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# Comparison of AIRS Dust Retrievals with other A-Train Instruments

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October 15, 2008

# Effects on Climate

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- Magnitude of climate forcing by clouds/aerosols is uncertain, and is as large as that due to greenhouse gases
- Space based instruments (mainly UV/VIS) detect dust storms with nearly daily global coverage
- Work still needs to be done in the IR eg
  - dust affects (TOA,surface) forcing
  - dust contaminates spectra used for atmospheric state retrievals
  - radiative forcing estimates need both the SW and LW components; LW component might be smaller than SW, but is affected day *and* night
- Dust in the atmosphere can dry/heat atmospheric layers, suppress hurricane formation

# IPCC Radiative Forcings

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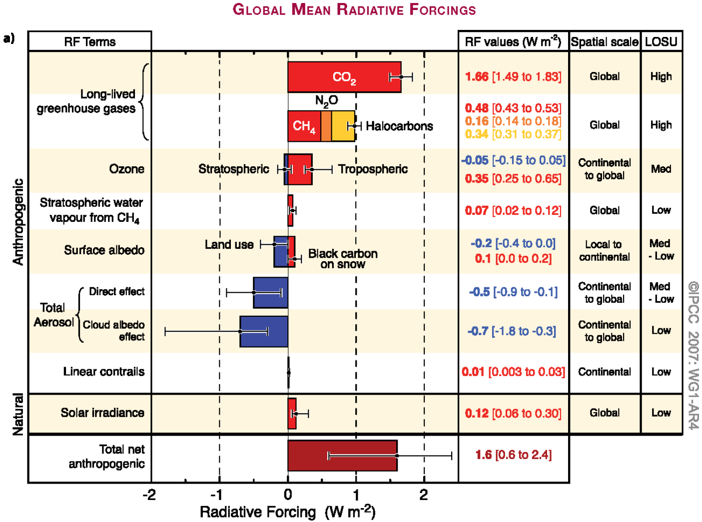

# AIRS and dust

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- Many of the A-Train instruments (eg MODIS) can be used to study dust
- AIRS is *VERY* competitive with them (dust ODs, heights)
- AIRS also works day/night, over ocean (sunglint) and land
- AIRS can directly provide OLR forcing due to dust
- AIRS has sensitivity to dust height, but OLR forcing and L2 retrievals relatively insensitive to height, unlike dust optical depth.

# AIRS Contributions : Synergy with other instruments

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- Land : MODIS Deep Blue has problems over bright surfaces (deserts) and OMI may not detect low-altitude dust.
- Sunglint : MODIS has trouble in sunglint regions
- Smoke/dust : MODIS can have difficulty distinguishing between the two aerosols
- Can help future missions eg GLORY
- Aerosol SW forcing : depends on single scattering albedo; good height info (from AIRS) will reduce uncertainty in SSA retrieval by OMI

# The A-Train

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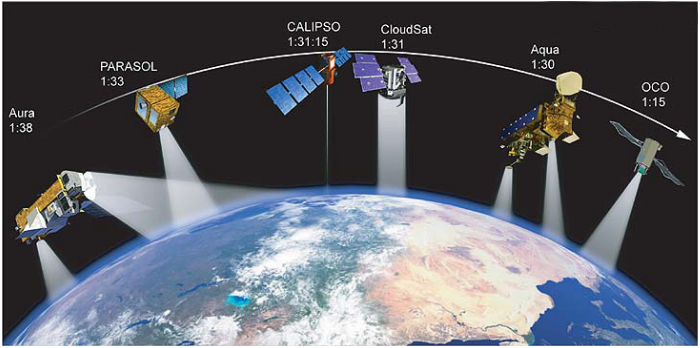


Intercompare results between 5 A-Train instruments
Aura : OMI
PARASOL : POLDER
CALIPSO : CALIOP
Aqua : AIRS and MODIS

# Instruments used in this study

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| Instrument | Footprint (km) | Retrieval (km) | Swath (km) | Available channels | Retrieval reported at |
|---|---|---|---|---|---|
| AIRS | 15 | 15 | 2000 | IR | 900 $cm^{-1}$ |
| CALIPSO | 0.1 | 15 | 0 | 532,1064 nm | 532 nm |
| PARASOL | 7x6 | 20 | 1600 | UV, Vis,NIR | 865 nm |
| MODIS (land) | 1 | 10 | 2330 | Vis,NIR,IR | 550 nm |
| MODIS (ocean) | 1 | 10 | 2330 | Vis,NIR,IR | 858 nm |
| OMI | $13 \times 24$ | $13 \times 24$ | 2600 | UV | 500 nm |
| AERONET | point | point | ground | VIS | 500 nm |

