Some comments on weather modification and its science base

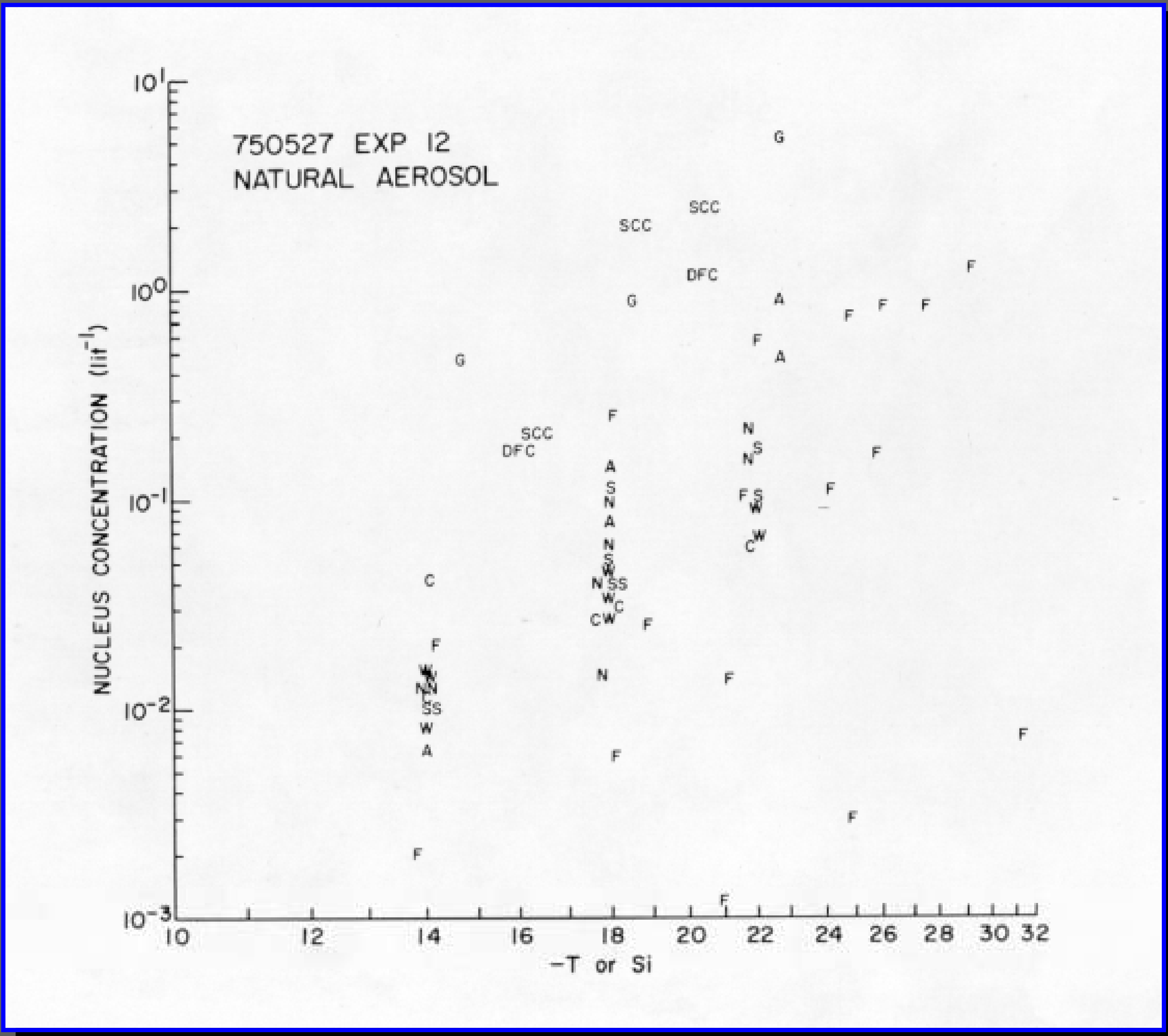
Woods Hole -- July 31, 2002

Gabor Vali
University of Wyoming

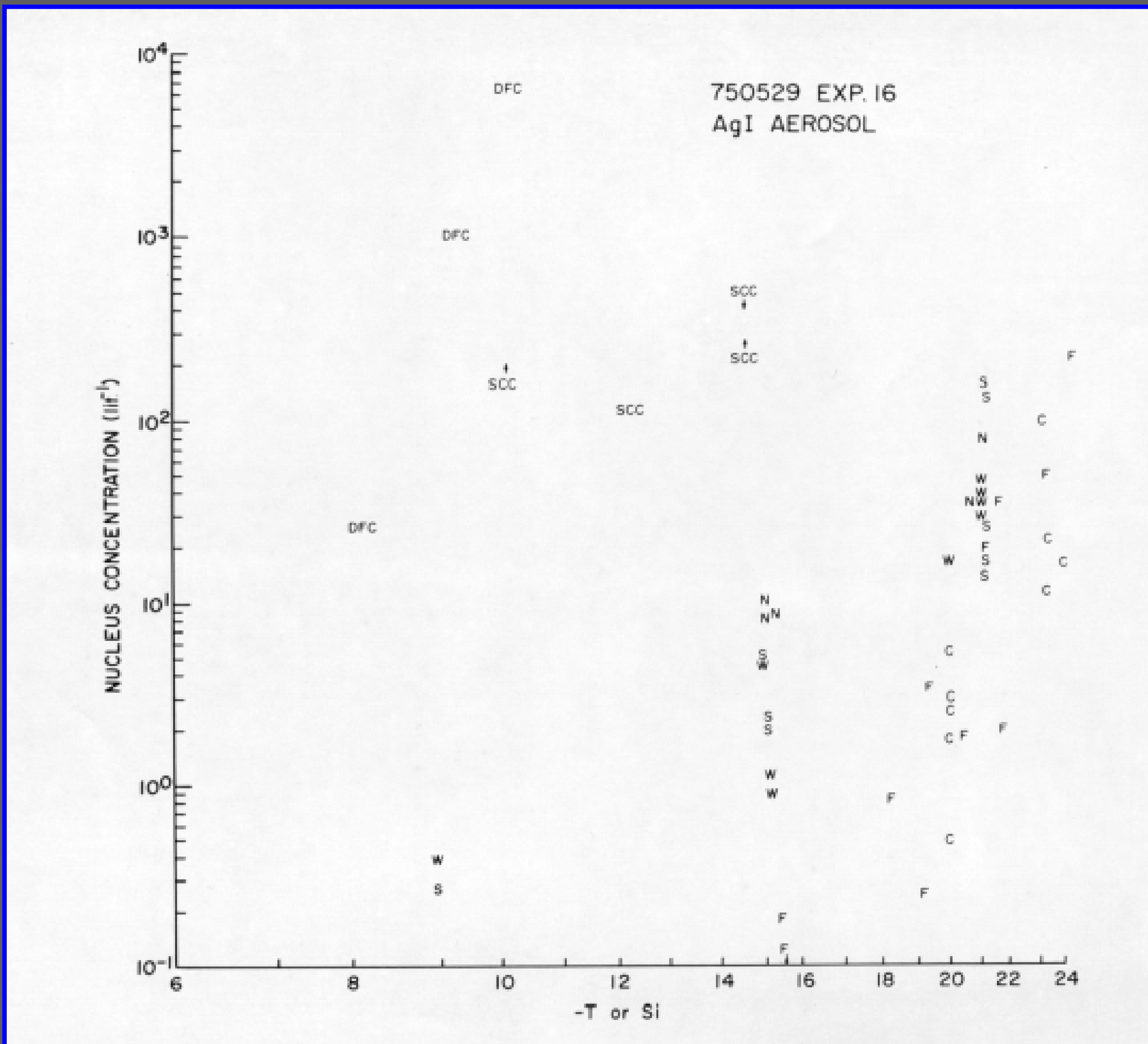
Collaborators: R.D. Kelly, D. Leon, S. Haimov, S. Gill

Discussion **topics:**

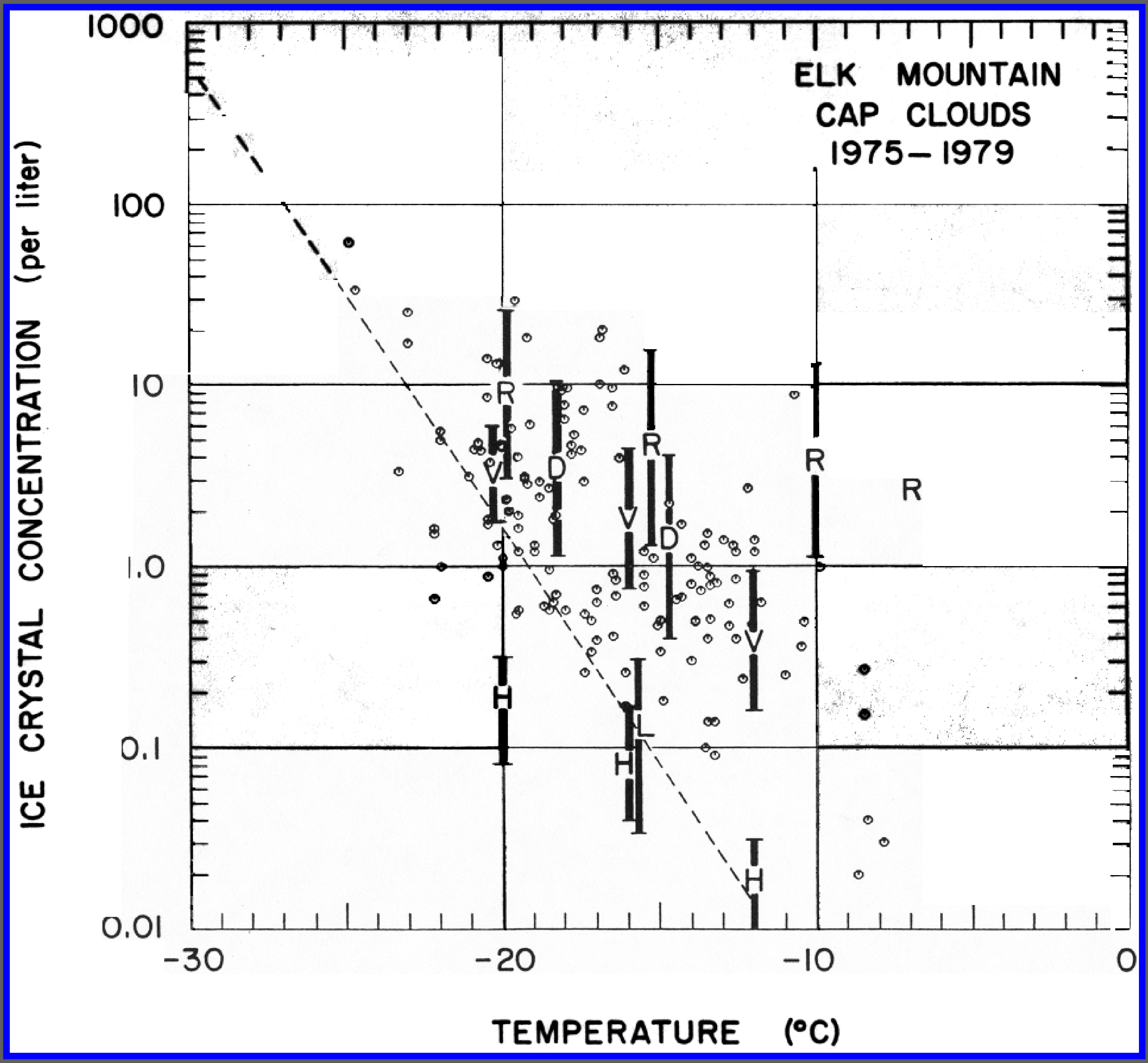
- Bad old news
- Good news
- Ideas



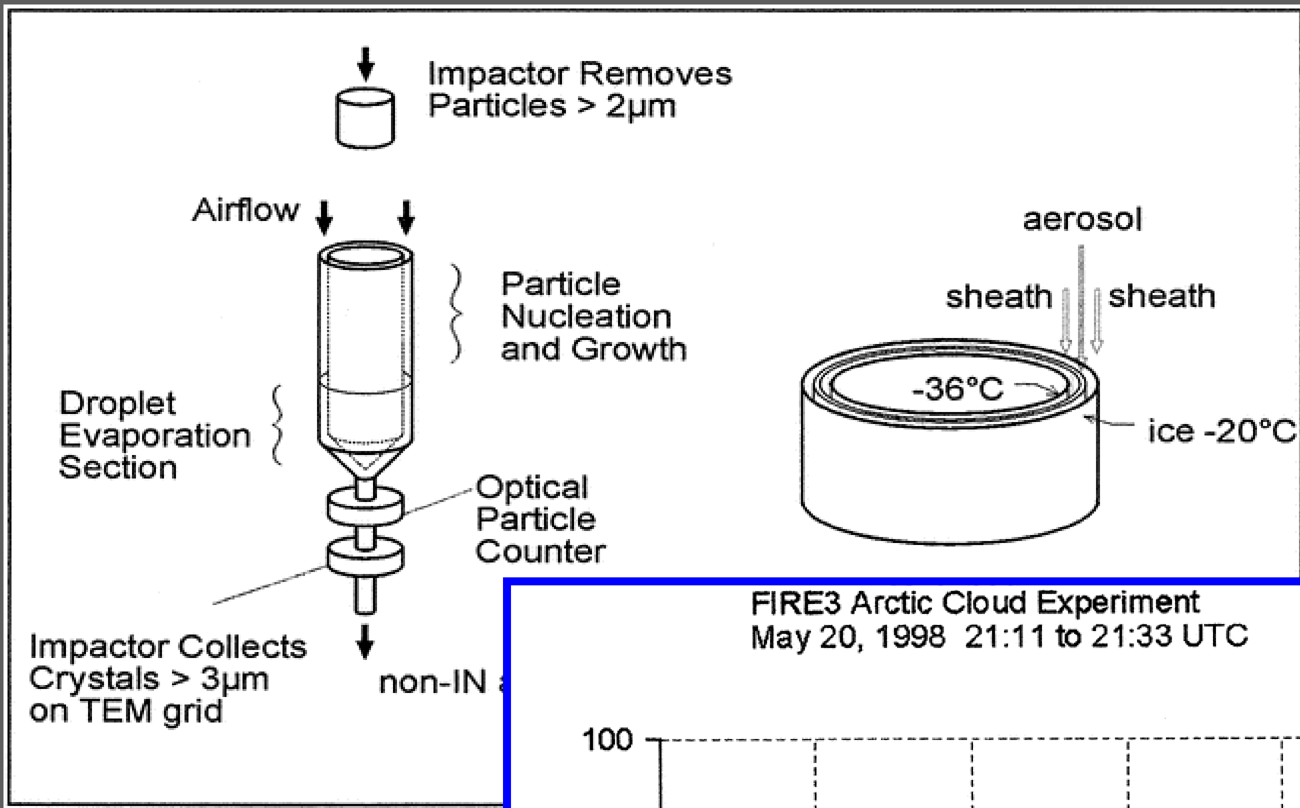
The Third International Nucleation Workshop showed that ice nucleus measurements by different techniques range over roughly two orders of magnitude and cannot detect natural nuclei at temperatures above -10C.

