GRAINEX Radar Wind Profiler Report

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OVERVIEW

This document describes NCAR/EOL wind profiler data for the GRAINEX 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 W.O.J. Brown, (2021): GRAINEX 2018 NCAR/EOL ISS Radar Wind Profiler Data Report.

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ISS Operations and quicklook plots: https://www.eol.ucar.edu/content/grainex-eol-iss-report ISS Homepage: https://www.eol.ucar.edu/observing_facilities/iss

If EOL wind profiler data are used for research resulting in publication, please acknowledge EOL and NSF and include the following citations in your paper similarly to the following

1. UCAR/NCAR - Earth Observing Laboratory. 2021. NCAR/EOL ISS Radar Wind Profiler - ISS2 Rogers Farm Site. Version 2.0. UCAR/NCAR - Earth Observing Laboratory. *https://doi.org/10.26023/5Z74-JHT9-JT0X* Accessed 26 Mar 2021.

2. UCAR/NCAR - Earth Observing Laboratory. 2021. NCAR/EOL ISS Radar Wind profiler ISS3 York Airport Site. Version 2.0. UCAR/NCAR - Earth Observing Laboratory. *https://doi.org/10.26023/A1T4-WXNF-3E0K* Accessed 26 Mar 2021.

INTRODUCTION

ISS deployed wind profilers at two field sites for the GRAINEX campaign [1,Rappin et.al. 2021]. The sites were at the University of Nebraska Rogers Memorial research farm east of Lincoln NE and at York Airport near York NE.

Rogers Farm ISS2 : 40.844°N 96.468°W 373m
York Airport ISS3 : 40.892°N 97.626°W 508m

The wind profilers are Vaisala LAP3000 915 MHz DBS (Doppler Beam Swinging) radar wind profilers using LapXM hardware and software. This class of wind profiler was originally developed at the NOAA Aeronomy Lab (Ecklund et al, 1990) and has undergone a series of improvements as they were developed into the commercial product (the LAP3000), initially by Radian Inc, then by Vaisala (and now Scintec) [3].

Instrument	Vaisala LAP3000	915 MHz radar wind profiler
Antenna	64 element phased array	X-plane 263°, elevation 69°
Data Collection Software	LapXM (version 2.6.1)	Produces raw files in various formats
Data Processing Software	NIMA (EOL version r7727)	Produces corrected wind and moment data files

The profilers used the standard DBS (Doppler Beam Swinging) technique to measure winds. Raw Doppler spectra data were recorded every 30 seconds in SPC files as the radar antenna was steered along five beam directions. Winds were calculated from spectral moments averaged over 30 minutes. The raw spectra and moments were saved so it is possible to reprocess the data for shorter (or longer) averaging periods, however wind estimates at periods shorter than ten minutes may have significant errors due to inhomogeneities in the wind and the widely separated sampling volumes in the oblique beams. The wind profilers were supplemented with RASS (Radio Acoustic Sounding System) for estimating virtual temperatures.

The radar is controlled and raw data is recorded using Vaisala software known Lap-XM. This produces a range of files including raw spectral files in a binary format, as well as processed data such as wind profiles and Doppler moments in netcdf and ascii formats. For GRAINEX the profiler was operated in low height range mode only, sampling from around the 150 meter level up to 5.5 km in approx 60 m steps. During precip, winds were available through the full sampling depth, although during clear-air conditions winds were generally available through the full depth of the boundary layer.

The wind profilers were principally operated to the two 3-week periods that made up the Intensive Operation Periods for the campaign, although there were additional measurements during the installation and test phase of the campaign. The two IOP periods were

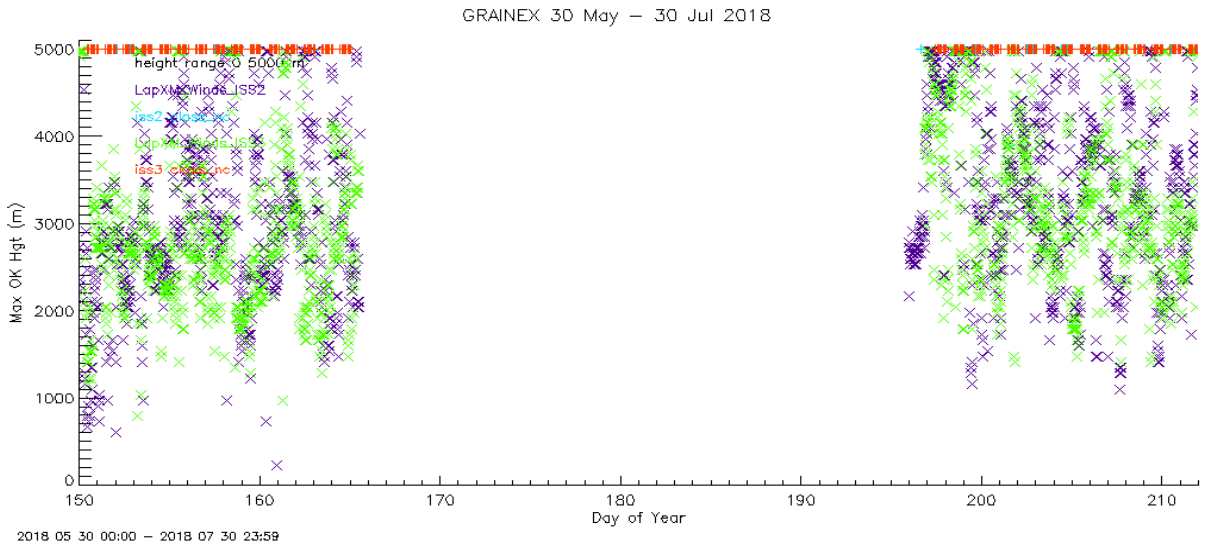
IOP1: 30 May 2018 - 13 June 2018
IOP2: 16 July 2018 - 30 July 2018

