Geophysical Research Letters

RESEARCH LETTER
10.1029/2019GL083332

Key Points:
- In the Arctic, radiosonde observations substantially improve the operational analyses and cannot be replaced by satellite observations
- The impact of radiosoundings on analyses varies substantially in space and is largest in the northern Atlantic and in the central Arctic
- Where the sounding network is sufficiently dense, the background field quality depends on the quality and utilization of radiosoundings

Supporting Information:
- Supporting Information S1

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Citation:
Naakka, T., Nygård, T., Tjernström, M., Vihma, T., Pirazzini, R., & Brooks, I. M. (2019). The impact of radiosounding observations on numerical weather prediction analyses in the Arctic. *Geophysical Research Letters*, *46*, 8527–8535. https://doi.org/10.1029/2019GL083332

Received 17 APR 2019
Accepted 15 JUL 2019
Accepted article online 18 JUL 2019
Published online 29 JUL 2019

The Impact of Radiosounding Observations on Numerical Weather Prediction Analyses in the Arctic

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Abstract The radiosounding network in the Arctic, despite being sparse, is a crucial part of the atmospheric observing system for weather prediction and reanalysis. The spatial coverage of the network was evaluated using a numerical weather prediction model, comparing radiosonde observations from Arctic land stations and expeditions in the central Arctic Ocean with operational analyses and background fields (12-hr forecasts) from European Centre for Medium-Range Weather Forecasts for January 2016 to September 2018. The results show that the impact of radiosonde observations on analyses has large geographical variation. In data-sparse areas, such as the central Arctic Ocean, high-quality radiosonde observations substantially improve the analyses, while satellite observations are not able to compensate for the large spatial gap in the radiosounding network. In areas where the network is reasonably dense, the quality of background field is more related to how radiosonde observations are utilized in the assimilation and to the quality of those observations.

Plain Language Summary The radiosounding network is a crucial part of the atmospheric observing system, because radiosoundings provide accurate direct information on vertical profiles of temperature, humidity and winds. However, the radiosounding network is sparse in the Arctic; 76 sounding stations are located on continents and islands north of 60°N, and no radiosoundings are regularly made over the Arctic Ocean. In this study, the spatial coverage of the network was evaluated using a numerical weather prediction system, comparing radiosonde observations with operational weather forecast system products of the European Centre for Medium-Range Weather Forecasts. In the forecasting system, data assimilation is used to produce initial conditions for forecasts. In the data assimilation, background information from the previous short forecast is corrected by observations, resulting in an analysis, the initial conditions for the next forecast. Our results show that radiosoundings substantially improve these analyses. Satellite observations cannot compensate for the large spatial gap in the radiosounding network in the central Arctic. Over continents, where the network is reasonably dense, the quality of background field is more related to how radiosoundings are utilized in the data assimilation, and to the quality of those observations, than to the density of the radiosounding network.

1. Introduction

Information about the vertical structure of the Arctic atmosphere is essential for understanding Arctic climate and weather. The radiosounding network is a critical component of the Arctic atmospheric observing system and is indispensable for climate monitoring and reanalysis. Radiosonde observations provide accurate information on vertical temperature, humidity and wind profiles with a high vertical resolution; this information is assimilated into numerical weather prediction (NWP) models, along with other observational data from, for example, surface stations and satellites. Importantly, the same data assimilation is used for the production of reanalyses (e.g., Dee et al., 2011), one of the most widely used tools for Arctic climate studies and also as a priori information in satellite retrievals. Radiosonde observations are also utilized in studies of physical/dynamical processes (e.g., Dufour et al., 2016) and climatology (Nygård et al., 2014; Zhang et al., 2011), for verification of NWP forecasts (Ingleby, Rodwell, & Isaksen, 2016) and as reference for bias correction of satellite soundings and aircraft data (Carminati et al., 2019).

In the Arctic, the radiosounding network is sparse, with only 76 sounding stations located north of 60°N, all located on land, although some are on islands. The Arctic network is densest in northern Europe and in western Russia, whereas no radiosonde observations are regularly made over the Arctic Ocean; such observations are typically only available from icebreaker-based field experiments (e.g., Tjernström et al., 2014). It has been suggested that one reason for the relatively low skill of weather forecasts in the Arctic is the sparse observational coverage (Jung et al., 2016). Recognizing that atmospheric observations in the Arctic, especially the Arctic Ocean, are expensive and logistically challenging, it is important to evaluate the existing spatial coverage and to identify the most critical gaps in the sounding network.

