SAVANT 2018

SODAR-RASS Data Report

NCAR/EOL Integrated Sounding System

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Earth Observing Laboratory
In situ Sensing Facility

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OVERVIEW

This document describes data from the NCAR / EOL SODAR-RASS at the SAVANT field project. In the event that information from this document are used for publication or presentation purposes, please provide appropriate acknowledgement to NSF and NCAR/EOL and make reference to *Brown, W.O.J. (2020): SAVANT 2018 NCAR/EOL ISS SODAR-RASS Data Report.*

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SAVANT Homepage: https://www.eol.ucar.edu/field_projects/savant
SAVANT data archive: https://data.eol.ucar.edu/master_lists/generated/savant/
ISS Operations and quicklook plots: https://www.eol.ucar.edu/content/iss-savant
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Citations:

If data from the EOL SODAR-RASS are used for research resulting in publication, please acknowledge EOL and NSF and include the following citations in your paper as appropriate:

NCAR/EOL In-situ Sensing Facility. 2020. SAVANT: NCAR/EOL ISS Sodar-RASS Data. Version 1.0. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.26023/PSDT-PFEP-YY09. *Access date should be included in the citation.*

INTRODUCTION

NCAR/EOL deployed the SODAR-RASS during the SAVANT (Stable Atmospheric Variability and Transport) field campaign between September 15 and November 15, 2018 [1]. The sodar was operated as part of the Integrated Sounding Systems (ISS) [2] at a site in Champaign County, Illinois, near the town of Mahomet, IL. The ISS was split between the main study area in a field about 1 km north of Mahomet (with the ISFS tower array, ISS sodar-RASS and other instruments) and a farm homestead approx 4.5 km to the west. The homestead site included a radar wind profiler and radiosonde soundings.

