

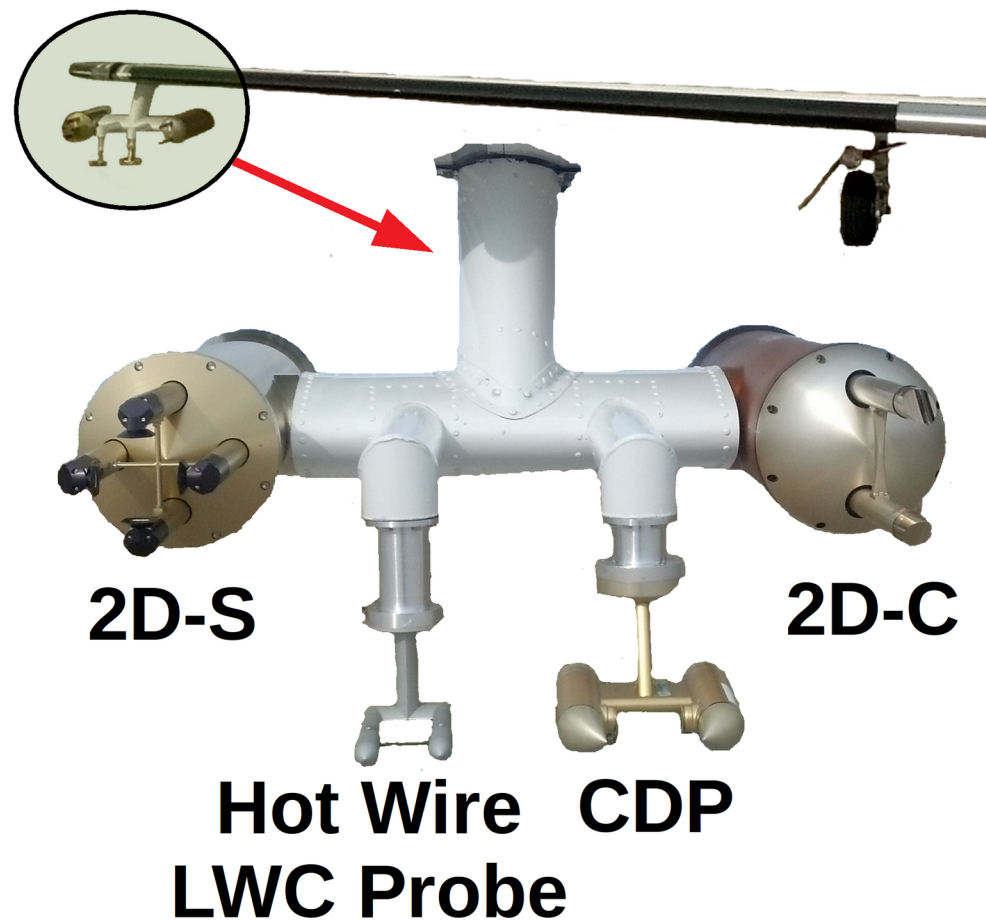
Airborne Measurements

Liquid Water Content



Liquid Water Content (LWC)

- Basic Cloud Parameter
- Icing Studies
- Precipitation Potential
- Comparison with Remote Sensing Measurements
- **Compare Measurements using Different Techniques**



Liquid Water Content (LWC) Calculation

The amount of liquid water in a given volume of air is determined through mass integration of the cloud droplet distribution.

$$LWC = \left(\frac{\pi}{6} \right) \rho_w \sum_{i=1}^m N_i d_i^3$$

ρ_w – Density of Water

N_i – Concentration of Droplets in Size Channel i

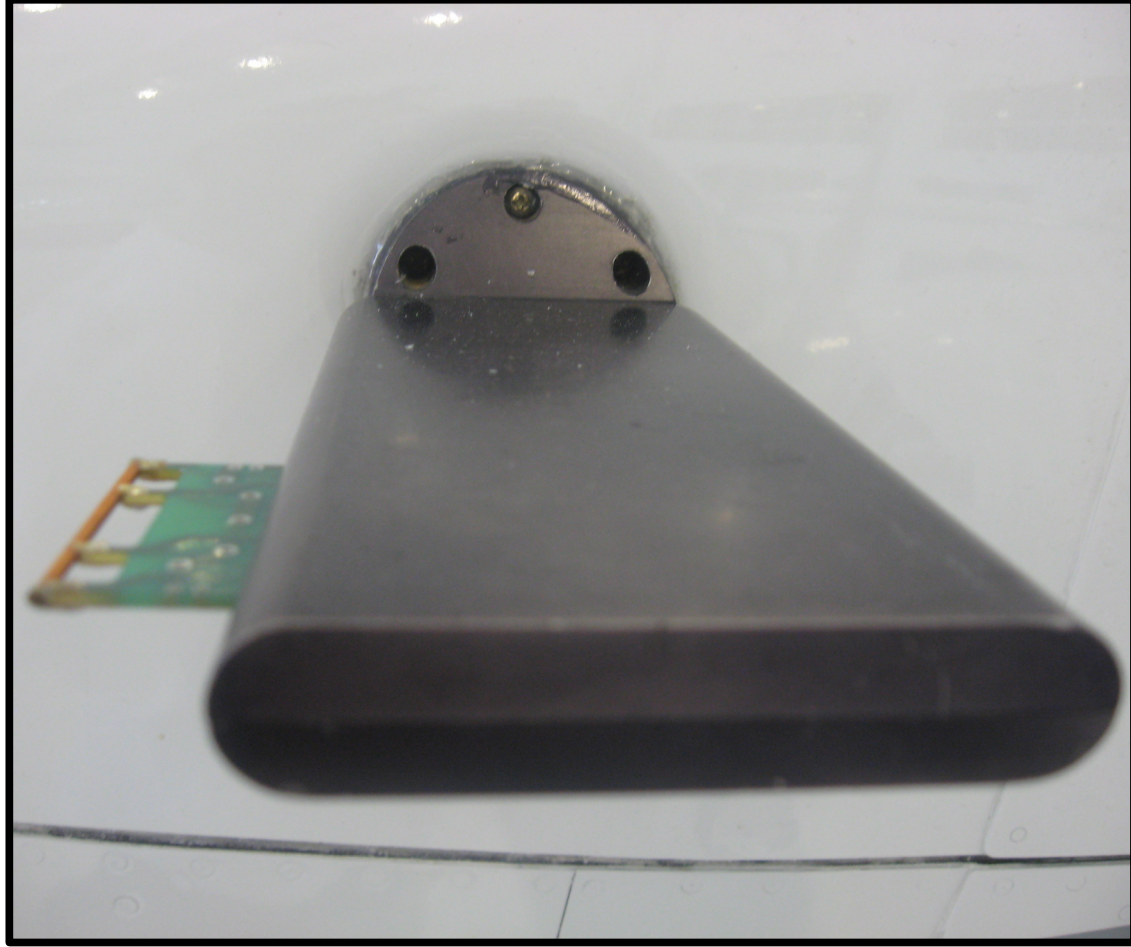
d_i – Droplet Diameter in Size Channel i

m – Total Number of Channels

King Hotwire Probe



DMT Hotwire Probe



King Hot Wire Probe Equations

$$P_{Measured} = P_{Dry} + P_{Wet}$$

$$P_{Dry} = C(T_s - T_a) * (\rho v)^x + a$$

$$P_{Wet} = M l d v [L_v + c_w(T_v - T_a)]$$

$$M \approx \frac{(P_{measured} - C(T_s - T_a) * (\rho v)^x + a)}{(l d v [L_v + c_w(T_v - T_a)])}$$

M – Liquid Water Content (LWC)

