CFLOS opportunities update with CALIPSO and impact on simulating GWOS and ADM in OSSEs

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NASA/LaRC

Lidar Working Group Meeting
Snowmass
July 17 – 20 2007

Evaluation of T511(1°) clouds

Simpson Weather Associates

7 June 2007

NCEP OSSE meeting

Objectives

- Evaluate the ECMWF Nature Run (T511 - 1 degree test) cloud type and amounts
- If necessary, provide modification algorithms
- Recommend techniques for deriving cloud optical properties, CMV targets and radiative transfer model inputs

Background

- Similar evaluations were done for T106 and T213 Nature Runs
  - Thin cirrus had to be added in both cases
  - Marine stratocumulus had to be augmented in the T213.
- Meeting regarding clouds in the new T511 and T799 Nature Runs was held at NASA/GSFC (Fall 06)
- NASA funded study of GLAS CFLOS statistics completed September 2006. Useful for calibrating simulated DWL coverage based upon Nature Runs.
- IPO funded simulations of GLAS and DWL observations using the T213.

Process

- Use month of August 2005 from T511 NR
- 1 X 1 degree test data set
- Use reported NR values of total, high, middle and low cloud cover.
  - Derive zonal average values for 10 degree latitudinal bands
  - Derive global cloud coverage
  - Concerned with effects of cloud overlap functions

Process (2)

- Compare NR statistics with those based upon the following:
  - ISCCP monthly cloud climatologies (August)
  - MODIS based cloud climatology
  - UW/HIRS based climatology (August)
  - GLAS and CALIOP cloud statistics (October)
  - WWMCA (Nephanalyses) (August, 2005)
- Develop cloud statistics from NR using individual layer data
  - Invoke contiguous/random overlap function

Process (3)

- Investigate enhanced thin cirrus algorithm for T511 NR
- Using the NASA/NOAA/DoD Doppler Lidar Simulation Model (DLSM), simulate GLAS and CALIOP observations within T511 Nature Run using derived optical properties.

Summary

- The T511 cloud distributions (vertical and horizontal), in general, compare best with the HIRS cloud climatology.
- The NR understates the presence of thin cirrus as detected by GLAS and CALILOP.
- Lidar data shows high cloud is often higher than passive sensor based assignments.
- An algorithm to adjust the NR ice cloud coverage yields better comparisons with the GLAS and CALIOP findings.

Recommendations

- Look at marine stratocumulus
- Decide on cloud overlap function to be used with NR
- Decide on including cirrus augmentation
- Decide on how instrument simulation will employ overlap and cloud augmentation algorithms.

Global cloud statistics

	ECMWF NR[1]	HIRS[2]	ISCCP	WWMCA
Hor. Res.	1° by 1°	1° by 1°	2.5° by 2.5°	1° by 1°
Low CC	800mb - sfc	800mb – sfc*	650mb - sfc	650mb – sfc**
Mid CC	450 – 800mb	440 – 800mb*	440 – 680mb	450 -650mb**
High CC	Above 45 mb	Above 440mb	Above 440mb	Above 450mb**
Input	Model	HIRS on NOAA POES	NOAA, GOES-E,W; Meteosat; GMS	DMSP,GOES, Meteosat, GMS, ???
Time Period	"August 2005"	1979-2002	1983-2005	August 2005

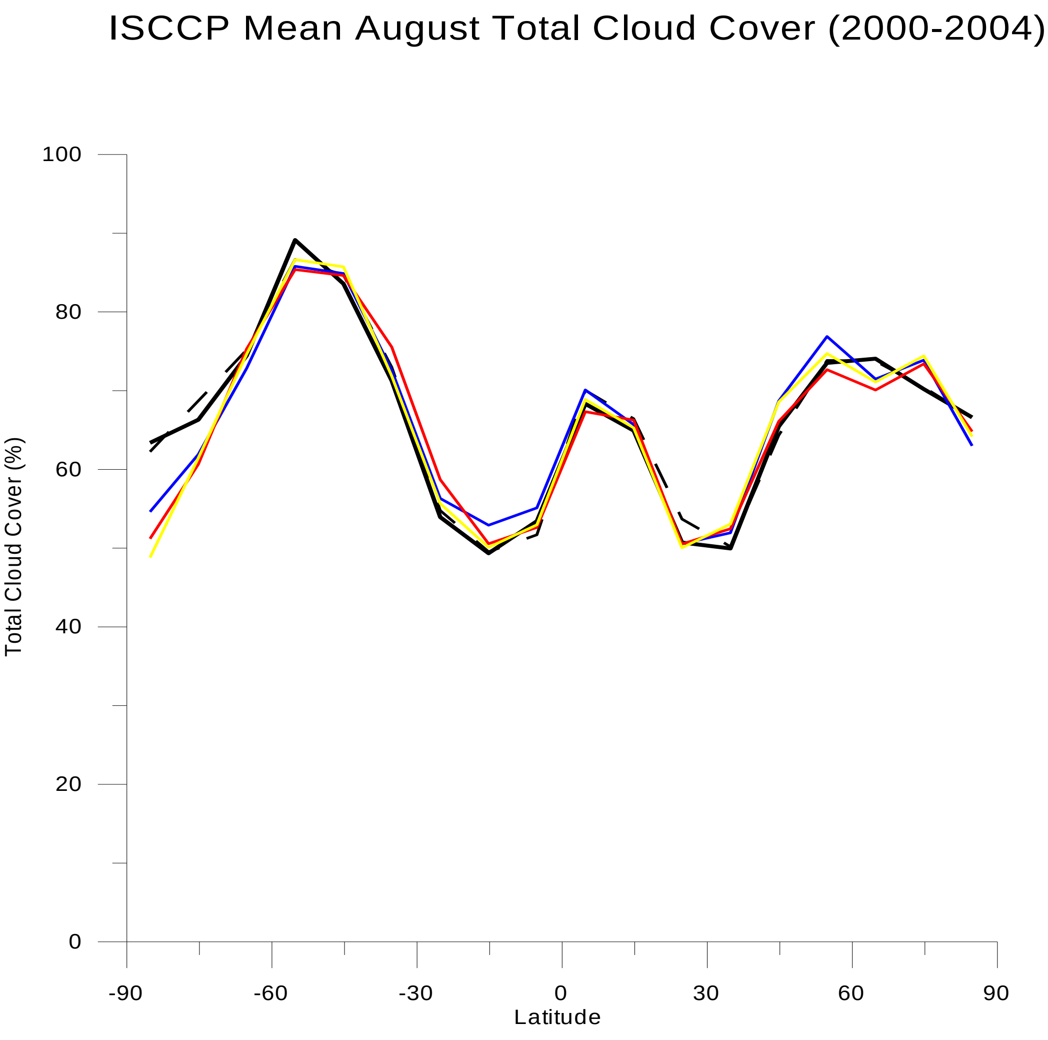
* - calculated for this study
* * - Equatorward of 45°

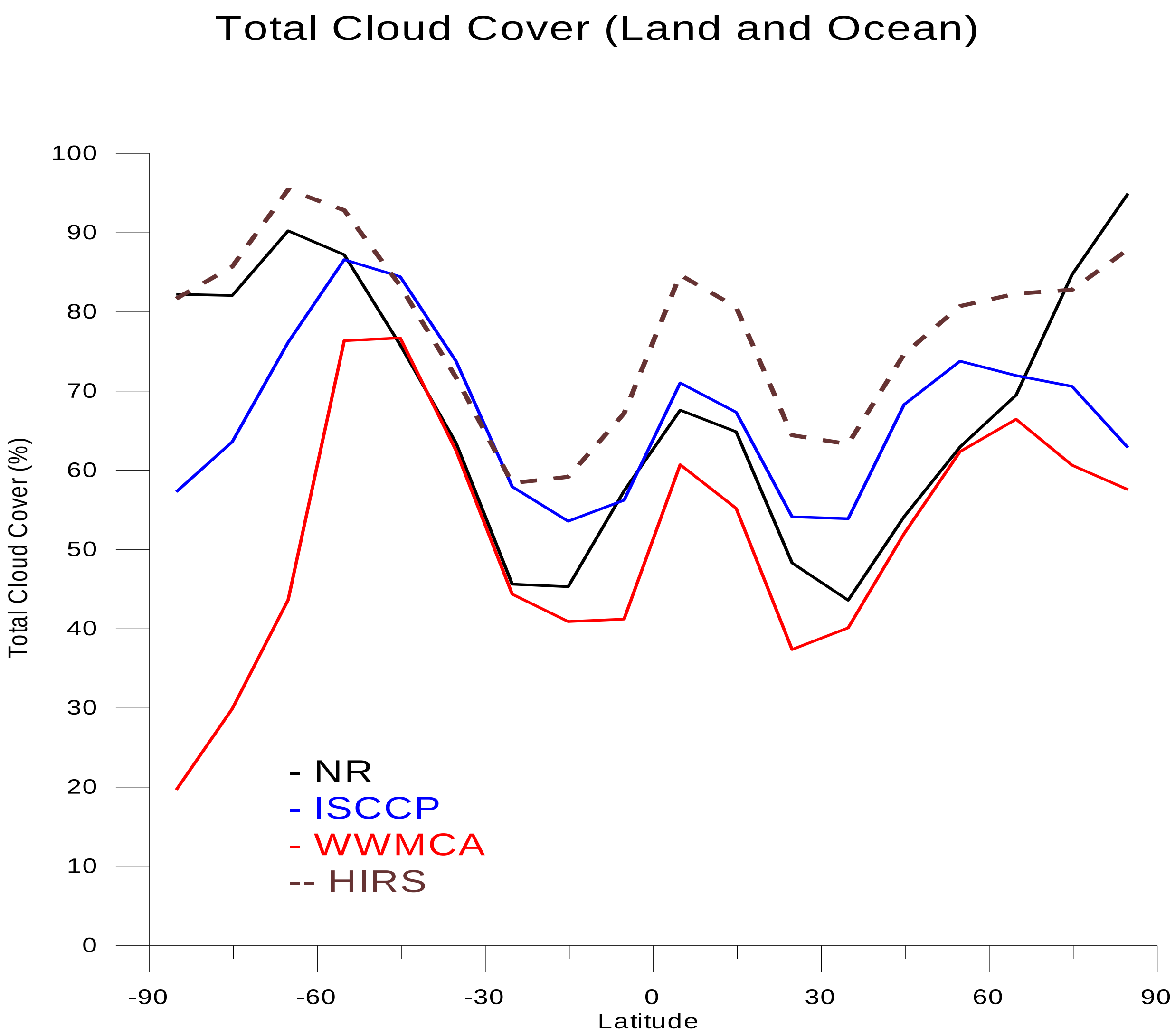
[1]ECMWF utilizes a "maximum random cloud overlap function to determine total cloud coverage. As well as within the other layers to determine low, middle and high CC.

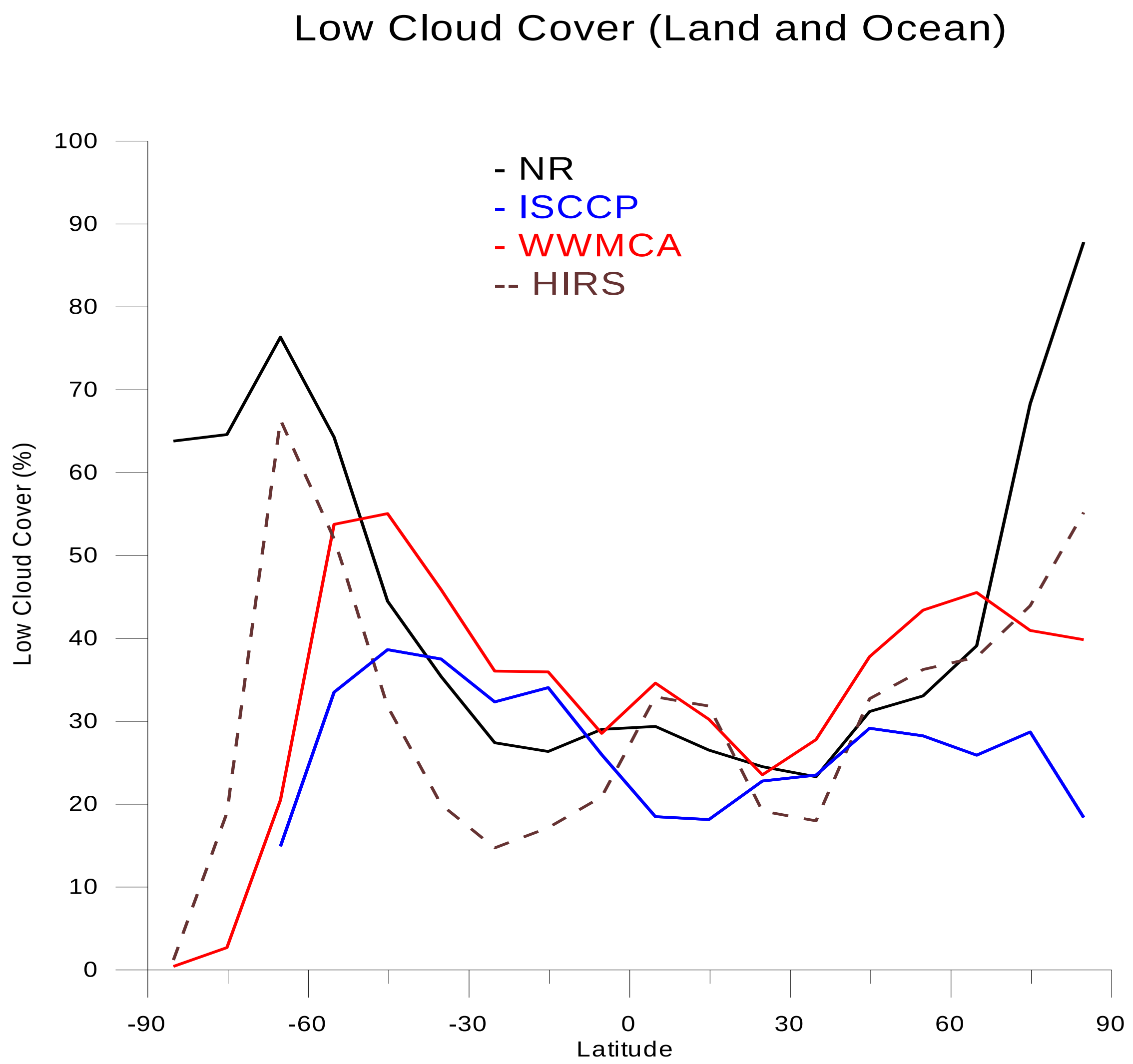
Prognostic equations for cloud fraction described in Tiedtke (1993)

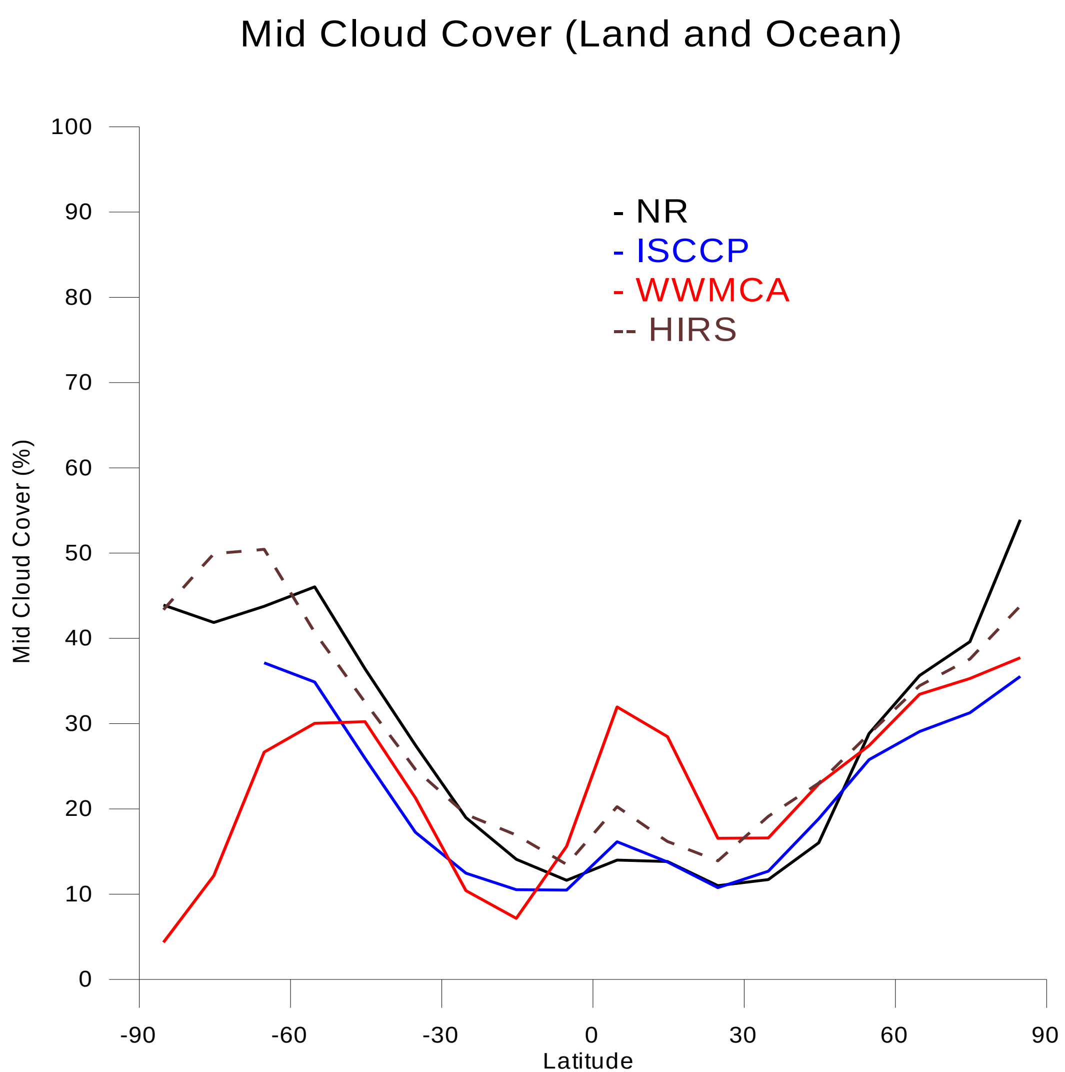
[2] HIRS data represents a "top down" cumulative frequency.