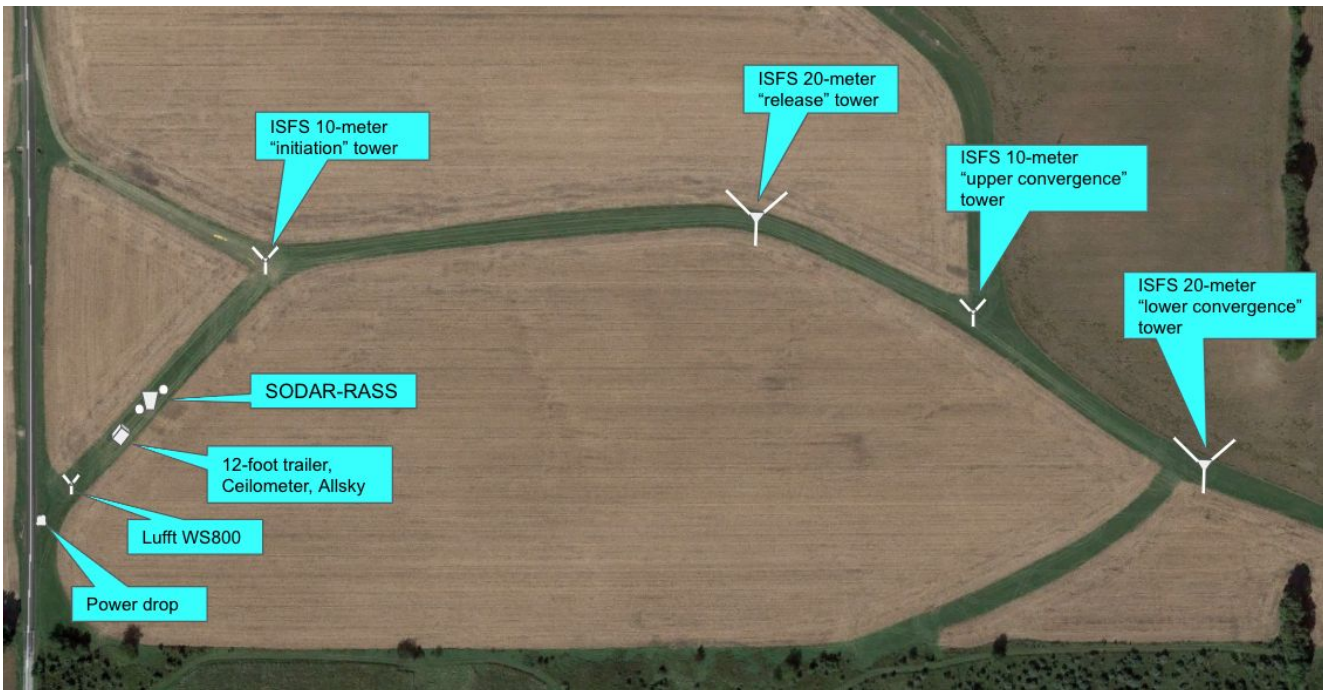

Figure 1: Approximate layout of the main study area at SAVANT. The area shown is approx 800 x 400 meters.

SODAR-RASS

The sodar used was a Metek DSDPA.90-24 mini-sodar which is a smaller version of the DSDPA.90-64 described in Engelbart, et al (1999) [3]. The sodar uses the Doppler beam swinging technique to measure winds, by steering an acoustic beam through 4 directions over a 20-second cycle. Virtual temperatures were measured using the Radio Acoustic Sounding System (RASS) technique via a CW radar attached to the sodar. Winds and virtual temperature products were generated every 10 minutes. The operating parameters for SAVANT are summarized in Table 1.

SODAR-RASS	Metek DSDPA.90-24 mini-Doppler SODAR-RASS
Location	40.21053°N, 88.411750°W, 229 m MSL
Acoustic Antenna	24 speaker phased array (however 2 speakers disabled) steered vertically and to 16° off zenith at azimuth 70° & 340° Transmitted chirp pulses around 2 kHz
RASS	25 W, CW radar at 915 MHz driving two vertically pointing 2-meter parabolic dish antennas 6 m apart
Time Sampling	Raw spectra and moments approx every 20 seconds Wind and virtual temperate profile every 10 minutes
Range sampling	20m sampling 40 - 400 m, noise only at 500m

Table 1: Typical operating characteristics of the SODAR-RASS as configured for SAVANT.

SODAR-RASS Data

Winds and virtual temperatures were calculated using Metek standard processing software which generates daily ascii raw Doppler moment data with ~ 20 second sampling and 10-minute averaged product files. These 10-minute average files are then processed by IDL code at NCAR to generate the netcdf files that make up this data set. The netCDF format [4] is self-documented and the CDL (header information with variable names) is in Table 2.

The data are mainly in 2-dimensional arrays corresponding to time, height coordinates. The most useful variables to many users are likely to be fWindSpeed, fWindDirection, fRassTV and fRassPTV corresponding to wind speed and direction, RASS virtual temperature and RASS potential virtual temperature. The first letter of each variable indicates the variable type (e.g. “f” indicates float).

