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Article

Impact of profile observations on the German Weather Service's NWP system

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Abstract

In preparation for a study on the potential impact of a space-borne Doppler wind lidar on the quality of NWP products, a series of assimilations and forecasts were conducted to estimate the potential benefit of conventional wind and temperature profile measurements over North America to numerical weather forecasts for the Northern Hemisphere and specifically, Europe. A comparison of the forecast quality of a control run, using all available observations, to experiments omitting wind and temperature data from specific instruments (radiosondes, pilot stations and aircraft) makes it possible to estimate the importance of the omitted data, and clarify whether winds derived from the geostrophic relation are sufficient or whether observed wind profiles result in a more realistic definition of the initial state for numerical weather prediction systems in the extratropic regions.

Very little impact on forecast quality was noted when wind or temperature observations from radiosondes and pilots were excluded from the assimilation process. However, a clear deterioration in forecast quality was observed when additionally all available wind or temperature measurements from aircraft were also withheld. Comparisons of the relative utility of wind and temperature observations over North America show that assimilations and forecasts derive more benefit from wind data than from temperature data. The greatest deterioration could be observed if both wind and temperature observations were omitted from the assimilation cycle. By tracing the differences between the control forecasts and the experimental forecasts to their initial difference, the regions around Hudson Bay, Novia Scotia, Buffin Bay and Northern Canada could be identified as sensitive areas, i.e. those where a missing observation could have a substantial effect on the forecast for the Northern Hemisphere and Europe.

Comparisons of the relative utility of radiosonde wind and temperature observations over Canada and Alaska to numerical weather forecast quality, in contrast to the sonde and aircraft network over the United States, reveal the importance of the conventional radiosonde network in the higher northern latitudes.

Zusammenfassung

Im Rahmen von Untersuchungen des möglichen Einflusses satellitengestützter Windprofilbeobachtungen auf die NWV wird in einer ersten Studie die grundsätzliche Bedeutung von Wind- und Temperaturmessungen für die Qualität der numerischen Wettervorhersage untersucht werden. Durch Vergleich der Vorhersagequalität eines Kontrolllaufs, der alle verfügbaren Beobachtungen enthält, mit Experimenten, die keine Wind- und Temperaturmessungen spezifischer Instrumente (Radiosonden, Pilotstationen und Flugzeuge) berücksichtigen, kann die jeweilige Bedeutung der nicht genutzten Beobachtungsinstrumente für die NWV abgeschätzt werden. Außerdem kann die Frage untersucht werden, ob näherungsweise aus den Druckfeldgradienten abgeleitete "geostrophische" Winde echte Windmessungen in der Datenassimilation ersetzen können.

Wenig Einfluss auf die Vorhersagequalität wurde festgestellt, wenn Wind- oder Temperaturbeobachtungen von Radiosonden und Piloten von der Assimilation entfernt wurden. Erst wenn zusätzlich alle Wind- oder Temperaturbeobachtungen von Flugzeugen ausgeschlossen wurden, konnte ein deutlicher Einfluss auf die Vorhersagequalität beobachtet werden, wobei Windbeobachtungen einen größeren Einfluss ausübten als Temperaturbeobachtungen. Der stärkste Einfluss wurde sichtbar, sobald sowohl Wind- als auch Temperaturmessungen aus dem Assimilationszyklus ausgeschlossen wurden. Verfolgt man die zeitliche Entwicklung der Differenzen zwischen Routinevorhersage und Vorhersage ohne die Benutzung von Wind- und/oder Temperaturbeobachtungen, so konnten die Regionen um die Hudson Bay, Neufundland, Baffin Bay und das arktische Kanada als sensitive Regionen ermittelt werden, in denen fehlende Beobachtungen wesentlich die Vorhersagequalität beinflussen können.

Untersuchungen des Einflusses der Wind- und Temperaturbeobachtungen der konventionellen Radiosondennetzwerke über Kanada und den USA verdeutlichten die Wichtigkeit von Radiosondenmessungen in höheren nördlichen Breiten.

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1 Introduction

Numerical weather prediction (NWP) systems require exact three-dimensional global observations of wind, temperature, humidity, etc. as initial conditions to achieve a skillful weather forecast. Several studies have concluded that knowledge of the global wind field is essential in order to represent synoptic and small-scale features of the atmosphere in a meteorological analysis and to improve our understanding of the global atmospheric transport processes of energy, water and other airborne materials (BAKER et.al., 1995; GRAHAM and ANDERSON, 1995). Recently, in their evaluation of user requirements and satellite capabilities, the World Meteorological Organization (WMO) came to the conclusion that, for global meteorological analyses, measurements of wind profiles remain both challenging and of critical importance (WMO, 1998). Global assimilation systems currently use directly measured wind data from conventional observation systems (radiosondes, aircraft reports, balloon measurements) and satellite-based remote sensing systems (cloud-drift winds, scatterometers). Each observing system has its deficiencies in spatial coverage and frequency. One major shortcoming of the current global observing system is the poor distribution of observations of the vertical wind profile over the oceans, in the tropics and in the Southern Hemisphere.

In general, there are two main techniques to estimate the effectiveness of atmospheric observations in data assimilation systems. In Observing System Experiments (OSEs) the contribution of existing observation systems on the analysis and forecast quality of the NWP system to be evaluated is assessed by running two parallel assimilations: one with all the available observations as a control and the other omitting the specific observation being investigated. Forecasts from both assimilations are then generated, and the impact of the observation system is estimated by comparing the accuracy of the forecasts with and without the data type being evaluated (ATLAS, 1998; KELLY, 1997; GRAHAM and ANDERSON, 1995; BELL et.al., 1994; SMITH and BENJAMIN, 1994). The impact of future observing systems on NWP models can be evaluated by using Observing Simulation System Experiments (OSSEs), in which a numerical NWP model is used to simulate the real atmosphere (Nature Run). After that, observations are generated for both conventional and new systems from the Nature Run, including their error characteristics. Then, forecasts are performed using the simulated observations with and without the data from the new observing system. The impact of the new system on the Nature Run is then assessed by comparing and verifying both forecasts (GADD et. al., 1995; MCNALLY and VESPERINI, 1995; STOFFELEN and MARSEILLE, 1998; TOMASSINI et al., 1996).

In the present study, OSEs were used to evaluate the impact of conventional wind and temperature observations on the forecast quality of the German Weather Service's (DWD) Global-Modell (GM). First a short introduction to the global modeling system of the DWD will be given (Section 2), followed by an illustration of the experiment design (Section 3). In Section 4, the effect of wind and temperature observations from the radiosonde and aircraft network over North America on the forecast quality of the GM will be discussed. Furthermore, the consequences of missing observation types on synoptic weather patterns in the Atlantic/European area will be discussed and sensitive areas singled out. Finally, the relative importance of observations from higher latitudes as compared to the continental United States will be addressed. Section 5 contains a summary and an outlook on the work to be reported in a companion paper.

