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# Profiling at Oliktok Point to Enhance Year of Polar Prediction (YOPP) Experiments (POPEYE) Field Campaign Report

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ARM

# DISCLAIMER

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# Executive Summary

The arctic region is rapidly evolving, and enhanced predictive capabilities, for both weather and climate, are urgently required. Therefore, the international community is executing an extended period of focused observations and modeling of the arctic environment, dubbed the Year of Polar Prediction or YOPP. The YOPP featured two special observing periods (SOPs) (and will feature a third in 2020). The first of the completed SOPs occurred in the spring of 2018, and the second during the late summer and early fall of 2018. Here, we summarize the deployment of additional U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) user facility resources to the third ARM Mobile Facility (AMF3) at Oliktok Point, Alaska during the second three-month SOP (1 July 2018–30 September 2018). This deployment, named POPEYE (Profiling at Oliktok Point to Enhance YOPP Experiments), included the launching of extra radiosondes (one more per day) and operation of ARM-operated unmanned aircraft (DataHawk 2s) and ARM-operated tethered balloons. These instruments conducted routine profiling activities over the course of the special observing period to obtain measurements of atmospheric thermodynamic structure, cloud and precipitation properties, and aerosol properties. These measurements are expected to be used for a variety of purposes, including: 1) to conduct detailed studies of arctic cloud and aerosol processes; 2) to inform YOPP modeling efforts through real-time availability for assimilation into operational and research analysis products; 3) to evaluate and improve retrieval algorithms involving ARM remote sensors; 4) to evaluate and improve a variety of modeling tools being used to forecast arctic weather and climate; and 5) to initialize and evaluate simulations associated with a potential arctic large-eddy (LES) simulation framework similar to the ongoing LES ARM Symbiotic Simulation and Observation (LASSO) project.

# Acronyms and Abbreviations

| | |
|---|---|
| AERI | atmospheric emitted radiance interferometer |
| AGL | above ground level |
| AKDT | Alaska Daylight Time |
| AMF | ARM Mobile Facility |
| ARM | Atmospheric Radiation Measurement |
| AVPOP | Aerosol Vertical Profiling at Oliktok Point |
| CAFS | Coupled Arctic Forecasting System |
| CPC | condensation particle counter |
| DMF | Data Management Facility |
| DOE | U.S. Department of Energy |
| DOI | Digital Object Identifier |
| DTS | distributed temperature sensing |
| ERASMUS | Evaluation of Routine Atmospheric Sounding Measurements using Unmanned Systems |
| ESSD | *Earth System Science Data* |
| IARPC | Interagency Arctic Research Policy Committee |
| IASOA | Integrated Arctic Systems for Observing the Atmosphere |
| ICARUS | Inaugural Campaigns for ARM Research using Unmanned Systems |
| LASSO | LES ARM Symbiotic Simulation and Observation |
| LES | large-eddy simulation |
| NOAA | National Oceanic and Atmospheric Administration |
| POPEYE | Profiling at Oliktok Point to Enhance YOPP Experiments |
| POPS | printed optical particle spectrometer |
| PPP | Polar Prediction Project |
| SCM | single-column model |
| SLWC | supercooled liquid water content |
| SOP | special observing period |
| sUAS | small unmanned aircraft systems |
| TBS | tethered balloon system |
| UAS | unmanned aerial system |
| UTC | Coordinated Universal Time |
| WWRP | World Weather Research Programme |
| YOPP | Year of Polar Prediction |

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# 1.0 Background

Recent decades have seen notable shifts in arctic climate (Serreze et al. 2007; Screen and Simmonds 2010). Reductions in sea ice (Maslanik et al. 2011; Comiso et al. 2008), evident as an integrator of a warming arctic atmosphere (Dobricic et al. 2016; Graversen et al. 2008) and evolving surface energy budget (Mayer et al. 2016; Hudson et al. 2013), act to enhance absorption of solar radiation at the surface due to a dramatic shift in surface albedo, potentially enhancing arctic warming. Such reductions in sea ice also present opportunities for commerce, including shipping, natural resource extraction, and fishing (Smith and Stephenson 2013; Ho 2010). Finally, these changes have direct implications on border security due to reduced difficulties with navigation in arctic waters.

In recognition of the importance of these changes and our need to be able to predict and understand them, the World Weather Research Programme (WWRP) established the Polar Prediction Project (PPP). As a part of this project, an extended period of coordinated and intensive observations has been developed in conjunction with focused modeling activities. This period has come to be known as the Year of Polar Prediction (YOPP), and it targets the improvement of prediction capabilities across a wide variety of time scales, from hours to seasons. The core phase for YOPP started in mid-2017, lasting through mid-2020. During 2018, YOPP featured two special observing periods in the Arctic, including one spring and one late summer (1 July 2018 to 30 September 2018) period. Following the core phase will be a three-year consolidation phase, during which a variety of experiments and analysis projects will use the various data sets collected during the core phase to evaluate and improve models, conduct data denial experiments, and evaluate the state of polar prediction.

