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GRAINEX 2018
Radiosonde Data Quality Report

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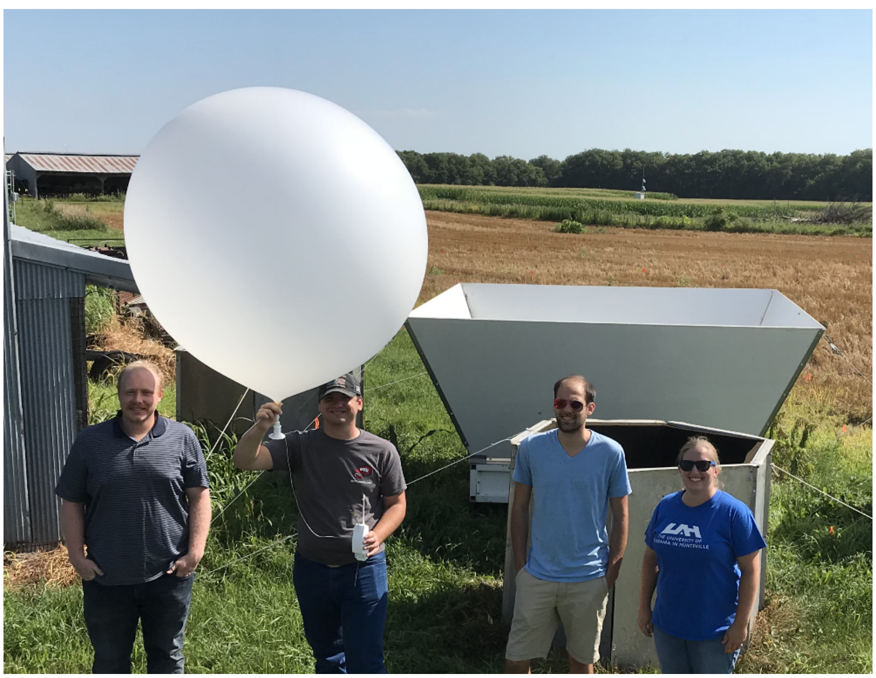

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The radiosonde data for this project were quality controlled and are maintained by the Earth Observing Laboratory at the National Center for Atmospheric Research (NCAR). The National Center for Atmospheric Research is managed by the University Corporation for Atmospheric Research and sponsored by the National Science Foundation.

If these radiosonde data or any information or plots from this document are used for publication or presentation purposes, please provide appropriate acknowledgement to NCAR/EOL and NSF and refer to the citations listed below. Please feel free to contact the authors for further information.

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Integrated sounding system home page: https://www.eol.ucar.edu/content/grainex-iss

To refer to these datasets or report, please include the following citations:

UCAR/NCAR -Earth Observing Laboratory. 2018. NCAR/EOL Quality Controlled Radiosonde Data - ISS2 Rogers Farm Site. Version 1.0. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.5065/D6WH2NV0. Accessed 06 Dec 2018.

UCAR/NCAR -Earth Observing Laboratory. 2018. NCAR/EOL Quality Controlled Radiosonde Data - ISS3 York Site. Version 1.0. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.5065/D6RR1X4P. Accessed 06 Dec 2018.

Document Version Control

Version	Date	Author	Change Description
1.0	3 Dec 2018	H. Vömel	Initial Data Release

1 Table of Contents

2 Dataset Overview

The Great Plains Irrigation Experiment (GRAINEX) investigates the impacts of rapid commencement irrigation and subsequent sustained irrigation on the evolution of the planetary boundary layer atmosphere in the Central Great Plains, specifically in Nebraska. This document describes the quality of the data obtained from the radiosonde launches at the two ISS locations at the York Municipal Airport and at the University of Nebraska Rogers Memorial Farm. At York Municipal Airport (ISS3), 240 successful radiosondes, and at Rogers Farm (ISS2) near Lincoln, NE, 243 successful radiosondes were launched during the campaign. Soundings were launched in two intensive periods from 30 May to 13 June 2018 and from 16 July to 30 July 2018. At both sites, soundings were launched in 2-hour intervals starting at 06:00 local time with the last launch at 20:00 local time. This schedule provided 8 soundings every day at each site for the duration of each intensive campaign.

