MMS on the NASA Global Hawk:
Initial Results from the Global Hawk Pacific Mission (GloPac)

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Airborne Tropical Tropopause Experiment (ATTREX)

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Meteorological Measurement System: Precision and Accuracy Metrics

Variable	Typical Value	Precision	Accuracy
Static Pressure (p)	**60 hPa**	**± 0.01 hPa**	**± 0.3 hPa**
Static Temperature (T)	**190 K**	**± 0.01 K**	**± 0.3 K**
Horizontal Wind (u, v)	**30 ms^{-1}**	**± 0.1 ms^{-1}**	**± 1 ms^{-1}**
Vertical Wind (w)	**< 1 ms^{-1}**	**± 0.1 ms^{-1}**	**± 0.3 ms^{-1}**

Other Meteorological Parameters Available at 20 Hz:

Potential Temperature ([illegible]), True Air Speed, Turbulence Intensity ([illegible]),
GPS Position, Velocity, and Acceleration; Pitch, Roll, and Heading;
Angle of Attack, Angle of Sideslip (Yaw);
Dynamic and Total Pressures, Total Temperature

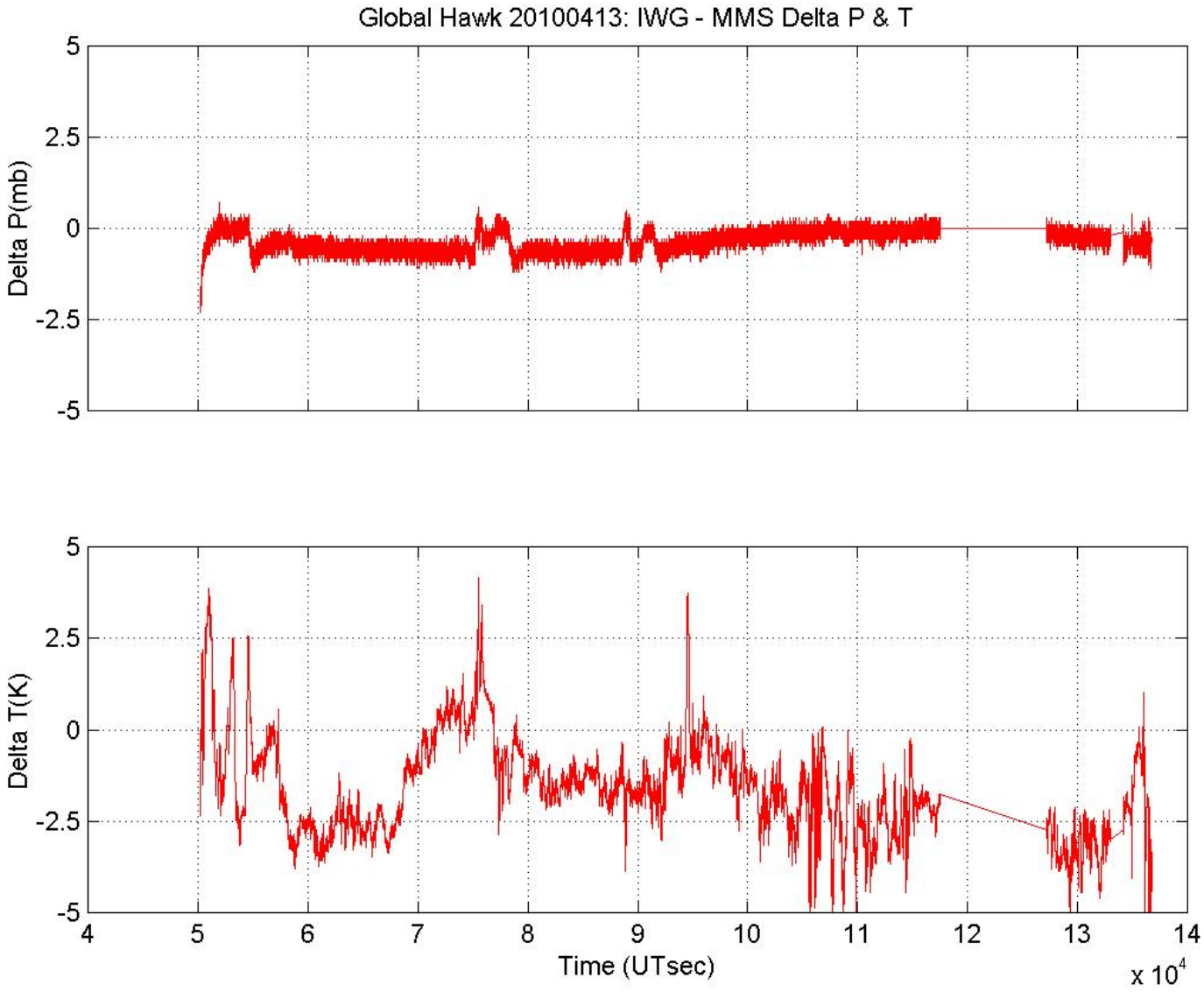
MMS Calibration / Quality Control & Verification Process