The Profiling at Oliktok Point to Enhance YOPP Experiments (POPEYE) intensive operational period (IOP), included high-frequency profiling of thermodynamics, clouds, and aerosols using ARM’s unmanned capabilities (DataHawks and tethered balloon system [TBS]) during the second of the two identified YOPP special observing periods. Based on the input of the global weather and climate modeling communities, YOPP established a set of detailed modeling priorities. The priority topics most directly benefiting from these POPEYE measurements are listed below, accompanied by a brief description of the potential benefits:

1. ***Boundary layer including mixed-phase clouds:*** The lower-atmospheric thermodynamic observations provided by the DataHawks and tethered balloon offer one of the most detailed data sets of arctic summer time boundary layers ever collected. These detailed measurements provide insight into the structure of the boundary layer and its evolution, and could additionally be used to validate and improve retrieval algorithms from remote sensors (e.g., atmospheric emitted radiance interferometer [AERI], Raman lidar). Additionally, in conjunction with information from AMF3 remote sensors and TBS-deployed supercooled liquid water content (SLWC) and aerosol measurement systems, these measurements provide detailed information on liquid-containing cloud properties and the environment that sustains them. Finally, this combined suite of observations provides measurements to directly support the stated YOPP goal of pursuing an integrated modeling framework to connect cloud, boundary-layer and surface energy exchange schemes through LES-based development.
2. ***Sea ice modeling:*** Measurements collected as part of POPEYE will complement a variety of observational efforts occurring during YOPP, and be used to advance our ability to predict sea ice variability at timescales from 0 to 10 days. For example, initial work is underway to use POPEYE

measurements to evaluate and improve the Coupled Arctic Forecasting System (CAFS), a fully coupled, ice-ocean-atmosphere regional prediction system being used for forecasting sea ice. Such work includes both direct comparisons between collected measurements and the model, which is run routinely at the National Oceanic and Atmospheric Administration (NOAA) Physical Sciences Division, as well as using POPEYE measurements to force and evaluate large-eddy simulations and single-column model (SCM) work.

3. ***Physics of coupling, including snow on sea ice:*** The high-resolution measurements of the lowest portion of the atmosphere offer insight into the structure of the surface and boundary layers, helping to understand coupling and the influence of the surface on the development of the atmospheric boundary layer and convective cloud cover during the summer months.
4. ***Model validation and intercomparison:*** The detailed measurements provided as part of POPEYE offer a highly detailed data set that can be used to evaluate model performance. Specifically, the detailed structure and evolution of the boundary layer and lower troposphere, as well as the additional insight provided into cloud properties, are items worth investigating across a variety of model products (e.g., reanalyses, weather forecast models, coupled regional forecast models, SCMs, global climate models). Additionally, measurements collected provide detailed constraints on the initial and boundary conditions for intercomparisons of single-column and large-eddy simulation models.
5. ***The stratosphere:*** The increased frequency of radiosonde launches provided increased detail for stratospheric observation. This is particularly interesting in conjunction with similar increases in radiosonde launch frequency at other sites, such as those in the Integrated Arctic Systems for Observing the Atmosphere (IASOA) consortium of observatories, or over the Beaufort Sea from planned ship activities such as those to be carried out by the Japanese research vessel *Mirai*.
6. ***Chemistry, including aerosols and ozone:*** The aerosol measurements provided by the ARM tethered balloon system included information on particle number concentration, size distribution, and small particle concentrations. Profiling these properties, even at low altitudes, provided a rare opportunity to evaluate stratification of aerosol properties in the arctic atmosphere over an extended period and in coordination with detailed boundary-layer measurements. Additionally, these measurements can be combined with similar data collected during the ERASMUS (Evaluation of Routine Atmospheric Sounding Measurements using Unmanned Systems), ICARUS (Inaugural Campaigns for ARM Research using Unmanned Systems), and AVPOP campaigns (Aerosol Vertical Profiling at Oliktok Point) campaigns.

To support such research, POPEYE included the deployment of the DataHawk2 small unmanned aircraft system (sUAS), two tethered balloon systems (TBSs), and extra radiosondes. All systems were deployed by DOE ARM operators, and the Datahawk2 and TBS have been deployed regularly at Oliktok Point over the past few years (de Boer et al. 2018). Here we provide information on these systems and the sensors operated on each.

***Tethered Balloon Systems:*** Two different balloons were used for POPEYE, including a 35 $m^3$ helikite and a 79 $m^3$ aerostat. The helikite uses lighter-than-air principles to obtain its initial lift, and a kite-like structure to achieve stability and dynamic lift. The larger aerostat uses a skirt instead of a kite to achieve stability in flight. For POPEYE operations, both systems were operated using an electric winch integrated into a dedicated balloon trailer by Sandia National Laboratories. The payload and operating guidelines for the TBSs vary significantly with location and environmental conditions. The aerostat can be operated at higher altitudes, but due to its larger size is not launched in sustained surface wind speeds > 7 m $s^{-1}$. The helikite is not launched in sustained surface wind speeds > 11 m $s^{-1}$. Operation of either platform was suspended and the balloon was immediately retrieved when sustained wind speeds at the altitude of the balloon exceeded 15 m $s^{-1}$. In general, the strength of the wind was the main limiting factor governing the launch and final altitude of the TBSs.

