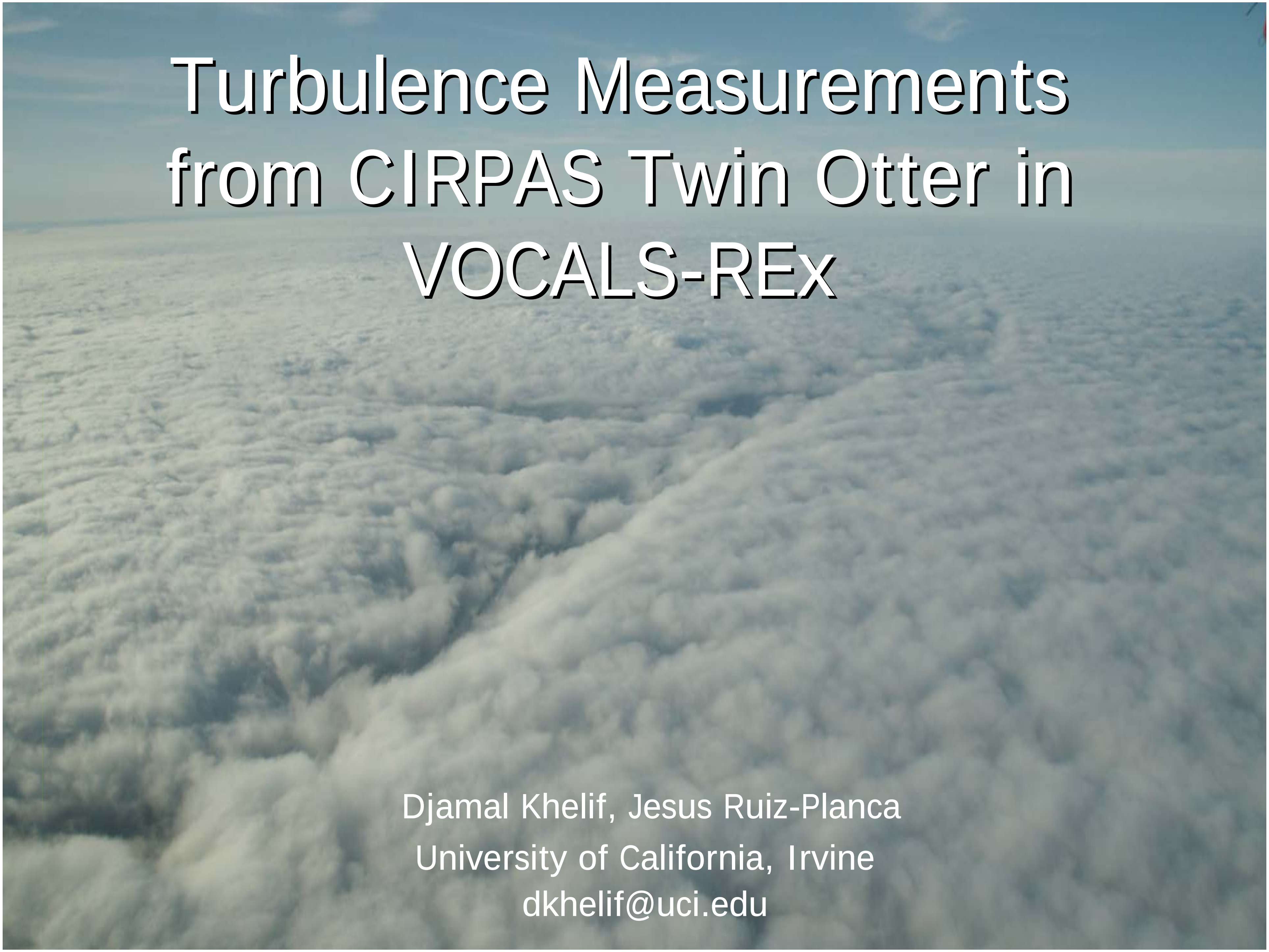
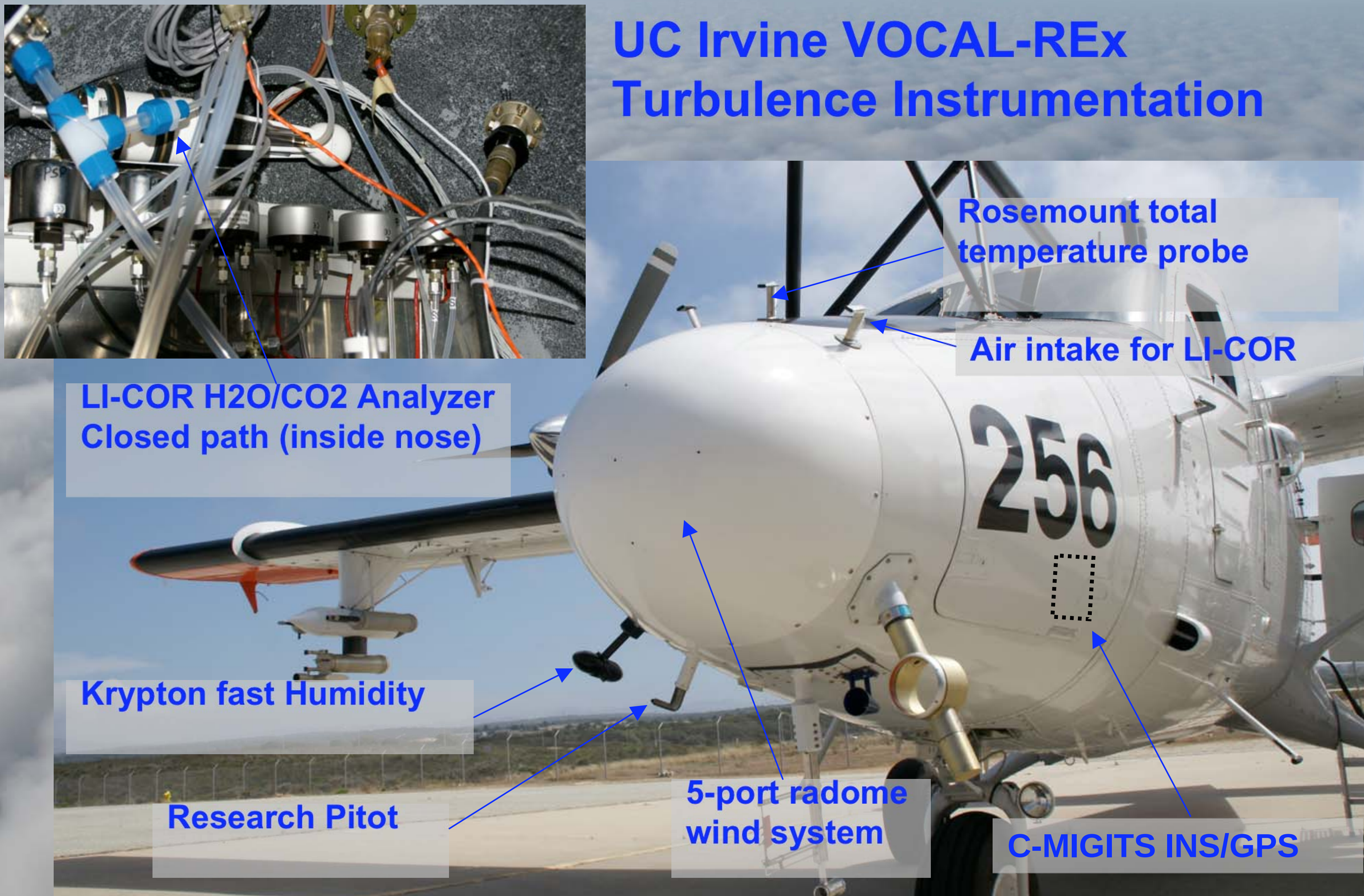


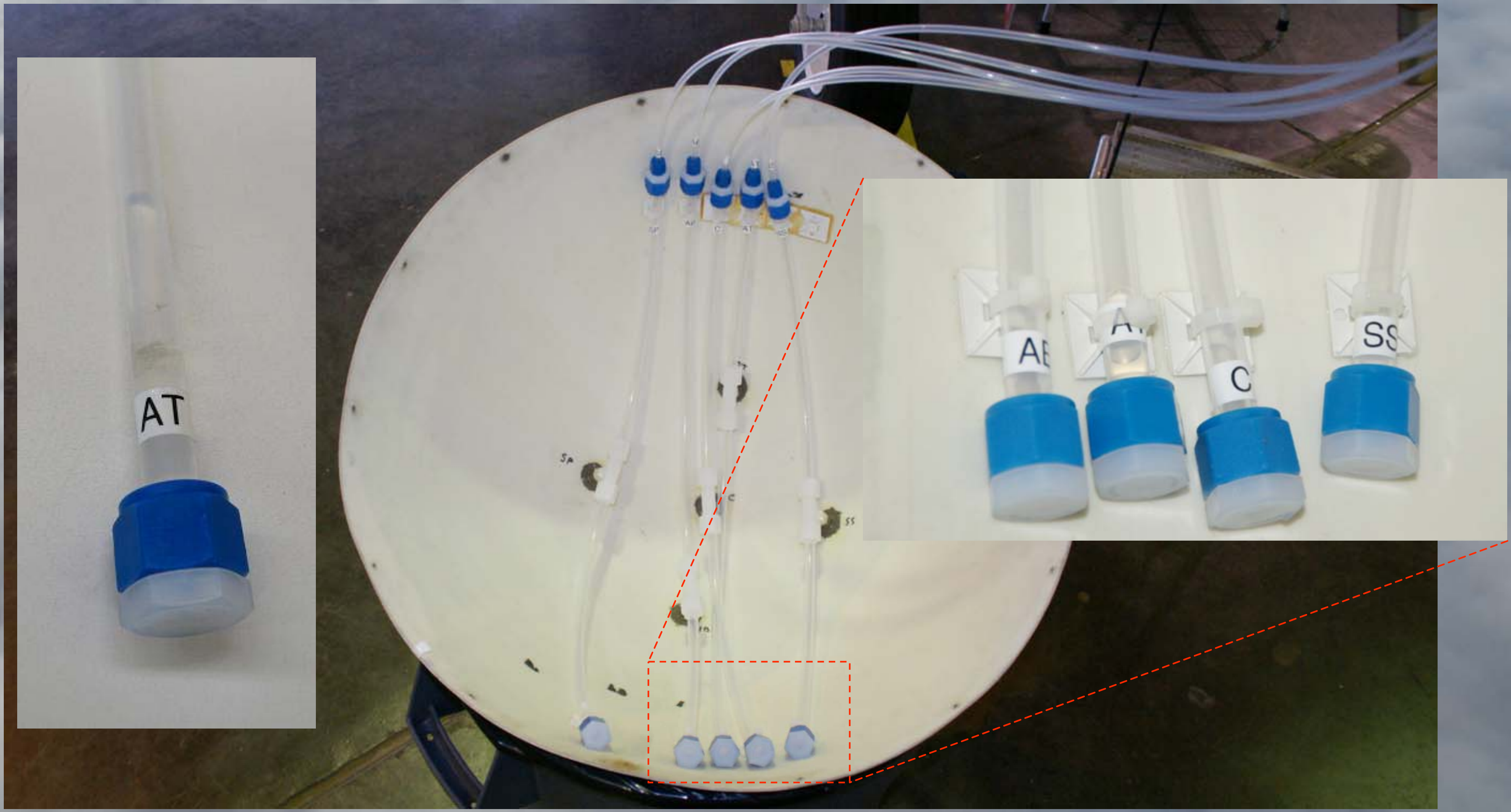
Turbulence Measurements from CIRPAS Twin Otter in VOCALS-REx

Djamal Khelif, Jesus Ruiz-Planca
University of California, Irvine
dkhelif@uci.edu

UC Irvine VOCAL-REx Turbulence Instrumentation



New radome plumbing, effectively traps clouds (or rain) liquid water preventing it from obstructing the pressure xducers lines. **Zero failure in POST and VOCALS-REx.**



