Title: NSSL Mobile Lidar Truck DELTA 2024

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1.0 Dataset Overview
These files contain periods of data collected from the NSSL Lidar Truck Halo Streamline XR+ Doppler lidar. These data were collected during the DELTA 2024 project. The Doppler lidar conducts regular conical scans at a set elevation angle as well as vertically pointing stares. These data are then passed through a typical VAD algorithm to retrieve horizontal wind speed and direction profiles. This platform was nomadic, and collected data on a deployment-to-deployment basis, so availability depends on the deployment decisions made each day by the project. Data for IOP1 and IOP3 below was collected using a "continuous scanning mode" strategy, wherein the lidar completes a 360 scan every ~3-5 s, but the VAD algorithm applied to this data outputs wind profiles every ~5 minutes. Data for IOP2 was collected using the standard practice of completing 360 degree scans every ~25-30 s and vertical stares in-between.

These data are not necessarily final. See remark in Section 5.2

1.1 Date range: 28 February -- 2 April 2024

1.2 Region of data collection: IN, OK, TX

1.3 Estimated data availability
IOP1: 2024-02-28 01:45 UTC – 2024-02-28 07:00 UTC

IOP2: 2024-03-24 22:10 UTC – 2022-03-25 00:00 UTC
IOP3: 2024-04-01 19:00 UTC – 2022-04-02 01:45 UTC

2.0 Instrument Description
The Halo Streamline XR+ is a commercial platform. The Doppler lidar (DL) is an active remote-sensing instrument that provides range- and time-resolved measurements of radial velocity, attenuated backscatter, and signal-to-noise ratio (SNR). The principle of operation is similar to radar in that pulses of electromagnetic energy (infrared in this case) are transmitted into the atmosphere; the energy scattered back to the transceiver is collected and measured as a time-resolved signal.

From the time delay between each outgoing transmitted pulse and the backscattered signal, the distance to the scatterer is inferred. The radial or line-of-sight velocity of the scatterers is determined from the Doppler frequency shift of the backscattered radiation. The DL uses a heterodyne detection technique in which the return signal is mixed with a reference laser beam (i.e., local oscillator) of known frequency. An onboard signal-processing computer then determines the Doppler frequency shift from the power spectra of the heterodyne signal. The energy content of the Doppler spectra can also be used to estimate attenuated backscatter. The DL operates in the near-infrared (IR;1.5 microns) and is sensitive to backscatter from micron-sized aerosols. Aerosols are ubiquitous in the lower troposphere and behave as ideal tracers of atmospheric winds. In contrast to radar, the DL is capable of measuring radial velocities under clear-sky conditions with very good precision – typically ~10 cm/sec (Newsom and Krishnamurthy 2020). It is important to note that DL scans are fully user configurable, so special attention should be paid to the scan strategy applied for this dataset.

Instrument specifications: Max range	12 km (aerosol load dependent)
Min. range	50-90m
Nyquist Limit	~39 m/s
Range gate	Configurable, 18-60m
Precision	Velocity: <0.2 m/s

2.1 Platform Configuration
For this project, one Doppler lidar was mounted onto the NSSL mobile lidar truck. This meant that one lidar shares the duty of scanning to profile horizontal winds and pointing vertically to observe vertical velocity. This data set includes only the vertical velocity information.

3.0 Data collection and processing:
For the DELTA campaign, the Doppler lidar collected PPI scans at 70 deg elevation and post-processed the data every 5 minutes. The Doppler lidar provides range-resolved, line-of-sight measurements of radial velocity, intensity (signal-to-noise ratio [SNR]+1), and attenuated backscatter. In the case of PPI scans meant for VAD analysis, these data are passed through a VAD code to produce profiles of horizontal wind speed and direction. Vertical velocity is also provided, but it is not as high quality as vertical velocity more directly measured by vertical

stares. The provided files provide the intensity field (SNR+1), which can be used as a 'filter' for noise. A good rule of thumb cutoff is 1.01.

3.1 Vertical Velocities

The Doppler lidar provides range-resolved, line-of-sight measurements of radial velocity, intensity (signal-to-noise ratio [SNR]+1), and attenuated backscatter. This measurement of vertical velocity is much more direct than that provided within the CSM wind files, described below. The provided files provide the intensity field (SNR+1), which can be used as a 'filter' for noise. A good rule of thumb cutoff is 1.01.

