SAND2019-7974C

ARM Tethered Balloon System Measurements from POPEYE IOP at AMF3

Darielle Dexheimer[1], Fan Mei[2], Gijs de Boer[3,4], Jasper Hardesty[1], Mark Ivey[1]

1. Sandia National Laboratories, Albuquerque, NM, United States.
2. Pacific Northwest National Laboratory, Richland, WA, United States.
3. Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, CO, USA
4. NOAA Physical Sciences Division, Boulder, CO USA

Introduction

TBS flights under the POPEYE (Profiling at Oliktok Point to Enhance YOPP Experiments) IOP occurred at the AMF3 during daylight to altitudes of 1.45 km AGL and with durations from one to six hours in various atmospheric conditions including clear sky, broken to overcast clouds, rain, sleet, snow, and temperatures from -6 °C to 25 °C.

Dates of POPEYE TBS deployment	TBS Flight Hours
July 1 – 11, 2018	41.8
July 24 – August 3, 2018	43.5
August 17 – 26, 2018	22.9
September 21 - 28, 2018	29.5

TBS-Derived Datastreams

The instruments deployed on the TBS during POPEYE, and during other TBS deployments at the AMF3 and SGP are listed below. Datastream names, primary measurements, QC processes, and data availability are also shown.

#	Instrument name	Primary Measurements	Sites	Input Datastream	Output Datastream	QC	Availability
1	tbsslwc	raw SLWC wire frequency is converted to SLWC using tbsimet and tbswind data	OLI	tbsimet.00, tbswind.00	tbsslwc.b1	1. tbsimet and tbswind QC flags are applied. 2. SLWC invalid if <= .02 g/m^3 (below noise threshold) 3. SLWC invalid if >= 1.5 g/m^3 (above response capability of sensor)	b1 data will be available on Data Discovery in 2019. Data available upon request from Darielle Dexheimer, ddexhei@sandia.gov.
2	tbsground	T, RH, 1 s wind gust, 1 min mean wind speed	OLI, SGP	tbsground.00	tbsground.b1	1. Pressure fields invalid if < 850 or > 1050 mb. 2. Temperature fields invalid if < -45 or > 25 °C, < -25 or > 45 °C. 3. Humidity fields invalid if < 0 or > 105 %. 4. Wind Speed fields invalid if < 0 or > 100 m/s.	OLI data available on Data Discovery. SGP data will be available on Data Discovery in 2019. Data available upon request from Darielle Dexheimer, ddexhei@sandia.gov.
3	tbsimet	3d GPS, T, RH	OLI, SGP	tbsimet.00	tbsimet.b1	1. if ascent_rate is <= 0 m/s and gps_altitude < .010 km all fields are invalid. 2. air_temperature, air_temperature_raw invalid if < -40 or > 24 °C, < -10 or > 45 °C. 3. rh invalid if < 0 or > 100 %. 4. pressure invalid if < 800 or > 1050 mb, < 850 or > 1050 mb. 5. gps_altitude invalid if < 0 or > 2 km, < 0 or > 1.1 km. 6. if air_temperature, air_temperature_raw, or rh invalid then imet_altitude invalid. 7. if gps_latitude or gps_longitude invalid then gps_altitude invalid. 8. if abs(gps_altitude(i+1)-gps_altitude(i))>=.01 km then gps_altitude(i) invalid. 9. if abs(imet_altitude (i+1)- imet_altitude (i))>=.01 km then imet_altitude (i) invalid. 