Overview of YES Dropsonde Performance During CPEX and YES QC

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CPEX Science Team Workshop

June 7-8, 2018, HCI Research Building, Salt Lake City, UT

7 June 2018

Overview

- HDSS/XDD Overview
- CPEX Dropsonde Inventory and Performance
- CPEX Dropsonde Issues and Fixes
- YES Processing and QC
- DAWN-Dropsonde Wind Measurement Comparison
- DAWN-Dropsonde Buoy Near-Surface Wind Comparisons
- Surface Temperature
- Summary

HDSS and XDD Overview

The HDSS (High Definition Sounding System) and eXpendable Digital Dropsonde (XDD)developed through ONR (Black et al., (2107) was used. Before CPEX this dropsonde system had been deployed over the past seven years including :

- Test deployments on the Twin Otter (2011), DC-8 (2013) and WB57 (2013)
- Polar Winds (2015)
- Tropical Cyclone Intensity (TCI) Experiment (2015)

The HDSS was selected for three primary advantages over prior dropsonde technologies:

- high fall speeds (~30m/s) reduces horizontal drift distances which is highly desirable in the proximity of organized convection
- surface temperature sensor was seen as particularly important near and under deep convection generating cold pools
- >12 simultaneous sonde tracking capability enables rapid deployment in areas which the science team identified as meeting mission priority.

HDSS and XDD Overview

1) The HDSS is the integrated system of antennas, receivers, and telemetry that receives data from XDDs deployed by the Automated Dropsonde Dispenser (ADD) and then telemeters the data.
   The XDD measures:
   - GPS location and altitude at 2-Hz rate
   - vertical profiles of PTU at 2-Hz rate
   - horizontal wind and sonde fall speed at 4-Hz rate
   - SSTir at 1 Hz rate
2) HDSS derives GPS location and winds from state-of-the-art u-blox chip technology and proprietary GPS tracking technology.
3) PTU Instruments:
   - pressure transducer
   - fast-response thermistor with digital oversampling
   - relatively slow response hygrometer

4) SSTir is measured with an infrared micro-radiometer at 8–12-mm

TABLE 2. XDD Sensor Specifications

Parameter	Sensor type/data rate	Accuracy	Resolution
Temperature	Thermistor/2 Hz/1 Hz	.148 degC	0.0168degC
Pressure	MEMS/2–1 Hz	1.5 hPa at 25C	2.5 hPa
Humidity	MEMS/2–1 Hz	1.8% at 25C	0.1%
SST	IR micro-radiometer 9–11 mm/1 Hz	0.2 at 25C	0.0168C

CPEX DROPSONDE INVENTORY AND PERFORMANCE

Dropsonde File Name	Bad Sonde/NI	Lost Signal out of DC8	Not Launhed/ Used Again	Terminated Early	Bad/Missing T or Moisture
rt_20170610-204209-2-A-E0BF.dat.txt				X – 400mb	
rt_20170610-204532-3-A-09AA.dat.txt					X – Moisture Discontinuity
rt_20170610-205046-4-A-054D.dat.txt					
rt_20170610-211022-7-A-D9B2.dat.txt					
rt_20170610-212416-0-A-1C13.dat.txt					X – Missing T/Moist.
rt_20170610-213344-1-A-172F.dat.txt					X – Little > 700mb
rt_20170610-213933-2-A-A033.dat.txt					X – Moisture Discontinuity
rt_20170610-214806-5-A-94BE.dat.txt	X (FYS)				
rt_20170611-175146-5-A-B565.dat.txt		X (FYS)			

Example of sonde inventory

Dropsonde File Name	ALT Start (m)	ALT END (m)	Packets Received (#)	Packets Received (%)	Xpr Tap	Foam (white/ Blue)	SST Sensor (standard/ Grad. Comp)	Hydrometeor Shield
rt_20170610-204209-2-A-E0BF.dat.txt	9927	9	402	97.6	2.85	white	std	no
rt_20170610-204532-3-A-09AA.dat.txt	9960	20	419	97.4	2.85	white	std	no
rt_20170617-193501-5-A-79D3.dat.txt	11249	63	346	73.7	0.7	blue	Grad_comp	yes

Example of sonde inventory

Date	Sondes Attempted	Bad Sonde/ No Signal	Lost Signal Out of DC8	Terminated Early	Bad/Missing Moisture (Moisture Jump)
0527	13	4	0	0	0
0529	22	6	1	1	1
0531	17	1	0	0	2
0601	26	4	1	6	1
0602	22	3	0	1	3
0606	11	3	1	2	0
0610	28	2	0	2	4 (2)
0611[a]	31	0	3	0	8(2)
0615	10	1	0	6	1(1)
0616	31	3	0	11	8
0617	20	0	0	10	0
0619	19	0	0	8	0
0620b	16	0	0	1	1(1)
0621	31	1	0	0	2
0623	7	0	0	0	0
0624	10	1	0	1	0
CPEX	314	29 (9.2%)	6 (1.9%)	49 (15.6%) *	31(6) (9.9%)
CPEX Successful Drops	279 (88.9%)			49 (17.6%)	31(6) (11.1%)

CPEX Dropsondes – Terminated Early

1) **49 of the total 314 Attempted (15.6 %)**
2) **49 of the total 279 “Successful” (17.6 %)**
3) **Of the 49 Dropsondes that terminated early:**
   - **8.2 % above 400mb**
   - **8.2% between 400 and 500mb**
   - **16.2% between 500 and 600 mb**
   - **28.6% between 600 and 700 mb**
   - **18.4% between 700 and 800 mb**
   - **20.4% below 800 mb**

CPEX Dropsonde Issues

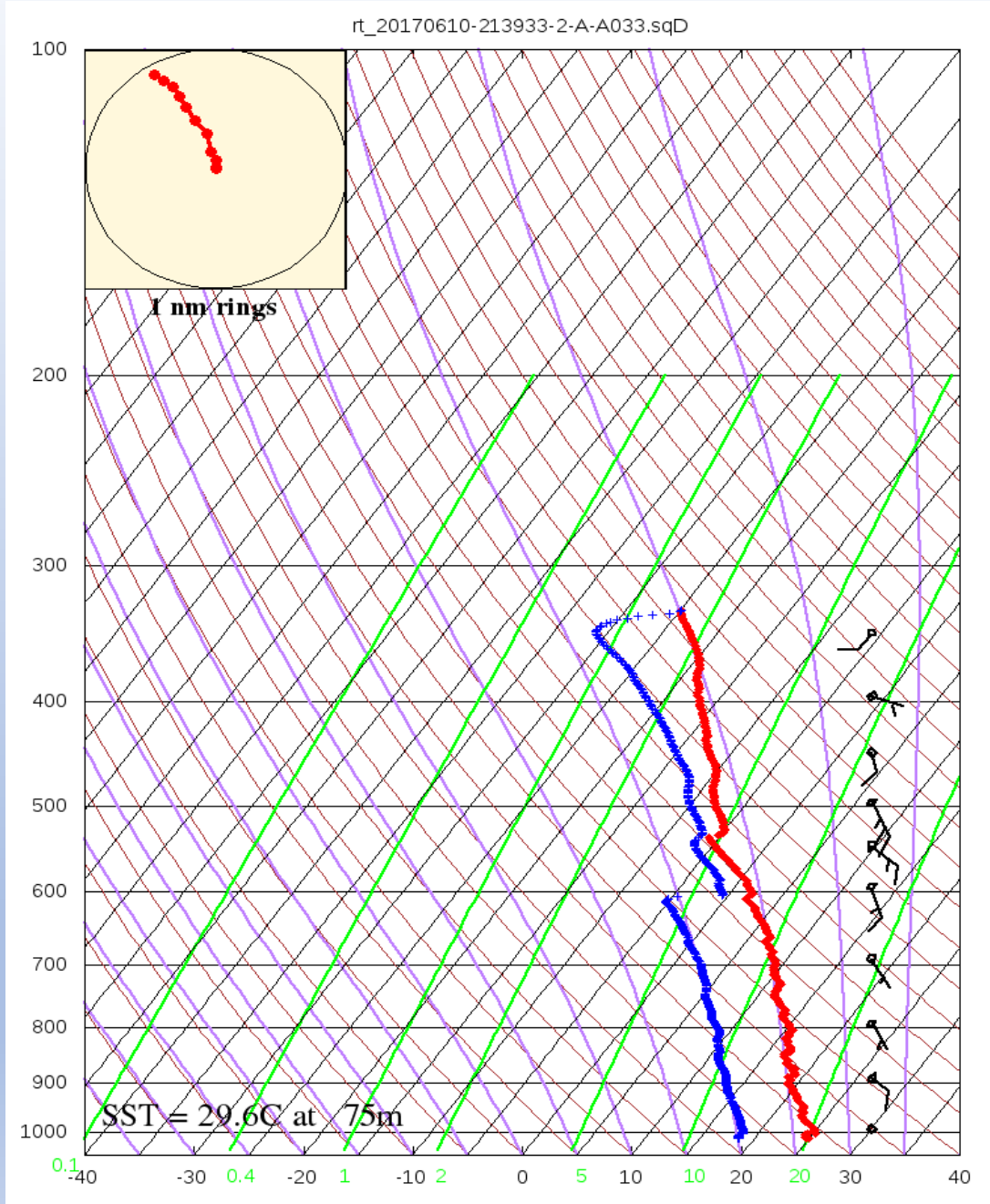
1) During Field Campaign

- Loss of telemetry - Receiver experienced higher noise levels in aircraft than expected, resulting in lower data recovery from the dropsondes
- Shock on launch caused the battery to shift enough to lose power and link to sonde was lost
- Water ingress was also suspected to lead to failures lower in the flight, especially drops into heavy precipitation.
- Issues with RH sensor - RH measured at the RH sensor temperature was transformed on the dropsonde to RH at ambient (thermistor) temperature. This led to difficulties if RH sensor below ambient temperature and RH too high. RH of sensor at sensor temperature found to never exceed 95% or go below 5% (sensor limitation).

2) Post-Campaign Analysis

- GPS/LAT/LONG jumps within profiles (fixed as of 04/18)
- Moisture “Jumps” or Discontinuities
- ??????

Example of Moisture "Jump"

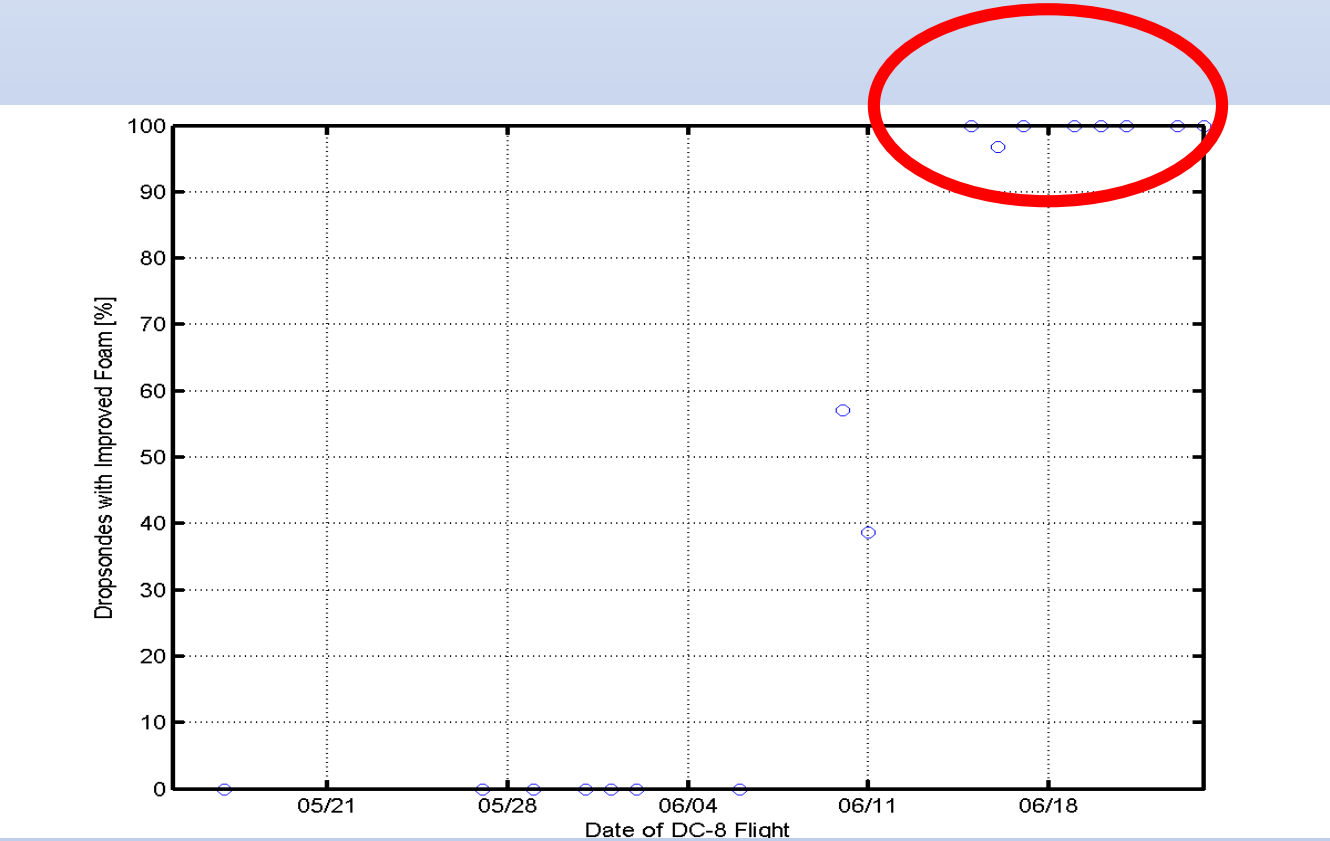


Failure of Dropsonde Upon Exit From DC8

1) Early in CPEX, shock on launch caused the battery to shift enough to lose power and link to sonde was lost
2) YES dropsonde production procedures modified to improve bond between the battery and the circuit board.
3) Mark Beaubien also traveled to the field (June 10) to fix all previous existing sondes by securing the batteries with a small injection of a strong, flexible adhesive
4) The fixes were a success and performance significantly improved after June 11 (see previous Table) – decreased # of Bad Sondes/No Signal

Loss of Telemetry – Terminated Early

- The packaging of the sonde was improved by denser foam and better sealing after the first week of CPEX
- YES installed a replacement receiver with improved shielding before the June 20 flight
- As seen in the Figure 1, the over 97% of all possible packets were received on 6/20, 6/21, and 6/23.