POPEYE TBS operations involved a variety of sensors and payloads. To measure the thermodynamic properties of the atmosphere, the TBS team operated multiple different sensor packages from interMet. This includes the interMet iMet-1-RSB radiosonde package as well as the interMet XQ2 sensor packages developed for use on UAS. Additionally, a Silixa XT distributed temperature sensing (DTS) system was flown. This system, which includes a long fiber optic cable suspended along the tether, provides a high-resolution, continuous measurement of air temperature based on Raman scattering. Using this system, temperature is typically measured along the length of the optical fiber every 30 to 60 seconds at 0.65 cm spatial resolution. To provide information on the winds aloft, vaned cup anemometers from APRS World were operated at specified intervals along the tether. It is important to note that while wind speed from these sensors appears to be relatively accurate when compared with Doppler lidar measurements, a variety of factors including the high-latitude location make the directional measurement inaccurate. Information on the aerosol particle population was provided using a combination of two Handix Scientific Printed Optical Particle Spectrometers (POPS) and a TSI Condensation Particle Counter (CPC) 3007. The two POPS provide information on the aerosol size distribution for particles between 140-3000 nm while the CPC provides information on the total number of particles between 10-1000 nm. Additionally, vibrating wire sensors from Anasphere and the University of Reading provide information on the amount of supercooled liquid water in cloud. These sensors were collectively referred to as Supercooled Liquid Water Content (SLWC) sensors.

The main role of the TBS in POPEYE was to collect detailed information on the vertical structure of the lower atmosphere over the AMF3. This provides information on stratification and the temporal evolution of the lower atmospheric structure. Additionally, the TBS is able to fly in and above cloud for extended time periods, providing opportunities to collect in situ measurements of thermodynamic, aerosol and cloud microphysical properties on low-altitude arctic clouds. To accomplish this, the TBS was flown as high as weather conditions would permit, conducting repeated profiles with sensors distributed along the tether. While the exact placement of the sensors would change from flight to flight to adapt to conditions, in general the system was operated with a cluster of sensors including a POPS, CPC, iMet and SLWC near the top of the tether under the balloon, a DTS fiber along the entire length of the tether, and subsequent iMet sensors and anemometers below the main package as most desirable based on the meteorological conditions. When flying the aerostat, a second POPS would also be flown to get more detailed measurements of evolution of the aerosol profile in time. Figure 1 provides a schematic outlining this strategy.