10. if gps_altitude and imet_altitude are both valid, but abs(gps_altitude – imet_altitude)>.040 km then gps_altitude is invalid. 11. if imet_altitude is valid and std(air_temperature,3) >= 0.1 °C then air_temperature(i) is invalid. 12. if imet_altitude is valid and std(rh,3) is >= 1 % then rh(i) is invalid. 13. if air_temperature_raw or pressure invalid then theta invalid. 14. if air_temperature_raw or rh invalid then frostpoint invalid. 15. if air_temperature_raw, pressure, or rh invalid then vapor_mixing_ratio invalid. 16. if gps_altitude invalid then ascent_rate invalid.	OLI data available on Data Discovery. SGP data will be available on Data Discovery in 2019. Data available upon request from Darielle Dexheimer, ddexhei@sandia.gov.
4	tbsimetxq2	3d GPS, T, RH	OLI, SGP	tbsimetxq2.00	tbsimetxq2.b1	1. All fields are inaccurate when Sat Count is <=5. 2. Pressure invalid if < 800 or > 1050 mb, < 850 or > 1050 mb. 3. Air Temperature invalid if < -40 or > 24 °C, < -10 or > 45 °C. 4. Humidity invalid if < 0 or > 100 %. 5. Humidity Temp invalid if < -40 or > 24 °C, < -10 or > 45 °C.	b1 data will be available on Data Discovery in 2019. Data available upon request from Darielle Dexheimer, ddexhei@sandia.gov.
5	tbswind	1 min mean wind speed, 1 s wind gust, wind direction (in progress)	OLI, SGP	tbswinds.00	tbswinds.b1	1. Unit serial number invalid if not R1001 – R1020. 2. Wind speed invalid if < 0 or > 40 m/s. 3. Wind gust invalid if < 0 or > 40 m/s. 4. Pulse count invalid if < 0 or > 10000.	b1 data will be available on Data Discovery in 2019. Data available upon request from Darielle Dexheimer, ddexhei@sandia.gov.
6	tbsdts	T	OLI, SGP	tbsdtssnforjch1.00 tbsdtssnforjch2.00 tbsdtssnch1.00 tbsdtssnch2.00 tbsdtssxforjch1.00 tbsdtssxforjch2.00 tbsdtssxach1.00 tbsdtssxach2.00	PI-provided	1. tbsimet QC flags are applied. 2. Invalid if calibration RMSE >= 0.2 °C.	Contact Darielle Dexheimer, ddexhei@sandia.gov, for link to data.
7	tbscpc	total number concentration of aerosol particles larger than 10 nm	OLI, SGP	tbscpcM1.00	PI-provided	CPC concentration is valid between 0-10,000 particles per cc. The rest of the environmental parameters follow the same QC criteria as tbsimet.	Contact Fan Mei, fan.mei@pnnl.gov, for link to data.
8	tbspops	aerosol particle size distribution from 150 - 3000 nm	OLI, SGP	tbspopwetM1.00 tbspopdryM1.00	PI-provided	POPS concentration is valid between 0-4,000 particles per cc. The rest of the environmental parameters follow the same QC criteria as tbsimet.	Contact Fan Mei, fan.mei@pnnl.gov, for link to data.
	FUTURE INSTRUMENTS						
1	Three Sioutas Personal Cascade Impactors	Chemical compositions of aerosol particles < .25 µm, .25 - .50 µm, .50 - 1.0 µm, 1.0 - 2.5 µm.	OLI, SGP	First deployment at SGP in July 2019.			EMSL will provide the TEM/SEM analysis for the July TBS deployment.

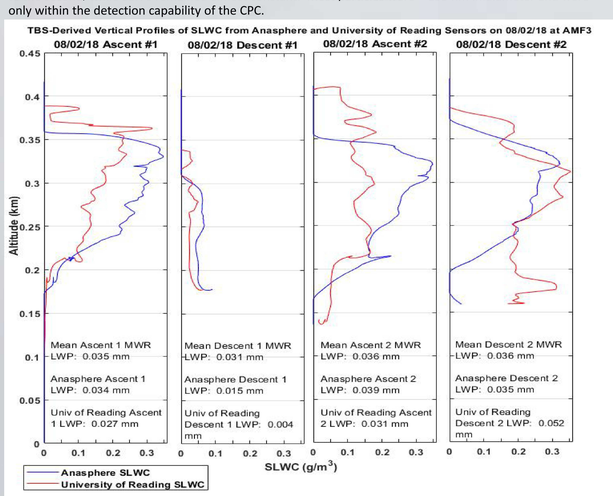
TBS Supercooled Liquid Water Content (SLWC) Measurements during POPEYE

