28 November 2018

SOCRATES 2018
Radiosonde Data Quality Report

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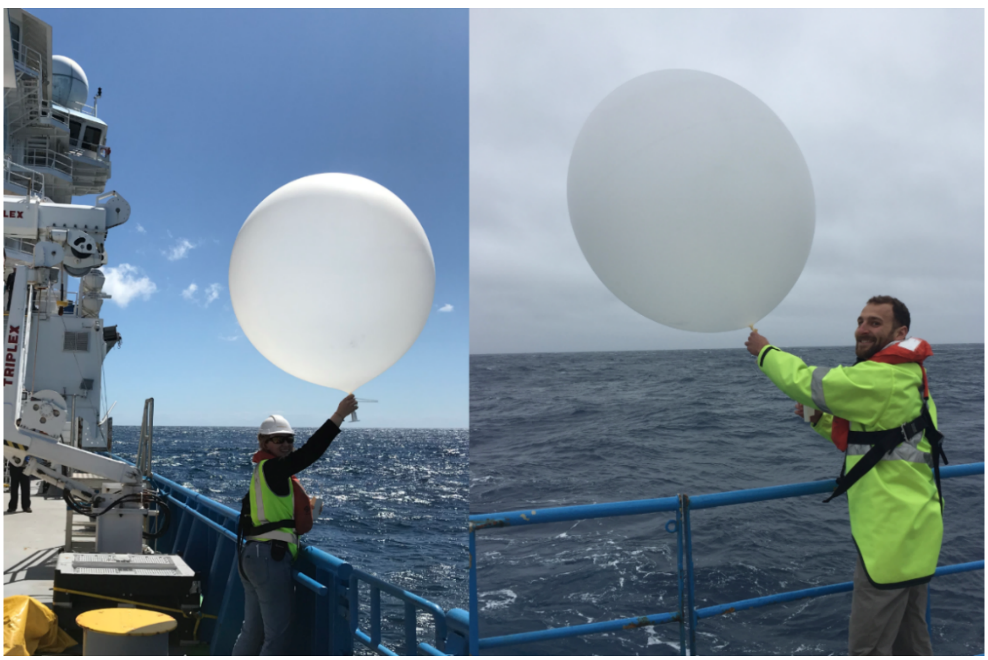

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Campaign websites:

Socrates home page: https://www.eol.ucar.edu/field_projects/socrates
Integrated sounding system home page: https://www.eol.ucar.edu/content/socrates-iss-0

To refer to this report, please include the following citation:

Vömel, H., W. Brown, 2018. SOCRATES -2018 Radiosonde Data Quality Report, UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.5065/D69P30HG.

Document Version Control

Version	Date	Author	Change Description
1.0	28 Nov 2018	H. Vömel	Initial Data Release

1 Table of Contents

2 Dataset Overview

The Southern Ocean Clouds, Radiation, Aerosol Transport Experimental Study (SOCRATES) was a multi-agency, multi-national NSF funded research campaign conducted in the Southern Ocean between Tasmania and Antarctica. Observation platforms were the NSF/NCAR Gulfstream-V research aircraft and the R/V Investigator, a deep-ocean research vessel operated by the Australian Marine National Facility of CSIRO. This document describes the quality of the data obtained from the radiosonde launches onboard the R/V Investigator during its 6 weeks voyage (IN2018-V01) in the Southern Ocean. A total of 234 successful radiosondes were launched between 11 January and 21 February 2018. In addition, the dataset contains six radiosondes launched during the test cruise between 8 and 10 of December 2017 off the coast of Tasmania.

Error! Reference source not found. shows the cruise track, the release locations, as well as the balloon flight tracks for all radiosonde launches during this cruise. Radiosondes were released in three to six hour intervals for the duration of the campaign, providing typically between 4 and 8 radiosonde profiles daily. No soundings were launched during parts of 13 and 14 of January, while the R/V Investigator briefly returned to Hobart.

