The July 16, 2002 Crystal FACE Early Anvil Event: A Case Study Combining Ground, Aircraft and Satellite Data

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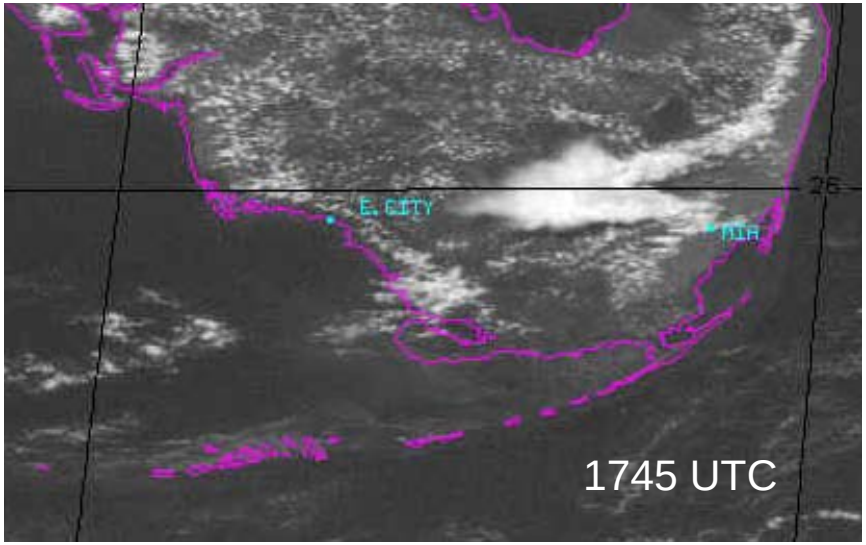
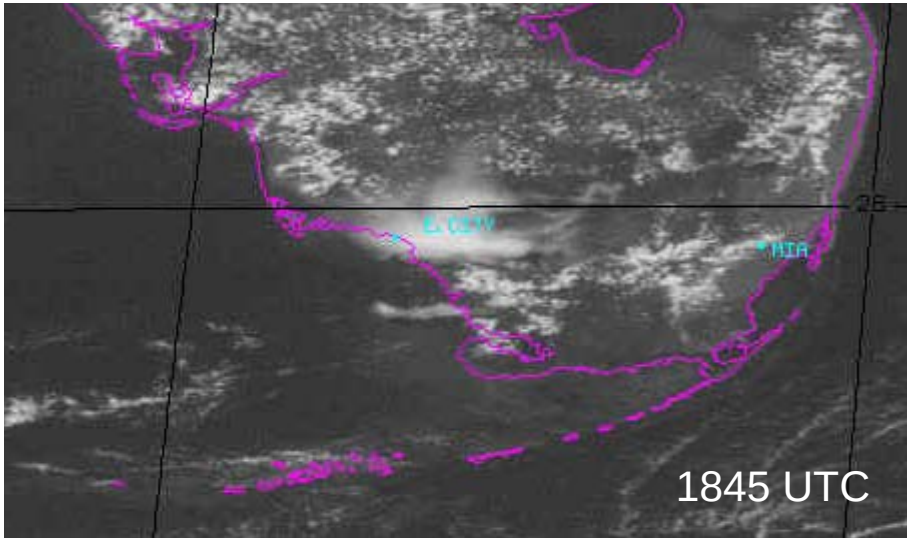
Motivation: Characterizing the life cycle of convective cirrus is an important issue for understanding the global hydrological cycle

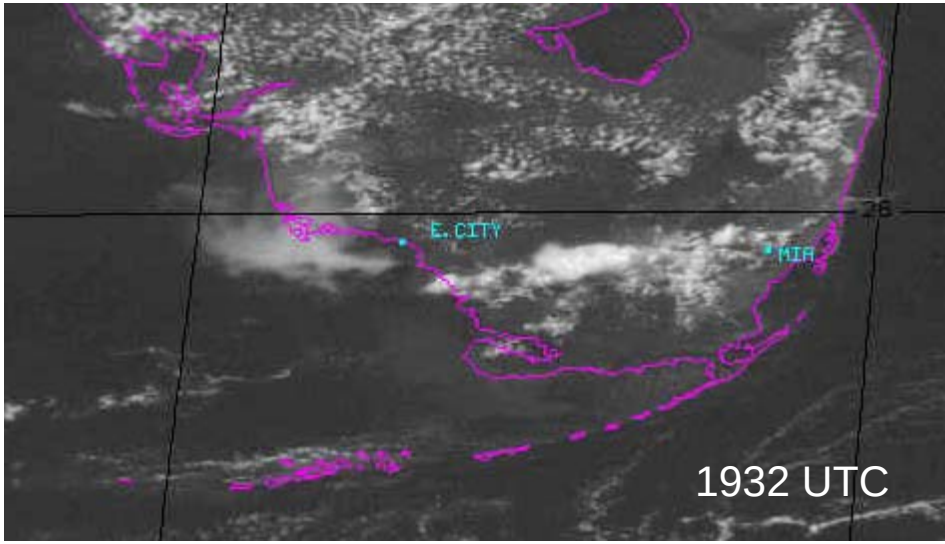
Goal: Document an anvil cirrus event from birth to death using a unique combination of data

- GOES satellite provides the temporal context
- Aircraft and ground-based provide a unique vertical cross section
- The combination provides a unique opportunity for validation

The July 16, 2002 Crystal FACE Early Anvil Event







GOES Imagery courtesy Pat Minnis and Co.

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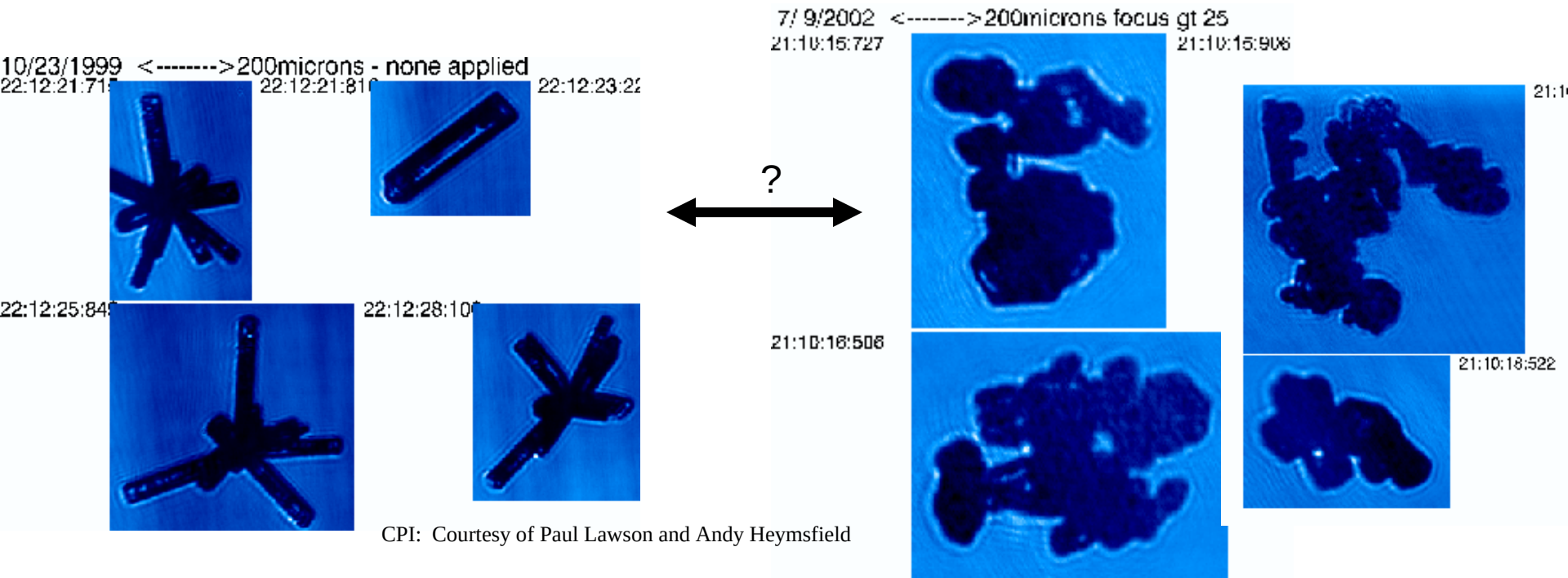
$$Z_e = IWC \frac{a_z b_z}{a_m b_m} \frac{\Gamma\{b_z\}}{\Gamma\{b_m\}} \left(\frac{b_m + 1}{D_{mass}} \right)^{b_m - b_Z}$$

$$\bar{V}_D^q = a_v \left(\frac{b_m + 1}{D_{mass}} \right)^{-b_v} \left(1 + \frac{b_v}{b_Z} \right) \frac{\Gamma\{b_z + b_v\}}{\Gamma\{b_z\}}$$

$$n(L) = N \exp[-\lambda L]$$

$$m = a_m D^{b_m}$$

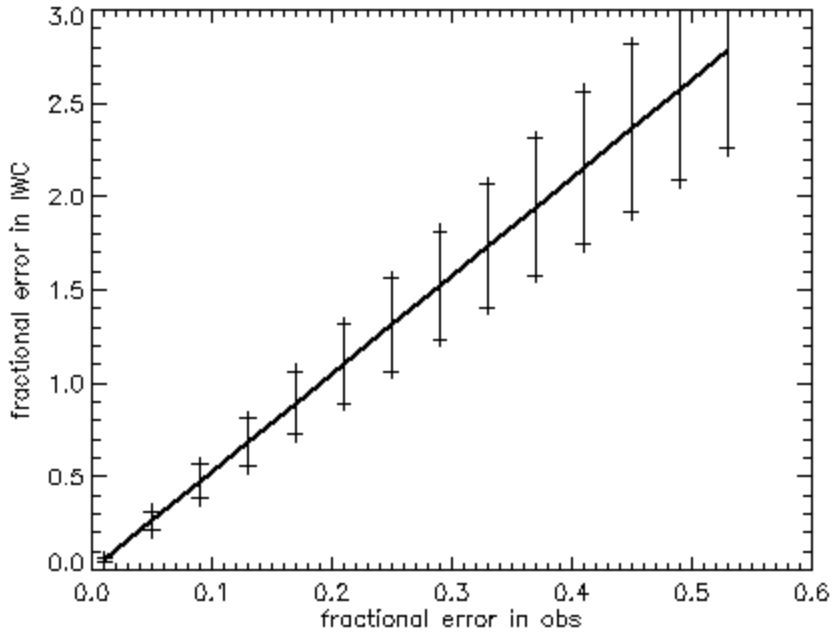
$$V = a_v D^{b_v}$$



CPI: Courtesy of Paul Lawson and Andy Heymsfield

The July 16, 2002 Crystal FACE Early Anvil Event

Sensitivity of retrieved IWC to the error in the exponent of the mass-dimensional power law assumption:



i.e. a 25% error in the exponent leads to 100% errors in IWC!

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Explore a new relationship between aircraft and ground-based data:

- the empirical relations are fundamental to the accuracy of the ground based result. Knowing their statistics in a given cloud type nearly totally controls the accuracy of the retrieval.

- So instead of viewing the aircraft-ground based relationship as just validation, the synergy should be exploited more fully.

- aircraft data should be used in two fundamental modes:

  - Case Study: Where the empirical relations can be known with high precision for a particular cloud event.

  - Statistical: Where the ensemble of aircraft events can be used intelligently to characterize the statistics of the empirical relationships for a particular cloud type.

