

# HAIC/HIWC Science Meeting, May 2016

## DC-8 Nose Mounted Hot Wire & F-20 Belly Mounted Probes

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# Three Different Types of Probes Were Flown On the Nose of the DC-8

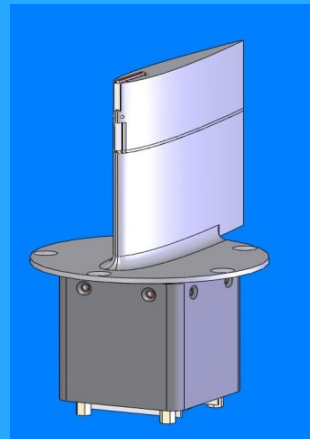
Probe Name	Probe Type	Number of Flights
Ice Crystal Detector (ICD)	Dual Element LWC+TWC	10
Standard Robust	Single Smooth TWC Element	1
Textured Robust	Single 3D Printed TWC Element	1

Pitot Probe    TAT Probe    Hot Wire Probe

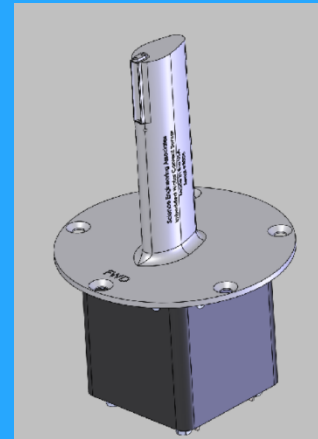


Hot Wire Probe Location

Xtal Detector



Robust



Hot Wire Probe Types

New  
3D Printed  
Element  
(Textured)



Standard  
Robust  
Element  
(Smooth)

Robust Element Styles



# Hot Wire Sensor Basics

- Heated Elements are Exposed to Airflow Containing Water in the form of Ice Crystals and Liquid Drops
- Amount of Electrical Power Needed to Maintain Constant Temperature in the Presence of Water is a Direct Measurement of Water Content
- Amount of Power Required to Maintain Temperature in the Presence of Dry Air Alone Needs to be Subtracted before Calculation of Water Content
- Different Shaped Elements can be used to Discriminate Between Ice Crystals and Liquid Water
- Nose Location Chosen to Provide Water Content Measurements at Actual Location of TAT and Pitot Probes – Concentration Factor