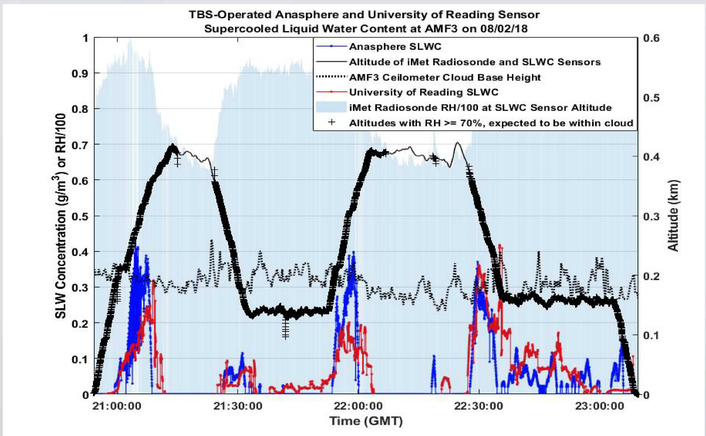
Two types of SLWC sondes were operated on the TBS during POPEYE. One flight was conducted on 08/02/18, where the sensors were deployed on the helikite platform through the cloud base to an altitude of ~400 m and returned to ~150 m below the cloud base over two cycles. Both sensors detected SLW, particularly during the ascent and descent phases at approximately 2100, 2130, 2200, and 2230.

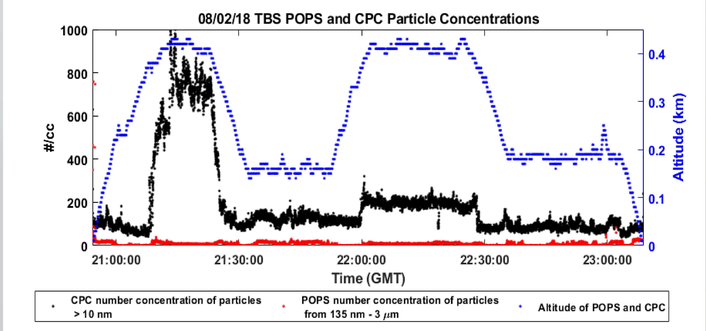
During the initial ascent a gradual increase in SLWC is observed between 200 – 400 m from 0 – 0.3 g/m^3. At the maximum altitude, SLWC decreased to 0 g/m^3 as the sensors emerge into a region of low relative humidity (~65%) interpreted to be above the cloud top. During the subsequent descent, both sensors once again detected similar values of SLWC, albeit lower, probably due to the vibrating wires being at maximum ice loading. The final descent also shows reasonably good agreement, peaking at ~0.3 g/m^3 between 300-350 m as observed in the preceding ascents. Following the final descent, both sensors continue to detect SLW while they are held at ~150 m, somewhat higher than the period following the first descent and, in this case, coinciding periodically with the cloud base, which would account for the continued detection.

The calculated LWP from each sonde is compared with that derived from the MWR and show both sensors achieving good agreement with the MWR data during the ascents (to within ±0.008 mm for the Reading sensor and ±0.003 mm for the Anasphere sensor); however, this is less good during the descents for the possible reasons discussed above.

CPC particle concentrations were much higher on the first ascent and descent through the cloud as compared to the second, while SLWC remained almost constant. Most particles were < 135 nm in diameter and were only within the detection capability of the CPC.