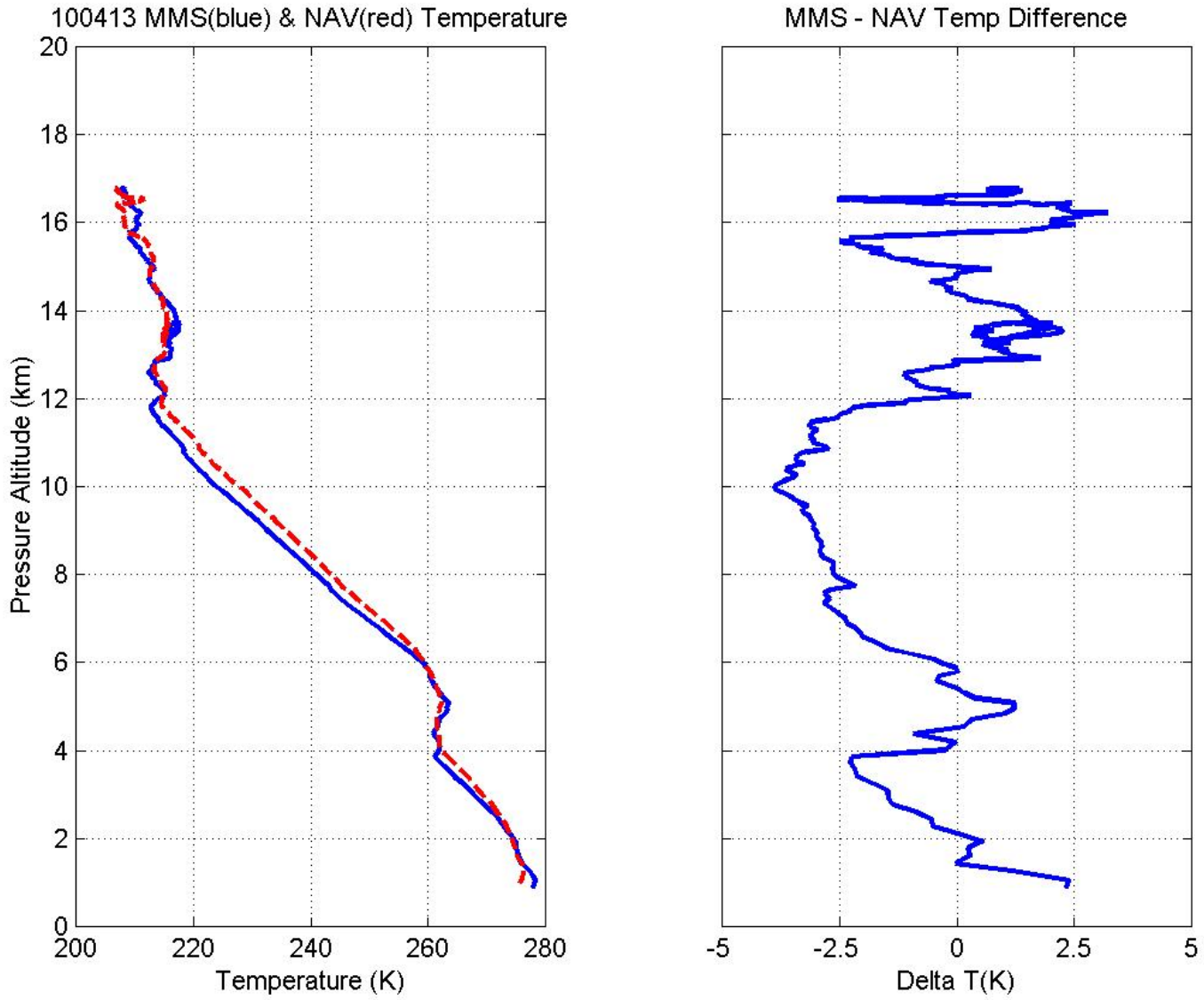
- Individual Sensor Calibrations (re-certification to NIST standards)
- Sensor Dynamic Response Tests
- Dynamic Characterization of Inertial Navigation System
- In-Flight Aerodynamic Calibration (aircraft pitch, yaw, turning maneuvers)