Most are passive VIS or UV instruments and so can only be used during the day

AIRS : IR instrument; acquires data day and night

CALIPSO : active (LIDAR) instrument; acquires data day and night

MODIS also has some TIR channels

# Dust and Cirrus Flags


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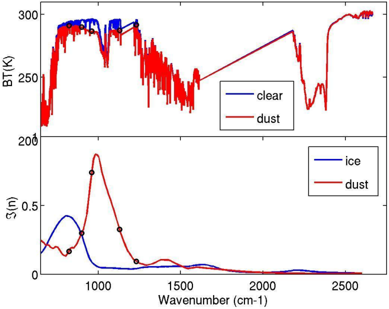


- Set up a sequence of “threshold dust cloud tests”
- 5 channels chosen are [822.4 900.3 961.1 1129.03 1231.3] $cm^{-1}$
- Threshold tests $tt_i$ involve split window BTD
- $tt$=380 over water; $tt$=360 over land (needs improvement)
- Cirrus flag : BT(960)-BT(820) $\geq$ 2 K and BT(960) $\leq$ 275 K

# Feb 20-24, 2007

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- Weather system arrived over NW Africa on 02/20/2007
- Progressed over Algeria, Libya, Egypt and over the Mediterranean towards Turkey by 02/24/2007
- Multiple overpasses by A-train instruments (and eg SEVIRI)
- Have retrieved aerosol ODs over land and sea for AIRS, CALIPSO, PARASOL (sea only), MODIS, OMI
- Some AIRS FOVs have dust *and* cirrus, others totally cloudy

# Feb 20-24, 2007


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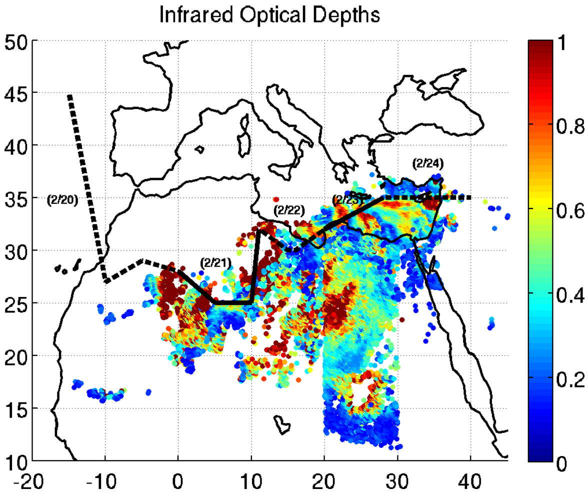

# AIRS retrieval scheme

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- ECMWF for estimate of atmospheric profile and surface temps
- Emissivity : Masuda over ocean, U-Wisc database over land
- Lognormal size distribution with *reff* = 2um over land; over ocean use PARASOL retrieved effective radii $\simeq$ 2 um
- Use *Volz* database of IR optical constants (see later)

Details :

- Use $\simeq$ 30 TIR channels between 800-1200 $cm^{-1}$ (hgt sensitive)
- Use 2602,2616 $cm^{-1}$ SWIR channels (OD sensitive)
- OD errors dominated by dust height placement : (CALIPSO can help, but ...)
- Linearized Newton Raphson scheme used to retrieved ODs at fixed AIRS layers; look for minimum spectral bias and average over 0.5 $\times$ 0.5 grid to retrieve height
- Go back one more time to retrieve final AIRS OD estimate

# Feb 24, 2007

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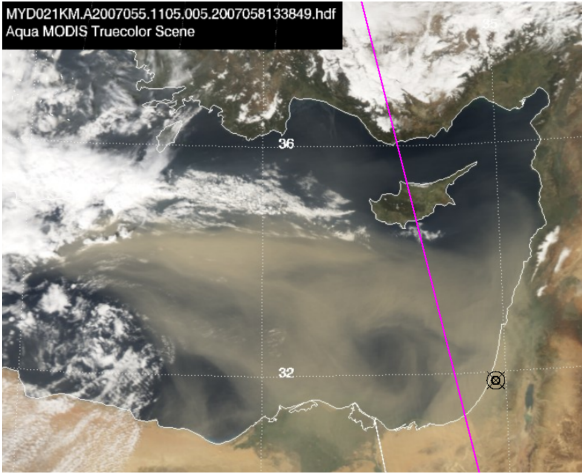