3.2 Horizontal Winds

The horizontal winds were produced using the Step-Stare mode feature available on Halo Streamline DLs. In this mode, the scanner head stops at each point in a scan to capture its sample. These scans were post-processed using the VAD method to get the horizontal wind speed and direction.

4.0 Data format

Data are provided in netcdf format. The files have time and height dimensions.

<u>The files containing data processed from the continuous scanning mode (IOP1 and IOP3) follow the naming convention dltruckdlcsmDL1.c0.YYYYMMDD.HHmmss.cdf are contains the following data:</u>

```
variables:
	double height(height) ;
		height:long_name = "Height" ;
		height:units = "km AGL" ;
	int64 base_time ;
		base_time:long_name = "Time" ;
		base_time:units = "seconds since 1970-01-01 00:00:00 UTC" ;
	float rows(rows) ;
		rows:long_name = "rows of covariance matrix" ;
		rows:units = "1" ;
	float cols(cols) ;
		cols:long_name = "columns of covariance matrix" ;
		cols:units = "1" ;
	double time_offset(time) ;
		time_offset:long_name = "Time offset" ;
		time_offset:units = "seconds since base_time" ;
	double hour(time) ;
		hour:long_name = "Hour of Day" ;
		hour:units = "UTC" ;
	float u(time, height) ;
		u:long_name = "Zonal wind velocity" ;
		u:units = "m/s" ;
	float v(time, height) ;
		v:long_name = "Meridional wind velocity" ;
		v:units = "m/s" ;
```

```
        float w(time, height) ;
                w:long_name = "Vertical Velocity" ;
                w:units = "m/s" ;
        float wspd(time, height) ;
                wspd:long_name = "Horizontal wind speed" ;
                wspd:units = "m/s" ;
        float wdir(time, height) ;
                wdir:long_name = "Wind Direction" ;
                wdir:units = "degrees" ;
        float wspd_sigma(time, height) ;
                wspd_sigma:long_name = "Horizontal wind speed 1-sigma uncertainty" ;
                wspd_sigma:units = "m/s" ;
        float wdir_sigma(time, height) ;
                wdir_sigma:long_name = "Wind Direction 1-sigma uncertainty" ;
                wdir_sigma:units = "degrees" ;
        float rms(time, height) ;
                rms:long_name = "RMS between observed PPI velocities and fitted values" ;
                rms:units = "m/s" ;
        float covariance_matrix(time, height, rows, cols) ;
                covariance_matrix:_FillValue = -999.f ;
                covariance_matrix:standard_name = "covariance matrix of wind" ;
                covariance_matrix:units = "m^2 s^-2" ;
        float cn(time, height) ;
                cn:_FillValue = -999.f ;
                cn:standard_name = "Condition number" ;
                cn:long_name = "Condition number of A*diag((A^T*A)^(-1/2))" ;
                cn:units = "1" ;
        float r_sq(time, height) ;
                r_sq:long_name = "Coefficient of determination" ;
                r_sq:comment = "This works as a measure of homogeneity" ;
        float intensity(time, height) ;
                    intensity:long_name = "Intensity" ;
```

<u>The file containing data processed from the standard VAD strategy (IOP2) follows the naming convention dltruckdlvadDL1.c1.YYYYMMDD.HHmmss.cdf.</u>

```
variables:
        double height(height) ;
                height:long_name = "Height" ;
                height:units = "km AGL" ;
        int64 base_time ;
                base_time:long_name = "Time" ;
                base_time:units = "seconds since 1970-01-01 00:00:00 UTC" ;
        double time_offset(time) ;
                time_offset:long_name = "Time offset" ;
                time_offset:units = "seconds since base_time" ;
        double hour(time) ;
                hour:long_name = "Hour of Day" ;
                hour:units = "UTC" ;
        float wdir(time, height) ;
                wdir:long_name = "Horizontal wind direction" ;
                wdir:units = "degrees" ;
```

```
float wspd(time, height) ;
        wspd:long_name = "Horizontal wind speed" ;
        wspd:units = "m/s" ;
float w(time, height) ;
        w:long_name = "Vertical Velocity" ;
        w:units = "m/s" ;
float rms(time, height) ;
        rms:long_name = "RMS between observed PPI velocities and fitted values" ;
        rms:units = "m/s" ;
float r_sq(time, height) ;
        r_sq:long_name = "Coefficient of determination" ;
        r_sq:comment = "This works as a measure of homogeneity" ;
float intensity(time, height) ;
        intensity:long_name = "Intensity" ;
        intensity:units = "unitless" ;
        intensity:comment = "This is computed as (SNR+1)" ;
float lat(time) ;
        lat:long_name = "Latitude" ;
        lat:units = "degrees North" ;
float lon(time) ;
        lon:long_name = "Longitude" ;
        lon:units = "degrees East" ;
float alt(time) ;
        alt:long_name = "Altitude" ;
            alt:units = "m MSL" ;
```