Date	Sondes Attempted	Bad Sonde/ No Signal	Lost Signal Out of DC8	Terminated Early	Bad/Missing Moisture (Moisture Jump)
0619[b]	19	0	0	8	0
0620	16	0	0	1	1(1)
0621	31	1	0	0	2
0623	7	0	0	0	0
0624	10	1	0	1	0
CPEX	314	29 (9.2%)	6 (1.9%)	49 (15.6%) *	31(6) (9.9%)
CPEX Successful Drops	279 (88.9%)			49 (17.6%)	31(6) (11.1%)

After the installment of a replacement receiver with improved shielding before the June 20 flight, only 4 out of 64 sondes experienced telemetry issues

Humidity and RH Sensor

- RH of sensor at sensor temperature found to never exceed 95% or go below 5% (sensor limitation).
- RH measurement shifted dramatically, without recovery, on at least 6 sondes.
- Best guess: water got to leads on RH sensor, shifting capacitance measurement.
- RH measurement on other drops shifted, but then recovered (water on sensor?)
- A hydrometeor shield for the RH sensor was designed and implemented during the latter part experiment and will be used in future deployments.

CPEX Dropsonde Processing and QC

NCAR/AVAPS (RD-94) - Have been using ASPEN software to further filter out bad data and further process and QC dropsonde data

1) unpublished data smoothing/modification routines (QC)
2) ASPEN appears to screen/eliminate wild outlier errors in telemetry
3) applies derivative or "speed up" thermodynamic corrections to temperature and RH
4) other functions to mask undesirable data artifacts
5) Hard to tell what else – ASPEN source code is proprietary and unpublished but….

Procedure		Sounding Direction		Variable				Note
		Dn	Up	P	T	RH	Wind	
6.	Limit Check	✓	✓	✓	✓	✓	✓	
7.	Satellite Check	✓	✓				✓	b
8.	Buddy Check	✓	✓	✓	✓	✓	✓	
9.	Outlier Check	✓	✓	✓	✓	✓	✓	
10.	Filter Check	✓	✓	✓	✓	✓	✓	
11.	Pressure Smoothing	✓	✓	✓				
12.	Monotonic Pressure Check	✓	✓	✓				

13.	Temperature Dynamic Adjustment	✓	✓		✓			
14.	RH Lower Limiting	✓	✓			✓		
15.	Final Smoothing	✓	✓		✓	✓	✓	
16.	RH Lower Limiting	✓	✓			✓		
17.	Pressure Adjustment	✓		✓				
18.	Compute Vertical Velocity	✓	✓					
19.	Vertical Velocity Check	✓	✓				✓	b
20.	Create Surface Observation	✓		✓	✓	✓		
21.	Winds Dynamic Adjustment	✓	✓				✓	
22.	Compute Altitude	✓	✓					
23.	Compute Position	✓	✓					

YES XDD Dropsonde Processing and QC

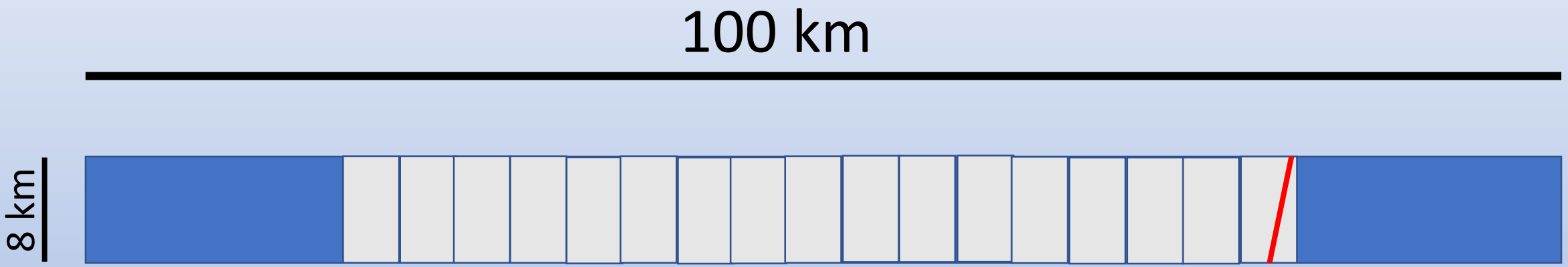
- **Works entirely in the digital domain and reports calibrated data directly from sensors**
- **Only calculated data is the use of the hypsometric equation to calculate pressure altitude after splash**
- **YES implements forward error correction which, while nearly always resulting in protected data transmission, could introduce outliers in the data.**
- **Most effected fields: latitude, longitude, battery voltage**
- **PTU and winds virtually never affected**
- **Outliers filter Minimum of Multiple Interpolated/Extrapolated Differences (MMIED) applied to screen the lat/long fields for errors–PERFORMED BY YES to fix the GPS/Lat/Long issue in April 2018**

YES CPEX Dropsonde Processing and QC

- **YES Provides no other QC**
- **Leaves it up to the user of data for further QC, averaging, smoothing, excluding, etc..**
- **At this time, no solution suggested for Moisture “jump” other then disregarding the data after the jump**
- **Perhaps a modified version of ASPEN that can handle YES dropsonde data can be used**