2 The global modeling system of the DWD

2.1 Assimilation scheme

The quality of a forecast from a numerical weather prediction model depends on the accurate determination of the initial state of the atmosphere and a sophisticated forecast model to simulate the subsequent atmospheric evolution realistically. Unfortunately, the number of observations currently available is not adequate to uniquely determine the initial state of all prognostic variables of a NWP model at all grid points. The purpose of modern data assimilation systems is to combine the incomplete and erroneous observations of the present with a forecast model that contains all the information about the atmospheric state of the past to achieve a regular, physically consistent, three-dimensional "best estimate" of the true atmospheric state at the starting point of an analysis in some statistical sense (DALEY, 1991; PAILLEUX, 1997).

The DWD's global assimilation system consists of a three-dimensional multivariate optimal interpolation of deviations of observations from a 6-h forecast (first guess) for the analyzed variables horizontal wind, geopotential height and surface pressure. A three-dimensional univariate statistical interpolation is performed for relative humidity. The global assimilation scheme takes into account all available observations in a 6-h window centered around the analysis times 00, 06, 12 and 18 UTC. At present, the DWD uses the following types of observations in its global assimilation system:

- **SYNOP and SHIP:** Surface observations of the conventional meteorological parameters temperature, wind, pressure, humidity, clouds and precipitation.
- **TEMPS:** Upper air observations of wind, temperature and humidity by radiosondes.
- **PILOTS:** Wind observations obtained by tracking of balloons in the free atmosphere.
- **AIREP/AMDAR reports:** Manual or automatic observations of temperature and wind by commercial aircraft at cruising altitude (200–300 hPa) and during takeoff and landing.

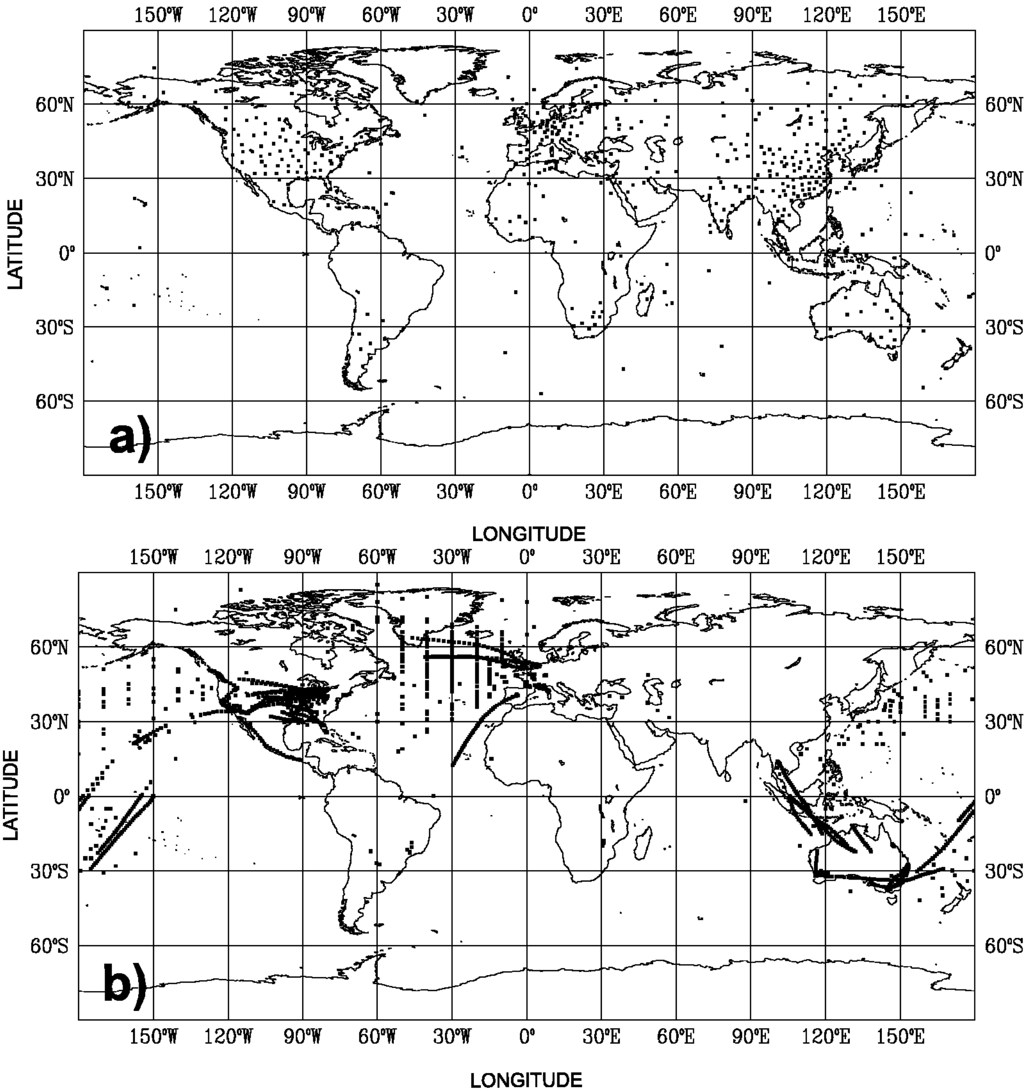

Figure 1: Global coverage maps for radiosonde (a) and aircraft observations [AIREP/AMDAR, (b)] for 19 January 1998, 12 UTC ± 3 hours.

- **BUOYS:** Measurements of temperature, wind and humidity from buoys in the ocean.

- **SATOB:** Single-level wind observations derived from cloud motion detected by geostationary satellite images. They are not used over extratropical land areas.

- **SATEM:** Temperature soundings that are retrieved from the radiance measured by polar orbiting satellites with a resolution of 500 km. They are not used over land below 100 hPa.

The global coverage maps of radiosonde and aircraft observations for a ± 3-hour period around 19 January 1998 at 12 UTC are illustrated in Figure 1. The radiosonde stations are distributed irregularly over the globe, with particularly high density in North America, Europe, China and the Far East. Aircraft measurements are mainly reported over the United States and the major North Atlantic routes.

The sea surface temperature (SST) is analyzed daily at 00 UTC using a correction method. All SST reports from ships and buoys for the last seven days are taken into account. For each sea grid point a local data selection is performed. The weight given to the observations depends on each grid point's distance from the observation point and the age of the observations. The global SST analysis from NMC Washington serves as the background field for the global SST analysis. Ice edge data from the NOAA/NAVY Joint Ice Center are used to create the ice border in the GM-grid.

