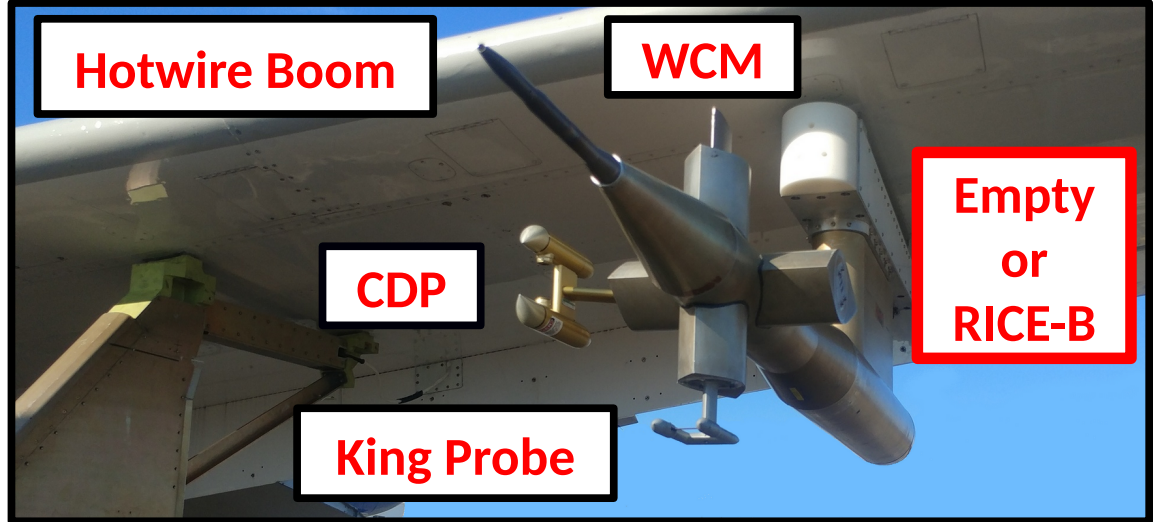
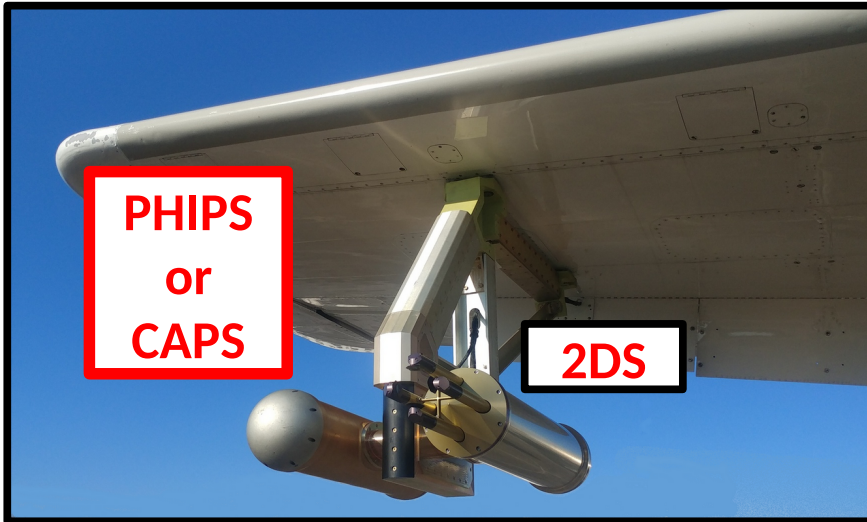
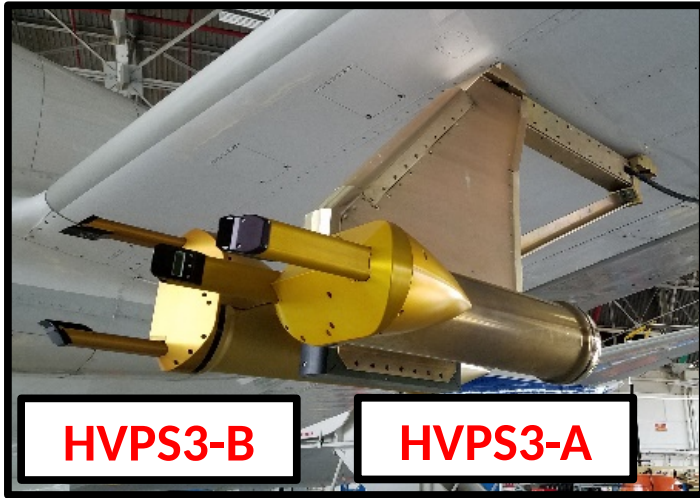


2-Dimensional Probe Aircraft Measurements



NASA IMPACTS 2022 Cloud Probes



Size Range Classification of Cloud Probes

Measurement Size Range

1 μm 10 μm 100 μm 1 mm 10 mm

CDP (2.0-50.0 μm)

FCDP (2.0-50.0 μm)

CAPS/CAS (0.5-50.0 μm)

CAPS/CIP (25 μm to 1.55 mm)

CPI (2.3 μm to 1 mm)

PHIPS (3 μm to 2 mm)

2DS (10/50 μm to 1.280/6.400 mm)

(2) HVPS-3 (150 μm to 19.2 mm)

King (wire) (LWC for 5 to 200 μm)

WCM (wire) (LWC for 5 to 200 μm)

(2) Rosemount Ice Detector (RICE) (SLW)

Measurement Method

Forward Scattering Probes

Imaging
Probes

Hot-wire Probes

Vibrating Cylinder

Two Dimensional Cloud (2D-C) Probe Optics

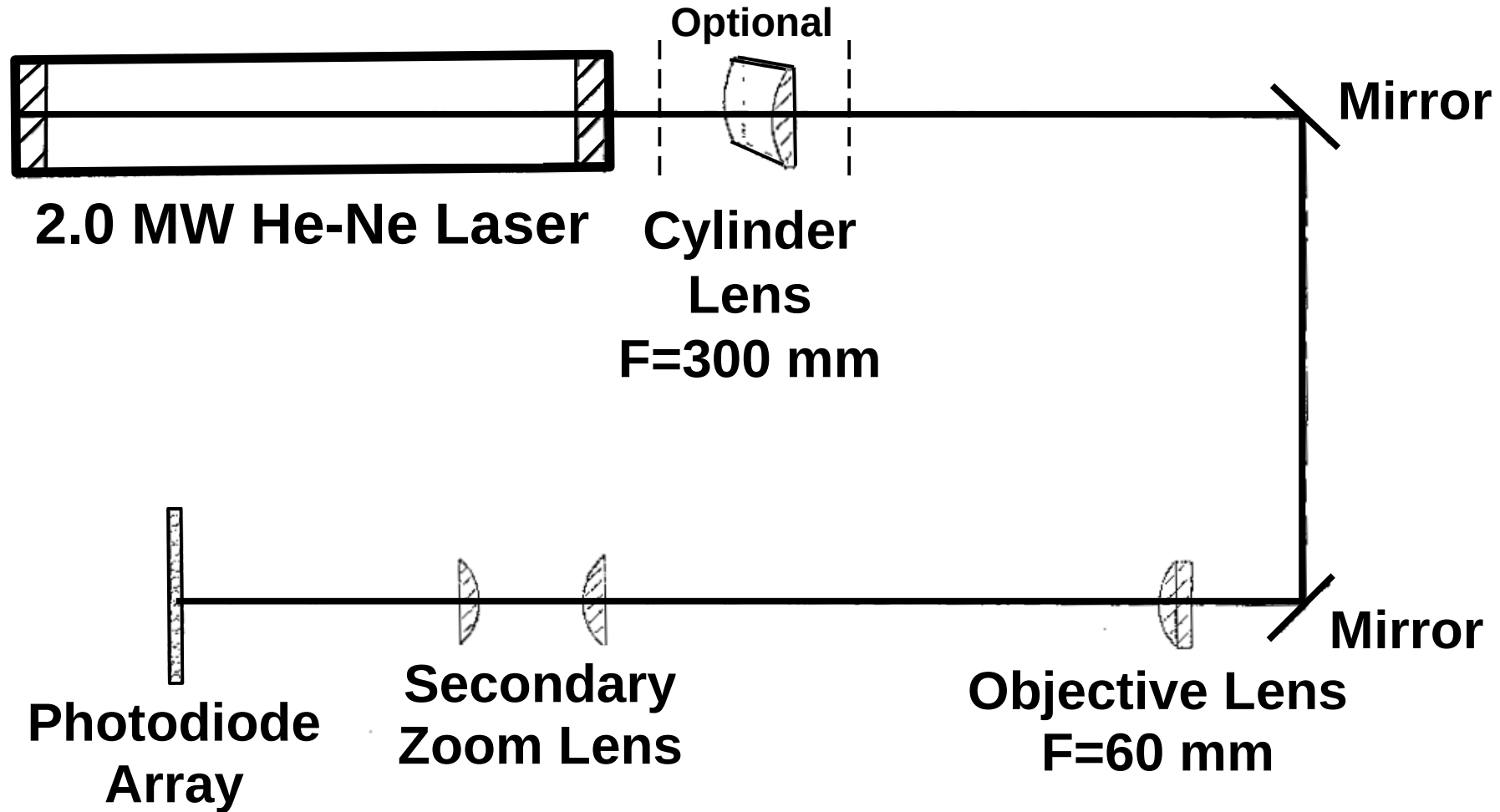


Image Array Elements

- The zeros (0) Denote Extinction of a photodiode by 50 %.
- The ones (1) Represent less than 50 % extinction.
- At 100 m s^{-1} and 25 um resolution along flight path, there are 4 million image slices per second.