DAWN – DROPSONDE WIND COMPARISONS

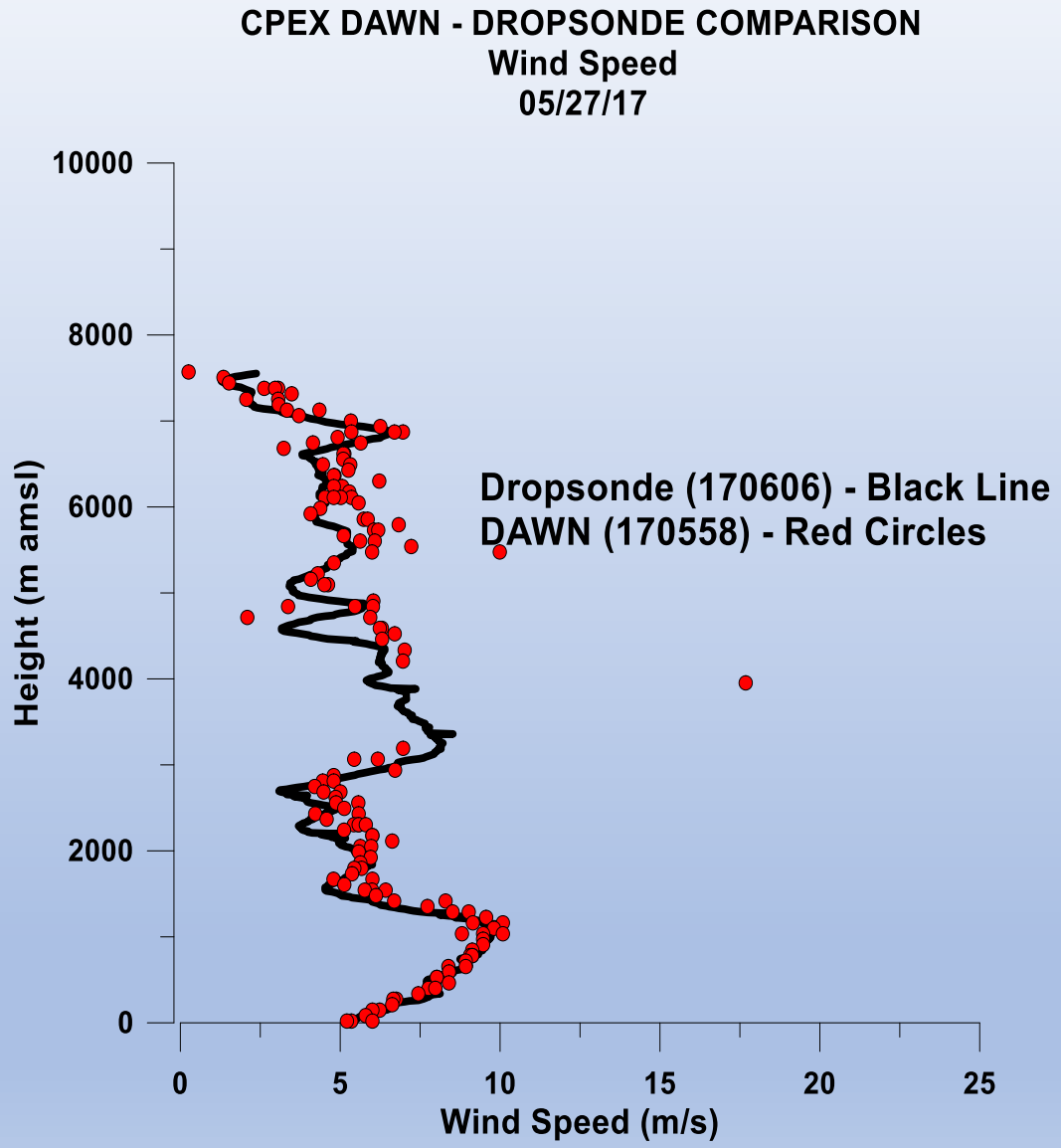
DAWN vs dropsonde sampling comparisons

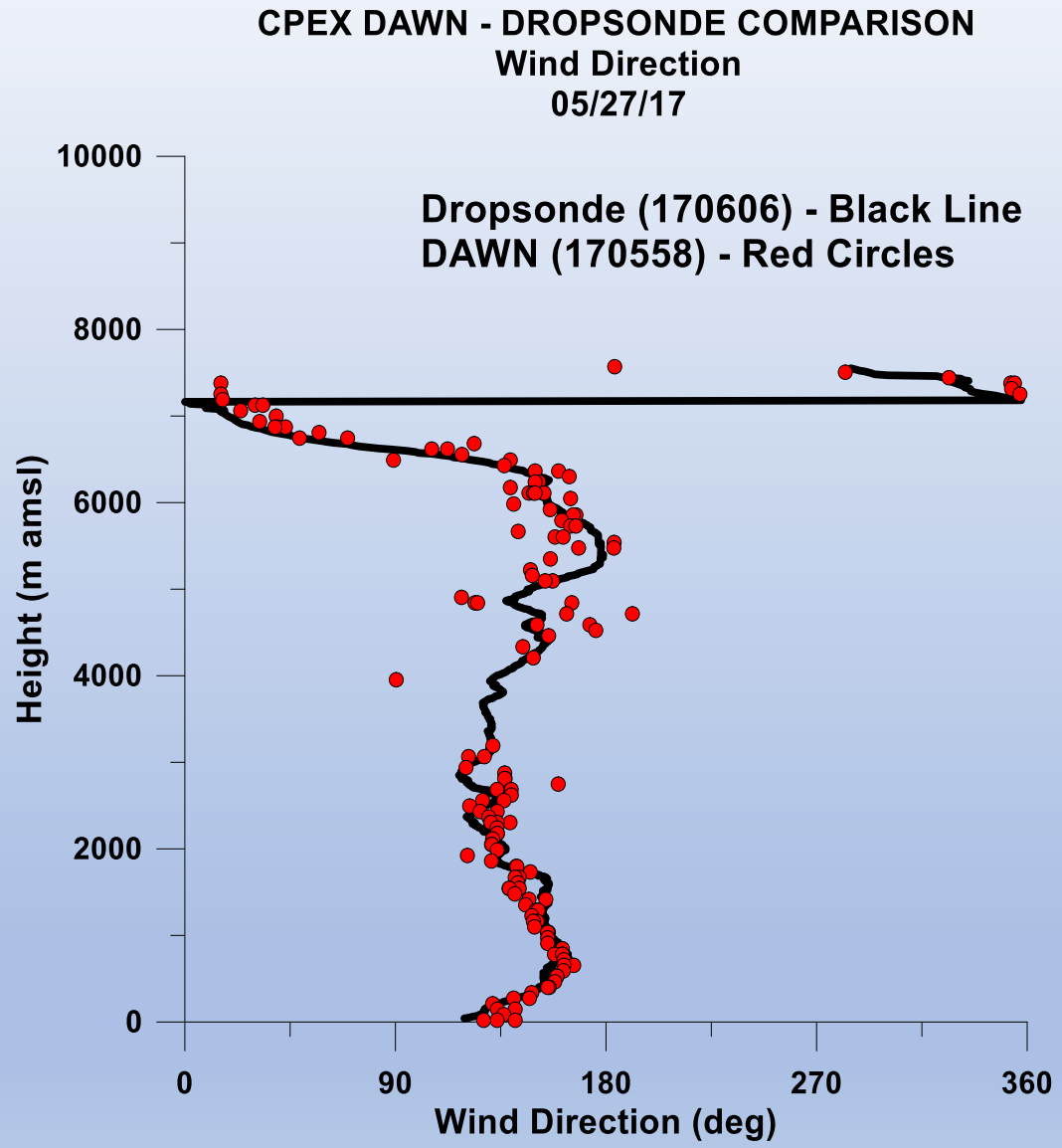


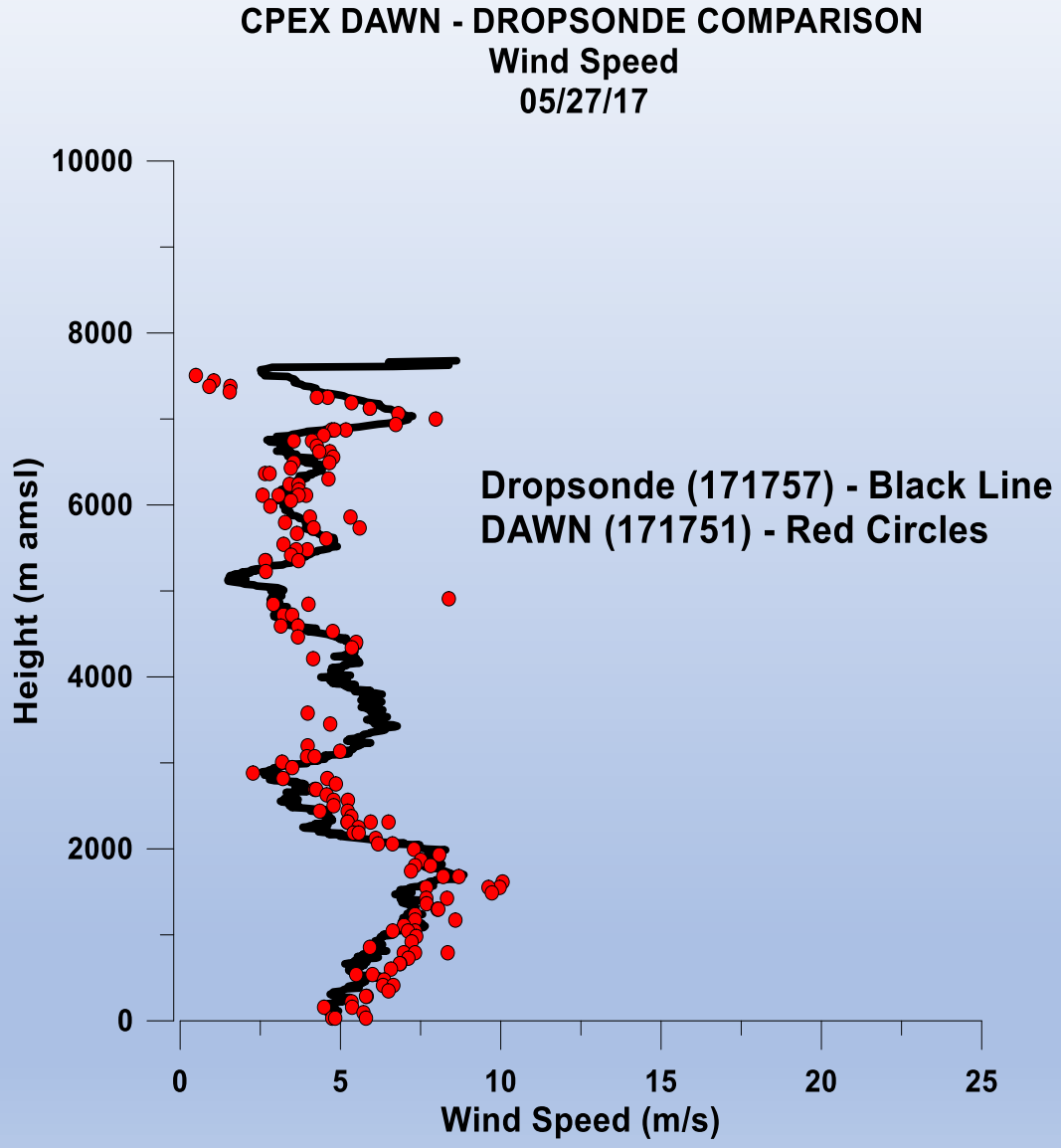
Dropsonde: 30 -20m/s fall speeds
Time in flight: 8000 m in ~5.3 minutes
DC-8 ground distance: ~ 65 km
Horizontal drift (10m/s wind): 3.2 km

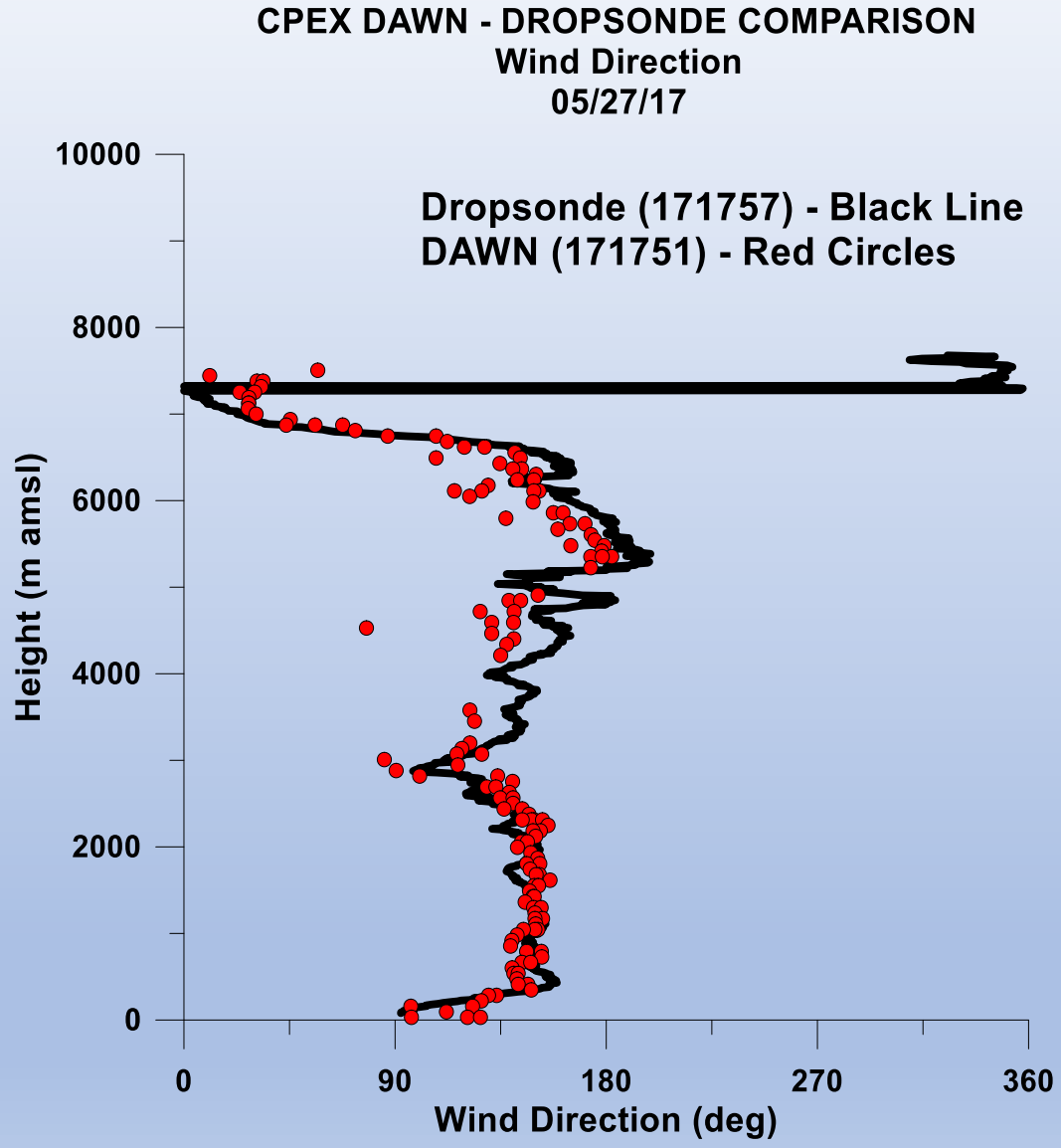
DAWN: ~10 seconds sampling +9 seconds overhead per sounding (3.8km)

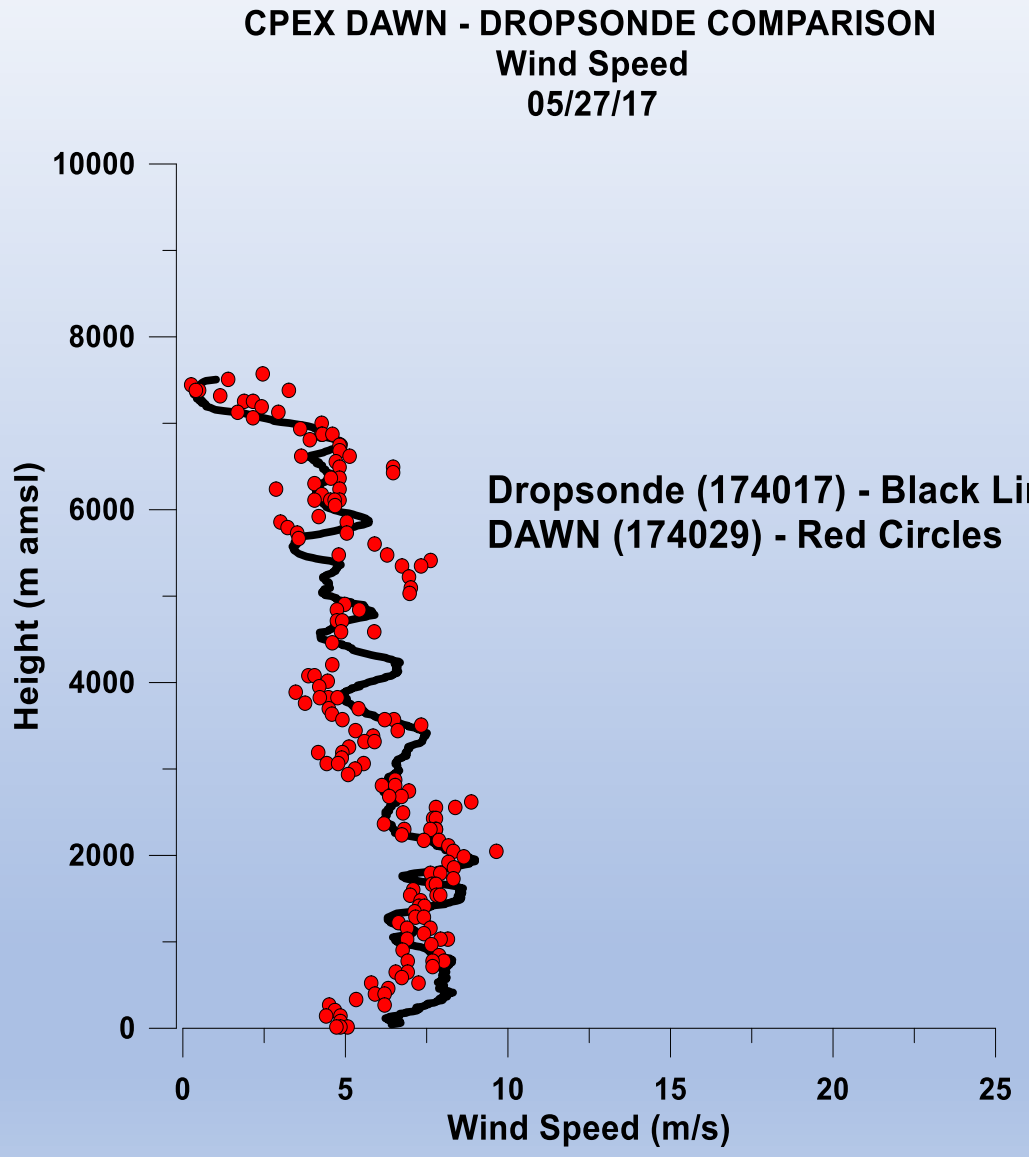

2017-05-27 21:00:00
210606
211757
205728
194958
214017
100 km
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
SOI-MBARI
N
100 km