# Results along CALIPSO ground track (Hgt)

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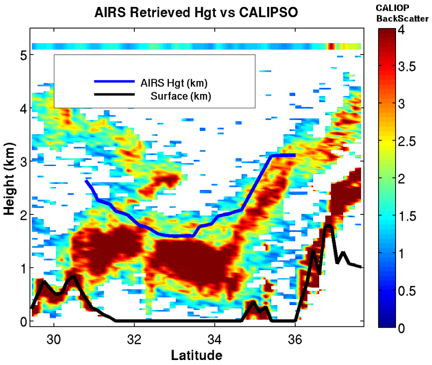


- background is CALIPSO backscatter
  - black is surface, traversing Egypt(left) to Turkey(right)
  - horizontal line at 5.5 km shows peak backscatter between 5-20 km (indicator of high clouds)
  - vertical structure cannot be retrieved by AIRS
- Blue is AIRS height retrieval captures strong features

# Results along CALIPSO ground track (OD)

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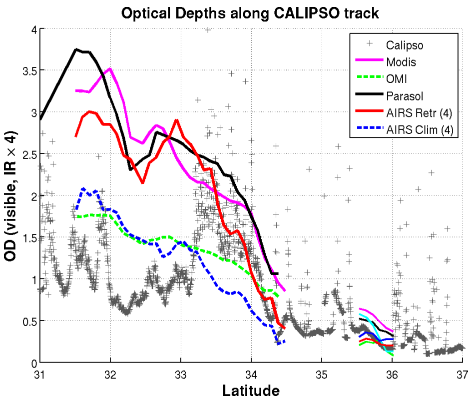


- CALIPSO assumes single scattering; not good at high ODs
- OMI uses GOCART heights; incorrect (higher than CALIOP)
  AIRS III uses same GOCART heights
- AIRS TIR ODs using retrieved height agree very well with MODIS and PARASOL total ODs

# Feb 24, 2007 summary of regressions along CALIOP track vs MODIS

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| Instrument | Slope | Intercept | Correlation |
|---|---|---|---|
| CALIOP (512 nm) | 0.22 | 0.58 | 0.46 |
| PARASOL (865 nm) | 1.00 | 0.20 | 0.95 |
| OMI (500 nm) | 0.22 | 0.57 | 0.91 |
| AIRS I (900 $cm^{-1}$) | 0.27 | 0.23 | 0.85 |
| AIRS II (900 $cm^{-1}$) | 0.25 | -0.01 | 0.95 |
| AIRS III (900 $cm^{-1}$) | 0.14 | 0.02 | 0.95 |

Regressions done against MODIS 0.55 um total OD

# Retrieved heights (km)

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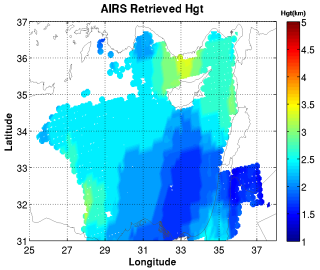
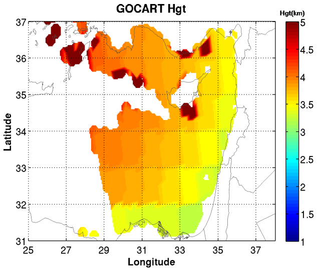
AIRS retrieval



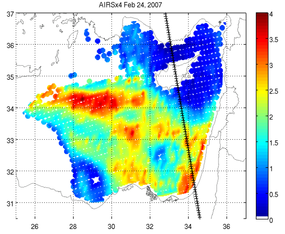

GOCART



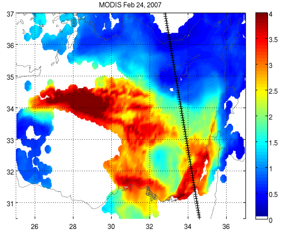

- GOCART is usually too high
  - NE Mediterranean : $hgt(GOCART) - hgt(AIRS) \simeq 1km$
  - south of Cyprus, along CALIOP track : $hgt(GOCART) - hgt(AIRS) \simeq 1.5 - 2km$
  - west/SW of Cyprus : $hgt(GOCART) - hgt(AIRS) \simeq 1 - 1.5km$
- mean(AIRS) hgt $\simeq$ 2 km, mean(GOCART) hgt $\simeq$ 3 km