Time is recorded in the 1-dimensional variable fTime_vec and is the number of seconds since the beginning of the file (recorded in variables fTime_begin and strTime_begin, both in UTC). Note that the time stamp is at the end of the averaging time and since fTime_vec[0] is typically zero seconds after 0 UTC, the first sample is typically the average of the last 10 seconds of the previous day. Heights are in meters AGL in the fHeight variable.

```
netcdf sodar_20181001.avg {
dimensions:
        dim_time = 144 ;
        dim_string = 256 ;
        dim_heights = 21 ;
        dim_beams = 4 ;
        dim_fTime = 6 ;
        dim_MixFreqs = 5 ;
        dim_SpFreqs = 1 ;
variables:
        char strProject(dim_string) ;
        char strSite(dim_string) ;
        char strName(dim_string) ;
        char strOperator(dim_string) ;
        float fLatitude ;
                fLatitude:long_name = "North of equator" ;
                fLatitude:units = "degrees" ;
        float fLongitude ;
                fLongitude:long_name = "East of Greenwich" ;
                fLongitude:units = "degrees" ;
        float fAltitude ;
                fAltitude:long_name = "Above mean sea level" ;
                fAltitude:units = "metres" ;
        int lAverageTime(dim_time) ;
                lAverageTime:long_name = "Averaging Time" ;
                lAverageTime:units = "s" ;
        float fMinHeight(dim_time) ;
                fMinHeight:long_name = "Minimum Height" ;
                fMinHeight:units = "m" ;
        float fMaxHeight(dim_time) ;
                fMaxHeight:long_name = "Maximum Height" ;
                fMaxHeight:units = "m" ;
        int fNoise(dim_time) ;
                fNoise:long_name = "Noise" ;
                fNoise:units = " " ;
        int fStep(dim_time) ;
                fStep:long_name = "Step" ;
        float fVolume(dim_time, dim_beams) ;
                fVolume:long_name = "Volume" ;
                fVolume:units = " " ;
        int fTXFreq(dim_time) ;
                fTXFreq:long_name = "Transmitter Frequency" ;
                fTXFreq:units = "Hz" ;
        float fMixFreqs(dim_time, dim_MixFreqs) ;
                fMixFreqs:long_name = "Transmitted Freqs" ;
                fMixFreqs:units = "Hz" ;
        float fSampleFreq(dim_time) ;
                fSampleFreq:long_name = "Sampling Frequency" ;
                fSampleFreq:units = "Hz" ;
        float fAzimuth(dim_time, dim_beams) ;
                fAzimuth:long_name = "Azimuth angle of beams"
                fAzimuth:units = "Deg" ;
        float fZenith(dim_time, dim_beams) ;
                fZenith:long_name = "Zenith angle of beams" ;
                fZenith:units = "Deg" ;
        float fGndTemp(dim_time) ;
                fGndTemp:long_name = "Ground Temperature" ;
                fGndTemp:units = "C" ;
        float fCrossTalk(dim_time) ;
                fCrossTalk:long_name = "RASS Cross Talk" ;
                fCrossTalk:units = "V" ;
        char strTime_begin(dim_string) ;
                strTime_begin:long_name = "Start time" ;
        float fTime_begin(dim_fTime) ;
        char strTime_end(dim_string) ;
                strTime_end:long_name = "End time" ;
        float fTime_end(dim_fTime) ;
        float fUtc_offset ;
                fUtc_offset:long_name = "Offset from UTC" ;
        float fTime_vec(dim_time) ;
                fTime_vec:long_name = "Since start time" ;
                fTime_vec:units = "seconds" ;
        float fHeight(dim_time, dim_heights) ;