PROCESSING:

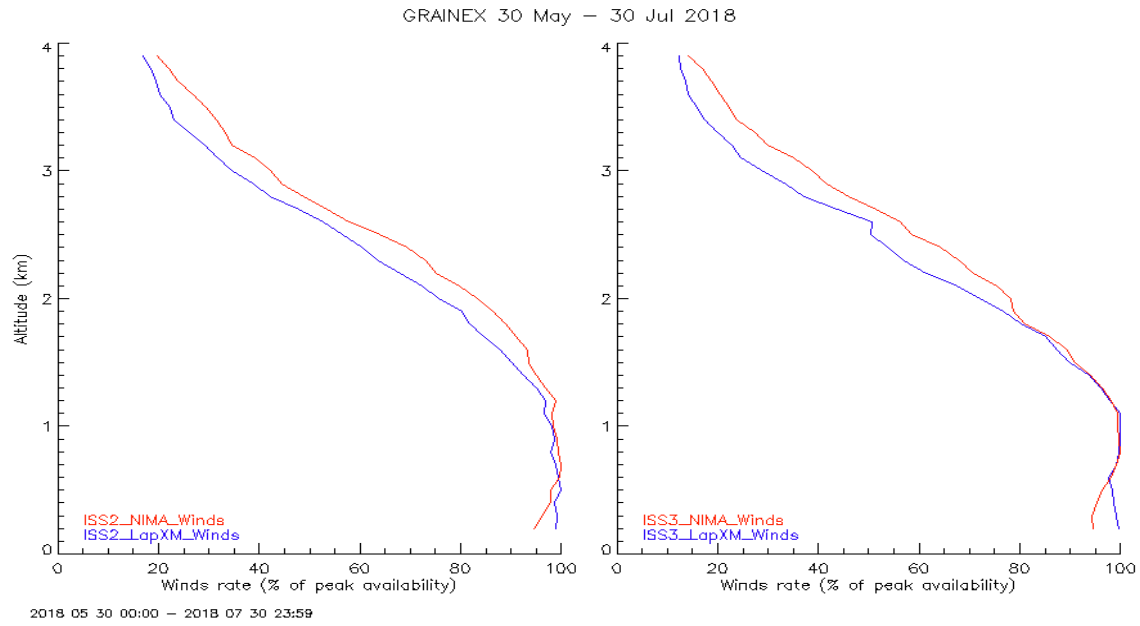
The GRAINEX profilers used Vaisala LapXM data systems with LapXM software version 2.6.1. This software applies a number of algorithms to process the data including wavelet and Gabor filtering of the raw IQ time series data. Spectral moments are estimated with a multiple peak picking algorithm and used to determine consensus averaged winds, which are filtered using the Weber Wuertz algorithm [3][Bianco et. al. 2013].

The LapXM spectral data was reprocessed using the NCAR/RAL NIMA (NCAR Improved Moments Algorithm) [4] which uses image processing and fuzzy logic techniques to analyze the spectral data and separate atmospheric echoes from unwanted signals such as radio interference and clutter. NIMA enables recovery of winds in weak or noisy data, for example typically extending the range 100 to 300 meters. NIMA also unwraps Doppler velocities that exceed Nyquist aliasing limits, for example during hail or very high winds. The version of NIMA used is EOL version r7727, which is based on RAL version 2.8.