Evaluation of the impact of observations in a NWP system can be accomplished by observing system experiments (OSEs) using NWP models with different observational data assimilated in numerical experiments. Hence, additional Arctic radiosonde observations, from new locations or with increased frequency, have been shown to substantially improve forecasts and contribute to a more accurate representation of the atmospheric circulation, both in the Arctic and in midlatitudes (Inoue et al., 2013; Inoue et al., 2015; Sato et al., 2017; Sato et al., 2018; Yamazaki et al., 2015). Effects of radiosonde observations propagate downstream and their influence in improved forecasts may be seen far away from the sounding station (Sato et al., 2017; Sato et al., 2018; Yamazaki et al., 2015). The benefits of additional radiosoundings also proceed to the next assimilation cycle via an improved first-guess field (Inoue et al., 2013). The impact of additional observations has been found to be flow dependent (Inoue et al., 2015). An aim of the World Meteorological Organization Year of Polar Prediction is to evaluate benefits of additional Arctic radiosonde observations from the special observation periods (February–March and July–September 2018) by applying OSEs.

However, although OSEs provide useful information about the impacts of observations, they are expensive, requiring repeat execution of full NWP systems and are hence typically limited to relatively short time periods. The approach used in this study is instead to compare existing model products and observations (Dahoui et al., 2017; Lawrence et al., 2019; Todling, 2013), allowing evaluation over longer time periods and for a more comprehensive analysis on the flow dependency. The price paid for this is that it makes a separation of the impact of radiosoundings from the other measurements more challenging. The aims of this study are (1) to detect geographical areas where the deviation of model background fields from the radiosonde observations is largest, (2) to evaluate the impact of radiosoundings in the operational analyses, and (3) to identify the key geographical areas where additional radiosonde observations could potentially improve analyses and forecasts. We address the time period January 2016 to September 2018 with a focus on 850-hPa level air temperature (T850), as this is an important quantity often used to characterize air mass properties and frontal zones. The study is based on the operational analyses and short forecasts with the Integrated Forecast System (IFS) from the European Centre for Medium-Range Weather Forecasts (ECMWF) and uses radiosonde observations from land stations and research expeditions in the Arctic Ocean. Importantly, radiosonde observations from the icebreaker Oden from summer 2016 were not available for assimilation, whereas similar observations from summer 2018, in the same area of the Arctic Ocean, were. Comparison of those results allowed us to distinguish the impact of radiosonde observations from other observations.

2. Materials and Methods

2.1. Radiosoundings

The radiosounding network in the circumpolar Arctic north of 60°N is addressed (Figure 1). Analyses were made for January 2016 to September 2018; an additional trajectory analysis was carried out for a shorter period, January 2016 to December 2017. Radiosonde observations, at 00 and 12 UTC, were extracted from the Integrated Global Radiosonde Archive (Durre et al., 2006), a global data set of quality-assured radiosonde observations. We focused on T850, although temperatures at several other levels below and above were also investigated. Radiosonde types varied between the stations. In Canada, North Atlantic, and Europe, Vaisala RS92, recently upgraded to Vaisala RS41, were used, whereas in Alaska the most common type was Lockheed LMS6, although the Global Climate Observing System Reference Upper-Air Network (GRUAN) station at Barrow used RS92. Global Climate Observing System Reference Upper-Air Network evaluations essentially confirm the uncertainty specifications of the RS92 manufacturer (Dirksen et al., 2014). In Russia, various Russian-made radiosondes were used (Ingleby, 2017). Finding authoritative uncertainty information for these is difficult, but the body of evidence (*e.g.,* Ho et al., 2017; Ingleby, 2017; Sun et al., 2010; Sun et al., 2013) suggests that the temperature uncertainty is about a factor 2 larger than more modern sondes. Nevertheless, the Russian radiosondes contribute to the ECMWF/IFS forecast quality (Ingleby, Rodwell, & Isaksen, 2016).