Figure 1 shows the flight tracks of the ascending part of all soundings at both locations. The soundings at York (ISS3) are shown in green and those at Rogers Farm (ISS2) are shown in red. The distance between the two ISS sites is approximately 98 km.

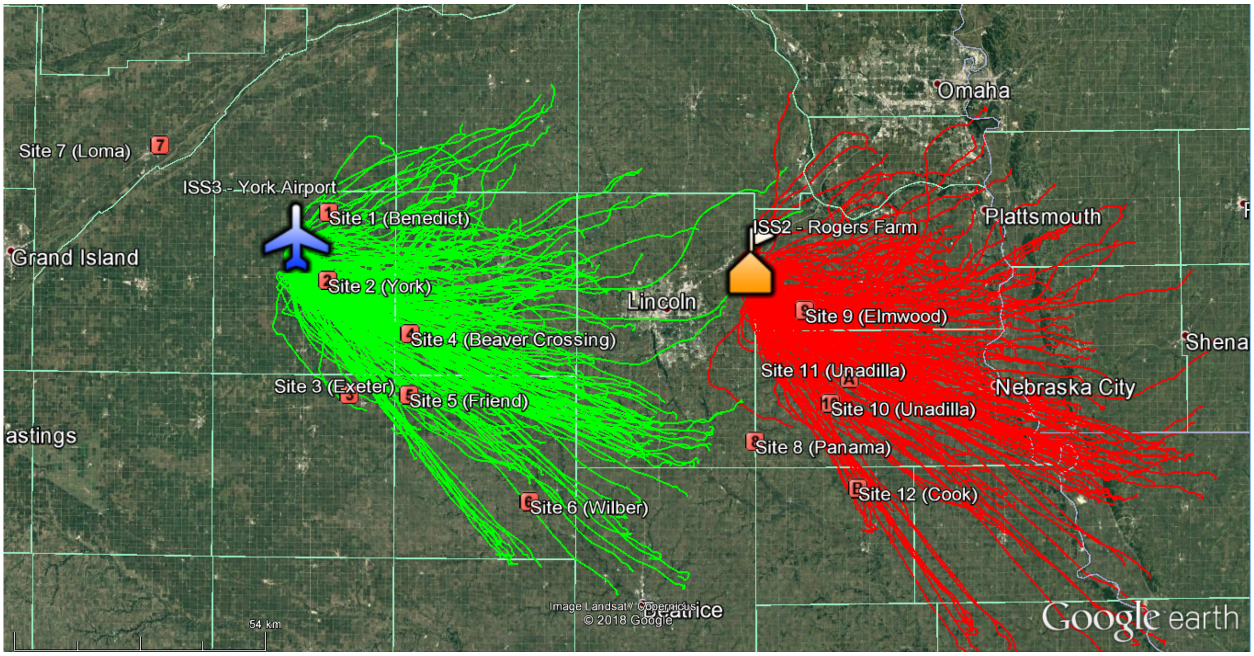

Figure 1: Location of the ISF sites during GRAINEX and flight tracks of all ascending radiosonde profiles. The sounding locations were at the municipal airport at York (ISS3) and at Rogers Farm (ISS2). The masts of the Integrated Surface Flux System (ISFS, red squares) are shown for reference.

3 Radiosonde sounding system

This campaign used Vaisala RS41-SGP radiosondes, which were received and processed by the Vaisala MW41 sounding system using software version 2.5.0. The radiosondes used by NCAR/EOL include a pressure sensor, which provides a better altitude and pressure determination in the boundary layer and is more suitable for unstable conditions in convective environments. The sounding system was configured to meet the needs of NCAR for high-resolution data and complete metadata description. All sondes were launched using 100 g balloons supplied by Scientific Sales.

The MWX raw data files from the sounding system were saved along with the ASCII output files, which contained the initially processed profiles.

High-resolution BUFR messages and low-resolution TEMP messages were transmitted to the WMO Global Telecommunication System (GTS) in real time to provide operational data for weather prediction by the international weather forecasting centers.