The file containing vertical stare data during IOP2 follows the naming convention dltruckdlfpDL1.c1.YYYYMMDD.HHmmss.cdf.

```
variables:
    int64 base_time ;
        base_time:long_name = "Time" ;
        base_time:units = "seconds since 1970-01-01 00:00:00 UTC" ;
    double time_offset(time) ;
        time_offset:long_name = "Time offset" ;
        time_offset:units = "seconds since base_time" ;
    double hour(time) ;
        hour:long_name = "Hour of Day" ;
        hour:units = "UTC" ;
    float height(height) ;
        height:long_name = "Height" ;
        height:units = "km AGL" ;
    float azimuth(time) ;
        azimuth:long_name = "Azimuth angle" ;
        azimuth:units = "degrees" ;
        azimuth:comment = "0 degrees is north" ;
    float elevation(time) ;
        elevation:long_name = "Elevation angle" ;
        elevation:units = "degrees above the horizon" ;
    float pitch(time) ;
        pitch:long_name = "Pitch recorded by the lidar" ;
        pitch:units = "degrees" ;
```

```
float roll(time) ;
        roll:long_name = "Roll recorded by the lidar" ;
        roll:units = "degrees" ;
float velocity(time, height) ;
        velocity:long_name = "Doppler velocity" ;
        velocity:units = "m/s" ;
        velocity:comment = "Positive values are towards the lidar" ;
float intensity(time, height) ;
        intensity:long_name = "Intensity" ;
        intensity:units = "unitless" ;
        intensity:comment = "This is computed as (SNR+1)" ;
float backscatter(time, height) ;
        backscatter:long_name = "Attenuated backscatter" ;
        backscatter:units = "km^(-1) sr^(-1)" ;
float cbh(time) ;
        cbh:long_name = "Cloud base height" ;
        cbh:units = "km AGL" ;
        cbh:comment = "Simple threshold method applied to backscatter field" ;
float internal_temp(time) ;
        internal_temp:long_name = "Internal temperature" ;
        internal_temp:units = "C" ;
float internal_rh(time) ;
        internal_rh:long_name = "Internal relative humidity" ;
        internal_rh:units = "%" ;
float tec_flag(time) ;
        tec_flag:long_name = "Thermal environment control system flag" ;
        tec_flag:units = "unitless" ;
float tec_voltage(time) ;
        tec_voltage:long_name = "Thermal environment control system voltage" ;
        tec_voltage:units = "V" ;
float lat(time) ;
        lat:long_name = "Latitude" ;
        lat:units = "degrees North" ;
float lon(time) ;
        lon:long_name = "Longitude" ;
        lon:units = "degrees East" ;
float alt(time) ;
        alt:long_name = "Altitude" ;
        alt:units = "m MSL" ;
float heading(time) ;
        heading:long_name = "Heading" ;
            heading:units = "Degrees" ;
```

5.0 Data Remarks

5.1. Data should be consistently available, but note that periods of precipitation, fog, or other very low cloud may limit the level to which good data are collected. Note also that vertical velocity in light precipitation will be contaminated by the fall speed of the precipitation itself.

5.2. Vertical velocity obtained from the continuous scanning modes (IOP1 and IOP3) is a retrieval, whereas the vertical velocity from the “fp” IOP2 files is obtained from line-of-sight stares in the vertical direction.

6.0 References

Newsom, R. K., R. Krishnamurthy, 2020: Doppler lidar (DL) handbook. DOE Office of Science Atmospheric Radiation Measurement (ARM) Program (United States). DOE/SC/ARM/TR-101.

7.0 Appendix

GCMD Science Keywords: WIND PROFILES; WIND VELOCITY/SPEED PROFILES; WIND DIRECTION PROFILES; VERTICAL WIND VELOCITY/SPEED