

Preliminary Comparisons of DAWN, Dropsonde and Aeolus Wind Observations

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Working Group Meeting for Space Lidar Winds

Hampton, Virginia

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Airborne DAWN Underflights of Aeolus

- April 17-30, 2019 NASA Airborne Campaign
- Based out of Palmdale, CA
- Airborne DAWN and YES Dropsonde aboard NASA DC-8
- 5 underpasses of Aeolus in April 2019
- Over the eastern Pacific Ocean
 - Two transects between US west coast and Hawaii
 - **Three missions off west coast of US (30 – 50 N)**
 - **Mostly clear to partly cloudy conditions**
 - **Low and high aerosol segments**

DAWN Wind Measurements

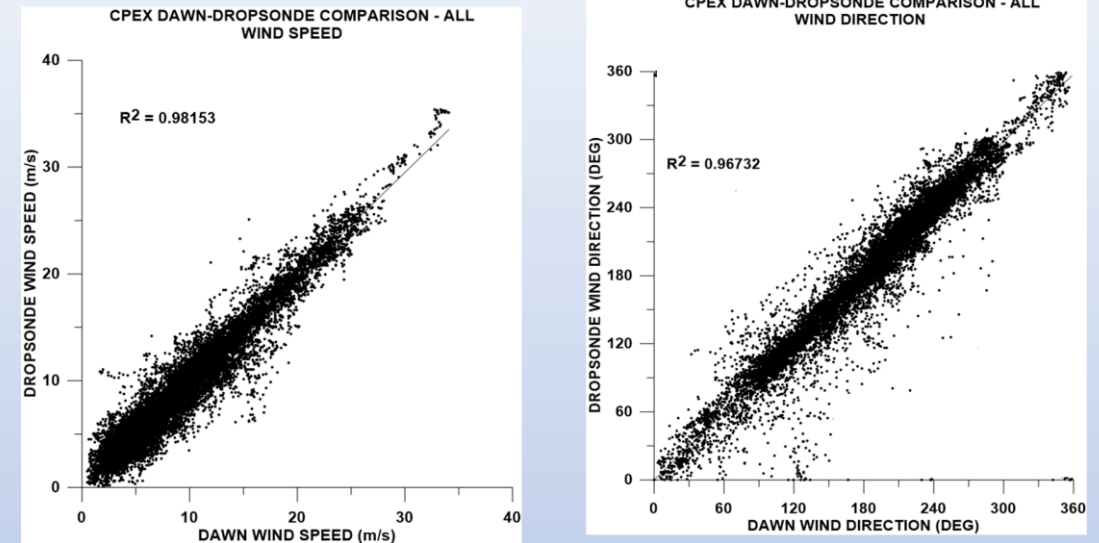
- DAWN
 - 2 micron coherent
 - 5Hz, 20 shots per look for April flights
- DAWN wind vector products are low bias ($< .25\text{m/s}$) and good RMSD in comparisons with dropsondes (see next slide)
- 3-D Wind Profiles computed for 5-look DAWN scanning pattern (5 LOS)
 - 20 shot integration
 - 4-5km horizontal resolution
 - 75m vertical resolution along LOS
 - 33m resolution for vertical profiles
- U and V of DAWN profile used to compute a DAWN Aeolus projection of HLOS for every scan

DAWN data quality

DAWN-Dropsonde comparisons from CPEX 2017
Wind Speed (m/s)

	Number 37m seg	MEAN Z DIFF (m)	BIAS (m/s)	MEAN ABS (Δ WS)	Δ WS RMSD
ALL	15517	3.08	0.09	1.13	1.55
2 LOOK	6921	3.26	0.05	1.28	1.72
5 LOOK	8596	2.93	0.13	1.01	1.39

All DAWN – Dropsonde Comparisons from 2017 CPEX
(162 ~ co-located, coincident DAWN and Dropsonde Profiles)



DAWN-Dropsonde comparisons from CPEX 2017
Wind Direction (degrees)

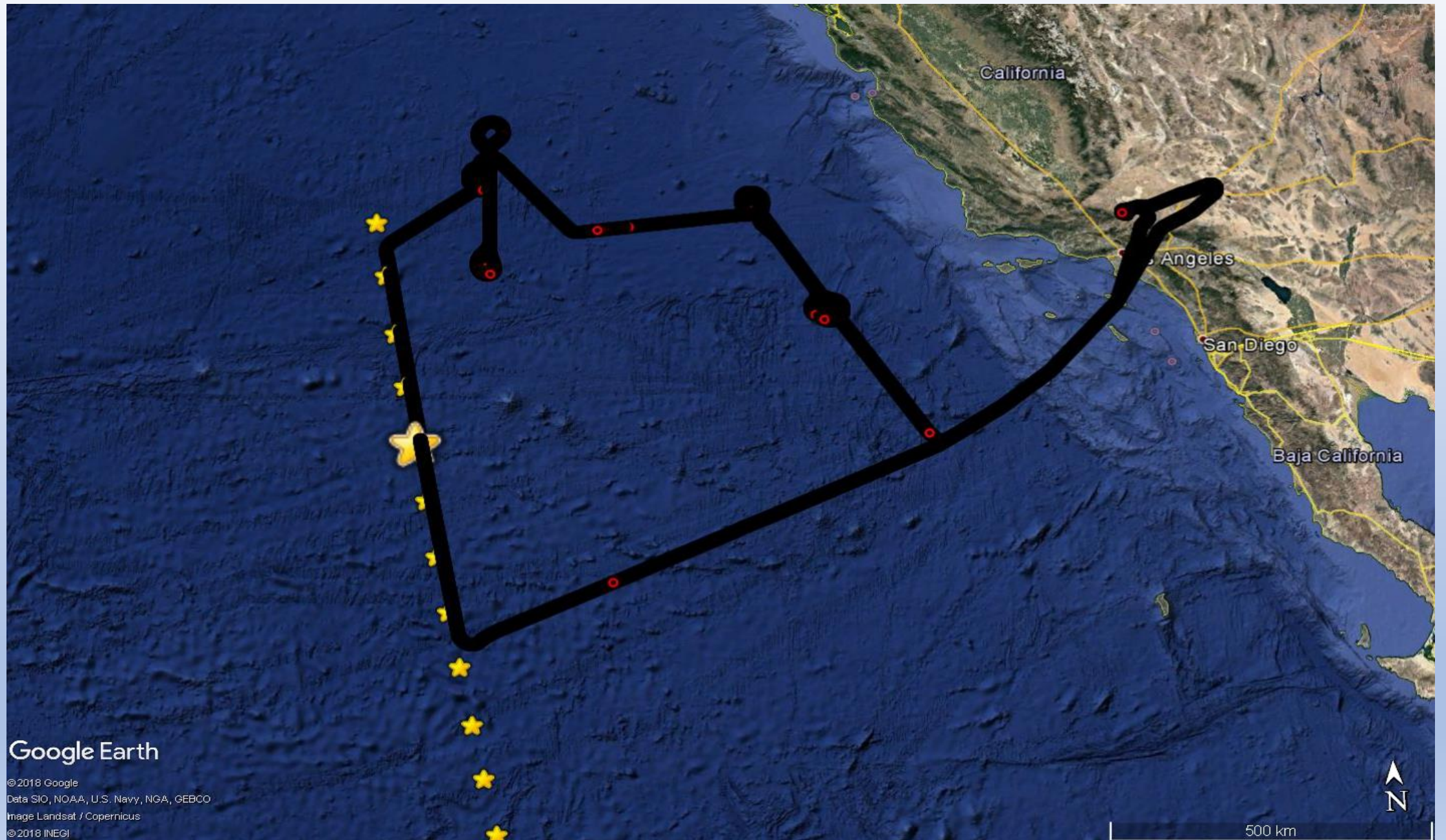
	Number 37m seg	MEAN Z DIFF (m)	BIAS (deg)	MEAN ABS (Δ WD)	Δ WD RMSD
ALL	15517	3.08	0.62	11.19	20.69
2 LOOK	6921	3.26	0.68	12.66	24.10
5 LOOK	8596	2.93	0.56	10.01	17.44

Aeolus LOS Wind Product

- Non-scanning single LOS for Rayleigh and Mie channels
 - During April underflights the first laser was operating at nearly 50% of the design optical power
 - Not all biases or best calibration data have been accounted for in the preliminary comparison to be shown here
- Using Level 2B data for comparison
 - RAYLEIGH CLEAR
 - RAYLEIGH CLOUDY
 - MIE CLEAR product
 - MIE COUDY product
- Rayleigh derives wind from molecular returns
 - Baseline horizontal integration: ~85km; 24 vertical levels
 - Vertical coverage - ~ 250-500m in PBL to 1km in troposphere
 - Rejection – observation error quantifier > 6.6 m/s (below 200 mb)
- Mie derived winds from clouds and aerosols
 - Horizontal integration: ~ 10-12 km; 24 vertical levels
 - Vertical resolution: in bottom 1km; 500m; 250-400m for 1-4km; 1km > 4km
 - Rejection – observation error quantifier > 4.5 m/s

0430 DAWN-AEOLUS HLOS COMPARSIONS

- 1) AEOLUS S-N 02:27 - 02:29Z
- 2) DAWN N-S 02:13 – 02:54Z (~ 600 km)
- 3) DAWN profiles from 5 Looks computed every ~5km
- 4) 7 AEOLUS profiles along DAWN under-flight track
 - Rayleigh Clear (uses 21-24 winds)
 - Mie Cloudy (uses 1-4 winds)
- 4) DAWN Aeolus projection HLOS shown for 123 DAWN profiles along DAWN underflight
- 5) 7 DAWN “Integrated” profiles each utilizing 17 individual DAWN profiles to match Aeolus Level 2B resolution



DC8 FLIGHT TRACK
APR 30, 2019

TIME (GMT)

02: 25-02: 26

02: 27-02: 28

02: 29-02: 29

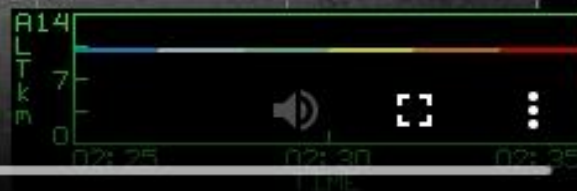
02: 30-02: 30

02: 32-02: 32

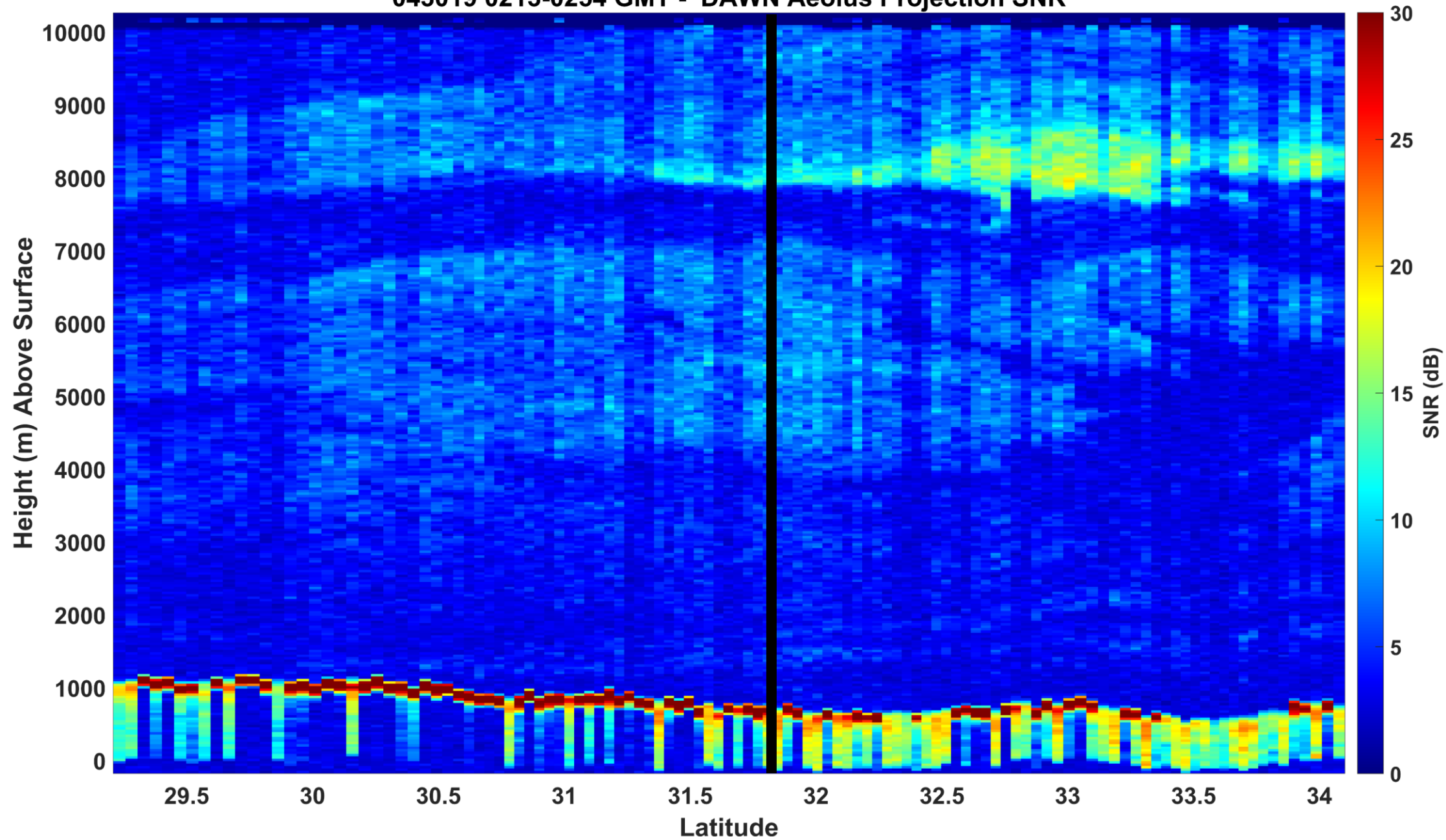
02: 33-02: 34

▶ 0:04 / 0:09

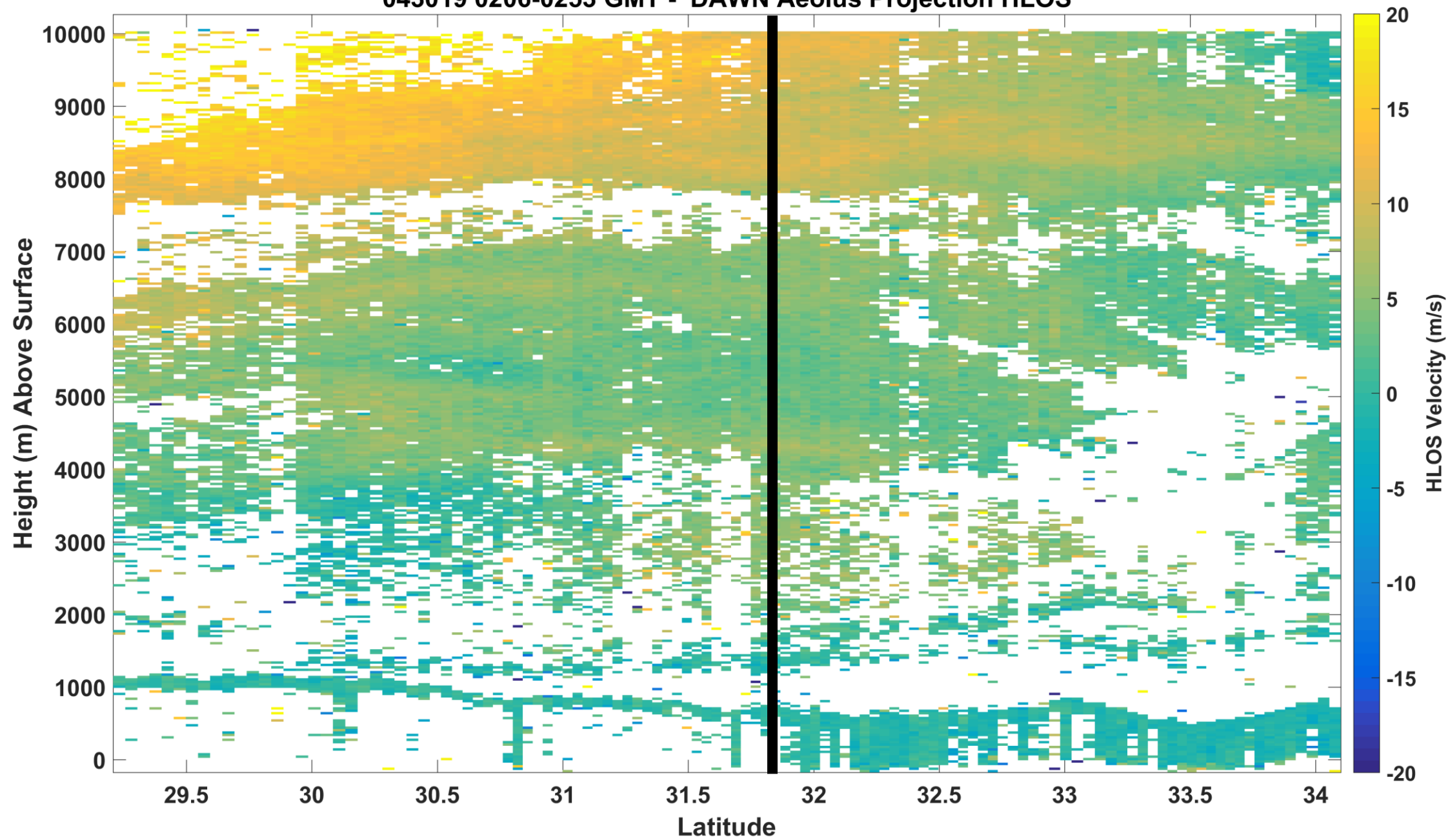
02: 31: 20 127W 128W 129W APR 30, 2019 02: 31: 20 NASA LARC