Data for many, but not all soundings were recorded also on descent; however, these data are not analyzed or archived and can be made available only upon request.

The sounding systems automatically ingest surface reference observations, which are provided by sets of reference sensors near each launch site. These observations are stored in the surface observations metadata fields of the sounding files and used in the quality control procedures of the sounding data.

During GRAINEX, both sites used the same sounding system setup and the same set of reference sensors (Table 1).

Table 1: Surface reference observations provided by the ISS meteorological reference sensors at both ISS locations during GRAINEX.

Parameter	Location	Sensor
Pressure	The reference pressure was installed on a mast at 3 m height near the launch site.	Vaisala PTB210
Temperature, humidity, and wind	The reference sensors for temperature, humidity, wind speed, and wind direction were installed on a mast at 3 m height near the launch site.	Lufft WS700 (ISS2) Lufft WS800 (ISS3)

4 Quality control procedures

4.1 Standard quality control

The Vaisala system performs a sequence of standard quality control procedures and corrections for all radiosonde data:

- Applies a ground check correction for pressure using the pressure correction measured during the sonde preparation to compensate for small biases inherent in this type of pressure sensor.
- Performs a coarse outlier check for all measurement parameters
- Automatically detects launch based on change in pressure
- Performs a radiation correction for the temperature measurement using the radiation correction lookup table for the Vaisala RS41 radiosonde
- Corrects for response time lag of the temperature sensor
- Smooths the temperature profile
- Corrects for response time lag of the humidity sensor
- Filters out the balloon pendulum effect in the calculation of winds
- Calculates geopotential altitude based on the measured pressure profile

4.2 Custom quality control

In addition to the standard Vaisala procedures, all metadata are verified, and all measured parameters including reference measurements are checked for consistency and for any previously unidentified issue. The radiosonde measurements before launch are compared against the reference measurements and the causes for early termination are investigated. In the GRAINEX data set, the following issues were identified and corrected:

a. At York (ISS3), the data acquisition of the reference sensors was not operational between 19 and 20 July. For this period, the reference observations for temperature, humidity and winds was taken from the station of the National Weather Service (NWS), which was located near the launch site. The comparison of the NWS data with the ISF surface reference data for the entire campaign shows good agreement without noticeable bias. Therefore, the reference observations for these two days are considered equivalent. The original reference pressure readings had been incorrectly adjusted to sea level pressure, which was corrected.

b. The sounding systems incorrectly detected launch with a difference of more than 3 s in eighteen soundings. The largest difference from true launch was 19 s. In five cases, launch was detected late. The missing data were recovered from raw data. In the other 13 cases, launch was detected early. The superfluous surface data were removed from the profiles.

c. The sounding system ISS3 at the York municipal airport was configured with a slightly higher altitude of 513 m. This was changed to the correct value of 508 m.

d. The sounding 20180717_165816 at Rogers Farm (ISS2) encountered several periods, where the balloon descended inside a cloud (see below). Relative humidity readings during parts of this sounding phase were erratic, possibly due to missing ventilation or other environmental factors. These readings were set to missing. The humidity sensor returned to normal once the balloon exited this part of the cloud.

e. The sounding 20180611_230014 at Rogers Farm (ISS2) encountered very strong updrafts inside a cloud (see below). The measured temperature inside this updraft is significantly warmer than the surrounding air and may be incorrect. The measured relative humidity values may be at the edge of what is physically possible. These data have not been flagged, but should be treated with caution, since the environmental conditions were extreme for a typical radiosonde and artifacts due to severe icing of the temperature sensor may be possible. Data up to 3.3 km are considered reliable.

In six soundings, no launch was detected and the operators proceeded to relaunch a second sonde. This issue caused minor delays in the otherwise regular schedule.

The final quality controlled data are provided in NetCDF format following the CF-1.6 metadata convention for climate and forecasting. For a detailed description of the data format, refer to Vömel et al., 2018, https://doi.org/10.5065/D65X27SR.

5 Sounding metrics

At both sites, soundings were launched in 2-hour intervals starting at 06:00 local time with the last launch at 20:00 local time. This schedule provided eight soundings every day at each site for the duration of each intensive campaign.