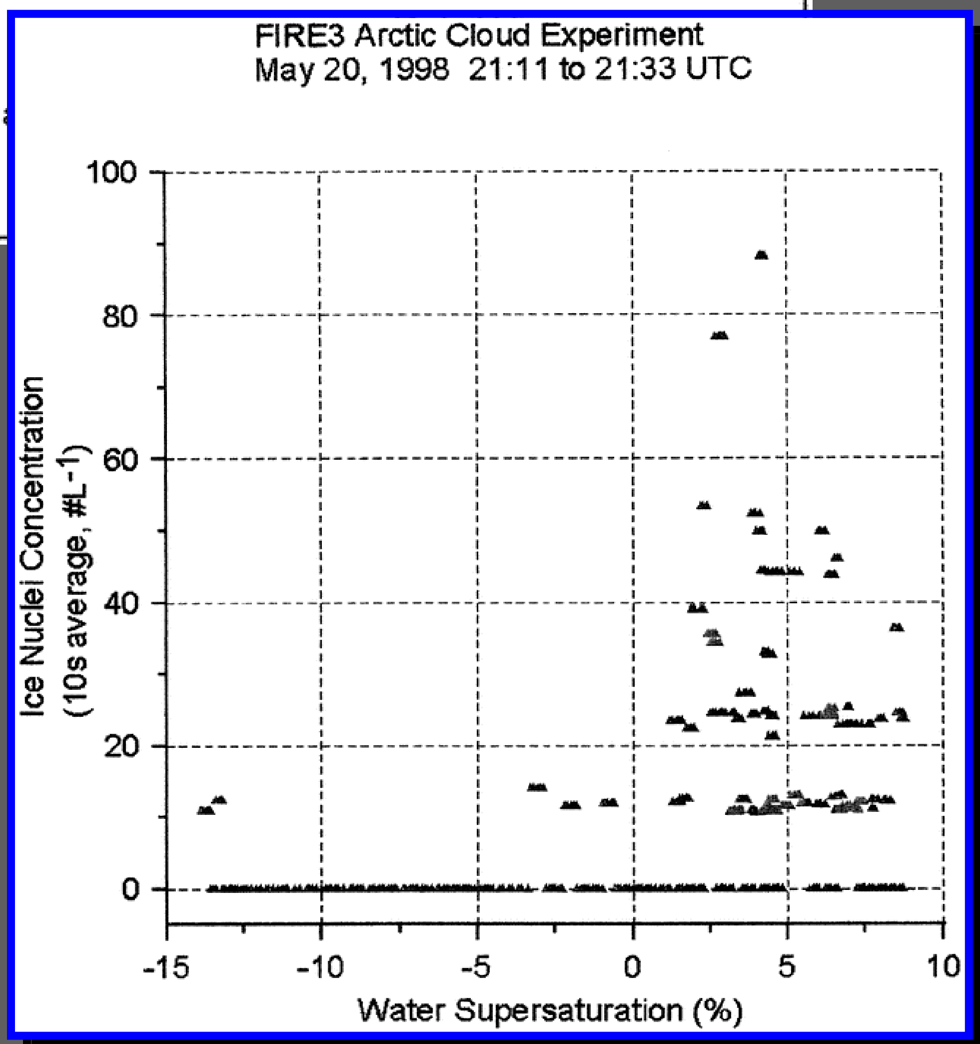


The same for silver iodide nuclei.

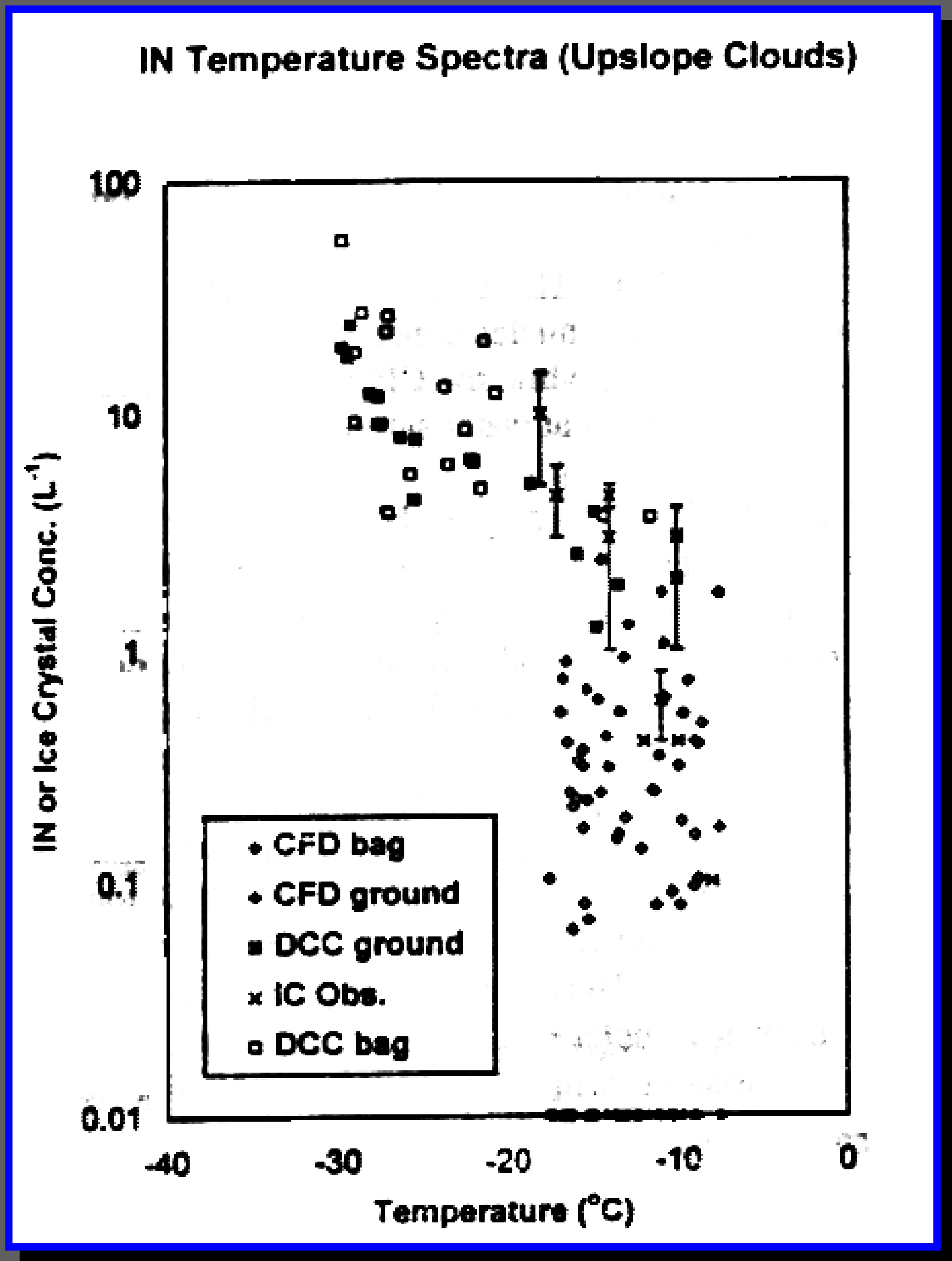


In “simple” cloud situations, ice crystal and ice nucleus concentrations are comparable (in order of magnitude), but this falls short of providing evidence for a cause and effect relationship.

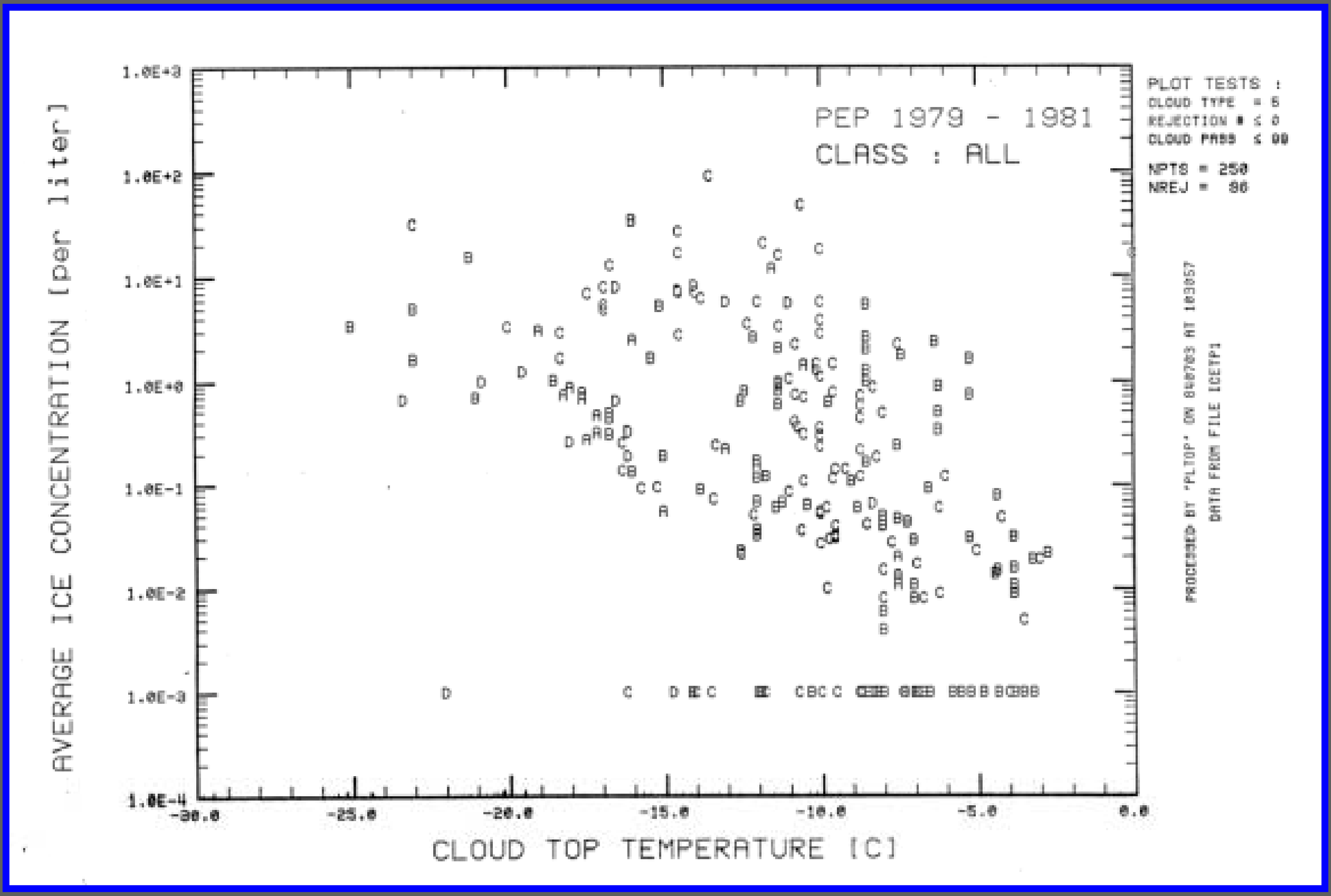




Rogers' continuous-flow IN counter provided some of the only new data over the last 20 years.