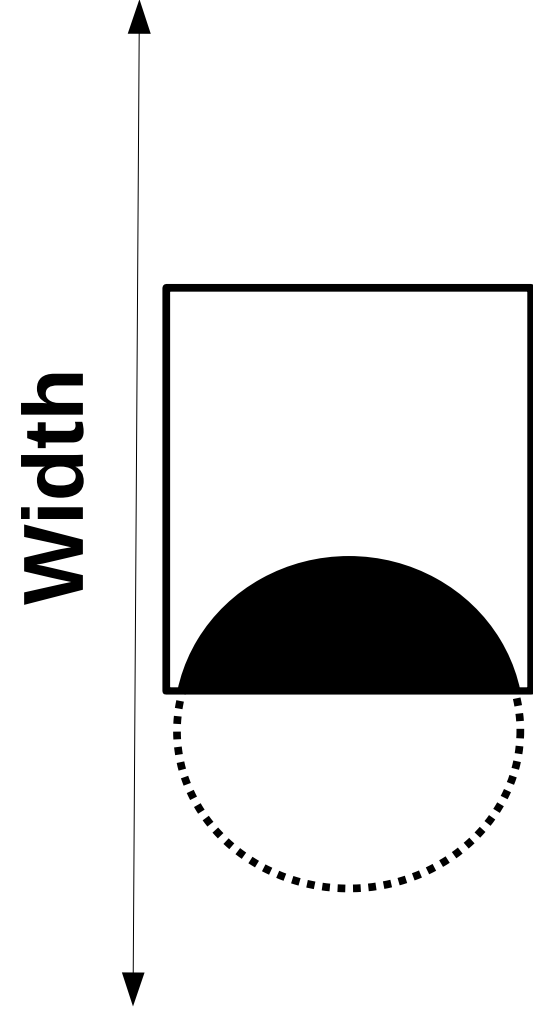
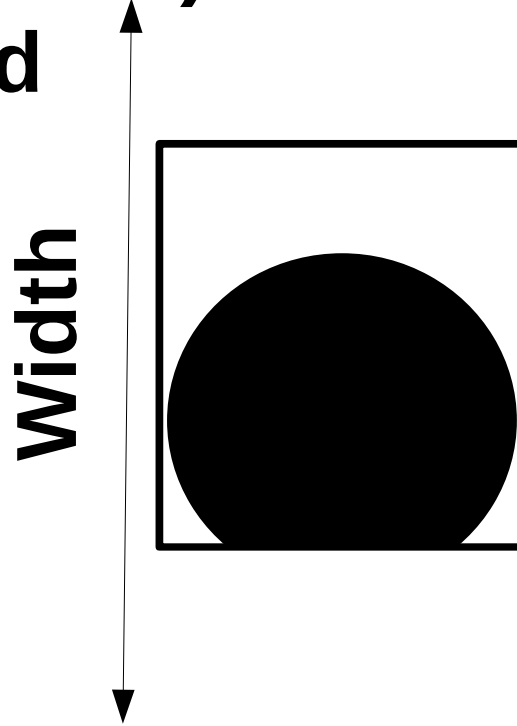
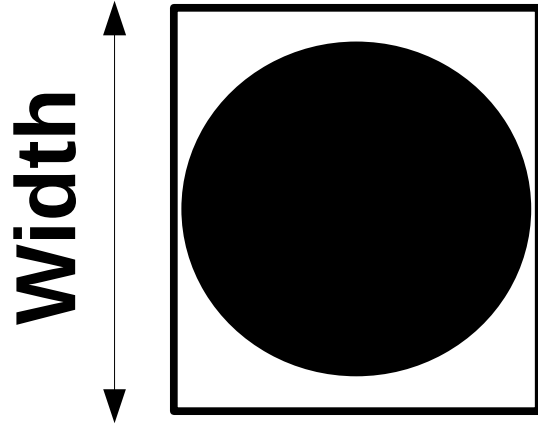
Elements
Time Data Slice
All '0' Data

All '1' Data
Time Data Slice
All '0' Data

32	001111111111111111111111111100
31	101111111111111111111111111110
30	001111111111111111111111111100
29	101111111111111111111111111110
28	001111111111111111111111111100
27	101111111111111111111111111110
26	00111111111110111111111111100
25	0011111111110001111111111110
24	001111111100000111111111100
23	001111111000000011111111100
22	001111110000000001111111100
21	001111100000000000111111100
20	00111100000000000001111100
19	00111000000000000000011100
18	00110000000000000000001100
17	00100000000000000000000100
16	001000000000000000000000100
15	000000000000000000000000100
14	0000000000000000000000000100
13	1010000000000000000000000100
12	1010000000000000000000001110
11	0011000000000000000000011110
10	0011100000000000000000111100
09	1011110000000000000001111110
08	0011111000000000000111111100
07	0011111100000000011111111100
06	001111111000000111111111110
05	10111111110001111111111110
04	00111111111011111111111100
03	101111111111111111111111110
02	001111111111111111111111100
01	1011111111111111111111111100

Effective Width of the Array

- All-in (Entire-in Particle) Method
- Center-in (Most of Particle) Method
- Reconstructed Method



