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Dropsonde Data Quality Report

Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS, 2020)

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Campaign Websites:
IMPACTS home page:
https://espo.nasa.gov/impacts/content/IMPACTS
AVAPS dropsondes home page:
https://www.eol.ucar.edu/observing_facilities/avaps-dropsonde-system

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1.0	6 May 2020	H. Vömel	Initial Version
1.1	14 May 2020	H. Vömel	Minor edits including comments by C. Robinson, L. Thornhill, and T. Hock.

1 Table of Contents

2 Dataset overview

The Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) provides observations critical to understanding the mechanisms of snowband formation, organization, and evolution. A complementary suite of remote sensing and in-situ instruments will be flown for three 6-week deployments on the ER-2 and P-3 aircraft and examines how the microphysical characteristics and likely growth mechanisms of snow particles vary across snowbands. IMPACTS will improve snowfall remote sensing interpretation and modeling to significantly advance predictive capabilities.

The NASA Earth Science Division operated NASA's P-3 (tail number N426NA) research aircraft out of Wallops Island during the period 18 January to 20 February 2020. This aircraft conducted five research flights, during which between two and eight NCAR NRD41 dropsondes were released for a total of 22 sondes to provide in situ thermodynamic profiles.

The flight tracks of all P-3 dropsonde flights are shown in Figure 1, including the locations of all dropsonde releases.

Table 1 provides a summary of the dropsondes that were released during IMPACTS in 2020.

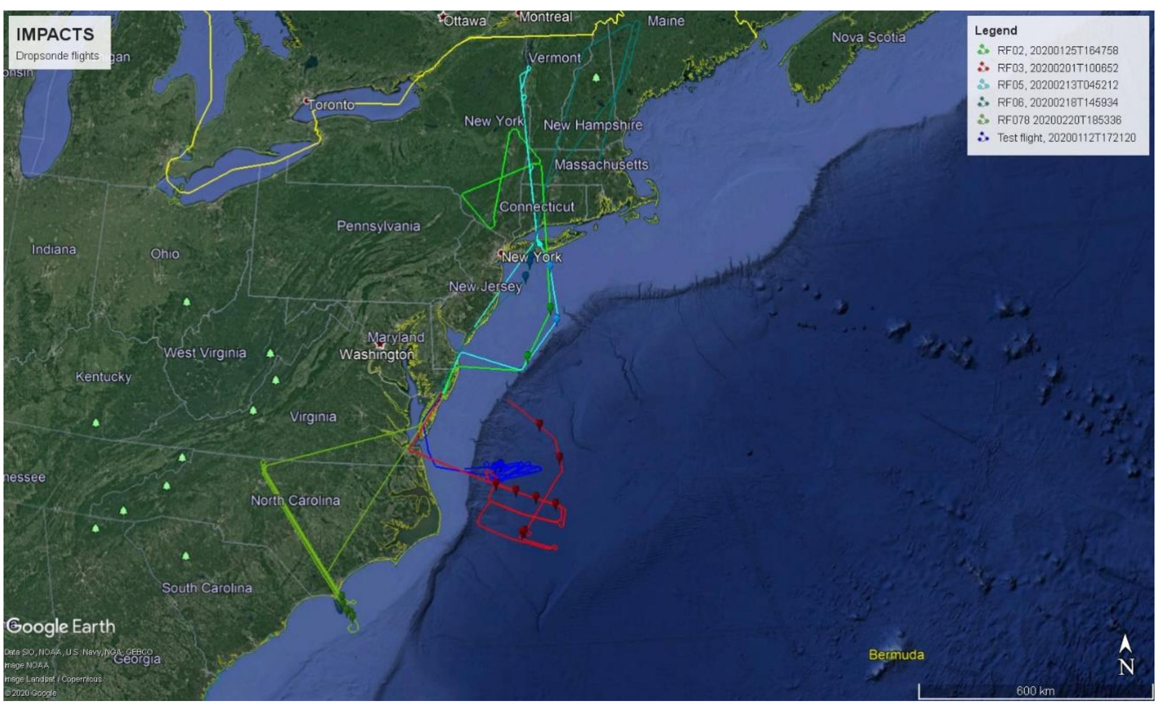

Figure 1: NASA P-3 science flights and dropsonde locations.