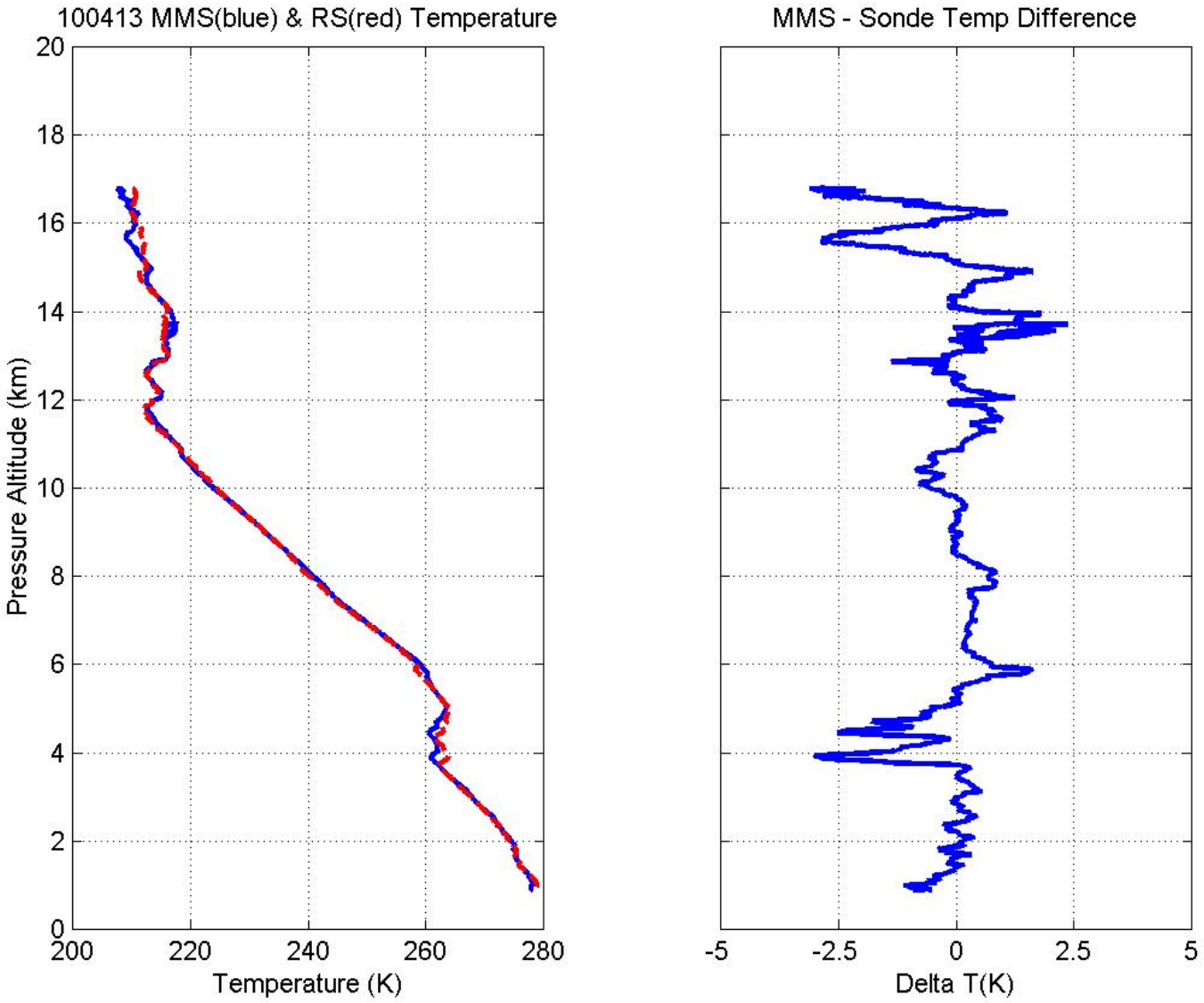
- Comparison with Radiosondes (close proximity with space & time)

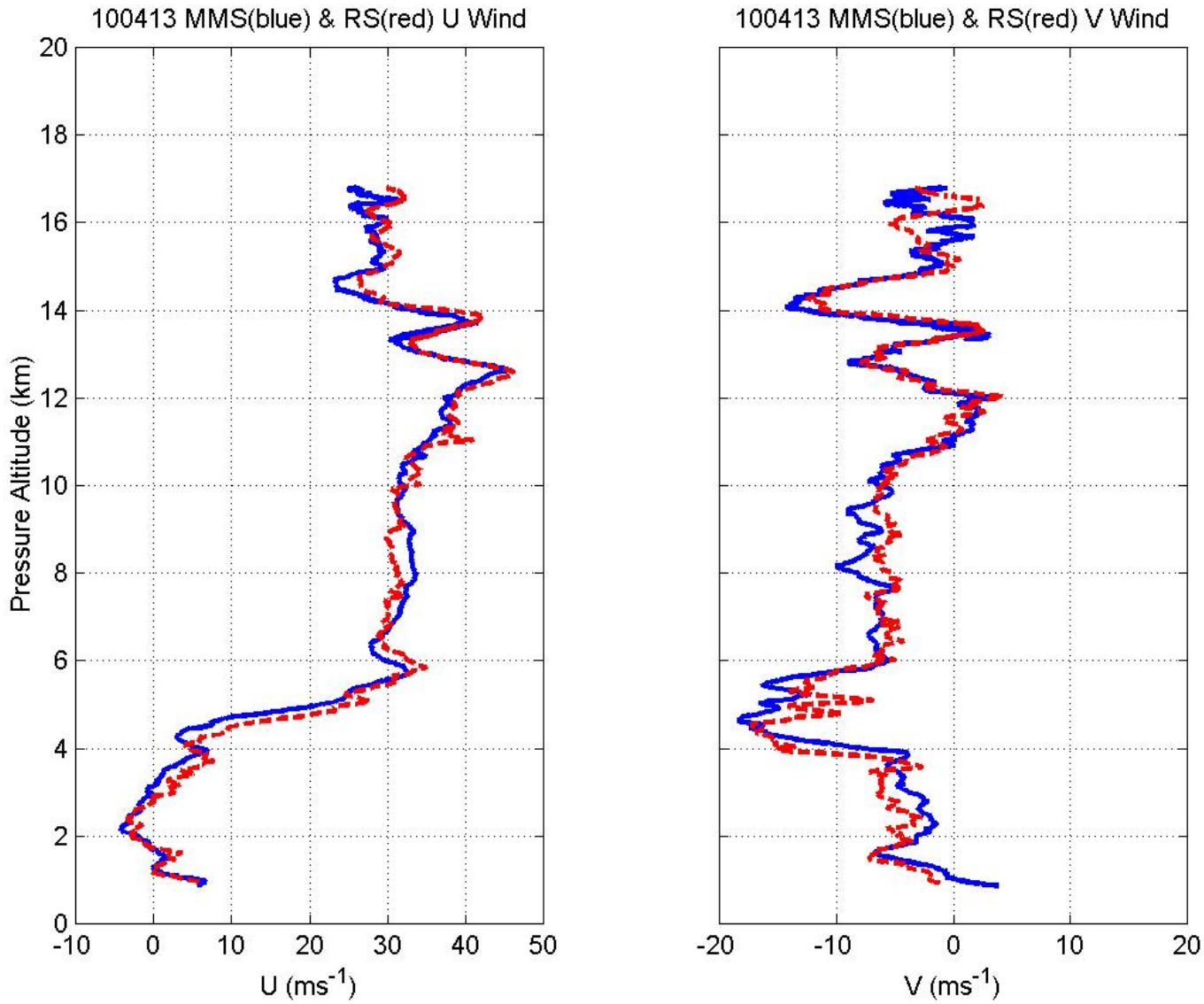
and other measurements as available (aircraft navigation system)