Interannual variability

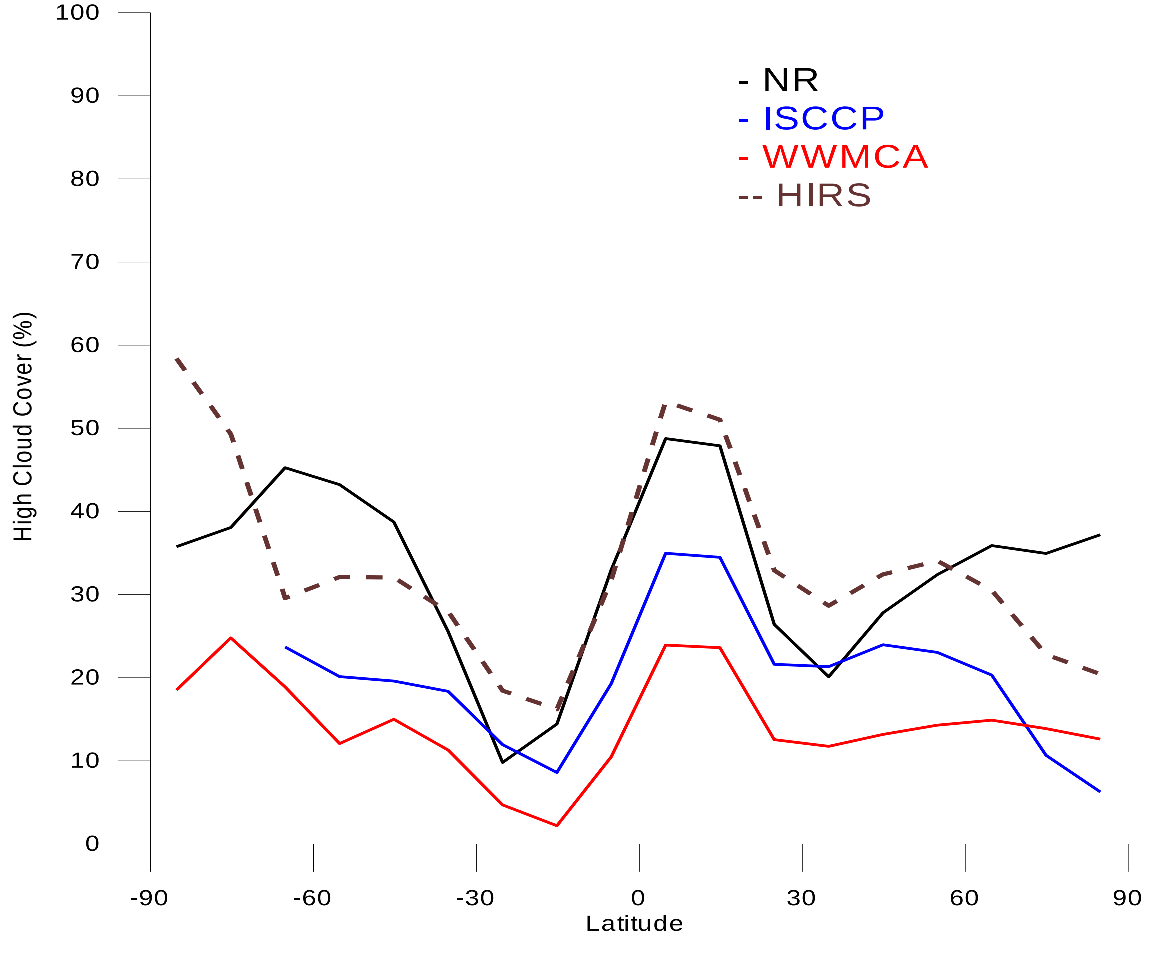


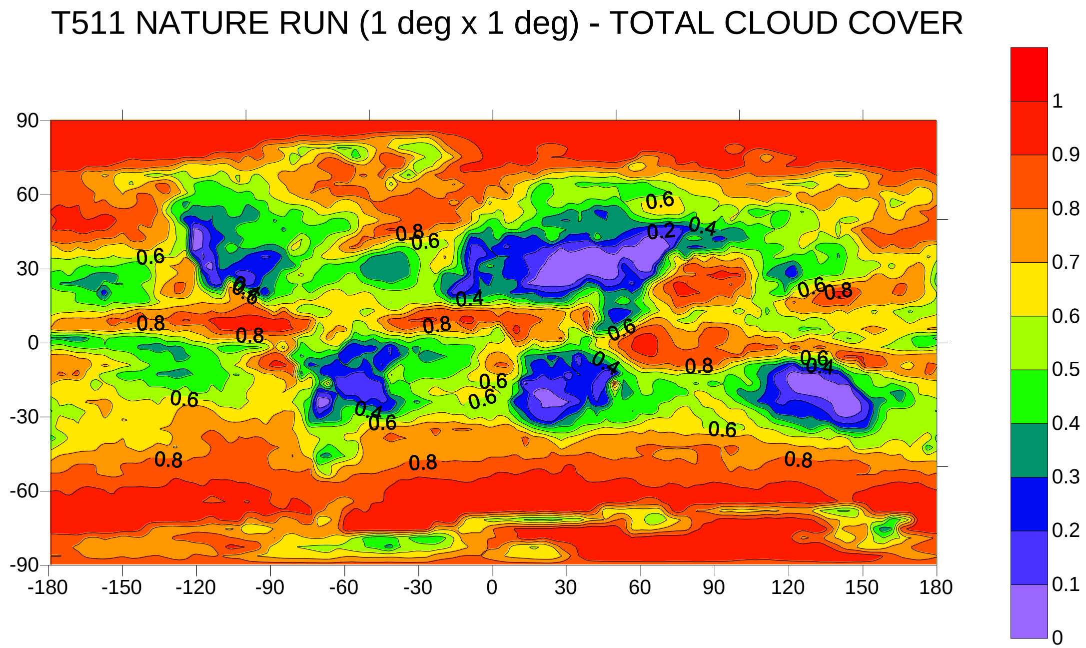

Total Cloud Cover (Land and Ocean)
Total Cloud Cover (%)
100
90
80
70
60
50
40
30
20
10
0
-90
-60
-30
0
30
60
90
Latitude
- NR
- ISCCP
- WWMCA
-- HIRS

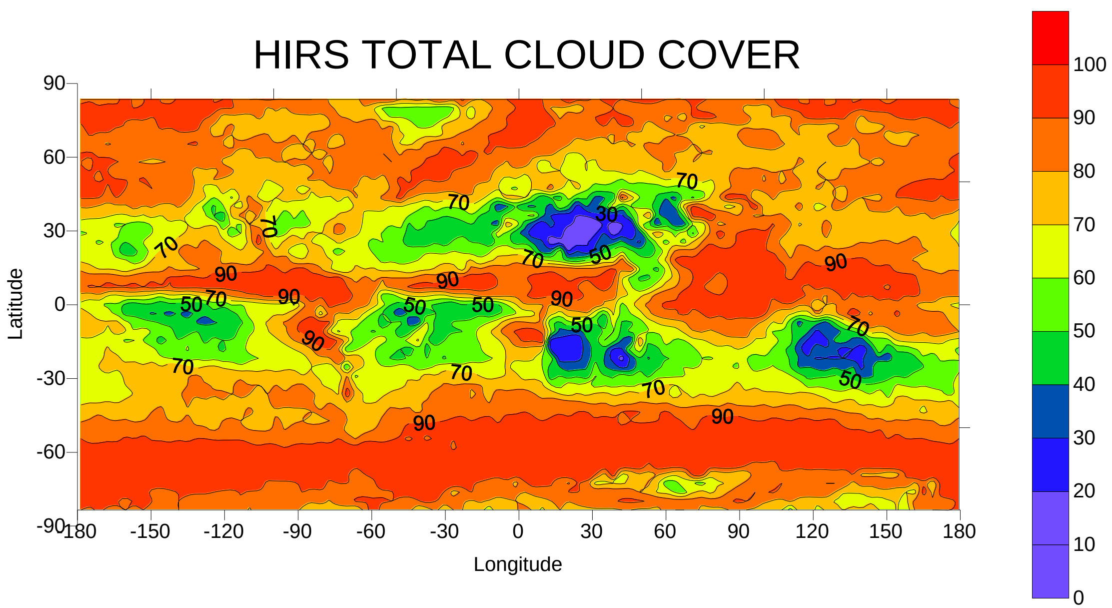

Low Cloud Cover (Land and Ocean)
- NR
- ISCCP
- WWMCA
-- HIRS
100
90
80
70
60
50
40
30
20
10
0
Low Cloud Cover (%)
-90
-60
-30
0
30
60
90
Latitude


Mid Cloud Cover (Land and Ocean)
- NR
- ISCCP
- WWMCA
-- HIRS
Mid Cloud Cover (%)
100
90
80
70
60
50
40
30
20
10
0
-90
-60
-30
0
30
60
90
Latitude

High Cloud Cover (Land and Ocean)




T511 NATURE RUN (1 deg x 1 deg) - TOTAL CLOUD COVER
90
60
30
0
-30
-60
-90
-180 -150 -120 -90 -60 -30 0 30 60 90 120 150 180
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


HIRS TOTAL CLOUD COVER
Latitude
90
60
30
0
-30
-60
-90
-180 -150 -120 -90 -60 -30 0 30 60 90 120 150 180
Longitude
100
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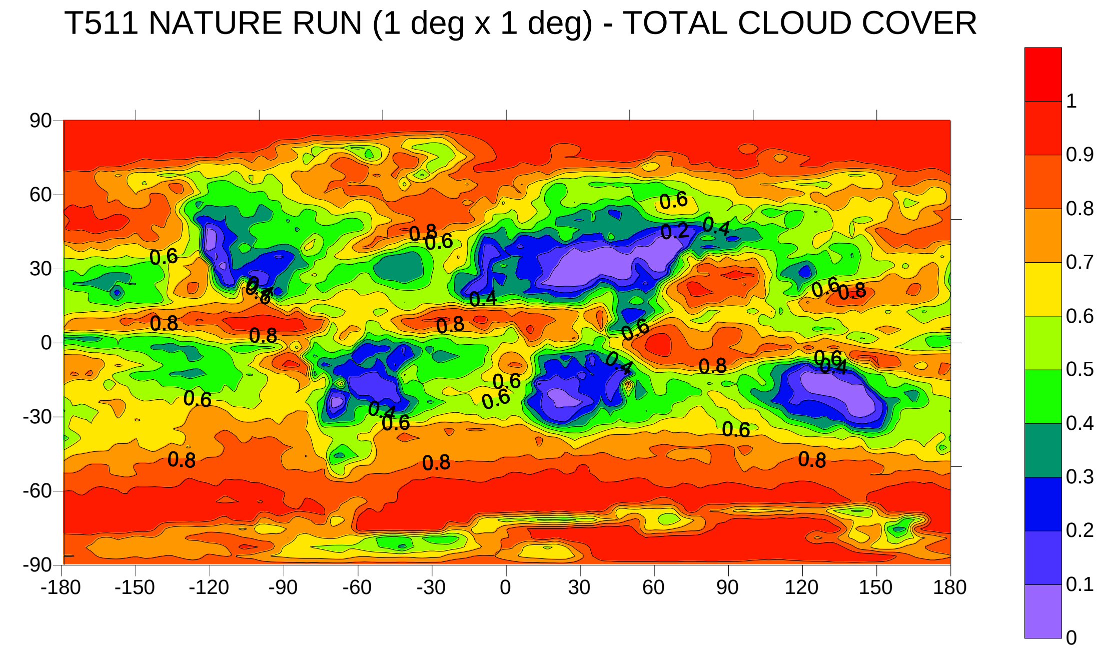
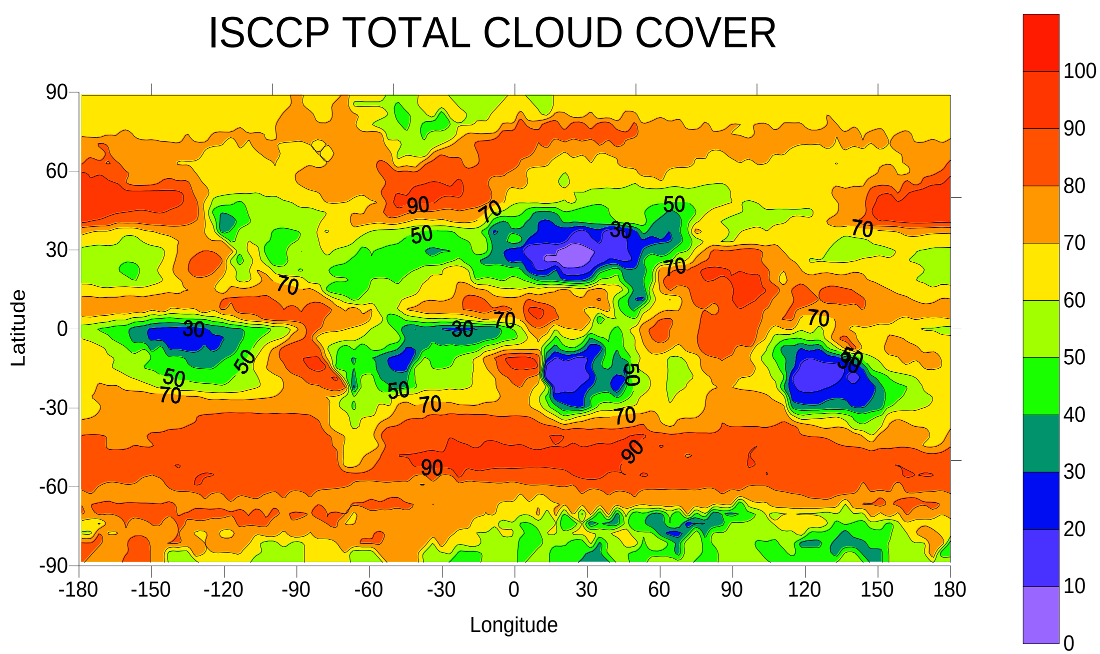
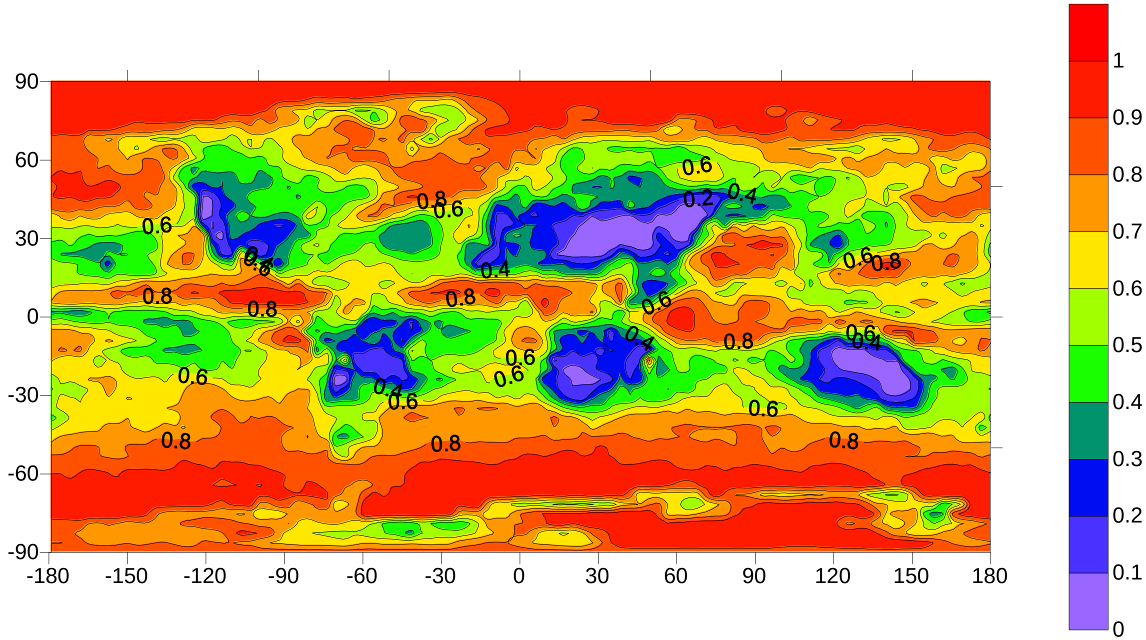
40
30
20
10
0

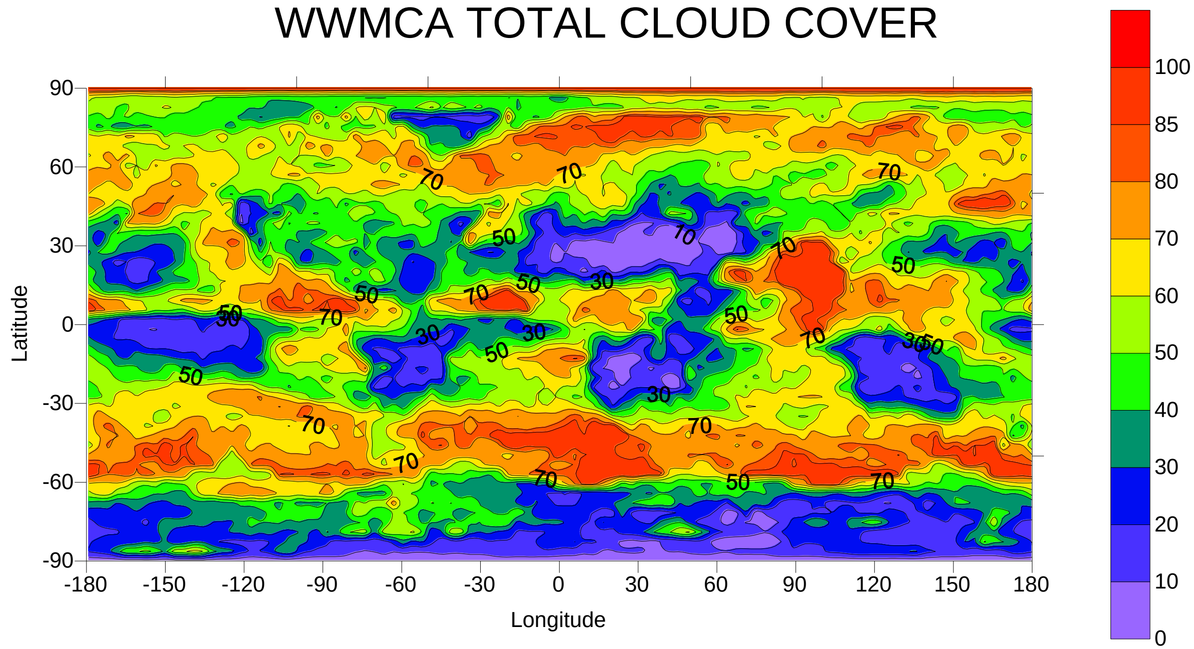

T511 NATURE RUN (1 deg x 1 deg) - TOTAL CLOUD COVER
90
60
30
0
-30
-60
-90
-180 -150 -120 -90 -60 -30 0 30 60 90 120 150 180
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


ISCCP TOTAL CLOUD COVER
Latitude
90
60
30
0
-30
-60
-90
-180 -150 -120 -90 -60 -30 0 30 60 90 120 150 180
Longitude
100
90
80
70
60
50
40
30
20
10
0

