CLOUD TOP PROPERTIES:

RESULTS AND VALIDATION OF HEIGHTS, EIGHT YEAR HIRS TRENDS, PROGRESS WITH CLOUD PHASE, AND OTHER PROPERTIES

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difficulty estimating cirrus cloud parameters
validation of CO2 heights with lidar
comparisons with SAGE
observations of sub-visible cirrus
eight year HIRS cloud trends
progress estimating cloud phase
opportunities for particle size and IWP
conclusions

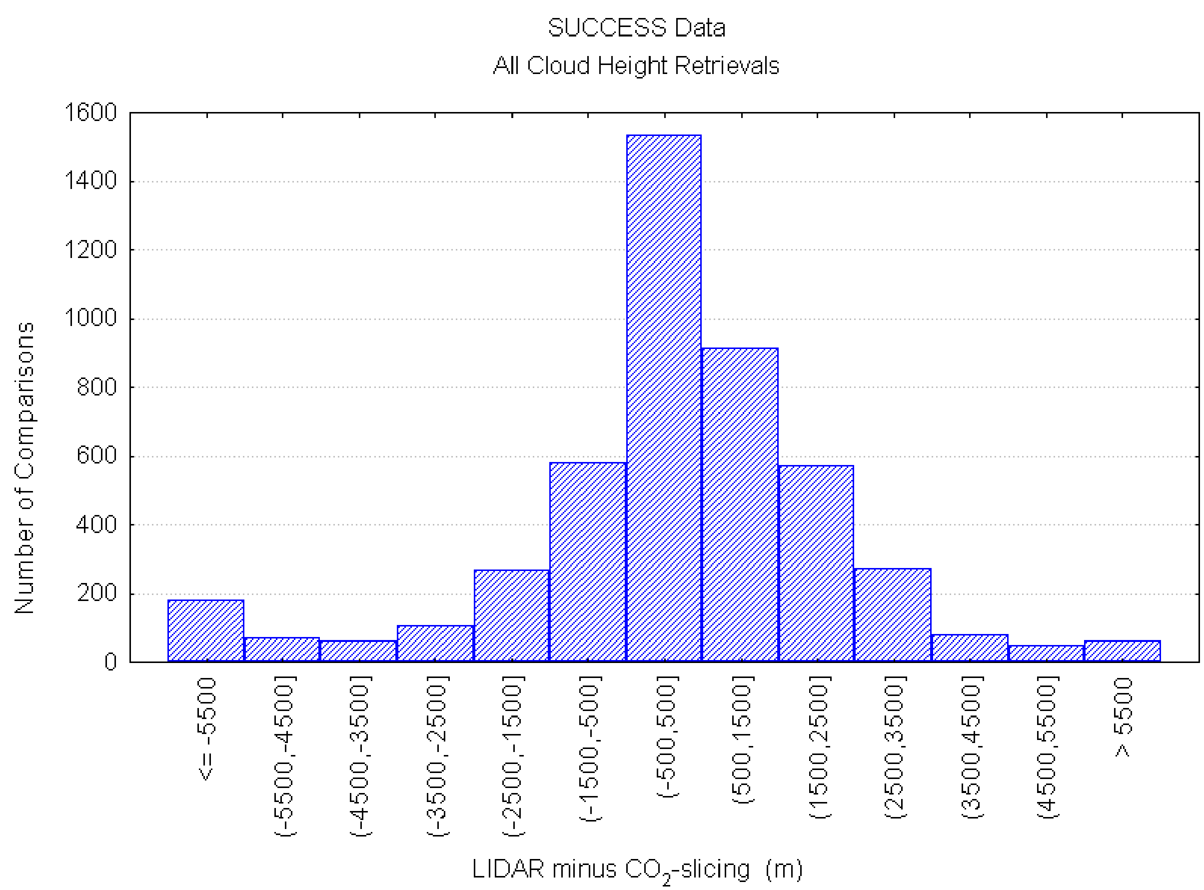
CO2 heights validated against lidar measurements during SUCCESS

4700 MAS and CLS co-located measurements of cloud height compared well

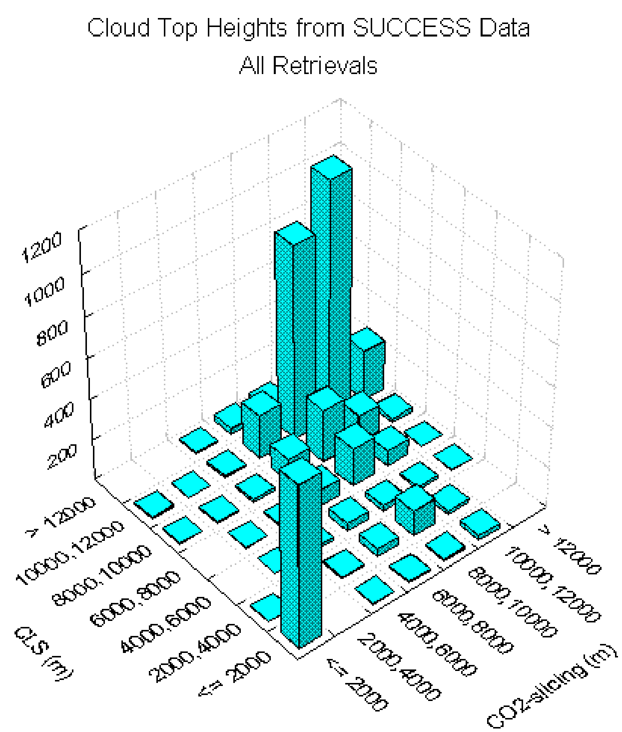
1/3 within 500 m
2/3 within 1500 m

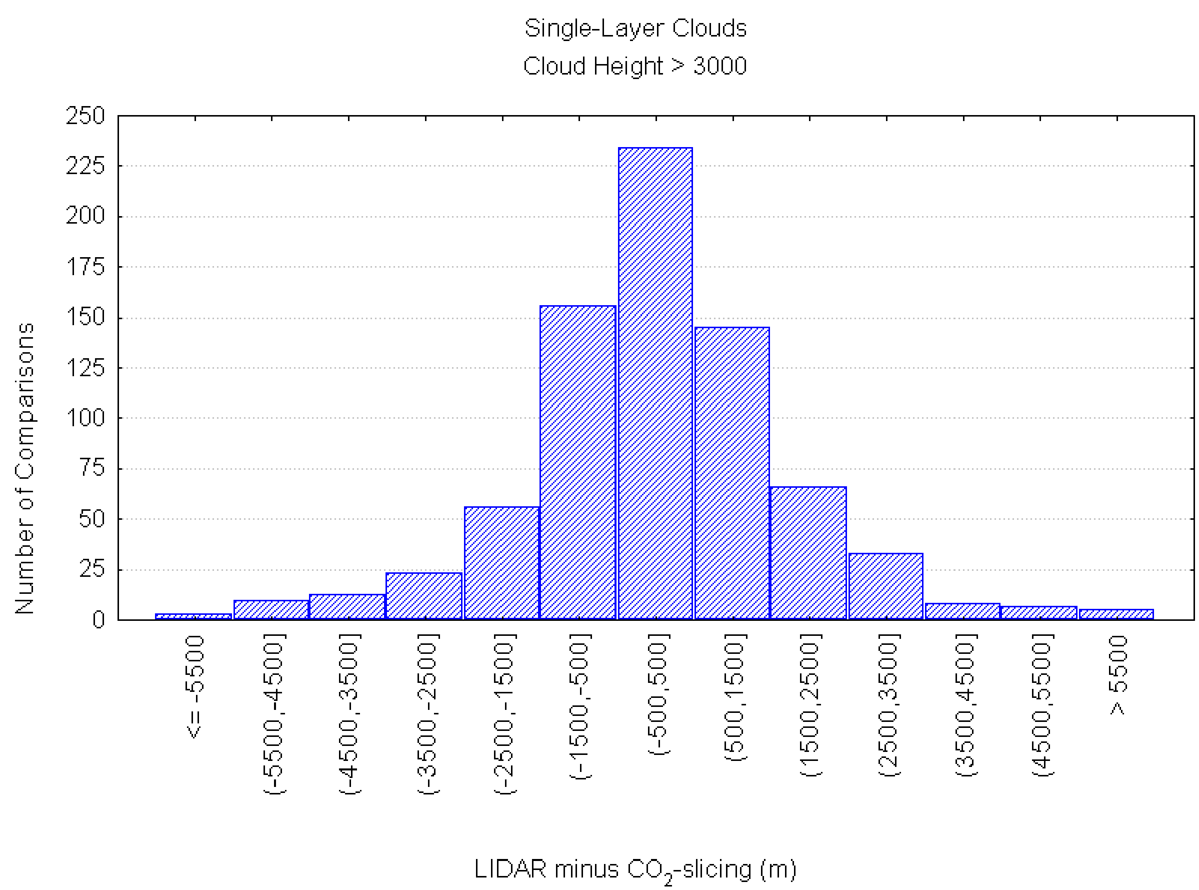
Optically thin clouds (of which 3/4 are multi-layer) show a little more scatter

