Tethered Balloon System & AALCO Activities at ARM AMF3

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ARM CLIMATE RESEARCH FACILITY

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Introduction

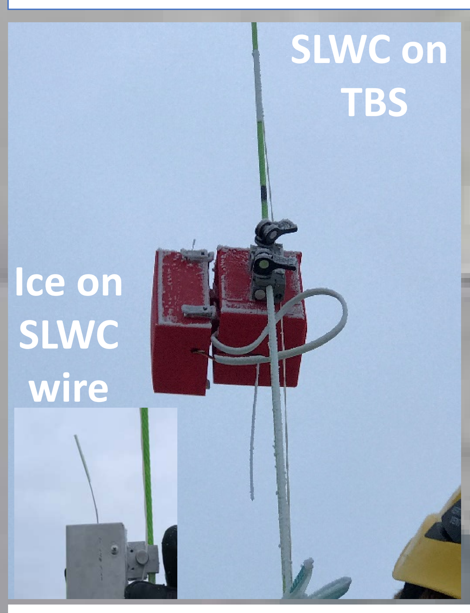
Restricted Airspace at AMF3

- ARM North Slope of Alaska (NSA) Science Mission is to collect high latitude atmospheric data to refine climate models as they relate to the Arctic.
- Sandia National Laboratories (SNL) manages the DOE ARM facilities in Alaska and has operated the ARM Mobile Facility #3 (AMF3) at Oliktok Point since 2013 on behalf of ARM.
- SNL operates Restricted Area R-2204 and Warning Area W-220 at AMF3, the only ARM site with restricted airspaces.
- SNL operates a tethered balloon system (TBS) on behalf of ARM up to 1.5 km in altitude within DOE's R-2204 Restricted Area at AMF3.
- TBS flights have been conducted since 2015 at AMF3, as part of the AALCO (Aerial Assessment of Liquid in Clouds at Oliktok) and ERASMUS (Evaluation of Routine Atmospheric Sounding Measurements using Unmanned Systems) campaigns.
- AALCO was a SNL campaign conducted at Oliktok Point from April 2016 – October 2017, that used in-situ cloud measurements from the tethered balloon system to improve the parameterization of SNL high-resolution Arctic cloud models.
- ERASMUS was an internal ARM effort to demonstrate how small UAV and TBS could be used to continuously study the atmosphere in the Arctic and collect spatial information about the rapidly changing arctic environment in conjunction with ground-based instruments.
- Supercooled liquid water content sondes (SLWCs) and distributed temperature sensing systems were operated as part of ERASMUS and AALCO on the TBS as detailed to the right.

