Airborne DWL in Polar Winds: Greenland and Iceland Campaigns

G. D. Emmitt[a], Steven Greco[a], Kevin Godwin[a], Michael Kavaya[b], Grady Koch[b] and Upendra Singh[b]

a – Simpson Weather Associates, 809 East Jefferson St., Charlottesville, VA 22902
b – NASA Langley Research Center, Langley, VA, 23681
gde@swa.com

During 2014 and 2015, NASA funded an airborne expedition to the Arctic called Polar Winds in order to conduct experiments focused on documenting the low level wind circulations around Greenland and validating numerical models and reanalyzes, particularly in the boundary layer transition zones between land, water and ice. The NASA/LaRC DAWN coherent 2 micron lidar was flown on the LaRC UC-12B aircraft in November, 2014 and on the NASA DC-8 in May 2015. More than 100 hours of lidar data were obtained during the two campaigns along with ~100 dropsondes launched during the May 2015 campaign. These data are being used in several studies including the perfunctory lidar dropsonde comparisons, pointing error corrections and aircraft motion projection removal. This paper will report on both the instrument related performance as well as a case study of Barrier winds off the east coast of Greenland.

Keywords: airborne Doppler wind lidar, DAWN, boundary layer

1. Introduction

During Oct-Nov 2014 and May 2015, NASA sponsored two airborne missions designed to fly the Doppler Aerosol WiNd (DAWN) and TWiLiTE lidars to take wind measurements of the Arctic atmosphere, specifically over and off the coasts of Greenland. Polar Winds Campaign I was based in Kangerlussuaq, Greenland while Polar Winds Campaign II was based in Keflavik, Iceland. This presentation will only cover the DAWN contributions to Polar Winds.

The campaigns were designed to study and document lower level atmospheric circulations and to provide validation for the numerical models and reanalyses used over the polar/arctic regions. Another goal of both campaigns was to practice underflying and validating measurements from existing satellites and sensors such as CALIPSO, MODIS (AQUA and TERRA), ASCAT (METOP-A/B) and others. In addition, much of Campaign II was planned in collaboration with ESA and DLR of Germany to conduct coordinated (with the DLR Falcon) underflights of a simulated Aeolus ADM (due to be launched in 2017) while using ADM scanning strategies and taking measurements (lidar and dropsondes) that would benefit future development.

2. DAWN

The DAWN lidar developed by NASA Langley was selected for both campaigns. DAWN, which was also previously flown on the NASA DC-8 during the 2010 Genesis and Rapid Intensification Processes (GRIP) [1], is designed to be the most powerful coherent Doppler wind lidar available today for airborne missions. A summary of the DAWN system compared to two other airborne coherent DWLs is provided in Table 1. During Campaign I, DAWN was flown on board the NASA King Air UC-12B aircraft, but was later transferred to the NASA DC-8 for the Campaign II missions.

Table 1: Specifications of DAWN

Parameter	DAWN	TODWL	P3DWL	Comments
Wavelength (microns)	2.05	2.05	1.67	Eyesafe
Energy per pulse (mJ)	250	1	2	
Pulse rate(Hz)	10	500	500	
Pulse length(m)	~37	90	90	Range resolution
Telescope diameter(m)	.15	.10	.10	
Detection type	Coherent	Coherent	Coherent	~ .05 m/s LOS precision
Weight(kg)	Varies	300	275	
Power(watts)	Varies	900	550	

Note: TODWL: Twin Otter Doppler Wind Lidar owned by Center for Interdisciplinary Remotely Piloted Aircraft Studies in Monterey, CA. P3DWL: P3 Doppler Wind Lidar owned by US Army and flown on NOAA's P3 hurricane reconnaissance aircraft.

In addition to DAWN, we also utilized the dropsonde delivery system developed by Yankee Environmental Services to drop over 100 dropsondes during Campaign II in an attempt to obtain additional high-resolution vertical wind profiles during most missions. These dropsondes would also provide wind sounding comparisons for DAWN and for validation of numerical models.