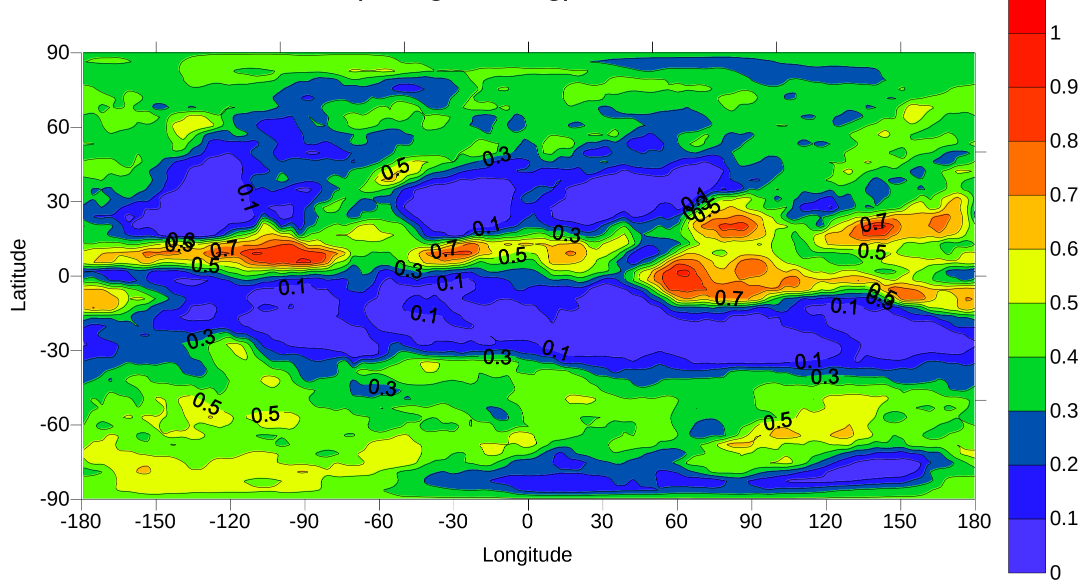
T511 NATURE RUN (1 deg x 1 deg) - TOTAL CLOUD COVER



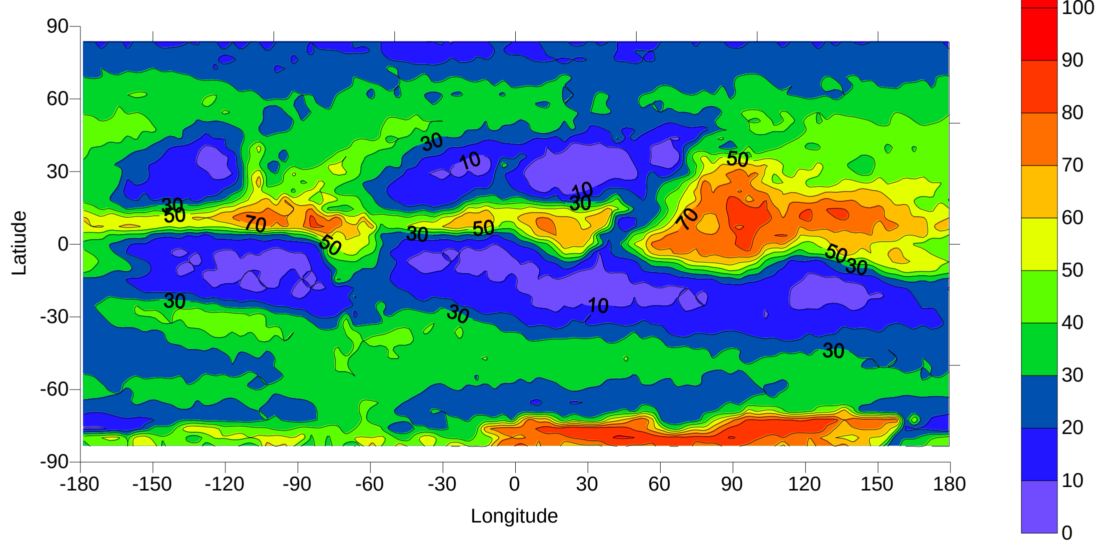
WWMCA TOTAL CLOUD COVER

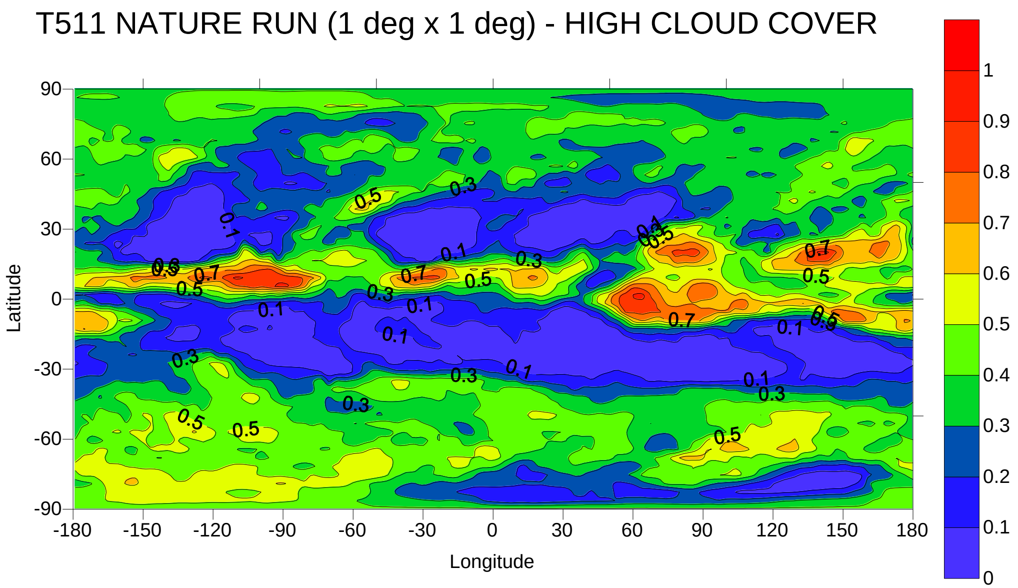


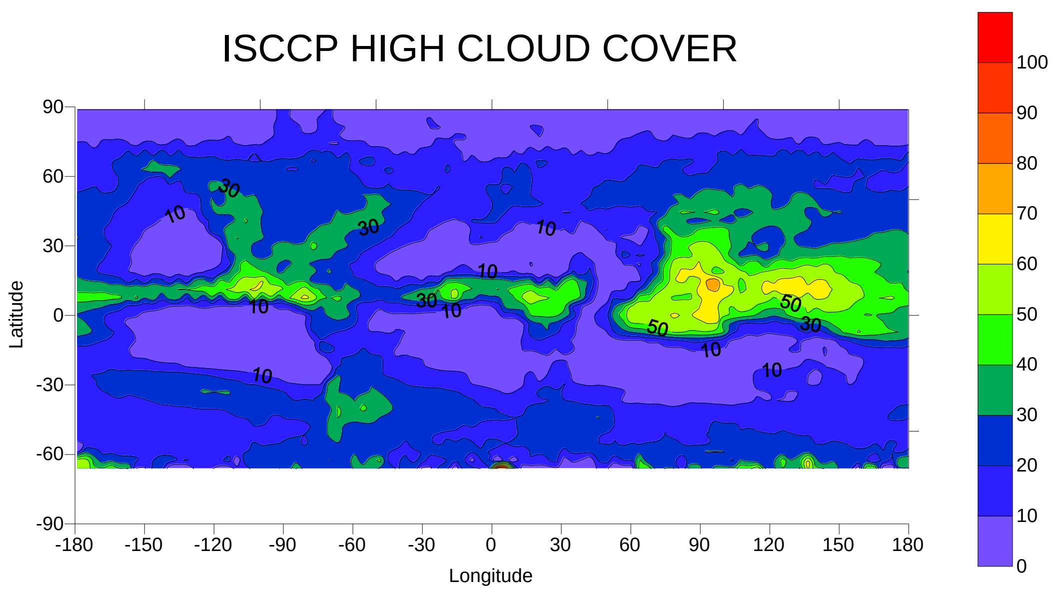
T511 NATURE RUN (1 deg x 1 deg) - HIGH CLOUD COVER



HIRS HIGH CLOUD COVER




T511 NATURE RUN (1 deg x 1 deg) - HIGH CLOUD COVER
Latitude
Longitude
90
60
30
0
-30
-60
-90
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


ISCCP HIGH CLOUD COVER
Latitude
Longitude
90
60
30
0
-30
-60
-90
-180
-150
-120
-90
-60
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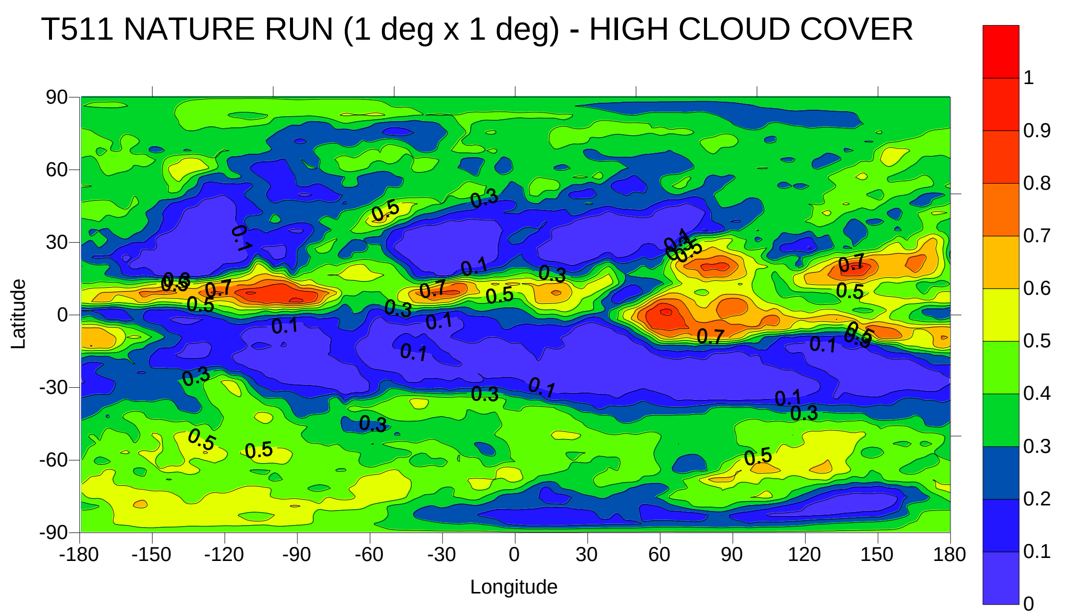
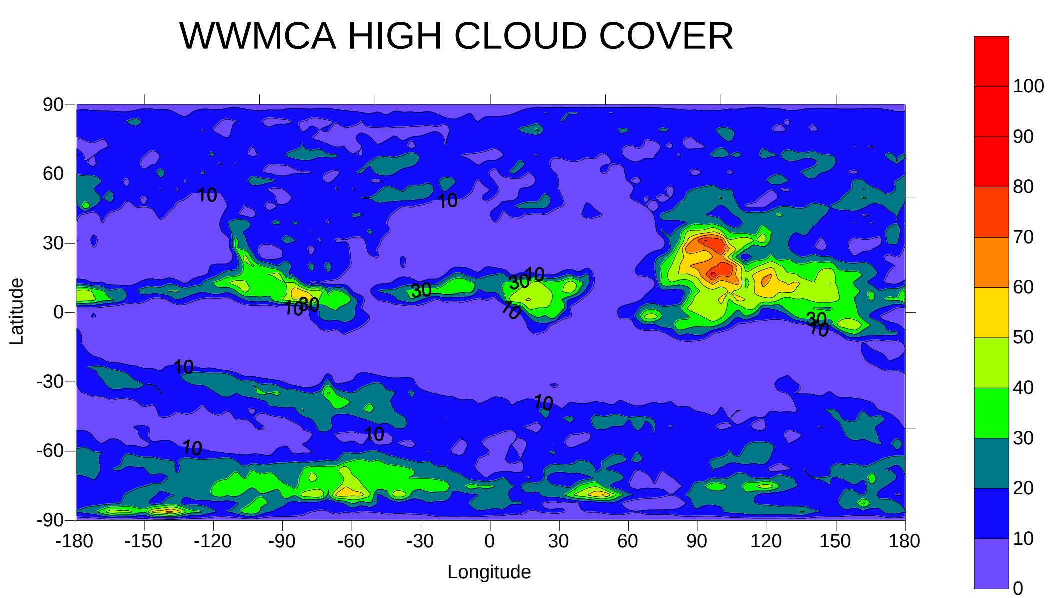
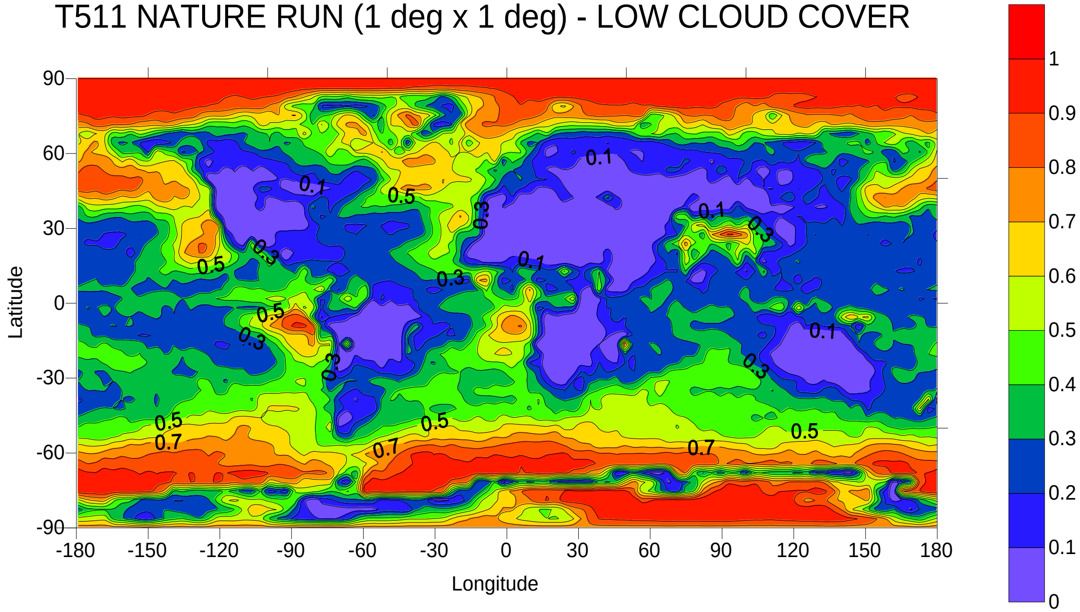
0

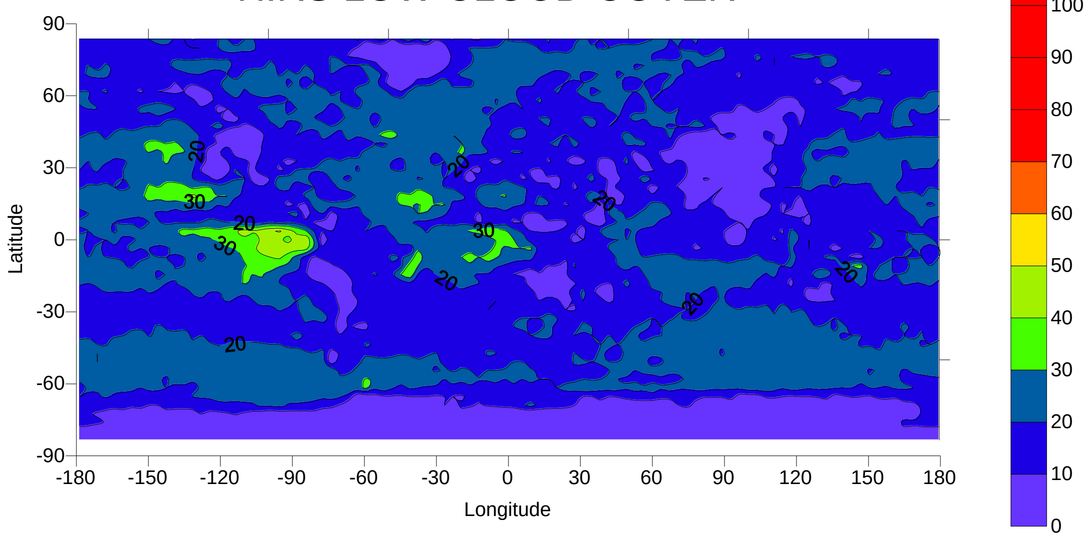

T511 NATURE RUN (1 deg x 1 deg) - HIGH CLOUD COVER
Latitude
Longitude

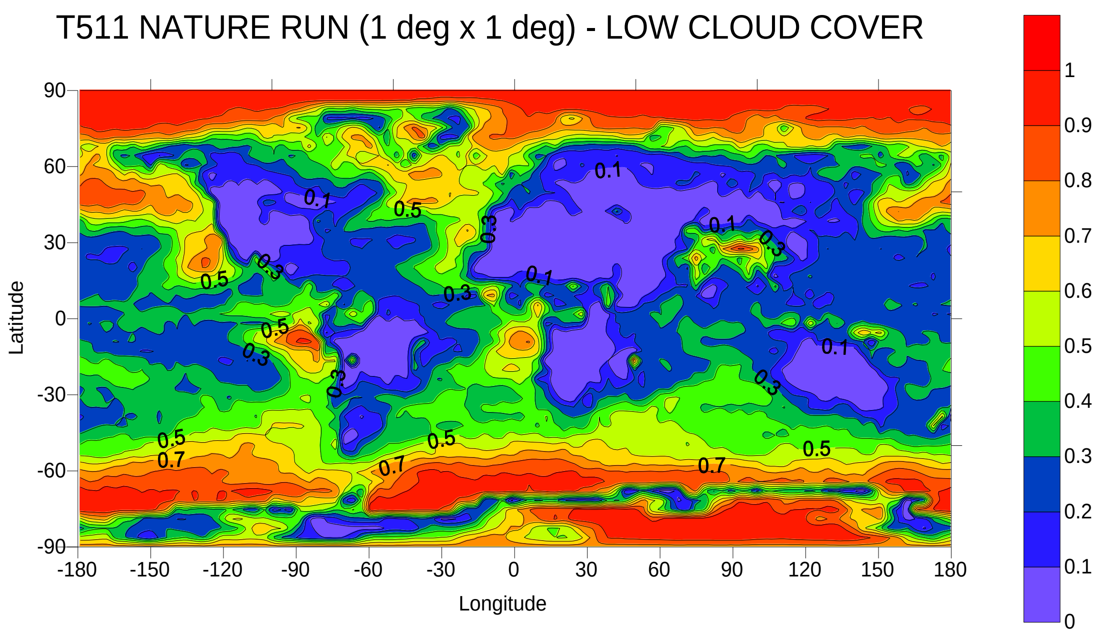

WWMCA HIGH CLOUD COVER
Latitude
Longitude

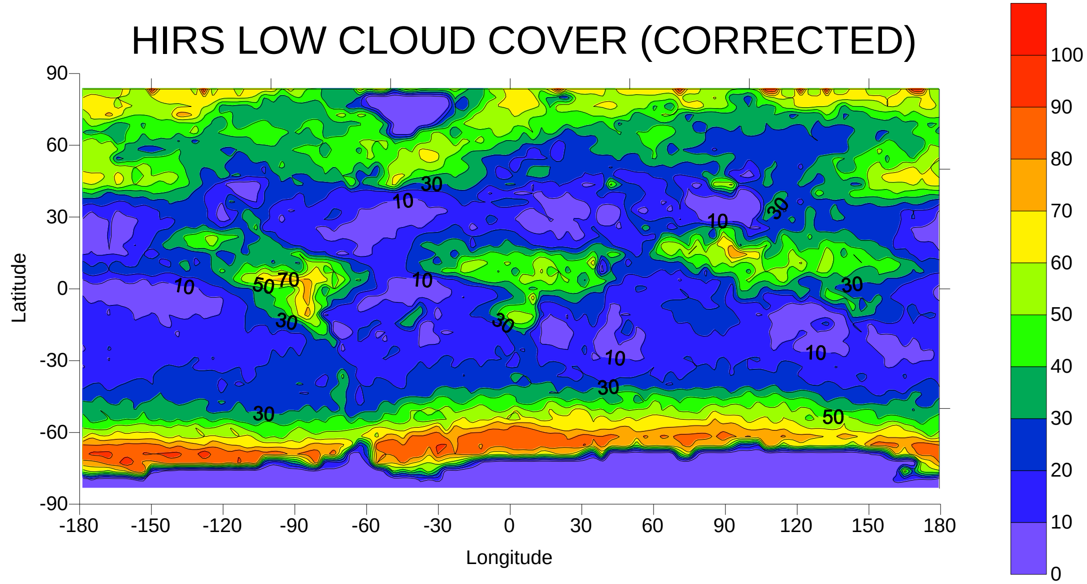
T511 NATURE RUN (1 deg x 1 deg) - LOW CLOUD COVER