Status of Instruments Logged on UCI Data System

VOCALS-REx Oct16 - Nov13 2008		UTC Date	10/16	10/17	10/19	10/21	10/22	10/24	10/26	10/27	10/29	10/30	11/01	11/02	11/04	11/05	11/08	11/09	11/10	11/12	11/13
Contact Scientist	**Instrument**	**Fltight**	**TO1**	**TO2**	**TO3**	**TO4**	**TO5**	**TO6**	**TO7**	**TO8**	**TO9**	**TO10**	**TO11**	**TO12**	**TO13**	**TO14**	**TO15**	**TO16**	**TO17**	**TO18**	**TO19**
hjonsson@nps.edu	Rosemount Temperature																				
dkhelif@uci.edu	Rosemount Temperature (UCI)																				
dkhelif@uci.edu	LI-COR 7500 CO2 (UCI)																				
dkhelif@uci.edu	LI-COR 7500 Humidity (UCI)		xx																		
hjonsson@nps.edu	Edge-Tech Dewpoint																				
dkhelif@uci.edu	Mod. Krypton Hygrometer (UCI)																				
hjonsson@nps.edu	Radar Altimeter																				
hjonsson@nps.edu	Static Pressure																				
dkhelif@uci.edu	Radome Gust System (UCI) (x)																				
hjonsson@nps.edu	Heiman SST																				
dkhelif@uci.edu	Upward-looking IR Temp. (UCI)																				
dkhelif@uci.edu	C-MIGITS (UCI)																				

Legend

UCI | UCI and CIRPAS | Operational | Some data | No data | (x) Different processing | (xx) Clipped at 3.6 g/m^3

UCI 40-Hz MATLAB data available to Iquique Group

Name	Description	Units	Accuracy
t	elapsed Time in seconds since 0 UTC of flight (data file) start day	s	0.5 ms
ap	Pressured Altitude (adjusted to radar altitude)	m	1 m
lat	Latitude	deg N (decimal)	< 0.00002 deg
lon	Longitude	deg E (decimal)	< 0.00002 deg
hdg	true HeaDinG from UCI's C-MIGITS III range [0 360] deg	deg	0.3 deg
wx	Wind component in the east direction (X-axis)	m/s	0.4 m/s
wy	Wind component in the north direction (Y-axis)	m/s	0.4 ms
wz	Wind component in the vertical direction (Z-axis)	m/s	0.2 m/s
ah	Absolute Humidity from UCI's LI-COR 7500	g/m^3	?
ta	static Ambient Temperature from UCI's Rosemount fast-response sensor	^oC	0.4 ^oC
td	ambient Dewpoint Temperature from CIRPAS's Edgtech Chilled mirror	^oC	0.4 ^oC
ts	Sea surface Temperature from CIRPAS's downlooking Heiman KT 19.85 IR sensor	^oC	0.4 ^oC
ps	Static atmospheric Pressure from fuselage flush ports and Setra 270 transduce	hPa	5 Pa
tas	True Air Speed (Dry Air)	m/s	0.2 m/s
rhoa	Moist Air density	kg/m^3	?
mr	Mixing Ratio from UCI's LI-COR 7500	g/kg	?
thet	potential temperature (theta)	K	0.4 ^oC
tvir	VIRtual Temperature	^oC	0.4 ^oC
thete	Equivalent potential temperature (thetae)	K	0.4 ^oC
tirup	Temperature from UCI's IR UPward-looking temperature sensor	^oC	?
flip	FLIP-flop 1/2 Hz GPS synchronisation signal from 1-Hz CIRPAS C-MIGITS III pulse	V	?
tdl	Dewpoint Temperature from UCI's LI-COR 7500	^oC	0.3 ^oC

Data Policy

data_policy - Notepad

File Edit Format View Help

IMPORTANT NOTE TO USERS OF UCI DATA

1. P.I.s have ready access to the data produced by the other P.I.s.
2. The data is not available to the public for 1 year.
3. P.I.s can provide at any time copies of their probe'ssensor's data to whomever they chose.
4. Data from a P.I. may not be shared with others without the P.I.'s agreement.
5. Publications using another P.I.'s data give this other P.I. the option of being a co-author.

Please register as a UCI VOCALS-REx data user to be updated on future modifications to the data set and for possible cooperation in the data analysis and publication of results. To do so, please send a message with VOCALS-REx UCI data registration as the subject and your contactinstitution information in the message body to

Djamal Khelif
University of California, Irvine
Dept. Mech. & Aerospace Eng.
Irvine, CA 92697-3975 USA
e-mail dkhelif@uci.edu
Phone 949 824 7437

Available Data on UCI server

http://wave.eng.uci.edu/files/vocals/datacuts/matlab_40Hz/

User name: otter

Password: [to get it, send me a request at: dkhelif@uci.edu]

40-Hz MATLAB data
1-Hz MATLAB data
Will add ASCII version of the data (if required)

Latest online version is May 01, 2009
Newer version with KH20 hygrometer is ready (need to be put online)

http://wave.eng.uci.edu/files/vocals/flights_plots/
(no password needed)

Description of Plots from UCI Data System on CIRPAS Twin Otter
Physics Of Stratocumulus Top (POST) Jul 16 - Aug 15, 2008.

Page 1: Twin Otter 2-D Track with map overlay
LON: C-MIGITS Aircraft Longitude [deg]
LAT: C-MIGITS Aircraft Latitude [deg]

Page 2: Twin Otter 3-D Track with map overlay
LON: UCI C-MIGITS Aircraft Longitude [deg]
LAT: UCI C-MIGITS Aircraft Latitude [deg]
PALT: Pressure Altitude (adjusted to radar altitude) [m]

Page 3: Continuity Check of 40-Hz GPS Time from UCI DAQ system
Top panel:
Samples: 40-Hz sample number
40-Hz GPS Time, [s]
Bottom panel:
Samples: 40-Hz sample number
Delta (Time): Differential of 40-Hz GPS Time (Time(i+1)-Time(i)) [s]

Note: Pages 4-12 are Time series of grouped variables versus UTC [HH:MM]

Page 4: Twin Otter Attitude from UCI C-MIGITS
LAT: Aircraft Latitude [deg]
LON: Aircraft Longitude [deg]
THETA: Aircraft Pitch [deg]
PHI: Aircraft Roll [deg]
PSI: Aircraft True Heading [deg]

Page 5: Twin Otter Velocities from UCI C-MIGITS. (Earth Reference Frame)
Vx: Aircraft East Velocity [m/s]
Vy: Aircraft North Velocity [m/s]
Vz: Aircraft Vertical Velocity [m/s]

Page 6-8: Pressures from Radome and Fuselage
PDAR: Differential Pressure of angle of Attack from Radome [mb]
PDSR: Differential Pressure of angle of Sideslip from Radome [mb]
PQR: Dynamic Pressure from Radome [mb]
PQF: Dynamic Pressure from Fuselage (UCI Pitot) [mb]
PTR: Total Pressure from Radome [mb]
PSF: Static Pressure from Fuselage [mb]

Page 9: Temperature Measurements
TTR: CIRPAS Rosemount Recovery Temperature [C]
TTR2: UCI Rosemount Recovery Temperature [C]
TAD: Ambient Temperature from reference temperature (ttr or ttr2) [C]
TIRKTD: Heiman KT Sea-surface IR Temperature [C]

Page 10: Humidity and CO2 Measurements
DPET: EdgeTech chilled mirror dew point temperature [C]
AHK: Campbell Sci. Krypton absolute humidity [V]
AHL: LI-COR 7500 absolute humidity (before in situ calibration) [g/m^3]
CO2L: LI-COR 7500 CO2 density [g/m^3]
PALTC: Pressure Altidude (adjusted to radar altitude) [m]

Page 11: Temperature and TAS Measurements
TAD: Ambient Temperature from reference temperature [C]
DPET: EdgeTech chilled mirror dew point temperature [C]
THETA: Potential Temperature [C (not customary K)]
TIRKTD: Heiman KT Sea-surface IR Temperature [C]
TASD: True Airspeed using dry air properties [m/s]

Page 12: Wind Measurements
WSR: Wind Speed [m/s]
WDR: Direction the wind is blowing from (meteorological convention) [deg]
WXR: East Wind Component - Earth Ref. [m/s]
WYR: North Wind Component - Earth Ref. [m/s]
WZR: Vertical Wind Component - Earth Ref. [m/s]
WLRG: Longitudinal Wind Component - Aircraft Ref. [m/s]
WLTR: Lateral Wind Component - Aircraft Ref. [m/s]
VZBS: Aircraft Vertical Velocity - Earth Ref. [m/s]

Wind Measurements

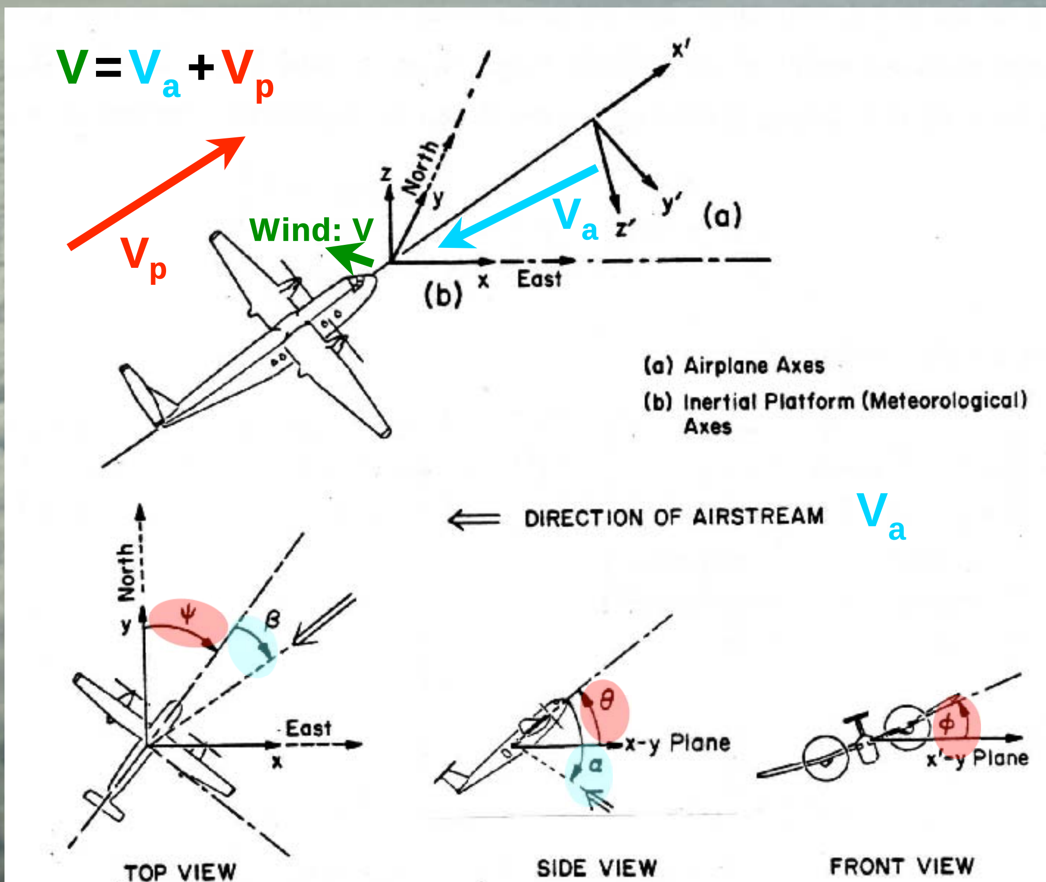


Figure from D.H. Lenschow and P. Spyers-Duran, NCAR/RAF Bulletin 23

$$u = u_p - U_a D \times [\sin\psi\cos\theta + \tan\beta(\cos\psi\cos\phi + \sin\psi\sin\theta\sin\phi) + \tan\alpha(\sin\psi\sin\theta\cos\phi - \cos\psi\sin\phi)] - L(\dot\theta\sin\theta\sin\psi - \dot\psi\cos\psi\cos\theta)$$

$$v = v_p - U_a D \times [\cos\psi\cos\theta - \tan\beta(\sin\psi\cos\phi - \cos\psi\sin\theta\sin\phi) + \tan\alpha(\cos\psi\sin\theta\cos\phi + \sin\psi\sin\phi)] - L(\dot\psi\sin\psi\cos\theta + \dot\theta\cos\psi\sin\theta),$$

