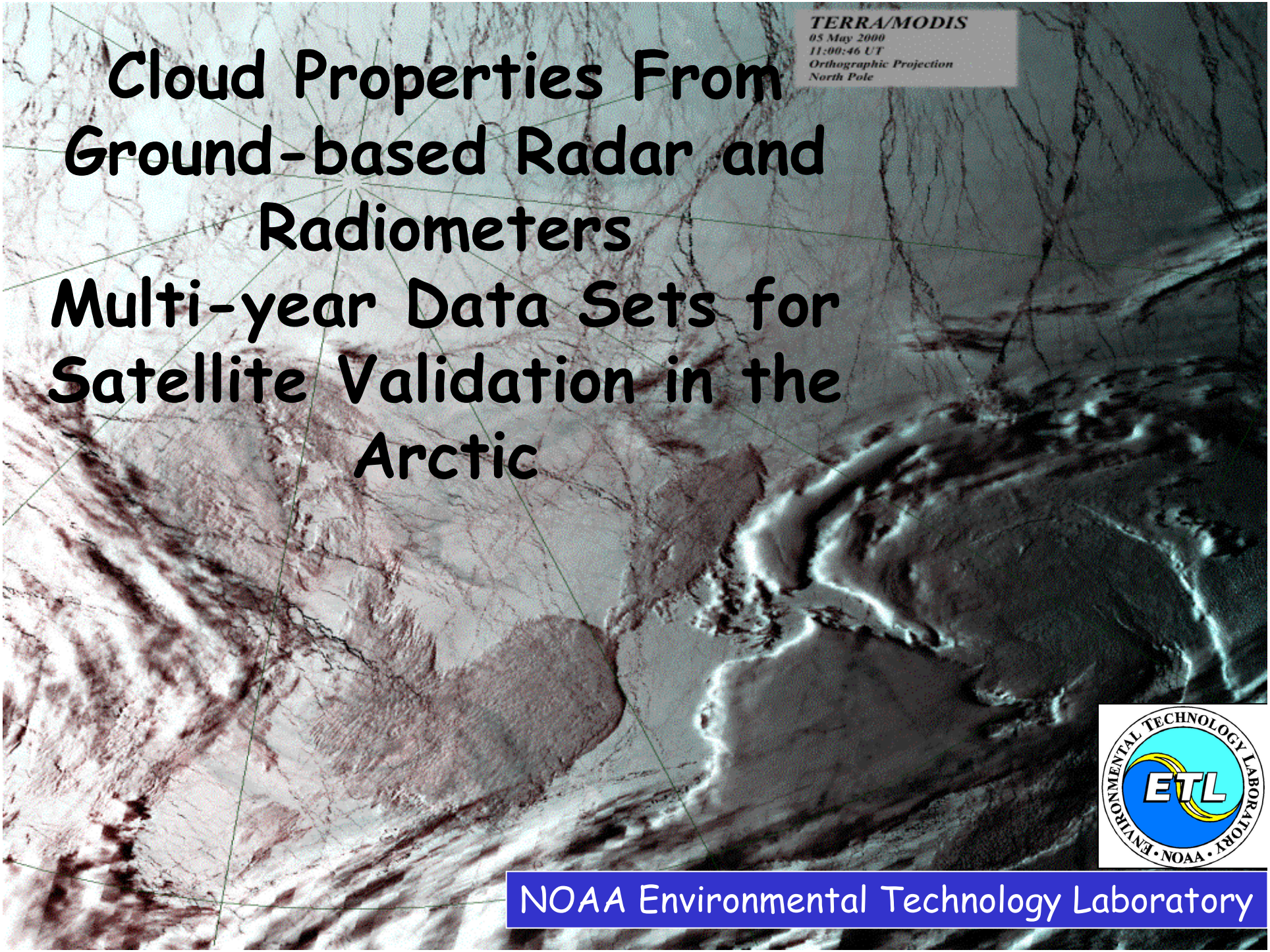


Cloud Properties From Ground-based Radar and Radiometers Multi-year Data Sets for Satellite Validation in the Arctic

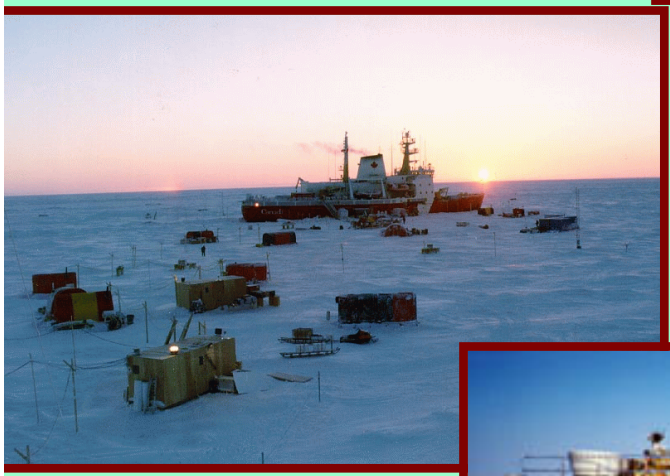
NOAA Environmental Technology Laboratory

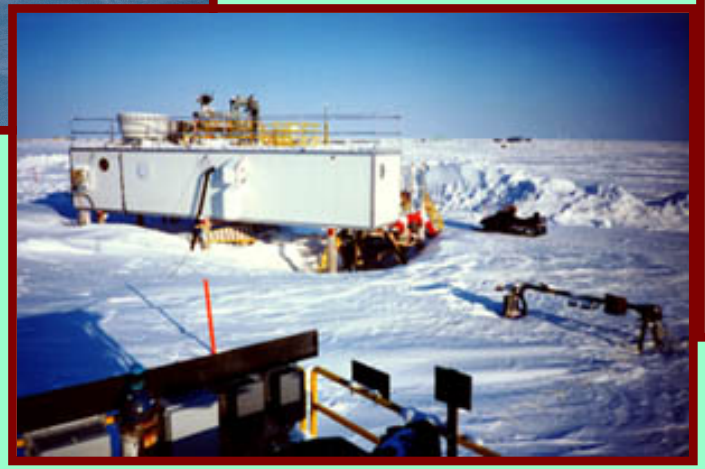
SHEBA

DOE/ARM/NSA

FIRE ACE

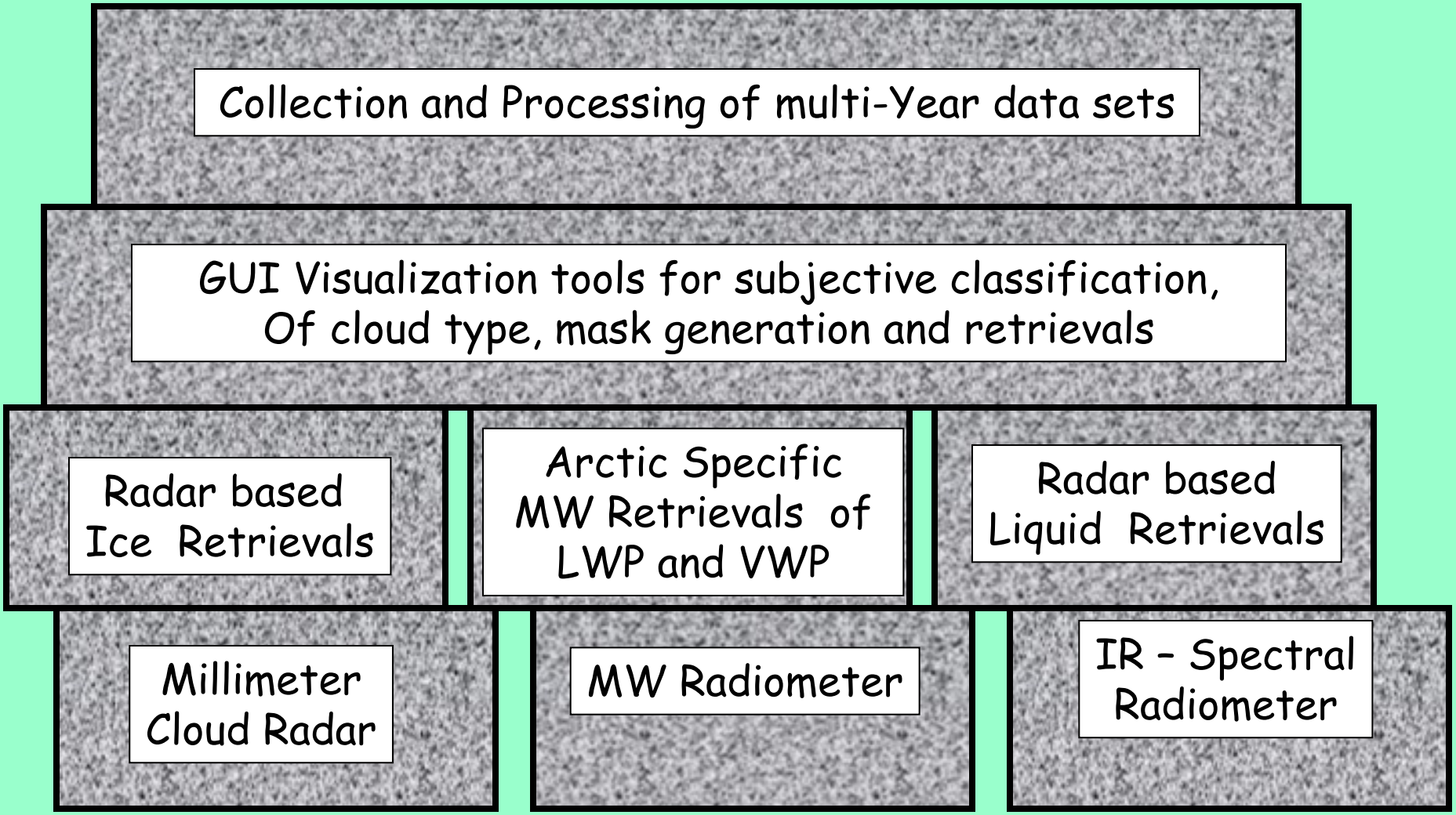
–





Instruments

ETL Building Blocks



Liquid Cloud Retrievals

Simple regressions between cloud parameters and radar reflectivity have the form:

$$LWC = a_1(N,\sigma)Z_e^{1/2} \qquad R_e = a_2(N,\sigma)Z_e^{1/6}$$

Advantages: Easy to apply, only used radar measurements.
Disadvantages: If a fixed set of coefficients is used the retrieval uncertainty due to inter-cloud and regional variability between clouds is quite high (LWC ~ 50-100%).

Region Specific: Can apply information on particle concentration (N) and width of the particle size distribution (σ) for a given geographic region to improve the coefficients. Using aircraft *in situ* FSSP measurements we have done this for the Arctic and SGP regions.

Radar-radiometer technique With the addition of the LWP derived from the microwave radiometer, a constraint can be put on the liquid cloud retrieval, which improves the general retrieval agreement with aircraft (LWC ~ 30%).

Requirements:
- Cloud must contain only liquid water.
- All liquid in column must be in all-liquid layers.
- Cloud cannot contain drizzle or precipitation.

$$LWC \propto LWP \frac{Z^{1/2}}{\sum_{clouddepth} Z^{1/2}}$$

Frisch et al., 1995 & 1998.