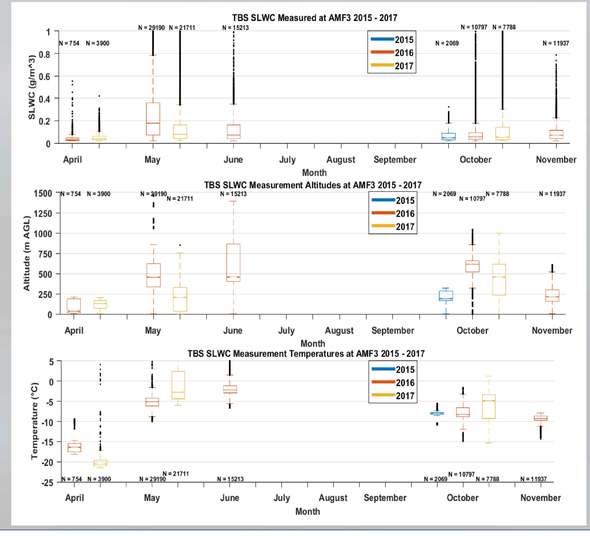


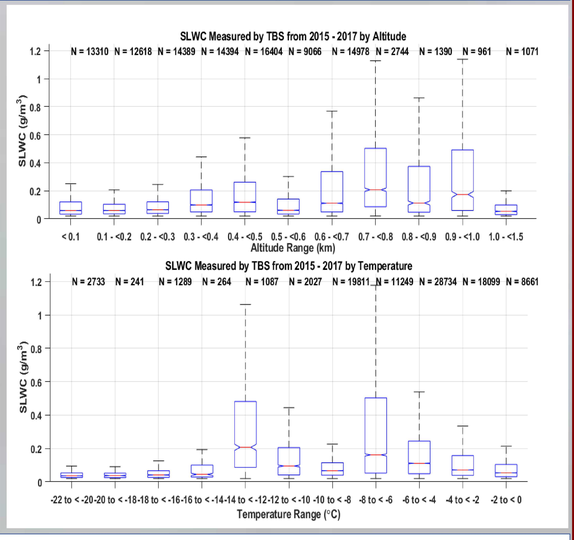


TBS SLWC from 2015 – 2017 by Month, Altitude, and Temperature

Recurring TBS Anasphere SLWC sonde deployments occurred at the ARM AMF3 during fall and spring months between 2015 and 2017.

- The highest SLWC values were measured in the late spring during May and June, with lower values being measured in fall and early spring.
- Measured SLWC values increased at flight altitudes between 400 m and 1 km AGL and were lower below 400 m.
- The highest measured SLWC values occurred at temperatures above -14 °C and below -2 °C.
- In respect to interannual variability of SLWC, the mean SLWC values in three sequential Octobers were 0.06, 0.10, and 0.14 g/m^3; sequential average April values were both 0.05 g/m^3, and sequential May means were 0.26 and 0.14 g/m^3, respectively.

