CALIPSO/CALIOP: Cloud Cover

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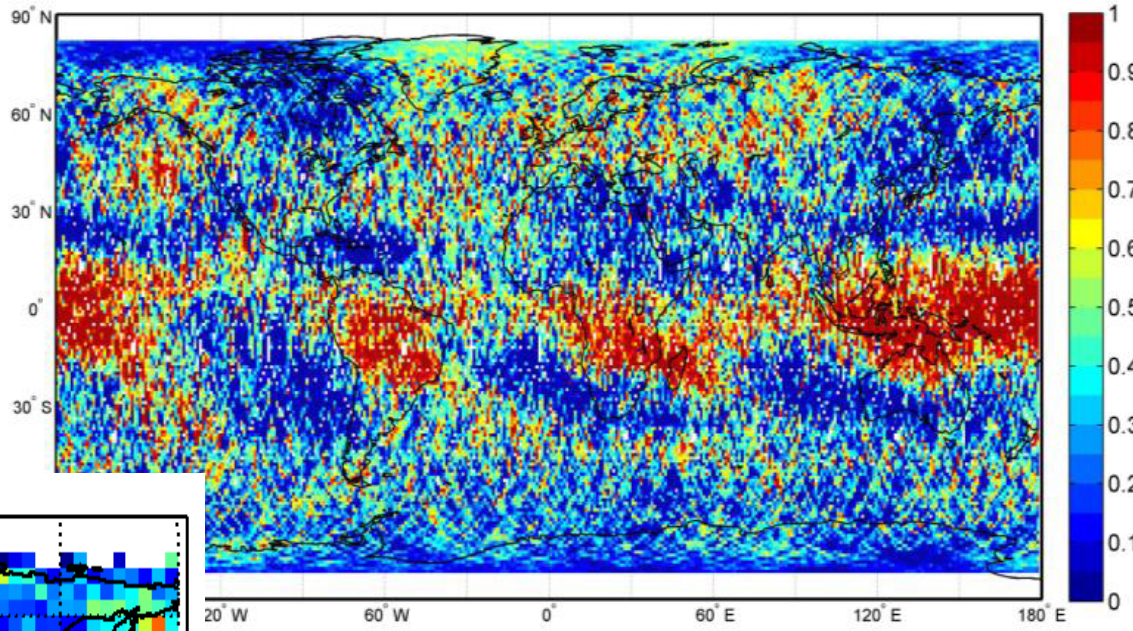
Strengths and Limitations

- **Strengths**
  - **Unambiguous cloud altitude**
    - > **to 60 m or so**
  - **Small footprint (~100 m)**
  - **Very sensitive**
    - > **to OD = 0.01 or so**
  - **Unambiguous multi-layer detection**
    - > **if upper clouds not opaque**
  - **Day/night with relatively low day/night bias**
    - > **Same algorithm, D vs. N, but different detection limits**
  - **Much improved polar statistics**
  - **Much improved cloud ice-water phase determination**
  - **Better IWC? (to be demonstrated)**
    - > **for optically thin clouds**

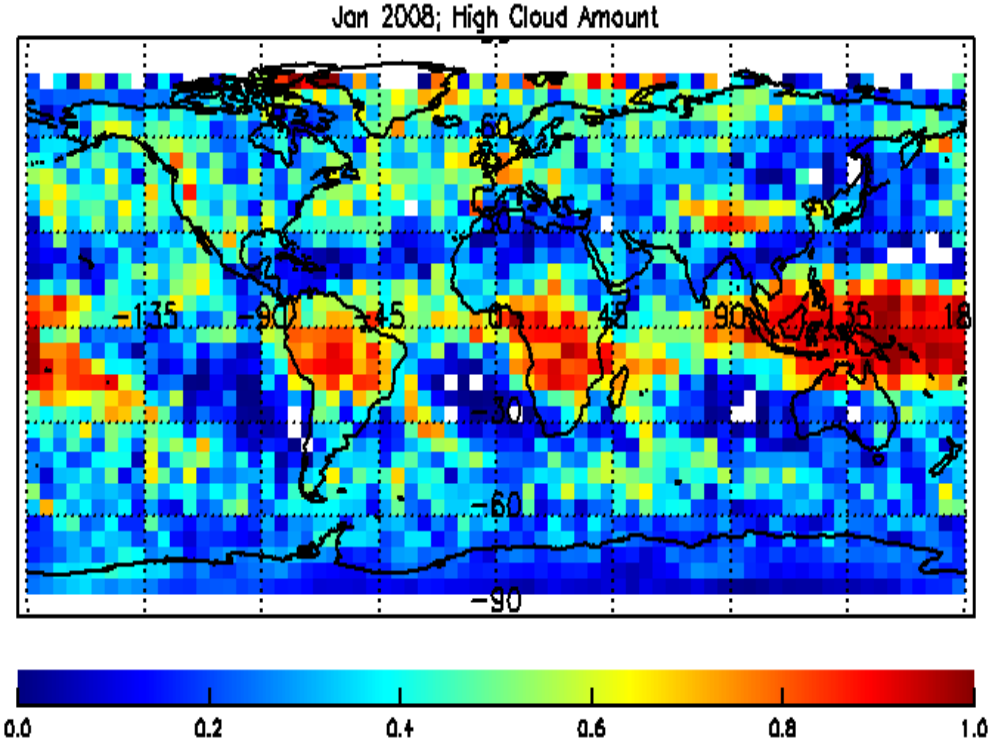
- **Limitations**
  - **Sampling is sparse → requirements on spatial and temporal averaging**
  - **Short data record (6/06 – present)**
  - **Only sensitive to highest 3 optical depths or so**
  - **Detection of thinnest clouds (OD < 0.1?) has diurnal bias**