Preliminary MMS data for GloPac was submitted in April 2010


Global Hawk 20100413: IWG - MMS Delta P & T
Delta P(mb)
5
2.5
0
-2.5
-5
Delta T(K)
5
2.5
0
-2.5
-5
4
5
6
7
8
9
10
11
12
13
14
Time (UTsec)
x 10^4


100413 MMS(blue) & NAV(red) Temperature
Pressure Altitude (km)
Temperature (K)
0
2
4
6
8
10
12
14
16
18
20
200
220
240
260
280
MMS - NAV Temp Difference
Delta T(K)
-5
-2.5
0
2.5
5


100413 MMS(blue) & RS(red) Temperature
Pressure Altitude (km)
0
2
4
6
8
10
12
14
16
18
20
200
220
240
260
280
Temperature (K)
MMS - Sonde Temp Difference
-5
-2.5
0
2.5
5
Delta T(K)

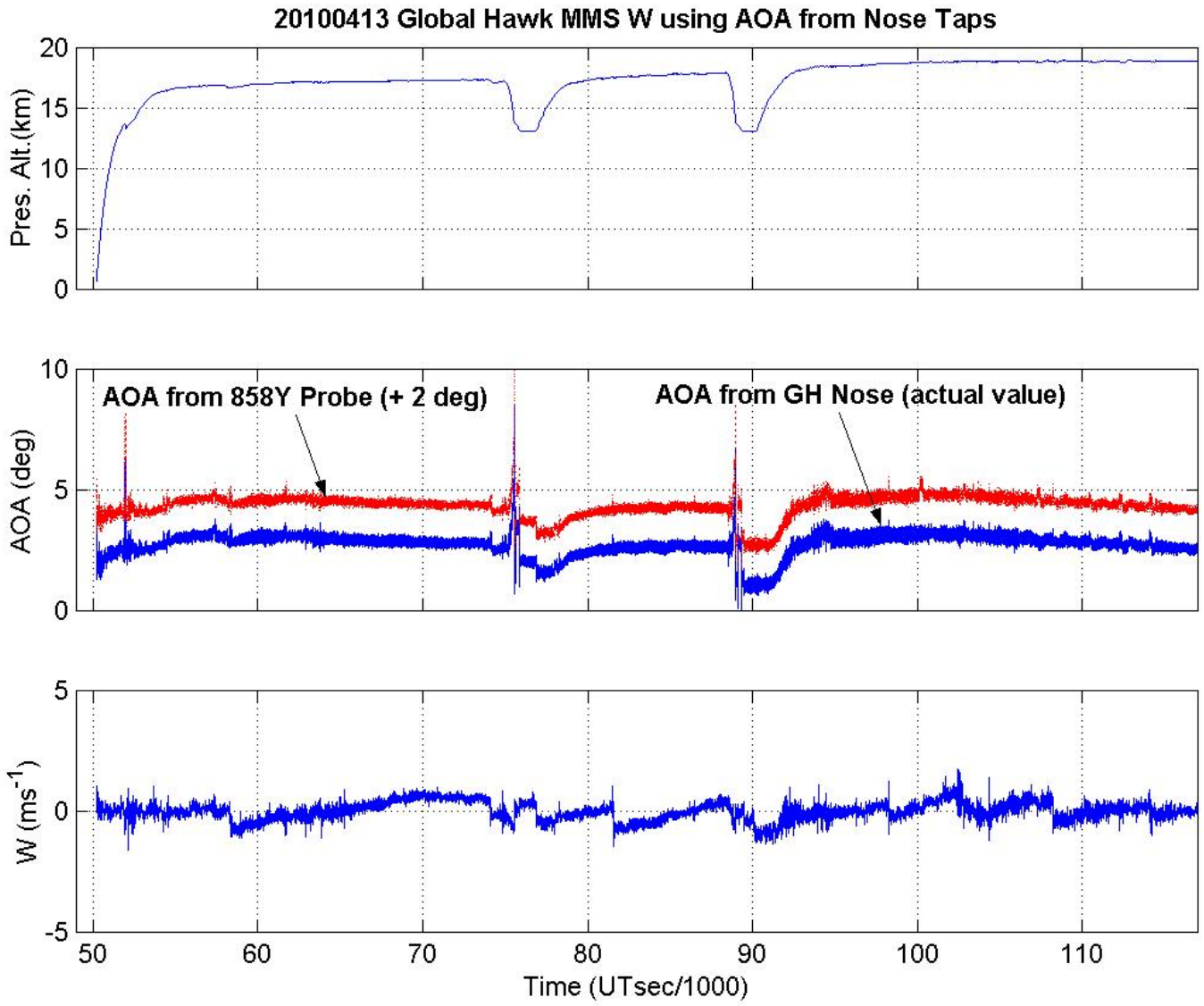

100413 MMS(blue) & RS(red) U Wind
Pressure Altitude (km)
U (ms-1)
100413 MMS(blue) & RS(red) V Wind
V (ms-1)

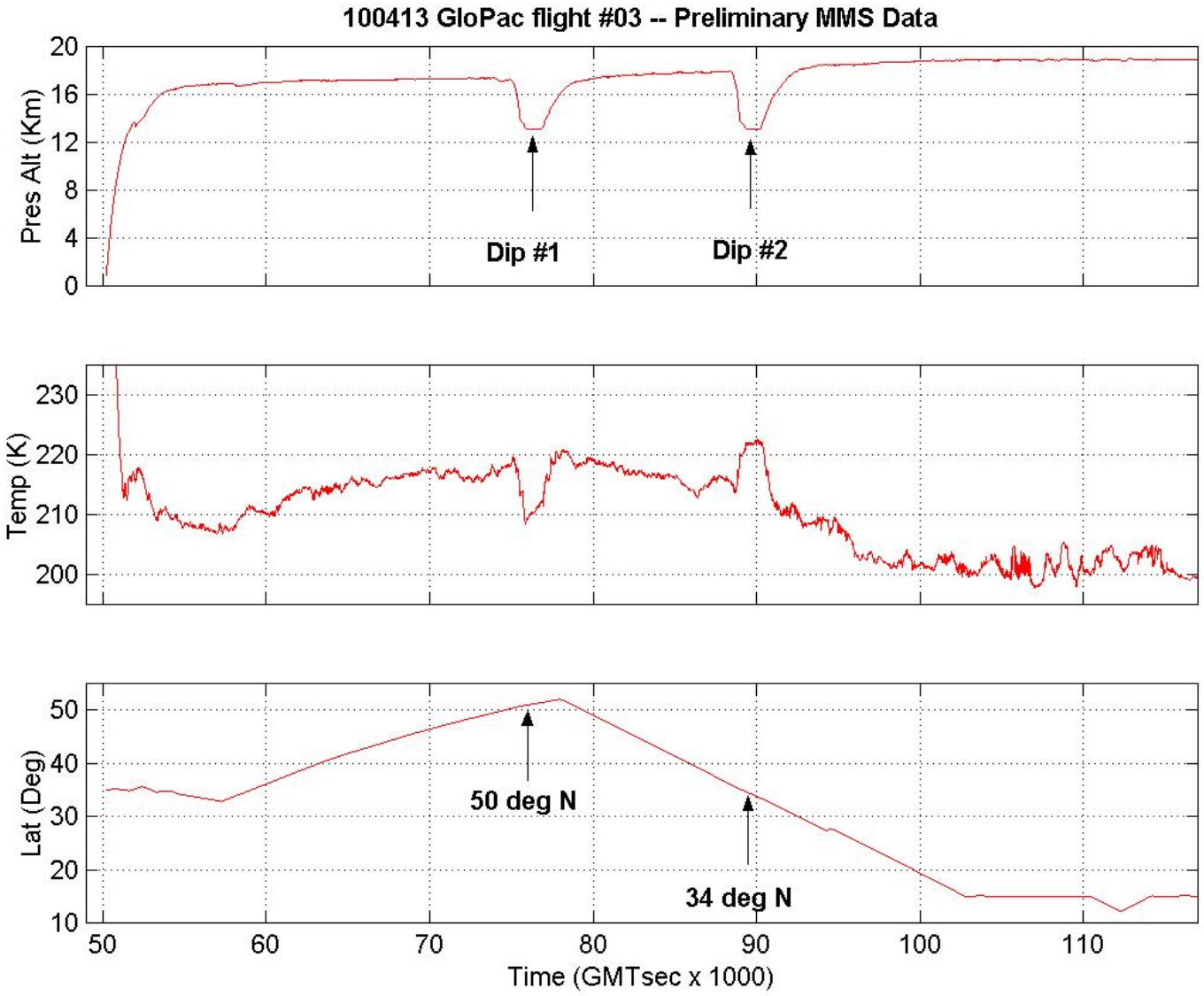
MMS – EDW Radiosonde Comparison Statistics