At each site, 239 successful soundings were launched during the two intensive observation periods. As part of staff training, four additional sondes were launched at Rogers Farm (ISS2) and one additional sonde at York (ISS3). The total number of successful soundings is 483 for the entire campaign.

Radiosondes were launched under all weather conditions, including rain and strong winds. Only one scheduled launch was missed at both sites. At 11:00 UTC on 9 June 2018, the site at Rogers Farm (ISS2) reported heavy lightning activity and decided not to launch for the safety of the observers. The same launch window was missed at ISS3 due to a power outage at the access gate, which prevented the launch team to access the site. Most likely, the power outage was caused by the same storm.

Balloons at York (ISS3) were nominally filled with 23 ft^3 of helium, records at Rogers Farm (ISS2) show that balloons were filled with 24-25 ft^3 of helium. The distribution of ceiling heights is shown in Figure 2. The median ceiling height is 18.8 km at Rogers Farm (ISS2) and 18.4 km at York (ISS3). 98% of all balloons reached an altitude of at least 15 km, and the maximum altitude reached was 22.6 km. Of the 11 soundings that did not reach 15 km, five soundings terminated early due to early balloon burst, three terminated early due to a failure of the radiosonde, and three were terminated manually by the operator.

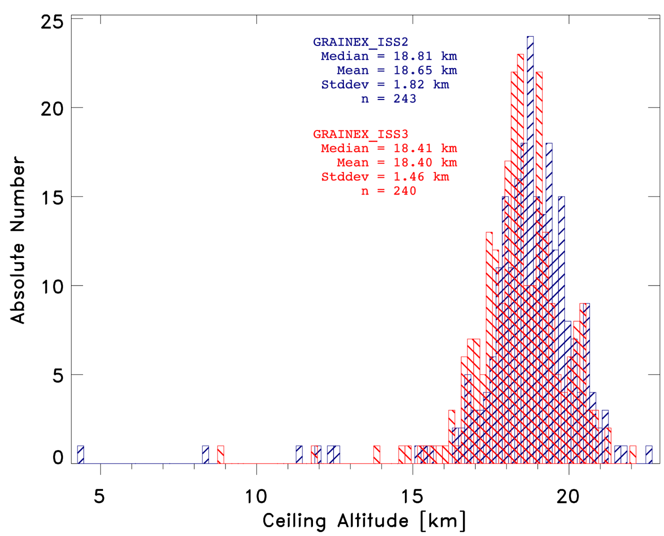

Figure 2: Distribution of ceiling heights for all radiosondes launched from Rogers Farm (ISS2 in blue) and York (ISS3 in red).

Two of the three radiosonde failures are related to storm activity and were possibly caused by environmental influences. Two soundings were terminated due to PTU sensor problems. At York (ISS3, 20180602_170118), data were lost at 8.7 km; and at Rogers Farm (ISS2, 20180612_010009), data were lost at 8.4 km. In both profiles, malfunction of the sensors is not suspected in the data, which were reported prior to termination. One sounding at York (ISS3, 20180602_210537) terminated at 11.9 km due to the loss of telemetry signal from the radiosonde.

At burst, data were received up to a distance of 130 km. The distribution of balloon distances at burst and at 1 km above ground is shown in Figure 3. The median distance at which a sounding was terminated was 56 km and the smallest distance was 15 km. At 1 km above ground, most balloons were less than 3 km away from the launch site; and half of all balloons was less than about 1.5 km from the launch site at they reached 1 km.

