SWEX_TODWL_WIND_PROFILES_PRELIMINARY_V01_README

1. Data Set Description

A) Dataset Name: SWEX_TODWL_WIND_PROFILES_PRELIMINARY_V01
B) Simpson Weather Associates (SWA) Authors:

Table 1: SWA authors of SWEX data set

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C) Introduction/Abstract

The Sundowner Wind EXperiment (SWEX) was an NSF funded field campaign that took place during 1 April 2022 – 15 May 2022 and included airborne missions based out of Oxnard, CA. Supplemental funding was also provided by the ONR for additional flight hours. The purpose of SWEX was to study the complex interactions of the atmosphere and the surface in a coastal area impacted by affected by “Sundowner Wildfires”. The field campaign was designed to measure atmospheric variables, including winds, from the air and the ground in an area centered on Santa Barbara. As part of SWEX, dropsondes and the Twin Otter Doppler Wind Lidar (TOWDL) were flown on board a CIRPAS NPS Twin Otter aircraft to measure vertical profiles of the horizontal wind during 16 flight days and 27 missions. The TODWL wind profiles were often obtained with a horizontal resolution of 2-4 km and a vertical resolution of 90 m interpolated to 20m for graphical display.

D) Data Version: V01
E) Data Status: Preliminary
F) Dataset Time Period: April 1 – May 11, 2022
G) Physical Location: Aircraft campaign based out of Oxnard, CA
Data Bounded By:
SW Corner: 33.75 deg N, -120.50 deg W
NW Corner: 35.00 deg N, -120.50 deg W
NE Corner: 35.00 deg N, -119.00 deg W

SE Corner: 33.75 deg N, -119.00 deg W

H) Data Frequency: Wind profiles provided every 40-50 seconds
I) Data Source: NA
J) Web addresses: http://catalog.eol.ucar.edu/swex
https://www.eol.ucar.edu/field_projects/swex
www.swa.com
K) Dataset Restrictions: None

2. Instrument Description

The TODWL shown on board a Twin Otter aircraft (Figure 1) is a 2 micron coherent laser system built by Coherent Technologies, Inc. Table 2 summarizes many of the technical details of the lidar. A defining capability of the TODWL is the ability to profile above and below the flight level. This is possible because the lidar includes a bi-axis scanner mounted on the side door of the aircraft that allows vertical soundings of the wind profile above and below the aircraft as well as taking data with fixed horizontal or vertical perspectives. With this side door mounted, bi-axis scanner (Figure 2) the beam can be adaptively directed in flight in a variety of scan patterns including conical, nadir stares and flight level stares.

Figure 1: TODWL on board a Twin Otter aircraft

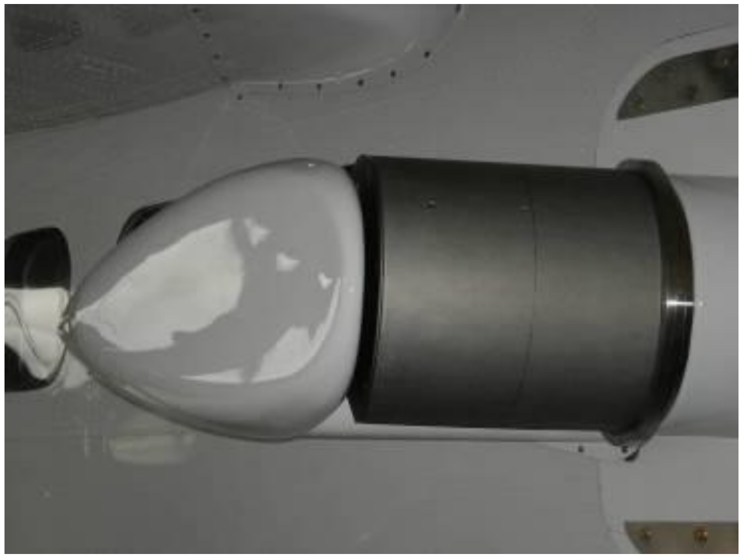

Figure 2: Close-up of TODWL scanner on board a Twin Otter aircraft

Table 2: Description of TODWL scanner and TODWL measurements

Wavelength (microns)	2.05 (eyesafe)
Energy per pulse (mJ)	2 mj
Pulse repetition frequency (Hz)	500 (decimated to 166Hz to reduce data volume)
Pulse length (m)	90
Scanner (side door mounted)	2 axis (+- 120; +- 30)
Telescope diameter (cm)	10
Range resolution (meters)	50-100
Total System Efficiency (%)	7-10
Power (KW)	1.5
Weight (lbs.)	750 including door mounted scanner
LOS measurement accuracy (m/s)	< .05 with .5 sec integration
Wind component accuracy (m/s)	u,v,w < .1 m/s nominal using a 30 degree VAD
Aerosol backscatter threshold sensitivity	Range dependent: ~ 10 -08 m sr-1 at 10km
Nominal range to insensitivity (km)	Aerosol dependent: nominal 15-20 km in PBL and 2-5 km above PBL.

