Validation of Climate Sounding Algorithm Cloud Heights

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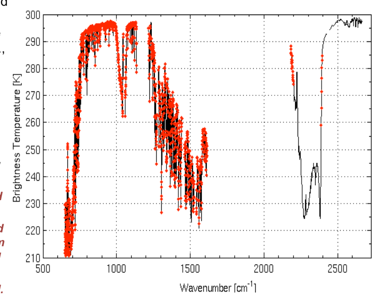
A Hyperspectral Vertical Resolution Profile Technique That Enables the Use of the Infrared Radiance Spectrum to Define the Cloud Height with High Accuracy

The Technique

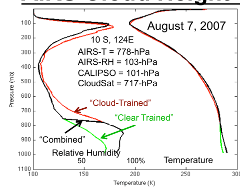
Use rapidly produced **"Clear-trained" and "Cloud-trained"** EOF regression IR hyperspectral sounder retrievals of surface skin temperature, effective cloud optical depth, and atmospheric temperature and moisture profiles to specify cloud top altitude, cloud attenuation, clear atmospheric thermodynamic profile above the cloud, and thermodynamic profile below thin or scattered cloud (i.e., cloud effective optical depth < 1.5 and emissivity < 88%, or an effective cloud transmissivity > 35 %, and a cloud induced temperature attenuation < 15 K.

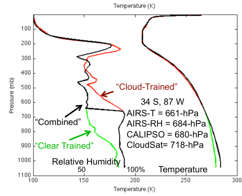
- ***Optically thick cloud height is specified as that point where "cloud-trained" temperature profile retrieval becomes systematically greater than the "clear-trained" temperature profile retrieval.*** ***(The Cloud-trained EOF regression solution coefficients are selected from a set of ten classes of cloud-height stratified 200-hPa overlapping layers. The proper class is determined using a non-linear (i.e., iterative) cloud pressure regression estimator. The initial value is determined using an unclassified by cloud height linear regression operator.)***
- ***Optically thin cloud height is specified as the highest altitude where an isolated peak in the "clear-trained" relative humidity profile is > 75%.***
- ***Cloud optical depth is obtained from classified EOF regression operator. Cloud emissivity/transmissivity is defined from cloud top temperature and the maximum difference between cloud-trained and "clear-trained" retrievals beneath the cloud top.)***
- ***Atmospheric profile above the cloud is specified as the "clear-trained" retrieval.***
- ***Atmospheric profile below the cloud is specified as the "cloud-trained" retrieval.***

Channels Used



AIRS Cloud Height & T/RH Profile Examples

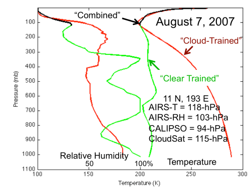




Cloud and Profile Determination:

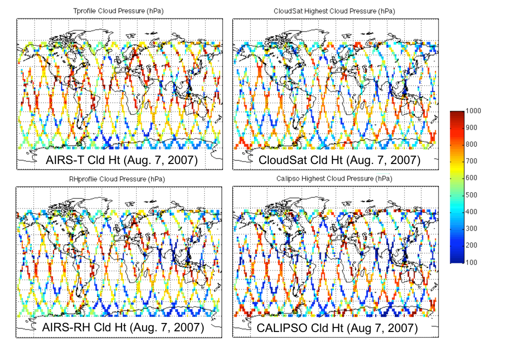
1. T-cloud: Highest level where $T_{cld}(p) > T_{clr}(p)$ to the ground where $T_{cld}(p)$ & $T_{clr}(p)$ obtained by EOF regression
2. RH-cloud: Highest RH_{clr} peak > 75%
3. Final Pcld estimate is the lowest of (1) & (2)
4. $T = T_{clr}$ & $RH = RH_{clr}$ above cloud
5. If ["Optical Depth" <= 1.5 and Emissivity < 88%] or "Transmissivity">50%, & Max[$(T_{cld}(p) - T_{clr}(p))$] < 15K then the below cloud profiles are.:
   $T(p) = T_{cld}(p)$ and $RH(p) = RH_{cld}(p)$
   Otherwise:
   T(p) & RH(p) = "missing"

RH-profile senses optically thin cirrus
T-profile senses lower cloud



AIRS-T, AIRS-RH, CALIPSO, & CloudSat

Highest Co-located AIRS FOV Cloud Altitudes (2.5 deg. grid average)



Inter-comparison Criteria

(AIRS, CALIPSO, and CloudSat co-located* fields of view)

CloudSat Filtered Comparisons

- MODIS Clear Probability = 0%
- IIR FOV average radiance difference ≤ 1 %
- CALIPSO Number of Cloud Layers ≤ 2