All-in (Entire-in) Processing

$$w(cm) = [RS * (N - 1) - (D)] * 10^{-4}$$

$$w(cm) = [RS * (N - 1) - (I * RS)] * 10^{-4}$$

w – Effective Width of the Array

D – Diameter of Sphere

N – Number of Array Elements

RS – Probe Resolution

I – Number of Diodes Shadowed

$$w(cm) = RS [31 - I] * 10^{-4}$$

N – 32 for 2-DC

Center-in Processing

$$w(cm) = [RS * N] * 10^{-4}$$

w – Effective Width of the Array

N – Number of Array Elements

RS – Probe Resolution

$$w(cm) = RS * 32 * 10^{-4}$$

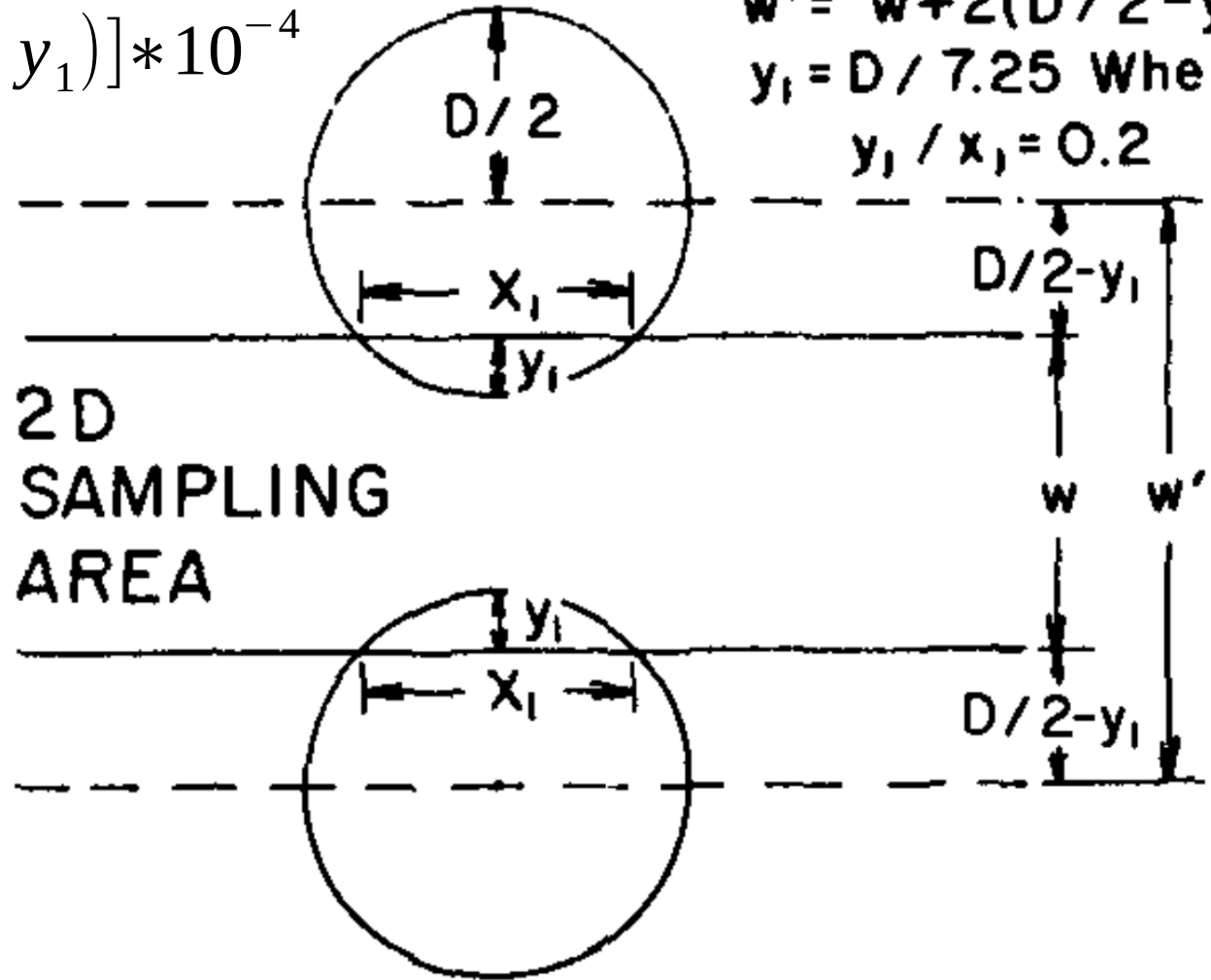
N – 32 for 2-DC

Reconstructed

$$w'(cm) = w + 2 * [(D/2 - y_1)] * 10^{-4}$$

$$w^l = w + 2(D/2 - y_1)$$

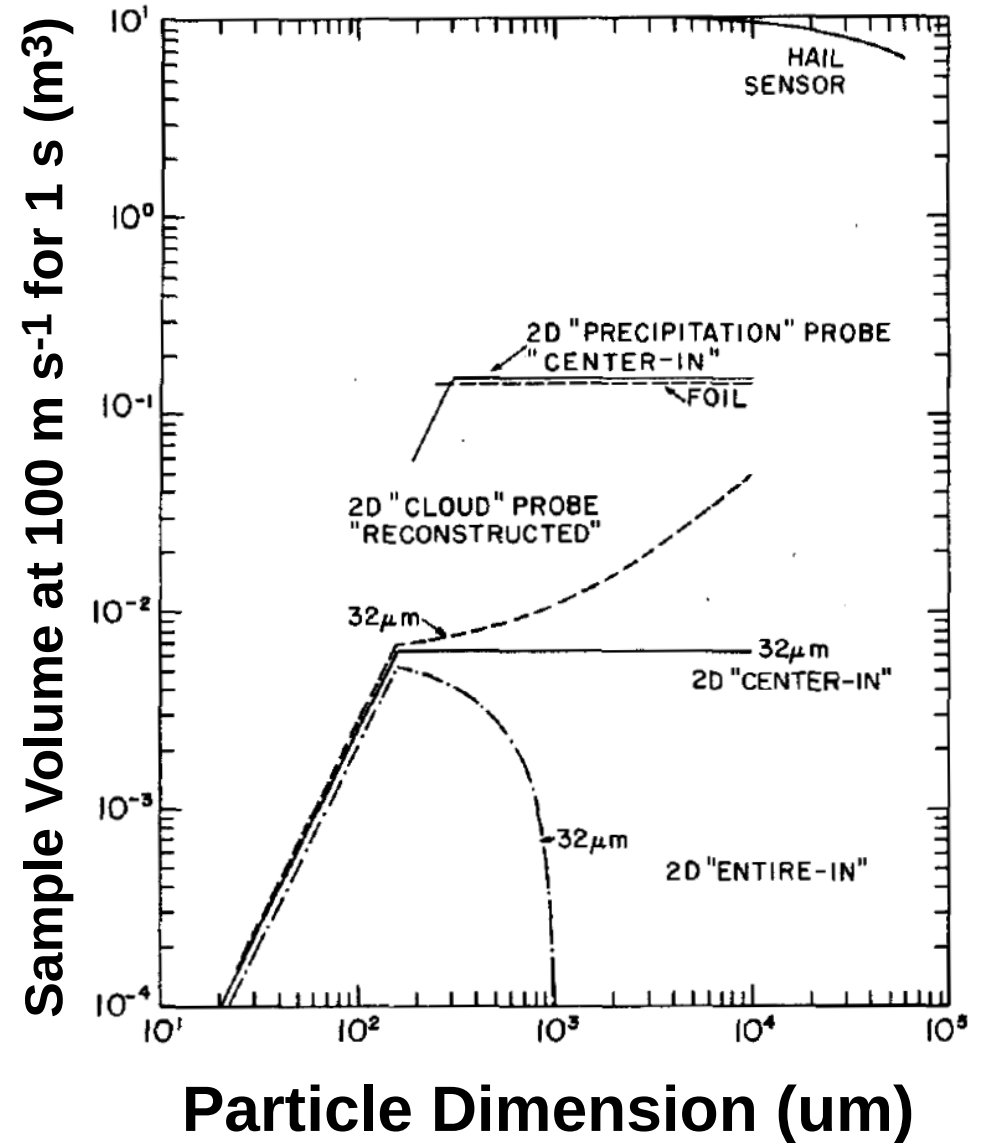
$y_1 = D / 7.25$ When
 $y_1 / x_1 = 0.2$



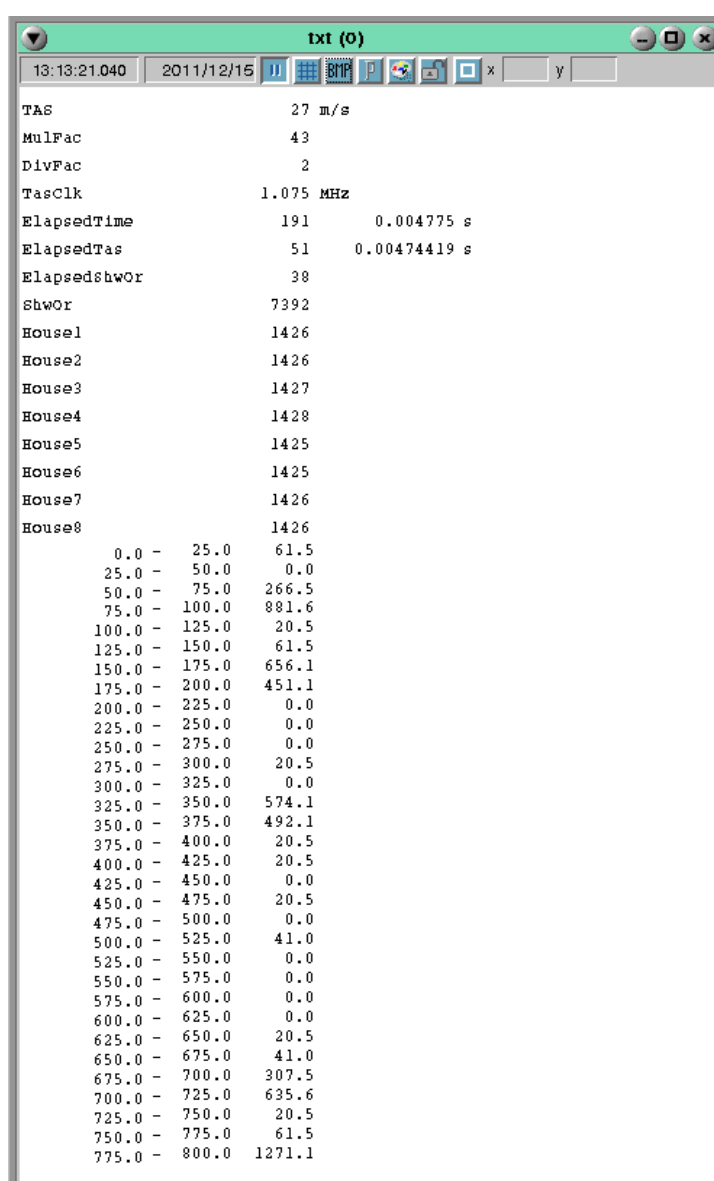
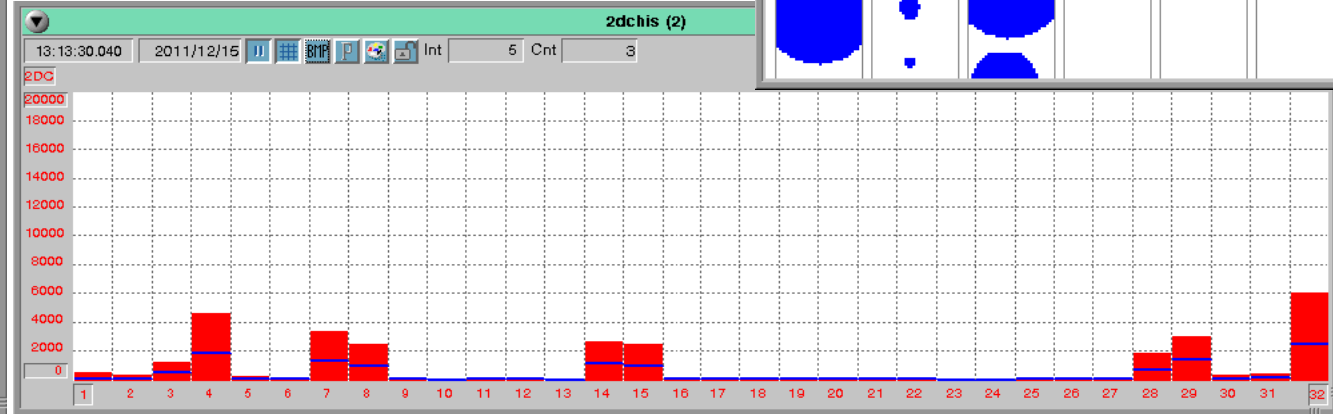
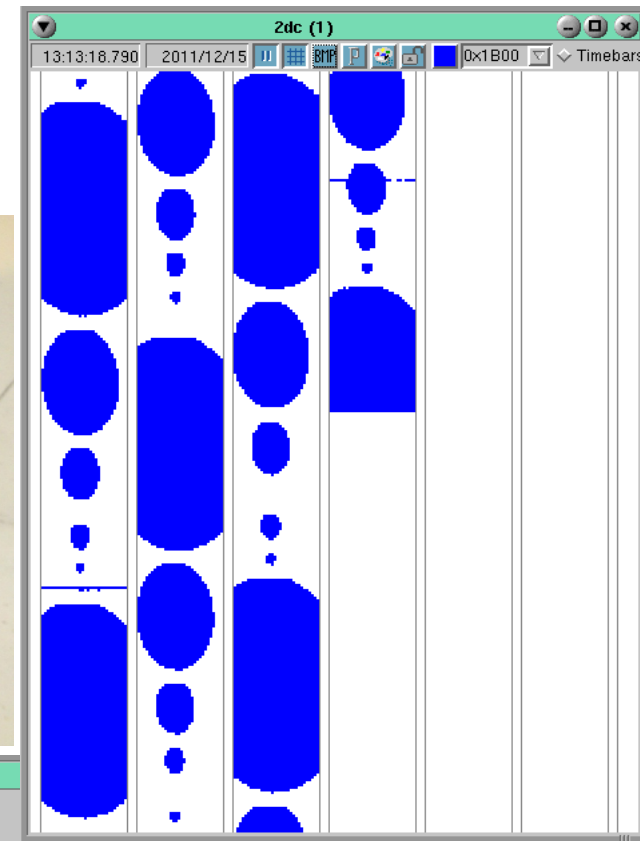
Width Processing Method Sample Volume (SV) Comparison

$$SV = SA * TAS * t$$

$$SA = DOF * w$$



2-DC Spinning Disk



2-DC Spinning Disk

Flight Date: 12/16/11 Start Time = 75731.2188(21:02:11.2188) End Time = 75731.2266(21:02:11.2266) Delta Time = 0.00781250 [s] TAS = 27.96 [m/s]