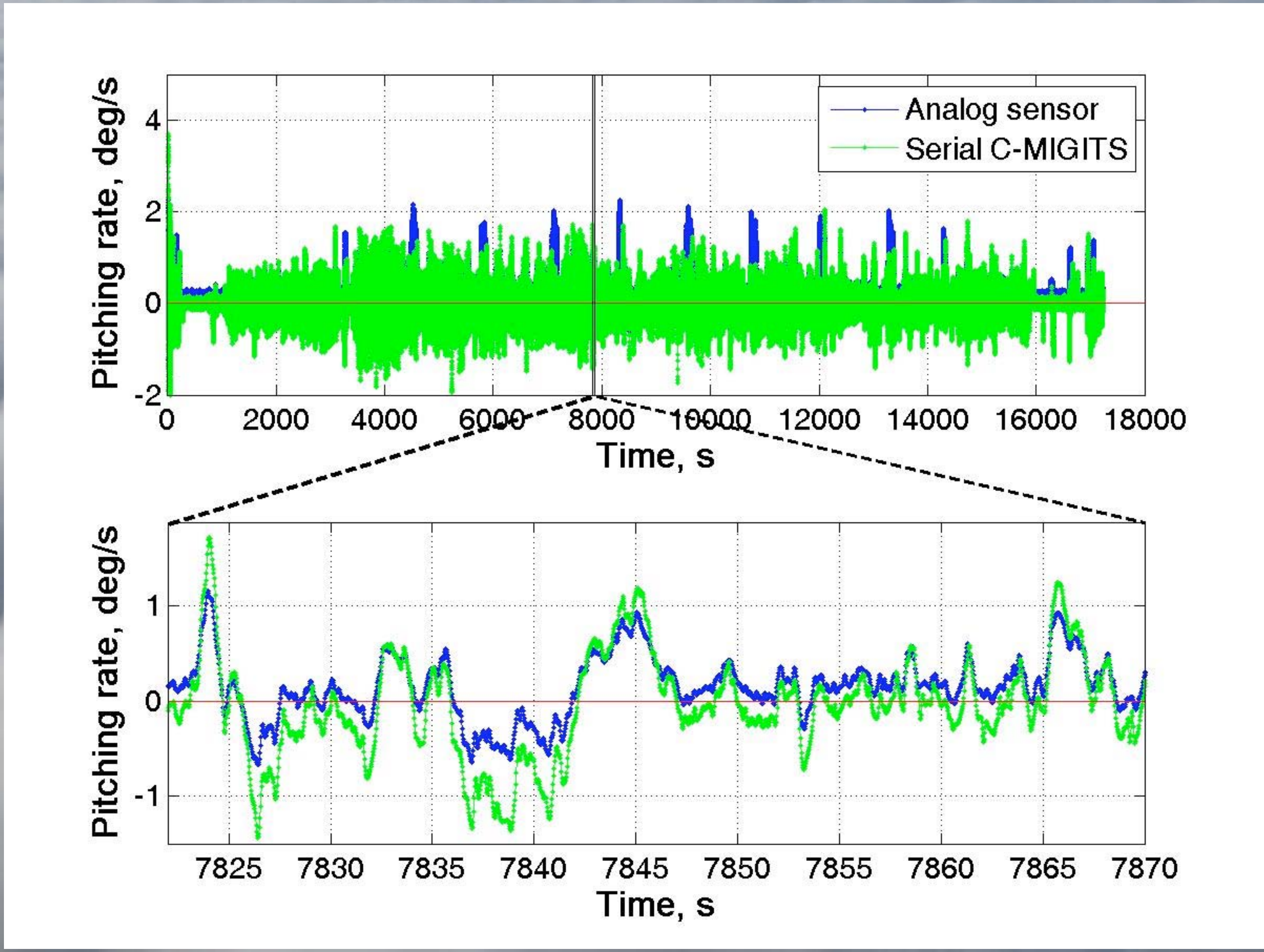
$$w = w_p - U_a D[\sin\theta - \tan\beta\cos\theta\sin\phi - \tan\alpha\cos\theta\cos\phi] + L\dot\theta\cos\theta$$

where u_p and v_p are the east and north aircraft velocity components, respectively; U_a is the true airspeed; α, β, θ, ϕ, and ψ are the aircraft attack, sideslip, pitch, roll, and true heading angles, respectively; L is the distance separating the INS and gust probe along the aircraft's center line; $D = (1 + \tan^2\alpha + \tan^2\beta)^{-1/2}$; and $\dot\psi = d\psi/dt$ and $\dot\theta = d\theta/dt$; w_p is the aircraft vertical velocity.

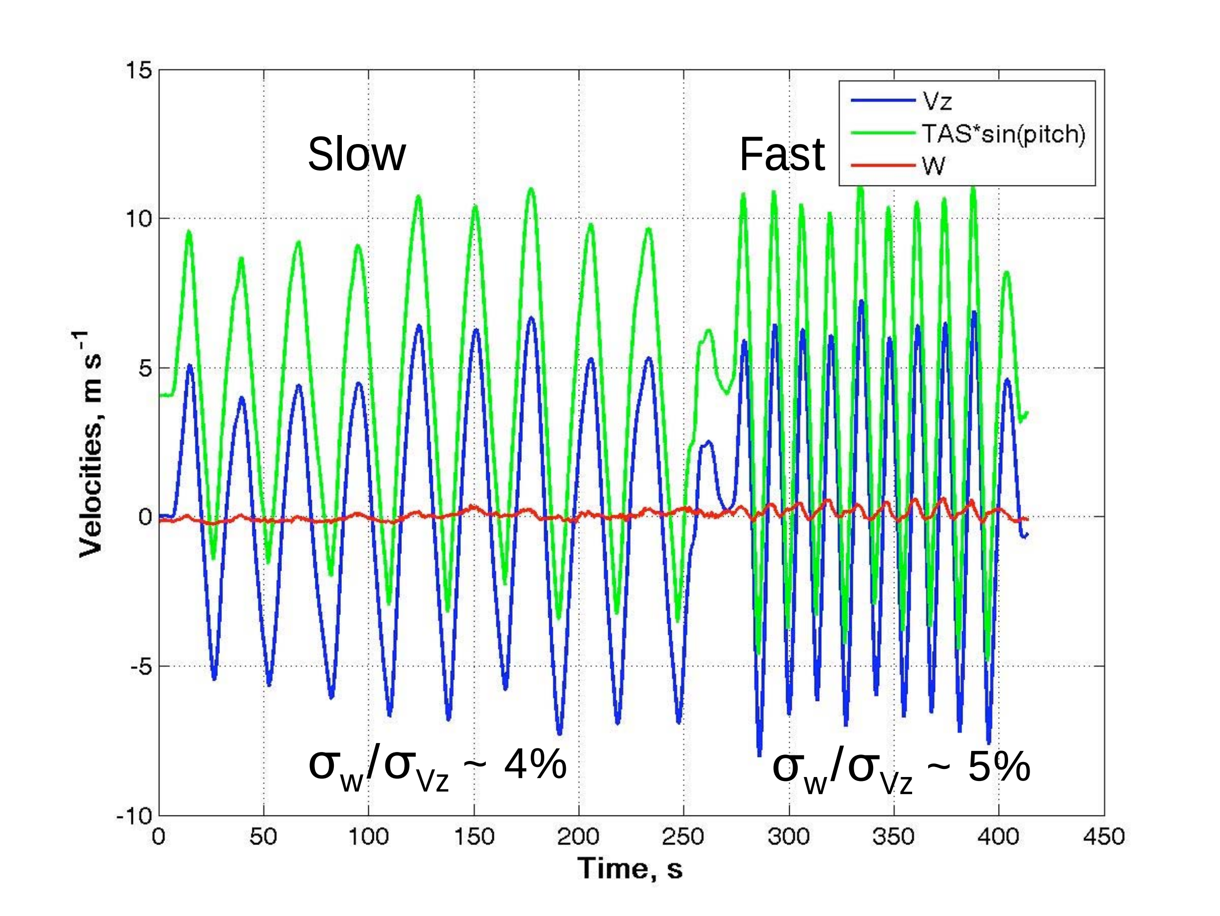
Serial data from INS/GPS C-MIGITS III unit.

Analog data (5-port radome gust system, P_s and T_r)

