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Performance of the in-situ cloud microphysical instrumentation during the HIWC/HAIC Cayenne field campaign

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HIWC/HACI Science team meeting, 9-12 November, 2015

Overview

1. Isokinetic probe and background humidity
2. Particle probes
   (a) Scattering probes: UHSAS, FSSP, CDP
   (b) 2D probes: 2D-S, CIP, 2DC, PIP
3. Robust probe
4. Nevzorov probe
5. Rosemount icing detector
6. Extinction probe

Strategy for data quality control and data processing

1. Visualization of all housekeeping data
2. Identify time periods, when the instruments were malfunctioning
3. Identify whether the data are recoverable or unrecoverable
4. Process good and recoverable data using existing algorithm
5. Utilize intercomparisons between redundant measurements to identify potential issues in processing
6. Use results of intercomparisons to improve processing algorithms
7. Perform calibrations to verify exiting processing algorithms and develop new ones.

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Disclaimer:

- The data presented below did not pass full processing cycle.
- Bias offsets were not completely removed, correction coefficients and correction algorithms need to re-examined and reapplied.
- The data should be considered as preliminary and they should not be used for scientific publications.

IKP2 data set and background humidity

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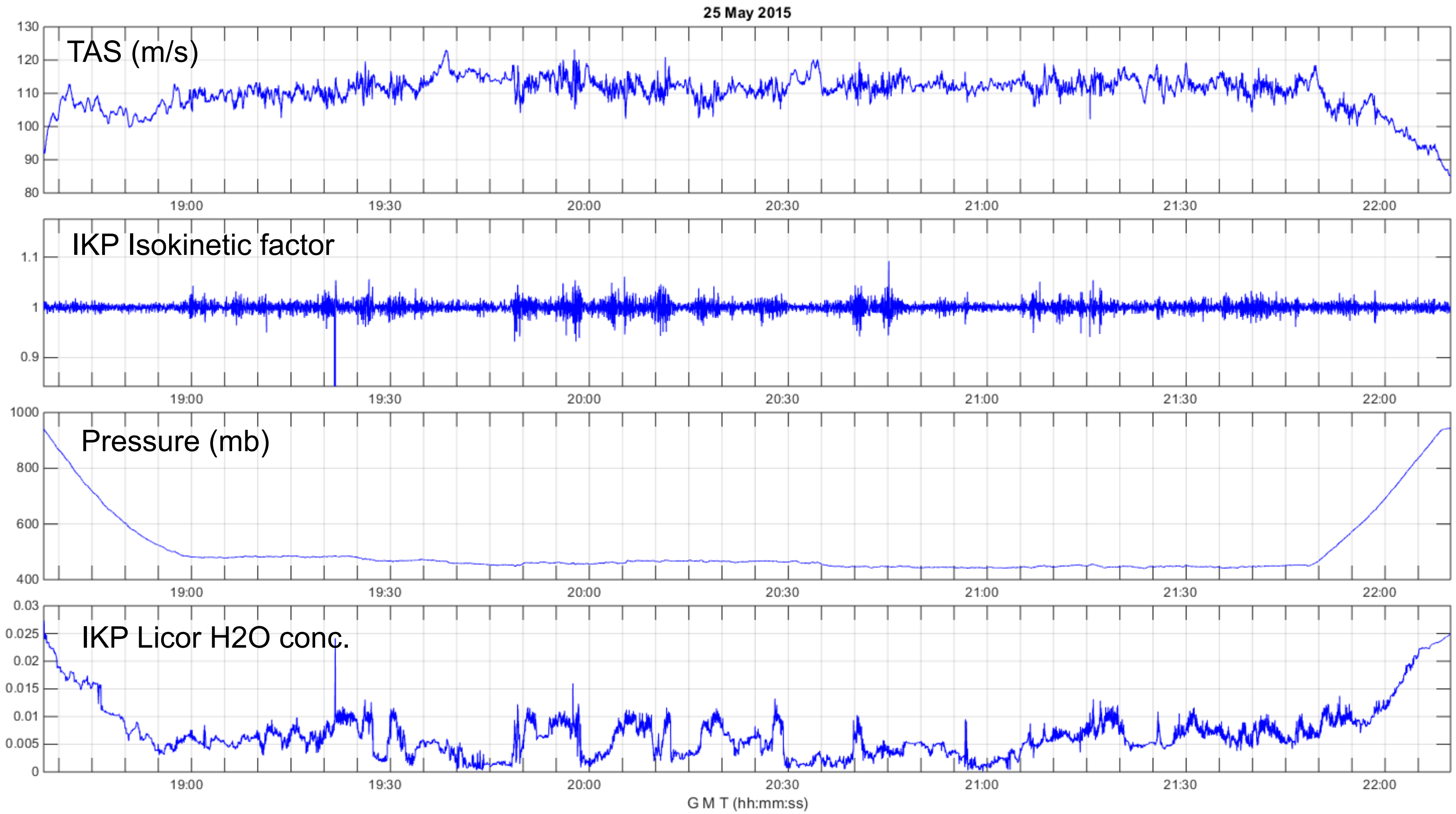
IKP-2 (NASA)

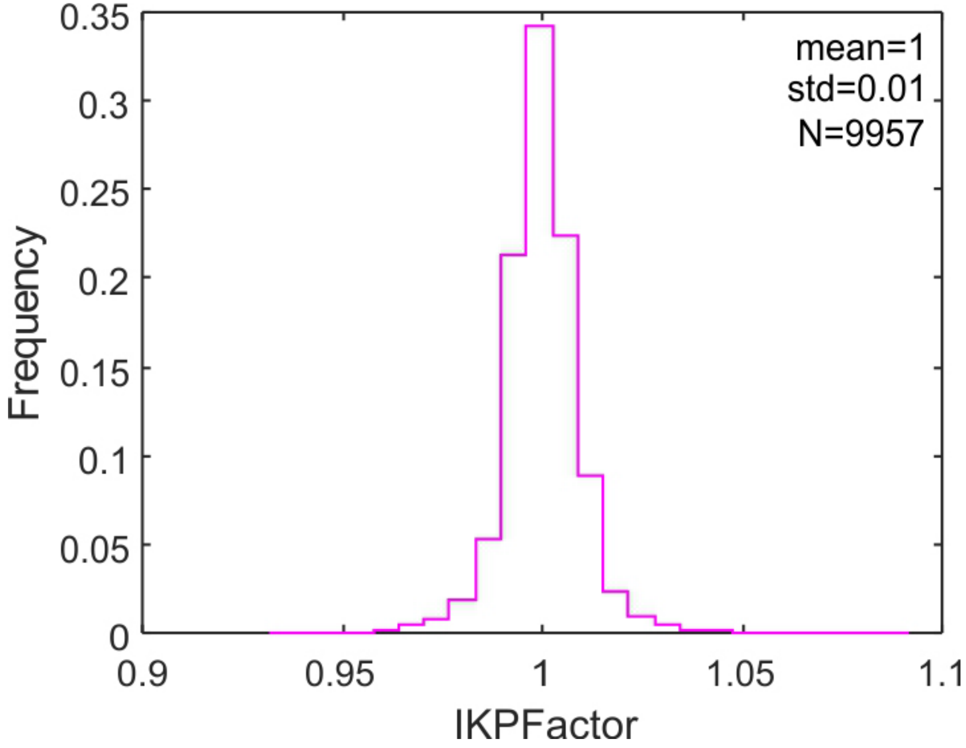
IKP data quality control

Stability of the IKP isokinetic factor

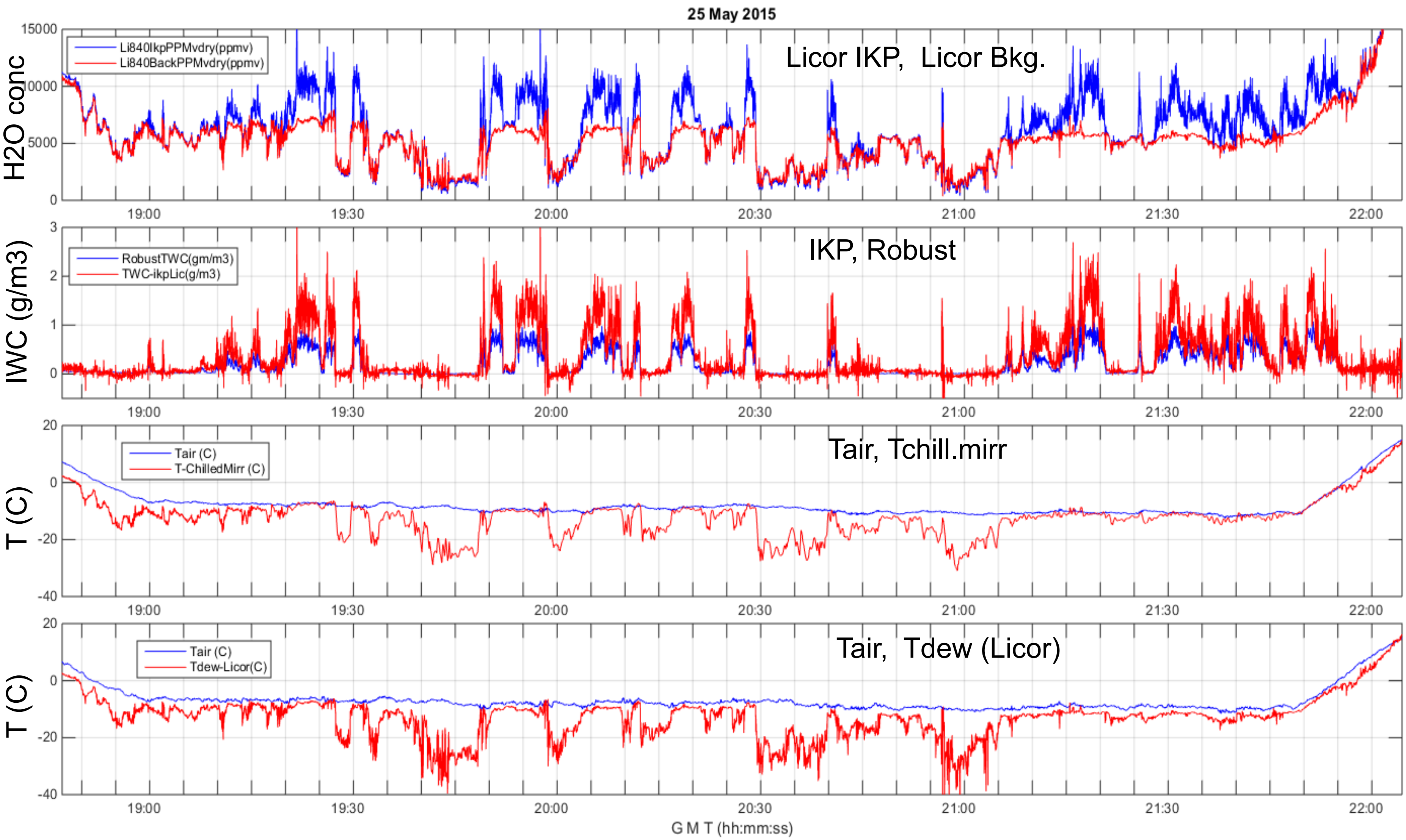


IKP data quality control

Stability of the IKP-2 isokinetic factor

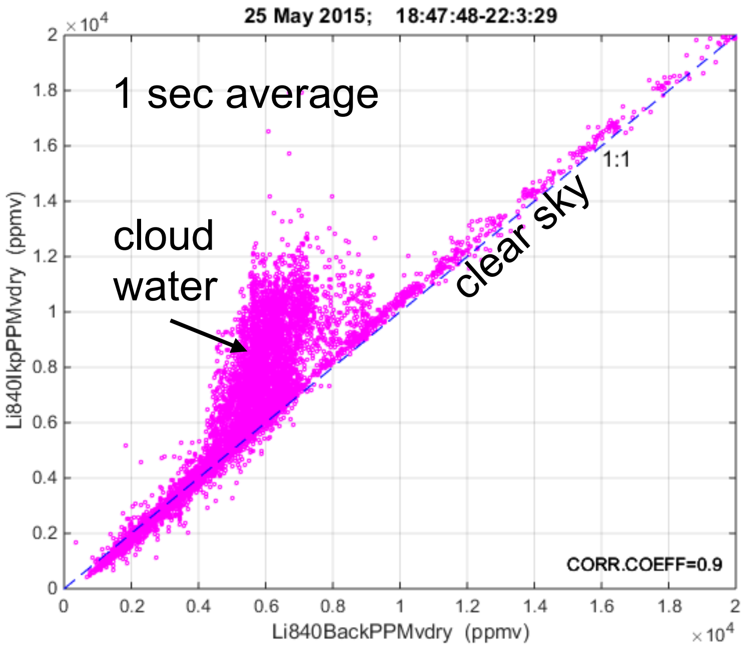


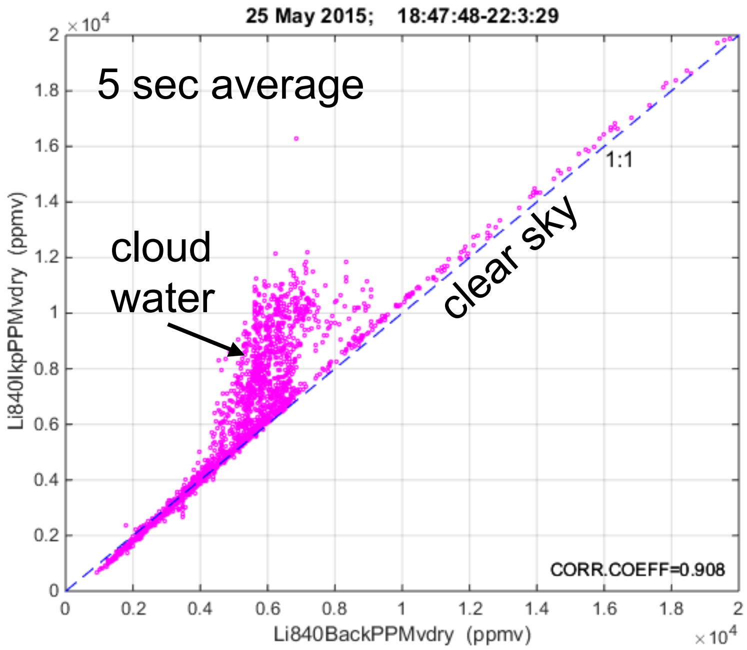
IKP data quality control



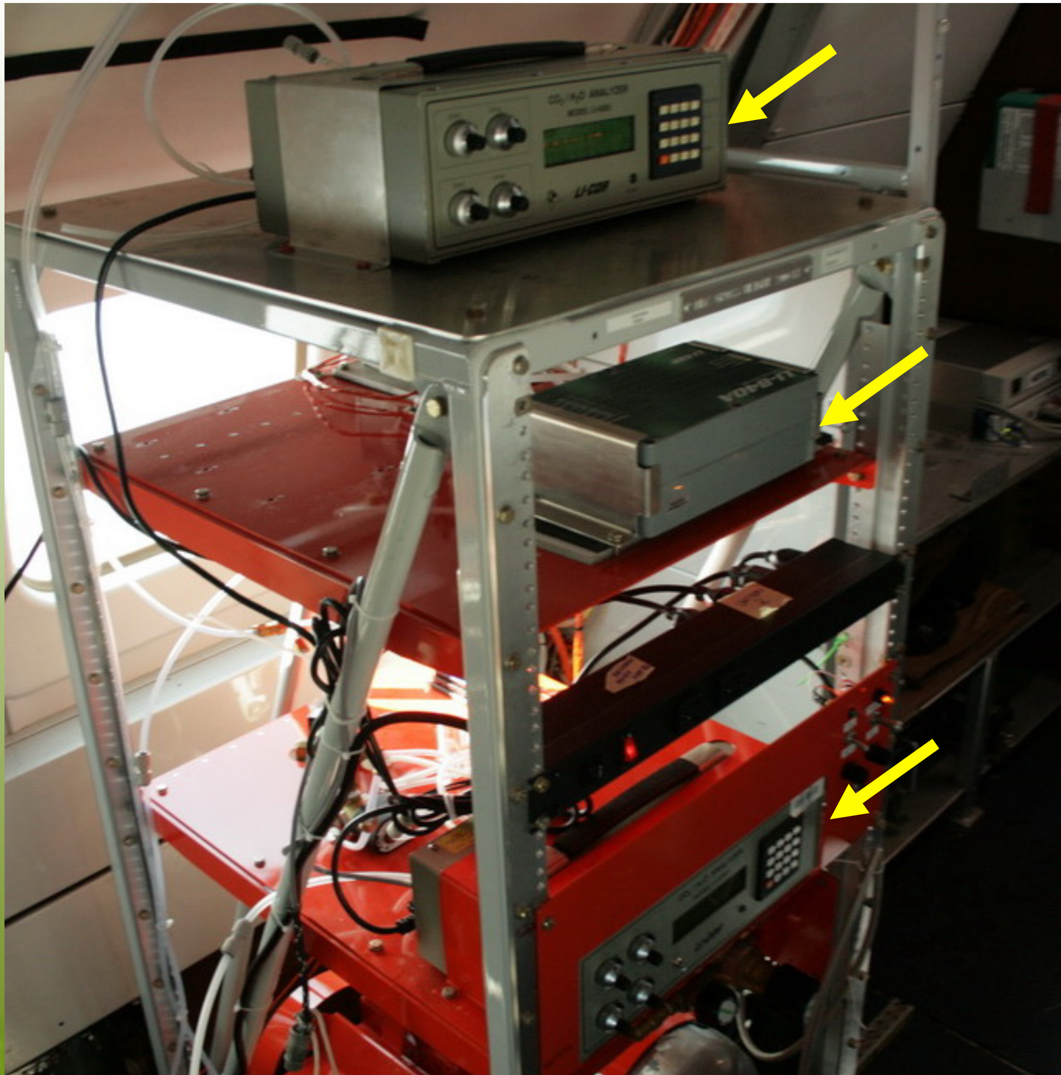
IKP data quality control

Performance of the IKP and background humidity measurements

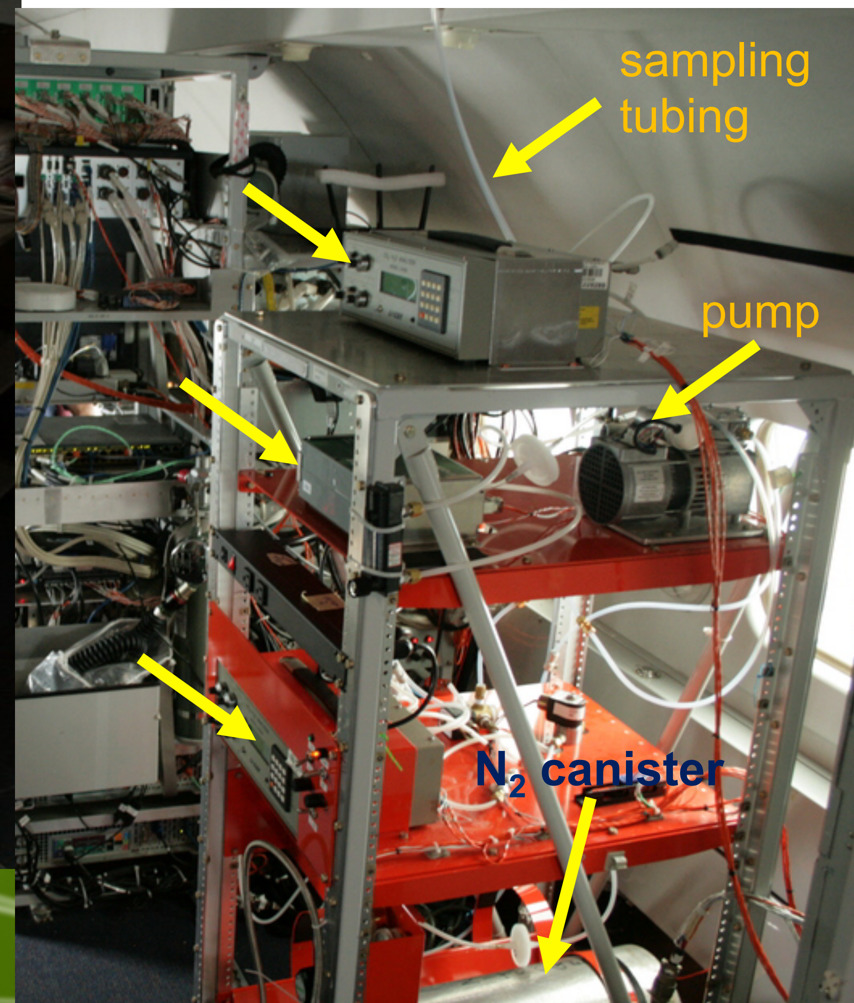




Background humidity measurements

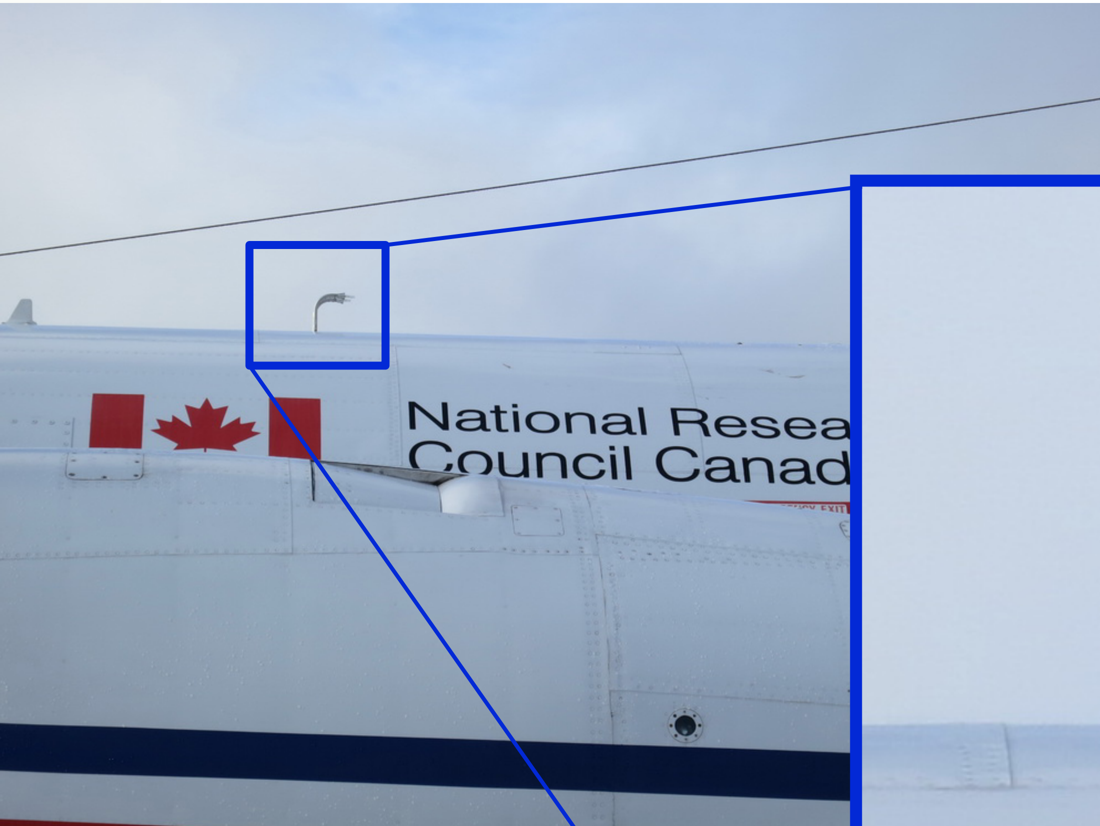


Licor 6262
Licor 6262
Licor 840A



Water vapor inlet

- Double inlet
- Reverse flow
- Shroud protecting from shedding water

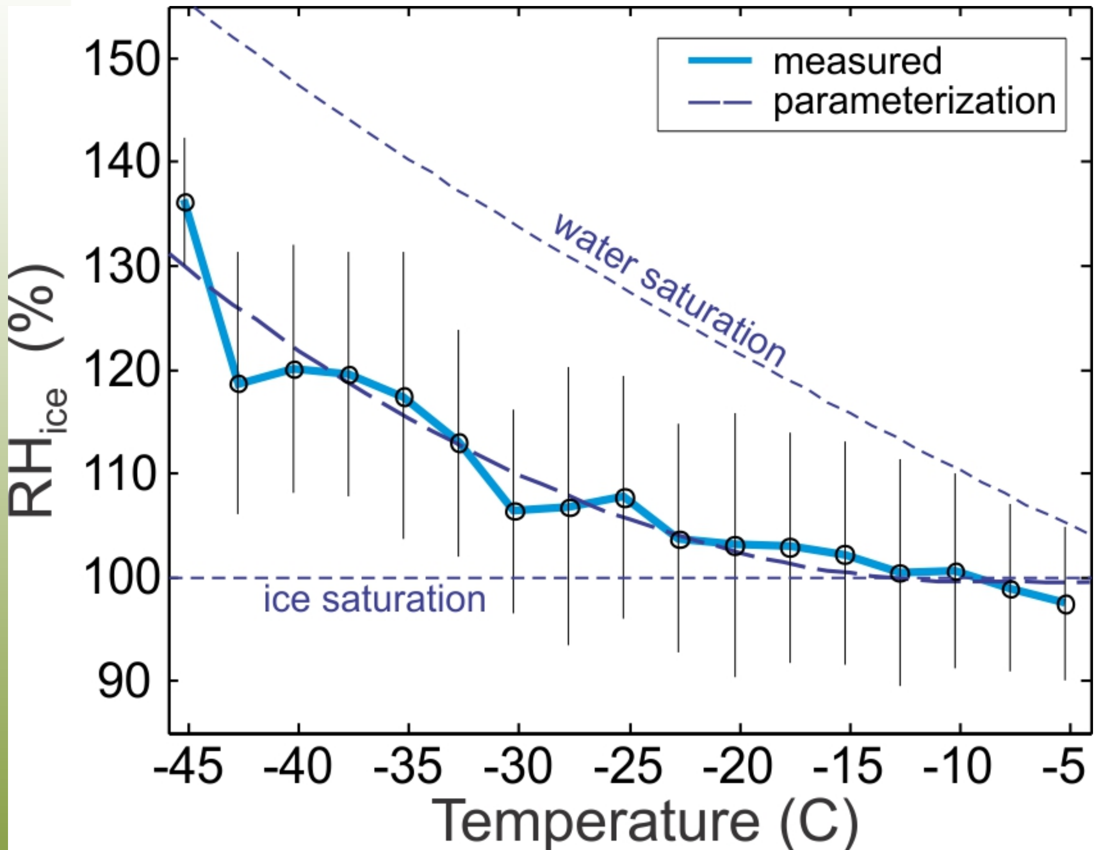


Performance matrix of the IKP and background humidity measurements

Flight#	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Date	10-May-15	12-May-15	14-May-15	15-May-15	16-May-15	16-May-15	20-May-15	23-May-15	23-May-15	25-May-15	26-May-15	26-May-15	27-May-15	27-May-15
IKP TWC	Y-	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Licor 840A/6262	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y
Chilled Mirror	M-	M-	M-	M-	M-	M-	M-	M+	M+	Y	Y	Y	Y	Y

- With the exception two days, the IKP performance during the Cayenne field deployment was good
- The background humidity measurements failed during the first half of the field campaign, and it was recovered during the second half.
- **What technique could be used to estimate the background humidity in ice clouds to recover the TWC IKP measurements?**

Statistics of humidity in ice clouds



At -45C<T<-30C RH in ice clouds is half way between saturation humidity if ice and liquid.