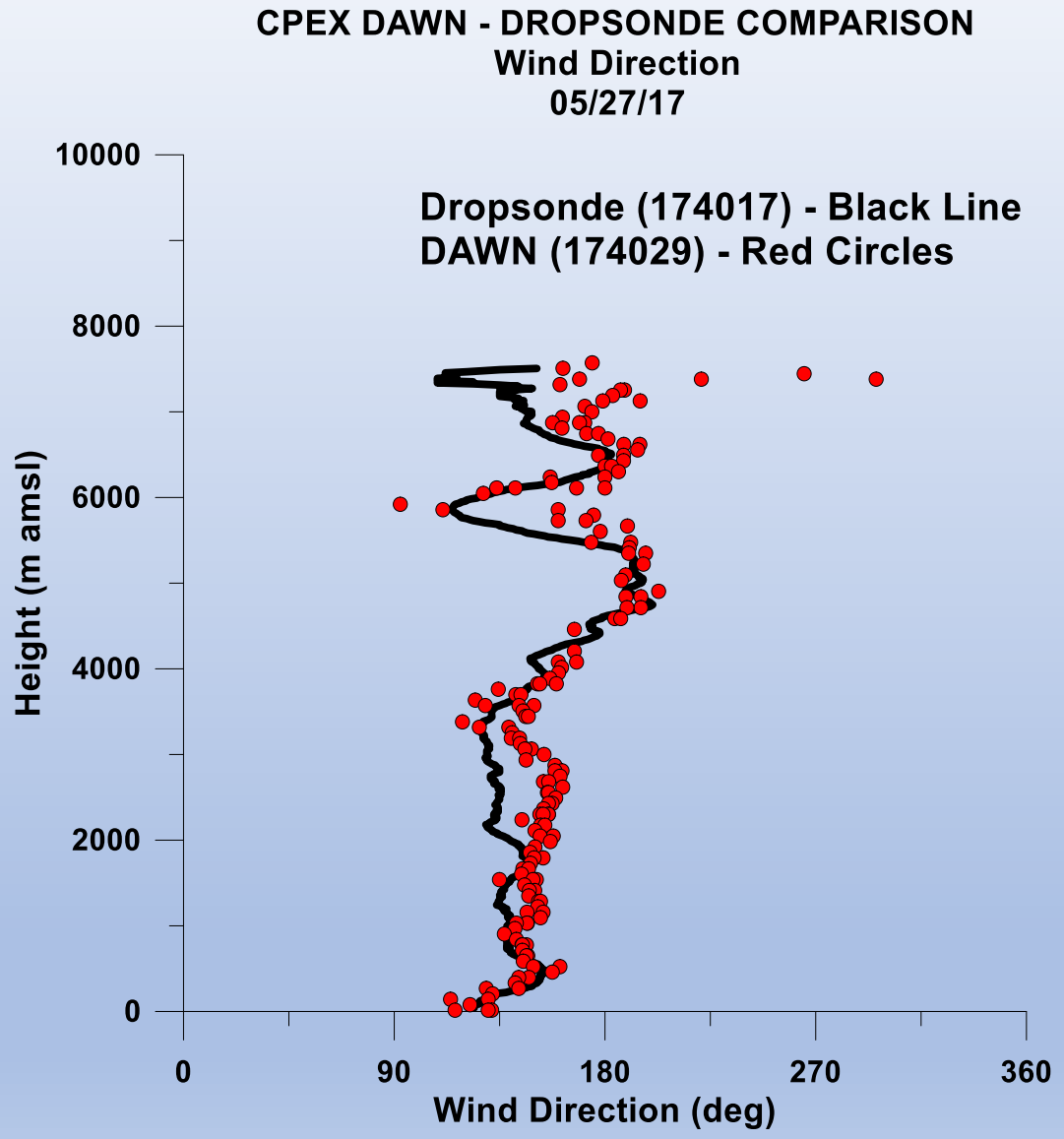

CPEX DAWN - DROPSONDE COMPARISON
Wind Speed
05/27/17
Dropsonde (170606) - Black Line
DAWN (170558) - Red Circles
Height (m amsl)
10000
8000
6000
4000
2000
0
0
5
10
15
20
25
Wind Speed (m/s)

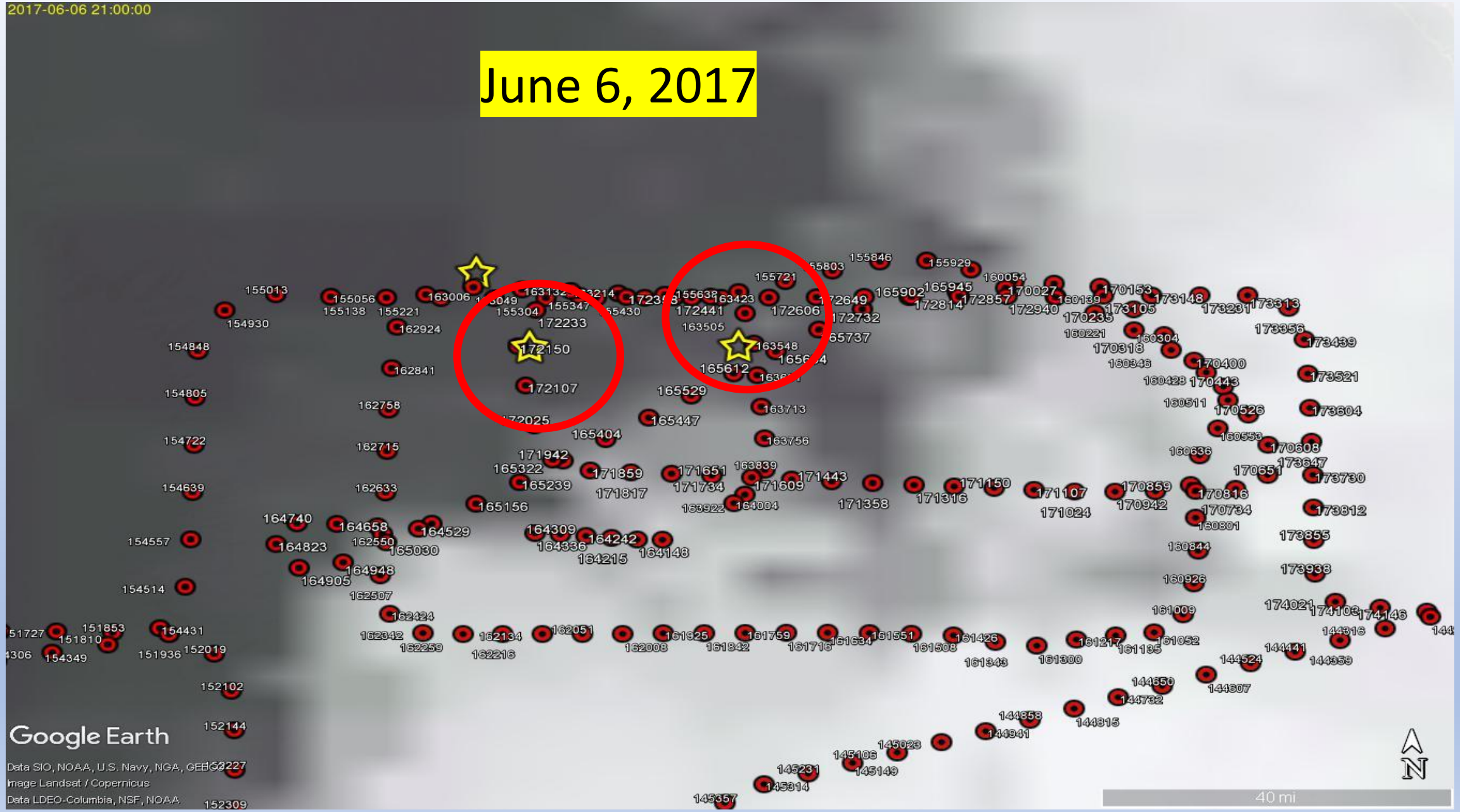

CPEX DAWN - DROPSONDE COMPARISON
Wind Direction
05/27/17
Dropsonde (170606) - Black Line
DAWN (170558) - Red Circles
Height (m amsl)
10000
8000
6000
4000
2000
0
0
90
180
270
360
Wind Direction (deg)

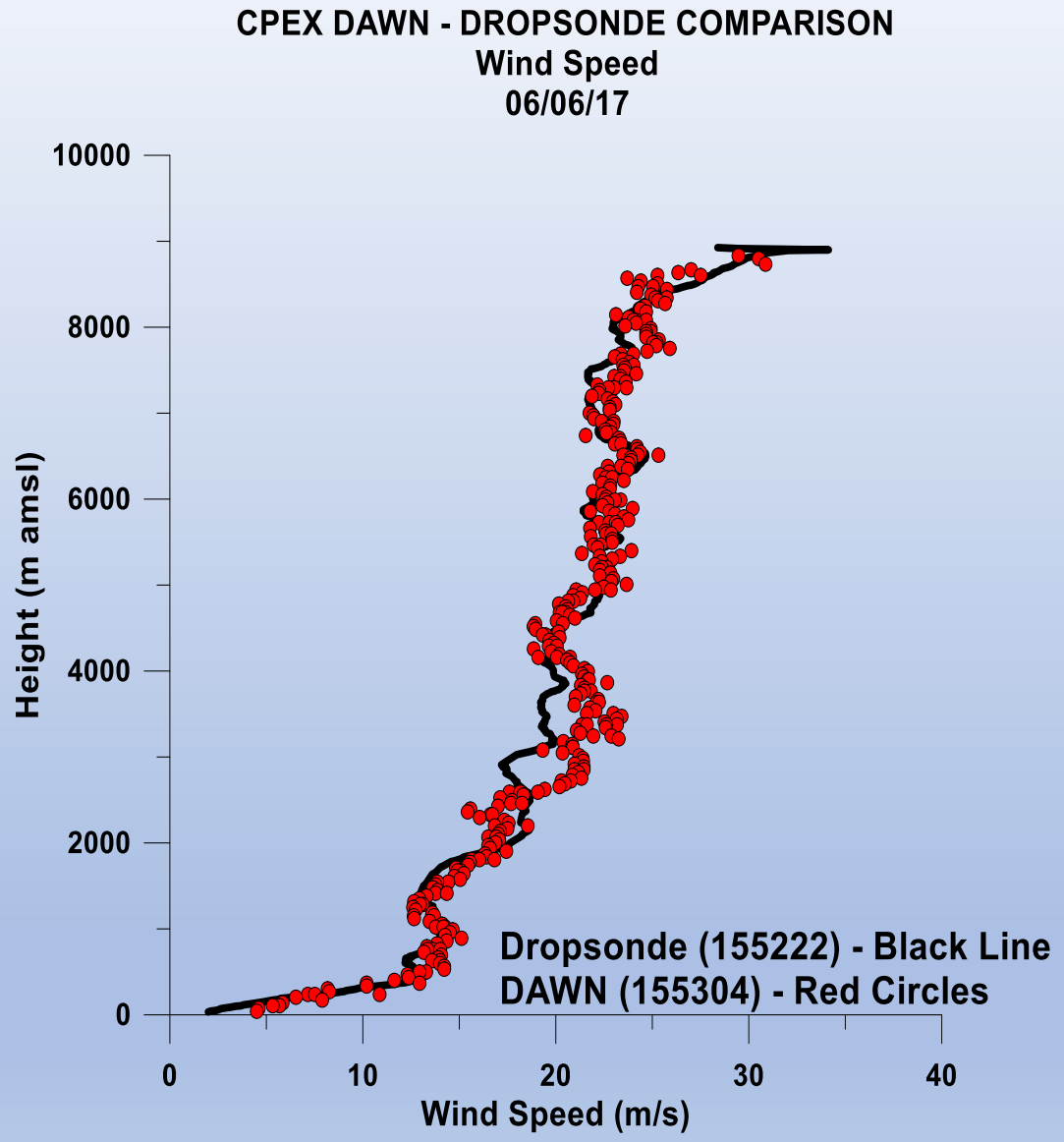

CPEX DAWN - DROPSONDE COMPARISON
Wind Speed
05/27/17
Height (m amsl)
10000
8000
6000
4000
2000
0
0
5
10
15
20
25
Wind Speed (m/s)
Dropsonde (171757) - Black Line
DAWN (171751) - Red Circles

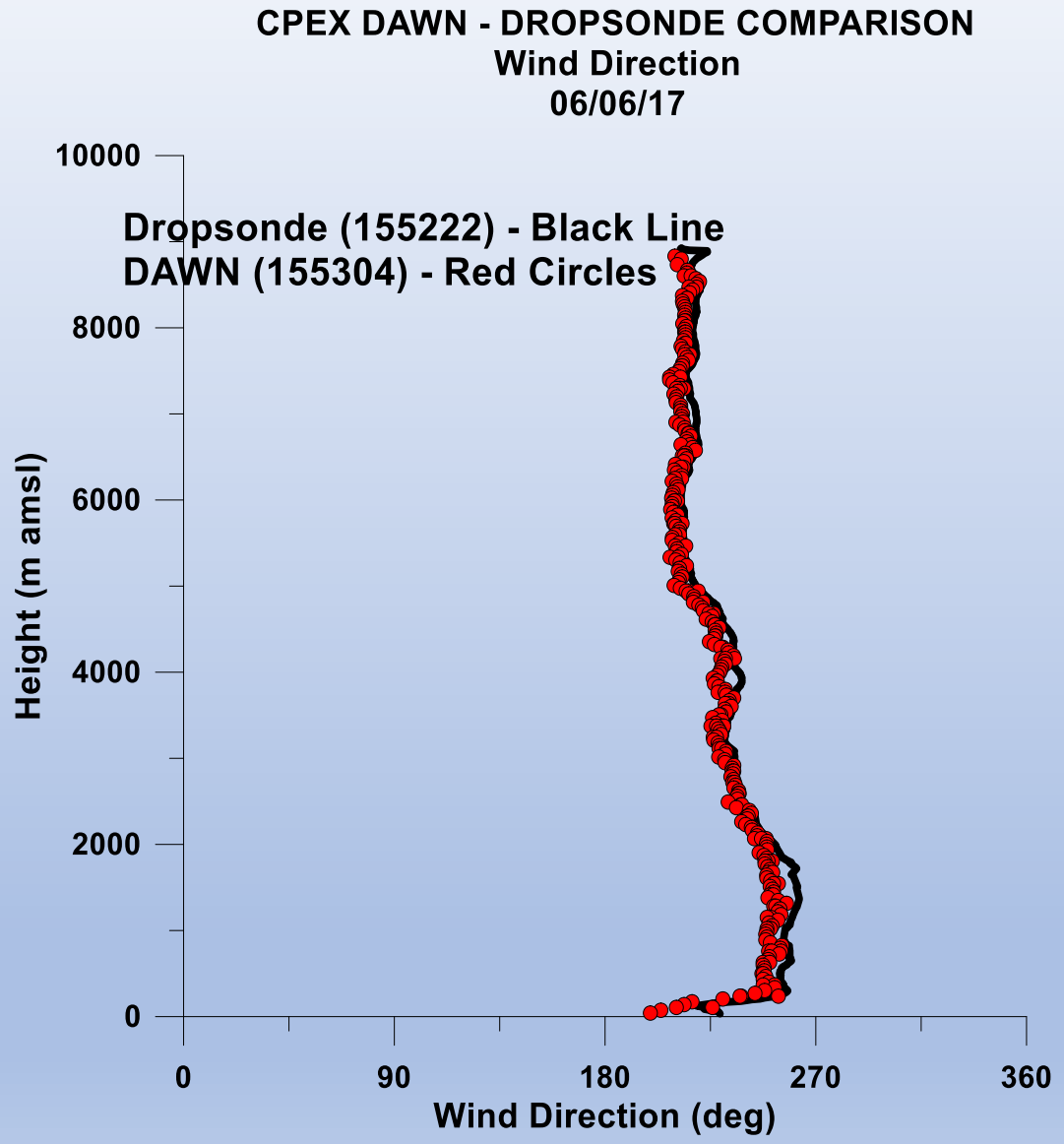

CPEX DAWN - DROPSONDE COMPARISON
Wind Direction
05/27/17
Height (m amsl)
10000
8000
6000
4000
2000
0
0
90
180
270
360
Wind Direction (deg)
Dropsonde (171757) - Black Line
DAWN (171751) - Red Circles