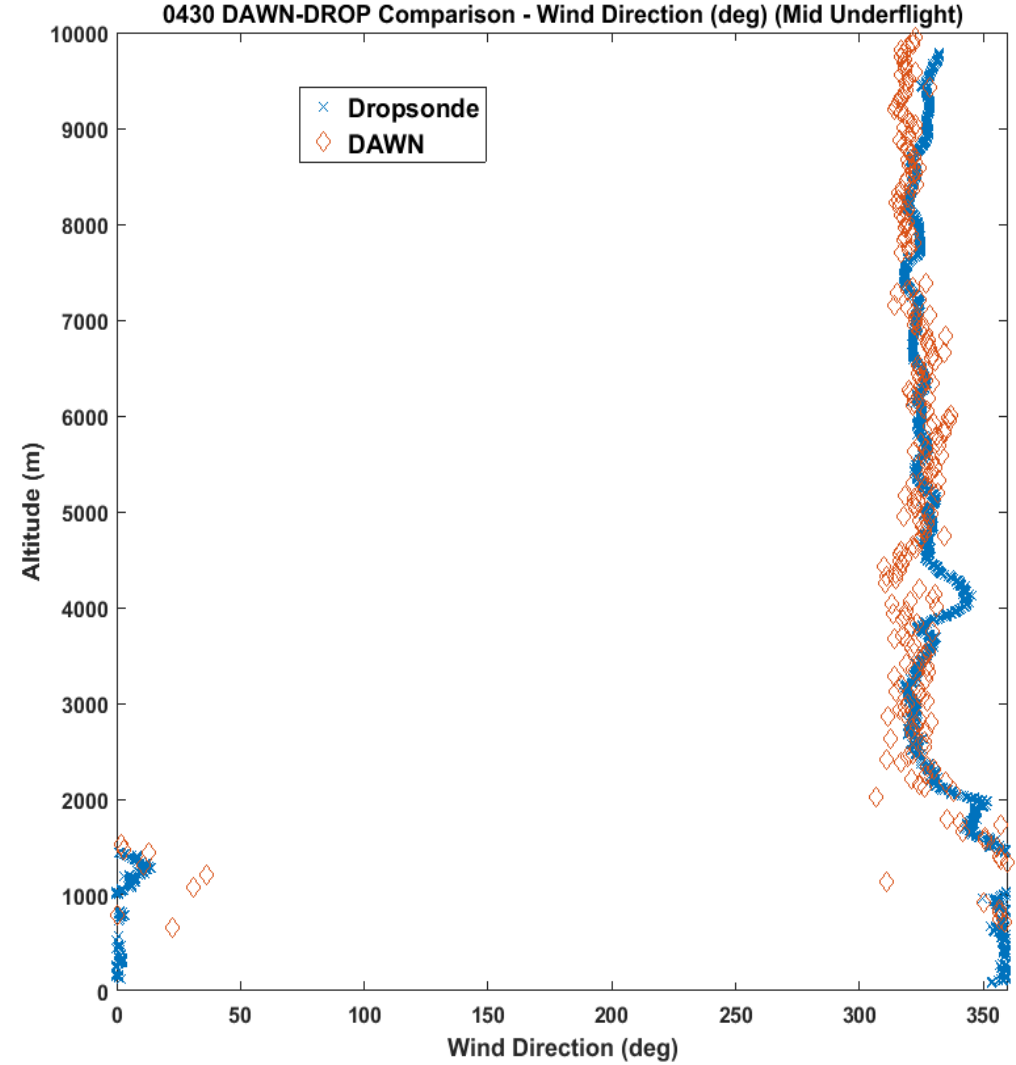
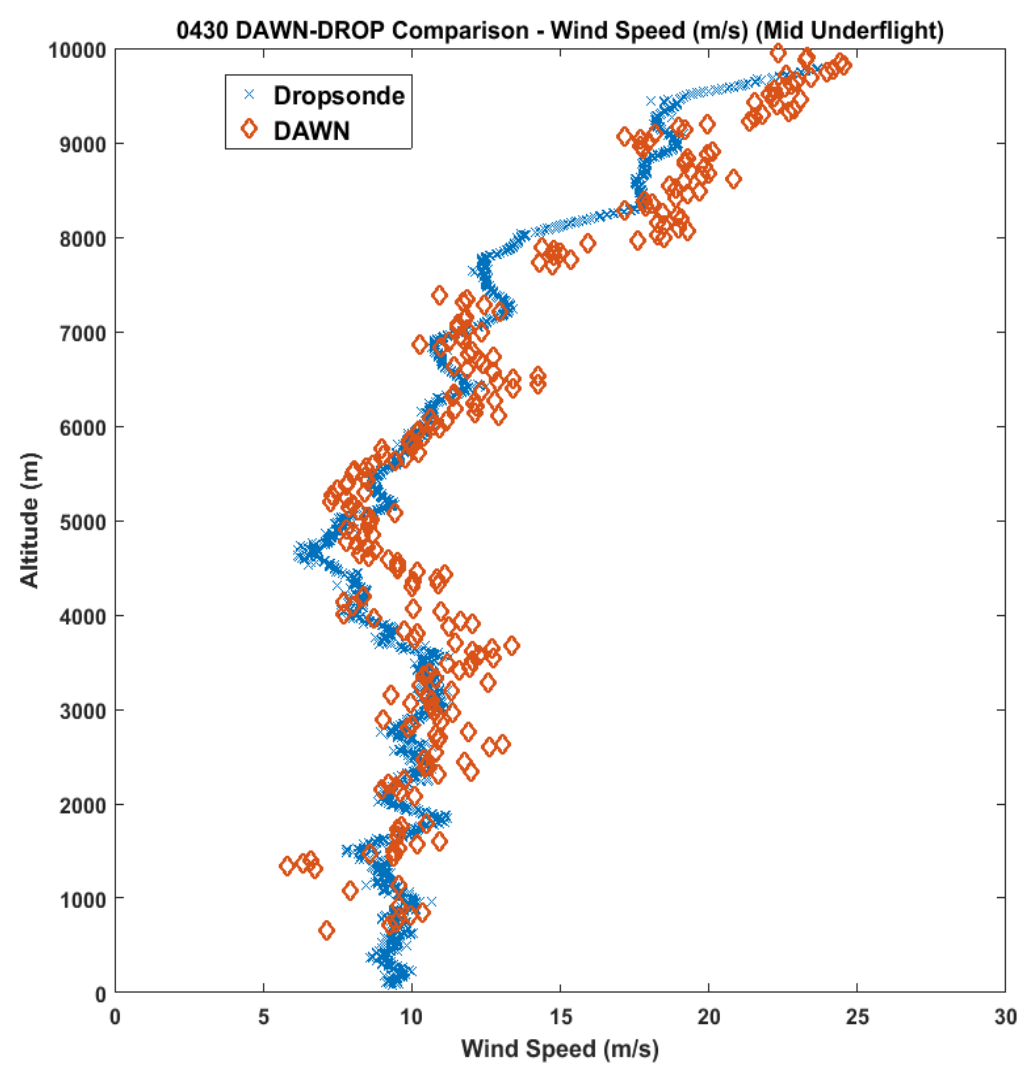
043019 0213-0254 GMT - DAWN Aeolus Projection SNR

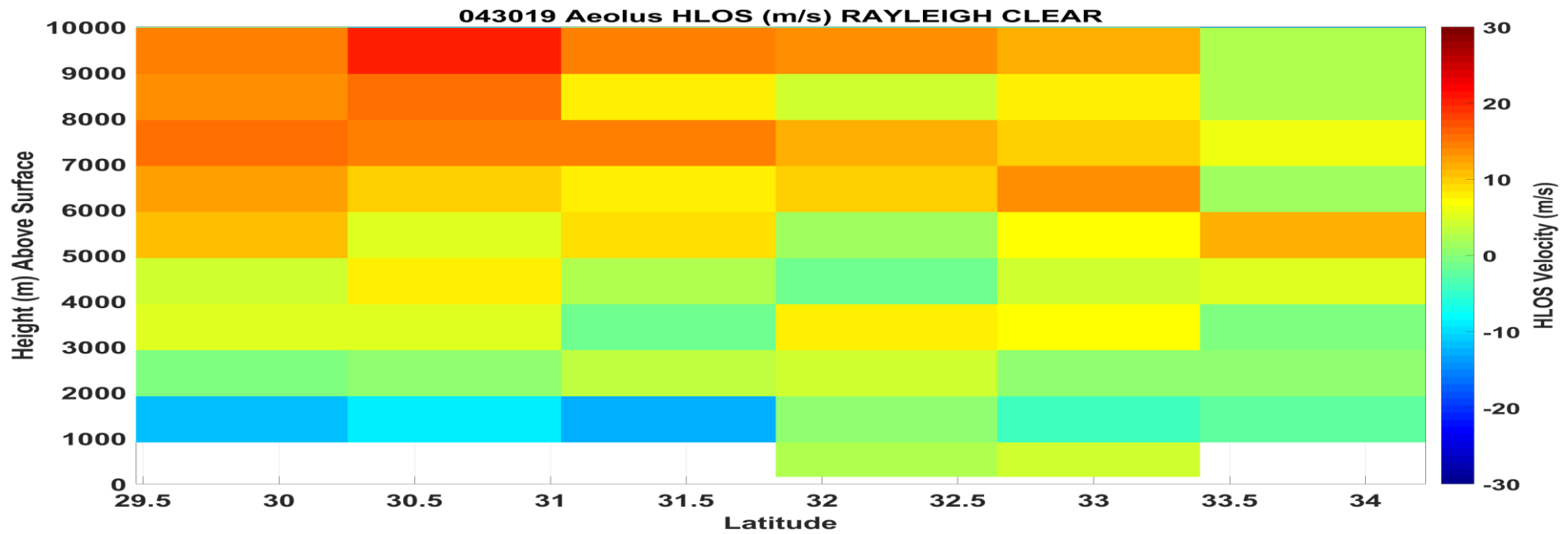
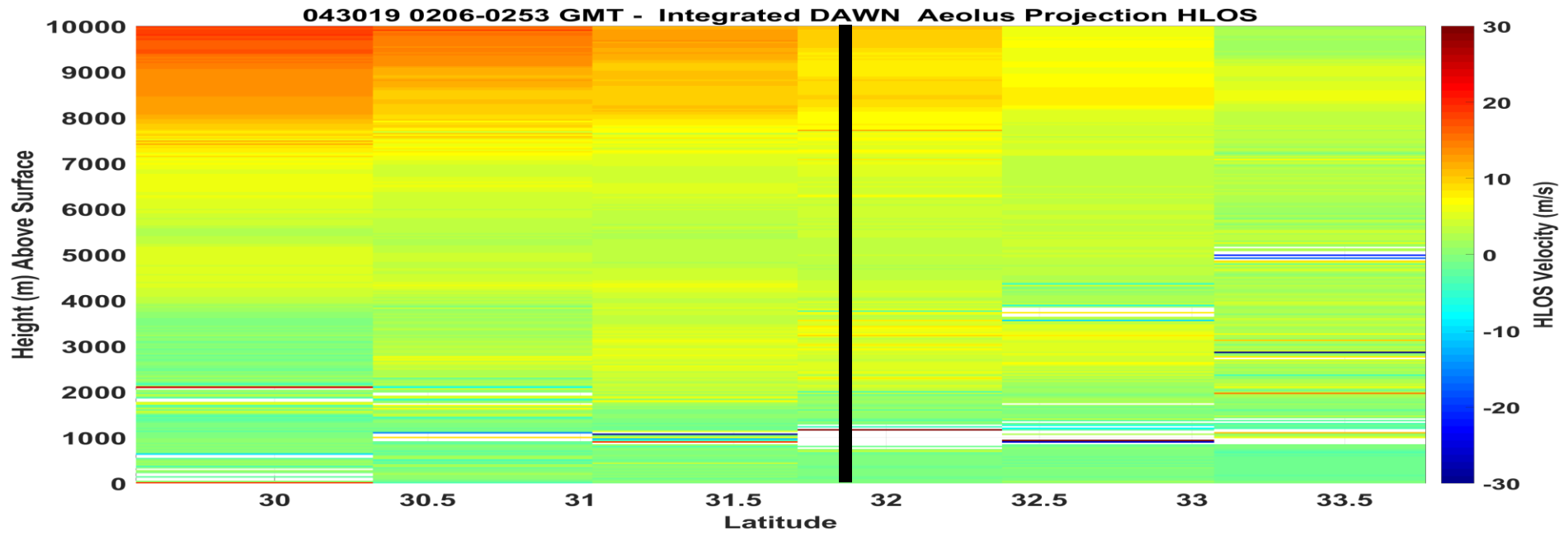


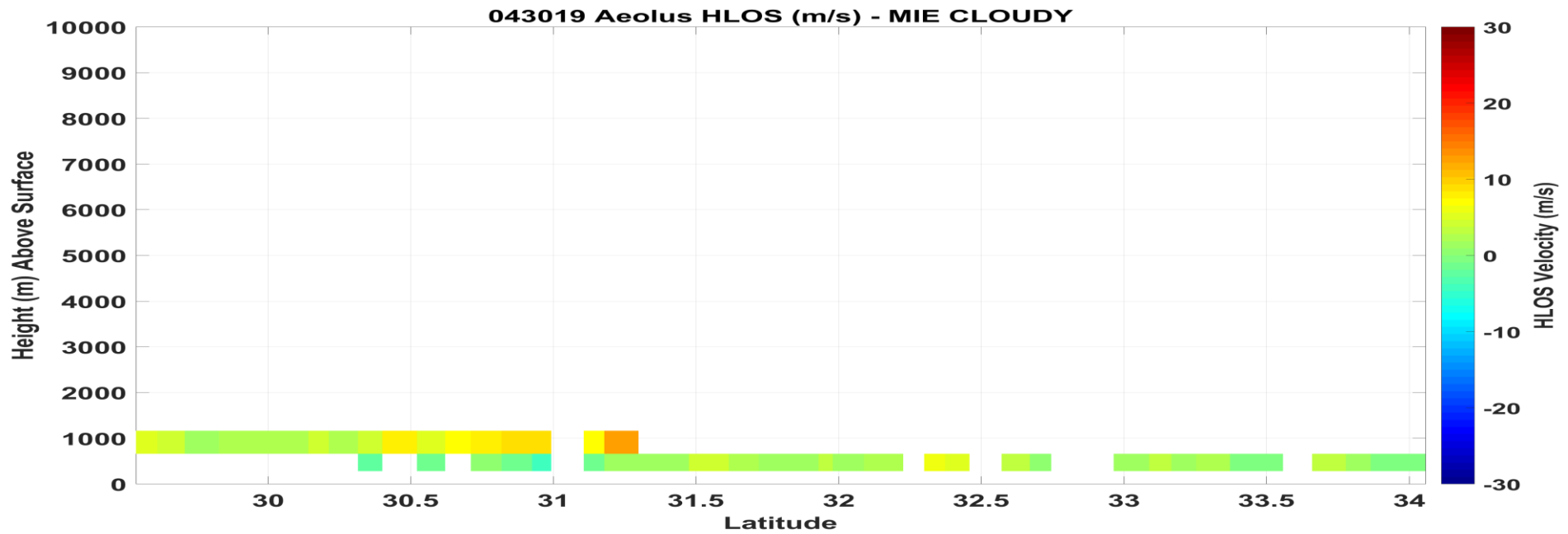
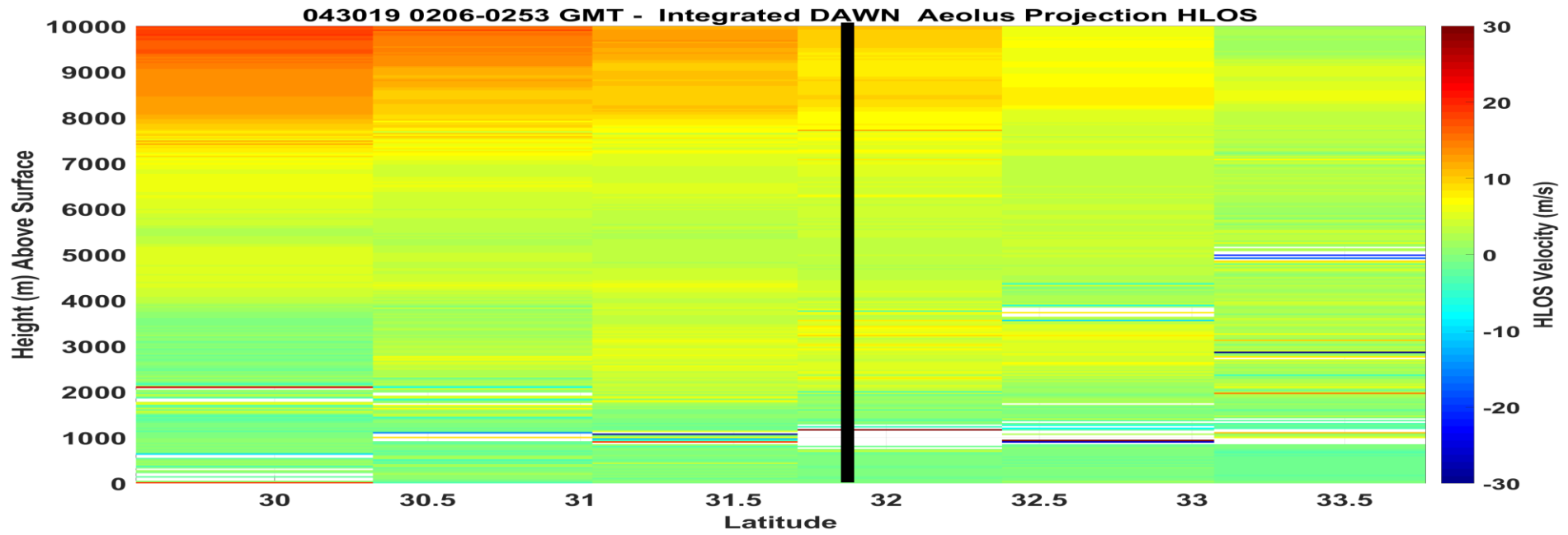
043019 0206-0253 GMT - DAWN Aeolus Projection HLOS