within 2 km in large majority

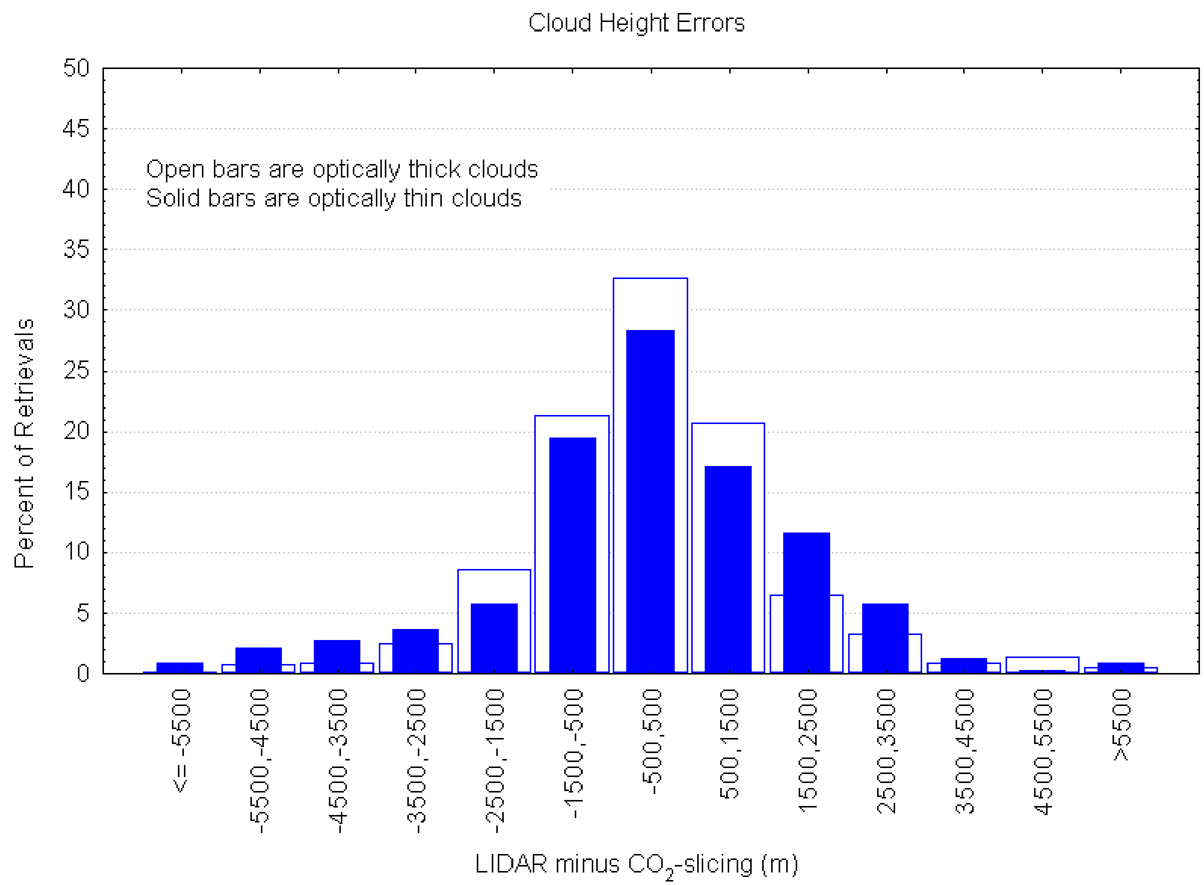


SUCCESS Data
All Cloud Height Retrievals
Number of Comparisons
0
200
400
600
800
1000
1200
1400
1600
<= -5500
(-5500,-4500]
(-4500,-3500]
(-3500,-2500]
(-2500,-1500]
(-1500,-500]
(-500,500]
(500,1500]
(1500,2500]
(2500,3500]
(3500,4500]
(4500,5500]
> 5500
LIDAR minus CO2-slicing (m)


Cloud Top Heights from SUCCESS Data
All Retrievals
1200
1000
800
600
400
200
> 12000
10000,12000
8000,10000
6000,8000
4000,6000
2000,4000
<= 2000
CLS (m)
<= 2000
2000,4000
4000,6000
6000,8000
8000,10000
10000, 12000
> 12000
CO2-slicing (m)



Single-Layer Clouds
Cloud Height > 3000
Number of Comparisons
0
25
50
75
100
125
150
175
200
225
250
<= -5500
(-5500,-4500]
(-4500,-3500]
(-3500,-2500]
(-2500,-1500]
(-1500,-500]
(-500,500]
(500,1500]
(1500,2500]
(2500,3500]
(3500,4500]
(4500,5500]
> 5500
LIDAR minus CO_2-slicing (m)


Cloud Height Errors
Percent of Retrievals
0
5
10
15
20
25
30
35
40
45
50
Open bars are optically thick clouds
Solid bars are optically thin clouds
<= -5500
-5500,-4500
-4500,-3500
-3500,-2500
-2500,-1500
-1500,-500
-500,500
500,1500
1500,2500
2500,3500
3500,4500
4500,5500
>5500
LIDAR minus CO2-slicing (m)

Comparison with SAGE (1989 - 1991)

sensitivity to thin cloud

- subvisual SAGE vis optical depth > 0.0002
- opaque SAGE vis optical depth > 0.02
- HIRS vis optical depth > 0.1

global averages

SAGE	87%
HIRS	76%

seasonal comparison

- good (within 5%) in winter and tropics
- SAGE finds up to 15% more clouds in summer

geographical

- good comparison for clouds above 5 km (corr .8 to .9)
- SAGE sub-visual cirrus found above but correlated in location with most HIRS clouds