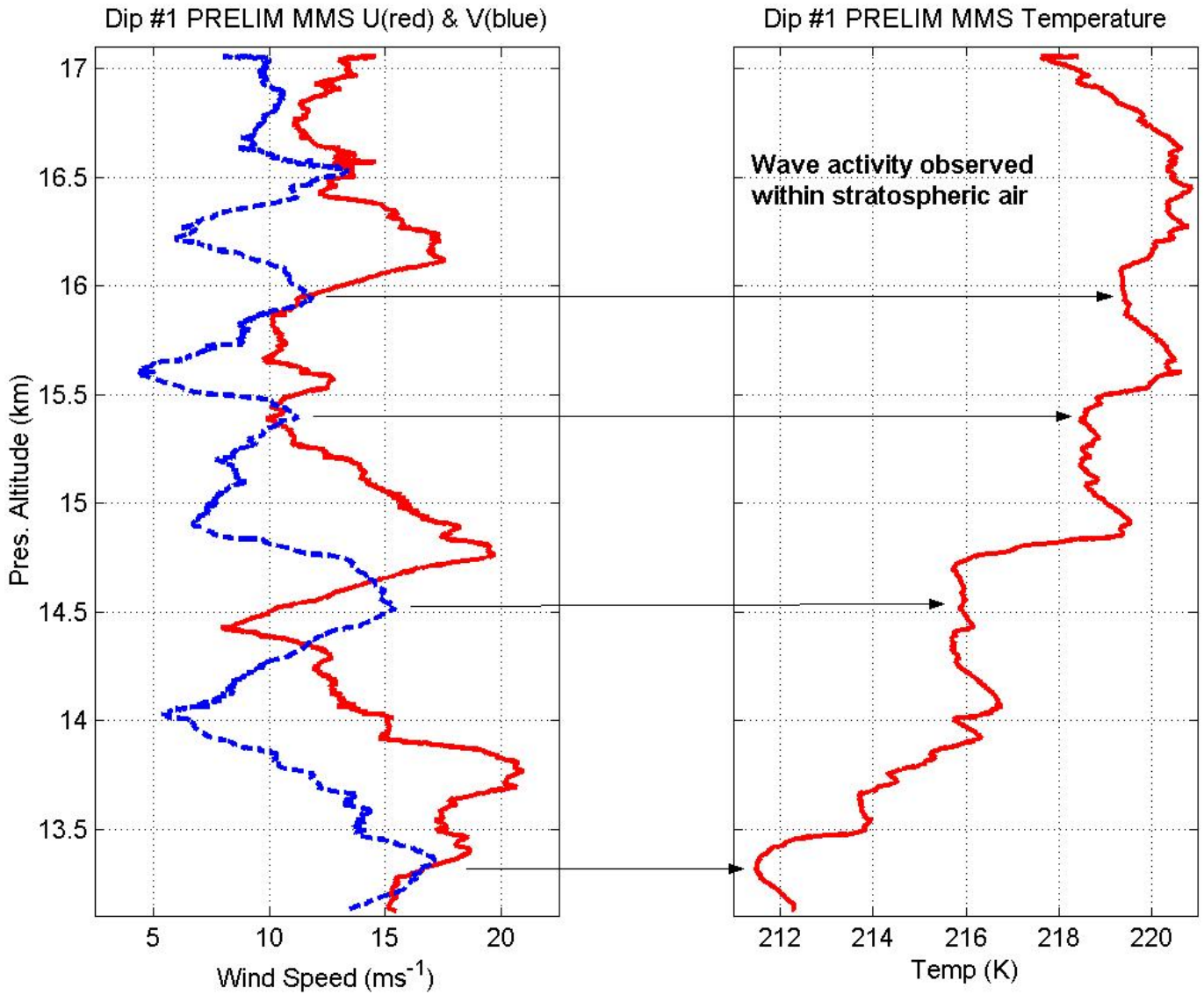
- Comparisons were made using GH ascent data on 4/2, 4/7, 4/13 & 4/23
- Pressure values were used as the independent variable (not altitude)
- Mesoscale variability was not accounted for (or removed)