Table 1: Summary of all sonde releases during IMPACTS.

Flight	Date	# of Soundings
RF00	12 Jan	2
RF02	25 Jan	2
RF03	01 Feb	8
RF05	13 Feb	2
RF06	18 Feb	3
RF08	20 Feb	5

Table 2 provides a summary of the performance of the dropsonde system as whole. Twenty-two sondes were released from the aircraft, all of which produced complete profiles of wind, pressure, temperature, and humidity to the surface. In all sondes launch was correctly detected and the parachutes performed nominally.

Table 2: Summary of the dropsonde system performance.

	# of Sondes	Percent
Total number of sondes released	22	100
Successful releases	22	100
Complete thermodynamic profiles to the ground	22	100
Complete wind profiles to the ground	22	100

3 Dropsonde sounding system

The NCAR dropsonde system deployed in IMPACTS used a manual launcher and the NCAR Dropsonde model NRD41, which was produced at NCAR.

The NRD41 dropsonde uses the pressure, temperature, and humidity sensor of the Vaisala RS41 radiosonde and includes an improved version of the GPS, telemetry, and parachute release system of the previous NRD94 dropsonde, which had been in use between 2010 and 2018. The NRD41 dropsonde is basically a smaller version of the RD41 dropsonde, which is used operationally by NOAA and Air Force for hurricane observations and used for science by a number of research organizations worldwide.

The NRD41 was most recently used during the Organization of Tropical East Pacific Convection (OTREC) campaign, which took place in the Eastern Pacific and Caribbean.

All dropsonde humidity sensors were reconditioned on the aircraft prior to take off. This process, which is unique to the xRD41 dropsondes, reduces the potential of humidity contamination to a minimum and assures the best measurement performance of the humidity sensor throughout the entire altitude and temperature range of a dropsonde profile.

The AVAPS LabVIEW based software receives and stores data from the dropsondes and the aircraft data system and monitors the entire AVAPS system. The AVAPS station and manual launch tube were installed in the rear of the NASA P-3. All sondes were initialized by the dropsonde operators prior to a drop and then placed inside the launch tube. At the intended drop location, the operator released the sondes by activating the electrically controlled launcher release valve. Due to the shielding provided by the launch tube, no data were received while the dropsondes were inside the launch tube.

IMPACTS scientific staff controlled the quality of each sounding after each science flight using the Atmospheric Sounding Processing ENvironment (ASPEN) software package.

The GPS receiver in the dropsondes were initialized as part of the pre-launch preparations to speed up the acquisition of the satellite signals and requires continued reception of GPS signals by the GPS dropsonde receiver for wind measurements immediately after launch. The previous campaign using this setup (Camp^{2}Ex) suffered some degraded GPS initialization due to a broken GPS coax cable. This had been fixed prior to IMPACTS and GPS initialization worked as expected with the exception of the first science launch, which saw a minor delay in GPS signal acquisition.

4 Quality control procedures

4.1 Standard quality control

Standard quality control in near real time and as part of the final data QC is based on the algorithms implemented in the ASPEN software. The following quality checks, corrections, and calculations are performed:

- Removal of outliers and suspect data points in pressure, temperature, humidity, zonal and meridional wind, latitude, and longitude
- Removal of data between release from the aircraft and equilibration with atmospheric conditions
- Dynamic correction to account for the lag of the NRD41 temperature sensor using the appropriate coefficients for the NRD41 dropsondes
- Dynamic correction to account for the sonde inertia in the determination of the wind profile using the appropriate parameters for the NRD41 dropsondes
- Smoothing of pressure, temperature, humidity, zonal and meridional wind
- Recomputation of wind speed and wind direction after smoothing of the wind components
- Extrapolation of the last reported pressure reading to a surface pressure value, based on the fall rate of the sonde
- Recalculation of the geopotential height from the surface to the top of the profile
- Computation of the vertical wind speed component

This campaign used the new NRD41 dropsonde, which has a faster temperature sensor and faster RH sensor than the older NRD94 sondes. This has been considered in the final dropsonde QC by changing the ASPEN QC parameters for these two sensors. The default equilibration times calculated by ASPEN for the temperature and RH sensor have been used for this data set. The equilibration times are in the range of 4.7 ± 0.4 s for pressure and temperature, 29.7 ± 7.8 s for relative humidity and exactly 10 s for winds.