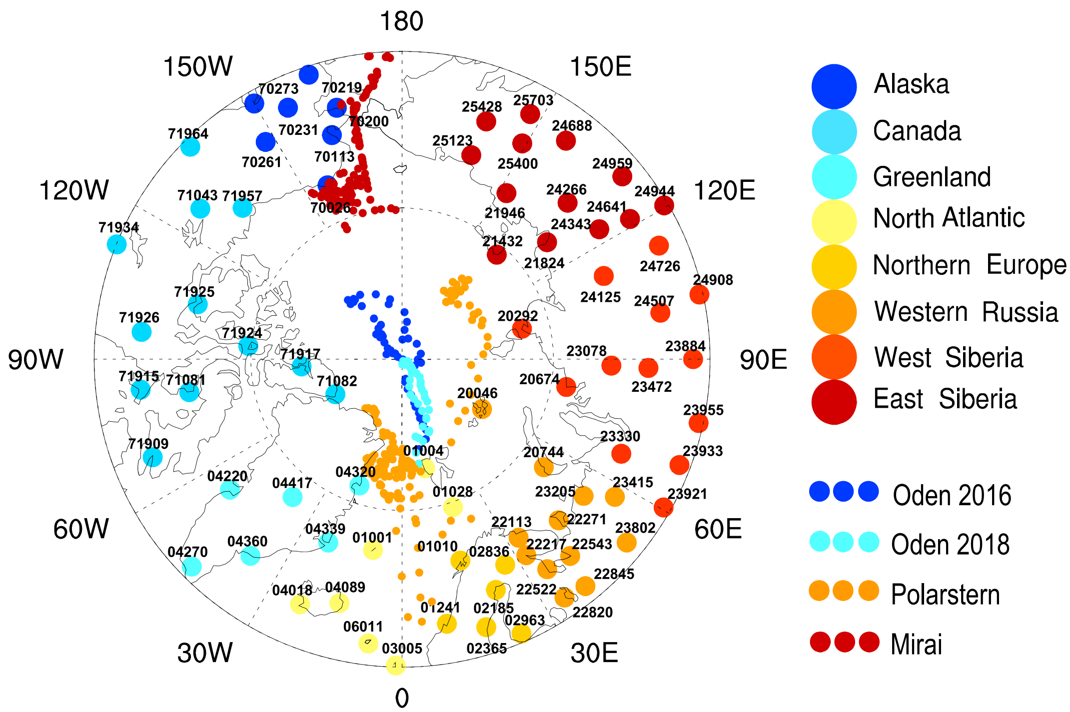

Figure 1. Locations of radiosounding stations north of 60°N and routes of expeditions of IB Oden, RV Polarstern, and RV Mirai in summers 2016–2018. Colors show the division into subregions.

Additionally, radiosonde observations from six expeditions in the Arctic Ocean during summers 2016–2018 were utilized. Locations of radiosonde observations made onboard IB Oden and RV Polarstern, using Vaisala RS92, and RV Mirai, using Vaisala RS41 sondes, are shown in Figure 1. Note that the radiosonde observations from Oden in summer 2016 were not sent to the Global Telecommunications System and, hence, were not assimilated into the ECMWF/IFS, whereas the radiosonde observations from the other expeditions were.

2.2. ECMWF Data Assimilation

ECMWF operational analyses and 12-hr forecasts were used. The model utilizes both spectral and grid point representations for calculations. The grid point representation uses a reduced Gaussian grid with 1,280 lines between the pole and equator yielding approximately 9-km horizontal resolution The model has 137 vertical levels with upward decreasing vertical resolution yielding approximately 20-m level spacing at 1,000 hPa and approximately 300-m level spacing at 500 hPa. To produce analyses, the ECMWF forecasting system uses 4-D variational data assimilation, cycles of which are repeated twice a day to assimilate various types of observations such as satellite, surface, aircraft, and radiosonde observations. Globally, satellite observations are very important for improving forecasts, whereas regionally in the winter Arctic in situ observations have the largest impact (Dahoui et al., 2017; Lawrence et al., 2019). The operational data assimilation consists of two procedures: (1) data assimilation with a long (12-hr) window provides first-guess fields for the next data assimilation cycle, while (2) data assimilation with a short (6 hr) window produces operational analyses used as initial conditions for the forecast (Owens & Hewson, 2018). Note that in operations the 12-hr forecasts do not serve as first-guess fields for the next assimilation cycle. For convenience, we use the 12-hr forecasts, valid at the analysis time, as an estimate for the first-guess field (Figure 2a), as previously by Ingleby, Rodwell, & Isaksen (2016) and Lawrence et al. (2019). These 12-hr forecasts are hereon referred to as background fields.

For comparisons with the radiosonde observations, air temperature in background fields and analyses were interpolated to a 0.25 × 0.25° grid, and averages in a 1 × 1° box around each sounding station were then taken. Only data from standard pressure levels (1,000, 925, 850, 700, and 500 hPa) were utilized for the comparisons.