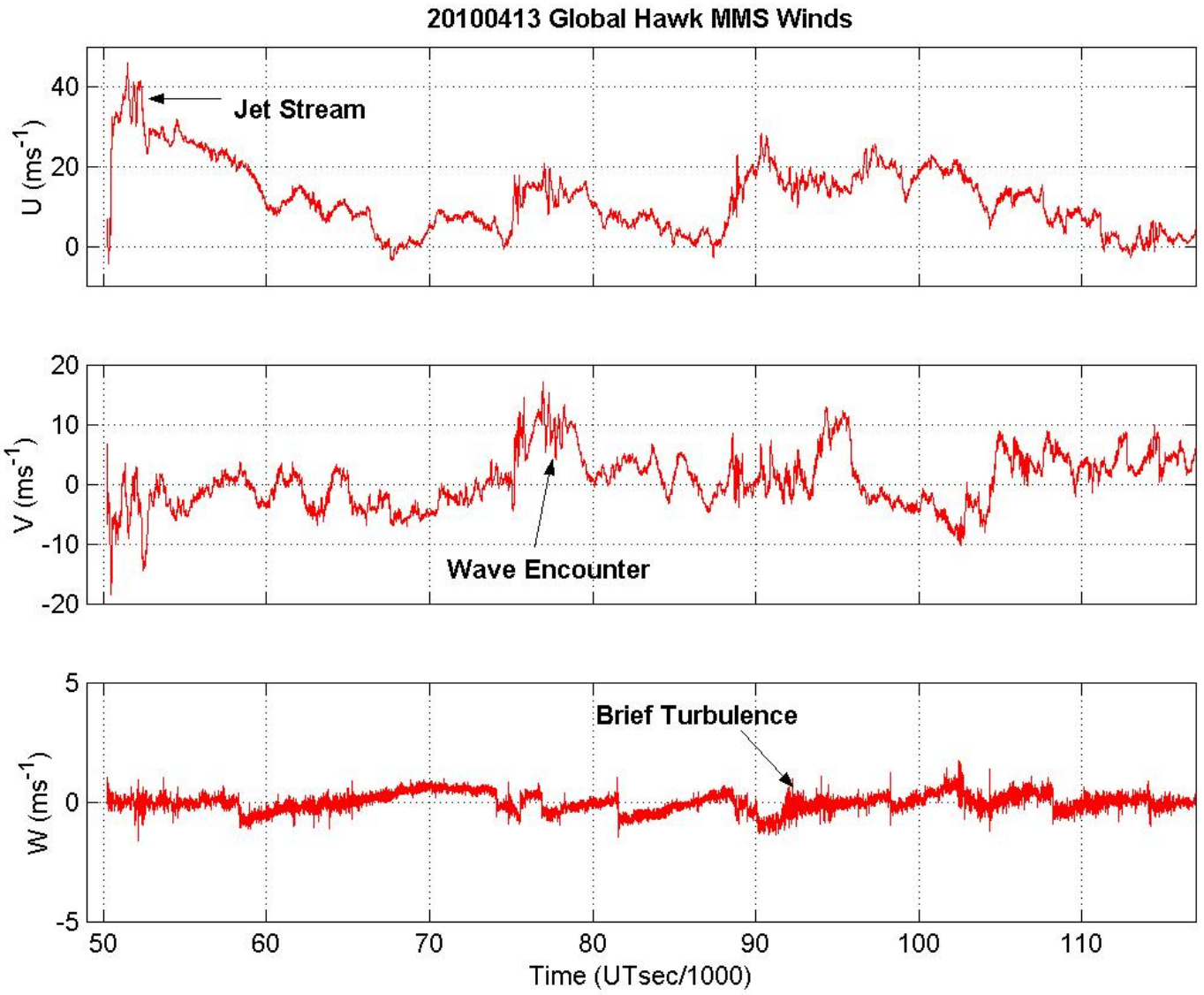
Variable	MMS – EDW difference	# Samples
T	-0.42 ± 0.61 K	4
u	-1.35 ± 1.48 ms^{-1}	3
v	-0.68 ± 2.07 ms^{-1}	3
$\left\|\vec{V}_H\right\|$	1.51 ± 2.54 ms^{-1}	