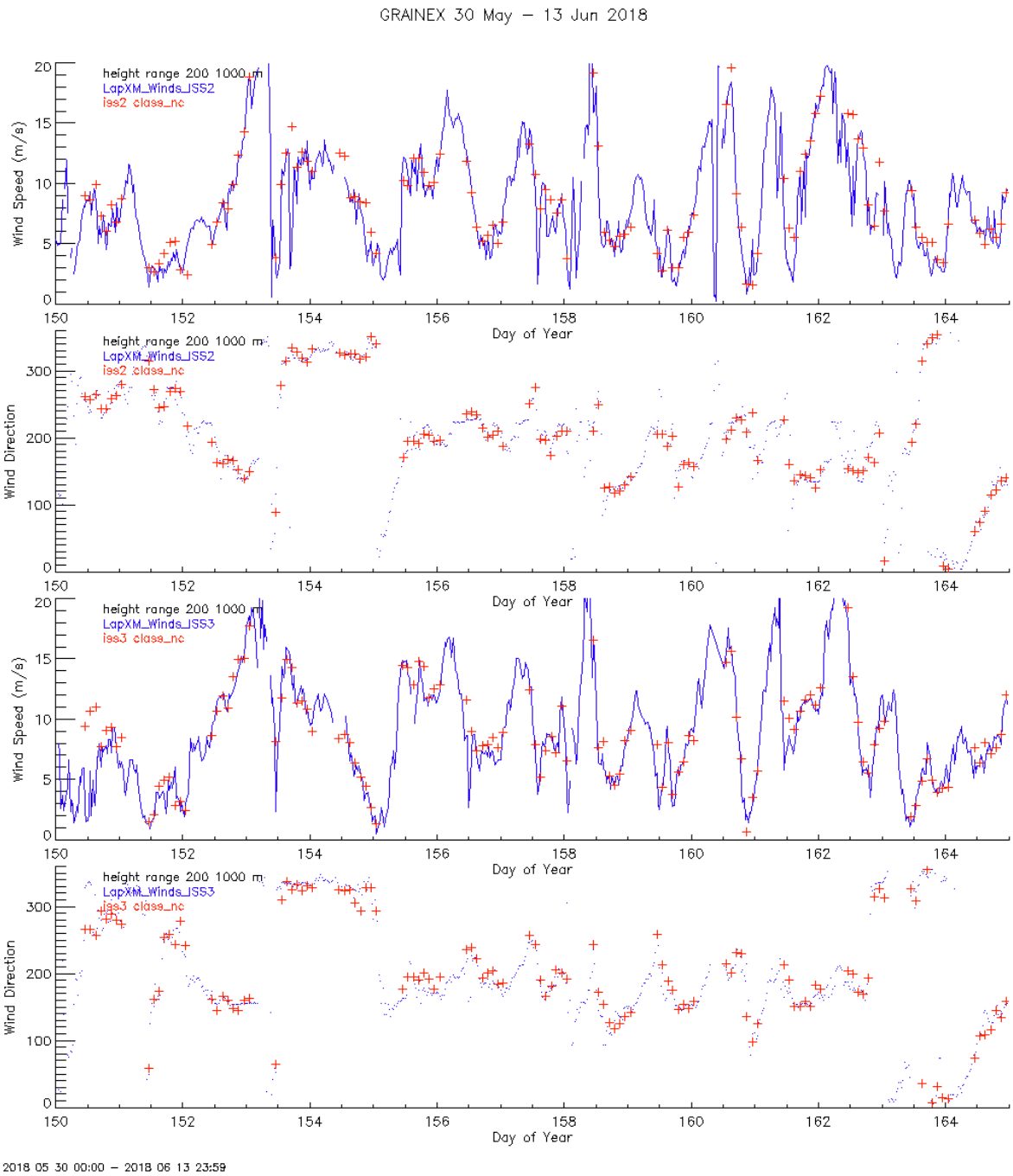
DATA NOTES:



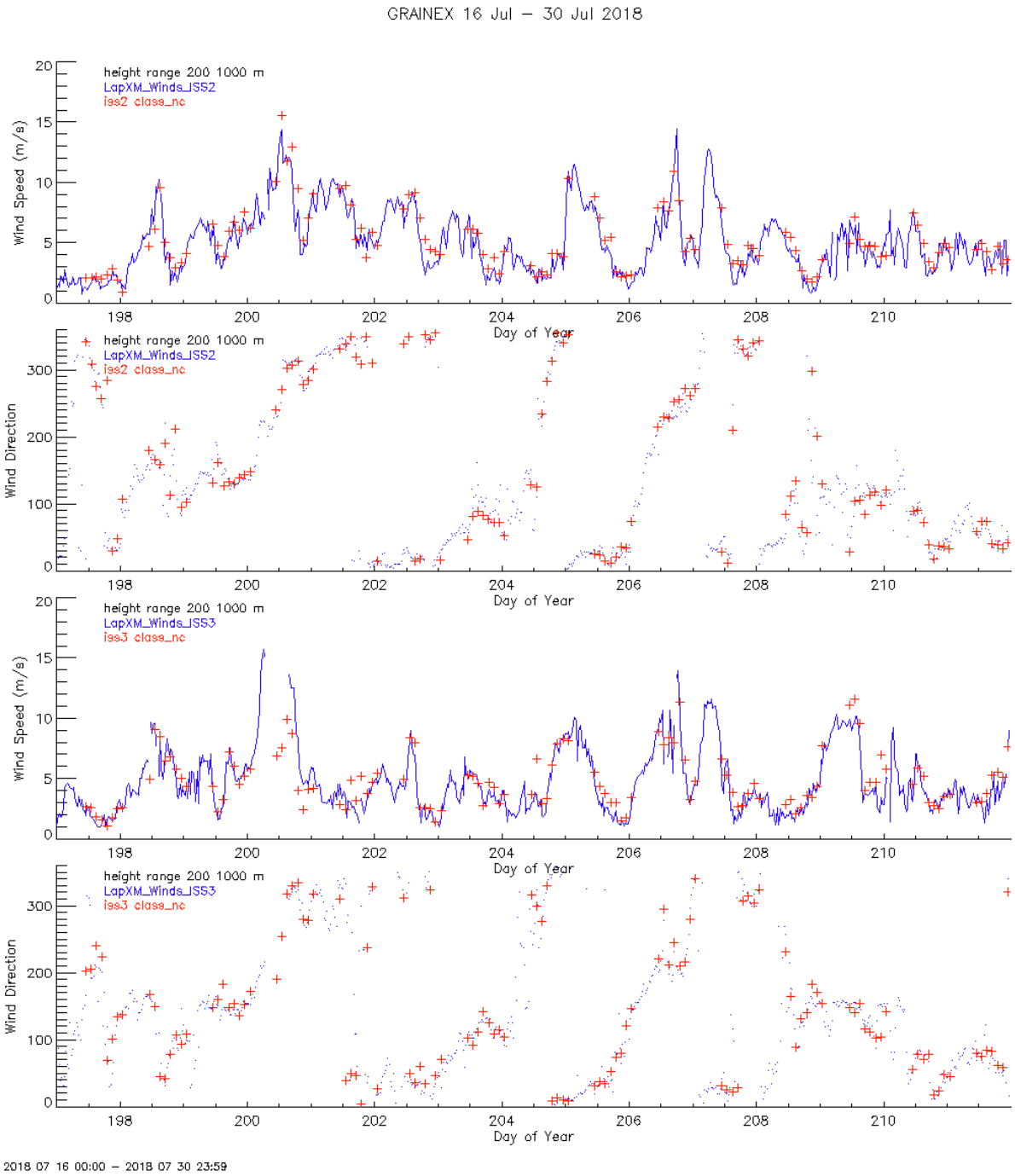
Wind availability in terms of max height coverage from the profilers (crosses - green for York ISS3 and blue for Lincoln ISS2) during the two IOP periods. The max coverage is slightly higher at the Lincoln site (median 3.1km) compared with the York site (median 2.9km). Max coverage is also a little higher for the second IOP. The red pluses indicate soundings.