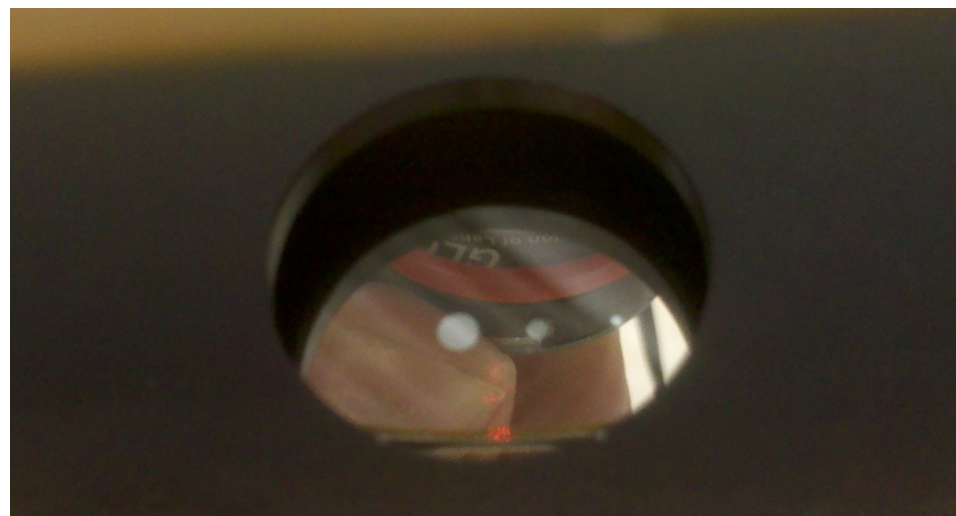
Flight Date: 12/16/11 Start Time = 75731.2734(21:02:11.2734) End Time = 75731.2734(21:02:11.2734) Delta Time = 0.00000 [s] TAS = 27.59 [m/s]



Flight Date: 12/16/11 Start Time = 75731.3203(21:02:11.3203) End Time = 75731.3281(21:02:11.3281) Delta Time = 0.00781250 [s] TAS = 27.67 [m/s]



Flight Date: 12/16/11 Start Time = 75731.3750(21:02:11.3750) End Time = 75731.3828(21:02:11.3828) Delta Time = 0.00781250 [s] TAS = 27.76 [m/s]



May 12, 2010 Ground Test with Spinning Disk on 2DC Probe

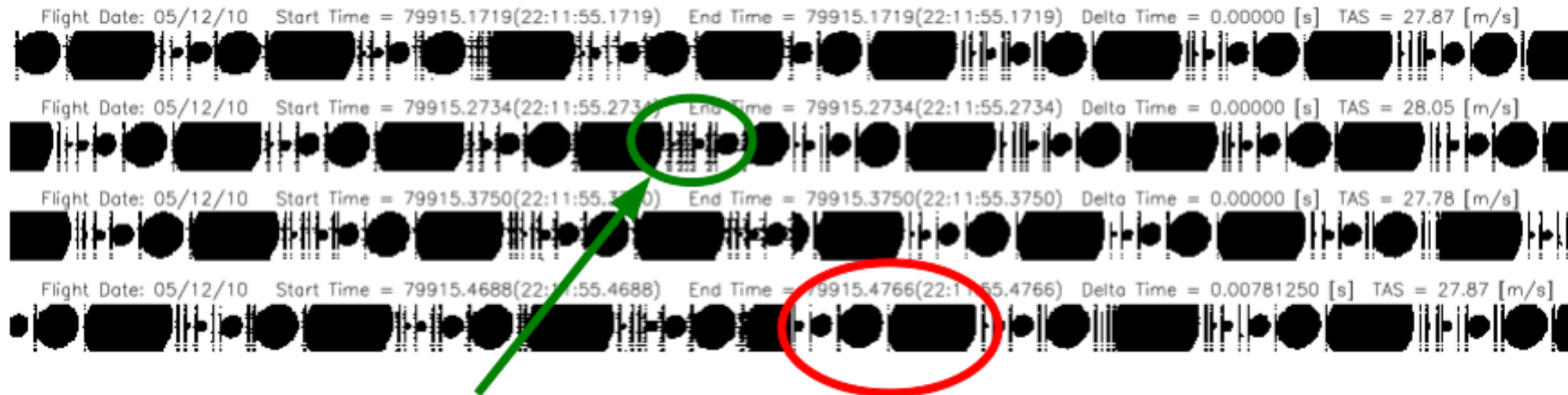
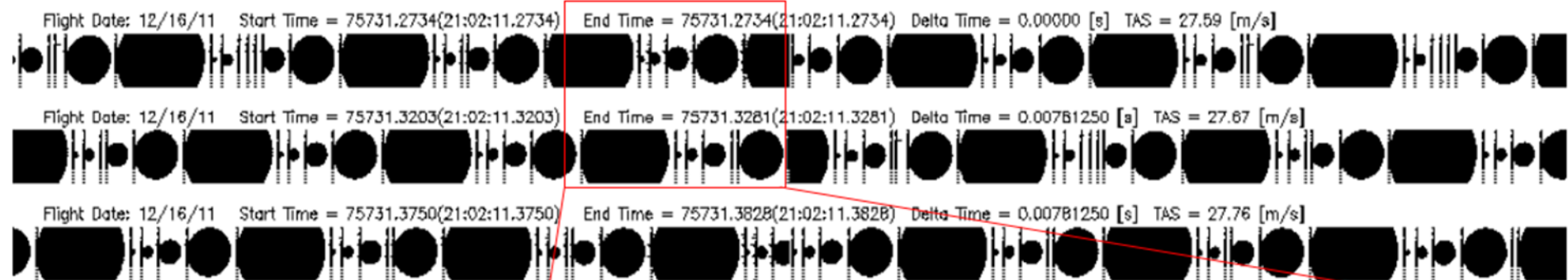