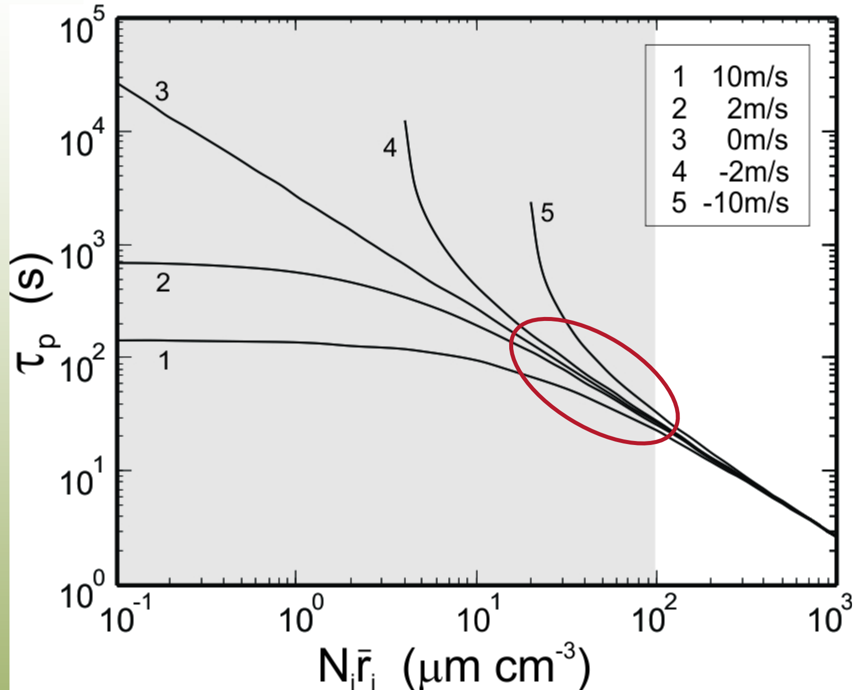
At -15C<T<-5C RH in ice clouds is close to ice saturation.

$T_{air} = T_{frost}$

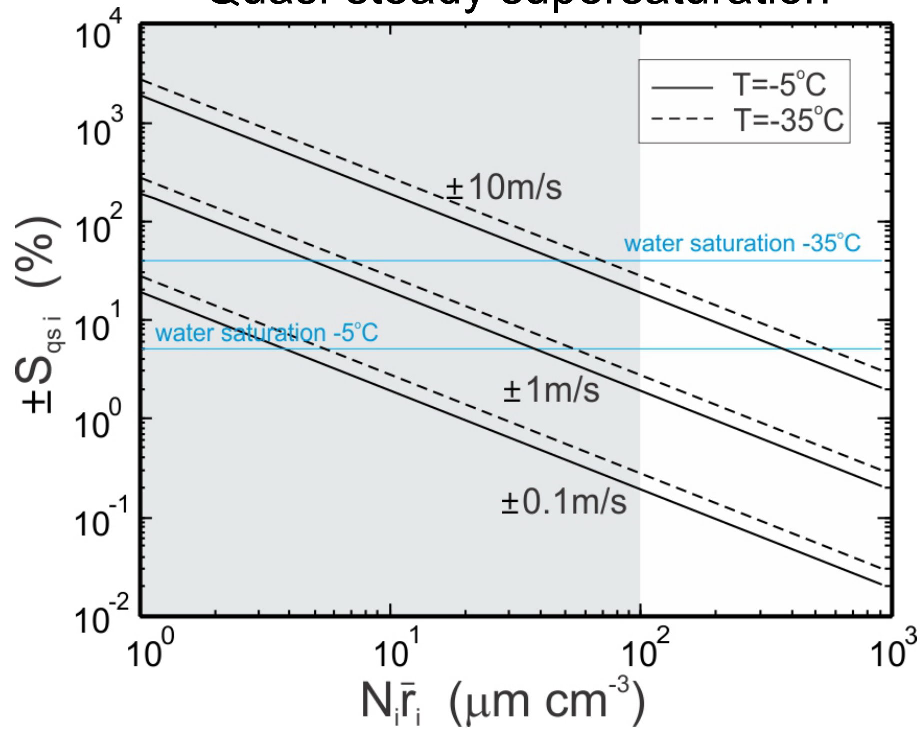
$T_{air} > T_{frost}$

Korolev and Isaac (JAS, 2006)

Phase relaxation time



Quasi-steady supersaturation



$$\tau_p = \frac{1}{a_0 u_z + b_i N_i \bar{r}_i}$$

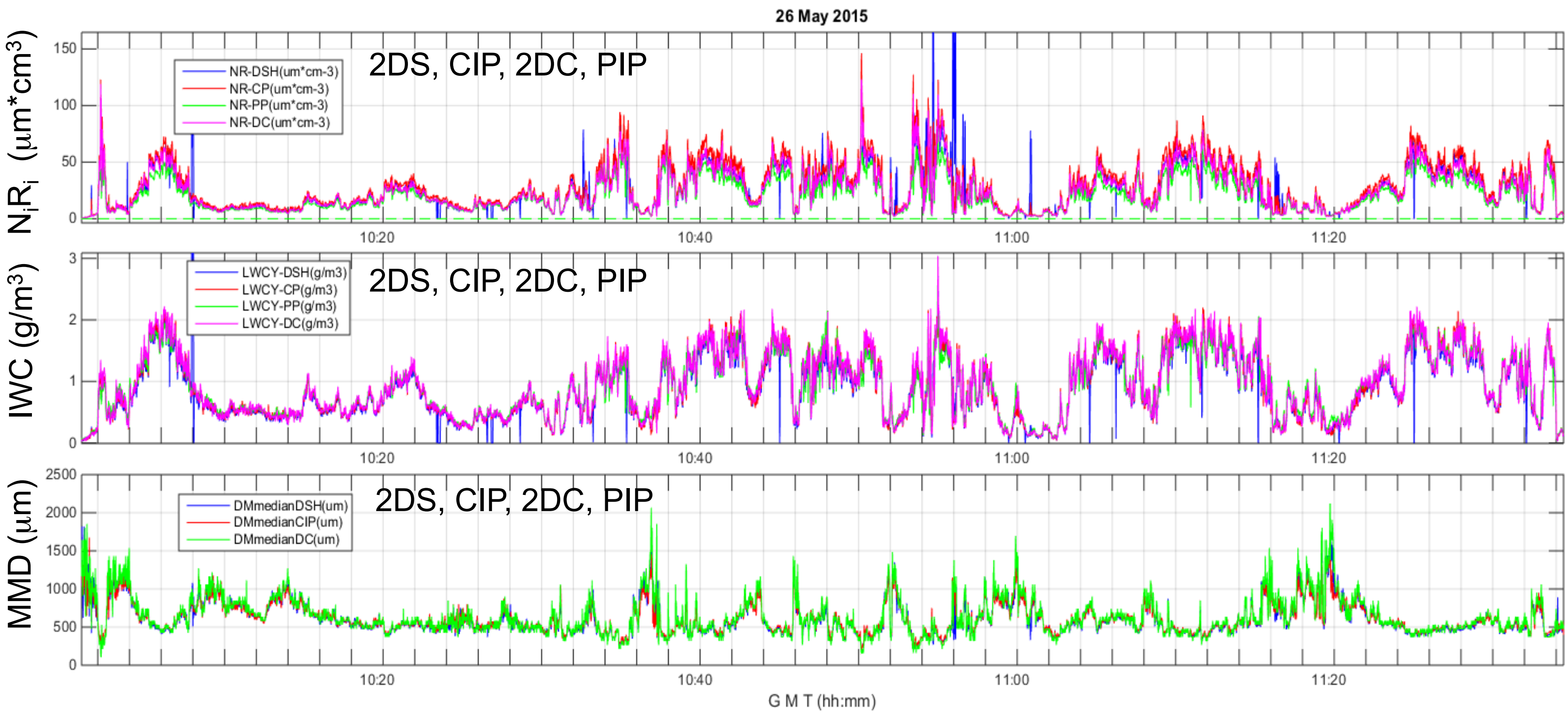
$$S_{qs\ i} = \frac{a_{0i} u_z}{b_i N_i \bar{r}_i}$$

Time of phase relaxation determines the characteristic time of relative humidity approaching to its equilibrium value S_{qsi}

- $10s < \tau_p < 100s$ HIWC cloud regions (small IWC errors)
- $10^2 s < \tau_p < 10^3$ low IWC cloud regions (large IWC errors)

Integral ice particle radius in MCSs

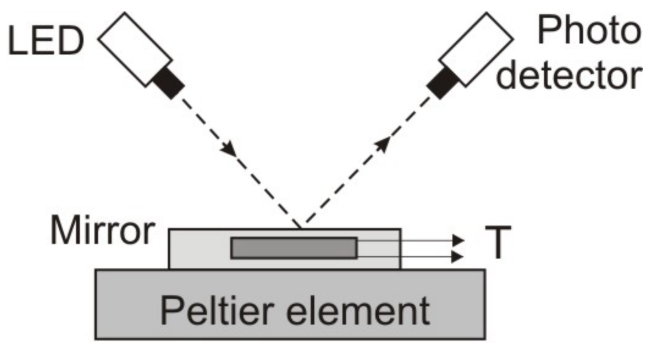
calculated from 2DS, CIP, 2DC, PIP

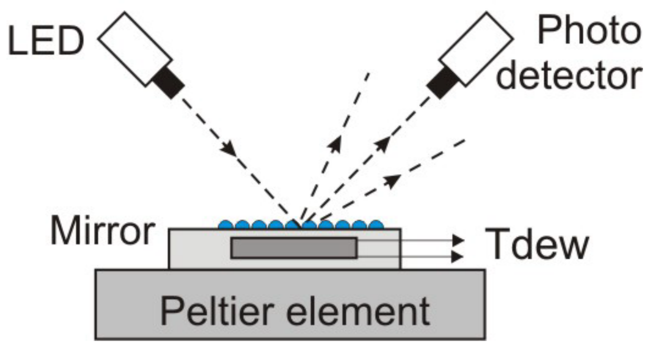


Characteristic range of changes of integral ice particle integral radii in MSCs

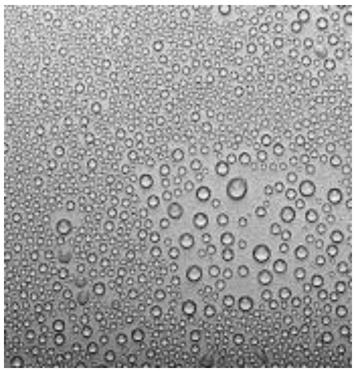
$10\mu m\ cm^{-3} < N_iR_i < 100\mu m\ cm^{-3}$

Principle of operation of the Chilled Mirror Hygrometer





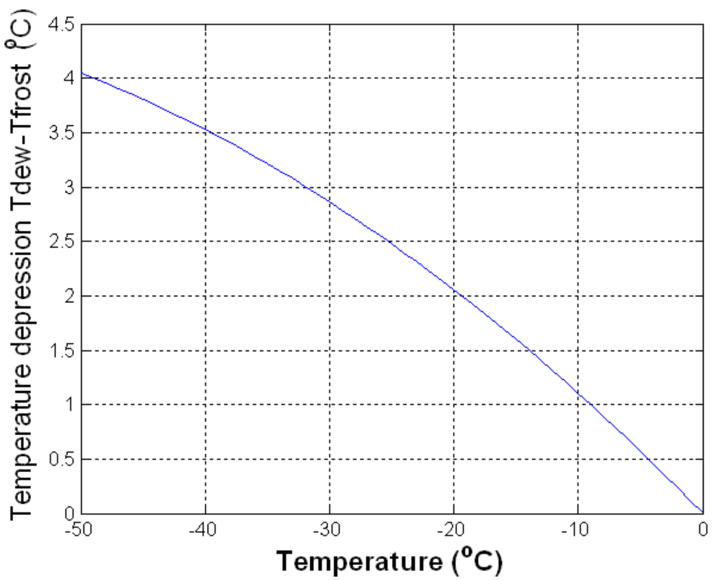
At T_{air}>0C dew is formed at the surface of the chilled mirror



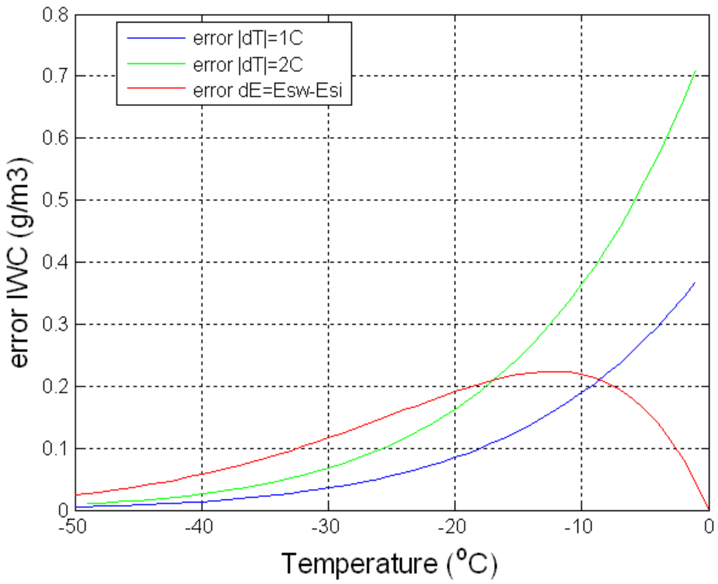
What is the temperature measured by chilled mirror hygrometer at T_{air}<0C?

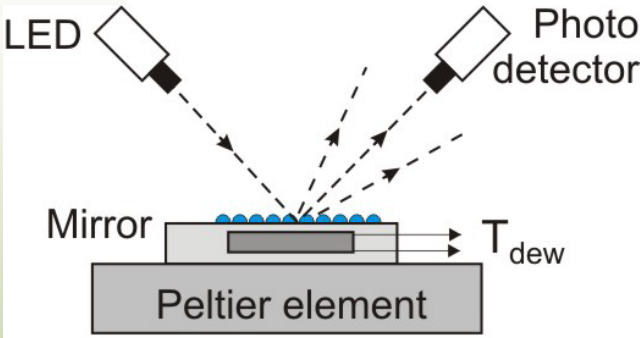
$$T_{frost} \leq T_{dew}$$

Difference between T_{dew} and T_{frost}

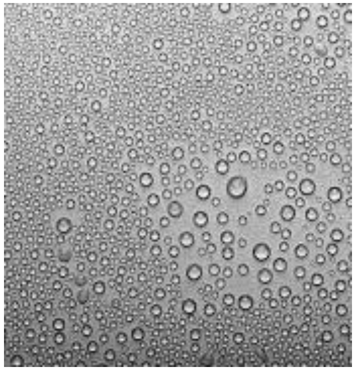


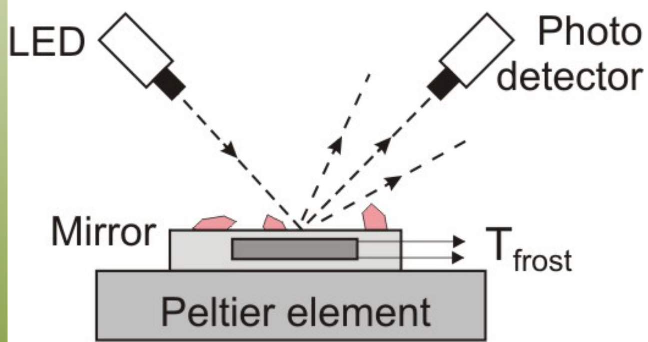
Error in IWC measurements



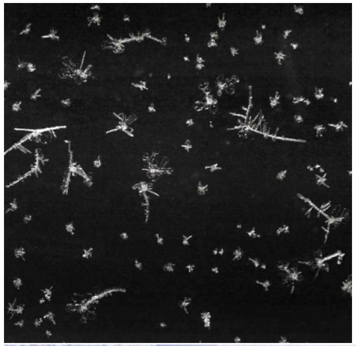


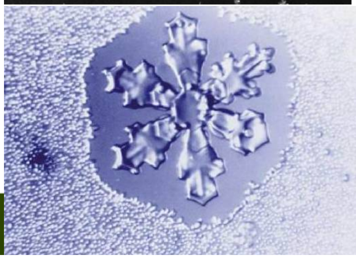
- Dew is composed of large number of small droplets, which uniformly cover the mirror surface.
- Small droplets rapidly reacts on changes of the humidity, resulting in a relatively fast response time of the chilled mirror hygrometer $\Delta t<1s$





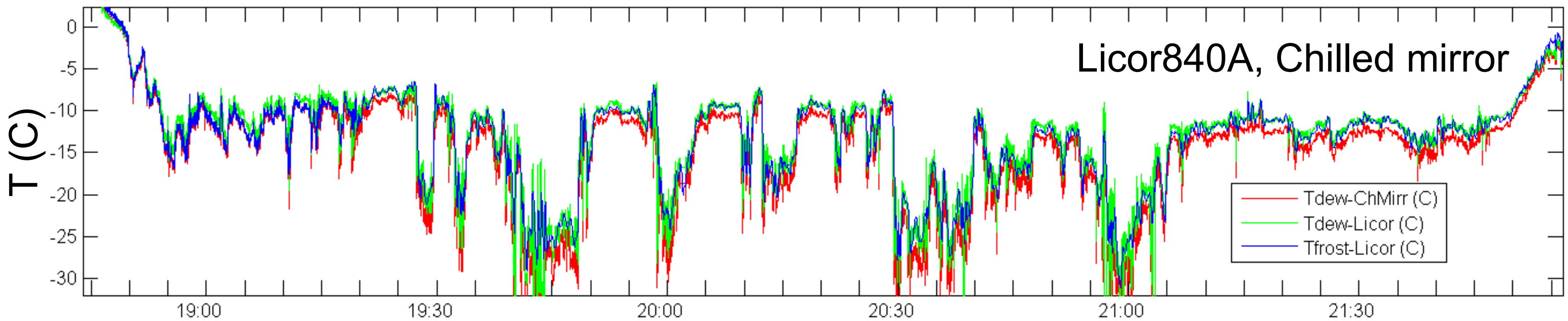
- Frost particles formed on the surface of the chilled mirror are sparse and they suppress formation of dew.
- Fewer frost particles have to grow to larger sizes to cause the same scattering signal as that for the dew.
- Longer growth time result in a time lag and longer response time $\Delta t \sim 10^1 \div 10^2 s$ depending on temperature

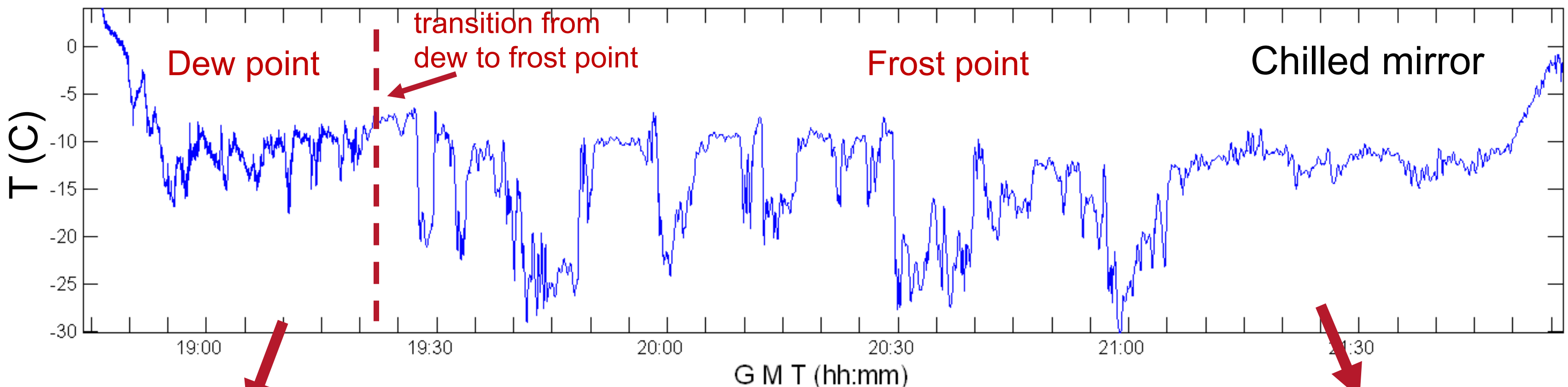




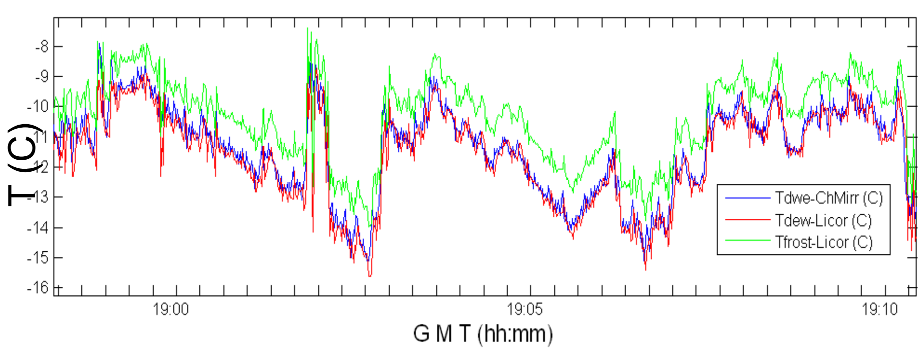
Effect of phase difference Bergeron-Findeisen process