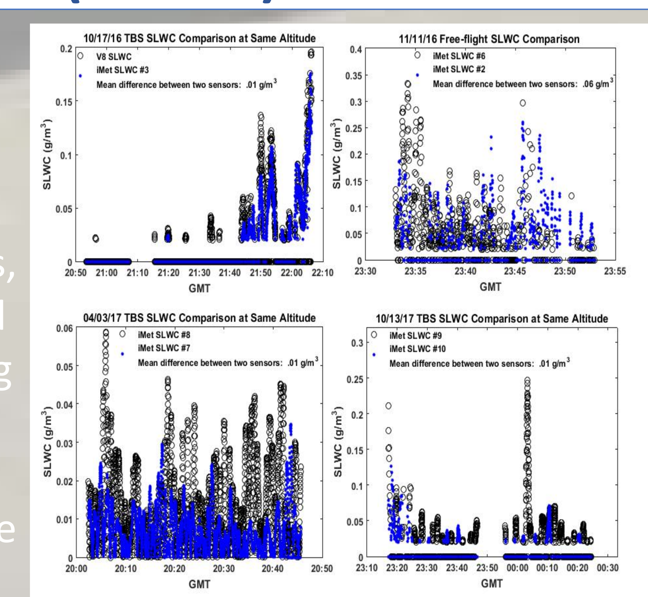
TBS Flights

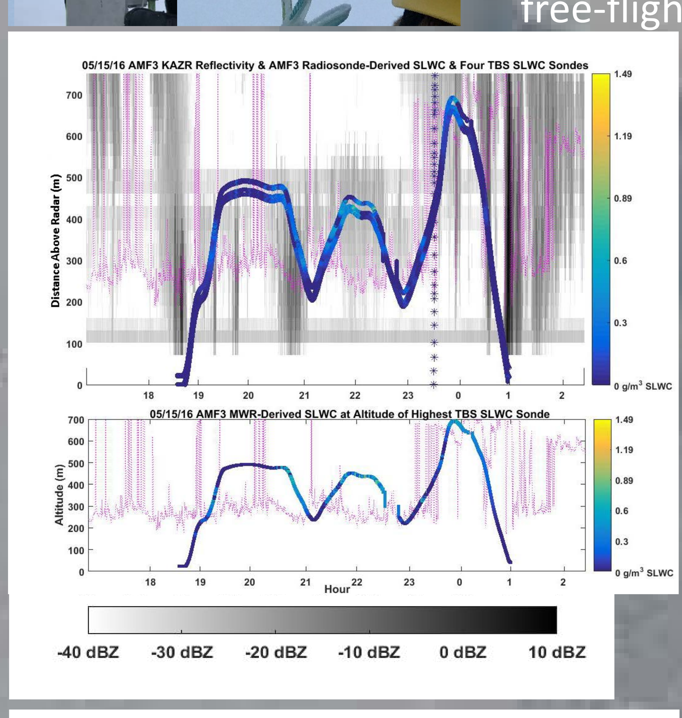
Dates	TBS Flight Hours	Relevant Sensors	Campaign
October 22-28, 2015	33.5	SLWC sondes	ERASMUS
April 3-20, 2016	9.3	SLWC sondes	AALCO, ERASMUS
May 13-16, 2016	14.8	SLWC sondes, Sensornet Oryx DTS	AALCO, ERASMUS
June 5-11, 2016	24.0	SLWC sondes, Sensornet Oryx DTS	AALCO, ERASMUS
July 24-27, 2016	7.4	Sensornet Oryx DTS	AALCO, ERASMUS
October 10-20, 2016	33.0	SLWC sondes, Sensornet Oryx DTS	AALCO, ERASMUS
November 14-17, 2016	10.5	SLWC sondes	AALCO
April 2-10, 2017	8.5	SLWC sondes	AALCO, ERASMUS
May 15 – 24, 2017	30.8	SLWC sondes, Sensornet Oryx DTS with Fiber Optic Rotary Joint (FORJ)	AALCO, ERASMUS
August 4 – 9, 2017	17.0	SLWC sondes, Sensornet Oryx DTS with Fiber Optic Rotary Joint (FORJ)	AALCO, ERASMUS
October 13 – 22, 2017	9.7	SLWC sondes, Silixa XT DTS with Fiber Optic Rotary Joint (FORJ)	AALCO, ERASMUS
TOTAL	198.5		

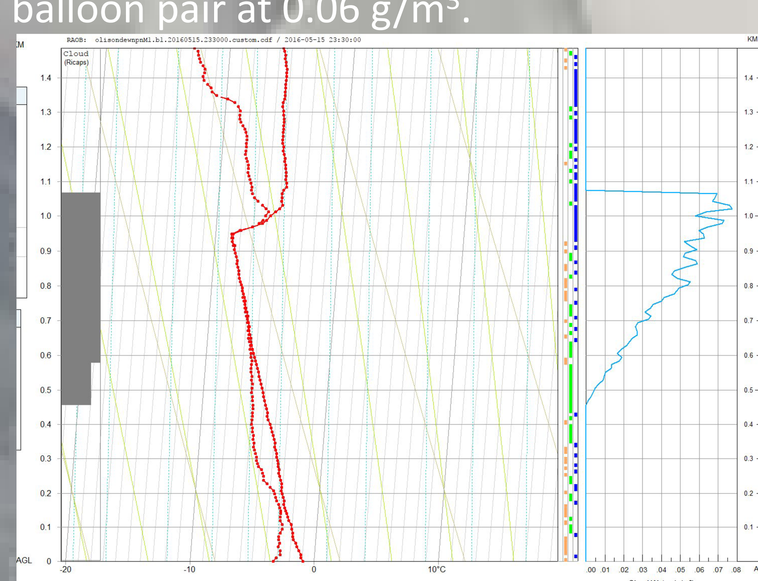
Supercooled Liquid Water Content sondes (SLWCs)