A snow depth analysis is performed every six hours using snow depth observations and snowfall data. A weighted average at grid points is used as an analysis method. The weight given to the observations depends on the horizontal and vertical displacement between observations and analysis points. In data-sparse areas a 6-h forecast of snow depth is used. No analysis of soil temperature or water content is performed, but 6-hour first guess fields are used.

After the analysis a nonlinear, diabatic normal mode initialization is computed to balance the mass and wind field of the GM and to remove high frequency gravity oscillations. Following the analysis and initialization, a six hour forecast of the Global-Modell is conducted, serving as a first guess field for the next analysis.

2.2 Global forecast model

All the experiments discussed in this paper used the DWD's operational Global-Modell derived from the ECMWF model (cycle 34; SIMMONS et al., 1989). It is a spectral model with T106 truncation, 19 vertical layers and a mean orography. This resolution is equivalent to a quasi-regular mesh size of 1.125°. The prognostic variables are surface pressure, temperature, specific humidity, relative vorticity and horizontal divergence. They are defined on a terrain-following hybrid coordinate system. The physical parameterizations consist of the δ-two-stream radiation scheme after RITTER and GELEYN (1992), a gravity wave drag scheme by MILLER et. al. (1989) and a mass-flux convection scheme by TIEDTKE (1989). Grid-scale precipitation is determined when a grid square is saturated. Evaporation of precipitation is taken into account. Rainfall and snowfall rates are derived diagnostically, assuming stationarity and neglecting advection.

For the formulation of vertical turbulent fluxes in the boundary layer, the Dyer-Businger relations as modified by LOUIS (1979) are used. In the free atmosphere, turbulent fluxes depend on mixing length and the Richardson number. The turbulent surface fluxes depend on the local roughness length and stability. If the land portion of a grid box is greater than 50%, this grid point is treated as a land point, where a soil model predicts the temporal evolution of temperature and moisture. The model comprises two layers in the soil. Below the two layers climate values in a third layer are specified as lower boundary values which are changed monthly (but fixed during forecasts). Further details can be found in DWD (1998).

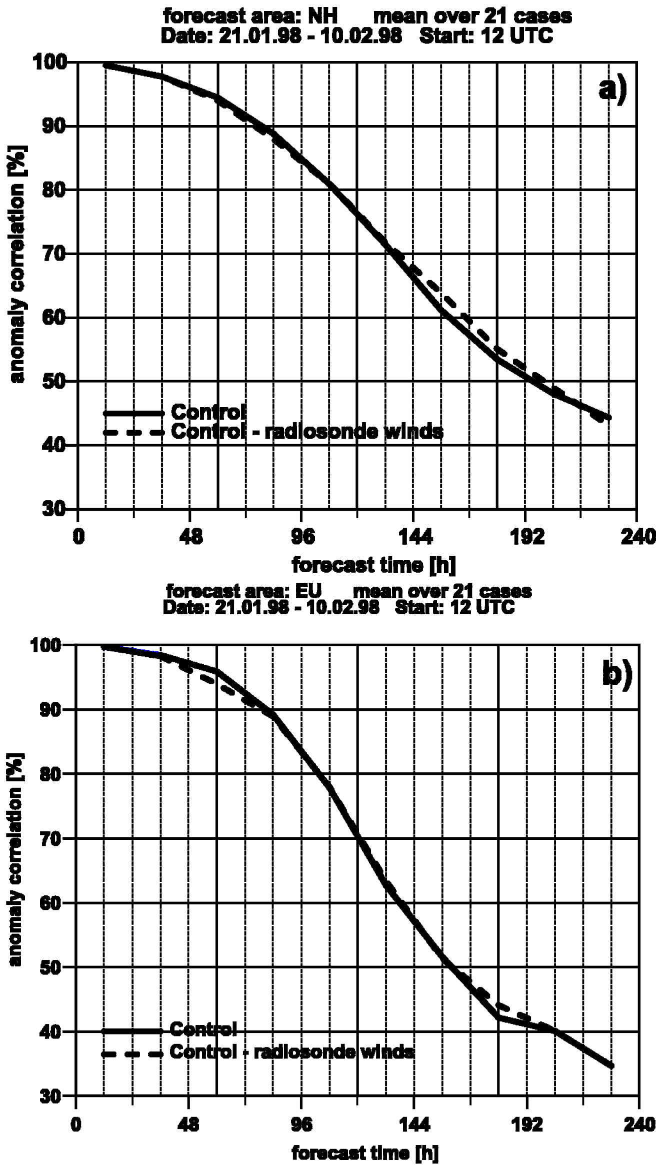

Figure 2: Mean anomaly correlation (21 Jan. to 10 Feb. 1998) of the 500 hPa geopotential height versus forecast time for control (full) and for assimilation without wind observations from radiosonde and pilot stations over North America (dashed) for a) the entire Northern Hemisphere and b) Europe.

3 Experiment design

All the OSEs were run for the period from 21 January to 10 February 1998. A period during the winter season was chosen because of the more intense dynamical activity of the atmosphere in winter compared to summer. The period was marked by strong baroclinic activity over North America. The North American area was chosen because of its dense coverage with a homogeneous network of radiosondes and pilots. Furthermore, there are numerous profiles from aircraft being taken during take-off and landing over the continental US. Also, as Europe lies downstream, these observations can be anticipated as crucial for forecast quality over Europe. Observations were withdrawn by WMO block numbers 70–79, with the exception of data from Hawaii, which were always included. The use of satellite observations (SATEM and SATOB) as well as of other conventional systems (SYNOPS, SHIPS, BUOYS) remained unchanged.

The first set of experiments was run with wind observations from sondes and pilots excluded. As these experiments did not yield the expected results, they were repeated with excluding wind reports from airplanes in addition.

The next set of runs was performed with denying mass field information. They were meant to clarify the relative importance of mass over wind data. As the hydrostatic assumption is used in the analysis scheme, mass data is equivalent to temperature and surface pressure observations. In the following, these experiments are mostly referred to as runs without temperature data.