Rogers et al. 1996 (Zurich ICCP conference)



Large range of ice concentrations observed on PEP with little differentiation among cloud types

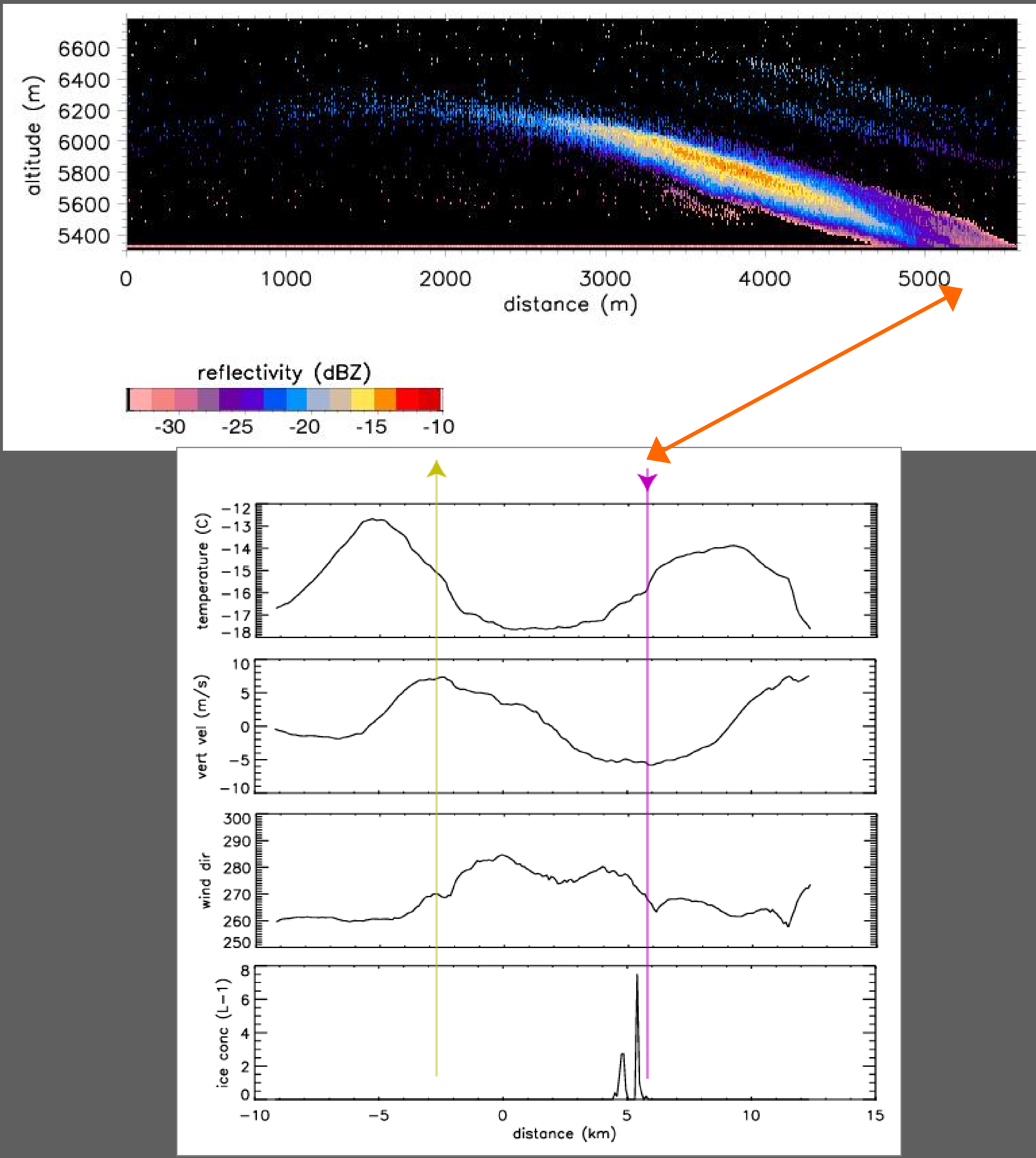
Conclusion #1:

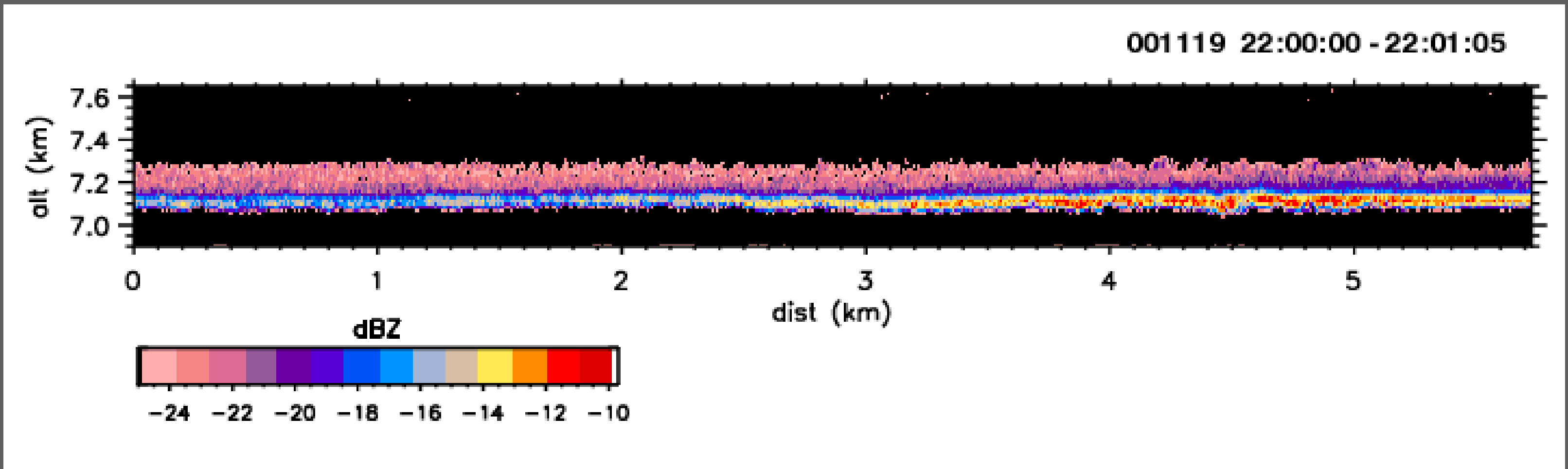
We have practically no predictive capability for ice nucleus or for ice crystal concentrations.

A priori estimates of ice crystal concentrations have a two-orders-of-magnitude error zone.

Finescale radar observations reveal some new complexities of ice formation in clouds.

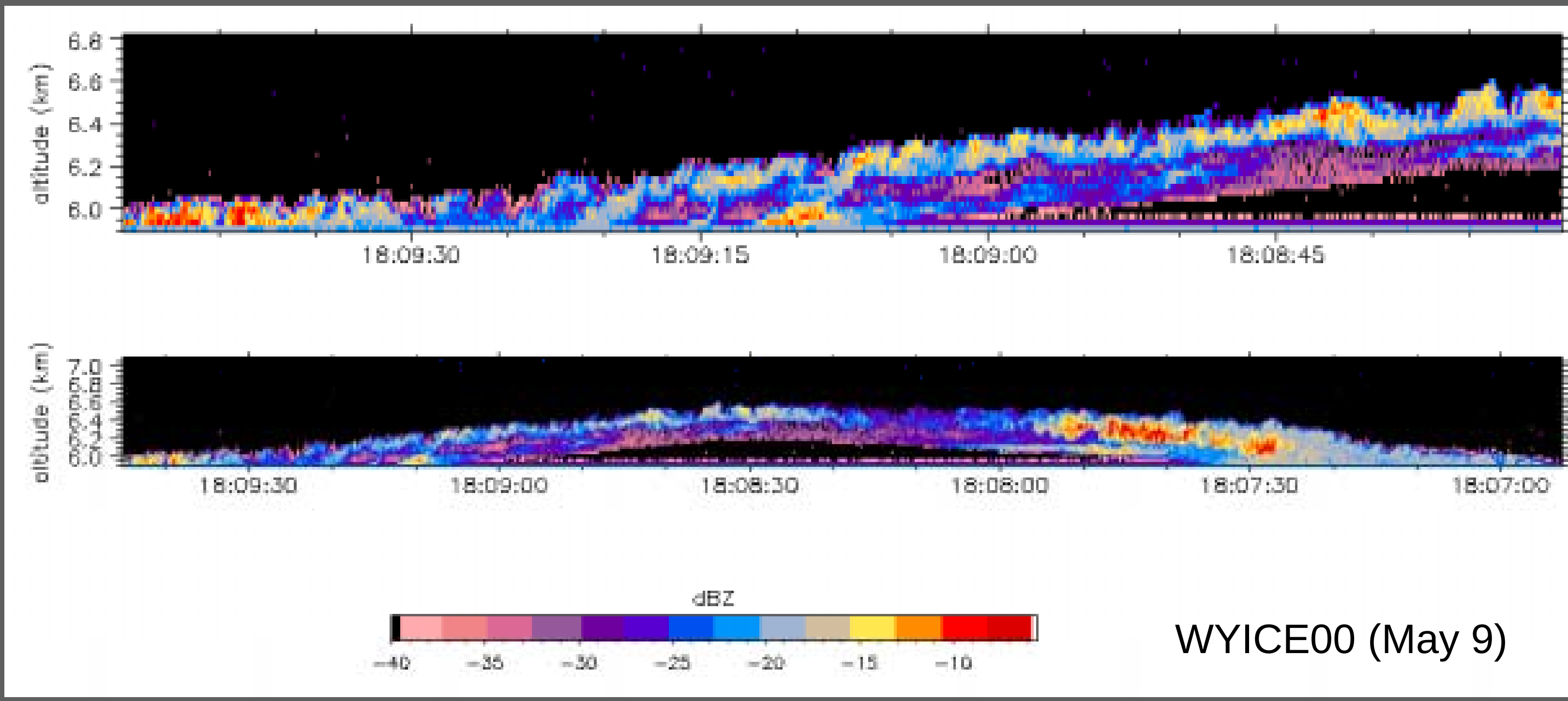
It appears that we are still missing some basic physics of the processes of ice initiation.


altitude (m)
6600
6400
6200
6000
5800
5600
5400
0
1000
2000
3000
4000
5000
distance (m)
reflectivity (dBZ)
-30
-25
-20
-15
-10
temperature (C)
−12
−13
−14
−15
−16
−17
−18
vert vel (m/s)
10
5
0
−5
−10
wind dir
300
290
280
270
260
250
ice conc (L−1)
8
6
4
2
0
−10
−5
0
5
10
15
distance (km)



Cloud at -33°C; wind 320° 40 m/s

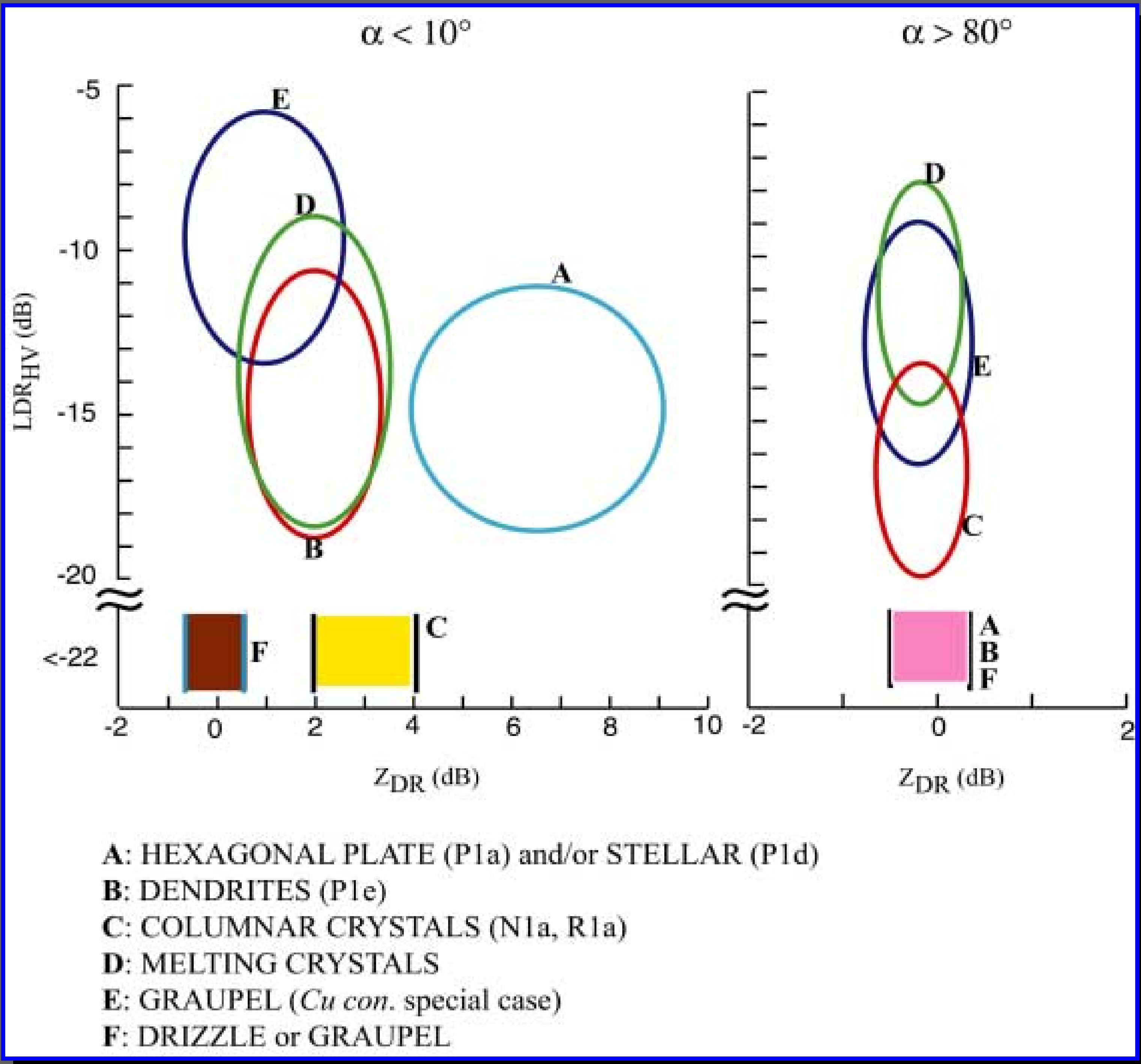
Ice concentrations 10 - 40 L^{-1}



Cloud traversed at -19^{o}C;
0.1 g m^{-3} LWC; 5-15 L^{-1} ice crystals

Note: localized ice generation

At high resolution can see correlation between vertical velocity and LWC. Resolution in ice crystal data is insufficient to see pattern.