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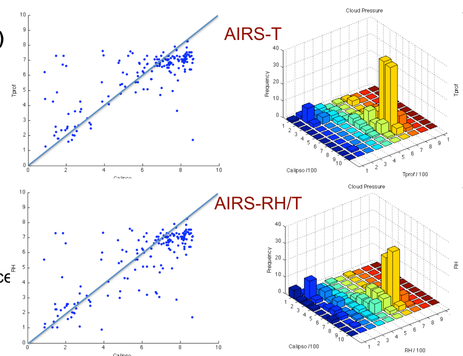
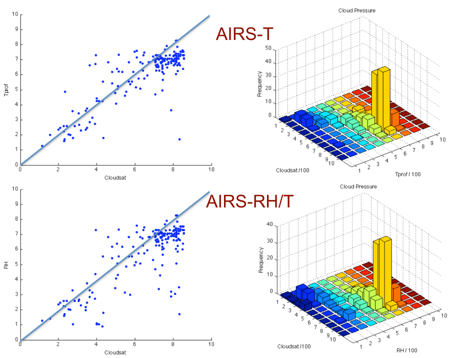
- CALIPSO – CloudSat Highest Cloud Pressure Difference ≤ 50-hPa

* Co-locations provided by Nagle and Holz (UW-CIMSS)

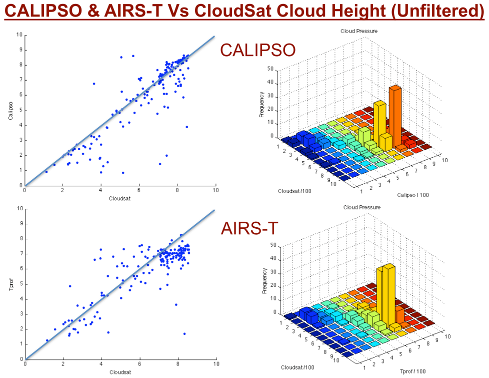
IR-Profile Vs CALIPSO Cloud Height (Unfiltered)



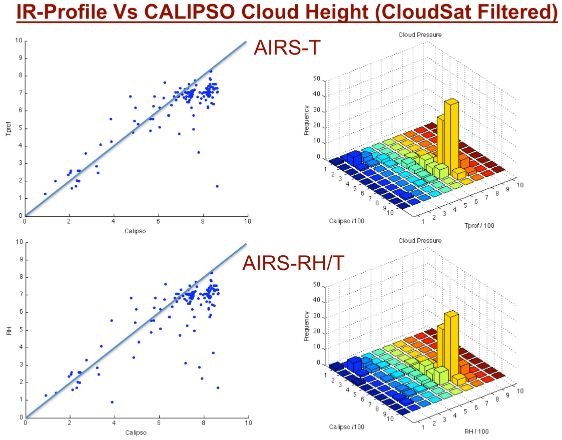
IR-Profile Vs CloudSat Cloud Height (Unfiltered)

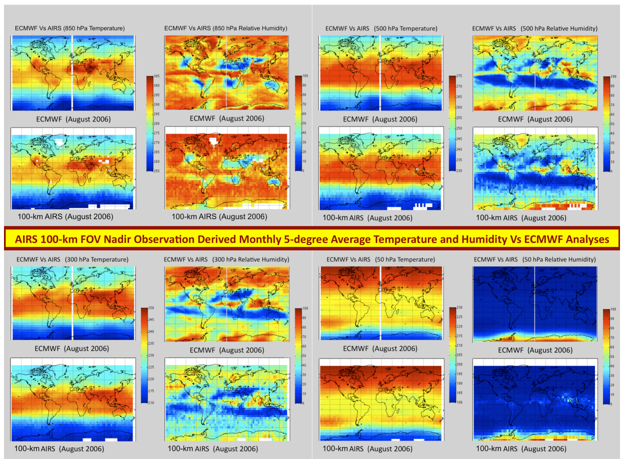


CALIPSO & AIRS-T Vs CloudSat Cloud Height (Unfiltered)



IR-Profile Vs CALIPSO Cloud Height (CloudSat Filtered)





Conclusion

- The hyperspectral vertical resolution profile technique enables the entire spectrum of radiance to be used to define the cloud height with relatively high accuracy.
- AIRS temperature (AIRS-T) and AIRS relative humidity (AIRS-RH) profile retrievals are able to specify the tops of relatively opaque and optically thin cloud layers, respectively.
- Comparisons of AIRS-T and and AIRS-RH Cloud Top Pressures with co-located CALIPSO and CloudSat Cloud Pressures reveal the following:
  - The scatter of AIRS-T Vs CALIPSO and AIRS-T Vs CloudSat is similar to that of CALIPSO Vs CloudSat
  - AIRS-T agrees better with CloudSat than it does with CALIPSO
  - AIRS-RH helps sense the height of optically thin cirrus cloud missed by most IR window and CO_2 channel cloud height sensing techniques
  - The correspondence between AIRS-T with CALIPSO is improved when a CALIPSO – CloudSat highest cloud height difference filter is applied to the data set
- *Much of the scatter between the IR-profile cloud heights and those from CALIPSO and CloudSat are believed to be due to the different FOVs of the instruments*
- The atmospheric profiles associated with the hyperspectral profile cloud heights compare well with ECMWF analyses of temperature and water vapor.