2.1 Data Processing

We continue to develop and modify algorithms to improve the processing of the DAWN raw lidar data. We are specifically focusing on algorithms that account for the projected component of the aircraft's motion as well as algorithms that provide higher sensitivity in the presence of weaker aerosols which often occurs in the arctic regions near Greenland. These algorithms still require some fine tuning but have already lead to more complete wind profiles in the vertical.

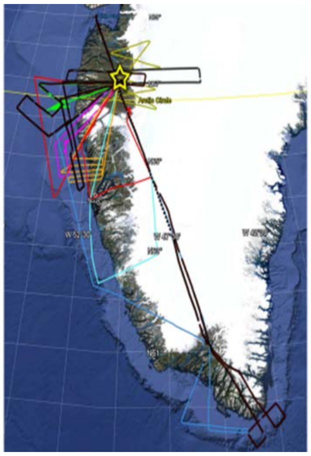
2.2 Instrument Related Performance

Although DAWN operated near the designed optical output (2.5W), there were losses associated with optical elements, alignment and other efficiencies. In spite of these losses in performance, soundings were obtained with sufficient coverage to meet the primary Polar Winds mission objective of numerical model validation.

3. *Science Objectives and Missions*

The airborne missions of the Polar Winds campaigns were designed in part to investigate the low-level and near surface winds over and off the coast of Greenland and between the open water between Greenland and Iceland. During Polar Winds Campaigns I and II, a total of 24 missions and ~ 100 flight hour was flown (Figure 1) with individual missions or parts of missions focusing on the measurement and analyses of lower tropospheric winds

Every mission was seen as a model validation experiment. The data base of 3-D wind, temperature and moisture information from DAWN and the dropsondes is being used for validation polar models and re-analyses, including the Polar WRF model run specifically for the campaign.



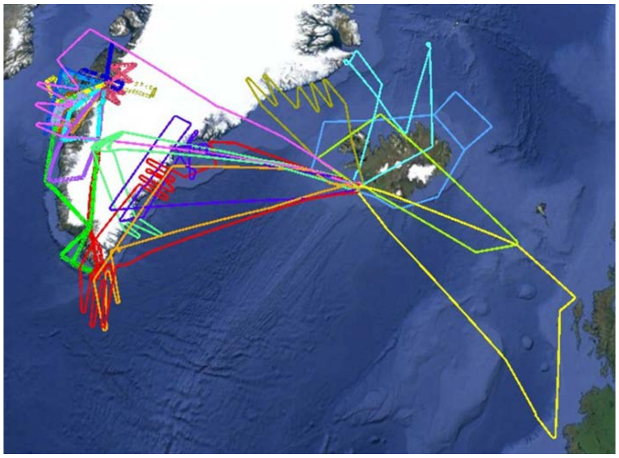


Figure 1: Composite of flight tracks of missions flown during Polar Winds Campaign I (left) and II (right).

4. Analysis and Comparisons

Although the final DAWN data set has yet to be released, we are confident enough with the existing near-final version to make comparisons with both the dropsondes dropsonde vs lidar comparisons

4.1 Comparison with Dropsondes

During Campaign II, the DC-8 and the DLR Falcon flew a coordinated flight with the DC-8 flying underneath the Falcon as both targeted the strong upper jet over the Atlantic between Iceland and Ireland. During this mission, 11 dropsondes were dropped over the Atlantic and as DAWN was in full operation. Although there were not many DAWN returns in the middle troposphere (very clean), there were strong returns in the upper and lower atmosphere. An example of dropsonde and DAWN wind profiles are provided for a mission called “The Barrier Winds”.

4.2 Barrier Winds Case Study

The region off the southern and central eastern coast of Greenland is an area noted for strong low-level Barrier winds as strong low pressure systems move eastward towards and past Iceland and the northerly/northeasterly flow is blocked and channeled by the Greenland land mass resulting in strong low level winds. May 21, 2015 was a prime example of this scenario as forecasted by the models, including the Polar WRF. A mission was flown to gather high-resolution DAWN and dropsonde wind data for this case and to compare against each other and the operational Polar WRF model [2]. The satellite image and flight track/drop location is shown in Figure 2.