Analog-Serial Synchronization

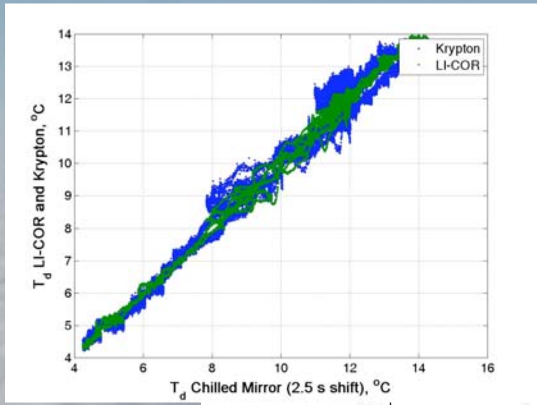


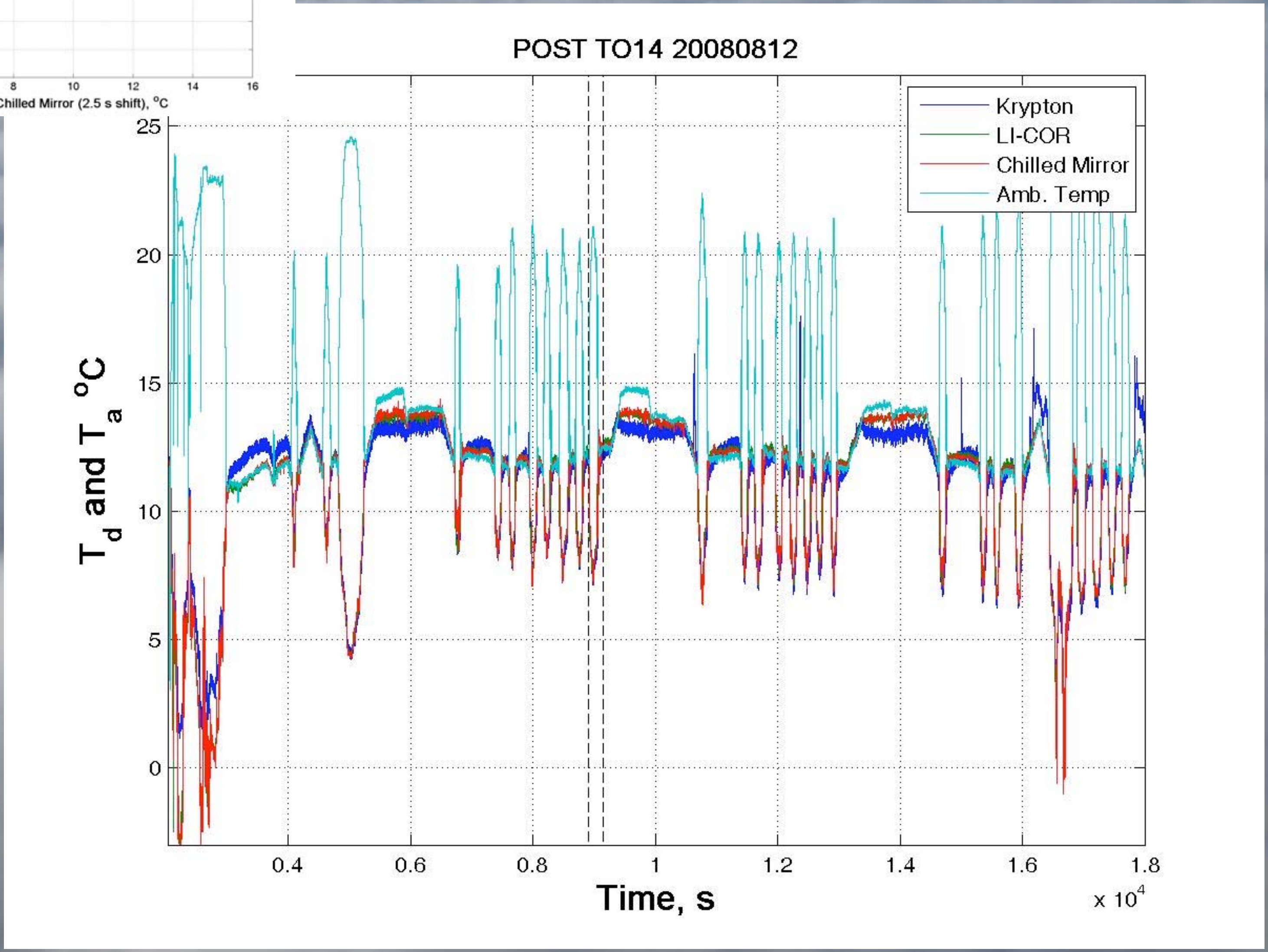
Pitching Maneuvers: w Test



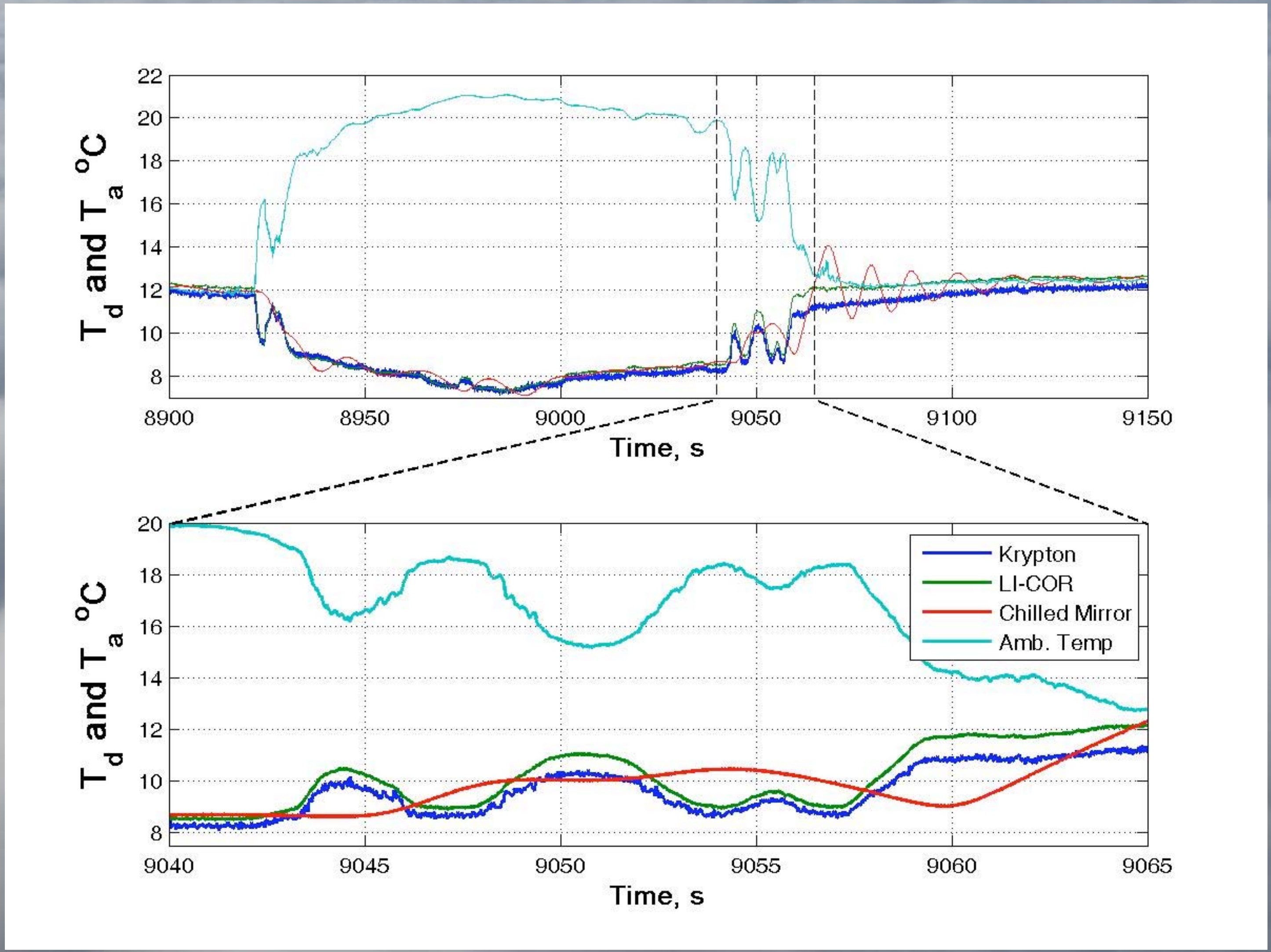
Rule of thumb: σ_w/σ_{Vz} <10% is acceptable