Global Cloud Statistics

effect of clouds on global radiative processes large

- 1% change in global cloud cover equivalent to about 4% change in CO_2 concentration

accurate determination of global cloud cover has been elusive

- semi transparent clouds often underestimated by 10%

CO_2 technique uses multispectral approach to better characterize global semi-transparent clouds

- Over 60 million observations processed from eight years of HIRS data (Jun 89 through Feb 97)

Clouds found in eight year HIRS CO2 slicing study
(June 1989 - Feb 1997)

Summer (Jun, Jul, Aug)				Winter (Dec, Jan, Feb)			
all	thn	thck	opq	all	thn	thck	opq
hi				hi			
34	15	14	5	34	15	15	4
mid				mid			
26	11	9	6	32	11	11	10
low				low			
45	0	0	45	47	0	0	47
all				all			
73	22	20	31	76	23	21	32

hi	> 6 km	thn	NE<.5
mid	3-6 km	thck	NE<.95
lo	< 3 km	opq	NE>.95

thin (thick) cloud IR optical depth defined to be less than 0.7 (3.0)

<u>Global Cloud Trends in UW HIRS Study</u>

global averages

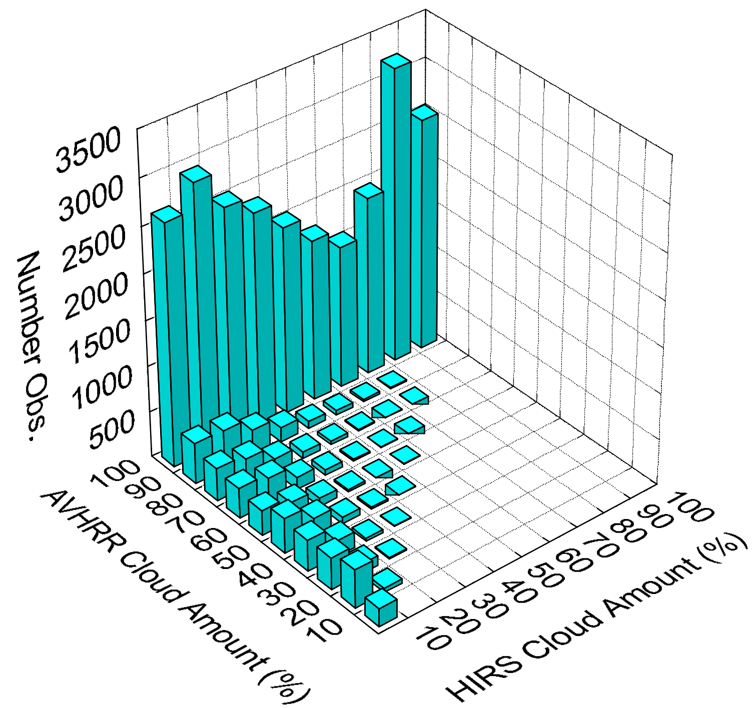
* clouds are found in 75% of all observations
  - they cover about 69% of 65N to 65S
* global preponderance of semi-transparent high clouds
  - 43% on the average between Jun 89 and Feb 97
* ITCZ shows high frequency of cirrus (greater than 50%)
* more cirrus in summer than winter in each hemisphere
* agreement with SAGE good in winters and tropics
* small ice particle clouds (jet contrails, cirrus)
  - often subvisible
  - remain for many hrs
  - can be highly IR absorbing

global trends

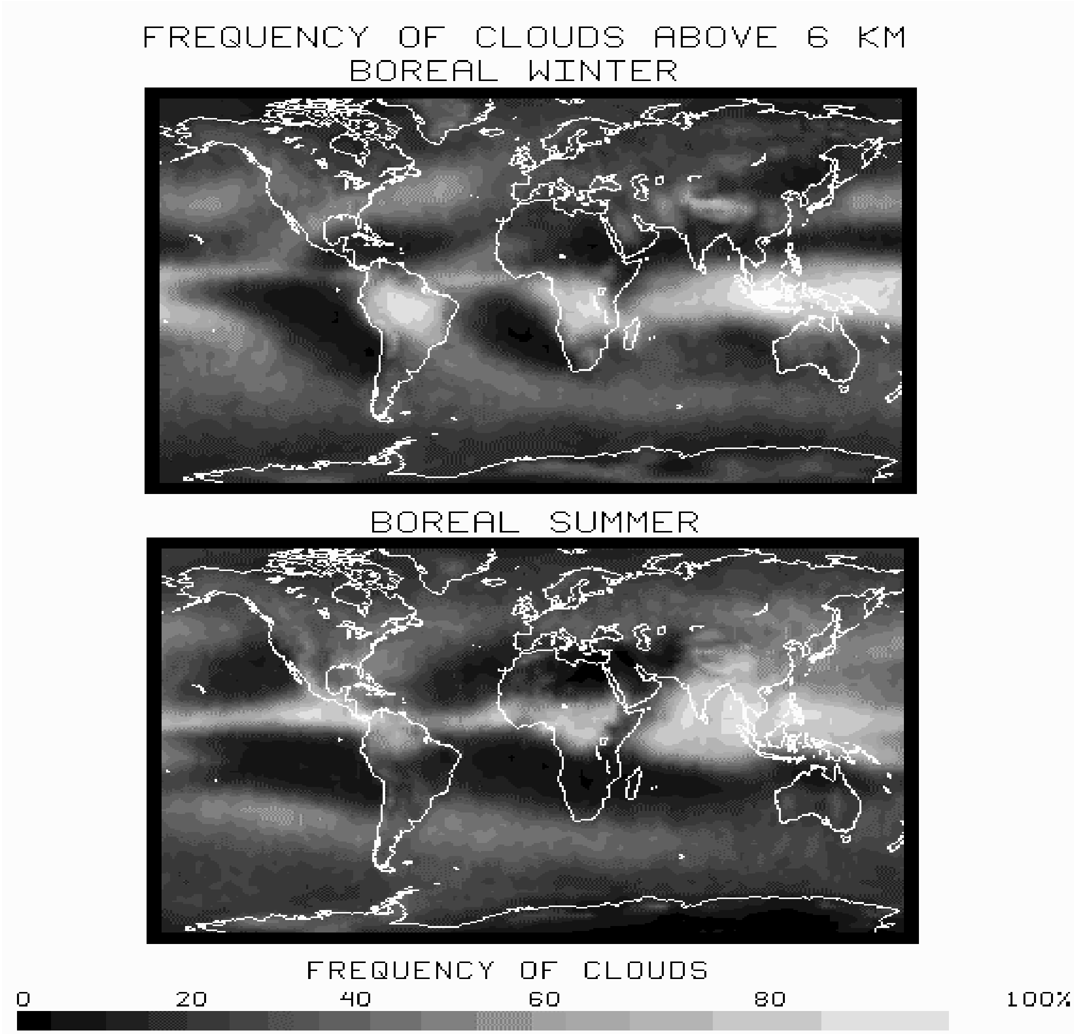
* global cloud cover remaining roughly constant
  - annual trends small wrt seasonal differences
  - NOAA-11 orbit drift caused false signals
* gradual increase of hi clds in north-mid-lats