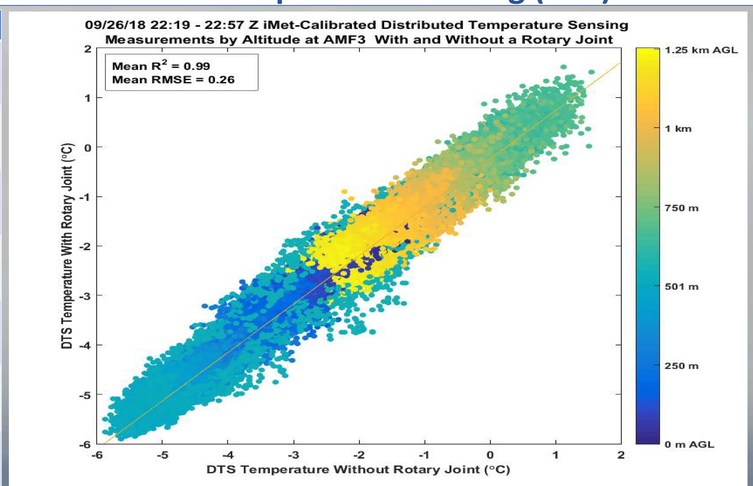




TBS Distributed Temperature Sensing (DTS) Measurements during POPEYE

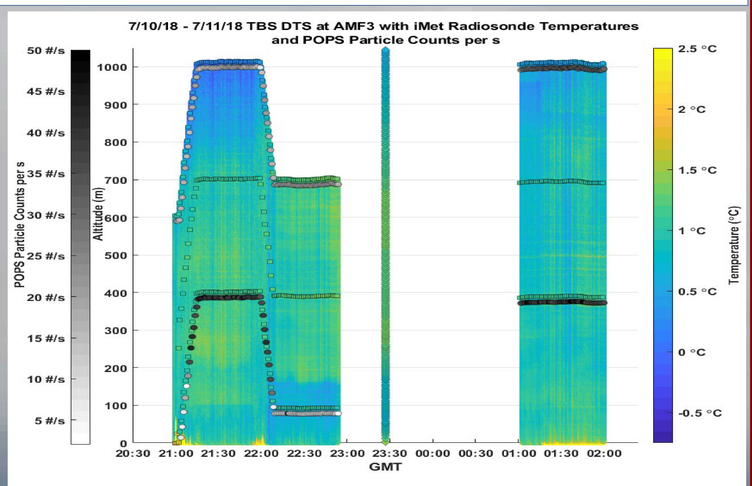
The DTS collected over 300 hours of 30s measurements with two fibers during the POPEYE field campaign. One fiber did not include a rotary joint and was in use only when the balloon was not ascending or descending. The other fiber was installed with a fiber optic rotary joint (FORJ) and measured continuously. The DTS measurements were calibrated with a reference temperature sensor installed on the tether at the maximum-altitude ends of the fibers. An iMet radiosonde and iMet XQ2 sensor were both used to provide reference temperatures. The DTS temperatures were averaged vertically over 5 m in order to compare with temperatures from simultaneous radiosonde profiles. The iMet radiosonde and XQ2 sensors performed almost identically as reference temperature sources. The FORJ and non-FORJ temperatures correlated to each other at 0.74 and had an RMSE of 0.5 °C. Both the FORJ and non-FORJ measurements correlated to radiosondes at 0.97 with RMSEs from 0.4 – 0.6 °C.

	Correlation	RMSE (°C)
Mean iMet-Calibrated, XQ-2-Calibrated	0.76	0.49
Mean iMet-Calibrated FORJ, iMet-Calibrated non-FORJ	0.74	0.51
Mean XQ2-Calibrated FORJ, XQ2-Calibrated non-FORJ	0.74	0.50
FORJ iMet-Calibrated vs Radiosonde	0.97	0.49
FORJ XQ2-Calibrated vs Radiosonde	0.97	0.60
Non-FORJ iMet-Calibrated vs Radiosonde	0.97	0.43
Non-FORJ XQ2-Calibrated vs Radiosonde	0.97	0.46



During the POPEYE field campaign a Silixa XT DTS system was operated on the TBS using 50 micron multimode optical fiber suspended along the tether. Temperature measurements were collected every 30 – 60 s with a spatial resolution of 0.65 cm. Two POPS (Printed Optical Particle Spectrometers) were suspended along the tether. One POPS was operated just below the balloon in order to reach the maximum possible altitude, which was ideally above cloud top. A second POPS was generally operated lower on the tether near cloud base.

On 7/10/18, the continuous DTS temperature profiles and iMet radiosonde temperatures reveal a cool layer at the surface below 100 m with a 2-3 °C warmer layer between 150 and 800 m, then another cooler layer above the inversion from 800 m to 1 km. The AMF3 radiosonde launch at 23:30 measured a similar temperature profile. The particle concentration per second measured by the POPS demonstrates increased particle concentration within the temperature inversion, with fewer particles above the inversion and in the surface-cooled layer. On 7/11/18 the surface was roughly 2 °C cooler than on the previous day, as were temperatures in the inversion layer between 200 m and 1.2 km. POPS particle concentration per second within the inversion was approximately double that observed on the previous day.



Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.