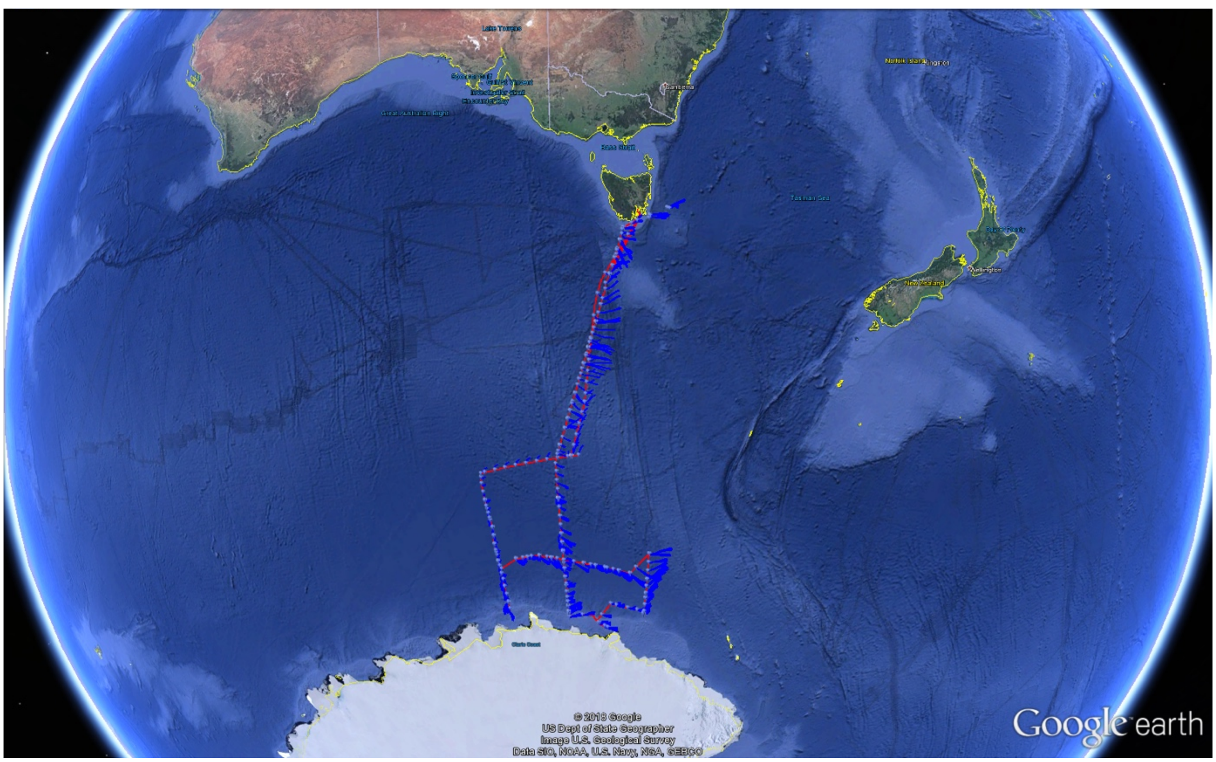

Figure 1: Cruise track of the R/V Investigator (red line) and locations (light blue dots) and flight tracks (dark blue lines) of all radiosonde releases

3 Radiosonde sounding system

This campaign used Vaisala RS41 radiosondes, which were received and processed by the Vaisala MW41 sounding system installed on the ship and using software version 2.4.0. 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 from the ship to the WMO Global Telecommunication System (GTS) in real time to provide operational data for weather prediction by the international weather forecasting centers.

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

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

https://www.eol.ucar.edu/system/files/NCAR_EOL_ISF_radiosonde_NetCDF_data_files.pdf

The sounding system automatically ingests surface reference observations (

Table 1), which are provided by the ship's data system. 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.