Ice Cloud Retrievals

Simple regressions between cloud parameters and radar reflectivity have the form:

$$IWC = aZ^b \qquad D_{mean} \propto \left(\frac{Z}{IWC}\right)^{1/1.9}$$

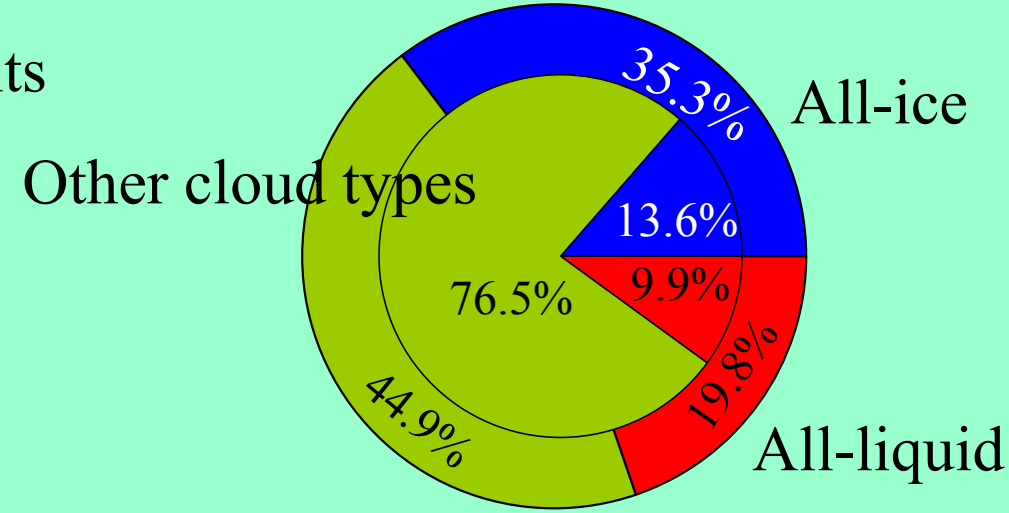
Advantages: Easy to apply, only radar measurements used.
Disadvantages: Such general relationships do not account for inter-cloud and regional variability of coefficients which can lead to large retrieval uncertainties (> a factor of 2)).

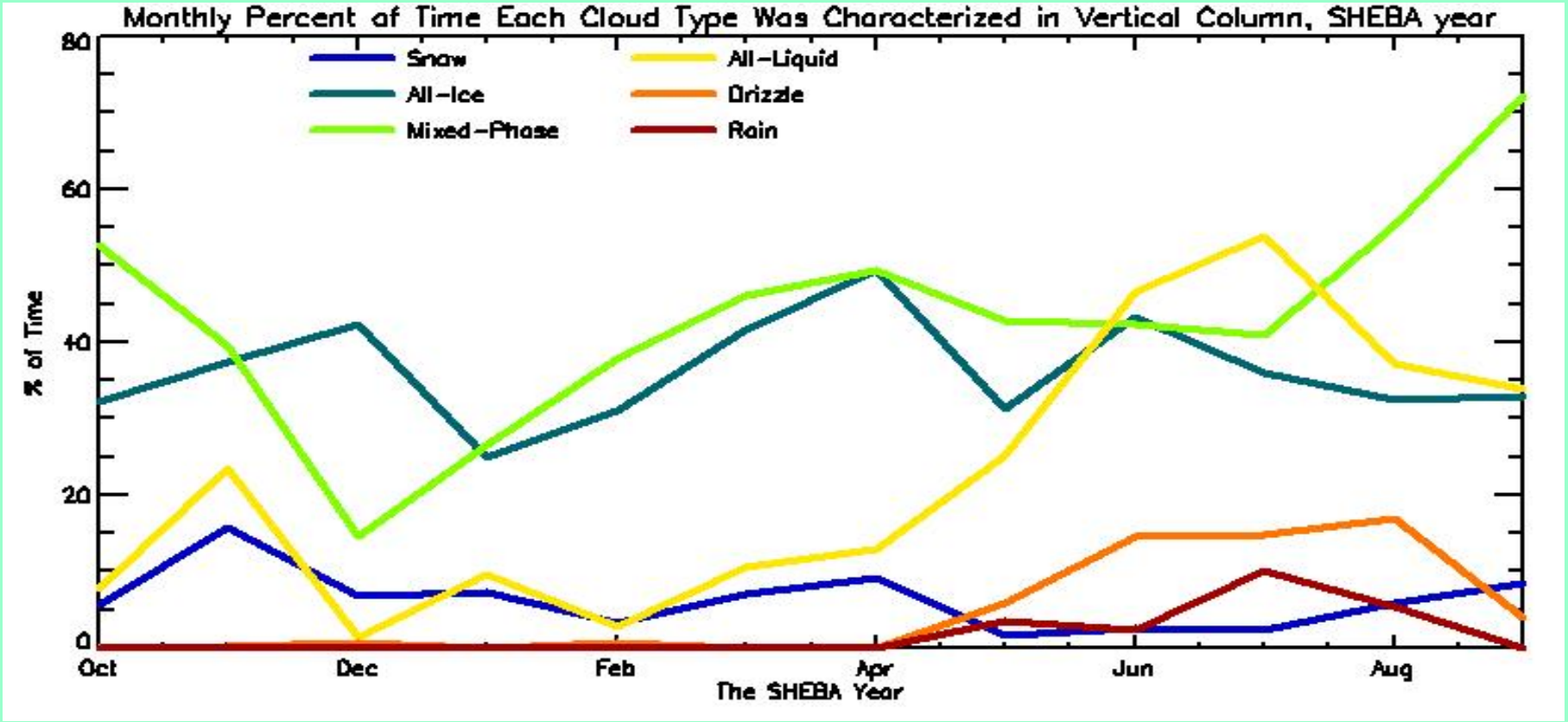
Radar-IR radiometer (tuned regression) Technique (Matrosov, 1999) Uses radiometer measurements of IR brightness temperature to effectively tune the "a" coefficient for a given cloud.
Advantages: Perhaps the most accurate ice cloud retrieval technique (IWC ~ 60% and Dmean ~ 30%) and a large improvement over any *a priori* empirical relationship.
Disadvantages: Any multi-sensor technique suffers from differing viewed scenes.
Requirements: No liquid in the atmospheric column.

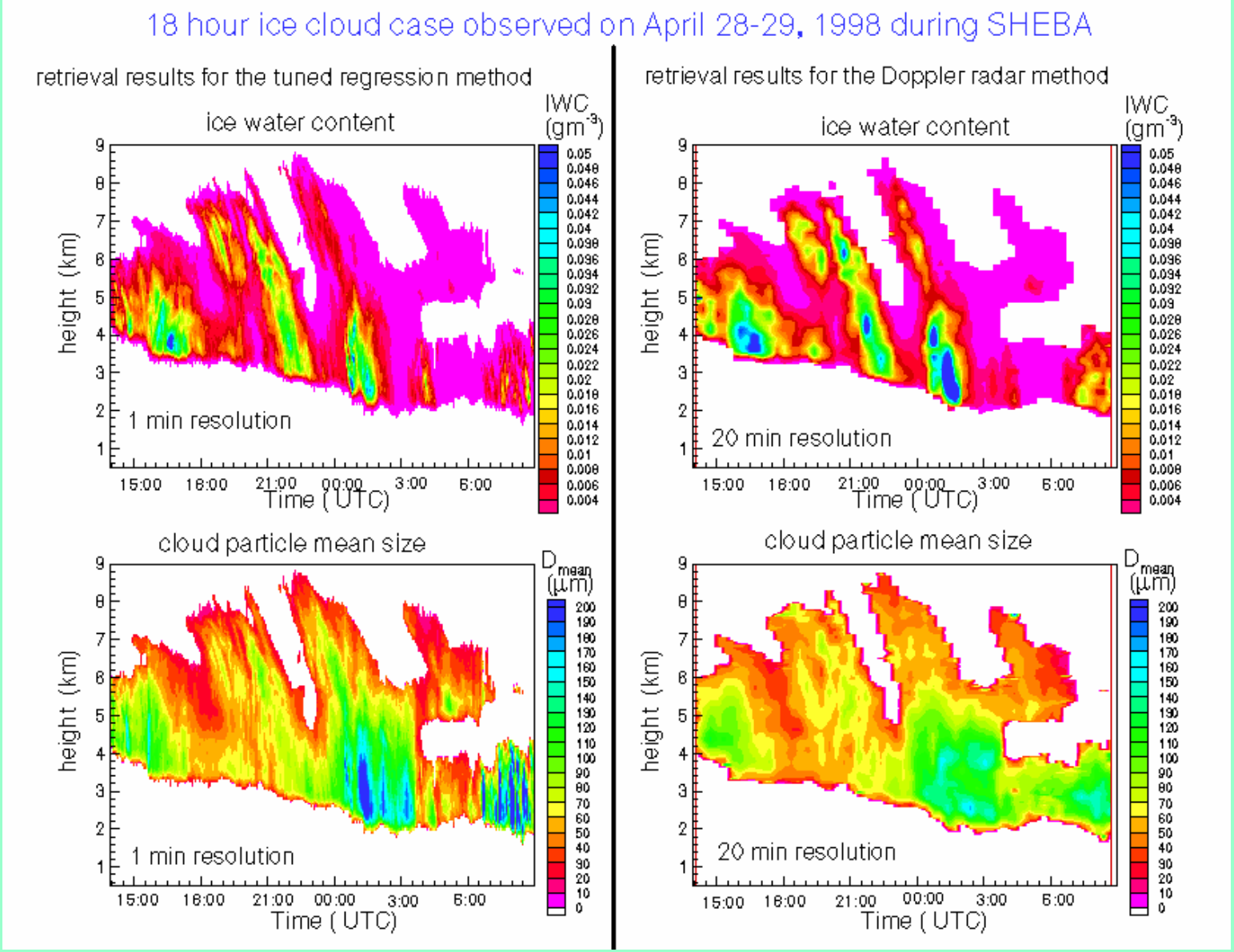
Reflectivity-Velocity Technique (Matrosov et al., 2002) Uses only radar measurements of reflectivity and Doppler velocity.

Advantages: Uses measurements from only one instrument. Can retrieve the ice component of both ice and mixed-phase clouds. *Disadvantages*: Must average radar parameters in time.