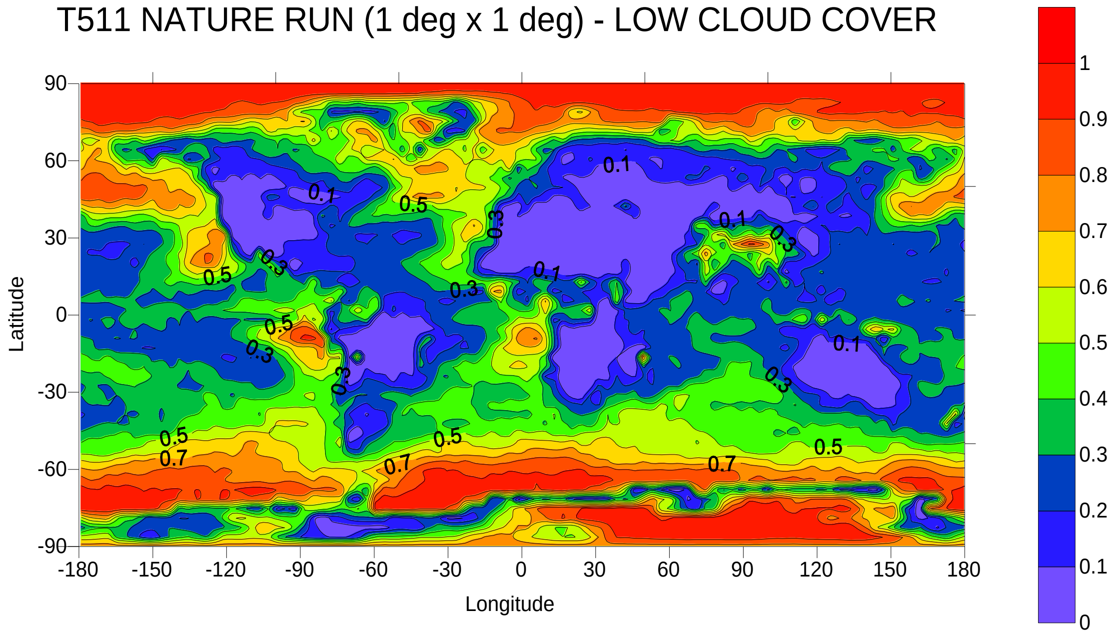


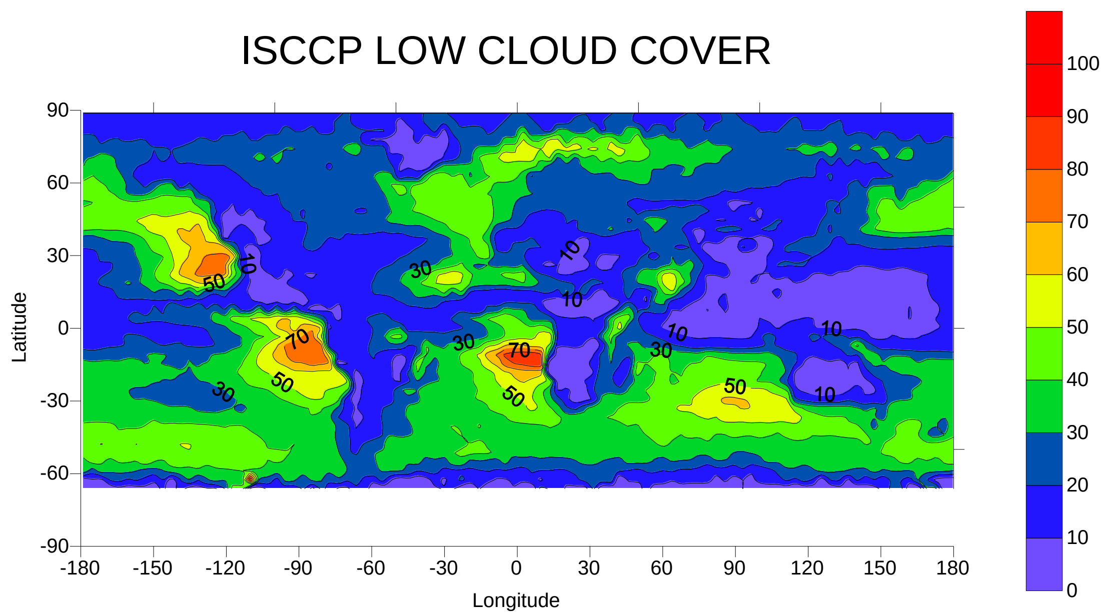
HIRS LOW CLOUD COVER

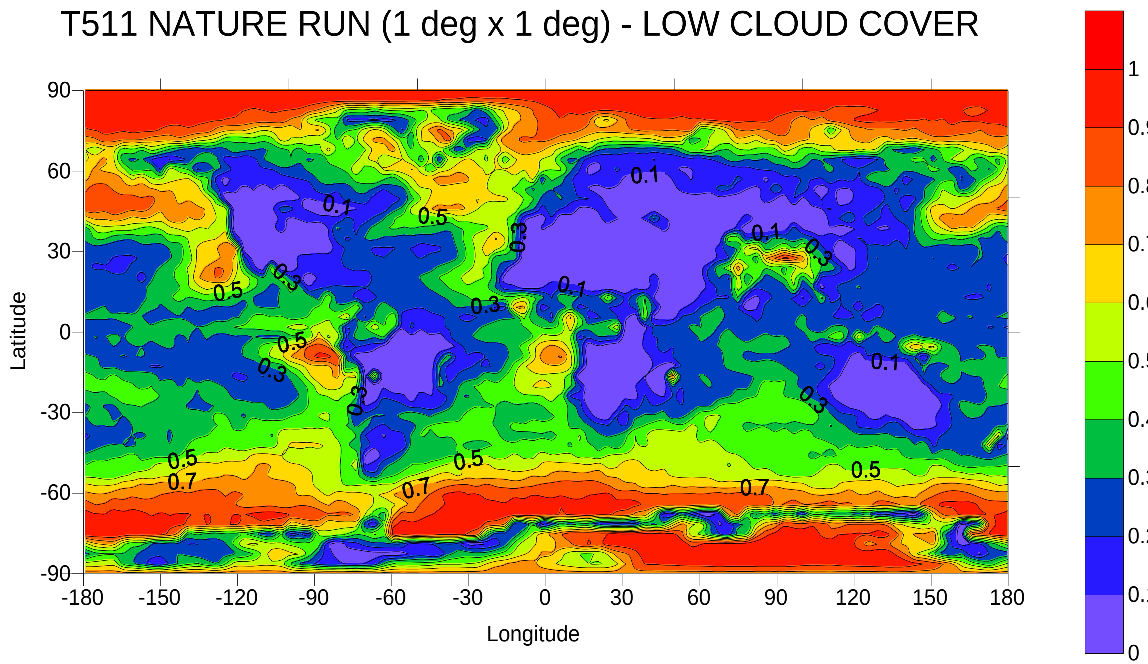


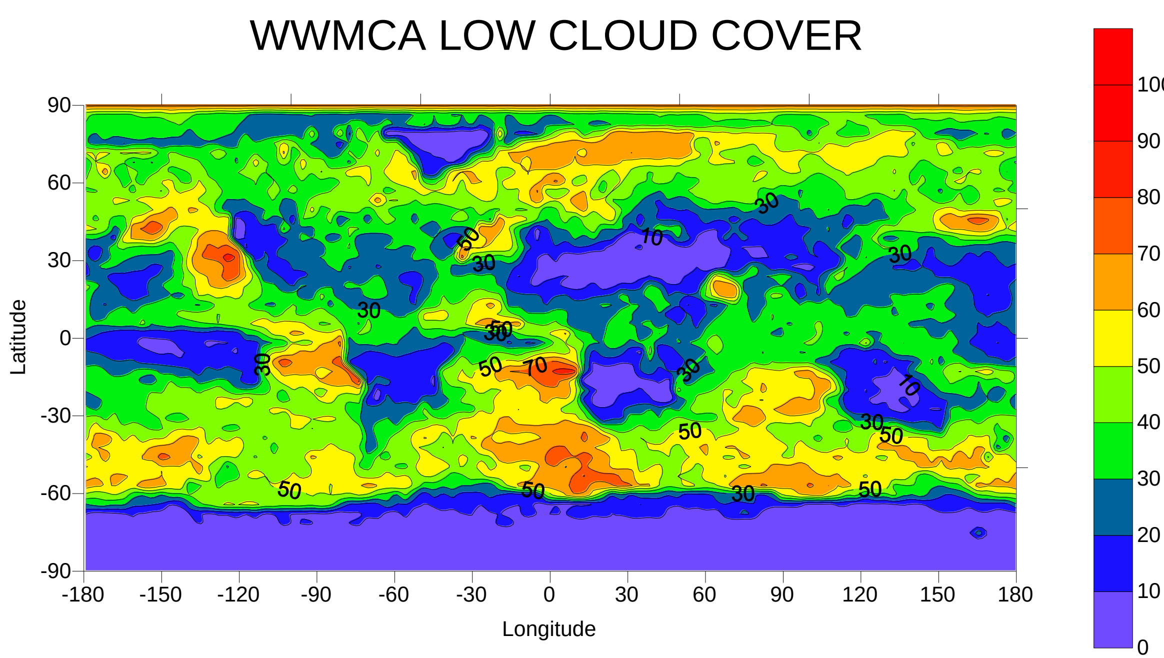

T511 NATURE RUN (1 deg x 1 deg) - LOW CLOUD COVER
Latitude
Longitude
90
60
30
0
-30
-60
-90
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


HIRS LOW CLOUD COVER (CORRECTED)
Latitude
Longitude
90
60
30
0
-30
-60
-90
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
100
90
80
70
60
50
40
30
20
10
0


T511 NATURE RUN (1 deg x 1 deg) - LOW CLOUD COVER
Latitude
Longitude
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


ISCCP LOW CLOUD COVER
Latitude
Longitude
100
90
80
70
60
50
40
30
20
10
0


T511 NATURE RUN (1 deg x 1 deg) - LOW CLOUD COVER
Latitude
Longitude
90
60
30
0
-30
-60
-90
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


WWMCA LOW CLOUD COVER
Latitude
Longitude
90
60
30
0
-30
-60
-90
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
100
90
80
70
60
50
40
30
20
10
0

GLOBAL CLOUD COVER PERCENTAGE (Land and Sea)

	T511 NR* (1 X 1)	ISCCP**	WWMCA*	HIRS**	GLAS[1]	CALIPSO[2]
Total CC	68.3/59.8	65.9	49.6	76.9	72.0 (80.0)	77.0
Low CC	44.0/34.3	27.4	32.2	30.6	33.5	32.5
Mid CC	28.0/22.9	17.8	21.9	28.2	21.0	13.0
High CC	32.9/30.6	21.1	14.2	32.8	21.0	24.5

* - August 2005
** - Long term mean for August
GLAS[1] - Nov 2003 (from Seze et al., 2007); 2nd Study by Emmitt and Greco (2006)
CALIPSO[2] - August 2006 (from Seze et al., 2007)

GLAS/CALIOP View

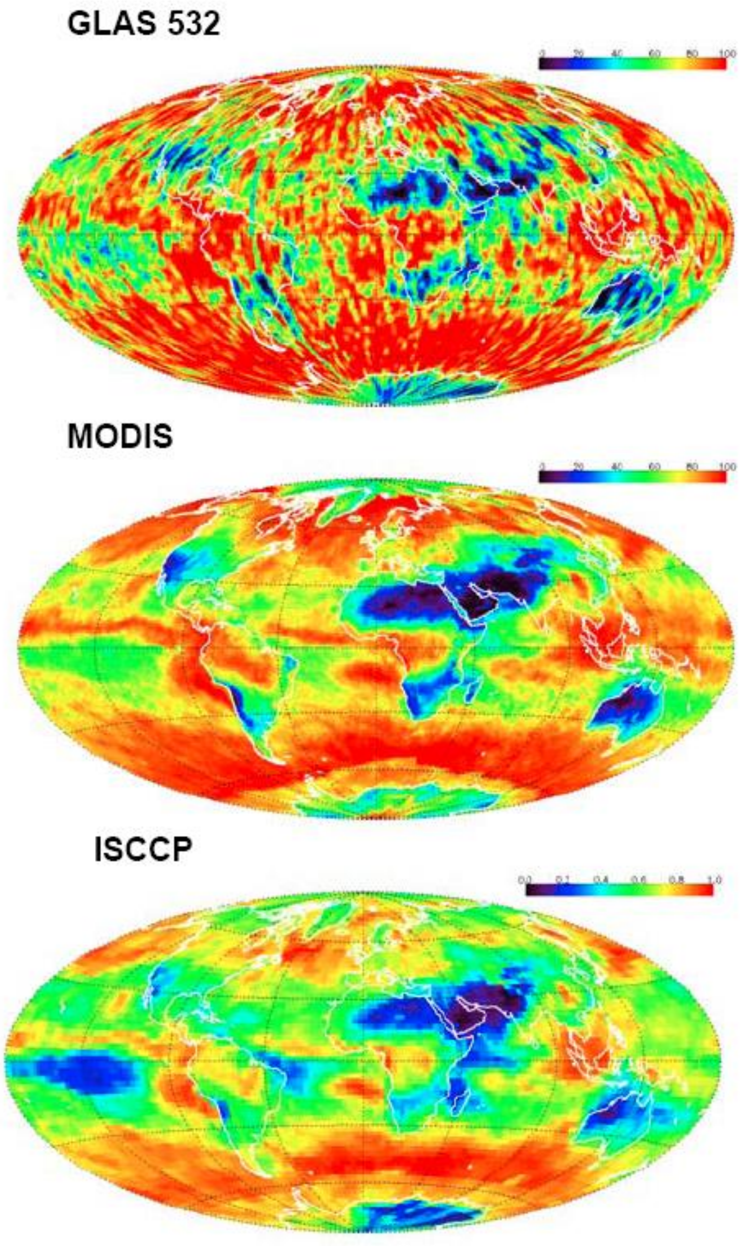


Figure 2A: Global maps of cloud frequency for GLAS, MODIS, ISCCP for October. 2003.

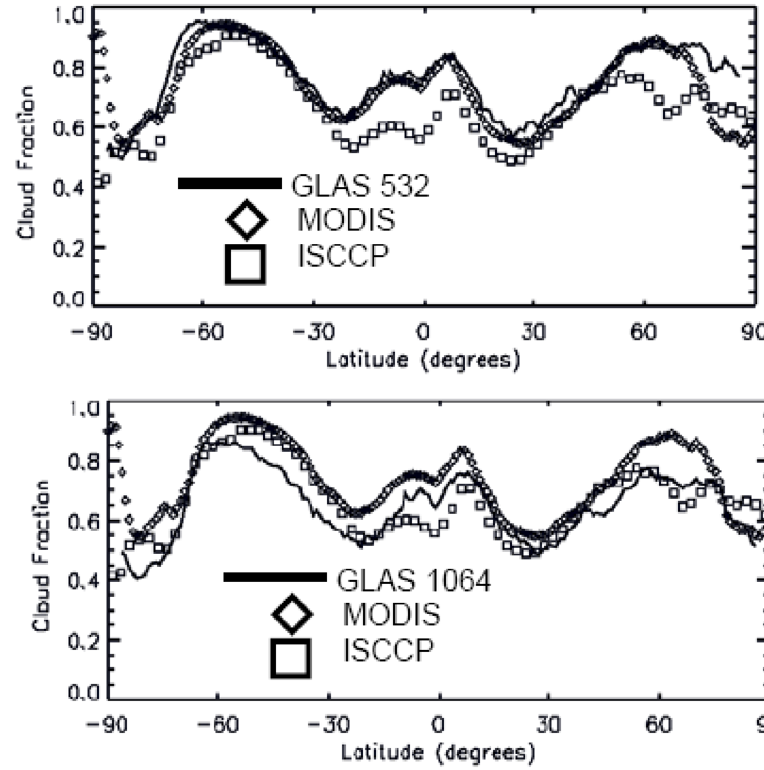
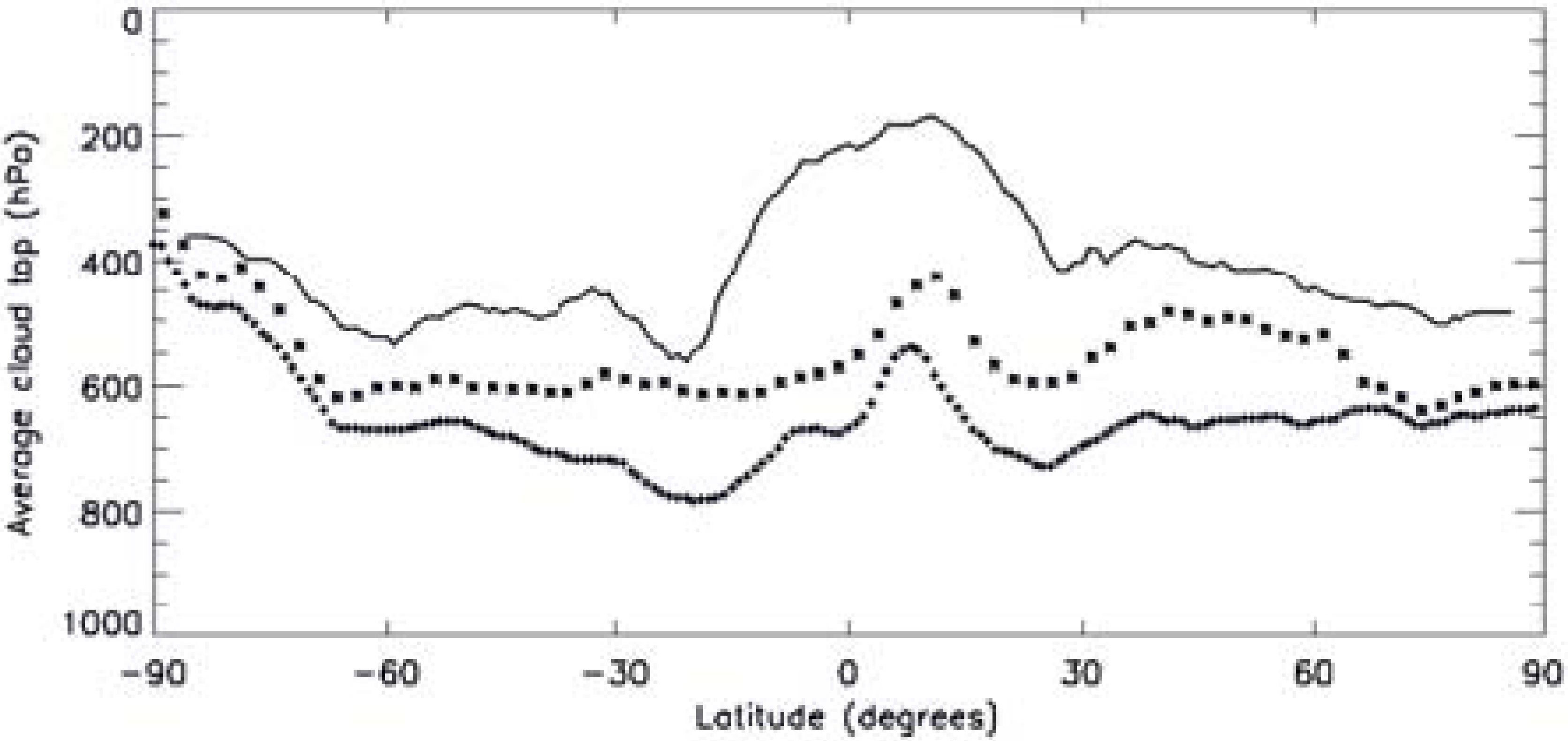


Fig. 3. Zonal cloud fraction for GLAS, ISCCP, and MODIS for October, 2003.