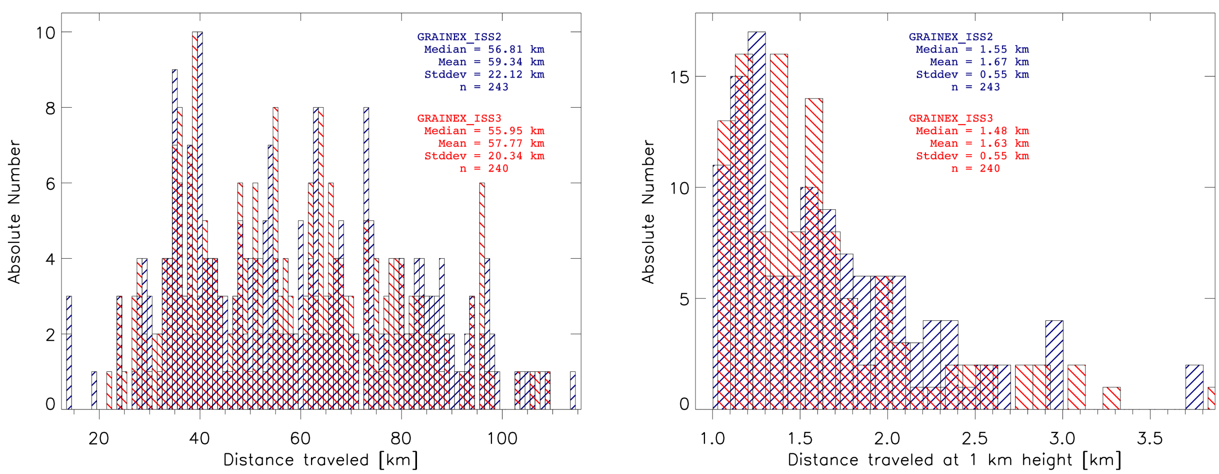

Figure 3: Distribution of balloon distance at end of data recording (left panel) and at 1 km above ground (right panel).

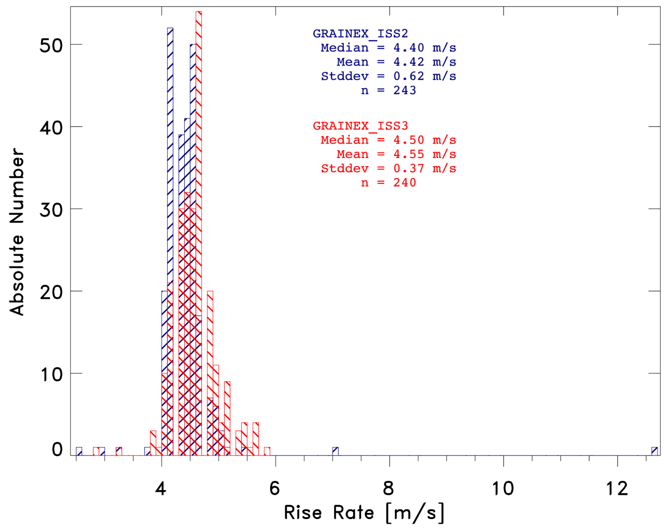

Figure 4: Distribution of rise rates for all radiosondes launched at Rogers Farm (ISS2, blue) and at York (ISS3, red).

The median rise rate over the entire profile varied typically between 2.5 m/s and 6.0 m/s with a mean value of around 4.5 m/s. The distribution of rise rates for all soundings is shown in Figure 4.

Two soundings at Rogers Farm (ISS2, 20180529_191604 and 20180611_230014) showed much faster rise rates. The sounding on 29 May showed a mean ascent rate of 7 m/s and the sounding on 11 June showed a mean ascent rate of 12.6 m/s. Both soundings were most likely caught in strong updrafts over an altitude range between 4 km and 12 km. The latter sonde showed peak updraft speeds in excess of 20 m/s. Both balloons burst prematurely at 11.4 km and 11.8 km respectively.

Three soundings at Rogers Farm (ISS2, 20180530_205744, 20180717_165816, and 20180731_005350) and two soundings at York (ISS3, 20180602_150650, 20180602_131111) rose unusually slowly with average ascent rates between 2.5 and 3.2 m/s. The two soundings at York and the May sounding at Rogers Farm may have been slightly underinflated. The two July soundings at Rogers Farm were impacted by thunderstorm activity.

The sounding on 31 July 00:53 UTC at Rogers Farm, which was also the last sounding of the campaign, encountered either a strong downdraft or heavy rain in which the balloon descended 2 km before rising again. Two additional profiles at Rogers Farm (ISS2, 20180607_110403, 20180720_185434) and one sounding at York (ISS3, 20180717_151137) descended for shorter periods in storm environments. Note that the quality-controlled soundings only contain the ascending part of the profiles, which is indicated by a gap in the continuous data between 1 and 18 min.