3. Data Collection and Processing

3.1 Description of data collection

During typical operations, the scanning TODWL aboard the Twin Otter takes individual Line-Of-Sight (LOS) measurements in 12 different azimuth angles, or “looks”, separated by 30 degrees. The usual nadir angle for TODWL operations is between 20 and 30 degrees depending upon the science objectives. The common operation was to take a scan which included 2 seconds of staring with 386 laser shots for each look separated by a 1 second repositioning between each look and a 5 second dwell looking straight down at the end of look 12 before proceeding to the next scan. Overall, it took ~ 42 seconds to for each scan and approximately 3-4 km of aircraft travel depending upon the head/tail wind.

3.1.1 TODWL scanning configuration unique to the SWEX campaign

During preparation for the SWEX campaign, the TODWL system experienced a hardware failure that could not be repaired before deployment. A “workaround” hardware fix was developed that required a fixed offset frequency related to the aircraft ground speed and a nadir angle of 15 degrees rather than the usual 30 degree angle. Consequently, the projection of the horizontal wind component on the TODWL LOS was reduced, necessitating an increase in the dwell time from the usual 1 second to 2 seconds to reduce sampling errors.

The accuracy of the atmospheric wind component retrievals depends primarily upon the accuracy of accounting for aircraft motion and attitude (roll, pitch, and yaw). The hardware failure was in the lidar component that removes the aircraft speed from the signal detection and digitization prior to recording the raw data. Since that function was lost, the wind retrievals became extremely sensitive to the aircraft speed (ground speed) when the scanner was pointed towards the direction of motion. While data was collected for all 12 “look” angles, it was determined during the post campaign data processing that the default option would be the elimination of 4 of the look angles in the direction of motion before sine fitting. The calibration using ground returns has confirmed that the use of 8 looks rather than 12 has not compromised the accuracy of the wind retrievals. The use of 12 looks has been the preferred sampling strategy when flying in partly cloudy scenes. Nearly all SWEX flights were in cloud free conditions.

3.2 Description of derived parameters and processing techniques

For each two second look, the spectral signal of the backscattered lidar illumination is integrated over all shots. The peak of the integrated spectral intensity of the lidar signal is used to calculate a Signal-to-Noise Ratio (SNR) and, together with using all aircraft motion and attitude information, the LOS velocity along each LOS. The LOS velocities are binned by distances along the LOS called range gates (nominal 50m resolution). The 12 LOS velocities were then fitted to a sine wave to obtain the horizontal wind (u, v, wind speed and wind direction) for that scan for each range gate along the LOS and, using the geometry of the laser sampling and the aircraft motion/attitude. This value was then interpolated to 20 m levels to give vertical profiles of the horizontal wind between the aircraft and the ground. In addition to the wind and SNR parameters, we also calculate a Goodness of Fit (GOF) index at each level which is a measure of how well the data from the 12 looks fit the sine wave. The GOF is an indicator of wind variability over the measurement area. A GOF threshold was selected which eliminated profiles with too much variability in the 12 looks (due to the complex terrain or clouds or lack of aerosols).

The resulting profiles are also referred to as a VAD (Volume Azimuth Display). Within the up to 5 minute data files mentioned in section 3.1, there may be up to 7 VADs or profiles.

3.3 Description of quality assurance

This version is only a preliminary version of the data set and though major strides have been made in accounting for the pointing of the laser beam over complex terrain, work still needs to be done and the user should take care in utilizing the measurements in the bottom 3-400 m over land.

3.4 Data intercomparisons

Comparisons of the wind speed and wind direction from the TODWL with those computed from the NCAR AVAPS dropsondes that were launched at the same time are shown in Figures 3 (over land) and 4 (over water). It should be noted that while the dropsonde provides a point measurement at each level, the TODWL wind measurements for each level utilizes 12 separate looks that are scanning in all different directions. This is illustrated in Figure 5 and, as shown in Figures 3 and 4, differences are to be expected especially at lower levels in complex terrain.