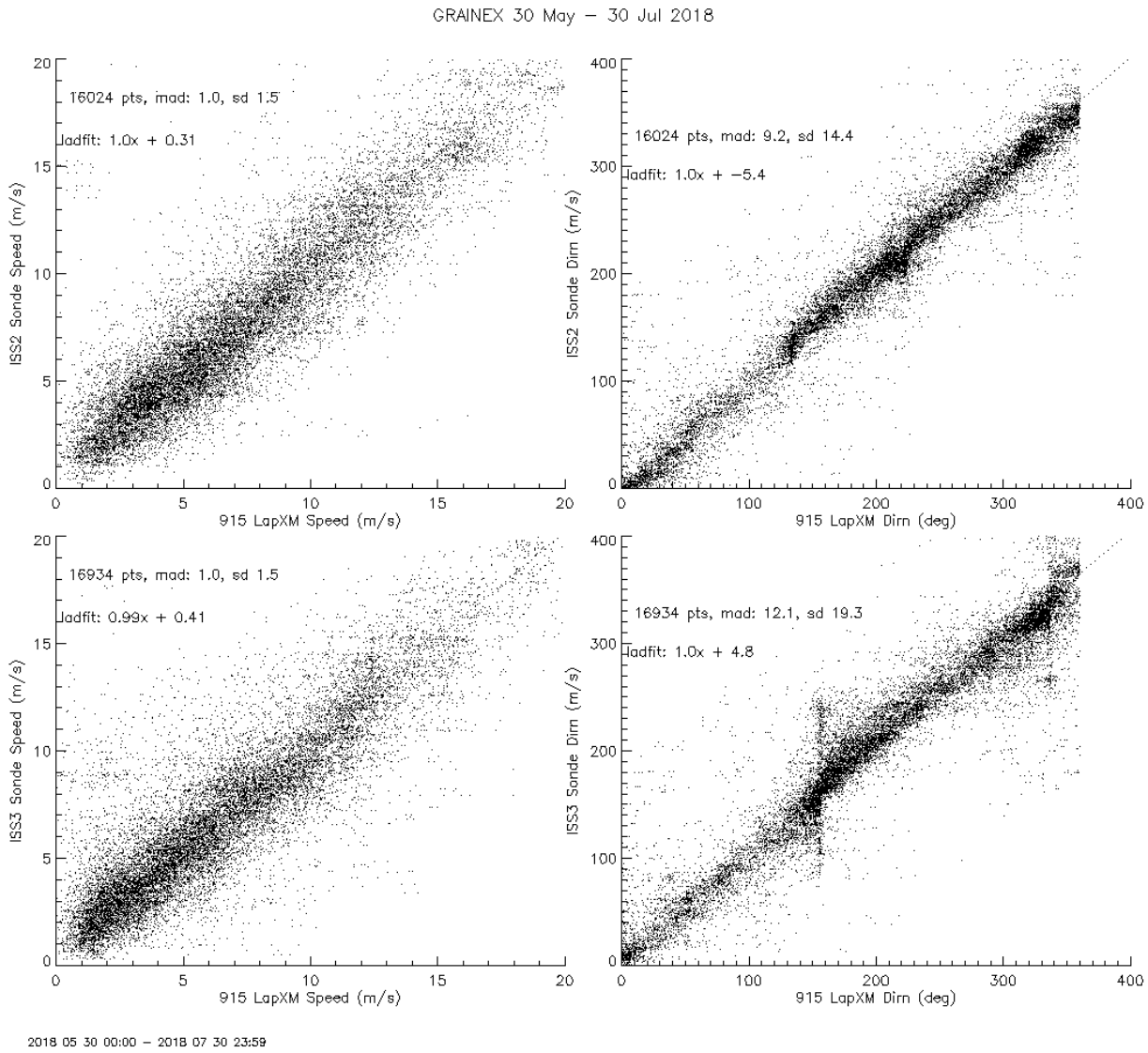
Winds height coverage profiles for the whole project, showing LapXM (blue) and NIMA (red). NIMA returns approximately an extra 200m at the 75% level (about 2.2 km for NIMA, 2.0 km for LapXM) at both sites. These profiles are normalized so don't reveal gaps in time.