Humidity measurements with chilled mirror hygrometer

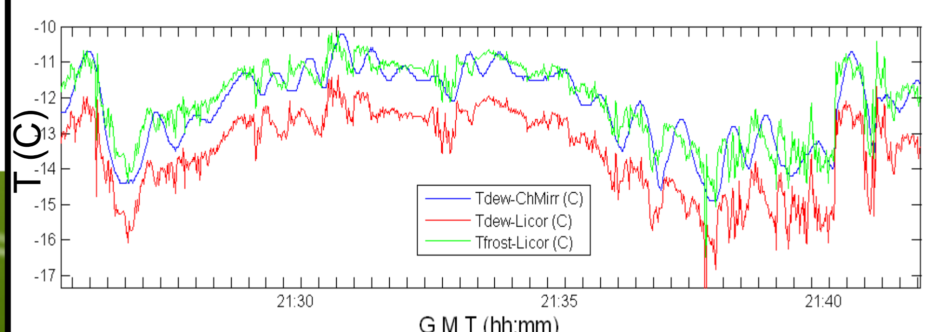




'fast' response, when dew point



'slow' response/time lagging, when frost point



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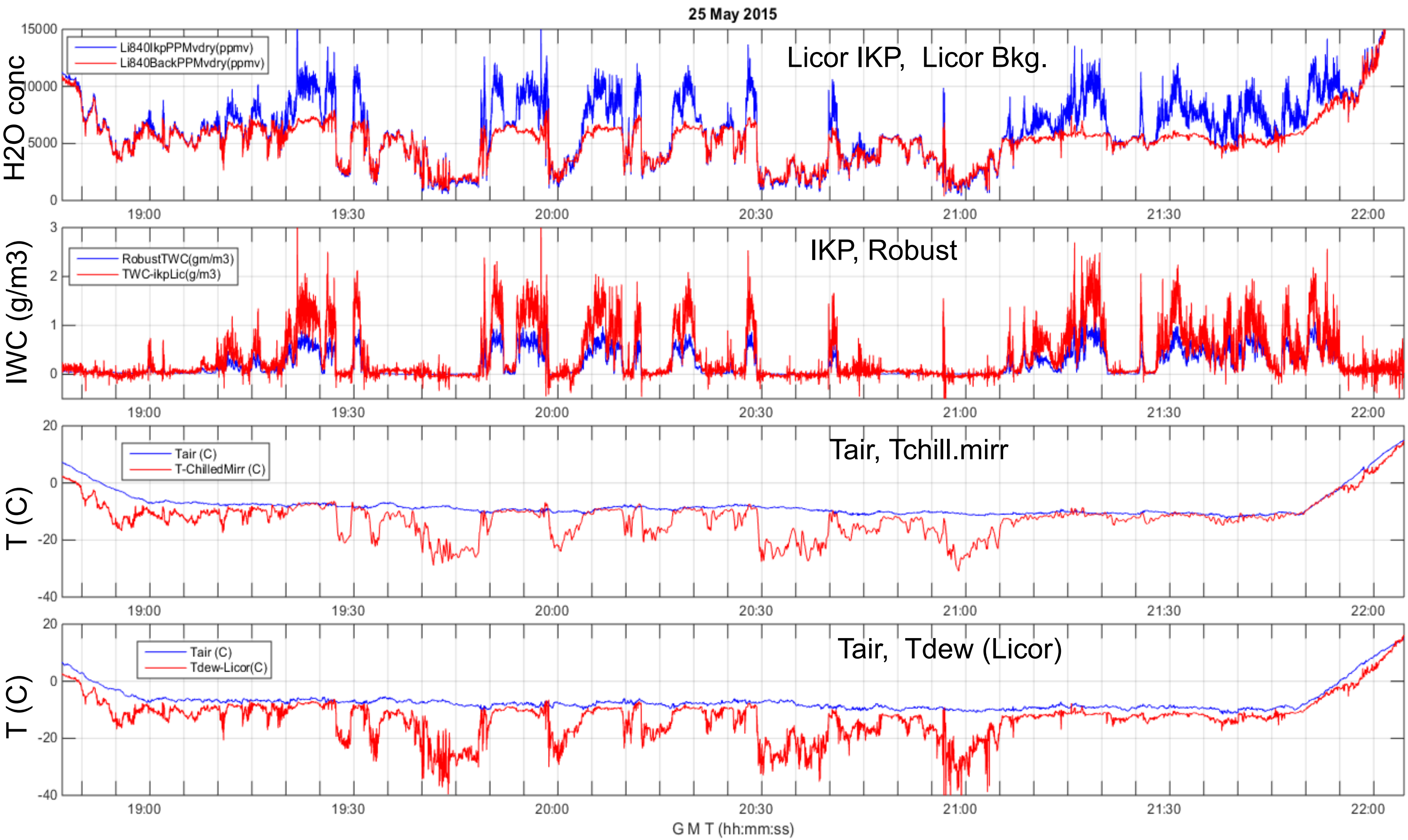
IKP data quality control



Ways of calculation of IWC from IKP in absence of Licor background humidity

1. Use assumption $T_{air} = T_{frost}$ in ice clouds
2. Use chilled mirror hygrometer measurements to estimate background RH
3. Use Robust and Nevzorov TWC probes as a reference
4. Put error bars on the IKP measurements based on the assessment of time of phase relaxation

Particle probes

and

PSD data set

Scattering probes: UHSAS, FSSP, CDP

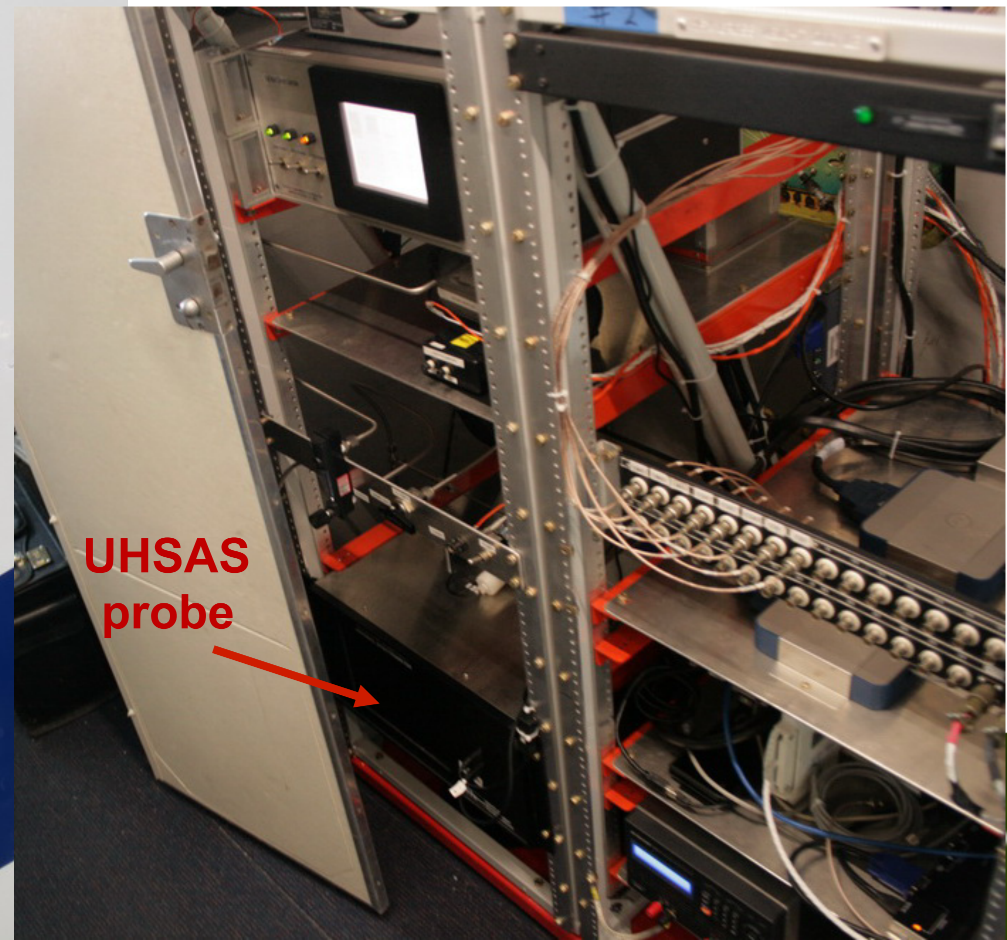
2D imaging probes: 2DS, CIP, OAP-2DC, PIP

Particle probes performance matrix

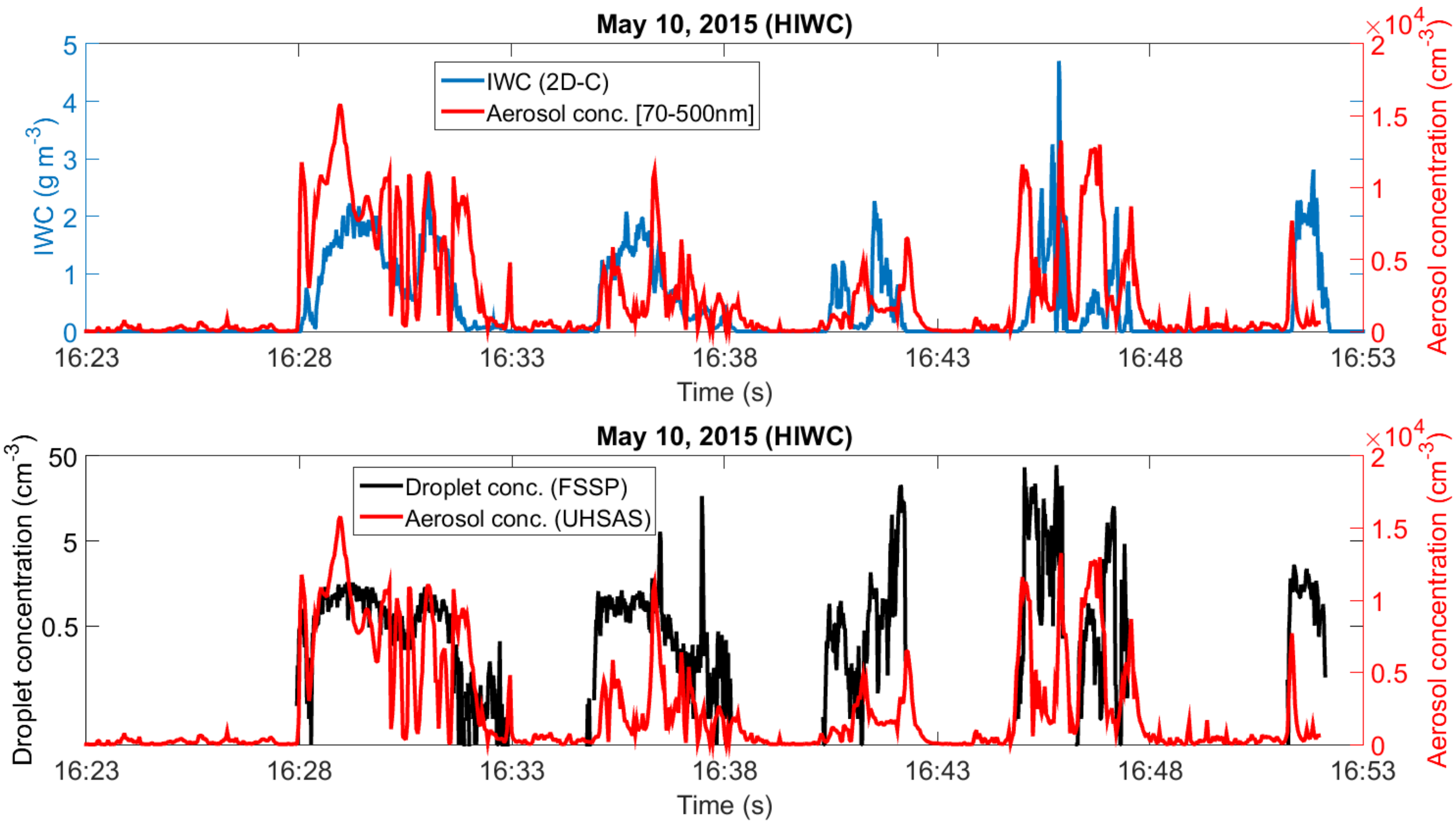
Flight#	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Date	10-May-15	12-May-15	14-May-15	15-May-15	16-May-15	16-May-15	20-May-15	23-May-15	23-May-15	25-May-15	26-May-15	26-May-15	27-May-15	27-May-15
UHSAS	Y	Y	M+	Y	M+	Y	N	Y	M+	Y	N	N	N	N
FSSP	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
CDP	Y	Y	Y	Y	Y	M	Y	Y	Y	Y	Y	Y	Y	Y
OAP-2DC	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	M
OAP-2DP	M	M	Y	M	M	M	M	M	M	M	M	M	M	M
PIP	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	M	Y	Y
CIP	M	M	N	M	N	M	Y	Y	Y	Y	Y	Y	Y	Y
2DS-H	N	M-	M	Y	Y	Y	M	Y	M	Y	Y	Y	Y	Y
2DS-V	N	M-	M	Y	Y	Y	M	Y	M	M	N	N	M	N
CPI	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Ultra-High Sensitivity Aerosol Spectrometer (UHSAS)

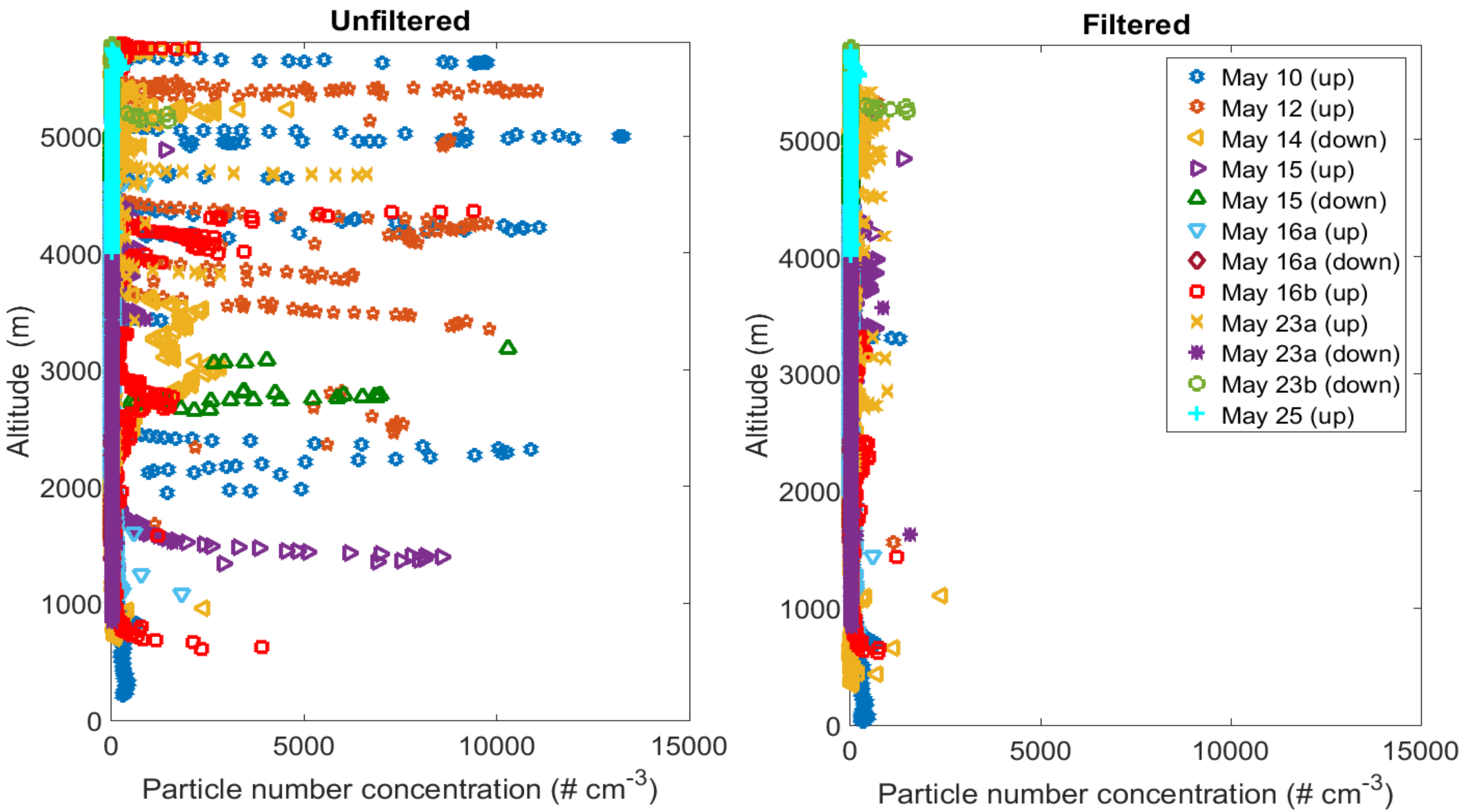
nomnal size range 60nm -1μm



UHSAS measurements are contaminated by artifacts when sampling cloud particles. In-cloud UHSAS data were excluded from analysis



Effect of UHSAS contamination by cloud particles



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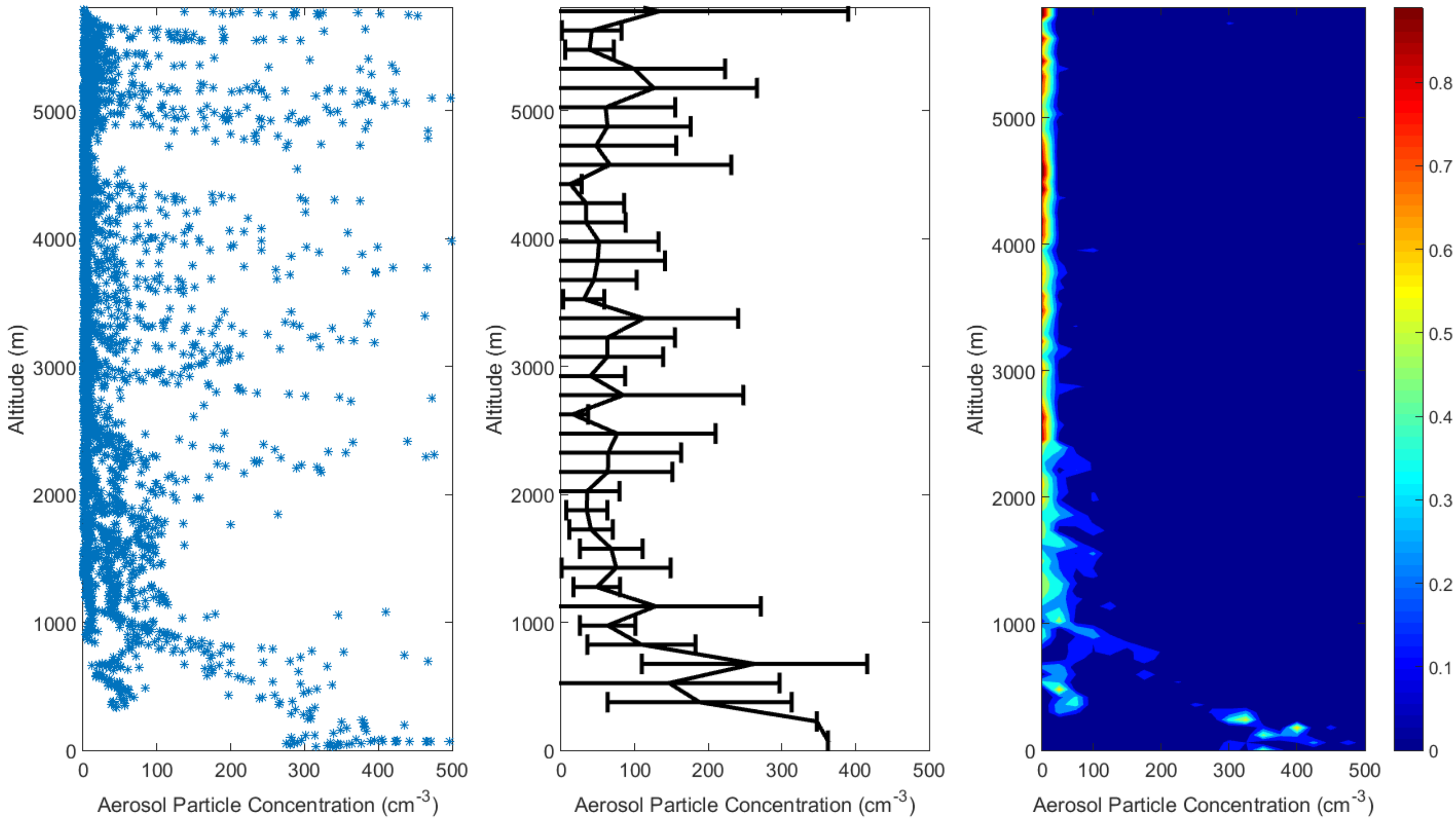
Vertical distribution of aerosol particles

UHSAS aerosol concentration 70-1000 nm



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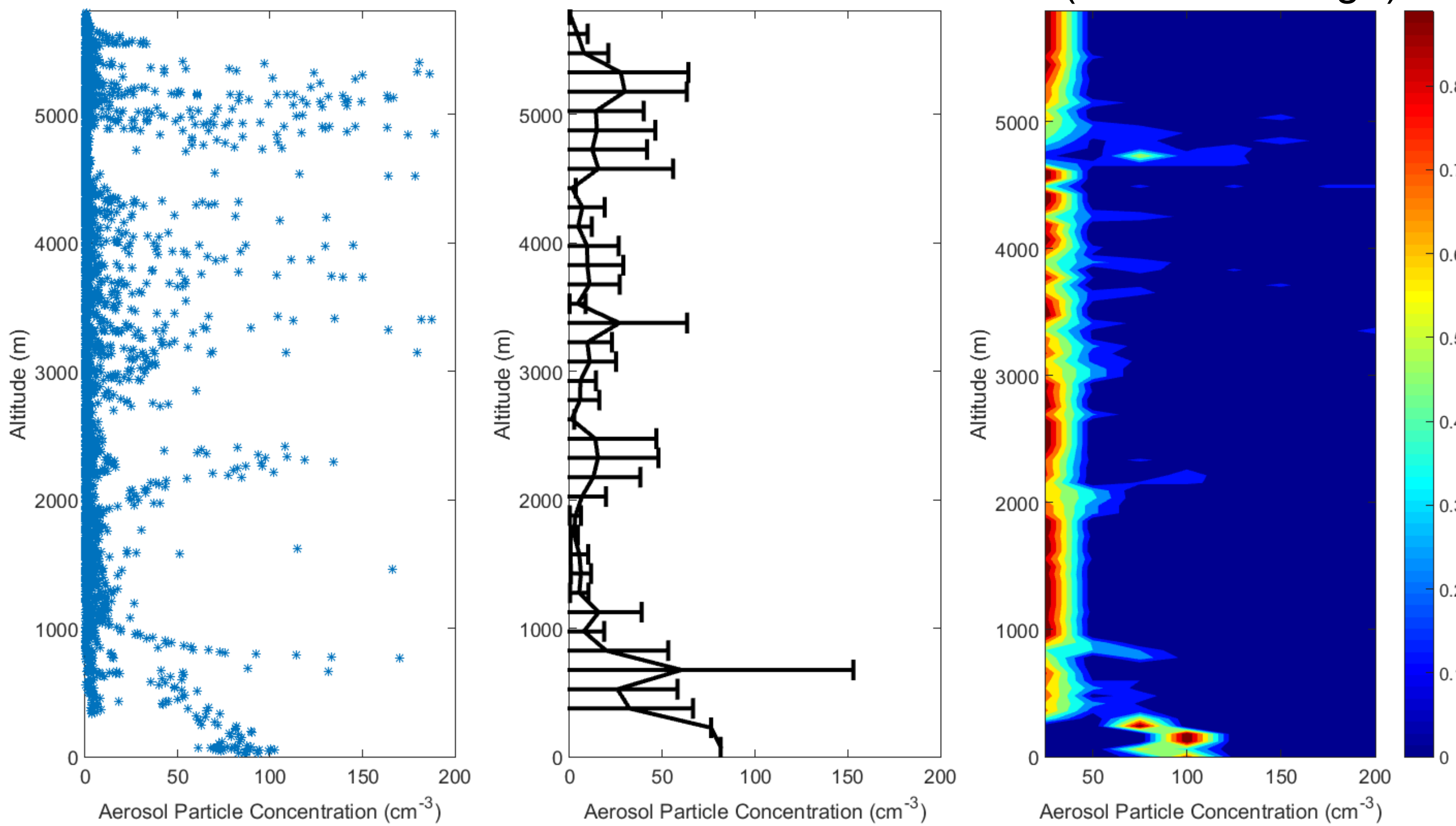
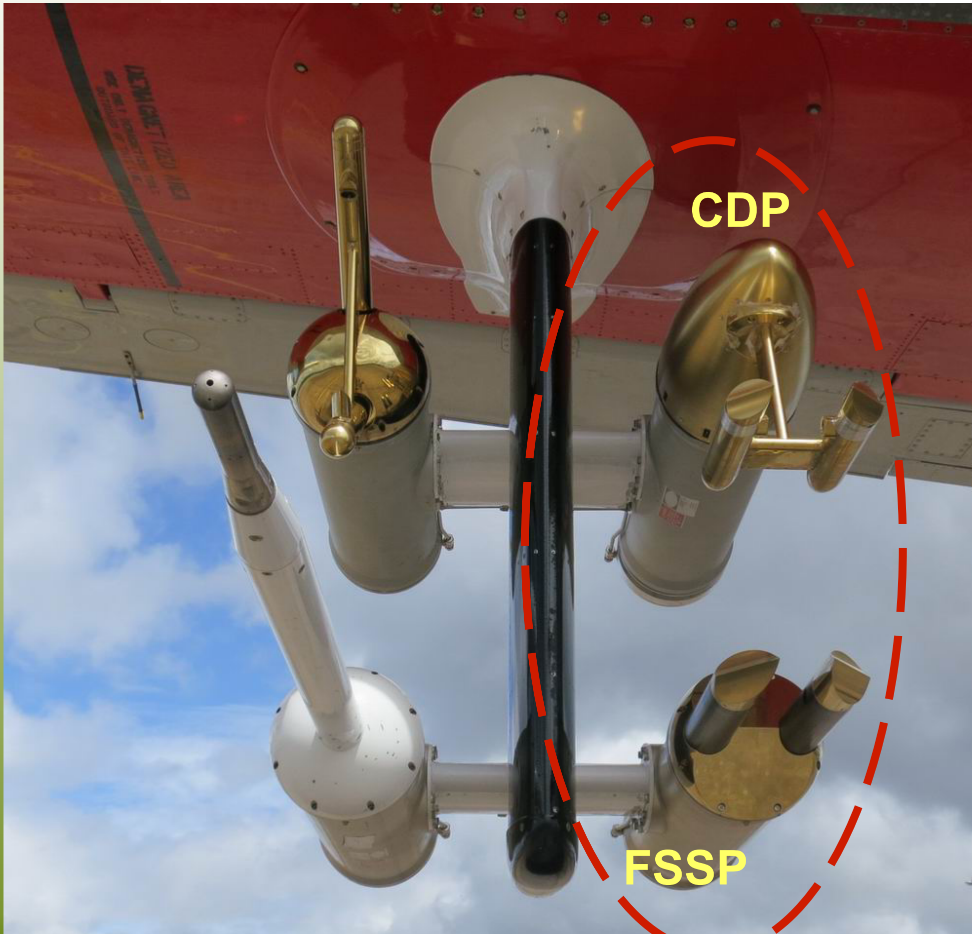
Vertical distribution of aerosol particles