home page for UW HIRS cloud work * http://wylie.ssec.wisc.edu

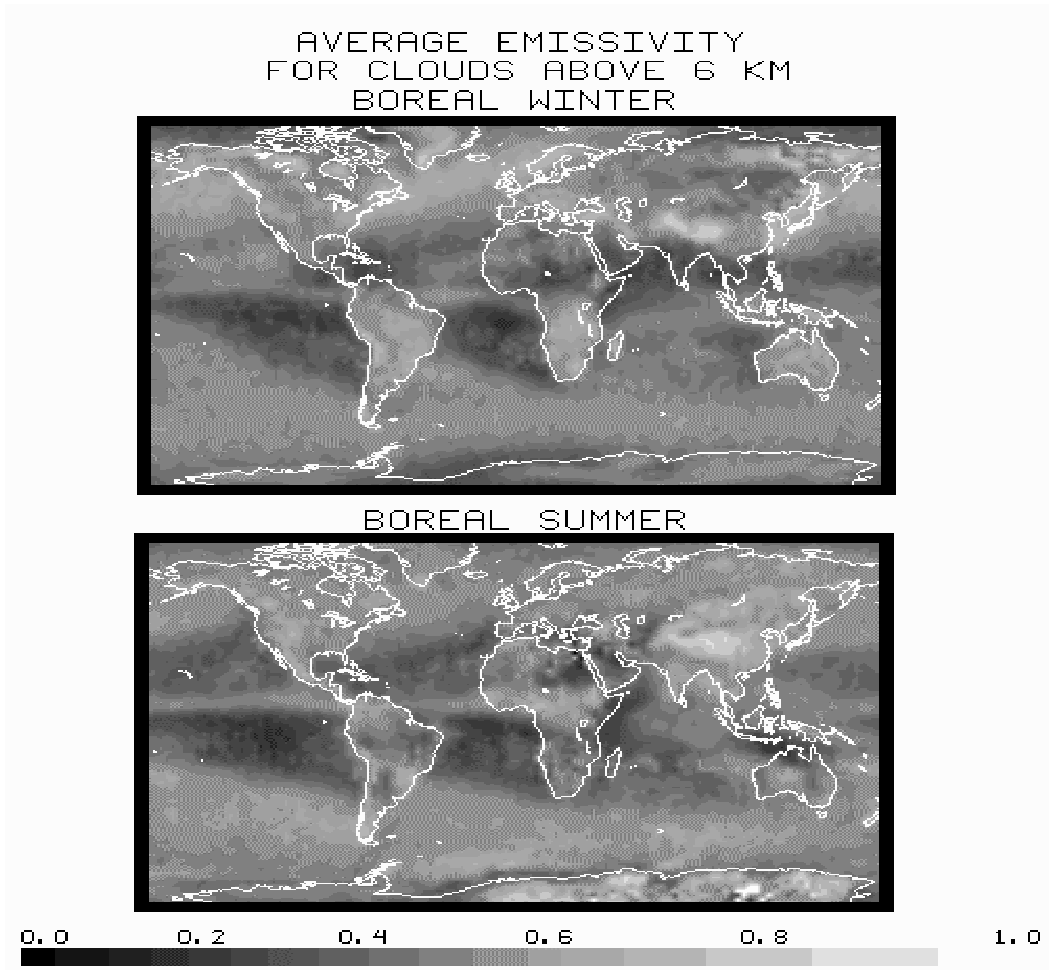
Cloud Amounts from HIRS and Collocated AVHRR Data
Cloud Heights < 700 mb from 20-40 N Latitude
July 1994



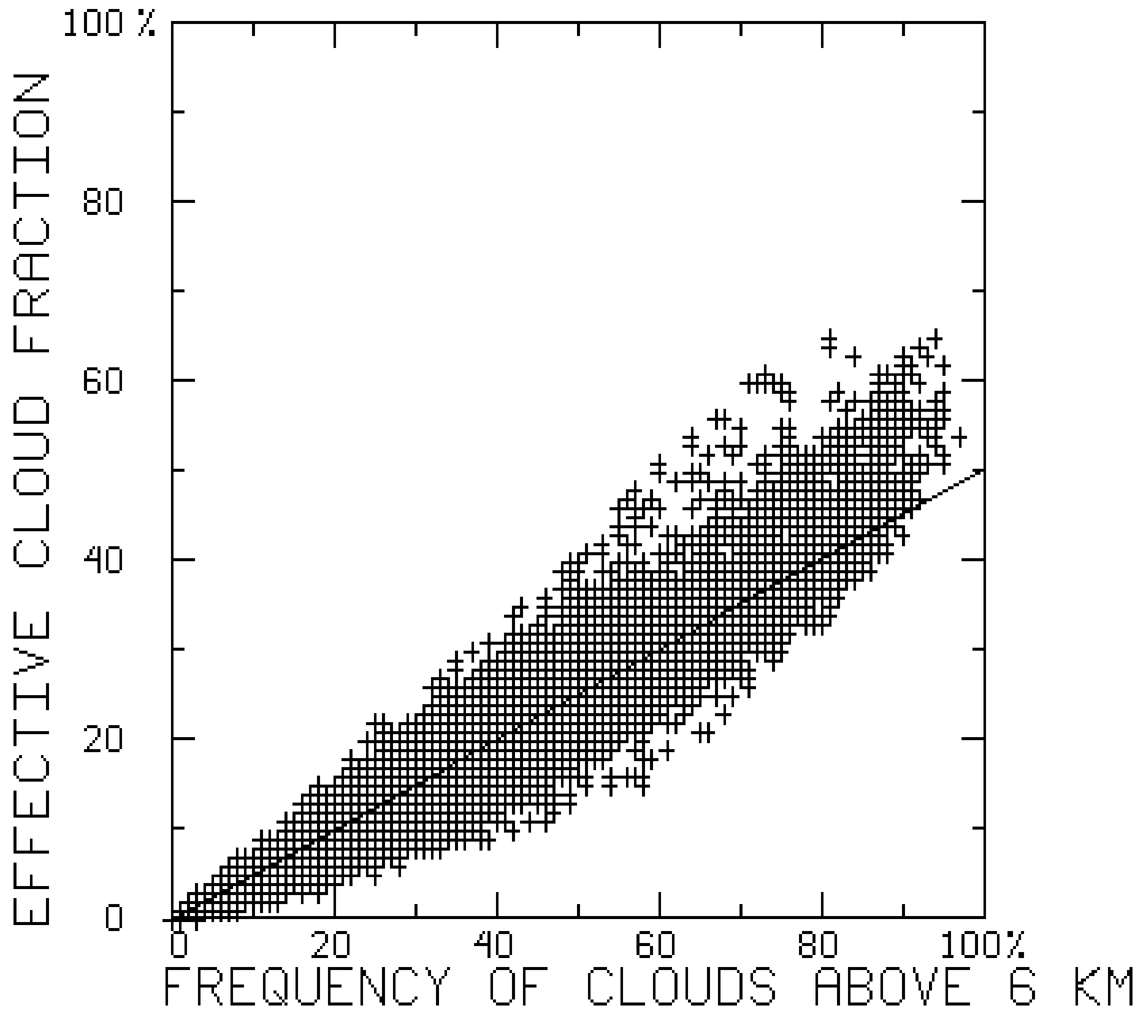
AVHRR cloud coverage within a HIRS FOV plotted against HIRS effective emissivity (effective cloud amount) for clouds above 700 hPa in the tropical oceans from 20 to 40 N latitude for July 1994.



The frequency of high (above 6 km) cloud detection in a HIRS FOV from 1989 to 1997.