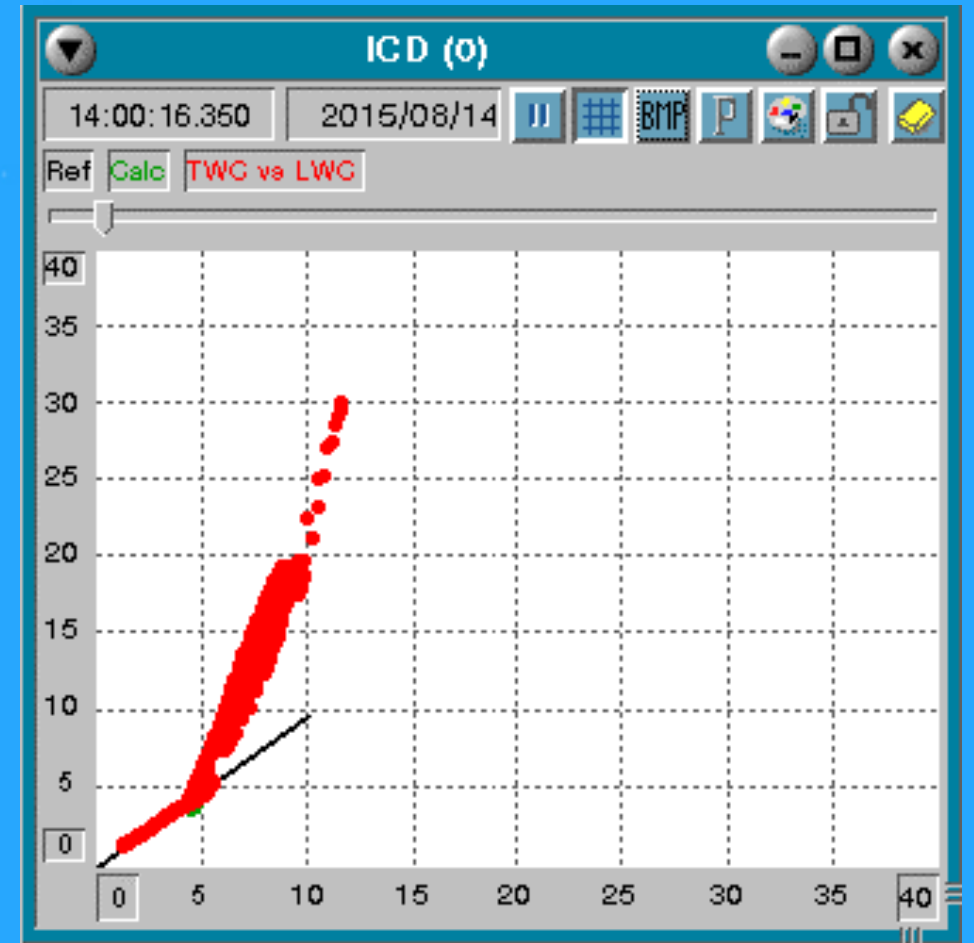
# Objectives

- Provide Real-Time, Easy to Interpret TWC Measurement During Flight
- Provide TWC Measurements at Actual Location of Pitot and TAT probes
  - Concentration Factor Due to:
    - Crystal Shattering on Aircraft Surfaces and Re-entering the Boundary Layer Flow
    - Aircraft Body Locations can be Enhancement Zones or Shadow Zones
- Standard (smooth) Robust
  - Common link to several HIWC programs that did or did not have the IKP as part of the Instrument Suite
    - Airbus
    - Falcon 20 Darwin, Cayenne
    - Various Wind Tunnel Tests – NRC, Cox, IRT, PSL
- Evaluate 3D Robust (textured) Robust Element for Collection Efficiency Improvement over the Standard Robust Element
- Evaluate Ice Crystal Detector in a Representative Installation Location for Large Aircraft

# Preliminary Results Ice Crystal Detector

- When processed as a conventional hot wire device, the ICD TWC Element Provided Good Real Time Data for Flight Operations (previous slide)
- Good Tracking of LWC and TWC Element Powers during shows good potential for simple detector mode operation in a non freestream location.

TWC Element Power - watts



LWC Element Power - watts

# Preliminary Results

## Real Time TWC Readings

Black Trace is from IKP – On Wing, Freestream

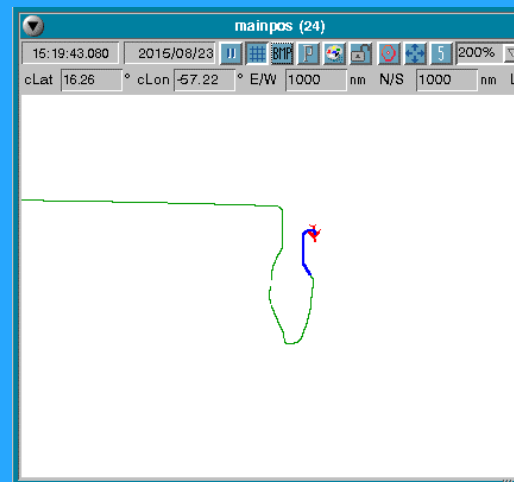
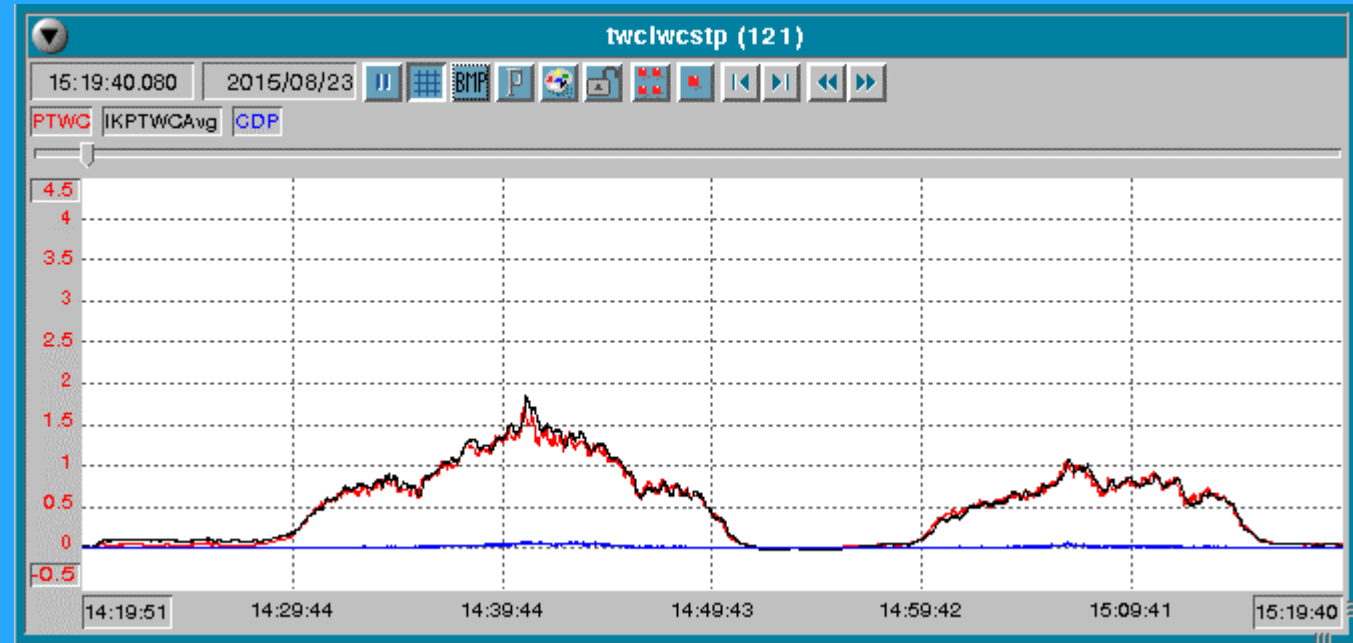
Red Trace is from ICD TWC Hotwire Element – On Nose