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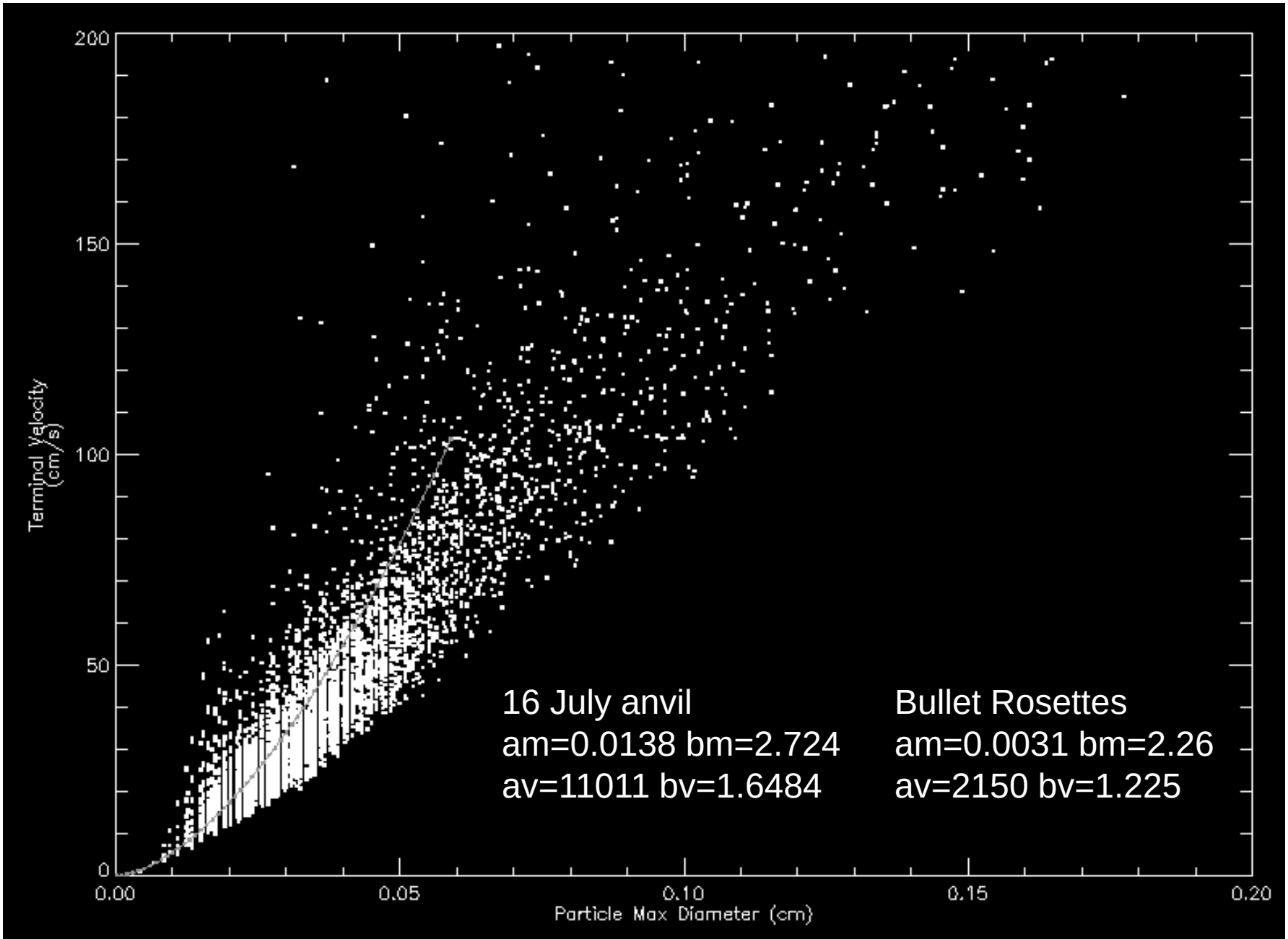
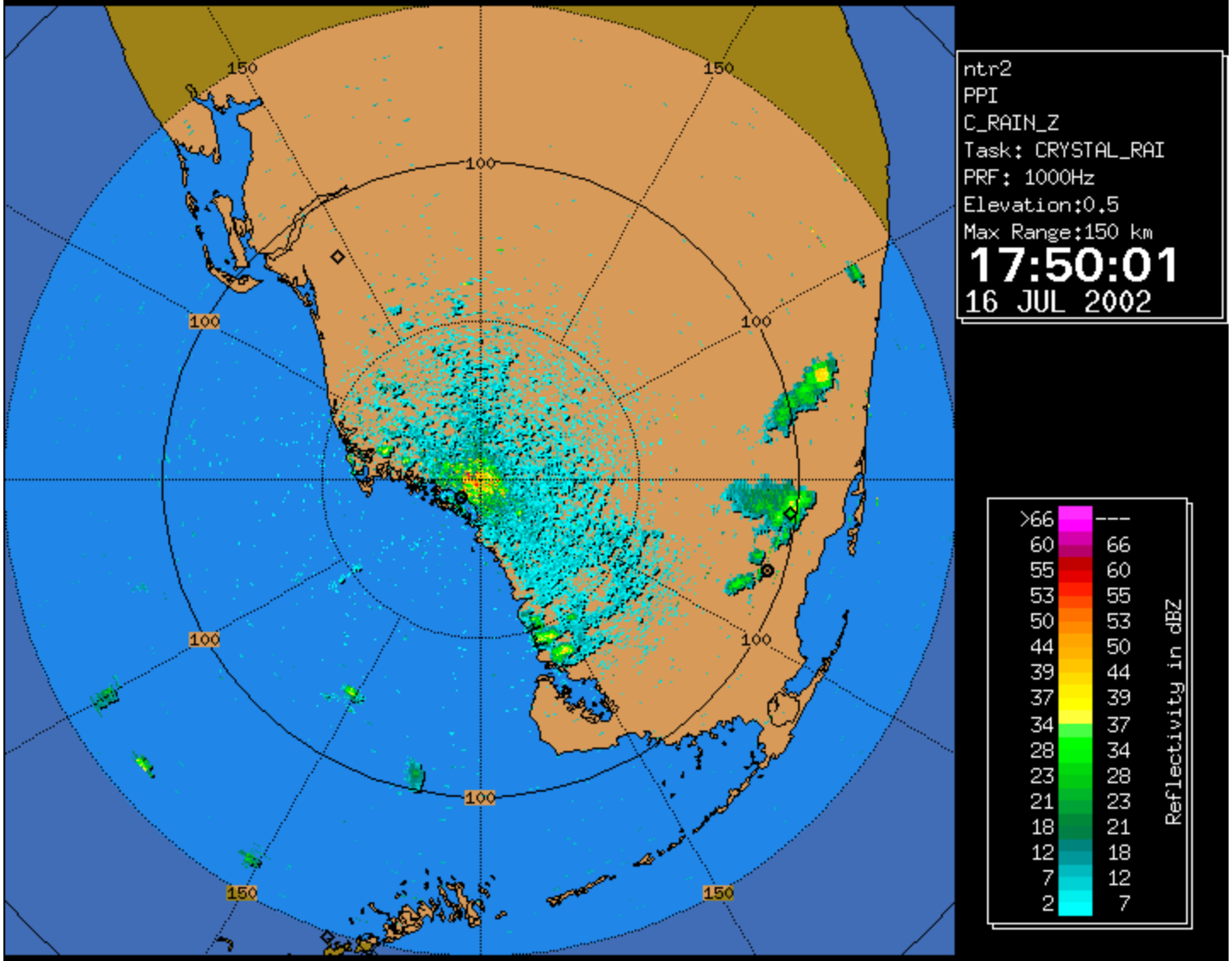
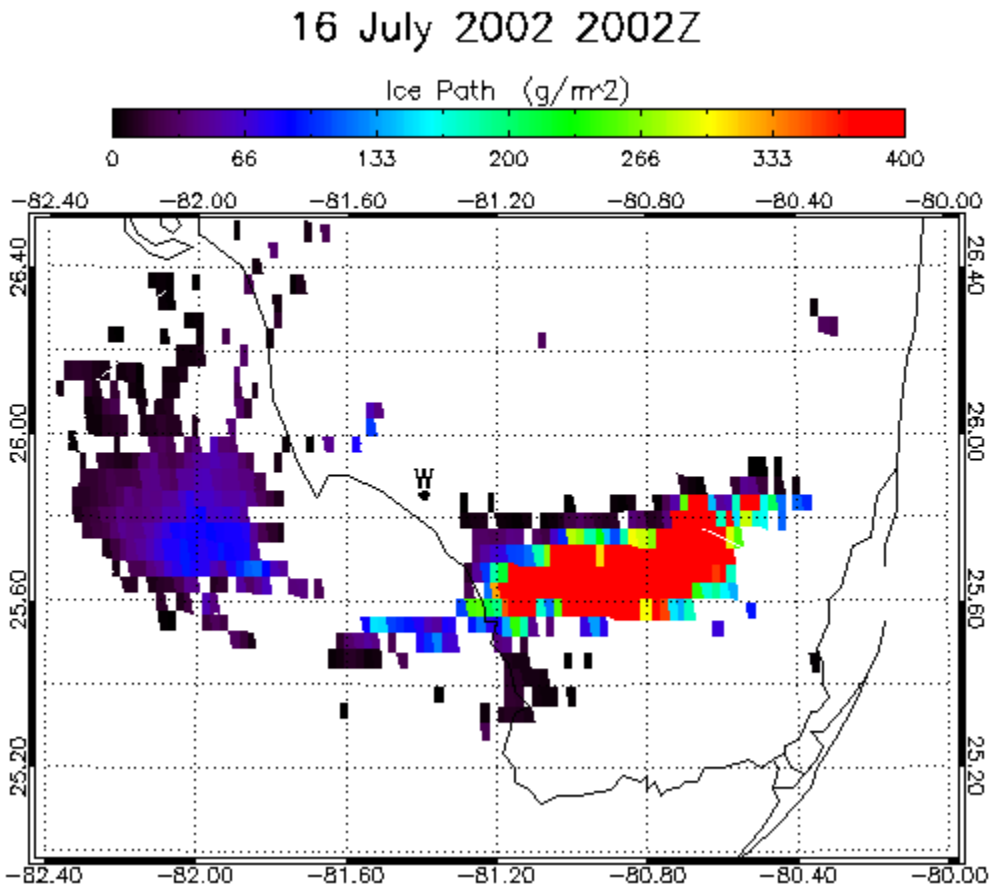
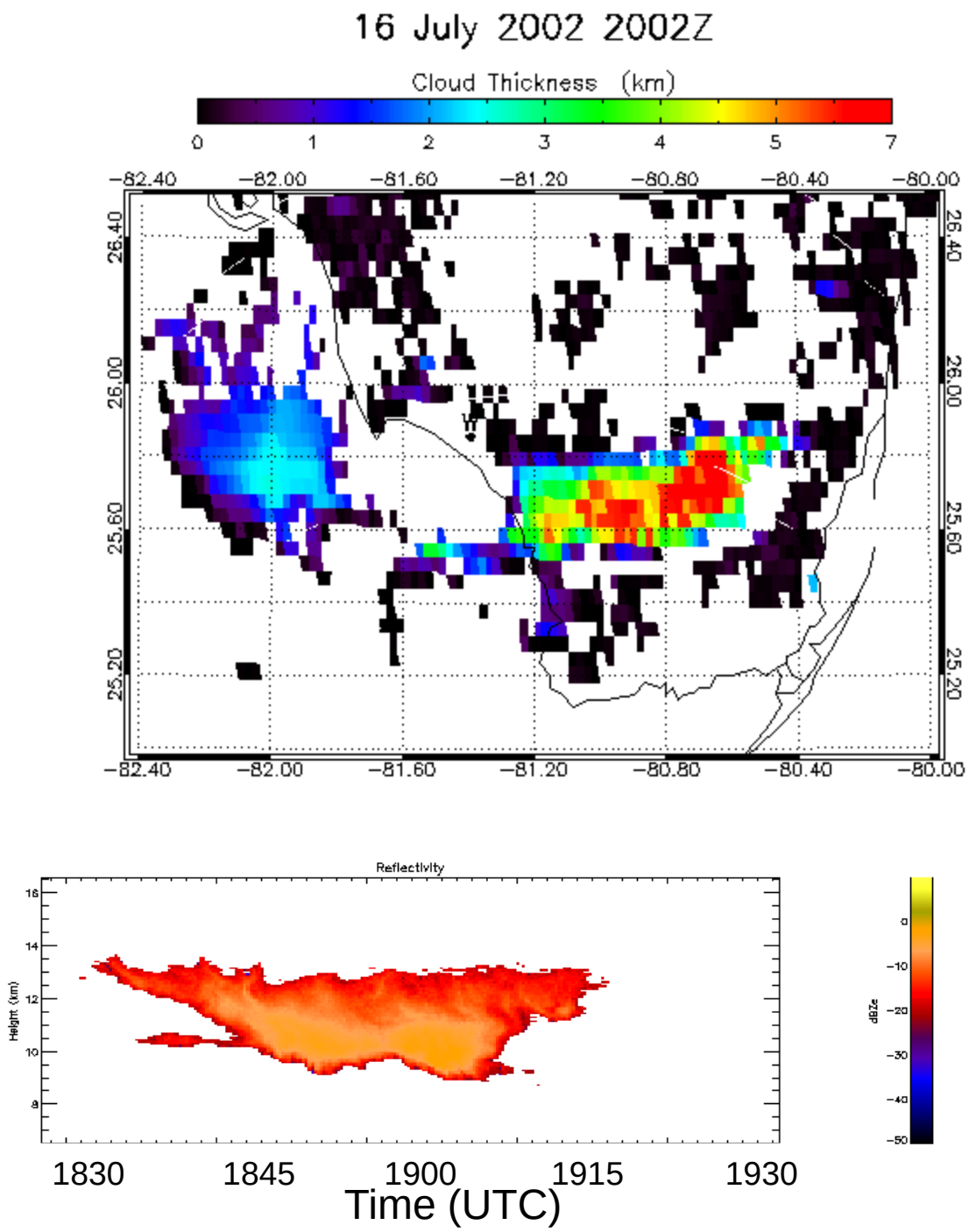
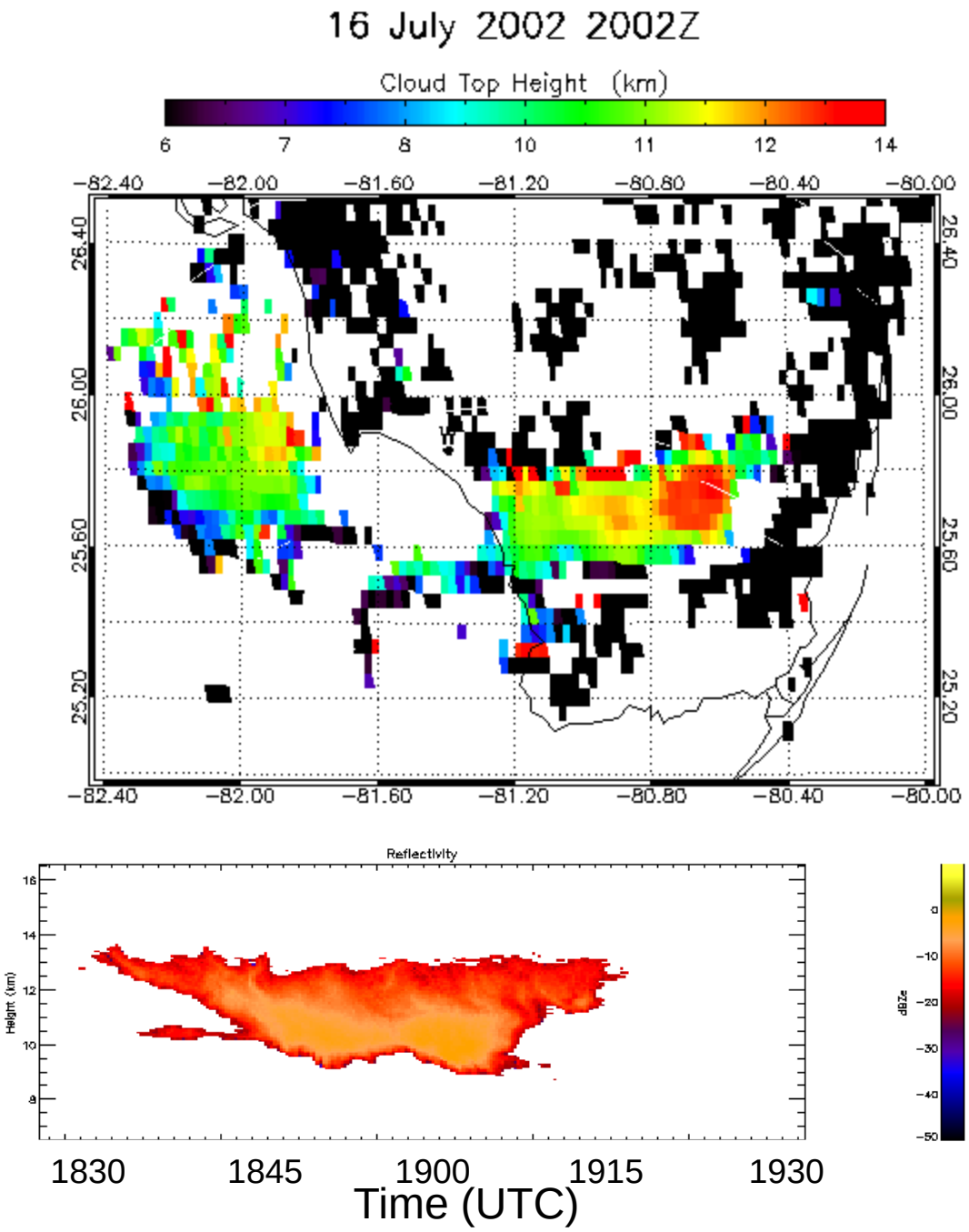