Table 1: Surface reference observations provided by the ship's meteorological sensors

Parameter	Location	Sensor
Pressure	The reference pressure was measured under the bridge wings at 19.5 m above sea level or 15.8 m above the balloon launch deck.	Vaisala PTB330
Temperature	The reference temperature was measured on the port side of the front mast about 19 m above sea level.	Vaisala HTM330
Humidity	The reference humidity was measured on the port side and on the starboard side of the front mast about 19 m above sea level. On 27 Jan. 2018, the port side sensor failed and the system was switched to read the starboard side sensor on 29 Jan 2018.	Vaisala HTM330

Wind	The reference winds were measured on the port side of the front mast about 24 m above sea level. The winds provided to the sounding system were relative to the ship.	RM Young Marine wind monitor, model 05106

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 are checked for consistency and for any previously unidentified issue. In SOCRATES data set, the following issues were identified and corrected:

a. During the setup of the system, the heights of the pressure sensor and the station GPS were inadvertently misconfigured. As a result, the geopotential and GPS heights in the original data may have a bias of up 30 m. In addition, processed data during the first few seconds of the sounding were lost and launch detection may have been off by up to 20 s. This issue was corrected by analyzing the raw data, adjusting the time of launch detect, calculating the reference pressure at launch, adjusting the GPS heights for the incorrect offset of the reference GPS antenna, and recalculating the geopotential height. For soundings in which the time of launch detect has been changed, the metadata fields showing the time of launch have been properly corrected. The filename has not been changed and may indicate an incorrect launch time with a difference of up to 30 s.

b. The reference surface-wind data provided by the ship and fed into the sounding system were relative to the ship and not in absolute coordinates. The Vaisala smoothing filter uses these data when filtering the balloon pendulum after launch. Since the pendulum motion of the radiosonde under the balloon may be very strong when it is launched from a moving ship, a meaningful wind determination is very difficult in the first seconds after launch until the unwinder has fully deployed and the pendulum motion has dampened to an acceptable level. Consequently, the wind measurements in the first 20 s after launch were set to missing. Furthermore, the reference wind data in the metadata variables were set to missing.

c. The version of the Vaisala software used during SOCRATES incorrectly assigned the latitude and longitude of the beginning of the launch preparation to the location of the balloon release. Since the ship was moving for many launches, this caused an error of up to 5 km in the location of the balloon release stored in the metadata. This was corrected by storing the correct release coordinates in the metadata fields of the balloon release latitude and longitude.

d. During the sounding SOCRATES_ISS3_20180202_065533, the sounding system software hung and did not generate the usual output files, even though all raw data were properly stored. This sounding was reprocessed during the campaign; however, an incorrect time stamp was generated as launch time. The time stamp was changed from the incorrect date and time 2018-02-08T06:31:29 to the correct date and time 2018-02-02T06:55:34.

No other sonde related issues were found in the quality control of the data.

4.3 Ship effects

Radiosonde measurements immediately after launch may be negatively affected by the ship itself. Due to the ship structure itself, the air in the immediate vicinity of the ship may be slightly warmer than the representative free atmosphere and the balloon may pass through the exhaust plume of the ships engine.

Artificial warm spikes in temperature at about 25 m were seen in 16 profiles (Figure 2 and Table 2). This height corresponds to the height of the ships superstructure. The thickness of the plume layer was up to 20 m or about 4-5 data points. The warm bias in this layer was up to 2.7 K with a median of 0 6 K and a lowest bias of 0.4 K. In two soundings, the Vaisala system improperly filtered out the data just above the warm spike, creating an artificially deep layer of warm bias. Above about 45 m above the ocean surface, a ship effect was no longer detected.

The impact of the ship's exhaust plume was removed in the final data and artificially deep warm biased layers above the plume were corrected using the raw data.

Temperature measurements immediately after release may still have a warm bias due to the proximity of the ship. This possible effect has not been corrected.