Cloud Classification Results





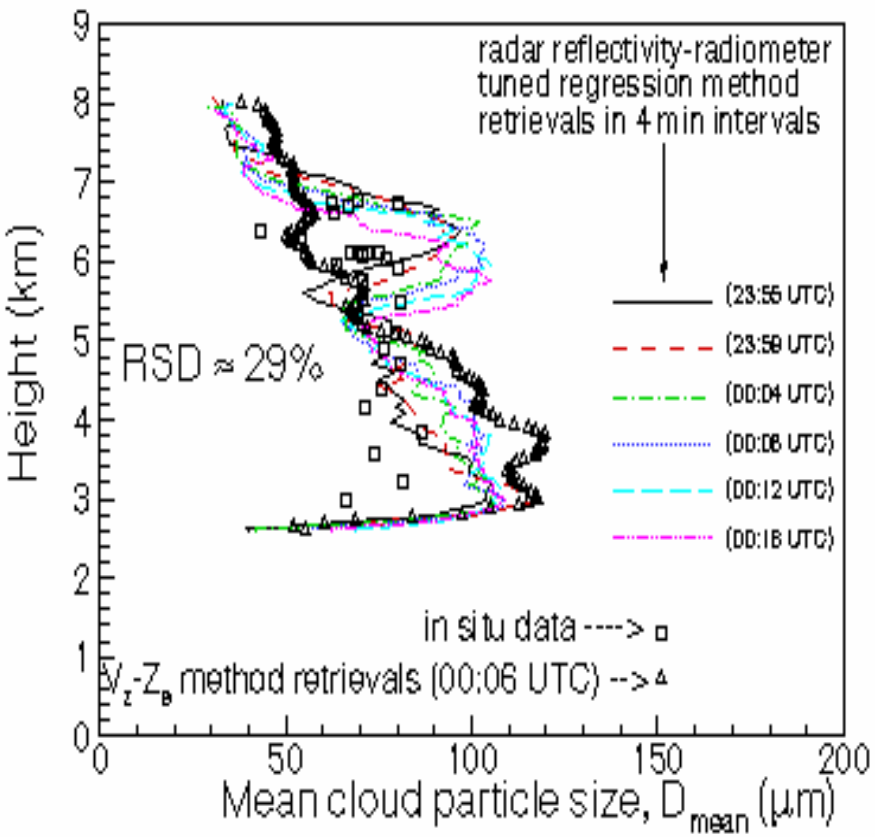


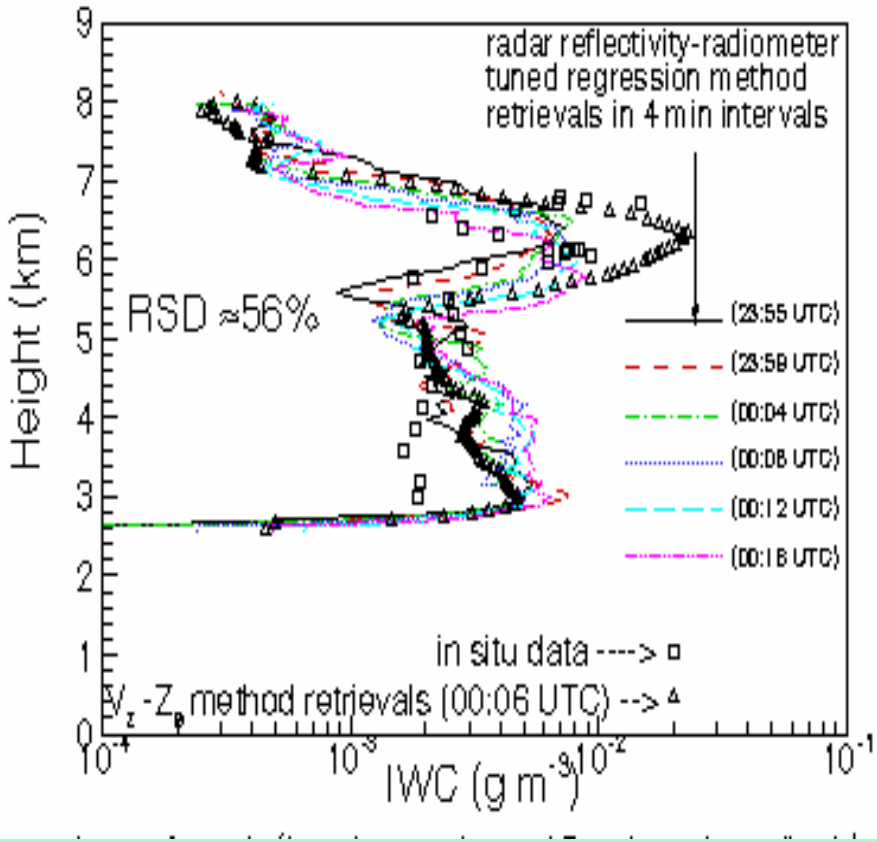
Radar-IR radiometer technique versus Doppler radar techniques (for the whole year):

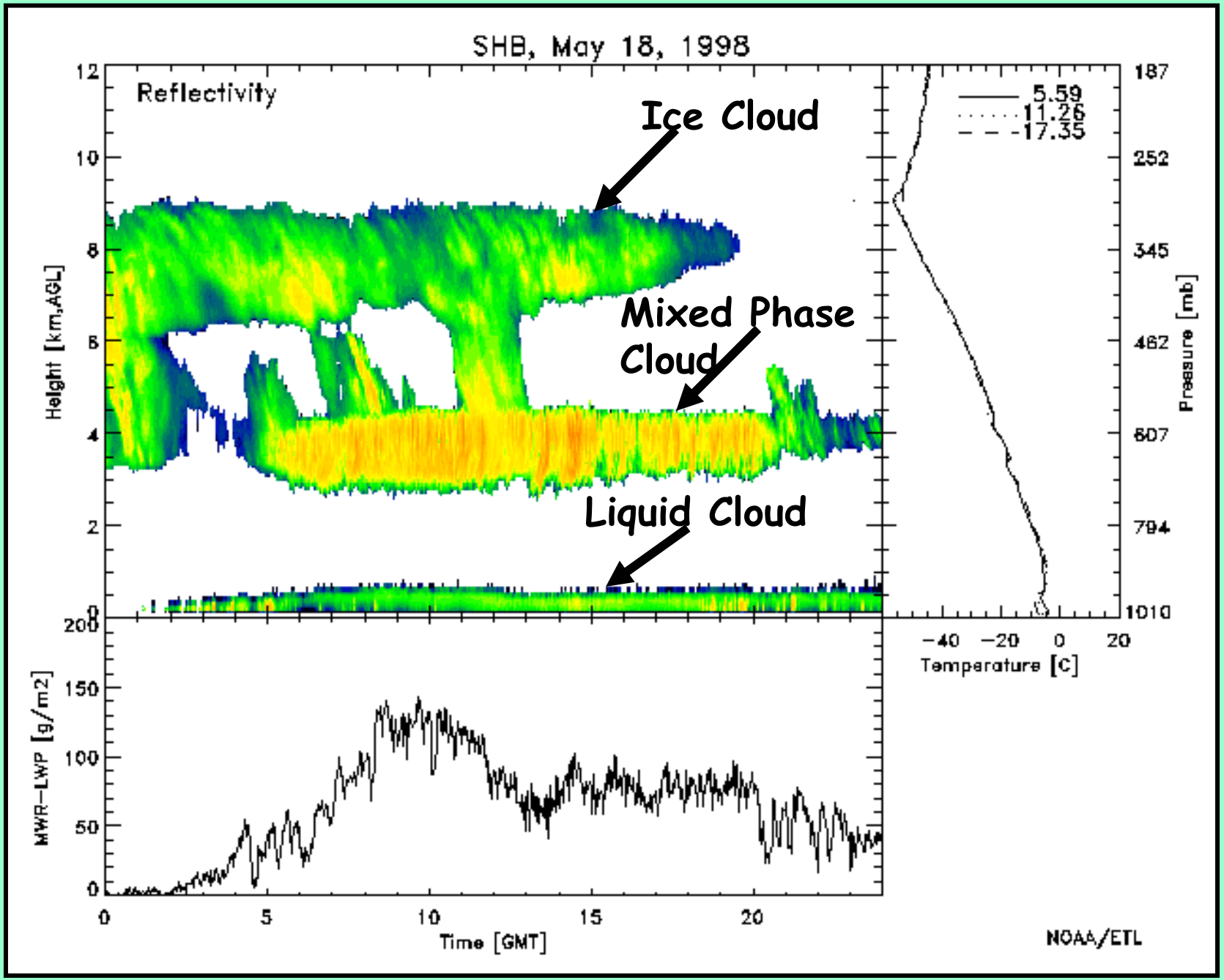
Relative bias in particle size retrievals 9%, Relative bias in IWC retrievals –9%

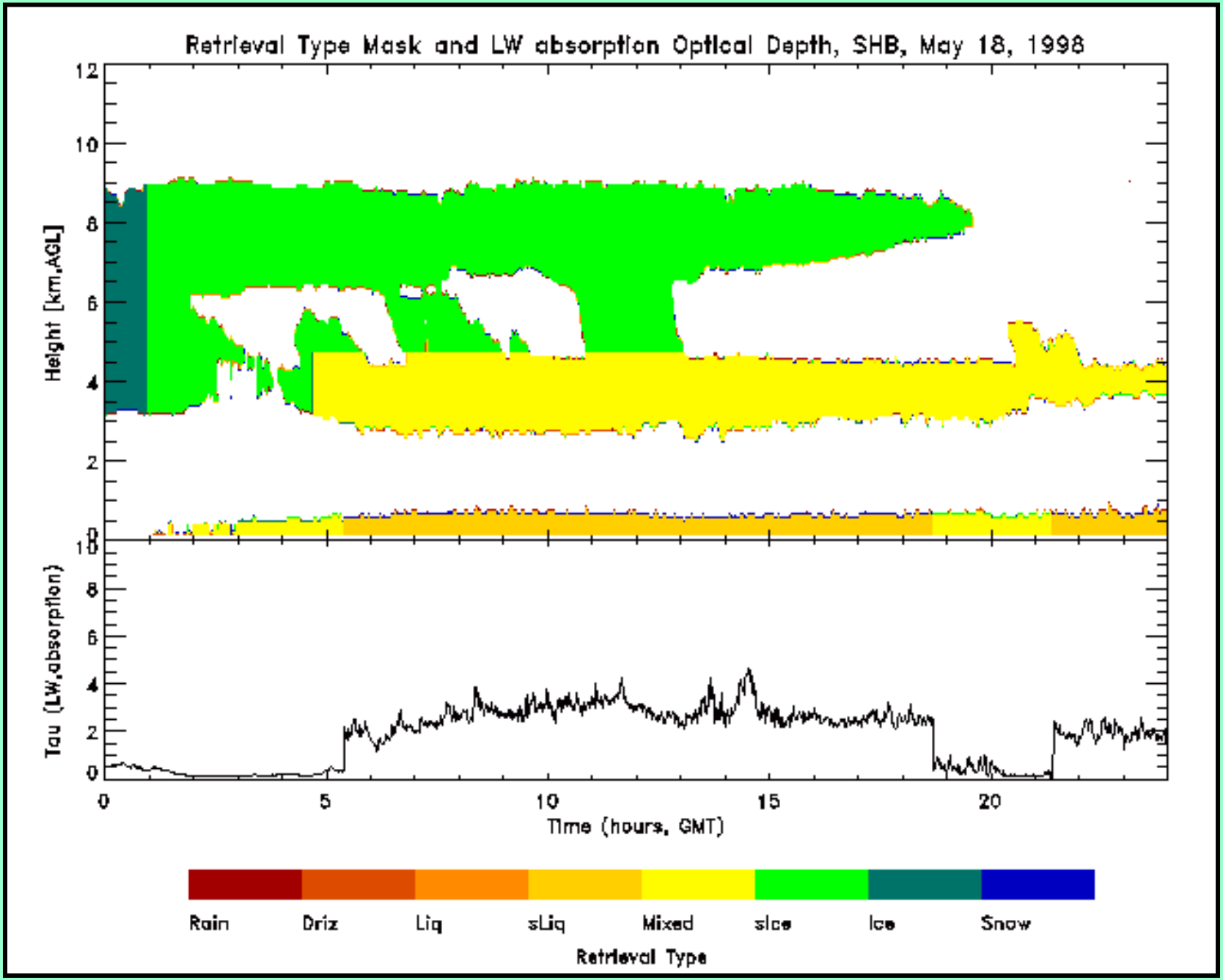
Relative standard deviation in size retrievals 38%, Relative standard deviation in IWC 66%