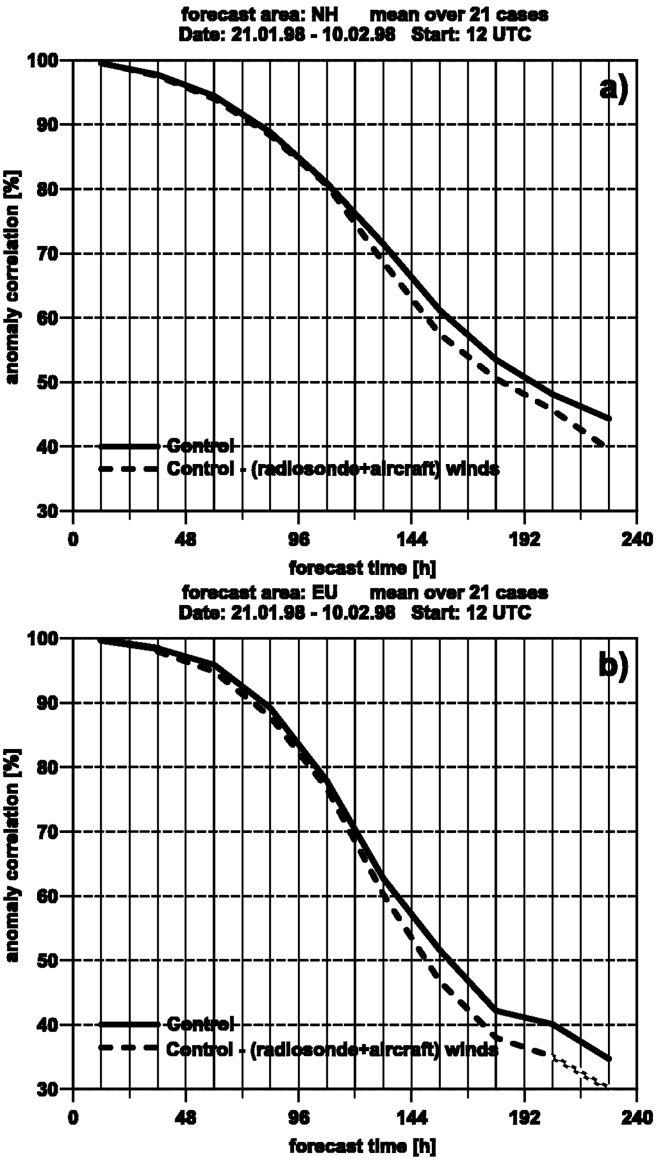

Figure 3: Mean anomaly correlation (21 Jan. to 10 Feb. 1998) of the 500 hPa geopotential height versus forecast time for control (full) and for assimilation without wind observations from radiosonde, pilot stations *and aircraft* over North America (dashed) for a) the entire Northern Hemisphere and b) Europe.

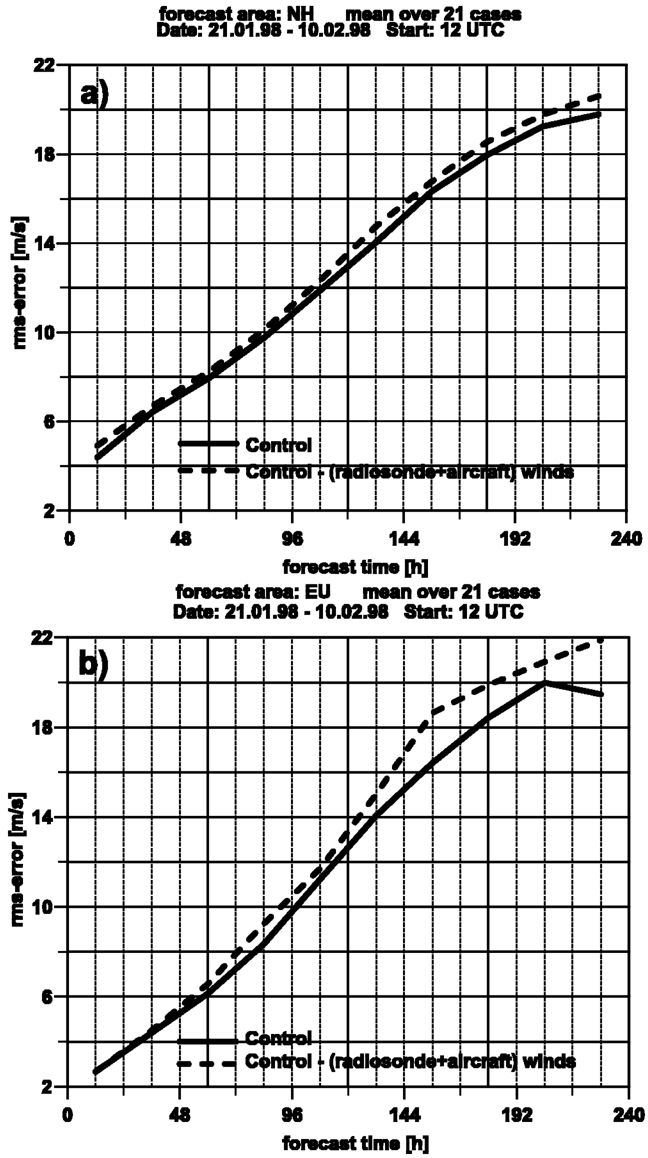

Figure 4: Root mean square error (RMS) of the 200 hPa wind vector forecasts in m/s for the control (full) and the experiment not using wind observations (dashed) from radiosondes, pilots and aircraft over North America averaged over a) the Northern Hemisphere and b) Europe. Time average from 21 Jan. to 10 Feb. 1998.

Finally, both mass- and wind profiles from conventional systems were excluded from the assimilation over North America.

In order to estimate the impact of the relatively few sondes and pilots in high latitudes north of 53°N, the series described above was repeated, but this time removing only data south of 53°N. By comparing results from these runs to the previous experiments not using data from the entire area, many interesting conclusions on the relative importance of high latitude mass– and/or wind data could be derived. On the request of one reviewer, only a very limited subset will be shown.

In summary, the following sections will discuss the impact of:

(1) Wind profile observations from radiosondes and pilots over North America

(2) Wind profile observations from radiosondes and pilots and aircraft over North America, i.e. as (1), but removing aircraft wind data in addition

(3) Temperature profile observations from radiosondes and aircraft over North America, i.e. as (2), but removing temperature observations instead of wind data

(4) Temperature and wind profile observations from radiosondes, pilots and aircraft over North America, i.e. a combination of (2) and (3)

(5) Temperature and wind profile observations from radiosondes, pilots and aircraft south of 53°N, i.e. as (4), but leaving the data north of 53°N in.