P – Power

ρ – Density of Air

v – True Air Speed

l – Wire Length

d – Wire Diameter

L_v – Latent Heat of Vaporization

C_w – Specific Heat of Liquid Water

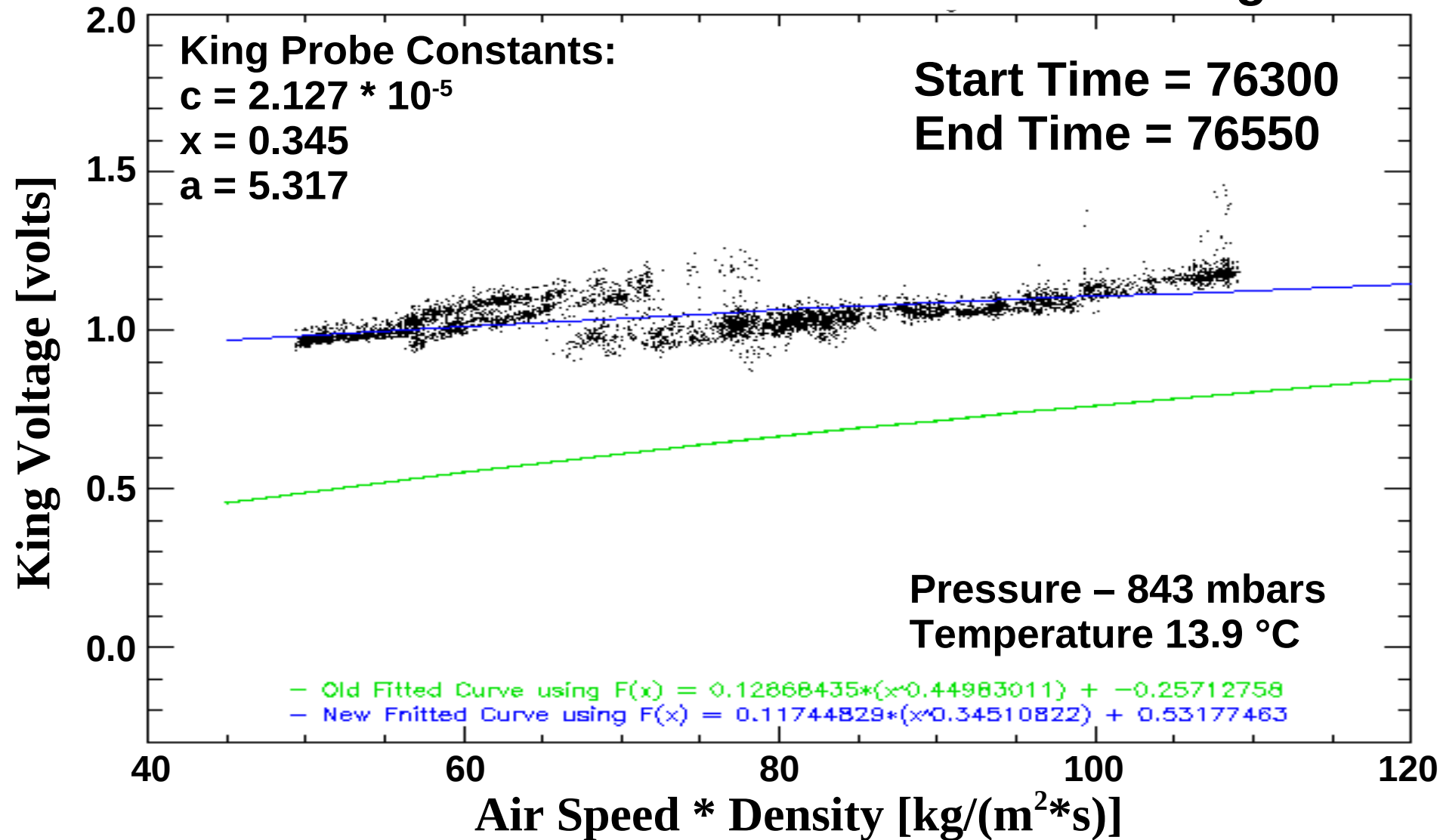
T_s – Temperature of Sensor Wire

T_v – Sensor Water Vaporization

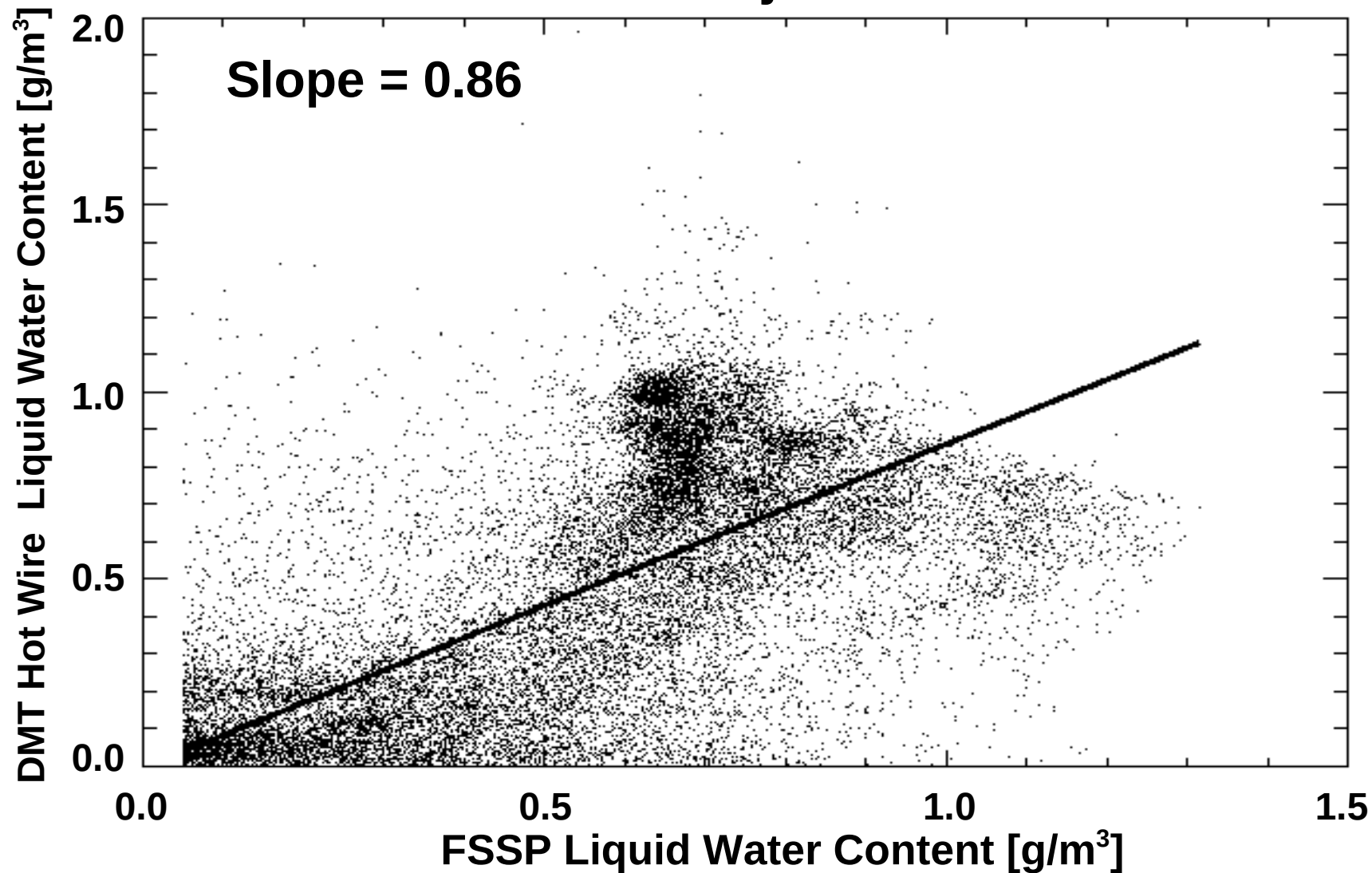
T_a – Air Temperature

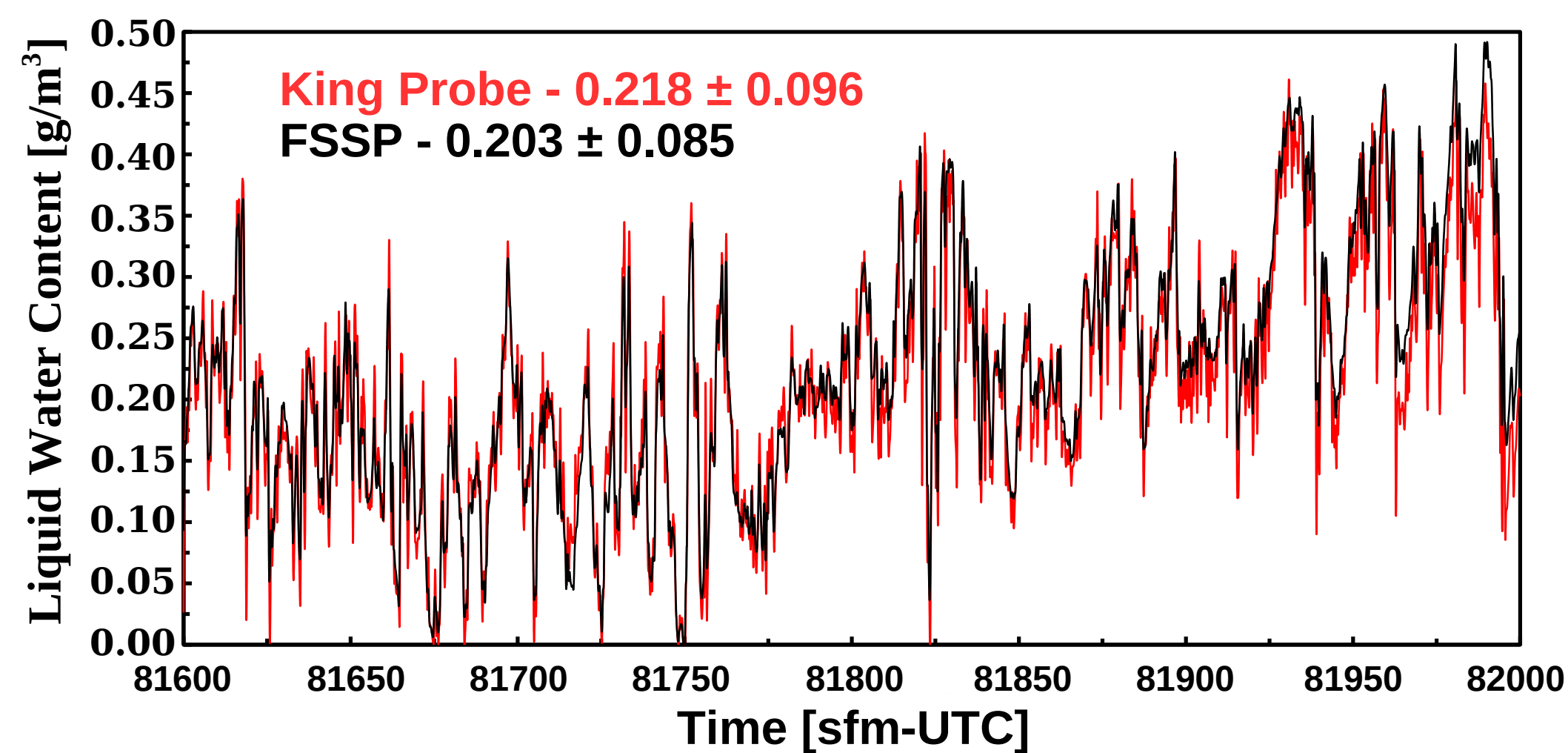