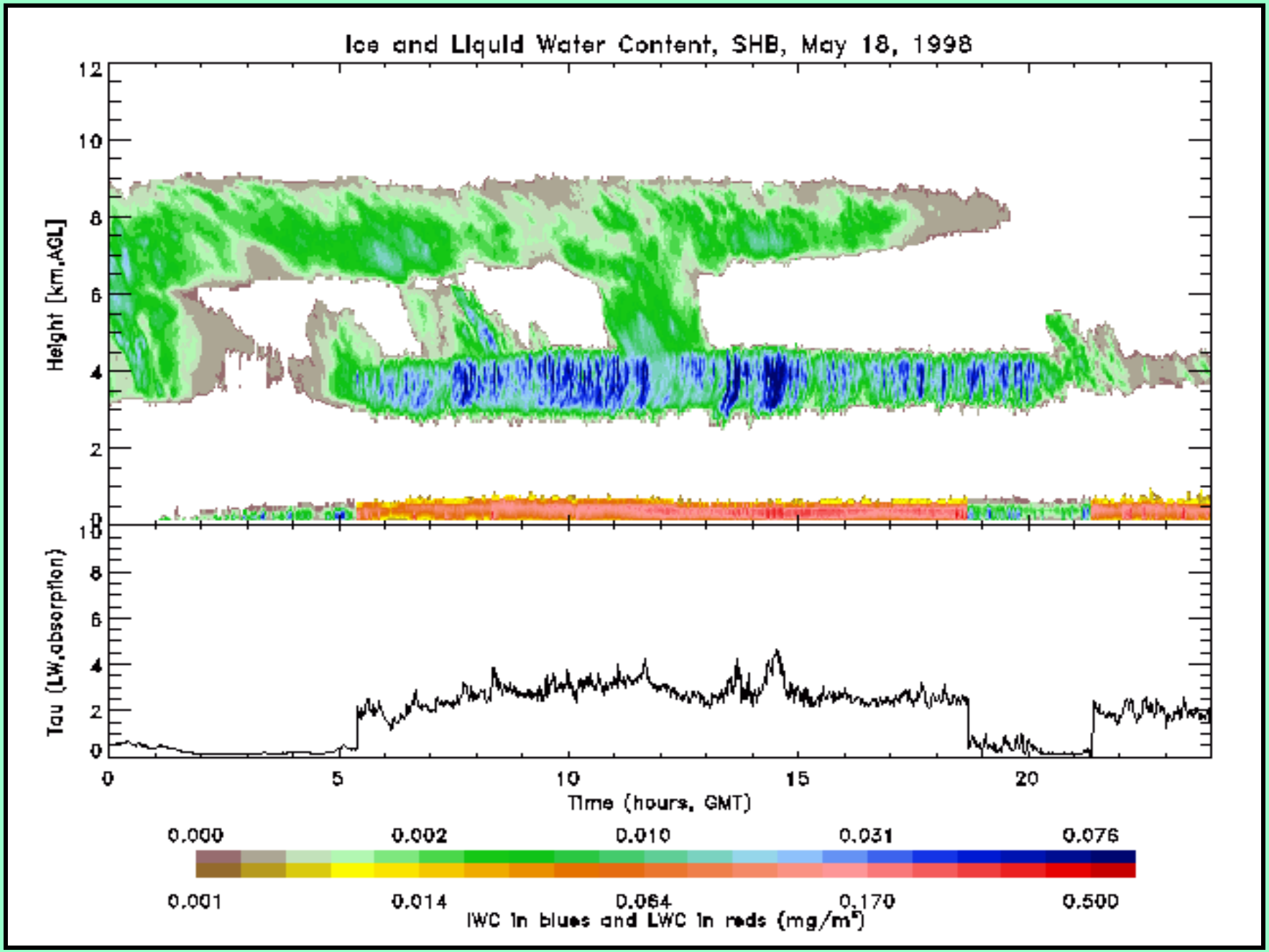
Comparisons of in situ and remote measurements April, 28-29, 1998






SHB, May 18, 1998
Reflectivity
Ice Cloud
Mixed Phase Cloud
Liquid Cloud
Height [km,AGL]
12
10
8
6
4
2
0
5.59
11.26
17.35
187
252
345
462
607
794
1010
Pressure [mb]
−40
−20
0
20
Temperature [C]
MWR-LWP [g/m2]
200
150
100
50
0
0
5
10
15
20
Time [GMT]
NOAA/ETL


Retrieval Type Mask and LW absorption Optical Depth, SHB, May 18, 1998
Height [km,AGL]
Tau (LW,absorption)
Time (hours, GMT)
Rain
Driz
Liq
sLiq
Mixed
slce
Ice
Snow
Retrieval Type


Ice and Liquid Water Content, SHB, May 18, 1998
Height [km,AGL]
Tau (LW,absorption)
Time (hours, GMT)
0.000
0.002
0.010
0.031
0.076
0.001
0.014
0.064
0.170
0.500
IWC in blues and LWC in reds (mg/m³)

ETL cloud retrieval products

Routine cloud products

profiles of cloud water content (i.e., IWC, LWC)

profiles of cloud particle characteristic sizes (e.g., r_e , D_{mean} , D_o)

cloud boundaries,

cloud fraction

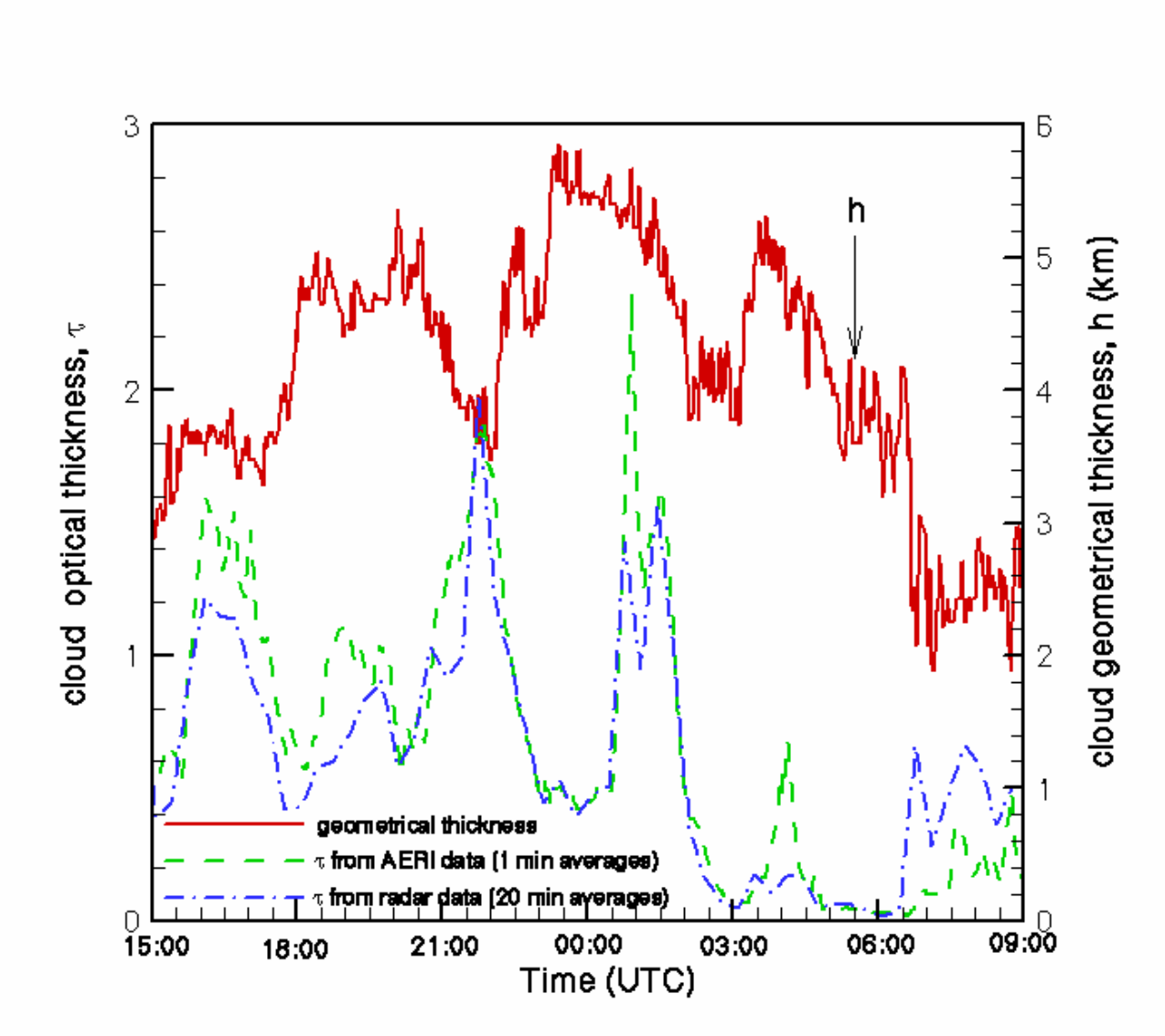
Advanced cloud products

profiles of extinction coefficient, $\acute{\alpha}$ (total cloud optical thickness, τ)

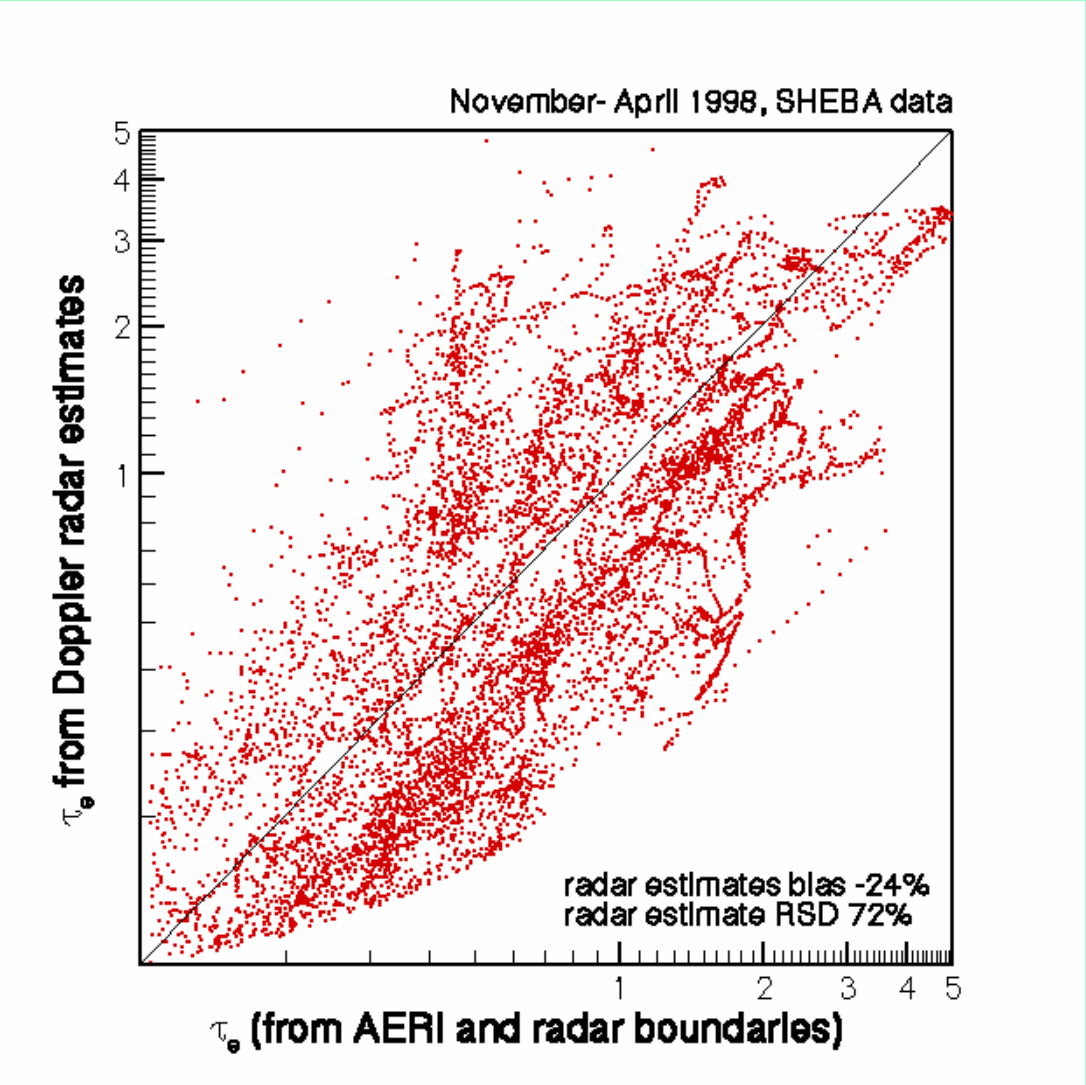
profiles of heating/cooling rates

cloud forcing estimates

Comparisons of cloud optical thickness from cloud radar only data with estimates using radiometric emmisivity measurements