In Situ Humidity Calibrations

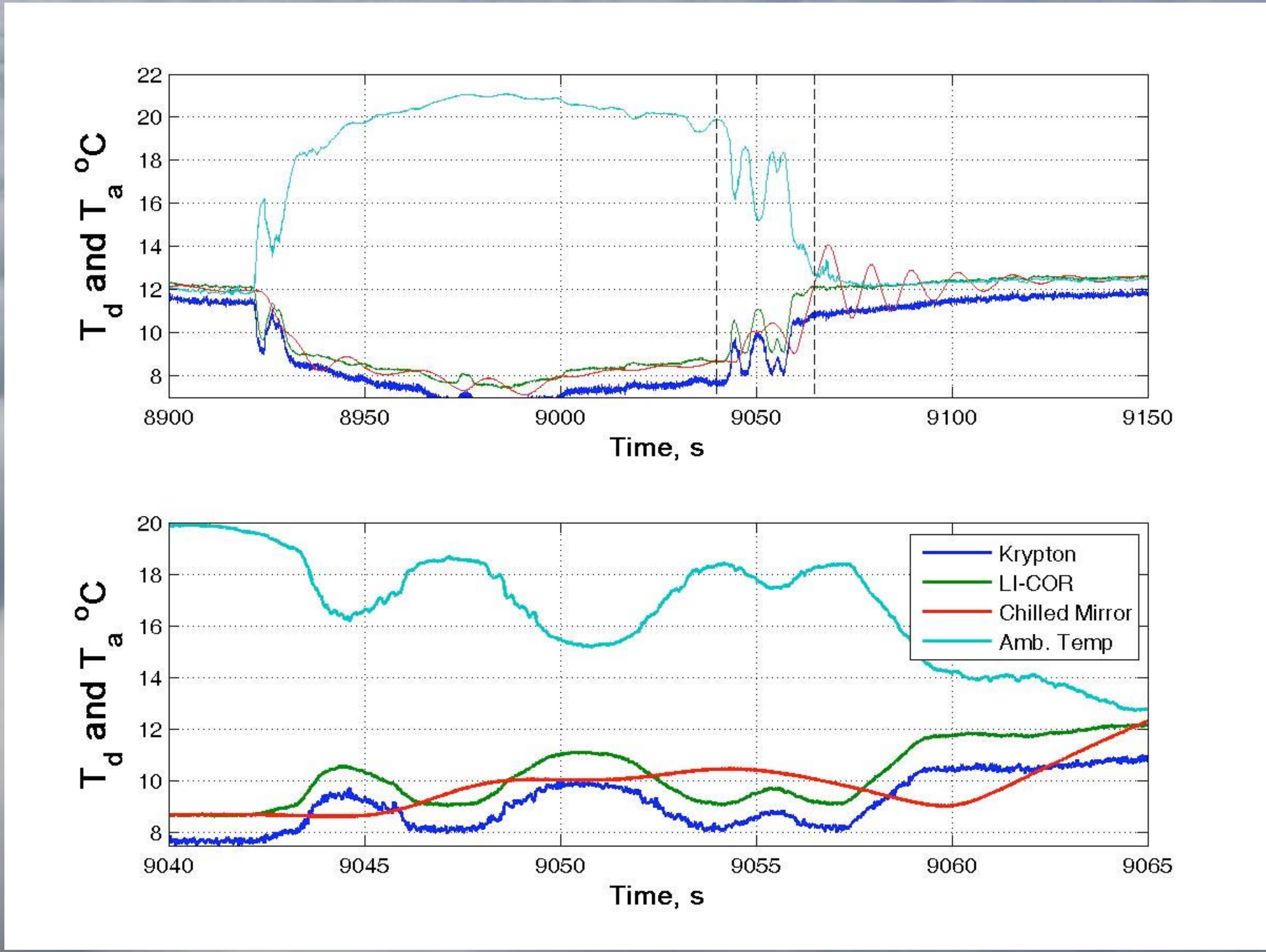


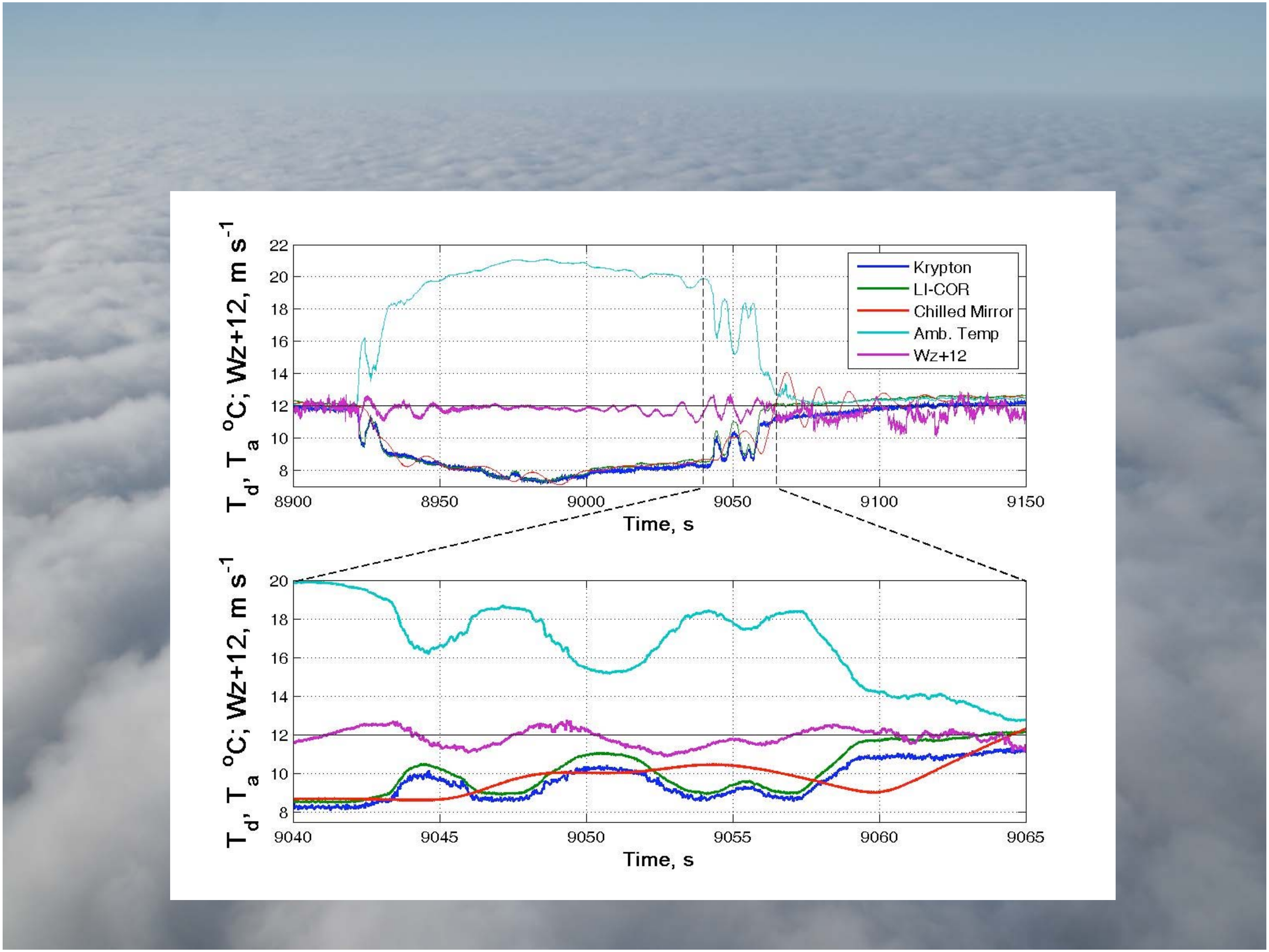


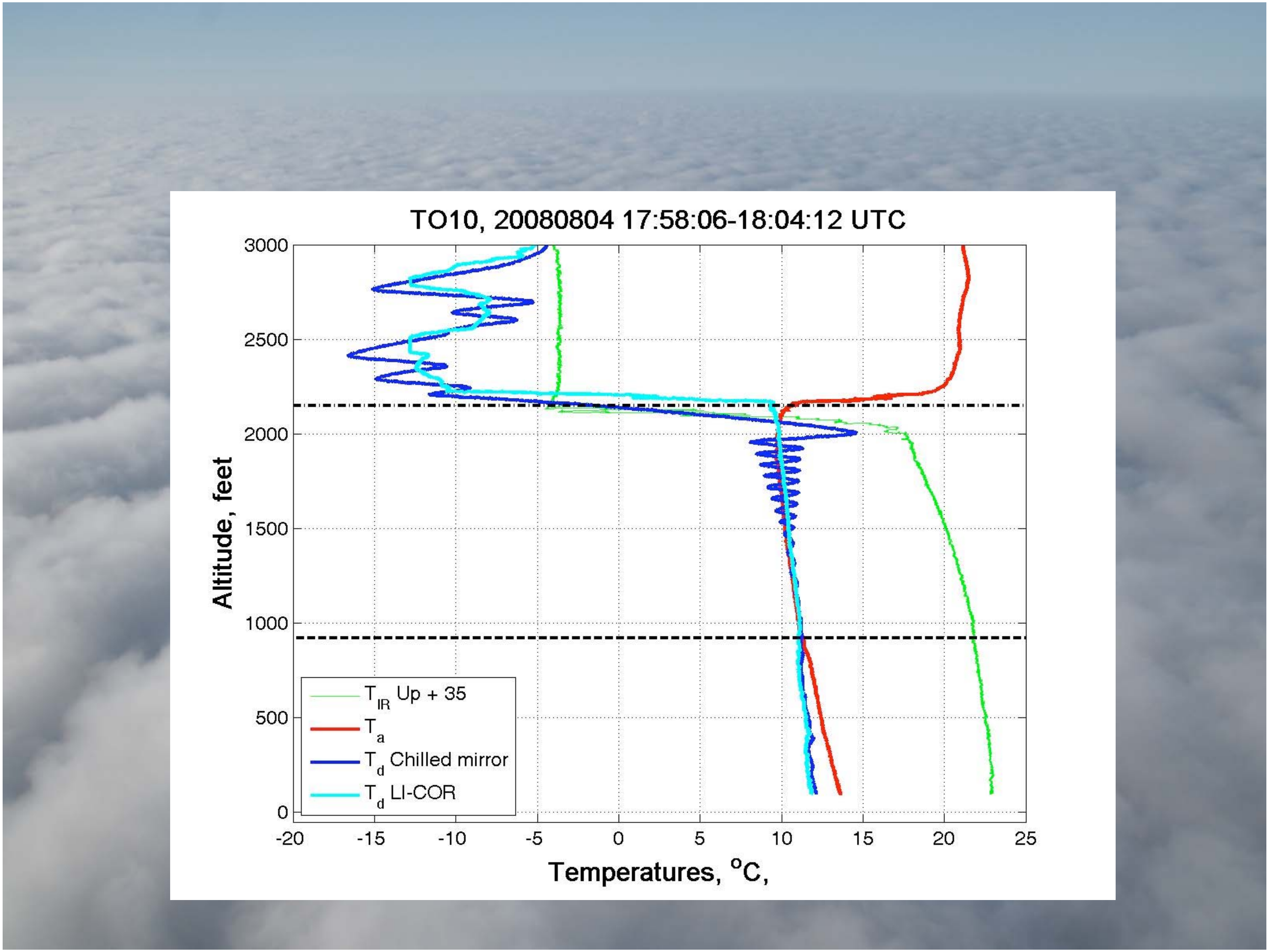
In Situ Humidity Calibrations



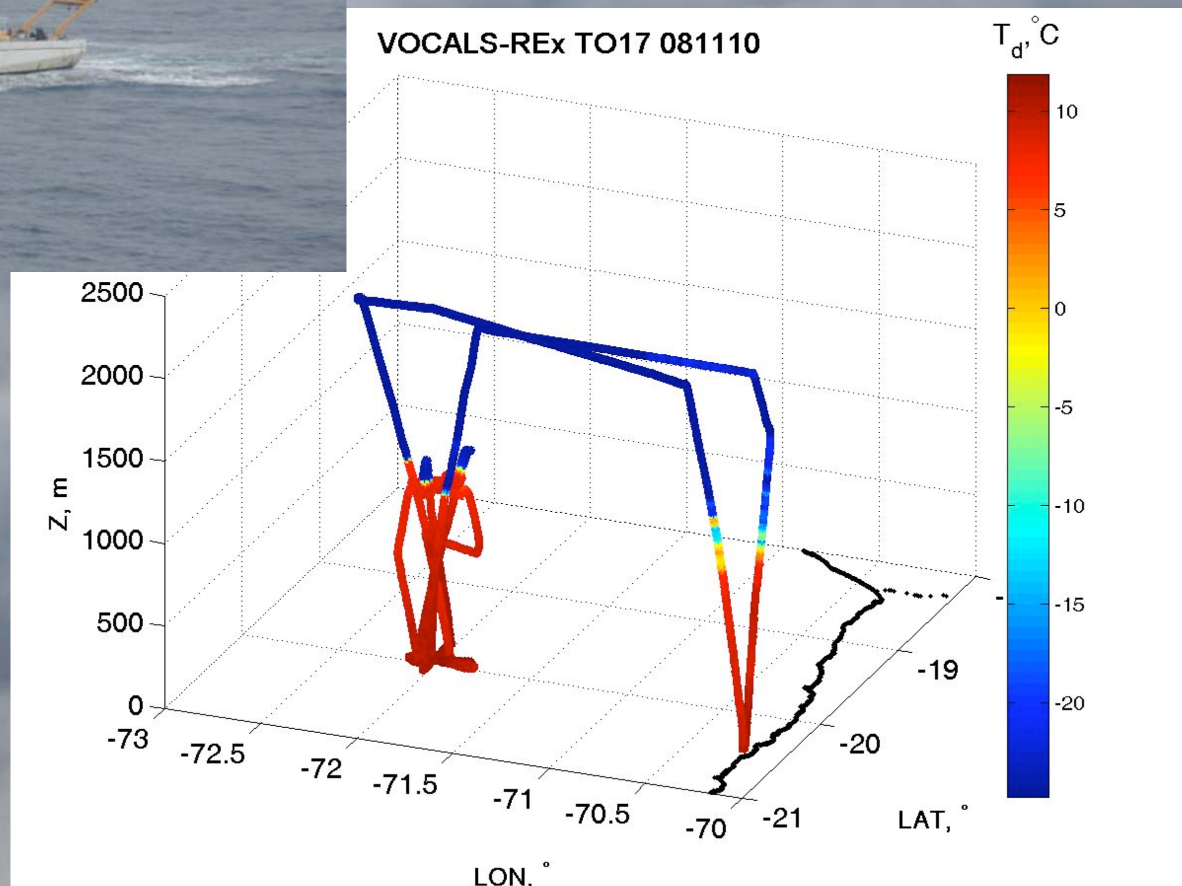
Older (Jan 9 2009) Humidity Calibrations




Krypton
LI-COR
Chilled Mirror
Amb. Temp
Wz+12
T_d, T_a °C; Wz+12, m s^-1
Time, s
8900
8950
9000
9050
9100
9150
22
20
18
16
14
12
10
8
9040
9045
9050
9055
9060
9065


TO10, 20080804 17:58:06-18:04:12 UTC
Altitude, feet
Temperatures, °C,
3000
2500
2000
1500
1000
500
0
-20
-15
-10
-5
0
5
10
15
20
25
T IR Up + 35
T a
T d Chilled mirror
T d LI-COR

Flight Track on TO17 081110



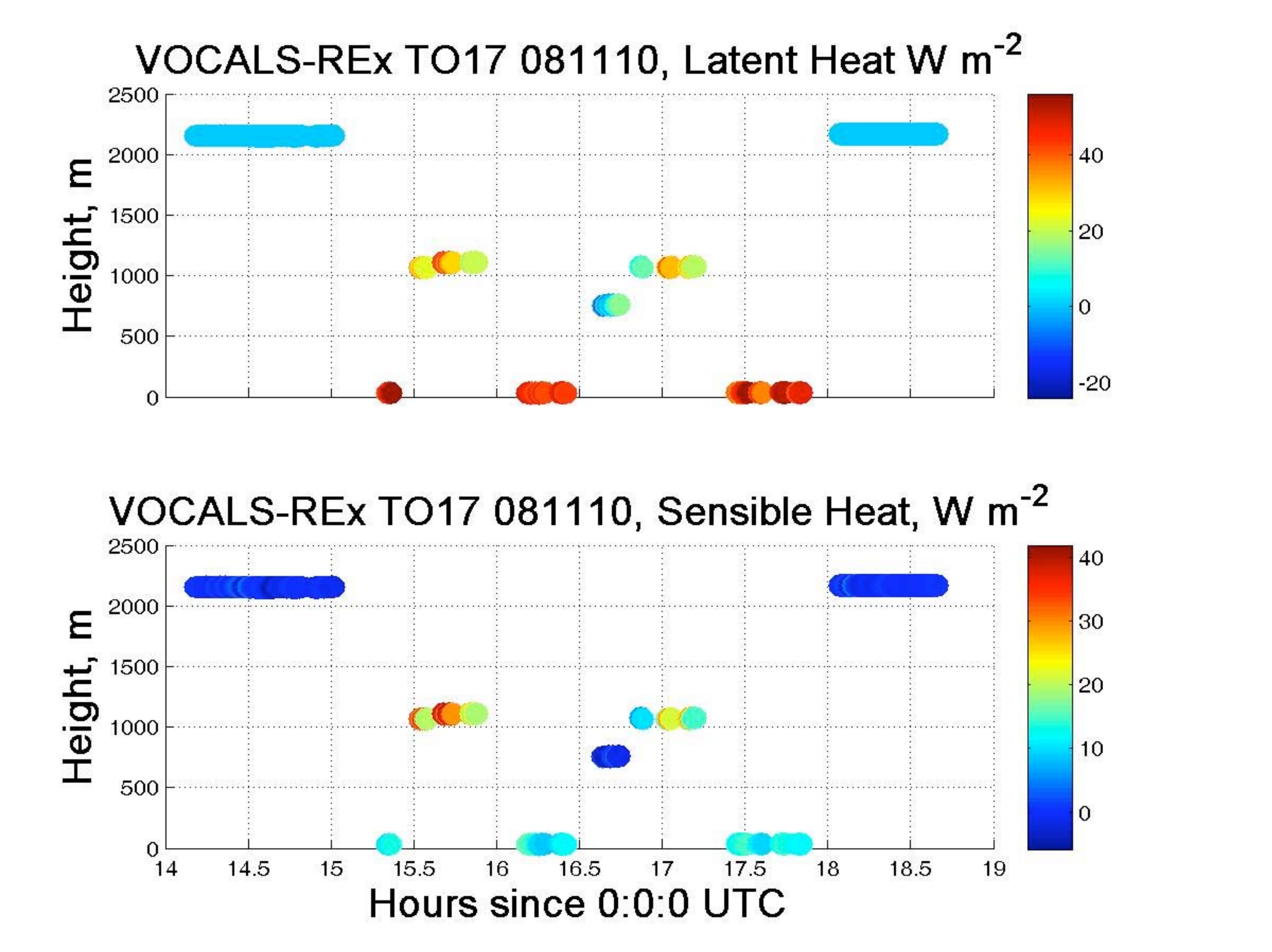
Twin Otter - R/V Ron Brown Intercomparisons

Table: Details of CIRPAS Twin Otter overflights of Ronald H Brown. (UCI data set was used for this table.)