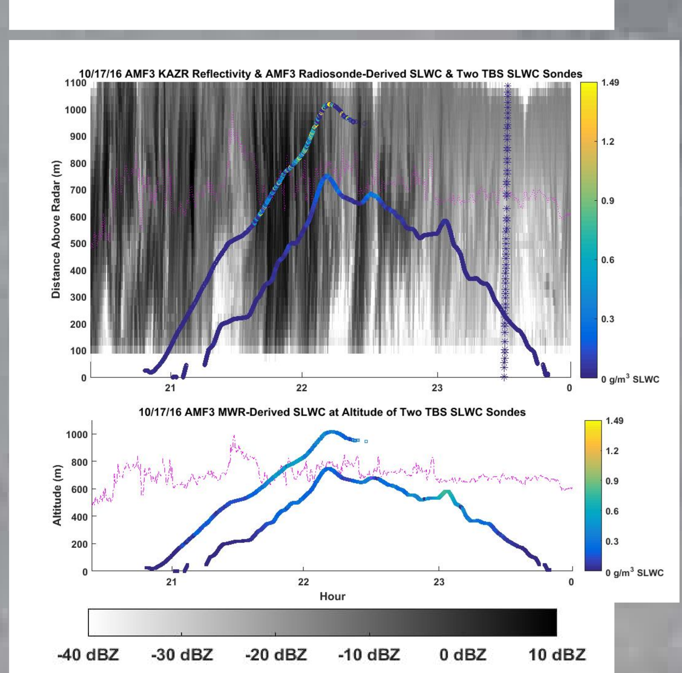


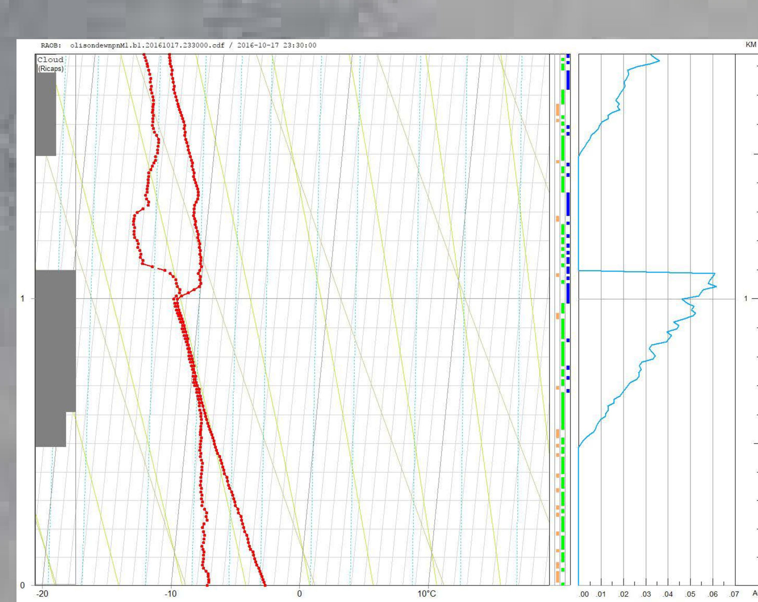
- The rate of change of the frequency of the steel vibrating wire on the SLWC sonde and other atmospheric parameters were used to calculate supercooled liquid water content.
- Throughout ERASMUS and AALCO pairs of eight different SLWC sondes were operated side-by-side, in the presence of SLWC clouds, for over four hours. Three such comparison flights were conducted with SLWC sondes on the TBS, while one flight was conducted using a free-flight meteorological balloon.
- The mean differences between the SLWC values calculated by all sonde pairs operated on the TBS were 0.01 g/m^3, and higher for the free-flight balloon pair at 0.06 g/m^3.