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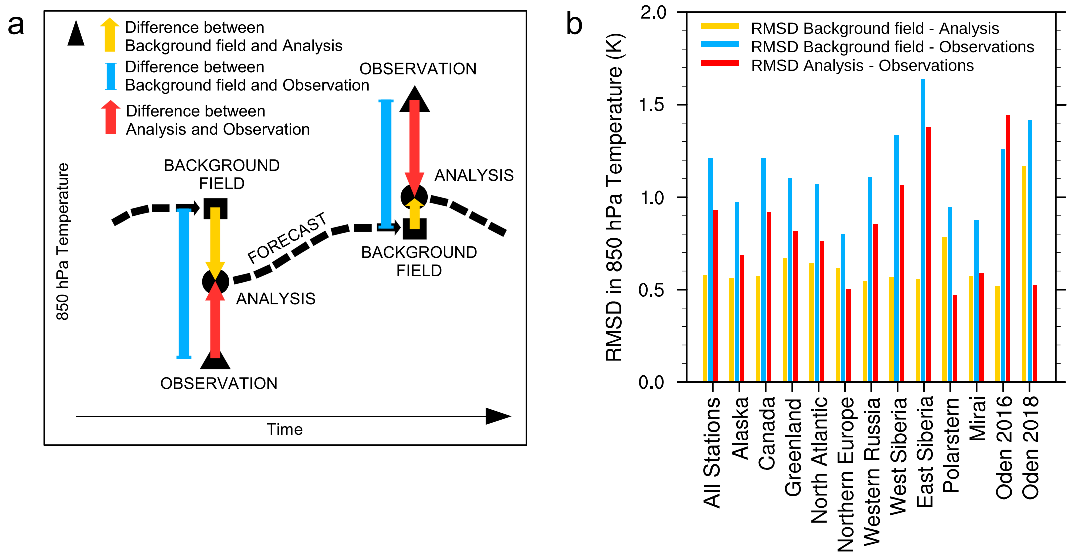

Figure 2. (a) Schematic illustration on assimilation cycles, (b) regional mean of root-mean-square difference (RMSD) in 850-hPa temperature between background fields and analyses (RMSD-BA), between background fields and radiosonde observations (RMSD-BO), and between analyses and radiosonde observations (RMSD-AO).

2.3. Trajectories and SOM Analysis

Trajectories, calculated 12-hr backward from the location of each sounding station with the receptor point at 850 hPa, were used to show how different air mass origins affect the deviation of background fields from the radiosonde observations. This assumes that background errors are advected with the air flow and the error growth of the model during the first 12 hr is smaller than initial condition errors. According to these assumptions, differences between the background field and observations provide an estimate of the errors in the previous analysis and indicate areas where previous analyses suffered from lack of observations. Three-dimensional trajectory calculations were made using Hybrid Single-Particle Lagrangian Integrated Trajectory (Stein et al., 2015). The trajectory departure points, the points from where the air mass had been advected to a sounding station, were organized into a regular grid. A single grid cell might contain departure points of trajectories ending up at several different sounding stations at different times. The difference between background field and radiosonde observation at the station to which the air mass had ended up was associated with the grid box of the air mass origin, allowing calculation of statistical measures for each air mass origin.

Relationships between synoptic-scale circulation and deviations of background fields from the radiosonde observations were investigated by comparing model products and observations in 20 characteristic atmospheric circulation regimes. These were obtained using the self-organizing map (SOM) method (Hewitson & Crane, 2002; Kohonen, 2001), applied to the mean sea level pressure fields from operational analyses, resulting in a 4×5 array of characteristic atmospheric circulation regimes.

3. Results

3.1. Differences Between the Background Field and Observations

Deviations of T850 background fields from the radiosonde observations had a large spatial variability (Figure 3a). Large root-mean-square differences (RMSDs) between the background field and observations (RMSD-BO) typically suggest a lower accuracy of the background field, but they may also, at least partly, be due to errors in the observations. The largest RMSD-BO was found in East Siberia (1.6 K), West Siberia (1.3 K), and for some Canadian stations (Figures 2b and 3a). Large RMSD-BO occurred also in the central Arctic Ocean during the Oden expeditions (1.3–1.4 K; Figure 2b). Accordingly, the background fields and/or radiosonde observations were most inaccurate in Siberia, although the density of sounding network is not the lowest there. The central Arctic Ocean represents a large area without regular radiosonde