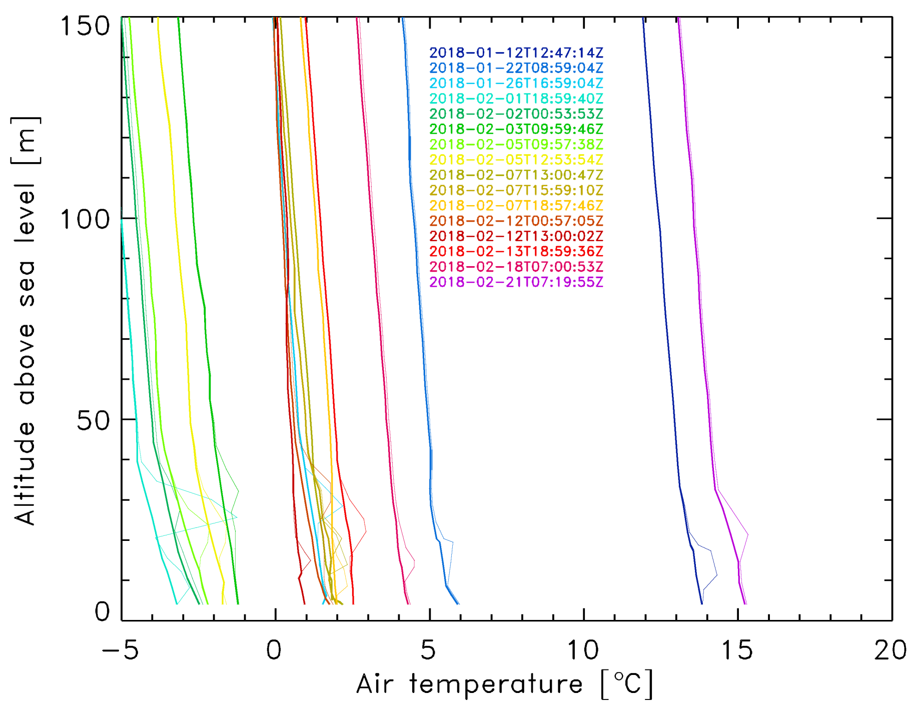

Figure 2: Raw and quality controlled temperature profiles in the lowest 100 m. Processed profiles are shown as thick lines, raw profiles are shown as thin lines. The effect of the ship's exhaust extends to at most 40 m.

Table 2: Soundings, which most likely passed through the exhaust plume of the ships engine.

SOCRATES_ISS3_20180112_124714	SOCRATES_ISS3_20180122_085904
SOCRATES_ISS3_20180126_165904	SOCRATES_ISS3_20180201_185940
SOCRATES_ISS3_20180202_005353	SOCRATES_ISS3_20180203_095946
SOCRATES_ISS3_20180205_095738	SOCRATES_ISS3_20180205_125354
SOCRATES_ISS3_20180207_130047	SOCRATES_ISS3_20180207_155910
SOCRATES_ISS3_20180207_185746	SOCRATES_ISS3_20180212_005705
SOCRATES_ISS3_20180212_130002	SOCRATES_ISS3_20180213_185936
SOCRATES_ISS3_20180218_070053	SOCRATES_ISS3_20180221_071955

5 Sounding metrics

Launching radiosondes from a moving ship in the Southern Ocean is particularly challenging, since high winds, strong turbulence around the ship superstructures, and icy conditions may at times create difficult if not dangerous launch conditions. It is noteworthy, that the EOL radiosonde team onboard the R/V investigator managed to keep ballooning issues to a minimum and was able to launch balloons under all conditions with an extremely high success rate. In 234 successful launches, only six soundings required a re-launch, which is a rate of success of 97.5%. In four soundings, the balloon burst almost immediately after launch, most likely due to the radiosonde hitting the balloon in the turbulence around the ship. In two soundings, the balloon hit the ship's superstructure, causing the balloon to burst. There were no radiosonde failures after the balloon had been successfully released; and, including the re-released soundings, all scheduled observations were achieved.