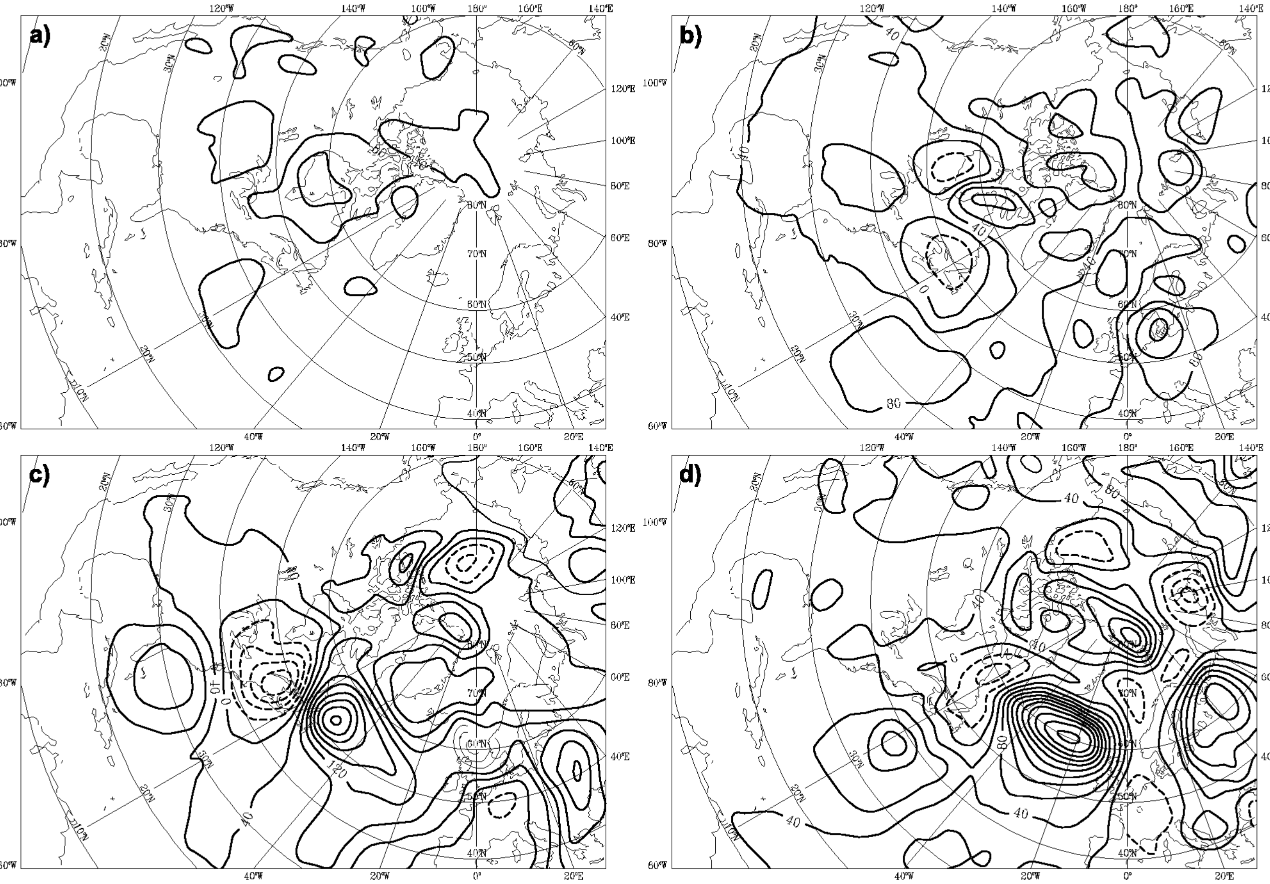

Figure 5: Differences in the 500 hPa geopotential height field in m between the forecast using all available observations (control) and the experiment not using radiosondes, pilots and aircraft wind data over the United States and Canada. The start date of the forecasts is 30 January 1998 12 UTC and the differences are for a) the initial state after b) 84, c) 132 and d) 180 hours forecast time. Contour interval is 40 m in all panels, negative values are dashed.

4 Results

4.1 Observations over the entire North American continent

In a first set of OSEs North America was selected as "target area", where a loss of observation information in the operational analysis could be anticipated to have a substantial influence on the forecast quality over the European/North Atlantic region.

4.1.1 Impact of wind observations from radiosondes and pilots

The first experiment was run with excluding wind observations from radiosondes and pilots over North America from the assimilation. From these degraded initial states, 21 forecasts were run from 12 UTC between 21 January 1998 and 10 February 1998. The experimental forecasts were verified against the operational analyses and compared to the operational forecasts, which had used all available observations. Verification was done for the 500 and 250 hPa geopotential, for the 200 hPa winds and for surface pressure. Only results for the 500 hPa geopotential and the 200 hPa winds will be discussed. Results will be presented as average over the entire northern hemisphere north of 20°N and for Europe (36°N–72°N,12°W–42°E). The operational reference forecasts will be labeled 'control' in the following figures. The difference in forecast quality between the control and the experiment gives an indication of the impact of a particular observing system.

Figure 2 shows the anomaly correlation of the 500 hPa geopotential as a function of forecast time for the operational forecast (full) and the experiment not using wind data from radiosondes and pilots (dashed). The values are shown for the entire Northern Hemisphere (left) and Europe (right). For the 500 hPa level, sonde wind observations from North America have very little impact in both areas. A marginal positive impact could only be found for the 250 hPa fields over Europe (not shown). There is even an indication that the wind data might lead to a slight deterioration in forecast quality later in the medium range. This could be caused by problems in the data themselves or their usage in the analysis.

A potential explanation of the overall neutral impact of wind data from sondes over North America is that other sources of wind information could compensate for the missing radiosonde wind profiles. As indicated in