# ODs : All instruments

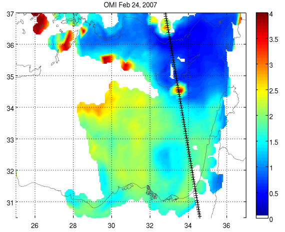
AIRS



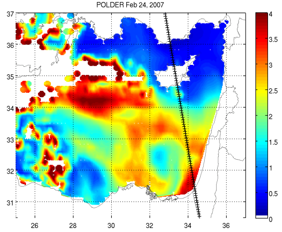

MODIS




OMI




PARASOL



# Correlations with MODIS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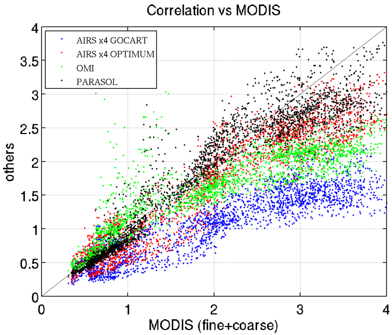


- All instruments roughly agree with each other
- PARASOL cloud mask has been relaxed for this study
- MODIS coarse mode is much smaller than PARASOL coarse mode as it assumes spherical particles
- OMI has lowest ODs, as GOCART heights were too high
- AIRS does not have sun glint problems

# All days (Land and Ocean)

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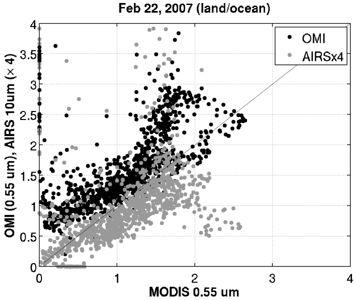
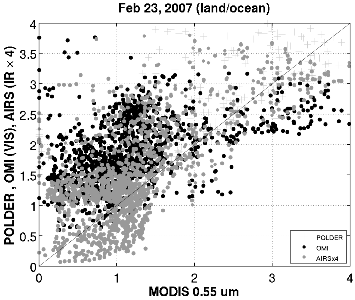
| Date | AIRS (900 $cm^{-1}$) (corr) slope, int | OMI (0.50 um) (corr) slope, int | PARASOL (0.87 um) (corr) slope, int |
|---|---|---|---|
| 21 (L) | (0.54) 0.13 MOD + 0.09 | (0.58) 0.91 MOD + 0.48 | (N/A) N/A MOD + N/A |
| 22 (L) | (0.66) 0.13 MOD + 0.08 | (0.77) 0.85 MOD + 0.64 | (N/A) N/A MOD + N/A |
| 23 (L) | (0.33) 0.11 MOD + 0.16 | (0.51) 0.63 MOD + 1.27 | (N/A) N/A MOD + N/A |
| 23 (W) | (0.80) 0.17 MOD + 0.20 | (0.73) 0.40 MOD + 1.11 | (0.86) 0.79 MOD + 0.76 |
| 24 (W) | (0.95) 0.19 MOD + 0.02 | (0.91) 0.50 MOD + 0.54 | (0.95) 0.82 MOD + 0.19 |

02/22/2007




02/23/2007




MODIS on horizontal axis, OMI and AIRS on vertical axis

# CALIPSO/AIRS on 02/22-23/2007

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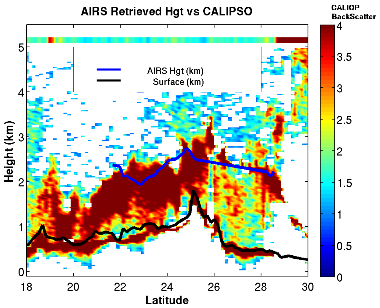
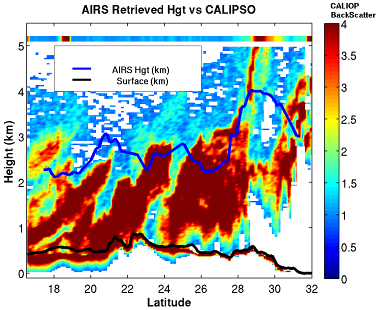
2007-02-22-G129
(daytime)
over land




2007-02-23-G010
(nighttime)
over land and ocean




AIRS hgts vs CALIPSO backscatter
AIRS ODs competitive with other instruments

# Identifying Species

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- Dust species have different optical constants in the thermal atmospheric window
- AIRS has many channels in this region, that could be used to differentiate between the spieces
- UV/VIS instruments cannot be used for this, as the refractive indices in those regions have less features