Spatial Resolution/Averaging



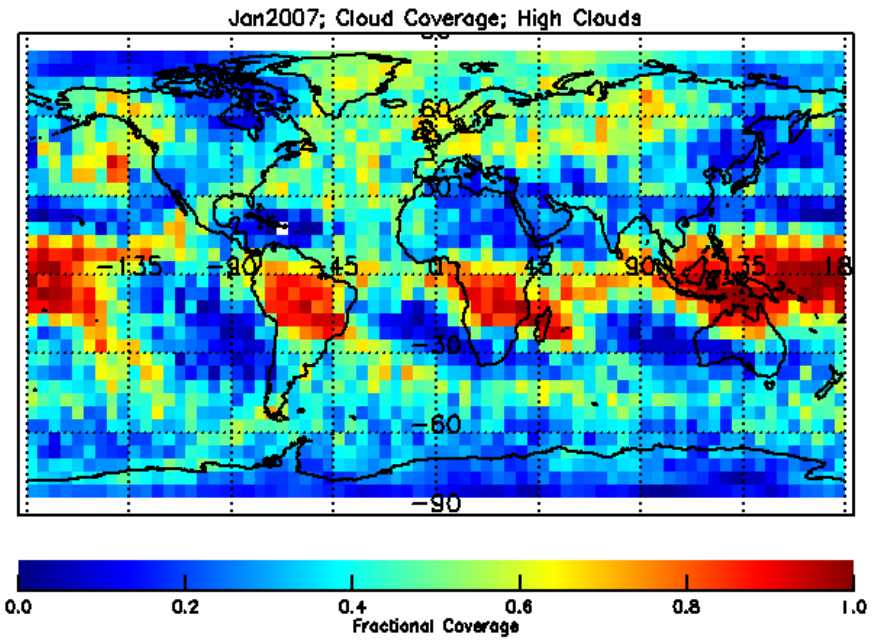
1° x 1°

5° x 5°, Jan 2008

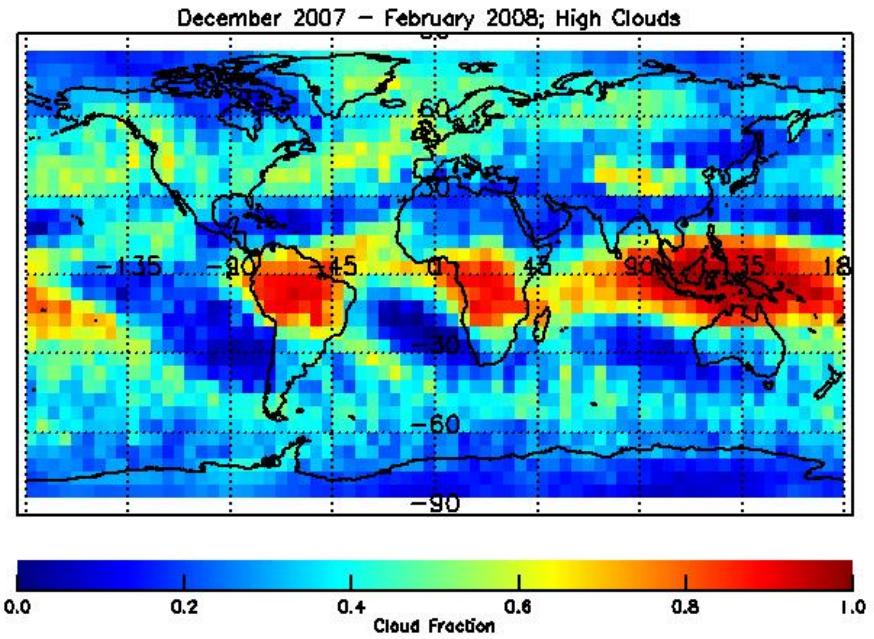


Temporal Averaging

one month

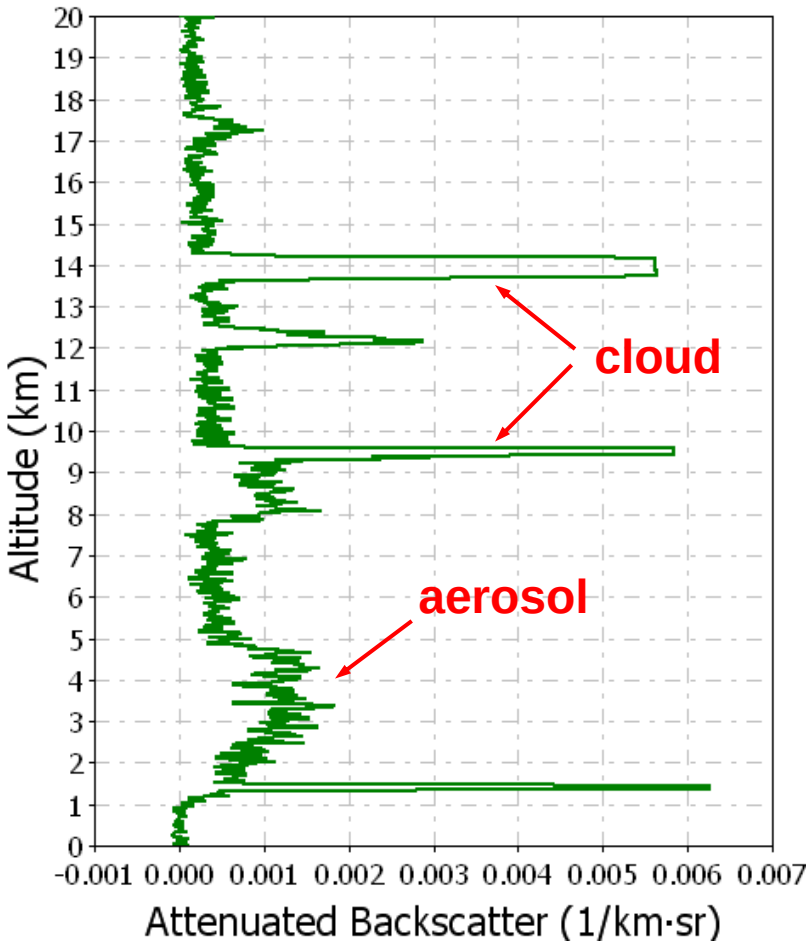


one season



Mean Fraction = 0.36791

Cloud Detection Principles

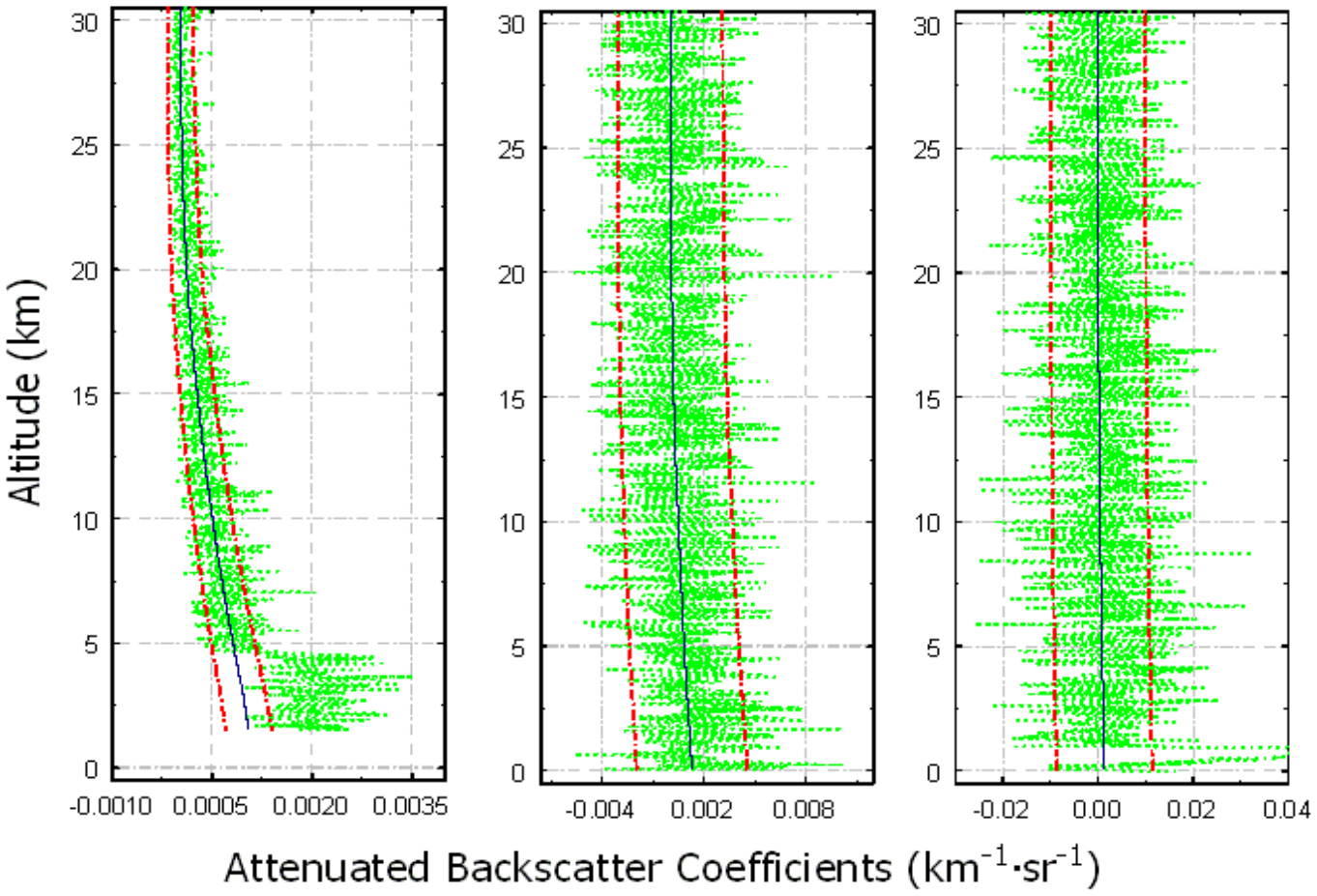


Layer detection algorithm compares signal levels to molecular background and applies a variable threshold test