C, x, a – Calibration Constants

Hot Wire Probe Calibration: 2008/07/09 Flight



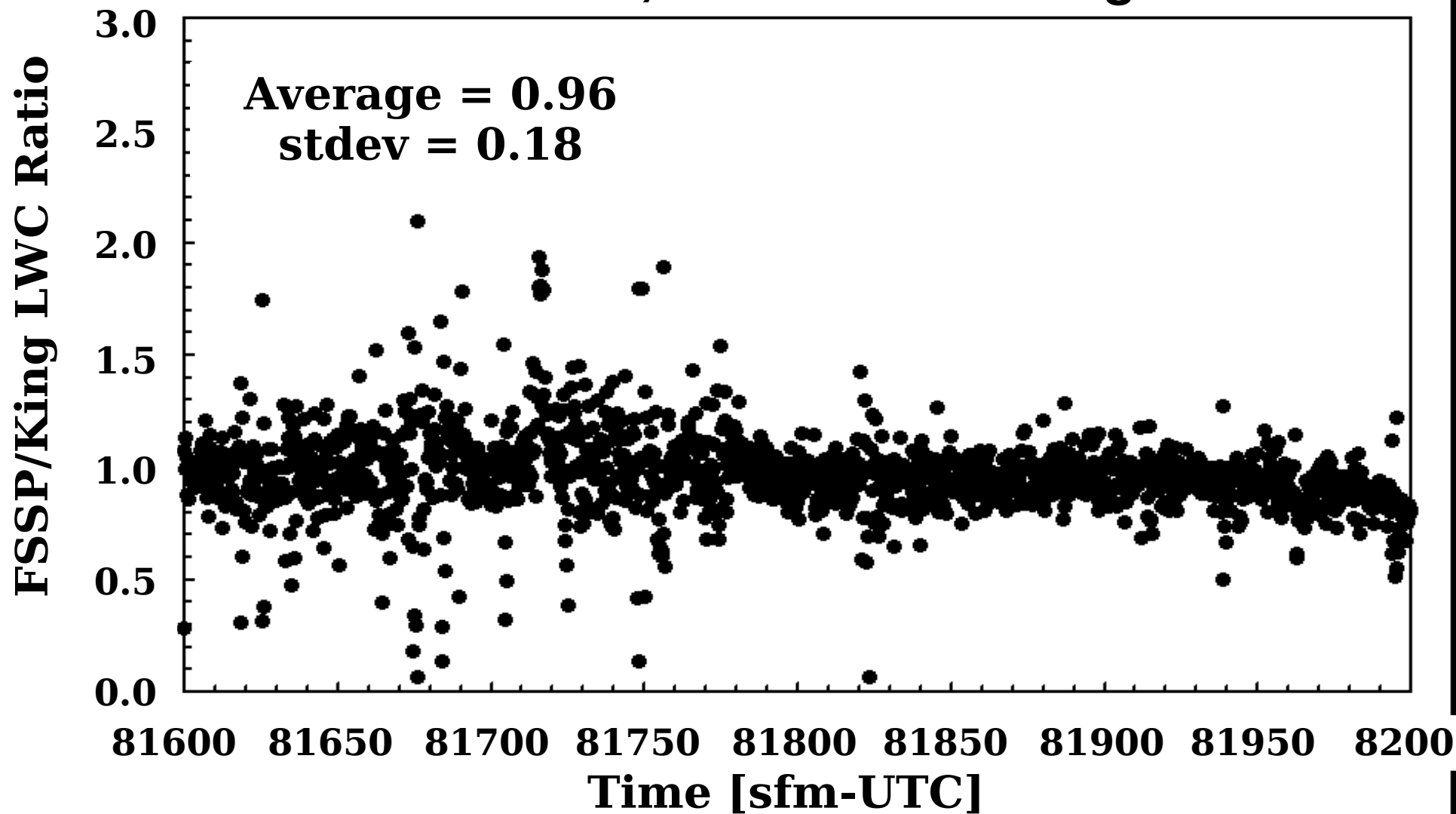
POLCAST2 Field Project: Summer 2008

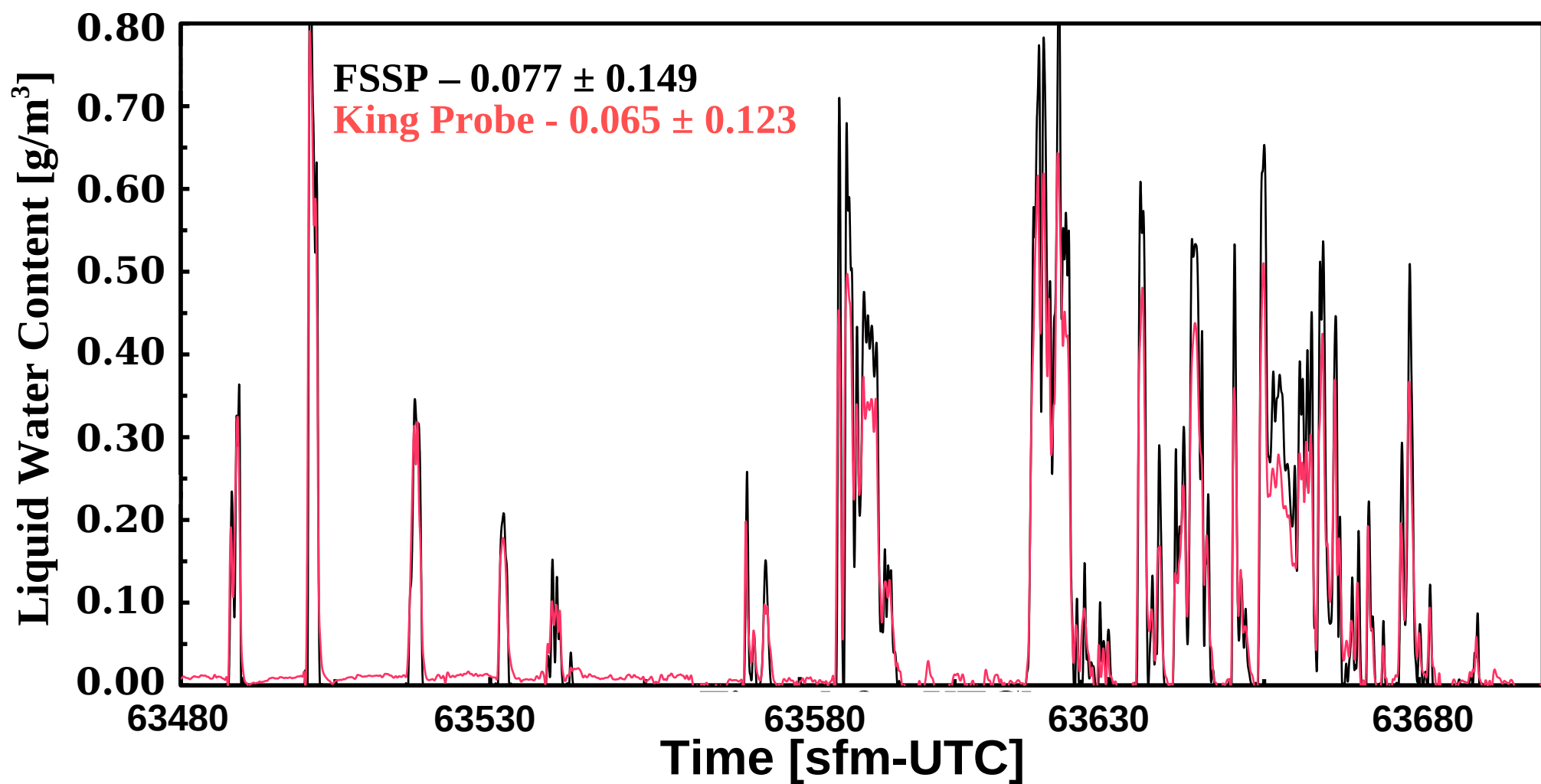




The 4 Hz averaged FSSP (Black line) and King Probe (Red Line) cloud liquid water content data for March 10, 2004 Citation flight.