        float fPower(dim_time, dim_heights, dim_beams) ;
                fPower:long_name = "Power" ;
                fPower:units = "dB" ;
                fPower:_FillValue = -999.f ;
        float fReflectivity(dim_time, dim_heights, dim_beams)
                fReflectivity:long_name = "Reflectivity" ;
                fReflectivity:units = "dB" ;
                fReflectivity:_FillValue = -999.f ;
        float fRadialVel(dim_time, dim_heights, dim_beams) ;
                fRadialVel:long_name = "Radial Vel along beam"
                fRadialVel:units = "dB" ;
                fRadialVel:_FillValue = -999.f ;
        float fU(dim_time, dim_heights) ;
                fU:long_name = "Eastward (U) Wind Vel" ;
                fU:units = "m/s" ;
                fU:_FillValue = -999.f ;
        float fV(dim_time, dim_heights) ;
                fV:long_name = "Northward (V) Wind Vel" ;
                fV:units = "m/s" ;
                fV:_FillValue = -999.f ;
        float fW(dim_time, dim_heights) ;
                fW:long_name = "Vertical (W) Wind Vel" ;
                fW:units = "m/s" ;
                fW:_FillValue = -999.f ;
        float fWindSpeed(dim_time, dim_heights) ;
                fWindSpeed:long_name = "Wind Speed" ;
                fWindSpeed:units = "m/s" ;
                fWindSpeed:_FillValue = -999.f ;
        float fWindDirection(dim_time, dim_heights) ;
                fWindDirection:long_name = "Wind Direction" ;
                fWindDirection:units = "degrees" ;
                fWindDirection:_FillValue = -999.f ;
        float fWindSpeedCL(dim_time, dim_heights) ;
                fWindSpeedCL:long_name = "Wind Speed Cluste" ;
                fWindSpeedCL:units = "m/s" ;
                fWindSpeedCL:_FillValue = -999.f ;
        float fWindDirectionCL(dim_time, dim_heights) ;
                fWindDirectionCL:long_name = "Wind Dirn Clust"
                fWindDirectionCL:units = "degrees" ;
                fWindDirectionCL:_FillValue = -999.f ;
        float fRadVelSigma(dim_time, dim_heights, dim_beams) ;
                fRadVelSigma:long_name = "Std dev radial vel"
                fRadVelSigma:units = "m/s" ;
                fRadVelSigma:_FillValue = -999.f ;
        float fWindPhiSigma(dim_time, dim_heights) ;
                fWindPhiSigma:long_name = "Std dev wind incl"
                fWindPhiSigma:units = "deg" ;
                fWindPhiSigma:_FillValue = -999.f ;
        char fDiffusionClass(dim_time, dim_heights) ;
                fDiffusionClass:long_name = "Diffusion Class"
        float fRassTV(dim_time, dim_heights) ;
                fRassTV:long_name = "RASS Virtual Temperature"
                fRassTV:units = "C" ;
                fRassTV:_FillValue = -999.f ;
        float fRassPTV(dim_time, dim_heights) ;
                fRassPTV:long_name = "RASS Potential Virtual
Temperature dry adiabatic" ;
                fRassPTV:units = "C" ;
                fRassPTV:_FillValue = -999.f ;
        short nDataAvailability(dim_time,dim_heights,dim_beams
                nDataAvailability:long_name = "Data Avail" ;
                nDataAvailability:units = "%" ;
        float fSNR(dim_time, dim_heights, dim_beams) ;
                fSNR:long_name = "Signal to Noise Ratio" ;
                fSNR:units = "dB" ;
                fSNR:_FillValue = -999.f ;
        int lPlausibility(dim_time, dim_heights, dim_beams) ;
                lPlausibility:long_name = "Data Plausibility"
                lPlausibility:note = "Converted from octal to
base10" ;
```