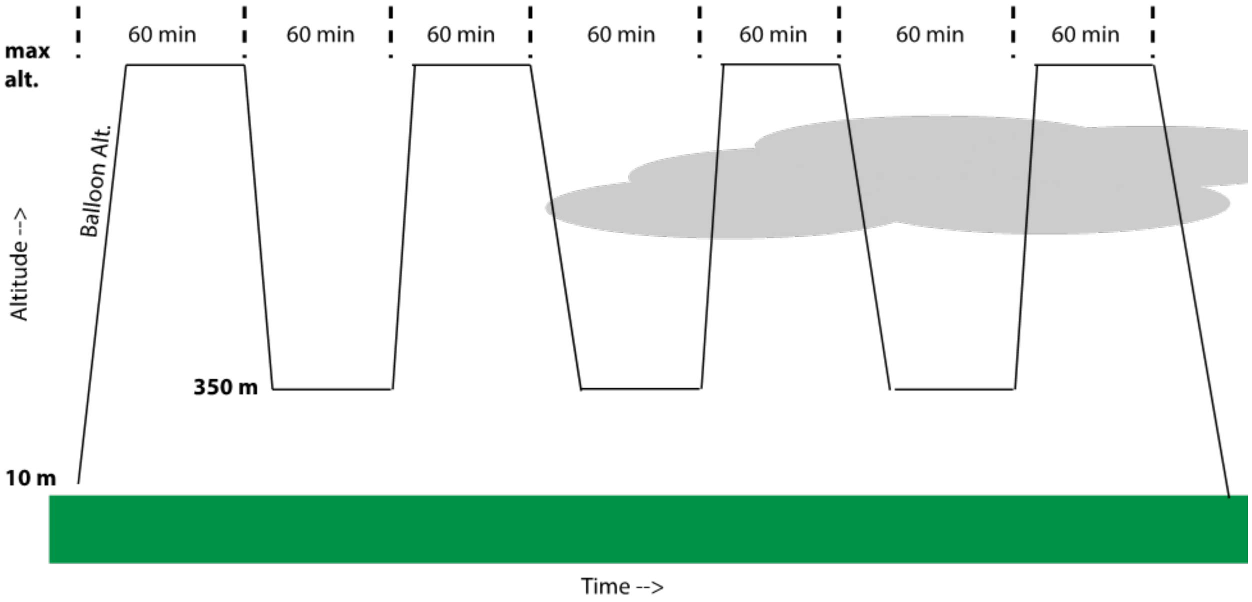

**Figure 1**. Schematic of the desired flight path for the TBSs.

***DataHawk2 sUAS:*** Another instrument platform used during POPEYE was the Datahawk2 sUAS, developed at the University of Colorado-Boulder (description of the first version of the DataHawk can be found in Lawrence and Balsley 2013). The DataHawk2 sUAS is a small (1.2 m wingspan, <1 kg take- off weight), robotic, pusher-prop aircraft designed to operate in a variety of conditions as a flexible and inexpensive measurement platform. The DataHawk2 has been used for a variety of purposes, including the study of turbulence (e.g., Kantha et al. 2017; Balsley et al. 2018) and high-latitude (e.g., de Boer et al. 2016, 2018) deployments. The relatively slow flight speed (14 m/s, burst up to 22 m/s) allows the platform to obtain measurements at high spatial resolution compared to other aerial vehicles. Given these operating speeds, DOE ARM guidelines restricting flight when winds top 7 m $s^{-1}$. DataHawk2 flights completed under POPEYE were generally autopilot guided except during take-off and landing, when they were under the control of a local pilot. All flights were completed within radio communication range and within sight of the ground operators and were conducted within restricted airspace (R-2204, see Figure 1 in de Boer et al. 2016) controlled by DOE. This allowed operators to adjust the flight plan in real time to meet the needs of the science objectives and adapt to the changing environment.

The DataHawk2 carries a variety of sensors to measure the atmospheric and surface states. Custom instrumentation includes a fine wire sensor employing two cold- and one hot-wire. These provide high-frequency (800 Hz) information on temperature and fine-scale turbulence. High bandwidth is enabled by small surface-area-to-volume ratios of very thin (5 µm diameter) wires. In addition, the DataHawk2 carries a custom configuration that includes integrated-circuit, slow-response sensors (Sensirion SHT) for measurement of temperature through a calibrated semiconductor, and relative humidity using a capacitive sensor. For information on surface and sky temperatures, DataHawk2s are equipped with up- and downward-looking thermopile sensors. These sensors undergo a calibration using targets of a known temperature.

The main objective for the DataHawk2 was to obtain as many profiles as possible of the lower atmosphere during daytime hours. To do this, the aircraft was programed to climb from the surface to the maximum obtainable altitude. This maximum altitude was constrained by the pilot’s ability to maintain visual contact with the aircraft (1000 m AGL) or by the cloud ceiling. Because the endurance of the aircraft is approximately 50 minutes in arctic operating conditions, the aircraft could generally complete between one and two full profiles before needing to land to change batteries. Because of the substantial interest in the interplay between thermodynamic and dynamic properties near cloud base, during cloudy conditions the operators were requested to hold altitude around cloud base for 10-15 minutes to collect statistics of that environment before descending back towards the surface. Figure 2 provides an illustration outlining this flight pattern.