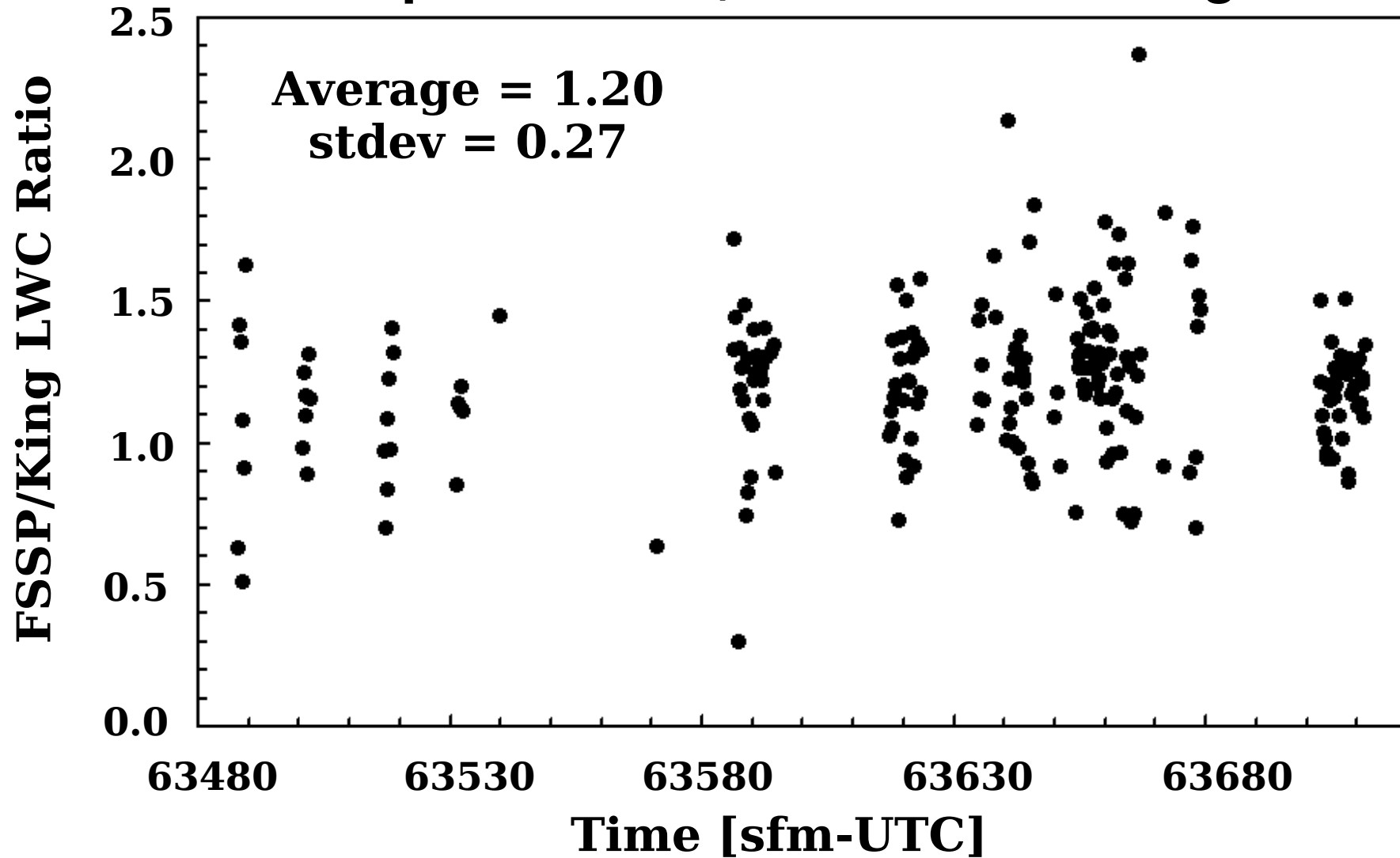
March 10, 2004 Citation Flight



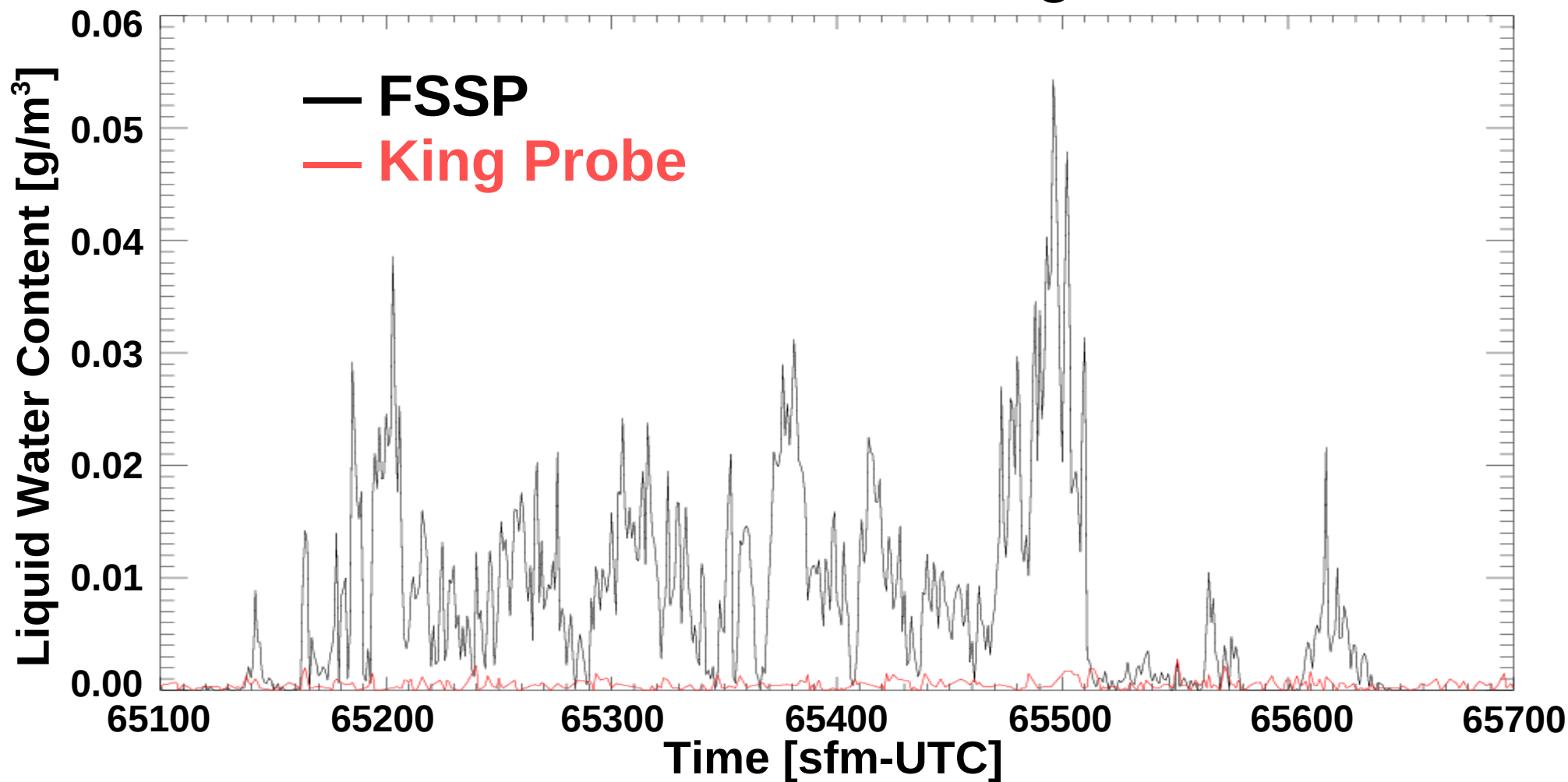


The 4 Hz averaged FSSP (Black line) and King Probe (Red Line) cloud liquid water content data for September 24, 2004 Citation Flight.

September 24, 2004 Citation Flight

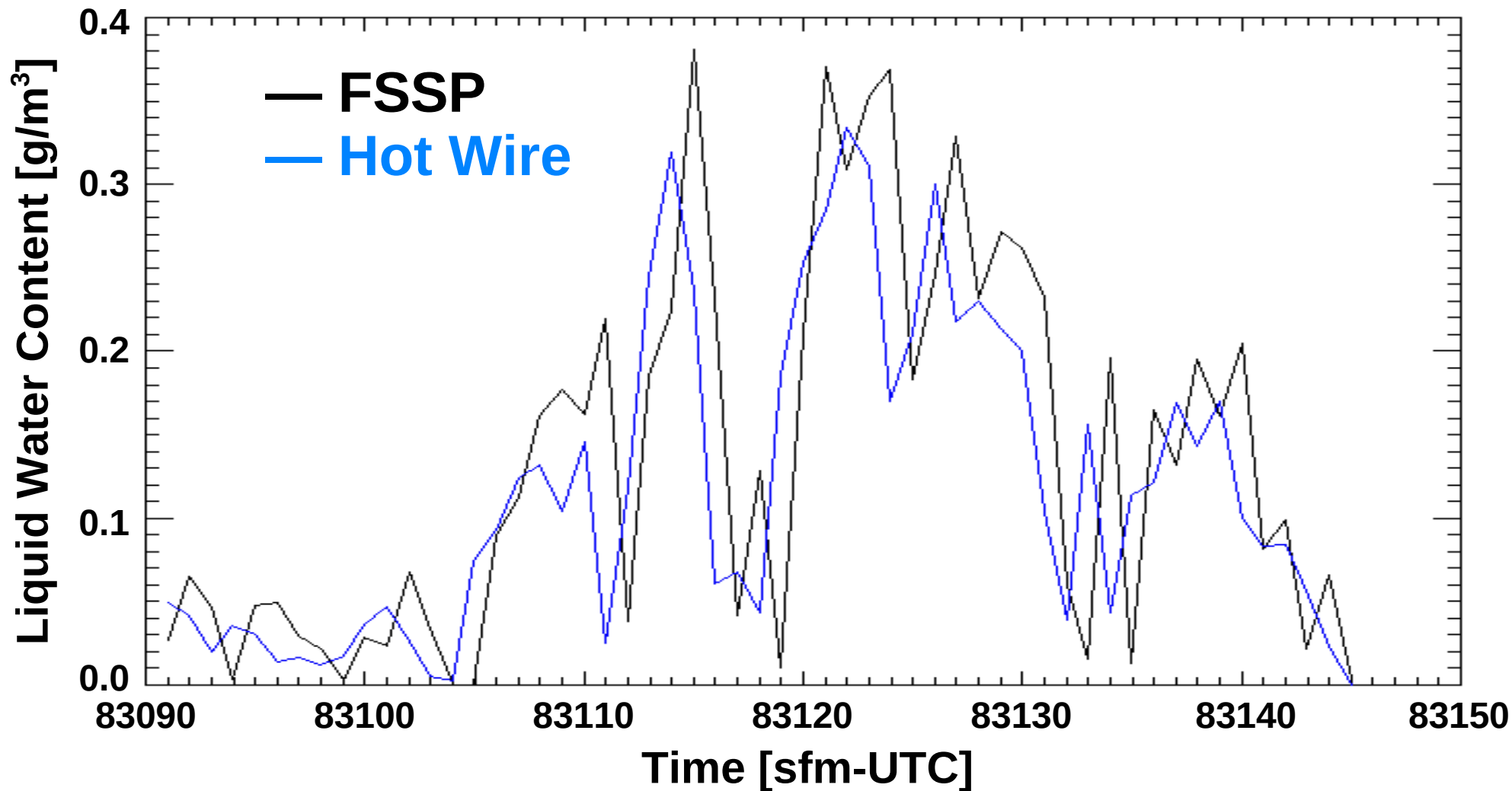


March 14, 2004 Flight

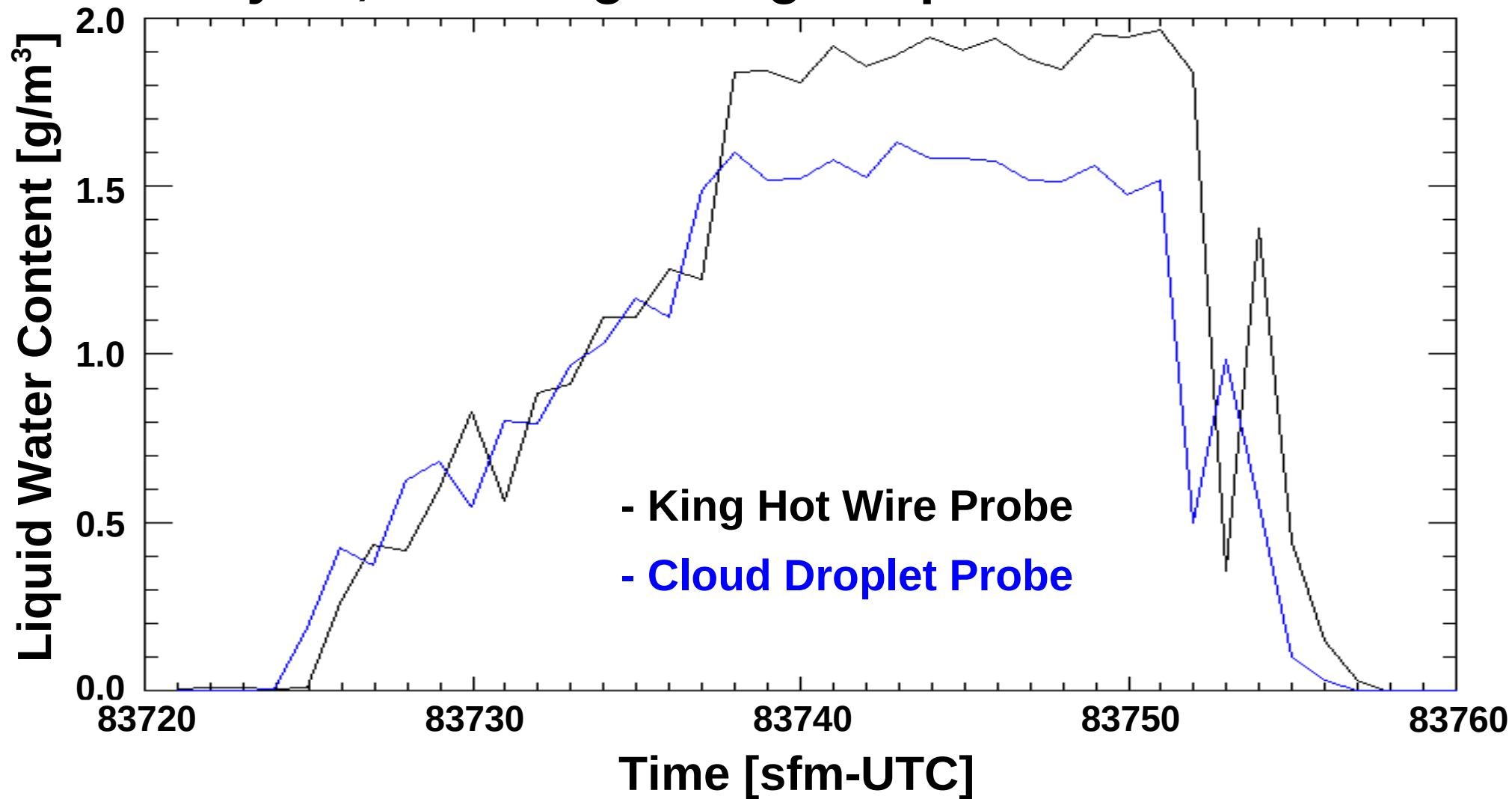


Ice Contamination of the FSSP LWC calculations assume spherical water droplets.