ntr2
PPI
C_RAIN_Z
Task: CRYSTAL_RAI
PRF: 1000Hz
Elevation:0.5
Max Range:150 km
17:50:01
16 JUL 2002
150
100
100
100
100
100
150
150
>66 ---
60 66
55 60
53 55
50 53
44 50
39 44
37 39
34 37
28 34
23 28
21 23
18 21
12 18
7 12
2 7
Reflectivity in dBZ

Ice Water Path Evolution of the Anvil Retrieved from GOES – Courtesy Pat




16 July 2002 2002Z
Cloud Thickness (km)
0
1
2
3
4
5
7
−82.40
−82.00
−81.60
−81.20
−80.80
−80.40
−80.00
26.40
26.00
25.60
25.20
Reflectivity
Height (km)
16
14
12
10
8
dBZ
0
−10
−20
−30
−40
−50
1830
1845
1900
1915
1930
Time (UTC)


16 July 2002 2002Z
Cloud Top Height (km)
6
7
8
10
11
12
14
−82.40
−82.00
−81.60
−81.20
−80.80
−80.40
−80.00
26.40
26.00
25.60
25.20
Reflectivity
Height (km)
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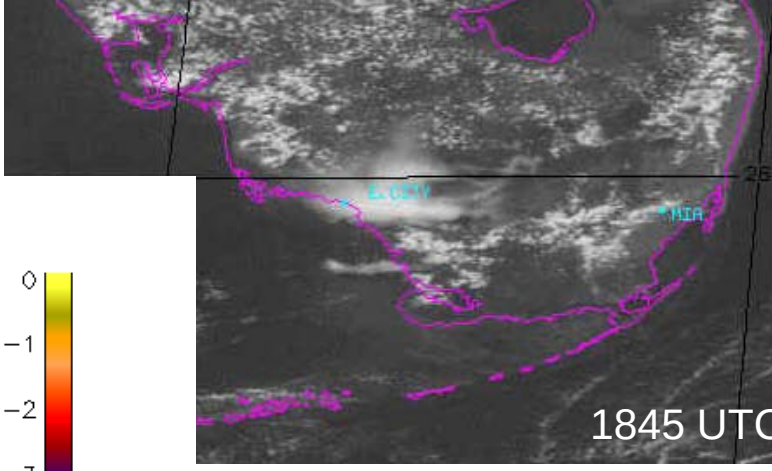
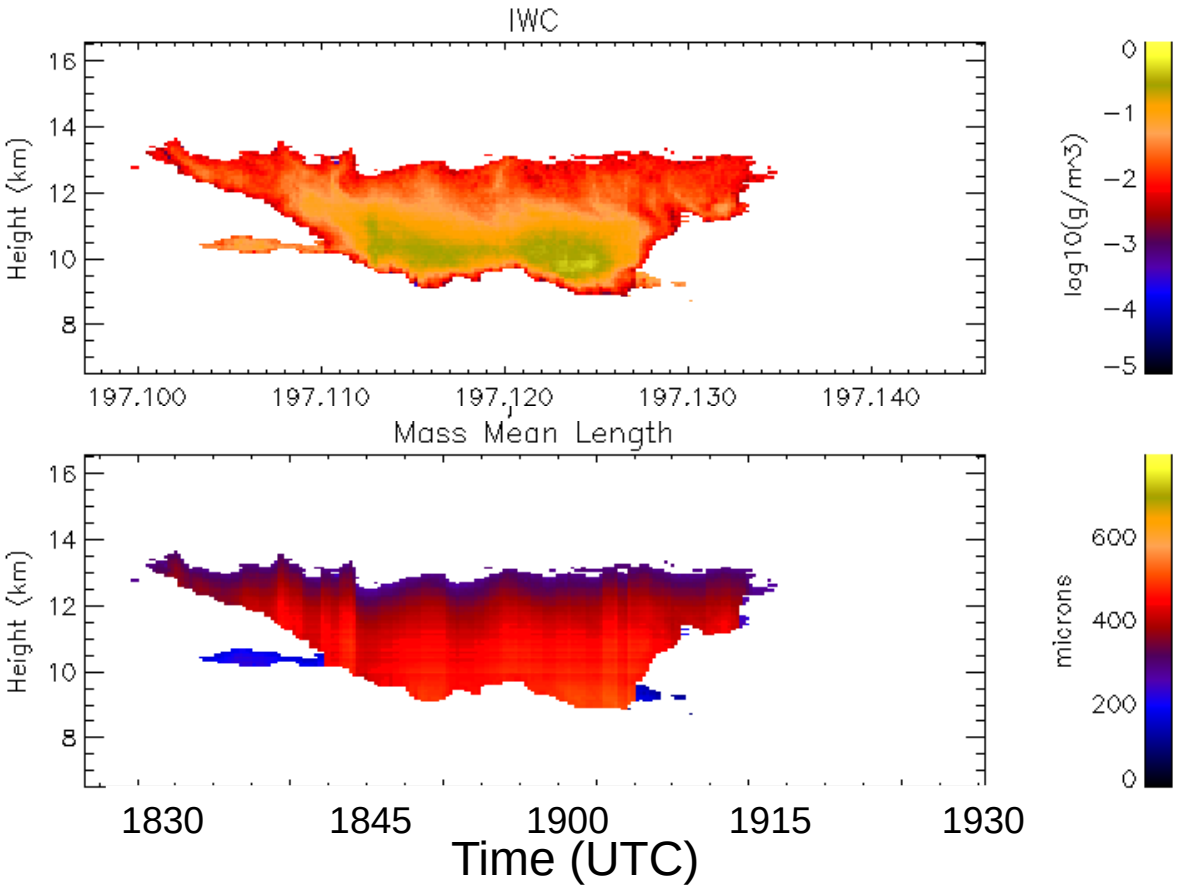
dBZ
0
−10
−20
−30
−40
−50
1830
1845
1900
1915
1930
Time (UTC)