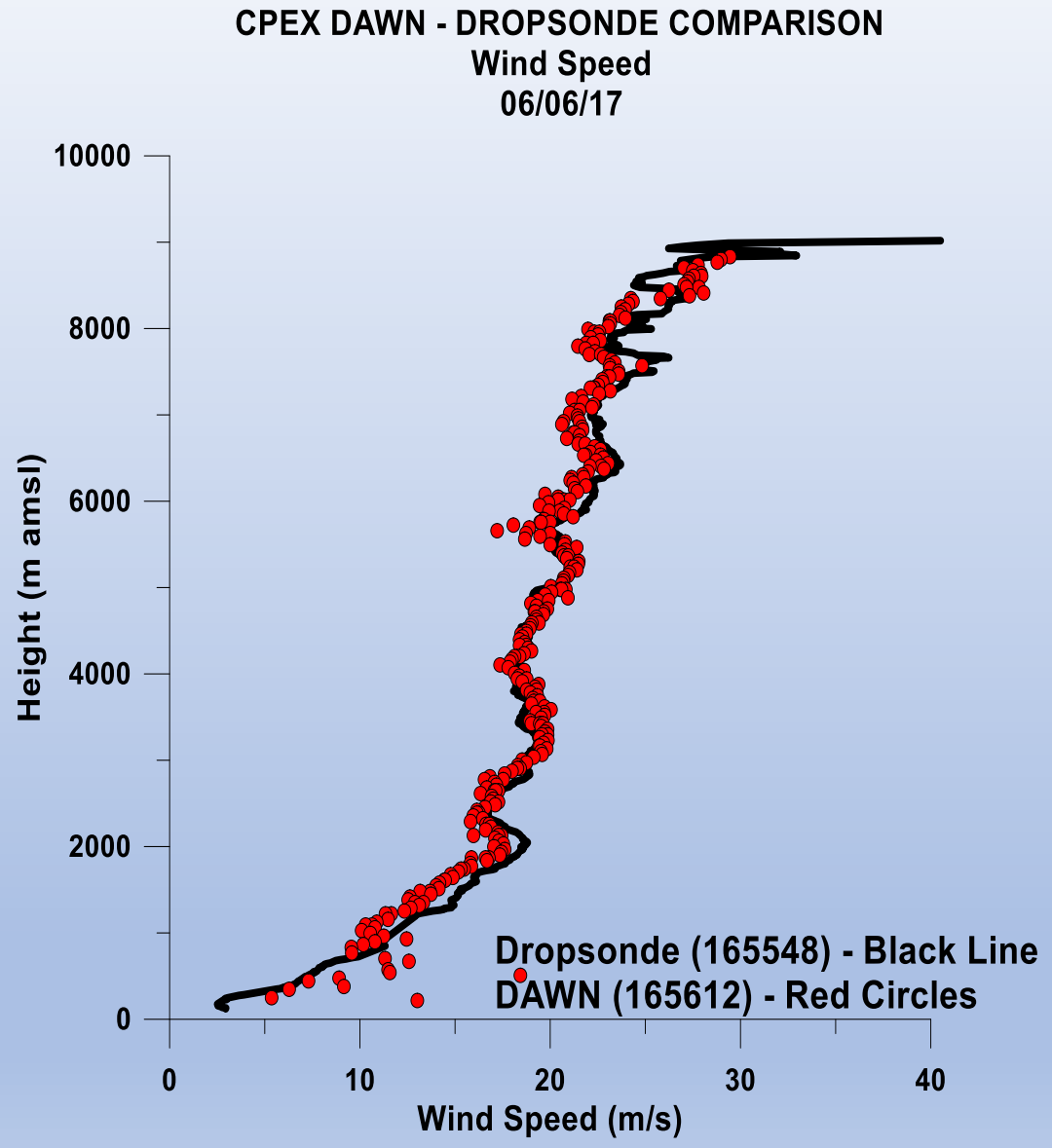

CPEX DAWN - DROPSONDE COMPARISON
Wind Speed
05/27/17
Dropsonde (174017) - Black Line
DAWN (174029) - Red Circles
Height (m amsl)
10000
8000
6000
4000
2000
0
0
5
10
15
20
25
Wind Speed (m/s)

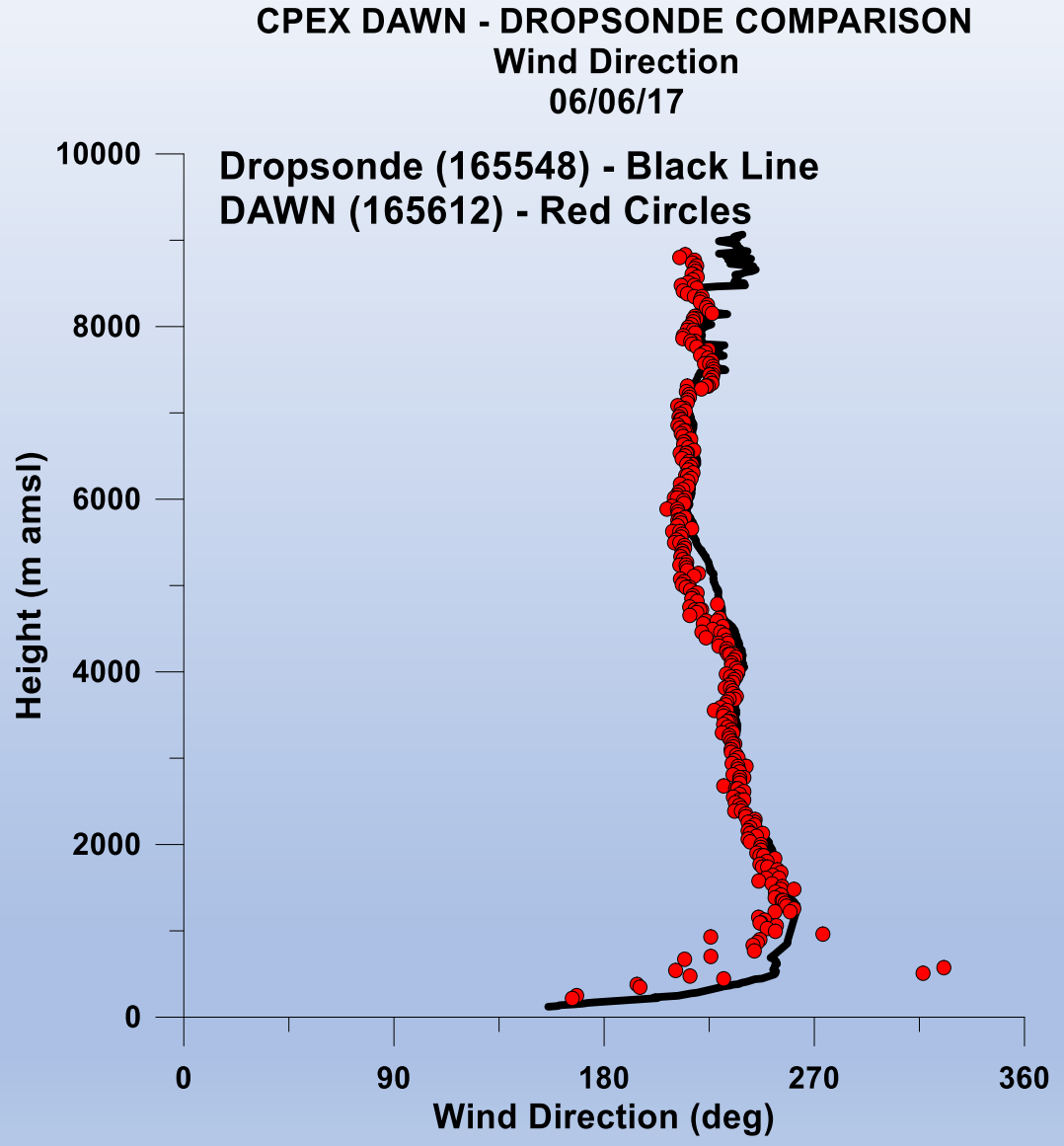

CPEX DAWN - DROPSONDE COMPARISON
Wind Direction
05/27/17
Dropsonde (174017) - Black Line
DAWN (174029) - Red Circles
Height (m amsl)
10000
8000
6000
4000
2000
0
0
90
180
270
360
Wind Direction (deg)

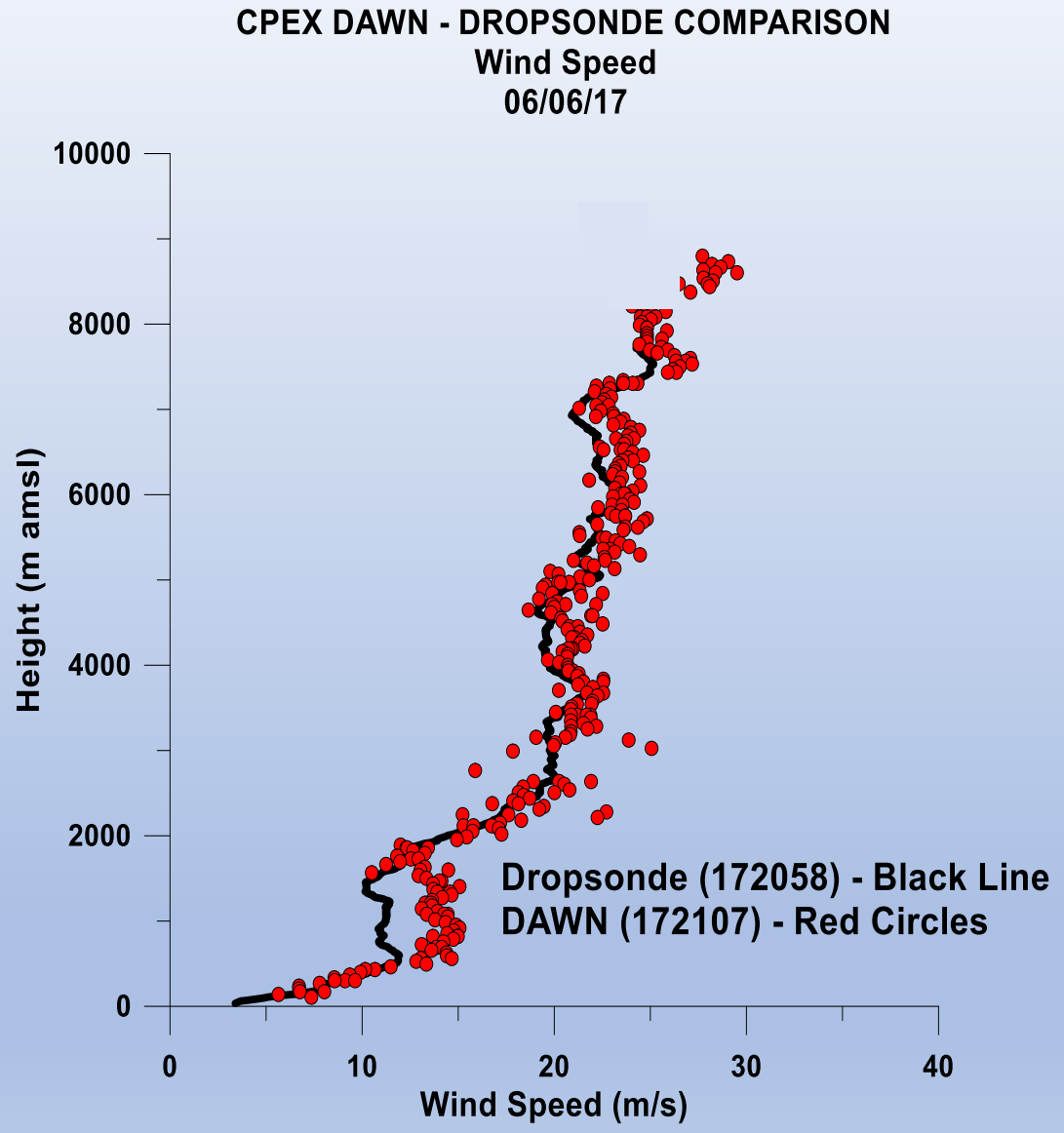

2017-06-06 21:00:00
June 6, 2017
Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Data LDEO-Columbia, NSF, NOAA
40 mi
N