The sequence of all balloon rise rates (Figure 5) shows that this type of balloon rises faster in the lowest 2 to 4 km with an average rise rate of about 5.9 m/s. Therefore, the vertical resolution of measurements in the lowest troposphere is about 6 m; and between the middle troposphere and the lowest-most stratosphere, it is about 4.2 m.

Lighter colors in the middle and upper troposphere indicate soundings, which encountered faster updrafts in some layers. In some cases, these layers were observed in more than one sounding, demonstrating the extent of the vertical instability of the atmosphere in these periods. With the exception of the extreme updraft at Rogers Farm (ISS2, 20180611_230014) in no other updraft case are the radiosonde observations considered suspect.

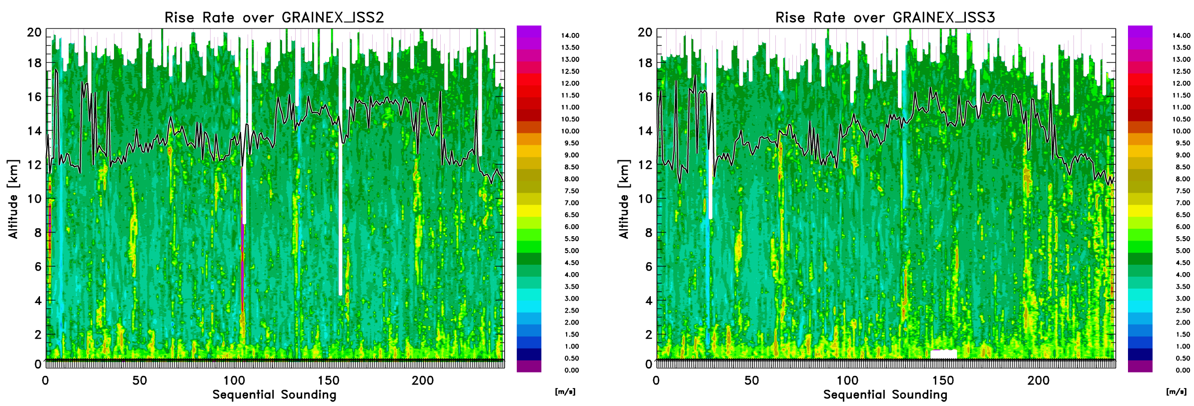

Figure 5: Sequence of rise rate profiles for all radiosondes launched at Rogers Farm (ISS2, left panel) and at York (ISS3, right panel). The tropopause is indicated as black line. Each launch is indicated by a small arrow at twhe bottom of the diagram. Both intensive periods are combined here. The break between the two periods occurs at sounding number 120.

6 Atmospheric Measurements

Air temperature and relative humidity measurements from all radiosondes are shown in Figure 6. The break between the two intensive observation periods occurs at sounding 120 in the middle of each panel. The tropopause varies between 12 and 16 km, which is typical for the summer convective season. The rapid drop of relative humidity above the tropopause (Figure 6, bottom panels) is an indication for the dryness of the stratosphere and shows that none of the humidity sensors suffered icing of the humidity sensor. As is customary, all relative humidity profiles are clipped at 100 % relative humidity over liquid.