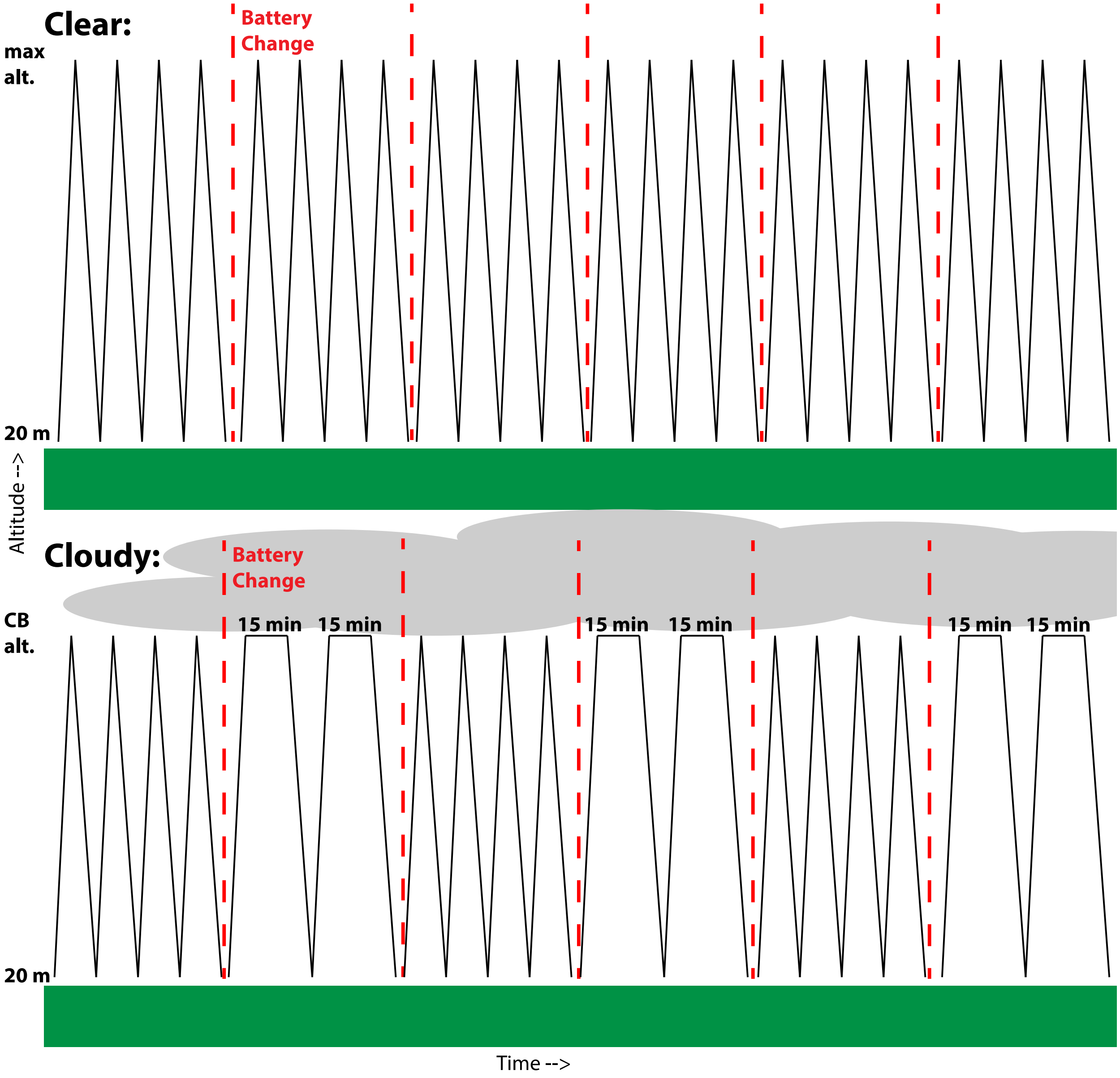

**Figure 2**. Schematic of the desired flight patterns for the DataHawk2s during POPEYE.

***Radiosondes:*** Finally, the ARM facility launched Vaisala RS-92 radiosondes on a regular schedule under POPEYE. Due to concerns about operator safety and fatigue, the number of radiosondes launched was scheduled at three per day, with requested launch times of 05:30, 17:30, and 23:30 UTC (21:30, 09:30, 15:30 AKDT) to match the 06:00, 18:00, and 00:00 UTC synoptic times. Radiosonde launches were at times suspended due to dangerous conditions, including the presence of bears on site, or high winds (>13.5 m $s^{-1}$ sustained and gusting >18 m $s^{-1}$) that could damage the sensor package if the balloon does not achieve enough vertical lift due to the strong crosswind. Radiosondes are lifted using 350g balloons with an average ascent rate target of 5.5 $ms^{-1}$.). Radiosonde data from the campaign are available through the ARM Data Center (Atmospheric Radiation Measurement program, 2013a).

We project that measurements obtained during POPEYE will be used for a variety of purposes. Specifically, these measurements will support the development of process and case studies within the DOE Atmospheric System Research (ASR) community related to understanding boundary-layer structure, cloud phase, cloud formation and lifetime, and aerosol processes. This includes the development of routine and individual model studies on these topics. For example, recent discussions about the potential for extending the current LASSO workflow to arctic ARM sites could benefit from POPEYE measurements. The POPEYE period provides a nice three-month test period for evaluating an arctic LASSO project, should such a project be desired at the coastal observatories, with the additional measurements serving as a source of information for model evaluation and the development of initial and boundary conditions. Additionally, these measurements should be used to evaluate retrieval products being developed using ARM instruments (e.g., the AERIoe value-added product).

In conclusion, POPEYE provides an opportunity to contribute to, and leverage, a wide-reaching international coordinated effort to improve understanding of arctic weather and climate. Such opportunities are rare due to the tremendous amount of support required to coordinate measurements across the vast, international, arctic region. DOE has made a unique contribution through the enhancement of its routine operational measurement framework at Oliktok Point, increasing the utility and visibility of the data set collected using the AMF3 to provide critically needed insight into the weather and climate of arctic Alaska.

# 2.0 Notable Events or Highlights

The suggested sampling pattern was followed with some success. Unfortunately, local electromagnetic interference resulted in challenges with command and control of the DataHawk2 during the second half of the campaign. This resulted in the grounding of this platform after 7 August (see Figure 3). Additionally, the frequency of successful three-per-day radiosonde launches decreased substantially during the second half of the campaign. It is difficult to tell whether this was the result of deteriorating weather conditions over this time window or other causes. TBS operations were generally successful, with numerous flights during each two-week operational window for that platform.