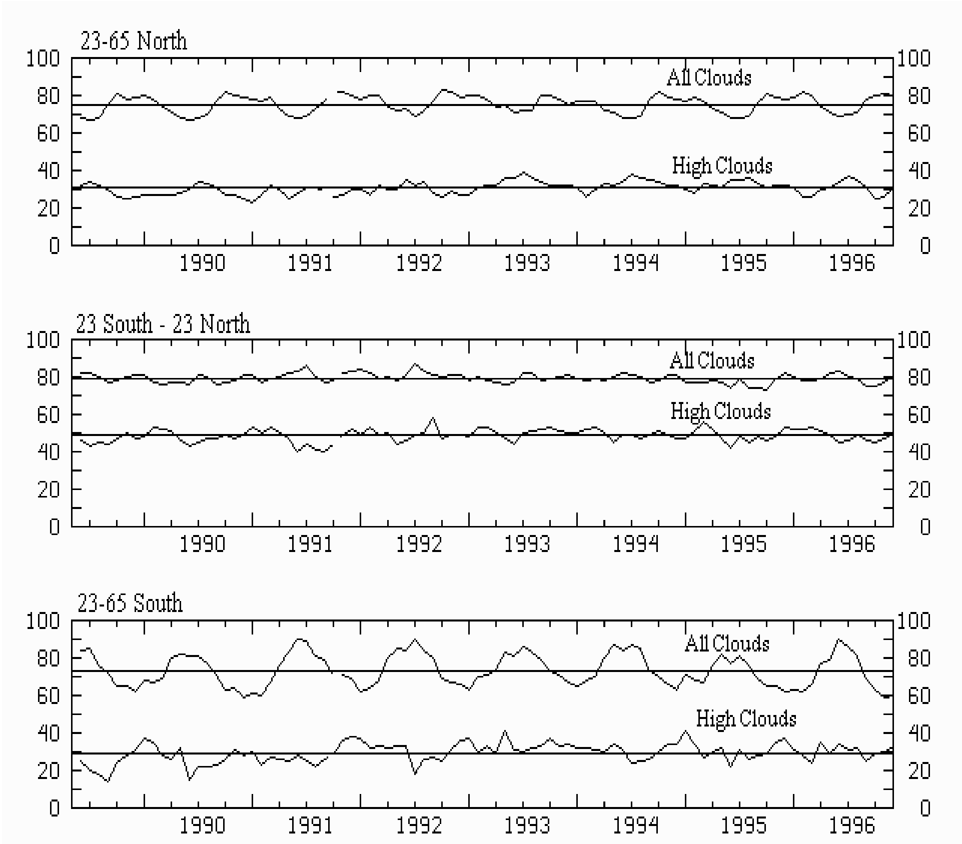


The mean Effective Emissivity (Nε) derived from the HIRS data from 1989 to 1997.



The Effective Cloud Fraction (CF_6) versus the frequency of clouds above 6 km.

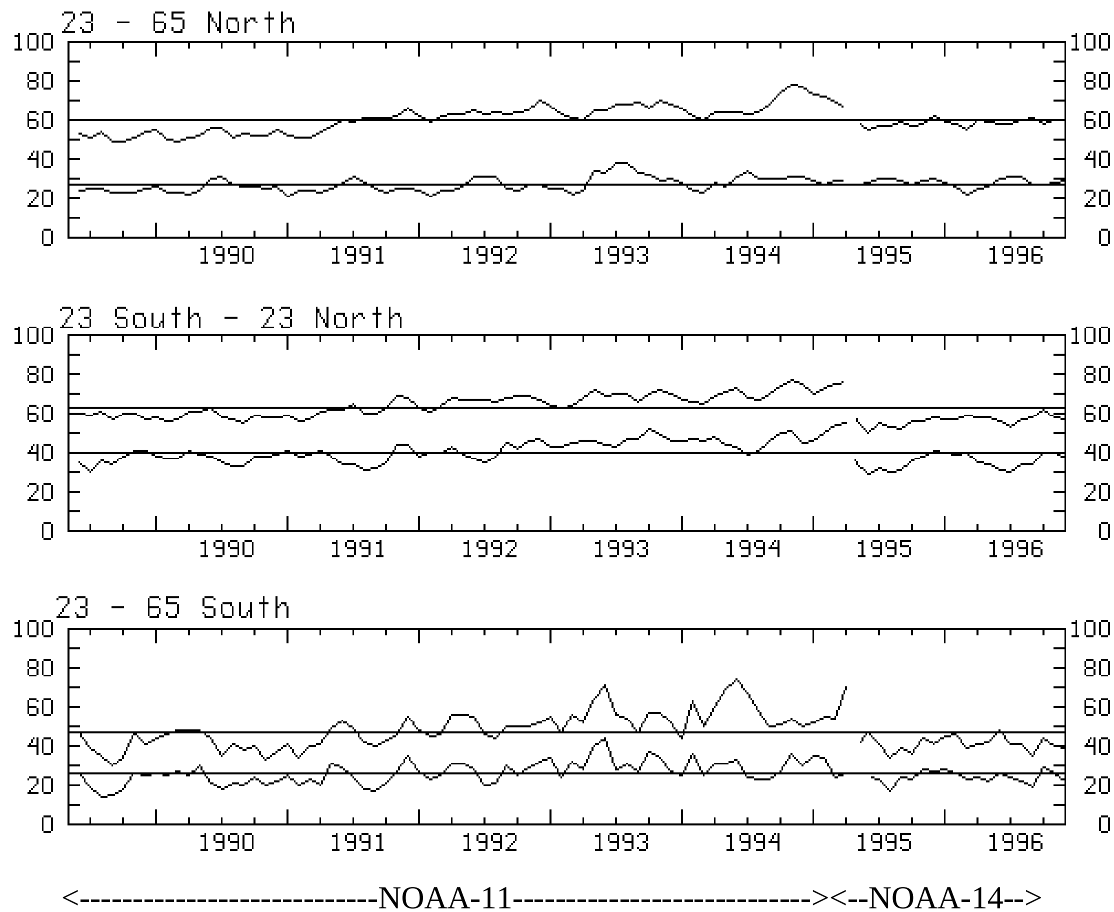
FREQUENCY OF CLOUD DETECTION IN HIRS FOV OVER LAND



<----NOAA-10----><---------NOAA-12--------------------->

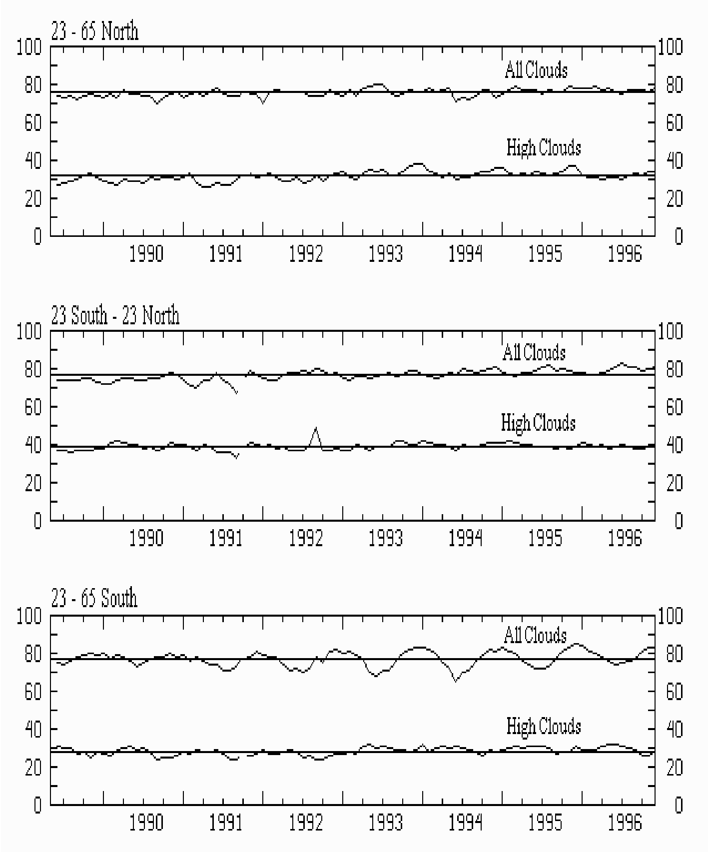
The frequency of all clouds (upper line) and high clouds above 440 hPa (lower line) over land for the sunrise and sunset satellites, NOAA 10 and 12. The three panels are for latitude belts of 23°-65 ° north, 23° S-23° N, and 65°-23° south as in Figure 8.