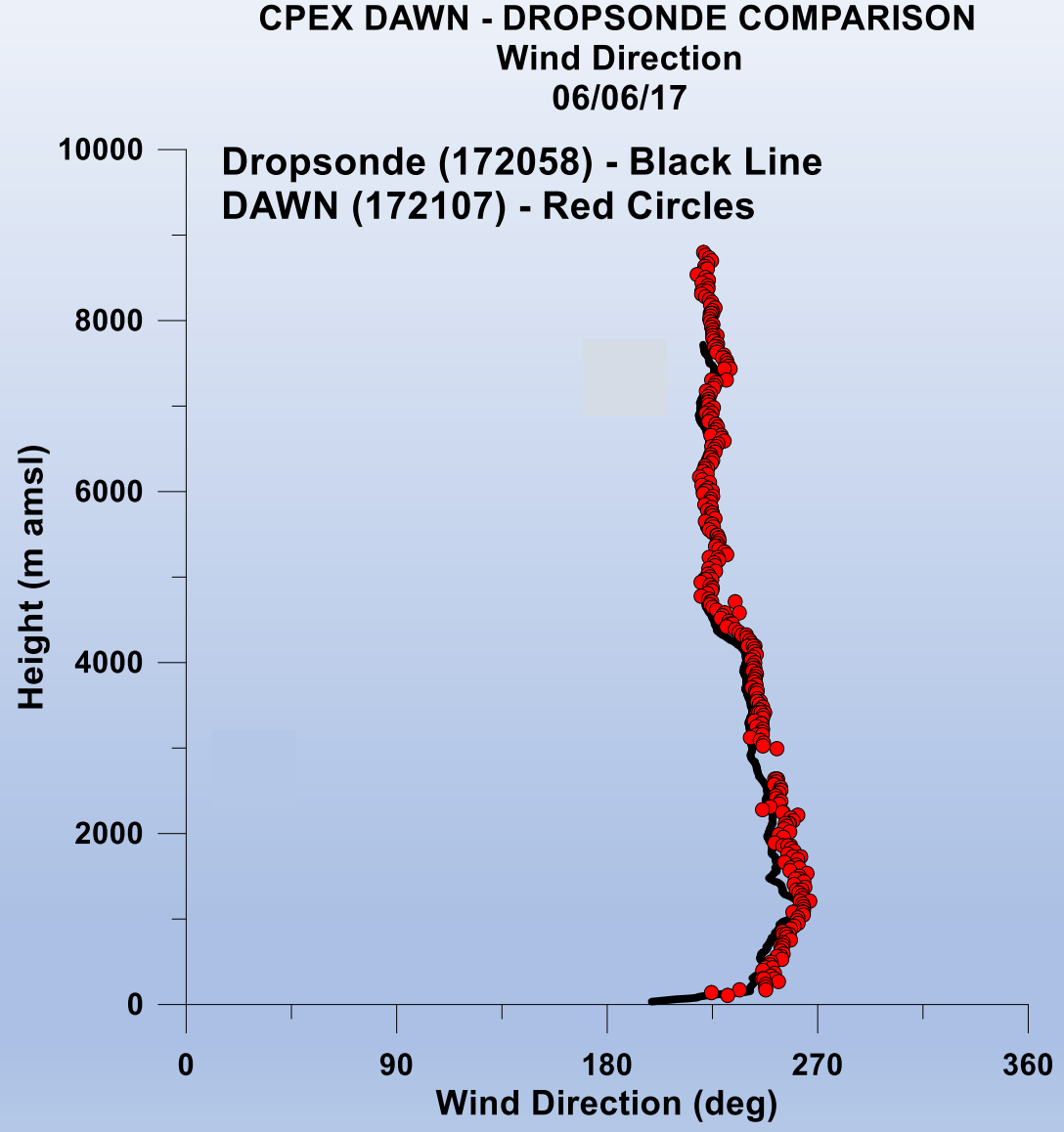

CPEX DAWN - DROPSONDE COMPARISON
Wind Speed
06/06/17
Height (m amsl)
10000
8000
6000
4000
2000
0
0
10
20
30
40
Wind Speed (m/s)
Dropsonde (155222) - Black Line
DAWN (155304) - Red Circles


CPEX DAWN - DROPSONDE COMPARISON
Wind Direction
06/06/17
Height (m amsl)
10000
8000
6000
4000
2000
0
Dropsonde (155222) - Black Line
DAWN (155304) - Red Circles
0
90
180
270
360
Wind Direction (deg)

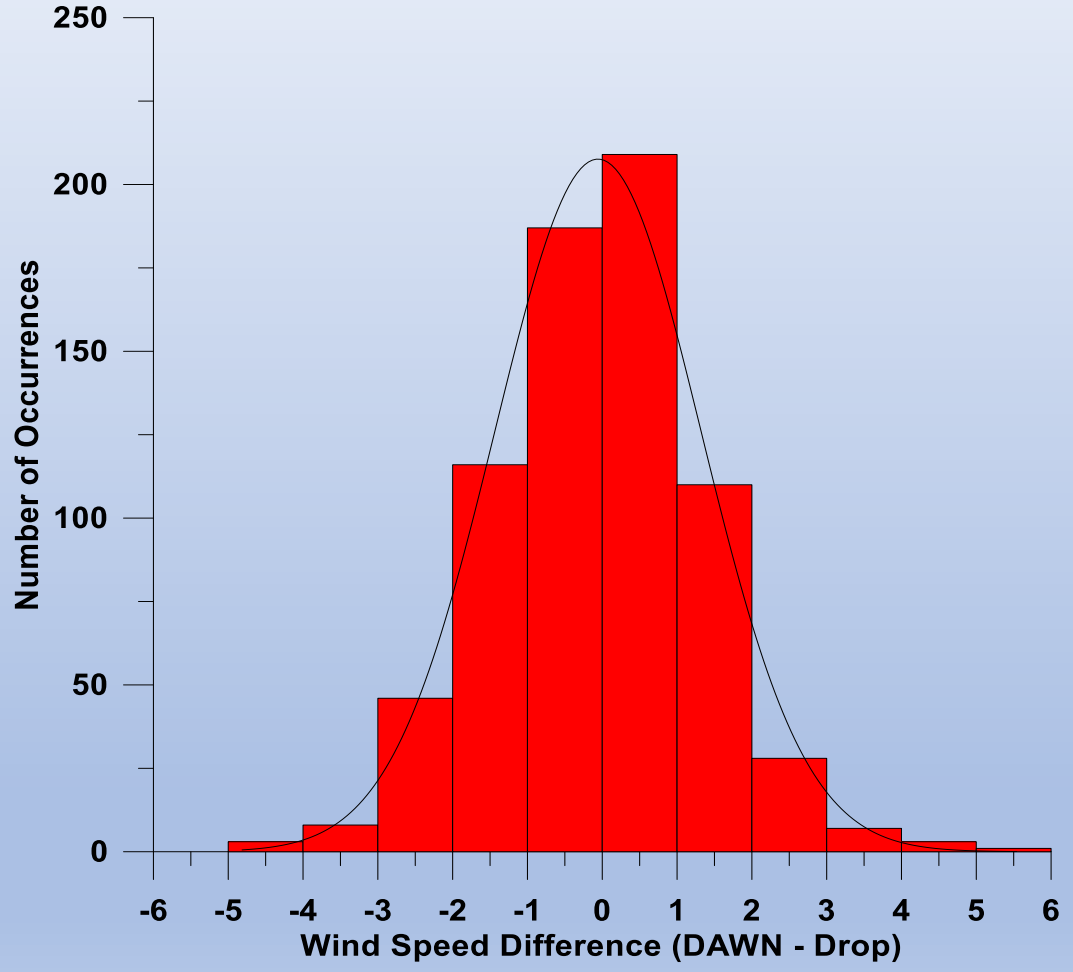

CPEX DAWN - DROPSONDE COMPARISON
Wind Speed
06/06/17
Height (m amsl)
10000
8000
6000
4000
2000
0
0
10
20
30
40
Wind Speed (m/s)
Dropsonde (165548) - Black Line
DAWN (165612) - Red Circles


CPEX DAWN - DROPSONDE COMPARISON
Wind Direction
06/06/17
Dropsonde (165548) - Black Line
DAWN (165612) - Red Circles
Height (m amsl)
10000
8000
6000
4000
2000
0
0
90
180
270
360
Wind Direction (deg)

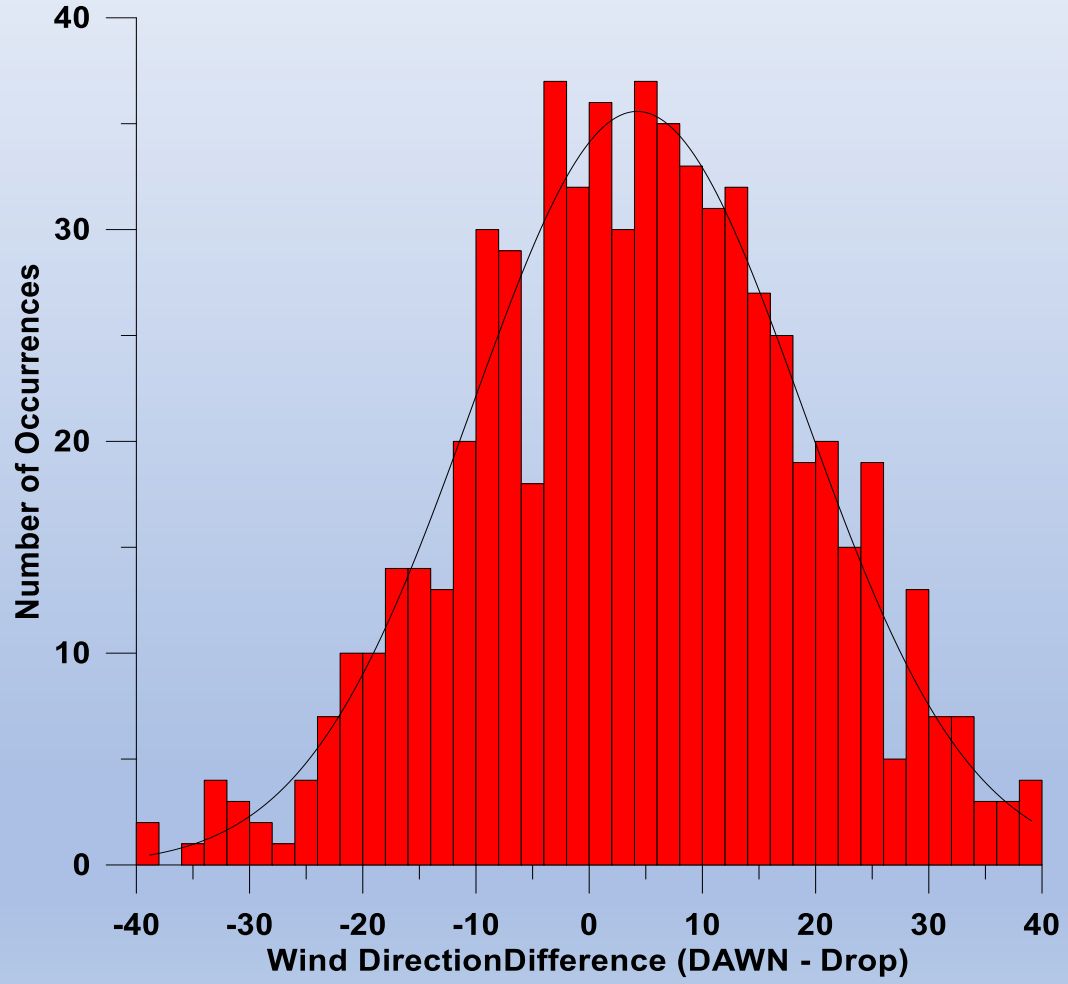

CPEX DAWN - DROPSONDE COMPARISON
Wind Speed
06/06/17
Height (m amsl)
10000
8000
6000
4000
2000
0
0
10
20
30
40
Wind Speed (m/s)
Dropsonde (172058) - Black Line
DAWN (172107) - Red Circles


CPEX DAWN - DROPSONDE COMPARISON
Wind Direction
06/06/17
Dropsonde (172058) - Black Line
DAWN (172107) - Red Circles
Height (m amsl)
10000
8000
6000
4000
2000
0
0
90
180
270
360
Wind Direction (deg)

DAWN - Dropsonde Wind Speed Comparisons
CPEX - May 27, 2017 (All Drops) - BASE



DAWN - Dropsonde Wind Direction Comparisons
CPEX - May 27, 2017 (All Drops) - BASE



Comparison biases and random differences

Date	# Comparisons	WS bias (m/s)	WS RMSD (m/s)	WD bias (deg)	WD RMSD (deg)
5/31/17 & 6/11/17	2174	.68	1.83	+2.11	6.9