Red Trace is the data sent to DC-8 data system in real time

Good match implies that the concentration factor on the nose must be nearly the inverse of the efficiency for the TWC element.

The TWC element (ICD or Standard Robust) have ice crystal efficiencies of approximately 0.5 which implies the concentration factor at the nose is approximately 2.0

Serendipity or something else going on?



Data From August 23, 2015  
Tropical Storm Danny



# Simultaneous Solution for IWC and LWC Using Two Elements with Differing LWC and IWC Sensitivities

(Korolev, et al J.R.Met 2003)

$$TWC_m = a * IWC + b * LWC$$

$$LWC_m = c * IWC + d * LWC$$

Where:

TWC<sub>m</sub> = Amount of Water Measured by the TWC Element

LWC<sub>m</sub> = Amount of Water Measured by the LWC Element

IWC = Actual Ice Water Content

LWC = Actual Liquid Water Content

a = Overall efficiency of TWC element with respect to Ice Water

b = Overall efficiency of TWC element with respect to Liquid Water

c = Overall efficiency of LWC element with respect to Ice Water

d = Overall efficiency of LWC element with respect to Liquid Water

# Simultaneous Solution for IWC and LWC

Actual Case: ICD TWC and LWC Elements

$$a=0.462$$

$$b=0.950$$

$$c=0.112$$

$$d=0.900$$

$$IWC=0.900*TWCM - 0.950*LWCm/0.309$$

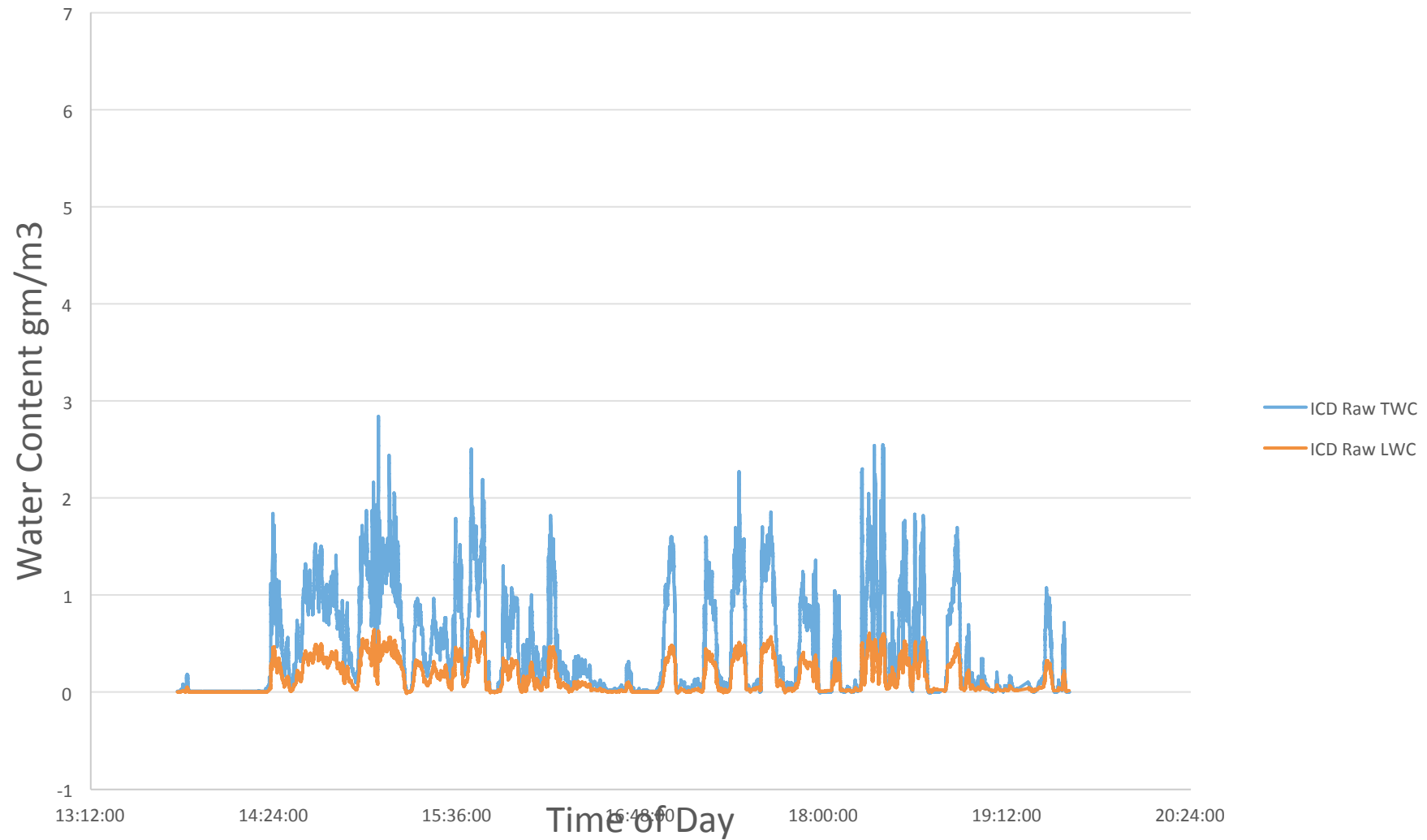
$$LWC=0.112*TWCM - 0.462*LWCm/-0.309$$



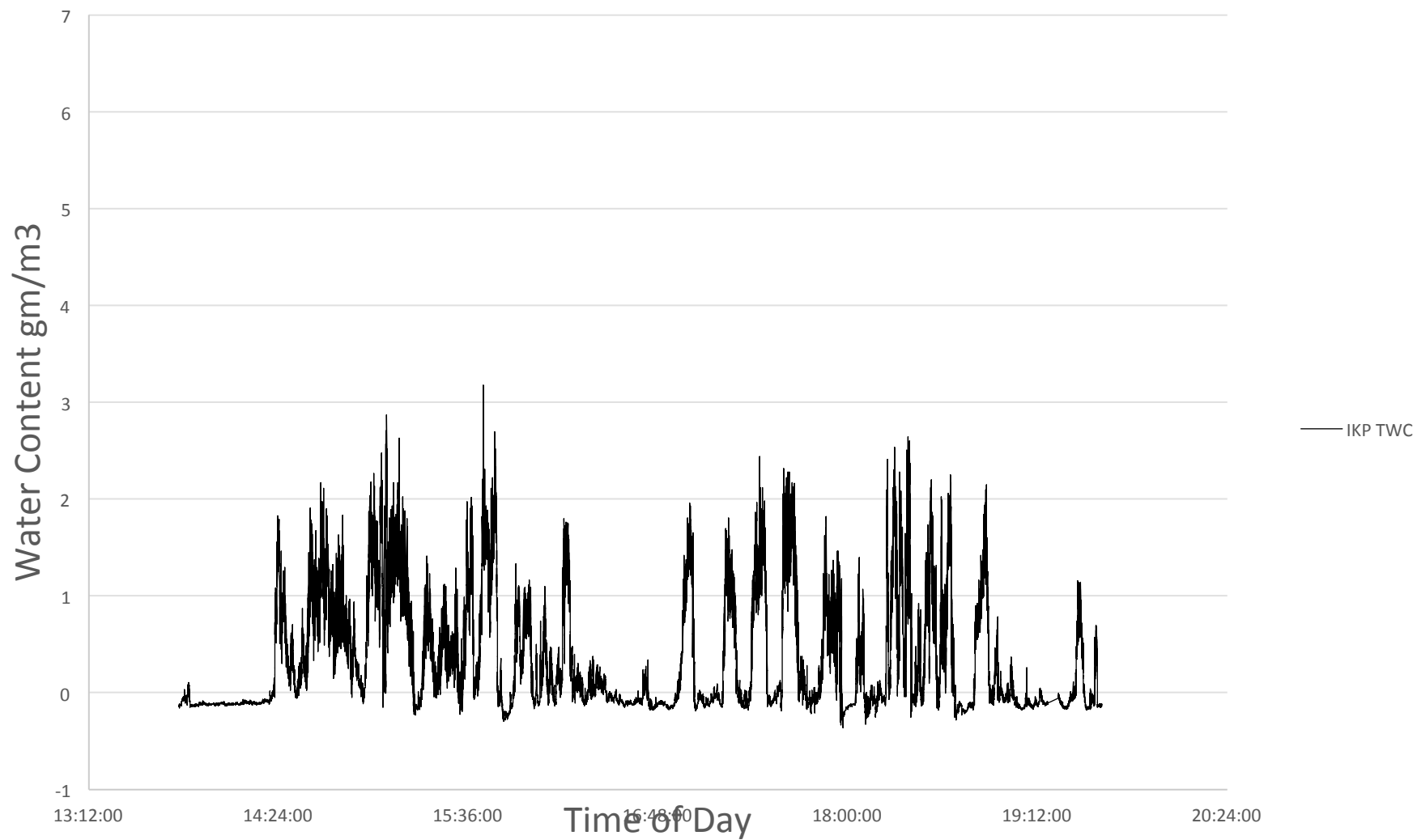


# ICD Raw Measurements - No Correction

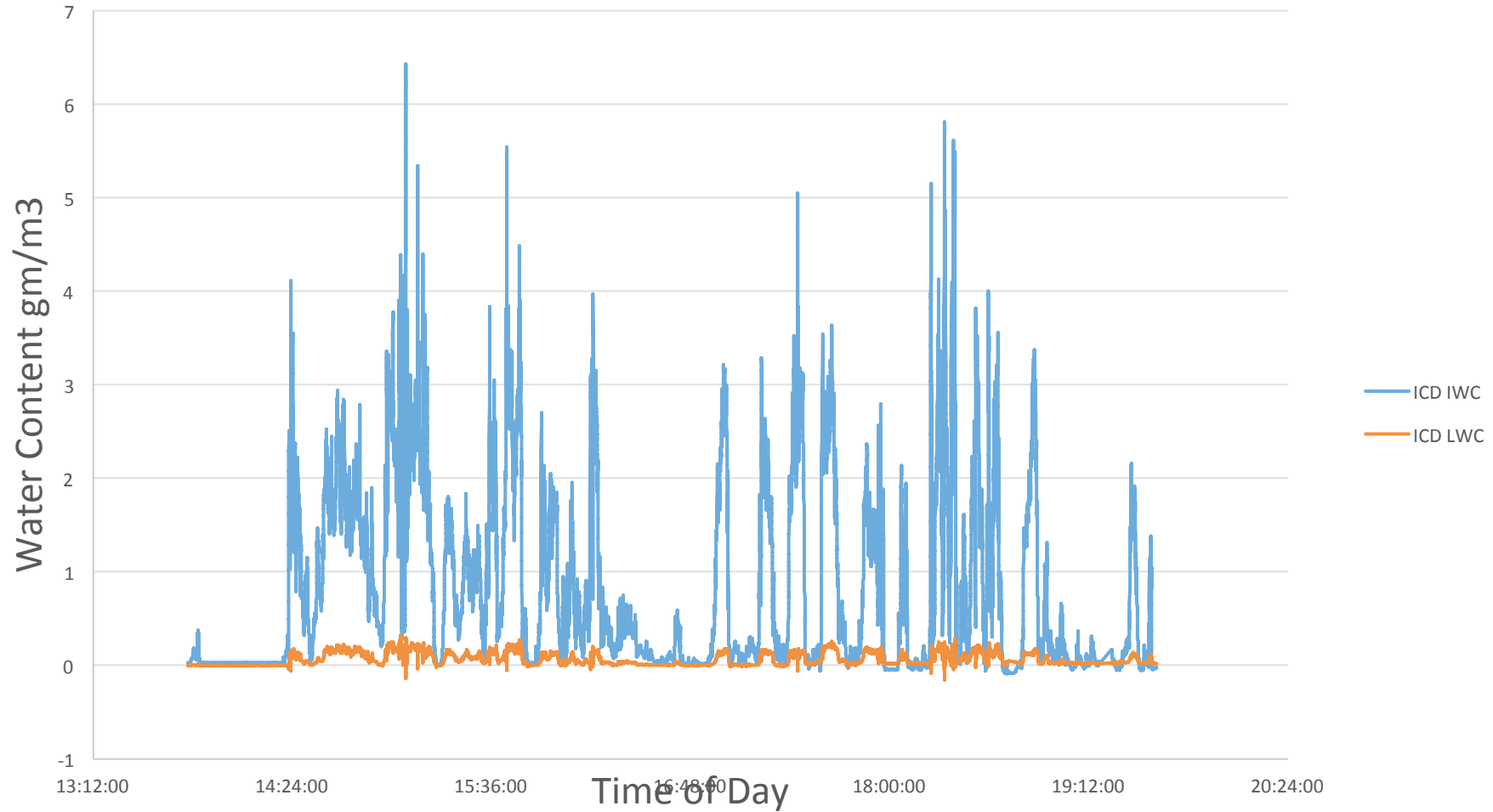
## DC-8 Flight 8/16/2015



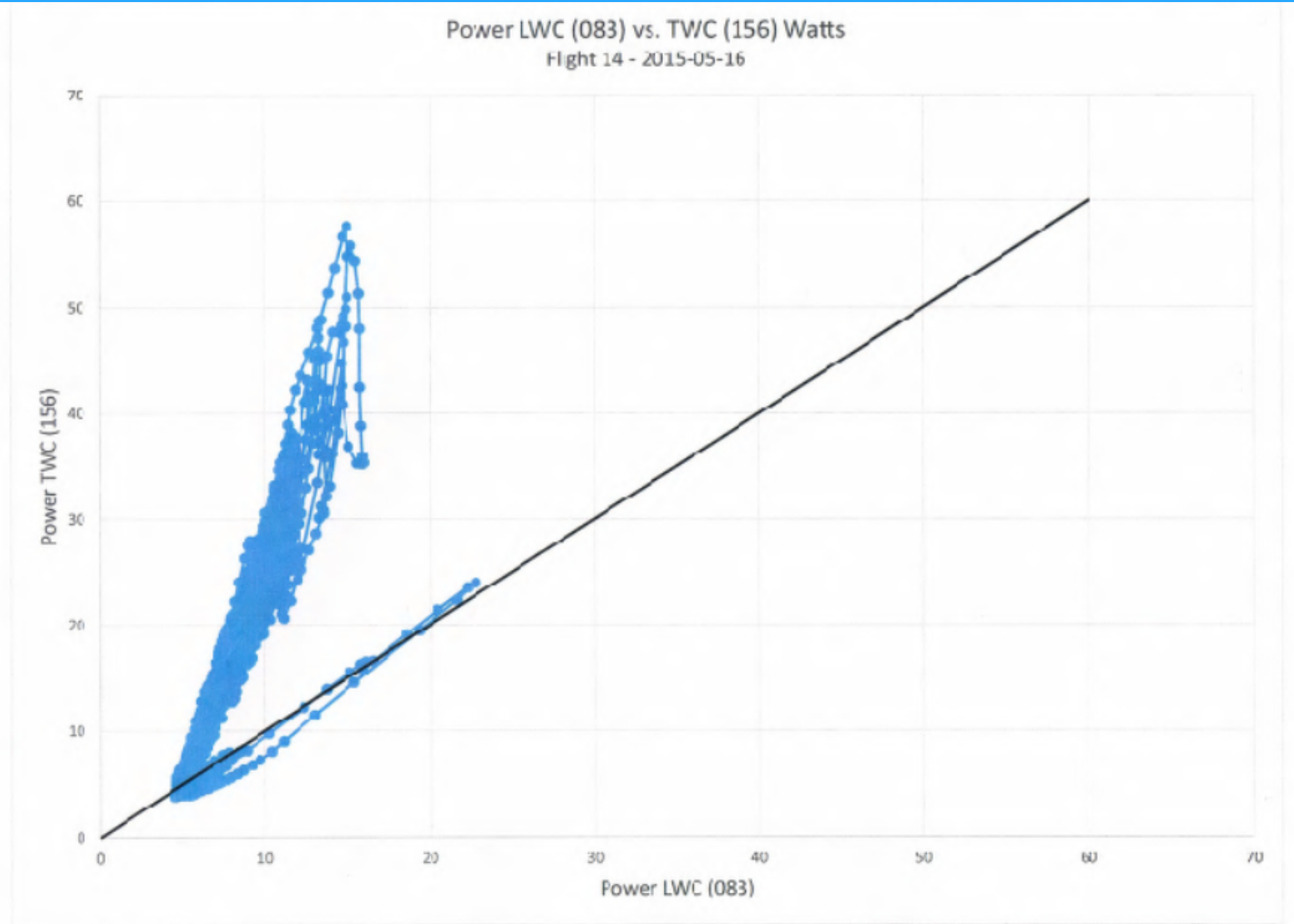
# ICD Raw Measurements - IKP DC-8 Flight 8/16/2015



