Transregio SFB 32
Subproject D2
Wind and Mixing Layer Height from Doppler Wind Lidar

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Figure 1: The Halo Photonics Streamline Doppler Lidar on roof of institute ICG2 in the research center Jülich in front of the 120 m meteorological tower.

1 Instrument

The Halo Photonics Streamline is a Doppler lidar with scanning capability. It sends Laserpulses with a wavelength of 1500 nm at 15 kHz and collects the backscattered signal over 15e3 Pulses or one second. The frequency of the backscattered light is due to the movement of the air (i.e. the wind) 'Doppler shifted'. An analysis of this Doppler shift allows the determination of the wind speed along the beam. The instrument relies on aerosol for the backscatter and can accordingly detect Doppler-speeds up to the top of the Boundary layer i.e. the lower 1-2km of the atmosphere where aerosol concentrations are usually high. Spatial resolution along the beam is 30 m and temporal resolution is 1.67 s.

The instrument performs different scan patterns to allow the determination of the different wind components and properties. In vertical-stare-mode the beam is aligned vertically and it is possible to directly measure the vertical wind speed. To derive horizontal wind it is necessary to tilt the beam and measure in different azimuth directions. This is done with the so called 'velocity-azimuth-display'-scan (or VAD-scan) at 75^o elevation and, to reduce uncertainties, at 36 azimuth angles. A faster but less acurate scan for the horizontal wind is the 'Doppler Beam swinging' (DBS) method where one vertical beam and two beams, tilted in the principal directions, are used. Times needed for the different scans are as follows: A VAD scan of the Doppler Lidar takes 124sec and is perfomed every 15 minutes, the DBS takes 15sec and is done every 5 minutes, and an additional RHI performed once every hour takes 104sec. The rest of the time, summing up to 47 minutes per hour, the instrument is in vertical-stare-mode.

When displaying the Doppler velocities from one range of the VAD-scan as a function of azimuth (hence the name) the result is a cos-curve. The offset of this curve is proportional to the average vertical wind speed along the scanning circle, the phase depicts the wind direction and the amplitude is proportional to the horizontal wind speed. The result of this analysis are wind profiles and can be found in daily `wind_vad_YYYYMMDD.nc`-files in the monthly `wind_vad_YYYYMMDD.zip`-archives. Fig.2 shows wind profiles derived from the DBS-scans. The DBS-scan is very sensitive to differences of the wind vector at the locations of the three beams, accordingly show the wind vectors during times of active convection large variations. In the `wind_vad_YYYYMMDD.zip`-archives are provided the vectors from the VAD scans which show much less variation.

The stare-data are used to calculate every 5 minutes profiles of 30 minute means of the vertical velocity, its standard deviation σ_w and skewness. From the σ_w-profiles an estimate of the mixing layer height is derived as the lowest height where $\sigma_w < 0.4m/s$ (see [Schween et al.(2014)]). This data is provided in daily `bl_height_YYYYMMDD.nc`-files contained in the monthly `bl_height_YYYYMM.zip` archives. Fig.2 shows the standard deviation of vertical velocity and the derived mixing layer height.

Data plots can be found in our data browser http://gop.meteo.uni-koeln.de/ Hatpro/ dataBrowser/.

2 data files

Table 1 shows the header of a `bl_height_YYYYMMDD.nc`-netcdf file. Table 2 shows the header of a `wind_vad_YYYYMMDD.nc`-netcdf file.