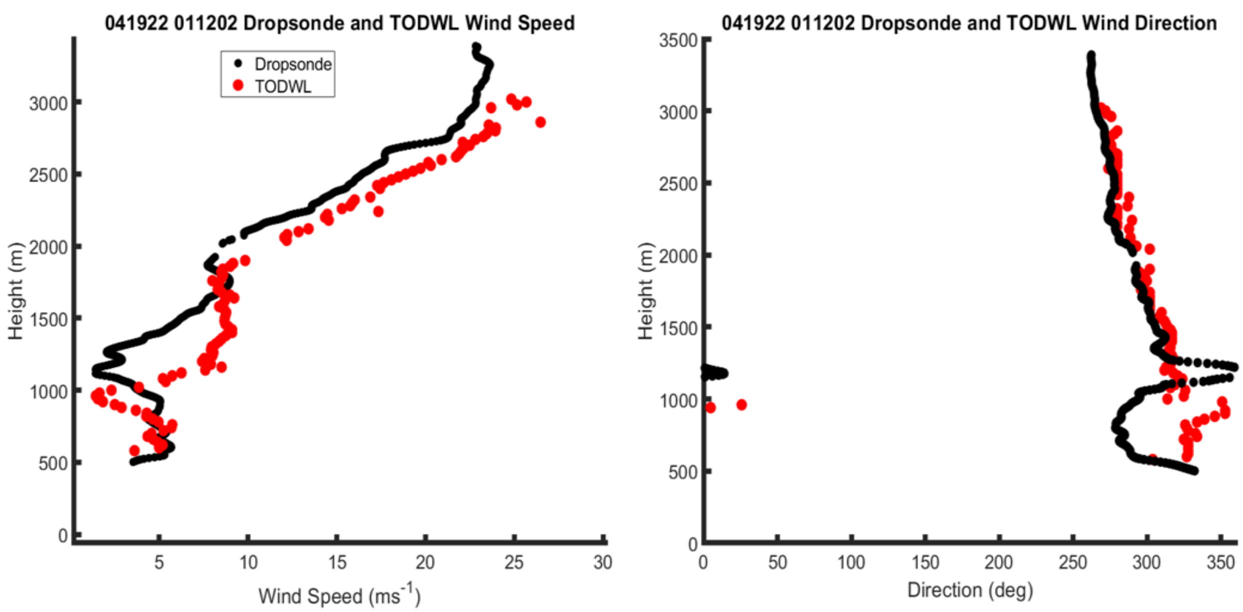

Figure 3: Example of a comparison of wind speed and wind direction taken by TODWL and coincident dropsondes launched from the Twin Otter aircraft over land.

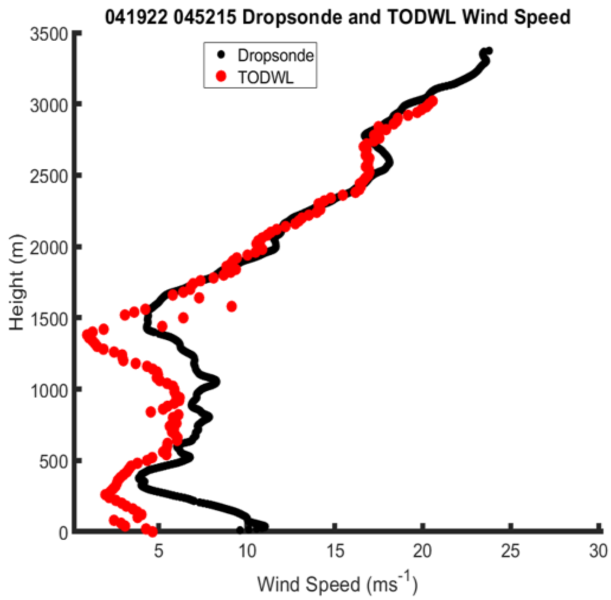

Figure 4: Example of a comparison of wind speed and wind direction taken by TODWL and coincident dropsondes launched from the Twin Otter aircraft over water.