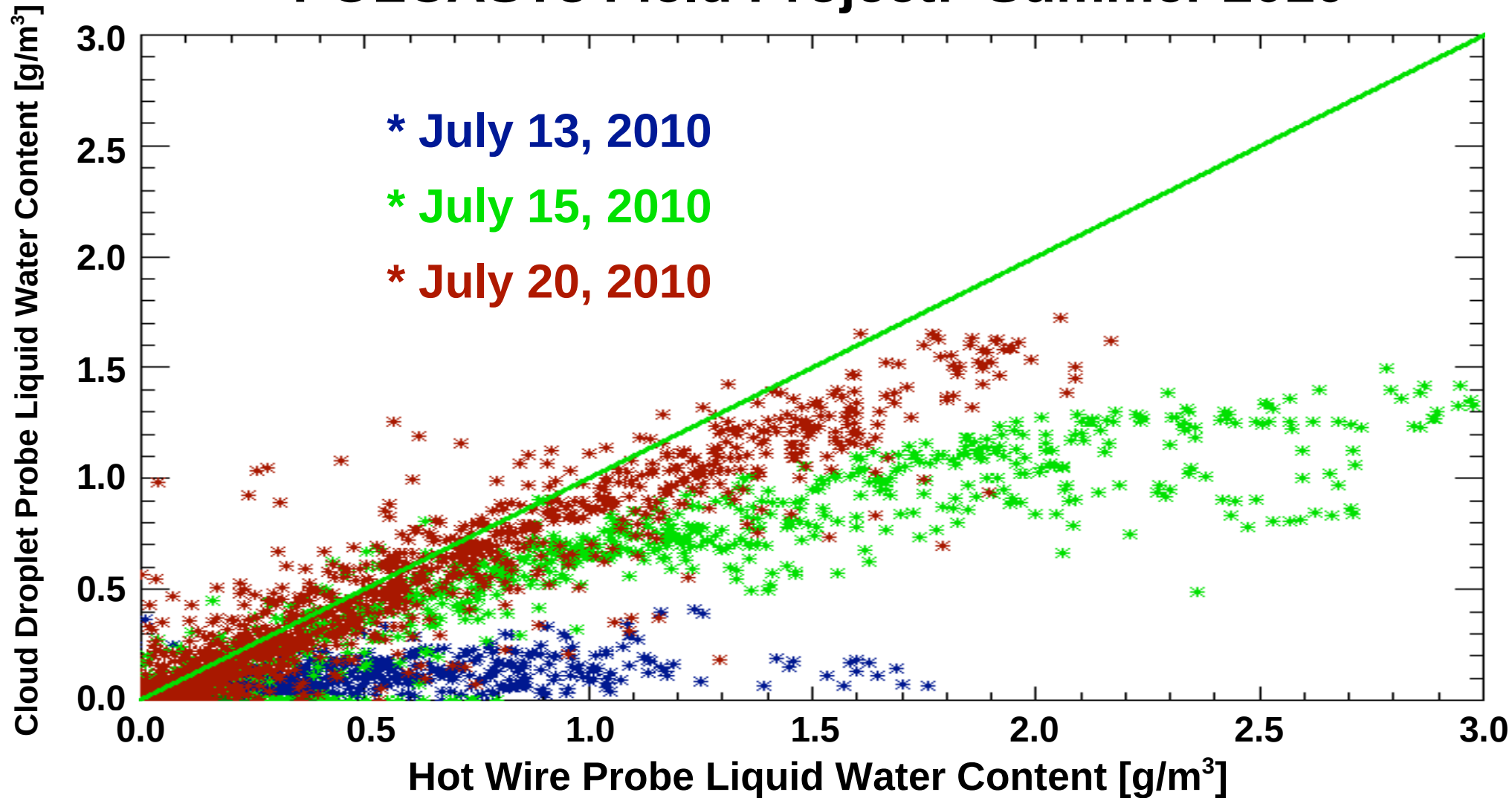
July 20, 2010 Flight: Low Liquid Water Content



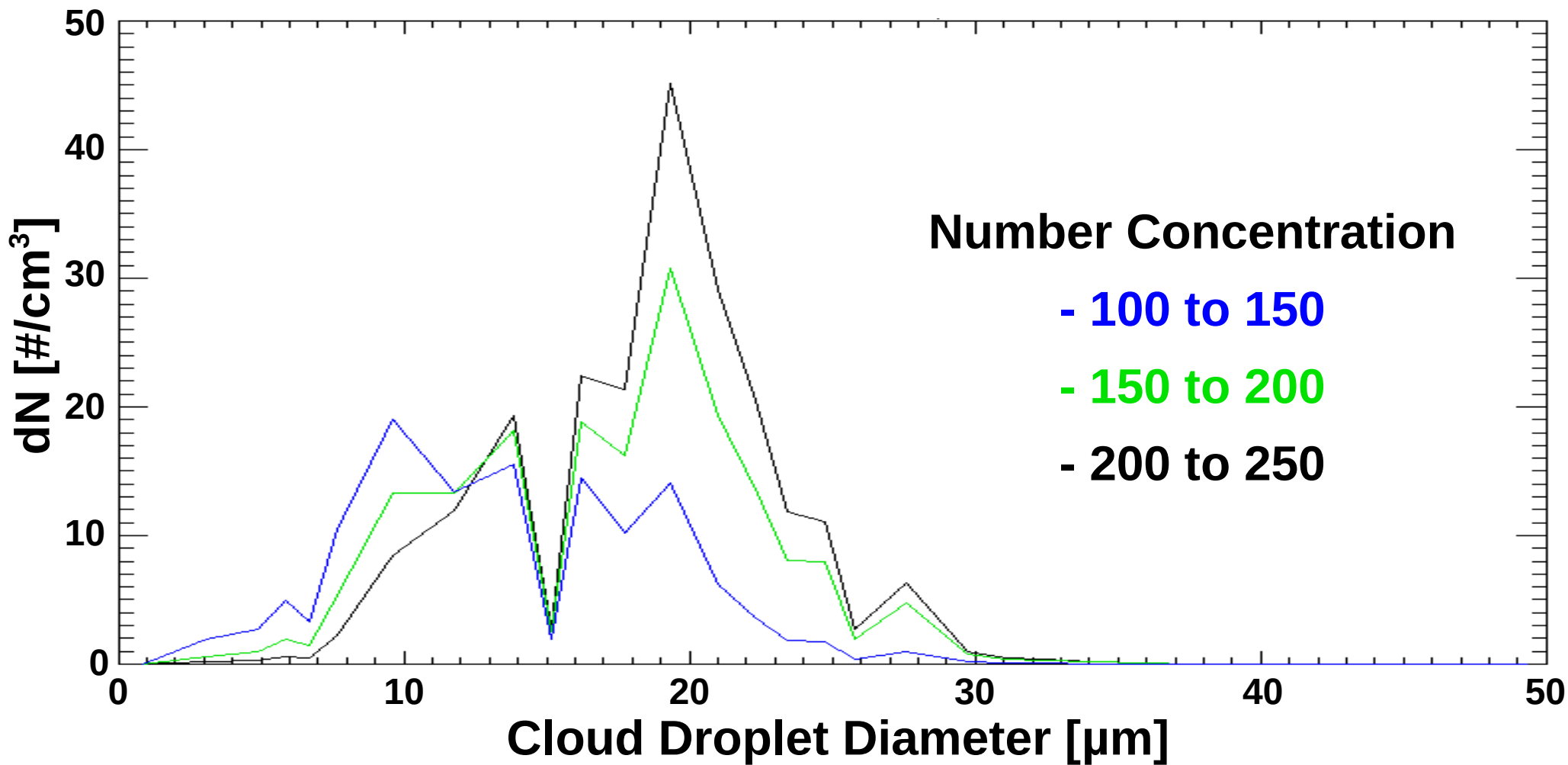
July 20, 2010 Flight: High Liquid Water Content