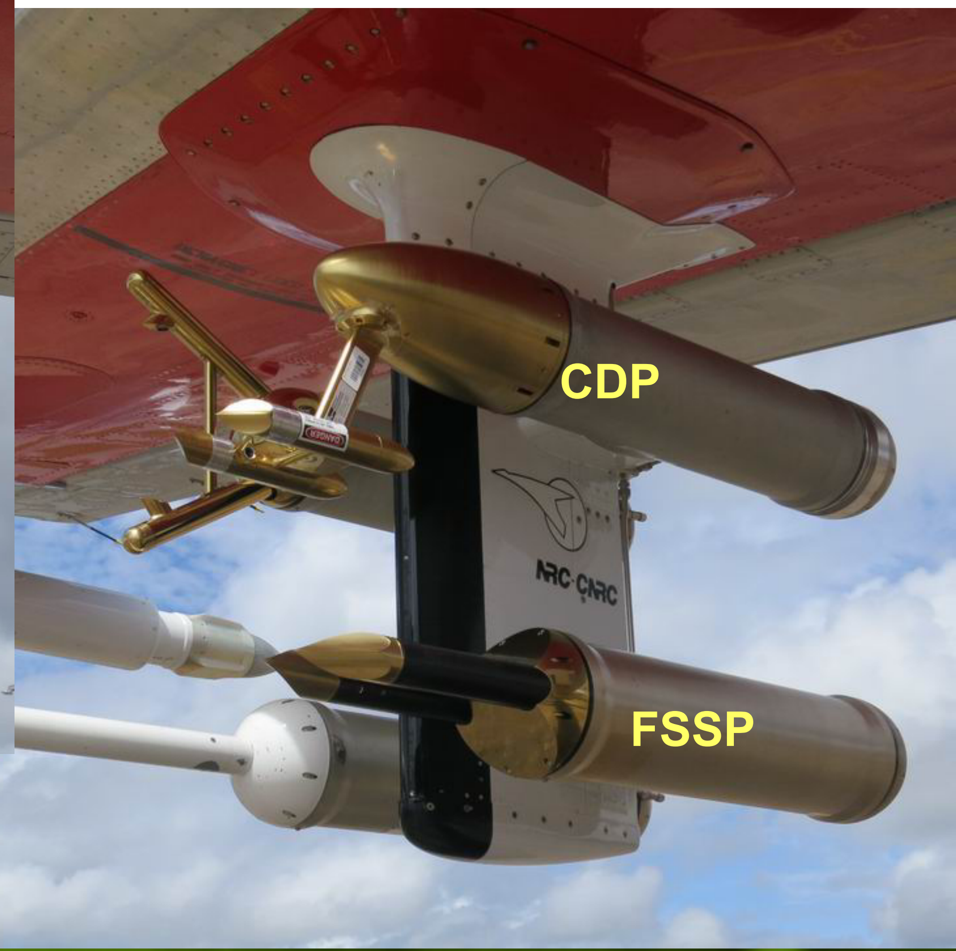
UHSAS aerosol concentration 200-1000 nm (CCN size range)



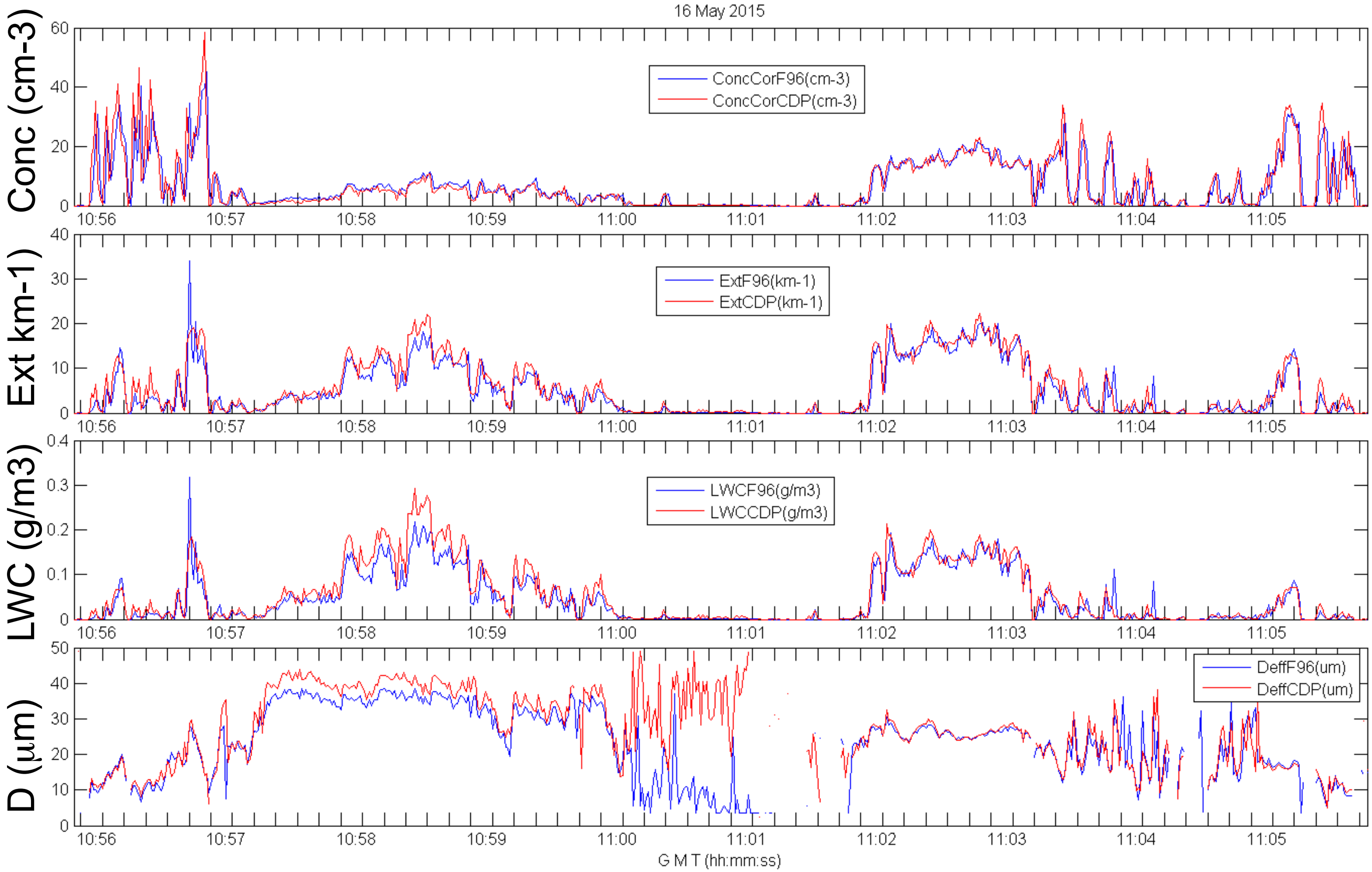
Scattering particle probes: FSSP, CDP



<u>nominal size ranges</u>
FSSP 2-32μm
CDP   2-50μm



FSSP and CDP response in liquid clouds



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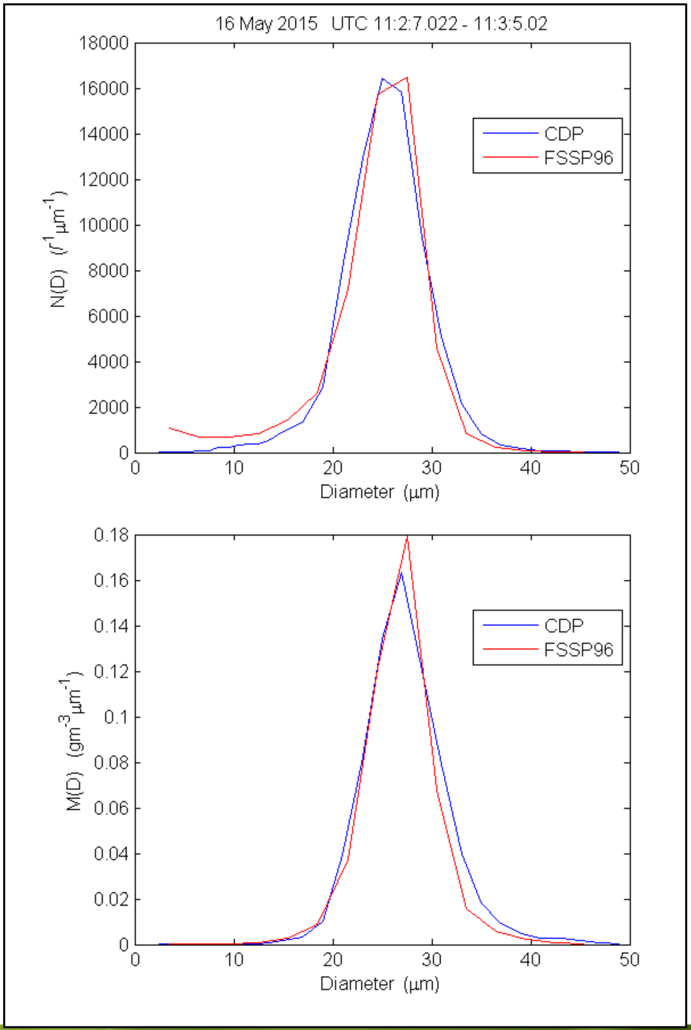
FSSP and CDP response in liquid clouds



Agreement between FSSP and CDP size and mass distributions in liquid clouds

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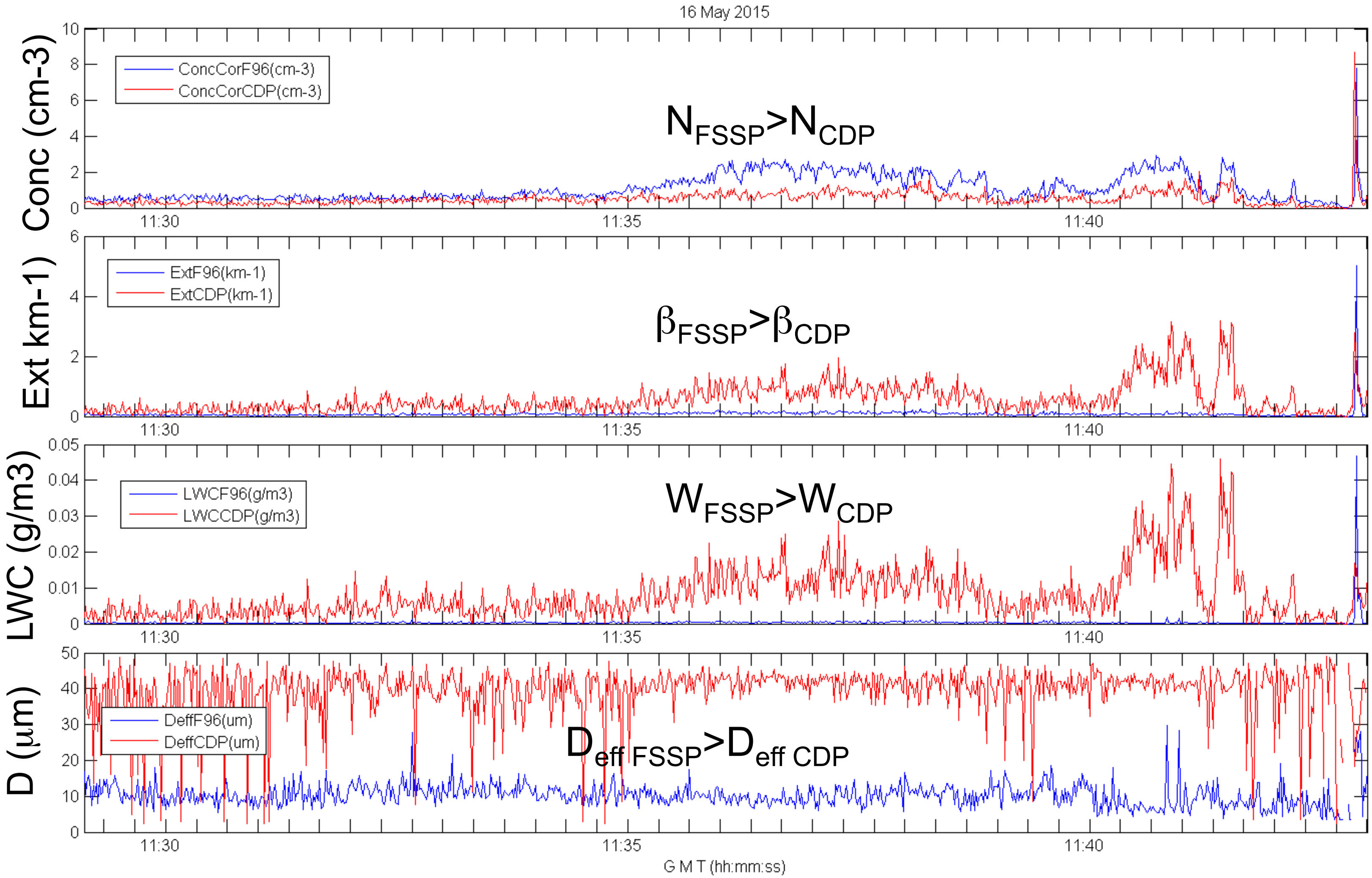
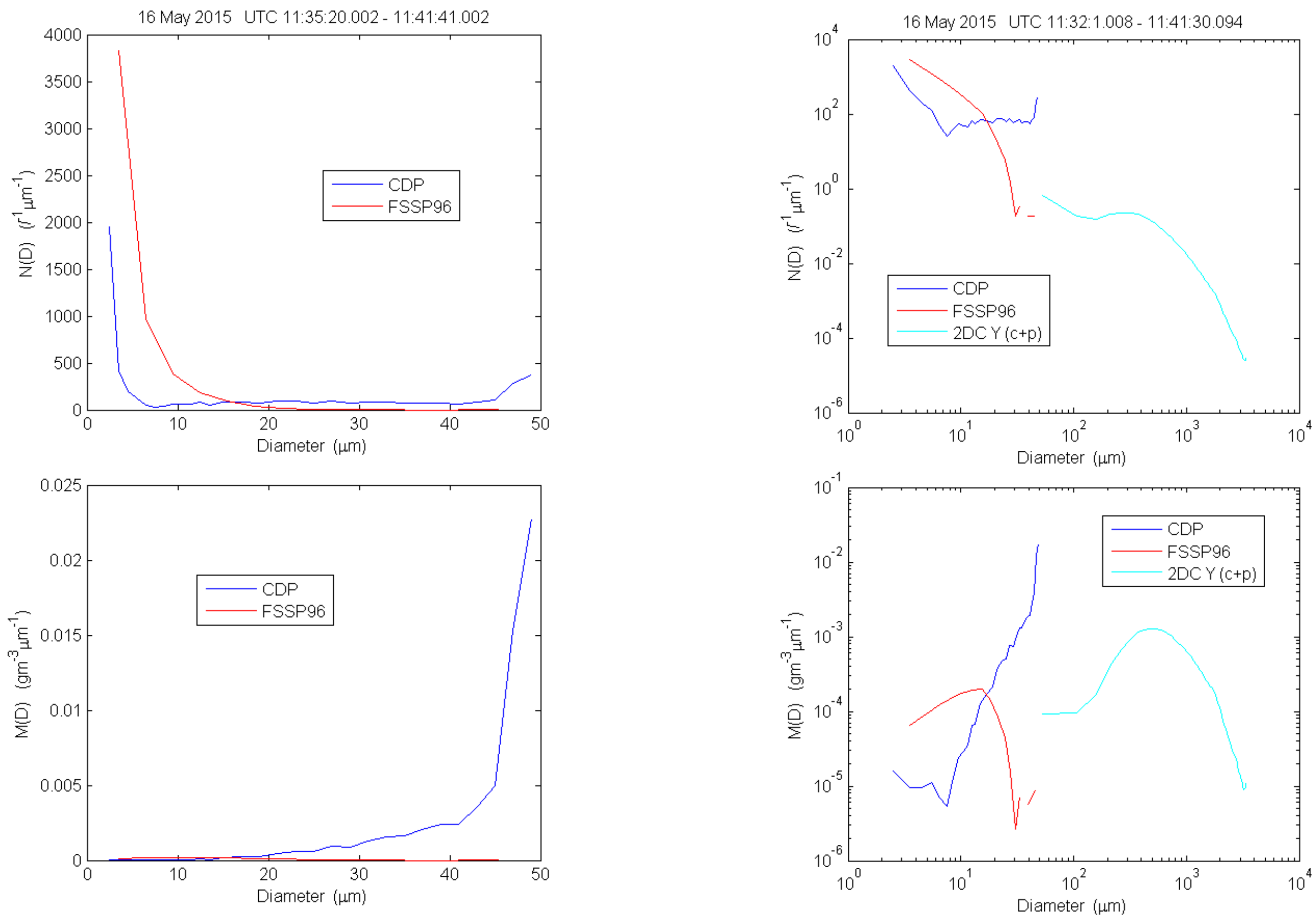
FSSP and CDP response in ice clouds

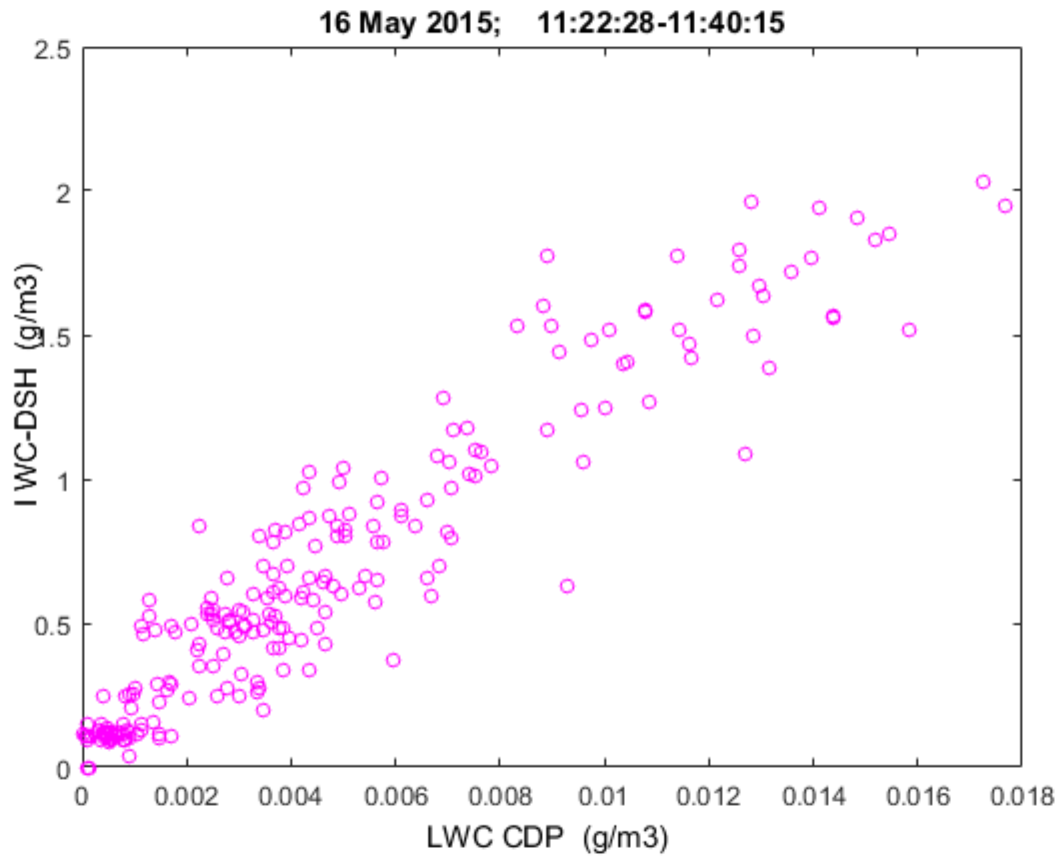


FSSP and CDP response in ice clouds

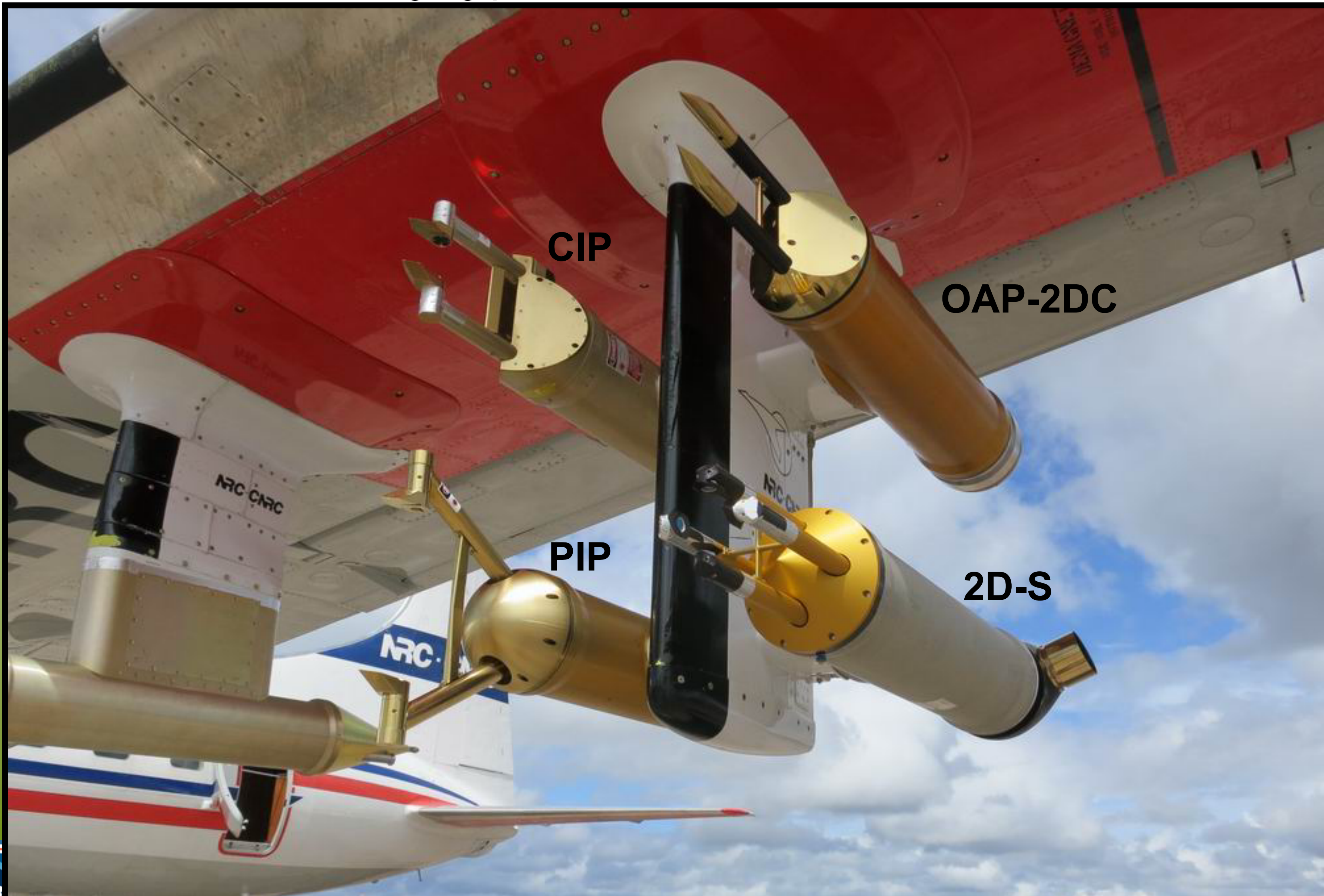


In ice clouds
FSSP has enhanced response to in ‘junior’ bins,
whereas
CDP has enhanced response in both ‘junior’ and ‘senior’ size bins