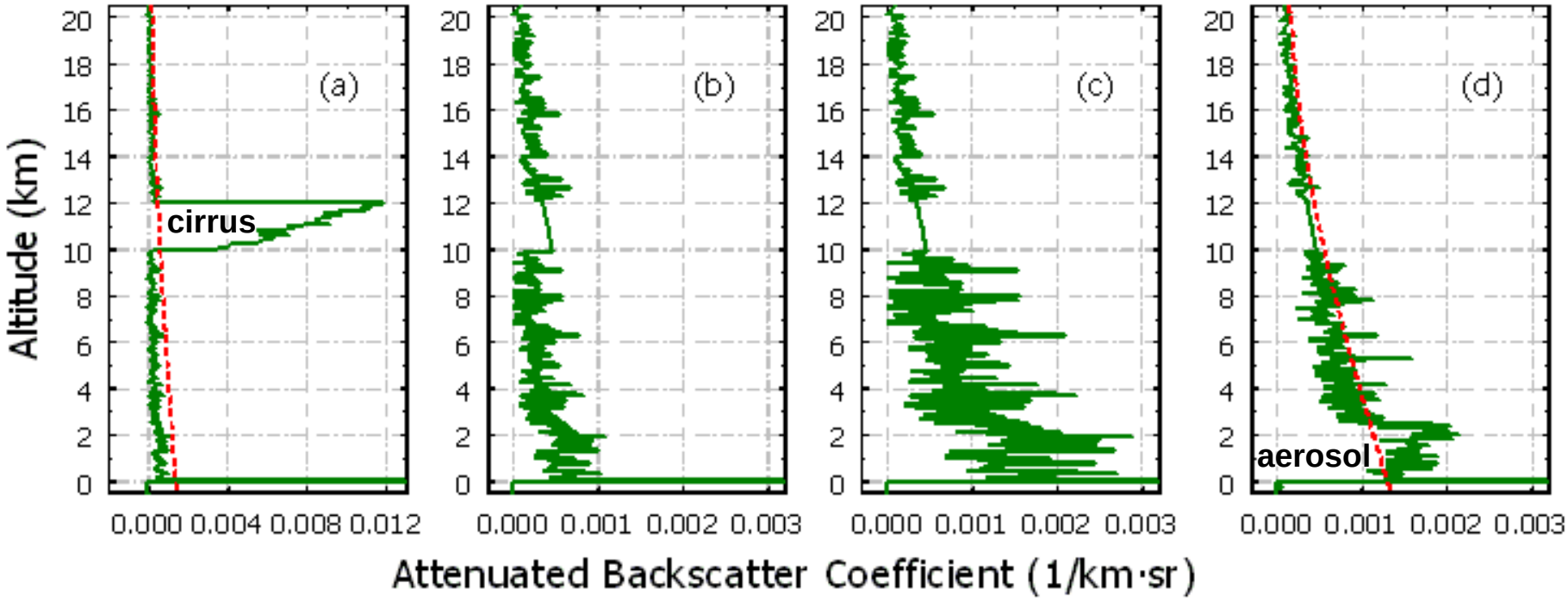
Must correct lower part of profile for attenuation of upper layers

Calibration errors usually have no impact on detection of cloud layers

Threshold adapts to noise level (solar background)



Correction of attenuation from upper layers



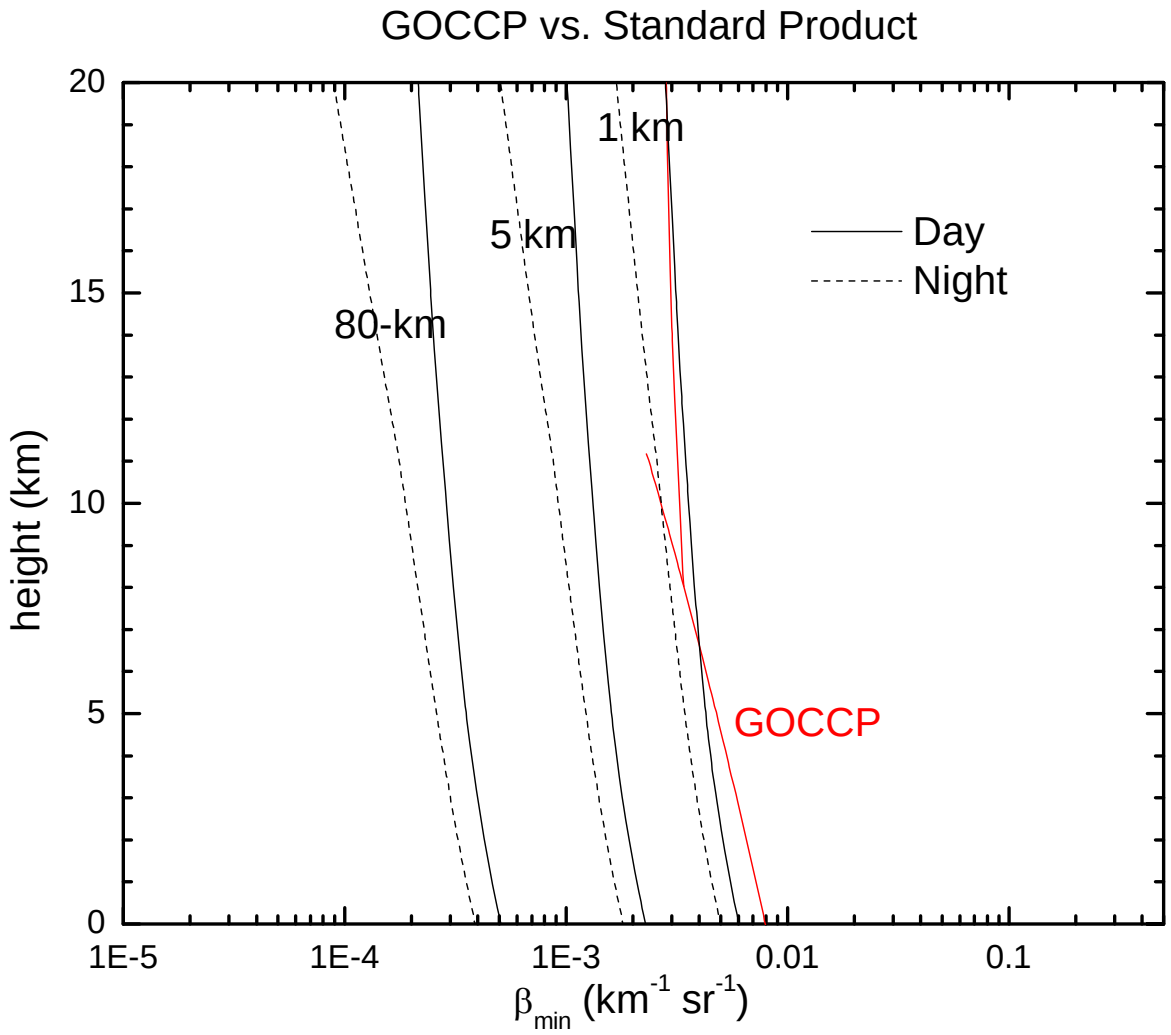
a) cirrus above aerosol
b) cirrus detected and removed
c) profile below corrected for attenuation
d) aerosol layer detected after further averaging

- detection thresholding applied to full-resolution Level 1 profiles and to cloud-cleared profiles averaged to 5, 20, 80 km

Algorithm Weaknesses

- **Sensitivity to calibration – small**
- **Sensitive to averaging/threshold used**
  - **GOCCP represents an extreme example**
- **Misclassification**
  - **Dense dust, smoke – not a big issue**
    - **would see artifacts in desert and boreal fire regions**
  - **In any case, better in Version 3**
- **Signal is attenuated in dense cloud**
  - **Limits observations in lower atmosphere**

GOCCP represents a test of sensitivity to β-threshold



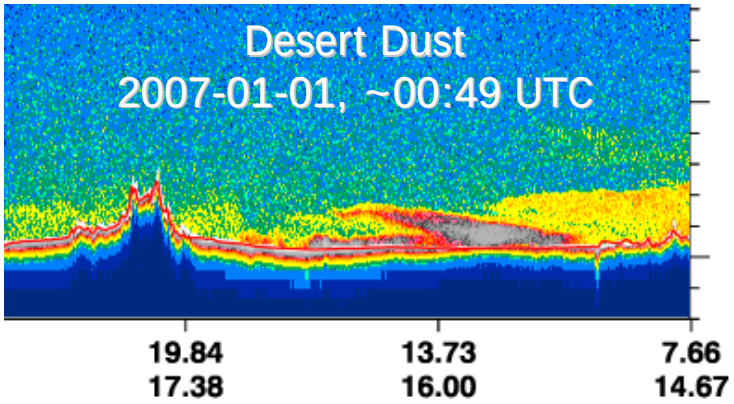
BminP106_532_vsGOCCP.opj

New CAD algorithm in Version 3

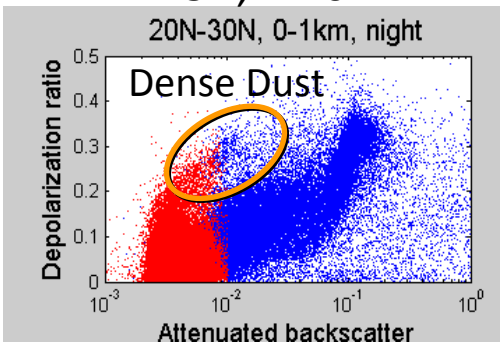
Some mis-classification of dense dust in Version 2