FREQUENCY OF CLOUD DETECTION IN HIRS FOV OVER LAND



The cloud frequencies over land for the midday and midnight satellites NOAA 11 and 14.

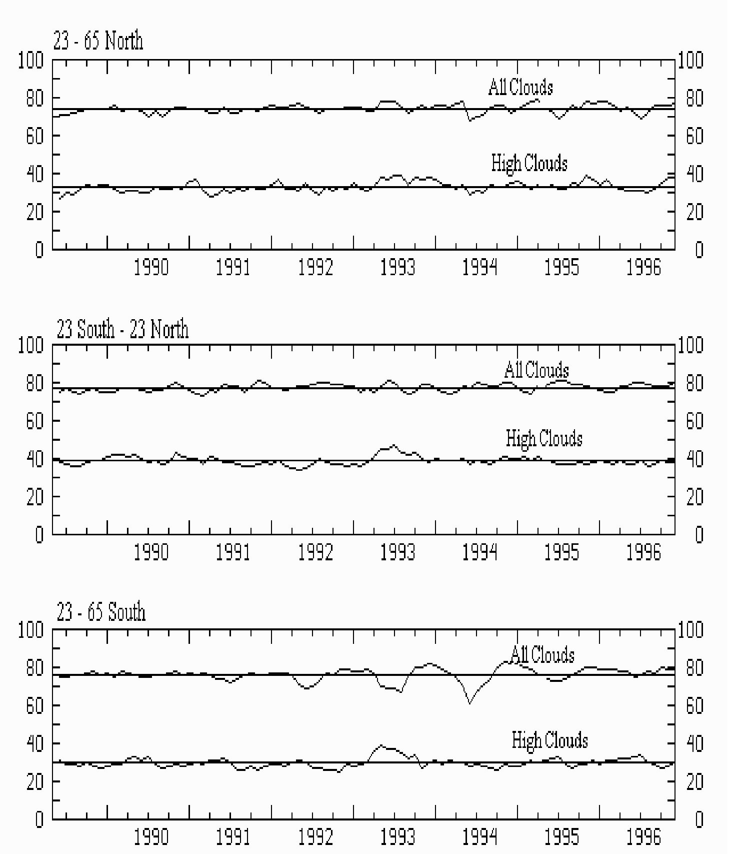
FREQUENCY OF CLOUD DETECTION IN HIRS FOV OVER OCEANS



<--NOAA-10--><-----------------NOAA-12-------------->

The cloud frequencies over water for sunrise and sunset satellites NOAA 10 and 12.

FREQUENCY OF CLOUD DETECTION IN HIRS FOV OVER OCEANS



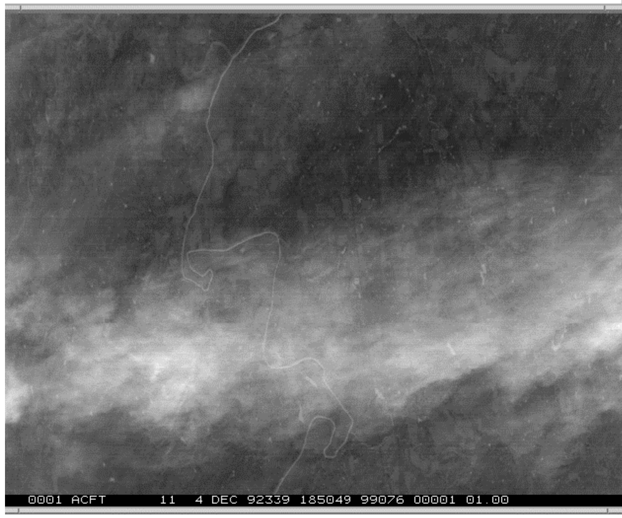
<------------------NOAA-11-------------------><-NOAA-14->

The cloud frequencies over water for midday and midnight satellites NOAA 11 and 14.

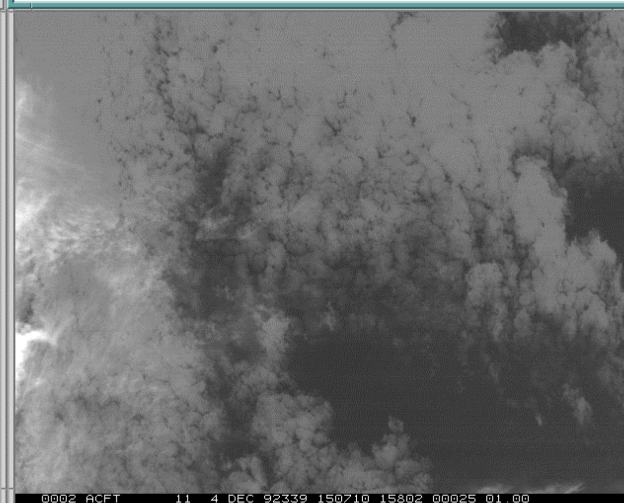
Micro- and macro-physical properties of cirrus clouds

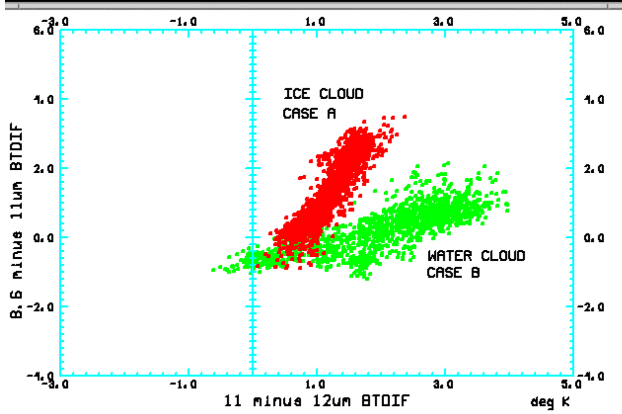
* cloud phase estimated from 8.6 – 11 and 11-12 Tb differences
    thin cirrus detected reliably
    mixed clouds present problems
* cloud forcing spectra studied between 700 and 1300 cm^{-1}
    sensitivity to particle size (4.5 to 22.5 um), and
    ice water path (7 to 50 g/m2),
    calc and meas agree within 2 K in 800-1000 cm^{-1}
    small from large particle clouds distinguished
    small ice particle clouds exhibit *S*-shaped cloud forcing
    opaque when IWP > 50 gm^{-2} (130 gm^{-2}) and r_{eff} = 7.5 µm (30µm)
* potential for MODIS to contrast large/small particle and IWP cirrus
    using IR window channel radiances