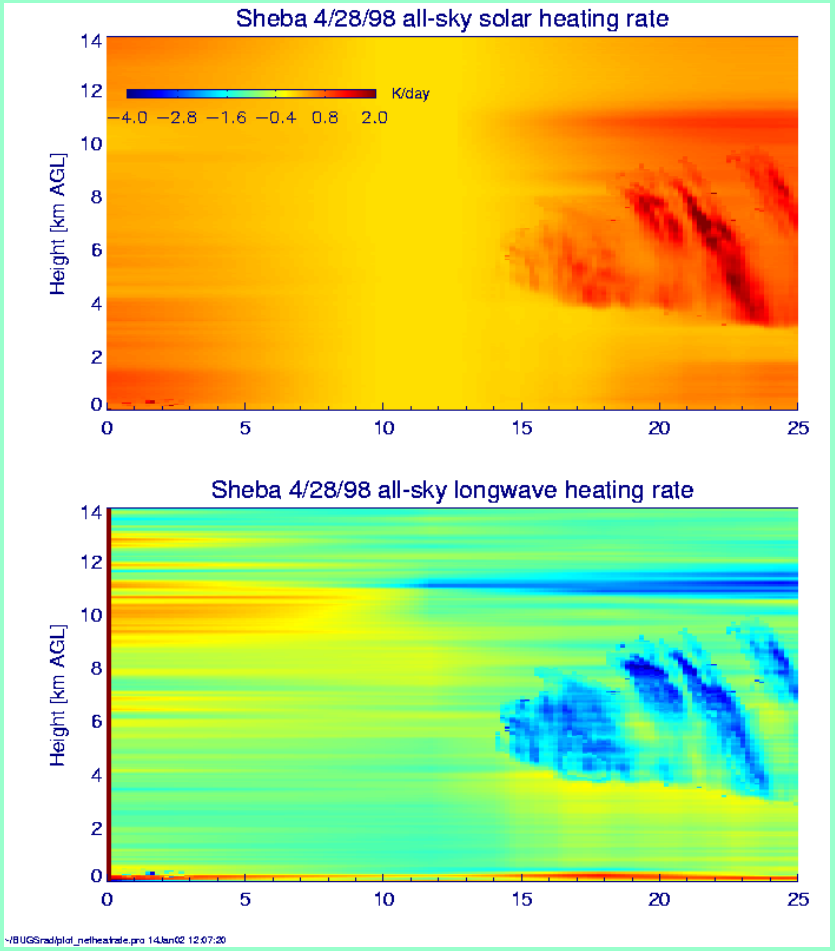


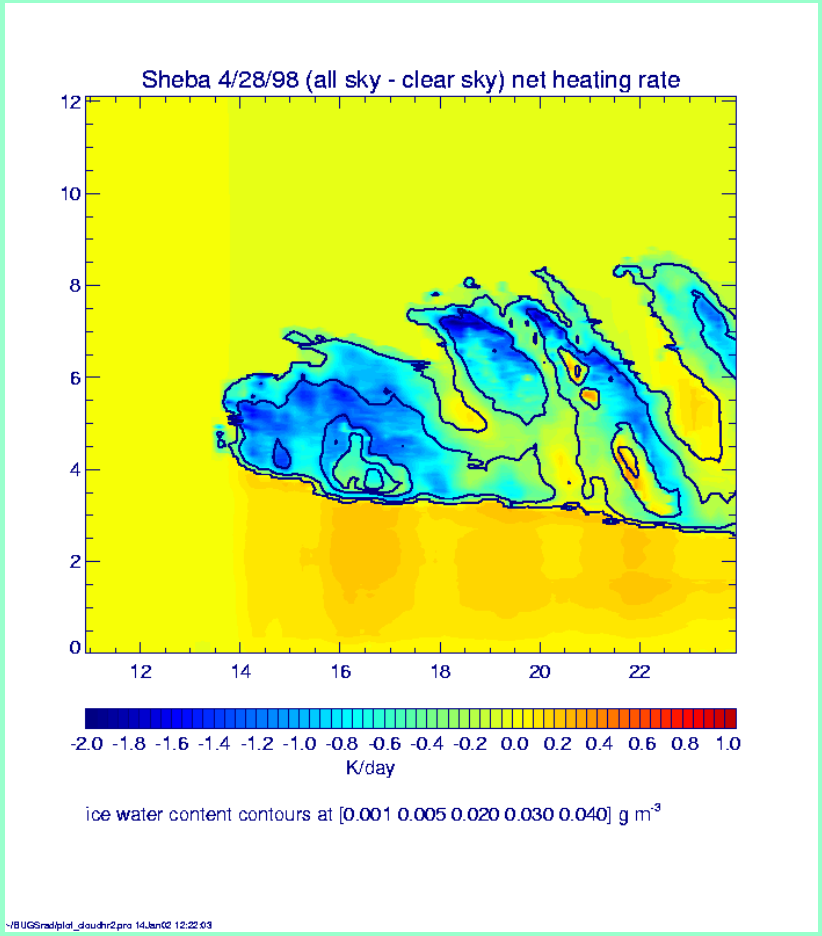
Ground-based radar only data can provide an estimate of ice cloud optical thickness with an uncertainty of about factor of 2