Image Problem

Good Images



End Time = 75731.2734(2

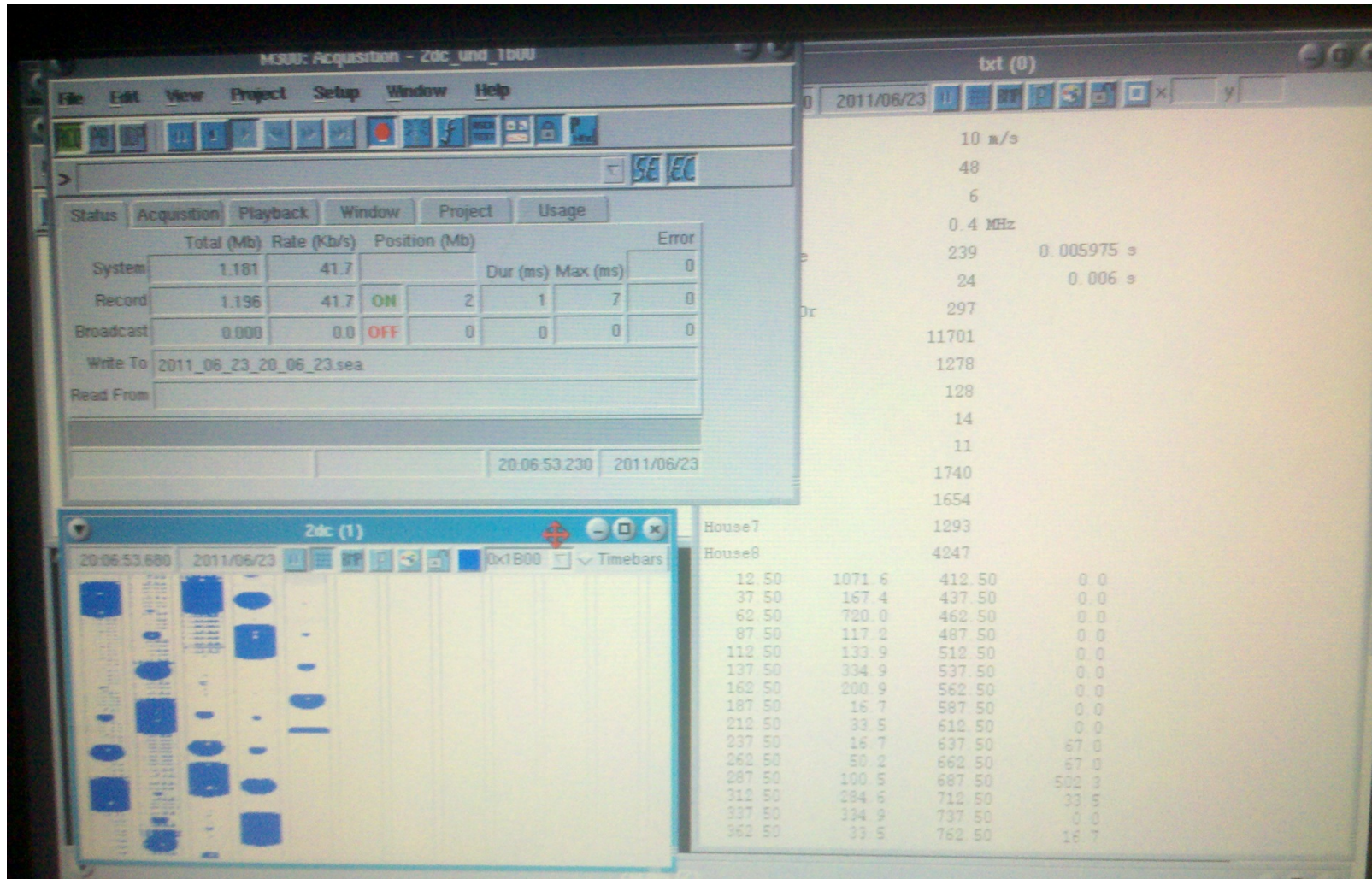


Additional Bits Set

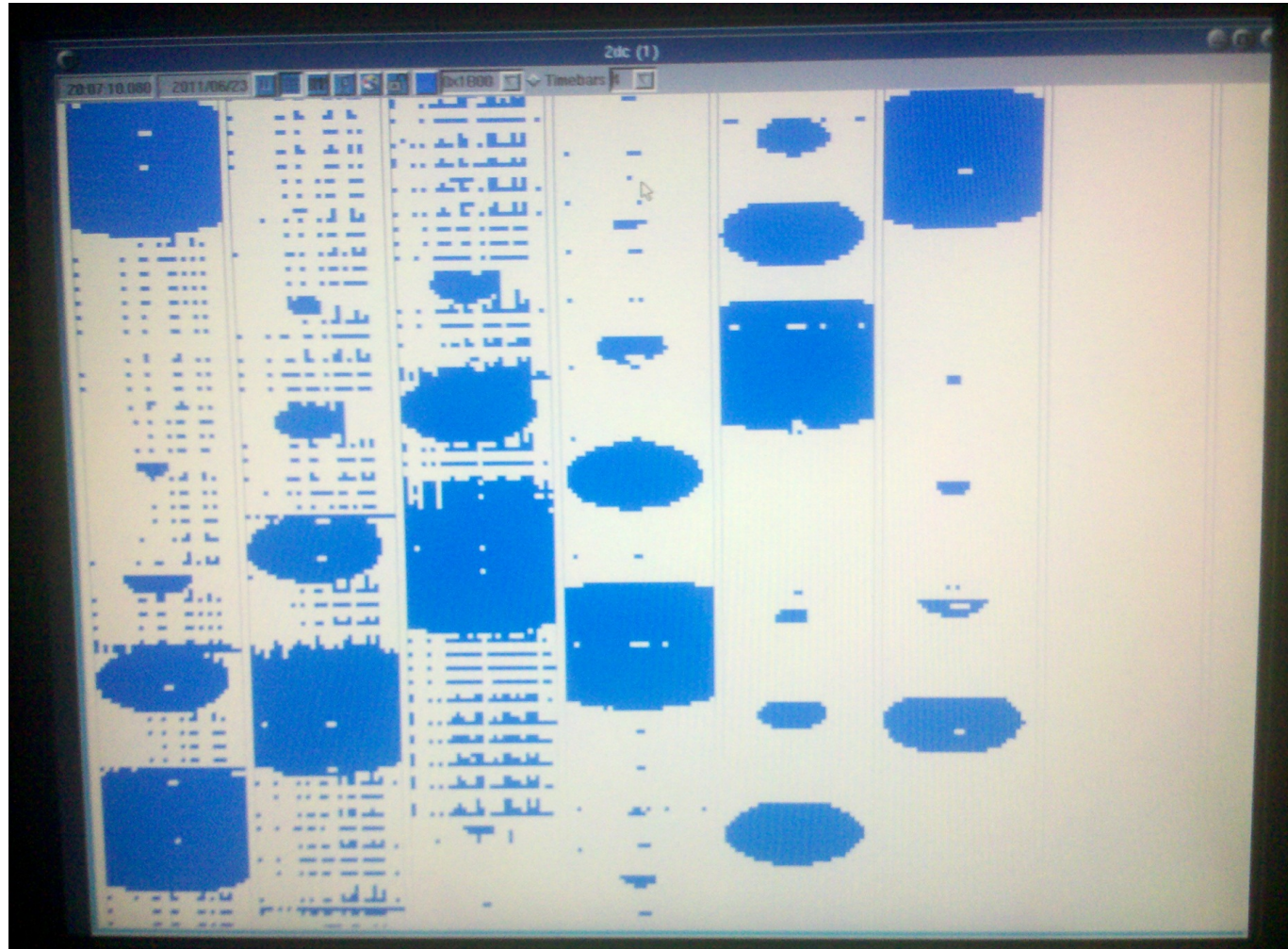
End Time = 75731.3281(2



Images from 2-DC Probe



Images from 2-DC Probe

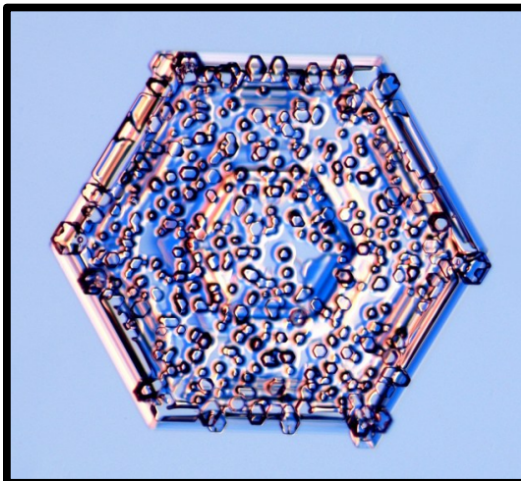


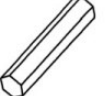
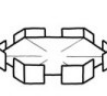
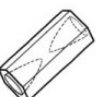
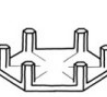
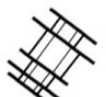
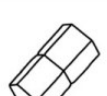
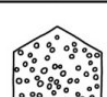
Crystal Shapes

<http://www.its.caltech.edu/~atomic/snowcrystals/class/class.htm>

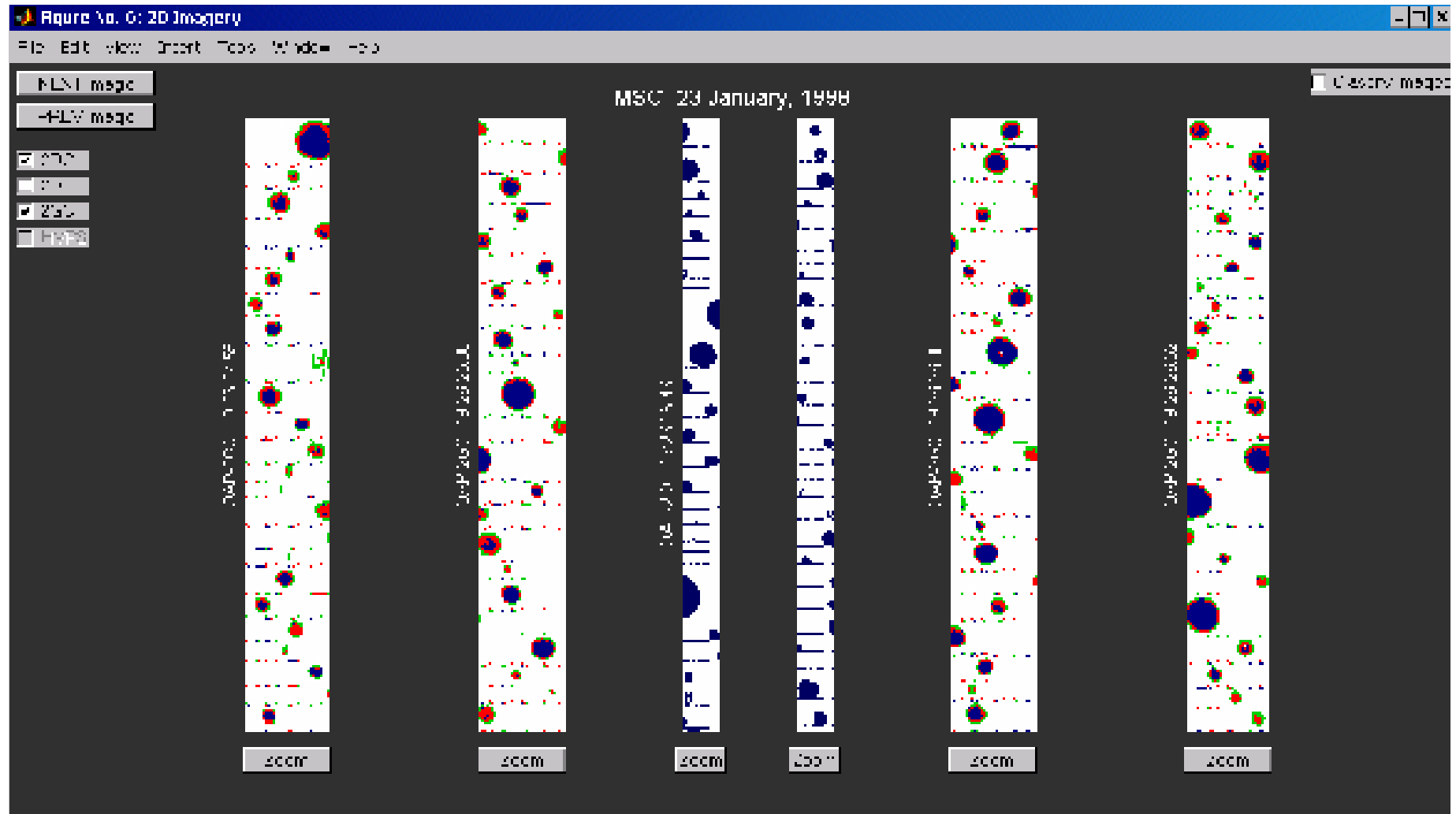
- **Spheres**
- **Needles**
- **Dendrites**
- **Irregulars**

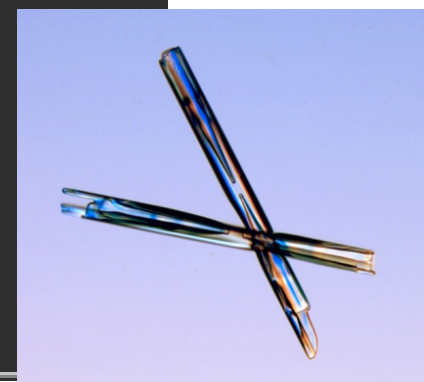
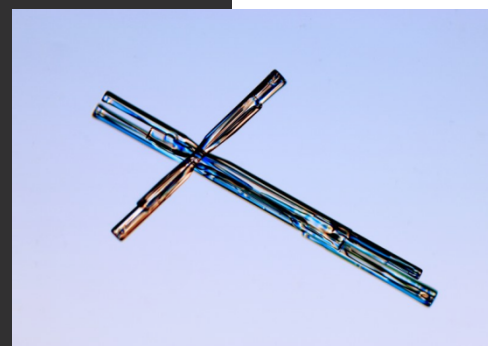
Rimed



				
Simple Prisms	Solid Columns	Sheaths	Scrolls on Plates	Triangular Forms
				
Hexagonal Plates	Hollow Columns	Cups	Columns on Plates	12-branched Stars
				
Stellar Plates	Bullet Rosettes	Capped Columns	Split Plates & Stars	Radiating Plates
				
Sectorial Plates	Isolated Bullets	Multiply Capped Columns	Skeletal Forms	Radiating Dendrites
				