Table 2: Sample header information in the averaged netCDF files (abbreviated). Key data are in the variables fWindSpeed, fWindDirection (or fU, fV) for winds, fRassTV and fRassPTV for RASS virtual temperature and potential virtual temperature variables. It is suggested that data with corresponding fSNR >= 3 dB and lPlausibility code <= 2 be used in analyses.

Note that the wind direction data follows the usual meteorological convention in that it is the direction the winds are coming from (ie, clockwise from north, with northerlies being 0°, 90° being easterlies, 180° being southerlies, and 270° being westerly). The eastward and northward winds are also available in variables fU and fV. There is an alternate method of measuring wind using a cluster average technique (variables fWindSpeedCL and fWindDirectionCL), however comparisons with soundings and tower measurements determined that the default winds (variables fWindSpeed and fWindDirection) were more accurate. The RASS potential virtual temperature (variable fRassPTV) is derived directly from the virtual temperature assuming a dry adiabatic height correction.

Two other variables that should be examined when using this data are the signal to noise ratio and Metek's plausibility code (variables fSNR and lPlausibility). Based on comparisons with soundings and an ISFS tower, it is found that samples with fSNR greater than or equal to 3 dB, and lPlausibility code 2 or less, are likely to be more accurate than samples outside those limits. The lPlausibility code is derived from Metek's plausibility bit code sequence for each beam. The lPlausibility limit of 2 means that either no problems were found (all bits are zero), bit 0 is set (saturation found in some samples but those were not used in the analysis), or bit 1 is set (noise was found in some samples but those were not used in the analysis). All other issues (such as excessive noise, spikes in the Doppler spectra, low SNR, statistical issues and a range of other problems) result in the sample being rejected. The SNR and lPlausibility limits can be relaxed if a particular case is being examined and measurements are found to be sparse (for example see the discussion on Figure 4 below), however the user should be aware that some measurements may be erroneous.