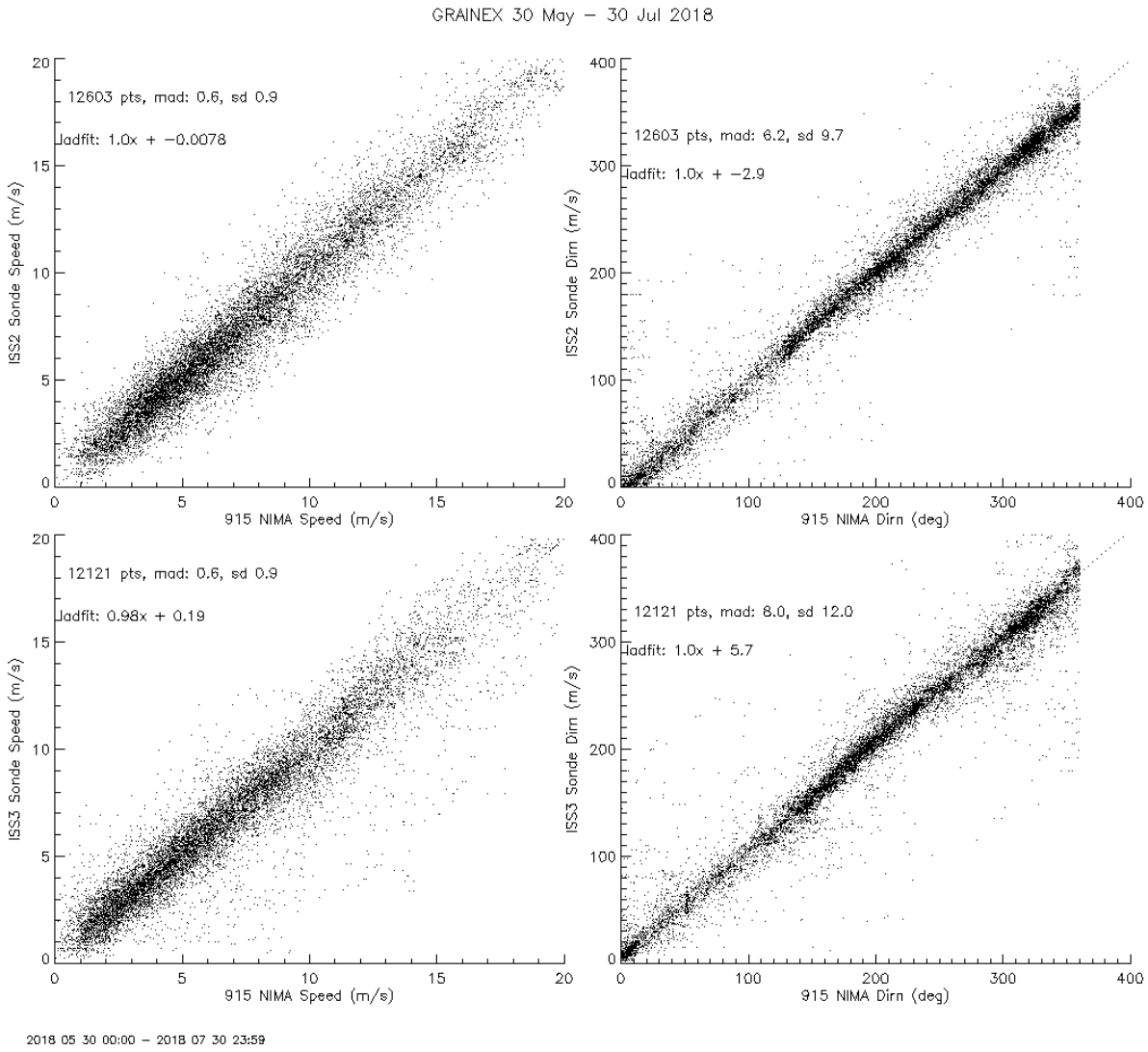
IOP #1 winds for both sites (averaged from 200m to 1km). Good agreement overall between soundings (red) and profiler winds (blue). Winds were slightly stronger at ISS3 (York, median 8.3 m/s) compared with ISS2 (Lincoln, median 7.8 m/s).