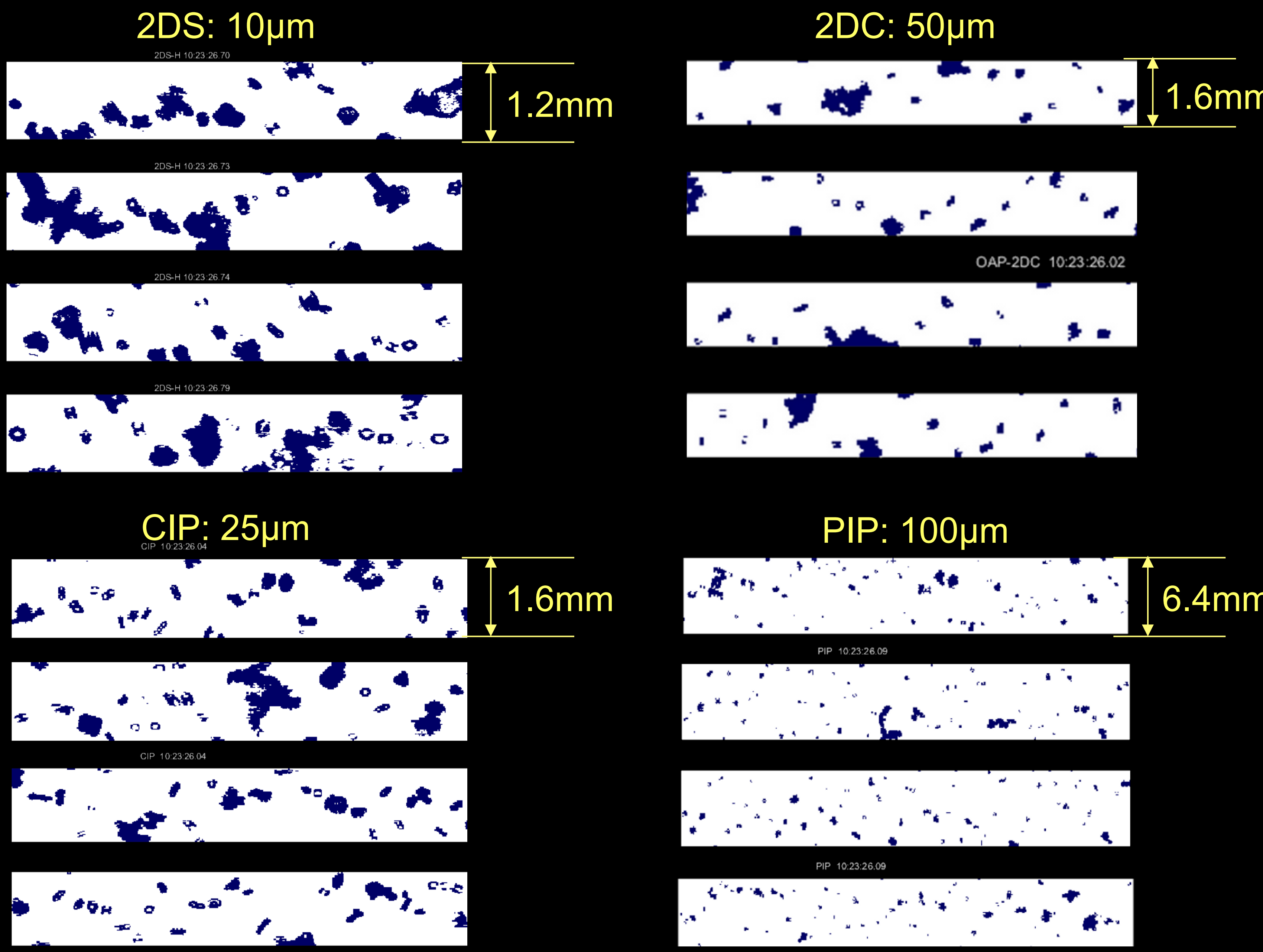
Relationship between LWC CDP and IWC



2D imaging probes: 2D-S, CIP, OAP-2DC, PIP

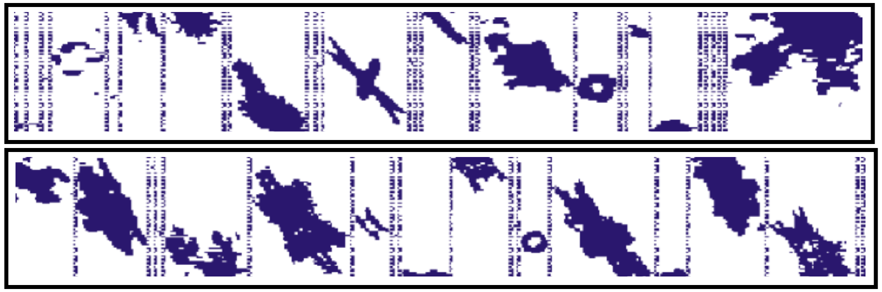


Examples of particle shadowgraphs registered by 2D probes



Effect of local flow on particle orientation

Depending on mounting location and configuration of the probe's housing the local flow may change orientation of particles.

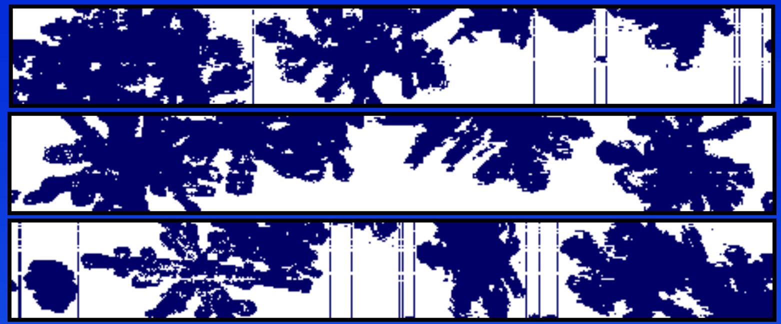


This effect may result in biasing results of image recognition and calculations of basic microphysical parameters (extinction coeff., IWC)

The degree of changing particle orientation depends on particle size and ice particle habit. Isometric large particles are less susceptible to the effect of the local flow

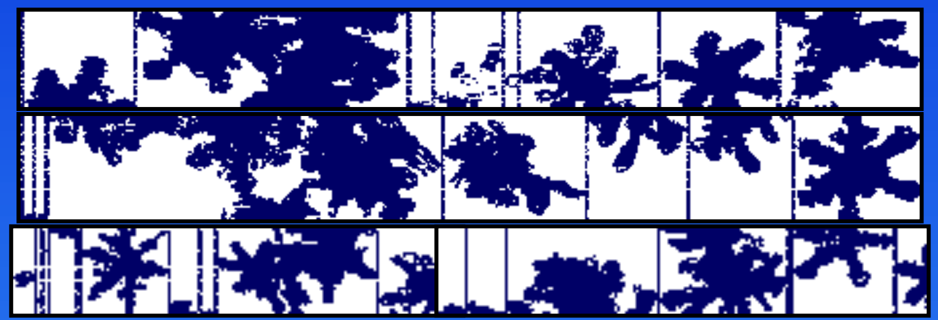
Effect of local flow on the planar particle orientation

No effect of the local flow on the orientation of planar particles (dendrites)



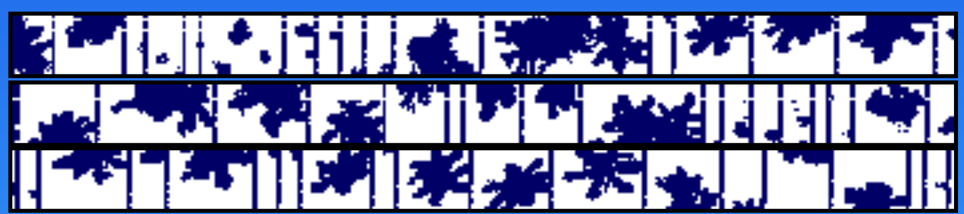
2DS (V)

Pixel resolution 10μm



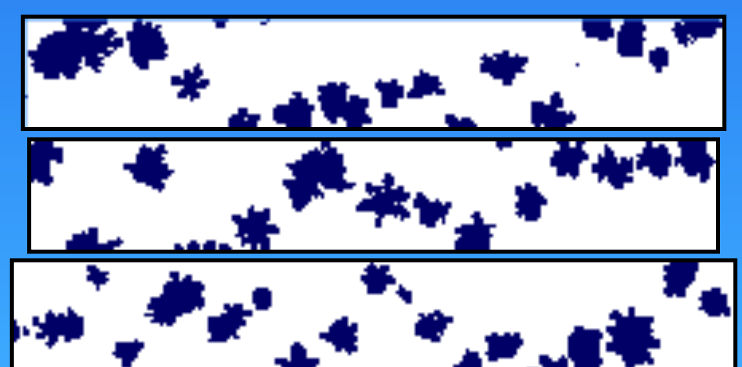
CIP

Pixel resolution 25μm



OAP-2DC

Pixel resolution 50μm

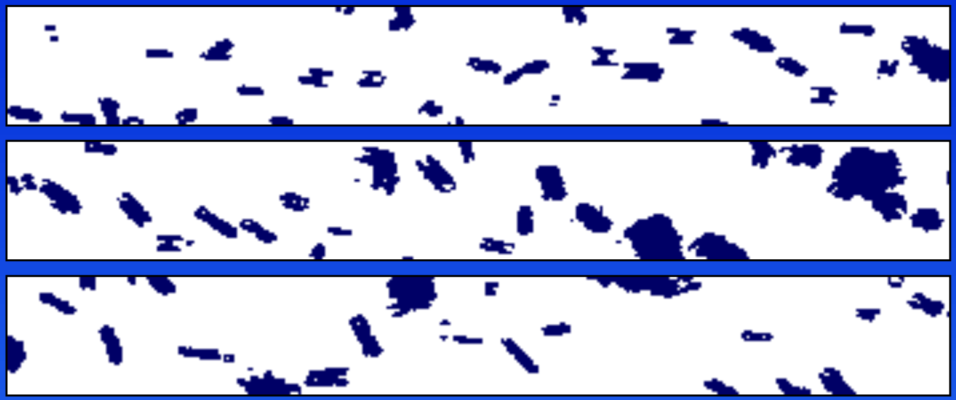


PIP

Pixel resolution 100μm

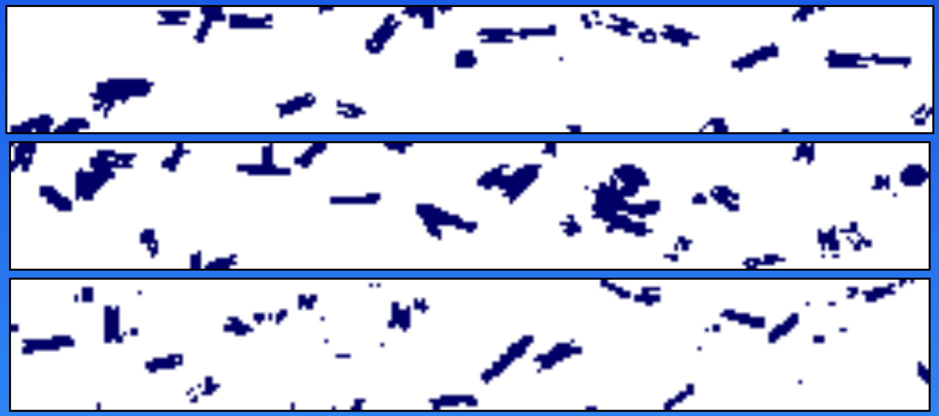
Effect of local flow on the columnar particle orientation

CASE: columnar particles are aligned along the flight direction



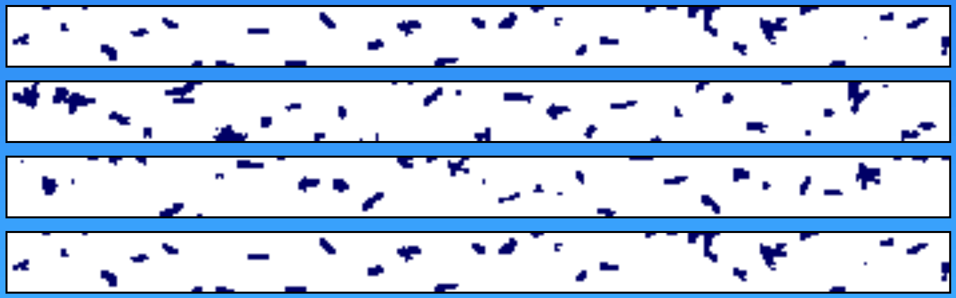
2DS (V)

Pixel resolution 10μm



CIP

Pixel resolution 25μm

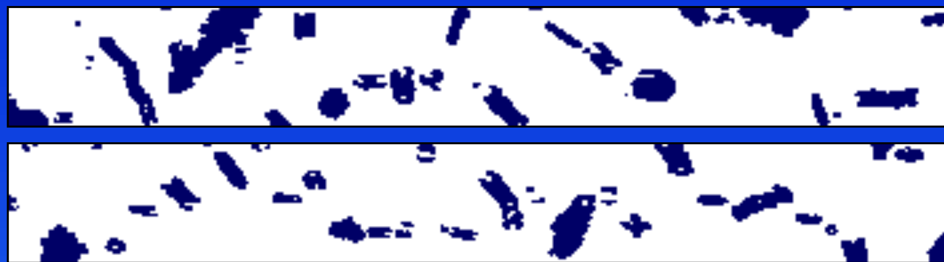


OAP-2DC

Pixel resolution 50μm

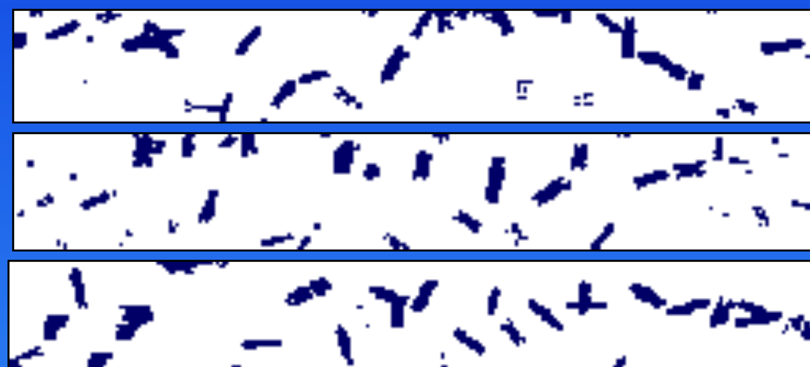
Effect of local flow on the columnar particle orientation

CASE: no effect of the local flow on the columnar particles orientation



2DS (V)

Pixel resolution 10μm



CIP

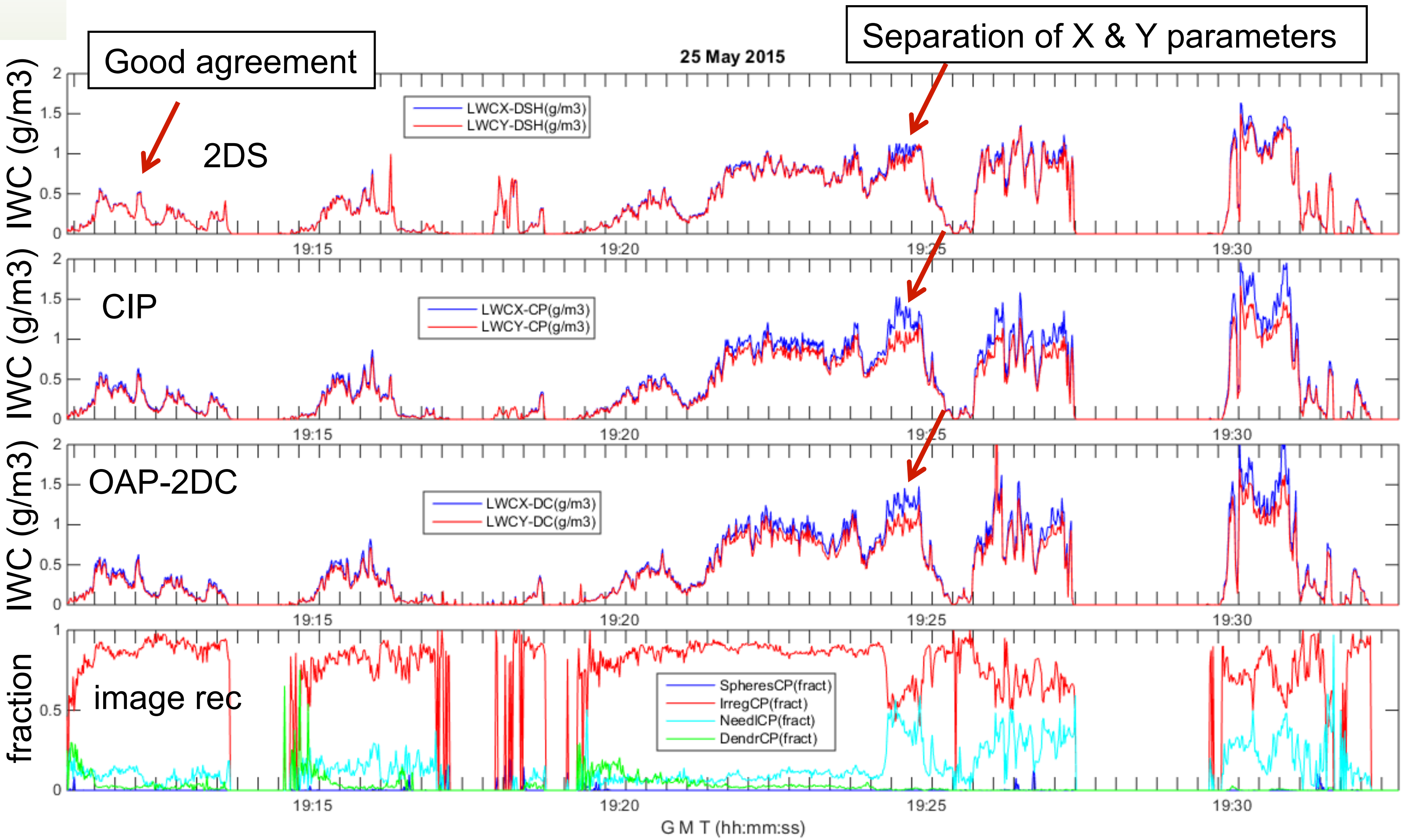
Pixel resolution 25μm

OAP-2DC

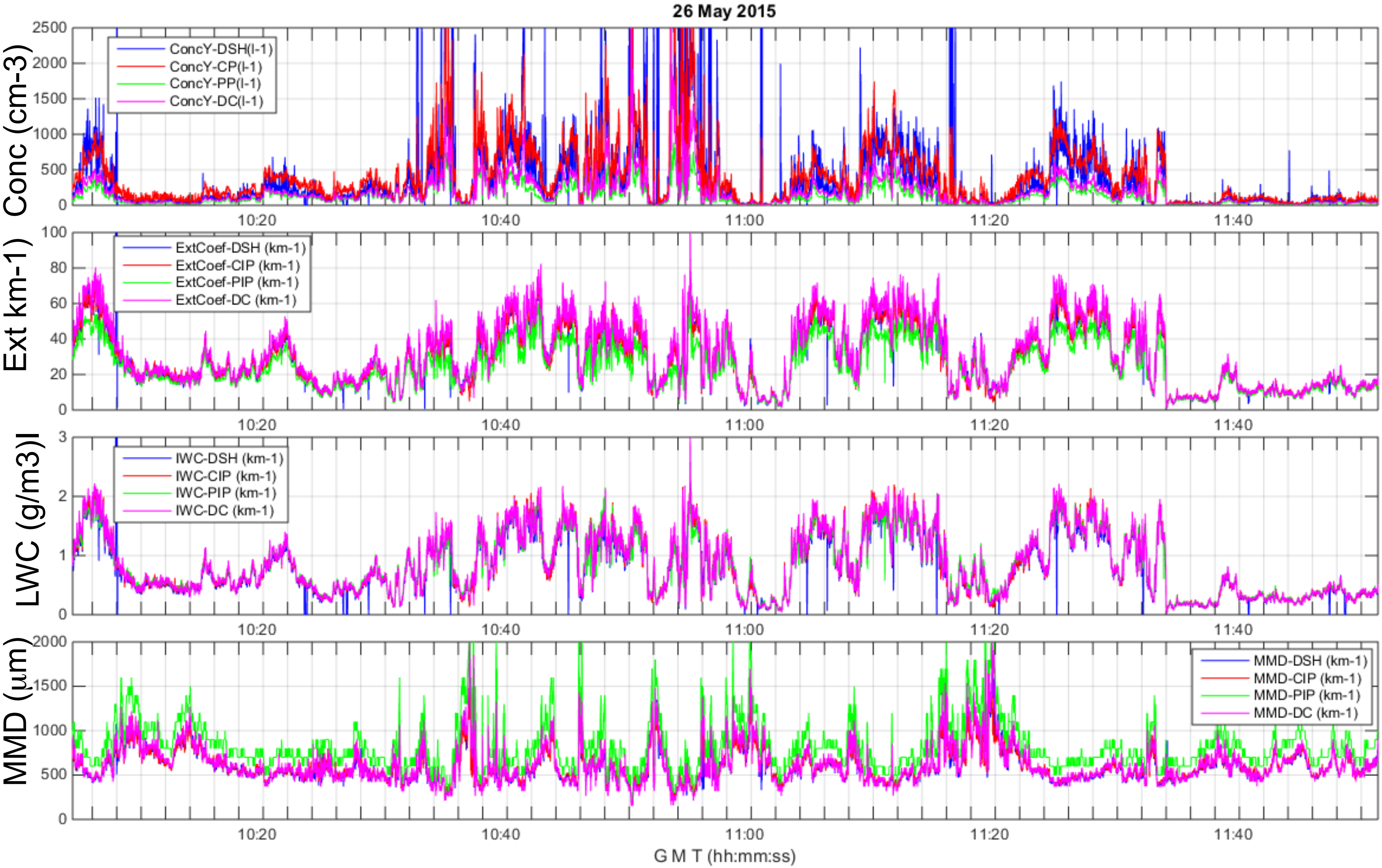
Pixel resolution 50μm

Particle orientation appears to depend of the aircraft maneuvering

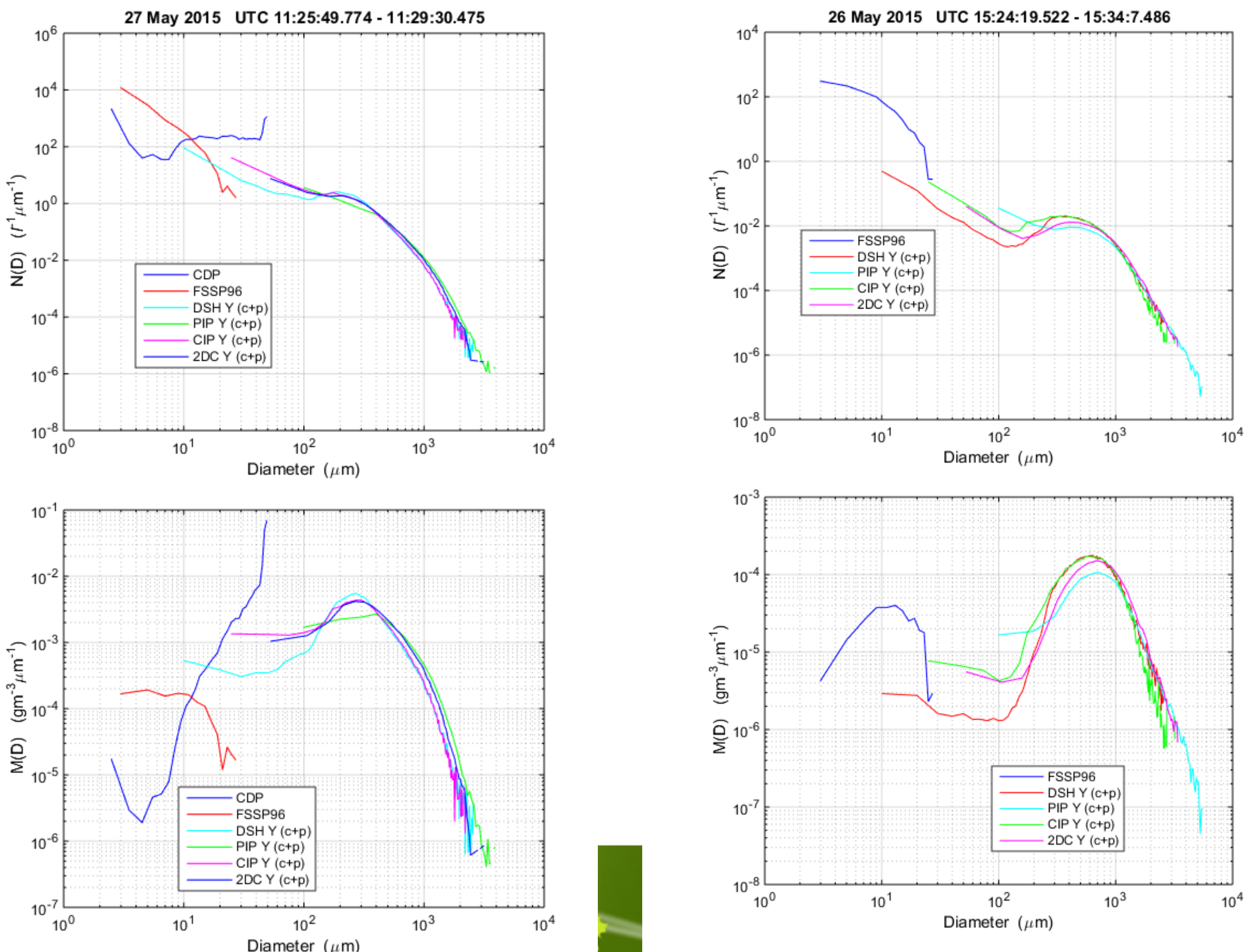
Effect of particle orientation of the microphysical parameters calculations