Wind speed and wind direction comparisons made between the model and observed data for the May 21 case are shown (Figure 3).Between 2020 and 2100, the DC-8 was flown around 2.5 km and enabled total DAWN coverage of the boundary layer and down to the surface.

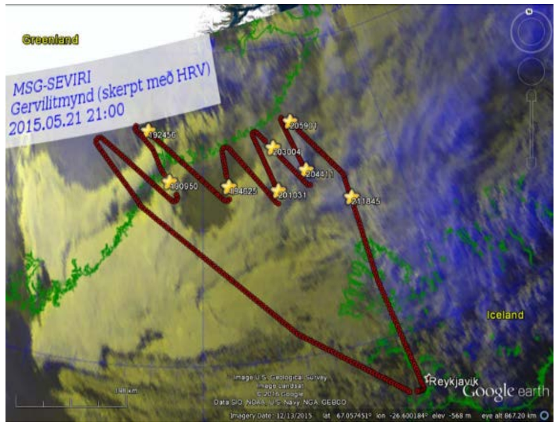


Figure 2: Satellite image on 5/21/15 21Z and location/time of flight track and drop location.

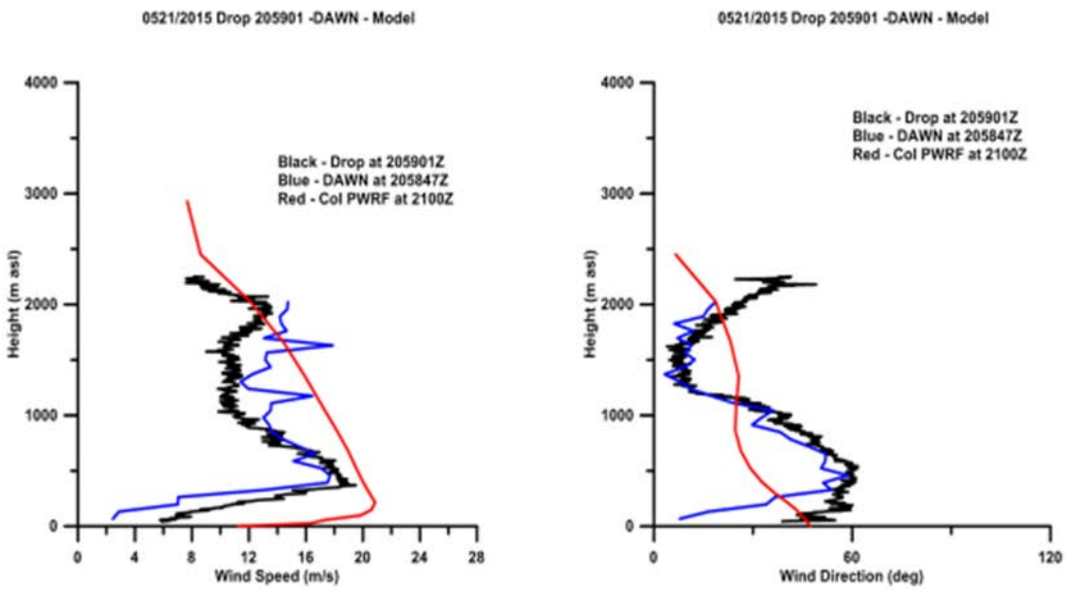


Figure 3. Wind speed and direction profiles for dropsonde (black), DAWN (blue) and Colorado Polar WRF (red) forecasts centered on the time and location of the 205901Z drop on 05/21/2015.

5. References

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[2] Bromwich, D. H., K. M. Hines, and L.-S. Bai, 2009, "Development and testing of Polar WRF: 2. Arctic Ocean", *J. Geophys. Res.*, 114, D08122, doi: 10.1029/2008JD010300