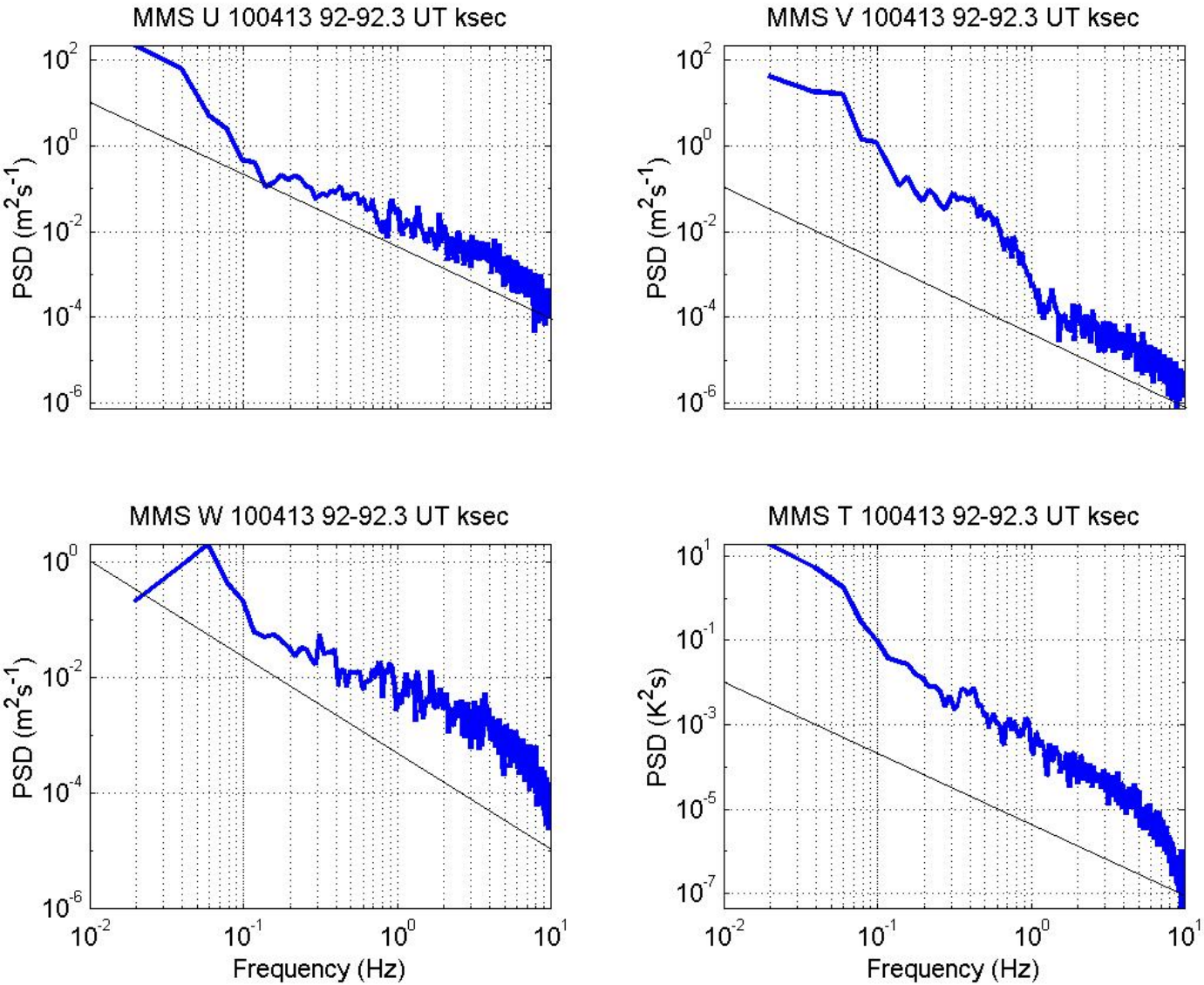
MMS on Global Hawk for GLOPAC


20100413 Global Hawk MMS W using AOA from Nose Taps
Pres. Alt.(km)
20
15
10
5
0
AOA (deg)
10
5
0
AOA from 858Y Probe (+ 2 deg)
AOA from GH Nose (actual value)
W (ms-1)
5
0
-5
50
60
70
80
90
100
110
Time (UTsec/1000)


100413 GloPac flight #03 -- Preliminary MMS Data
Pres Alt (Km)
20
16
12
8
4
0
Dip #1
Dip #2
Temp (K)
230
220
210
200
Lat (Deg)
50
40
30
20
10
50 deg N
34 deg N
50
60
70
80
90
100
110
Time (GMTsec x 1000)


Dip #1 PRELIM MMS U(red) & V(blue)
Dip #1 PRELIM MMS Temperature
Wave activity observed
within stratospheric air
Pres. Altitude (km)
17
16.5
16
15.5
15
14.5
14
13.5
5
10
15
20
Wind Speed (ms-1)
212
214
216
218
220
Temp (K)


20100413 Global Hawk MMS Winds
U (ms-1)
40
20
0
Jet Stream
V (ms-1)
20
10
0
-10
-20
Wave Encounter
W (ms-1)
5
0
-5
Brief Turbulence
50
60
70
80
90
100
110
Time (UTsec/1000)


MMS U 100413 92-92.3 UT ksec
MMS V 100413 92-92.3 UT ksec
MMS W 100413 92-92.3 UT ksec
MMS T 100413 92-92.3 UT ksec
PSD (m²s⁻¹)
PSD (K²s)
Frequency (Hz)

Looking Forward: MMS Concerns for ATTREX

- **Install dedicated GPS antenna in Zone 7**
  (GPS correction critical for INU accuracy)
- **Payload power availability during descent**
  (UPS capacity to maintain INU alignment)
- **Maintain aerodynamically clean air flow ahead of our static pressure ports**
- **More reliable data link**
- **Fly Litton LN-100G INS?** (subject to constraints)
- **Improved pitch maneuvers** (what algorithm yields the required motion?)
- **MMS Calibration for GloPac is incomplete** (Further work on $\boldsymbol{p}$, $\boldsymbol{w}$, etc.)