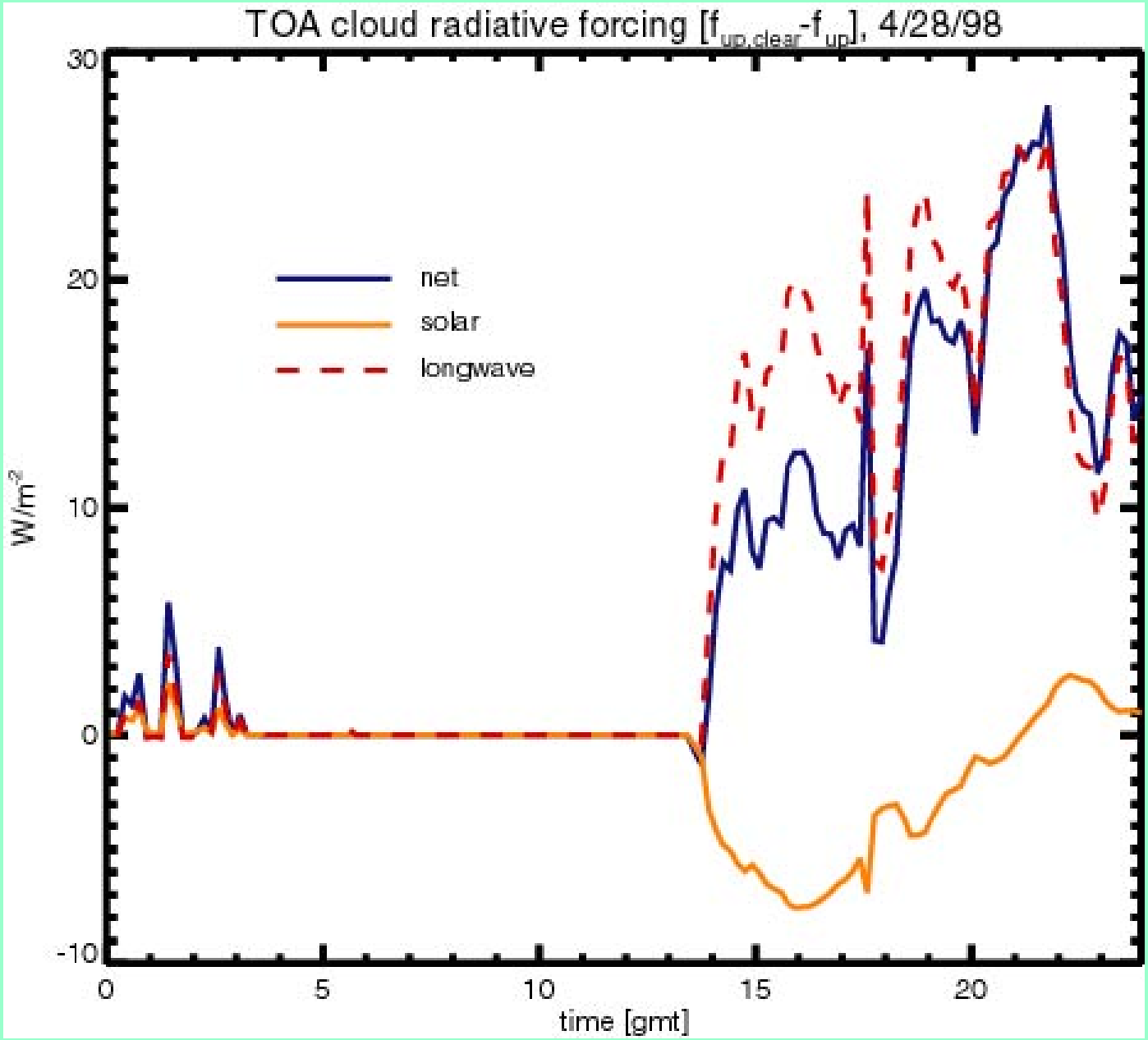


Some current work -

Radiative Transfer Modeling using explicit microphysics

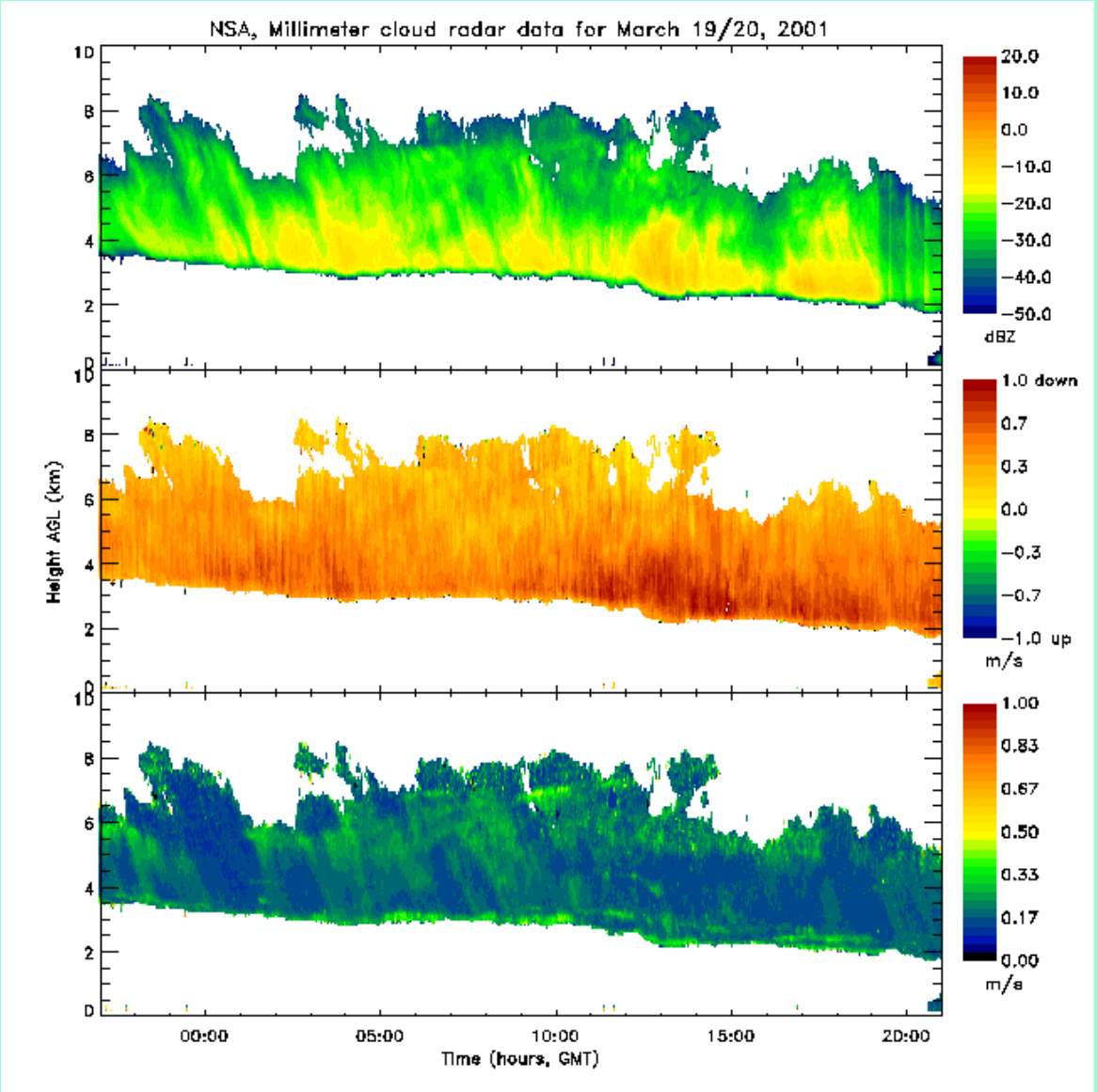


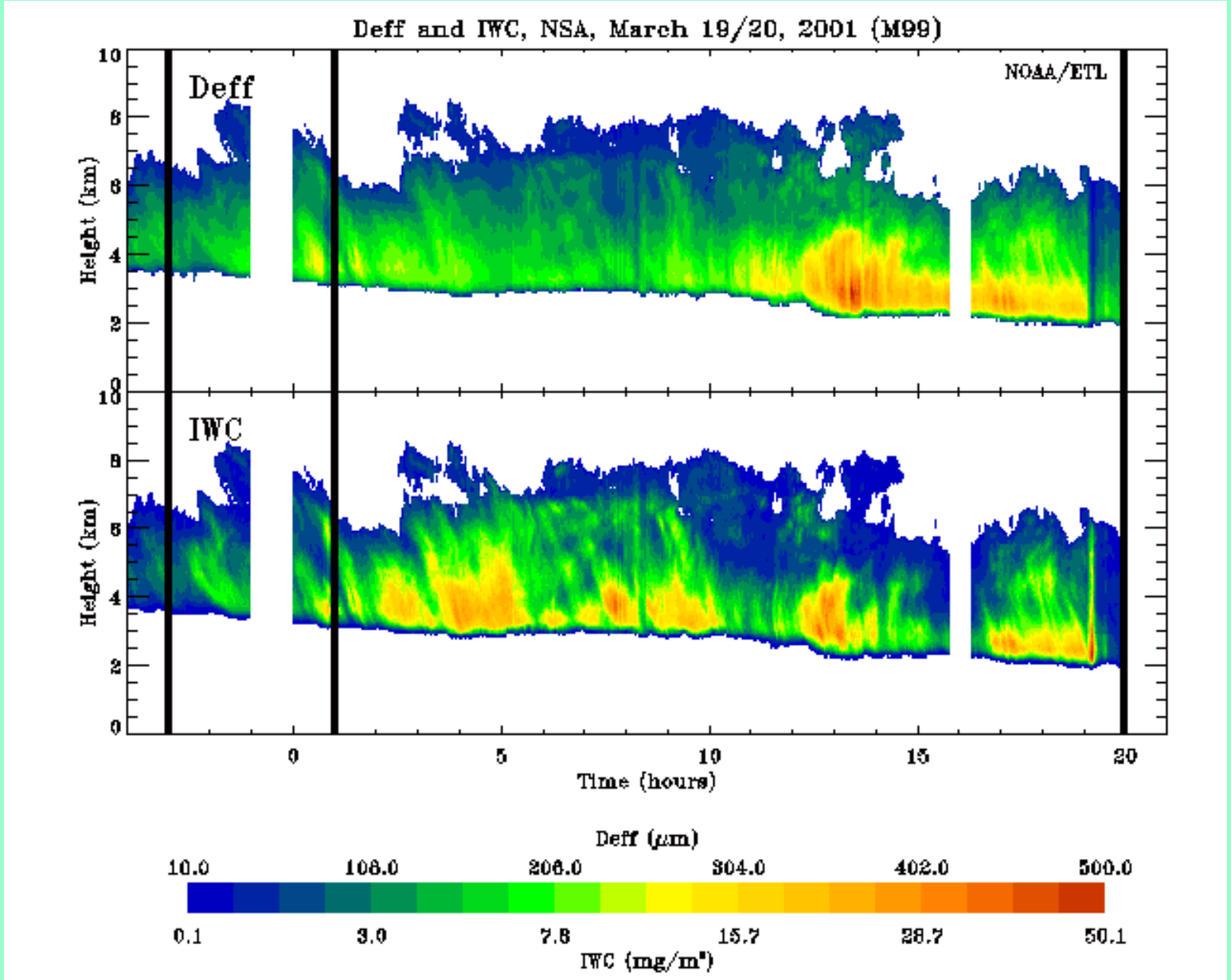



TOA cloud radiative forcing [$f_{up,clear}$-f_{up}], 4/28/98
net
solar
longwave
W/m^2
30
20
10
0
-10
0
5
10
15
20
time [gmt]

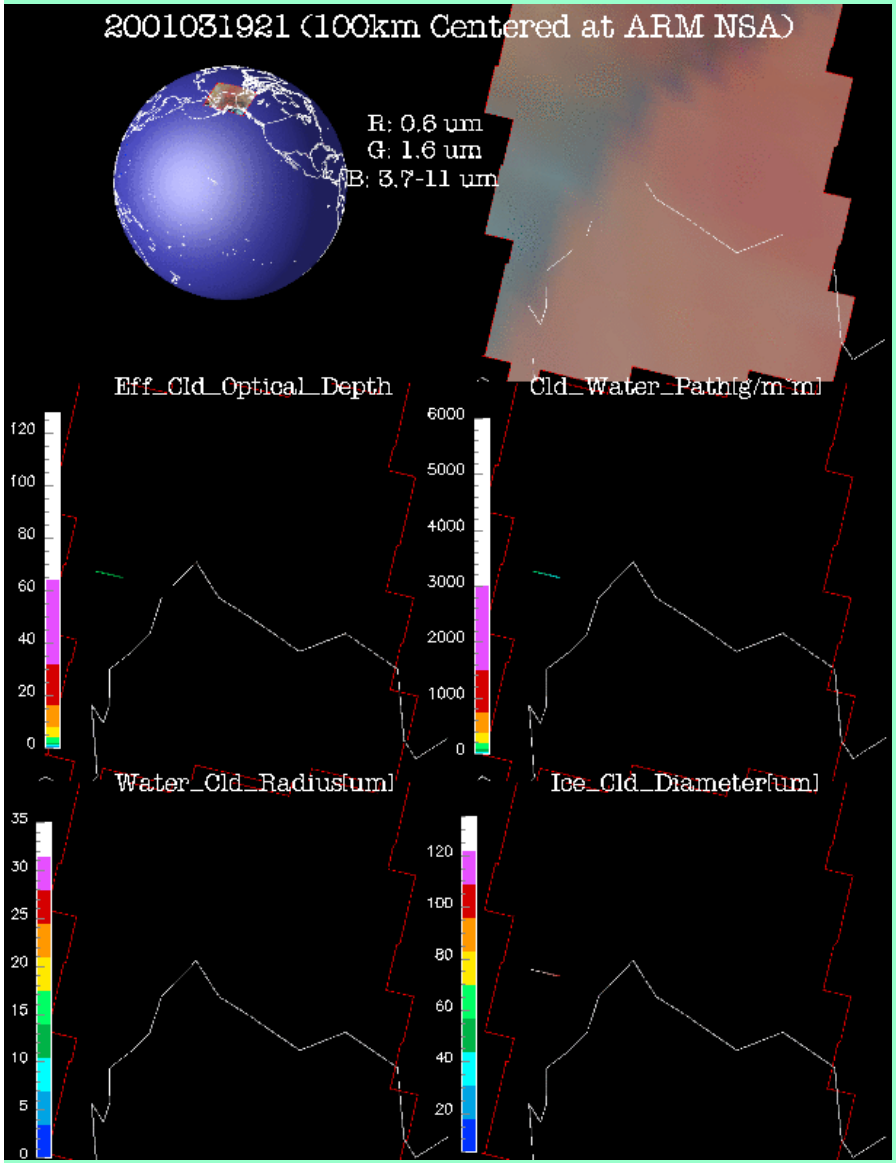
An ice cloud above the NSA ARM site 19-20/03/2001 with 3 Terra overpasses

March 19, 2001, 19 UTC; March 20, 2001, 1 UTC; March 20, 200, 20 UTC



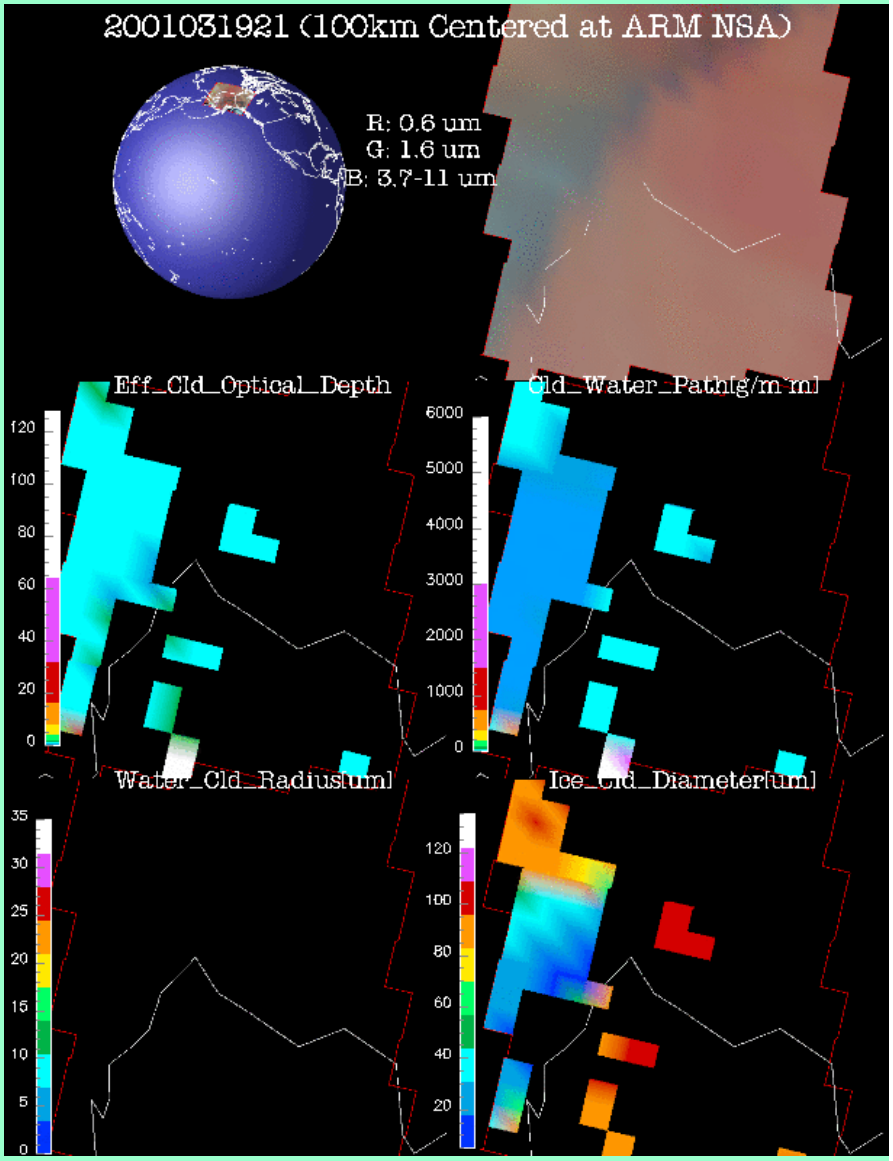

Deff and IWC, NSA, March 19/20, 2001 (M99)
Deff
IWC
NOAA/ETL
Height (km)
Time (hours)
Deff (μm)
10.0
108.0
206.0
304.0
402.0
500.0
0.1
3.0
7.8
15.7
28.7
50.1
IWC (mg/m³)