4.2 Custom quality control

4.2.1 Pressure corrections

The pressure sensor of the NRD41 dropsonde is known to have a small bias. The sensor bias is measured during the production of the dropsondes and stored in the sonde to minimize the bias during observation. A correction has already been applied in the generation of the raw data and all data are assumed to have only a minimal bias.

The statistics of the pressure correction built into the sonde is shown in Figure 2. The mean pressure offset is -1.02 hPa and the standard deviation 0.6 hPa.

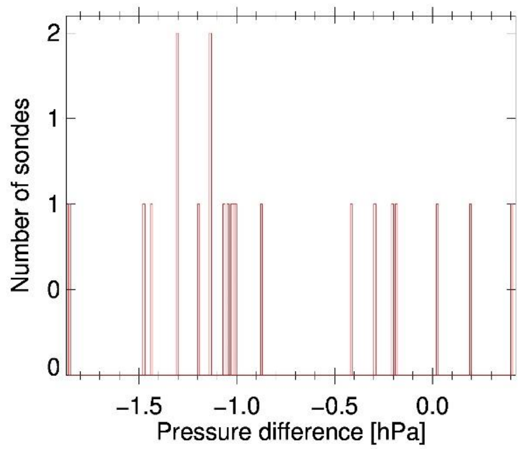

Figure 2: Pressure offset between the dropsonde and the reference stored in the sonde.

Most sondes exhibit a small pressure measurement issue. For reasons currently unknown, the dropsondes occasionally repeated a reported pressure measurement. This happened up to 20 times per sounding and in a few cases more frequently. While this is barely noticeable in any vertical profile, it slightly increases the noise in the calculated vertical fall rate. In post processing, these repeated pressure readings were interpolated and the fall rates recalculated. Only pressure readings had to be corrected. Temperature and relative humidity readings do not show any artificial repetition of measurements.

4.2.2 Temperature performance

The performance of the temperature sensor was without anomalies. In all soundings the sensor equilibrated to ambient conditions within less than 10 s after release.

4.2.3 Relative humidity

The relative humidity sensor on the NRD41 dropsondes should be reconditioned prior to launch and the sondes store whether the reconditioning was successful. With this information, we could verify that all sondes were properly reconditioned prior to take off on each flight. Any contamination in the sensor material was removed and the relative humidity sensors are expected to have a negligible calibration drift.

The RH sensor worked as expected. Half of all soundings show layers with a relative humidity well above 100% (Table 3). All high RH layers correlate with significant updrafts or turbulence, where water loading may influence the humidity sensor and microphysics may lead to humidities above 100%. While in these layers the uncertainty of the RH sensor may be larger than normal, there is no indication that the relative humidity measurements outside of these layers have been affected.

In the quality-controlled data, these layers have been set to 100% following meteorological convention.

Table 3: Layers with measurements of relative humidity well above 100%.

#	Research Flight	Sounding	Layer RH [%]	Mean layer thickness [m]
1	RF02	20200125_192256	104	825
2	RF03	20200201_121932	103.5	450
3	RF03	20200201_123138	107	2030
4	RF03	20200201_144216	103.4	205
5	RF03	20200201_145056	104.1	1655
6	RF05	20200213_064734	103.7	355
7	RF05	20200213_065931	105.1	1020
8	RF08	20200220_211524	106.5	905
9	RF08	20200220_211654	103.7	995
10	RF08	20200220_212700	103.6	230
11	RF08	20200220_224852	103.7	265

4.2.4 Data coverage

All soundings transmitted data to landing in the water and some sondes continued transmitting data from the ocean surface before sinking (Table 4). Data from the ocean surface were removed from the final data set.

Sounding 20200125_192256 experienced interference of the telemetry signal between approximately 1.3 km and 2.7 km. As a result, the vertical resolution of the received data is slightly reduced over this altitude range.

Table 4: Soundings in which data after landing in the water were manually removed.