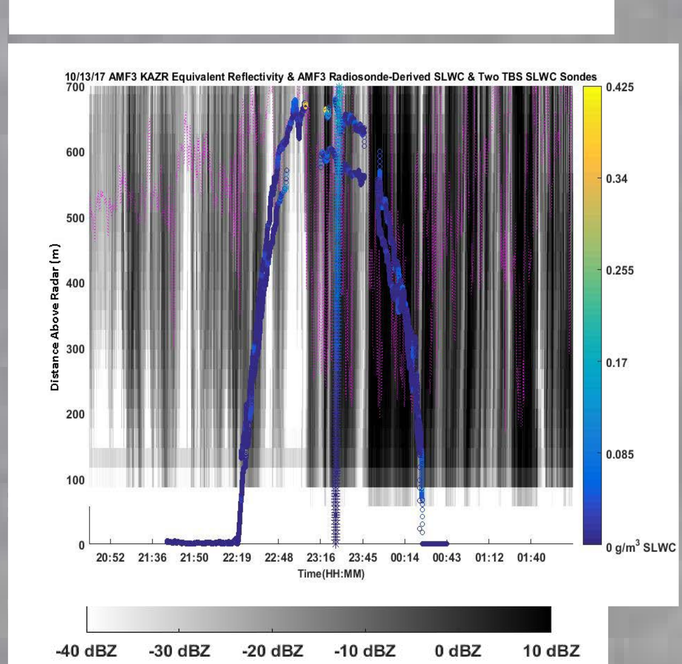


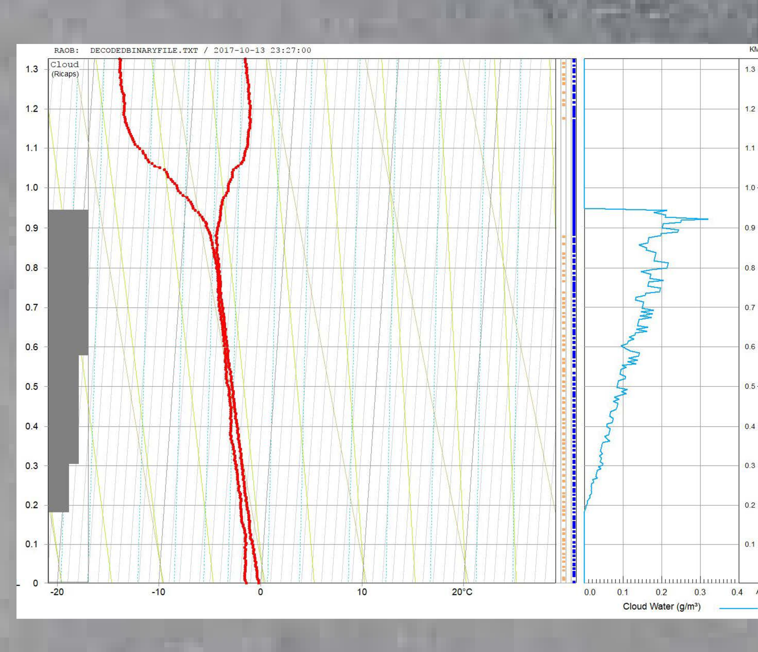












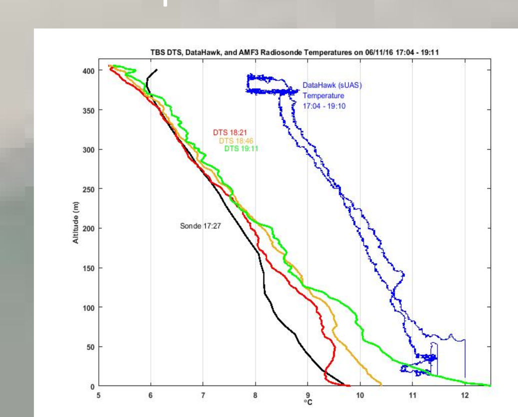
- Three sample cases showing TBS SLWC sonde-measured vertical profiles of SLWC. The grayscale background is radar reflectivity with the cloud base from the AMF3 ceilometer plotted in magenta.
- When available, LWC at the TBS SLWC sonde altitudes was derived by distributing LWP from the AMF3 MWR adiabatically through cloud layers. These values are shown on the subplot below the TBS SLWC sonde-measured profiles.
- Adiabatic SLWC calculated from the 23:30Z AMF3 radiosonde launch is shown with *. SLWC was calculated using the enthalpy methodology in the radiosonde processing software, RAOB.
- AMF3 radiosonde data including cloud layers and RAOB-calculated SLWC are shown on the right.

Summary

- There is generally good agreement between the TBS SLWC sonde measurements and MWR-derived SLWC values.
- There is generally good agreement between the TBS SLWC sonde measurements and MWR-derived SLWC values and occurrence of elevated AMF3 KAZR reflectivity.
- The radiosonde-derived SLWC values are generally lower than the TBS SLWC sonde measurements and MWR-derived SLWC values. The lower radiosonde-derived SLWC values could be due to the assumption that the clouds are adiabatic in the enthalpy methodology in the RAOB software.