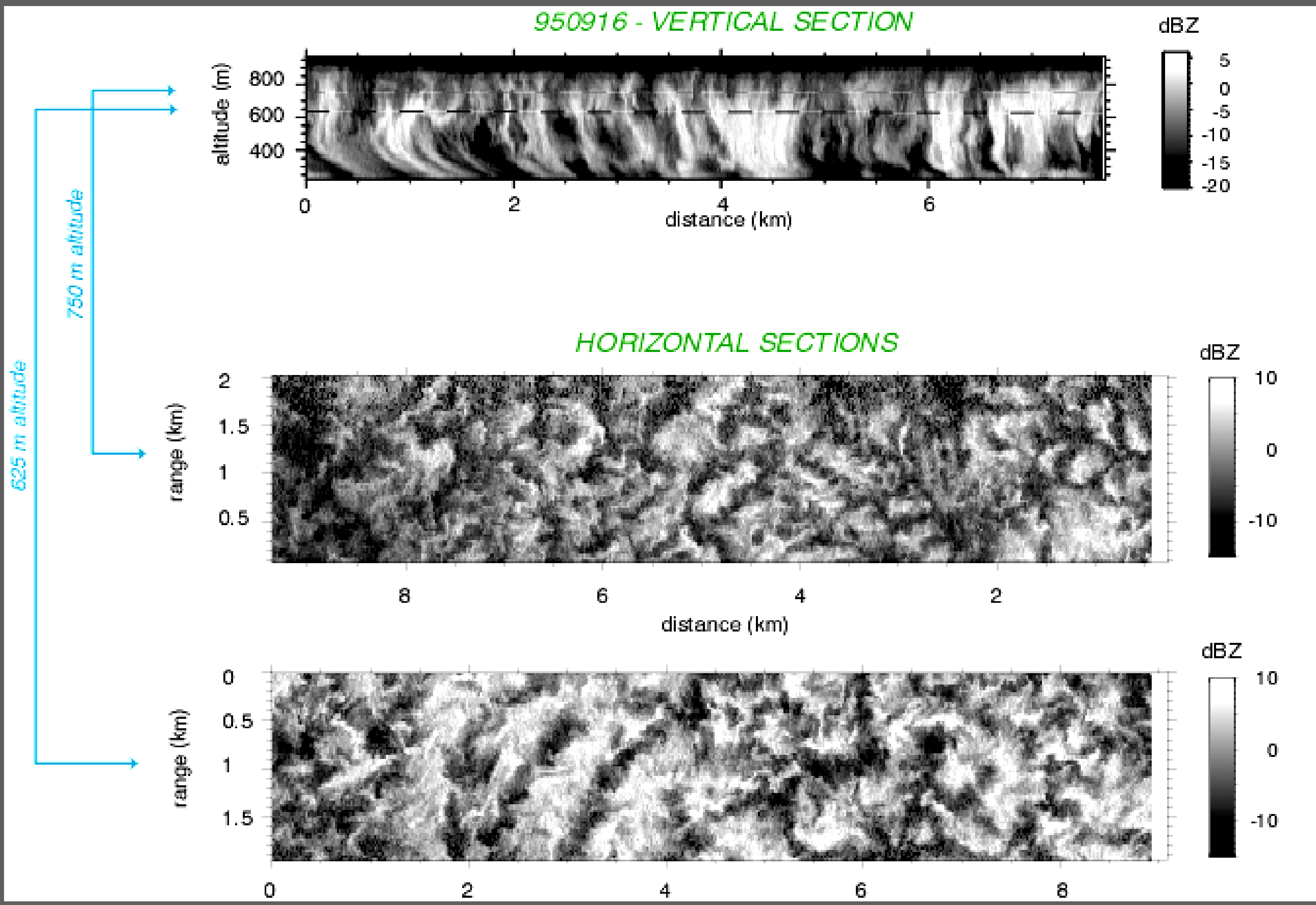
Polarization signatures can be identified.

Date	Cloud type	Z_{DR} > 3 dB α≤ 45°	Z_{DR} > 5 dB α≤45°	LDR_{HV} > -18 dB α≤45°	LDR_{HV} > -18 dB α>85°	LDR_{HV} > -16 dB α≤45°	LDR_{HV} > -16 dB α>85°
all data	various	3.7	0.8	5.1	1.3	1.5	0.3
02/18/97	*Ac*	72.6	43.5	30.9	1.2	15.1	0.1
02/11/97	*Ns*	0.5	0.0	4.5	2.7	0.6	0.3
04/04/97	*Cu con.*	0.1	0.0	10.2	2.2	3.0	1.0

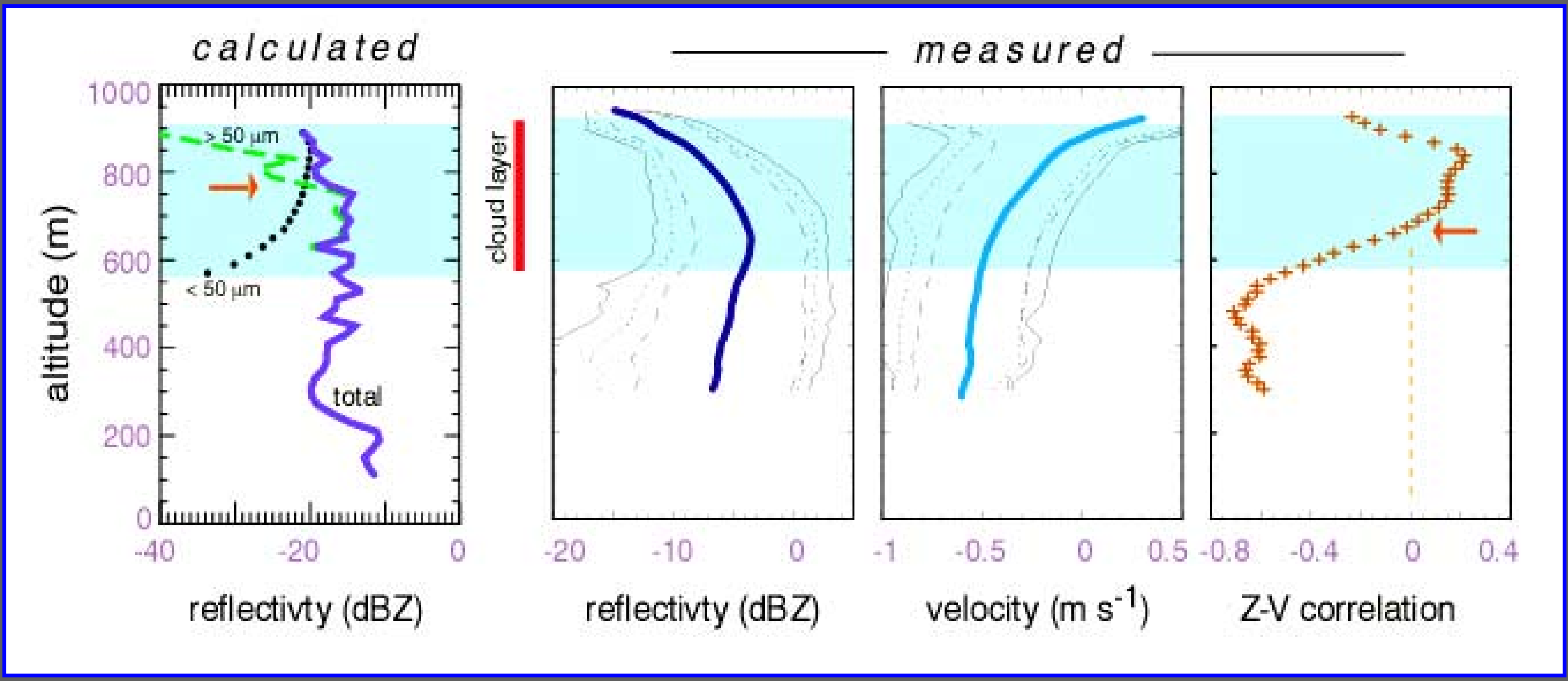
but the frequencies of pristine crystals are generally quite small (in the wintertime clouds of Wyoming)

Airborne radar observations of marine stratocumulus show the finscale structure in drizzle formation. Here, as in the case of ice initiation, better understanding is needed of the linkage between dynamics and microphysics.

On the positive side, these new tools are opening additional avenues for investigations.



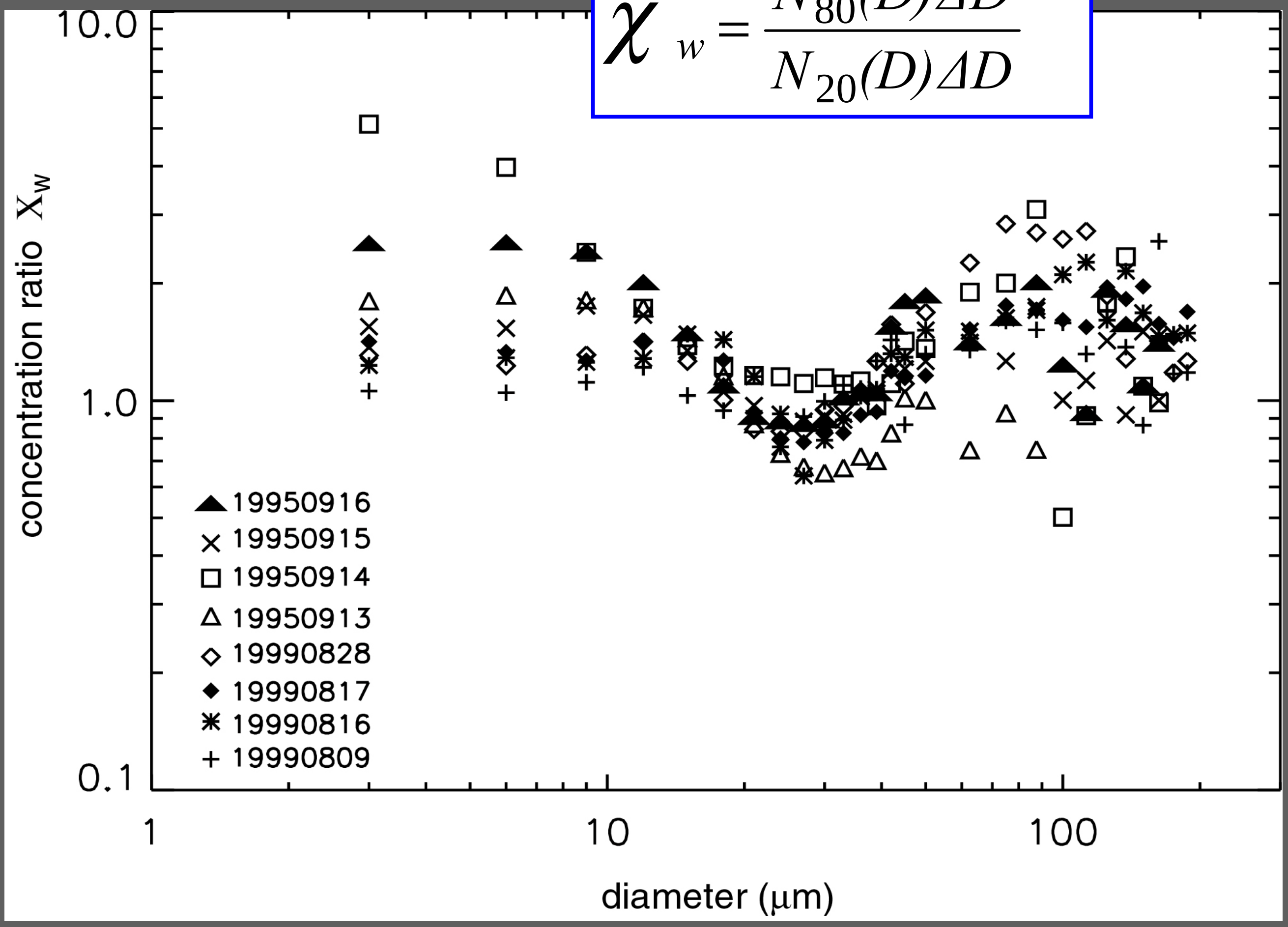
Vertical and horizontal sections through marine Sc.