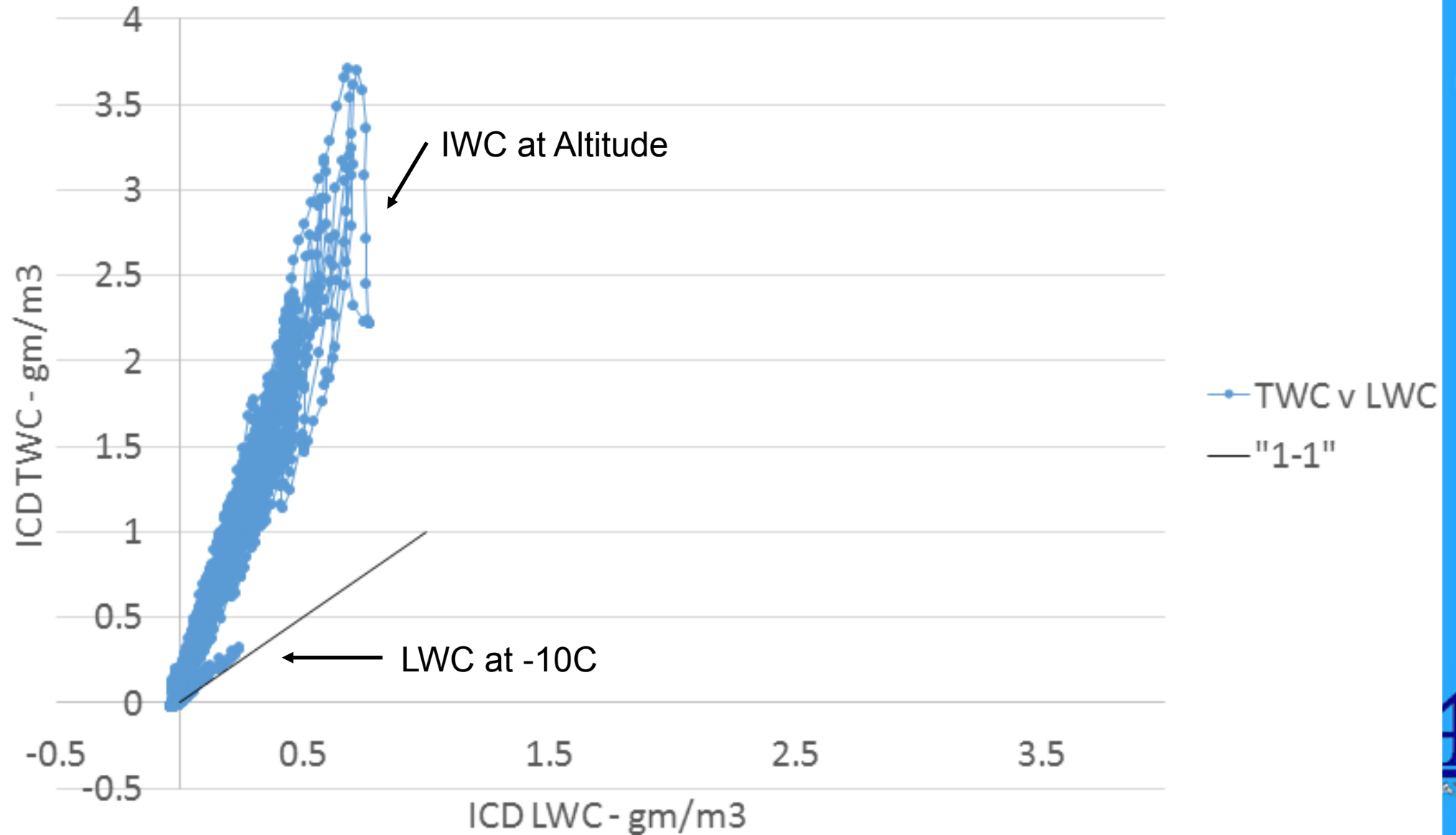
ICD Simultaneous IWC/LWC Solution  
DC-8 Flight 8/16/2015  
GKN Coefficients Coefficients