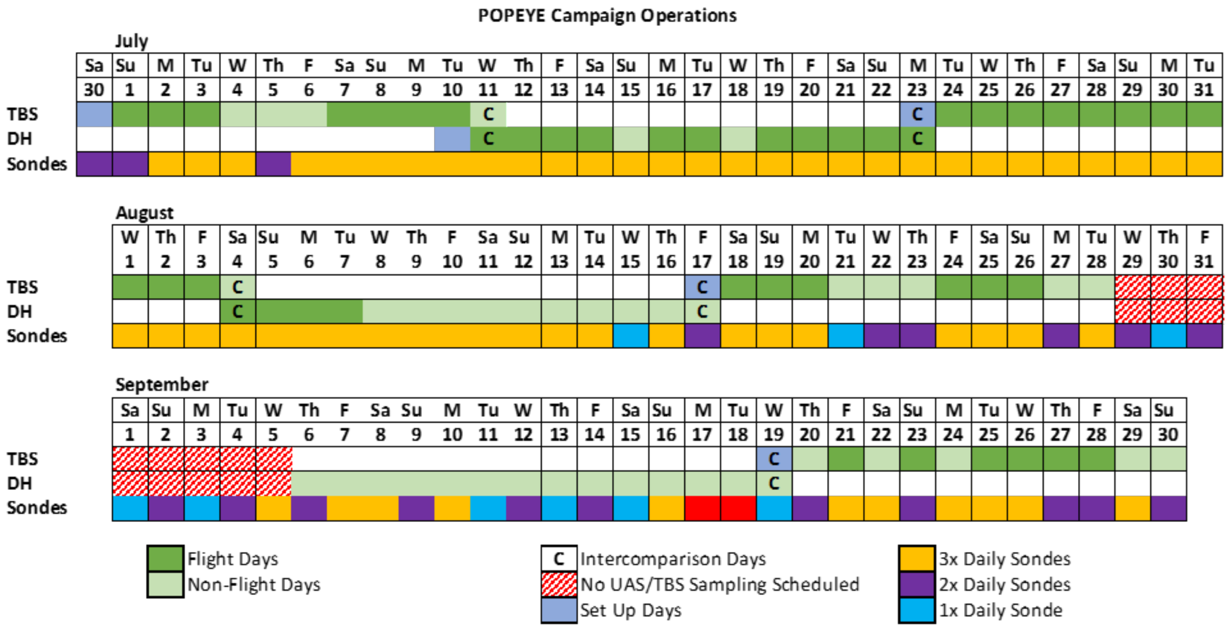

**Figure 3**. Graphical representation of actual UAS, TBS, and radiosonde operations during POPEYE.

Figure 4 shows measurements from the AMF3 surface meteorological instrumentation (Atmospheric Radiation Measurement Program, 2013a) over the three-month POPEYE period. Synoptically, this period featured several driving features. For much of the campaign, there was a stationary area of high pressure positioned over the Gulf of Alaska, and Oliktok Point sat on the gradient between this area of high pressure and transient low-pressure systems moving through the Chukchi and Beaufort Seas. This generally resulted in west-northwesterly winds during this period. Some of these cyclones passed closer to shore, thereby directly impacting the Oliktok Point area and creating precipitation events and shifting wind regimes (e.g., July 7–10; August 13; August 16–17; August 29–31). In late August there was a general shift in the pattern with high pressure beginning to set up over northern Alaska and eventually over the Beaufort Sea to the north. This caused a general shift towards easterly winds at the surface. The end of the POPEYE campaign featured a dominant area of high pressure over the area, resulting in weak easterly winds.