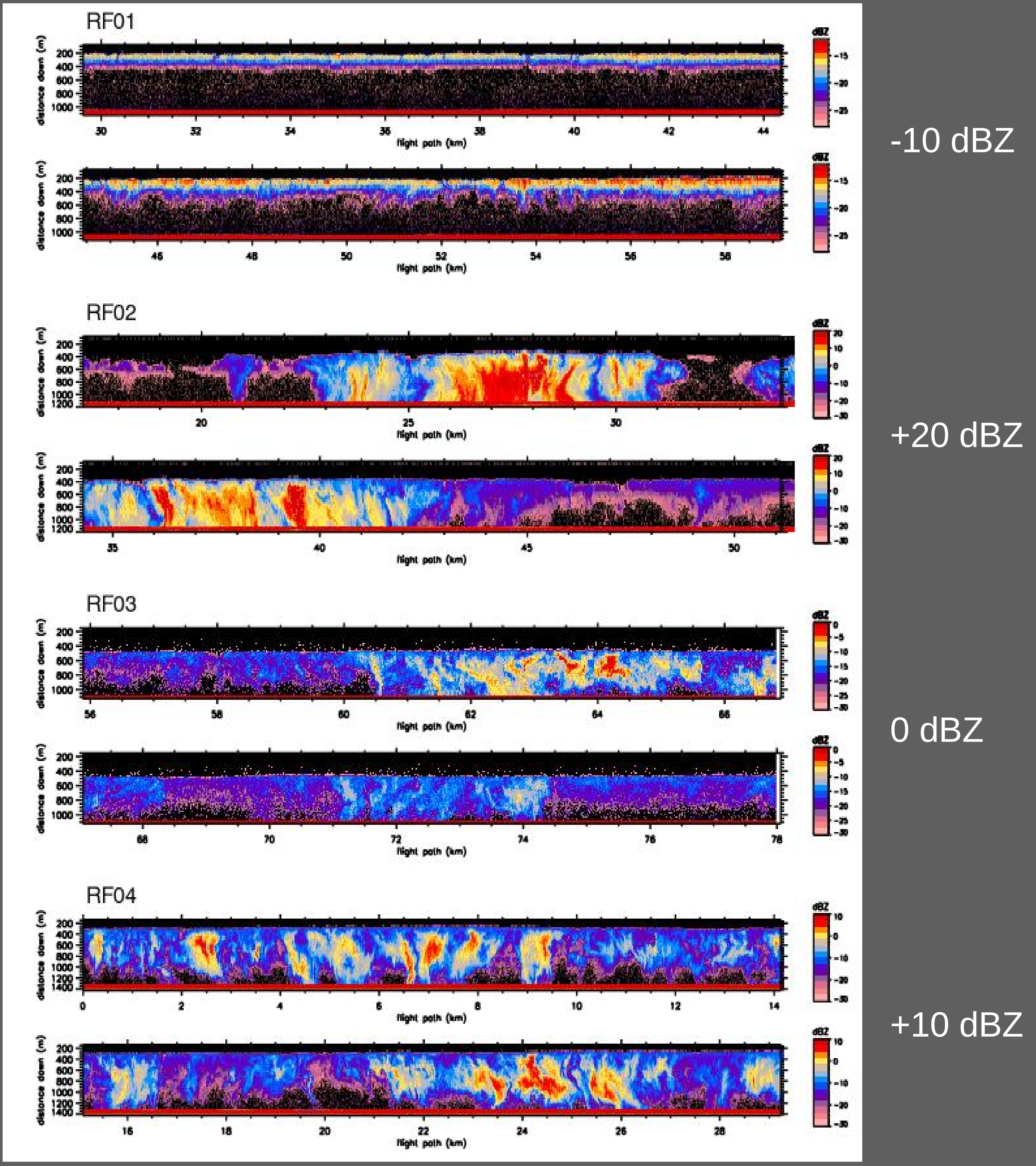


Basic characteristics of reflectivity profiles in Sc.

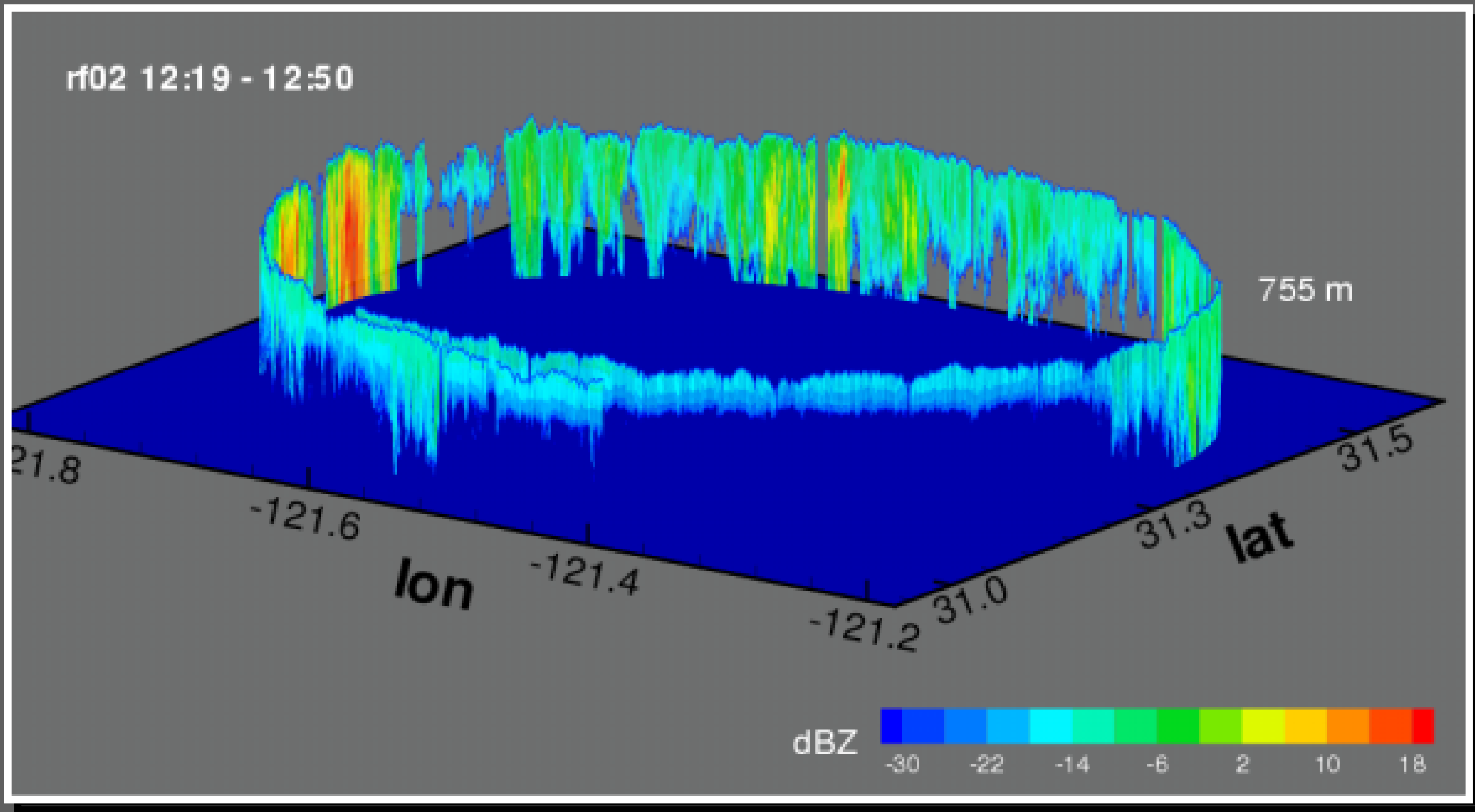
Vertical velocity in Sc modifies the droplet spectra in somewhat unexpected ways:

$$\chi_w = \frac{N_{80}(D)\Delta D}{N_{20}(D)\Delta D}$$



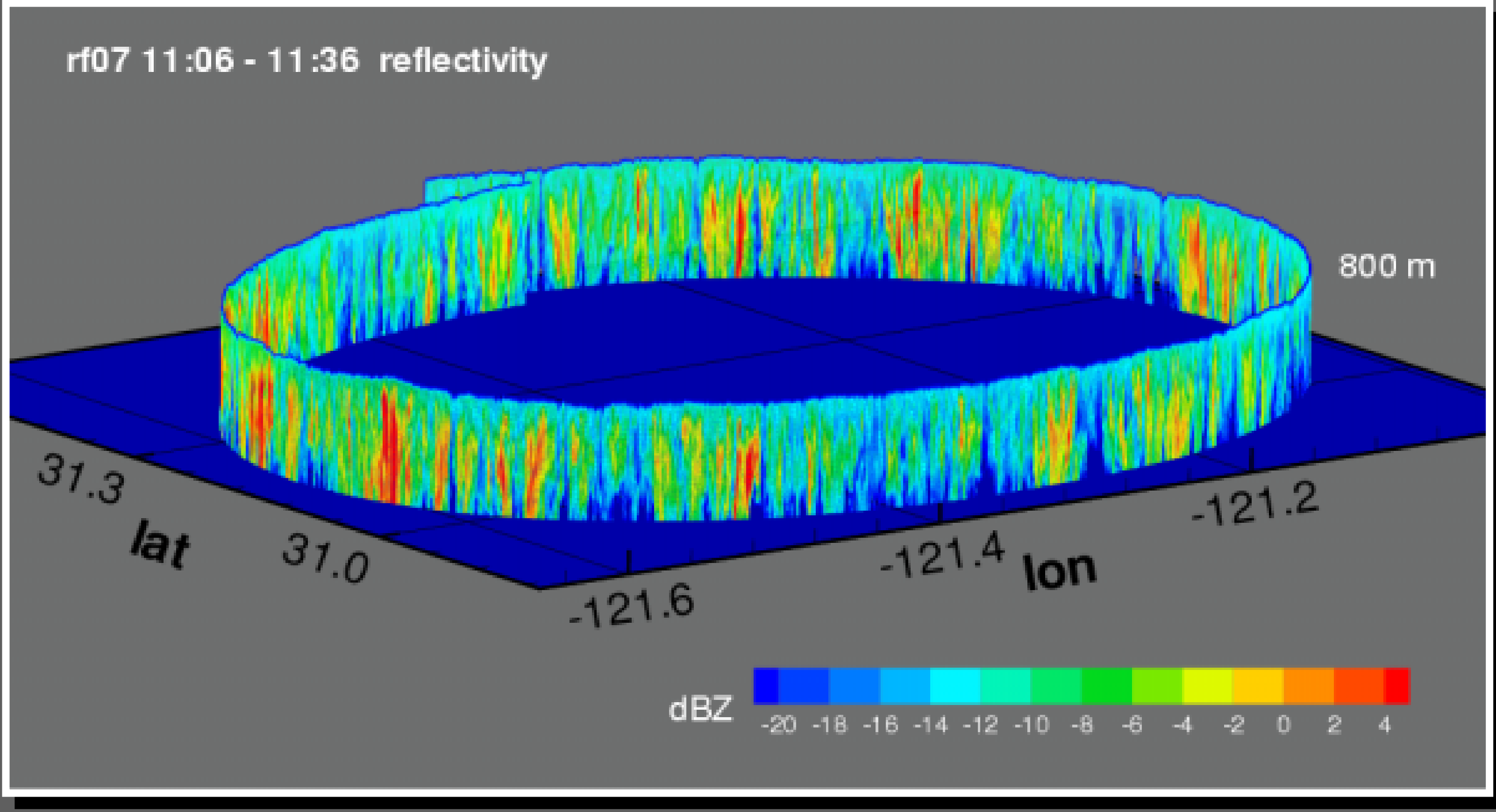


Radar reflectivity images depict the patterns of drizzle development and the large ranges of drizzle intensities.