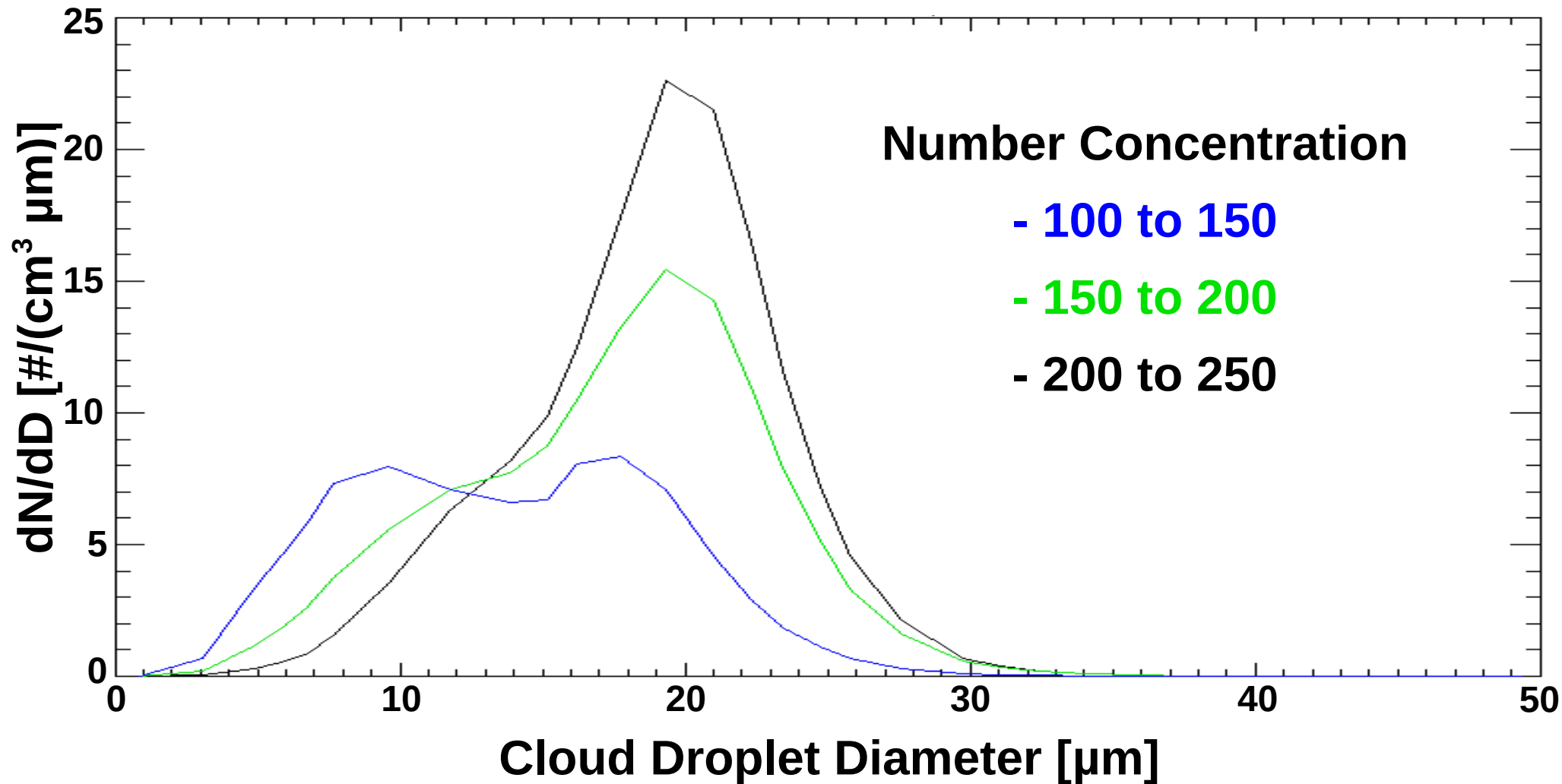
POLCAST3 Field Project: Summer 2010



CDP Number Concentration Spectrum: July 15, 2010

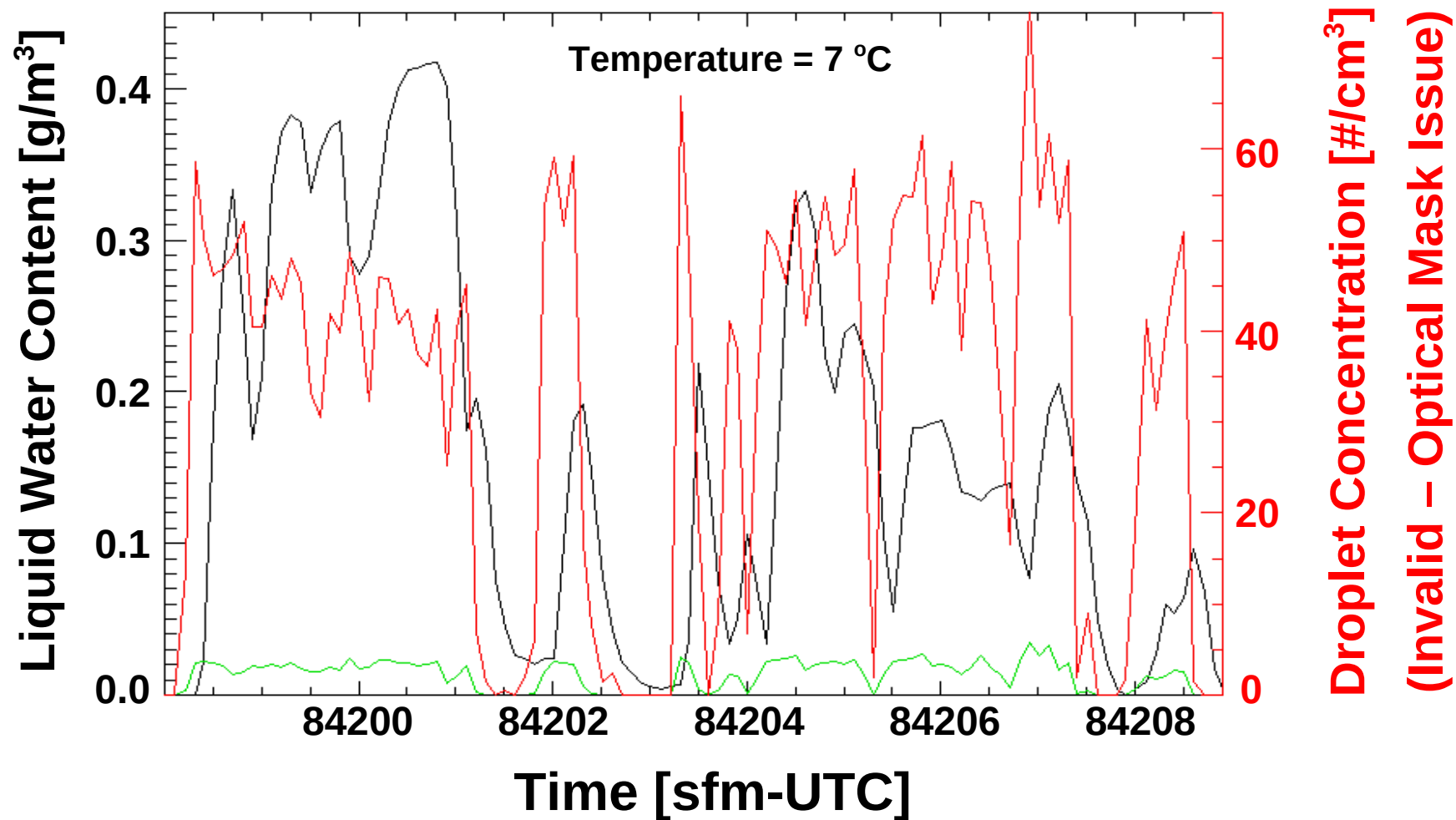


CDP Normalized Concentration Spectrum: July 15, 2010

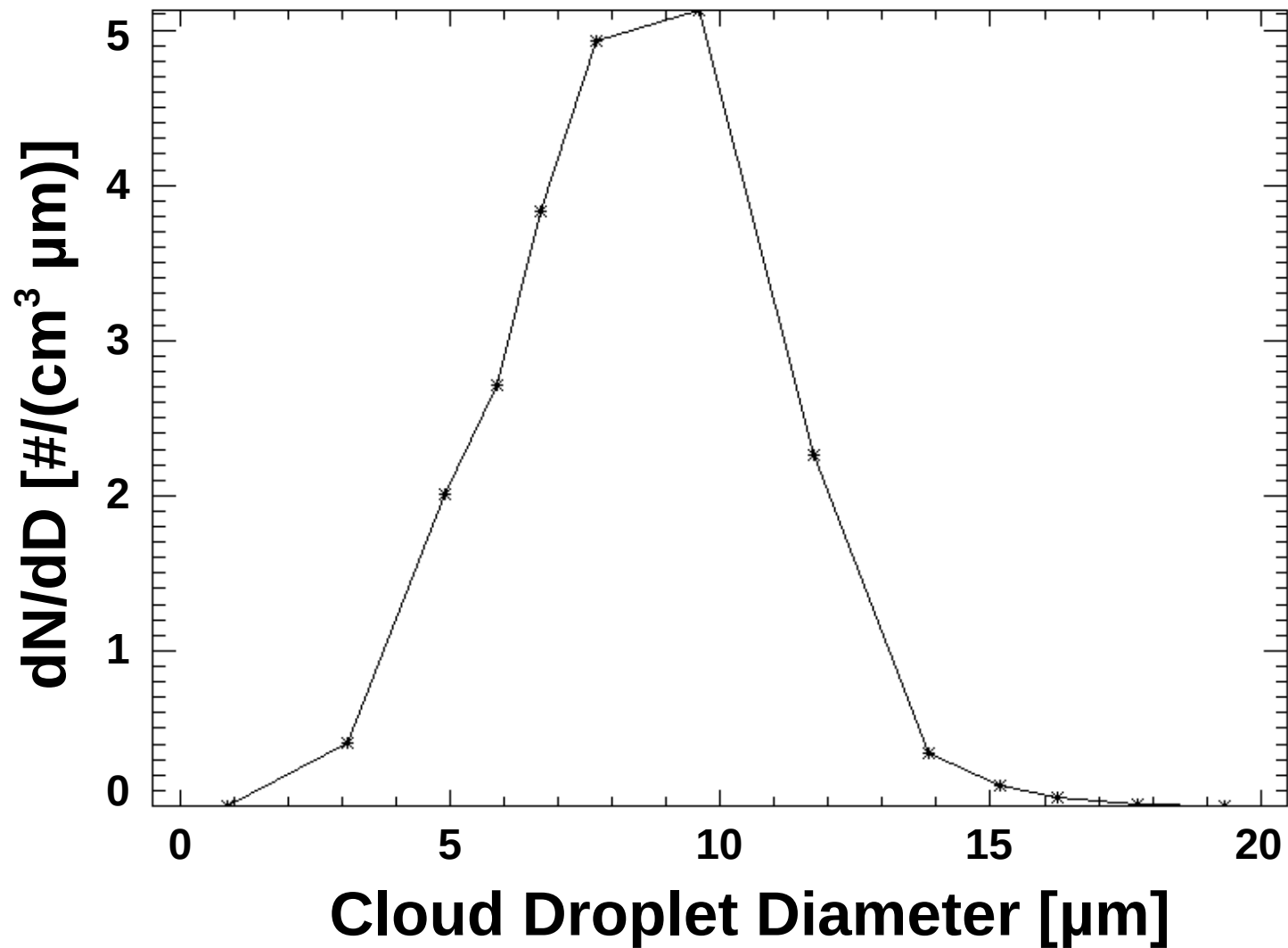


July 8, 2010 Flight

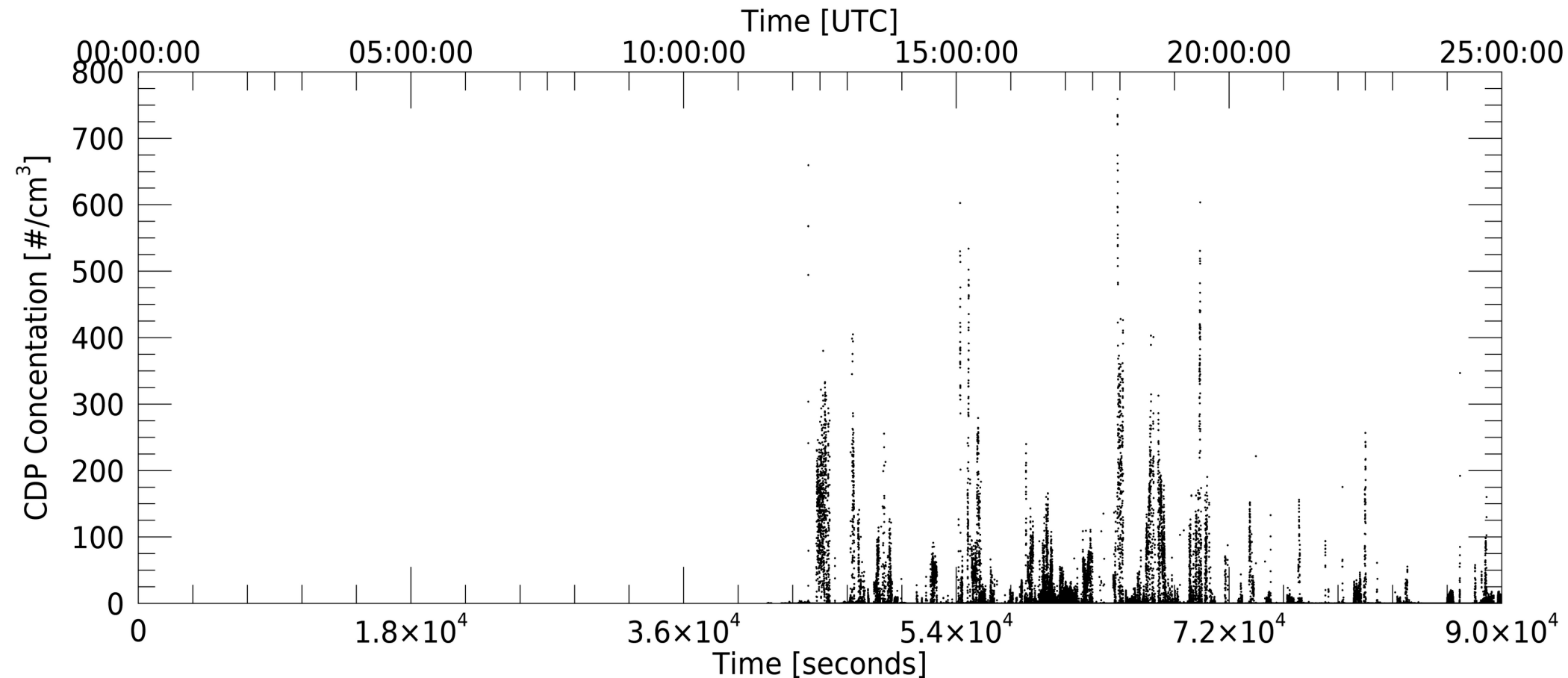
- King Hot Wire LWC - Cloud Droplet Probe LWC - Cloud Droplet Probe Conc.