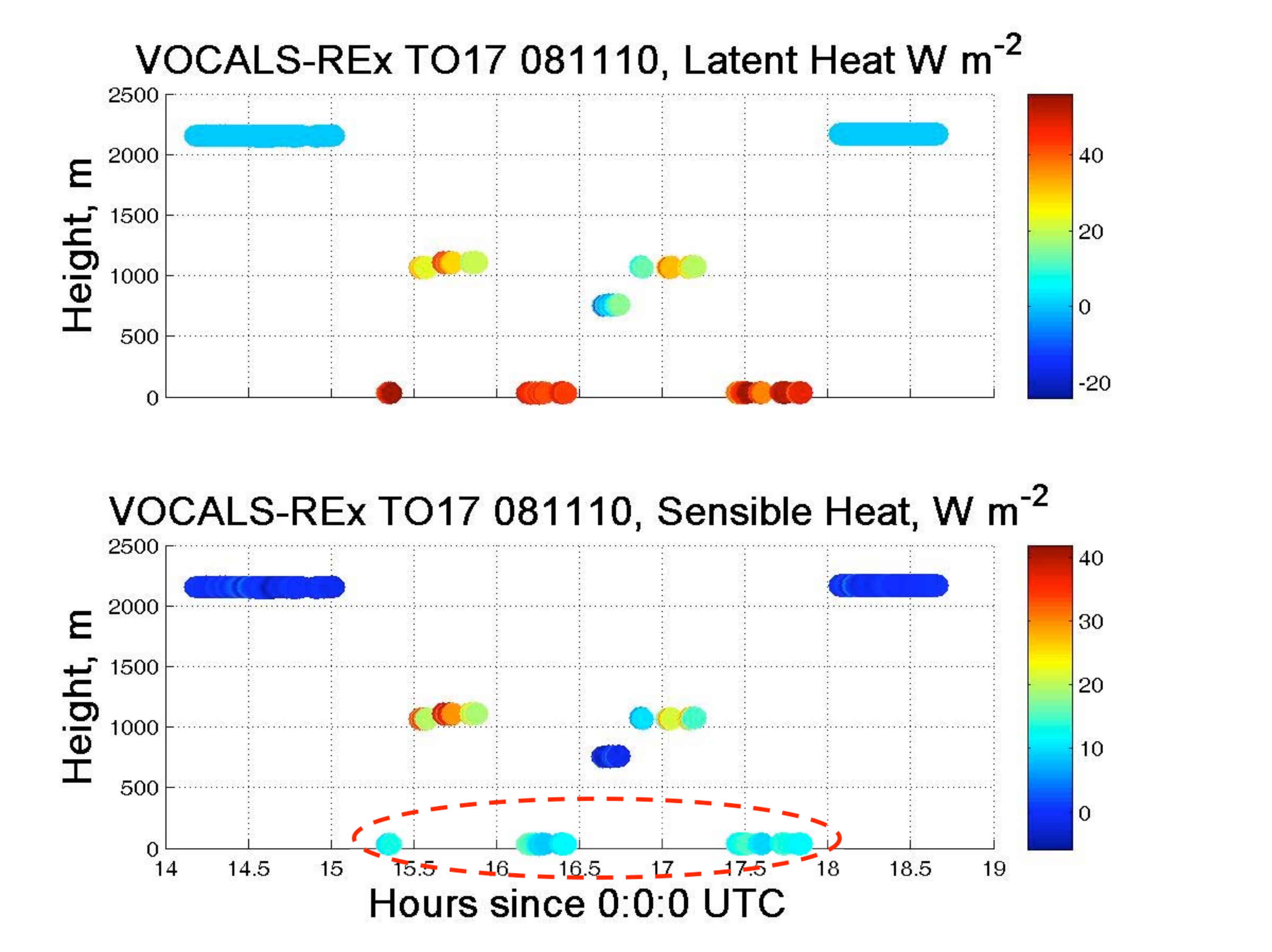
Campaign Day, Date, Fight ID	Twin Otter run times (UTC)	Level run mean(z) or Sounding $[z_1\ z_2]^1$ (m)	Closest time, (UTC)	Closest Horiz. Distance (km)/ Track, °	Details
Cd41 Nov 10 2008 TO17	145231-150237	2154	145231	1.51/287	Above clouds west of RHB at point alpha
	150356-151802	[2139 34]	151631	8.12/--	Sounding ↘ NW of RHB while turning (61-1605 deg)
	151825-152328	31	152050	0.58/224	Surface fluxes run SW-bound above RHB
	152334-152953	[26 1094]	152334	8.64/--	Sounding ↗ SW of RHB during U-turn (220-40 deg)
	153037-153648	1069	153321	0.97/46	Cloud-base run NE-bound above RHB
	153857-154556	1107	154252	1.23/230	In-cloud run SW-bound above RHB
	154823-155428	1110	155109	0.14/54	Reciprocal in-cloud run NE-bound above RHB
	155723-160607	[1286 33]	160238	0.10/234	Sounding ↘ SW-bound above RHB
	160919-161915	32	161241	0.15/93	Inbound surface fluxes run above RHB
	162115-162644	32	162644	0.96/285	Outbound surface fluxes run east of RHB
	162738-163026	30	162738	1.67/171	Southbound surface fluxes run south of RHB
	163028-163501	[29 755]	163351	0.35/346	Sounding ↗ above RHB while turning (166-349 deg)
	163635-164606	757	163719	0.42/111	Inbound Run below cloud base above RHB
	165034-165435	1071	165435	1.36/290	Reciprocal run at cloud base towards RHB
	165525-165750	1071	165525	1.78/178	Southbound cloud-base run south of RHB
	165956-170509	1070	170228	0.07/3	Northbound cloud-base run south above RHB
	170736-171337	1071	171034	0.38/186	Southbound cloud-base run south above RHB
	171510-172510	[1283 27]	171833	0.26/355	Sounding ↘ northbound above RHB
	172519-173233	34	173233	0.37/178	Southbound surface fluxes run north of RHB
	173324-173808	36	173324	2.04/81	Inbound surface fluxes run east of RHB
	174116-174637	37	174637	0.39/267	Outbound surface fluxes run east of RHB
	174710-175218	35	174710	1.44/177	Southbound surface fluxes run south of RHB
	175218-180140	[32 2177]	175218	16.7/97	Sounding ↗ eastbound SE of RHB

Note 1: z_1 and z_2 are respectively the initial and final elevations of each sounding.

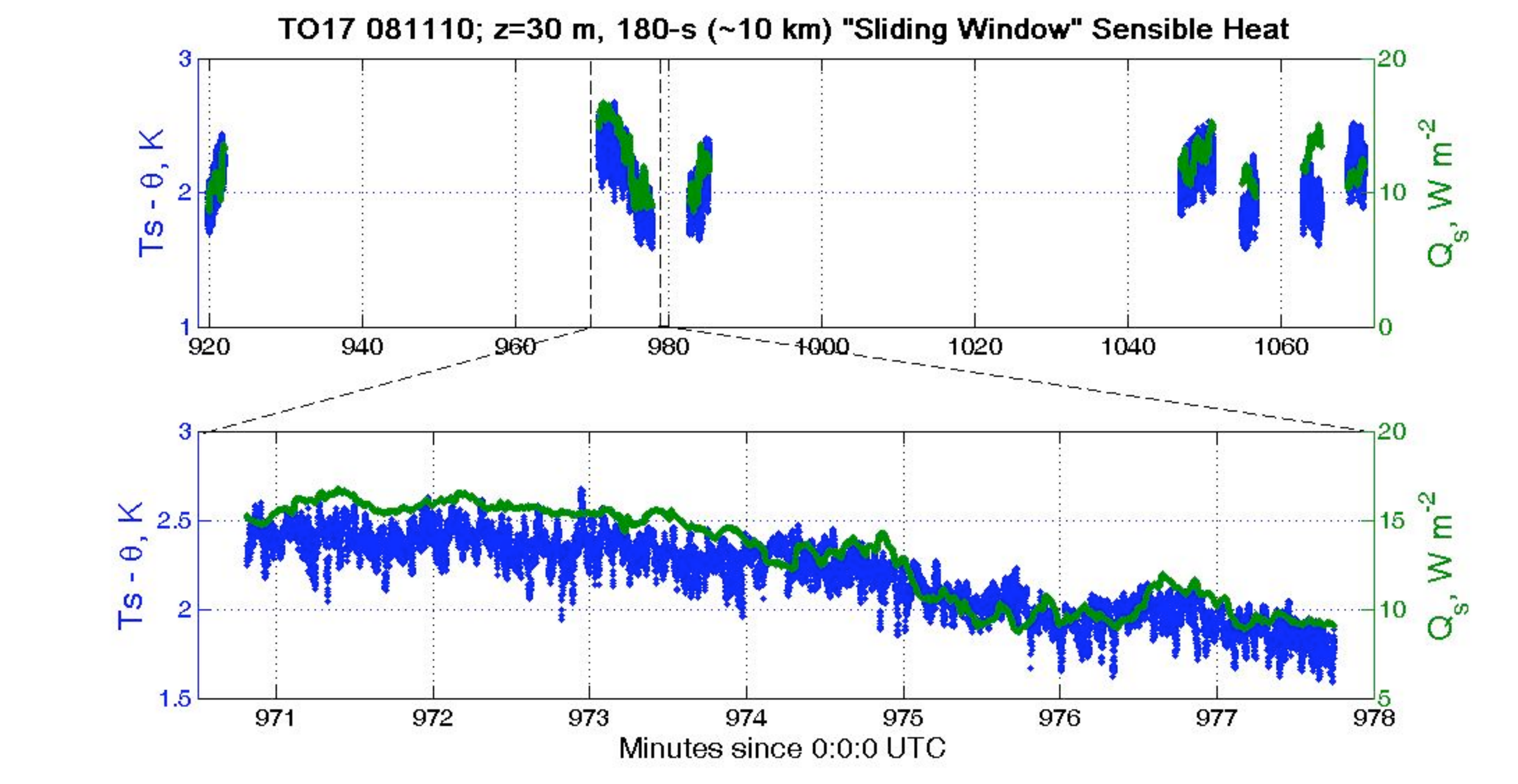
Heat Flux


VOCALS-REx TO17 081110, Latent Heat W m-2
Height, m
2500
2000
1500
1000
500
0
40
20
0
-20
VOCALS-REx TO17 081110, Sensible Heat, W m-2
Height, m
2500
2000
1500
1000
500
0
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
19
Hours since 0:0:0 UTC
40
30
20
10
0

Heat Flux


VOCALS-REx TO17 081110, Latent Heat W m-2
Height, m
2500
2000
1500
1000
500
0
40
20
0
-20
VOCALS-REx TO17 081110, Sensible Heat, W m-2
Height, m
2500
2000
1500
1000
500
0
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
19
40
30
20
10
0
Hours since 0:0:0 UTC

Surface sensible Heat Flux



Summary

- High-quality meteorological and turbulence data set was obtained.
- The data are ready for project archive (will wait for feedback from users)
- Having redundant instruments always pays off (c.f., chilled mirror problems)

What Next?