Simple Stars	Simple Needles	Capped Bullets	Twin Columns	Irregulars
				
Stellar Dendrites	Needle Clusters	Double Plates	Arrowhead Twins	Rimed
				
Fernlike Stellar Dendrites	Crossed Needles	Hollow Plates	Crossed Plates	Graupel

2-DC Probe: Spheres





2-DC Probe: Dendrites



Figure No. 1: 2D Imaging

File Edit View Patch Tools Window Help

NEW Image

PREV Image

☒ 2DC

☐ 2DP

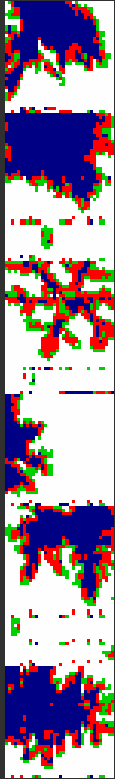
☒ 3DP

☐ HDP

23 January, 1998

Display: Image

04P-200 16.57.48.0



Zoom

04P-200 16.57.48.0



Zoom



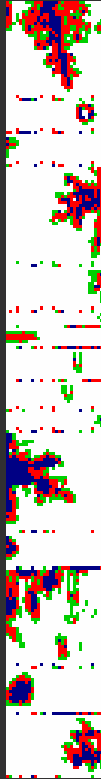
Zoom

04P-200 16.57.50.0



Zoom

04P-200 16.57.50.0



Zoom

04P-200 16.57.52.0

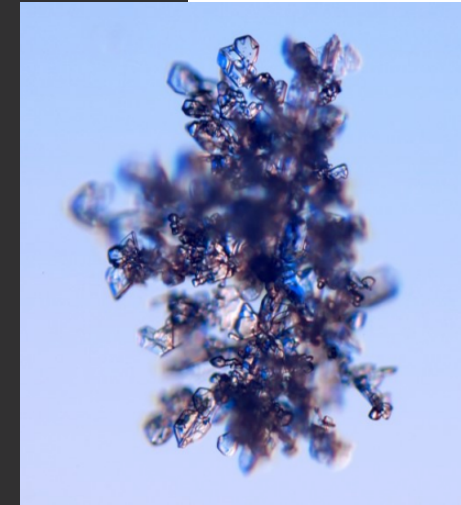
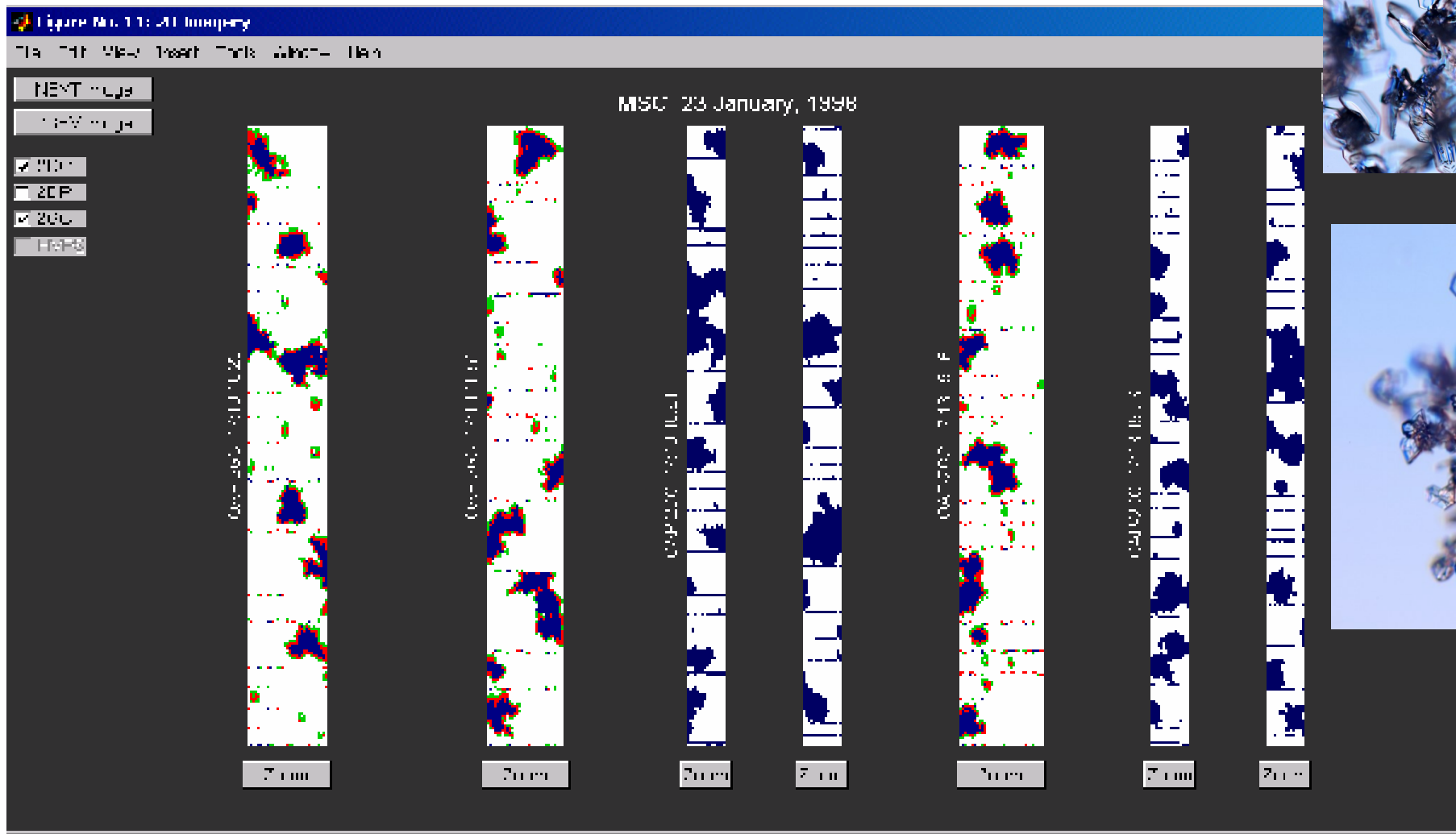


Zoom

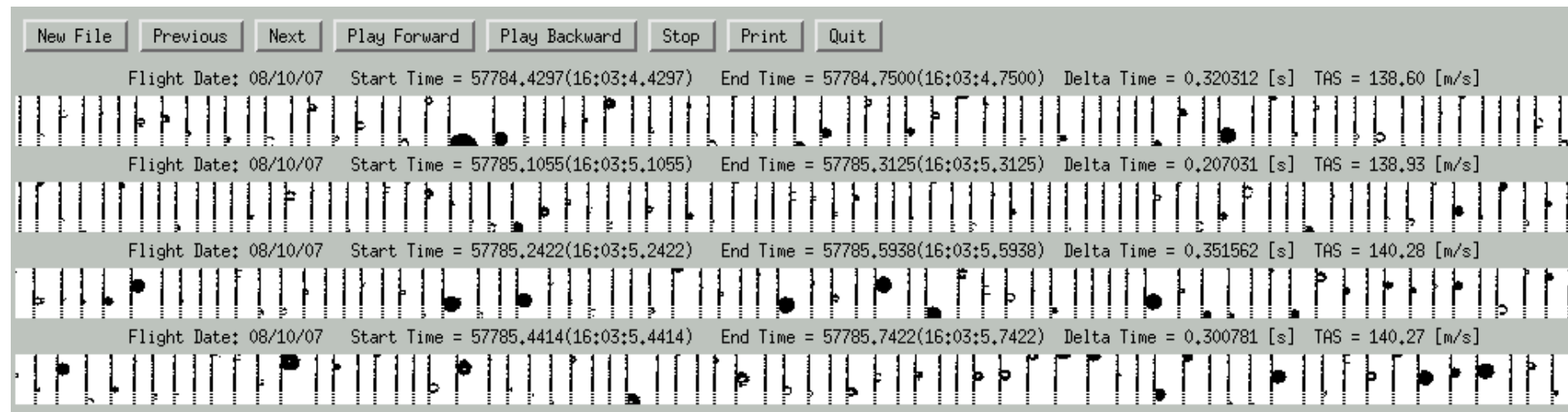
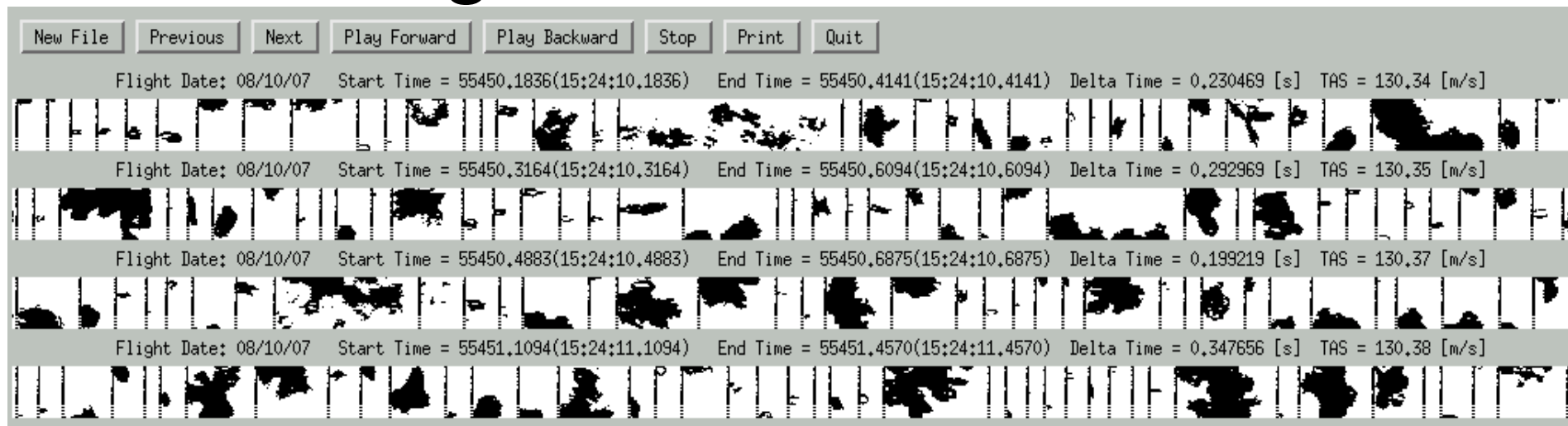