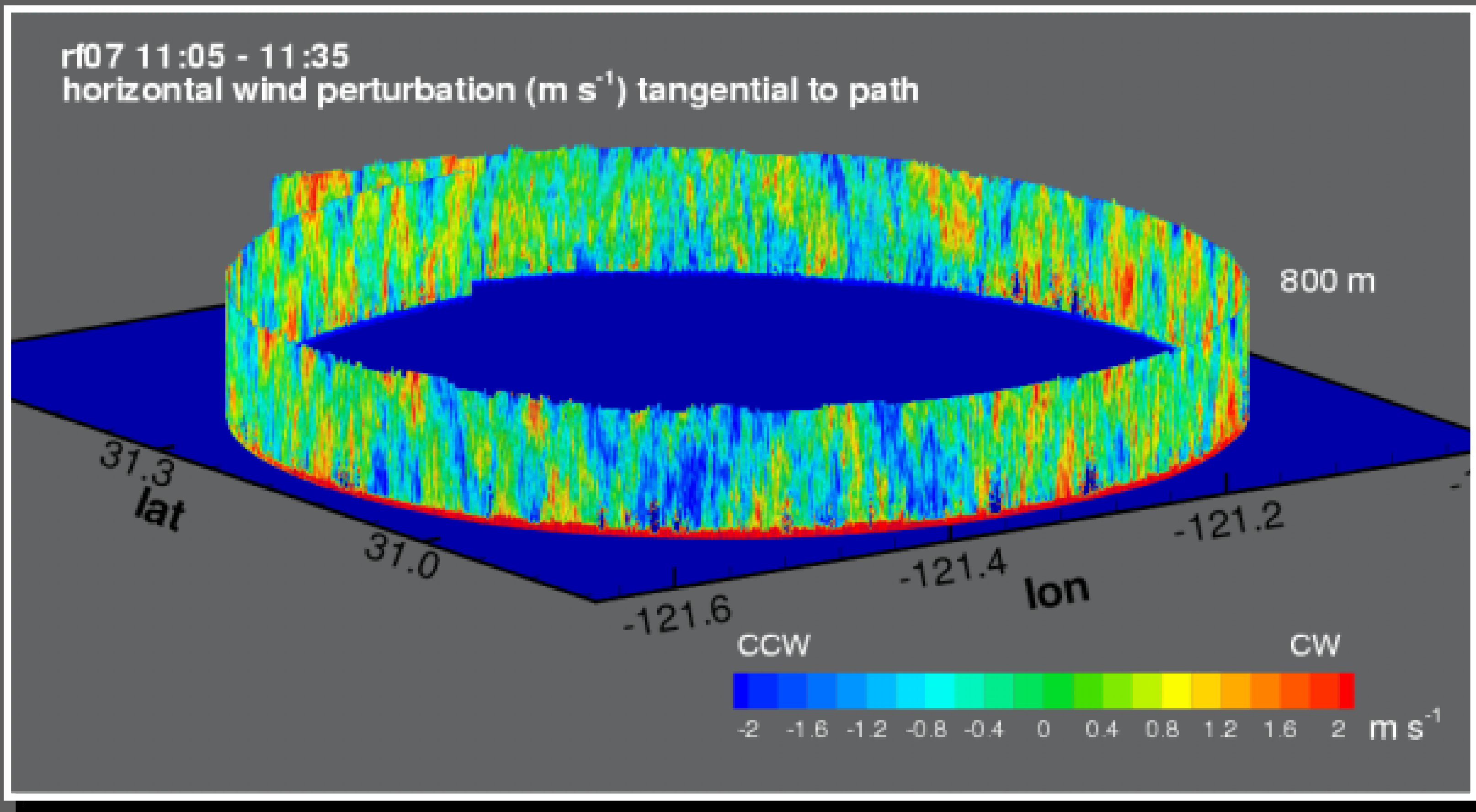


DYCOMS flight - 60 km diameter circle over Sc

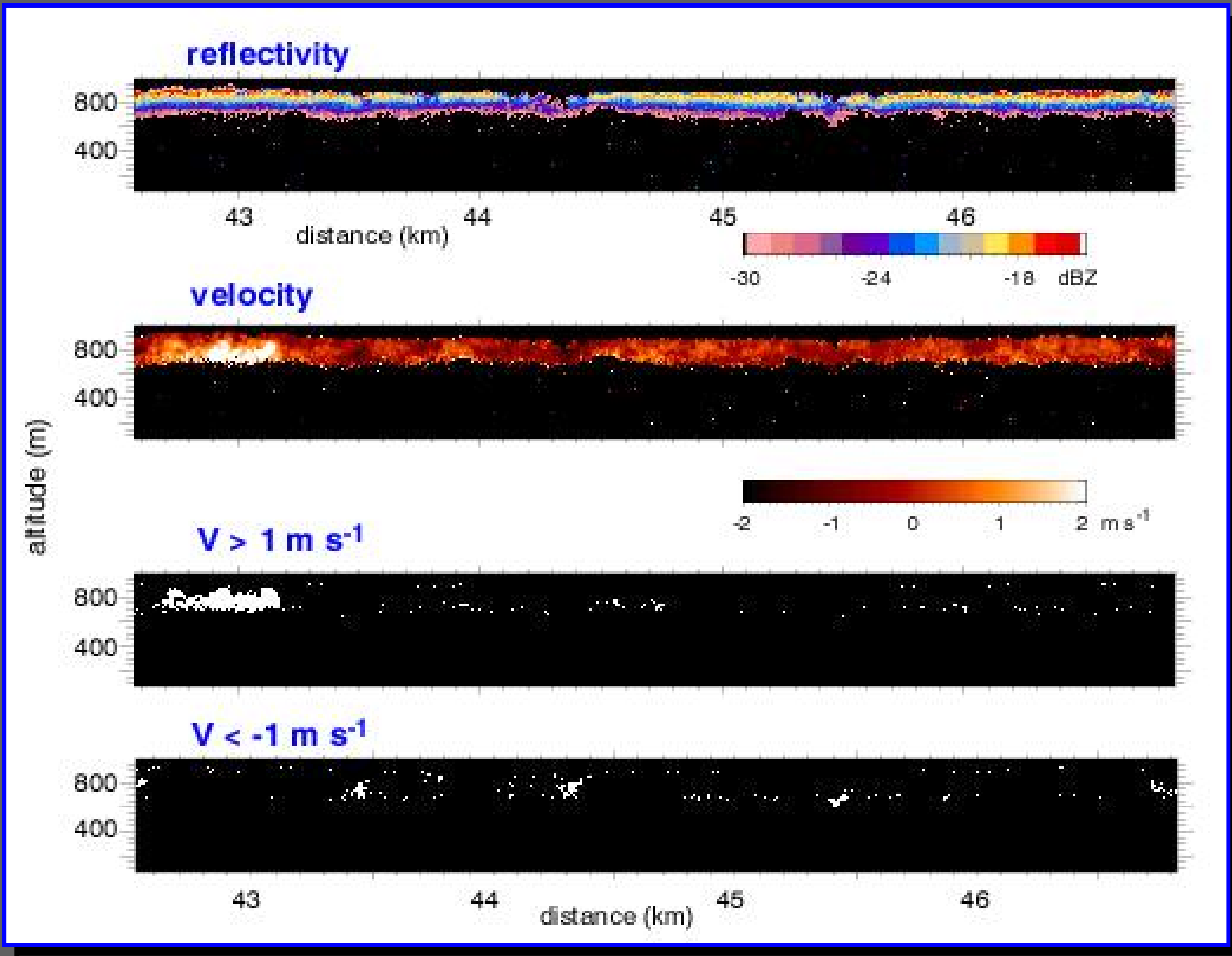
Example of large variation in drizzle intensity across the circle. Simple cloud base to cloud top gradient at the near point and heavy drizzle at the far quadrant.



More uniformly distributed drizzle. It reaches the surface at most places.

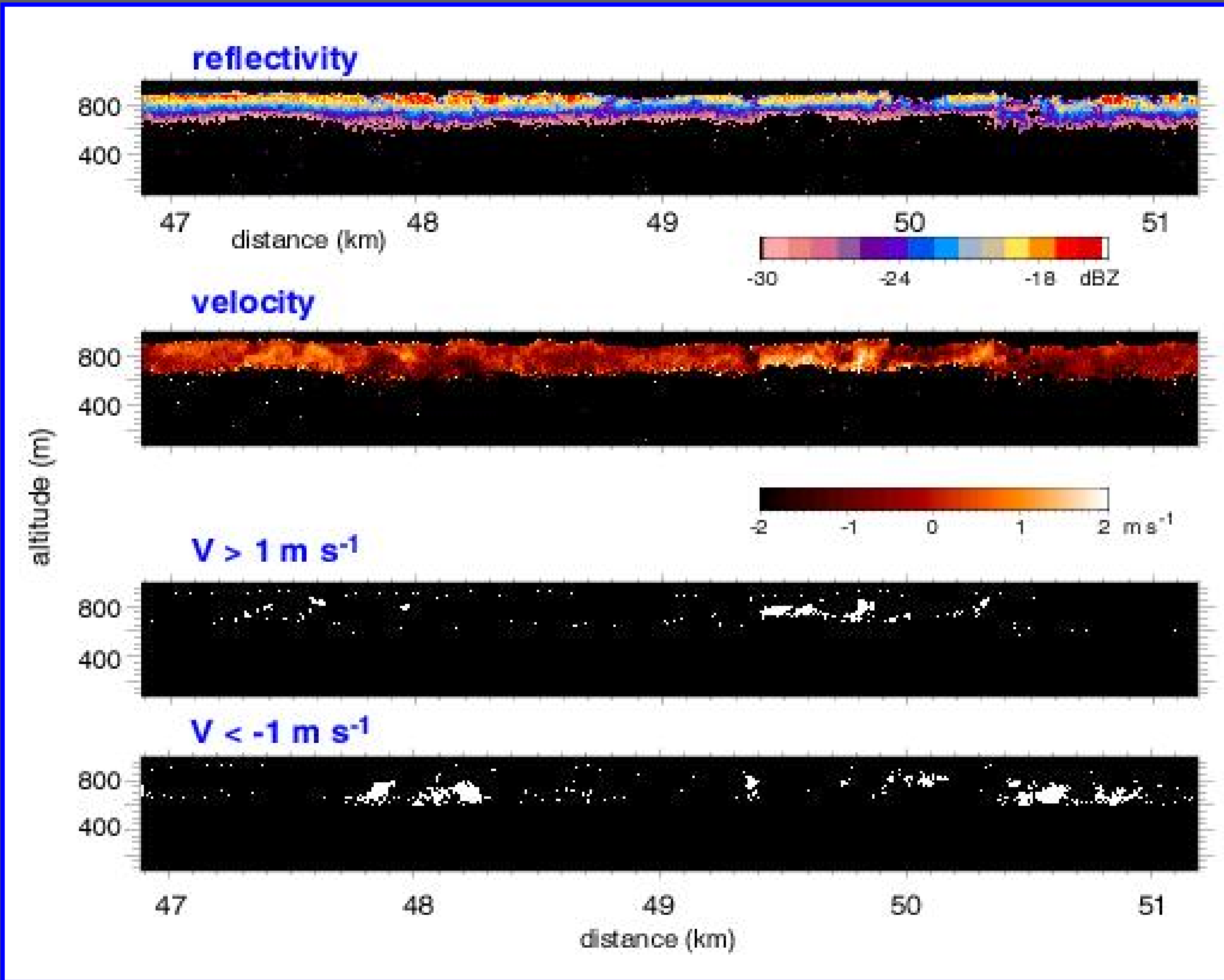


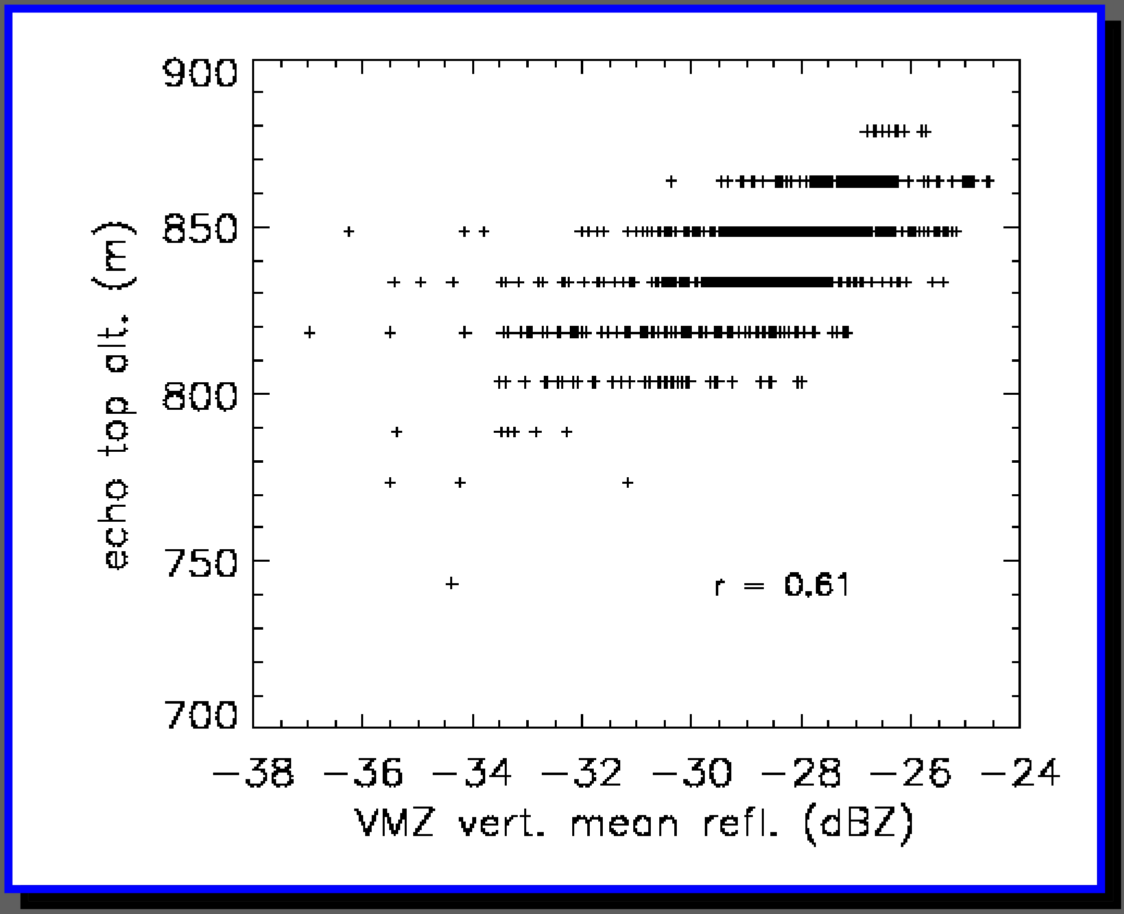
Horizontal wind perturbation (component added to the ambient wind in the plane of the scan) from dual-Doppler analysis. Solution of the continuity equation yields vertical air velocities even in the presence of drizzle which would otherwise dominate the Doppler vertical velocity. Convergence zones are evidenced by alternating colors.