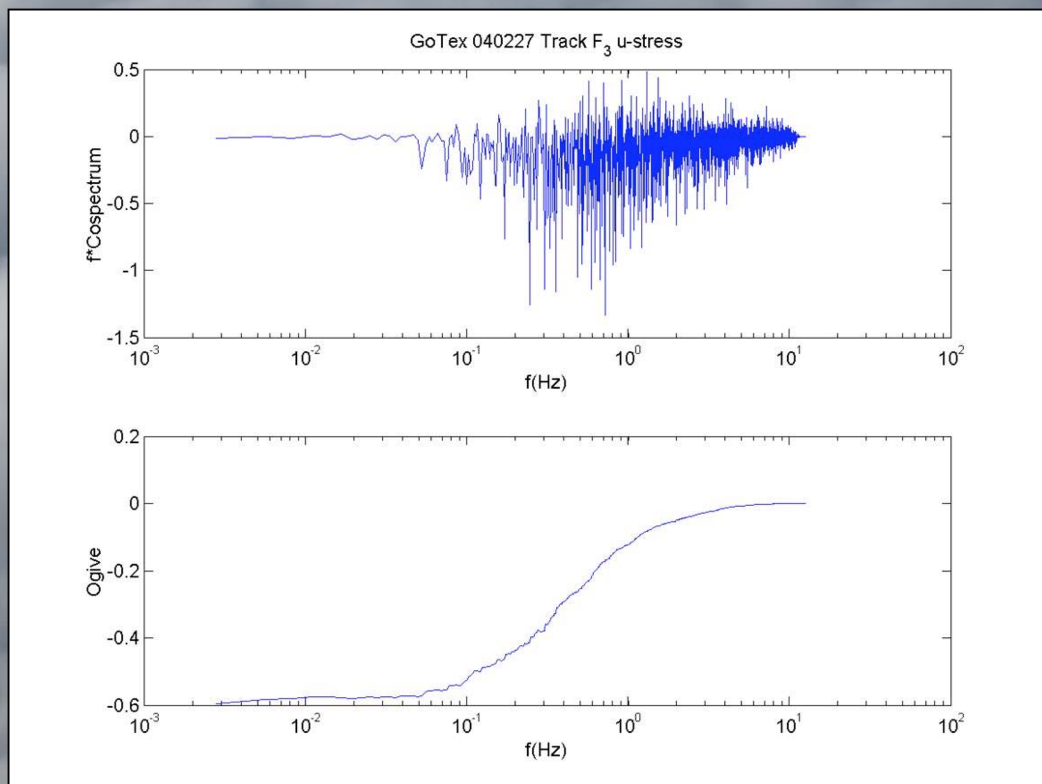
- Provide flux estimates for all flights
- Intercomparisons results (need data from the R/V Ron Brown)
- Compare the structure of Sc topped MABL off Chile and off CA central coast using POST and CARMA data we collected with the Twin Otter recently

Ogive Method

Ogive = Cumulative Integral of Cospectrum of w' u' (or w' T', w'ρ'$_v$, ...) from high to low frequencies. Asymptote as f ->0 is the **flux estimate.**

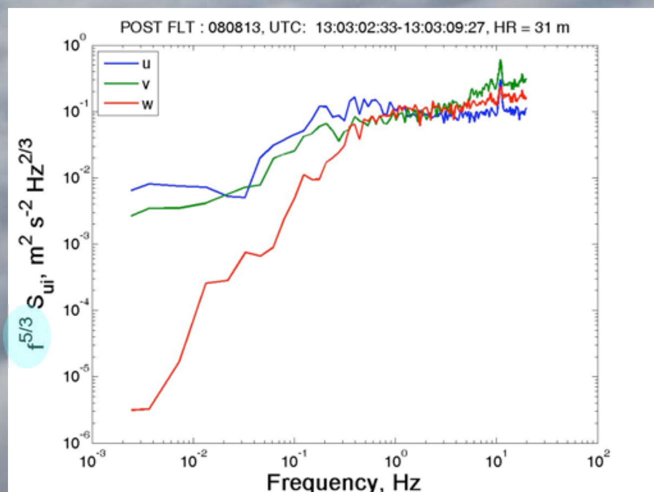
$$\overline{w'u'} = \int_0^\infty Co(w',u')df$$

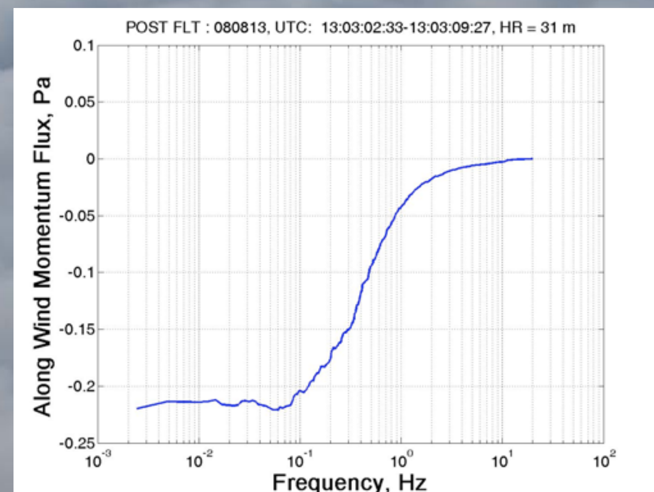
$$\mathcal{O}(f) = \int_\infty^f Co(w',u')df$$