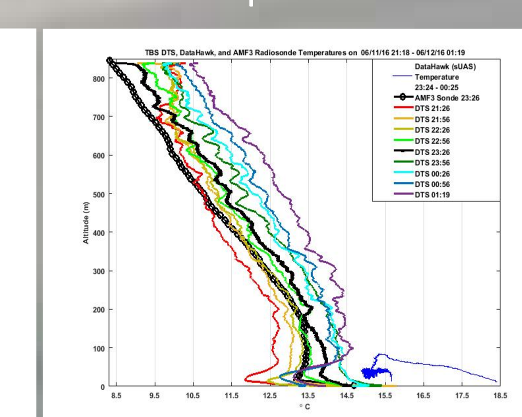
Distributed Temperature Sensing (DTS)

- Sensornet Oryx and Silixa XT DTS systems were operated on the TBS using 50 micron multimode optical fiber suspended along the tether.
- sUAS (DataHawk), TBS DTS, and AMF3 radiosonde temperature measurements are compared.



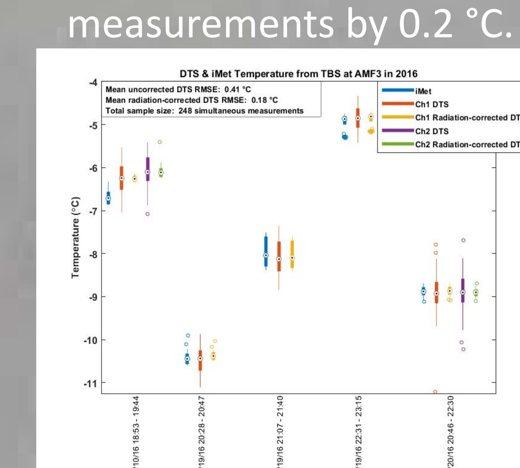
6/11/16 17:40 - 19:11			
	DH Temp	DTS	Sonde
DH Temp		0.96	0.98
DTS	0.96		0.97
Sonde	0.98	0.97	

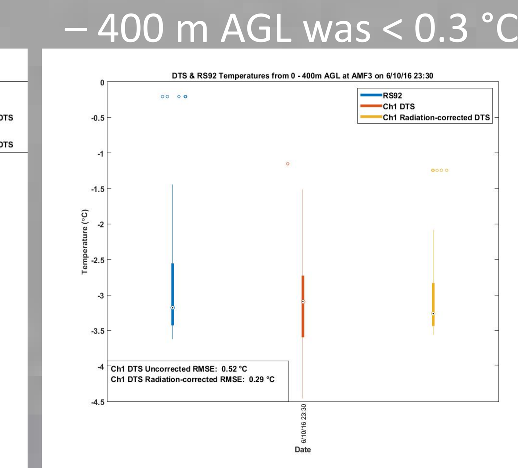
- DTS data and iMet radiosonde data at same altitude on tether are compared.
- Using solar radiation-corrected iMet radiosonde temperature data to calibrate DTS measurements improved RMSE between DTS and radiosonde measurements by 0.2 °C.



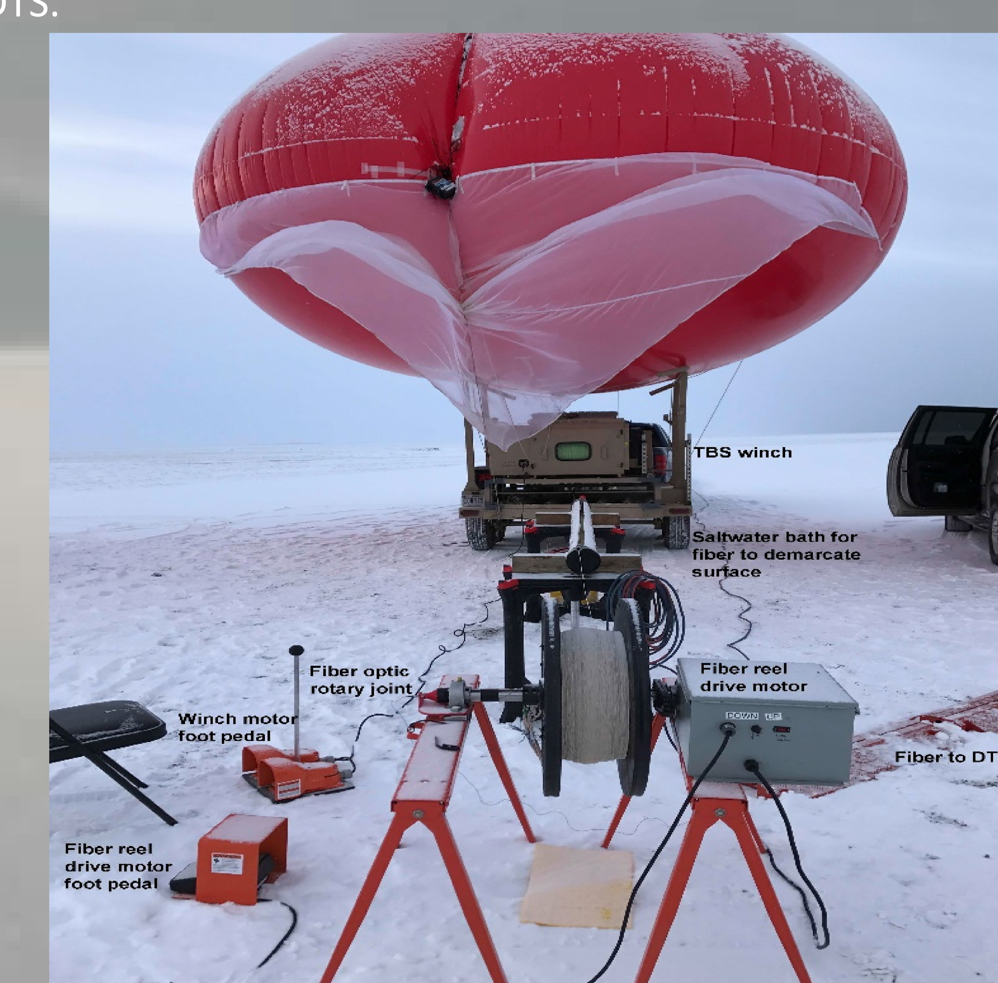
6/11/16 21:18 - 01:19			
	DH Temp	DTS	Sonde
DH Temp		0.30	0.23
DTS	0.30		0.97
Sonde	0.23	0.97	