HAIC Cayenne  
Falcon 20, 2015



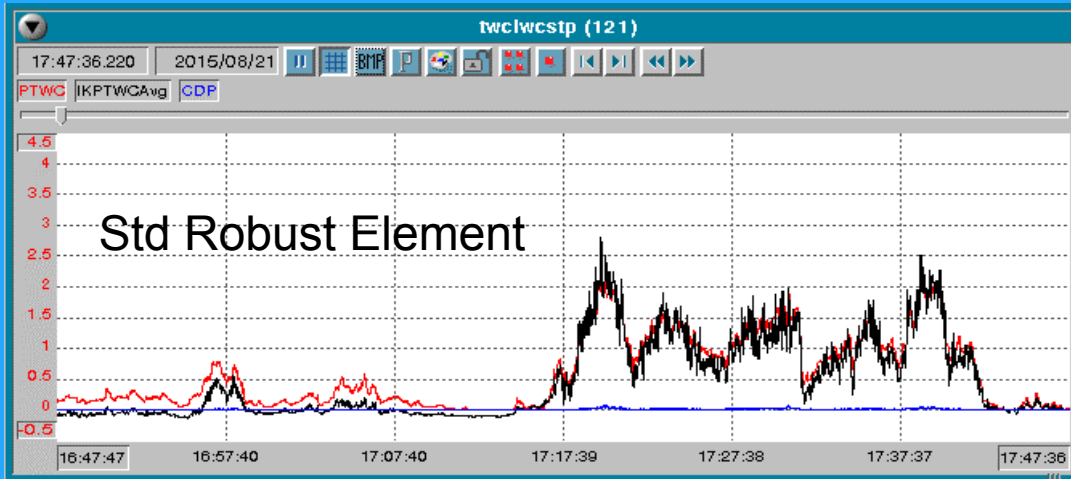
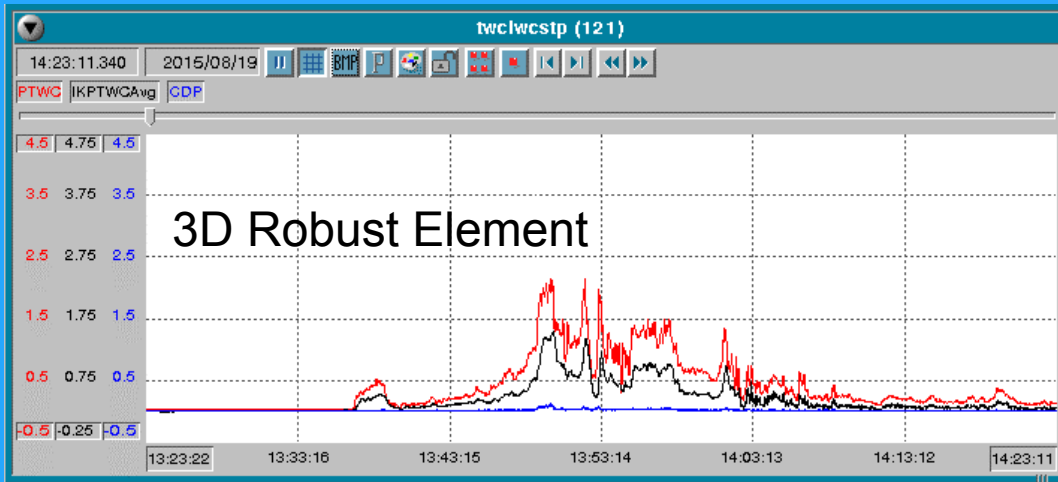
LWC Encounter at -10C During Climb to Altitude



# Preliminary Results

## 3D Robust Element

Black Trace is from IKP – On Wing  
 Red Trace is from TWC Hotwire Element – On Nose



Data From August 19, 2015

STD Robust / IKP	3D Robust / IKP	3D / STD Robust
0.84 Note 1	1.39 Note 1	1.65

Assumed STD Robust / True	Implied 3D Robust / True
0.50	0.82 Note 2

Note 1: Robust Probe(s) on Nose, IKP on Wing

Note 2: Very Preliminary Result Based on just two flights, one flight for each probe



# Future Activities

An ICD is currently reinstalled for medium/  
long term presence on DC-8

## Acknowledgements

- Boeing Commercial Aircraft
- FAA
- NASA Armstrong Research Center
- NASA Glenn Research Center
- NASA Langley Research Center
- UND NSERC
- SAFIRE
- HAIC
- Airbus
- GKN



Spare Slide  
#1

Facility	Date	Std Robust / Reference	3D Robust / Reference	3D Robust / Std Robust	Std Robust / True	3D Robust / True
DC_8	Aug 2015	0.84	1.39	1.65	0.5	0.82
GKN	Sept 2015	0.64	0.85	1.4	0.64	0.85