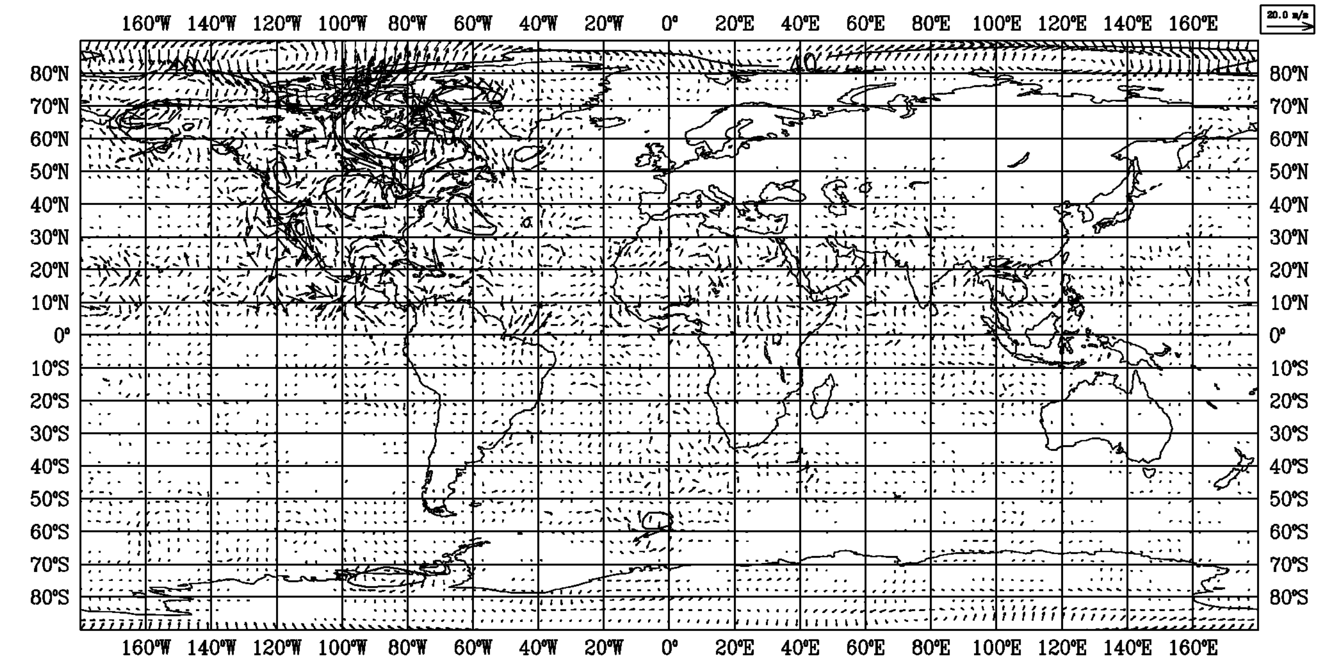

Figure 6: Differences in the wind and geopotential analysis at 500 hPa after eleven days of assimilation between the control and the experiment not using wind profile observations from radiosondes, pilots and aircraft over the United States and Canada. The difference is valid for 30 January 1998; the contour interval for the height field is 20 gpm.

Section 2.1, there is good coverage with aircraft data over the U.S. Apparently, these observations can successfully compensate for the loss of radiosonde and pilot data. Similar results are achieved if temperature instead of wind profile observations from radiosondes are omitted from the assimilation (not shown). Only if both wind and temperature data from radiosondes and pilots are excluded from the assimilation, an impact on forecast quality becomes detectable (not shown).

4.1.2 Impact of wind observations from radiosondes, pilots and aircraft

In order to verify that there is indeed a redundancy between sondes and aircraft, the experiments described above were re-done, but with excluding aircraft data in addition to radiosonde and pilot observations. Otherwise, the set-up was identical.

Figure 3 shows the results for the 500 hPa geopotential over the northern hemisphere (left) and Europe (right). This time, a clear deterioration in forecast quality is caused by the lack of wind observations from sondes and aircraft from North America. Taking the 60% correlation as limit for a useful forecast, not having wind data from North America would reduce predictability by 9 hours for the northern hemisphere and by 6 hours for Europe.

One major output of NWP models are upper-level wind forecasts for aviation customers. The impact of wind observations on the wind vector in the upper troposphere (jet stream level) is illustrated in Figure 4. Obviously, there is already an impact in the early forecast ranges which increases with time.

Besides evaluating the average impact of specific observation systems on a number of forecasts in the form of objective statistical scores, it is also helpful to look at individual cases. By tracing back the temporal evolution of the differences between the control and experiment, sensitive areas can be identified, where a missing observation in the initial state could affect the subsequent forecast substantially. In Figure 5, a strong signal in the initial analysis differences (Figure 5a) of the 500 hPa geopotential field is located over the Hudson Bay, extending over all of northeastern Canada. After 84 hours (Figure 5b), the differences expand over the Labrador Sea and Greenland, and a second area of significant differences becomes visible over eastern Canada and in the Atlantic Ocean south of 50°N. As the forecast time continues, the differences cover the entire eastern coastal region of North America, the Atlantic Ocean and Europe north of 30°N (Figure 5c,d).

In order to highlight the impact of observations from North America on global analyses, Figure 6 shows the difference in the wind and geopotential analysis at 500 hPa after eleven days of assimilation between the control and the experiment not using wind profile observations from radiosondes, pilots and aircraft over the United States and Canada. Even during the assimilation process, systematically omitting the North American wind observations produces uncertainties not only over the area where the data are removed, but also in other data-sparse regions (e.g. entire tropical area), indicating that the analysis of the tropical flow regime is rather uncertain in global modeling. Only over Europe and Asia, the observing networks are able to determine the initial state uniquely. The results clearly highlight the im-

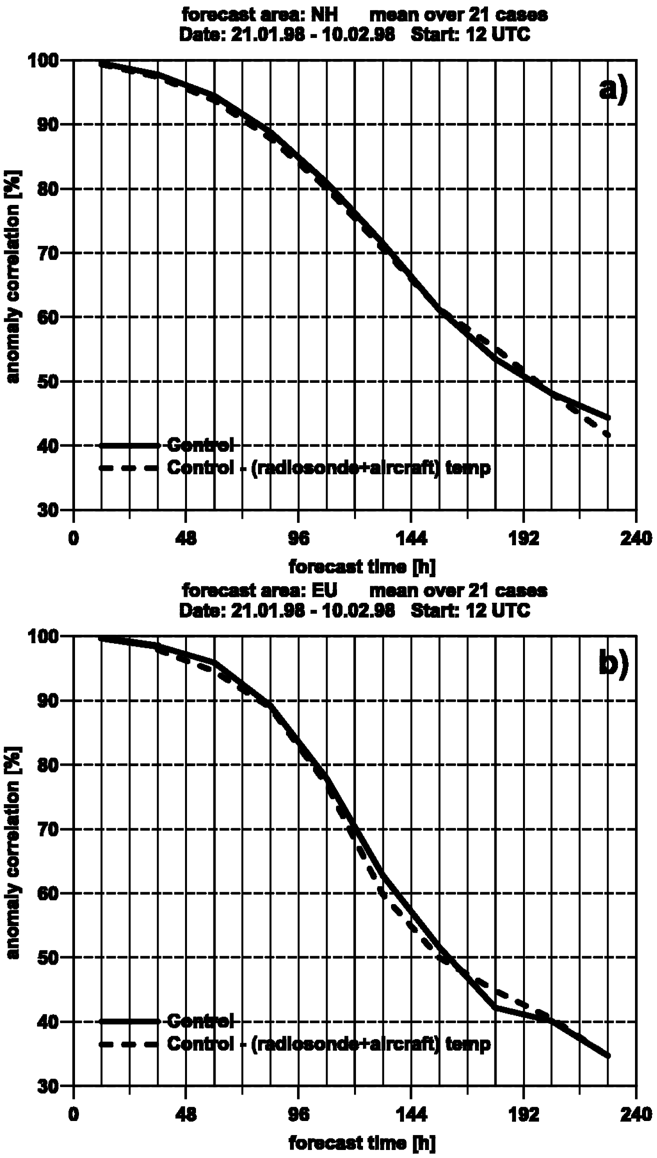

Figure 7: Mean anomaly correlation (21 Jan. to 10 Feb. 1998) of the 500 hPa geopotential height versus forecast time for control (full) and for assimilation without temperature observations from radiosonde, pilot stations and aircraft over North America (dashed) for a) the entire Northern Hemisphere and b) Europe.