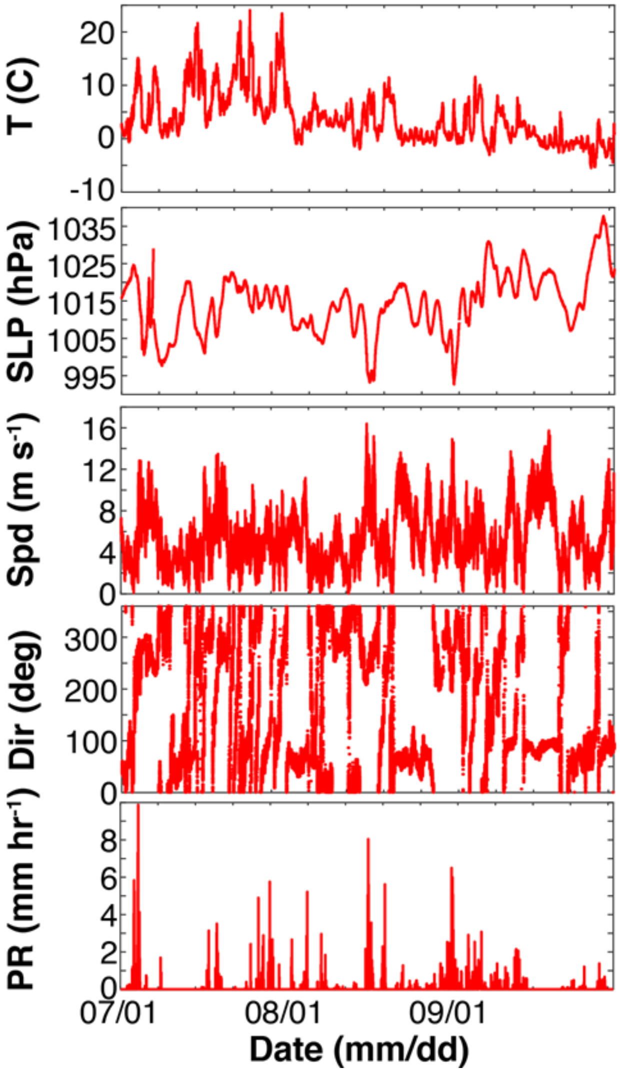

**Figure 4**. Surface meteorological conditions, as measured by instrumentation associated with the Oliktok Point AMF3 during POPEYE. From top to bottom are: 2-meter air temperature, sea level pressure, 10-meter wind speed, 10-meter wind direction, and surface precipitation rate.

Considering the vertical structure of the lower atmosphere, the observations included measurements from a variety of stability regimes. While the presence of the sun in summer months generally results in more adiabatic lower atmospheric states than during other times of year in the Arctic, the data collected indicates sampling of both well-mixed and stratified conditions. This includes several stable boundary-layer cases. Additionally, many of the completed flights were flown with some level of cloud cover in place. While the UAS did not sample through the cloud, the TBS was able to do so, providing insight into the thermodynamic and microphysical structure in and around these clouds. Based on ceilometer data from the AMF3 (Atmospheric Radiation Measurement Program, 2013b), a cloud base was detected during 76% of the campaign period. Of the times when clouds were detected, 73% of the cloud bases occurred below 1 km altitude, 21% occurred between 1-4 km altitude, and 6% were found above 4 km.

In general, it is relevant and important to note that to some extent all of the POPEYE platforms were weather-limited in terms of their operations. Therefore, there is an element of selective sampling to consider when using the collected data sets. Most directly, the TBS and UAS systems were generally not operated during high winds. The UAS additionally had limitations related to visibility. The radiosondes were least impacted, though high winds did also prevent some launches.

# 3.0 Results

The data files from POPEYE observations are available for public download through the ARM facility Data Center (http://www.archive.arm.gov/discovery/). The data are posted as individual datastreams, with each instrument possibly having several different levels of data available. The primary data set DOIs are 10.5439/1418259 (DataHawk2 measurements; Atmospheric Radiation Measurement Program, 2016), 10.5439/1426242 (TBS measurements; Atmospheric Radiation Measurement Program, 2017), and 10.5439/1021460 (radiosonde measurements; Atmospheric Radiation Measurement Program, 2013c).

The main TBS datastream for measurements from the iMet instruments and basic information on aerosol instrumentation is *olitbsimetM1.a1* (DOI: 10.5439/1246367). ARM is currently working to produce a quality-controlled b1 product. Data from the DTS system has been collected by the ARM Data Management Facility (DMF), and can be requested by email to armarchive@ornl.gov, with the appropriate DTS datastreams for POPEYE being *tbsdtssxforjch1*, *tbsdtssxforjch2, tbsdtssxch1*, *tbsdtssxch2*. SLW sensor data is available through the ARM Data Center under the *tbsslwc.b0* datastream, while the TBS aerosol instrumentation can also be downloaded through the Data Center as *tbscpcM1.00*, *tbspopdryM1.00*, *tbspopwetM1.00*. All of these data sets are currently provided at 1 Hz. TBS ground station data, including temperature, humidity, pressure, and winds at the surface, are available as b-level files at the Data Center under the file prefix “olitbsgroundM1” as 10-minute average values.

Quality-controlled DataHawk2 data can be downloaded as *oliaafdatahawkmetU1.b1* (DOI: 10.5439/1426242). Finally, the POPEYE radiosonde data set is available as a quality-controlled b1 data set, with filenames of the general form olisondewnpnM1.b1 (DOI: 10.5439/1021460), where wnpn” refers to the mode of the sonde data collection. Here, “w”=winds, “p”=PTU (pressure, temperature, humidity), and “n”=nominal indicates a normal flight with data collection during ascent only.

These data sets nicely support a variety of future research efforts. Specific examples of planned activities include use of the TBS measurements in conjunction with other AMF3 datastreams to understand the vertical stratification of aerosol properties in the Arctic, use of the data from stable regimes to conduct detailed studies of the stable boundary layer, use of all of the POPEYE data to guide and evaluate SCM simulations of specific phenomena of interest, and model evaluation studies across a variety of different modeling scales.