#	Research Flight	Sounding
1	Test flight	20200112_211122
2	Test flight	20200112_210330

4.2.5 GPS performance

The GPS receiver to measure horizontal winds and dropsonde fall rate worked as expected in all but two soundings. Dropsondes received a sufficient number of satellites within 25 s after dropsonde release, corresponding to 150 m to 450 m below the aircraft. In sounding 20200220_212800 (RF08), the GPS started reporting sufficient GPS winds only 550 m below the aircraft and had a reduced wind speed accuracy throughout the profile. In sounding 20200112_210330 (test flight), the GPS started reporting winds 725 m below the aircraft with nominal wind speed accuracy.

5 Data file format

The format follows that defined for the NCAR/EOL/ISF radiosonde NetCDF data files. It is based on the Climate and Forecasting (CF) convention version 1.6 and is compatible with any tool accepting this convention. The data file format is described in Vömel et al. (2018). A similar data format description for dropsondes is in preparation and will describe the more extensive metadata.

The format description can be found at:

Vömel, H., I. Suhr, and G. Granger, 2019,NCAR/EOL/ISF Dropsonde NetCDFData Files, UCAR/NCAR -Earth Observing Laboratory. https://doi.org/10.26023/54wh-rj45

6 Sounding metrics

6.1 Horizontal drift

Wind speeds observed by dropsondes during IMPACTS reached up to 57 m/s near aircraft level on some soundings. As a result, the horizontal drift of the dropsondes was significant (Figure 3) over a drop time of up to 10 min. The median horizontal distance the dropsondes traveled was 9.3 km and two sondes traveled about 19 km horizontally.

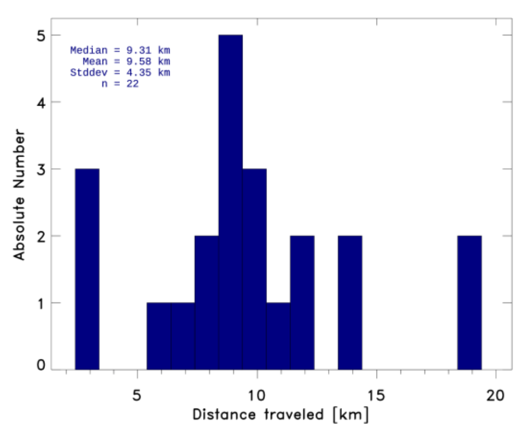

Figure 3: Distance between launch and landing for all dropsondes during IMPACTS.

6.2 Surface pressure

The surface pressure reported by the sondes is an extrapolation of the last measured air pressure above the surface to sea level using the current fall rate. The surface pressure reported by all sondes, which transmitted to the surface is shown in Figure 4. The first two surface pressure readings were taken during the test flight, the others during research flights.

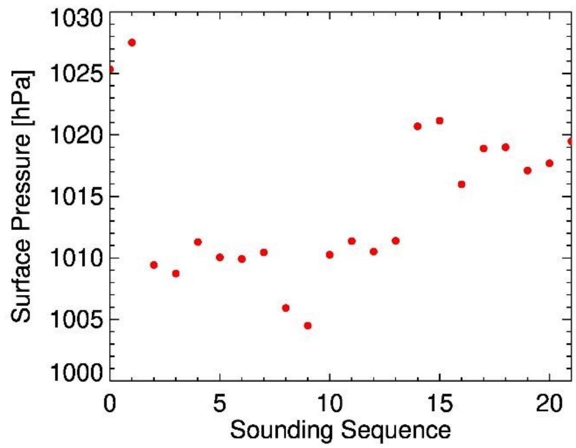

Figure 4: Surface pressure reported by all sondes

6.3 Humidity measurements

Relative humidity measurements from dropsondes are most challenging due to the fast fall rate relative to the typical response time of the sensors. The humidity sensor on the xRD41 dropsondes is identical to that on the Vaisala RS41 radiosondes and suitable for dropsonde observations. The correlation between all temperature and all relative humidity measurements, shown in Figure 5, reveals the sensitivity of this sensor over the parameter space during the campaign. This Figure indicates that most of the high RH observations in the raw data occur just below the freezing level and may indicate that the sensor had to cope with melting water at or near the sensor. Since the sensor is heated, this was most likely a transient effect. Following meteorological convention, values above 100% are limited to 100% in the quality-controlled data.