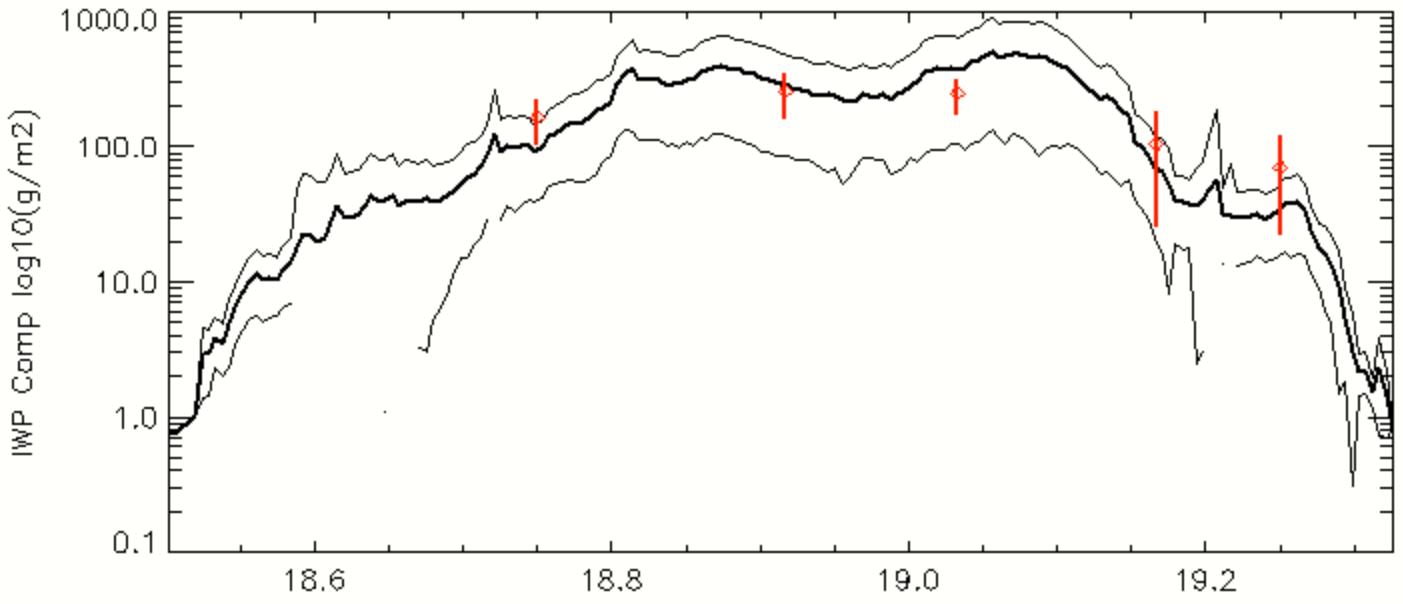
Crystal FACE Case Study: July 16



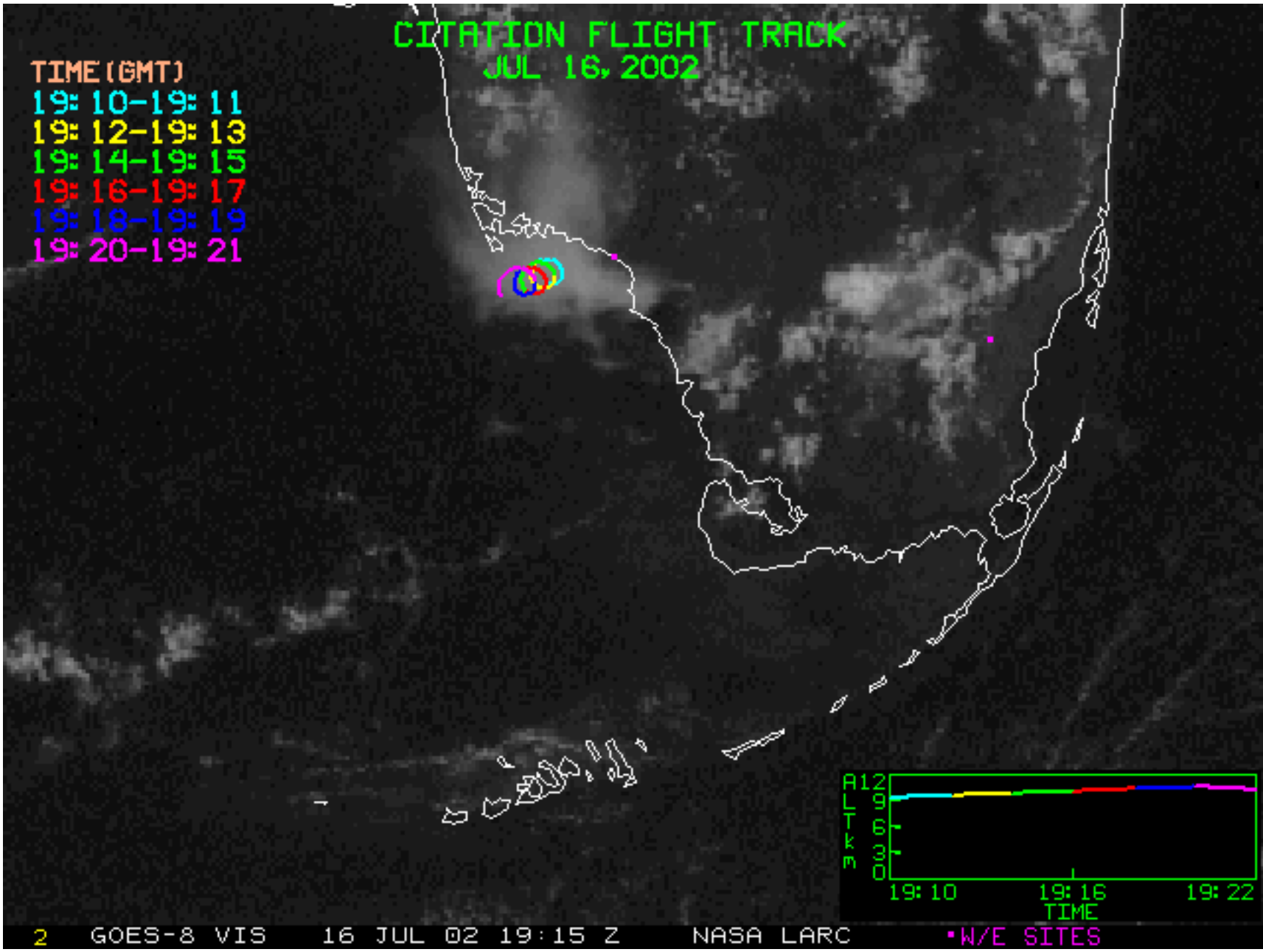


PARSL data courtesy Jim Mather and Tom Ackerman
Radar data courtesy Roger Marchand
TSI courtesy Chuck Long

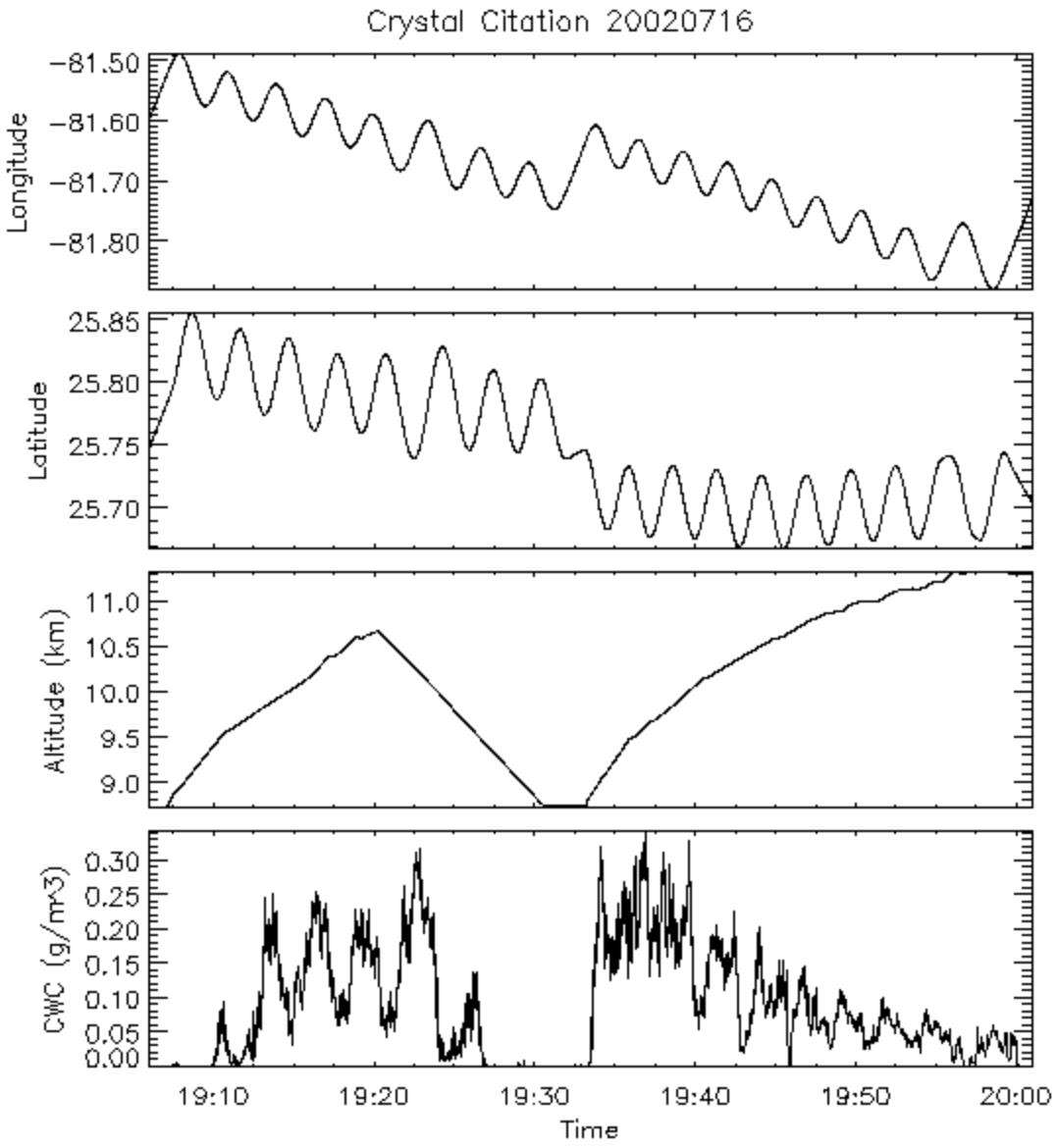
The July 16, 2002 Crystal FACE Early Anvil Event: IWP Comparison – ground vs GOES



The July 16, 2002 Crystal FACE Early Anvil Event: Aircraft Data



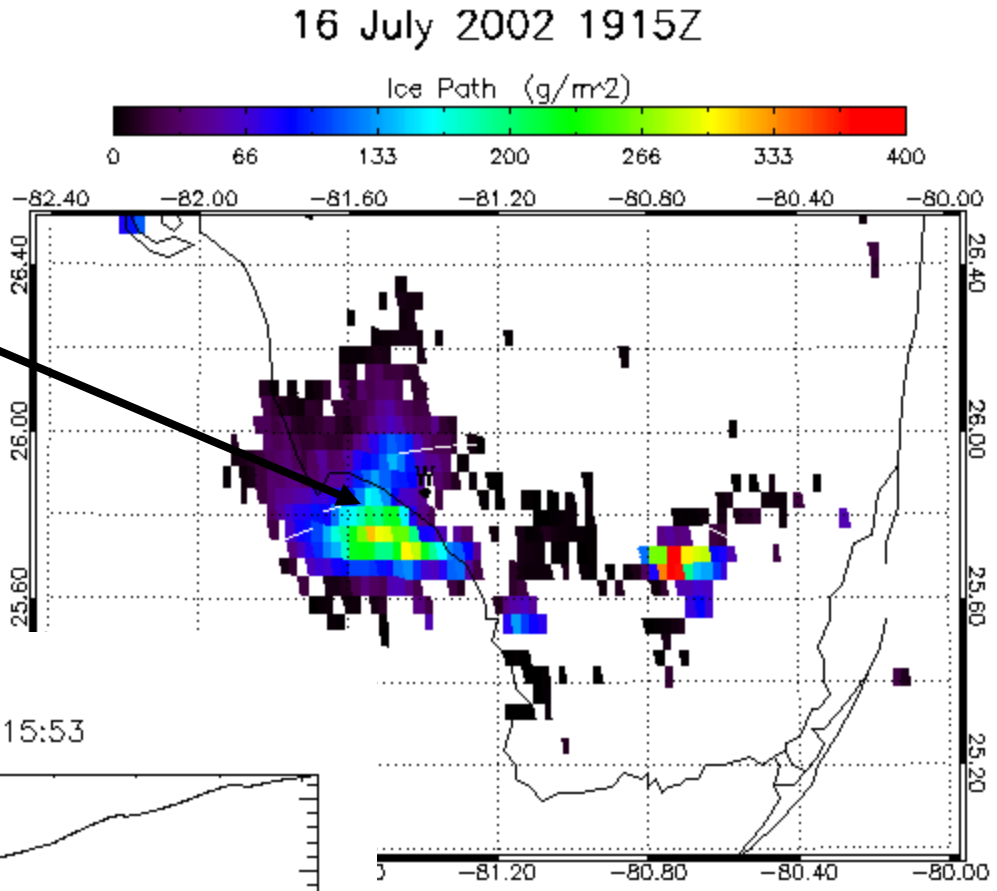
The July 16, 2002 Crystal FACE Early Anvil Event: Citation-Satellite Comparison

