SWEX_TODWL_WIND_PROFILES_FINAL_V01_README

1. Data Set Description

A) Dataset Name:SWEX_TODWL_WIND_PROFILES_FINAL_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: Final

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

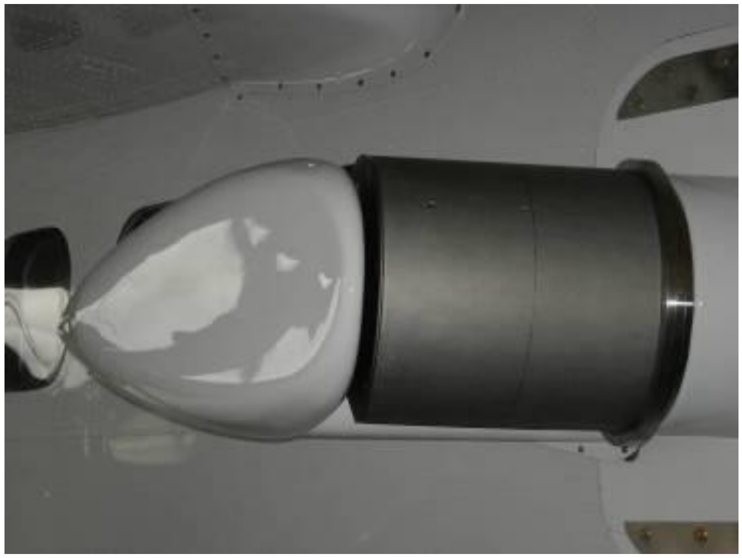

Figure 2: Close-up of TODWL scanner on board a Twin Otter aircraft

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. Nearly all SWEX flights were conducted in cloud free conditions.

3.2 Description of derived parameters and processing technique

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 air 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 8 looks fit the sine wave. The GOF is an indicator of wind variability over the measurement area. A GOF threshold of 3.0 was selected which eliminated profiles with too much variability in the 8 looks (due to the complex terrain or clouds or lack of aerosols). The used can select a more discriminating GOF if they wish for the generation profiles.

<u>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 8 VADs or profiles.</u>

Table 3: Catalogue of TODWL wind profiles collected and archived for SWEX.

SWEX Flight Missions	Twin Otter Flight	Dates and Times (UTC)	Number of Profiles Collected	Number of Good Profiles
IOP1 Afternoon	Flt2	4/4/22 2015-2255	188	183
IOP1 Evening	Flt3	4/5/22 0050-0400	223	196
IOP2 Evening	Flt4	4/6/22 0150-0350	41	34
IOP2 Night	Flt5	4/6/22 0615-0750	72	67
ONR1	Flt6	4/7/22 2010-2240	119	119
IOP3 Afternoon	Flt7	4/13/22 1950-2250	142	131
IOP3 Evening	Flt8	4/14/22 0025-0415	220	208
ONR2	Flt9	4/14/22 2000-2200	72	70
EOP1 Afternoon	Flt10	4/17/22 1940-2220	128	105
EOP1 Evening	Flt11	4/18/22 0025-0410	199	185
IOP4 Afternoon	Flt12	4/18/22 1935-2300	152	138
IOP4 Evening[a]	Flt13	4/19/22 0050-0525	234	186
ONR3	Flt14	4/21/22 0030-0250	78	48
SWEX Flight Missions	**Twin Otter Flight**	**Dates and Times (UTC)**	**Number of Profiles Collected**	**Number of Good Profiles**
IOP5 Evening	Flt15	4/23/22 2140 – 4/24 0040	152	136
IOP5 Night	Flt16	4/24/22 0210-0605	212	189
EOP2 Evening	Flt17	4/25/22 2129 – 4/26/22 0045	157	139
EOP2 Night	Flt18	4/26/22 0210-0600	200	185
IOP6 Evening	Flt19	4/28/22 2130 – 4/29/22 0040	163	155
IOP6 Night	Flt20	4/29/22 0155-0550	190	175
ONR4	Flt21	5/03/22 0030-0250	110	108
EOP3 Evening	Flt22	5/04/22 1945-2300	172	164
EOP3 Night	Flt23	5/05/22 0040-0505	191	171
IOP7/ONR5 [b]	Flt24	5/08/22 0055-0515	12	12
IOP8 Evening	Flt25	5/08/22 2130 – 5/09/22 0115	191	184
IOP8 Night	Flt26	5/09/22 0215-0650	238	232
IOP9 Evening	Flt27	5/10/22 2228 – 5/11/22 0205	193	184
IOP9 Night	Flt28	5/11/22 0330	223	218
SWEX FLIGHTS			**3905**	**3589 (~92%)**
ONR FLIGHTS			**379**	**34**