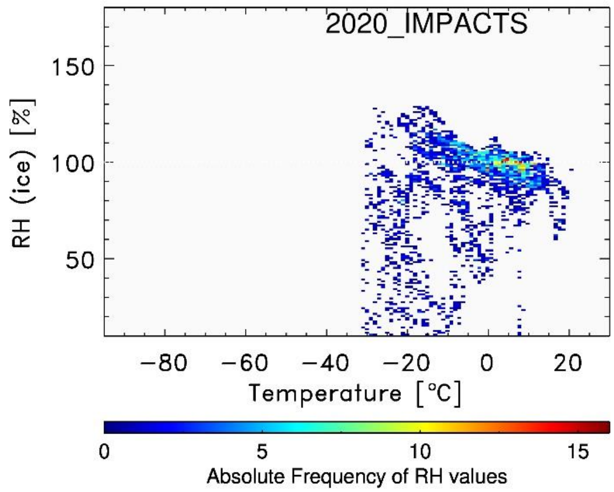

Figure 5: Density plots showing the correlation between all temperature and relative humidity measurements based on raw data. The color coding indicates the how often the combination of temperature and relative humidity was observed in the entire data set.

6.4 Fall rate

The parachute performed as expected in all soundings. The median fall rate at the time of landing was 11.4 ± 0.7 m/s. The consistency of the fall velocities near the surface highlights the quality of the parachutes used in IMPACTS.

A histogram of the mean fall rates over the entire profile is shown in Figure 6. The median fall rate for the entire data set was 13.4 m/s. The spread of this distribution is mostly due updraft and downdrafts observed during that campaign.

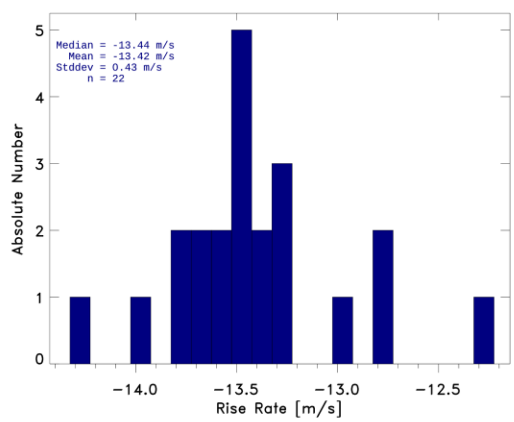

Figure 6: Median fall speed across the profiles for all dropsondes.

7 Atmospheric observations

7.1 Temperature

The temperature measured by all dropsondes is shown as contour plot in Figure 7. The individual research flights are separated by vertical lines. The temperature at flight level were in the range of -31°C to 0°C and near the surface in the range of 5°C to 21°C.