All balloons were filled with nominally 24 ft3 of helium. The distribution of ceiling heights is shown in Figure 3. The median ceiling height for all soundings is 17.9 km. 95% of all balloons reached an altitude of at least 15 km and the maximum altitude reached was 20.3 km. Two early terminations were related to software glitches, where the signal was lost prematurely. At least one early termination is suspected to be due to stresses on the balloon during a very windy launch.

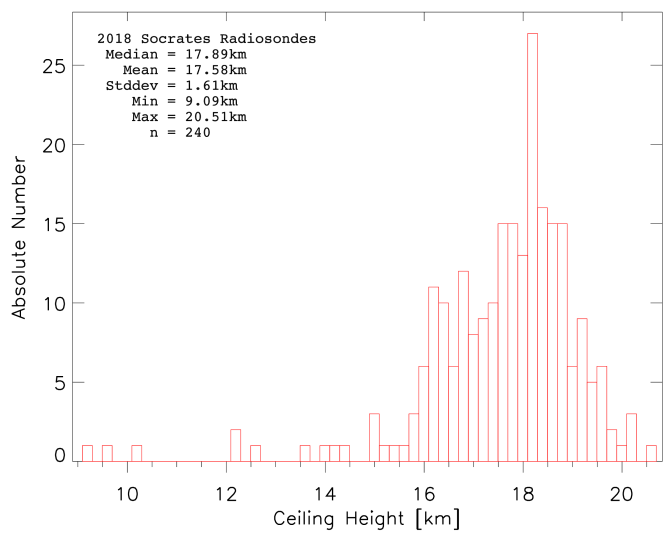

Figure 3: Distribution of ceiling heights for all radiosondes launched from the R/V Investigator during SOCRATES and the preceding test cruise.

The median rise rate over the entire profile varied between 3.1 m/s and 5.1 m/s with a mean value of 4.2 m/s. A distribution of the rise rates for all soundings is shown in Figure 4. Balloon rise rates near the high end and low end of this distribution are influenced by slightly higher or lower gas amounts, typically caused by operational constraints.

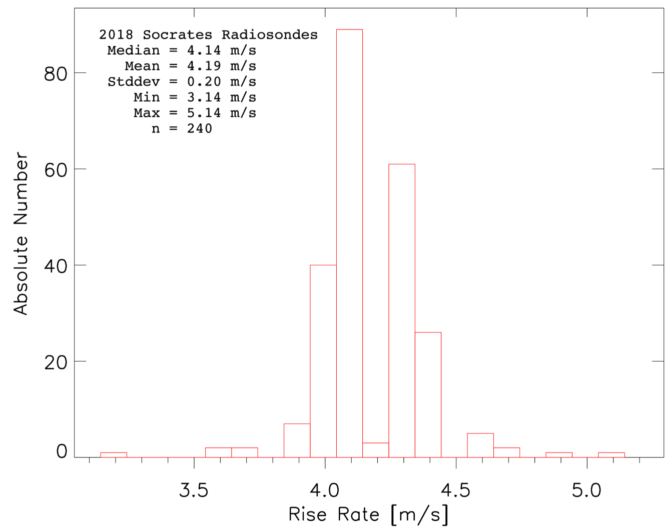

Figure 4: Distribution of rise rates for all radiosondes launched from the R/V Investigator during SOCRATES and the preceding test cruise.

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.