[a] - Up profiles not included; [b] - Majority of mission was vertical stares

3.3 Data collection and quality control

Table 3 shows the catalogue of TODWL wind data profiles taken and processed for each SWEX and ONR Augmentation mission. During the SWEX campaign, almost 3600 wind profiles were generated for dedicated SWEX missions that are included in this data set.

To the best of our ability, profiles contaminated by excessive turning of the aircraft, cloud and fog, and high complex terrain variability over land were omitted from this data set. However, as seen by Table 3 which includes the number of profiles collected and the number of good profiles, these omissions were only around 8% of the data profiles collected (and also included upward looking profiles that were not part of this data set).

It should be noted that in addition to the hardware issues mentioned above, there were sporadic problems with the TODWL GPS/INS unit during the second half of the campaign. As a result, we utilized the GPS/INS information from the Twin Otter aircraft for the processing of all data.

One caveat is that, although 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 2-300 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 were done for all missions, both over land and water. For the SWEX mission of 05/11/22 (Figure 3), examples of these comparisons are shown in Figures 4 (over land) and 5 (over water). A quantitative intercomparison of the entire two data sets has yet to be undertaken, but qualitative comparisons show good agreement in most cases. It should be noted that while the dropsonde provides a point measurement at each level, the TODWL wind measurements for each level utilize 8 separate looks that are pointed in different directions. This is illustrated in Figure 6 and, as shown in Figures 3 and 4, differences are to be expected especially at lower levels in complex terrain.