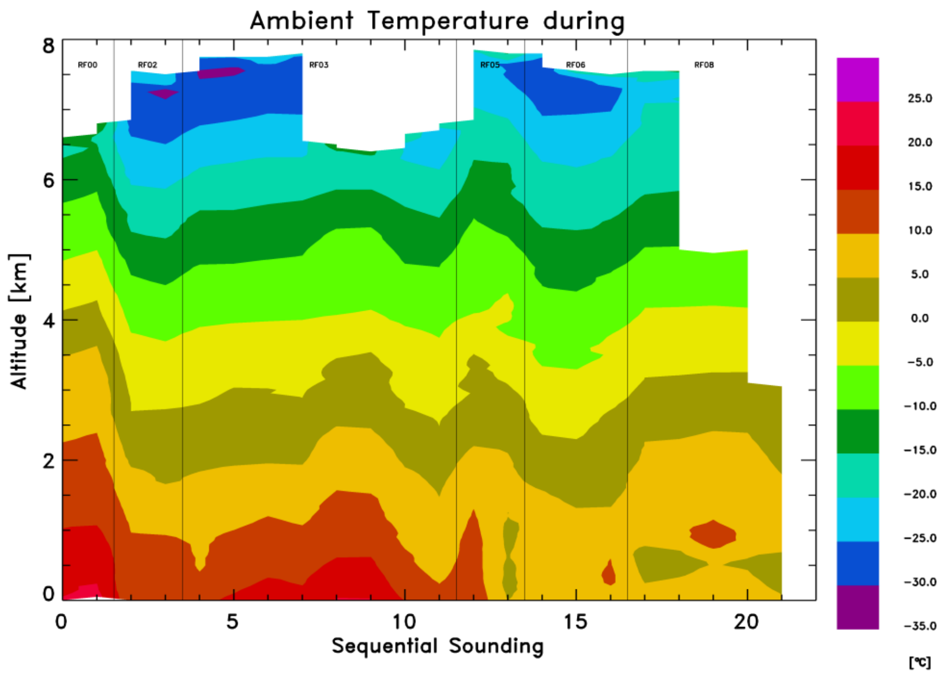

Figure 7: Color contours for all temperature measurements. All soundings are shown in the sequence in which they were released. White areas reflect the different release altitudes. The different science flights are separated by vertical lines and indicated near the top.

7.2 Relative humidity

Relative humidity measured by all dropsondes is shown in Figure 8. At temperatures below 0°C, relative humidity is expressed as relative humidity over ice instead of the conventional relative humidity over liquid water.

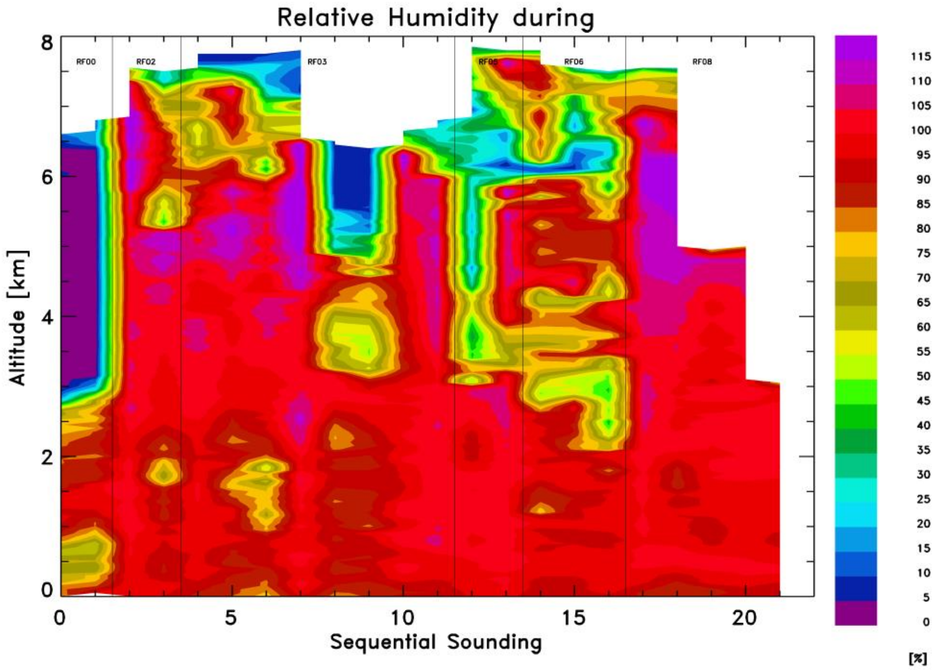

Figure 8: Color contours for all relative humidity measurements. Note that at temperatures below freezing, relative humidity is calculated with respect to ice.

7.3 Zonal winds

Zonal wind speeds are shown in Figure 9. Yellow to reddish colors indicate westerly winds, green to blue colors indicate easterly winds.