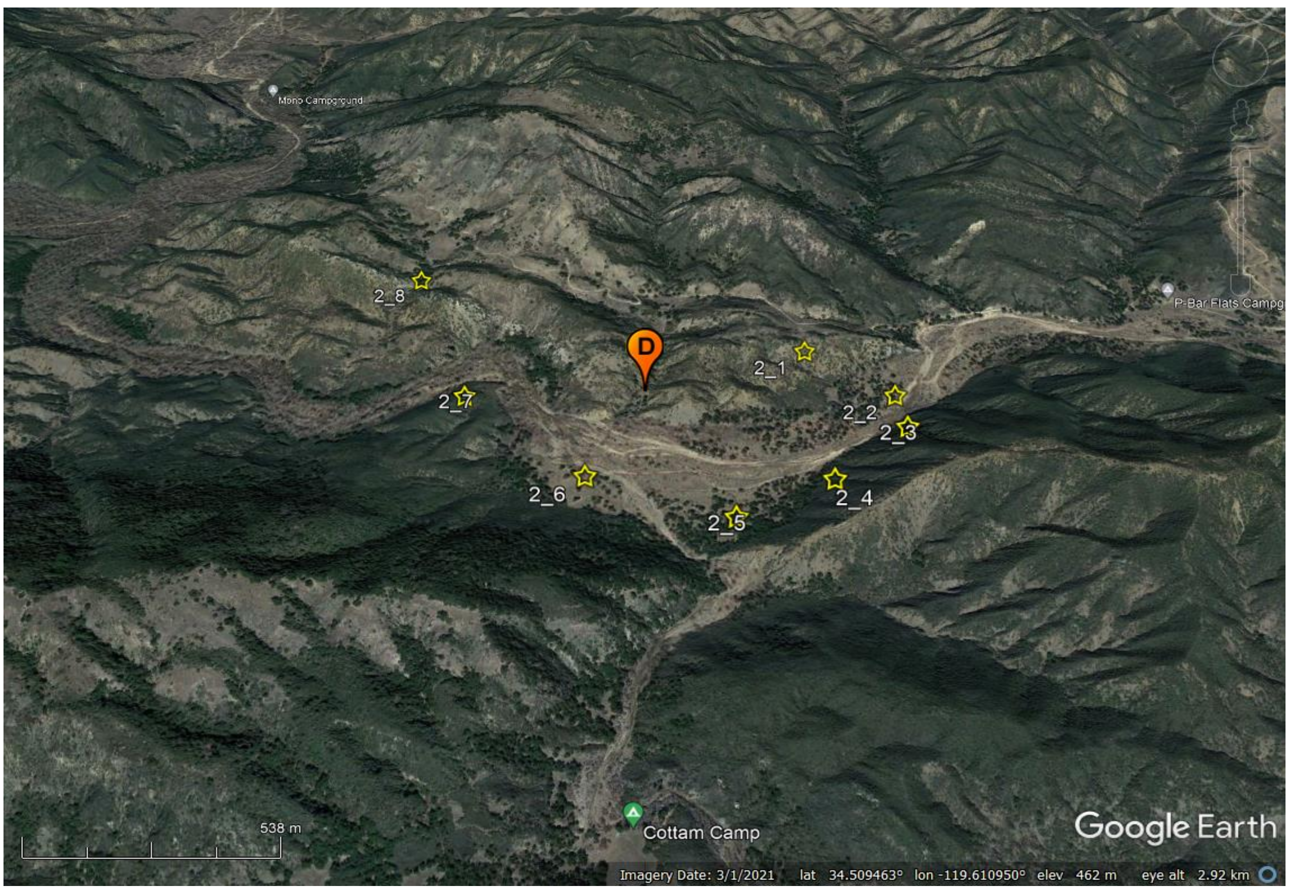

Figure 5: Example of the location of a Dropsonde measurement and those of the 8 looks used to calculate the wind measurement on the TODWL profile during SWEX.

4. Data Format

During the data recording or collection, computer memory limited us to recording the data in no larger than 5 minute files with no gaps between files.