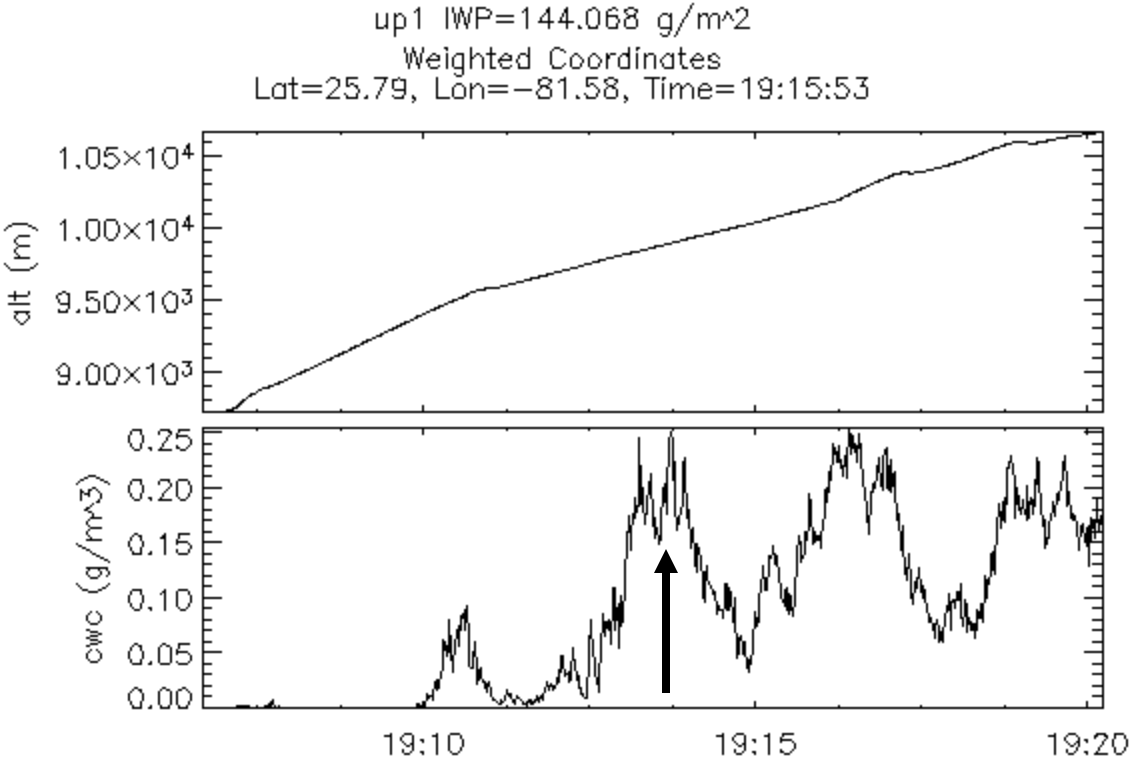


Citation Sprial 1: 1910-1920 UTC

Time	Pixel	Avg	SDV
1915	226.72	198.96	50.49

Citation IWP: 144 g/m^2

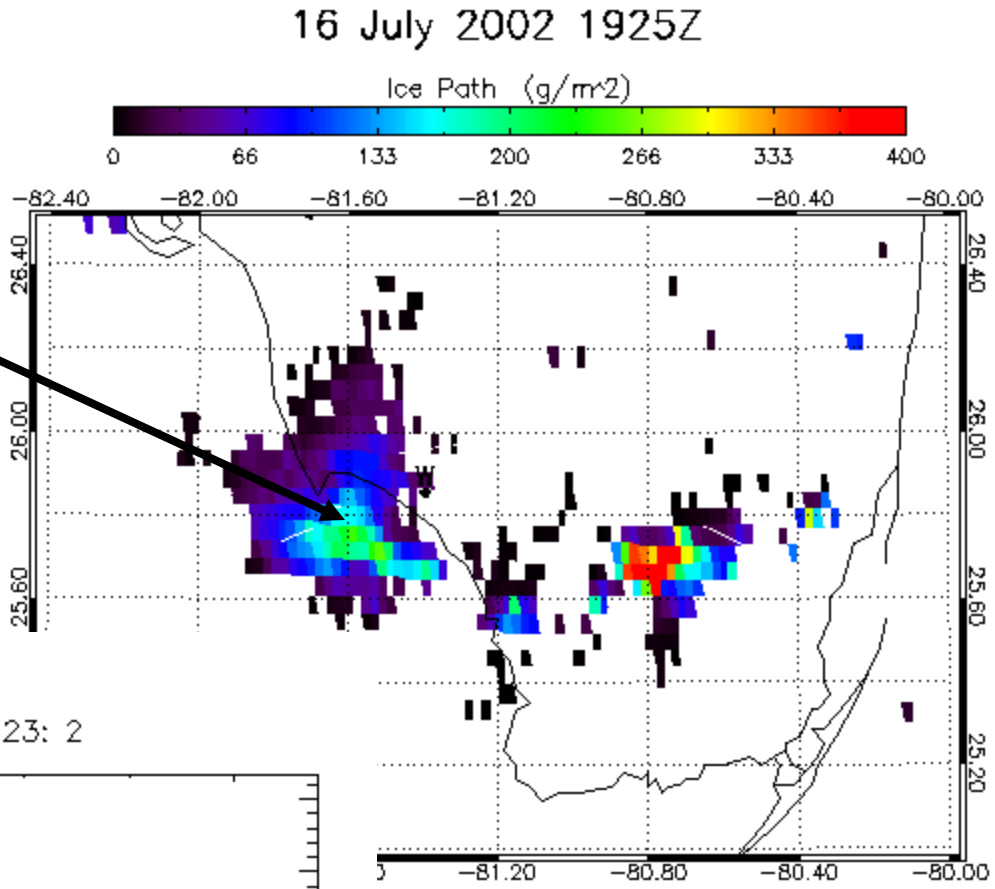


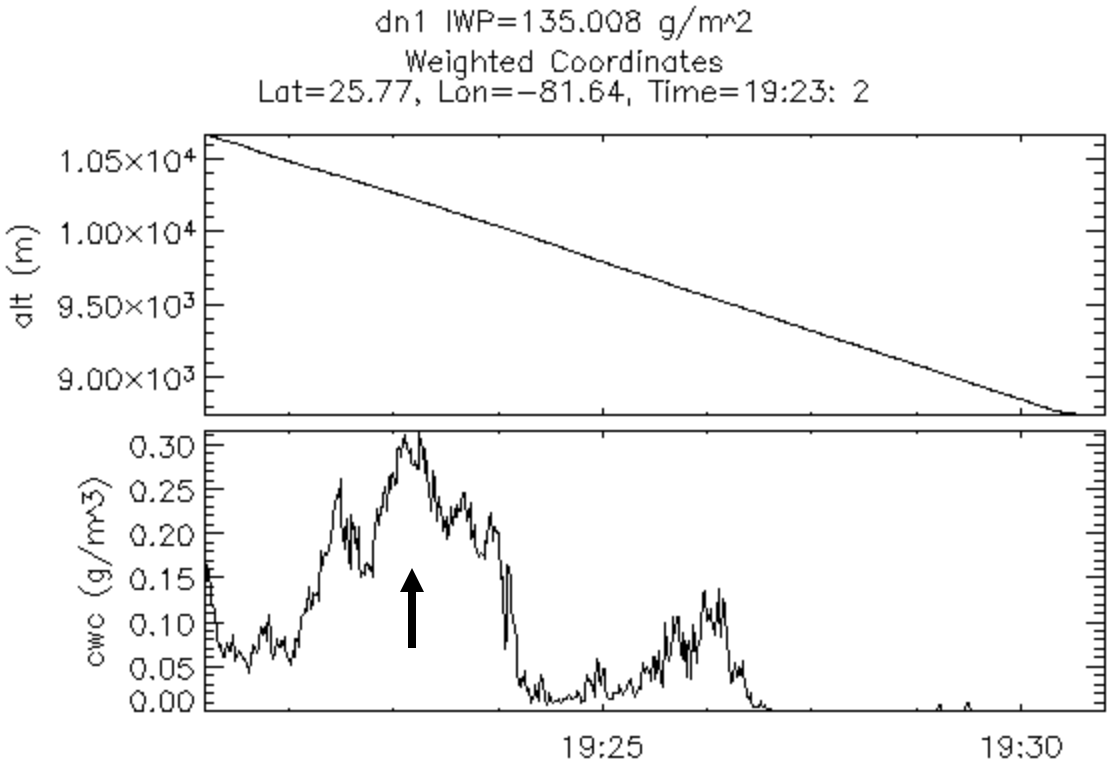


Citation Sprial 2: 1920-1930 UTC

Time	Pixel	Avg	Sdv
1925	192.35	179.15	33.76

Citation IWP: 135 g/m^2

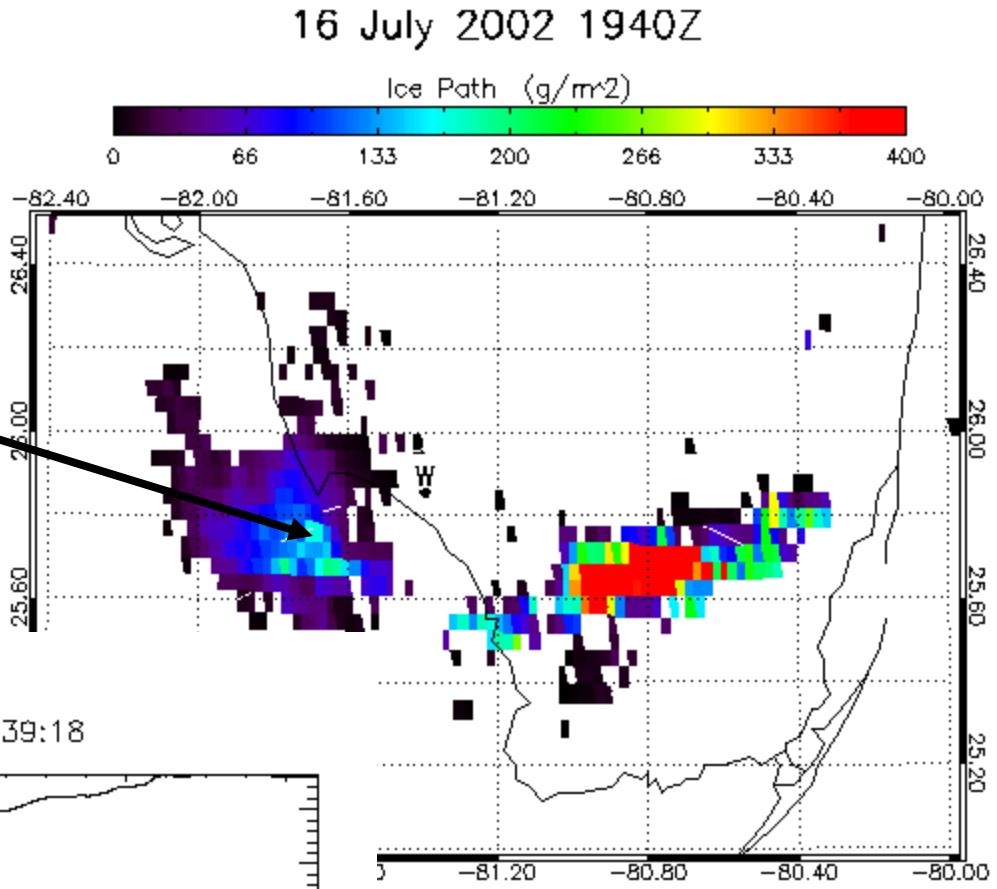


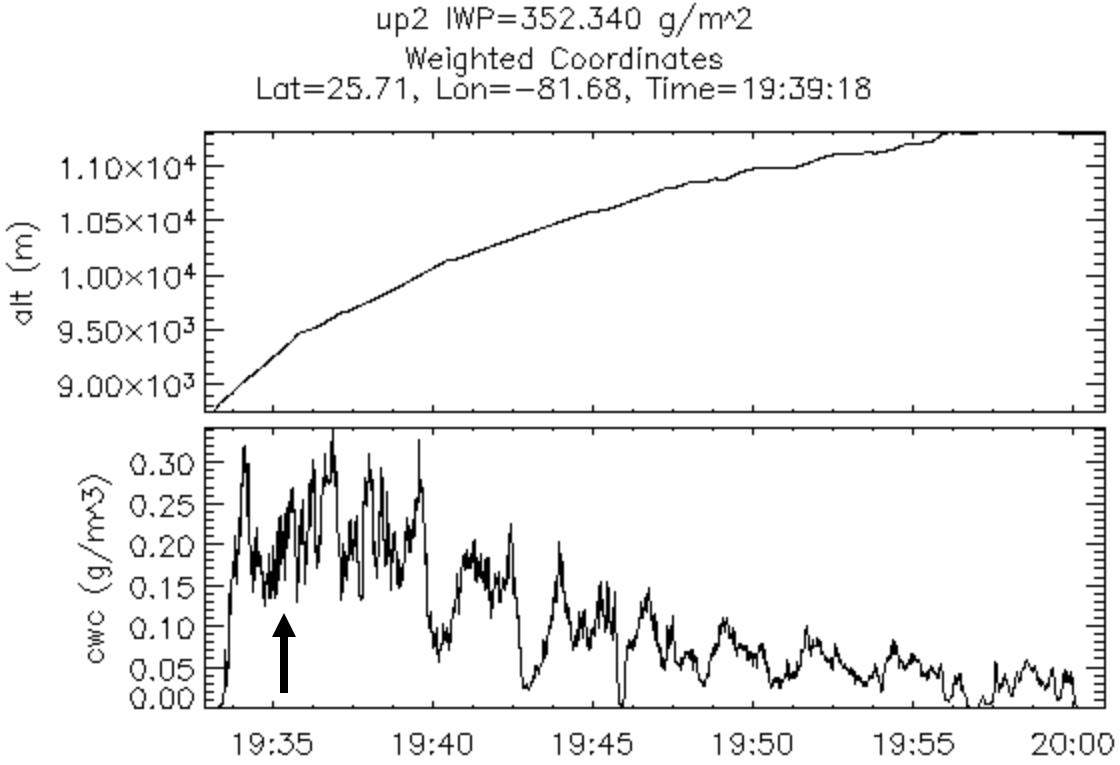


Citation Sprial 2: 1930-2000 UTC

Time	Pixel	Avg	Sdv
1940	161.96	111.33	54.07

Citation IWP: 352 g/m^2





Summary:

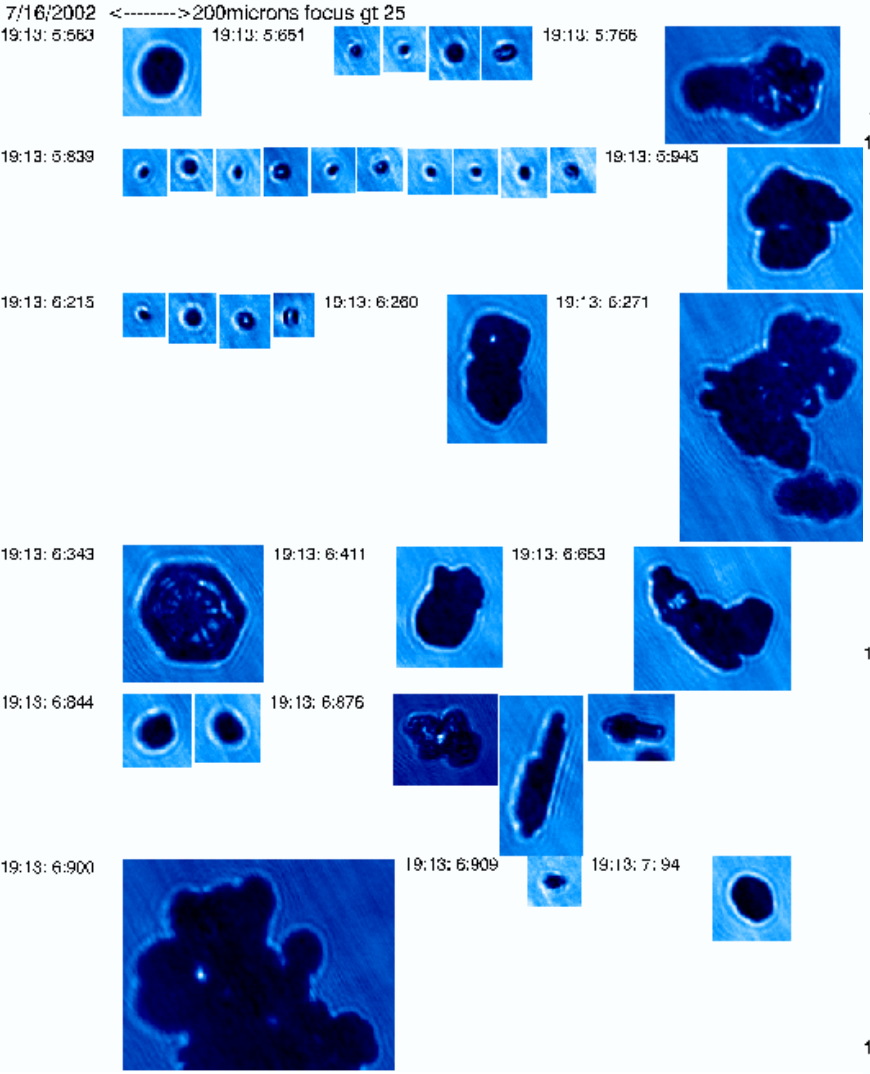
- The early anvil event on 16 July presents a reasonable case of anvil evolution in a fairly quiescent environment