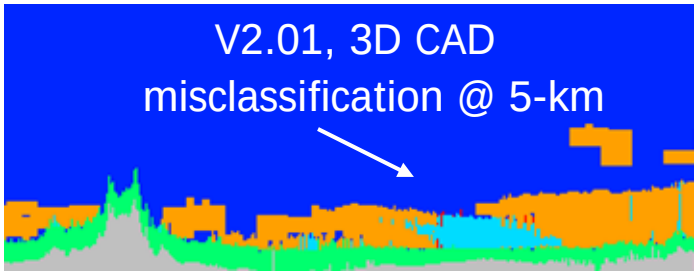
Version 3 adds depolarization to CAD

- **dust classification improved**
- **not a big change in cloud fraction**



3D, V2.01

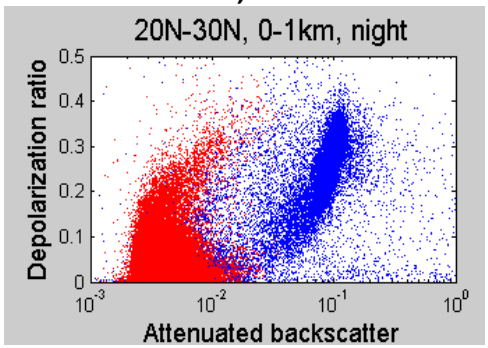


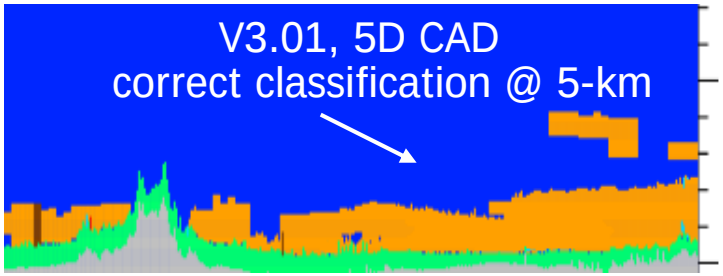


depol →

backscatter →

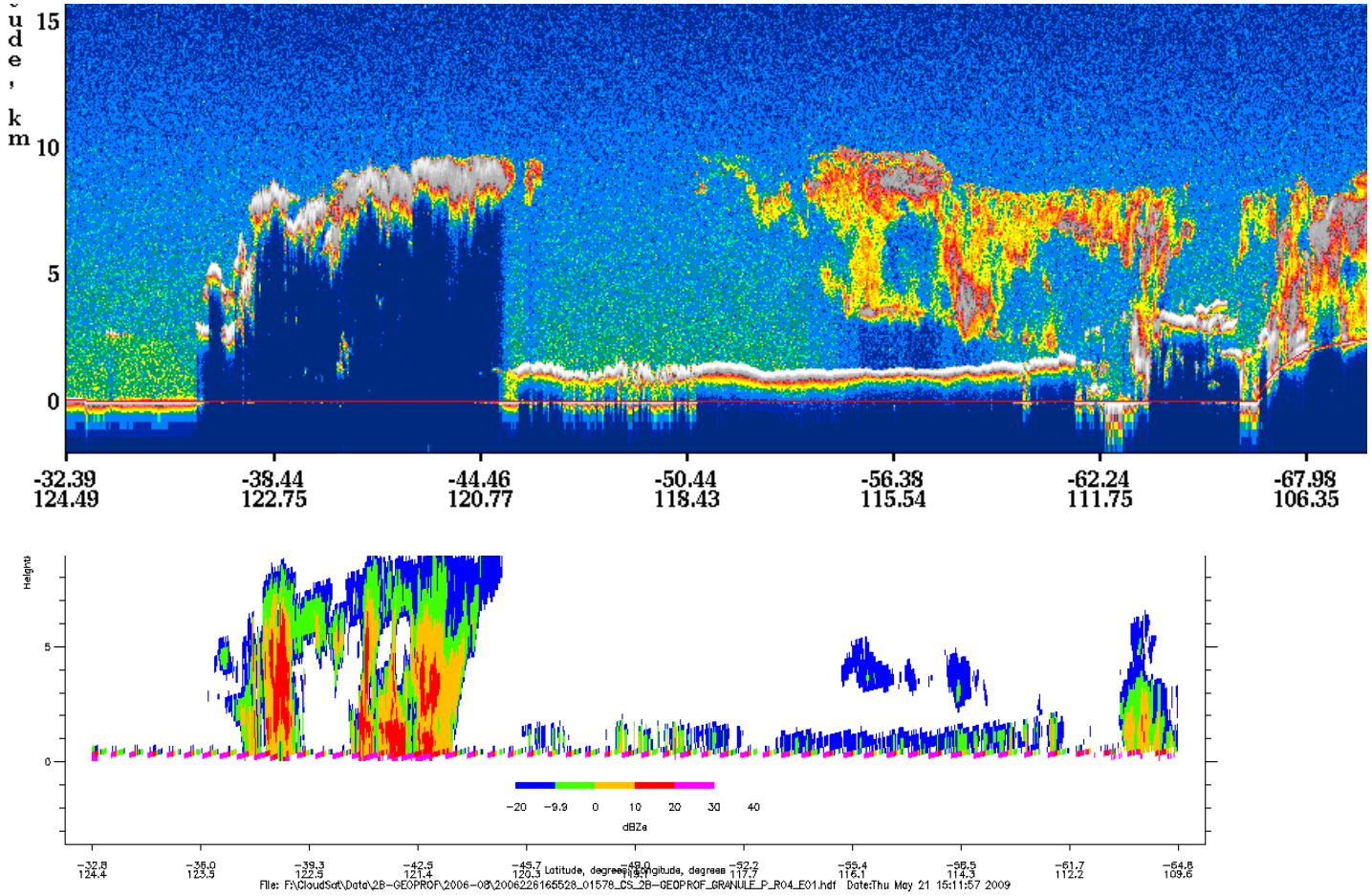
5D, v2.94





What are we missing w/o CloudSat?

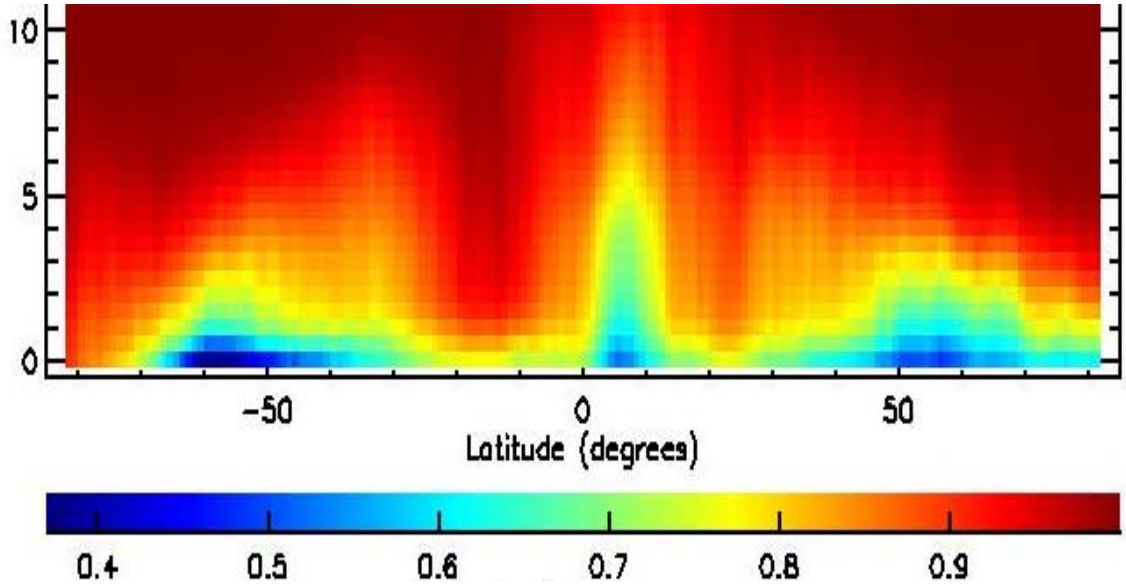
- The CloudSat radar profiles deep convective cloud and optically thick clouds
- CloudSat observes precip (drizzle, ice) under stratiform cloud (usually optically thick)