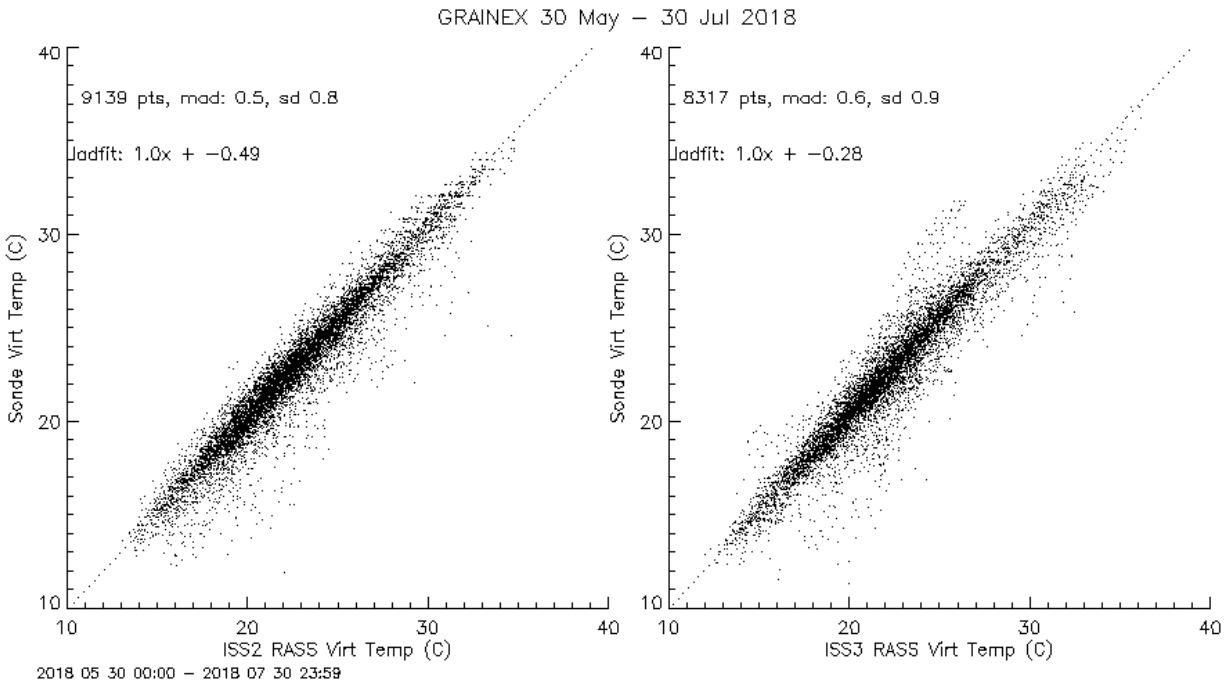
Winds for IOP #2. Again good agreement. This time median winds were a little stronger at ISS2 (Lincoln) 4.7 m/s compared with ISS3 (York) 4.4 m/s. Also note that these winds are considerably lighter than during IOP #1.



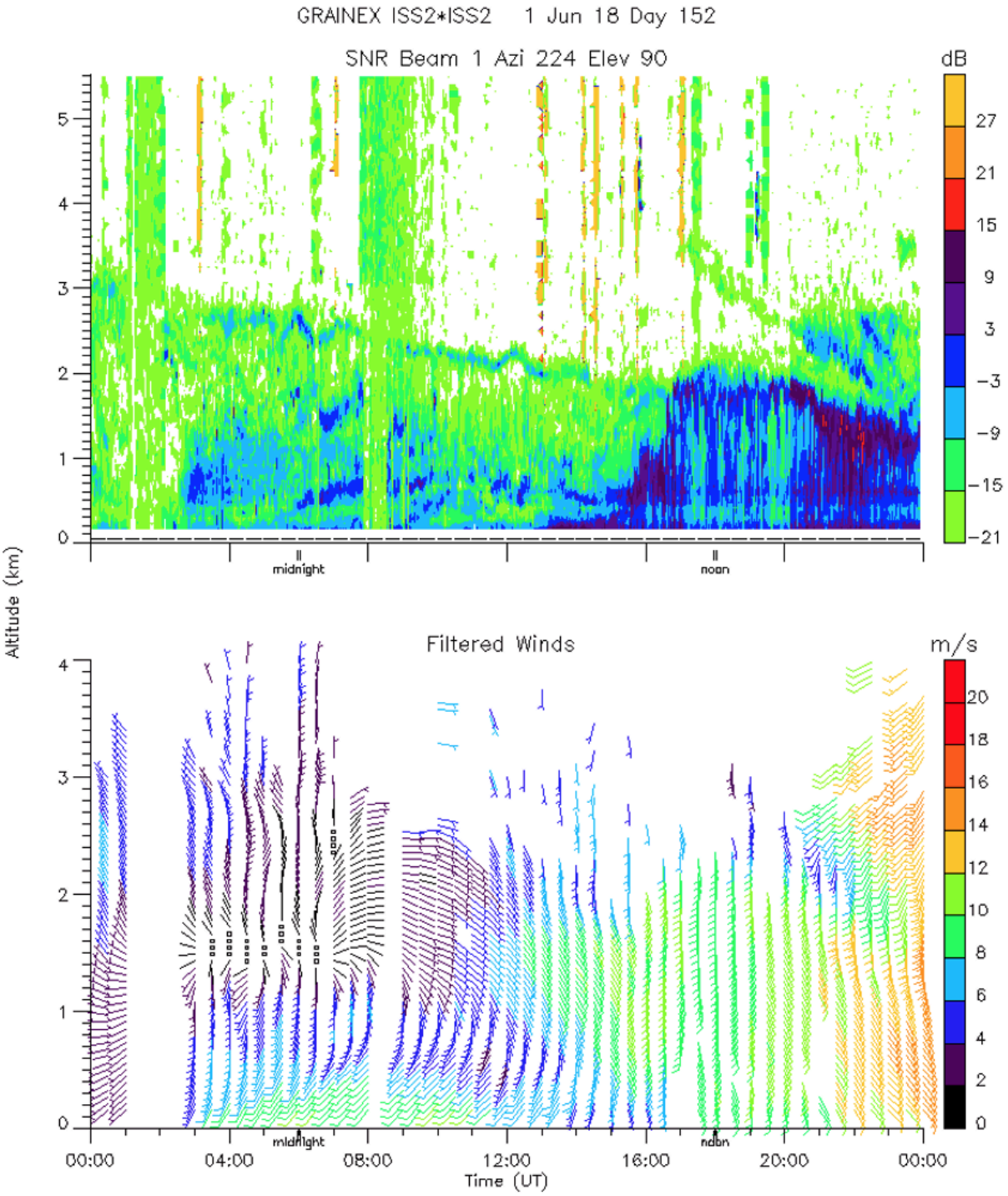
Profiler LapXM winds verses soundings for both sites and both IOPs for each height bin (instead of being averaged). Good agreement, although the ISS3 profiler wind directions have an artifact, particularly near the southerly direction. Ground clutter is suspected to play a role in this artifact.