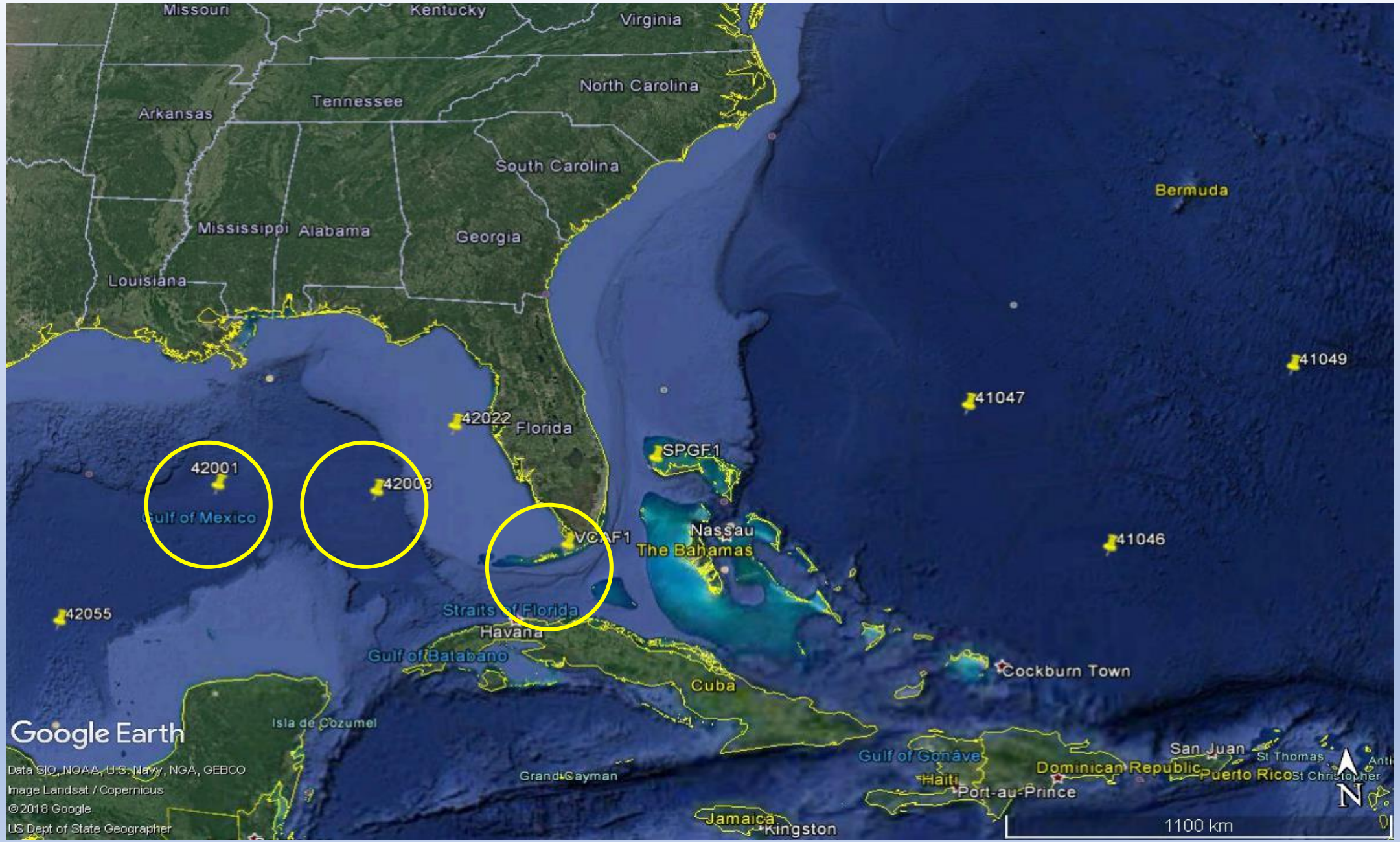
Note 1: Primary cause of bias is due to drift in reported heading from the true heading
Example: .1 degree heading error on DC-8 may introduce .34 m/s error in computed wind speed

Note 2: Primary reason for RMSD (root mean square differences) is spatial and temporal separation of dropsonde and DAWN samples

Height Layer	Number	Δz (m)	DWL –Drop WS BIAS	DWL – Drop WD BIAS
ALL	2175	3.12	0.68	2.11
>6000m	974	3.55	0.69	0.13
3-6000 m	443	2.85	0.80	2.57
< 3000m	757	2.77	0.62	4.37

Height layer	Number	Mean DWL WS (m/sec)	Mean Drop WS (m/sec)	Δ	Mean DWL WD (deg)	Mean Drop WDr (deg)	Δ
All	2175	8.644	7.95	0.68	154.30	155.77	-1.47
>6000m	974	8.885	8.198	0.69	177.29	185.16	-7.87
3-6000 m	443	9.835	9.04	0.80	144.32	141.75	2.57
< 3000m	757	7.635	7.016	0.62	130.57	126.19	4.38

DAWN-DROPSONDE-BUOY COMPARISONS


Missouri
Kentucky
Virginia
North Carolina
Tennessee
Arkansas
South Carolina
Bermuda
Mississippi
Alabama
Georgia
Louisiana
41049
41047
42022
Florida
SPGF1
42001
42003
Gulf of Mexico
VCAF1
Nassau
The Bahamas
41046
42055
Straits of Florida
Havana
Gulf of Batabano
Cuba
Cockburn Town
Isla de Cozumel
Gulf of Gonâve
San Juan
St Thomas
Dominican Republic
Puerto Rico
Haiti
Port-au-Prince
Grand Cayman
Jamaica
Kingston
Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
©2018 Google
US Dept of State Geographer
1100 km
N

Near Surface Wind Comparisons Near Buoys

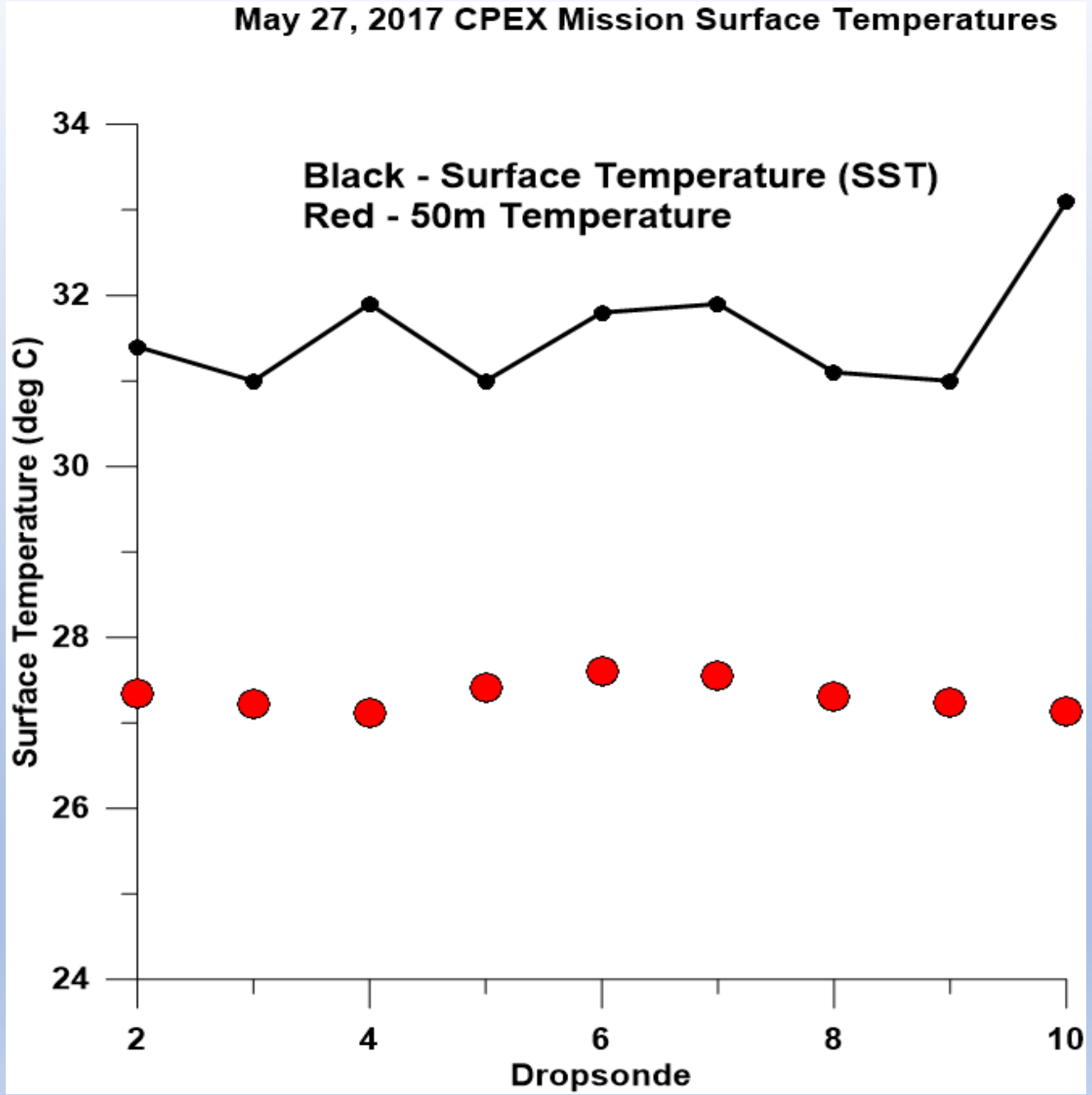
CPEX Mission	DAWN	Buoy (id #)	Dropsonde
May 27, 2017	4.3/110	3.8/121 (42001)	5.0/124
June 1, 2017	2.8/183	3.6/146 (42003)	NA
June 16, 2017	3.2/192	3.7/162 (VCAF1)	3.9/180
June 20, 2017	13.5/161	10.9/157 (42001)	13.2/160
June 20, 2017	12.6/162	11.7/352 (42395)	9.7/ 10
June 21, 2017	12.1/185	9.3/171 (42001)	11.6/173
June 21, 2017	10.5/192	9.0/167 (42001)	11.6/168
June 21, 2017	2.5/127	0.7/165 (42003)	13.3/154

Surface Temperature Parameter

- Sea surface temperature measured with an infrared sensor sensitive to thermal gradients within the sensor package.
- An improved sensor with gradient compensation was used towards the end of the experiment
- Better in dry conditions compared to rain

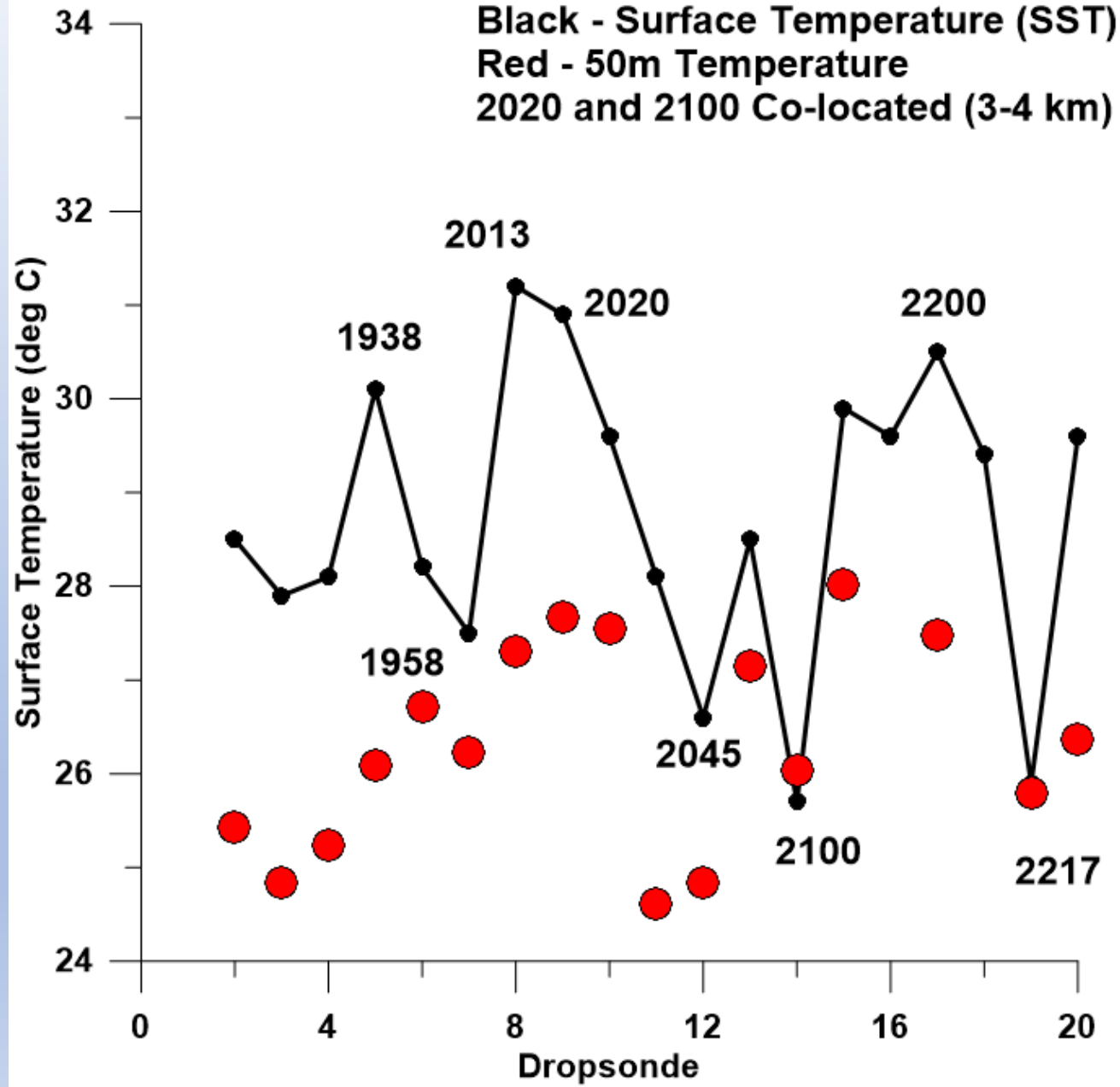
Buoy Air and Water Temperature vs Dropsonde SST