2001 03 19 21 1.6 um h= 0 km



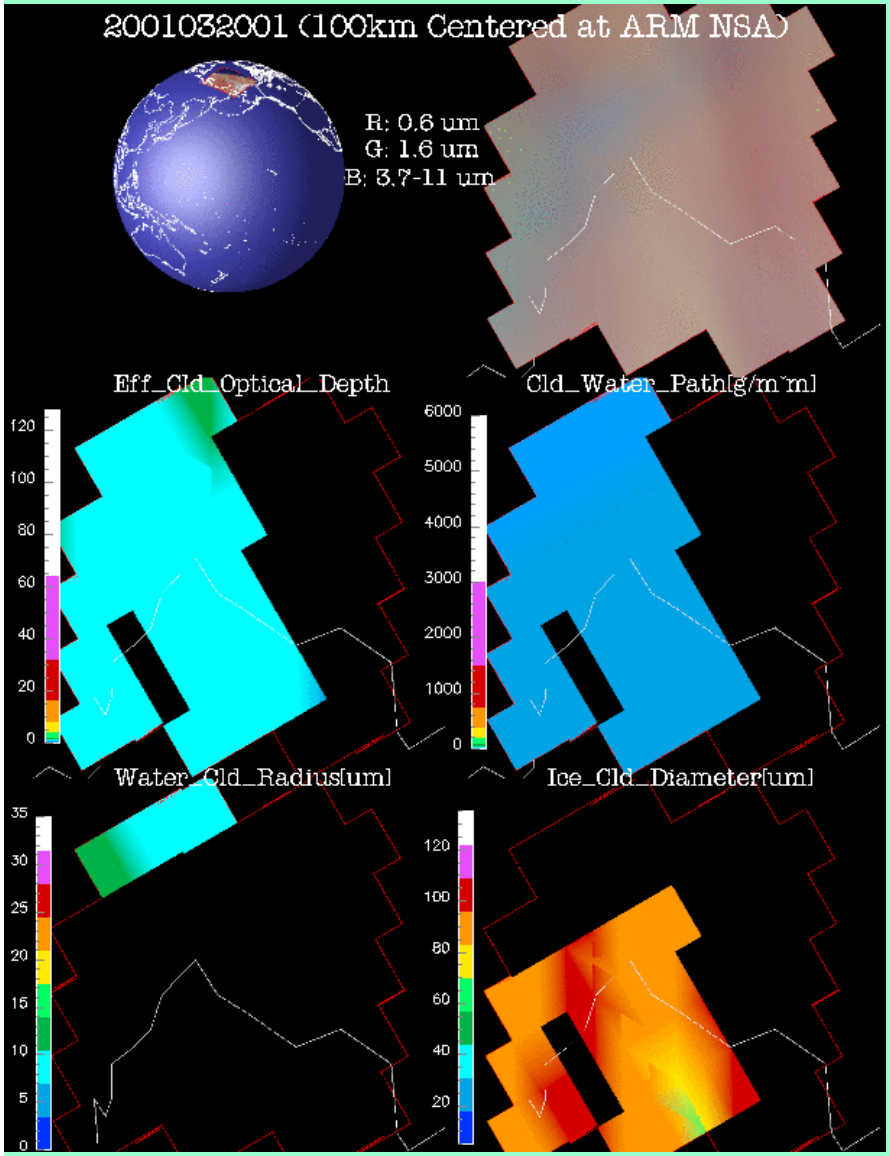
CERES retrievals above NSA ARM site
Ice D_e = 0 um, IWP= 0 g/m^2, tau=0.

2001 03 19 21 3.7 um h=5.73 km



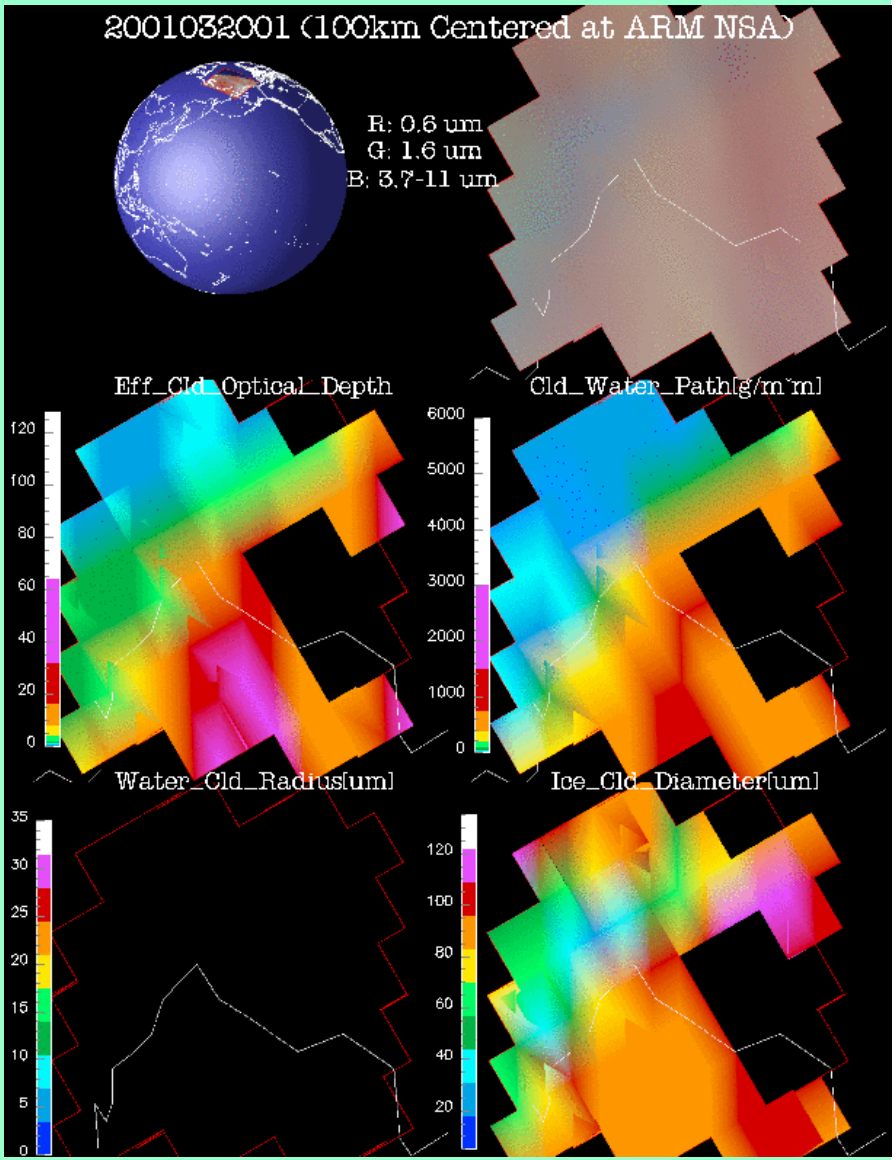
CERES retrievals above NSA ARM site
Ice D_e = 93.7 um, IWP=29.5 g/m^2, tau=0.96

2001 03 20 01 1.6 um h=5.15 km

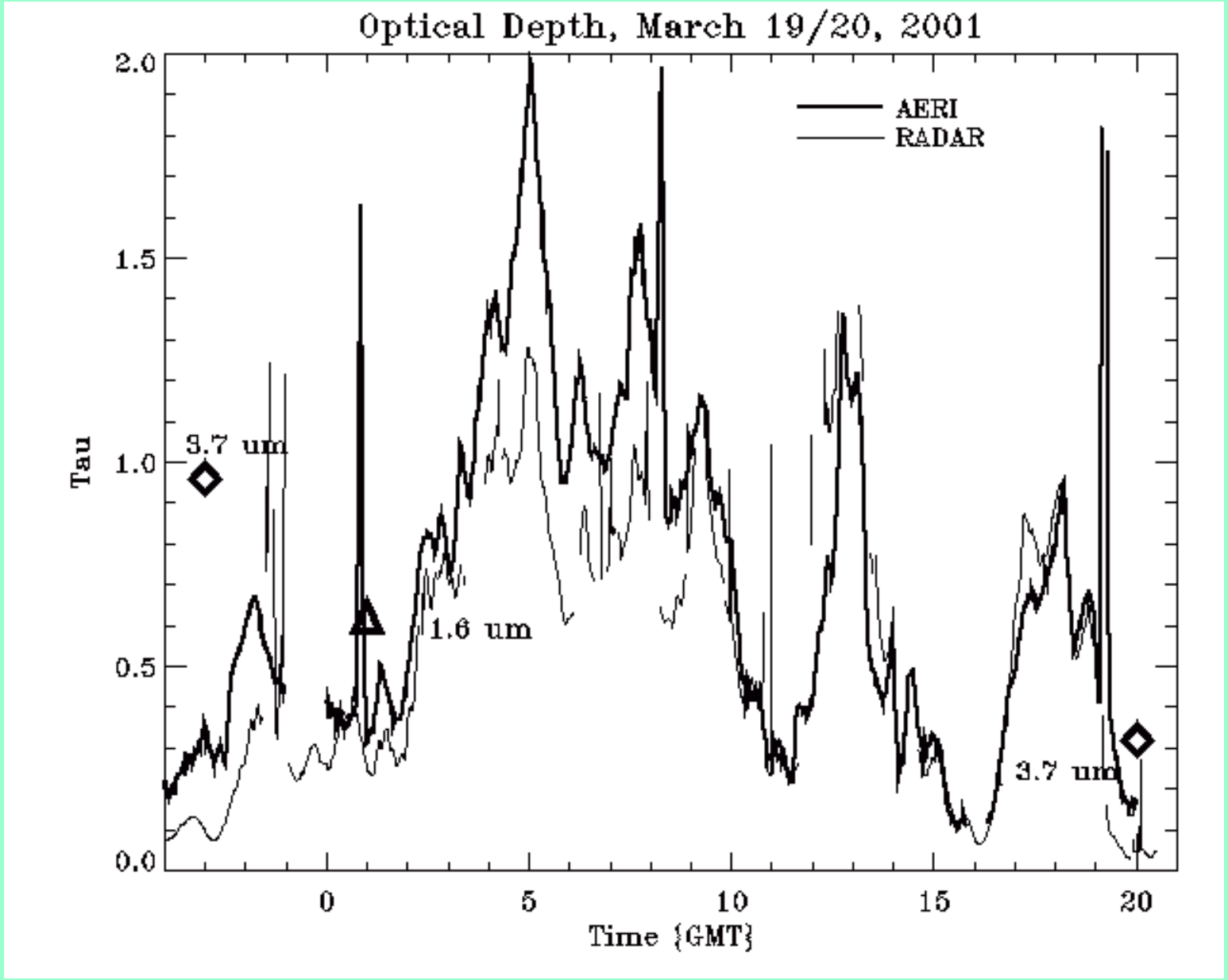


CERES retrievals above NSA ARM site, r_e=19um
Ice D_e = 92.3 um, IWP=18.6 g/m^2, tau=0.62