Other data such as reflectivity, radial velocity, sigma of radial velocity and wind direction and others are also available. Some of these are available for each beam direction. Three beam directions were used: vertical and two oblique beams (directed 16° off zenith to azimuths 70° and 340° clockwise from north) used to measure winds using the Doppler beam swinging technique. In the data files 4 beam directions are listed, the extra beam is for RASS however this is also vertical. The convention in the netCDF files is that beam 0 is for RASS, while the other beams are for wind measurements. In the ascii files beams 1, 2, & 3 are the wind measurement beams and the RASS beam is labeled with the letter "R".

Other files from the sodar that are available on request are:

- 10 minute average ascii files
- Raw moment data ascii files
- Plots of the data

Performance and Comparison with ISFS Tower

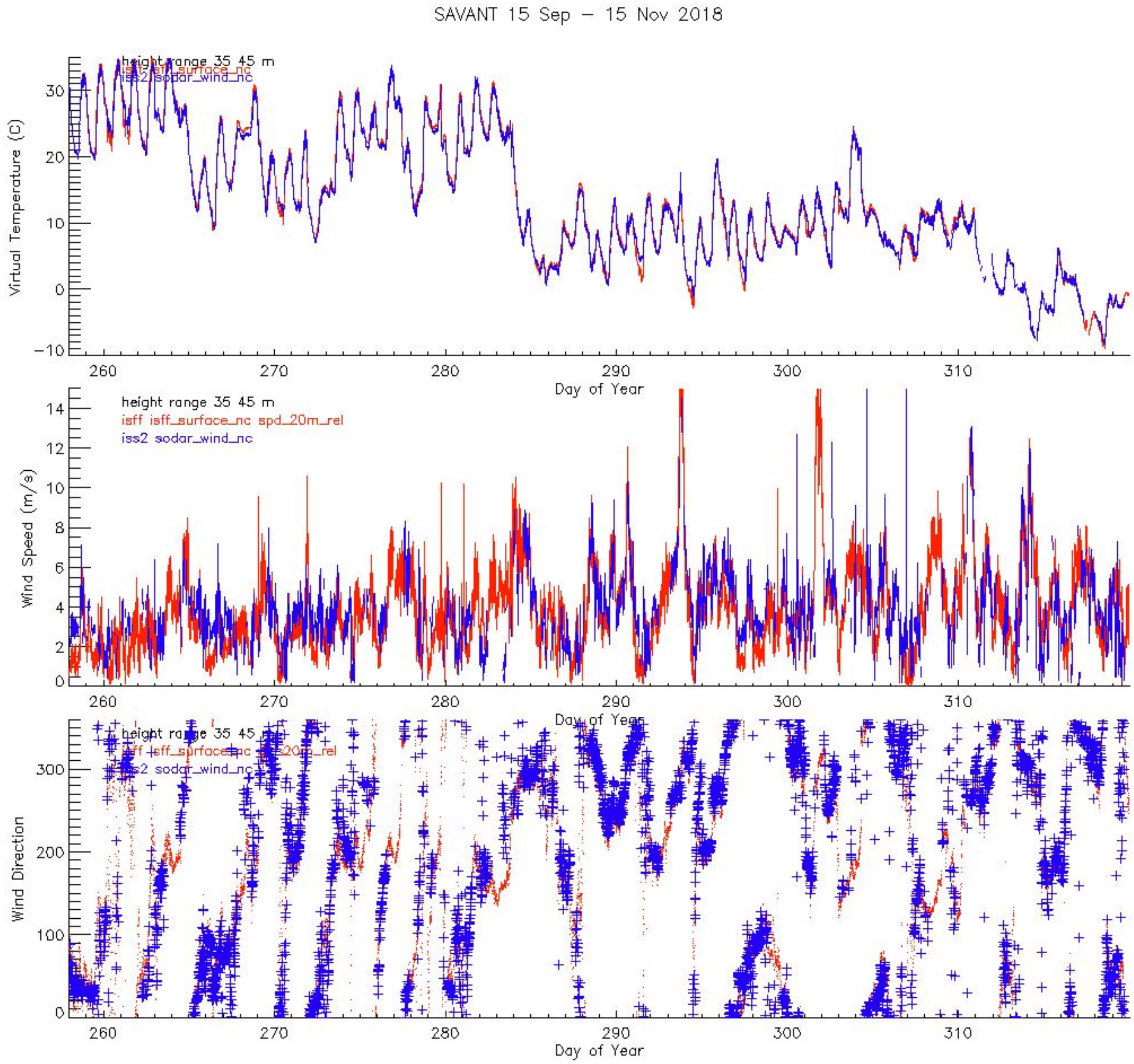

Figure 2: Comparing the sodar-RASS (blue) at the 40 m level and the ISFS tower (red) at the 20 m level. Time series plot of virtual temperature (top panel), wind speeds (middle panel) and wind directions (bottom panel).

The sodar was located approximately 420 meters from a 20-meter meteorological tower, the ISFS "Release" tower (Figure 1). Figures 2 and 3 compare measurements from the highest level of the tower (20 meters) with the lowest range gate of the sodar. These comparisons were made using the SNR >=3 dB and IPlausibility <= 2 filtering discussed above. Overall, considering the separation horizontally, and particularly in the vertical, the measurements agreed well. The virtual temperatures in particular agree very well, with a standard deviation of 0.75C. The winds agreed somewhat less well, with standard deviations in speed and direction being 1.26 m/s and 16° respectively. Similar comparisons were made with radiosonde soundings launched at the farm homestead site (4.5 km to the west), and despite the greater separation, the agreement rates were similar. As discussed in the next section, the lower agreement of winds may have been the result of a problem with some of the speakers on the sodar. Further statistics appear in Table 3.