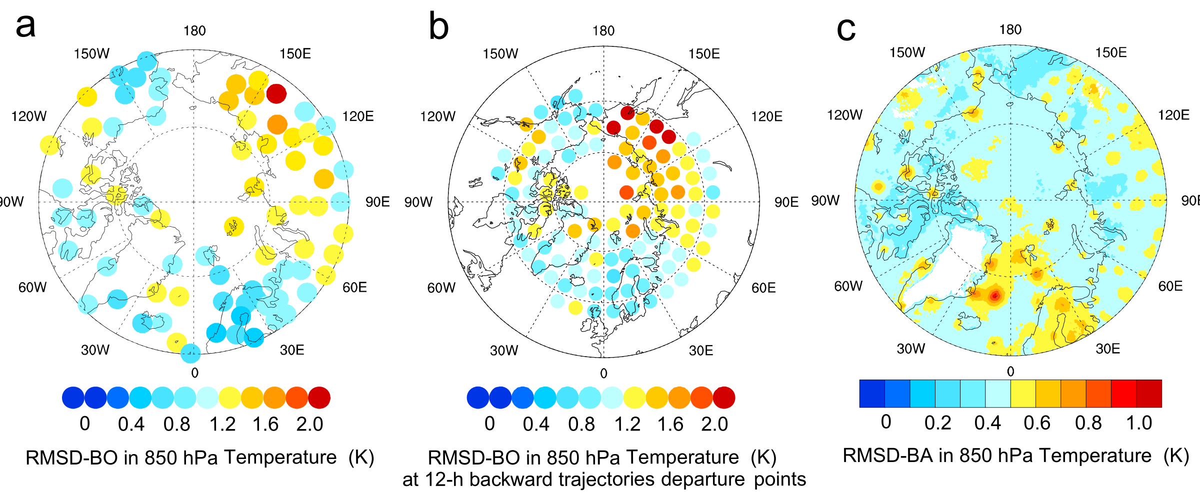

Figure 3. (a) Root-mean-square difference (RMSD) in 850-hPa temperature between background fields and radiosonde observations (RMSD-BO) at the sounding stations in January 2016 to September 2018. (b) Root-mean-square value of differences between background fields and radiosonde observations in 850-hPa temperature associated with departure points of 12-hr backward trajectories ending at the 76 Arctic radiosounding stations in January 2016 to December 2017. Only grid boxes containing more than 100 trajectory departure points were plotted. (c) RMSD in 850-hPa temperature between background fields and analyses (RMSD-BA) in January 2016 to September 2018.

observations, and this probably contributed substantially to the large deviation found there. The smallest RMSD-BO was found in northern Europe (0.8 K) and Alaska (1.0 K). Interestingly, RMSD-BO was relatively small also in the northern North Atlantic (1.1 K), where the radiosonde observation network is sparse. Hence, the deviation of background fields from the radiosonde observations does not depend only on the density of the radiosounding network. Additionally, RMSD-BO for temperature decreased with height, being largest for the lowest and smallest for the highest levels studied (1,000 and 500 hPa).

Trajectory analyses showed that deviations of background fields from the radiosonde observations increased northward but did not reveal any substantial systematic effect related to air mass origin (Figure 3b). The analysis indicated that when air mass origin was over northern Greenland, the Arctic Ocean, or the easternmost part of Siberia, background fields deviated slightly more from the radiosonde observations than when air mass origin was elsewhere. This might indicate that these regions would benefit from new or better observations. However, the same air mass origin often had different effects on RMSD-BO when ending up at different sounding stations, in fact, both trajectories and the accuracy of background fields depended on circulation patterns.

The SOM analysis confirmed that effects of spatial gaps in the sounding network varied with synoptic-scale circulation patterns, especially in winter (supporting information Figure S1). SOM analysis resulted in 12 regimes characterized by strong pressure gradients, mostly occurring in winter (October–April) and 8 regimes characterized by relatively weak pressure gradients, mostly occurring in summer (May–September). Sensitivity of RMSD-BO to atmospheric circulation was generally lower in summer than in winter. In winter, a relatively large RMSD-BO was found over northern Europe when the circulation was characterized by a high-pressure area over northern Eurasia and a low pressure over the North Atlantic, but the same surface pressure dipole-like structure was not associated with elevated RMSD-BO in other areas. Furthermore, deviation of background fields from the radiosonde observations increased in high-pressure conditions in East Siberia in winter. Overall, the variation of RMSD-BO at each sounding station due to either different synoptic-scale circulation patterns or different air mass origins was of the same order of magnitude.