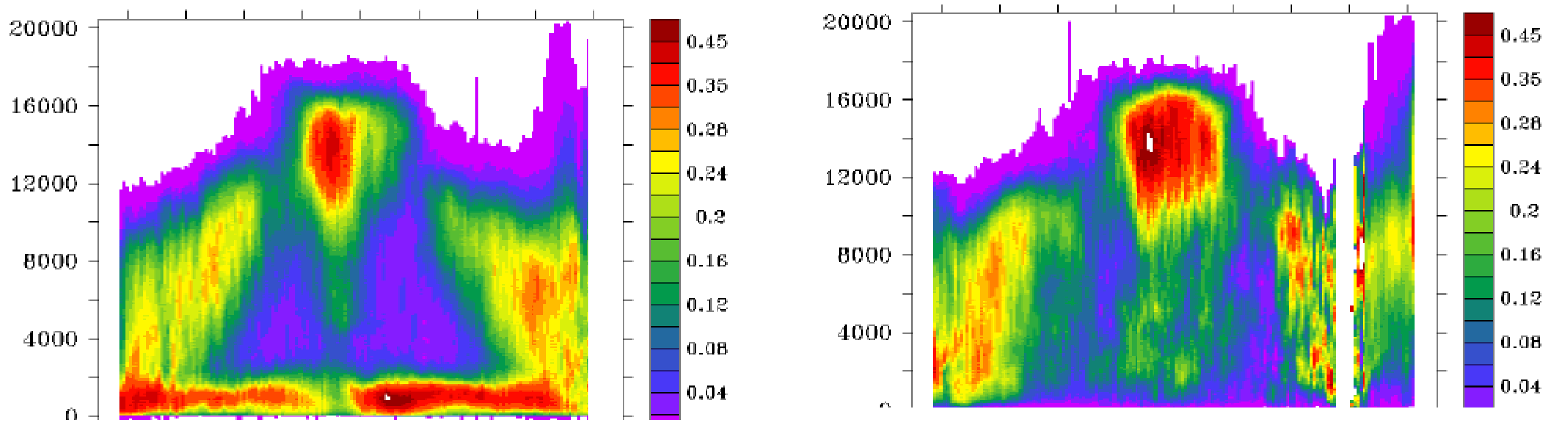


Zonal average cloud top for GLAS,ISCCP, and MODIS for October, 2003.

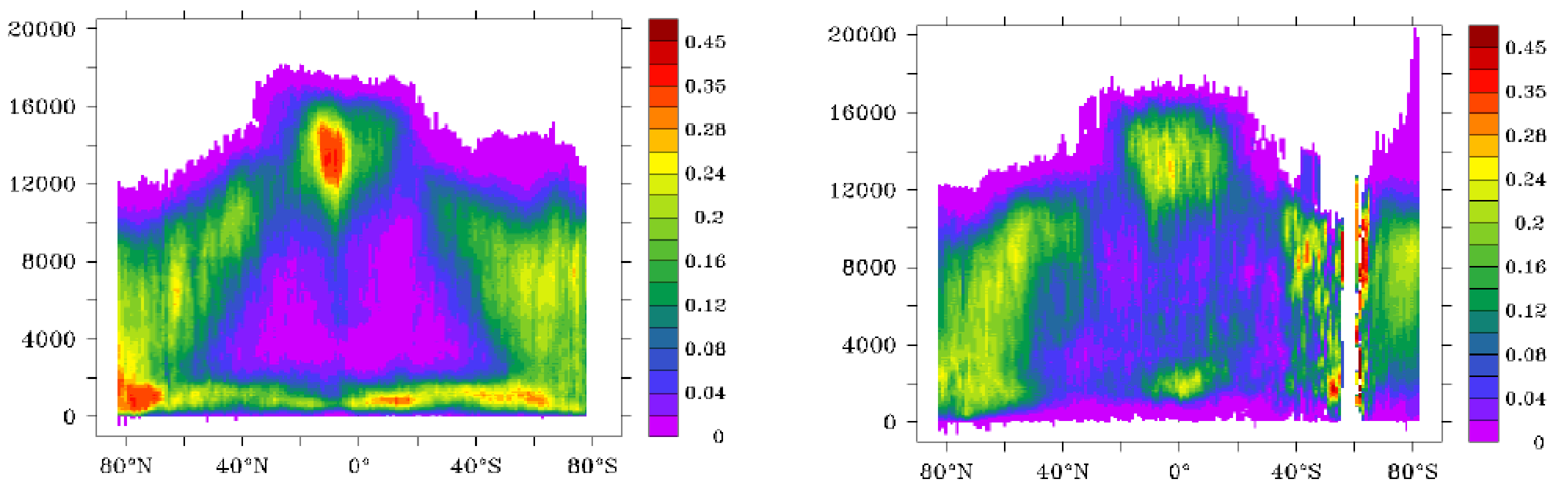
Taken from: William D. Hart*, Stephen P. Palm, James D. Spinhirne and Dennis L. Hlavka Global and polar cloud cover from the Geoscience Laser Altimeter System, observations and implications

WHAT IS OBTAINED From CALIOP/CALIPSO October 2006

Night Ocean Land

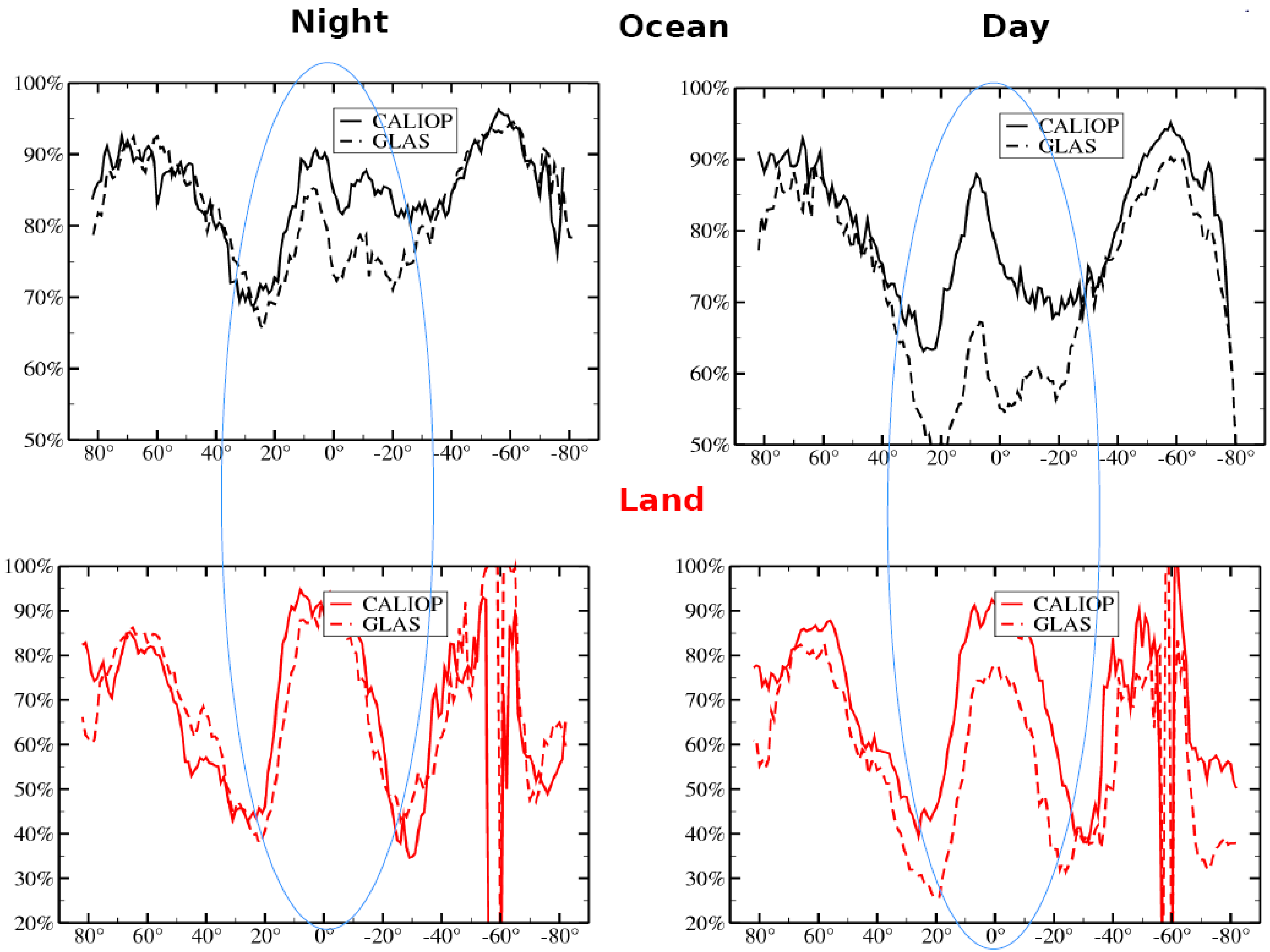


Day Calipso data v1.10



Earthcare workshop, ESTEC, 8 May 2007

Seze, Pelon, Flamant, Vaughn, Trepte and Winker



GLAS october 2003 – CALIOP october 2006

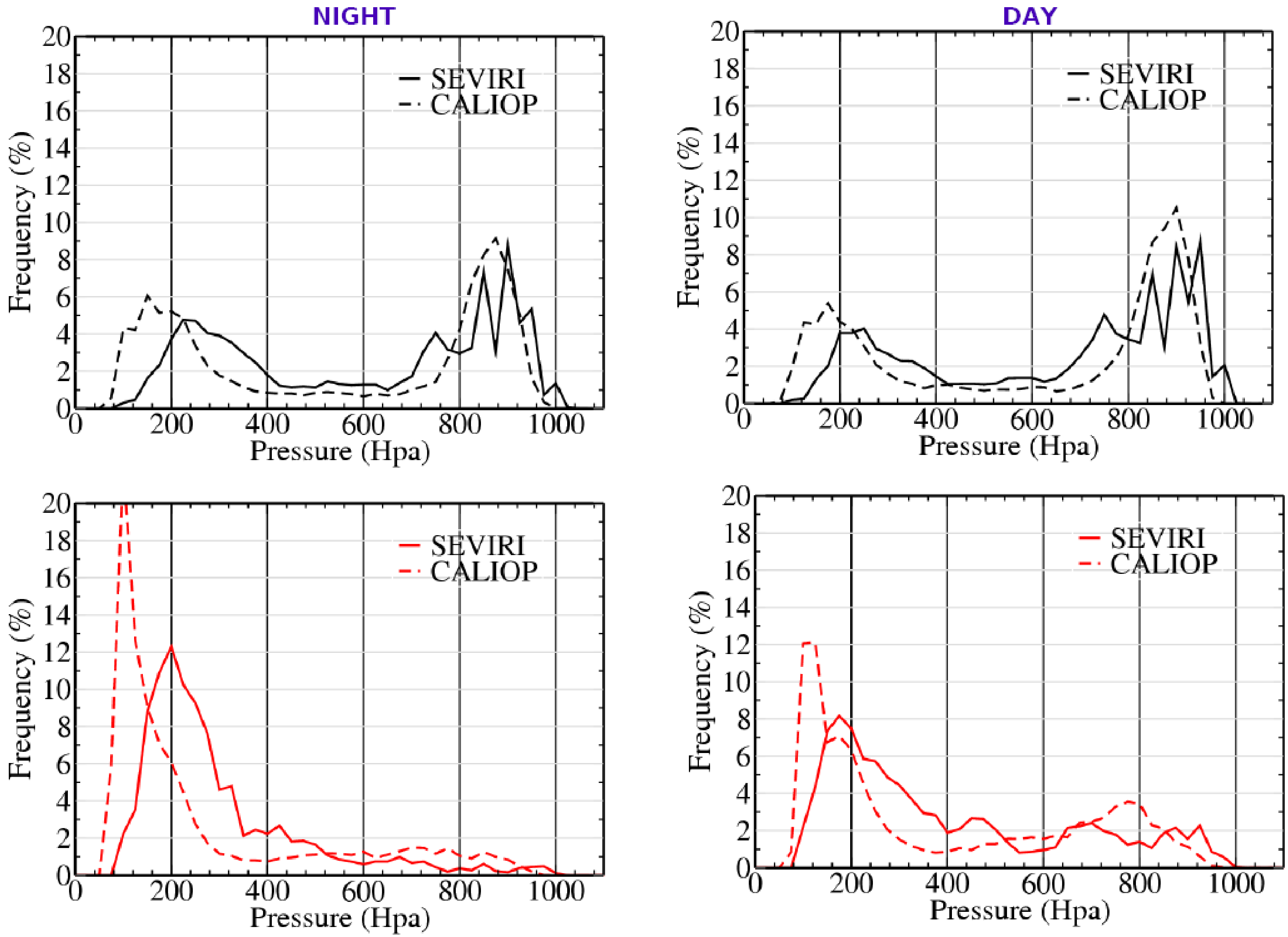
Night and day cloud cover

GLAS 50 days during the 2003 fall, CALIOP August and October 2006

	Night				Day		
	GLAS	CALIPSO			GLAS	CALIPSO	
	2003	*Oct*	*Aug*		*2003*	*Oct*	*Aug*
Total cloud cover	78%	79%	76%		65%	75%	78%
high cloud	21%	23%	29%		20%	23%	20%
middle cloud	19%	12%	11%		23%	13%	15%
high + middle	10%	11%	13%		8%	12%	11%
low cloud	30%	34%	29%		37%	35%	36%
low cloud with other	20%	20%	18%		11%	17%	18%