# 4.0 Public Outreach

To raise awareness of the POPEYE campaign and the availability of measurements, the team has presented the initial results of the campaign to a variety of interest groups. These include the Interagency Arctic Research Policy Committee (IARPC) Atmosphere Collaboration Team and the YOPP community and the greater arctic and atmospheric science communities through presentations at the American Geophysical Union Fall meeting (2018) and the ARM/ASR Principal Investigator Meeting (2018). These presentations, along with a submitted data publication to *Earth System Science Data* (ESSD), are listed below.

# 5.0 POPEYE Publications

## 5.1 Journal Articles/Manuscripts

de Boer, G, D Dexheimer, F Mei, J Hubbe, C Longbottom, PJ Carrol, M Apple, L Goldberger, D Oaks, J Lapierre, M Crume, N Bernard, MD Shupe, A Solomon, J Intrieri, D Lawrence, A Doddi, DJ Holdridge, MD Ivey, B Schmid, and M Hubbell. 2019. "Atmospheric observations made at Oliktok Point, Alaska as part of the Profiling at Oliktok Point to Enhance YOPP Experiments (POPEYE) campaign." *Earth System Science Data*, discussion paper, doi:10.5194/essd-2019-46

## 5.2 Meeting Abstracts/Presentations/Posters

de Boer, G, D Dexheimer, F Mei, J Hubbe, C Longbottom, PJ Carrol, M Apple, L Goldberger, D Oaks, J Lapierre, M Crume, N Bernard, MD Shupe, A Solomon, J Intrieri, D Lawrence, DJ Holdridge, MD Ivey, and B Schmid. 2019. "Profiling at Oliktok Point to Enhance YOPP Experiments (POPEYE) campaign overview." Atmospheric Radiation Measurement/Atmospheric System Research meeting, 10–14 June 2019, Bethesda, Maryland.

de Boer, G, D Dexheimer, F Mei, J Hubbe, C Longbottom, PJ Carrol, M Apple, L Goldberger, D Oaks, J Lapierre, M Crume, N Bernard, MD Shupe, A Solomon, J Intrieri, D Lawrence, DJ Holdridge, MD Ivey, and B Schmid. 2019. "Profiling at Oliktok Point to Enhance YOPP Experiments (POPEYE)." Year of Polar Prediction Arctic Science Workshop, 15 January 2019, Helsinki, Finland.

de Boer, G. 2018. "High-latitude unmanned aircraft operations: An introduction to recent and upcoming field campaigns." Fall Meeting of the American Geophysical Union, 12 December 2018, Washington, D.C.

de Boer, G, D Dexheimer, F Mei, J. Hubbe, C Longbottom, PJ Carrol, M Apple, L Goldberger, D Oaks, J Lapierre, M Crume, N Bernard, MD Shupe, A Solomon, J Intrieri, D Lawrence, DJ Holdridge, MD Ivey, and B Schmid. 2018. "Profiling at Oliktok Point to Enhance YOPP Experiments (POPEYE)." Interagency Arctic Research Policy Committee (IARPC) Atmosphere Collaboration Team Meeting, 30 October 2018, Online.

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Atmospheric Radiation Measurement (ARM) user facility. 2013b. Updated hourly. Ceilometer (CEIL). 2018-07-01 to 2018-10-01, ARM Mobile Facility (OLI) Oliktok Point, Alaska; AMF3 (M1). Compiled by B. Ermold and V. Morris. ARM Data Center. Data set accessed 2018-11-08 at https://www.archive.arm.gov/discovery/#v/results/s/fdsc::ceil

Atmospheric Radiation Measurement (ARM) user facility. 2013c. Updated hourly. Balloon-Borne Sounding System (SONDEWNPN). 2018-07-01 to 2018-10-01, ARM Mobile Facility (OLI) Oliktok Point, Alaska; AMF3 (M1). Compiled by D. Holdridge, J. Kyrouac and R. Coulter. ARM Data Center. Data set accessed 2018-11-08 at https://www.archive.arm.gov/discovery/#v/results/s/fdsc::sondewnpn

Atmospheric Radiation Measurement (ARM) user facility. 2017. Updated hourly. Tethered Balloon System (TBSIMET). 2017-04-09 to 2018-09-28, ARM Mobile Facility (OLI) Oliktok Point, Alaska; AMF3 (M1). Compiled by D. Dexheimer and Y. Shi. ARM Data Center. Data set accessed 2019-03-11 at https://www.archive.arm.gov/discovery/#v/results/s/s::tbsimet

Atmospheric Radiation Measurement (ARM) user facility. 2016. Updated hourly. Meteorological Instrumentation aboard Aircraft (AAFDATAHAWKMET). 2016-06-06 to 2018-08-07, ARM Mobile Facility (OLI) DataHawk Unmanned Aerial System (U1). Compiled by F. Mei and J. Hubbe. ARM Data Center. Data set accessed 2019-03-11 at https://www.archive.arm.gov/discovery/#v/results/s/fdsc::aafdatahawkmet

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