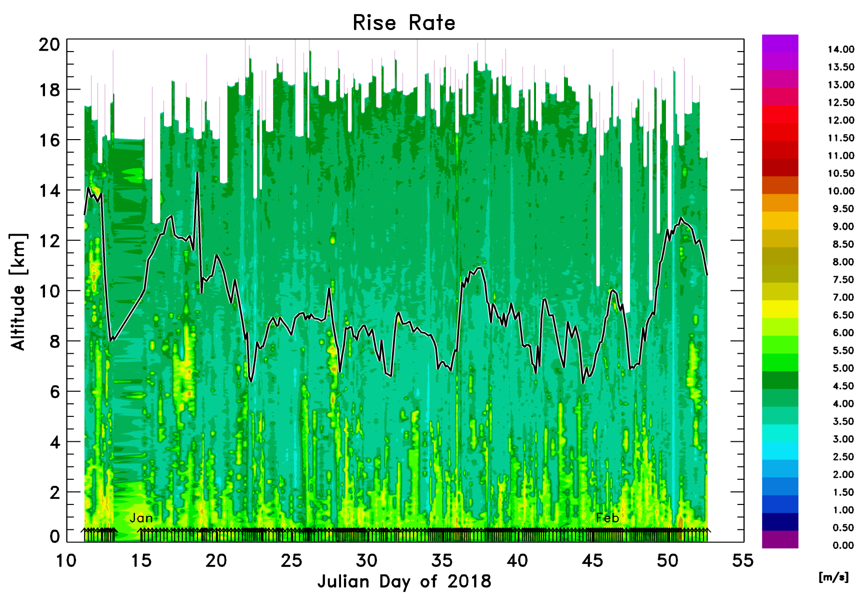

Figure 5: Sequence of rise rate profiles for all radiosondes launched from the R/V Investigator during SOCRATES. The tropopause is indicated as black line. Each launch is indicated by a small arrow at the bottom of the diagram.

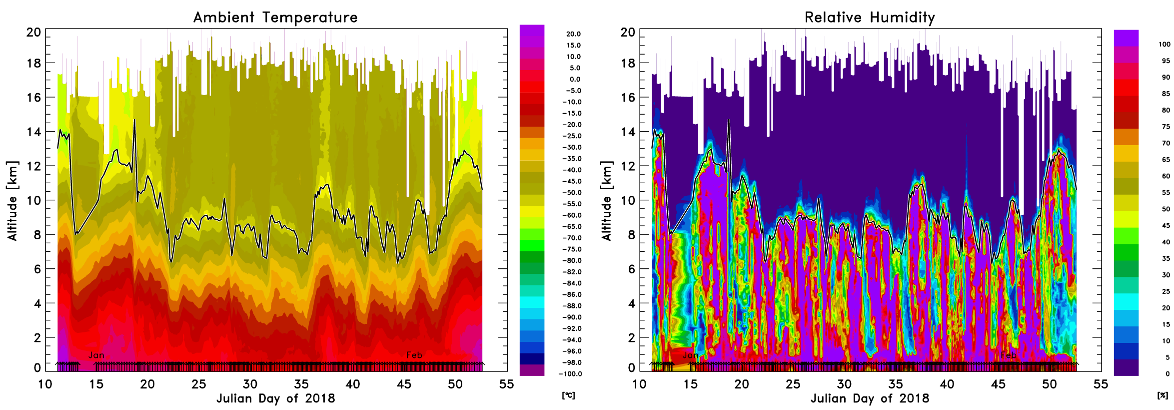

Figure 6: Sequence of temperature profiles (left) and relative humidity profiles (right) from all radiosondes launched from the R/V Investigator during SOCRATES. The tropopause is indicated as black line. Each launch is indicated by a small arrow at the bottom of the diagram.

Air temperature and relative humidity measurements from all radiosondes are shown in Figure 6. The lowest tropospheric temperatures were encountered during the middle of the cruise, while the ship was sailing in the southernmost part of the project. The rapid drop of relative humidity above the tropopause (Figure 6, right panel) is typical for the dryness of the stratosphere and an indication that none of the humidity sensors suffered icing of the sensor. As is customary, all relative humidity profiles are clipped at 100 % RH.

Wind speed measurements from all radiosondes are shown in Figure 7. The voyage crossed the region of the sub-tropical jet, i.e. the region with strong winds in the upper troposphere, during the first third and again on the return during the last third of the campaign. The voyage sailed in the region of the southern polar jet during the middle of the campaign.