Low < 700 hPa **Middle : 700-400 hPa** **High > 400 hPa**

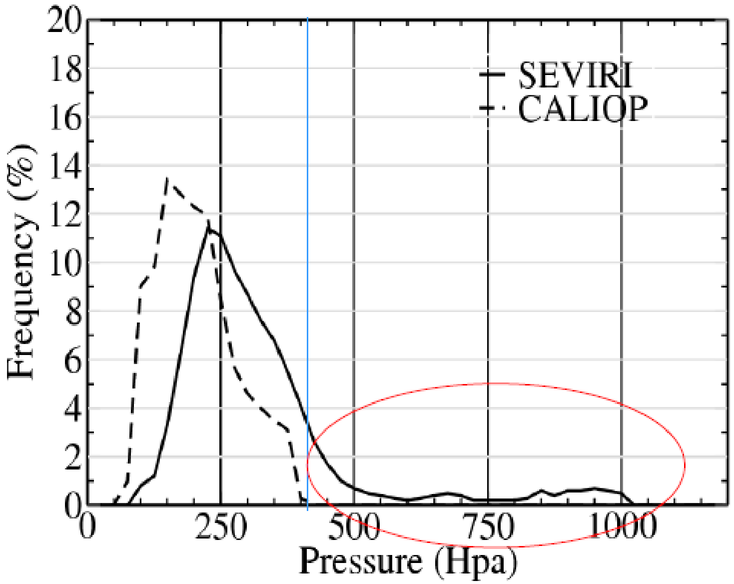
CALIOP OCEAN - LAND October 2006



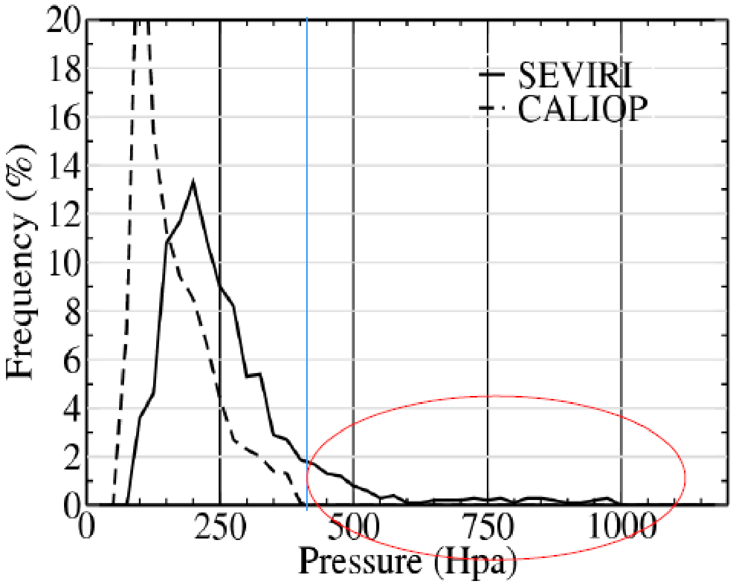
Earthcare Workshop, ESTEC, 8 May 2007

DISTRIBUTION OF SEVIRI CLOUD TOPS

FOR CALIOP high clouds tops below 400 hPa Night data



OCEAN



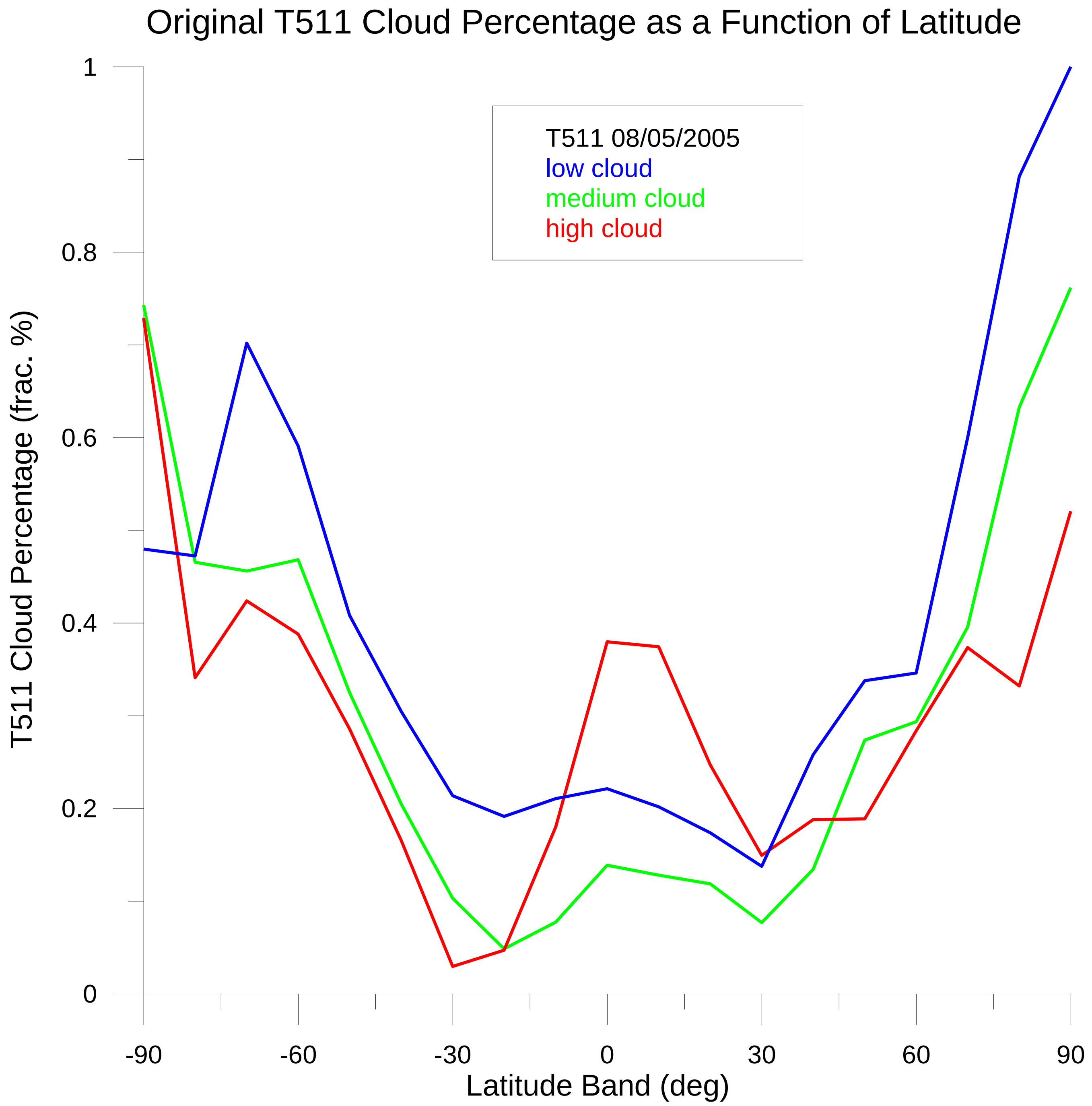
Land

Heads up from CALIPSO

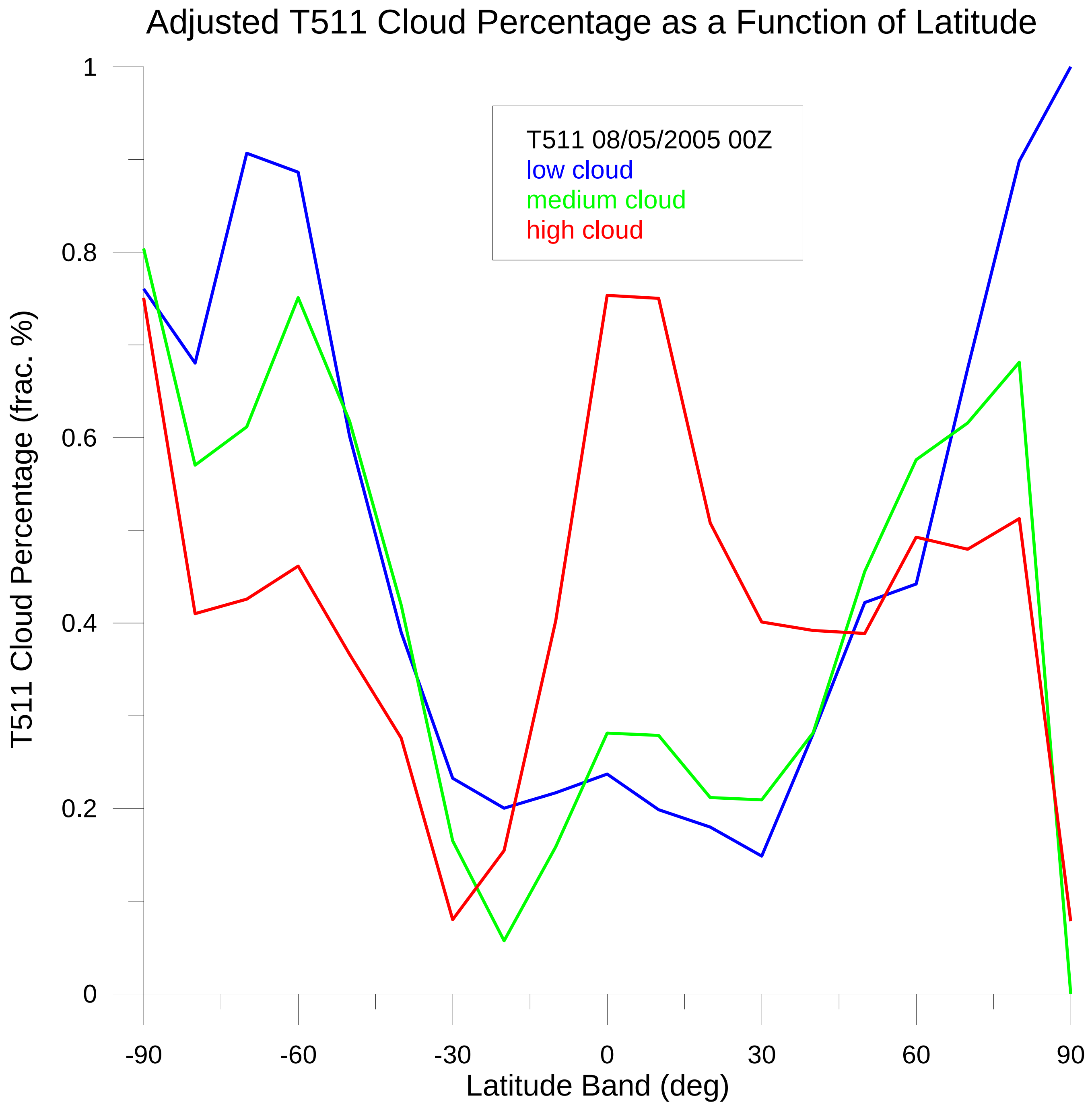
………. the ice cloud formation in the models
need to include the presence of the highly frequent thin ice clouds
with tiny amount of ice water content.

Conversation with CALIPSO team member (June, 2007)

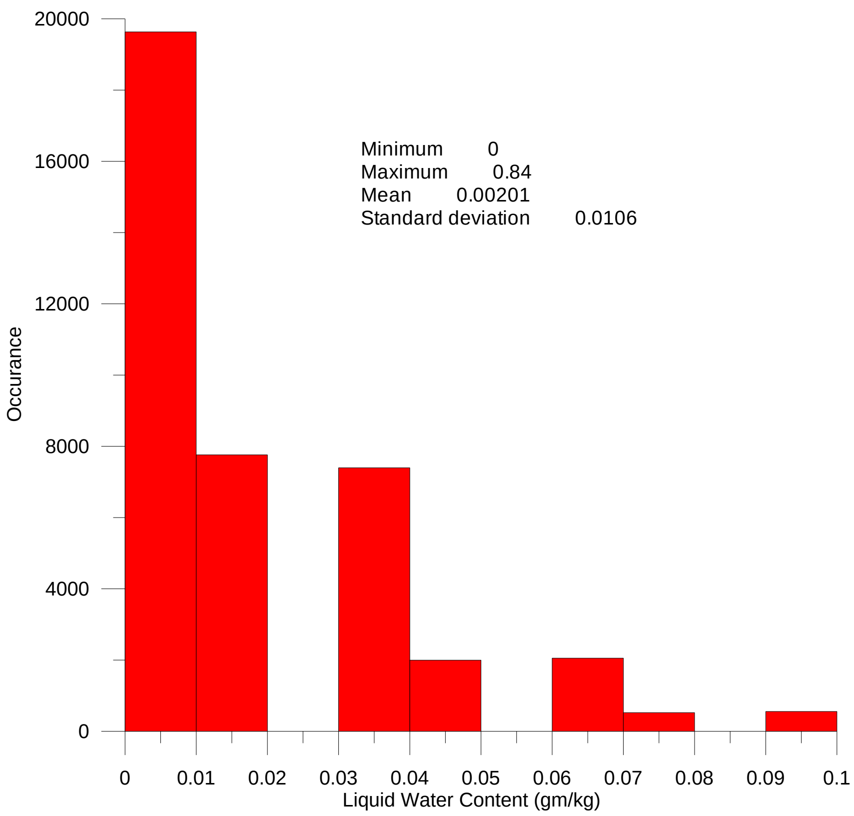
NR cloud distributions using individual layer cloud types and amounts

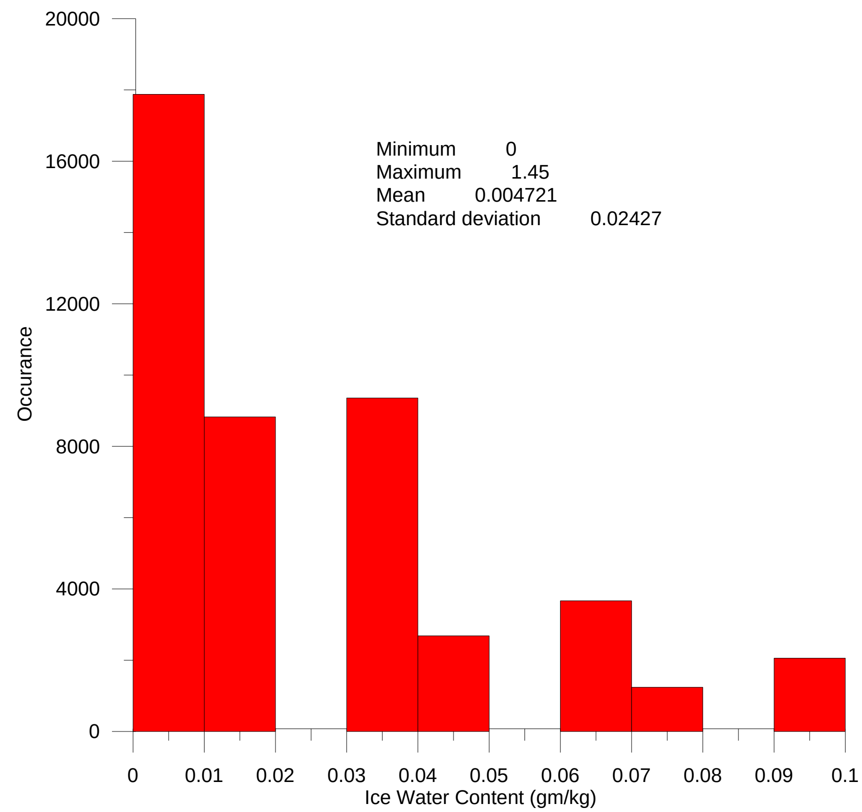


Original T511 Cloud Percentage as a Function of Latitude
T511 08/05/2005
low cloud
medium cloud
high cloud
T511 Cloud Percentage (frac. %)
1
0.8
0.6
0.4
0.2
0
-90
-60
-30
0
30
60
90
Latitude Band (deg)


Adjusted T511 Cloud Percentage as a Function of Latitude
T511 08/05/2005 00Z
low cloud
medium cloud
high cloud
T511 Cloud Percentage (frac. %)
Latitude Band (deg)
0
0.2
0.4
0.6
0.8
1
-90
-60
-30
0
30
60
90

Ice water content (gm/km) in NR





Simulating Lidars on T213

Clouds, shear and the simulation of hybrid wind lidar

S. Wood and G. D. Emmitt
Simpson Weather Associates

WGSBWL
Miami 2007

Role of Clouds

- Clouds and aerosols enable and confound profiling of winds from space
- NASA funded study of GLAS data to investigate the effects of clouds on the vertical distribution of lidar data
- Primary issues being addressed currently
  - General cloud distributions, particularly cirrus
  - Clouds and shear (using OSSE Nature Runs)
  - Clouds porosity (optical)

Lidar design issues

- The instrument accuracy of direct detection lidars for Doppler and DIAL are proportional to the number of photons detected. For molecular lidars, clouds are a source of error. If “integration on a chip” is employed, individual cloud returns contaminate the entire integration interval.
- Coherent detection lidars have the properties of threshold accuracy (i.e. instrument accuracy does not change much above some threshold of detected coherent photoelectrons). Sensitivity, however, is a function of the total number of PEs.
- For both detection techniques, the total observation error is dependent on the number and spacing of the samples.
  - Total error = Sqrt(instrument error^2 + representative error ^{2})

GLAS Study

- ESTO/NASA funded effort to use the GLAS data to gain insight into the patterns of CFLOSs (Cloud Free Line Of Sight) for input to the design of future space-based lidars (altimeters, Doppler, DIAL, LaserCom, imagers)
- Specific questions:
  - What percent of the time are there clouds in a laser beam's FOV? Single layer? Multiple layers?
  - What percent of the time is a ground return detected?
  - What are the statistics on consecutive CFLOSs down to different levels in the atmosphere? Number of CFLOSs within a specified distance?

Summary

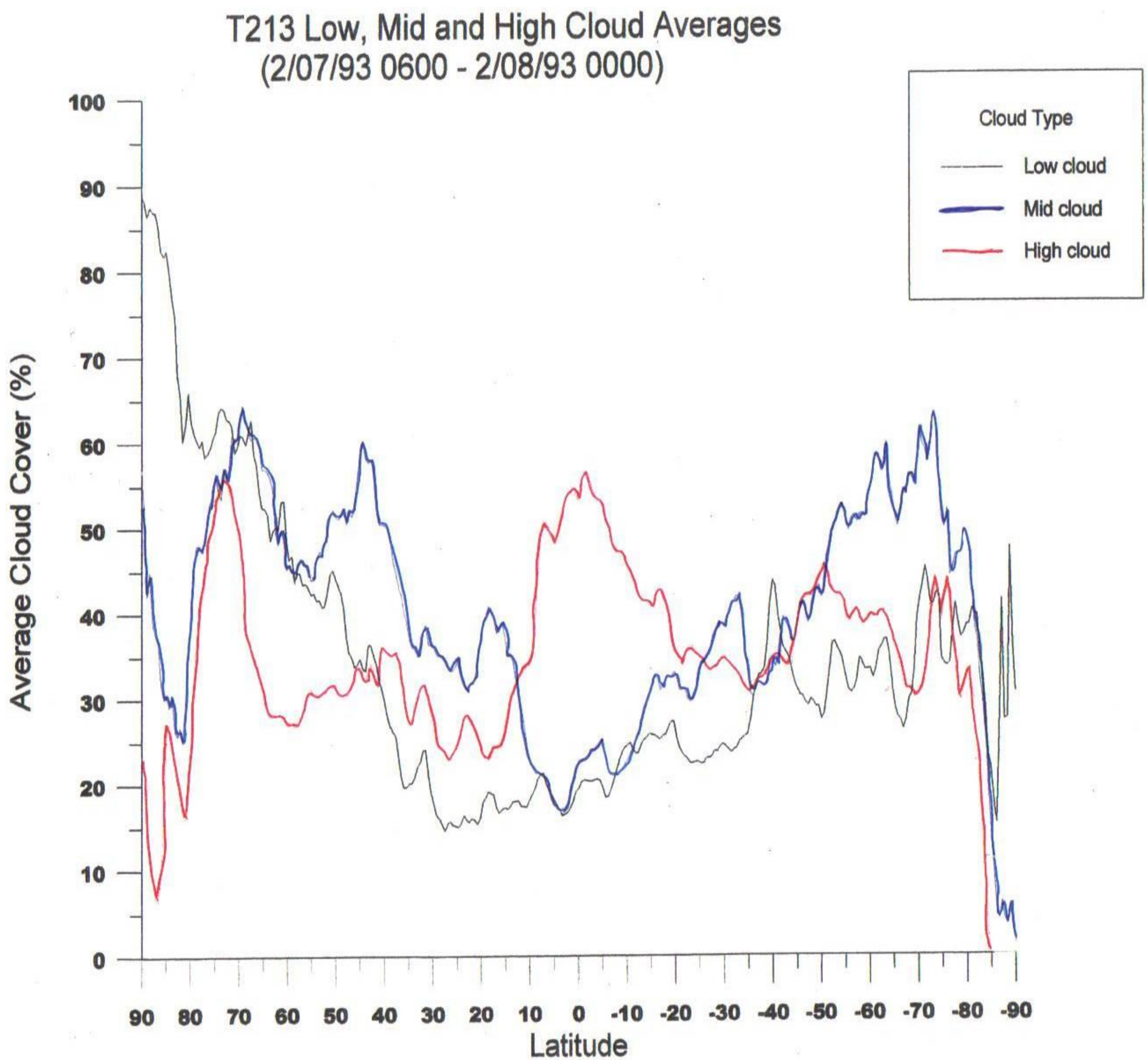
- Based upon the GLAS data, between 75 and 80% of lidar shots intercept clouds.
- GLAS data suggest that 70-80% of <u>its</u> shots reach the surface.
- Given that the EAP for the GLAS instrument was modest compared to lasers being planned for future missions, it is expected that both cloud and ground returns will increase in the future.