Zoom

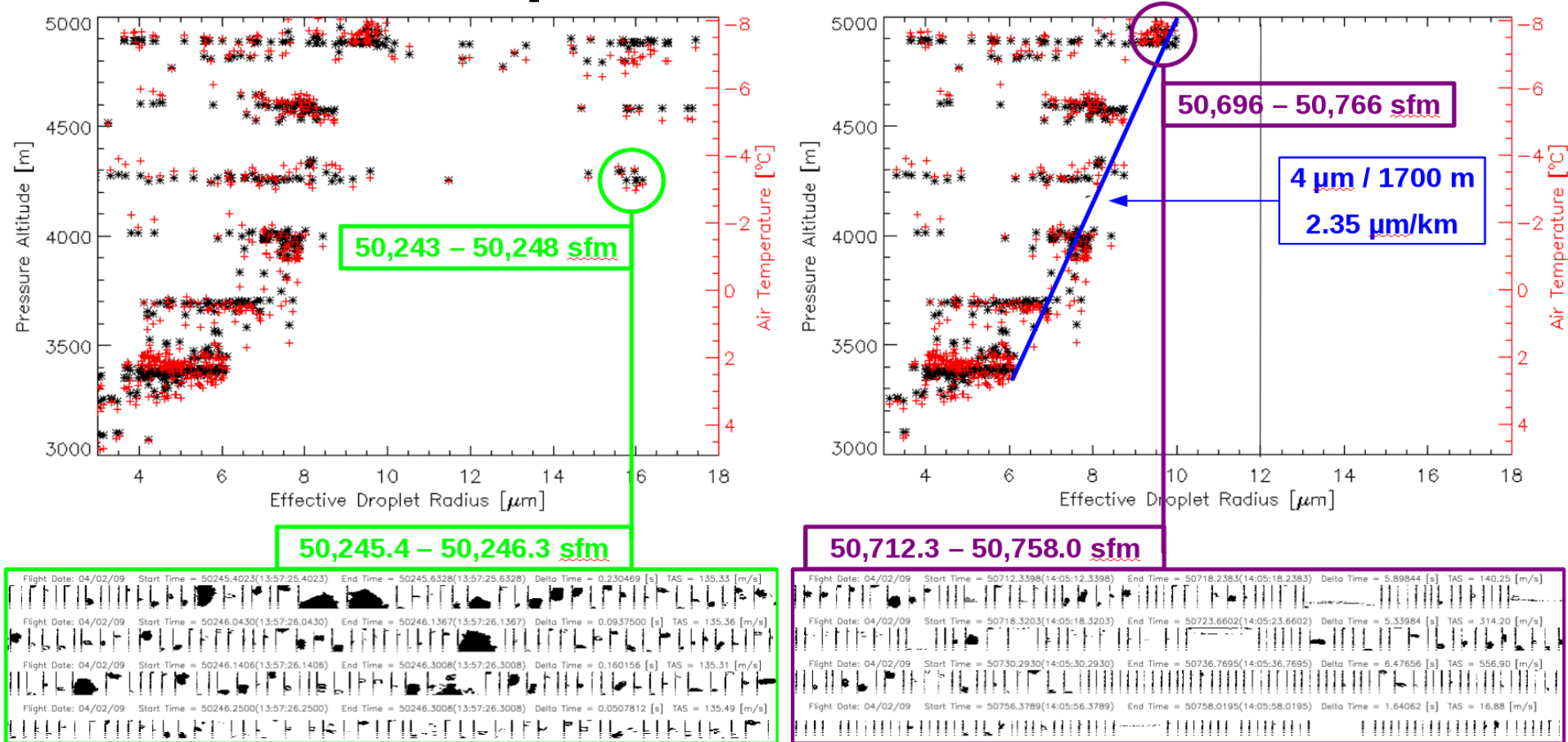
2-DC Probe: Irregulars



Images from 2-DC Probe



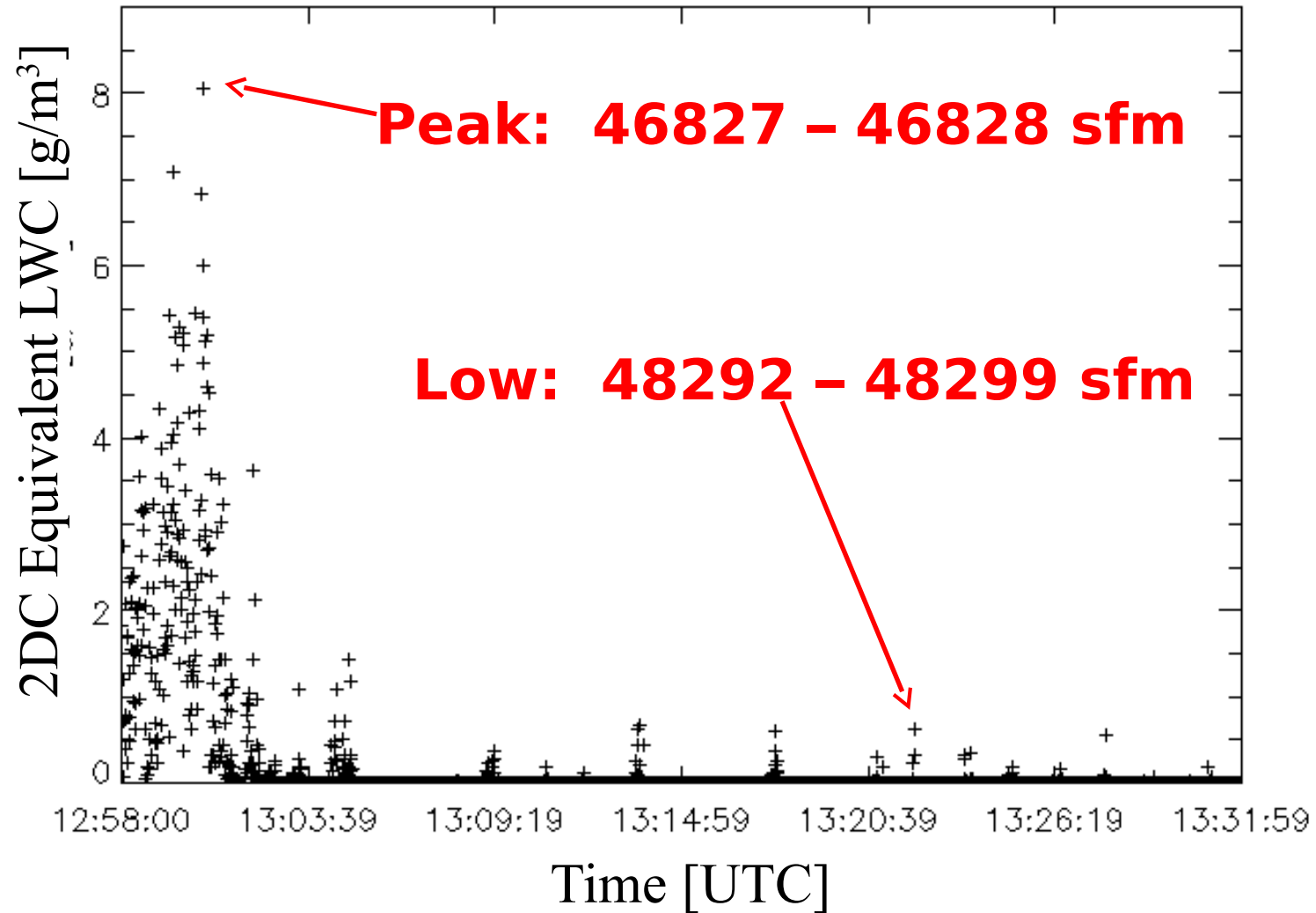
Droplet Effective Radius



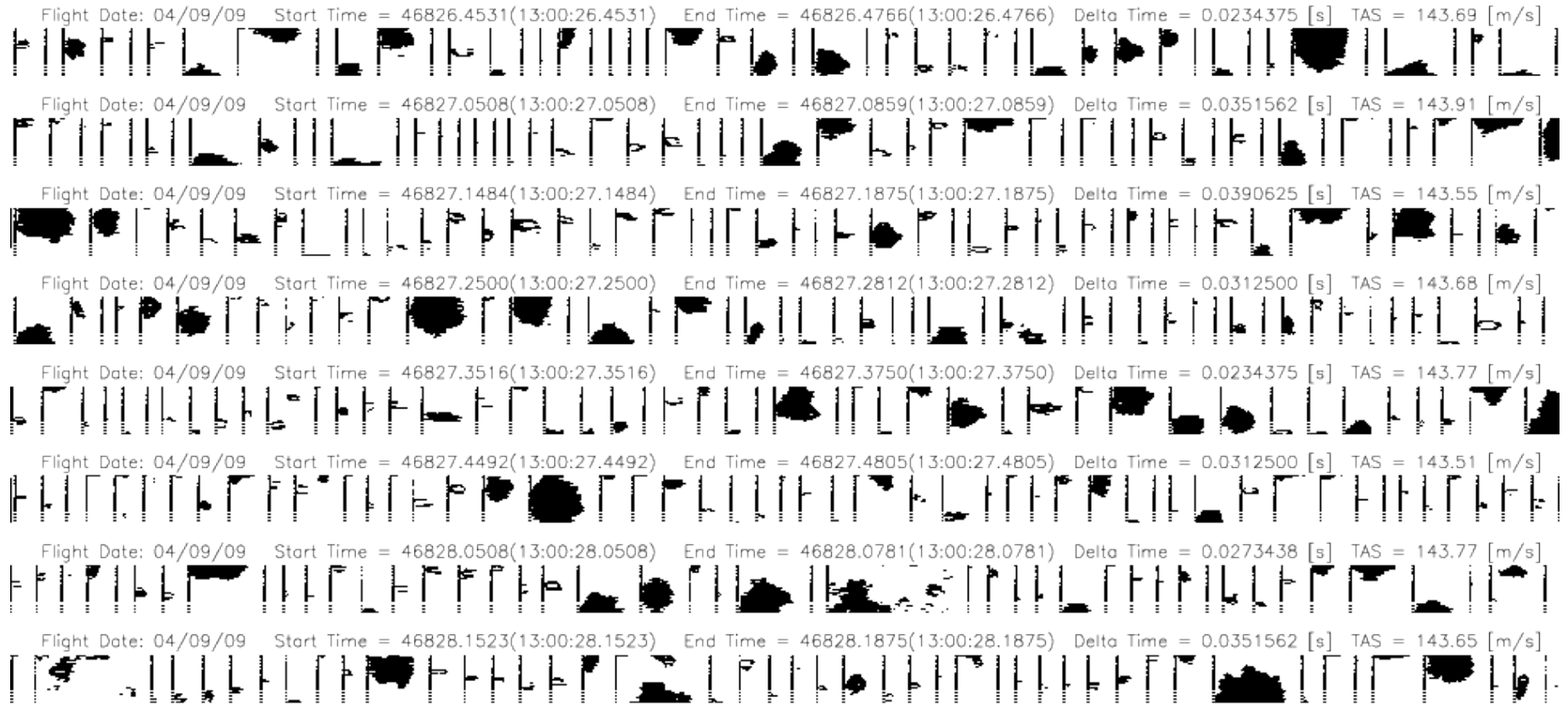
Sampling between cloud base and cloud top during time interval 49,100 to 50,800 sfm on 2 April 2008. Left panel shows all observations, while right panel only includes FSSP concentrations at STP greater than 100 $\#/\text{cm}^3$. The blue line is the approximate rate of increase of effective droplet radius with height.