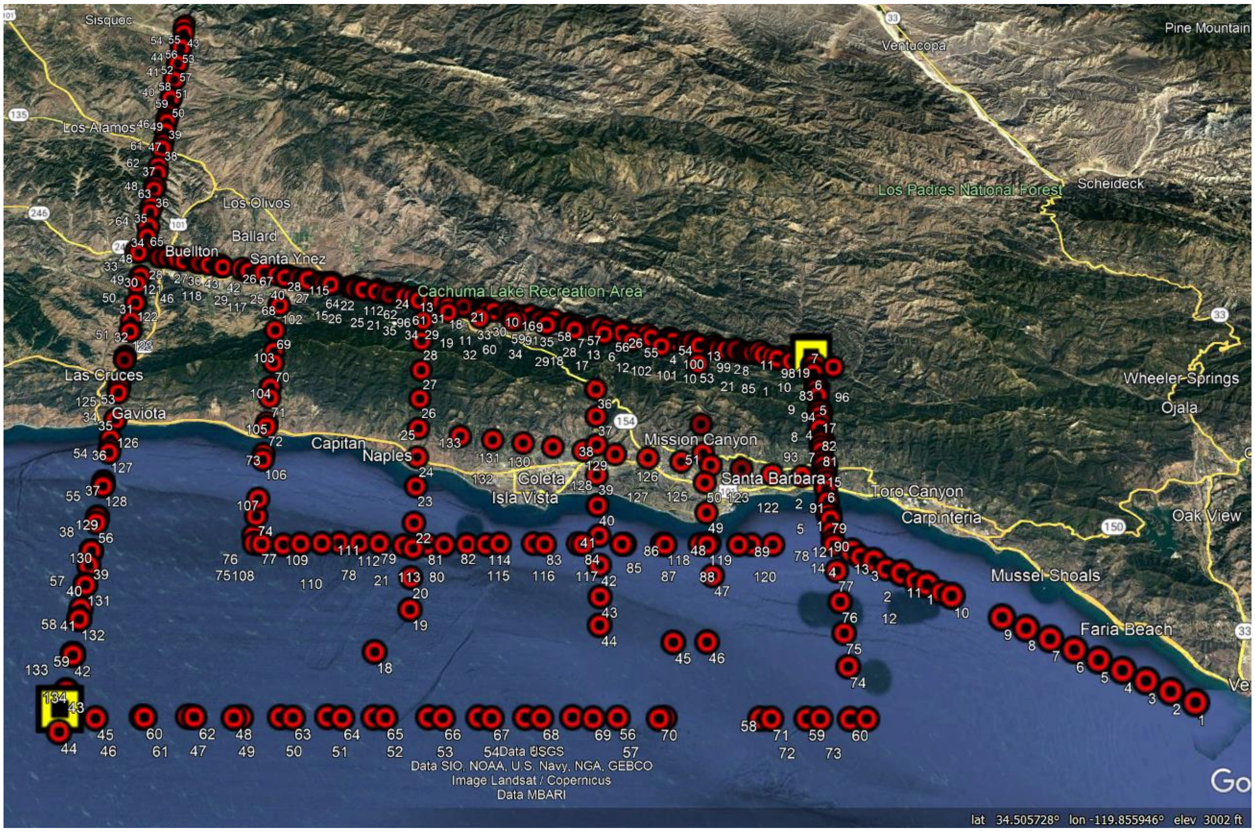

Figure 3: Flight track and TODWL profile locations on 0511 SWEX mission (red) and location of coincident dropsondes (yellow square).

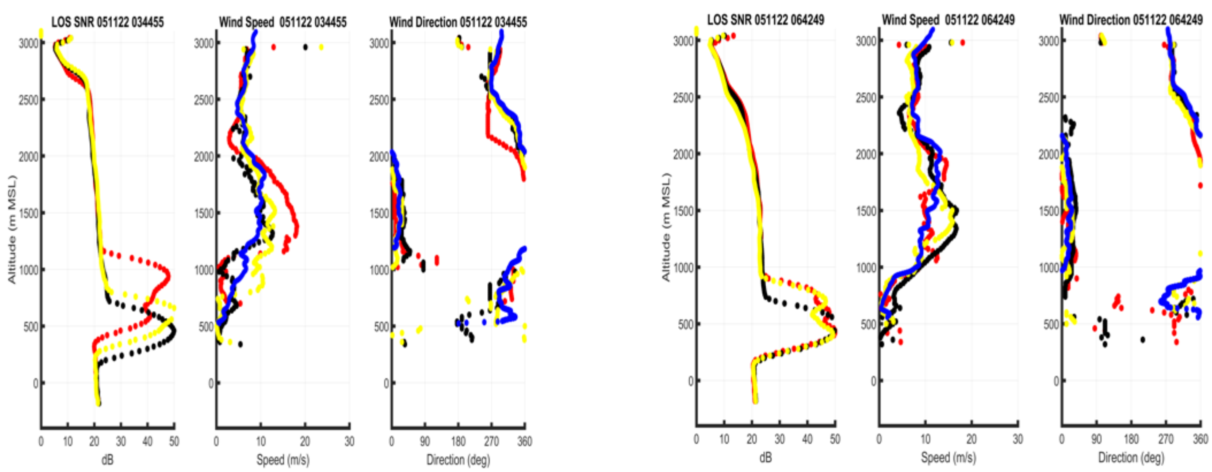

Figure 4: Example comparisons of wind speed and wind direction taken by TODWL and coincident dropsondes launched from the Twin Otter aircraft over land. Dropsonde in blue, three closest TODWL profiles in red, black and yellow.