CALIOP and CloudSat measurements over Indian Ocean and Antarctica

Detection of lower cloud layers

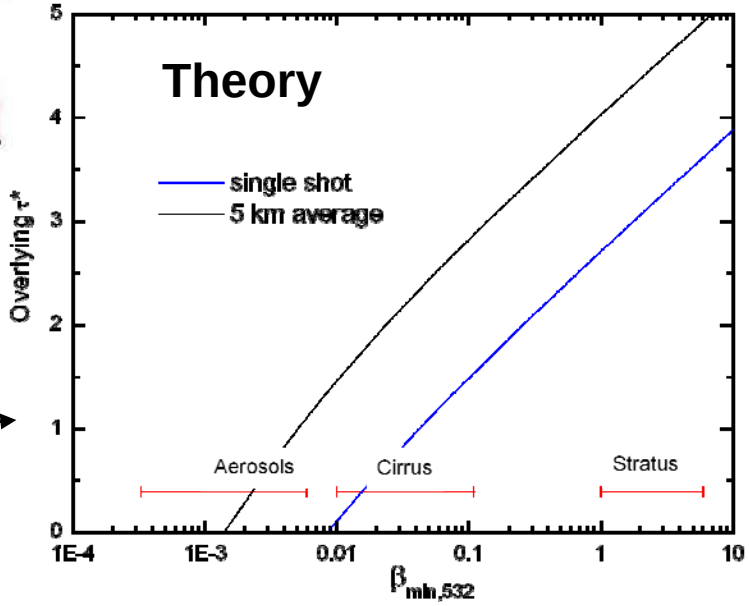
Zonal average penetration frequency (5-km average profiles)



Observed

Stratus detectable with single shots underneath clouds of optical depth < 3,

for optical depth < 5 with averaging



CALIOP-ST Statistics for Cloud Assessment

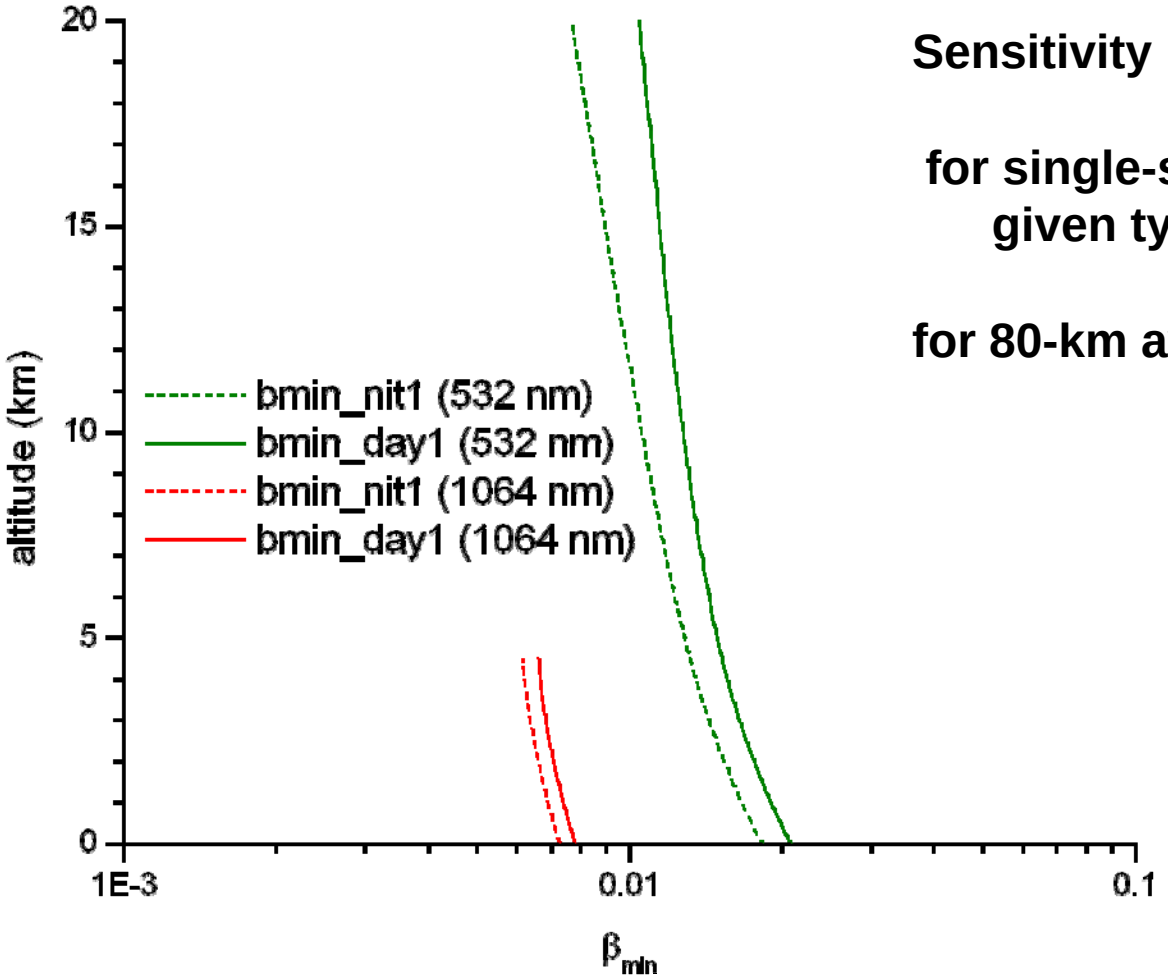
- **Based on 2007-2008 Version 2 cloud layer products**
  - **Version 3 production was completed last month**
- **We used Level 2 data:**
- **from 5-km layer product**
  - **Base and top heights for clouds detected at 5-km, 20-km and 80-km horizontal averaging**
  - **Cloud-Aerosol Discrimination (CAD) score**
  - **Ice/water phase**
  - **Opacity flag**
  - **Layer optical depth**
- **from 1/3-km layer product**
  - **Base and top heights for layers detected on single shots**
  - **Ice/water phase**

CALIPSO Level 2 Cloud Analysis

- **Merge ice clouds in 5-km cloud product into 1/3-km cloud product**
  - **1/3-km product has 'dense' water and ice clouds**
  - **5-km product has tenuous ice clouds**
  - **1/3-km clouds are cleared from 5-km profiles during Level 2 processing**
- **Screen out low confidence layers (CAD < 70)**
  - **Layers with CAD = 0 - 20 tend to be "spurious"**
- **Keep layers with CAD scores 101 and 102**
  - **101 = thin polar cirrus originally classified as aerosol, reclassified based on depolarization**
  - **102 = cloud dominated by horizontally oriented ice crystals**
- **Reclassify "aerosol" over Antarctic plateau as cloud**
  - **Increases cloud fraction by ~ 5%**
- **PSCs are not included in current statistics**
  - **Reject even PSCs mistakenly classified as tropospheric cloud (due to ambiguous GMAO tropopause)**

Why we screen out “5-km” water clouds: 1) Detection sensitivity

theoretical single-shot detection limit

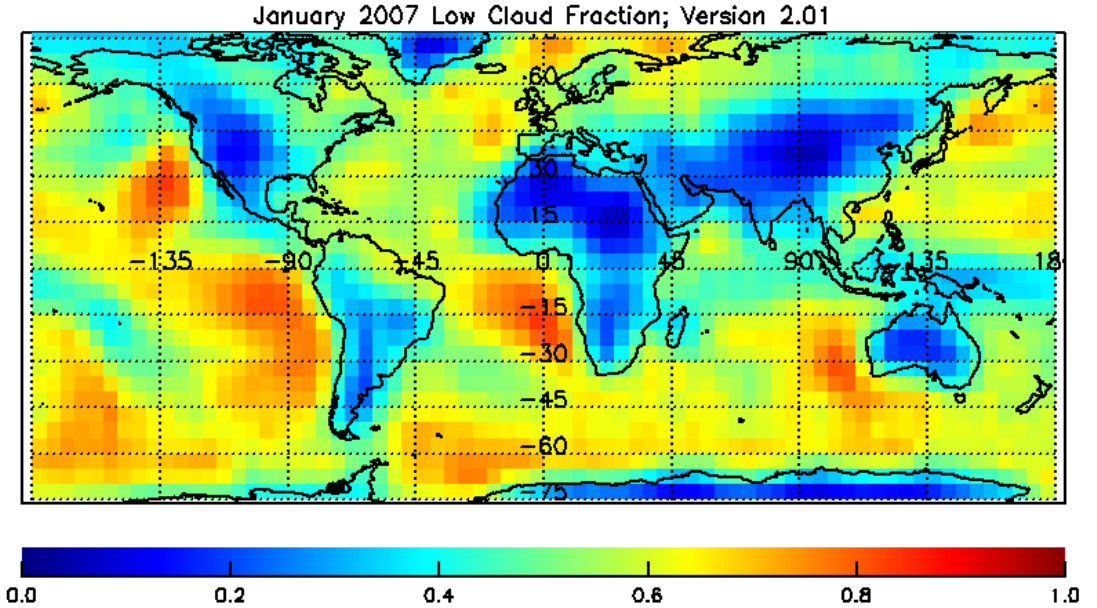


Sensitivity in practice:

for single-shots: τ_{min} ~ 0.05/ 0.1 (D/N)
given typical thickness of BL cloud

for 80-km averages: ~ 0.01

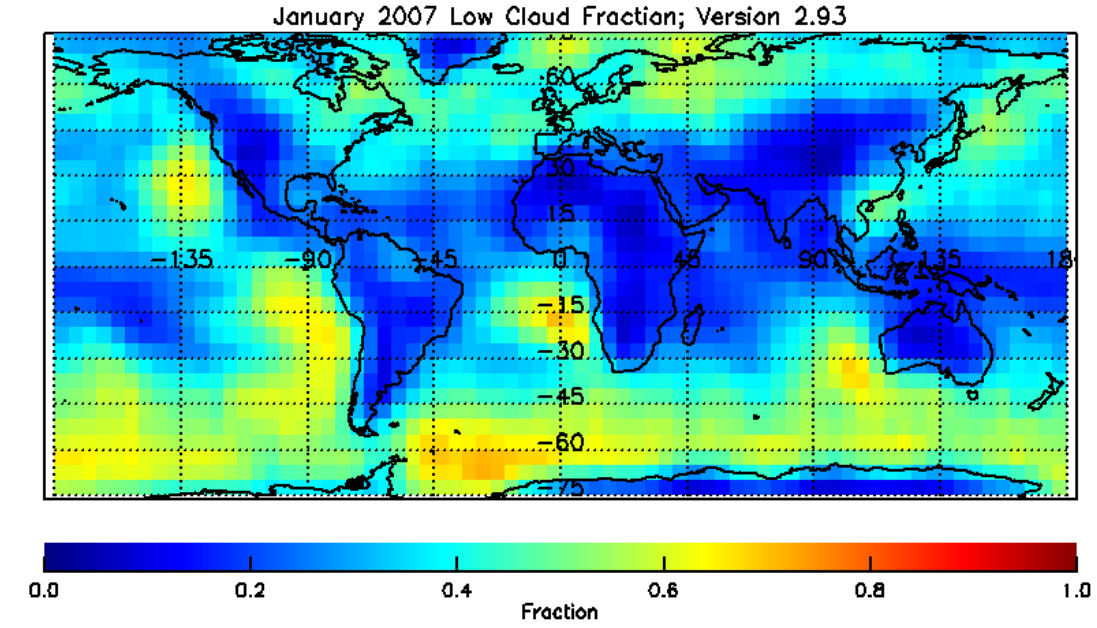
2) Version 2 bug in BL cloud-clearing



Version 2.01

Global mean = 0.261

(single-layer low clouds)



Version 3-alpha test

Global mean = 0.218

(single-layer low clouds)

CALIOP-NASA vs. CALIOP-CA

Table 2 of CA report: 2006-07

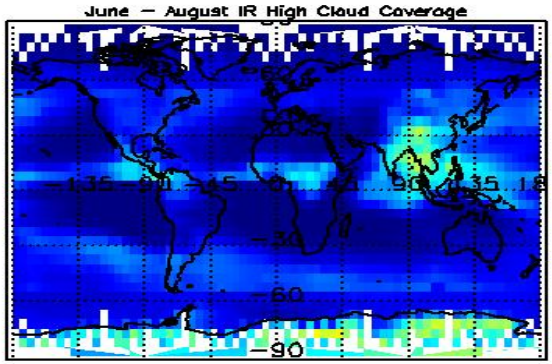
NASA: 2008

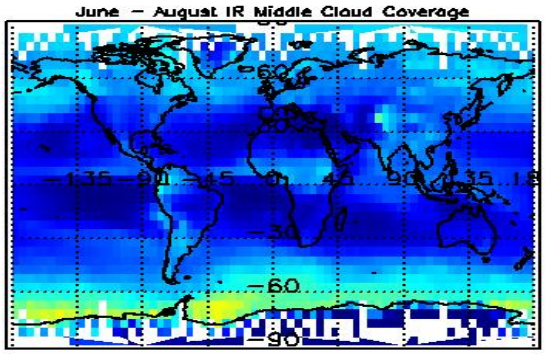
CA (%)	Global	Global ocean	Global land
Total	76 72.9	84 77.7	63 64.0
HCA/CA	50 50.4	46 47.3	61 57.5
MCA/CA	14 14.5	12 11.5	20 21.2
LCA/CA	35 35.1	42 41.3	19 21.3

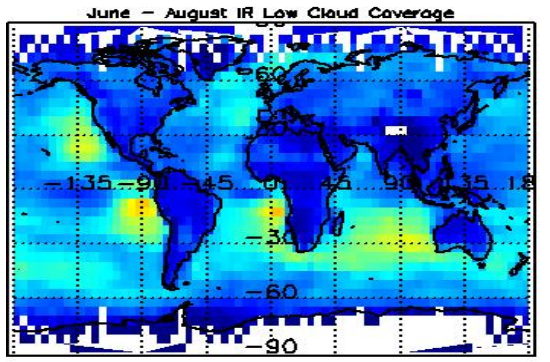
CA (%)	30N-60N	15N-15S	30S-60S
Total	74 72.1	84 78.3	87 81.8
HCA/CA	51 54.1	71 72.3	39 42.4
MCA/CA	17 14.1	4 4.8	16 11.3
LCA/CA	32 31.7	24 22.9	46 46.3

Comparison of cloud amount during JJA 2007.

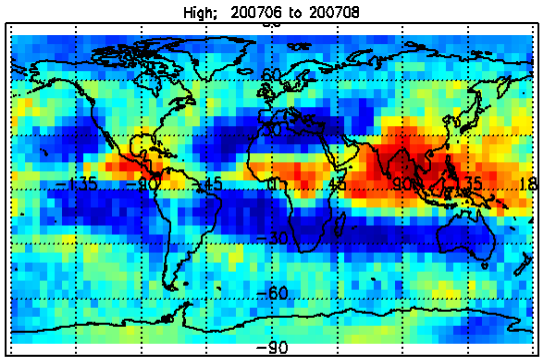
ISCCP-IR

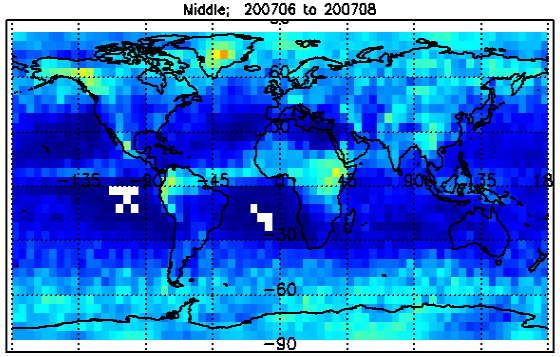


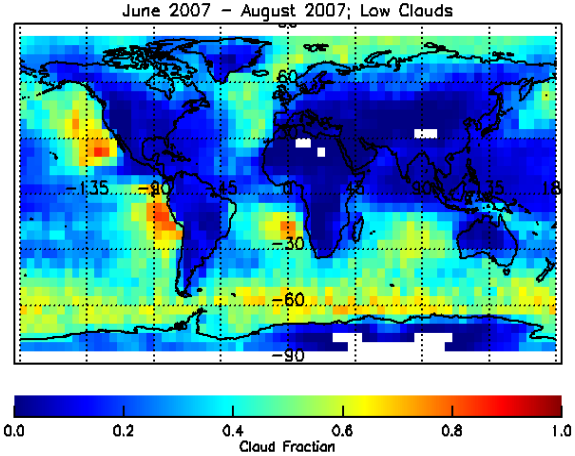




CALIOP (all)