3.2. Contribution of Observations in Analyses

The impacts of observations on operational analyses were identified by analyzing the differences between background fields and analyses (Figure 3c). Here, background fields were used as reference fields to show the impacts of assimilated observations in the analyses. The impact directly attributable to radiosonde observations could not be identified, because all assimilated observations influenced the analyses. However, the impact of radiosoundings was clearly identifiable as localized maxima of the RMSD between background fields and analyses (RMSD-BA) at the locations of sounding stations (Figure 3c). RMSD-BA decreased rapidly with the increasing distance from the sounding stations, suggesting that the direct impact of assimilating radiosoundings was limited to a relatively small area. This could especially be seen near Barrow (70026), Cambridge Bay (71925), and Jan Mayen (01001) stations. Nevertheless, an area-weighted mean of RMSD-BA of T850 over the whole Arctic north of 60°N (0.5 K) was only 0.1 K smaller than RMSD-BA averaged over the locations of sounding stations (0.6 K). However, at some individual stations, for example, Jan Mayen and Bear Island (01028) in the northern North Atlantic, RMSD-BA was 0.3–0.4 K larger than the average of all Arctic stations (Figure 3c). Hence, the largest collective impact of radiosoundings on the analysis was found in the northern North Atlantic, although the density of the network here is not higher. This shows that radiosoundings from a few stations can have a large impact on the analyses. Additionally, relatively large RMSD-BA, exceeding 0.5 K, occurred in the central Arctic Ocean, where there are no permanent sounding stations. This can probably be explained by large uncertainty of background field giving more weight on assimilation of satellite data, and by the impacts of radiosoundings from ships.

Relative influence of radiosoundings on analyses, that is, the weight of radiosonde observations in the assimilation process, was analyzed by comparing the RMSD between analyses and radiosonde observations (RMSD-AO) with RMSD-BA at sounding stations (Figure 2b). At stations where RMSD-AO was smaller than RMSD-BA, analyses were corrected close to observations in the assimilation process, indicating a large weight of observations in the analyses. Conversely, when RMSD-AO was large in comparison to RMSD-BA, the weight of observations in analyses was small, and analyses remained close to background fields. However, also other assimilated observations might have affected the results and an analysis closer to the radiosonde observations than the background field is due to the net effect of all the observations. As the surface observation network is not evenly distributed, this might yield larger corrections in the areas where the observation network is denser. Averaged over all Arctic sounding stations, RMSD-AO (0.9 K) was larger than RMSD-BA (0.6 K), both notably smaller than RMSD-BO (1.2 K; Figure 2b). This indicates that, at the locations of sounding stations, assimilation brought analyses closer to the observations, but analyses were still closer to background fields than to observations. RMSD-AO was smaller than RMSD-BA only at a limited set of stations indicating that analyses at these locations largely relied on radiosoundings (five northern European, three northern North Atlantic stations, Barrow in Alaska, RV Polarstern, and IB Oden 2018 expeditions; Figure 2b and supporting information Figure S2). In contrast, results for Siberia suggested a low weight of the radiosoundings: large RMSD-AO combined with small RMSD-BA means that only small corrections were made to background fields in the assimilation process, even though the differences between background fields and radiosonde observations were large.

Comparison of the RMSD-BA to RMSD-AO ratio with RMSD-BO at each station (supporting information Figure S2) shows that the spatial distribution of the weight of radiosoundings in the analyses was typically inversely related to the spatial distribution of RMSD-BO. This suggests that at the stations where radiosonde observations were close to background fields, observations had more weight in assimilations, and analyses were close to observations. At the stations where the differences between background fields and observations were large, differences between analyses and observations remained large. Jan Mayen, Bear Island and Barrow, as well as the Polarstern and Oden 2018 expeditions, were exceptions: Their RMSD-BO was large, but analyses were still brought close to the radiosonde observations. This means that radiosoundings from the expeditions in the Arctic Ocean and from stations in the northern North Atlantic, both regions with very few in situ observations, were very important for the quality of analysis.