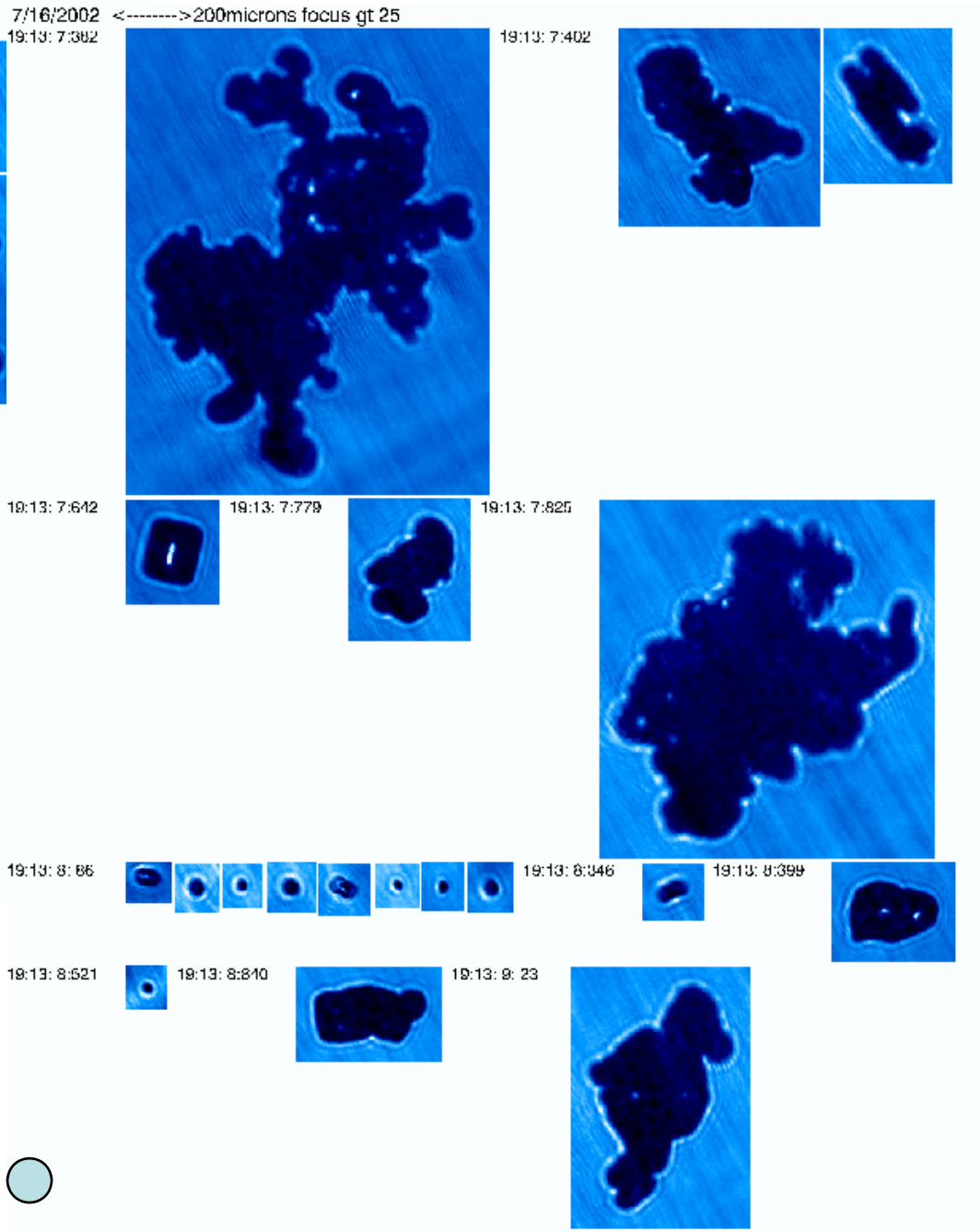
- We are in the process of combining satellite, ground based and aircraft into a consistent picture of the cloud field evolution

- Exploring an approach to ground based-aircraft data analysis that exploits the synergy between the data – allow the aircraft to supply the empirical relations that the ground based retrievals rely on.

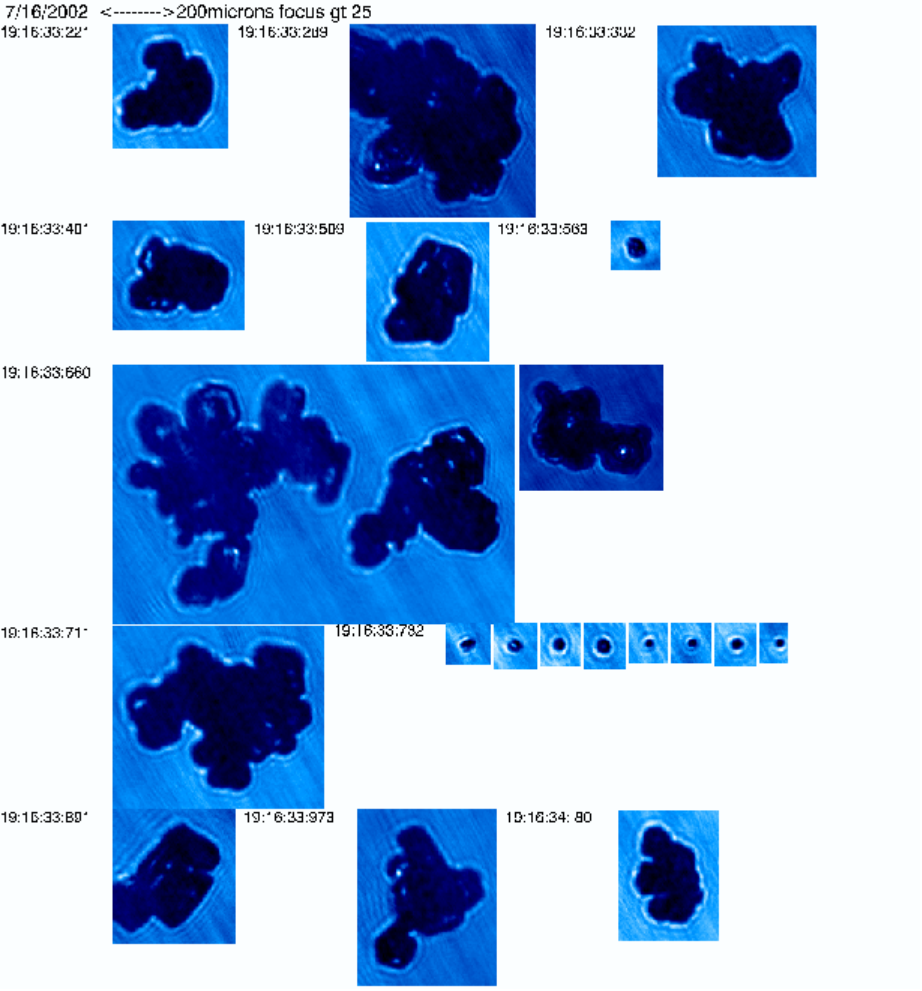
- The evolution of the 16 July anvil does not appear complicated:
    - IWP falls off monotonically
    - Cloud top remains fairly constant
    - Cloud thickness decreases slowly
    - Ground and aircraft show IWP weighted to layer bottom
    - Particle habits are reasonably constant with height – just different sizes

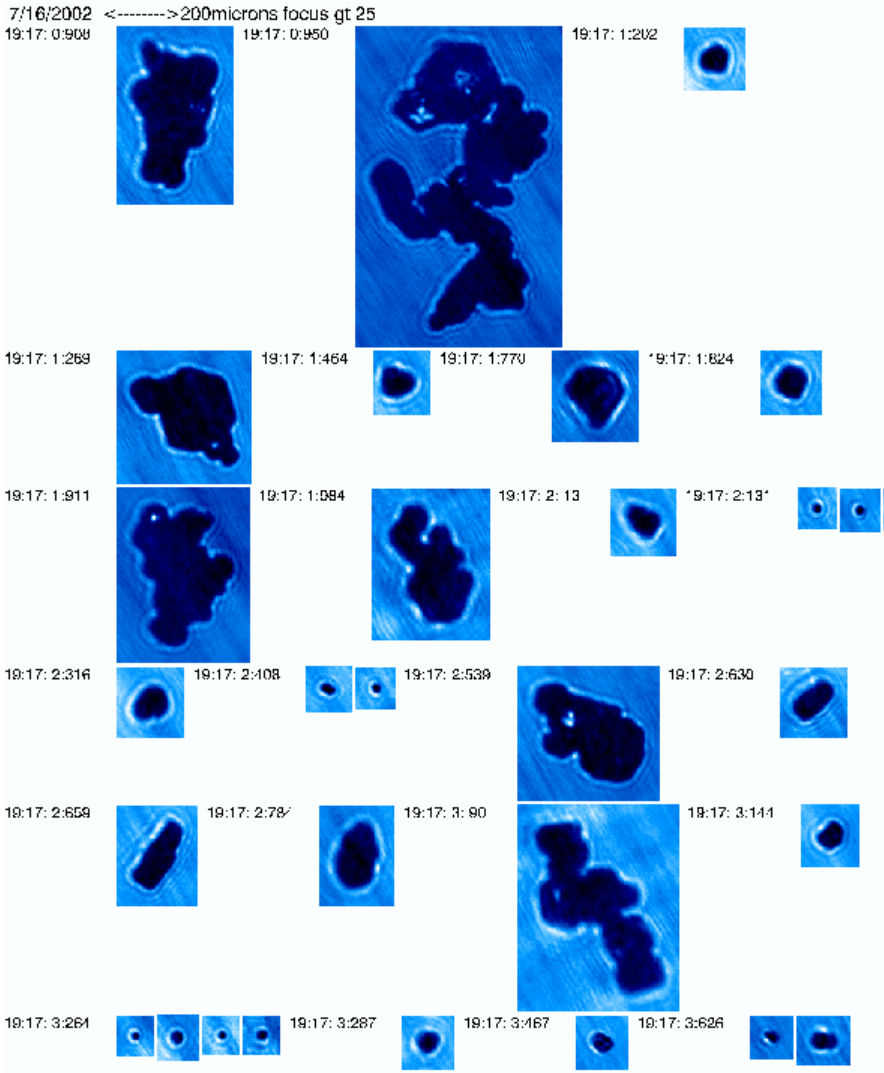
Questions: Does ice continue to grow? To nucleate?
What is the influence of radiative heating?





~1913 UTC near IWC Peak


7/16/2002 <--------->200microns focus gt 25
19:16:33:22
19:16:33:269
19:16:33:302
19:16:33:40
19:16:33:509
19:16:33:660
19:16:33:71
19:16:33:782
19:16:33:89
19:16:34: 80