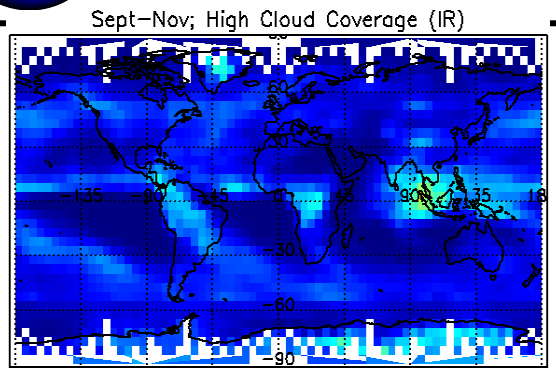
High Cloud

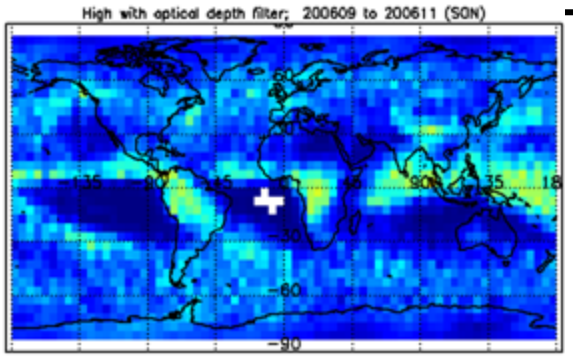
Middle Cloud

Low Cloud

CALIPSO filtered for consistency with ISCCP

ISCCP-IR CALIOP

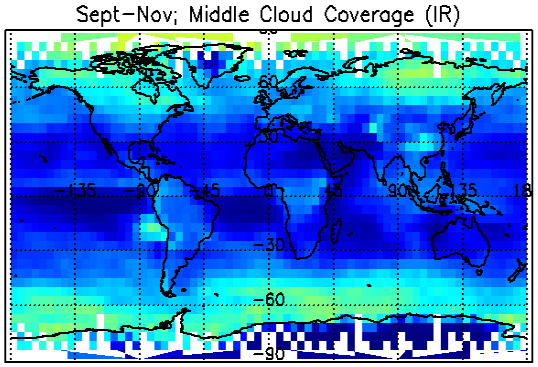


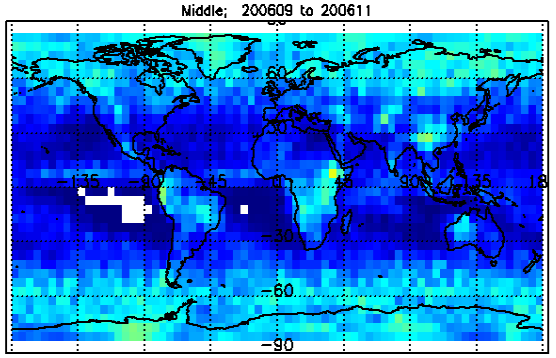


CALIPSO screening:

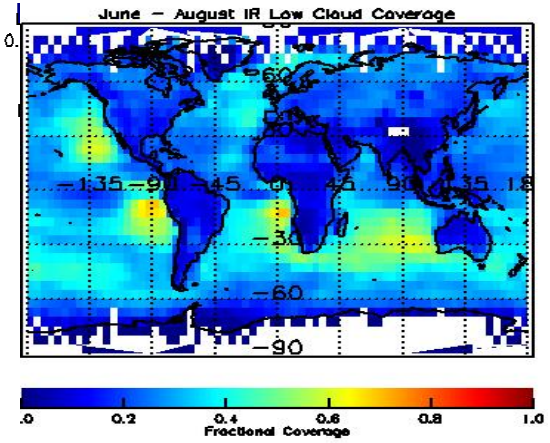
- **high cloud OD<0.3 removed**
- **low cloud: single-layer only**

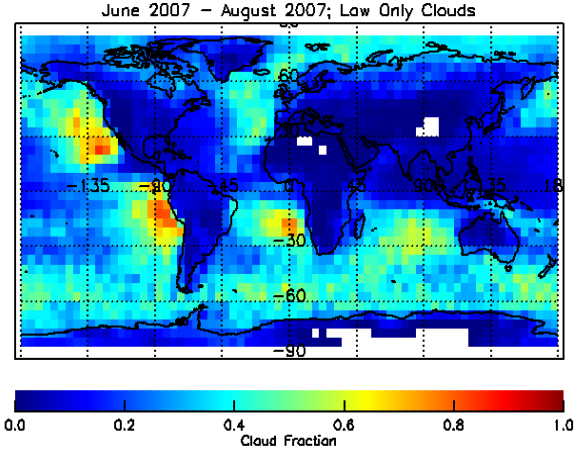
High Cloud





Middle Cloud



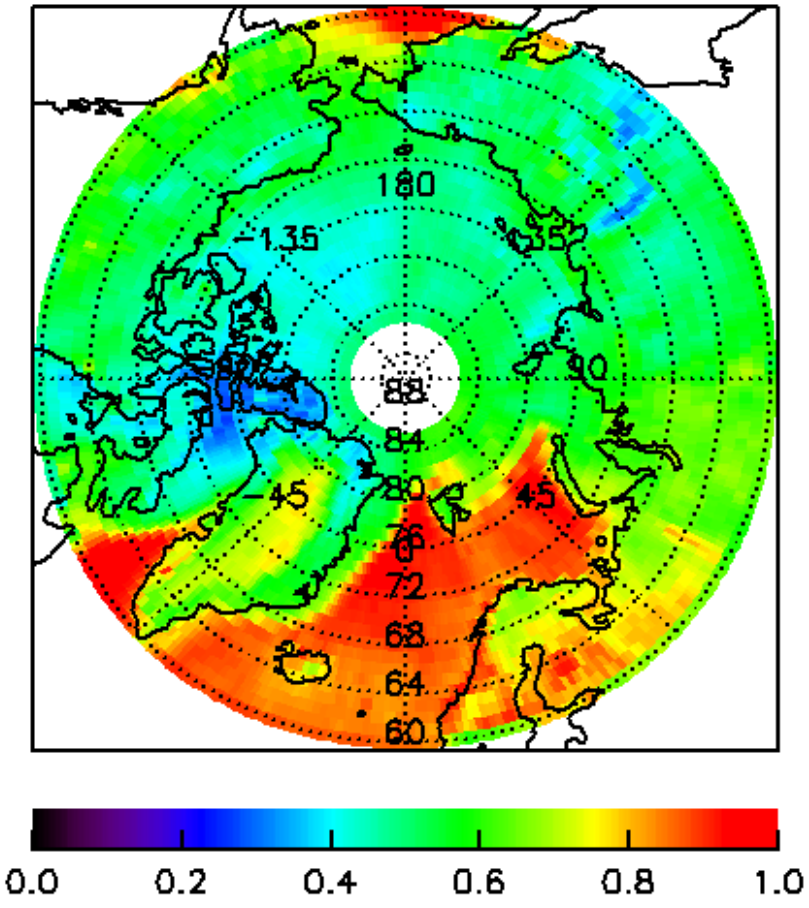


Low Cloud

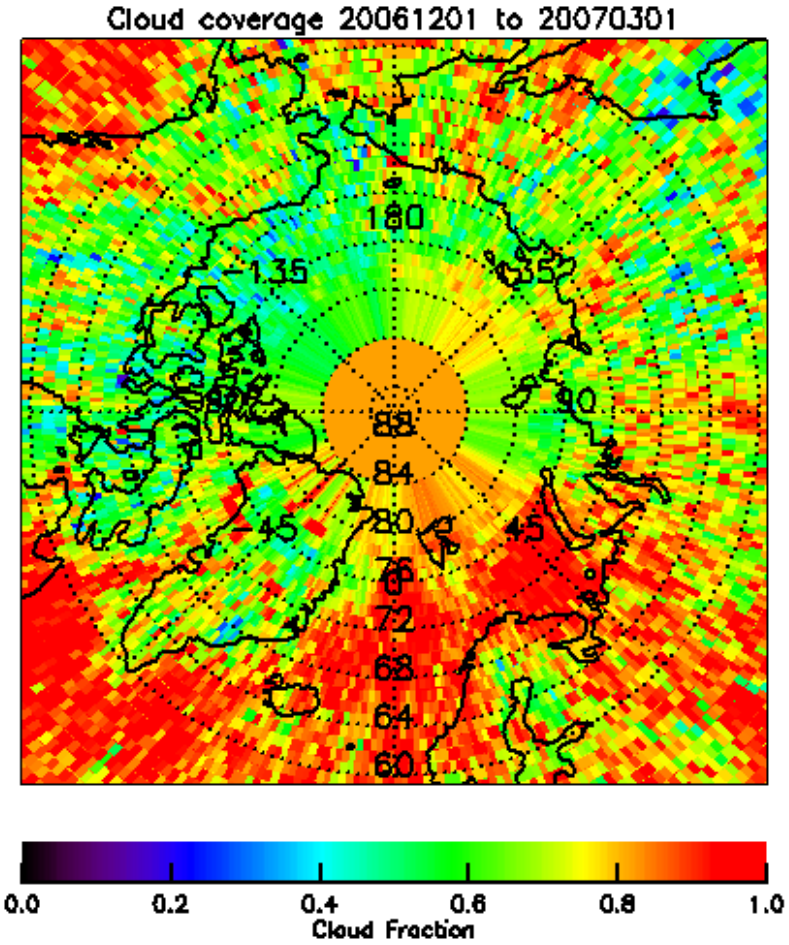
(season not consistent)

Arctic: cloud fraction, winter 2006/7.