4.1 File structure and naming convention

SWEX_TODWL_MMDDYY_HHMMSS_WIND_PRELIMINARY_V01.dat

Example: SWEX_TODWL_041922_154328_WIND
MMDDYY = 041922
HHMMSS = 154328 (Time in UTC)

4.2 Format and layout

File Header: Number of VADS (nvads), Number of Levels (numlvl) in each VAD (i.e., 186)

‘NVADS:’, nvads, ‘NUMLVL’, numlvl

For Each VAD

VAD Header: VAD (profile) number, latitude, longitude, aircraft height, ground speed components (u, v, w), ground track, heading, yaw roll, pitch

‘VAD:’, vadnum, ‘LAT:, lat, ‘LON:’, lon, aircraft_height, groundspeed_u, groundspeed_v, groundspeed_w, groundtrack, heading, yaw, pitch, roll

For Each Level (i.e., 1 to 186)

VAD Data: height, wdir1, wspd1, wdir2, wspd2, GOF1, offset1, GOF2, offset2, SNR, rms1, rms2, width, latitude, longitude

Two different sine fits were used for comparison purposes but the best one to use is #1 (wdir1, wspd1,GOF1).

4.3 List of parameters (units) – BOLDED are the ones to utilize

height = height (m aMSL)
wspd1= wind speed (m/s)
wdir1= wind direction (degrees)
wspd2= wind speed (m/s)
wdir2= wind direction (degrees)
gof1= goodness of fit1 (no units)
offset1 = offset (no units)
gof 2= goodness of fit1 (no units)
offset2 = offset (no units)
SNR= Signal to Noise Ratio (dbs)
rms1 = root mean square difference of the winds and the fit (no units)
rms2 = root mean square difference of the winds and the fit (no units)
width = mean peak width
lat= latitude (deg)
lon= longitude (deg)

4.4 Time

The date and time at the beginning of each data file is given in the file name with time in the form of HHMMSS (UTC). That will be the time for the first VAD of the data file

Future versions of the data will provide separate files for each individual VAD and include a specific time.

4.5 Missing/Bad data

The data has already been filtered to account for poor GOF to the sine curve. Data not passing the GOF test are given as -99.99.

In addition, due to saturation of the laser signal right out of the aircraft, measurements are not possible in the first 300 m below the aircraft altitude and are also given as -99.99 Similarly, data is reported at range gates below the surface to ~ -200m to confirm that the max signal was assigned to the correct latitude (m aMSL). These trailing levels are also filled with -99.99.

Processing algorithms for the SWEX TODWL data are still evolving due to the issues noted in section 5. As a result, there are still problems with occasional profiles (VADs). On occasion, the recorded data of the first (last—usually 5, 6 or 7)) VAD of a 5 minute file contains information when the aircraft is in the preceding (or following) turn that can corrupt the computed VAD (profile). These questionable/unreliable profiles are listed in Table 3.

Table 3: List of questionable processed SWEX profiles (VADs).

Date	File Name	VAD Number
041722	SWEX_TODWL_041722__202556_WIND_PRELIMINARY_V01.dat	3
041822	SWEX_TODWL_041822__213512_WIND_PRELIMINARY_V01.dat	4
	SWEX_TODWL_041822__003128_WIND_PRELIMINARY_V01.dat	1
	SWEX_TODWL_041822__003731_WIND_PRELIMINARY_V01.dat	2
	SWEX_TODWL_041822__005022_WIND_PRELIMINARY_V01.dat	3
	SWEX_TODWL_041822__005522_WIND_PRELIMINARY_V01.dat	2
	SWEX_TODWL_041822__010339_WIND_PRELIMINARY_V01.dat	2
	SWEX_TODWL_041822__011939_WIND_PRELIMINARY_V01.dat	3
	SWEX_TODWL_041822__013434_WIND_PRELIMINARY_V01.dat	4,6
	SWEX_TODWL_041822__020509_WIND_PRELIMINARY_V01.dat	1
	SWEX_TODWL_041822__020937_WIND_PRELIMINARY_V01.dat	6
	SWEX_TODWL_041822__025512_WIND_PRELIMINARY_V01.dat	5
	SWEX_TODWL_041822__030012_WIND_PRELIMINARY_V01.dat	3
	SWEX_TODWL_041822__030435_WIND_PRELIMINARY_V01.dat	6
	SWEX_TODWL_041822__031723_WIND_PRELIMINARY_V01.dat	1
	SWEX_TODWL_041822__033948_WIND_PRELIMINARY_V01.dat	1
	SWEX_TODWL_041822__192018_WIND_PRELIMINARY_V01.dat	1
	SWEX_TODWL_041822__200451_WIND_PRELIMINARY_V01.dat	1-7
	SWEX_TODWL_041822__200951_WIND_PRELIMINARY_V01.dat	4
	SWEX_TODWL_041822__202341_WIND_PRELIMINARY_V01.dat	1, 7
041922	SWEX_TODWL_041922__020058_WIND_PRELIMINARY_V01.dat	2,3,5
	SWEX_TODWL_041922__022627_WIND_PRELIMINARY_V01.dat	1
	SWEX_TODWL_041922__023127_WIND_PRELIMINARY_V01.dat	6
	SWEX_TODWL_041922__024119_WIND_PRELIMINARY_V01.dat	2,3,4
	SWEX_TODWL_041922__032206_WIND_PRELIMINARY_V01.dat	6
	SWEX_TODWL_041922__033648_WIND_PRELIMINARY_V01.dat	6
	SWEX_TODWL_041922__034148_WIND_PRELIMINARY_V01.dat	5