7/16/2002 <--------->200microns focus gt 25
19:17: 0:909
19:17: 0:950
19:17: 1:202
19:17: 1:269
19:17: 1:464
19:17: 1:770
19:17: 1:824
19:17: 1:911
19:17: 1:984
19:17: 2: 13
19:17: 2:316
19:17: 2:408
19:17: 2:539
19:17: 2:630
19:17: 2:659
19:17: 2:78
19:17: 3: 90
19:17: 3:144
19:17: 3:264
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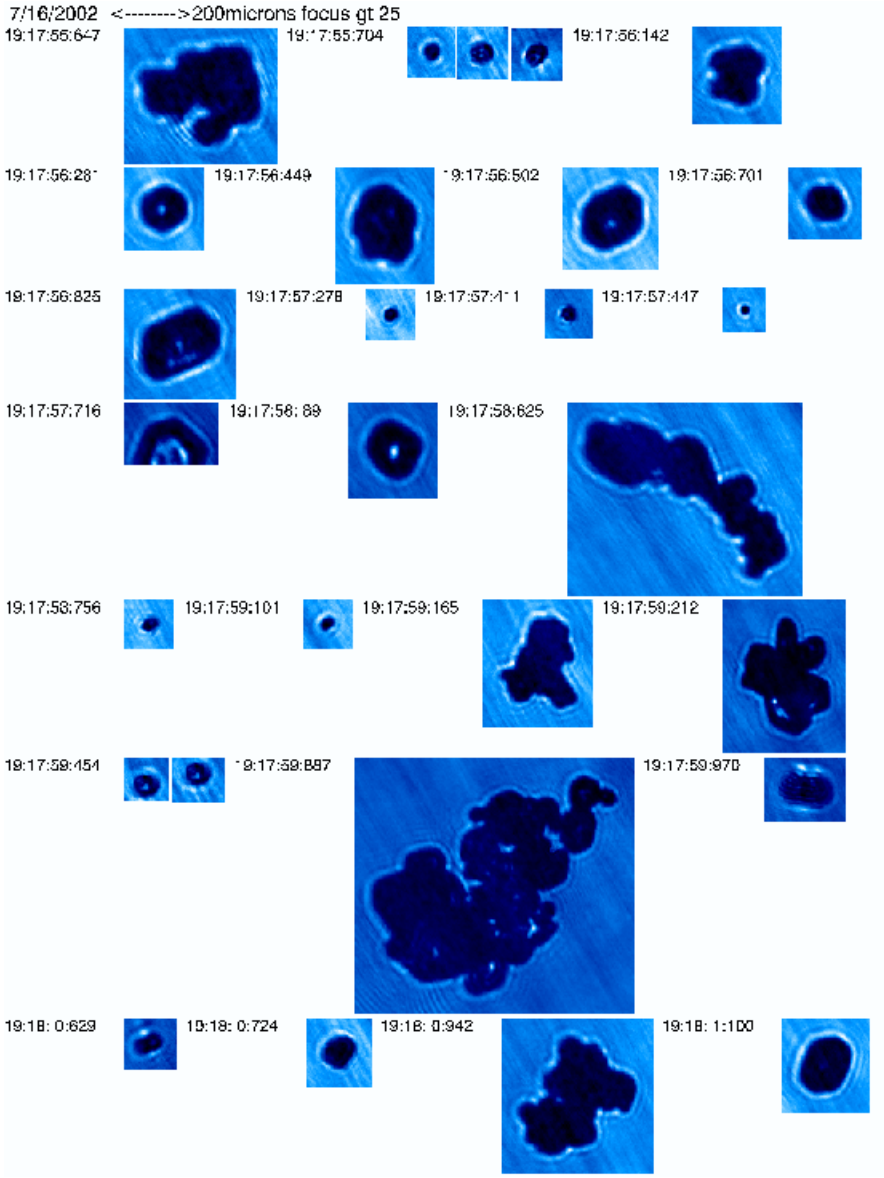
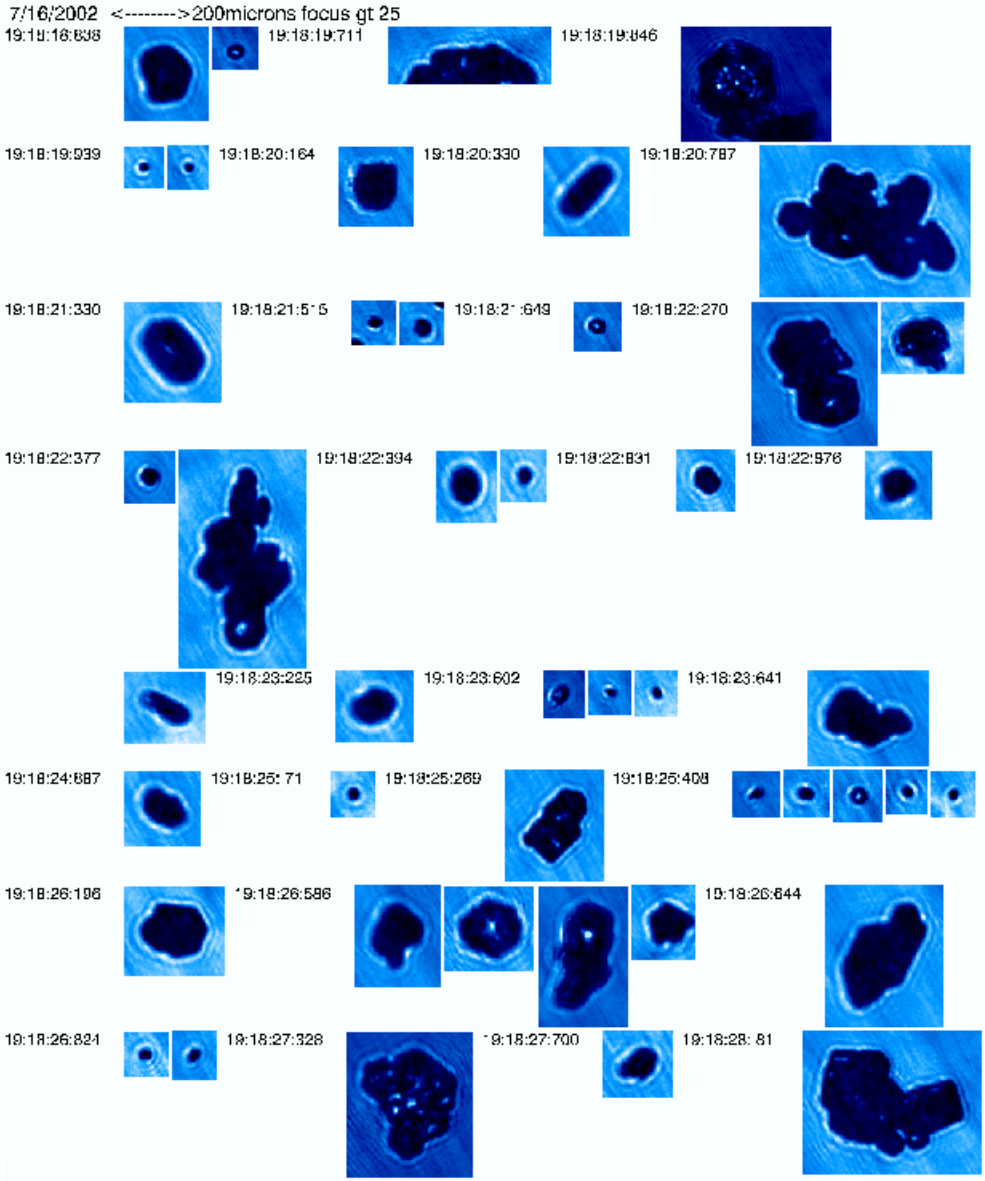
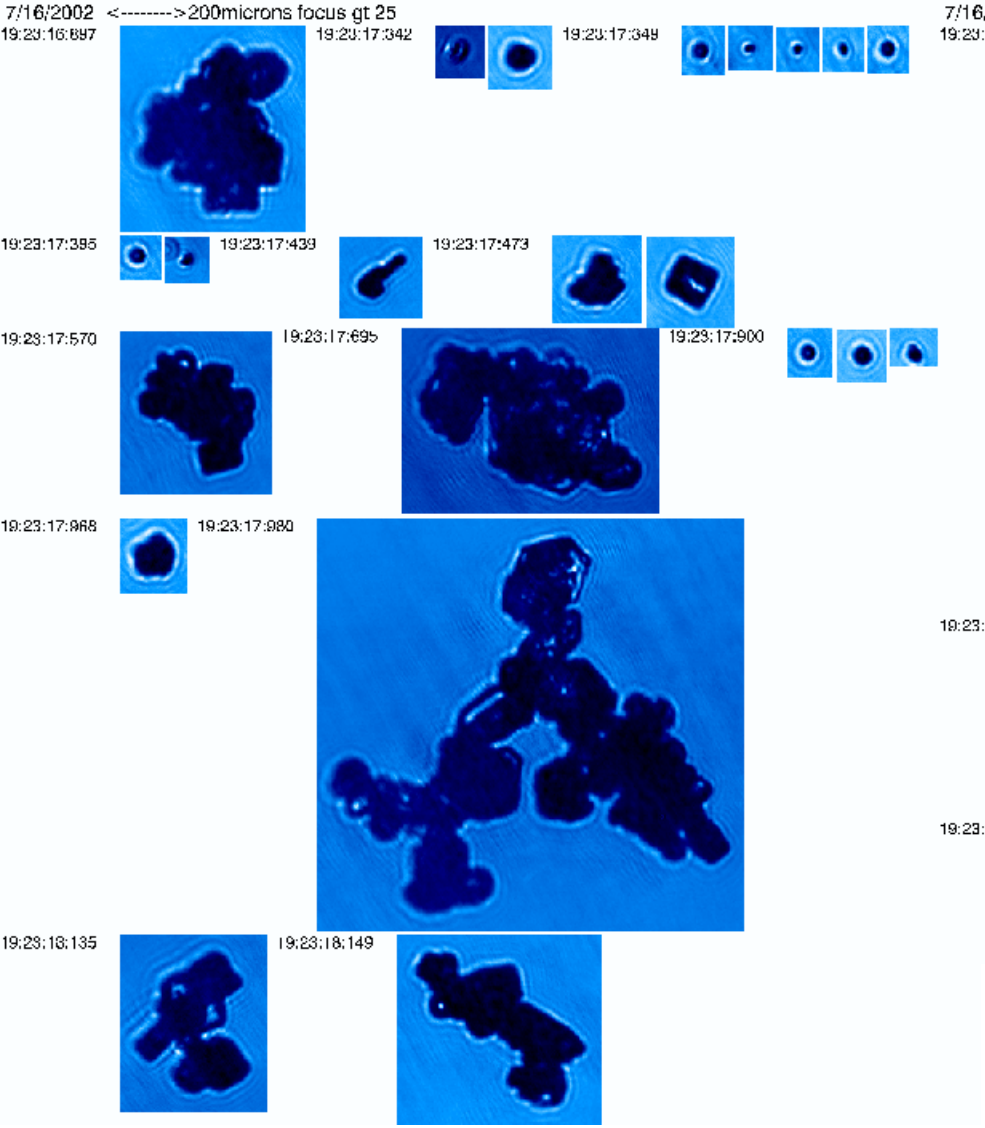
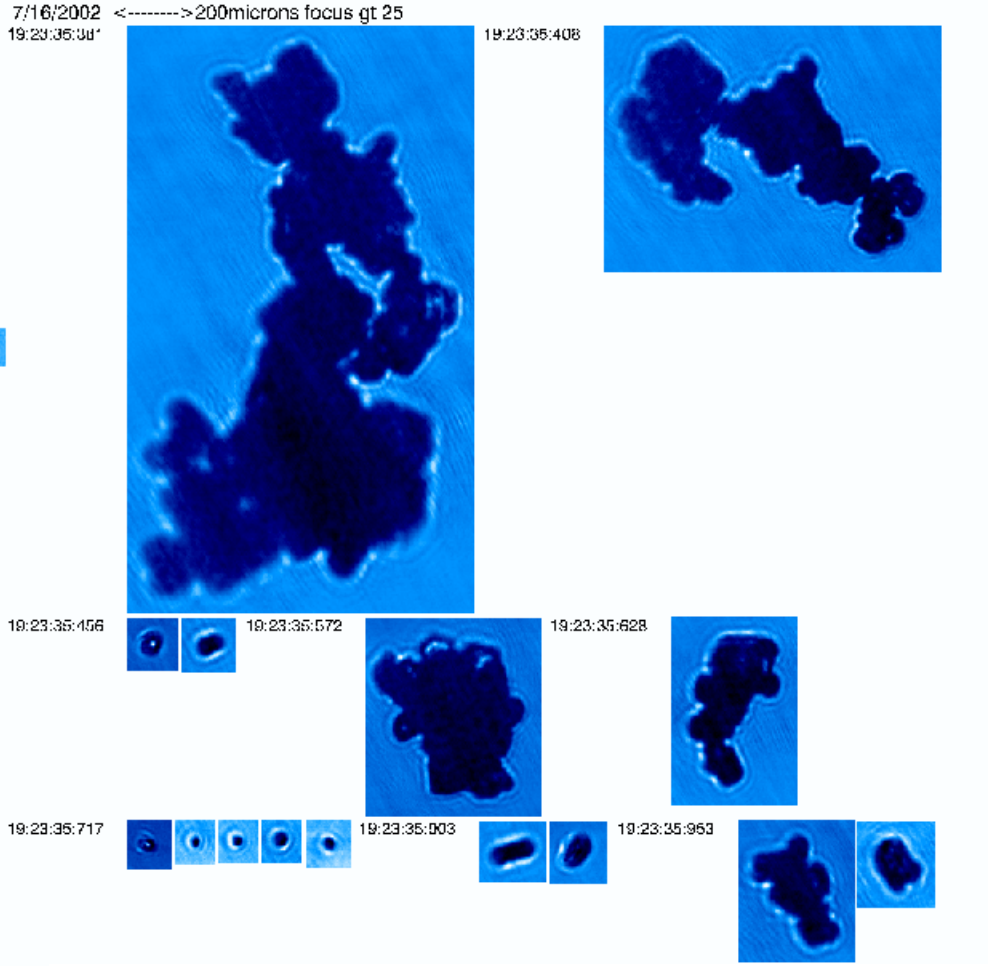
19:17: 3:626