NIMA winds verses soundings. The NIMA winds show better agreement for both speed and direction, and seem to have removed the directional artifacts at ISS3. Note that there were are fewer points however, so the NIMA processing has also filtered out some data. The median absolute deviation between the profilers and soundings was about 0.6 m/s in speed and 7 degrees in direction.

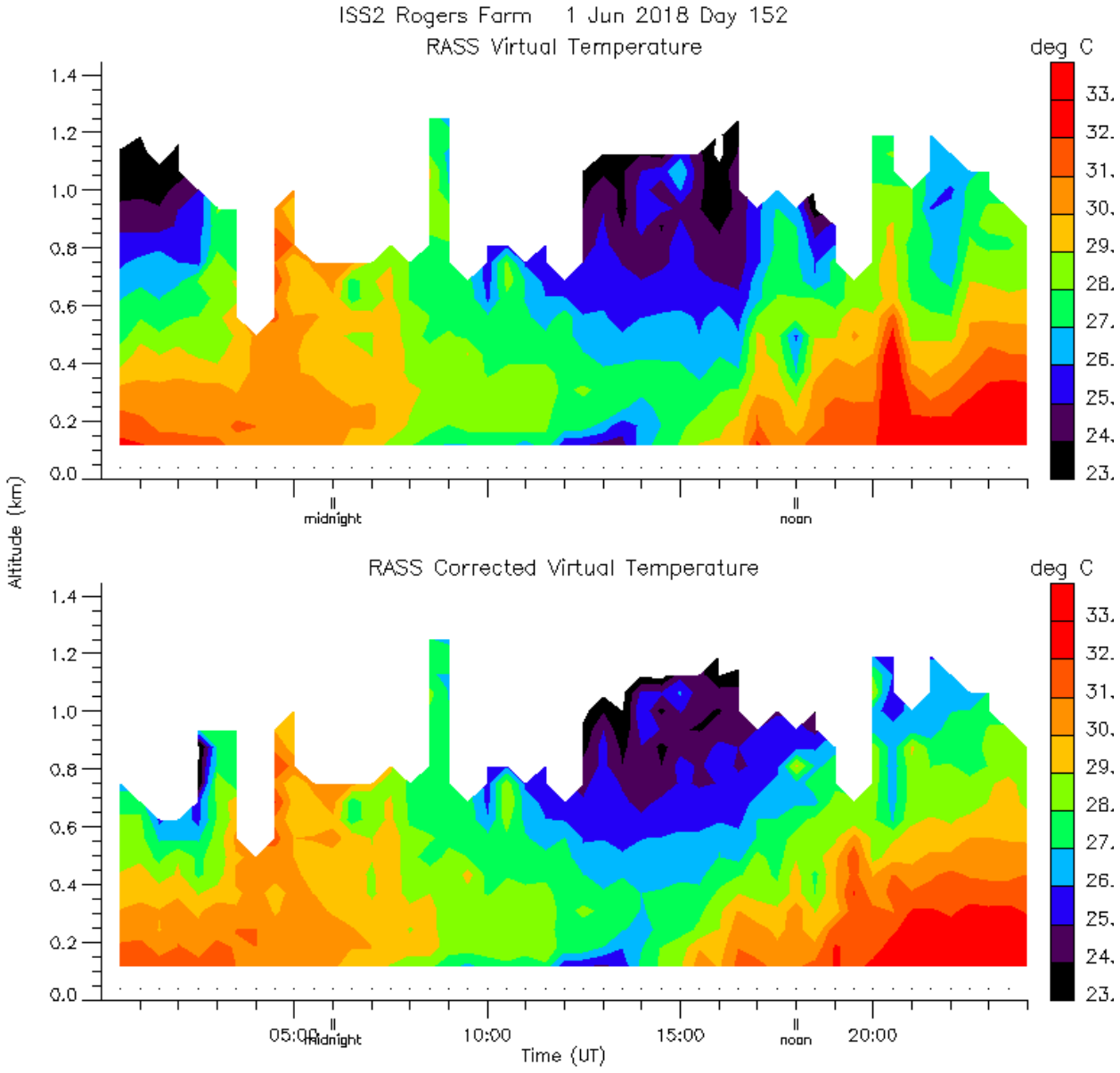


Comparison of RASS virtual temperatures from NIMA processing and from the soundings. The median absolute deviation is around 0.6 C and the standard deviation is around 0.9 C.



Data example from the Rogers Farm site for the UTC day of 1 June 2018. The upper panel shows Signal to Noise Ratio (SNR) which is a good indicator of the reflectivity of the atmosphere. The lower panel shows 30-minutes winds as determined using NIMA processing. This day is a typical clear-air day with a strong daytime planetary boundary layer which can be seen in the enhanced SNR growing from low levels about 16 UTC up to about the 2 km level around by about 18 UTC, then dying off in the late afternoon and evening. During the previous

night, residual layers and perhaps nighttime inversions can be seen in the multiple layers in the SNR plot.