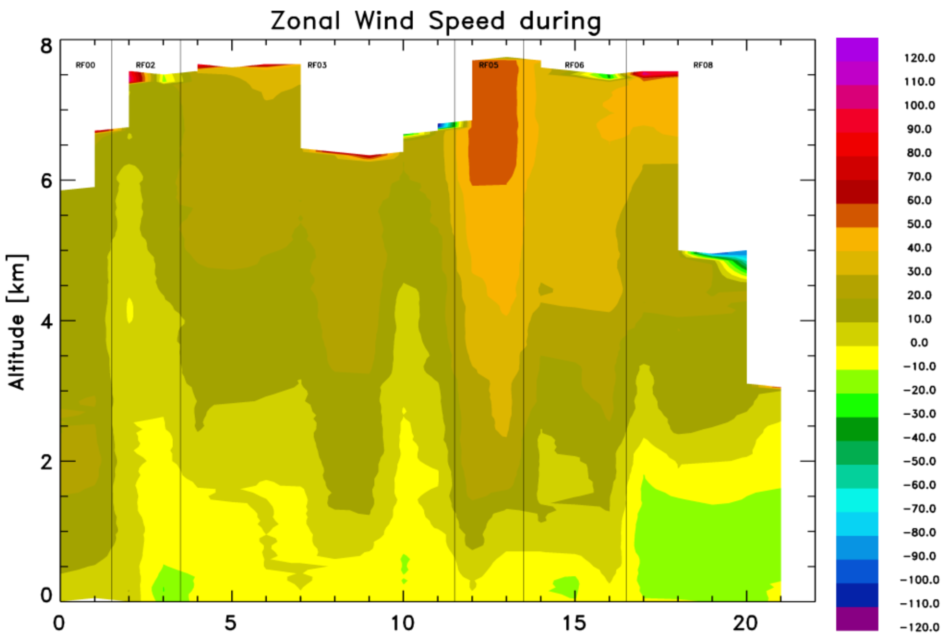

Figure 9: Color contours for all zonal wind speed measurements

8 List of all soundings

#	Date [UTC]	Time [UTC]	Research Flight	Serial number	Alt. [km]	Latitude [deg]	Longitude [deg]	Duration [min]
1	12 Jan 2020	21:03:29	Test Flight	190220512	6.6	36.56439	-74.13213	8.1
2	12 Jan 2020	21:11:22	Test Flight	190630341	6.6	36.61778	-73.99979	8.3
3	25 Jan 2020	19:22:55	RF02	190640171	7.4	38.67960	-73.32842	9.6
4	25 Jan 2020	19:33:29	RF02	190640439	7.4	39.60091	-72.75919	8.9
5	1 Feb 2020	12:19:31	RF03	190510313	7.7	36.25917	-74.10296	9.1
6	1 Feb 2020	12:23:37	RF03	190640443	7.7	36.12700	-73.63398	9.2
7	1 Feb 2020	12:27:35	RF03	190640106	7.8	35.99258	-73.15778	9.2
8	1 Feb 2020	12:31:38	RF03	190440702	7.8	35.86212	-72.69980	9.3
9	1 Feb 2020	14:20:05	RF03	190640160	6.4	35.30645	-73.49339	8.1
10	1 Feb 2020	14:20:38	RF03	190640103	6.4	35.33512	-73.43811	7.9
11	1 Feb 2020	14:42:16	RF03	190510314	6.6	36.74635	-72.58770	8.2
12	1 Feb 2020	14:50:56	RF03	190640159	6.8	37.38613	-73.05685	8.1
13	13 Feb 2020	06:47:34	RF05	190510315	7.8	39.38101	-72.60642	9.3
14	13 Feb 2020	06:59:30	RF05	190630812	7.8	40.40342	-72.75696	8.9
15	18 Feb 2020	17:55:29	RF06	190550224	7.8	40.20395	-73.36773	10.0
16	18 Feb 2020	17:58:27	RF06	180520414	7.5	40.47861	-73.26130	9.1
17	18 Feb 2020	21:27:34	RF06	190630781	7.4	40.58727	-73.22697	9.2
18	20 Feb 2020	21:15:24	RF08	190510711	7.5	33.79772	-77.72020	9.2
19	20 Feb 2020	21:16:54	RF08	190510670	7.5	33.67773	-77.62132	9.2
20	20 Feb 2020	21:27:00	RF08	190550207	4.9	33.54109	-77.50683	6.3
21	20 Feb 2020	21:27:59	RF08	180710897	4.9	33.60889	-77.56348	6.2
22	20 Feb 2020	22:48:52	RF08	190510704	3.0	33.89935	-77.79453	4.1