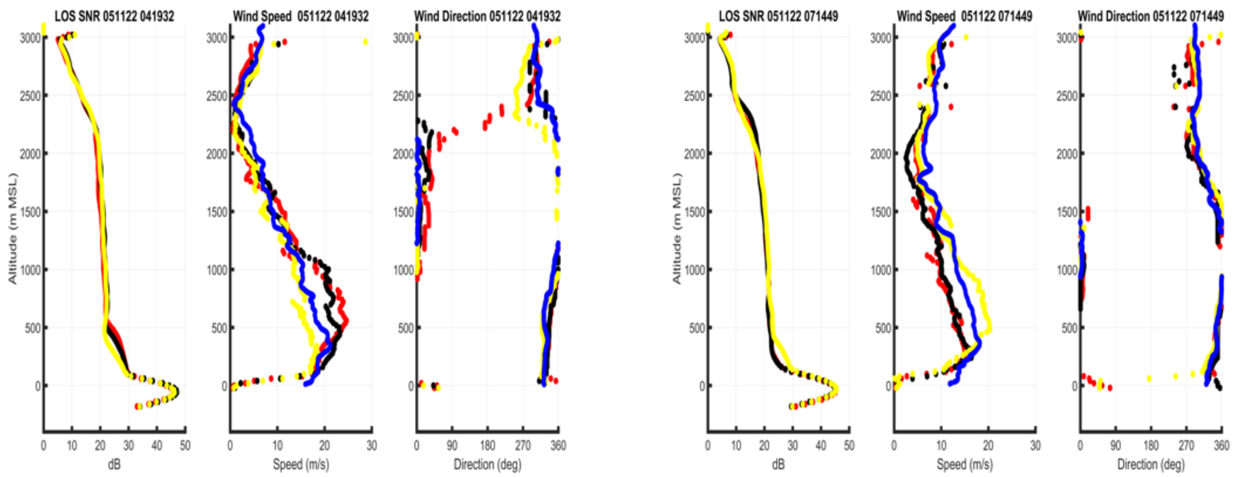

Figure 5: Example comparisons of wind speed and wind direction taken by TODWL and coincident dropsondes launched from the Twin Otter aircraft over water. Dropsonde in blue, three closest TODWL profiles in red, black and yellow.