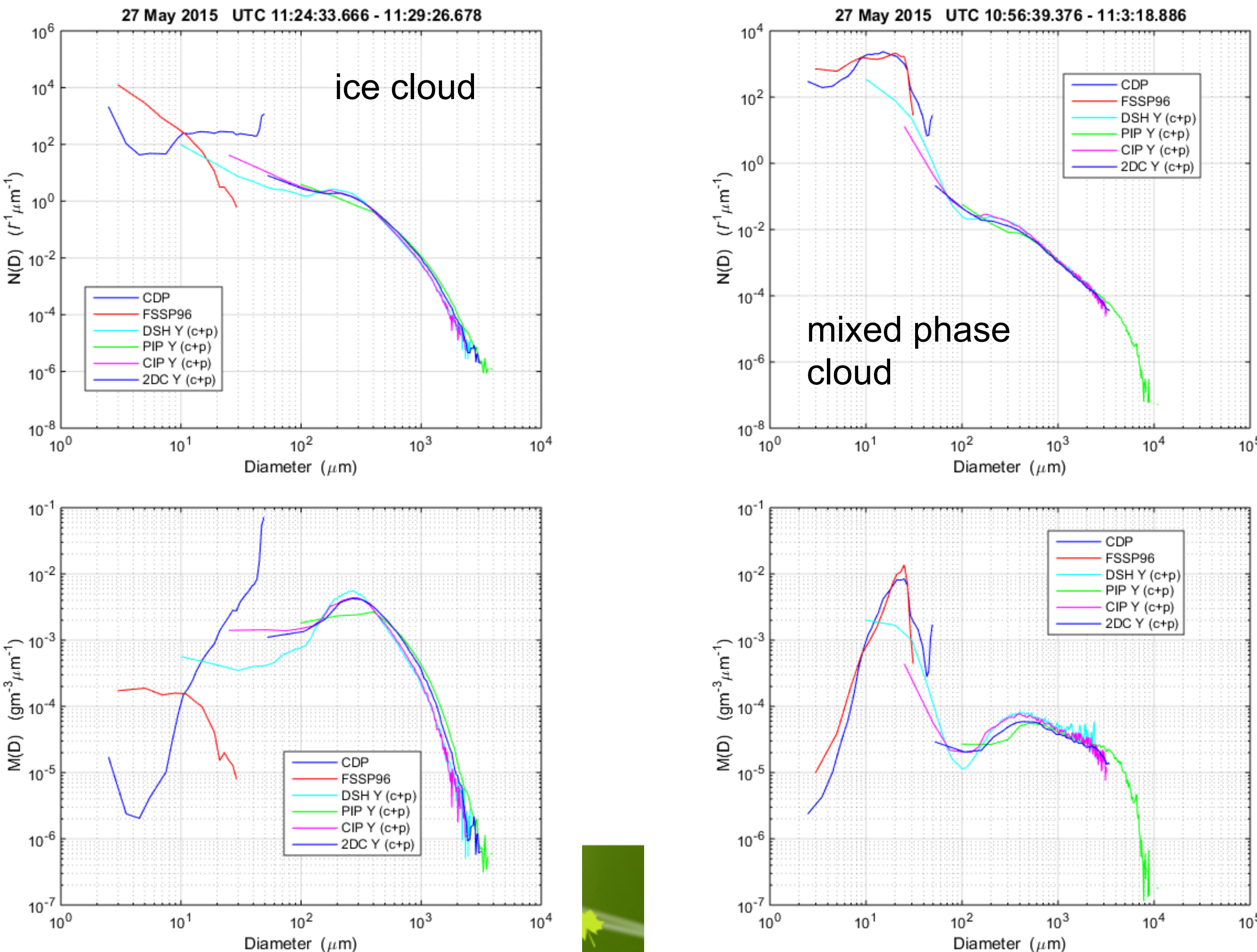
Example of measurements of particle concentration, extinction coeff., IWC, and MMD by 2D imaging probes



Comparisons of PSDs measured by particle probes



Comparisons of PSDs measured by particle probes



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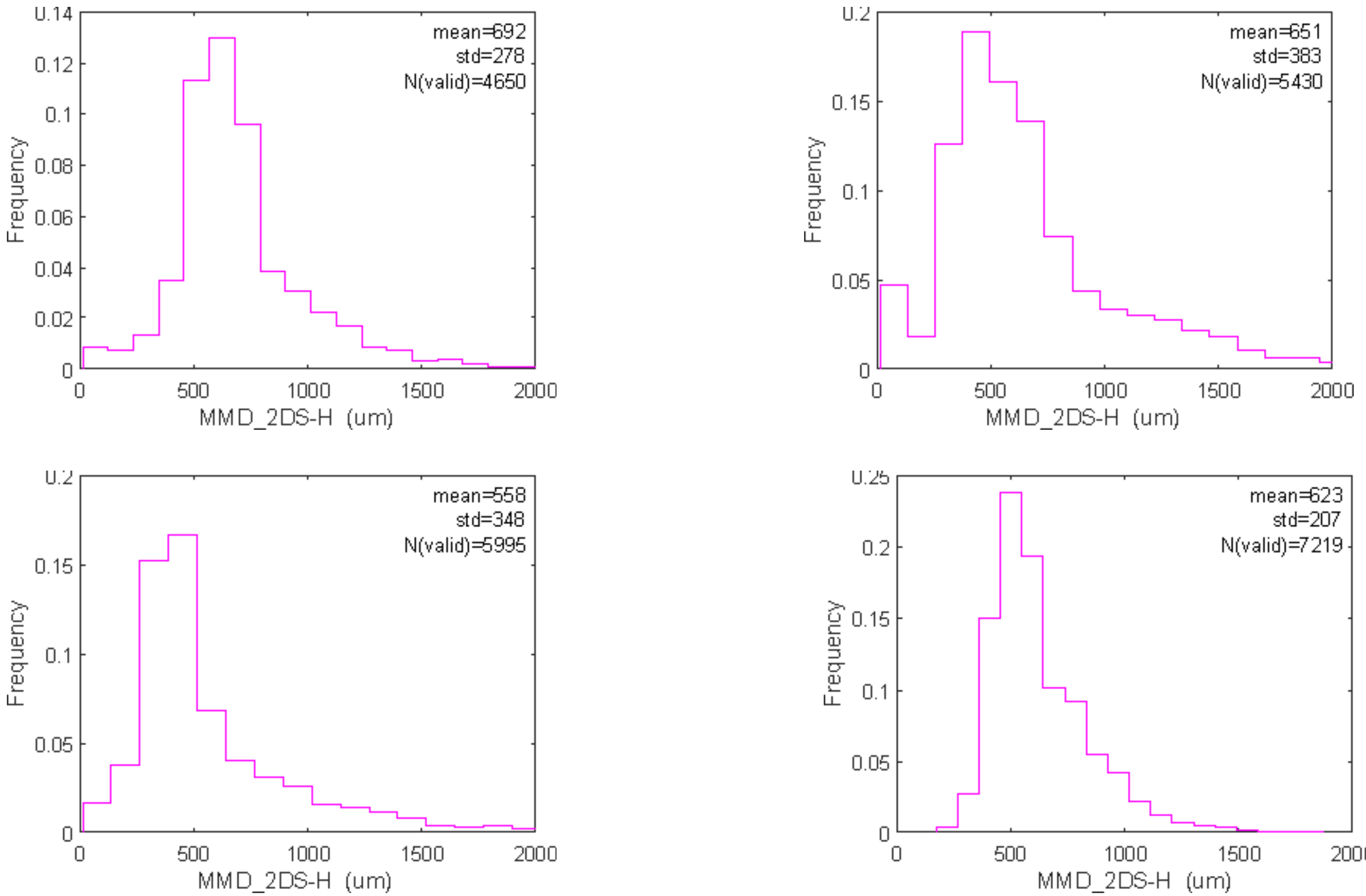
Examples of preliminary MMD statistics averaged over different flights



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SPEC Cloud Particle Imager (CPI)

Pixel resolution 2.3μm; 256 grey levels, photographic quality images

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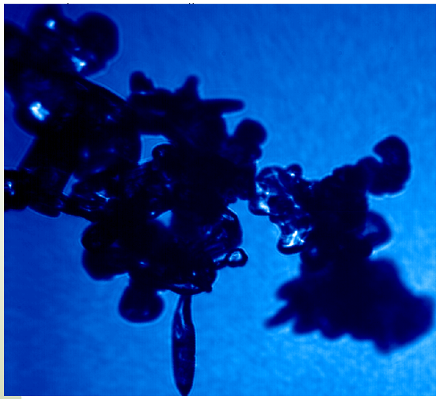

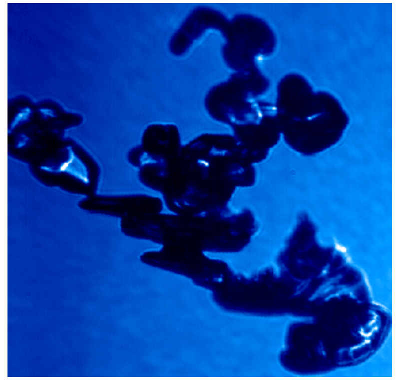

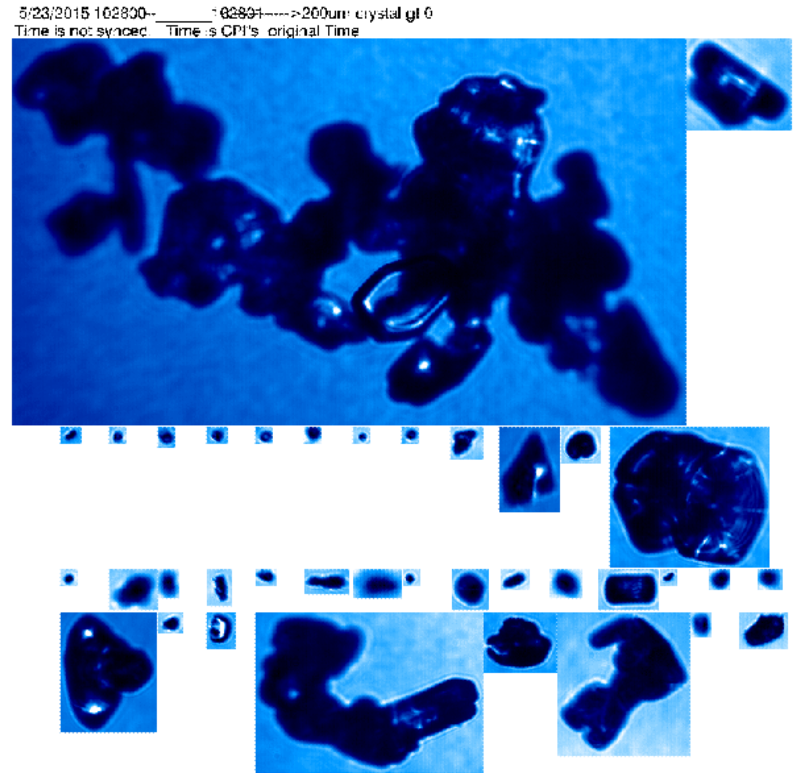

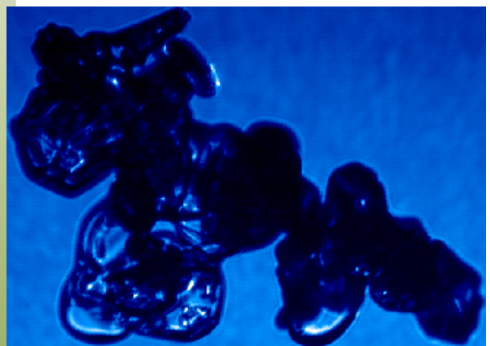

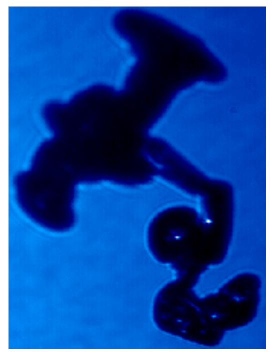

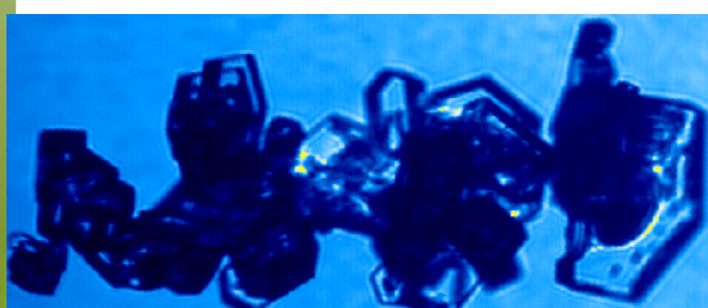

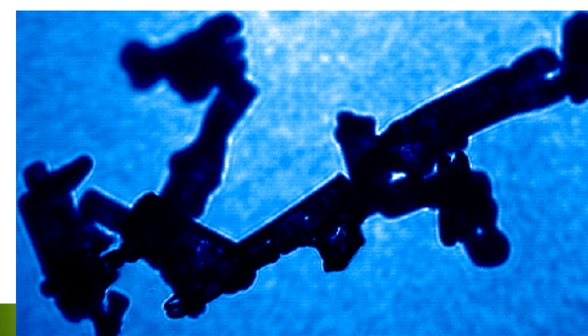

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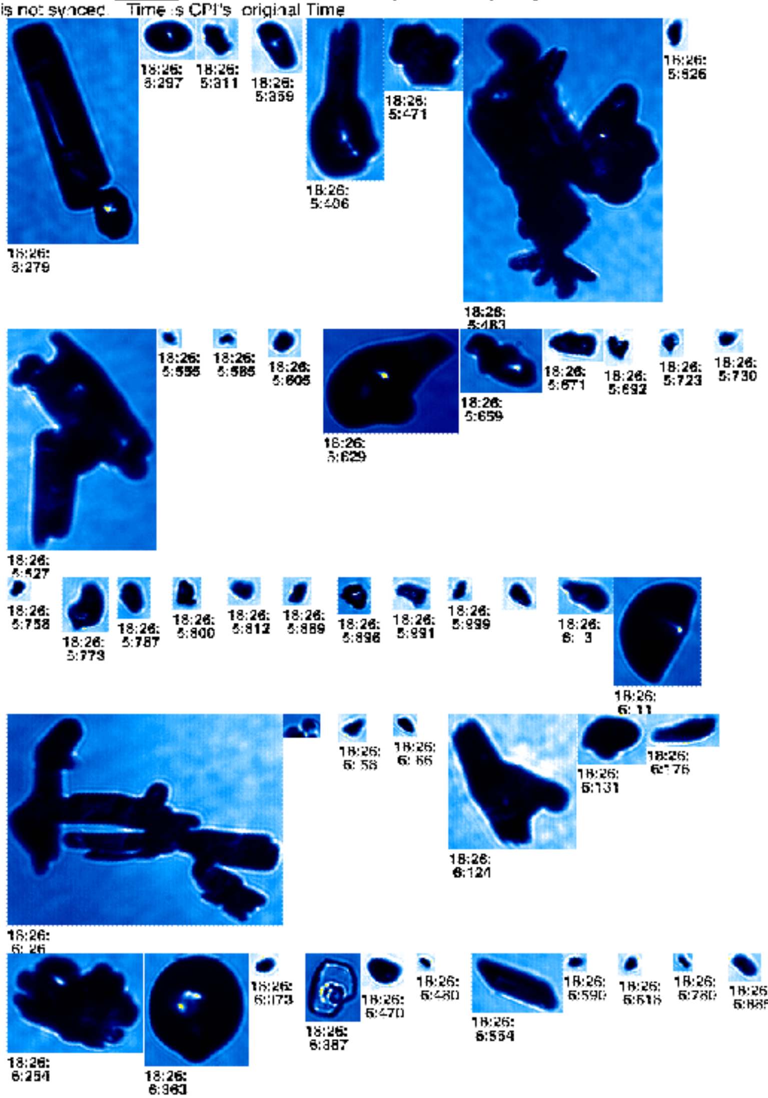
5/23/2015 182605--______182696---->200um focus gt 75 and Crystal gt 0
Time is not synced. Time is CPI's original Time



5/23/2015 182543--______182544----->200um Crystal gt 0 and focus gt 75
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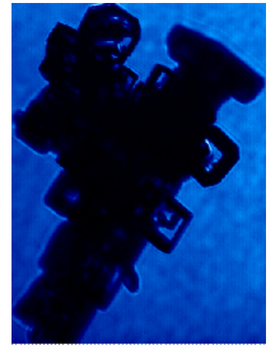
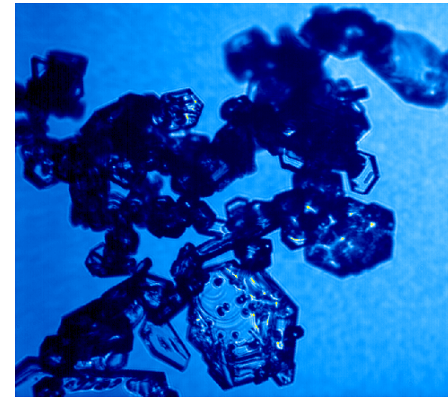
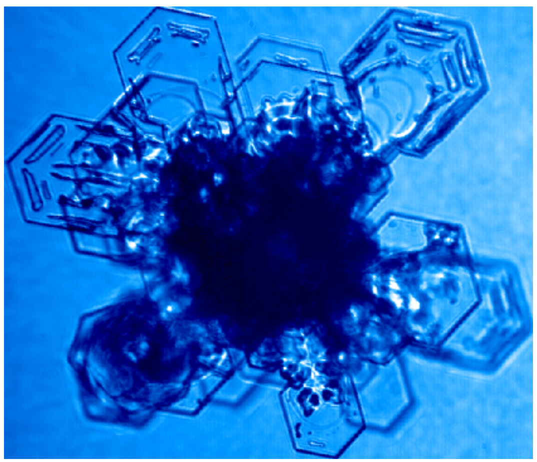

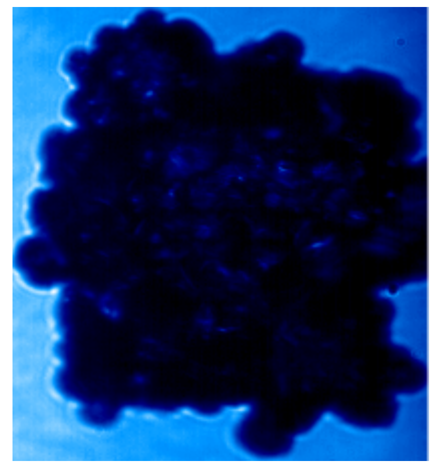


Biagio Esposito: Analysis of HSI data is work in progress.

Hot-Wire

Robust and Nevzorov probes

Bulk microphysics probes performance matrix

Flight#	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Date	10-May-15	12-May-15	14-May-15	15-May-15	16-May-15	16-May-15	20-May-15	23-May-15	23-May-15	25-May-15	26-May-15	26-May-15	27-May-15	27-May-15
Nevz. LWC1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Nevz. LWC2	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Nevz. TWC	Y	Y	Y	Y	Y	Y	M+	Y	Y	Y	Y	Y	Y	Y
Robust TWC	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Extinction	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
RICE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

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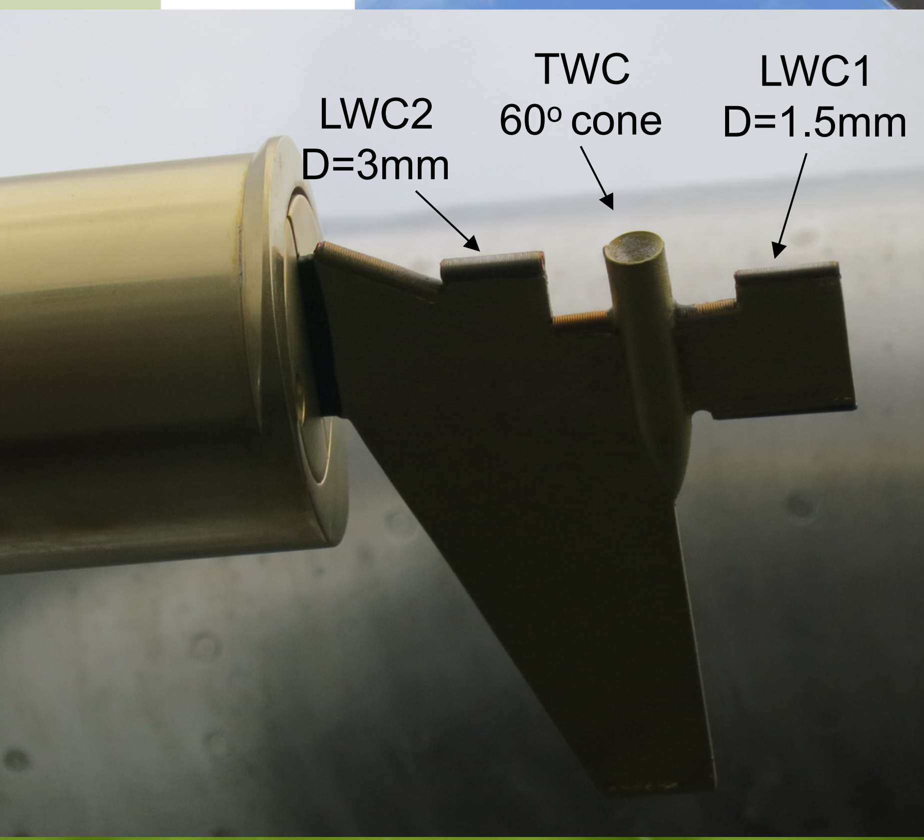
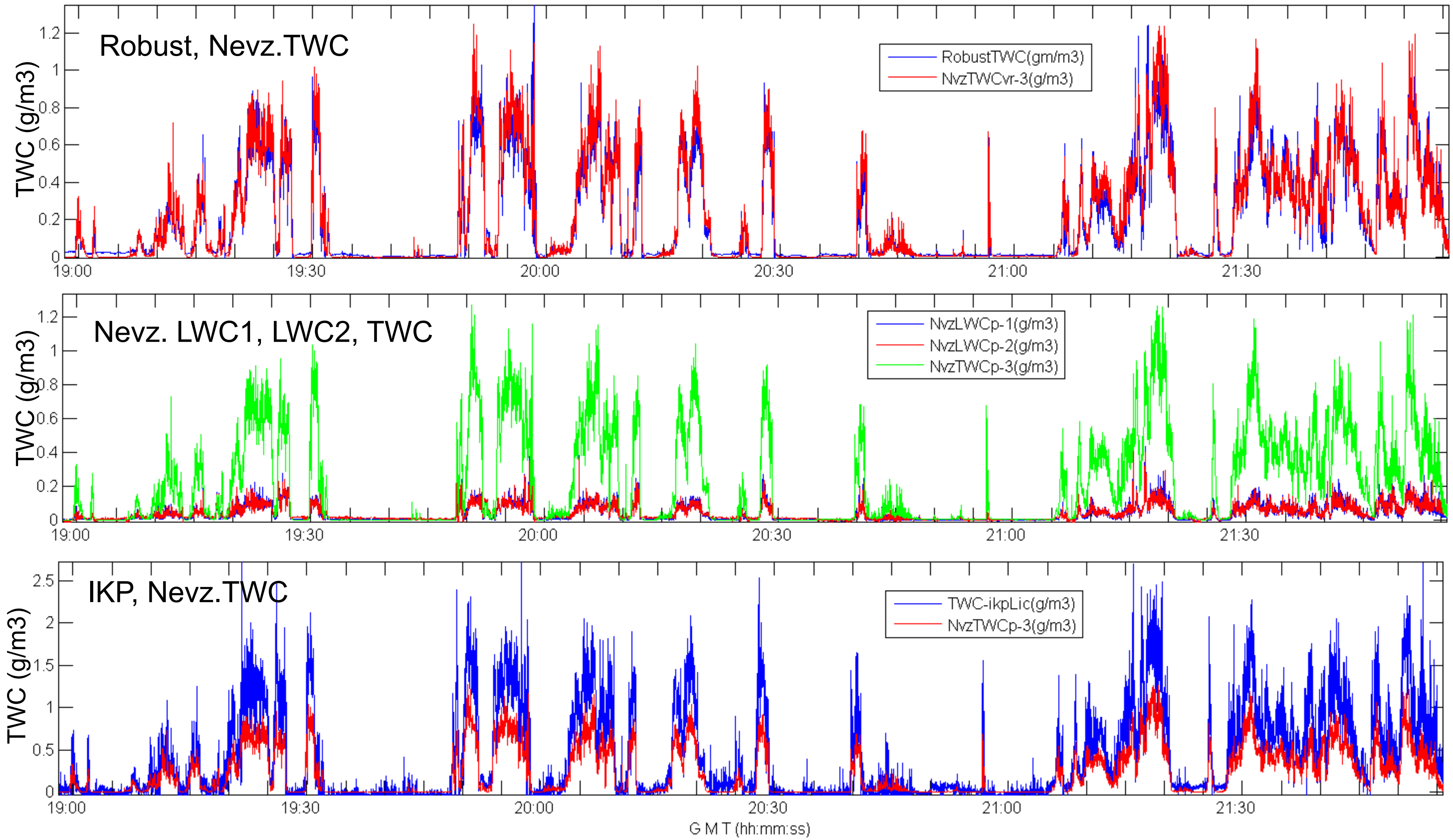
Robust Probe