A comparison of results for Oden in summer 2016 (not assimilated) and 2018 (assimilated) was especially enlightening as it made possible a distinction of the direct impact of radiosonde observations, relative to other observations. The comparison was made particularly interesting because of the location of these sounding near the North Pole, in the middle of an area where soundings are not regularly made and almost all assimilated data are based on satellite remote sensing. In 2016, the differences between individual radiosonde observations and individual analyses were large, indicated by a large deviation of points from the diagonal line in Figure 4a. The diagonal line represents a situation in which the analyses are brought to equal the radiosonde observations. In fact, in 2016 corrections made to background fields based on satellite observations brought the analyses even further away from the independent radiosonde observations,

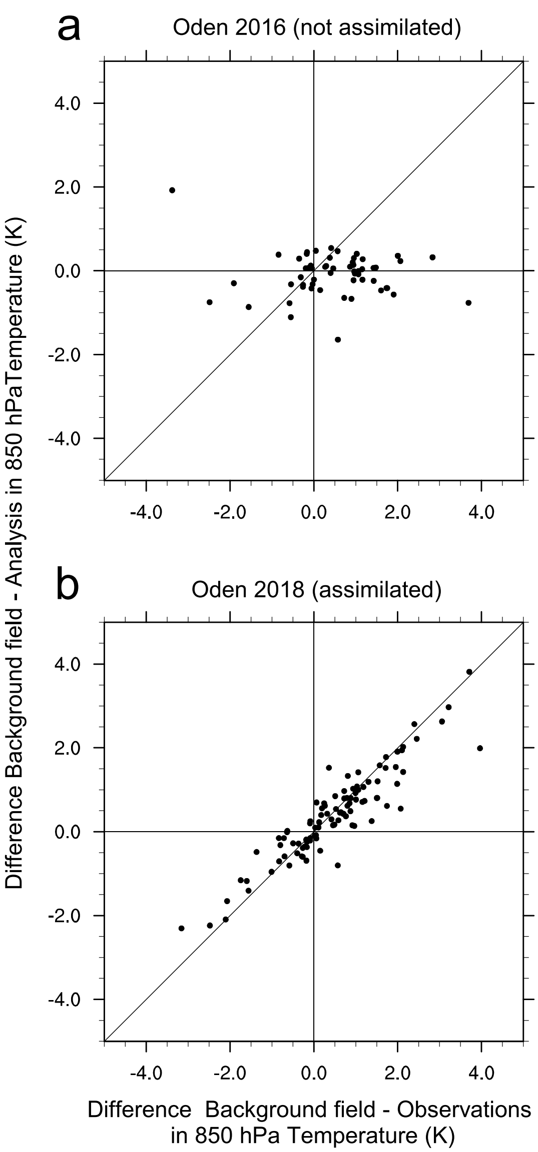

Figure 4. Scatter of instantaneous values of a radiosonde observation minus a forecasts as a function of instantaneous values of an analysis minus a forecast in 850-hPa level temperature for Oden expeditions in summer 2016 (a) and in summer 2018 (b). Distance of a point from the diagonal line is proportional to the difference between an analysis and an observation.

compared to background fields (Figure 2b). Conversely, in 2018 (Figure 4b), when soundings were assimilated, the analyses were brought very close to radiosonde observations. Furthermore, in 2016 analyses relied more on background fields compared to the situation in 2018 suggesting that notable corrections to the background field were made only when radiosonde observations were available. These results suggest that satellite observations alone were not capable of adequately correcting the background field. To exclude the possibility that the differences were due to improvements to the assimilation system over the time between expeditions, we explored the three model updates that occurred between summer 2016 and 2018. Comparison of results for the periods between the model updates showed that the pattern of local maxima of RMSD-BA nearby the sounding stations remained unchanged in all of the model updates (supporting information Figure S3), making the results for summer 2016 and 2018 comparable.

4. Discussion

Radiosonde observations had a notable impact in improving operational analysis, but the direct impact was limited to a relatively small area, suggesting that the density of the sounding network might affect the quality of the analysis. However, in regions where the radiosounding network is reasonably dense (distances between sounding stations less than 1,000 km), the density of the network did not seem to have an impact on the quality of the background field. In this area, which covers most of the continental area, the quality of the soundings and the way they are handled in the assimilation had a larger impact.