5. Data Remarks

5.1 PI's assessment of data

As has been stated since the beginning of the field campaign, the hardware issues we encountered on TODWL required scanning at shallow nadir angles (15 degrees rather than 30 degrees) which then required significant software workarounds to produce accurate wind profiles. For the most part, we have achieved particularly good profiles (ground speed checks and dropsonde comparisons) when the GPS/INS unit on the TODWL rack was working properly. Fortunately, we know when the GPS/INS information is wrong and have been turning to the Twin Otter GPS/INS for navigation data. By using the Twin Otter's GPS information, we expect to be able to achieve better than 90% research quality soundings.

From my point of view, there are two major cautions in using Airborne DWL observations in complex terrain and over the open water.

1. Combining multiple perspectives (e g 8 looks) at equal range gates (typical processing over water) can lead to plausible but inaccurate vector wind retrievals over complex terrain, especially within a few 100 meters of the surface. While SWA developed processing techniques that improve on these retrievals, I recommend that single Line of Sight (LOS) products be used along with a forward model when conducting numerical model experiments. This is also the case in making comparisons with dropsondes or ground based wind sounders.
2. Over water, the vector wind retrievals are less effected by wind observations from differing altitudes above the surface at differing perspectives. However, the near surface wind measurement is confounded by a spectral mixture of moving sea spray, water surface currents and foam patches. SWA is funded by ONR to develop processing strategies to discriminate on these factors. SWEX has provided an excellent set of data to develop these new algorithms. Once fully tested and validated, the SWEX "over water" soundings will be reprocessed and provided to the SWEX science team.

Based upon my personal involvement in developing and evaluating the SWEX workarounds, I am optimistic that the soundings will be extremely useful in advancing our understanding of the complex flow interactions in a coastal area. I recommend that a primary use of these soundings be numerical model (e.g., WRF) dependent studies. Comparisons with other sounders still require close interactions with the operators of those sounders. Investigations using flight segments designed to optimize retrievals from both the TODWL and the CRL should be very productive since this instrument combination has not been flown (to my knowledge) together on a slow flying platform such as the Twin Otter.

We continue to process and inspect individual TODWL soundings as well as evaluate the nadir stare segments that accompany each conical scan. While the lidar captures waves, upslope and down slope flows in detail, we expect that the most useful information will be generated when the TODWL and CRL data are combined with surface observations.

5.2 Missing data periods and data requests

This preliminary dataset only includes two full days (2 flight missions each) during SWEX: 0417-0418 EOP1 and 0418-0419 IOP4. The remainder of the missions will be populated in the coming months. However, if any SWEX science team member wants data for other missions, we will be happy to provide them. Please contact the authors as identified in section 1.

6. References

Thorpe, A.K., O'Handley, C., Emmitt, G.D., DeCola, P.L., Hopkins, F.M., Yadav, V., Guha, A., Newman, S., Herner, J.D., Falk, M., and Duren, R.M., 2021. Improved methane emission estimates using AVIRIS-NG and an Airborne Doppler Wind Lidar. *Remote Sensing of Environment*, *266*, p.112681.

Emmitt, G.D., C. O'Handley, S.A. Wood, S. Greco, R. Bluth, and H. Jonsson, 2005: TODWL: An airborne Doppler wind lidar for atmospheric research. Amer. Meteor. Soc. 85th Ann. Meeting, 2nd Symposium on Lidar Atmospheric Applications, San Diego, CA, January (http://www.swa.com/images/LidarAirborne/Emmitt_OHandley_Wood_Bluth_Jonsson_2005.pdf)

7. Keywords

Lidar, Twin Otter Doppler Wind Lidar, TODWL, SWEX, wind profiles, winds, wind speed, wind direction, aerosol, SNR, boundary layer