: IASI (two granules, daytime descending) 900 cm-1 optical depths
Dust storm near NW Africa: Aqua MODIS vs AIRS

July 28, 2007 off NW Africa
Left: Aqua MODIS (daytime ascending) 0.55 um optical depths
Right: AIRS (one granule, daytime ascending) 900 cm-1 optical depths
Dust storm near NW Africa: Day IASI vs AIRS

Optical depths

July 28, 2007 off NW Africa
Left: IASI (two granules, daytime descending)
Right: AIRS (one granule, daytime ascending)
Dust storm near NW Africa: Night IASI vs AIRS
Optical depths

July 28, 2007 off NW Africa
Left: IASI (one granule, nighttime ascending)
Right: AIRS (two granules, nighttime descending)
Comparing AIRS-L2 vs UMBC Retrievals vs ECMWF

- AIRS L2 retrievals chosen had Quality Flags set good or best for:
  - Cloud_OLR
  - Temp_Profile_Bot
  - H2O
  - Surf (*not used in some plots*)
  - Guess_PSurf

- UMBC retrievals used Optimal Estimation to simultaneously retrieve:
  - Temperature upto 200 mb (ECMWF first guess)
  - Water vapor upto 200 mb (ECMWF first guess)
  - Surface Temperature (ECMWF first guess)
  - Dust loading (UMBC first guess)
  - Dust top height (climatological model first guess)
  - Dust effective diameter (4 um first guess)
Left plot shows retrieved $\tau(900\, cm - 1)$
Right plot shows biases and std deviations over the channels used
March 09, 2006: Retrieved Radii and Particle Size

Left plot shows retrieved $reff(\text{um})$
Right plot shows retrieved height
March 09, 2006: Area coverage

Left plot shows retrieved $\tau (900 \, cm - 1)$
Right plot shows coincident AIRS retrievals (1 = surface quality best or good, 0 = ignore surface quality)
(far fewer FOVs!)
Histories of SST differences and col water ratios (upto 200mb)

Blue = UMBC compared to ECMWF
Red = “Good” AIRS L2 compared to ECMWF
Magenta = All AIRS L2 compared to ECMWF
AIRS L2 has higher SST, and is overall drier
March 09, 2006: Stemp grids

Left = ECMWF, top right = AIRS, bottom right = UMBC
March 09, 2006: Col Water grids

Left = ECMWF, top right = AIRS, bottom right = UMBC
Feb 24, 2007: Area coverage and biases

Left plot shows retrieved $\tau(900\text{ cm} - 1)$
Right plot shows biases and std deviations over the channels used
Left plot shows retrieved $\tau(900 cm - 1)$
Right plot shows coincident AIRS retrievals (1 = near-surface quality best or good, 0 = quality of near-surface retrieval is poor)
(far fewer FOVs!)
Histograms of SST differences and col water ratios (upto 200mb)

Blue = UMBC compared to ECMWF
Red = “Good” AIRS L2 compared to ECMWF
Black = “Bad” AIRS L2 compared to ECMWF
Magenta = “All” AIRS L2 compared to ECMWF
AIRS L2 has higher SST, and is overall drier
February 24, 2007: Stemp grids

Left = ECMWF, top right = AIRS, bottom right = UMBC
Feb 24, 2007: Col Water grids

Left = ECMWF, top right = AIRS, bottom right = UMBC
Conclusion

- AIRS L2 quality flag properly “fails” for many dust contaminated FOVs
- Dust contaminated FOVS often lead to incorrect L2 retrievals
- Dust sometimes end up in the emissivity, without affecting T(z),Q(z), sometimes in T(z) and Q(z)
- The L2 retrievals stemp can be biased either way (+ve or -ve)
- UMBC Optimal Estimation Retrievals of T(z),RH(z),dust amount
  Needs to be fine tuned, but first results look promising