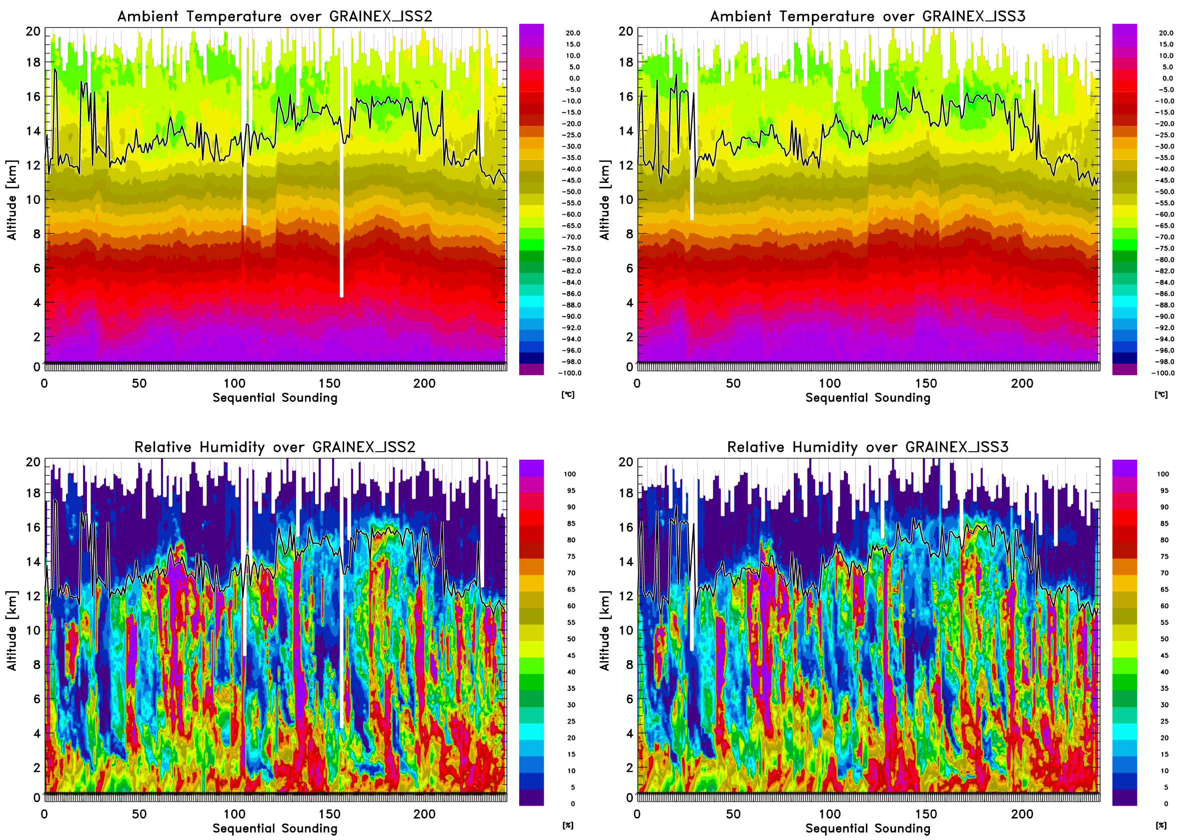

Figure 6: Sequence of temperature profiles (top) and relative humidity profiles (bottom) from all radiosondes launched at both sites. Note that the discontinuity between the two observation periods occurs at sounding number 120.

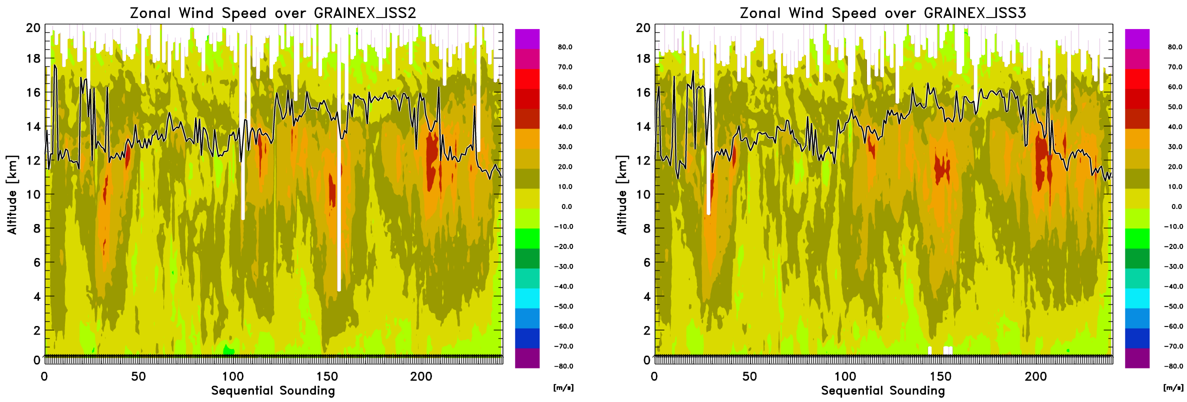

Figure 7: Sequence of zonal wind speed profiles for all radiosondes launched at Rogers Farm (ISS2, left panel) and at York (ISS3, right panel).