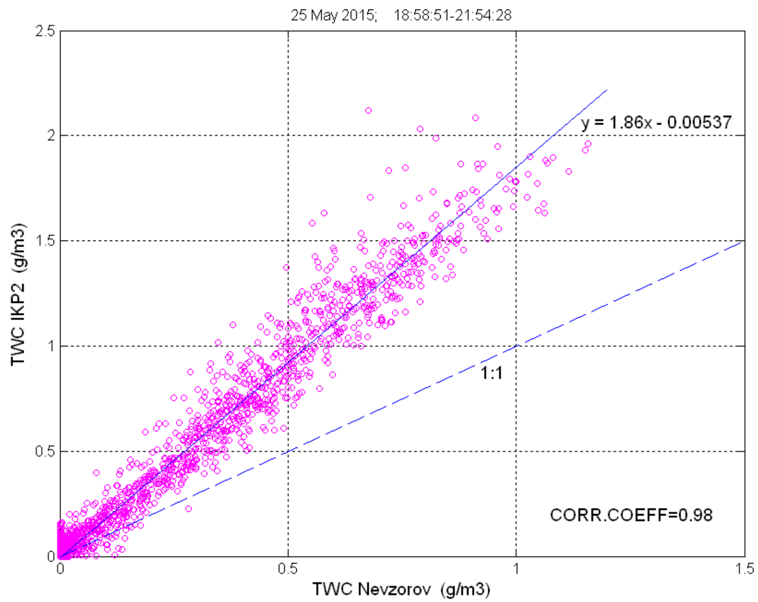
Nevzorov Hot-Wire LWC/TWC probe

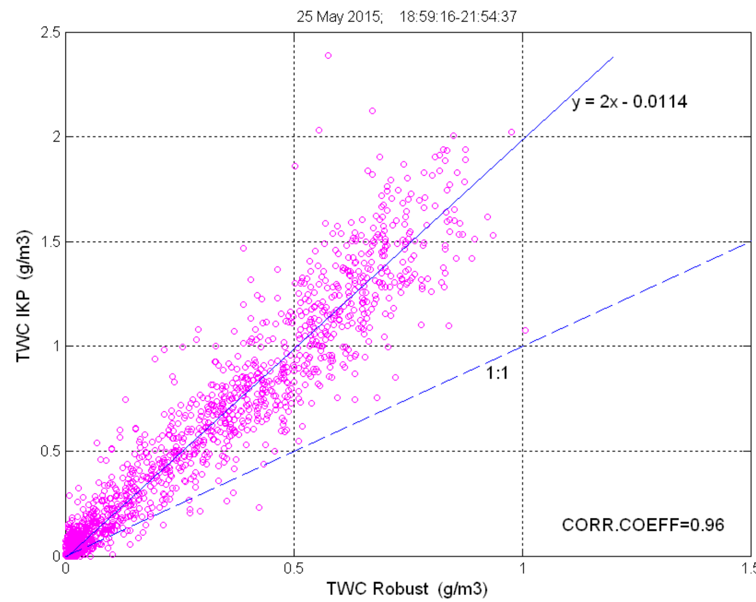


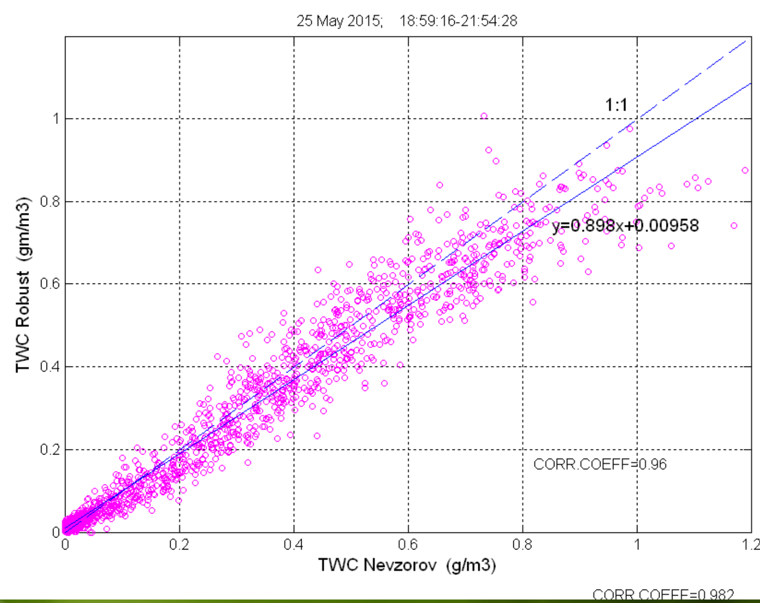
Example of IKP, Robust and Nevzorov TWC measurements



Comparisons of IKP, Robust and Nevzorov TWC measurements







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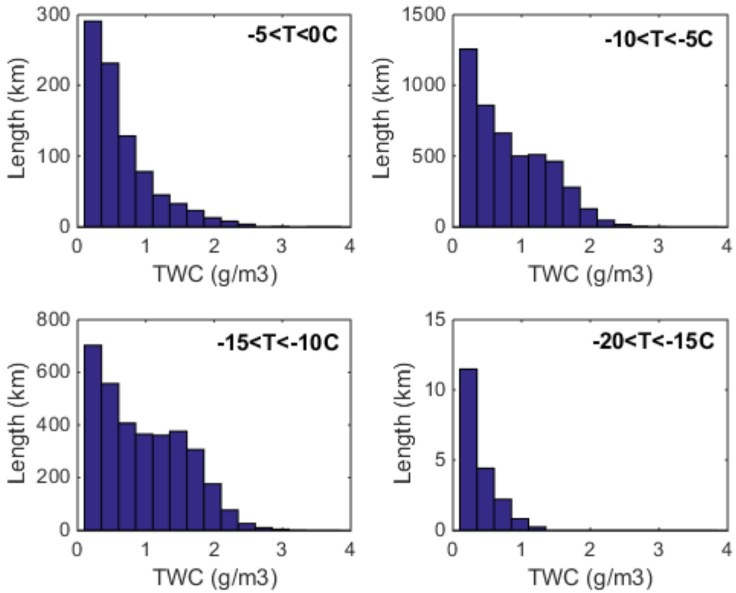
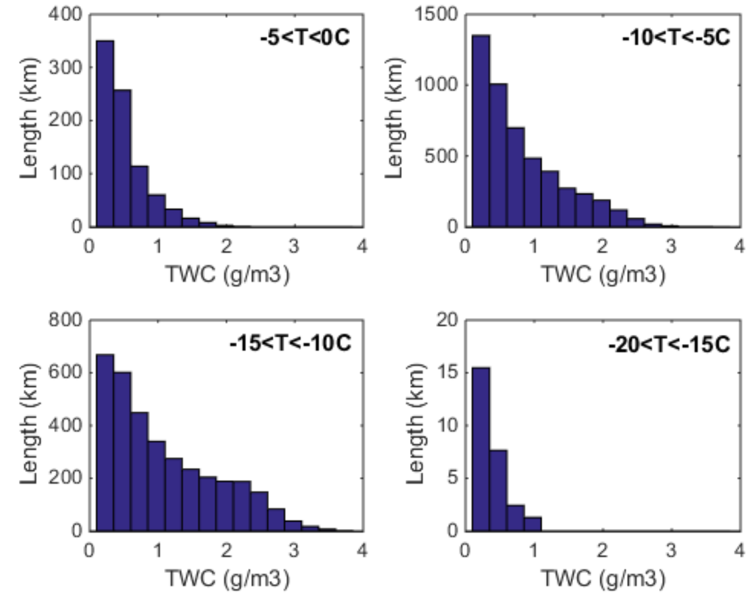
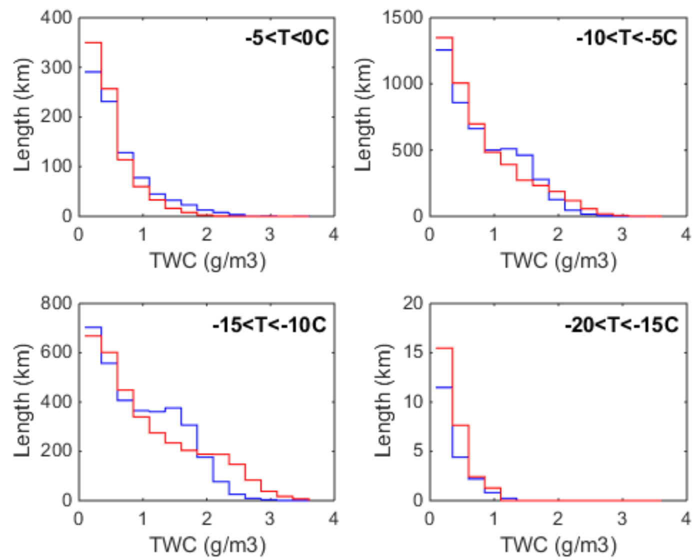
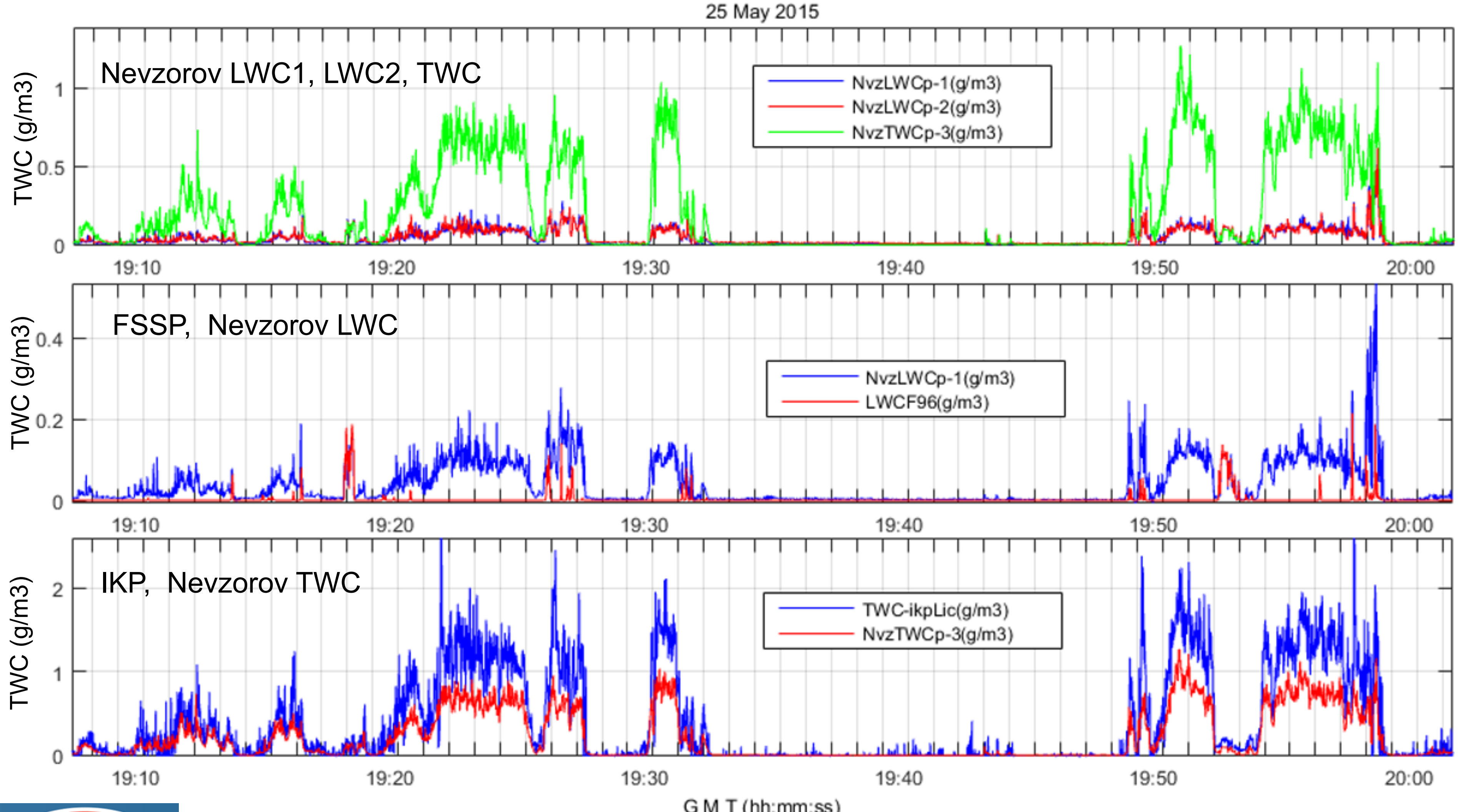
Preliminary statistics of IWC calculated from Robust*2 and NevzorovTWC*2 measurements



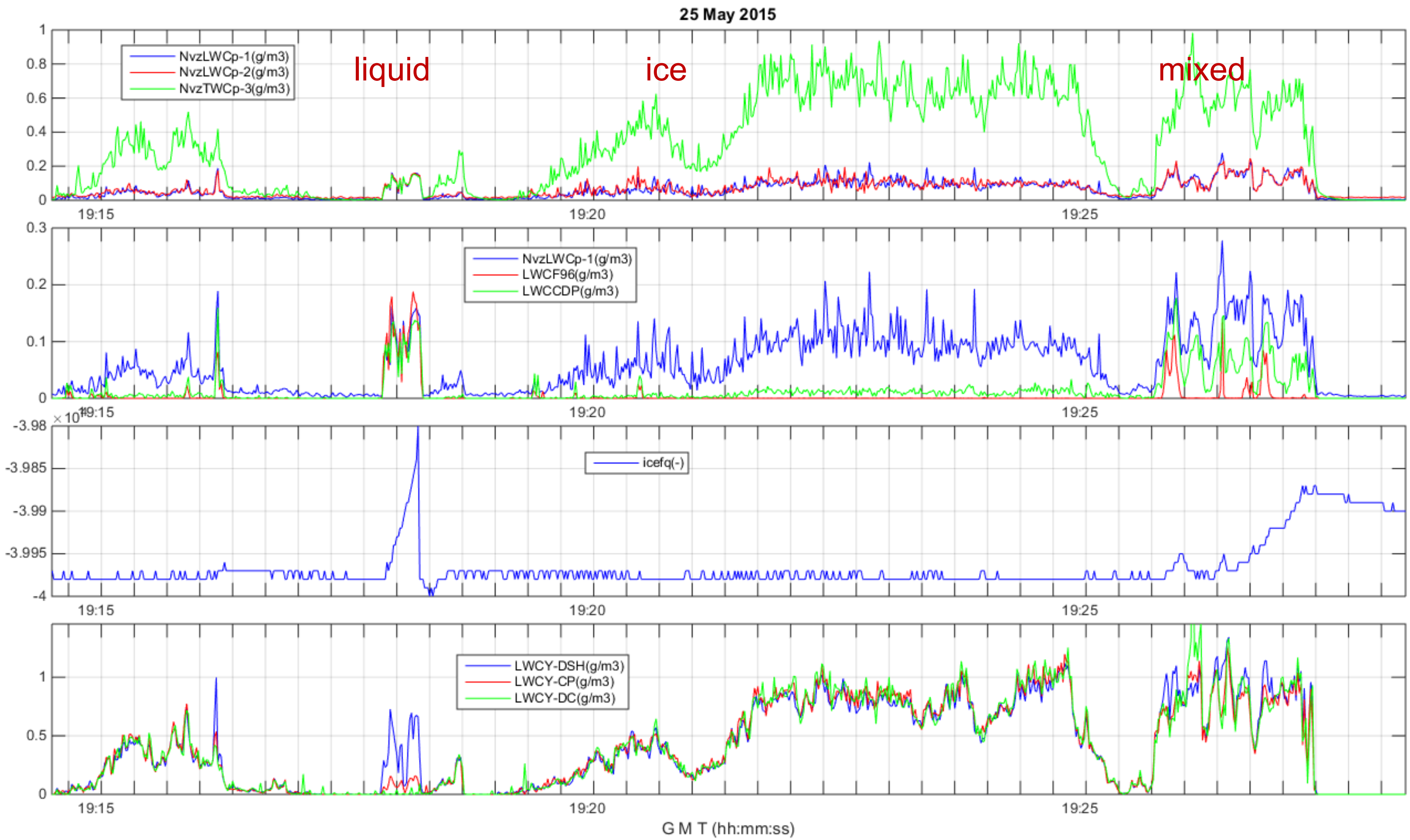




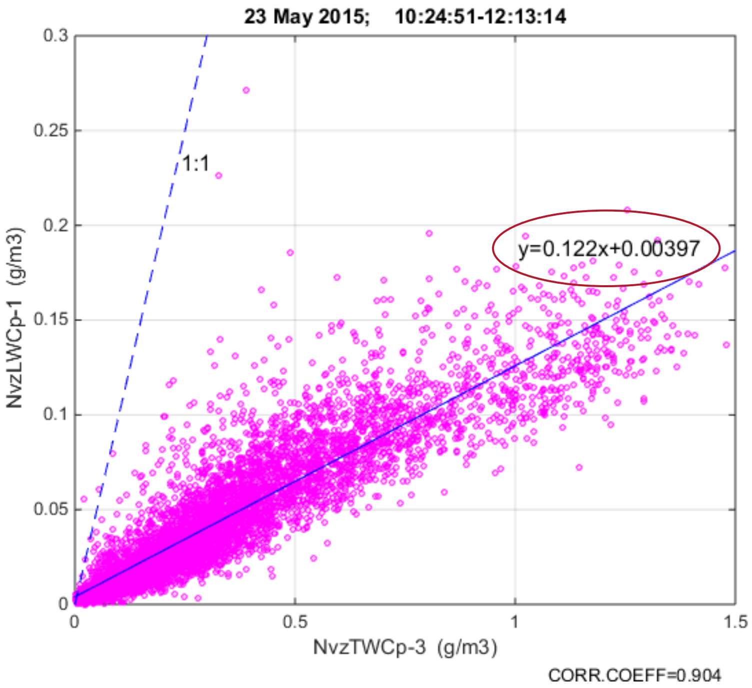
Example of the Nevzorov Probe measurements in ice, mixed phase and liquid clouds