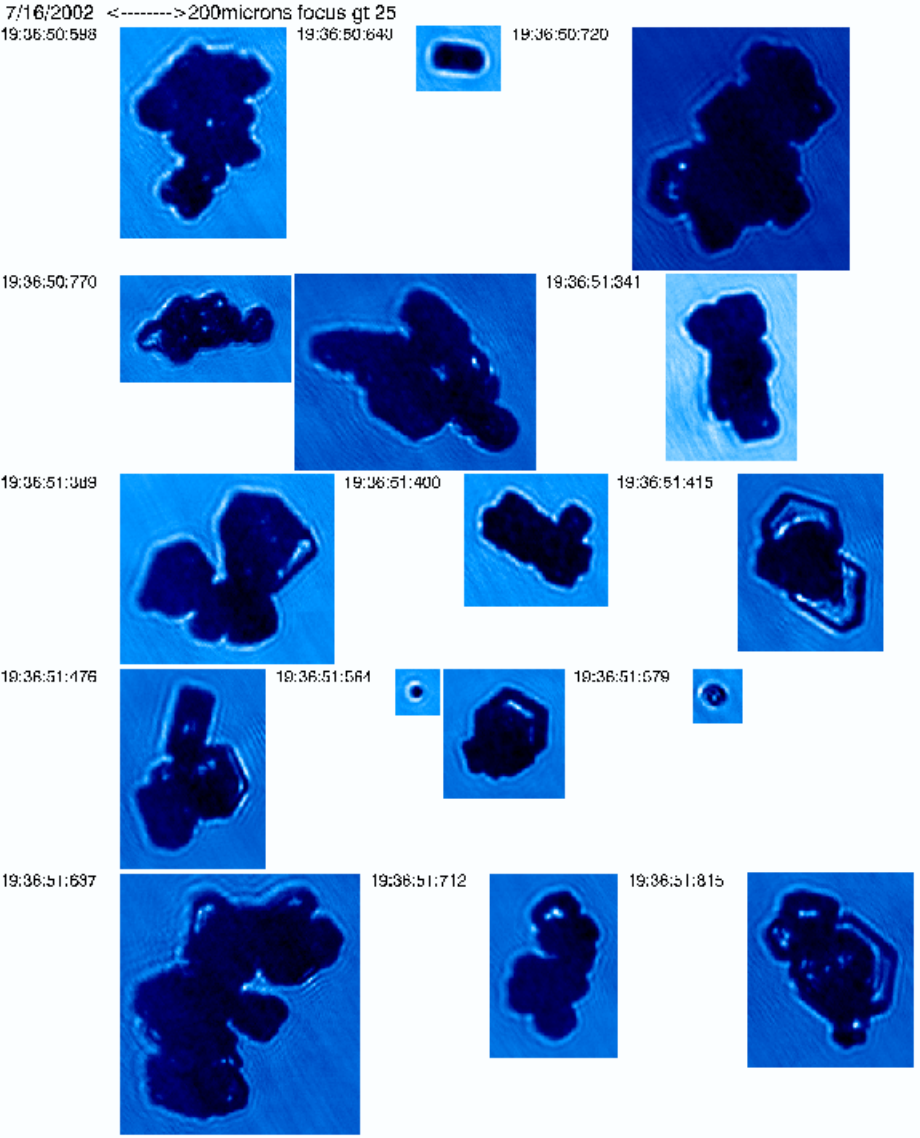


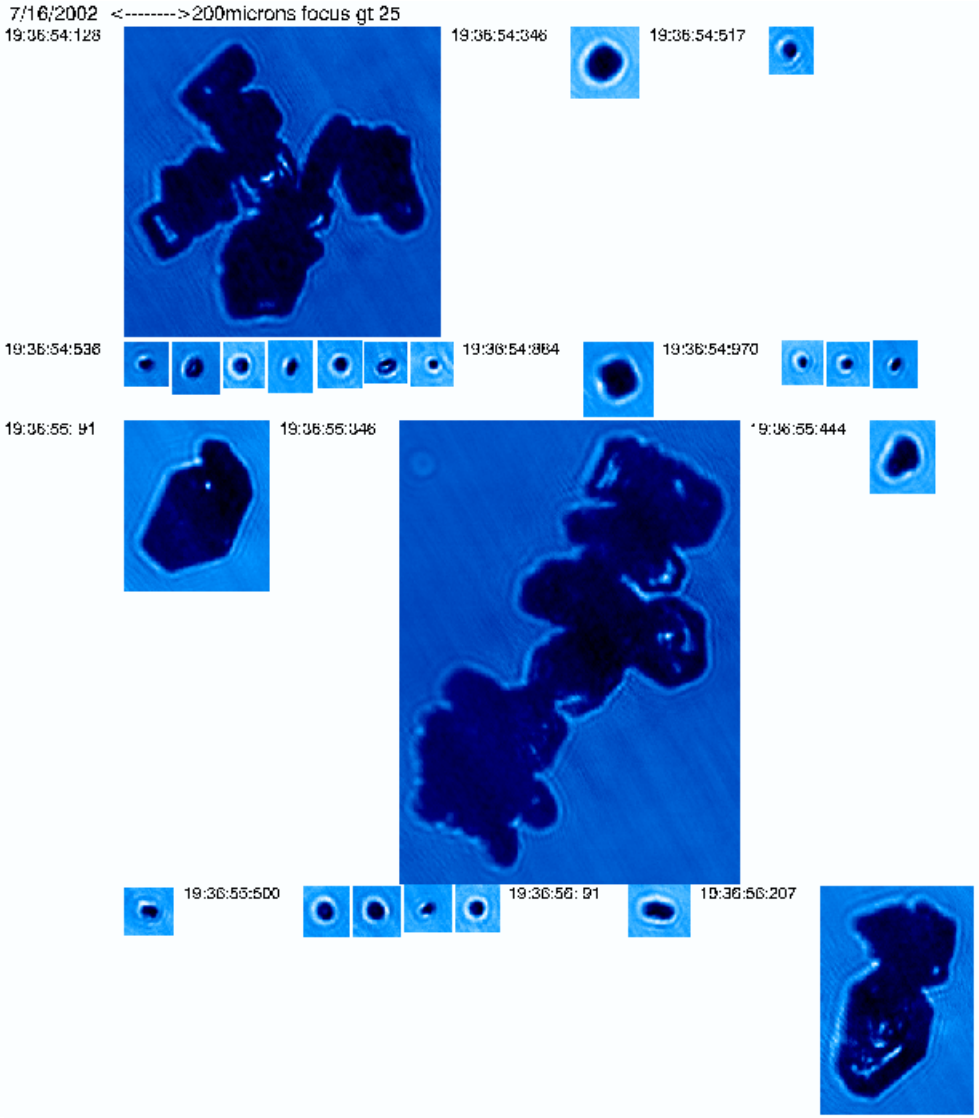
Near IWC min in first sprial



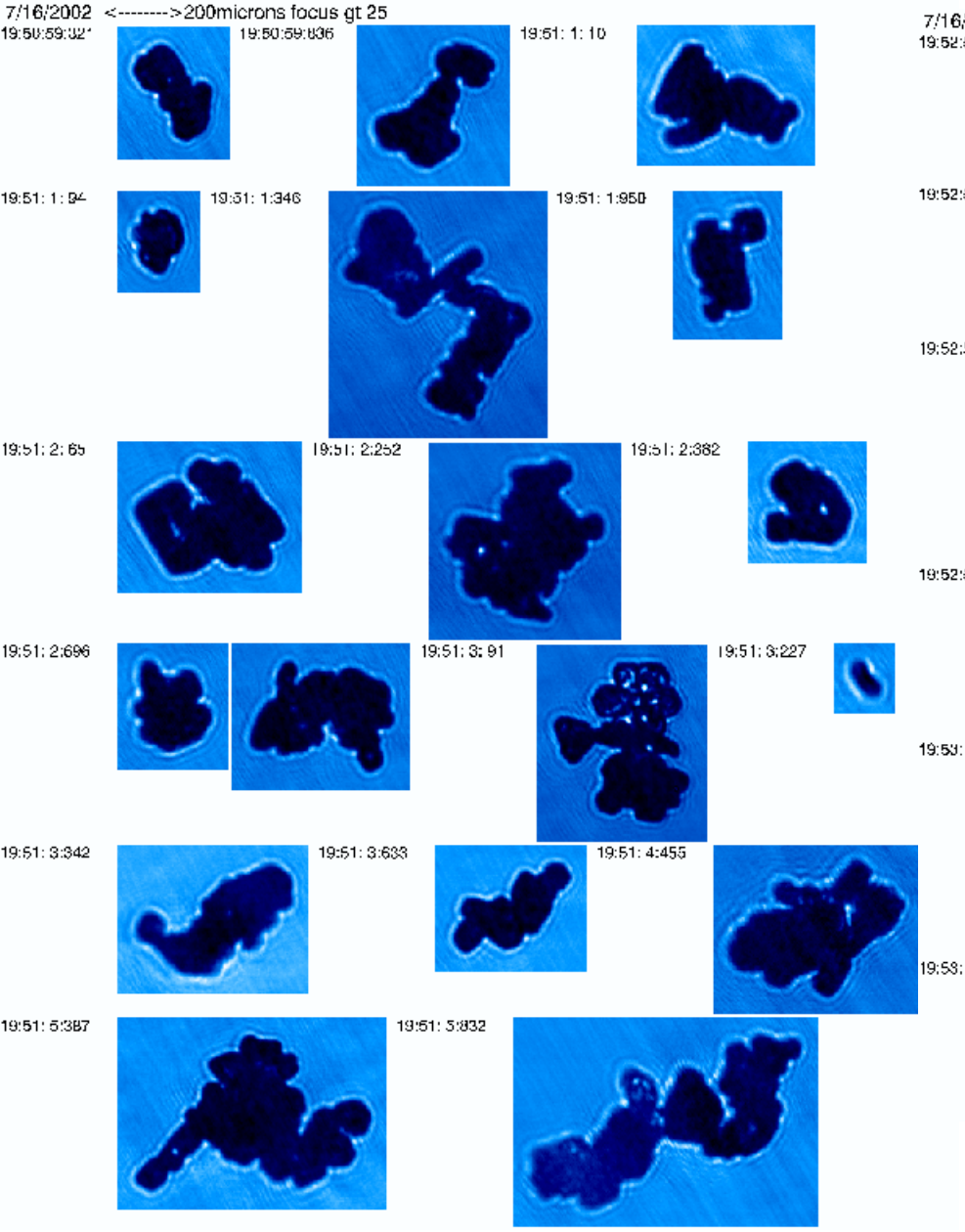


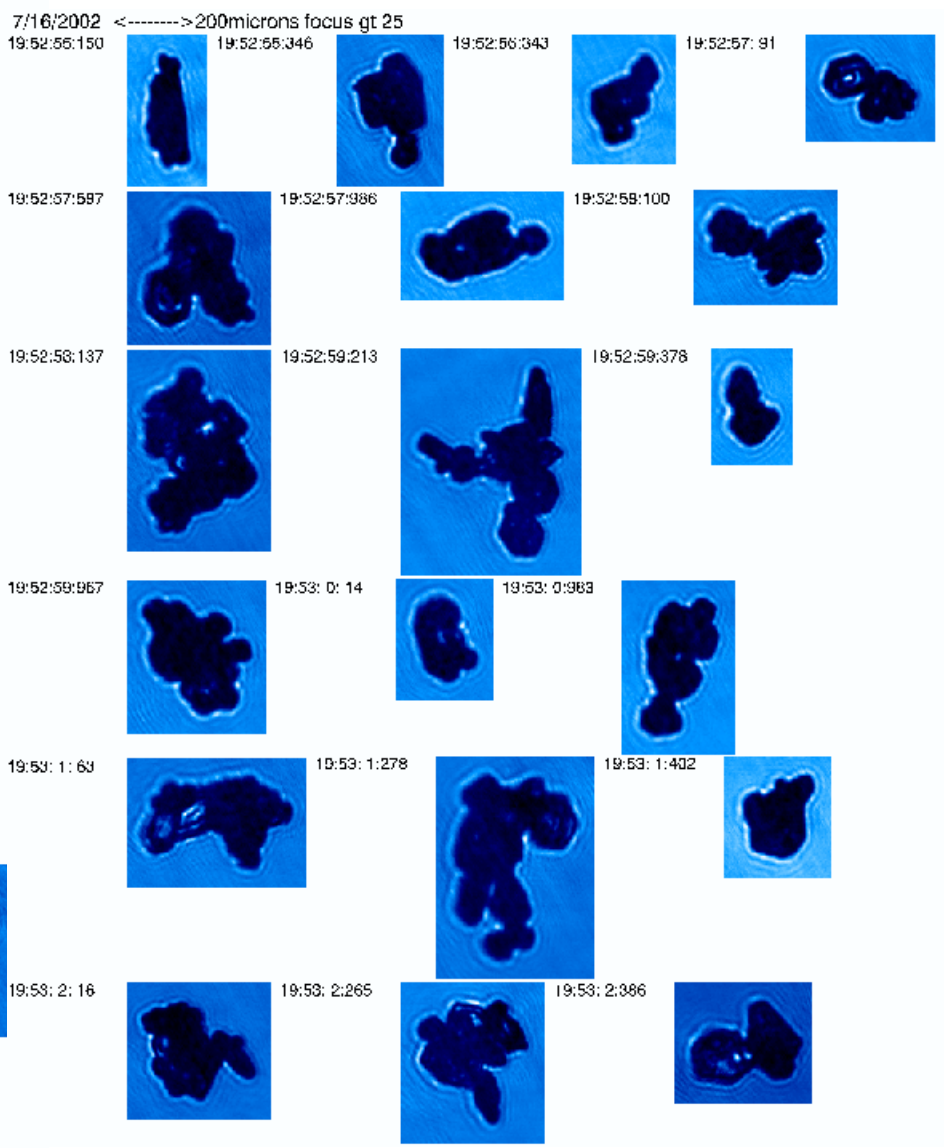
Near Peak IWC of second (down) sprial





Near Peak IWC of 3rd sprial





Near top of third spiral