The zonal wind speed measurements at both sites are shown in Figure 7. The proximity of the jet stream is indicated by high wind speeds in the upper troposphere in excess of 50 m/s.

Except for the training flights, at each scheduled observation time, two radiosondes were launched nearly in parallel, one from each site. In all but one sounding, the time difference between the launches at the two sites was less than 15 min and 63% were launched within 5 min of each other. This allows a statistical comparison of the two launches.

Figure 8 shows the statistical temperature and mixing ratio difference between the two sites. These plots show the pairwise differences of soundings at the two locations launched at the same scheduled time. In both intensive periods, the temperature profile at York is warmer than that at Rogers Farm up to an altitude of about 5 km. The maximum difference is at about 2 km with a temperature difference between the two sites of about 0.5 K. Between 6 km and 12 km the

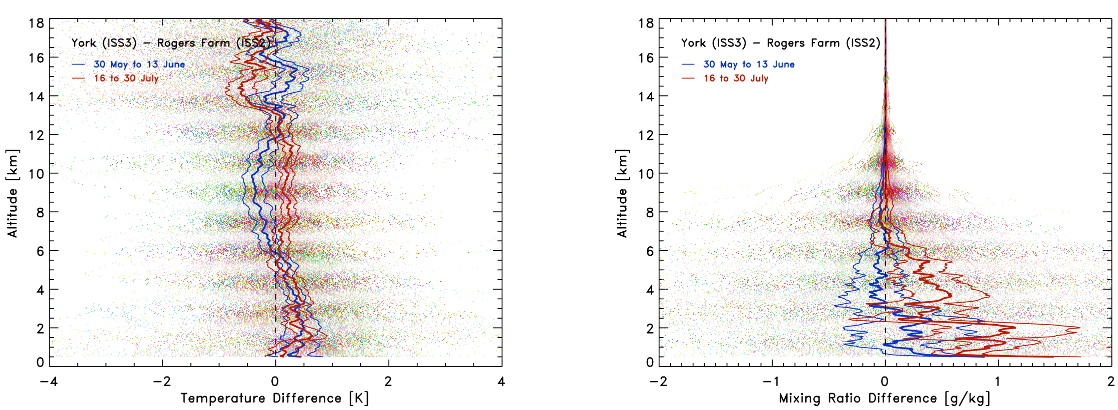

Figure 8: Statistical difference in temperature (left) and mixing ratio (right) between York (ISS3) and Rogers Farm (ISS2). Thick lines indicate the mean difference between the two sites; thin solid lines indicate the standard error around the mean at 95% statistical significance. The first intensive period from 30 May to 13 June is shown in blue; the second intensive period from 16 to 30 July is shown in red. Differences are calculated on a 50 m grid at constant altitude above mean sea level. The lowest altitude bin is that of the altitude at York (ISS3) centered around 500 m. Individual data points are shown as thin color-coded points to distinguish different soundings and to provide a feeling for the scatter of the data.

temperature profile at York is warmer than that at Rogers Farm only during the second intensive period, but not during the first. The profile at York is statistically moister during the second intensive campaign up to about 6 km; it is moister up to about 3 km during the first intensive campaign; however, this result is not significant at the 95% confidence level. The increased moisture at York is not only due to the higher temperature, but also due to a slightly higher relative humidity.

The details of the comparison between these two sites may be studied further than what can be done here. The comparison could be done on constant altitude above ground, or on potential temperature levels, which may lead to more insight into the mechanisms behind these differences. The comparison is included here to show that consistent high quality observations with careful quality control can be used to characterize the atmospheric state with high confidence and that measurement artifacts can be reduced to a level that no longer impact scientific analyses.

7 References

Vömel, H., G. Granger, and I. Suhr, 2018, NCAR/EOL/ISF Radiosonde NetCDF Data Files, UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.5065/D65X27SR.