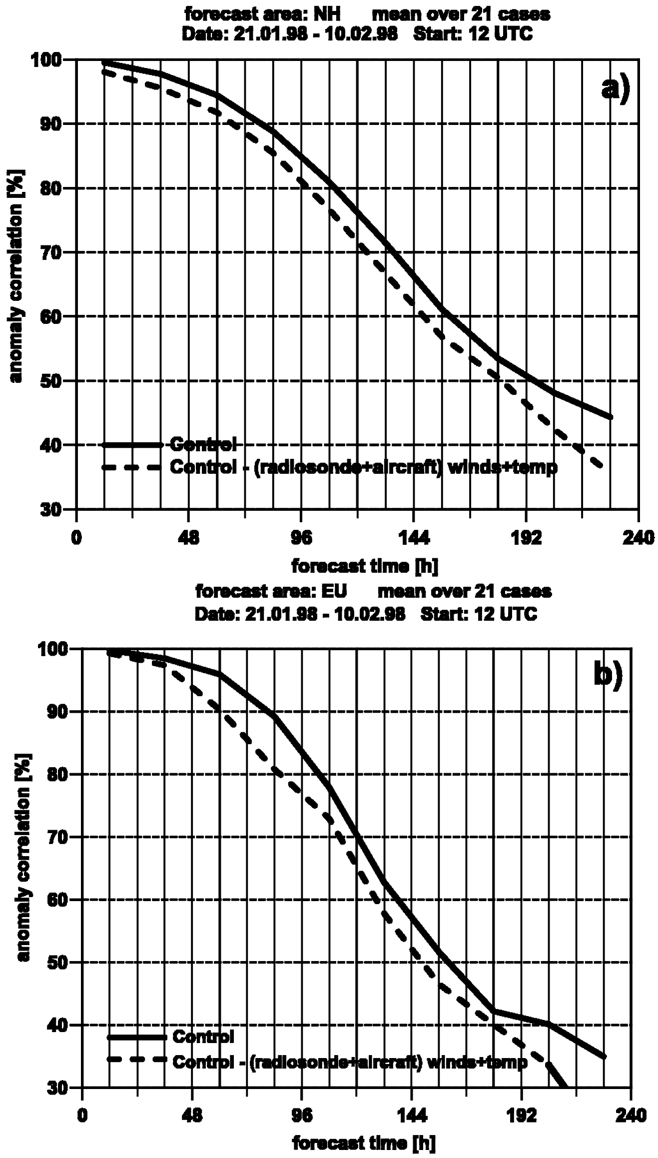

Figure 8: Mean anomaly correlation (21 Jan. to 10 Feb. 1998) of the 500 hPa geopotential height versus forecast time for control (full) and for assimilation without wind and temperature observations from radiosonde, pilot stations and aircraft over North America (dashed) for a) the entire Northern Hemisphere and b) Europe.

portance of wind observations when defining the initial state for a skillful forecast not only in the tropics but also in the extra-tropical regions. Apparently, the geostrophic winds generated from geopotential gradients by the multivariate ‘Optimum Interpolation (OI)’ scheme are not sufficient to define the motion field with sufficient accuracy. In reality, there exist considerable deviations from geostrophic balance for planetary and small scales, which can only be captured by high quality observations.

4.1.3 Impact of temperature observations from radiosondes and aircraft

In order to estimate the impact of wind data relative to mass data, a third series of experiments was conducted in which the temperature information from sondes and aircraft was denied to the assimilation scheme. Compared to wind observations, temperature profile measurements over North America have less impact on the forecast quality of the middle atmosphere, averaged over the entire Northern Hemisphere (Figure 7a) and Europe (Figure 7b). There is only a very modest reduction in forecast quality for the entire hemisphere but a noticeable impact on the downstream region over Europe. The impact becomes stronger in the upper troposphere but still remains smaller than the impact of wind observations. Similar conclusions hold for the impact on the wind field. Overall, these results support recent findings (GRAHAM et al., 1999) that wind information contributes more frequently than temperature information to a skillful NWP forecast.

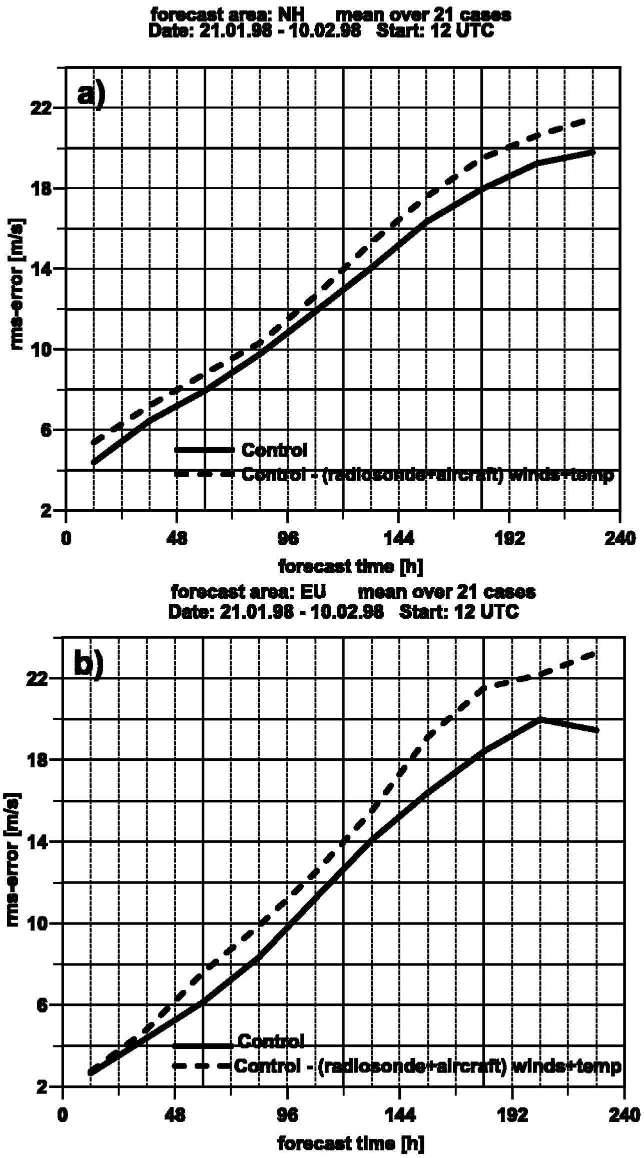

Figure 9: Root mean square error (RMS) of the 200 hPa wind vector forecasts in m/s for the control (full) and the experiment not using wind and temperature observations (dashed) from radiosondes, pilots and aircraft over North America averaged over a) the Northern Hemisphere and b) Europe. Time average from 21 Jan. to 10 Feb. 1998.