Summary(2)

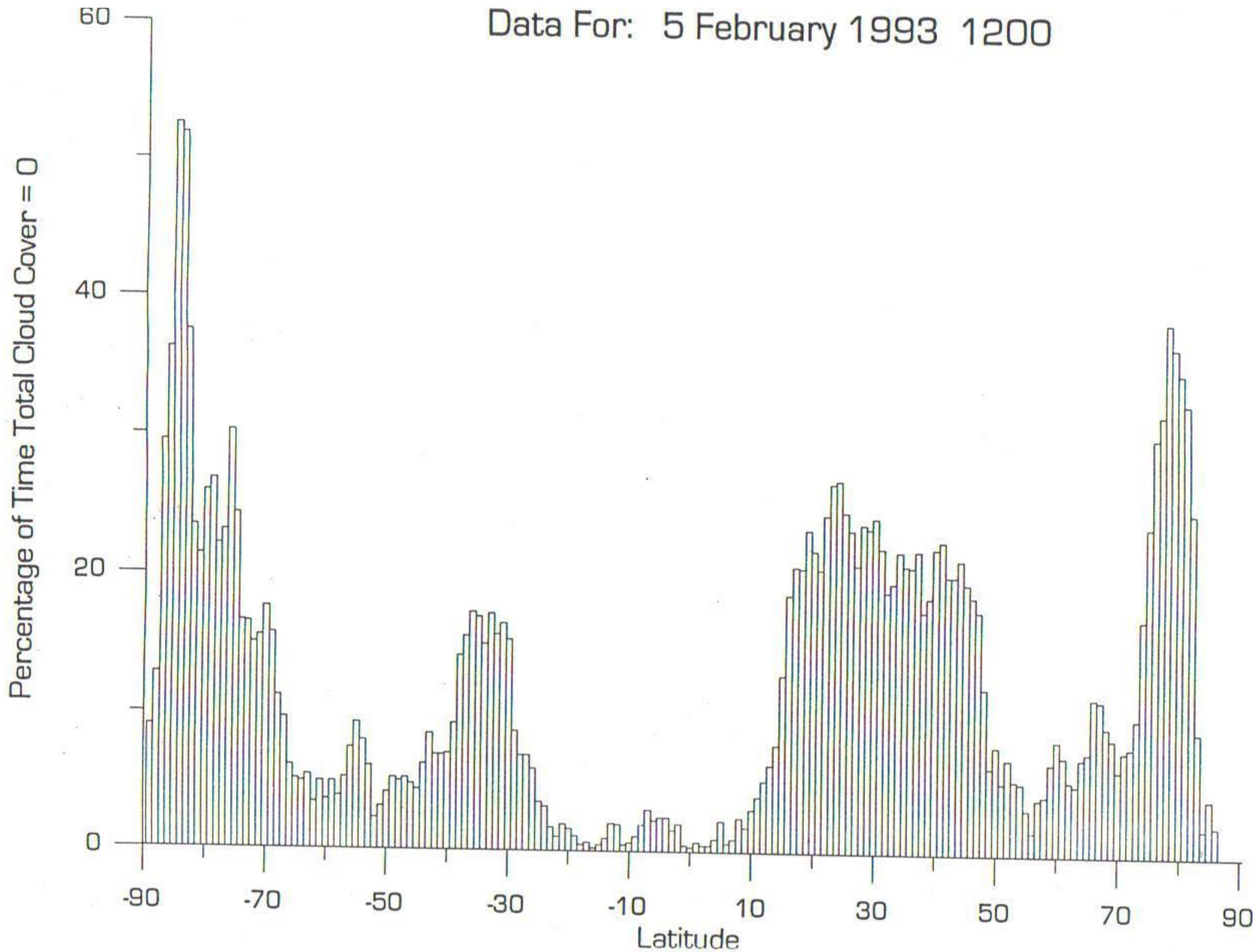
- ~ 30% of all integrated data products detected 2 or more layers of clouds when any cloud is present.
- While integrating over longer distances may improve sensitivity, it does not improve the probability of CFLOS integration.
- Although GLAS has provided the first global laser cloud statistics based upon more than a few hours of operation (i.e.LITE), CALIPSO promises an even better data set for use in the design of future lidars (DWL, DIAL, LaserCom).

Nature Run Clouds

- Use T213 & GSFC's FVGCM Nature Runs
- How do the Nature Run clouds compare to the ISCCP findings?
- How do high cirrus effect simulated DWL observations in OSSEs?
- How are shear and clouds correlated in Nature Run?
- How does a "porosity" factor alter the distribution of simulated hybrid (coherent subsystem only) DWL products?

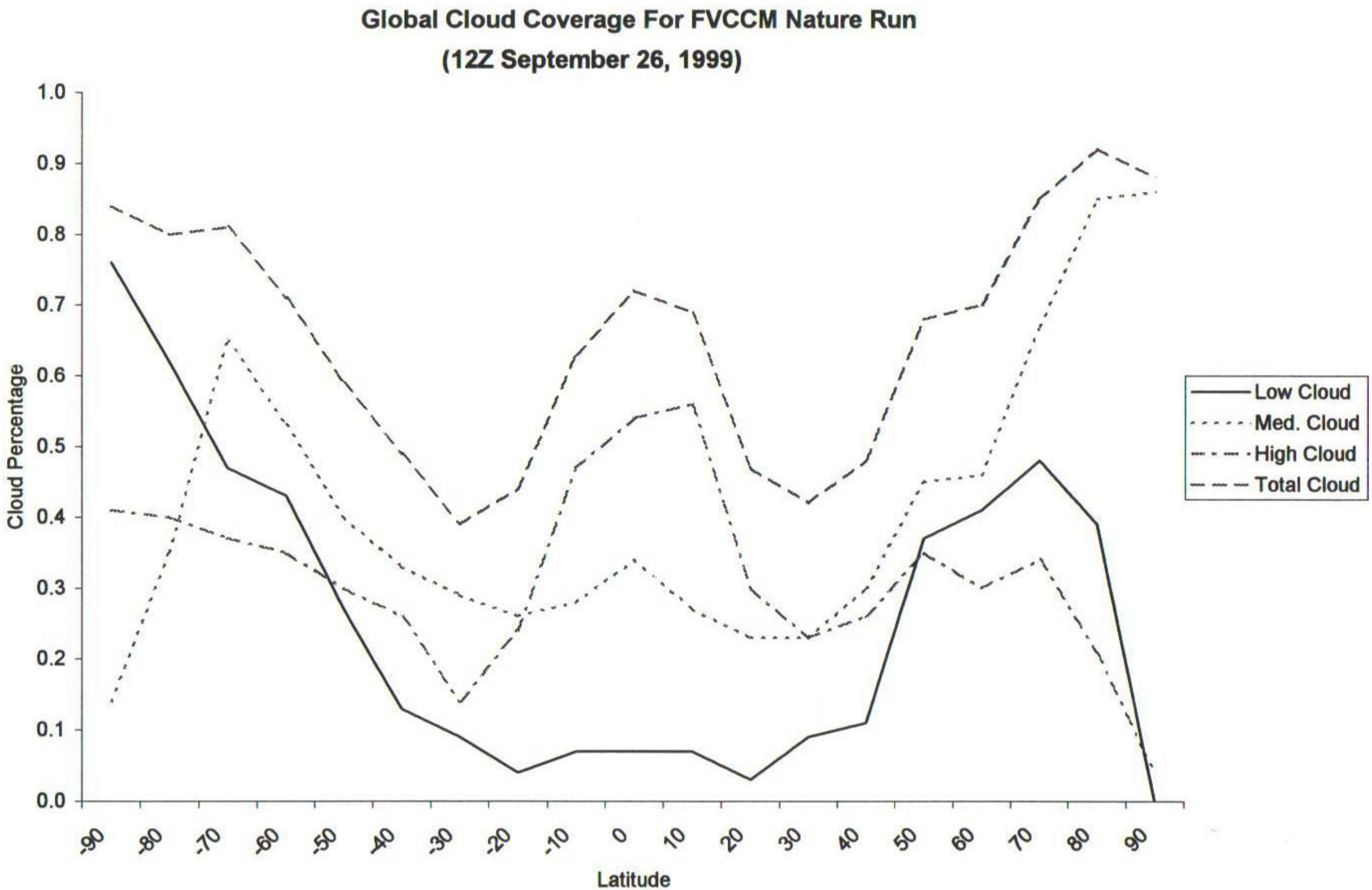


T213 Low, Mid and High Cloud Averages
(2/07/93 0600 - 2/08/93 0000)
Cloud Type
Low cloud
Mid cloud
High cloud
Average Cloud Cover (%)
100
90
80
70
60
50
40
30
20
10
0
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90
Latitude

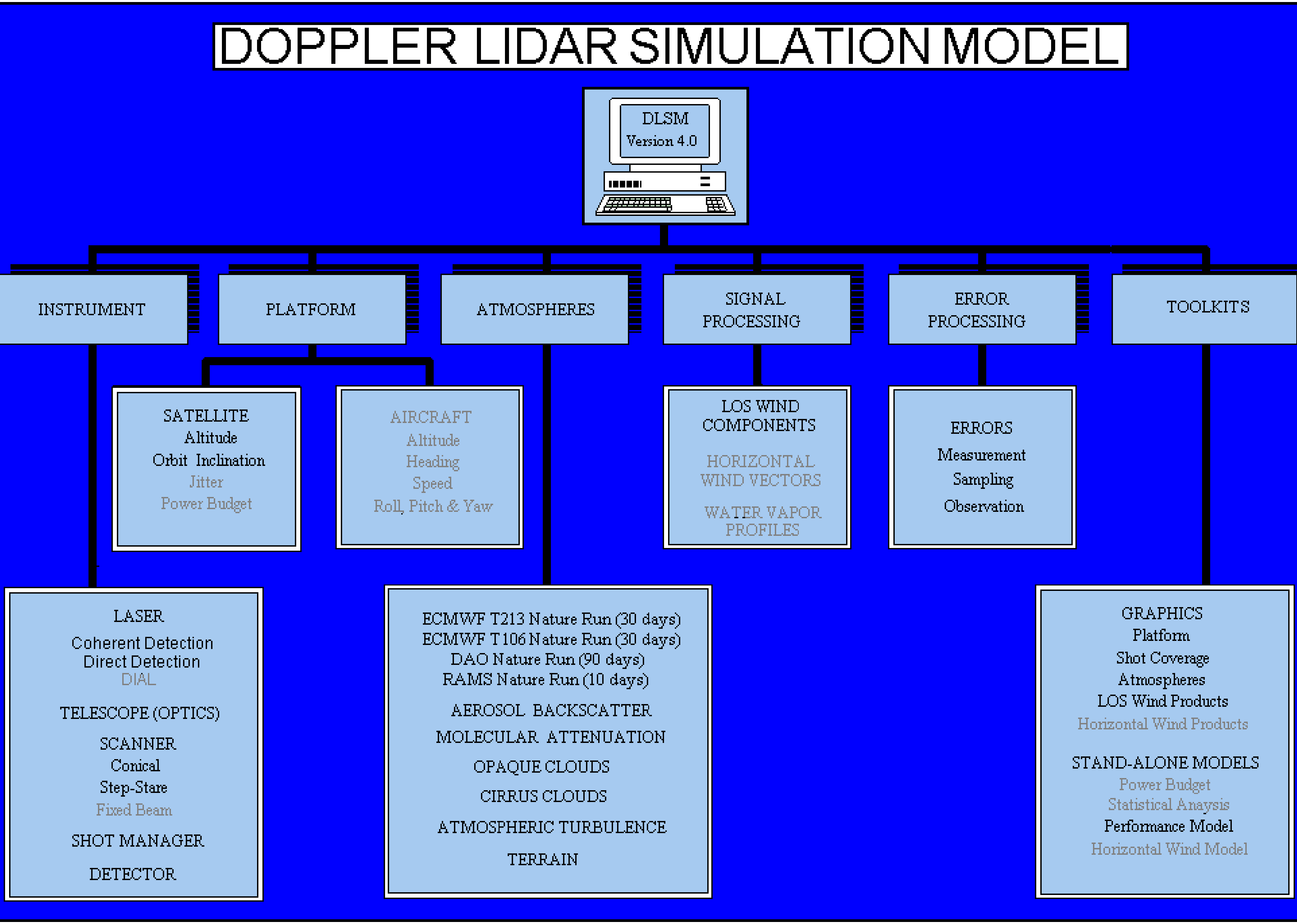


Data For: 5 February 1993 1200
Percentage of Time Total Cloud Cover = 0
60
40
20
0
-90
-70
-50
-30
-10
10
30
50
70
90
Latitude

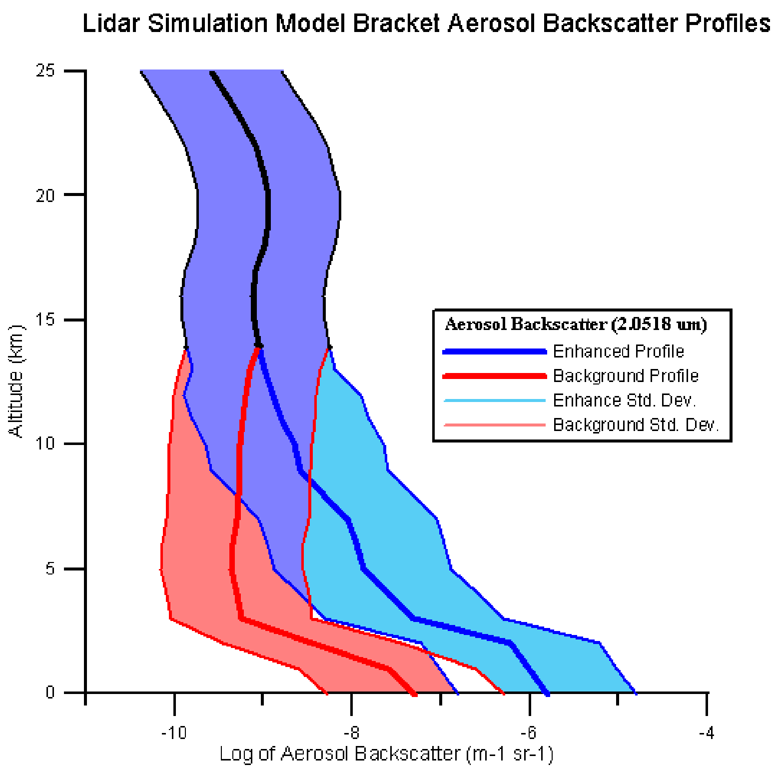
Figure 20



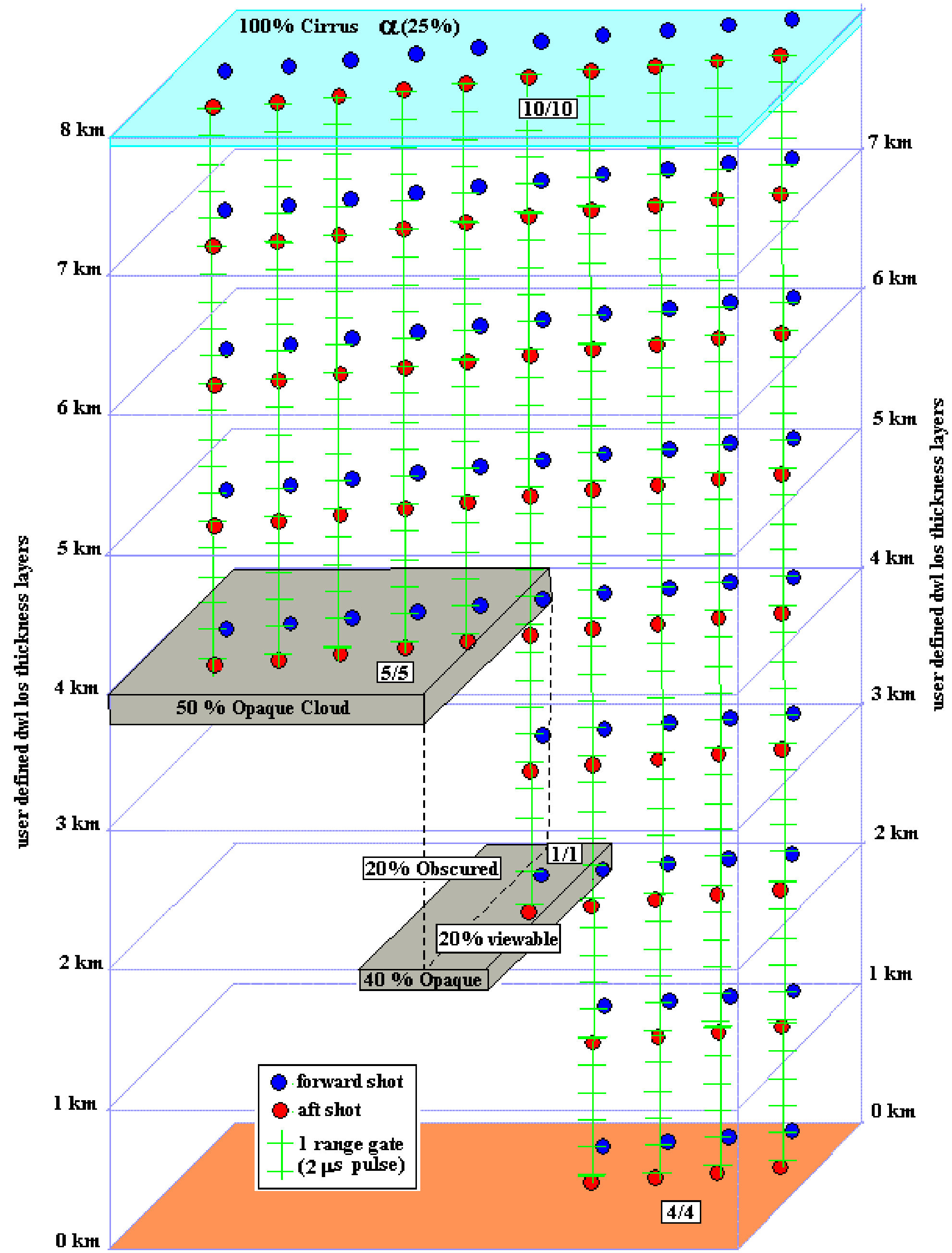
Global Cloud Coverage For FVCCM Nature Run
(12Z September 26, 1999)
Cloud Percentage
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Latitude
Low Cloud
Med. Cloud
High Cloud
Total Cloud



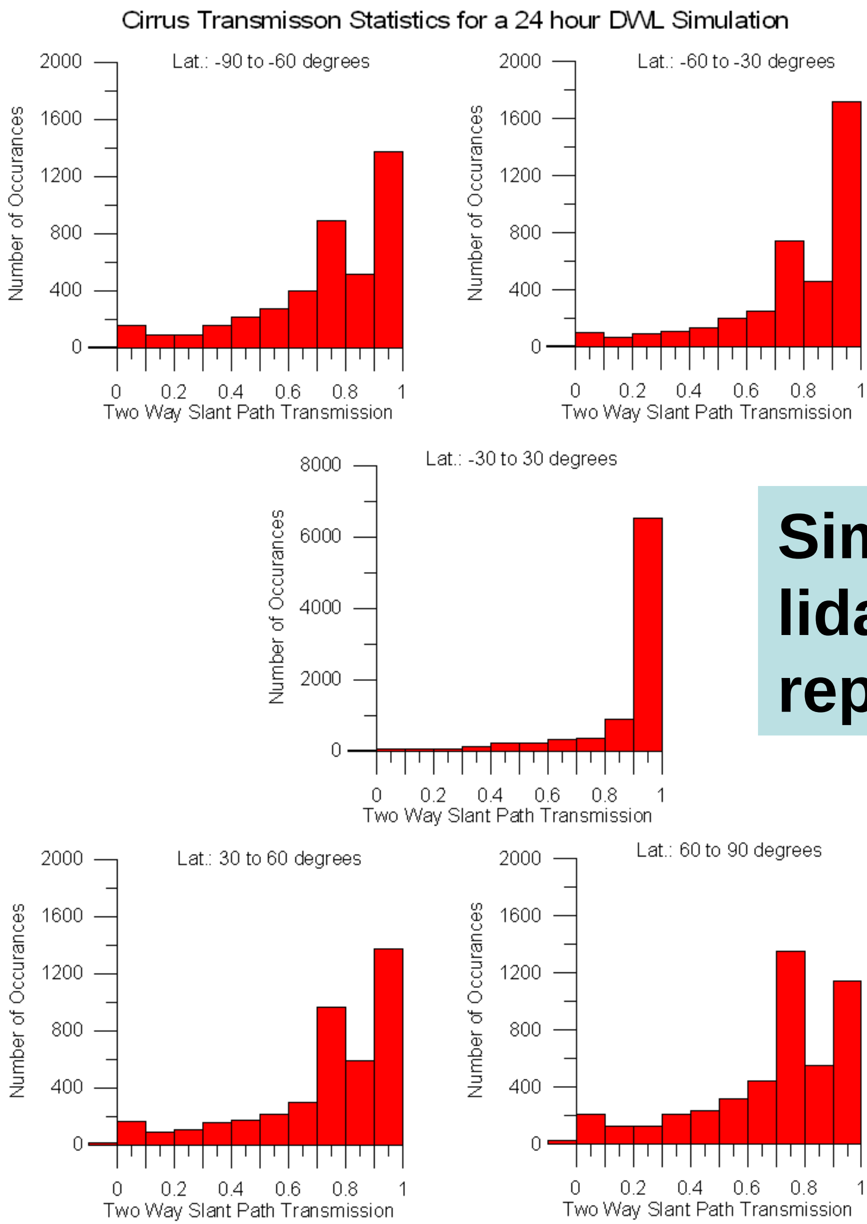
Model intergrated into the DLSM but has not been made operational in version 4.0



Lidar Simulation Model Bracket Aerosol Backscatter Profiles
Altitude (km)
25
20
15
10
5
0
-10
-8
-6
-4
Log of Aerosol Backscatter (m-1 sr-1)
Aerosol Backscatter (2.0518 um)
Enhanced Profile
Background Profile
Enhance Std. Dev.
Background Std. Dev.