July 8, 2010 Flight: CDP Spectrum (84198-84209 smf)

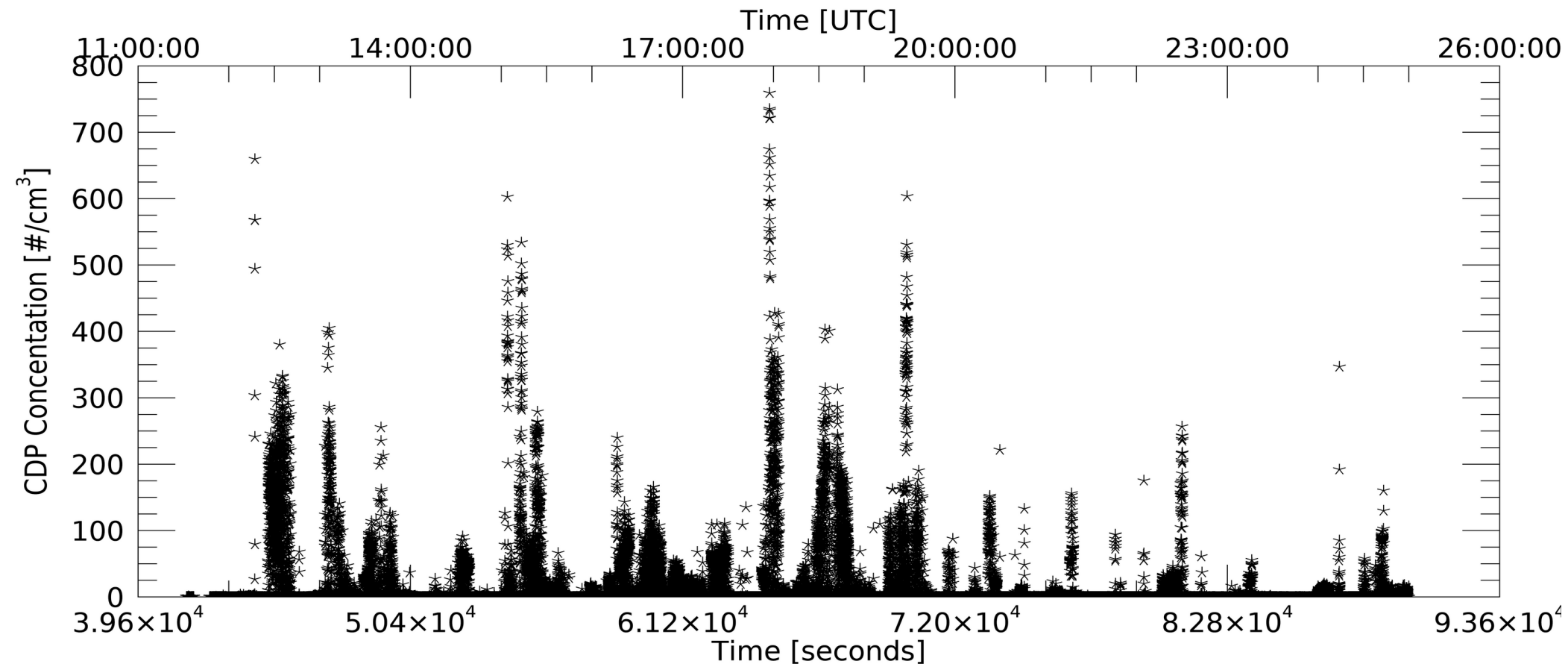


NASA IMPACTS 2022: CDP Total Concentration



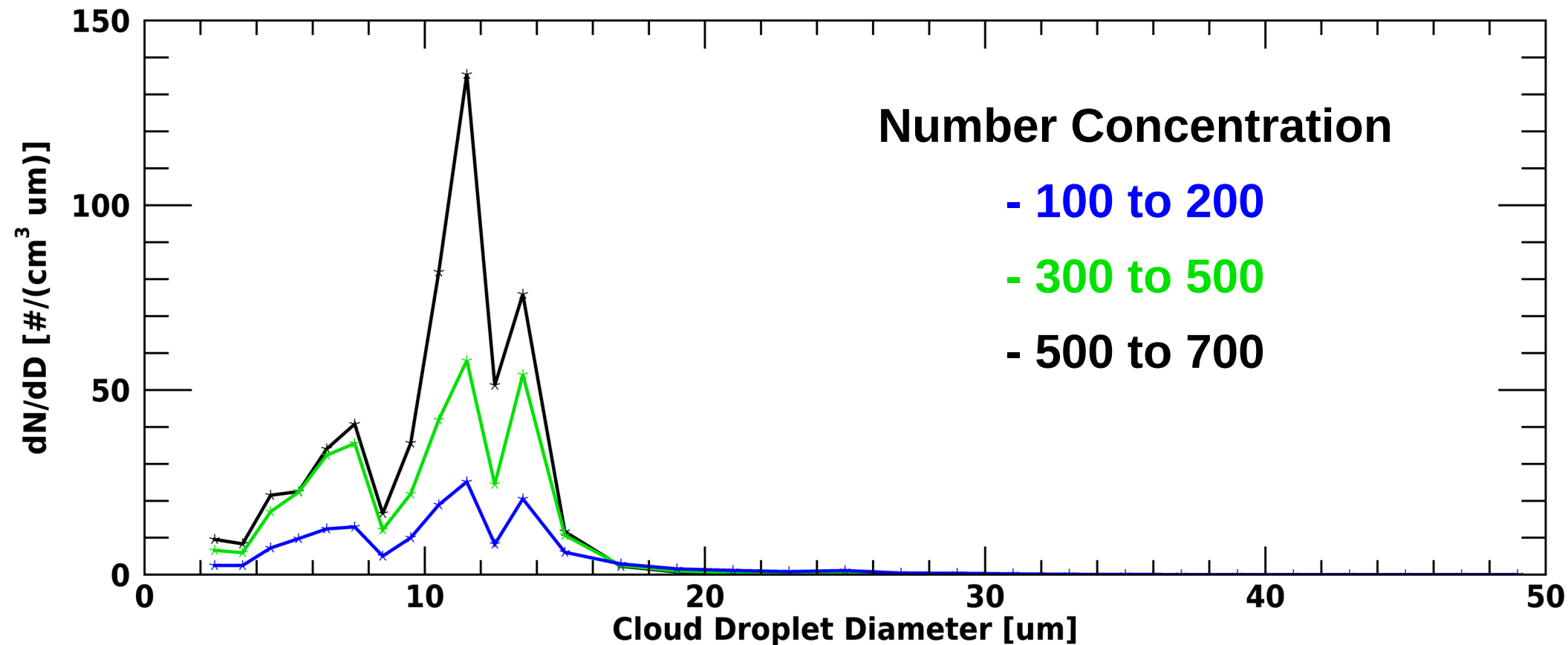
The 1 Hz averaged CDP total droplet concentration for all NASA IMPACTS 2022 flights with data limited from 0-25 hours.

NASA IMPACTS 2022: CDP Total Concentration



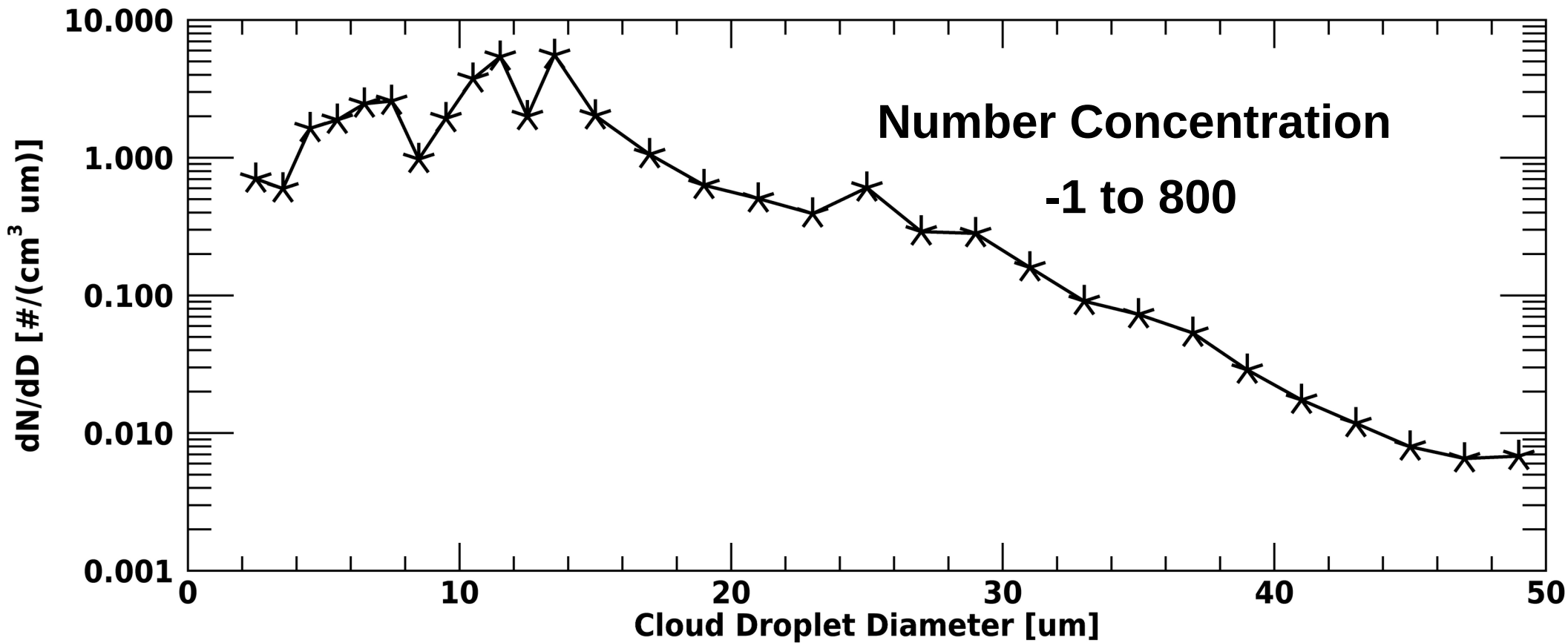
The 1 Hz averaged CDP total droplet concentration for all NASA IMPACTS 2022 flights with data limited from 11-26 hours.

NASA IMPACTS 2022: CDP Normalized Spectrum



The 1 Hz averaged CDP normalized number spectrum for all NASA IMPACTS 2022 flights with total number concentration limits applied.

NASA IMPACTS 2022: CDP Normalized Spectrum



The 1 Hz averaged CDP normalized number spectrum for all NASA IMPACTS 2022 flights with total number concentration limits applied.