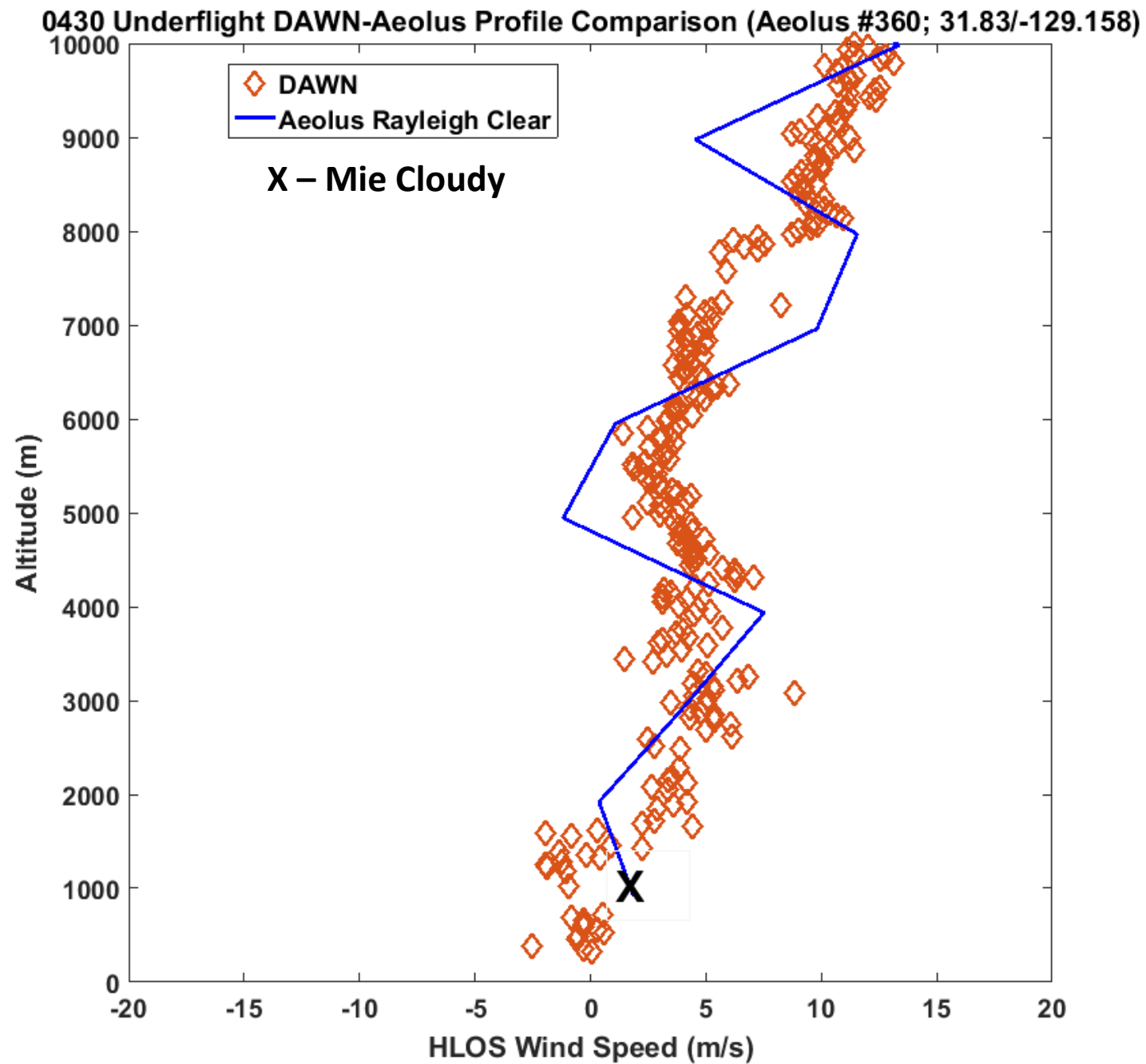
DAWN-DROP COMPARISON MIDDLE OF UNDERFLIGHT



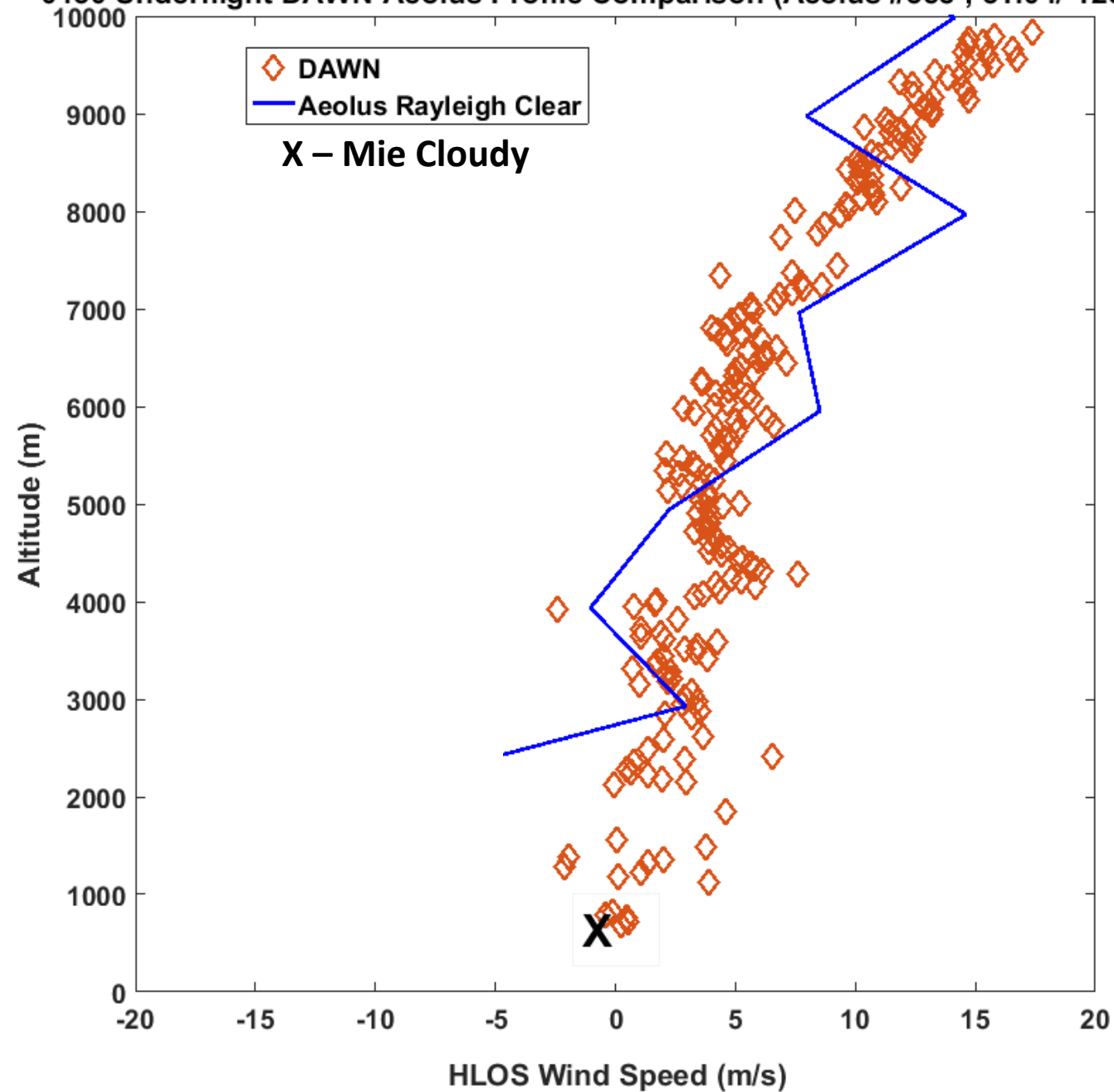




**AEOLUS
DIRECTLY
OVERHEAD**

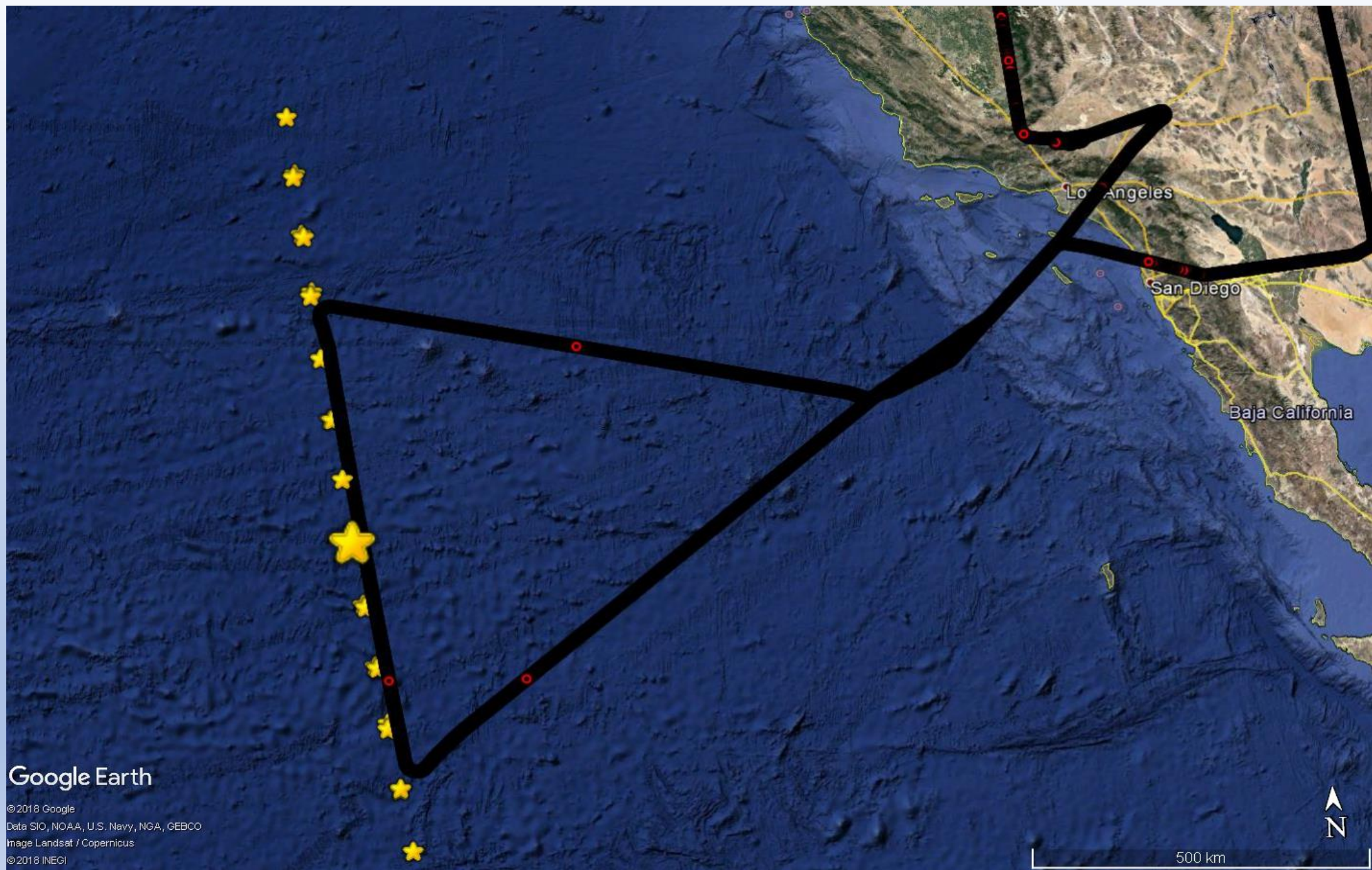


0430 Underflight DAWN-Aeolus Profile Comparison (Aeolus #358 ; 31.04/-128.997)



0423 DAWN-AEOLUS HLOS COMPARSIONS

- 1) AEOLUS S-N 02:28 - 02:29Z
- 2) DAWN N-S 02:06 – 02:53Z(~ 600 km)
- 3) DAWN profiles from 5 Looks computed every ~5km (119 profiles)
- 4) 7 AEOLUS profiles along DAWN under-flight track
 - Rayleigh Clear (21-24 winds used)
 - Mie Cloudy (1-4 winds used)
- 4) DAWN Aeolus projection HLOS shown for 123 DAWN profiles along DAWN underflight
- 5) 7 DAWN “Integrated” profiles each utilizing 17 individual DAWN profiles to match Aeolus Level 2B resolution