9 April 2009 Flight

Liquid water content equivalent (1 Hz) at 18,000 ft measured by 2-DC probe on a research flight in Saudi Arabia.

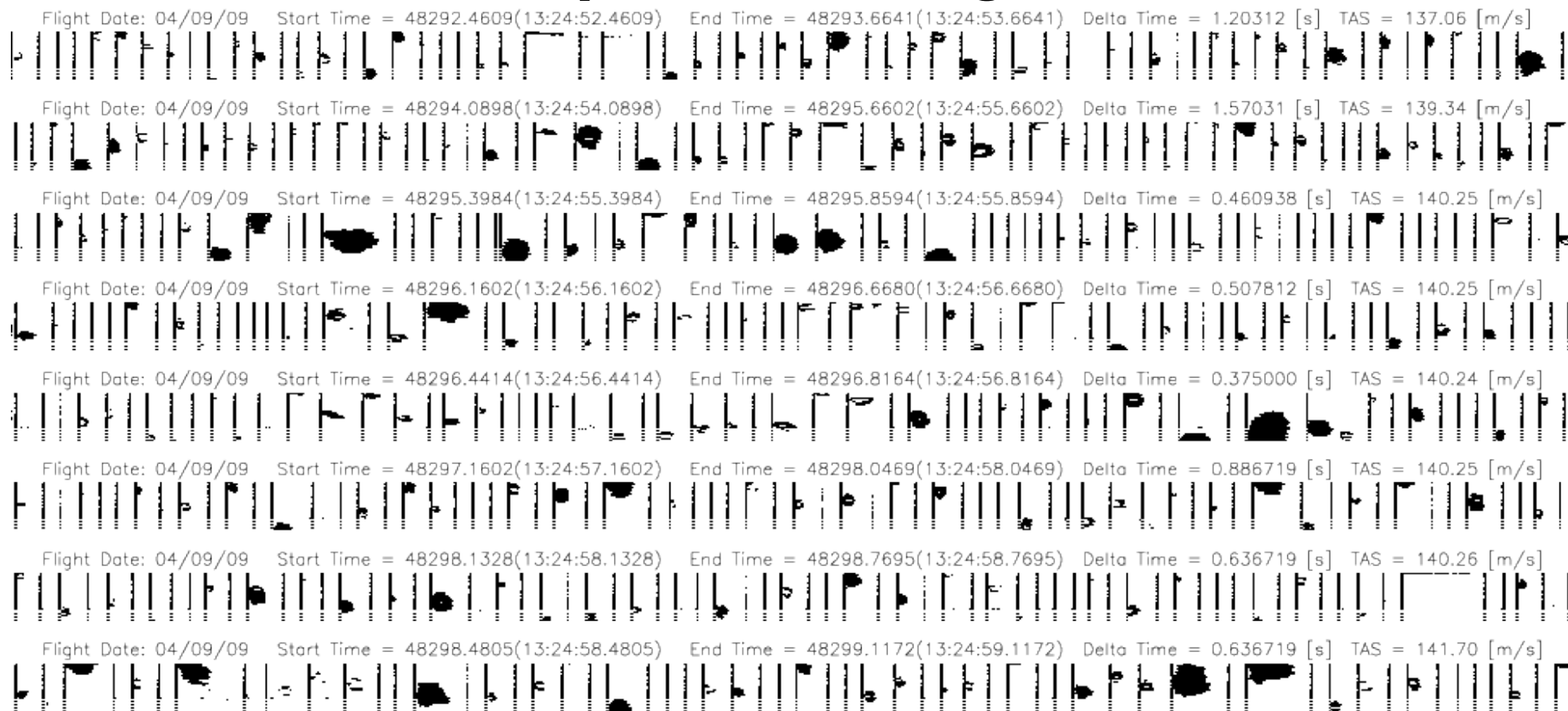


9 April 2009 Flight



Images from the 2-DC between 13:00:26.45 and 13:00:28.19 (less than 2 seconds total) which correspond to the maximum liquid water content equivalent (1 Hz data) measured by 2-DC probe between on 9 April 2009 research flight in Saudi Arabia.

9 April 2009 Flight



2-DC images between 13:24:52.46 and 13:24.59 (9 seconds total) which correspond to the low liquid water content equivalent (1 Hz data) measured by 2-DC probe on 9 April 2009 research flight in Saudi Arabia.

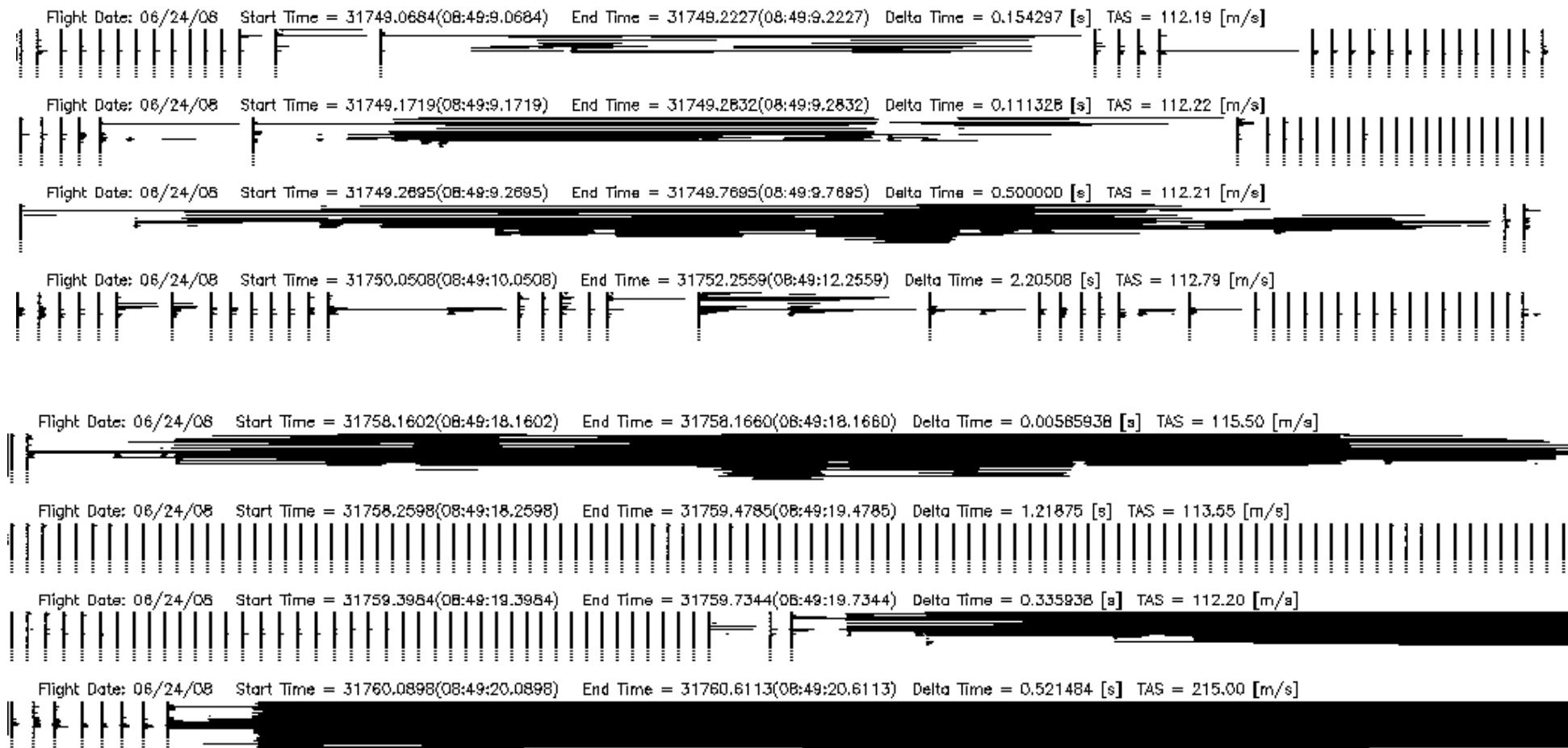
Conclusions

- It is important to conduct performance test on the 2DC using a spinning disk.
- It is important to clean the 2DC optics.



Conclusions

Liquid Droplets are round, ice is not.



Any Questions