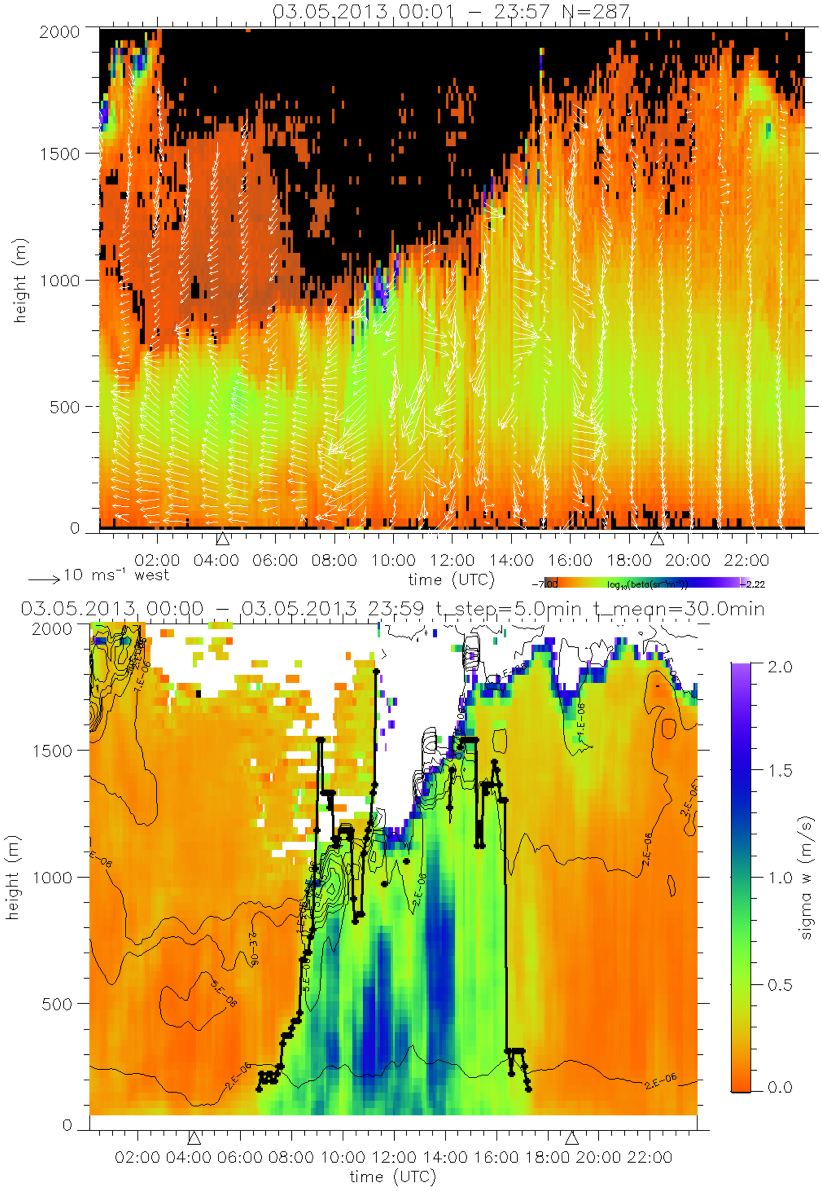

Figure 2: Top: VAD-plot for May 3, 2013, with vectors depicting horizontal wind direction and speed, over time (abscissa) and height (ordinate) together with backscatter (color shading). Wind vectors here were determined on basis of a DBS-scan (see text). Bottom: Standard deviation of vertical velocity (color shading) over time (abscissa) and height (ordinate) together with backscatter (iso lines) and mixing-layer-height (solid black line). Triangles at the abscissa indicate times of sunrise and sunset, respectively.

Table 1: Basic structure of the `bl_height_YYYYMMDD.nc`-netcdf files:

```
netcdf bl_height_20130502 {
dimensions:
  N_time = 289 ;
  N_range = 115 ;
variables:
  double time(N_time) ;
    time:units = "julian day" ;
    time:long_name = "julian day i.e. fractional days since January 1, 4713 BC Greenwich noon" ;
    time:missing_value = NaN ;
    time:_fillvalue = NaN ;
  float range(N_range) ;
    range:units = "m" ;
    range:long_name = "range" ;
    range:missing_value = NaNf ;
    range:_fillvalue = NaNf ;
  float bl_height(N_time) ;
    bl_height:long_name = "boundary layer height from w_sdev > w_sdev_ts" ;
    bl_height:units = "m" ;
    bl_height:missing_value = NaNf ;
    bl_height:_fillvalue = NaNf ;
  float w_sdev(N_range, N_time) ;
    w_sdev:long_name = "standard deviation of w" ;
    w_sdev:units = "m/s" ;
    w_sdev:missing_value = NaNf ;
    w_sdev:_fillvalue = NaNf ;
  float w_mean(N_range, N_time) ;
    w_mean:long_name = "mean of w" ;
    w_mean:units = "m/s" ;
    w_mean:missing_value = NaNf ;
    w_mean:_fillvalue = NaNf ;
  float w_skew(N_range, N_time) ;
    w_skew:long_name = "skewness of w" ;
    w_skew:units = "1" ;
    w_skew:missing_value = NaNf ;
    w_skew:_fillvalue = NaNf ;
  float b_mean(N_range, N_time) ;
    b_mean:long_name = "mean of backscatter coefficient" ;
    b_mean:units = "sr^-1 m^-1" ;
    b_mean:missing_value = NaNf ;
    b_mean:_fillvalue = NaNf ;

// global attributes:
    :Creator = "Jan Schween" ;
    :creation_date = "18.06.2014 10:55 UTC" ;
    :time_step = "      5.0000000min" ;
    :time_interval = "      30.000000min" ;
    :w_sdev_ts = "    0.400000m/s" ;
    :clouds = "excluded" ;
    :beta_cloud_ts = "  2.00000e-05 1/Sr/m" ;
}
```

Table 2: Basic structure of the `wind_vad_YYYYMMDD.nc`-netcdf files:

```
netcdf wind_vad_20130502 {
dimensions:
  time = 96 ;
  height = 280 ;
variables:
  double time(time) ;
    time:units = "julian day" ;
    time:long_name = "julian day i.e. fractional days since January 1, 4713 BC Greenwich noon; can be converted to unix epoch with t_unix=(time-244058
  float height(height) ;
    height:units = "m" ;
    height:long_name = "height above ground" ;
  float intensity(height, time) ;
    intensity:long_name = "intensity in vertical beam" ;
    intensity:units = "SNR+1" ;
  float beta(height, time) ;
    beta:long_name = "backscatter in vertical beam" ;
    beta:units = "Sr^-1 m^1" ;
  float speed(height, time) ;
    speed:units = "m s^-1" ;
    speed:long_name = "horizontal wind speed" ;
    speed:missing_value = NaNf ;
    speed:_fillvalue = NaNf ;
  float dir(height, time) ;
    dir:long_name = "horizontal wind direction" ;
    dir:units = "deg" ;
    dir:missing_value = NaNf ;
    dir:_fillvalue = NaNf ;
  float w_speed(height, time) ;
    w_speed:units = "m s^-1" ;
    w_speed:long_name = "vertical wind speed" ;
    w_speed:missing_value = NaNf ;
    w_speed:_fillvalue = NaNf ;

// global attributes:
    :title = "Wind profiles from doppler lidar" ;
    :creator = "write_wind_nc.pro by Jan Schween (Dec.2012)" ;
    :creation_date = "Tue Apr 26 10:50:39 2016 UTC" ;
    :method = "azimuth scan with 36 nodes" ;
    :location = "JOYCE: Juelich observatory for cloud evolution" ;
    :lon = 6.413536f ;
    :lat = 50.90855f ;
    :comment = "Values with intensity < 1.0150 were set to NaN" ;
}
```

References

[Schween et al.(2014)] Mixing layer height retrieval with ceilometer and Doppler lidar: from case studies to long-term assessment, Atmos. Meas. Tech., 7, 3685-3704, Doi:10.5194/amt-7-3685-2014