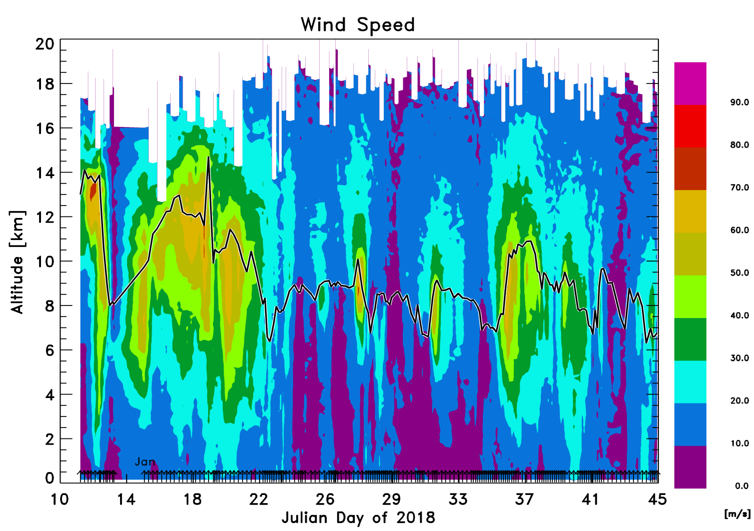

Figure 7: Sequence of wind speed profiles for all radiosondes launched from the R/V Investigator during SOCRATES. The tropopause is indicated as black line. Each launch is indicated by a small arrow at the bottom of the diagram.

6 Coordination with other operations

6.1 Coordination with the NCAR G-V dropsondes

The NCAR G-V aircraft passed over the R/V Investigator during five occasions (Table 3). For each overpass, the ballooning team onboard the ship launched a radiosonde in coordination with the aircraft operation to provide closely spaced profiles, which may be used for further studies. In all cases, the aircraft passed the ship within a few km. During the first three overflights, dedicated dropsondes were launched from the G-V near the ship. Due to a miscommunication on the first overpass, the radiosonde was launched one hour prior to the overpass and no coincidence with the dropsonde was achieved.

Table 3: Coordinated observations with the NCAR G-V research aircraft

Research Flight	Time of overpass (UT)	Balloon release time (UT)	Notes
RF02	19 Jan 2018 02:10 – 02:15	01:01:43	Distance about 5 km to the east. Dropsonde release at 02:12:45.
RF03	23 Jan 2018 00:55 - 01:05	00:52:03	Distance about 8 km to the west. Aircraft did a screw to higher altitude near the ship. Dropsonde release at 01:02:49.
RF04	24 Jan 2018 01:20 – 01:25 (high altitude) 03:45 – 03:50 (low altitude)	01:24:06 03:43:47	Aircraft passed twice on this mission. Distance about 3 km to the west (high altitude) and about 2 km (low altitude). Dropsonde release at 01:24:06.
RF05	26 Jan 2018 01:50 - 02:00	01:21:03 02:36:02	The aircraft returned immediately after the overpass. Distance about 3 km to the east. No dropsonde release during this fly-by.
RF12	18 Feb 2018 04:15 - 05:15	04:26:33	The aircraft performed several racetracks near the ship, about 3 km to the west. No dropsonde release during this fly-by.

6.2 Macquarie Island

The Australian Antarctic Division maintains a permanent station on Macquarie Island, which conducts routine meteorological observations. This station launches Vaisala RS41 radiosondes operationally twice daily. The R/V Investigator did not sail close to Macquarie Island; however, the NCAR G-V aircraft flew close to this station on two occasions (31 Jan and 20 Feb 2018), with dedicated radiosonde launches at the time of the closest approach to the island. The data quality of the Macquarie Island soundings is expected to be equivalent to the quality of the soundings from the R/V Investigator.

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.