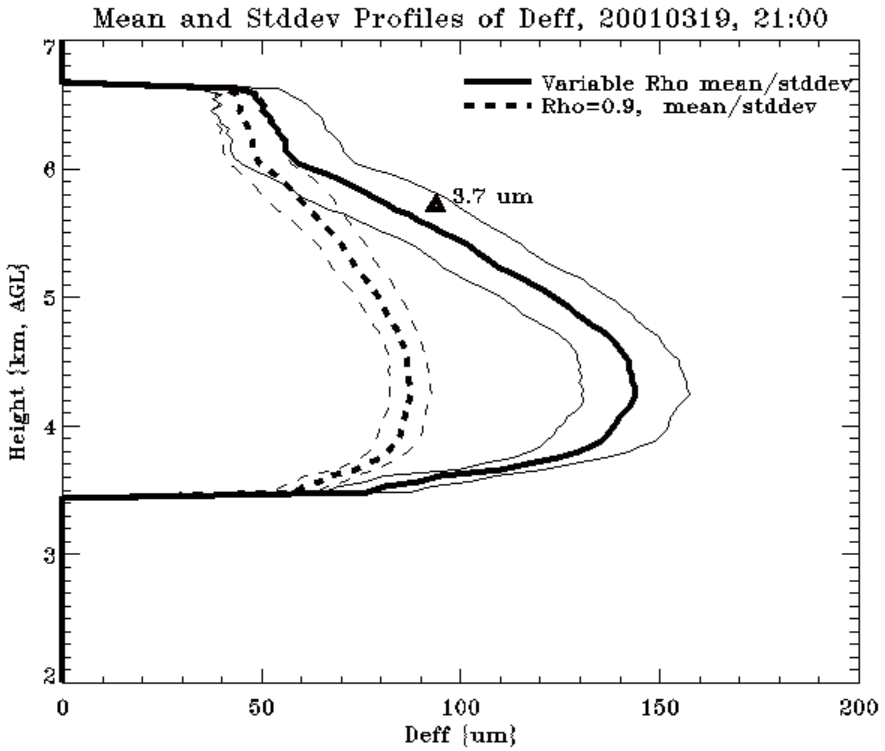
2001 03 20 01 3.7 um h=3.86 km

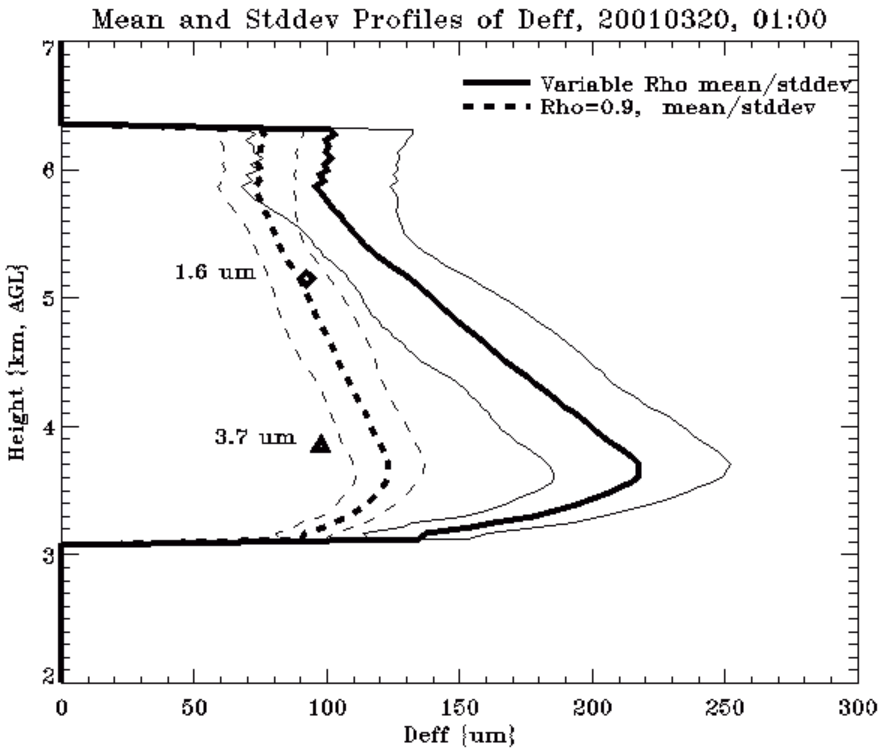


CERES retrievals above NSA ARM site
Ice D_e = 97.5 um, IWP=615 g/m^2, tau=19

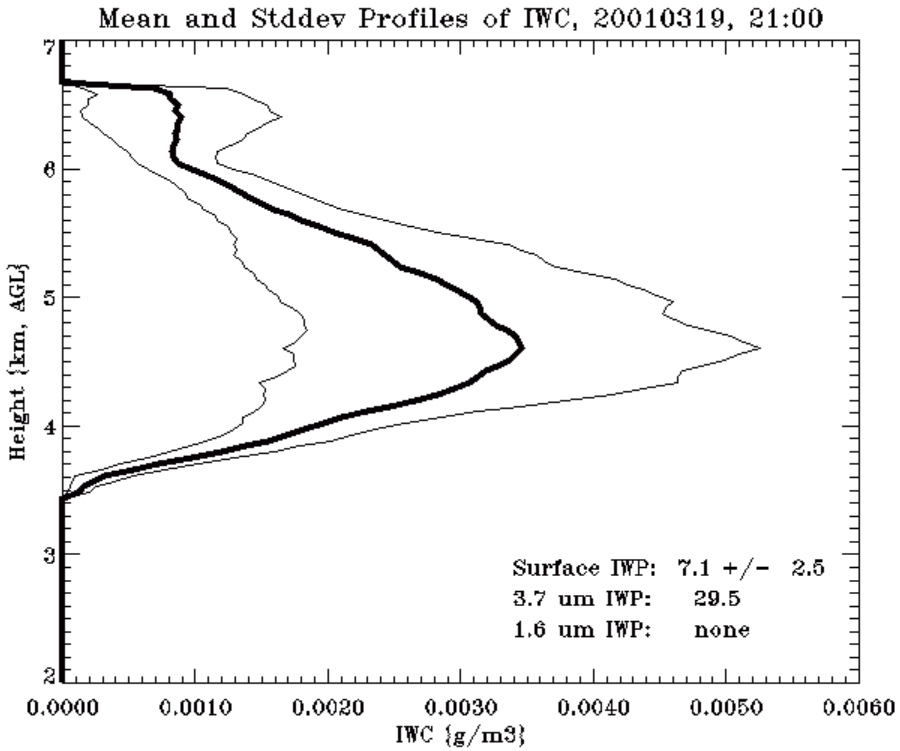

Optical Depth, March 19/20, 2001
AERI
RADAR
3.7 um
1.6 um
3.7 um
Tau
Time {GMT}
2.0
1.5
1.0
0.5
0.0
0
5
10
15
20

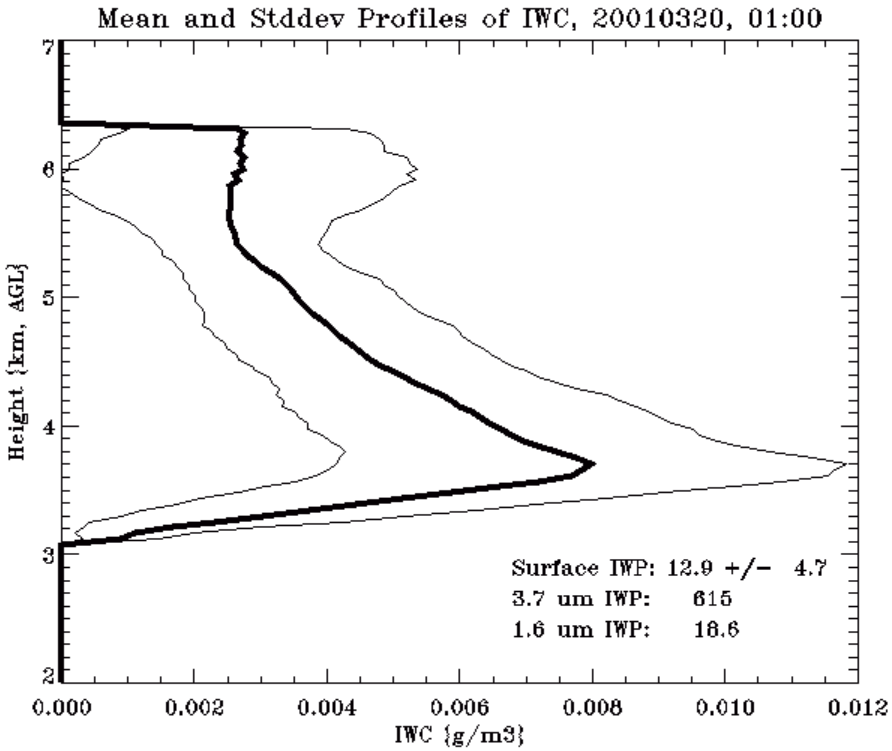
Comparisons of ice cloud particle size retrievals



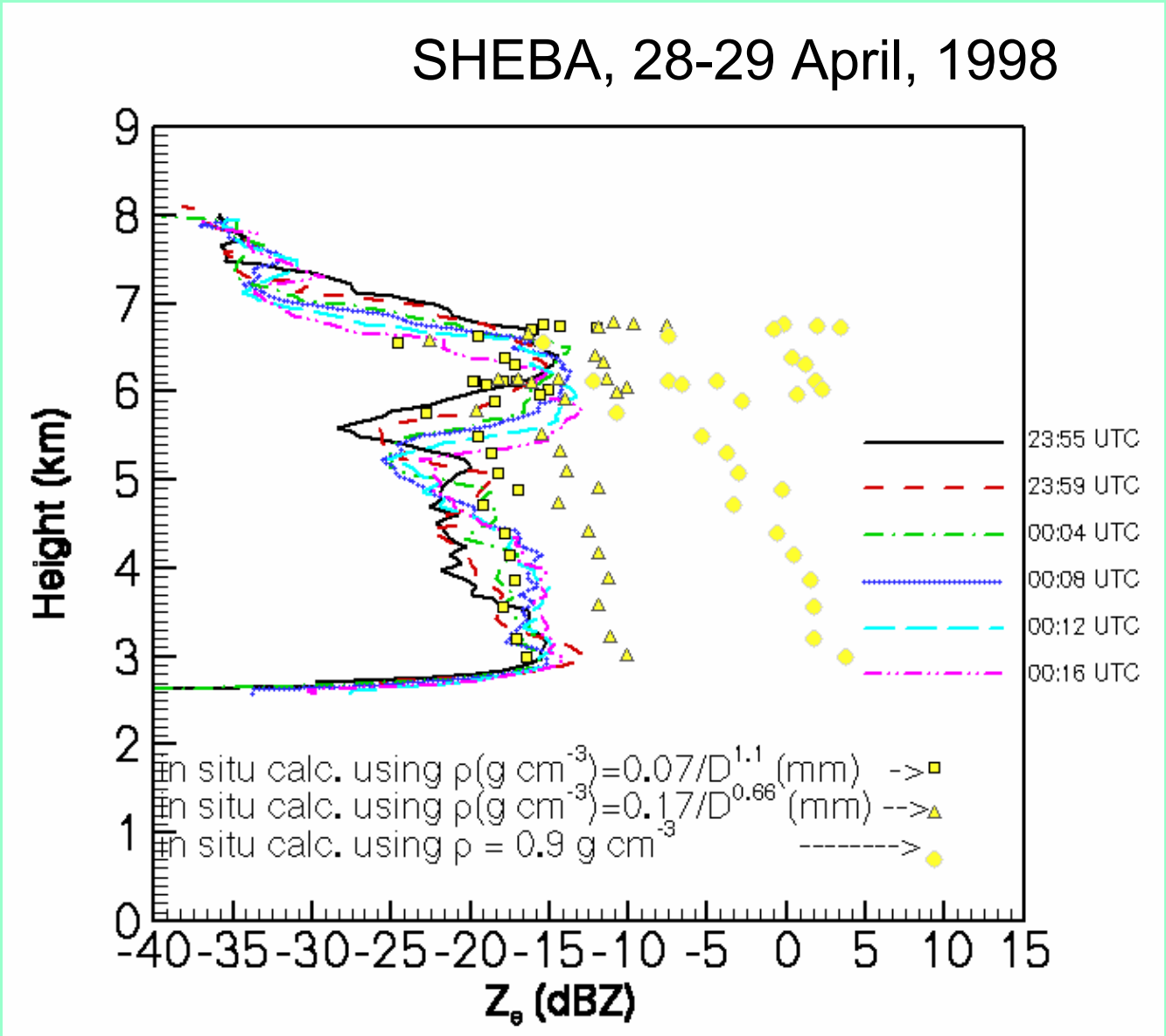


Comparisons of IWC / IWP retrievals





appropriateness of ice particle bulk density assumption



To Do List

Get NetCDF files on website

Compare to U of Utah

Expand to SGP and TWP

Validate with Aircraft

Develop More Cloud Property Statistics

Radiative Transfer Modeling
Using explicit microphysics

Compare to Satellites (case studies and statistical)

Model Parameterizations