CASE A - THIN ICE CLOUD
MAS BAND 11



CASE B - WATER CLOUD
MAS BAND 11





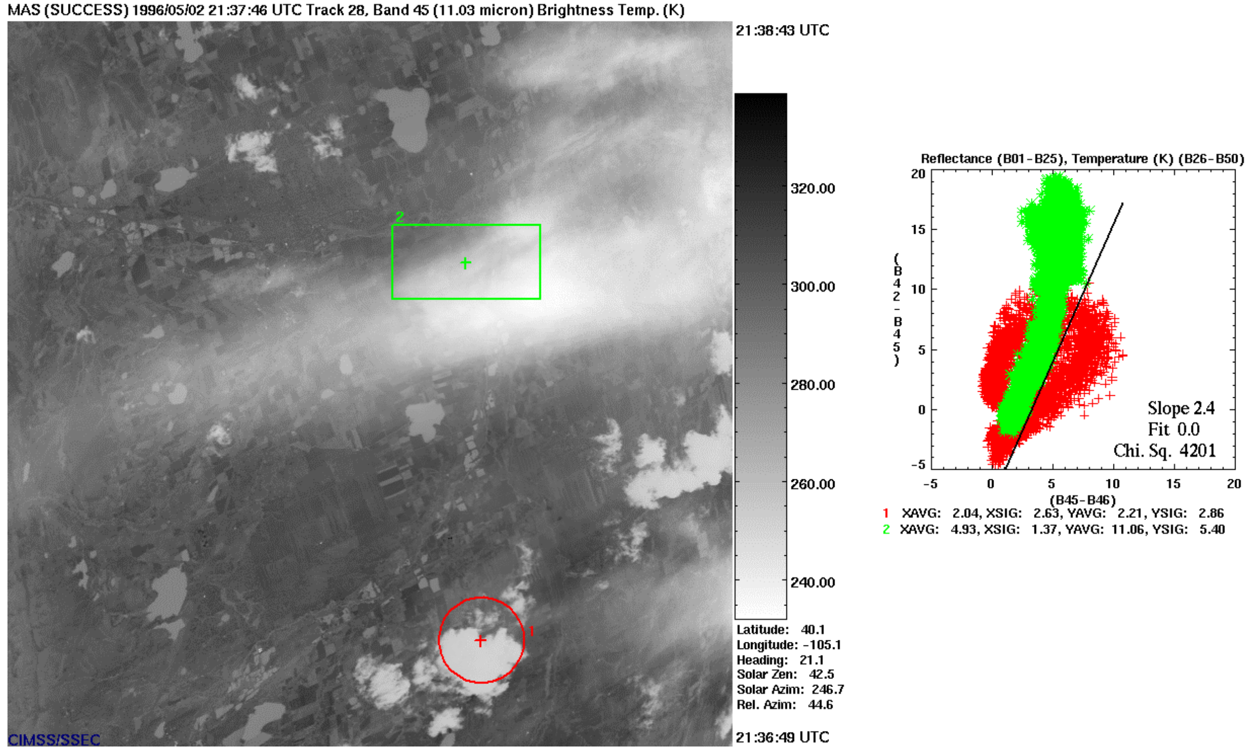
SPECTRAL SIGNATURE OF

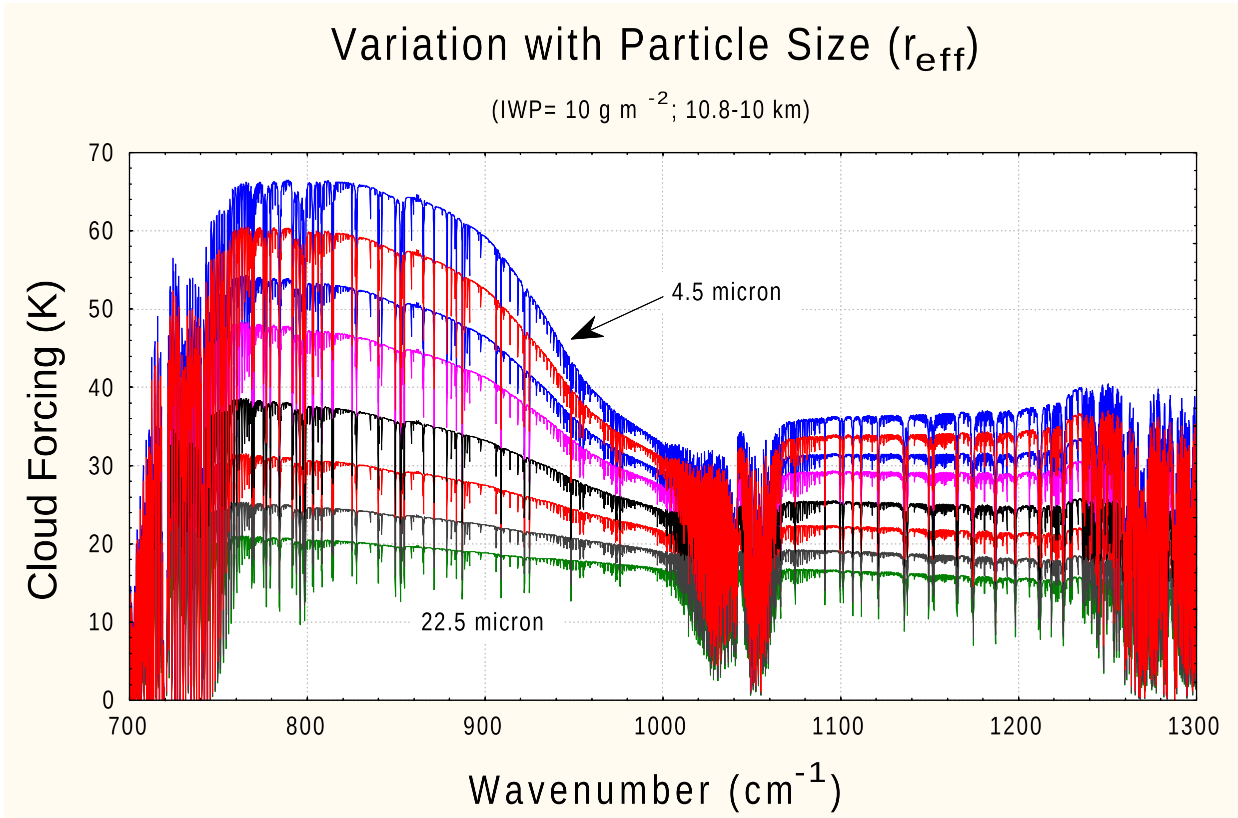
CLOUD PROPERTIES

AS DETERMINED BY
BRIGHTNESS TEMPERATURE DIFFERENCING
OF MODIS AIRBORNE SIMULATOR
INFRARED CHANNELS

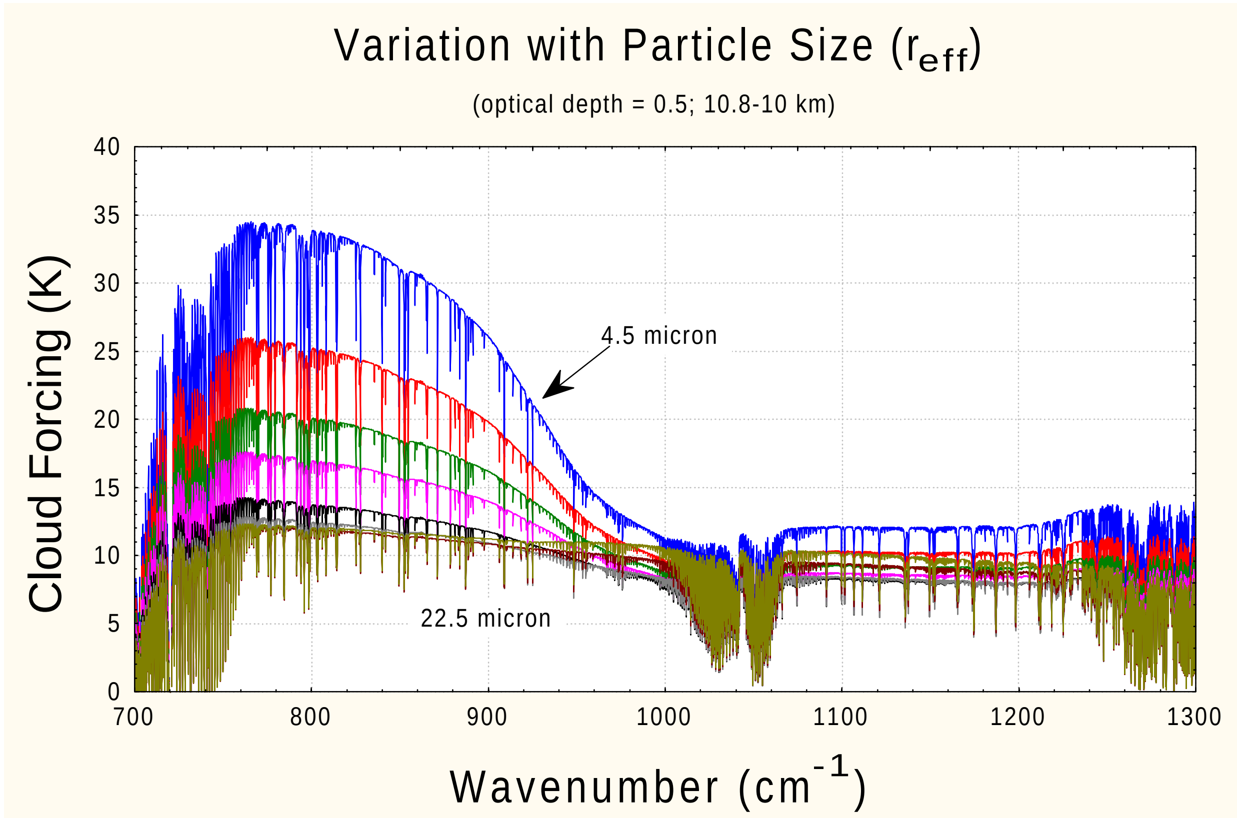
MAS FLIGHT
5 DECEMBER 1991

MAS (SUCCESS) 1996/05/02 21:37:46 UTC Track 28, Band 45 (11.03 micron) Brightness Temp. (K)

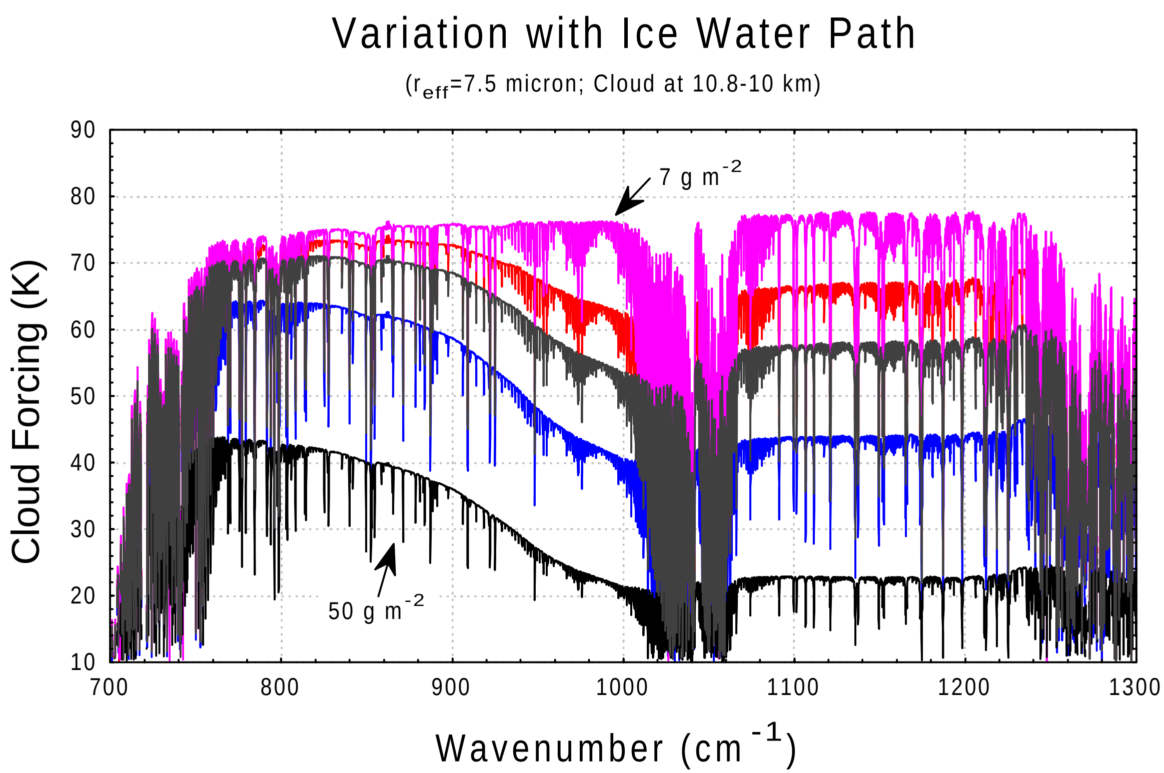




The sensitivity of high spectral resolution observations to variations in cloud particle effective radius. Cloud forcing represents the brightness temperature difference between a clear and a cloudy sky calculation. Eight different effective radii are assumed, they are (from the top curve to the bottom) 4.5, 6.0, 7.5, 9.0, 12.0, 15.0, 18.75, and 22.5 μm. The cloud has a constant IWP of 10 gm^{-2} and a cloud top altitude of 10.8 km.



The sensitivity of high spectral resolution observations to variations in cloud particle effective radius. Cloud forcing represents the brightness temperature difference between a clear and a cloudy sky calculation. Six different effective radii are assumed, they are (from the top curve to the bottom) 4.5, 6.0, 7.5, 9.0, 12.0, 15.0, 18.75, and 22.5 μm. The cloud has a constant optical depth at 1000 cm^{-1} of 0.5 and the cloud top altitude is 10.8 km.



Cloud forcing as a function of wavenumber for 5 different IWPs: 50, 30, 22.5, 15 and 7.0 gm^{-2} (from top to bottom). The clouds have the same r_{eff} of 7.5 μm, a cloud top altitude of 10.8 km, and a thickness of 0.8 km.

Conclusions

Definition of Cloud Top Properties with MODIS still appears to be very promising

Validation of height algorithm with lidar data has progressed very well

Global HIRS detected cloud trends represent an interesting start to the pending MODIS work

Cloud phase work with trispectral approach showing good sensitivity to thin cirrus

Opportunities for IR estimation of cloud particle size and optical path seem promising

Validation post-launch will rely on intercomparison with aircraft and other EOS instruments