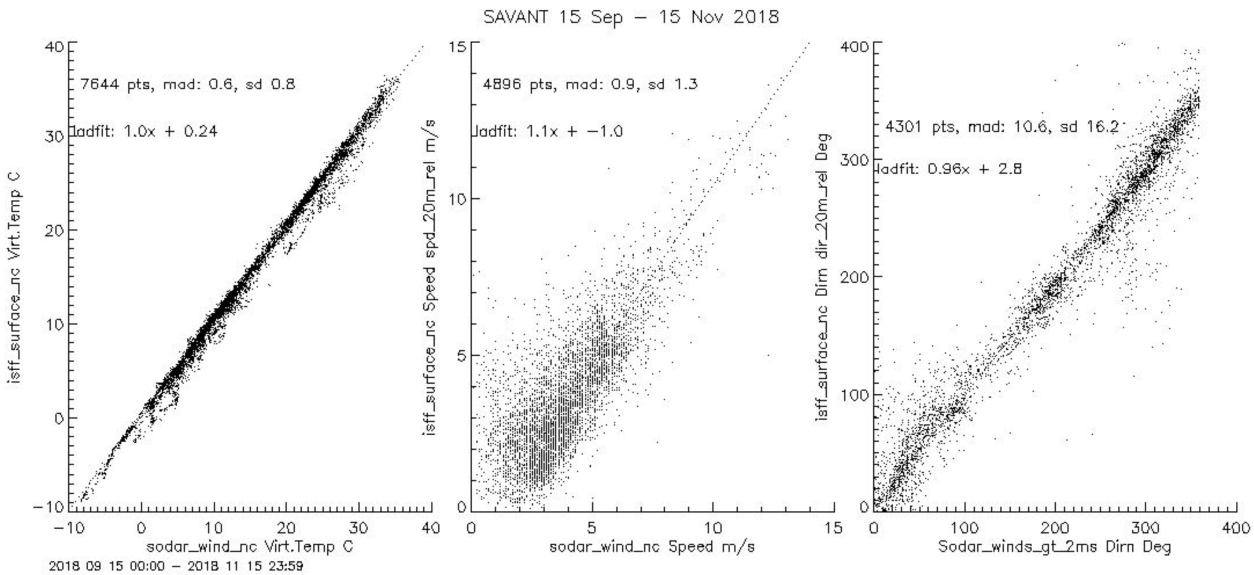

Figure 3: Scatter plots of sodar winds and virtual temperature virtual at the 40 m level compared with the ISFS release tower at the 20m level over the entire campaign.

	Median Abs Dev	***Std Deviation***	***Correlation Coef***
Wind Speed compared with tower	0.92 m/s	1.26 m/s	0.77
Wind Direction compared with tower	11°	16°	0.97
Virtual Temperature	0.57C	0.75C	0.99
Height	***50 m***	***100 m***	***150 m***
Night time (0-12Z) availability wind/TV	70% / 99%	65% / 80%	20% / 30%
Day time (12-24Z) availability wind/TV	65% / 95%	70% / 80%	40% / 50%

Table 3: Overall statistics of the sodar-RASS for the entire campaign. The upper panel shows the results of comparison of winds and virtual temperature at the 40 m level compared to the ISFS release tower at the 20 m level. The lower panel shows the availability for winds and virtual temperature at the 50m, 100m, and 150m levels. Peak availability was at the 60m level for winds (80% of the time) and 40m for virtual temperature (almost 100% of the time).

The maximum height of reliable measurement depends on many factors such as background noise, atmospheric conditions, and even the wind speed. For SAVANT, wind measurements were available 80% of the time and virtual temperature measurements were available 95% of the time at the 60 meter level.   There was a fairly rapid fall off with altitude, with winds being available 50% of the time at about 120 m and virtual temperatures being available 50% of the time at about 140 m. Coverage was generally higher during the day than at night. Further statistics on the height coverage are shown in the lower part of Table 3.