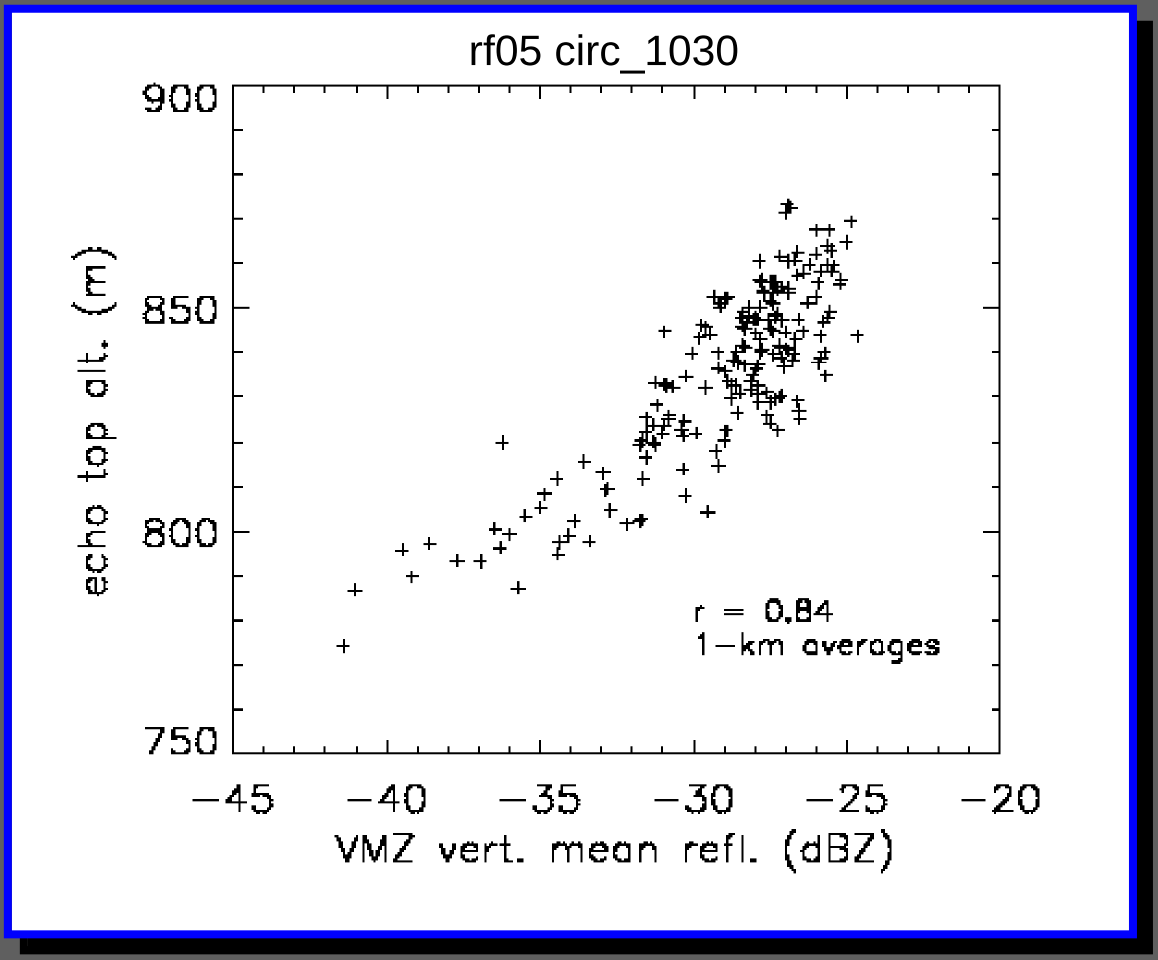
Marine stratocumulus reflectivity and velocity images. DYCOMS-II rf05 10:30 circle

With negligible drizzle present, the vertical Doppler velocities are very close to air velocities.


reflectivity
800
400
47
48
49
50
51
distance (km)
-30
-24
-18
dBZ
velocity
800
400
-2
-1
0
1
2
m s-1
altitude (m)
V > 1 m s-1
800
400
V < -1 m s-1
800
400
47
48
49
50
51
distance (km)



Correlation between echo top altitude and vertical mean reflectivity implies a coupling of the microphysics and the dynamics of the marine stratocumulus. This evidence holds for data on the 10-m scale

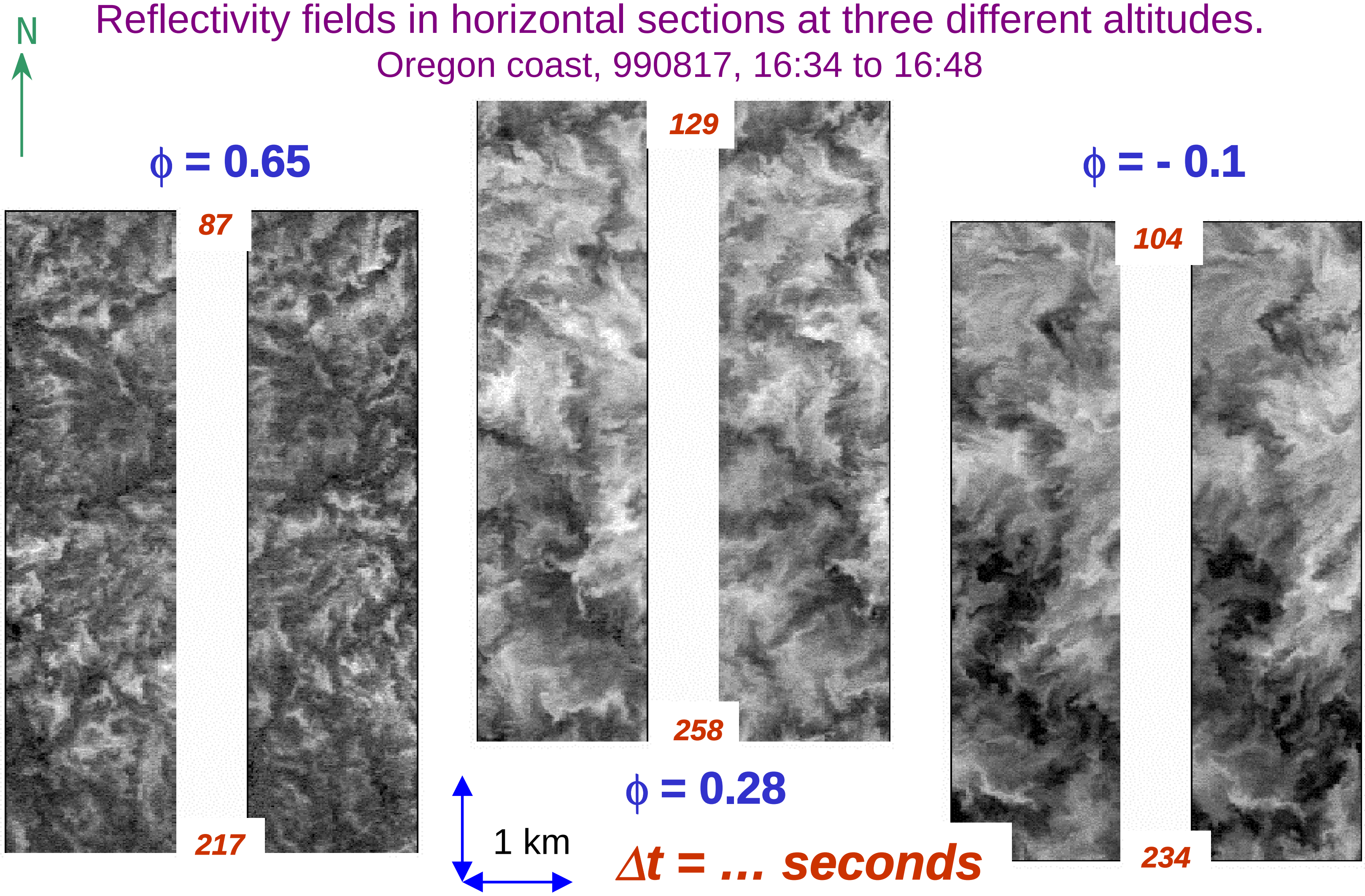


Correlation between echo top altitude and vertical mean reflectivity implies a coupling of the microphysics and the dynamics of the marine stratocumulus. This evidence holds for data on the 10-m scale and <u>also on the kilometer scale.</u>

Repeated sampling of same cloud region.

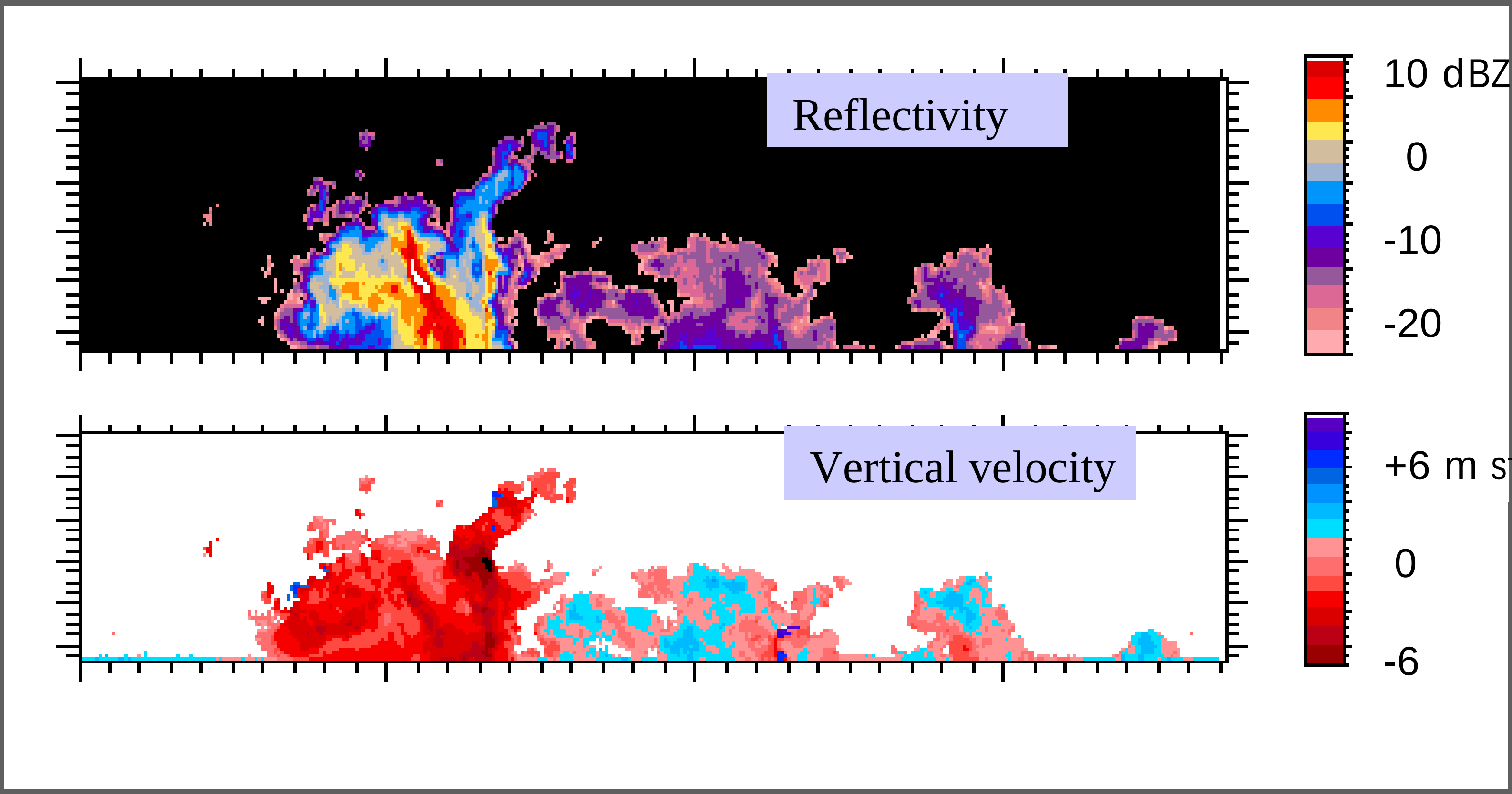
Reflectivity fields in horizontal sections at three different altitudes.

Oregon coast, 990817, 16:34 to 16:48

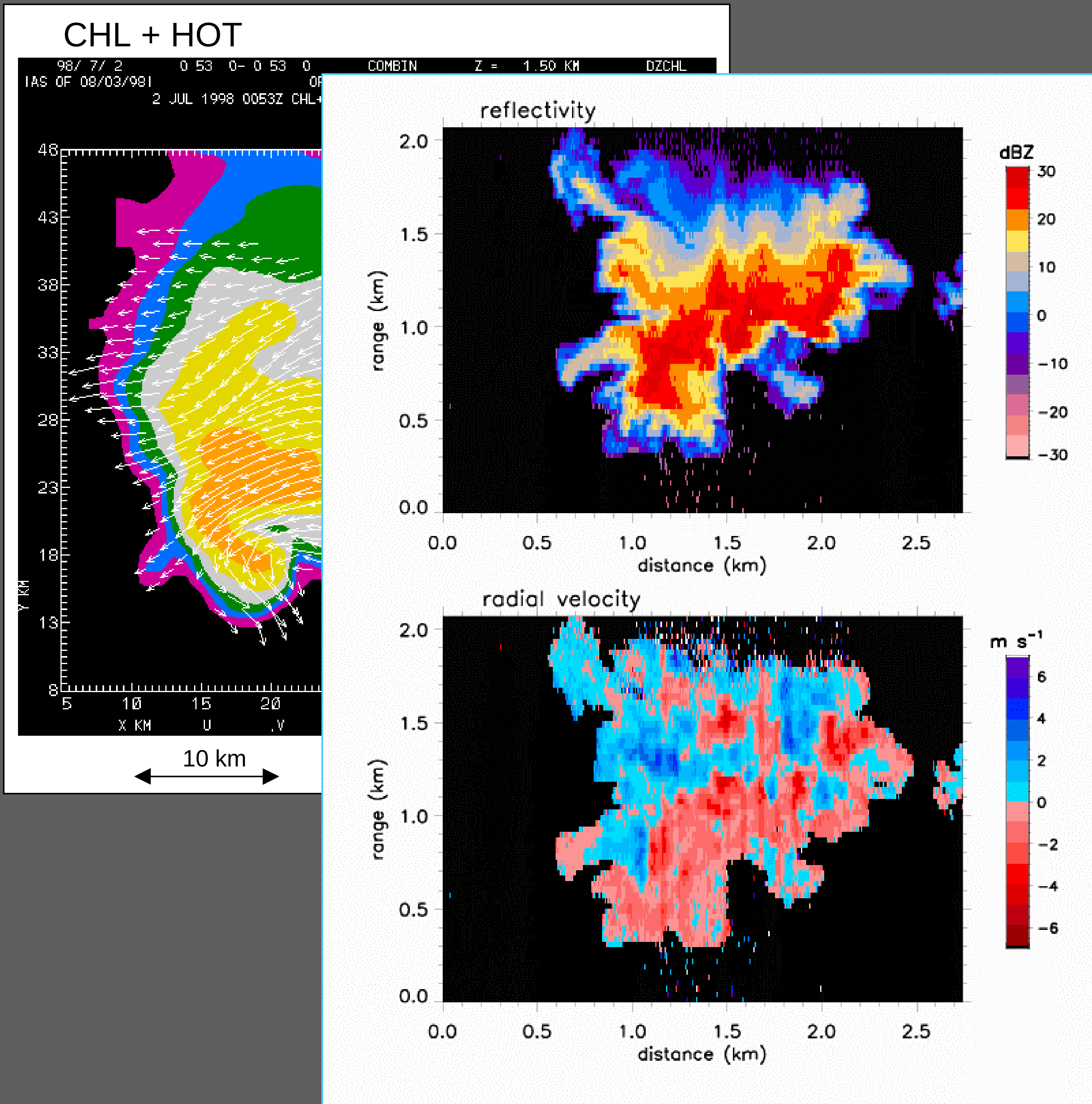


There is considerable steadiness in the horizontal reflectivity fields. The time scale of variation is least near cloud top, greatest in the drizzle below cloud base.