Google Earth

© 2018 Google

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Image Landsat / Copernicus

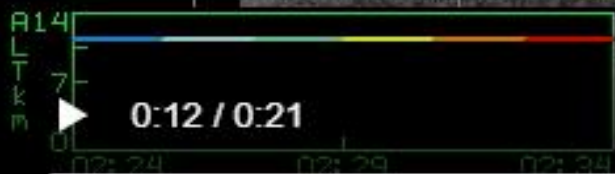
© 2018 INEGI



500 km

DC8 FLIGHT TRACK
APR 23, 2019

TIME (GMT)
02:24-02:25
02:26-02:27
02:28-02:28
02:29-02:29
02:31-02:31
02:32-02:33



128W

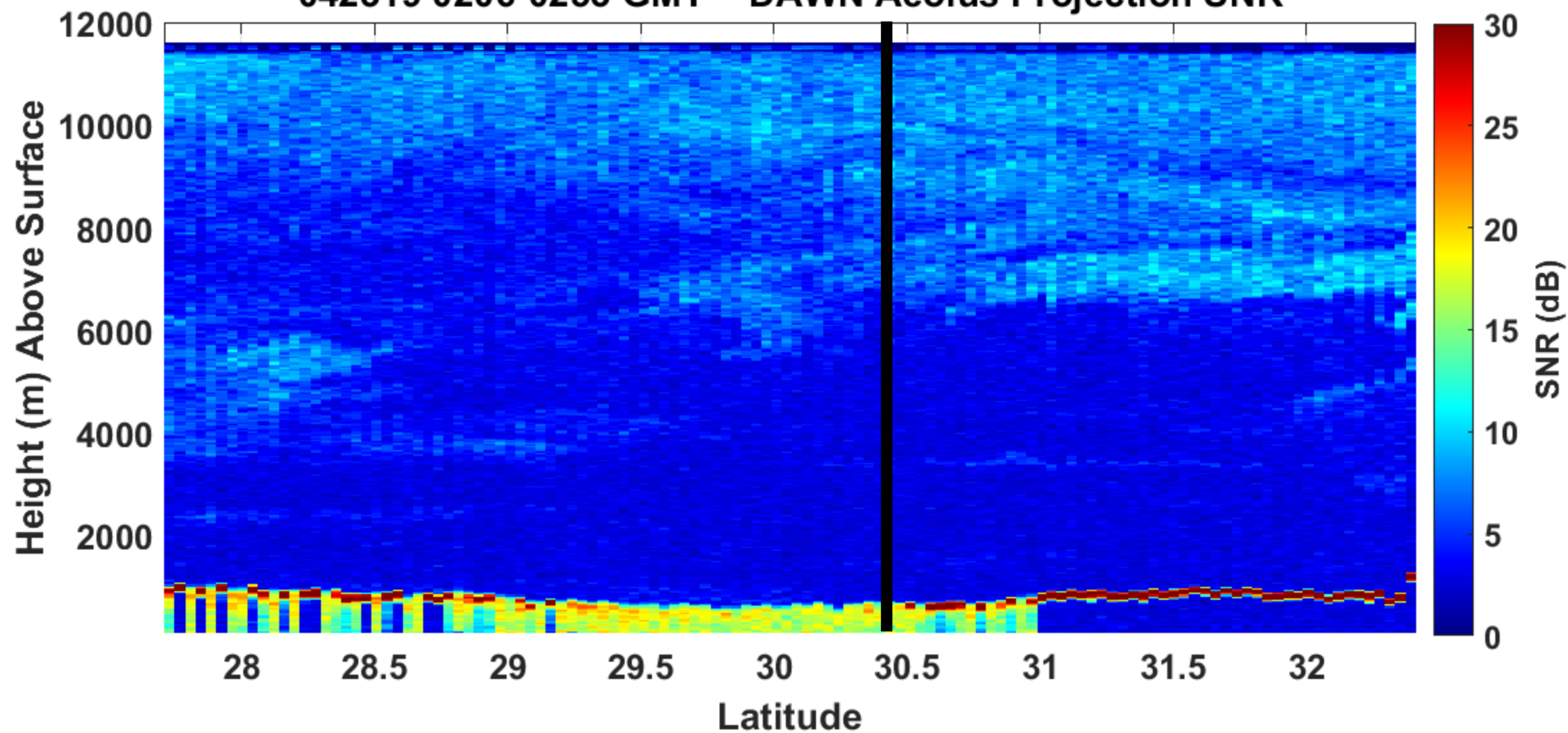
126W

124W

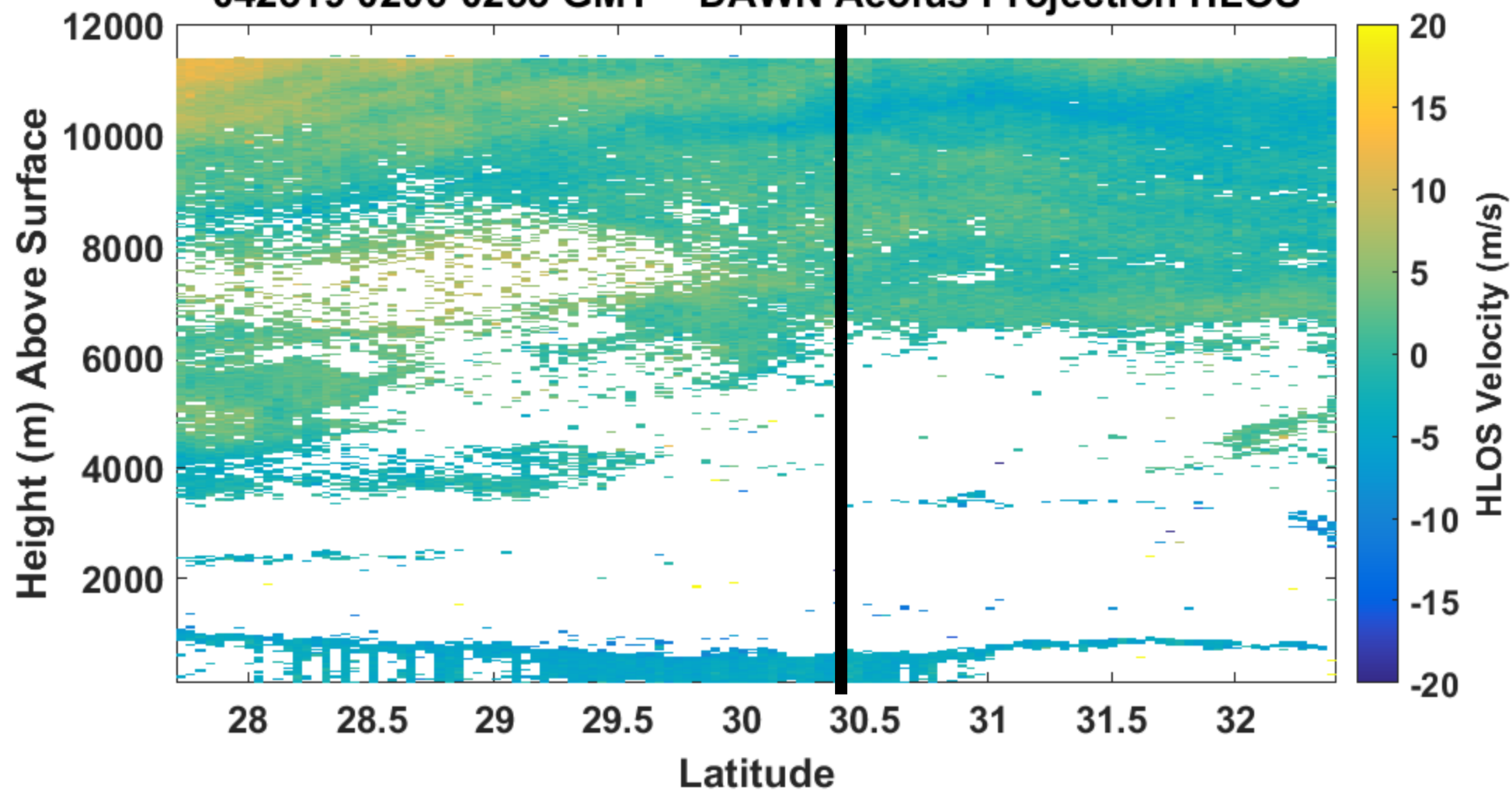
122W



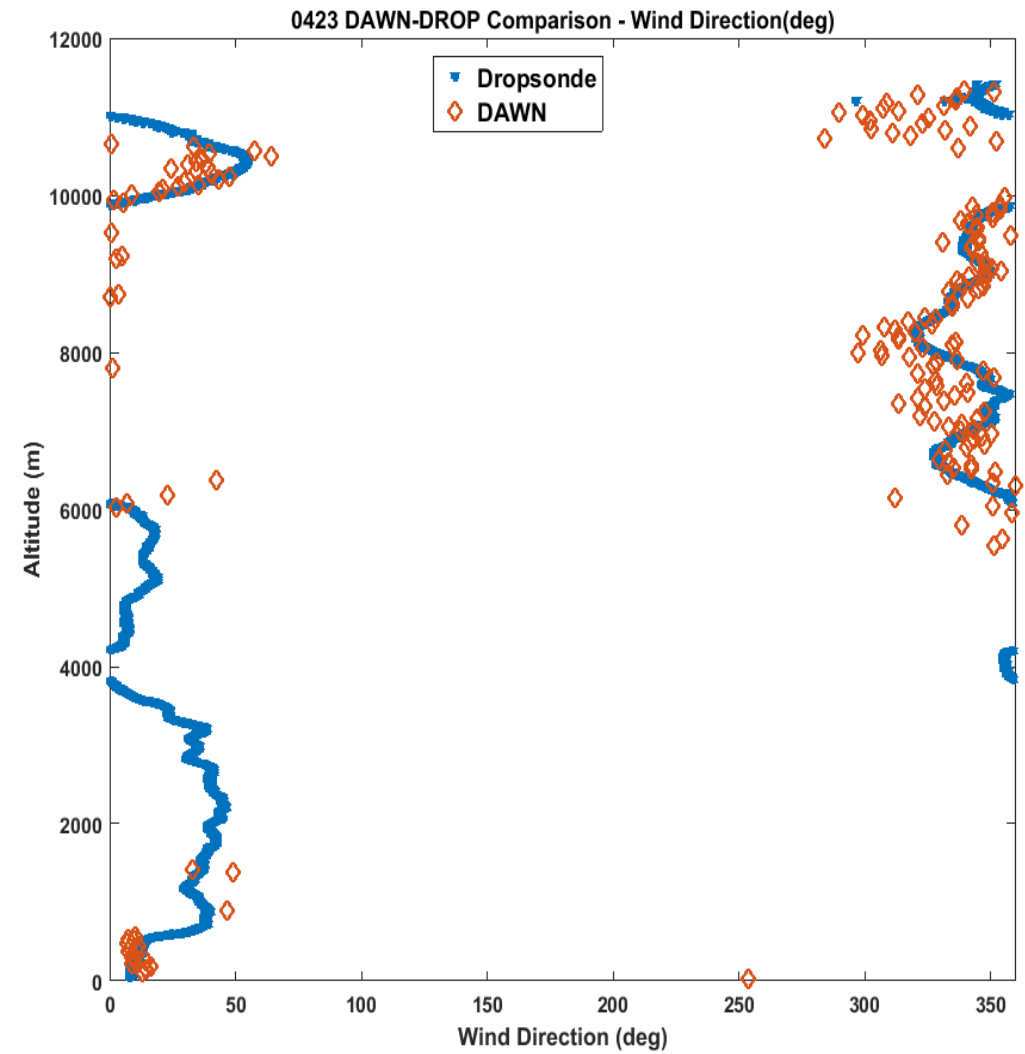
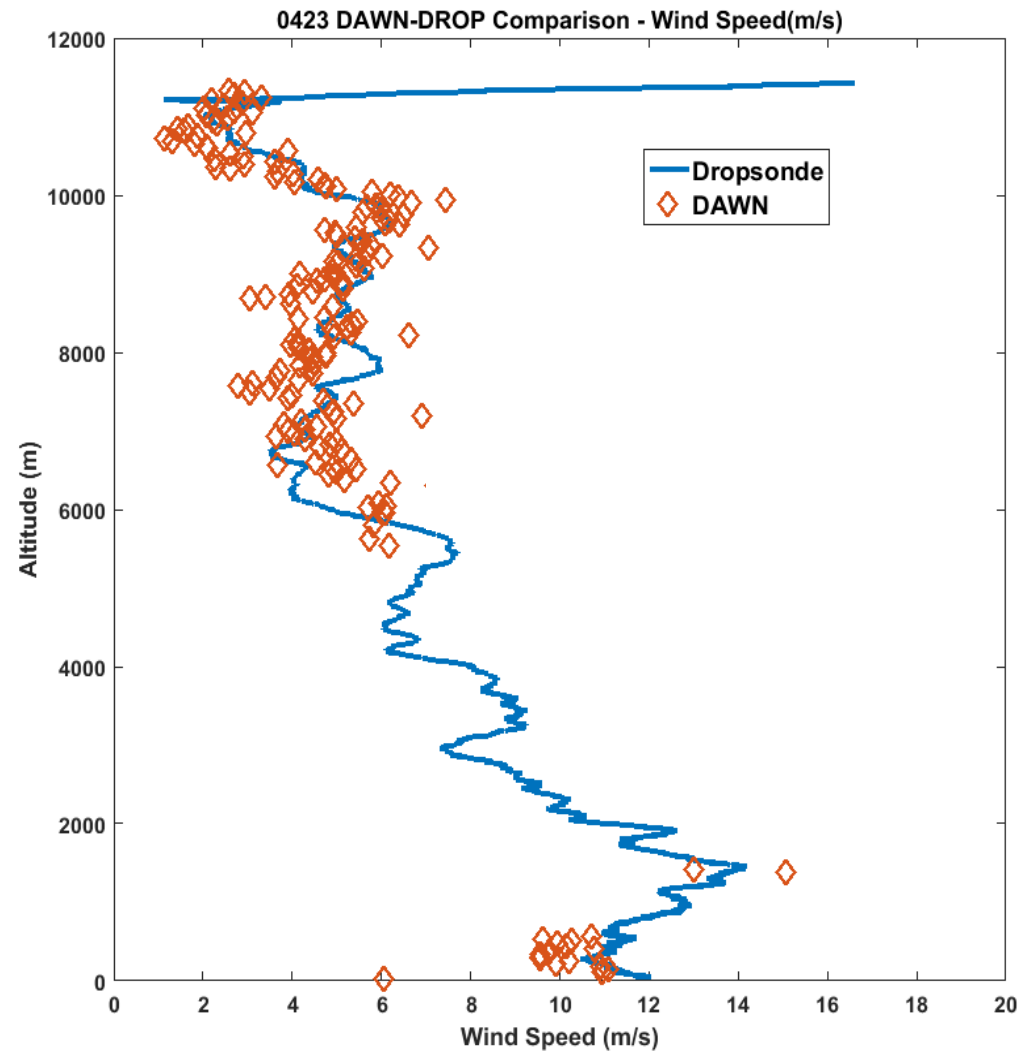
042319 0206-0253 GMT - DAWN Aeolus Projection SNR

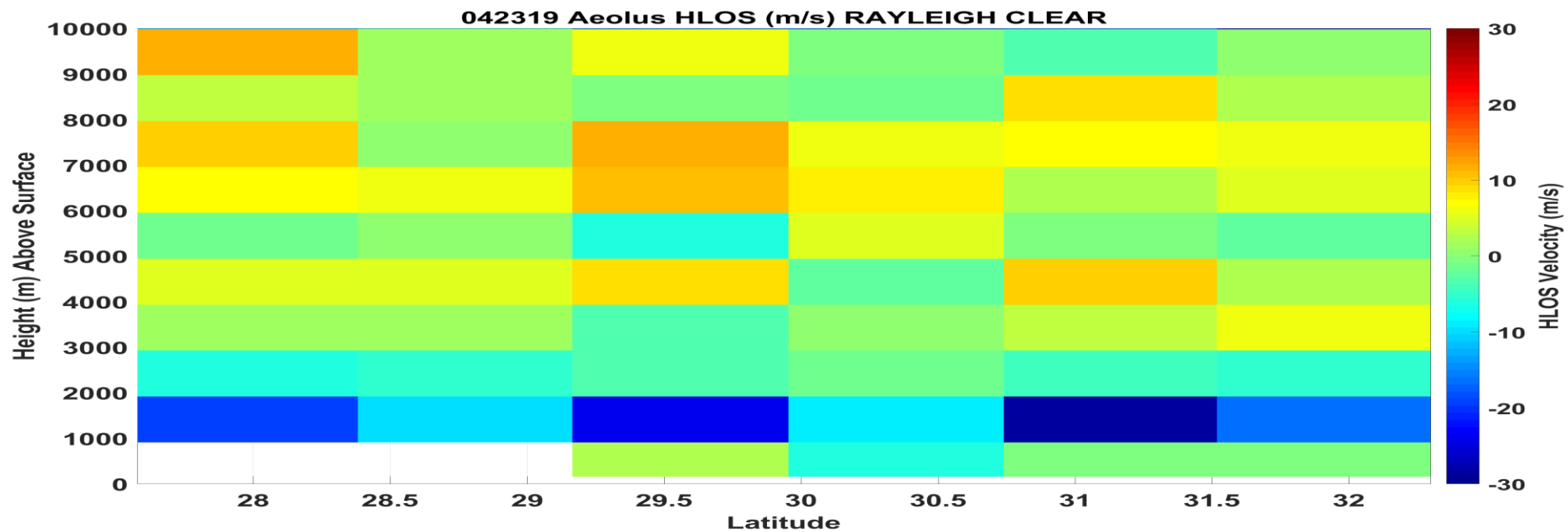
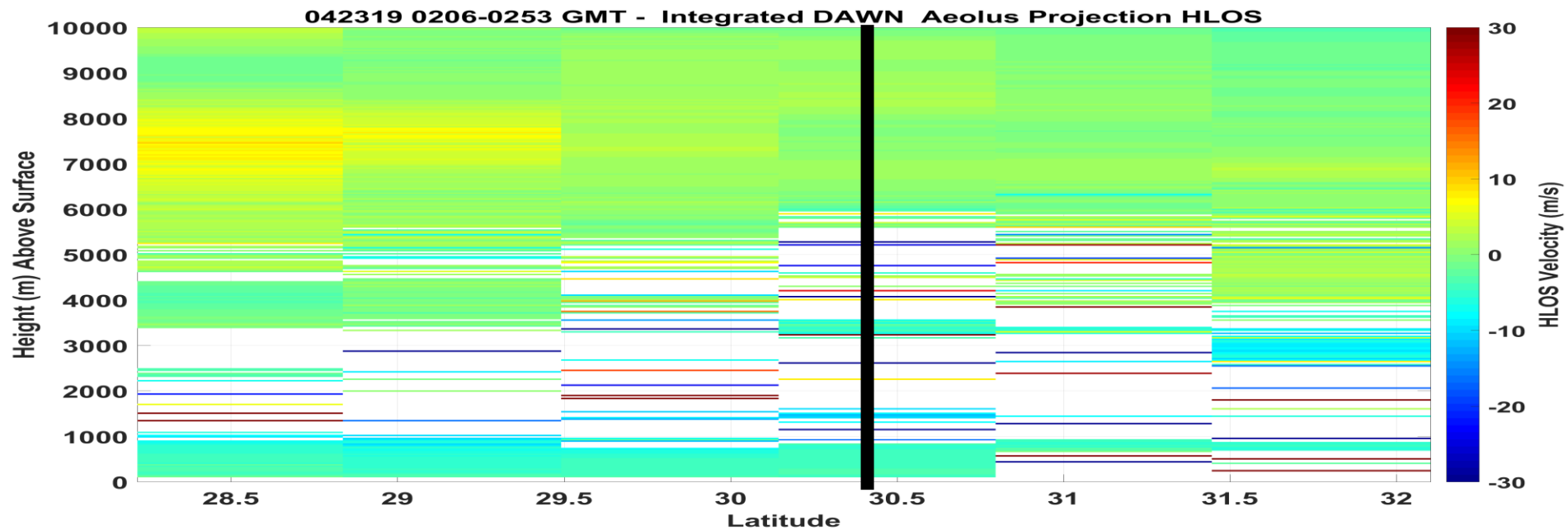