RASS virtual temperature measurements for the same day. Daytime boundary layer heating can be seen from about 16 UTC, although the RASS range does not extend the full depth of the boundary layer beyond mid-morning. A slight inversion can be seen after midnight at the 200 - 300 meter level.

DATA FILES:

The wind profiler data set in the EOL GRAINEX data archive comprises NIMA processed data files in netCDF format [5]. There are two types of data file, wind measurements (files with extension *.winds_LO*.nc) and spectral moments data (extension *.mom.nc). The moments data are the zeroth, first, and second moments of signals from each 30 second dwell of the steered beam. These moments are the signal strength (here SNR or Signal to Noise Ratio which can be used to estimate reflectivity), Doppler shift (from which the winds are derived), and spectral width (can be used to estimate turbulence with lots of caveats). We generally recommend that only experienced profiler users analyze the moment data.

The data is arranged in time, height coordinates. For winds (in the *.winds_LO.nc files) use variables wspd and wdir (wdir follows the meteorological convention, ie: the direction the wind comes from, measured clockwise in degrees from north). There is a confidence variable (eg, wind_conf), which describes the degree of confidence (0-1) that the NIMA algorithm places in the derived data. These variables have the same dimension as the wind data. The moments files have similar confidence variables. Use only those data points for which corresponding confidence level exceeds the threshold confidence level. Usually we use a threshold confidence level of 0.5.

Other data files for the wind profilers are available on request. These include the raw SPC spectral files, LapXM moments (netCDF), LapXM winds in POP (ascii) and netCDF formants, boundary layer depth estimates, and NIMA reprocessed spectral files (netCDF format). A range of plots are also available in addition to the plots on the project web page [1].

References:

[1] GRAINEX Campaign:

Rappin, E., Mahmood, R., Nair, U., Pielke, R. A., Sr., Brown, W., Oncley, S., Wurman, J., Kosiba, K., Kaulfus, A., Phillips, C., Lachenmeier, E., Santanello, J., Jr., Kim, E., & Lawston-Parker, P. (2021). "The Great Plains Irrigation Experiment (GRAINEX)", *Bulletin of the American Meteorological Society,* 102(9), E1756-E1785. https://journals.ametsoc.org/view/journals/bams/102/9/BAMS-D-20-0041.1.xml

Webpage: https://www.eol.ucar.edu/field_projects/grainex
Data archive: https://data.eol.ucar.edu/master_lists/generated/grainex/
Wind Profiler data DOIs
ISS2 site: *https://doi.org/10.26023/5Z74-JHT9-JT0X*
ISS3 site: *https://doi.org/10.26023/A1T4-WXNF-3E0K*

[2] ISS Integrated Sounding System

Website:https://www.eol.ucar.edu/observing_facilities/iss
DOI: http://dx.doi.org/10.5065/D6348HF9

Reference: Parsons, D., W. Dabberdt, H. Cole, T. Hock, C. Martin, A-L. Barrett, E. Miller, M. Spowart, M. Howard, W. Ecklund, D. Carter, K. Gage and J. Wilson, 1994: "The Integrated Sounding System: Description and preliminary observations from TOGA COARE". *Bull. Amer. Meteor. Soc.,* 75, 553–567, doi:10.1175/1520-0477(1994)075.

[3] Profiler: LAP3000 915 MHz Radar Wind Profiler:

Original reference: Ecklund, W. L., Carter, D. A., Balsley, B. B., Currier, P. E., Green, J. L., Weber, B. L., and Gage, K. S., 1990: "Field tests of a lower tropospheric wind profiler", *Radio Sci.*, 25, 899–906. doi: 10.1029/RS025i005p00899

LapXM processing reference: Bianco, L., D. Gottas, and J.M. Wilczak, 2013: Implementation of a Gabor Transform Data Quality-Control Algorithm for UHF Wind Profiling Radars. *J. Atmos. Oceanic Technol.,* **30**, 2697–2703, doi:10.1175/JTECH-D-13-00089.1

Current manufacturer web site:
http://www.scintec.com/english/Web/scintec/Products/LAP%20Radars.aspx

[4] NIMA (NCAR Improved Moment Algorithm):

Website: http://www.ral.ucar.edu/technology/profiler/

Cornman, L. B., R. K. Goodrich, C. S. Morse, and W. L. Ecklund, 1998: A fuzzy logic method for improved moment estimation from Doppler spectra. J. Atmos. Oceanic Technol., 15, 1287–1305. DOI:10.1175/1520-0426(1998)015<1287:AFLMFI>2.0.CO;2
Goodrich, R. K., C. S. Morse, L. B. Cornman, and S. A. Cohn, 2002: A horizontal wind and wind confidence algorithm for Doppler wind profilers. J. Atmos. Oceanic Technol., 19, 257–273. DOI: 10.1175/1520-0426-19.3.257
Morse, C. S., R. K. Goodrick, and L. B. Cornman, 2002: The NIMA method for improved moment estimation from Doppler spectra, J. Atmos. Ocean. Technol., 19, 274-295. DOI: 10.1175/1520-0426-19.3.274

Software: NIMA 2.8 EOL version r7727 subversion repository available at:
http://svn.eol.ucar.edu/svn/iss/nima/branches/nima2

[5] NetCDF:

UCAR/Unidata netcdf web site: http://www.unidata.ucar.edu/content/software/netcdf/