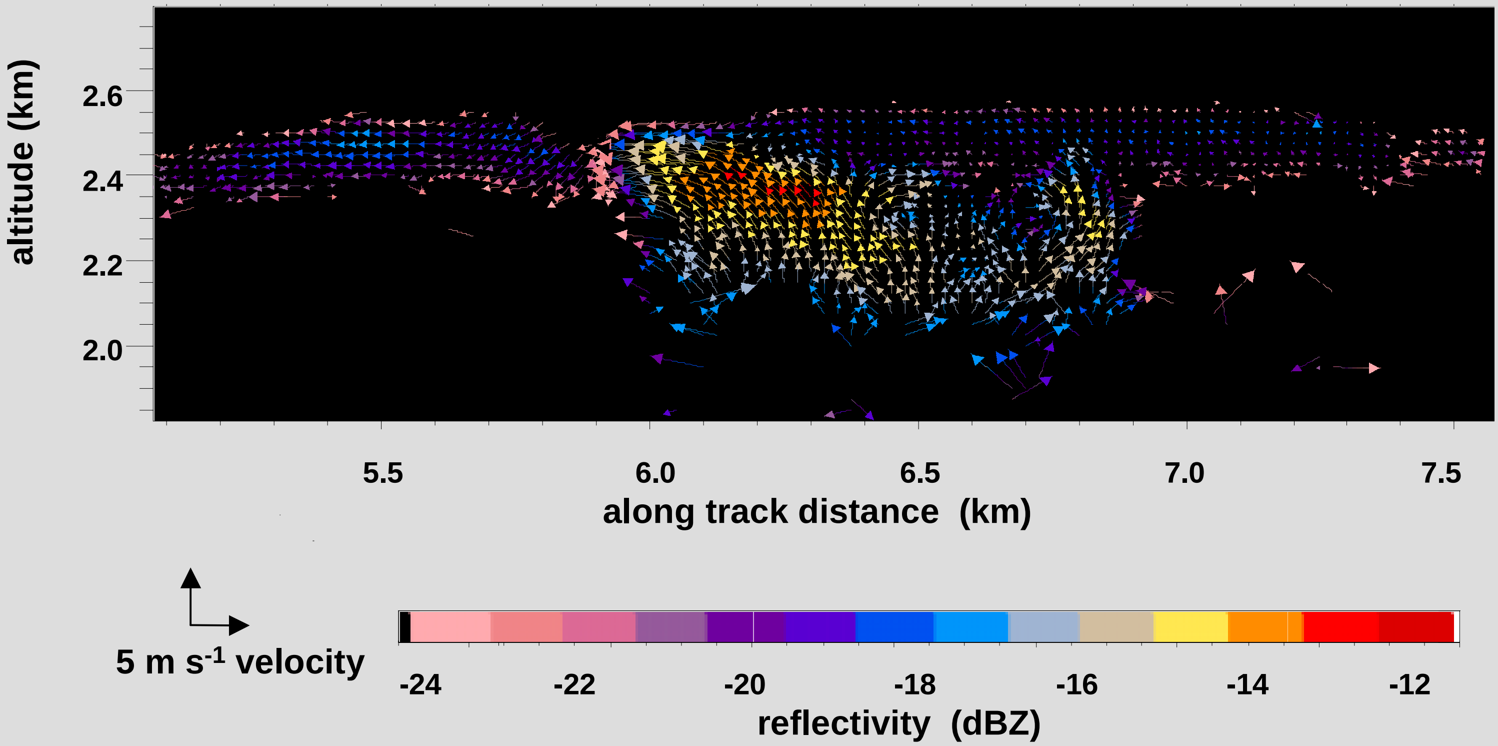
Studies of cumulus clouds with the airborne radar show structures that are not readily detected by other means and which provide new bases for conceptual models and for constraining numerical models.



Florida cumuli in vertical cross section.

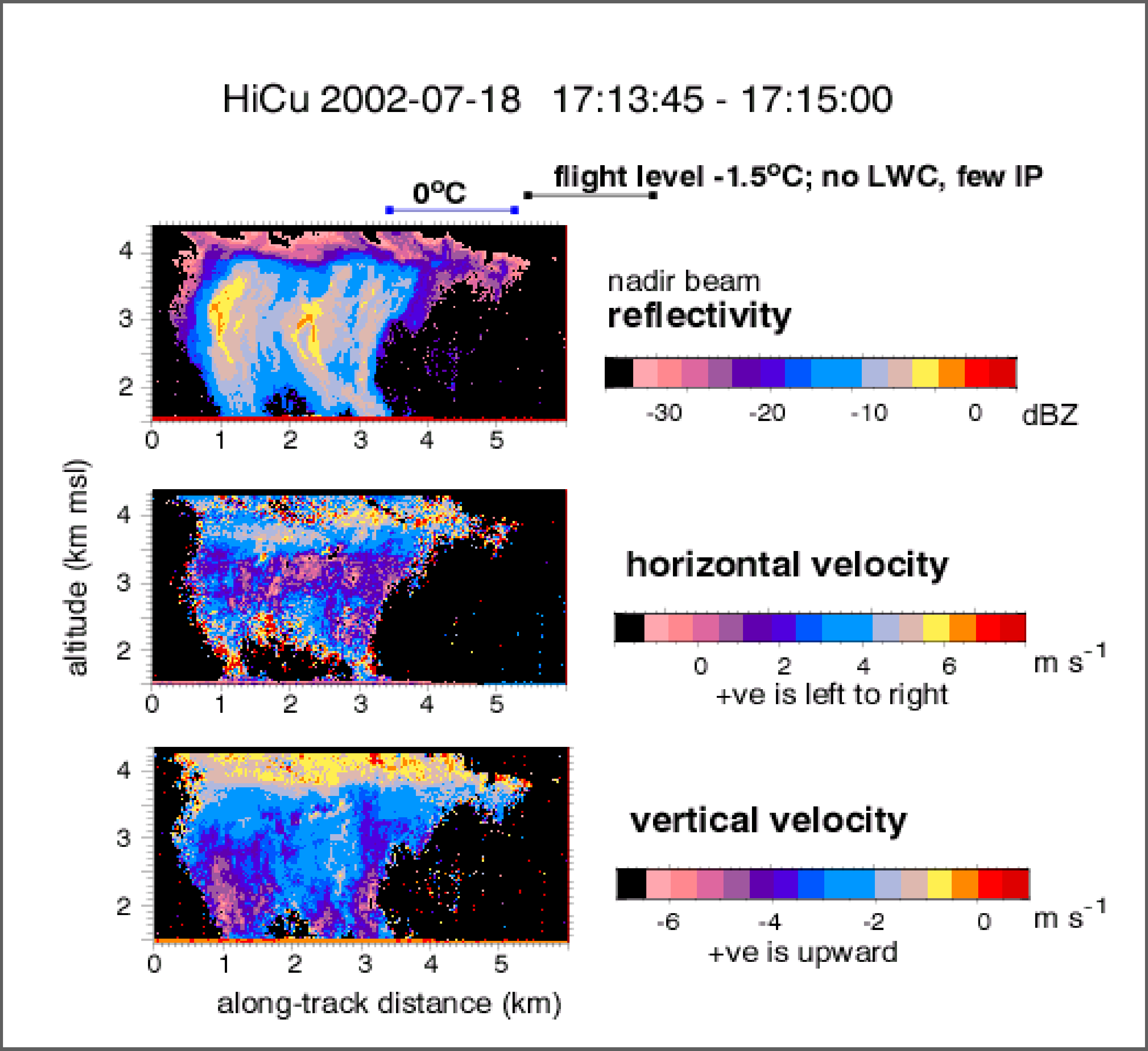


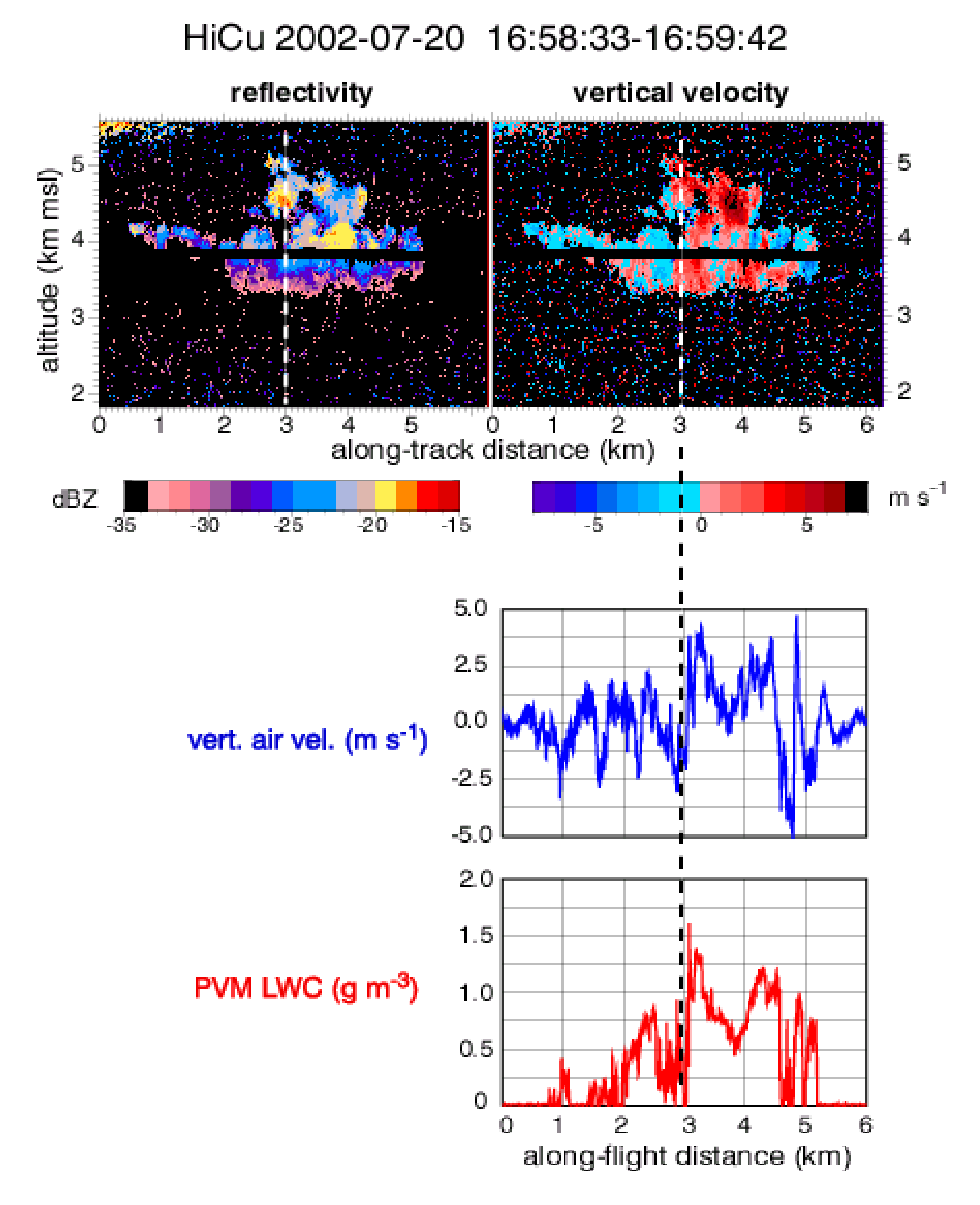
Increased resolution compared to ground-based radars, and the flexibility to move to selected clouds are the main advantages of airborne cloud radars. Limitation to vertical and horizontal planes, and attenuation, are the disadvantages. Attenuation does not influence the derived motion fields.



Dual-Doppler analysis of Ac observed in TRAC98

courtesy David Leon


HiCu 2002-07-18 17:13:45 - 17:15:00
flight level -1.5°C; no LWC, few IP
0°C
nadir beam
reflectivity
-30 -20 -10 0 dBZ
horizontal velocity
0 2 4 6 m s-1
+ve is left to right
vertical velocity
-6 -4 -2 0 m s-1
+ve is upward
altitude (km msl)
along-track distance (km)



HiCu 2002-07-20 16:58:33-16:59:42
reflectivity
vertical velocity
altitude (km msl)
along-track distance (km)
dBZ
-35 -30 -25 -20 -15
m s-1
-5 0 5
vert. air vel. (m s-1)
PVM LWC (g m-3)
along-flight distance (km)

Main points:

Science base is lacking in many important aspects.

Some basic science issues can be advanced by cloud seeding experiments.

Practical weather modification work represents an approach from another direction.

These two directions will converge only very slowly, yet the two activities can continuously learn from one another.

New tools can help both types of endeavors.

Suggestions:

Active tracer (chaff) experiment in cumulus, together with airborne radar observations.

Hygroscopic seeding experiment in marine stratocumulus -- has weather modification and climate study (aerosol impact) implications.