# Feb 2007 duststorm

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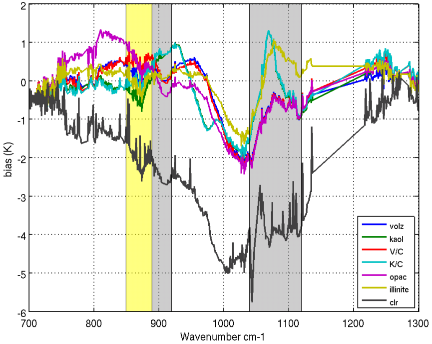


- Using Kaolinite only produces a very large bias at 1080 $cm^{-1}$
- Volz, OPAC, Kaolinite, Gypsum, Quartz, mixed with $CaCO_3$ (notch)
- Volz/$CaCO_3$ mixture yield smallest overall residuals
- Makes sense, as kaolinite is more from the Southern Sahara/Sahel

# Outgoing Long wave Radiation and Clouds/Aerosols

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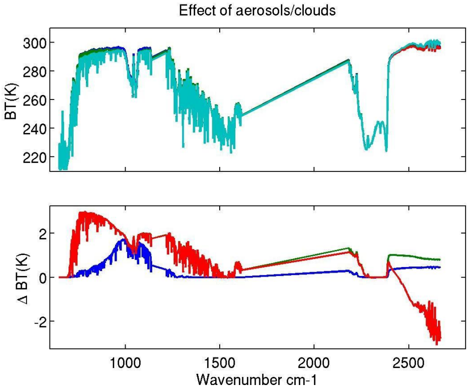
AIRS can provide unique information on dust LW forcing

SW forcing can be about $\simeq$ 10 W/m2

OLR forcing over ocean can be ($\simeq$ 5 W/m2)

OLR forcing over land can much larger ($\simeq$ 20 W/m2)



# OLR forcing over land/sea

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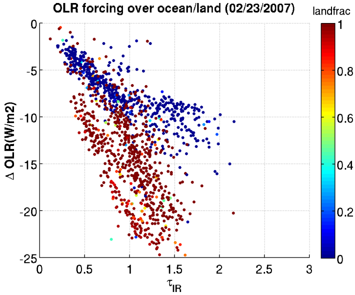
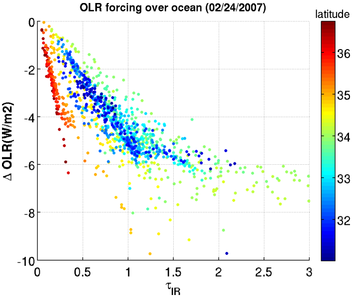
Sahara and Mediteranean (02/23)
Color axis : Landfraction




Mediteranean (02/24)
Color axis : latitude



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# AIRS L2 and dust

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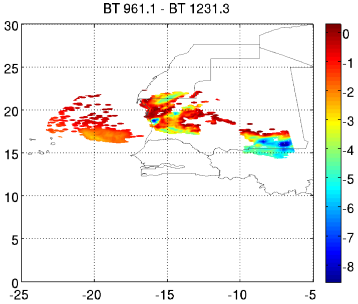
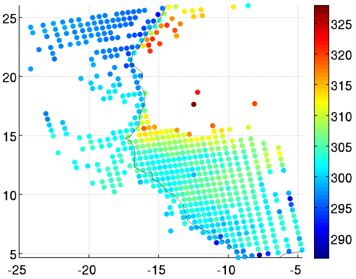
- AIRS L2 quality flags fail (down to surface) where there is dust
- Surface temps ($\pm$ 3 K), *sea* emissivities usually different (from ECMWF/Masuda)
- Temperature and water profiles also different from ECMWF
- Met in early Sept with Joel, Chris, Larrabee, John, Scott

# 2008/09/29 G 144

## AIRS dust flag




## AIRS QA




Qual.Cloud_OLR = 0,1
Qual.Temp_Profile_Bot = 0,1
Qual.H2O = 0,1
Qual.Guess_PSurf = 0,1

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# Conclusions

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- Over ocean, AIRS ODs very competitive with those from PARASOL, MODIS, OMI
- Over land, AIRS TIR ODs $\simeq$ MODIS, OMI ODs
- AIRS dust layer heights compare very well against CALIPSO
- Many synergy possibilities between AIRS and other instruments

AIRS provides estimates of dust OLR forcing
Scattering code works for dust, clouds, volcanic ash ...