Science Engineering Associates (SEA) Model WCM-3000



NASA IMPACTS 2022 Field Project

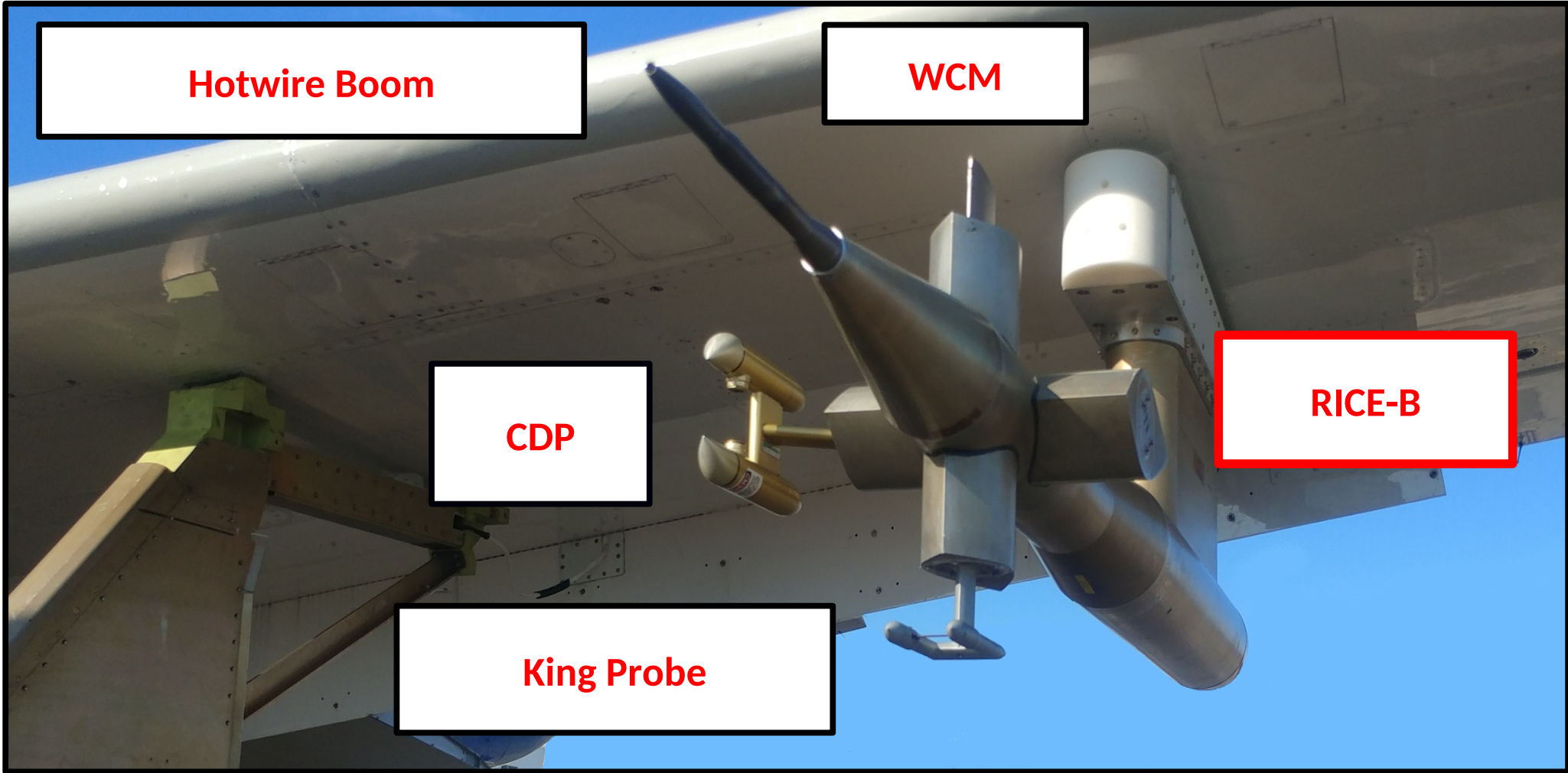
Hotwire Boom

WCM

CDP

RICE-B

King Probe



WCM - Total Water Content System

Science Engineering Associates (SEA) Model WCM-3000

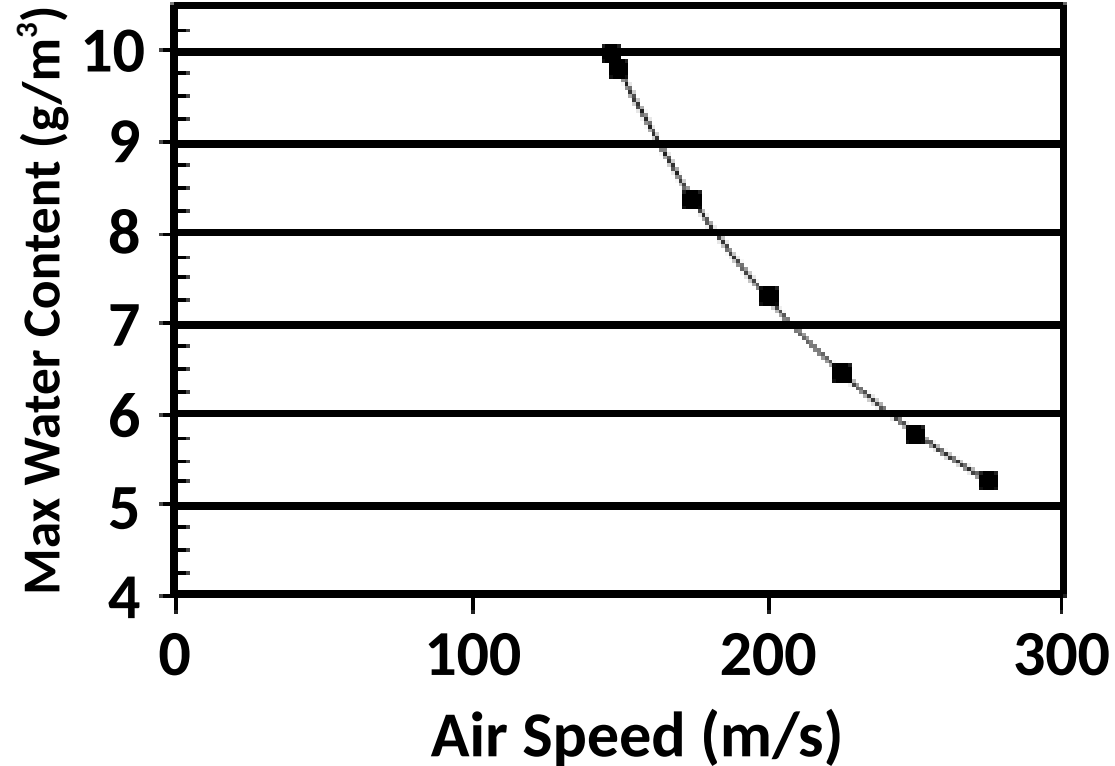


Total Water



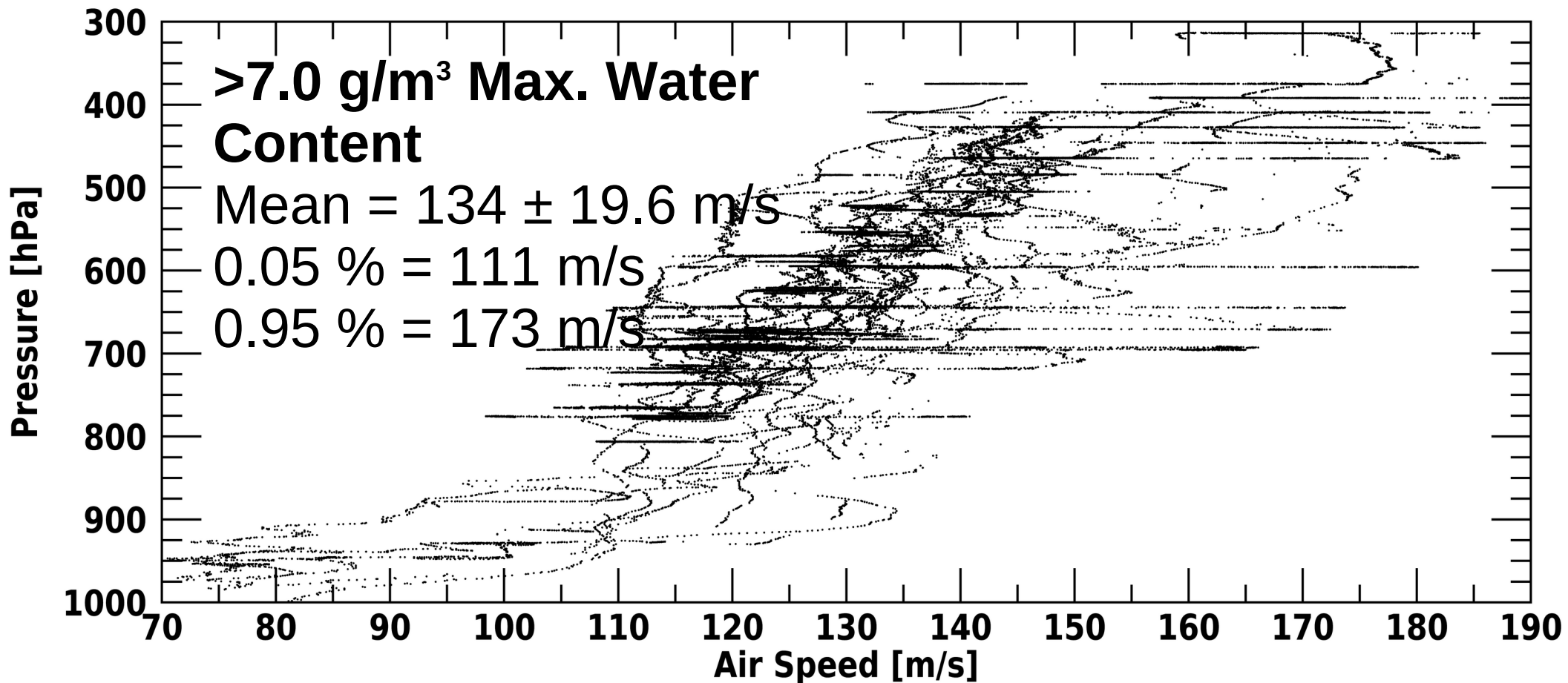
Liquid Water

140 °C Sensor Temperature



IMPACTS 2022: NASA P-3 Aircraft

Cloud Sampling ($\text{TWC}_{\text{WCM}} > 0.1 \text{ g/m}^3$) Air Speed



Water Content Meter (WCM) Probe Equations

Conclusions

The Forward Scattering Spectrum Probe (FSSP) and Cloud Droplet Probe have different optical systems that give different comparison to hot wire probes.

- The FSSP liquid water content agrees with the King Probe LWC in ice free conditions. Cases from two different field programs found FSSP to King ratios of 0.96 and 1.20.
- The cloud droplet probe uses different optical system than the FSSP. The July 20 POLCAST3 flights show CDP Liquid Water Content measurements 20% low compared to King Hot Wire probe measurements; however, other flights are worst.

Any Questions?