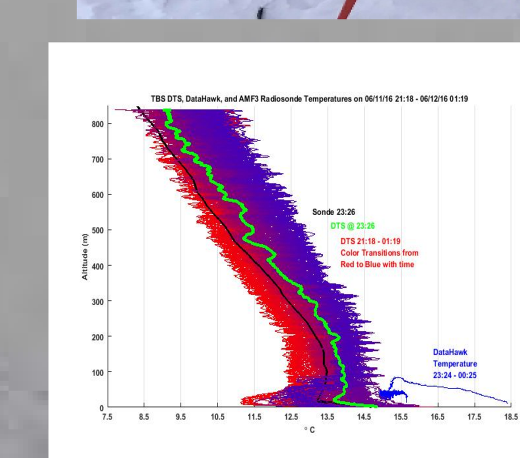
- DTS 1m vertical data was averaged over 10m to match simultaneous AMF3 radiosonde vertical resolution.
- RMSE between solar radiation-corrected DTS 10m-averaged temperature values and AMF3 radiosonde temperature values from 0 – 400 m AGL was < 0.3 °C.



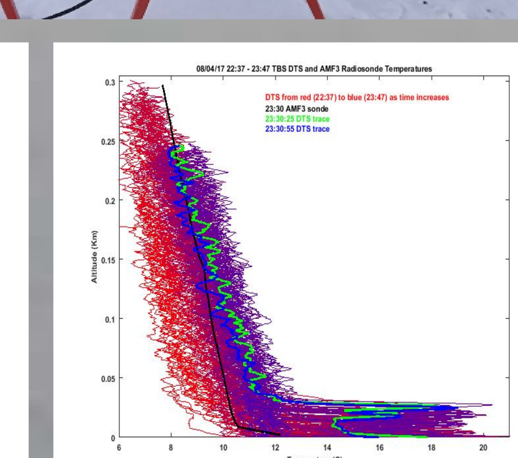


- When the balloon is stationary the optical fiber can be collected directly to the DTS system. Some negative aspects of this configuration are: at least twenty minutes are required to install and remove coils of fiber in calibration baths, there is a potential risk of damage to the fiber whenever it is coiled or uncoiled, and the TBS is required to float at a fixed altitude. To avoid these constraints DTS data may be collected when the balloon is in motion by using a fiber optic rotary joint (FORJ) between the optical fiber and DTS.





- TBS DTS measurements without a fiber optic rotary joint.



- TBS DTS measurements with a fiber optic rotary joint.

Summary

- There is generally good agreement between the TBS DTS, sUAS, and AMF3 radiosonde measurements.
- A large step function is present in the DTS temperature profile 30 m after the fiber optic rotary joint at the surface.
- The temperature is skewed for the lowest 100 m of the DTS temperature profile above the surface, but then the DTS temperature data through the rotary joint and AMF3 radiosonde temperature agreement improves.

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