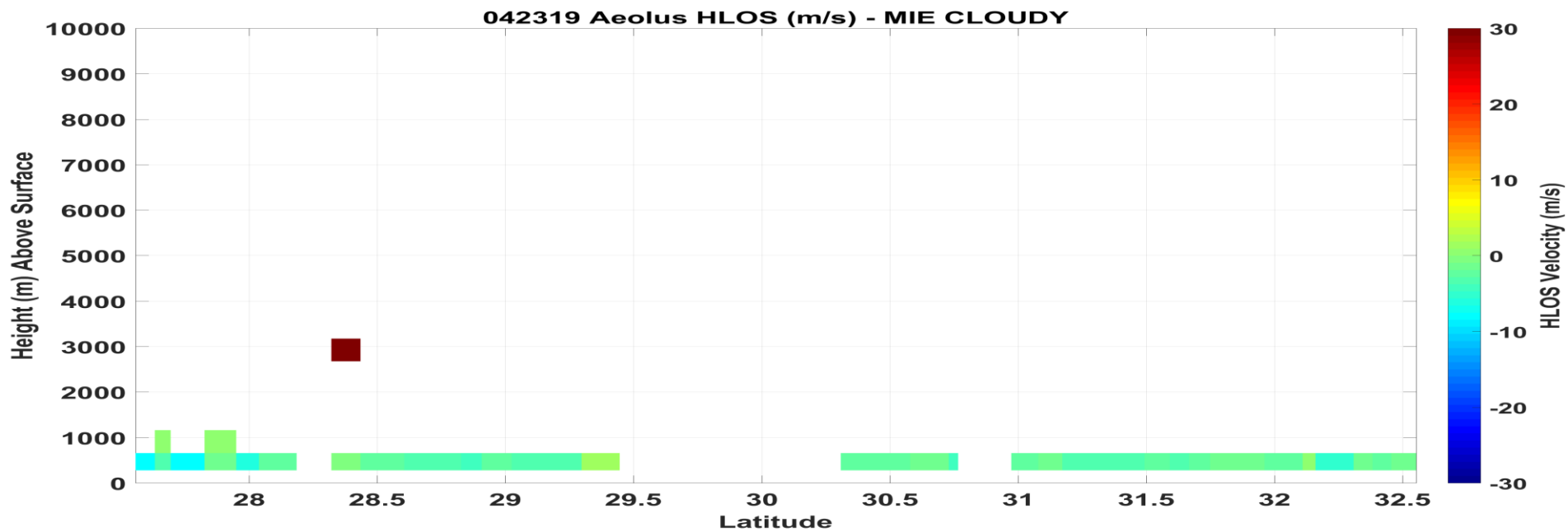
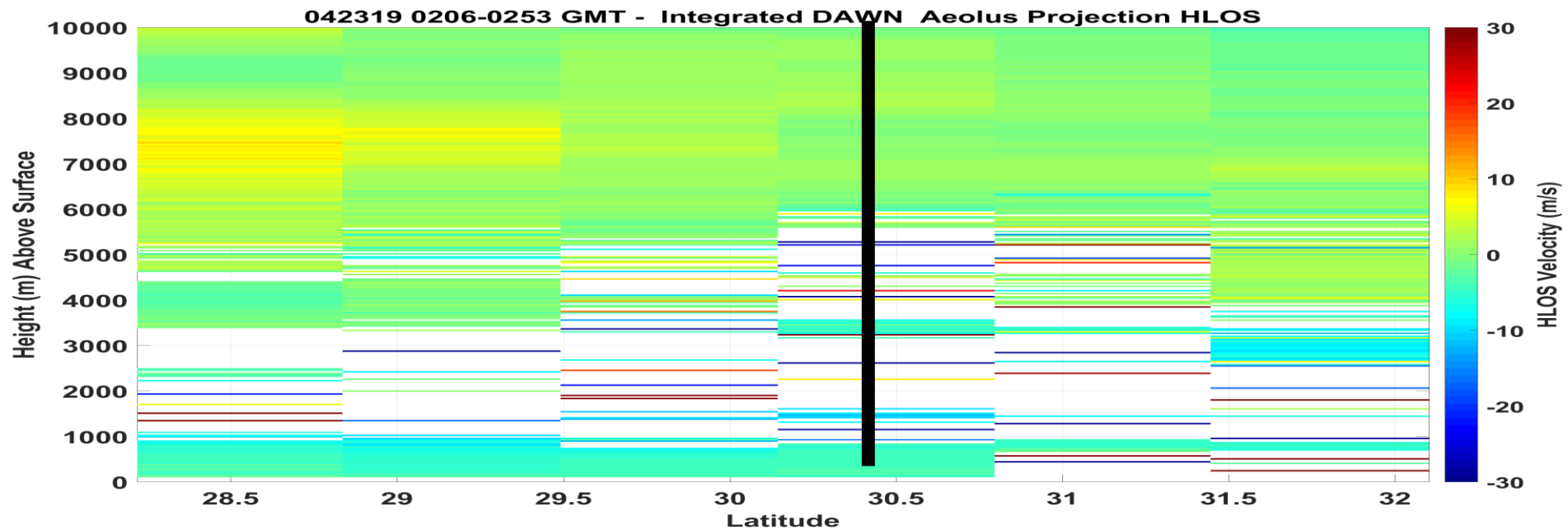
042319 0206-0253 GMT - DAWN Aeolus Projection HLOS



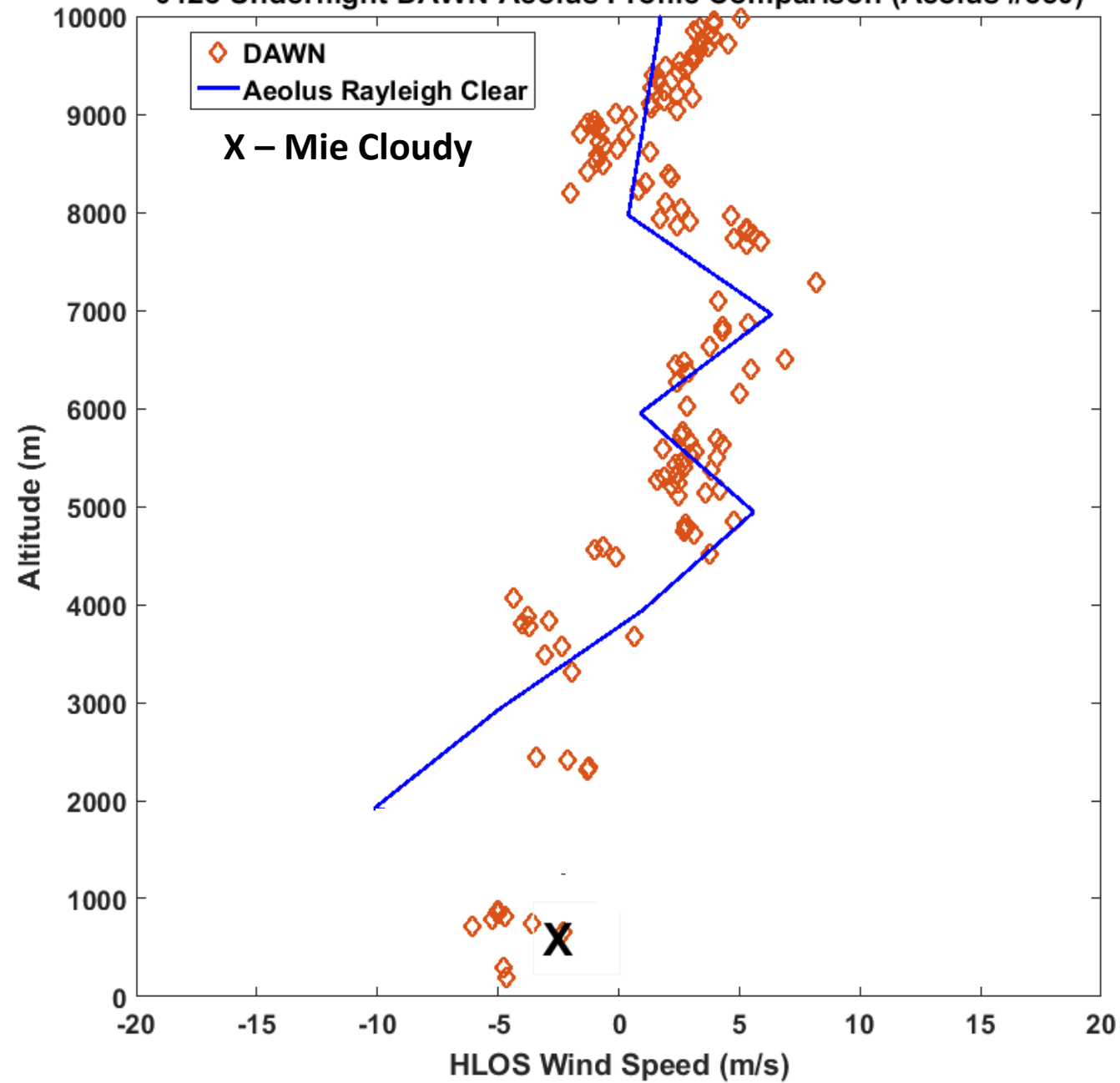
DAWN-DROP COMPARISON MIDDLE OF UNDERFLIGHT