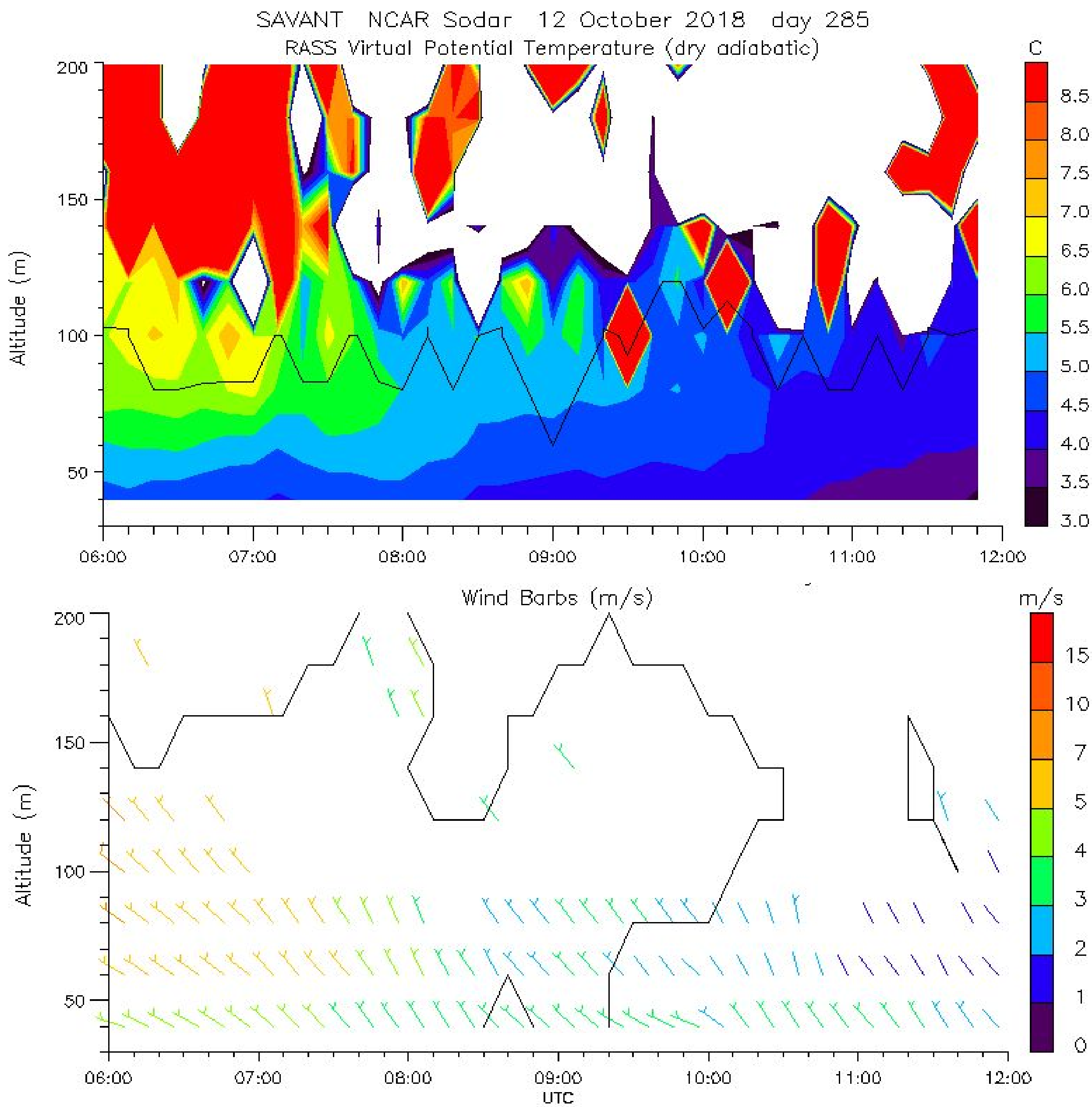

Figure 4: Sodar-RASS Virtual Potential Temperature and Wind measurements during IOP 3 at SAVANT. The contours indicate data with plausibility codes of 2 or less.

An example of the typical measurements during an IOP are shown in Figure 4. Virtual potential temperatures (q_{TV}) are shown in the upper panel and wind barbs in the lower panel. The contour lines overplotted on both panels indicate the level at which the plausibility codes are 2 or less (below about 100 meters in the upper panel; below about 150 - 200 meters and before around 10 UTC in the lower panel). Clearly the q_{TV} are less reliable at higher altitudes when the plausibility codes are greater than 2. In the case of the winds, the winds still look reasonable after 10 UTC even though the plausibility codes might indicate a problem with the data.

Known Data Issues

As seen above, the RASS virtual temperatures compared very well with both soundings and an ISFS tower. The wind measurements displayed a little less agreement which was probably related to problems discovered with the speaker system. The acoustic array consists of 24 speakers, however it was found that two of the speakers had faults and were likely damaged by nearby lightning. Unfortunately these speciality speakers (which act as transmitters and receivers) are no longer in production and could not be replaced or repaired. These problems would not have significantly affected the virtual temperature measurements, however may have contributed to some distortion in the wind measurements.

The altitude coverage range is very low on some nights, particularly later in the project when temperatures cooled and turbulence was very low (eg, Figure 4). For those cases the user might relax the SNR and plausibility limits to get more data as discussed above, however should be aware that uncertainties in the measurements may become more apparent.

References

[1] SAVANT
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Data Archive: https://data.eol.ucar.edu/master_lists/generated/savant/
Field Catalog: http://catalog.eol.ucar.edu/savant

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[4] NetCDF: UCAR/Unidata netcdf web site:
http://www.unidata.ucar.edu/content/software/netcdf/

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