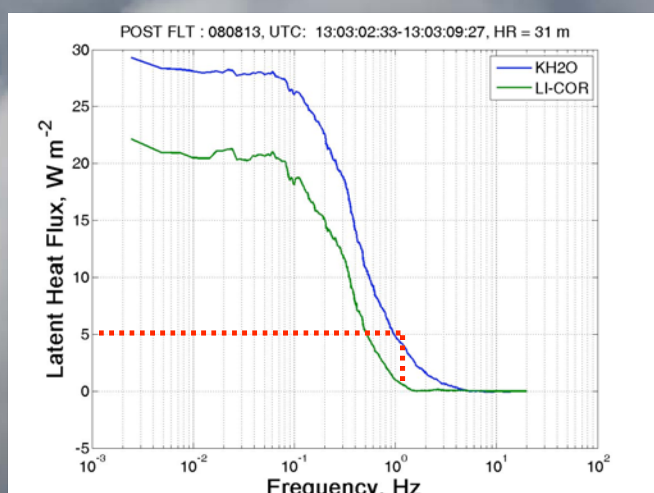


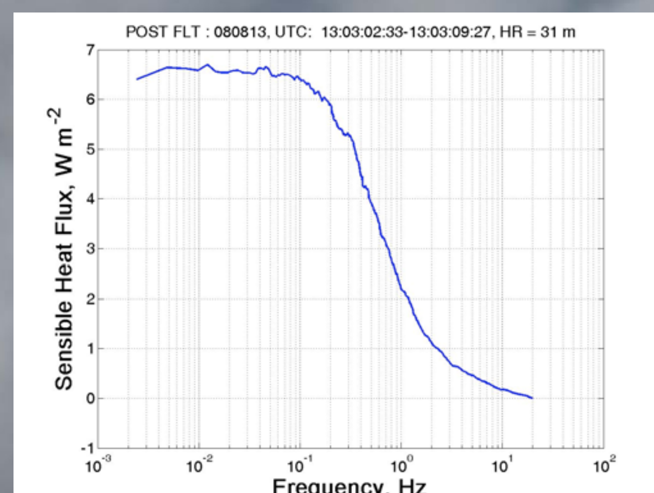
Example of Wind Spectra and Fluxes

TO15 080813, WS = 13 m s^{-1}

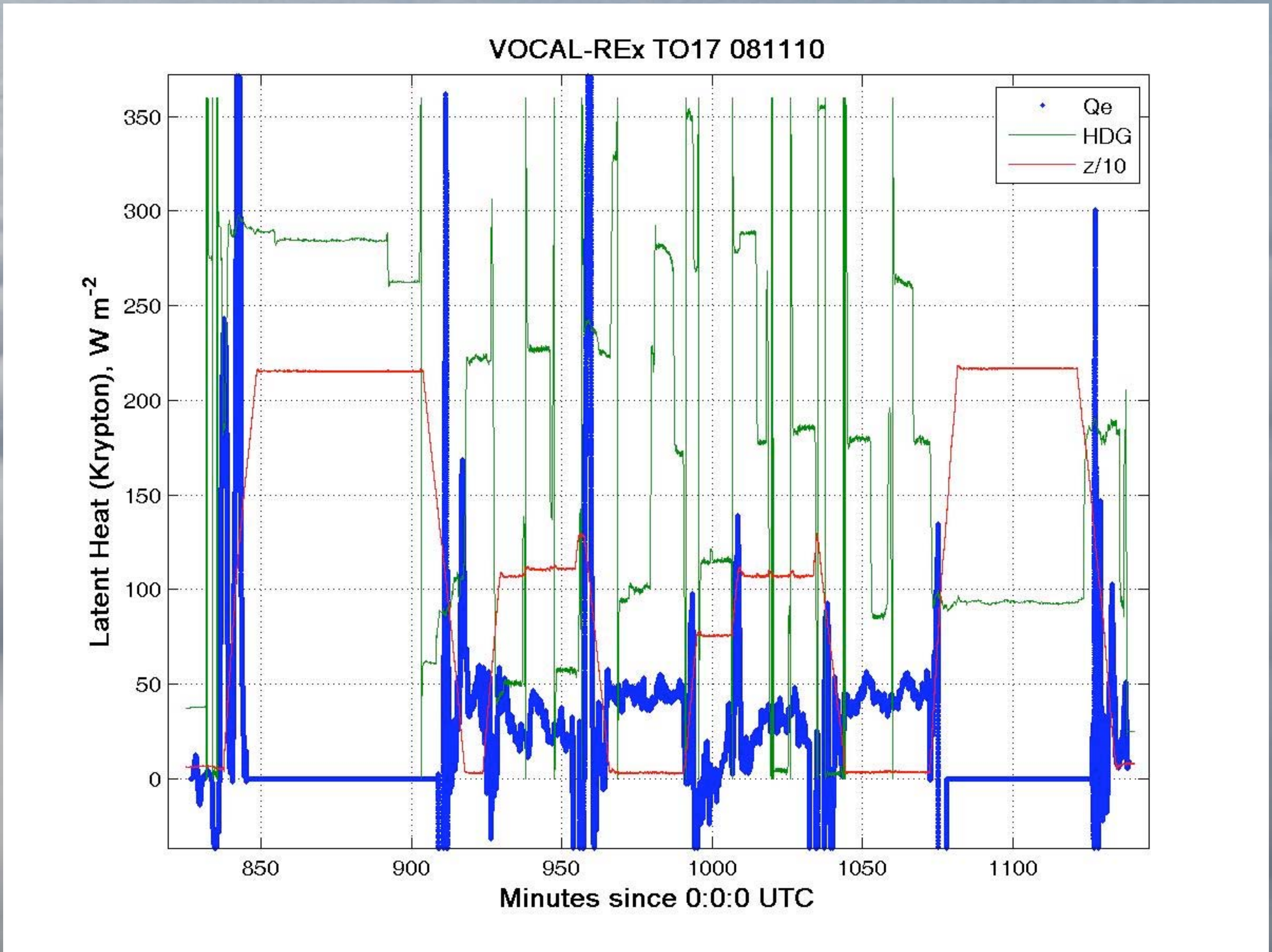






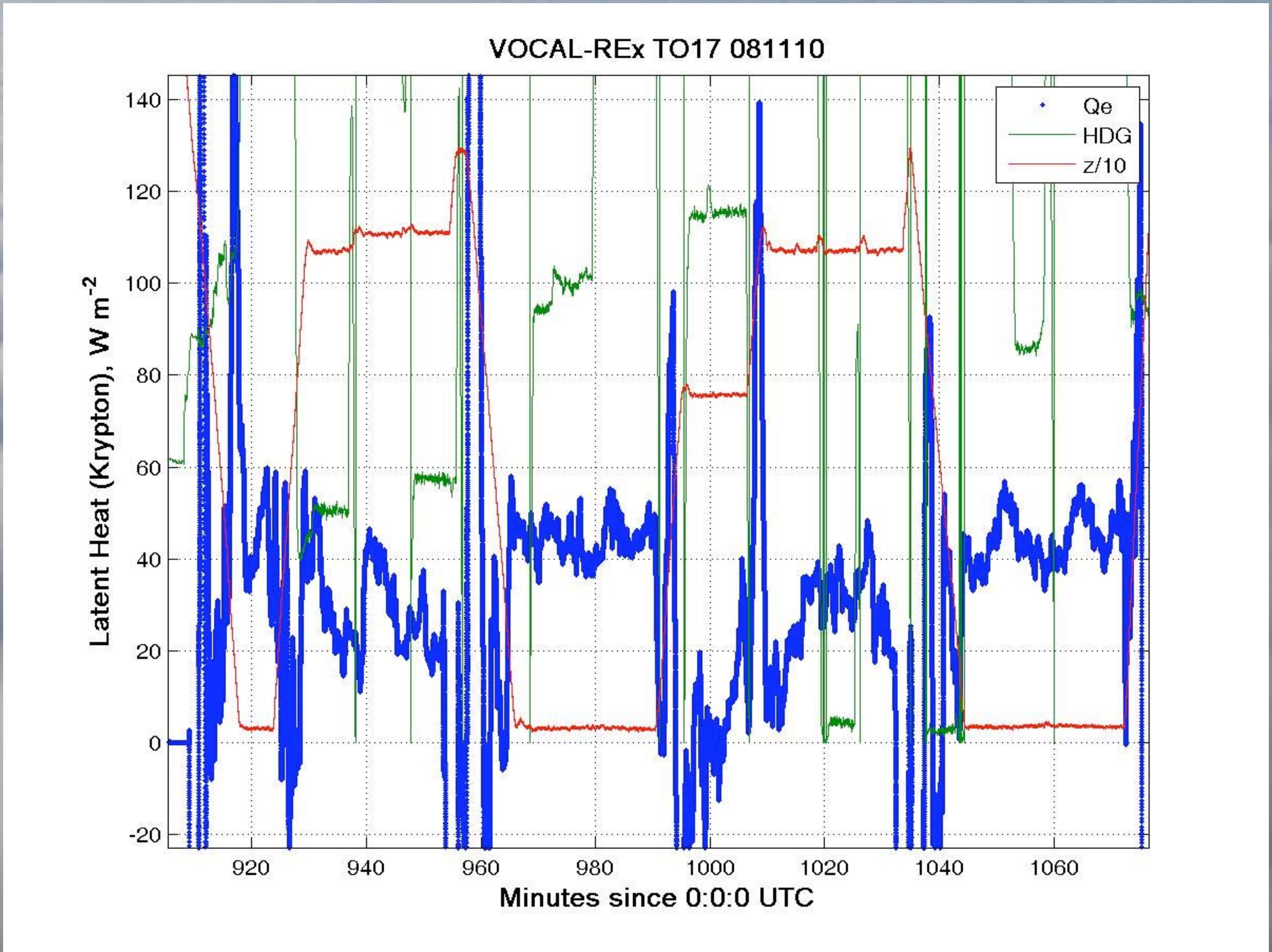


Latent Heat



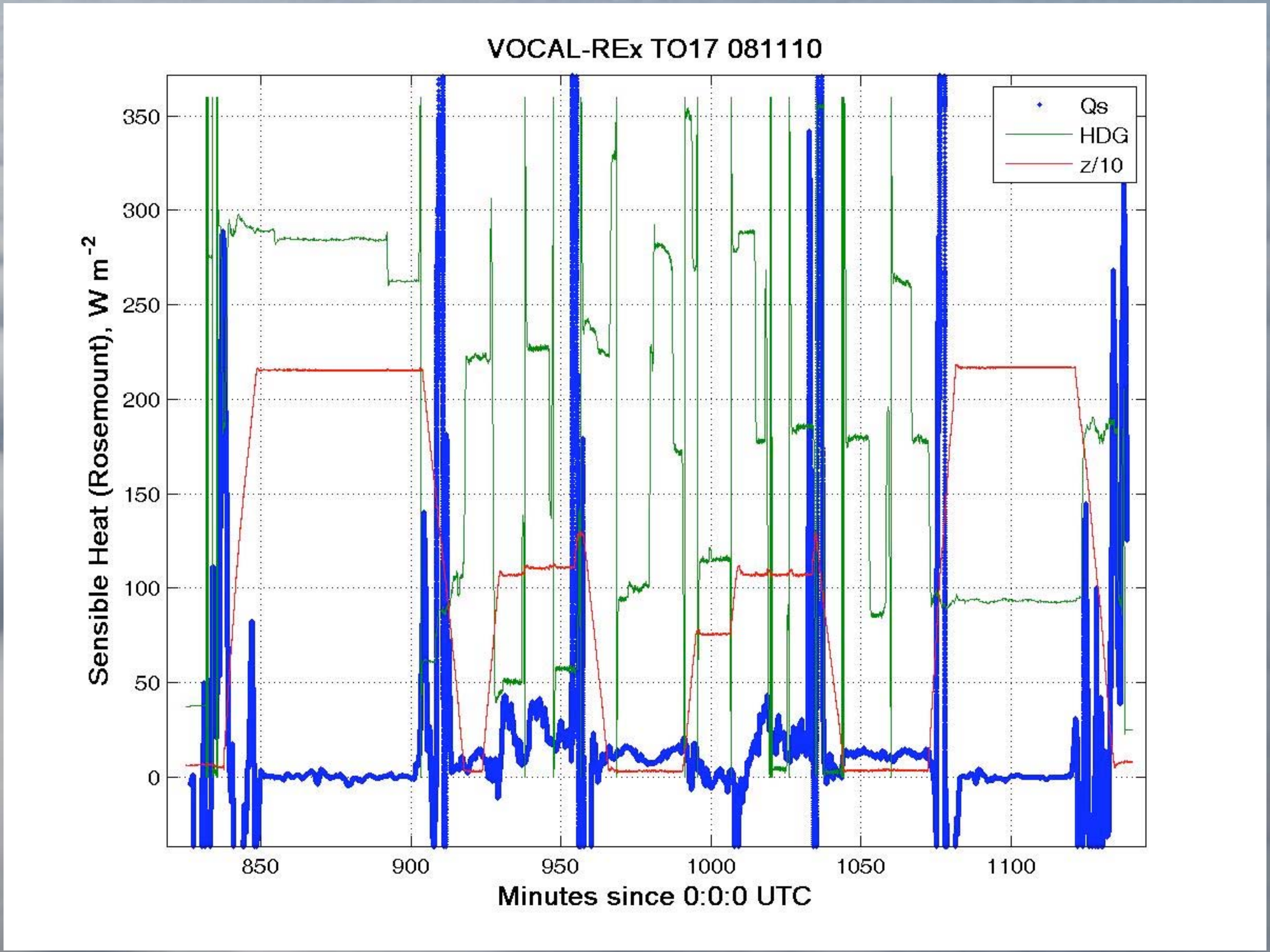
VOCAL-REx TO17 081110
Latent Heat (Krypton), W m^-2
Minutes since 0:0:0 UTC
Qe
HDG
z/10
350
300
250
200
150
100
50
0
850
900
950
1000
1050
1100

Latent Heat

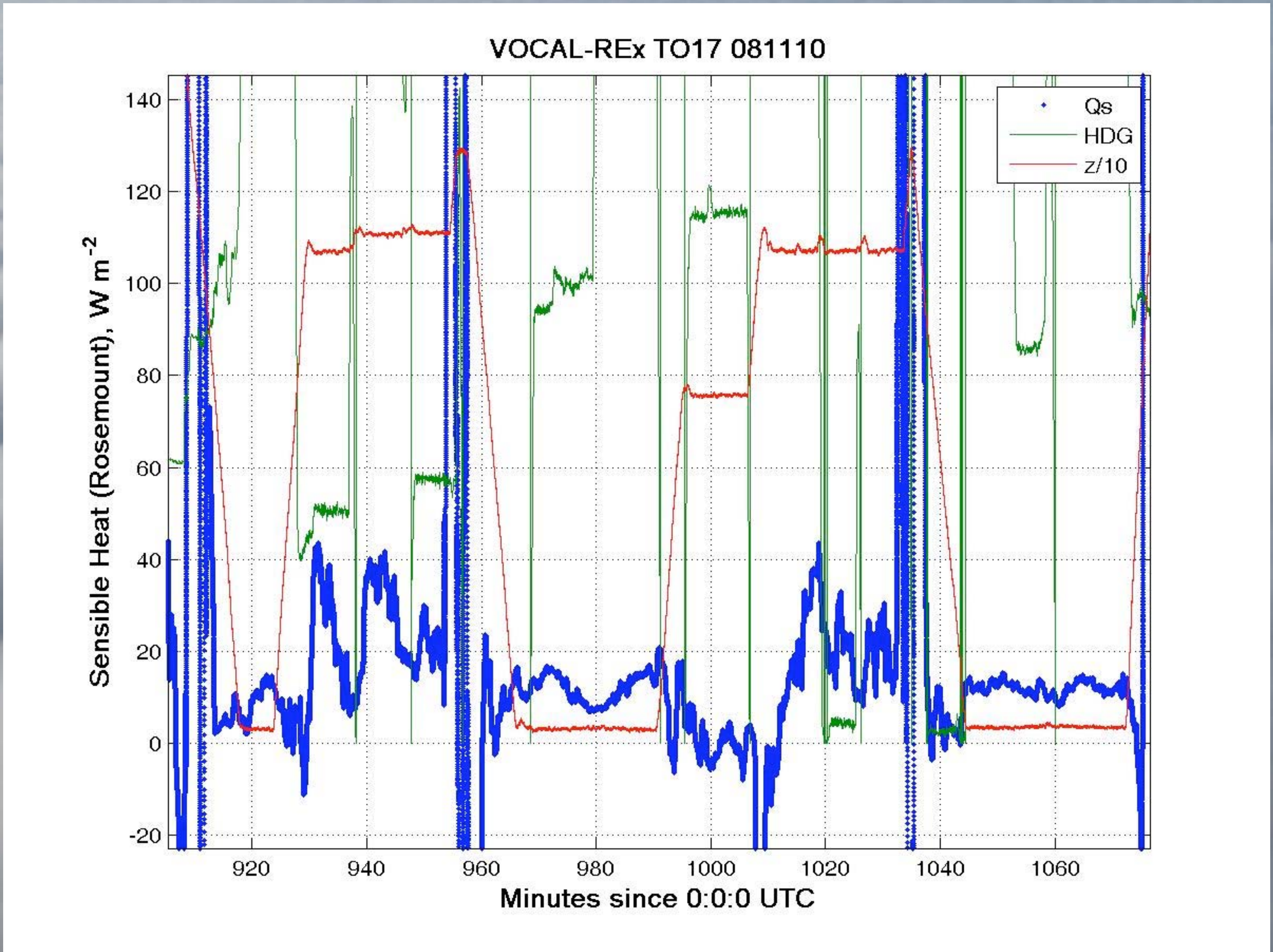


VOCAL-REx TO17 081110
Qe
HDG
z/10
Latent Heat (Krypton), W m^-2
Minutes since 0:0:0 UTC
140
120
100
80
60
40
20
0
-20
920
940
960
980
1000
1020
1040
1060

Sensible Heat



Sensible Heat



Sensible Heat