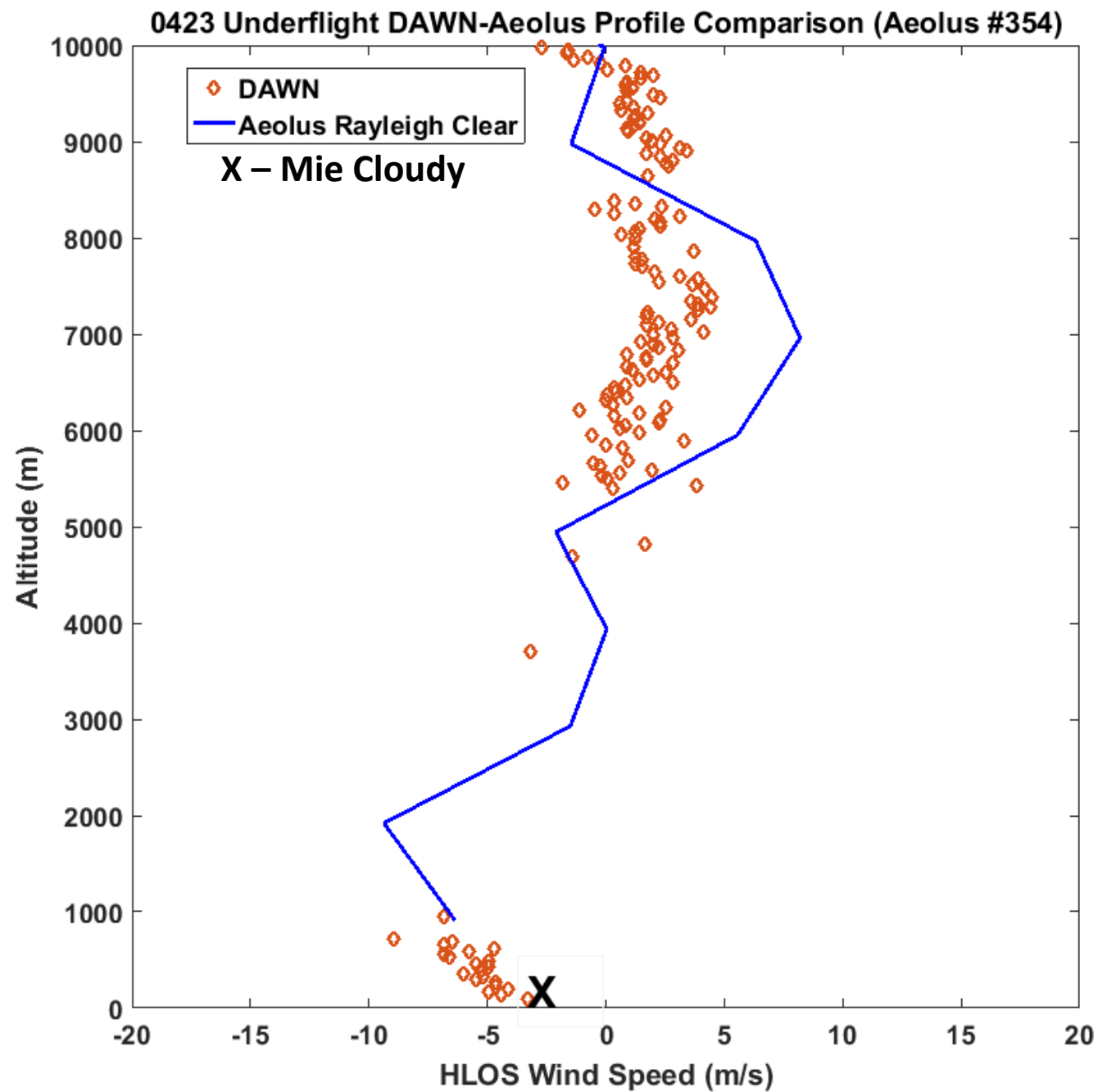




0423 Underflight DAWN-Aeolus Profile Comparison (Aeolus #350)

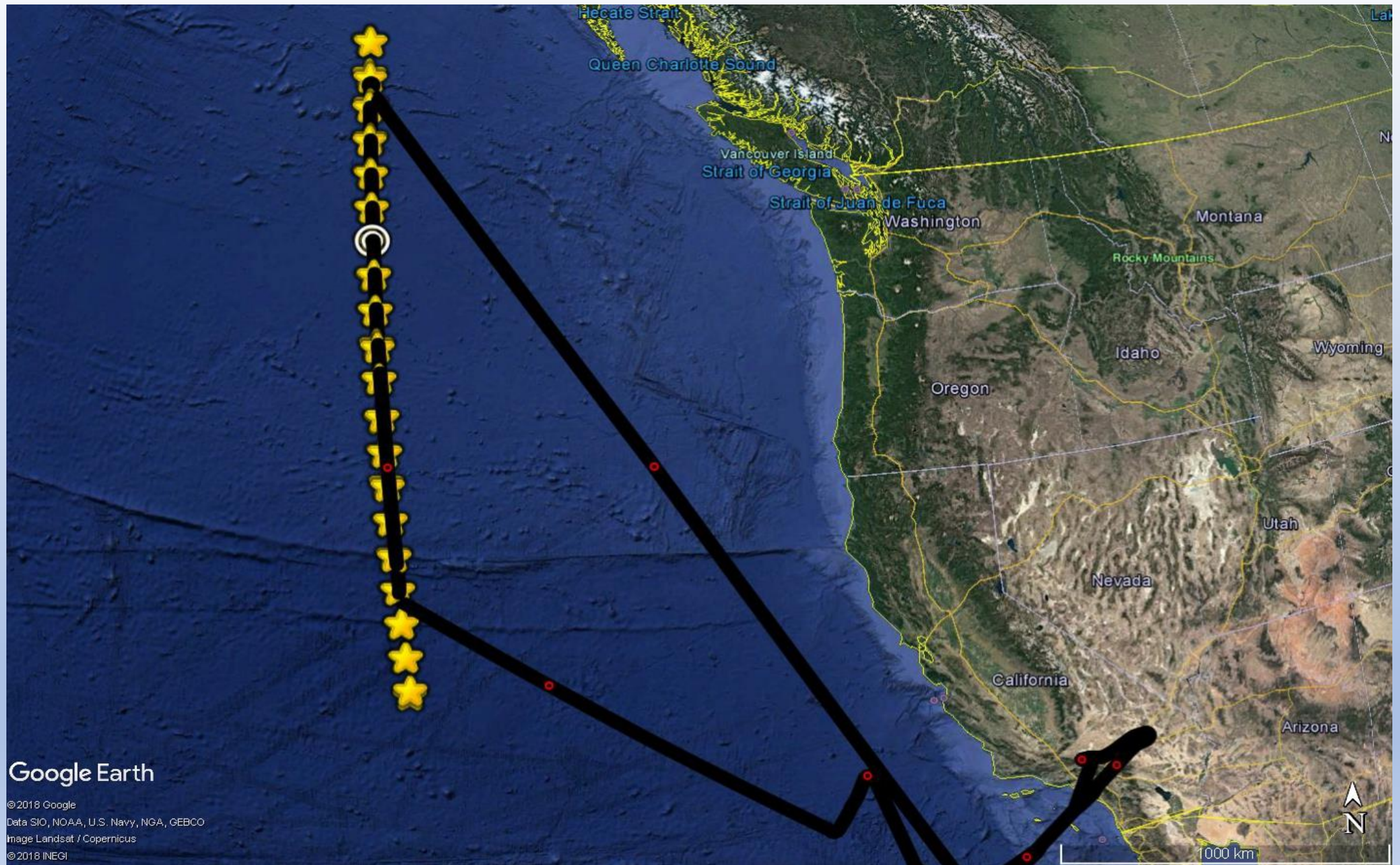


**AEOLUS
DIRECTLY
OVERHEAD**



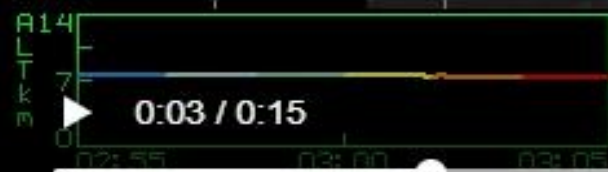
0418 DAWN-AEOLUS HLOS COMPARSIONS

- 1) AEOLUS S-N 02:56 - 03:00Z
- 2) DAWN N-S 01:51 – 03:32Z
- 3) 7 AEOLUS profiles along DAWN under-flight track
 - Rayleigh Clear (21-24 winds)
 - Mie Cloudy (1-4 winds)
- 4) DAWN mostly operated in STARE (1 Look) mode, only small portion of underflight where full profiles measured
- 5) DAWN SNR and Aeolus projection HLOS shown for 30 DAWN profiles along DAWN under-flight (but other short segments of 2-4 scans/profiles)



DC8 FLIGHT TRACK APR 18, 2019

TIME (GMT)
02:55-02:56
02:57-02:58
02:59-02:59
03:00-03:00
03:02-03:02
03:03-03:04



140W

138W

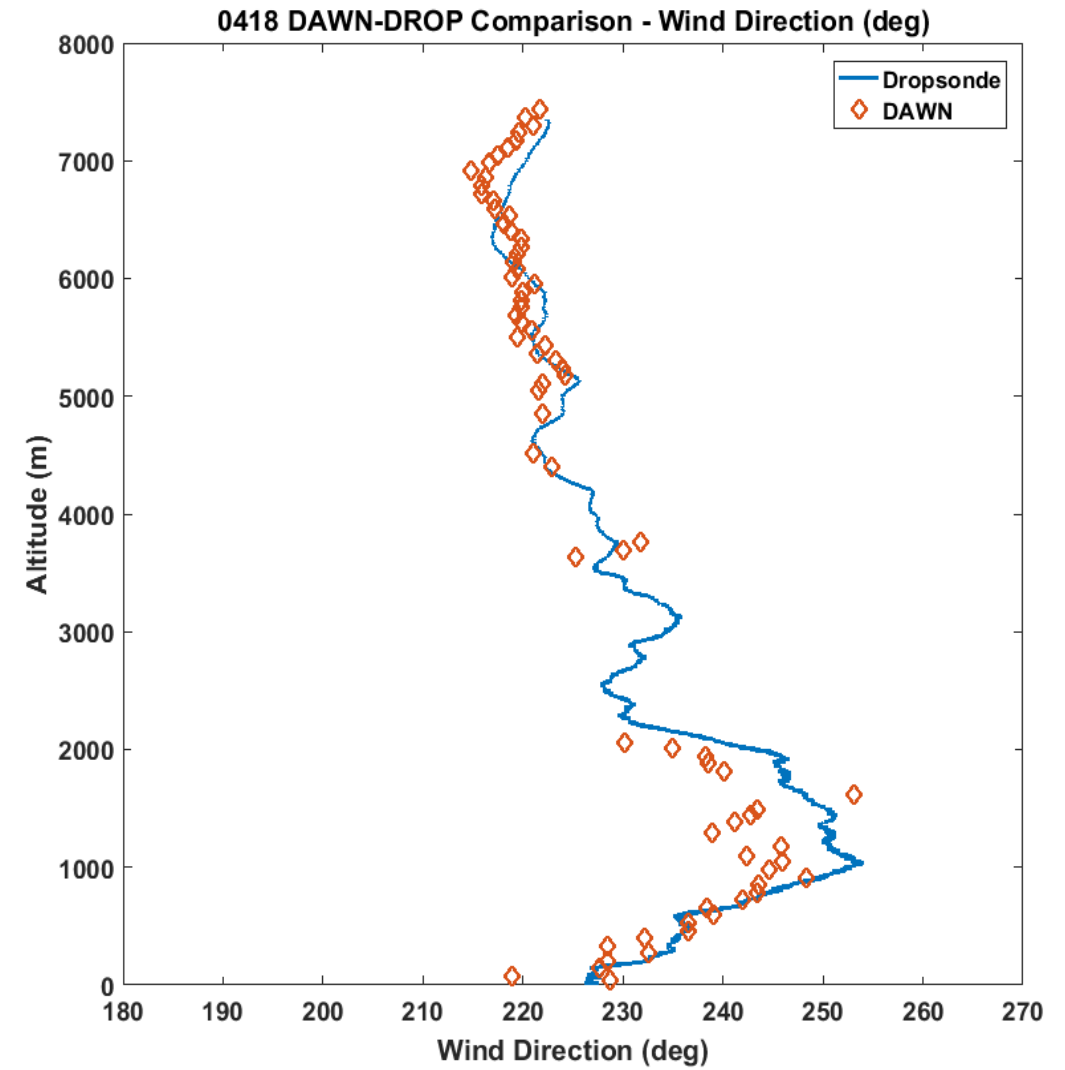
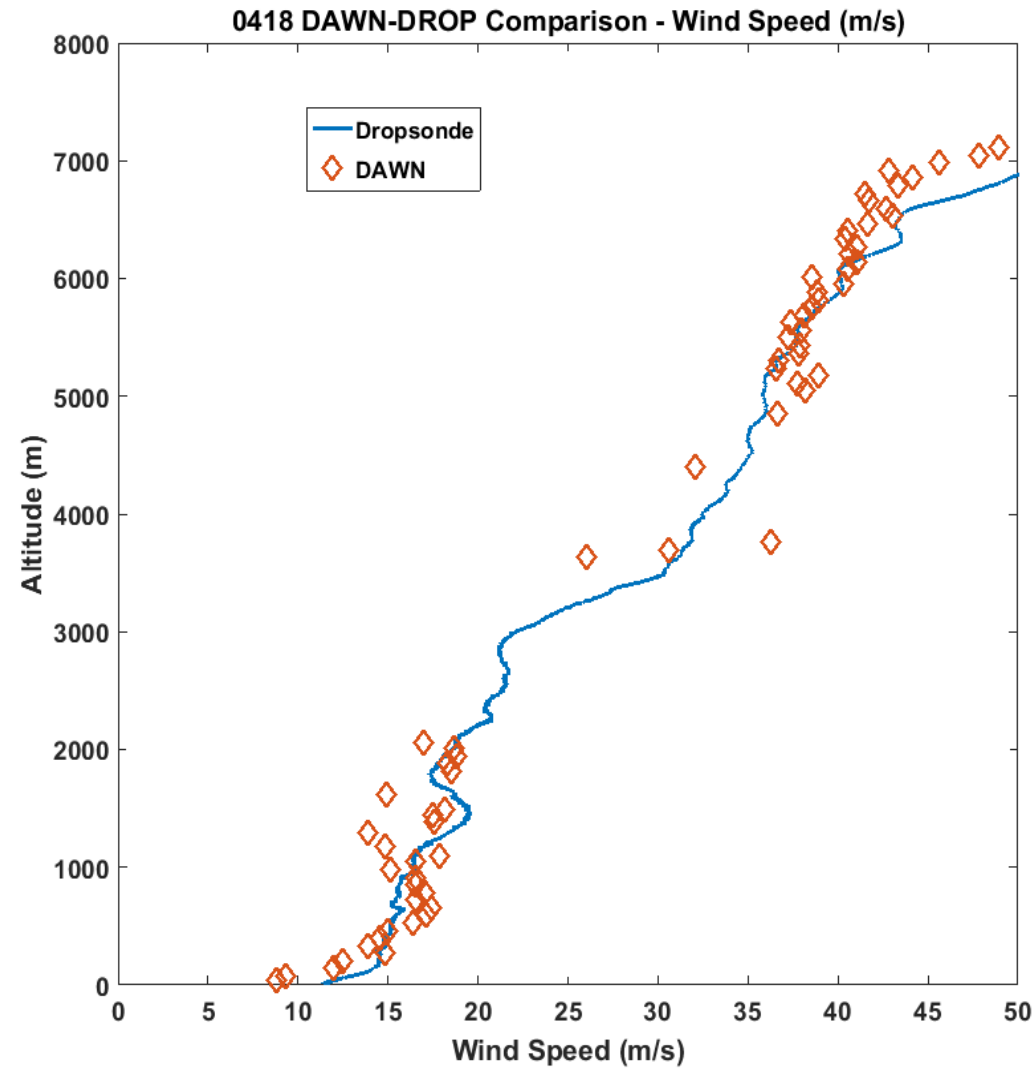
136W