The Arctic Ocean represents a large gap in the in situ atmospheric profile observation network and the observational input in data assimilation is almost entirely based on satellite observations. Expeditions to the Arctic Ocean provided valuable information on the potential importance of radiosoundings outside the regular network. Summertime radiosoundings from Polarstern and, in 2018, Oden had a remarkable impact for improving analyses. Radiosonde observations were important for the quality of analyses having, at least locally, larger impact than satellite observations. This was clearly demonstrated by the differences between the background fields and analyses on the locations of Oden soundings in summers 2016 and 2018. The result suggests that satellite observations alone are not able to compensate for the lack of in situ observations of atmospheric profiles in the central Arctic. Inoue et al. (2015) suggested that surface observations, such as from drifting buoys, decrease uncertainty in geopotential height background fields in the lower troposphere. However, here it seems that lower troposphere temperature is less closely linked to the near-surface temperature, compared to how geopotential height is related to surface pressure. Hence, the accuracy of lower troposphere temperature is more dependent on availability and quality of profile observations and hence an improved surface observation network will not help.

The weight of radiosonde observations in the analyses seemed to have an important effect on the quality of the background field evaluated against observations. A large RMSD-BO and a relatively low impact of radiosonde observations in Siberia give rise to concerns about the quality of those radiosoundings. A study of statistics between background fields and observations indicted a lower accuracy of Russian radiosondes than other radiosondes used in the Arctic (Ingleby, 2017). One source of uncertainty is atmospheric pressure which is derived from radar altitudes and temperature profiles (Ingleby, 2017; Kats et al., 2005). ECMWF/IFS uses radiosonde-specific error statistics (Ingleby et al., 2018) in the assimilation, which may also have resulted in a lower weight for Russian radiosonde observations, also affected by the low-resolution TEMP messages still used at Russian stations. Most other Arctic stations have changed to the higher-resolution BUFR messages, improving the data utilization and yielding a higher impact in the assimilation (Ingleby, Pauley, et al., 2016). Canadian stations use low-resolution BUFR messages (Ingleby et al., 2018), which may partly explain the relatively low weight of these observations in the assimilation. However, Ingleby, Rodwell, and Isaksen (2016) conclude that Russian radiosoundings contribute to NWP in high northern latitudes despite higher uncertainty.

With a focus on the impact of radiosonde observations on improving NWP analyses, our approach neither allows a detection of the particular observations most important in a specific region nor reveals how extended forecasts would benefit from radiosonde observations through improved initial conditions. OSE or relaxation experiments (Jung et al., 2014) are needed to show how the improvement of analyses affects the quality of forecasts. However, nonexisting data, like regular soundings over the Arctic Ocean, cannot be denied in data-denial experiments and since the benefits of observations are flow dependent, it remains challenging to show in shorter numerical experiments where an individual observation would yield the largest benefit. Our results, covering a long period, are not sensitive to individual flow patterns or seasons and are thus able to provide overall statistical indications of the potential impacts of radiosonde observations for improved analyses.

5. Conclusions

Based on the comparison of 850-hPa level temperature from ECMWF operational IFS analyses, background fields for these analyses, and radiosonde observations from 76 Arctic stations and several research expeditions in the Arctic Ocean we conclude the following:

1. Radiosonde observations have a large effect on improving analyses, especially in data-sparse areas. Comparison of analyses with assimilated and nonassimilated radiosoundings also showed that satellite observations are not able to compensate for the large spatial gap in the sounding network in the central Arctic Ocean.
2. The impact of radiosonde observations on analyses has a large geographical variation. Radiosoundings from expeditions in the Arctic Ocean and from islands in the northern North Atlantic, like Jan Mayen and Bear Island, improve the analysis substantially. Our interpretation is that these are the regions where additional sounding stations would be most beneficial.
3. Radiosounding station density is not the most critical factor for the quality of T850 background field in the areas where the density is already reasonable (distances between stations less than 1,000 km). Instead, the quality of background field is related to how radiosonde observations are utilized in the assimilation and/or to the quality of those observations.
4. Differences between the background field and radiosonde observations depend strongly on synoptic-scale circulation regime.

Acknowledgments
This work was funded by the INTAROS H2020 EU-project (Grant 727890) and the Academy of Finland (Grants 317999 and 308441). This is a contribution to the Year of Polar Prediction (YOPP) activity. Operational analyses and forecasts were provided ECMWF (https://www.ecmwf.int/en/forecasts/datasets). Radiosoundings were taken from the IGRA archive (https://www.ncdc.noaa.gov/data-access/weather-balloon/integrated-global-radiosonde-archive), except for data from Oden which can be found online (www.bolin.su.se/data). We are grateful to the organizations providing support for the expeditions. We are also grateful to Bruce Ingleby, Peter Thorne, and Leopold Heimberger for providing insights on radiosonde uncertainty.

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