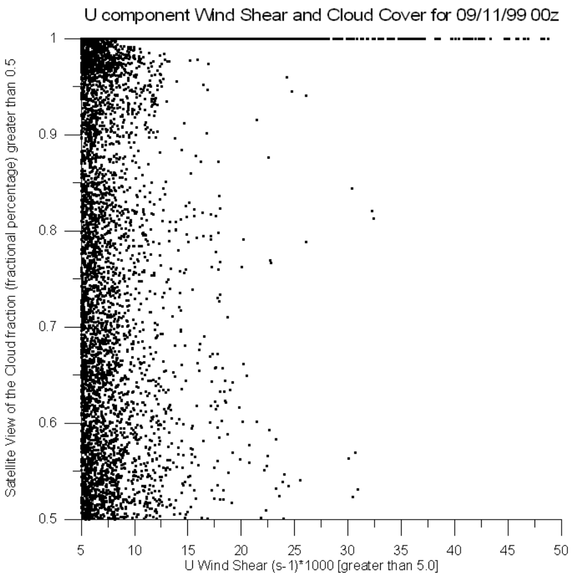


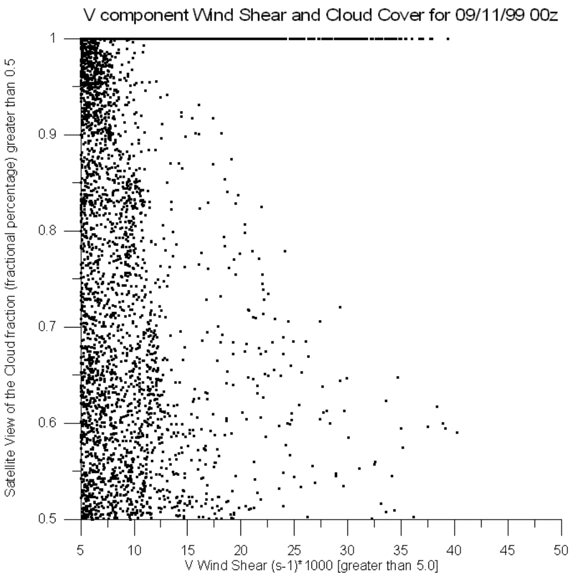
100% Cirrus
α(25%)
10/10
8 km
7 km
6 km
5 km
4 km
3 km
2 km
1 km
0 km
7 km
6 km
5 km
4 km
3 km
2 km
1 km
0 km
5/5
50 % Opaque Cloud
1/1
20% Obscured
20% viewable
40 % Opaque
4/4
forward shot
aft shot
1 range gate
(2 μs pulse)
user defined dwl los thickness layers
user defined dwl los thickness layers

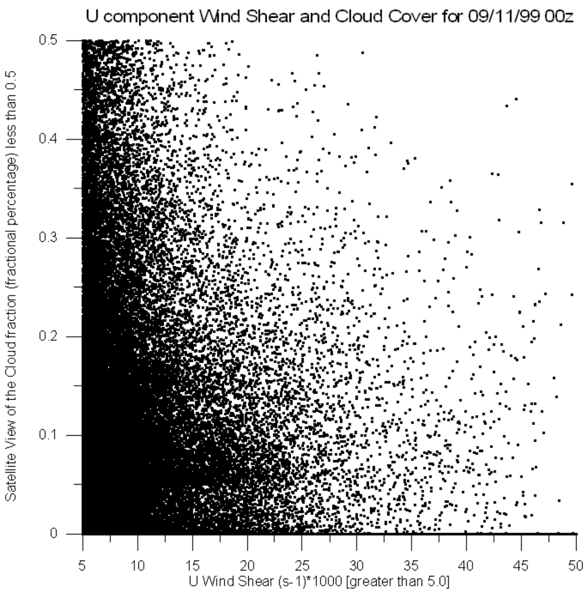


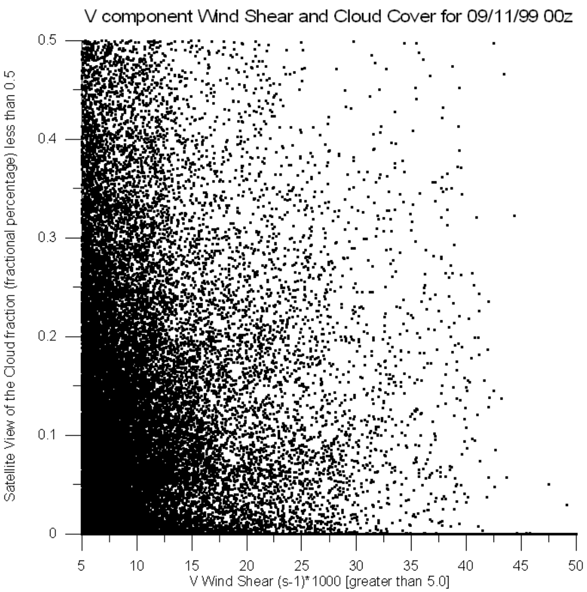
Simulated transmission of DWL lidar beam through cirrus as represented in Nature Run

Clouds and Shear









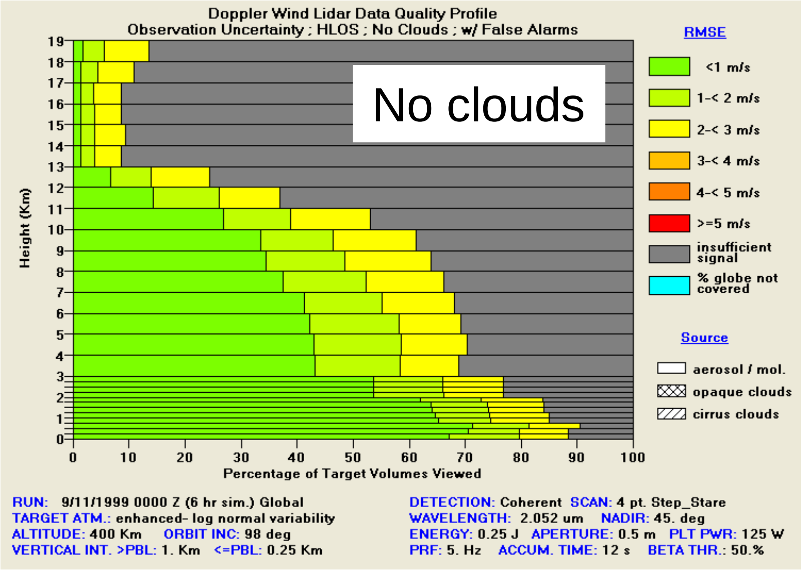
The Instrument

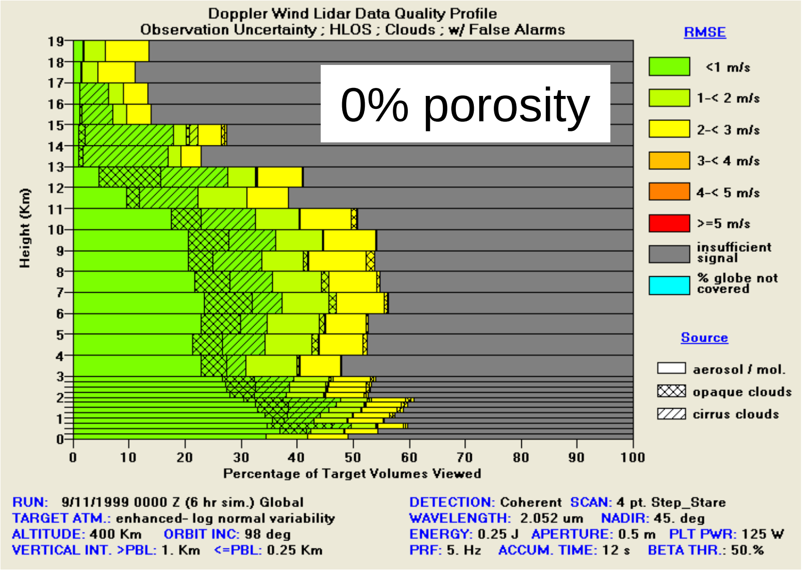
- Hybrid technology Doppler Lidar
  - Direct (molecular) detection for cloud free volumes and low aerosol loadings (mainly mid/upper troposphere and lower stratosphere)
  - Coherent detection for cloudy regions and “enhanced” aerosol loadings (mainly partly cloudy regions and PBL)
  - Use of both systems returns better data quality and coverage with smaller critical instrument components (lasers and telescopes) than single technology approaches
- ISAL/IMDC (NASA/GSFC)
  - November/December 2006 review of instrument concepts and mission scenarios with feasibility and cost conclusions

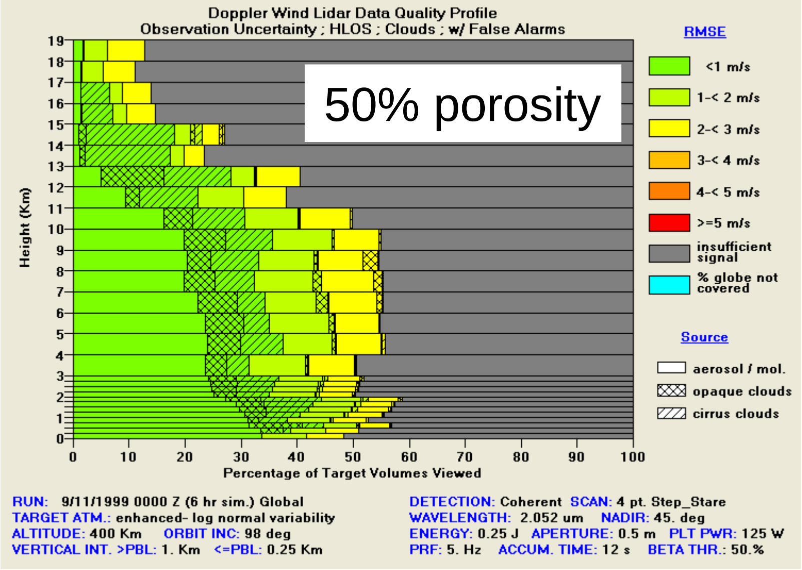
Performance modeling

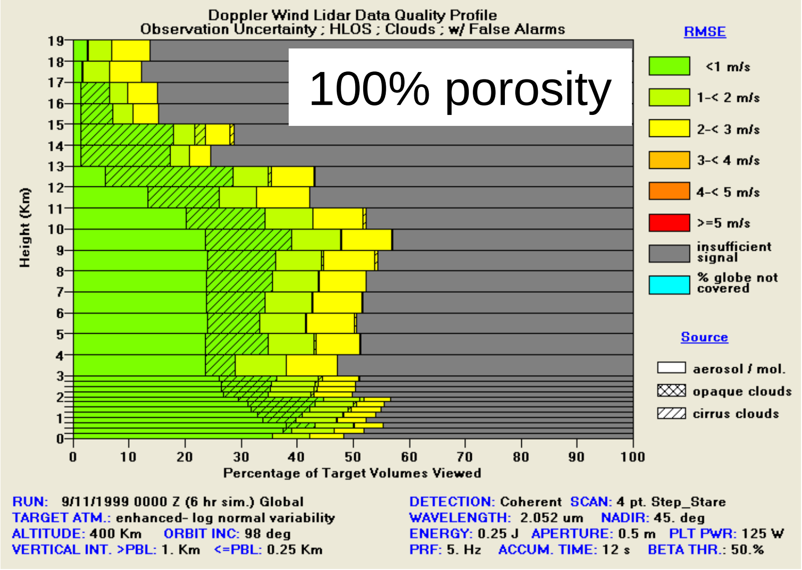
- The DWL community has available tools for simulating future DWL instrument and mission concepts
  - Doppler Lidar Simulation Model (DLSM/SWA)
  - Observing System Simulation Experiments (OSSEs by NOAA, NASA & DoD; NPOESS/IPO major funding)
    - Nature Runs are used as truth
- Performance profiles
  - Generated by running DLSM on Nature Runs
  - Summarizes vertical coverage of the simulated DWL data products and their accuracy
  - Uses “background” and “enhanced” aerosol distributions to bracket performance
  - Much emphasis on clouds

Cloud Porosity





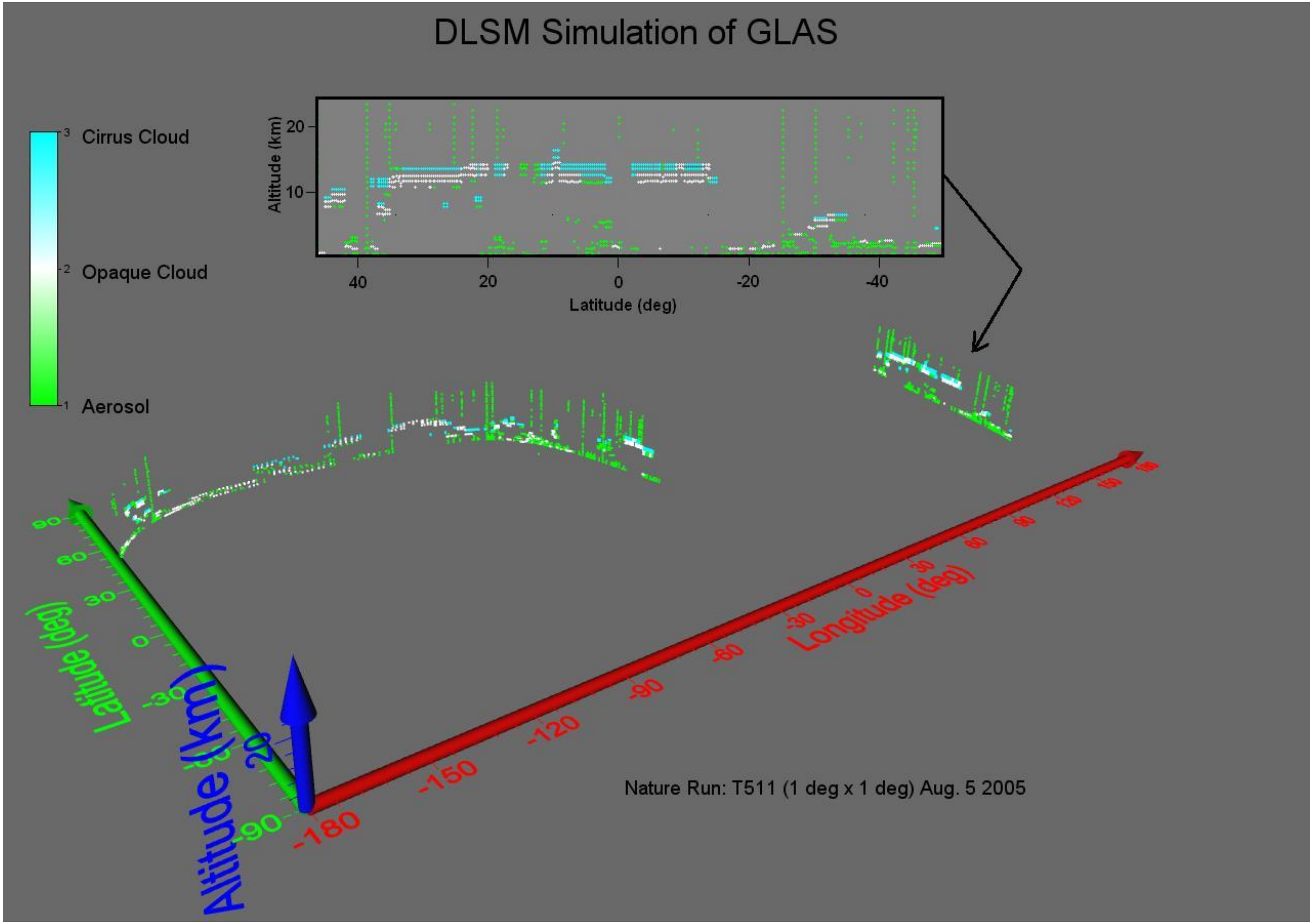




Porosity Summary

- For the coherent subsystem of the hybrid DWL, the vertical coverage of the data products meeting the requirements are reasonably “cloud proof ”.
- A remaining issue is how the utility of cloud returns (actual horizontal motion of the cloud particles) differs from those from the adjacent aerosols.

Simulating GLAS/CALIOP with T511


DLSM Simulation of GLAS
Cirrus Cloud
Opaque Cloud
Aerosol
Altitude (km)
Latitude (deg)
Longitude (deg)
Nature Run: T511 (1 deg x 1 deg) Aug. 5 2005

Summary

- The T511 cloud distributions (vertical and horizontal), in general, compare best with the HIRS cloud climatology.
- The NR understates the presence of thin cirrus as detected by GLAS and CALILOP.
- An algorithm to adjust the NR ice cloud coverage yields better comparisons with the GLAS and CALIOP findings.