MODIS-Terra



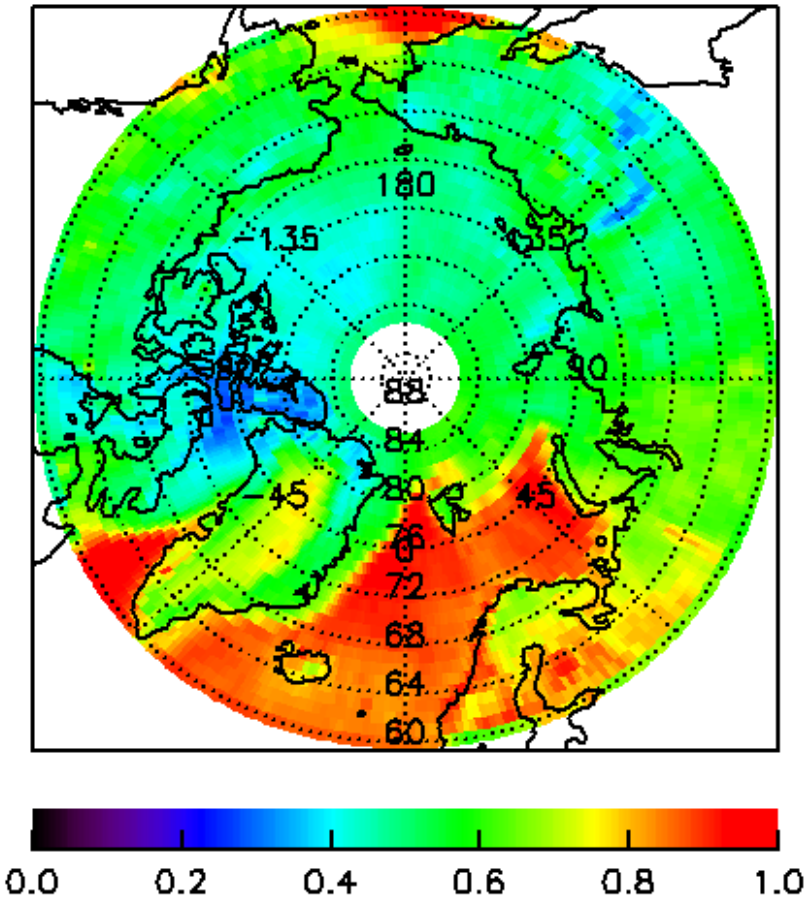
CALIOP (best merge)



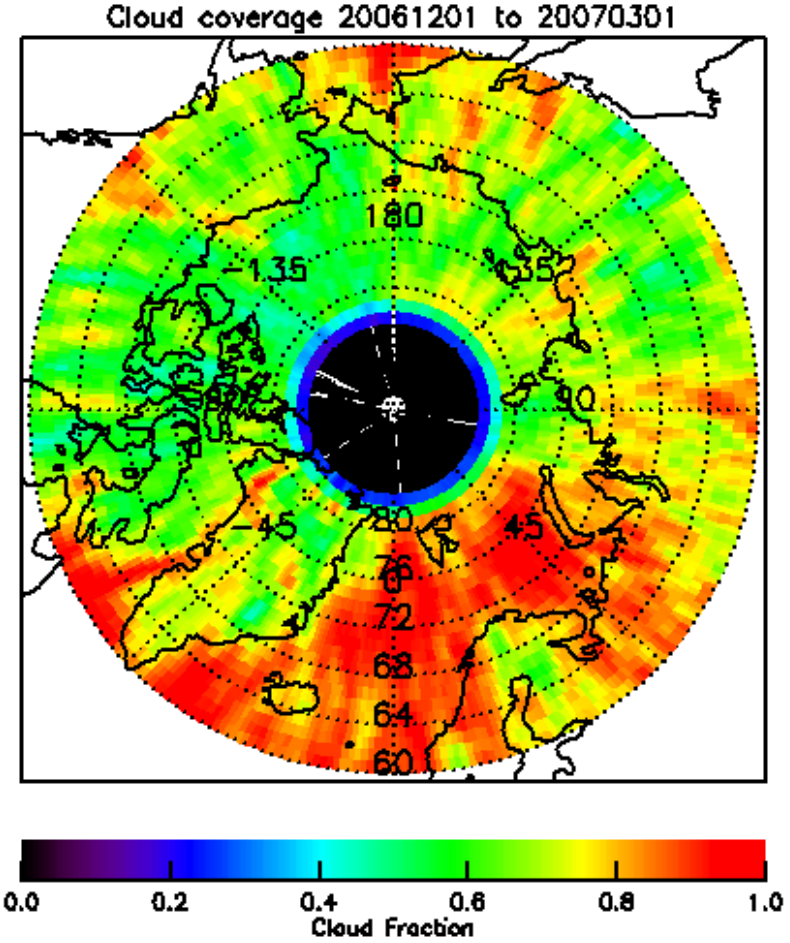
Both on a 1x1 degree grid

Arctic: cloud fraction, winter 2006/7.

MODIS-Terra

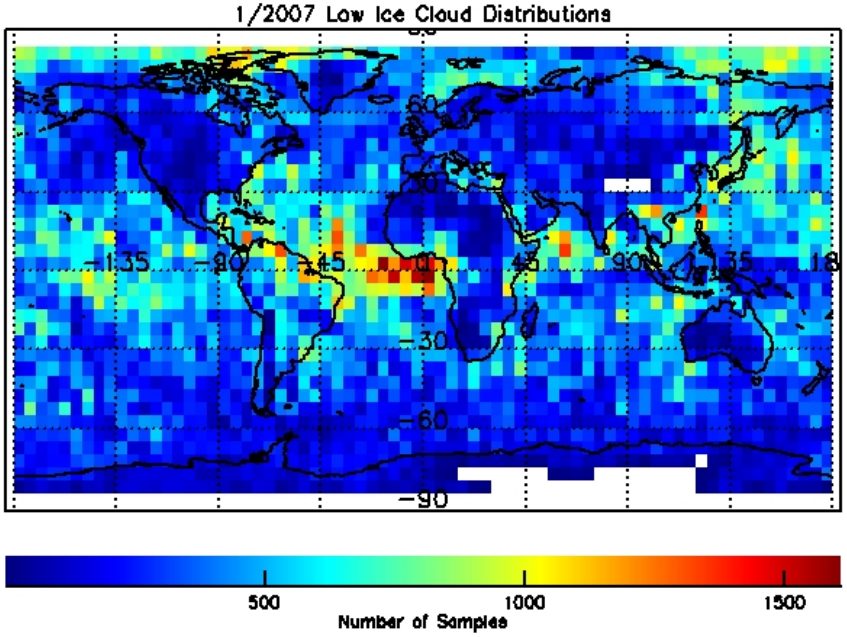


CALIOP – smoothed



Finally

also have included statistics on ice, water cloud



Number of ‘ice’ clouds with tops below 3.25 km (based on V 2.01)

Next Steps

- Have processed 2007-2008 of Version 2 data for Cloud Assessment
- Next: repeat this processing for all 4 years of Version 3
- Develop and distribute a Level 3 cloud product
- Characterize uncertainties due to sparse spatial sampling