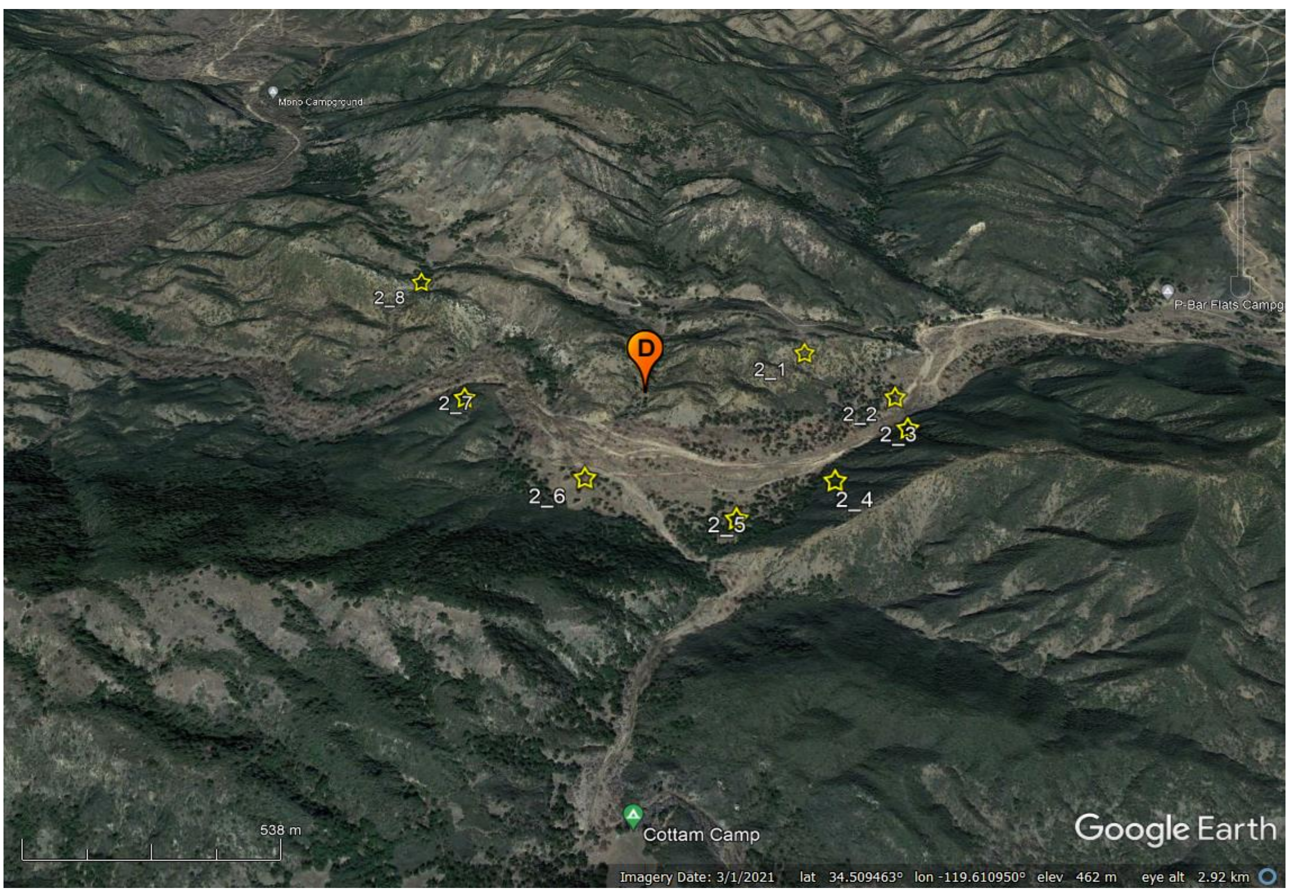

Figure 6: Example of the location of a Dropsonde measurement and those of the 8 looks used to calculate the wind measurement on the TODWL profile during SWEX.

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. As mentioned previously, there may be up to 8 individual profiles or VADS per file. The wind profiles are grouped by date and the classification of the mission, IOP (Intensive Operation Period), EOP (Enhanced Operation Period) or ONR (ONR Augmentation Flight).

4.1 File names

SWEX_TODWL_MMDDYY_HHMMSS_WIND_PROFILE_FINAL_V01

Example:

SWEX_TODWL_040522_012848_WIND_PROFILE_FINAL_V01
MMDDYY = 040522
HHMMSS = 012848 (Time in UTC)

4.2 Format and layout of each file

Line 1: File Header: Number of VADS (nvads), Number of Levels (numlvl) in each VAD (i.e., 186)

‘NVADS:’, nvads, ‘NUMLVL’, numlvl

Line 2: VAD #1 Header and before each VAD

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

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

Lines 3-188: 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).

Lines 2-188 are then repeated for successive number of VADS or profiles. As an example, for a file header noting 3 nvads, there will be the following:

Line 1 File header

Line 2 VAD #1 header

Lines 3-188 Data for the 186 levels of VAD #1

Line 189 VAD #2 header

Lines 190-375 Data for the 186 levels of VAD #2

Line 376 VAD #3 header

Lines 377-562 Data for the 186 levels of VAD #3

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

height = height (m aMSL)
wdir1= wind speed (m/s)
wspd1= wind direction (degrees)
wdir2= wind speed (m/s)
wspd2= 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 collection of each data file is given in the file name with time in the form of HHMMSS (UTC).

The time, in decimal notation, is given in the last column of the header for each VAD.

4.5 Missing/Bad data of good profiles

The data has already been filtered to account for poor GOF to the sine curve at each data level with a GOF threshold of 3.0. Data not passing the GOF test are given as -99.99.

In addition, “data” is provided up to 3500 m and down to -200 m. Data for levels above the flight level of the Twin Otter were given as -99.99 (00.00 for Lat/Long). 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 ~ -200 m to confirm that the max signal was assigned to the correct latitude (m aMSL). These trailing levels are also filled with -99.99.

5. Data Products

For this release, we are providing final, quality-controlled wind profiles as well as browse images of the profiles for all the missions during SWEX. The data are grouped by date and the classification of the mission, IOP (Intensive Operation Period), EOP (Enhanced Operation Period) or ONR (ONR Augmentation Flight) in folders such as:

a) SWEX_EOP1_A_041722_TODWL.
b) SWEX_IOP3_A_041322_TODWL
c) SWEX_ONR4_050322_TODWL

Each folder for the mission in question contains the following folders:

a) FINAL_QC_TODWL_WIND_PROFILES
b) TODWL_WIND_PROFILE_BROWSE_IMAGES

Included in the BROWSE IMAGE folders are images for all the “good’ profiles as well as a KMZ file for display in Google Earth which shows the location of each profile COLLECTED and an embedded image, with an example provided in Figure 7. The images omit all data with a GOF value over 3.0.