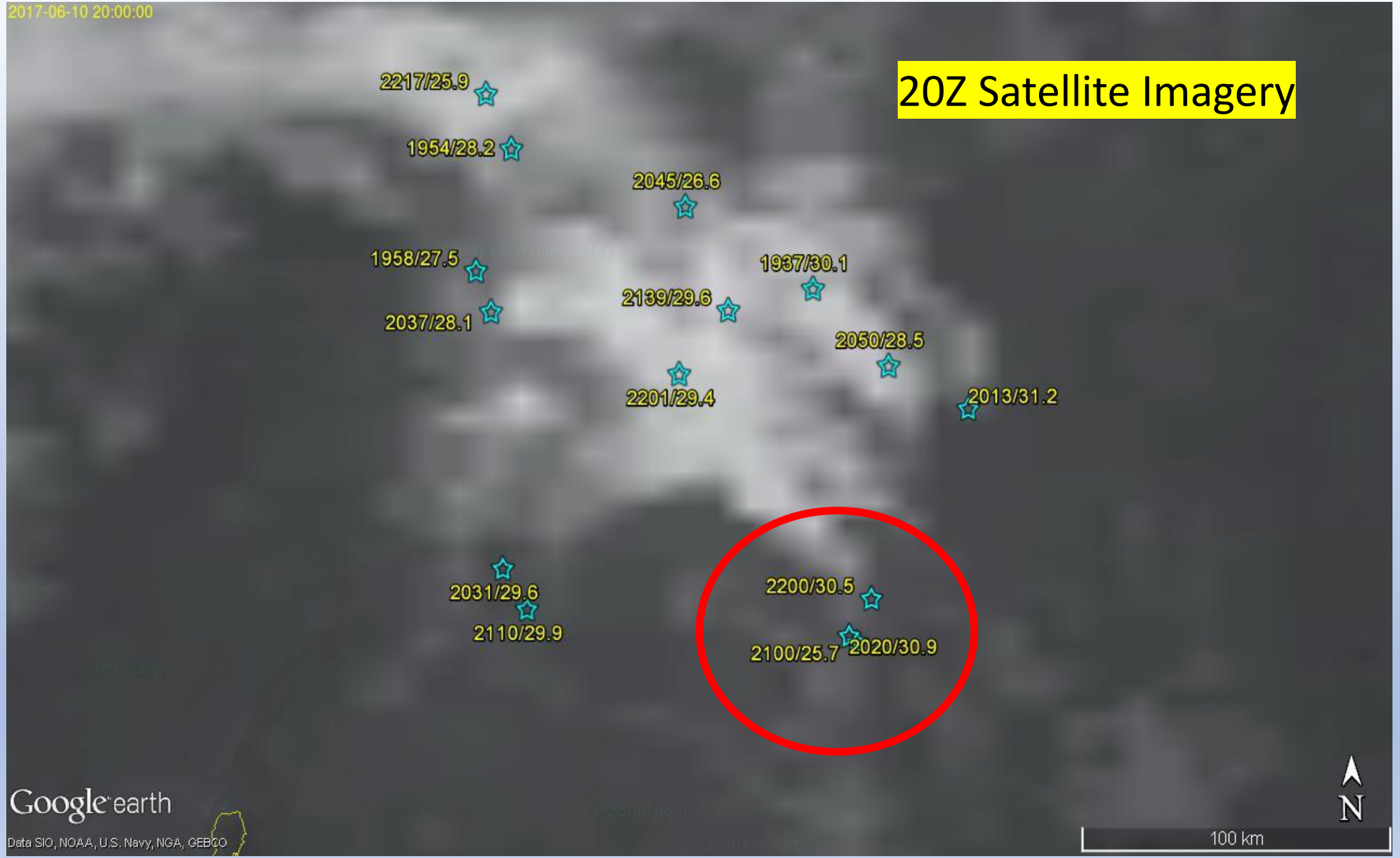
CPEX Mission	Buoy Number	Buoy Air Temperature	Buoy Water Temperature	Dropsonde SST
May 27, 2017	42001	27.5	27.4	31.4
June 16, 2017	VCAF	29.9	31.4	30.7
June 20, 2017	42001	27.5	27.8	26.8
June 20, 2017	42395	26.4	27.6	26.0
June 21, 2017	42001	27.6	27.6	27.5
June 21, 2017	42001	27.7	27.6	27.4
June 21, 2017	42003	29.6	?????	25.4

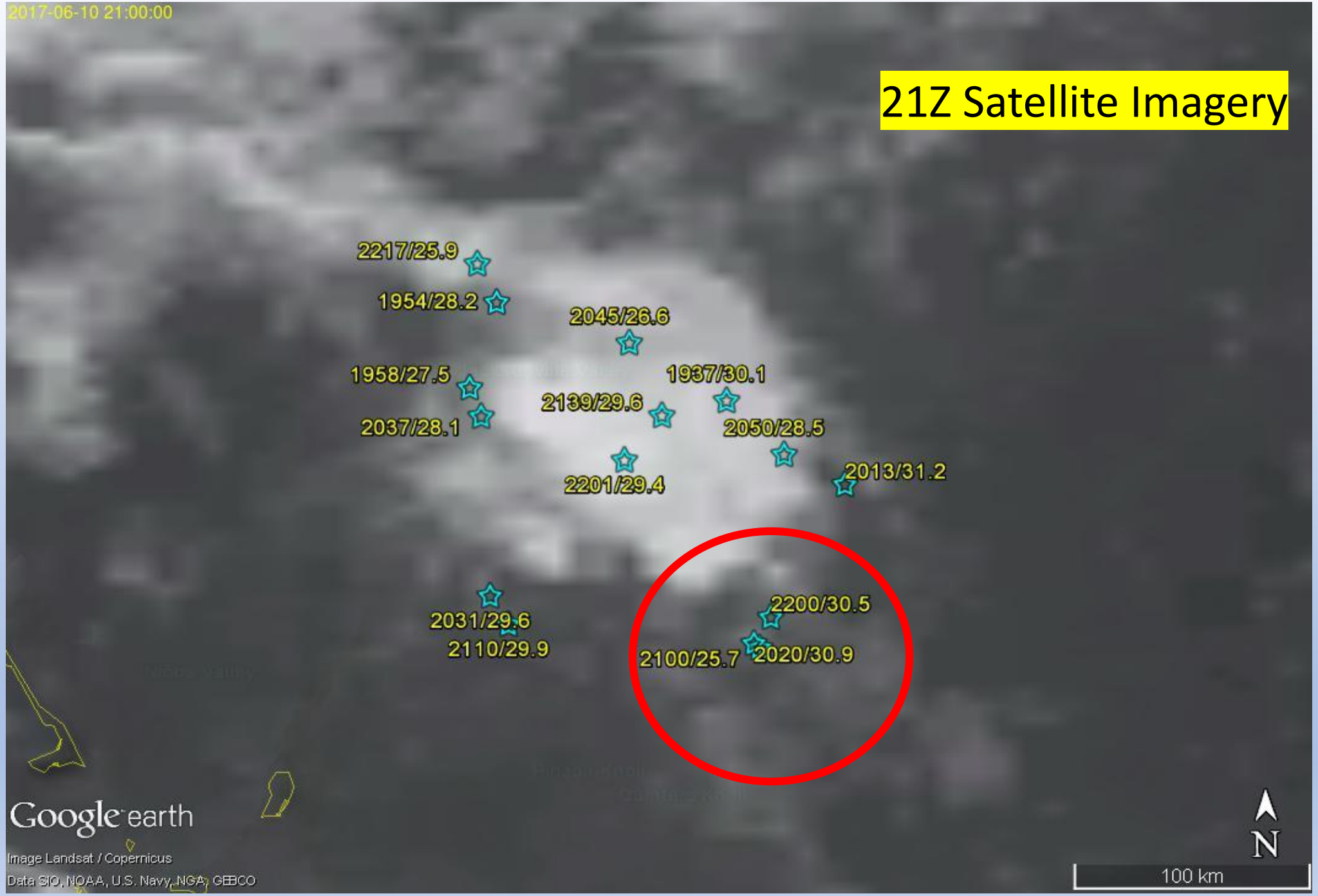

May 27, 2017 CPEX Mission Surface Temperatures
Black - Surface Temperature (SST)
Red - 50m Temperature
Surface Temperature (deg C)
34
32
30
28
26
24
2
4
6
8
10
Dropsonde

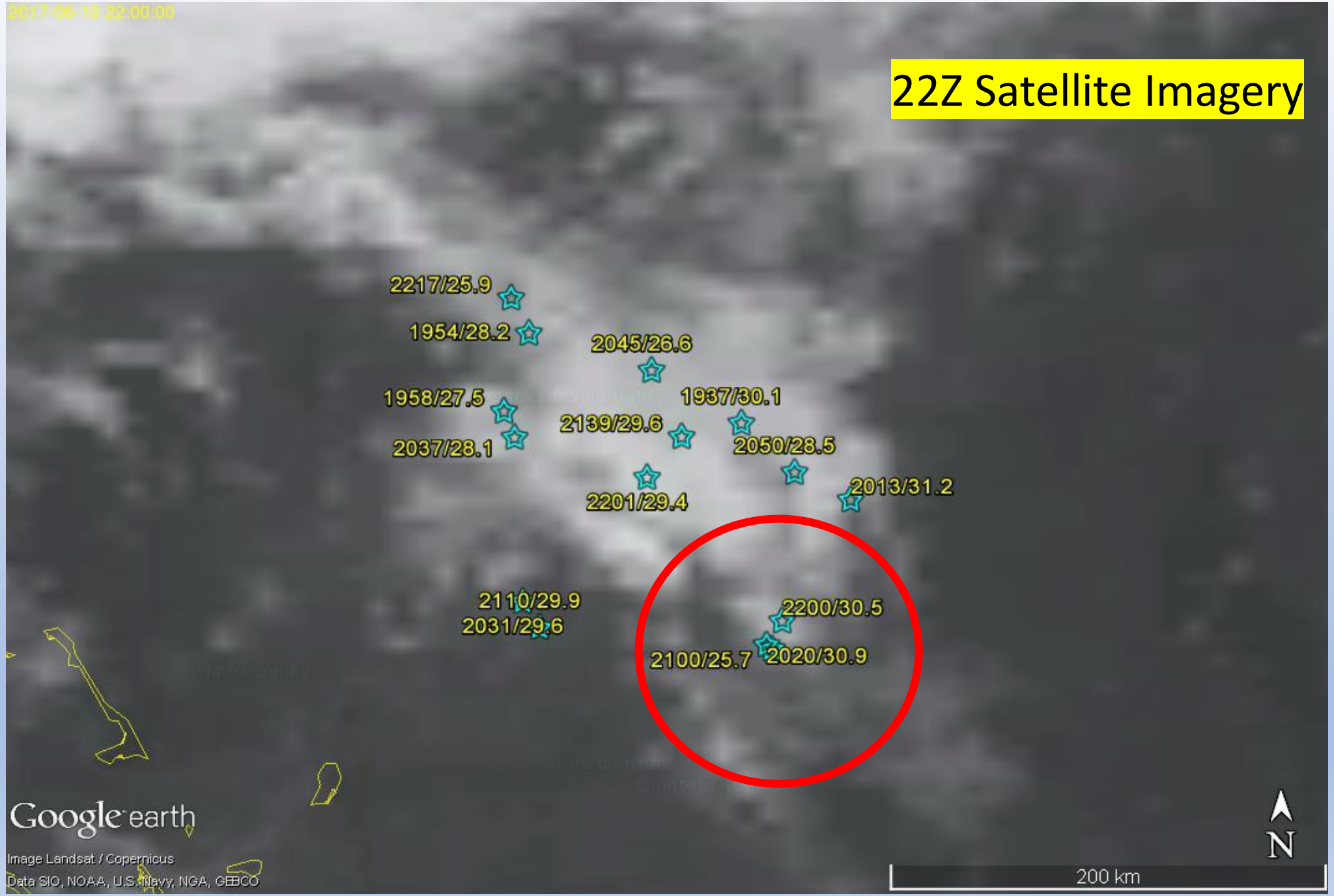

2017-05-27 22:00:00
2028/31.4
2106/31.8
2118/31.9
2039/31.9
2057/31.0
2158/33.1
2020/31.0
2140/31.0
2129/31.1
Gulf of Mexico
Google earth
SOI-MBARI
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
80 km

June 10, 2017 CPEX Mission Surface Temperatures




2017-06-10 20:00:00
20Z Satellite Imagery
2217/25.9
1954/28.2
2045/26.6
1958/27.5
1937/30.1
2139/29.6
2037/28.1
2050/28.5
2201/29.4
2013/31.2
2031/29.6
2110/29.9
2200/30.5
2100/25.7
2020/30.9
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
100 km


2017-06-10 21:00:00
21Z Satellite Imagery
2217/25.9
1954/28.2
2045/26.6
1958/27.5
1937/30.1
2139/29.6
2037/28.1
2050/28.5
2013/31.2
2201/29.4
2031/29.6
2110/29.9
2200/30.5
2100/25.7
2020/30.9
Google earth
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
100 km


22Z Satellite Imagery
2217/25.9
1954/28.2
2045/26.6
1958/27.5
1937/30.1
2139/29.6
2037/28.1
2050/28.5
2013/31.2
2201/29.4
2110/29.9
2031/29.6
2200/30.5
2100/25.7
2020/30.9
Google earth
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
200 km

Summary

1) **DAWN vs. dropsonde Wind comparisons support the following:**

- **Airborne DWL soundings and dropsonde soundings should never be expected to be identical and thus should never be used as a "calibration" of ADWL with the exception of bias estimates based upon 1000's of comparisons under differing conditions.**
- **Coherent DWL soundings limited to a few km (~ 2-5km) in the vicinity of a dropsonde sampling volumes provide "about as good as is possible" comparison for expressing differences of wind speed and wind direction on the scale of a few km.**

2) Moisture Issues have been noted – Correction for Moisture "Jump"?

3) Surface temperature show promise but need to be treated with caution- Works better in dry conditions

4) Further processing/QC up to Science team or Individual Users