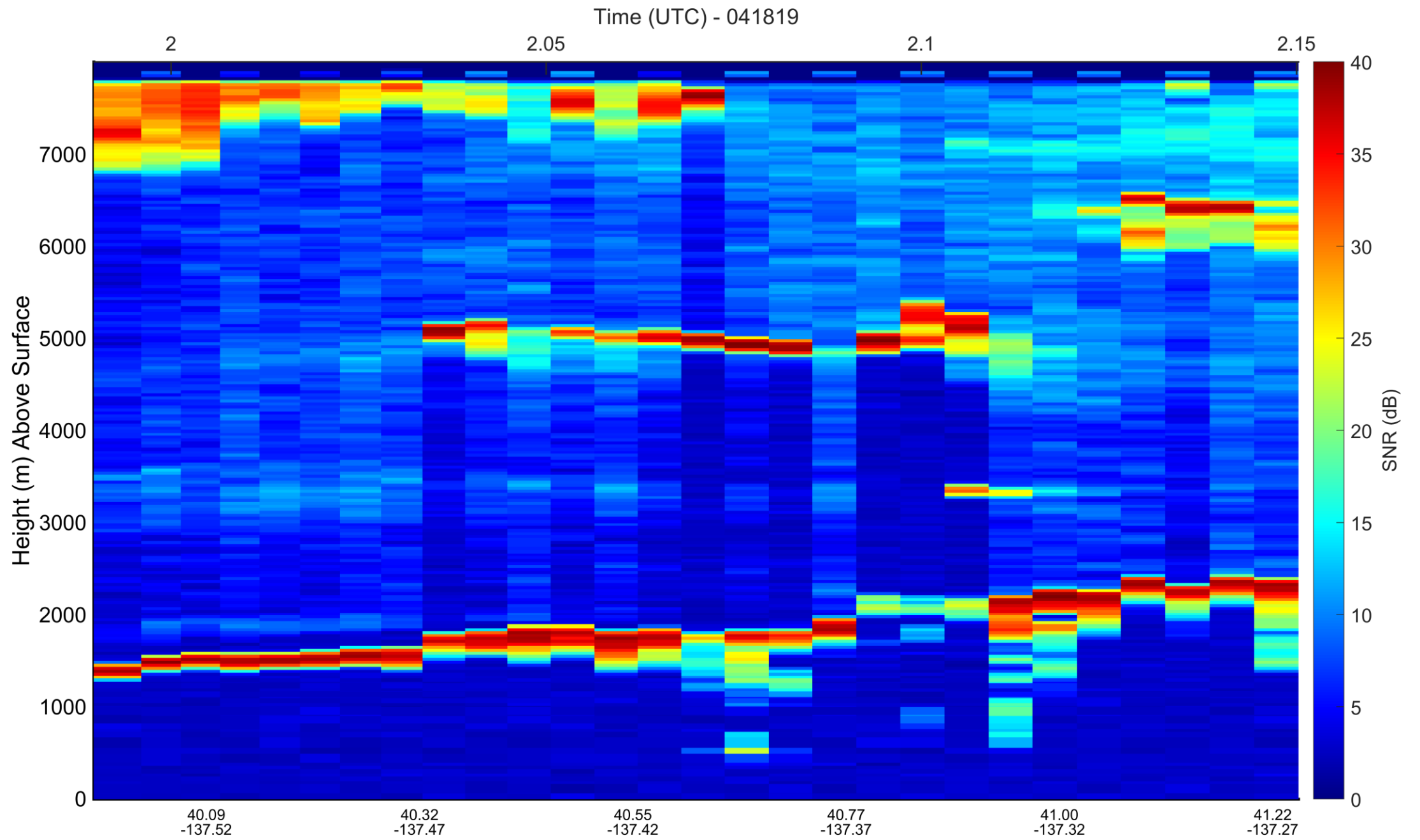
134W

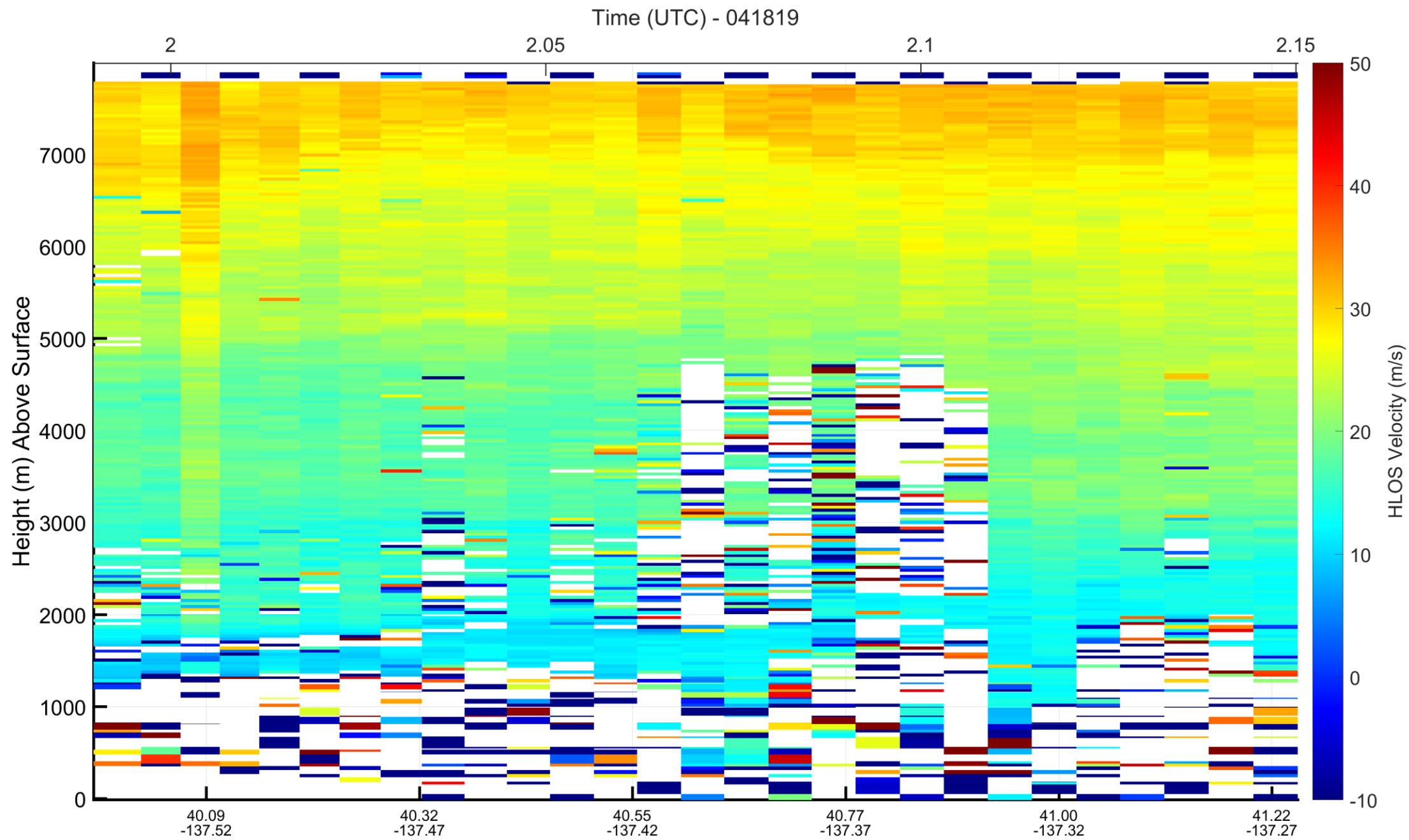


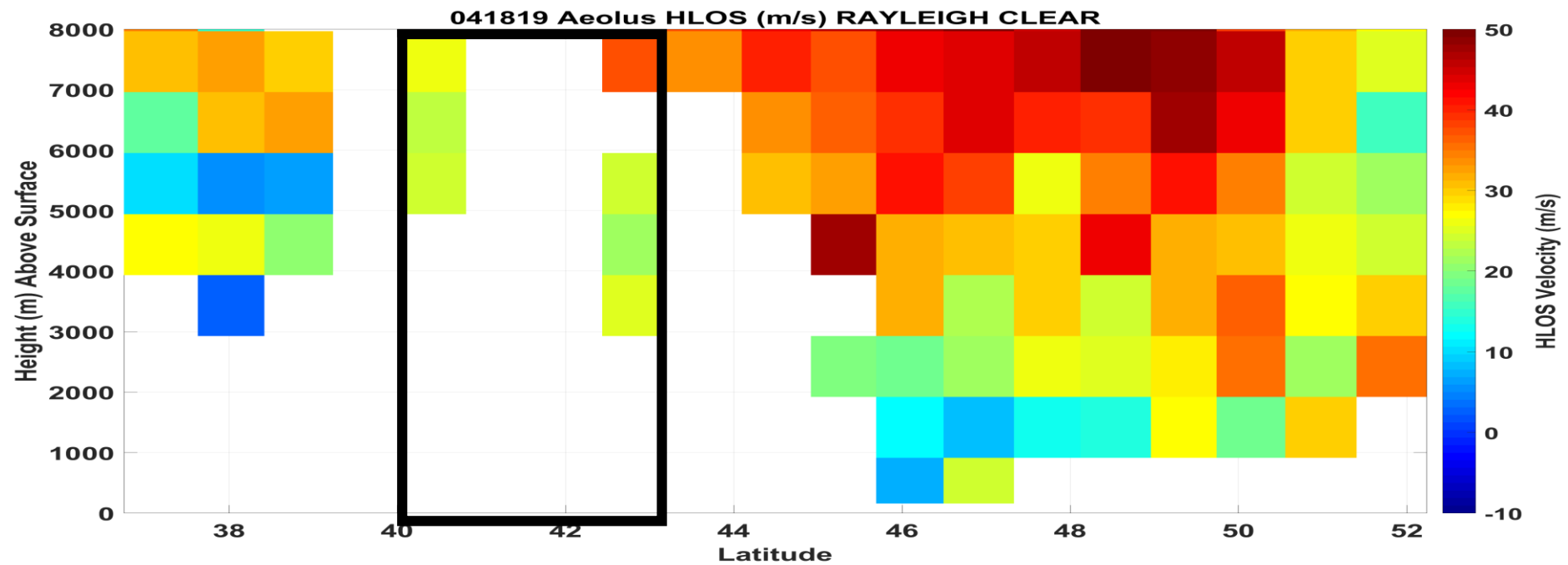
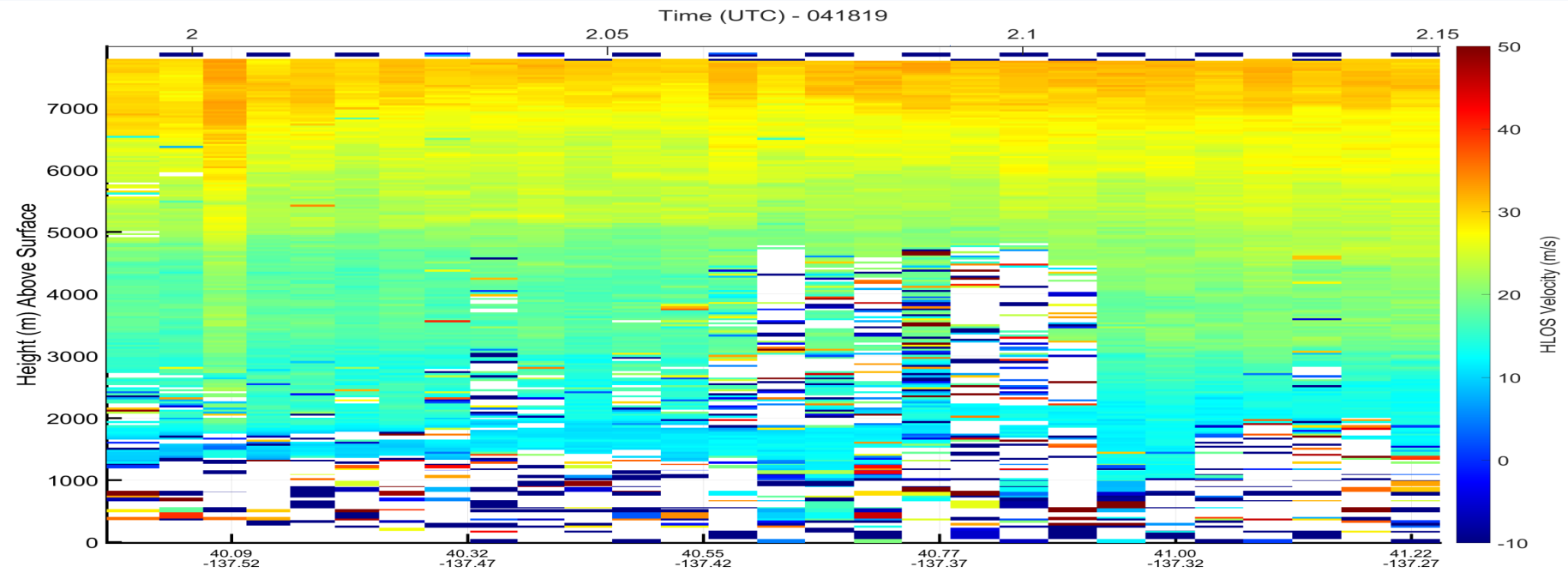
2 G17 VIS APR 18, 2019 03:01 Z NASA JARC

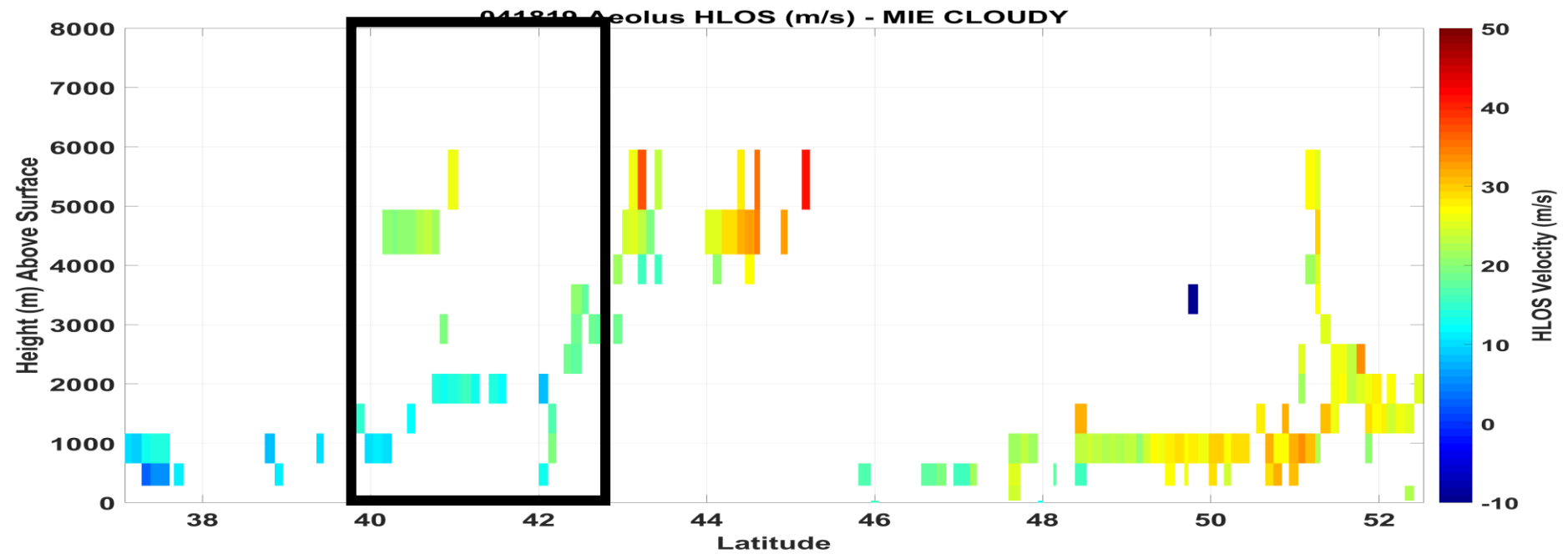
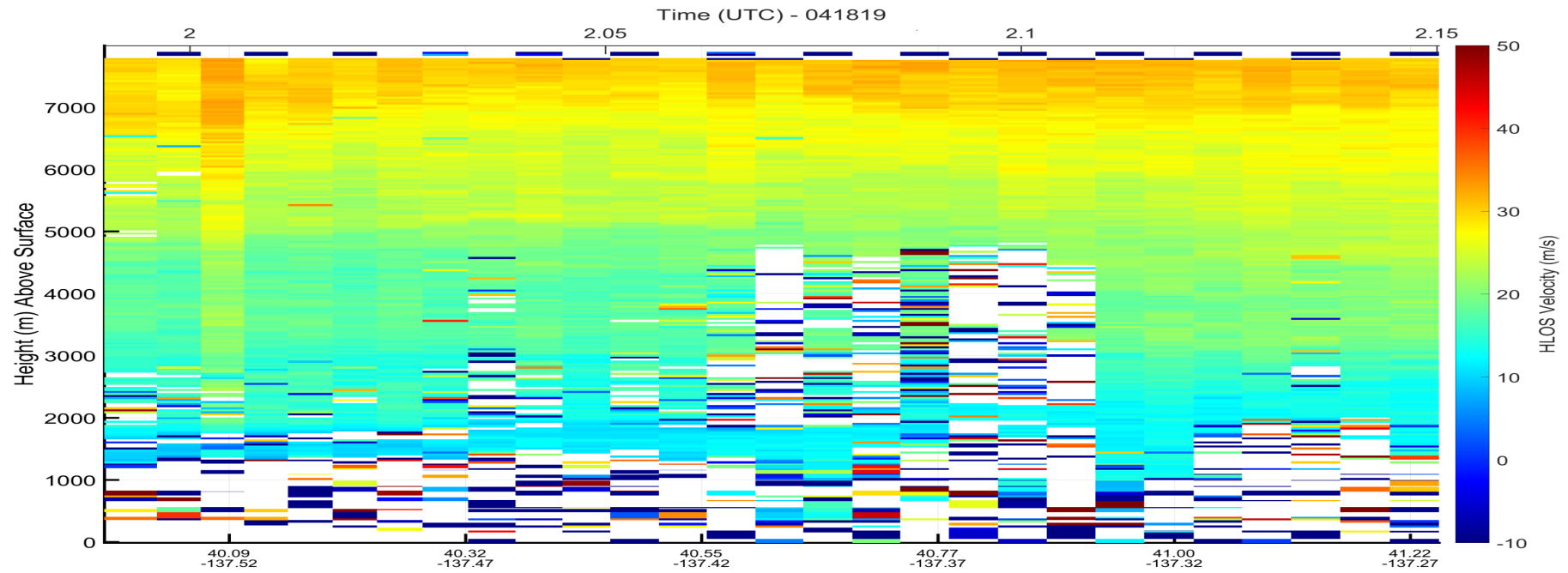
DAWN-DROP COMPARISON MIDDLE OF UNDERFLIGHT