It should be noted that the browse images were generated from original processing of the collected profiles. The images of the “bad” profiles were omitted but the location is kept with no embedded image in the KMZ file. The best way to match any profile product generated from the QC wind profile data and the browse images is the UTC time, in decimal notation, included in both.

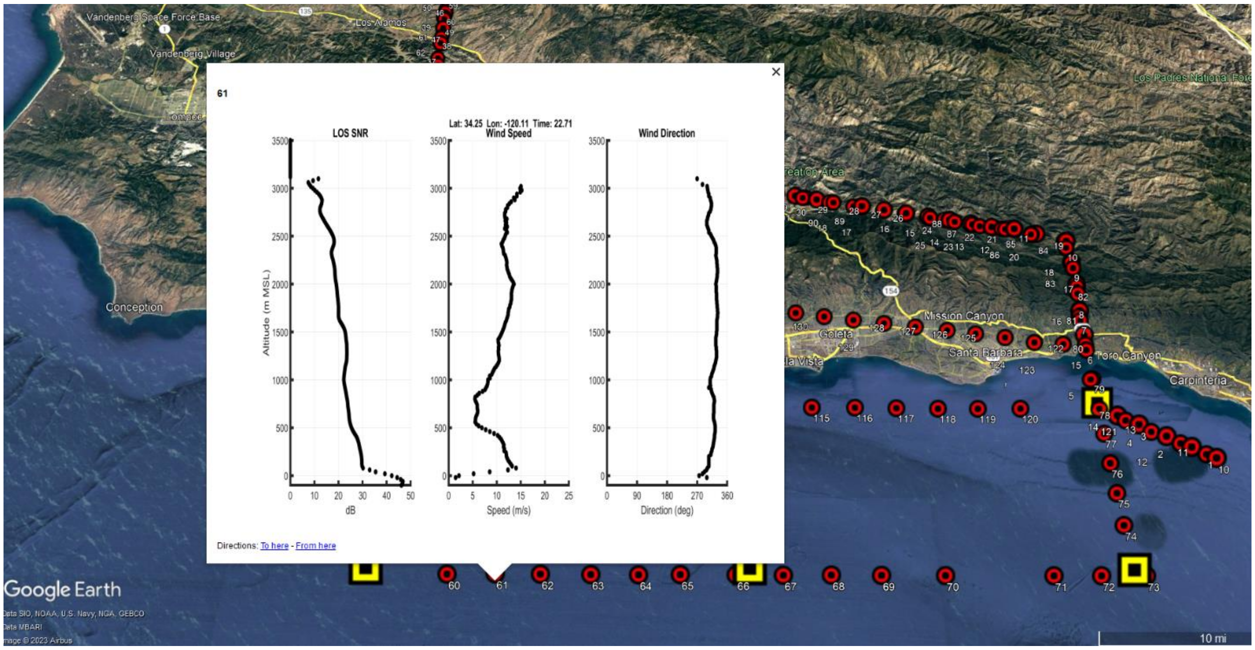

Figure 7: Example of the location of all TODWL wind profiles collected during a SWEX and an example of the embedded profile browse images provided.

6. Data Remarks

6.1 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. In addition, as mentioned in section 3.3,sporadic outages of the TODWL GPS/INS unit on the TODWL rack resulted in our using of the Twin Otter GPS information for all data processing. Using these two modifications, we have achieved particularly good profiles (ground speed checks and dropsonde comparisons (section 3.4)) with few bad profiles because of missing data (Table 3).

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 above a few hundred meters are less effected by wind observations from differing altitudes above the surface at differing perspectives. However, the near surface wind measurements are 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 upon request.

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 evaluating 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.

7.References

Thorpe, A.K., O'Handley, C., Emmitt, G.D., DeCola, P.L., Hopkins, F.M., Yadav, V., Guha, A., Newman, S., Hemer, 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)

8. Keywords

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