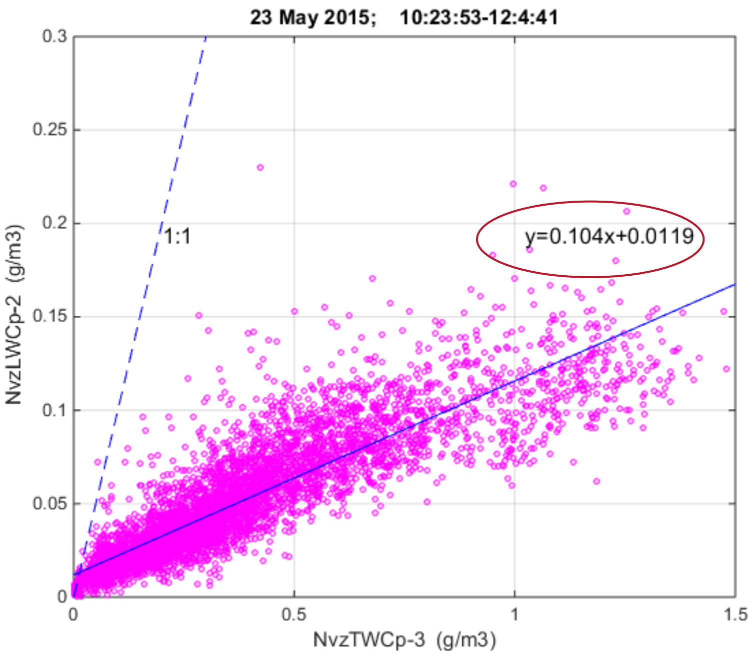


Response of the Nevzorov Probe in ice, mixed phase and liquid clouds



Residual effect of ice on the Nevzorov LWC1 and LWC2





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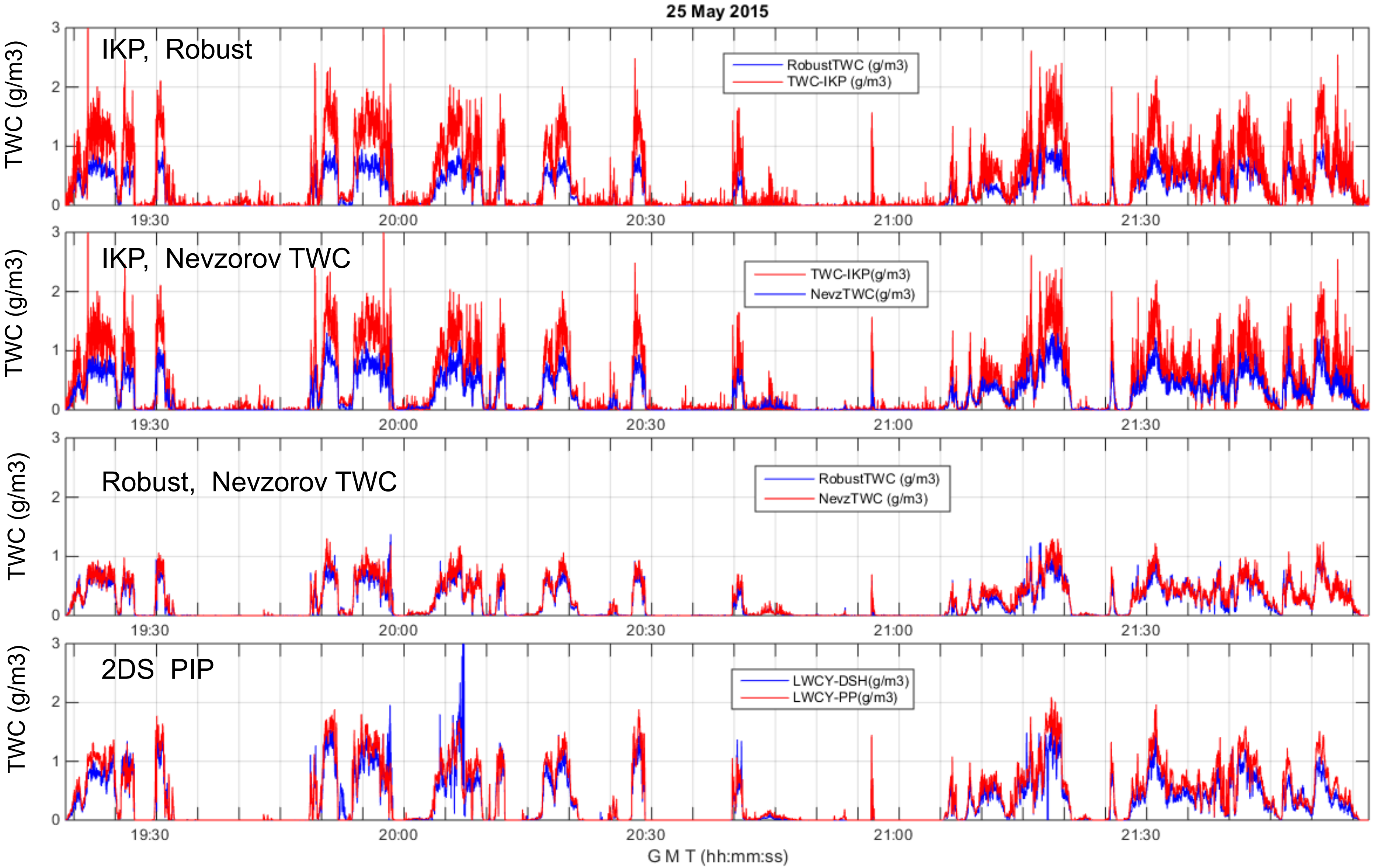
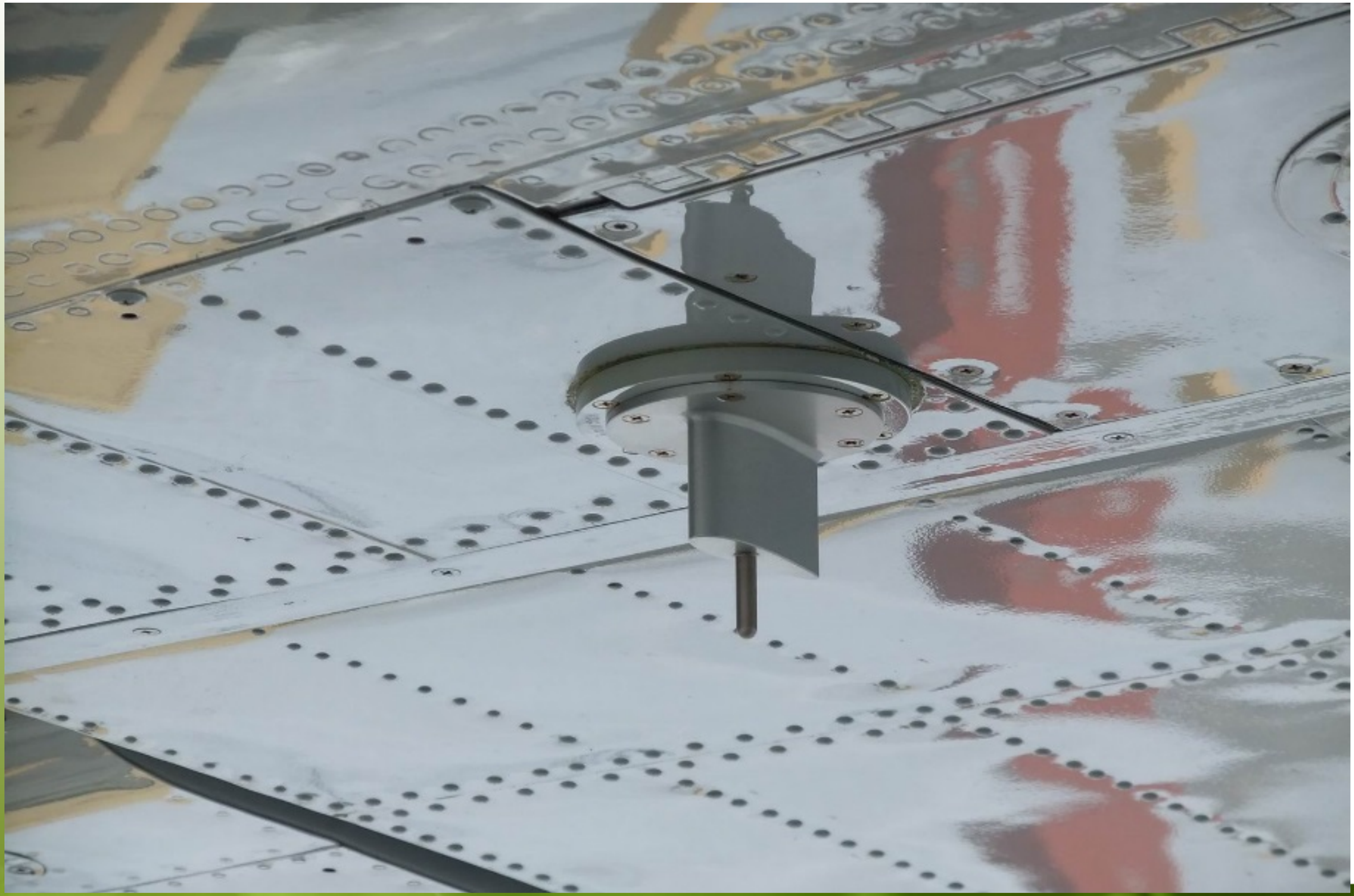
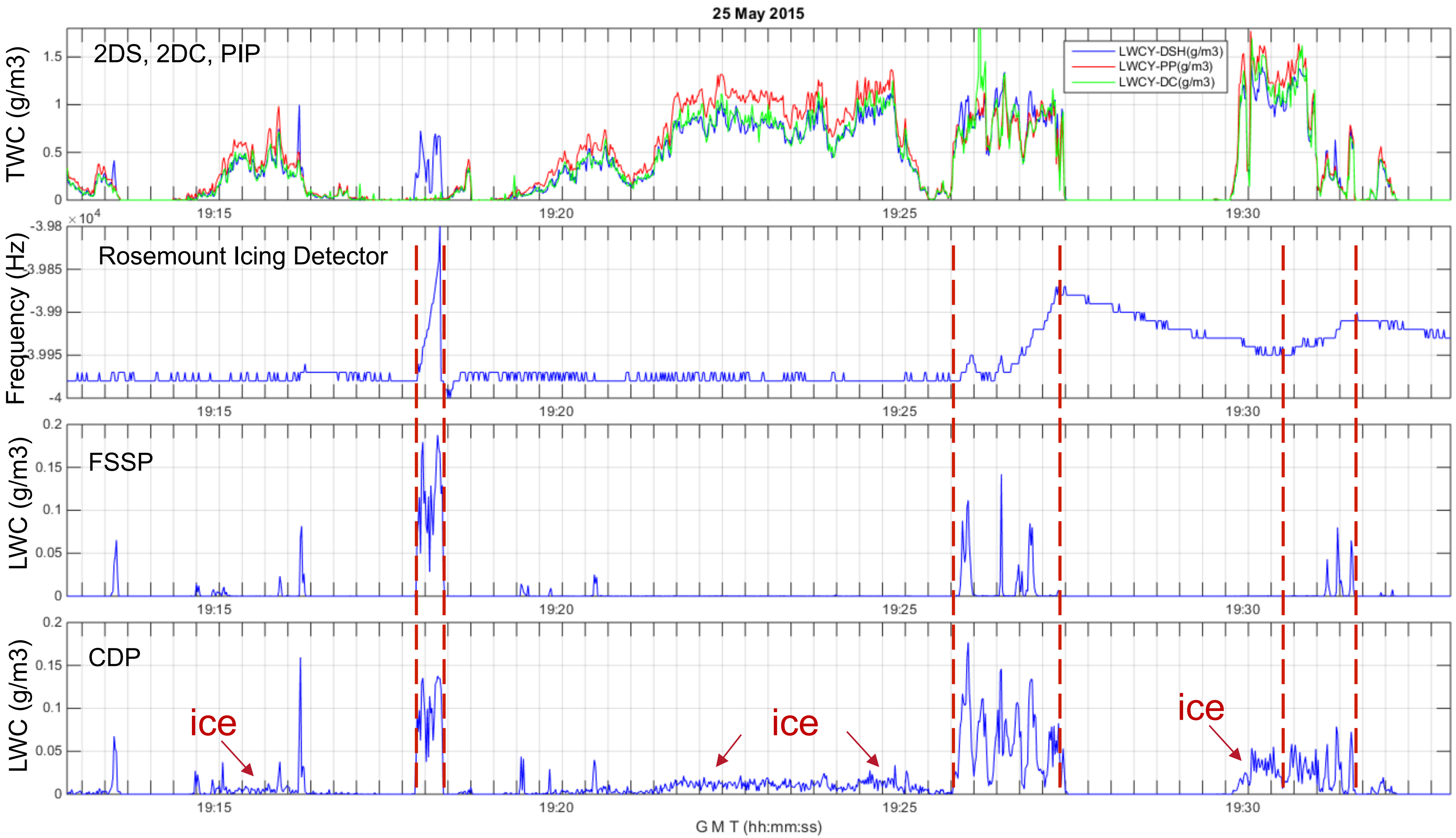
Comparisons of IWC measured by IKP, Robust and Nevzorov TWC probes



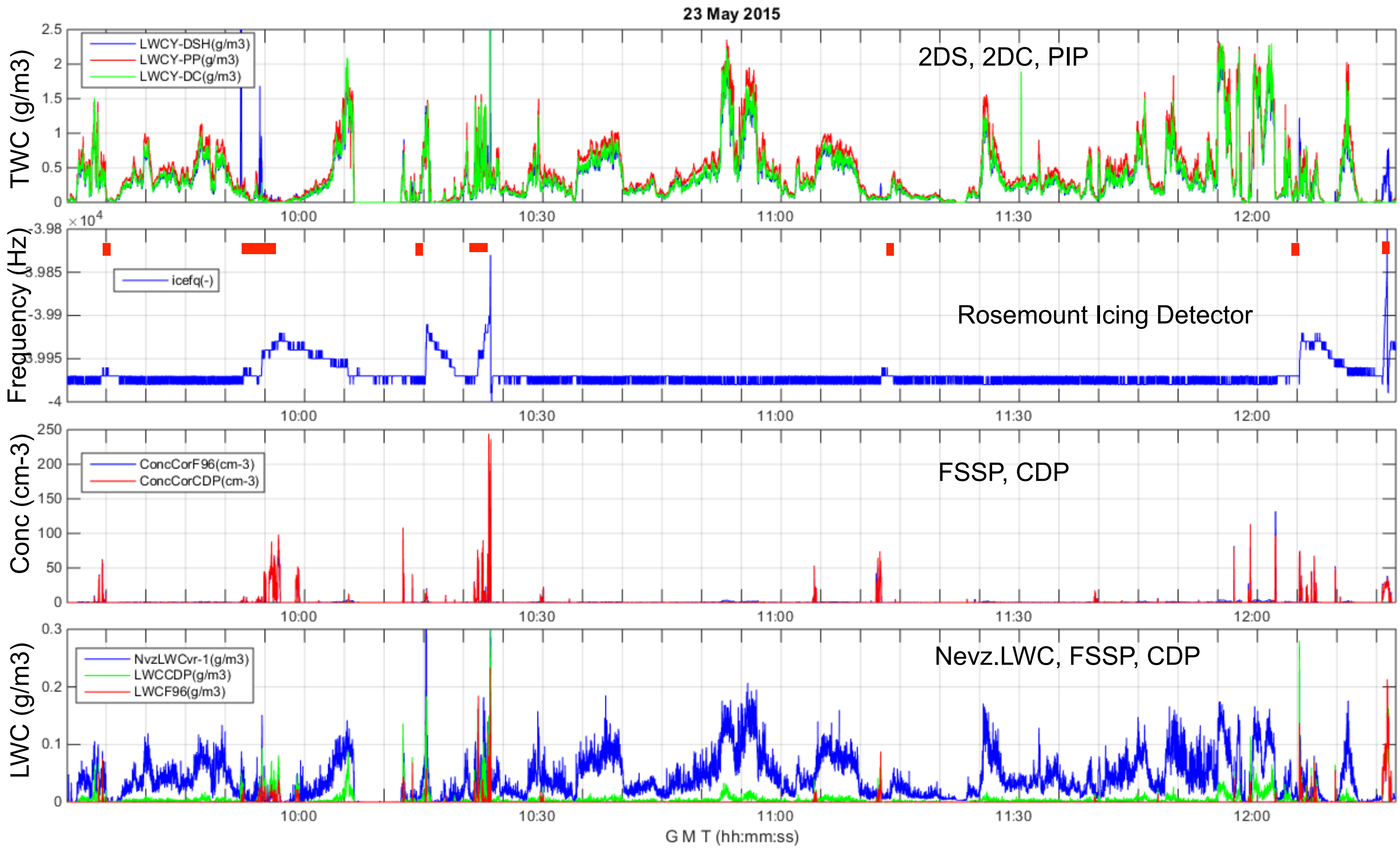
Rosemount Icing Detector



Rosemount Icing Cylinder response in liquid and mixed phase clouds



Occurrence of mixed phase during flight operations in Cayenne



Cloud Extinction Probe
and
Lidar measurements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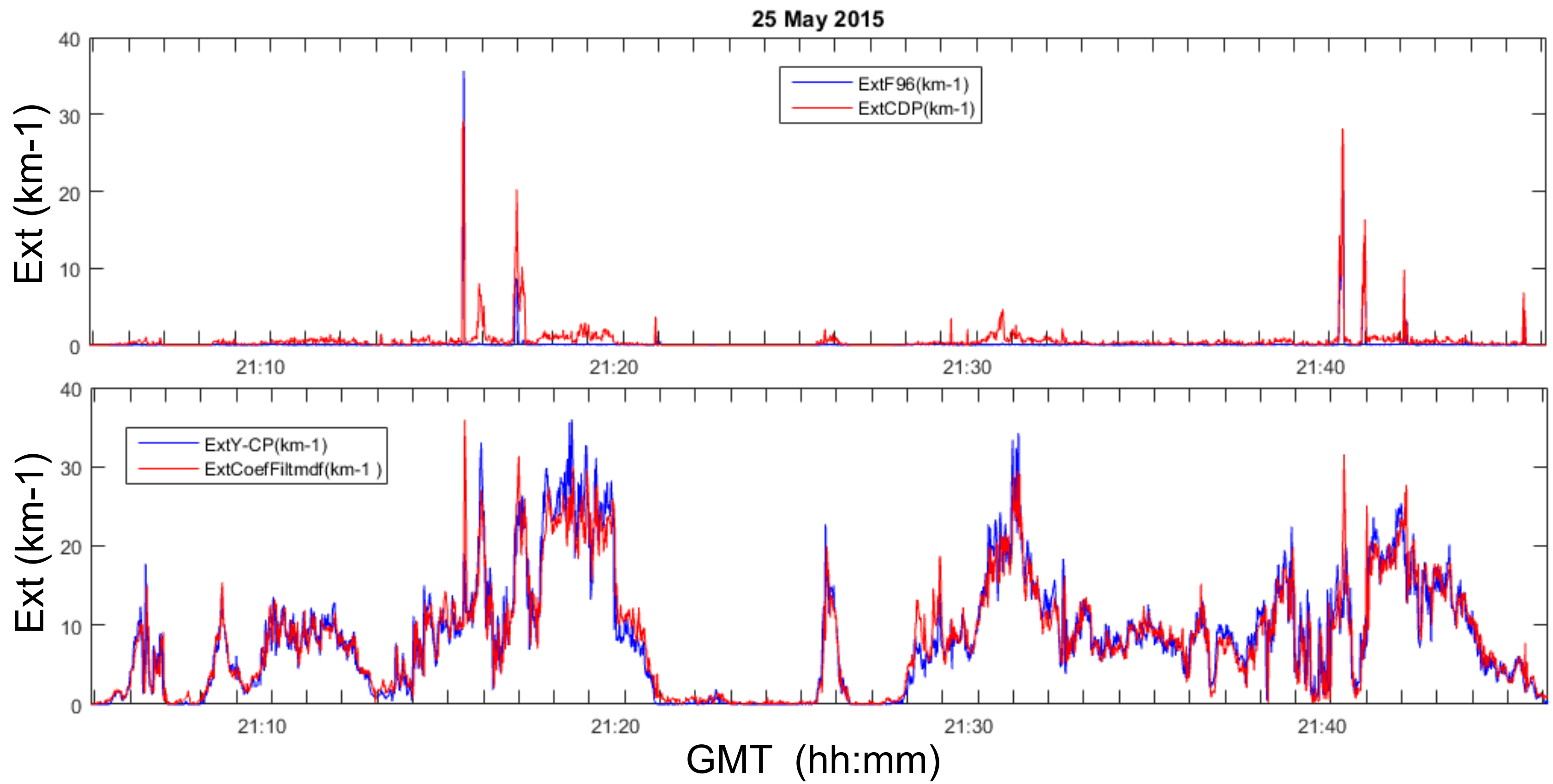
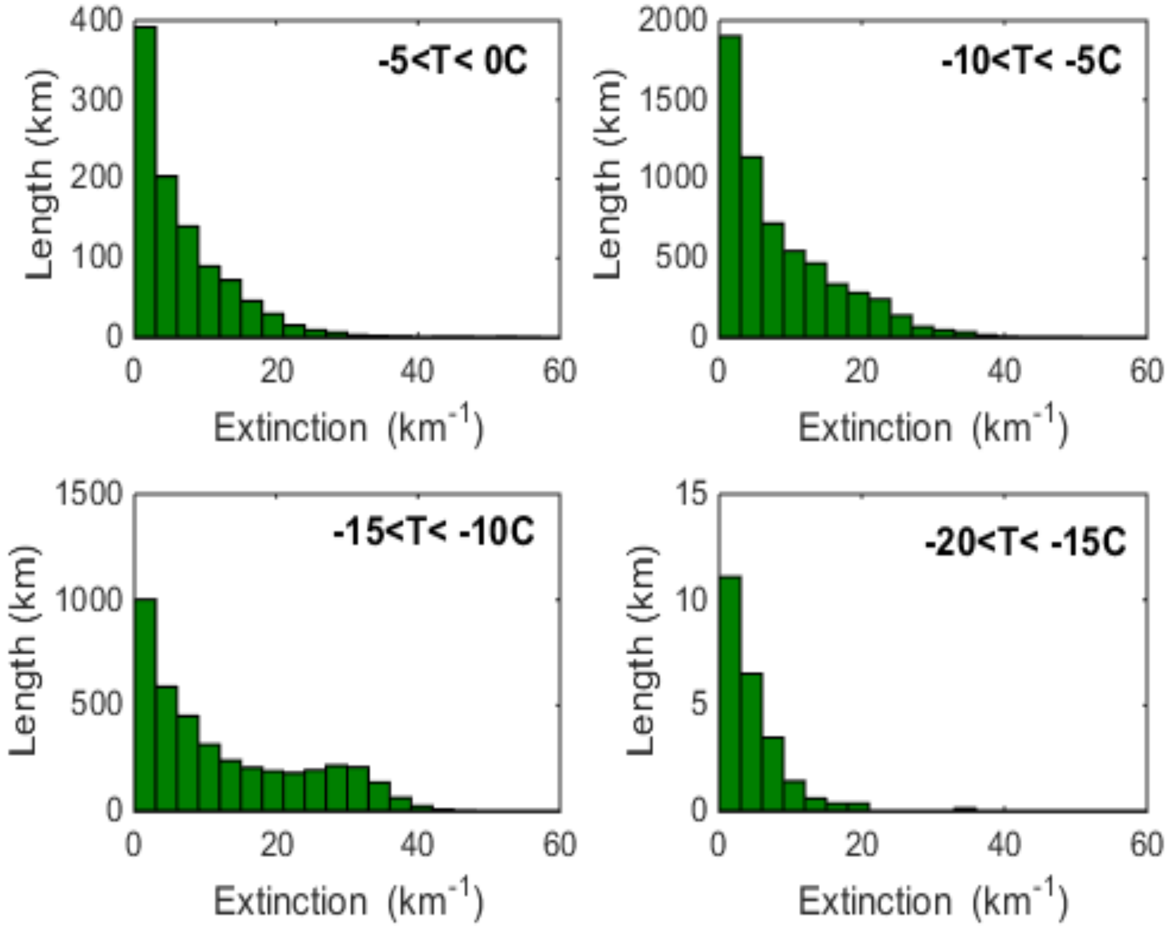
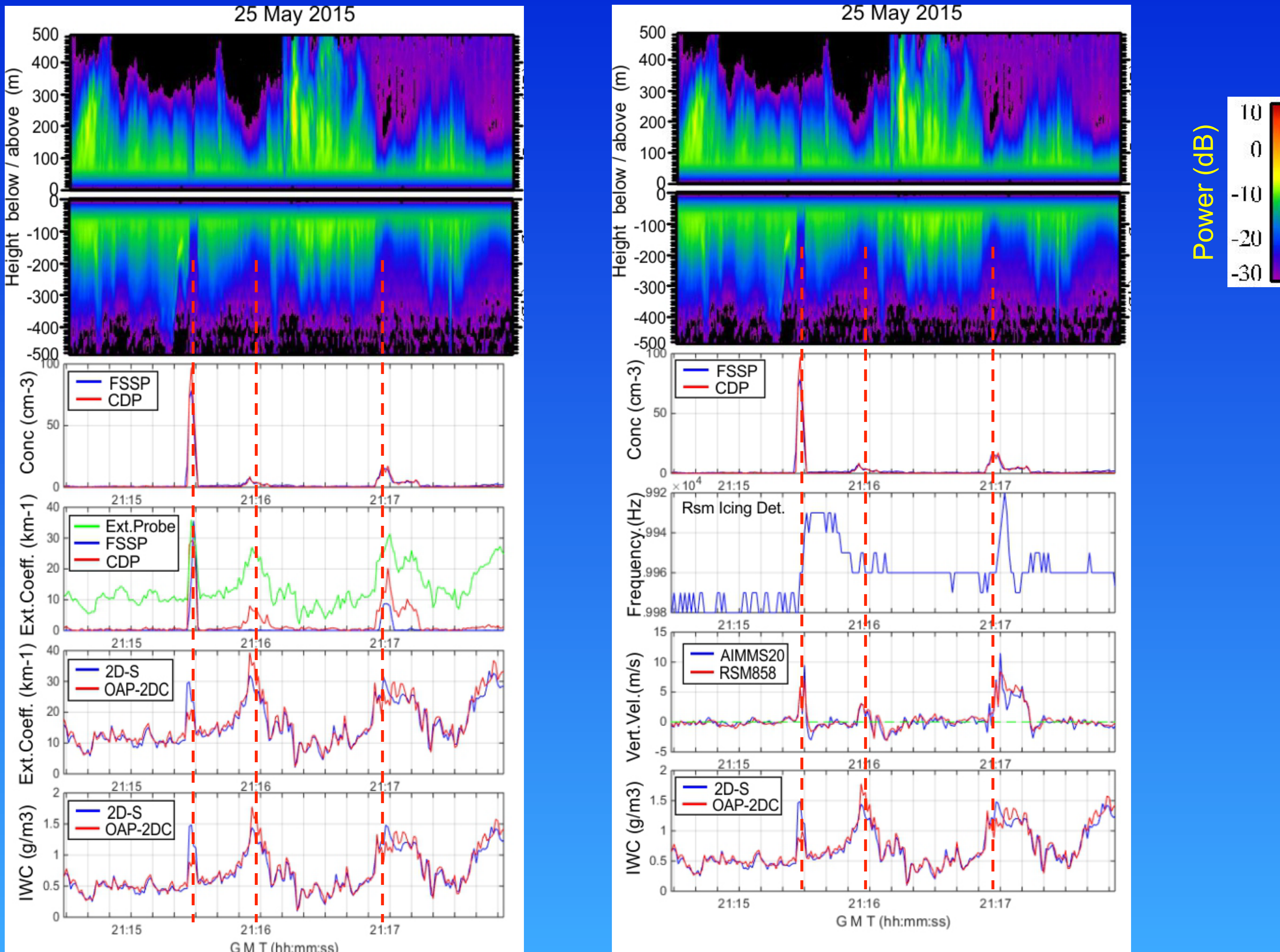

25 May 2015
Ext (km-1)
ExtF96(km-1)
ExtCDP(km-1)
ExtY-CP(km-1)
ExtCoefFiltmdf(km-1)
0
10
20
30
40
21:10
21:20
21:30
21:40
GMT (hh:mm)

Preliminary statistics of extinction coeff. obtained from the Cayenne campaign



ALPENGLOW airborne elastic lidar



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High Ice Water Content (HIWC) Program

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