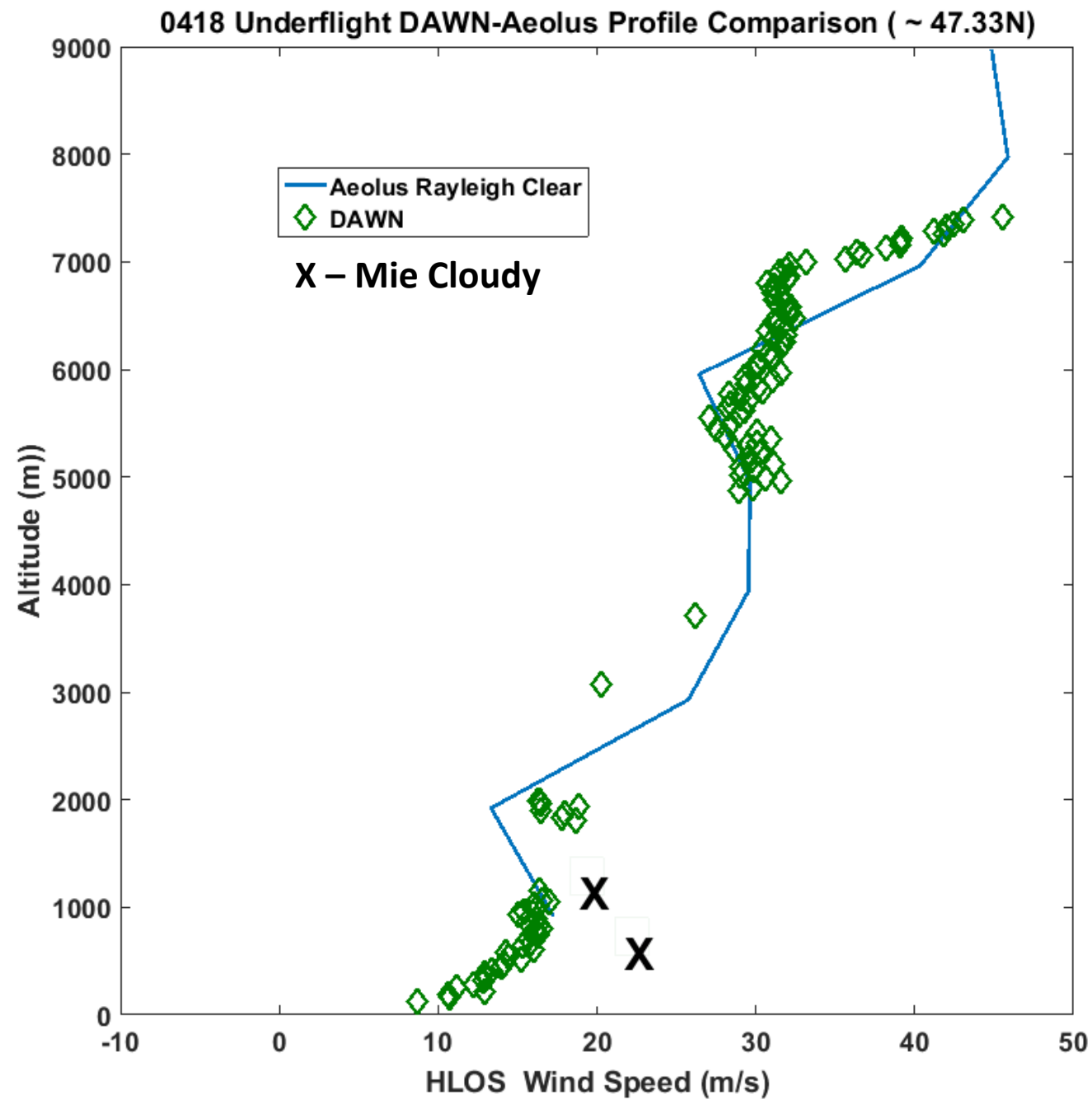




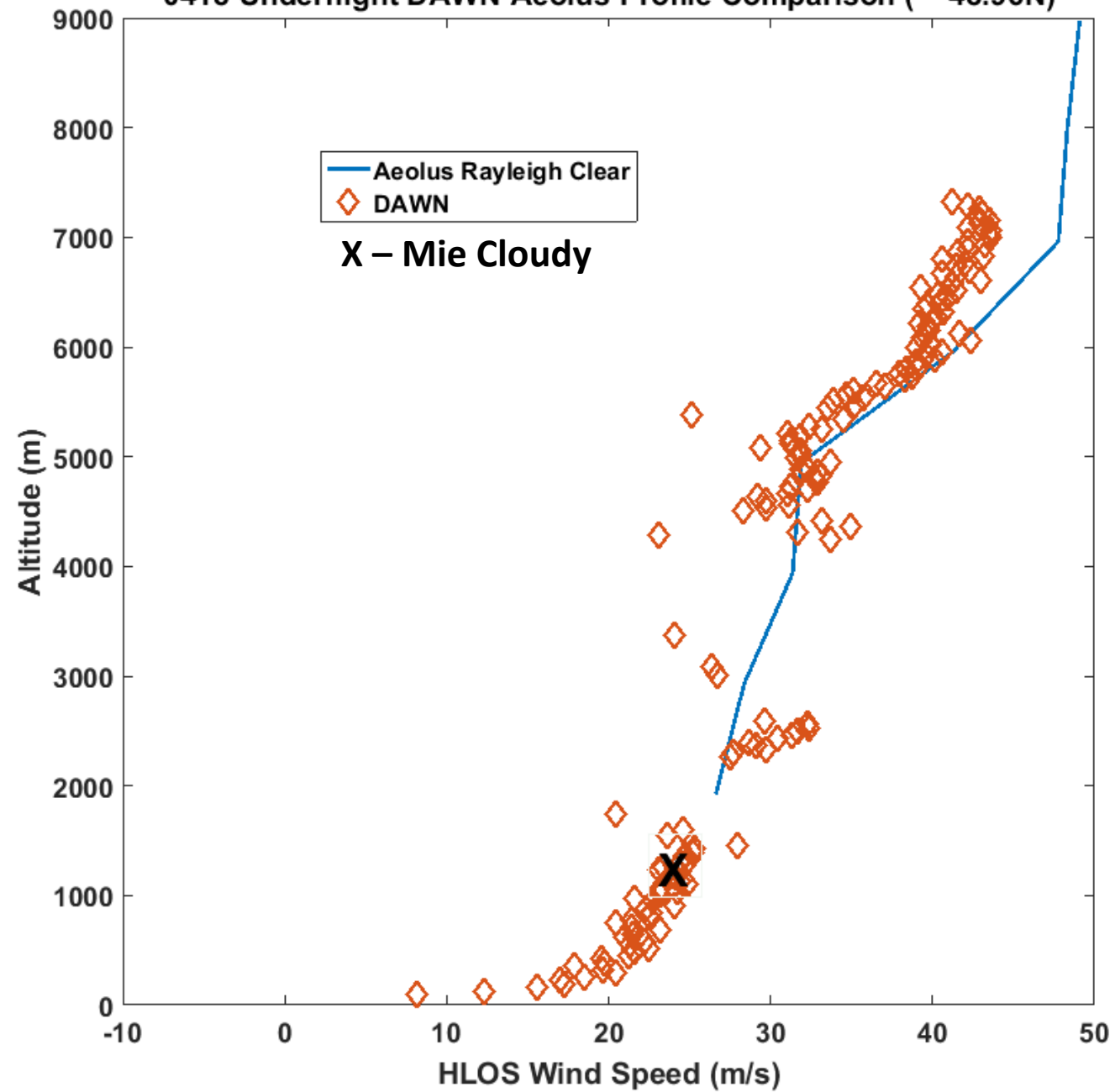




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0418 Underflight DAWN-Aeolus Profile Comparison (~ 48.96N)



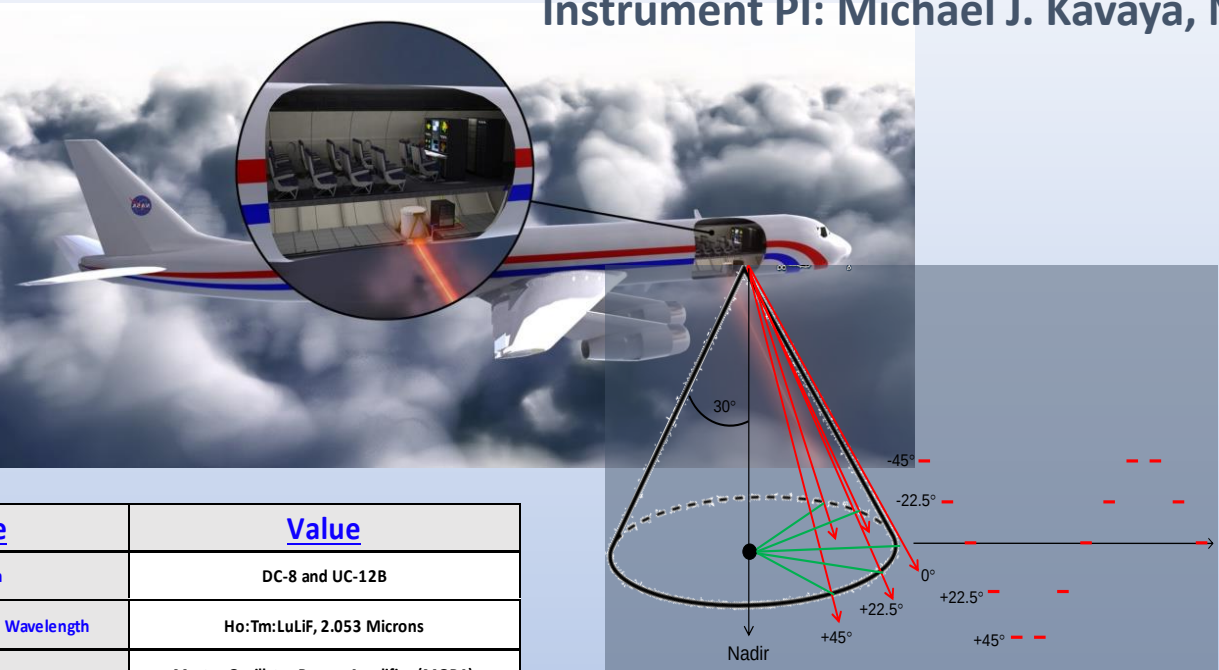
Summary

- Preliminary comparisons
 - Neither data set final
 - More experience needed working with Aeolus products
- DAWN performed well in relatively clean/low aerosol and low to partly cloud conditions
 - Comparison with Dropsondes
 - Often complete profiles
- Even with weakened laser in April 2019, very encouraging comparisons between DAWN and Aeolus
 - RAYLEIGH Clear
- More work to follow

ADDITIONAL SLIDES

Doppler Aerosol Wind (DAWN) Lidar System

Instrument PI: Michael J. Kavaya, NASA LaRC



DAWN Capabilities

High coherent Doppler lidar sensitivity to aerosol backscatter, enabling excellent vertical resolution, accuracy, and atmospheric coverage

Provides vertical profiles of horizontal wind vectors, LOS range wind and wind turbulence profiles, and relative aerosol backscatter profiles

Optional number of azimuth angles (up to 12) permits trade of wind variability determination vs. horizontal resolution

Optional number of laser shots averaged for each LOS wind profile permits trade of atmospheric coverage vs. horizontal resolution

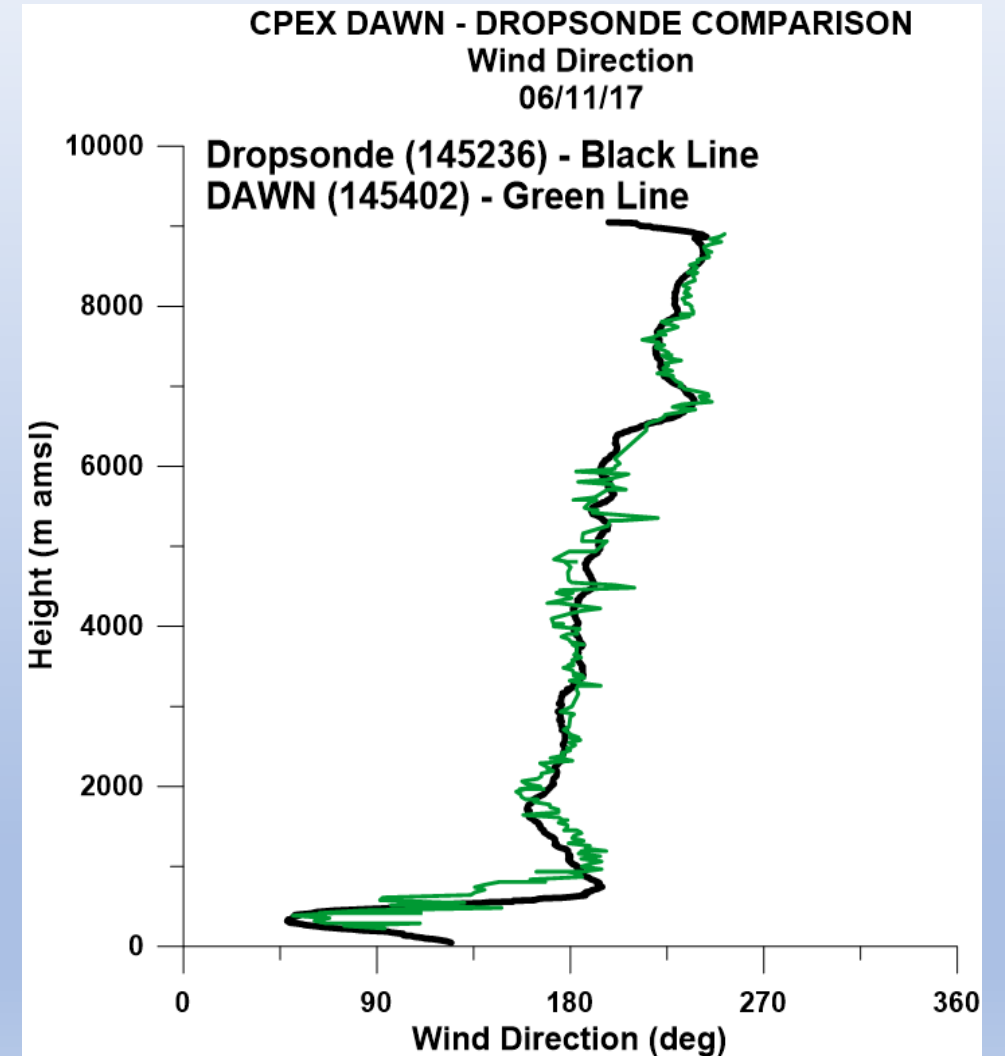
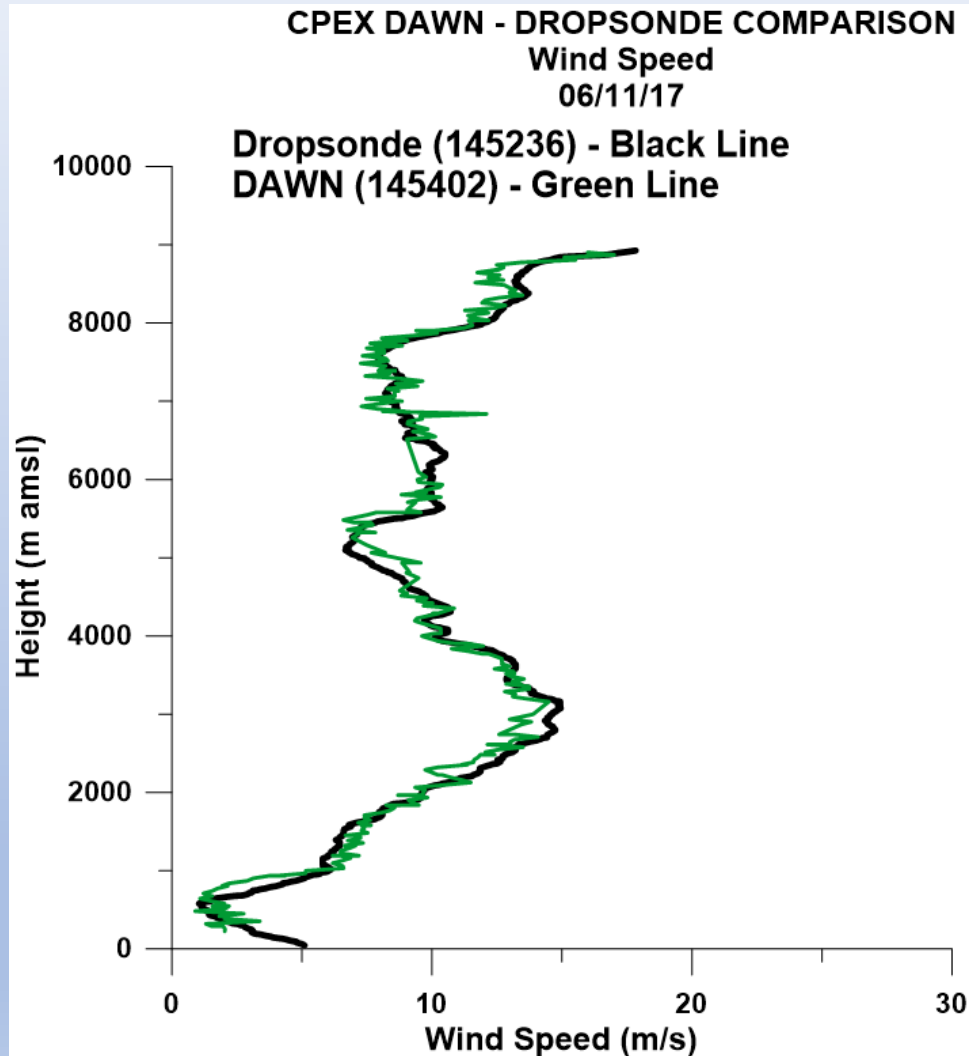
Data may be processed multiple ways to provide various combinations of vertical and horizontal resolution, atmospheric coverage, and expected accuracy statistics

Attribute	Value
Airplanes Flown	DC-8 and UC-12B
Solid-State Laser Crystal and Wavelength	Ho:Tm:LuLiF, 2.053 Microns
Laser Architecture	Master Oscillator Power Amplifier (MOPA)
Pumping Source, Wavelength, Duration	Laser Diode Arrays (LDA), 792 nm, 1 ms
Laser Pulse Energy E, Rate f, FWHM Duration t	100 mJ, 10 Hz, 180 ns
Telescope Diameter D, Magnification M	15 cm, 20
Light Detection Material, Technique	InGaAs, Coherent, Dual-Balanced
Scanner Diameter, Type, Deflection	15 cm, Step-Stare Rotating Wedge, 30° About Nadir
Eye Safety	Safe at any Range When DAWN Closed Up for Flight
Pointing Knowledge Technique	Dedicated INS/GPS on Lidar; dry land returns
LOS Wind Measurement Precision	< 1 m/s
Maximum LOS, Horizontal Wind	±80 m/s, ±160 m/s
Captured Data Length in Range, Altitude	0 – 16.4 km, 0 – 14.2 km
Vertical Resolution	133 m for 512-Sample Range Gate

Comparison setup

- Ground return calibration while over Florida peninsula
 - Straight and level between 3 and 4 km AGL
 - Perform calibration flight segment before and after an over-water mission clouds and time permitting.
 - Major changes in the DAWN system were made on June 17th.
 - Calibration products:
 - Pitch correction (~.5 degrees)
 - Yaw correction (~.5 degrees)
 - Roll correction ($\sim < .01$ degrees)
 - Height correction (timing of outgoing pulse)
 - Unknowns folded into the pitch corrections ($< .02$ degrees)
 - No other corrections made to the DAWN data prior to dropsonde comparisons.
- 162 dropsondes over 14 flights were used in the comparisons (~15,000 height segments of ~ 66 meter DWL vertical resolution)
- Used only DAWN high resolution (66m processing gates and 33m display gates)

Example DAWN-Dropsonde comparison during CPEX 2017



Differences by height interval (km)

Height Interval	Number 37m seg	MEAN Z DIFF (m)	BIAS (m/s)	MEAN ABS(Δ WS)	Δ WS RMSD
0-3 km	4935	2.52	-0.02	0.95	1.26
3-6 km	2079	2.91	0.26	1.20	1.62
6-9 km	5774	3.32	0.27	1.14	1.58
9-12 km	2732	3.70	-0.20	1.38	1.84

Height Interval	Number 37m seg	MEAN Z DIFF (m)	BIAS (deg)	MEAN ABS(Δ WD)	Δ WD RMSD
0-3 km	4935	2.52	1.62	9.79	17.5
3-6 km	2079	2.91	0.78	10.10	18.4
6-9 km	5774	3.32	0.31	14.25	26.4
9-12 km	2732	3.70	-0.68	8.09	11.88