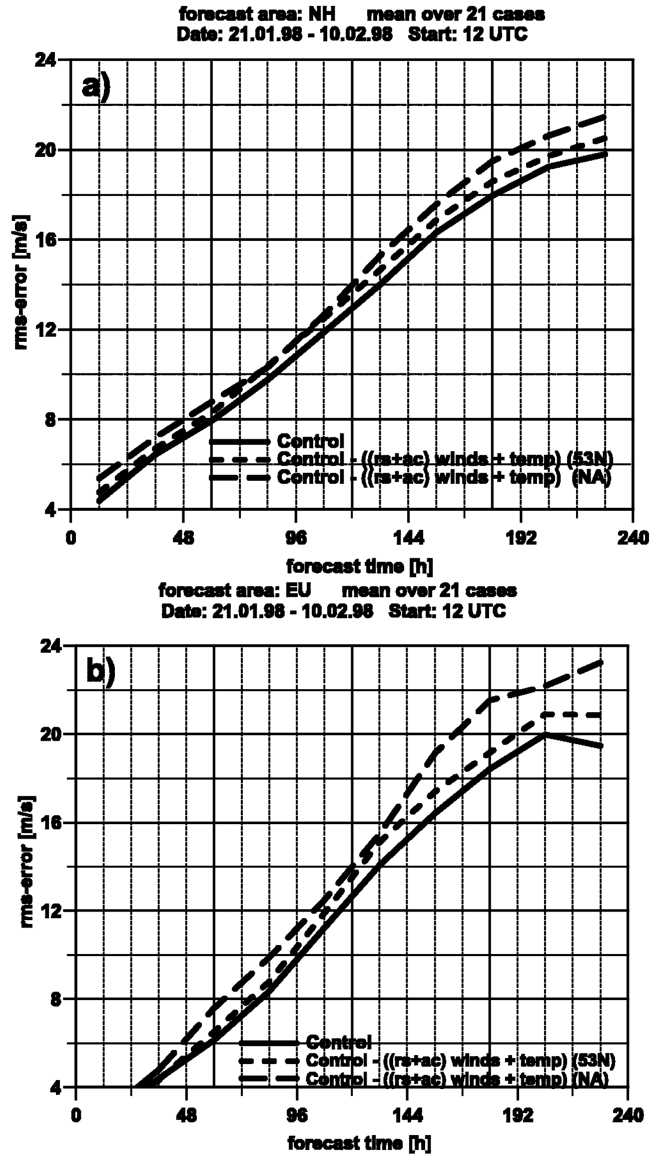

Figure 10: Root mean square error (RMS) of the 200 hPa wind vector forecasts in m/s for the control (full), the experiment not using wind and temperature observations (dashed) from radiosondes, pilots and aircraft south of 53°N and experiments omitting wind and temperature observations (long dashed) from radiosondes, pilots and aircraft over entire North America, averaged over a) the Northern Hemisphere and b) Europe. Time average from 21 Jan. to 10 Feb. 1998.

4.1.4 Impact of wind and temperature observations from radiosondes and aircraft

In a fourth set of experiments, both wind and temperature information from radiosondes, pilots and aircraft over North America were denied to the assimilation. As expected, this results in the largest reduction of forecast quality. The usability of the geopotential forecasts, averaged over the Northern Hemisphere and Europe, is reduced by almost 10 hours throughout the forecast range(Figure 8a,b). In contrast to the experiments described earlier, a clear deterioration is obvious already early in the forecast, in particular for the hemisphere. This reflects the uncertainties in the initial analysis not only in the area where the data usage was reduced, but also in other data void areas, as already demonstrated in Figure 6. Similar results are obtained for the 200 hPa wind field (Fig. 9). The effect of the missing observations over North America is even more noticeable in these fields. Retracing the temporal development of the differences between the control forecast and the experiment not using wind and temperature observations, reveals sensitive areas mainly in higher latitudes, with a maximum over the Hudson Bay. This signal amplifies during the forecast and leads to considerably less skillful predictions over Europe.

4.2 Impact of temperature and wind observations from sondes north of 53°N

There is growing political pressure to reduce the operating costs of meteorological services. A large part of these costs is incurred by the observing networks. This is particularly true in remote areas, such as Canada, where maintaining a radiosonde station is much more expensive than in densely populated areas. It is thus important to be able to demonstrate the value of these stations to the relevant authorities. Classical theory and recent studies suggest that upper northern latitudes tend to be the most sensitive areas, where missing observations can substantially influence forecast quality for the Northern Hemisphere and for Europe. To further address this, a series of OSEs was conducted in which all wind and temperature profile observations from radiosondes, pilot stations and aircraft were omitted only south of 53°N. By comparing forecasts generated from these analyses to forecasts generated from analyses described earlier (not using these observing systems over all of North America), the impact of the observation network in the United States compared to the observation network further north (Canada and Alaska) can be deduced.

Figure 10 presents the outcome of these experiments. It shows the RMS wind error at 200 hPa for the northern hemisphere (left) and Europe (right) as a function of forecast time. The full curve is for the control forecast, the long dashes are for the experiment with the wind and temperature data removed over entire North America. These two curves are repeated from Figure 9. Additionally, there are the values (short dashes) for forecasts started from analyses where only the corresponding observations south of 53°N have been removed. Thus, the difference between the two dashed curves corresponds to the impact of the observations north of 53°N. Europe in particular derives more benefit from the sparse observation network over Canada than from the US data for this period. It should, however, be stressed that a single period of three weeks does not allow to draw general conclusions. Results might depend on season and on flow regime.

5 Conclusions and outlook

The impact of sonde and aircraft observations from the North American continent on the global NWP system of DWD has been investigated by ‘Observing System Experiments’ for a period in winter 1998. The following results have been obtained:

- There is redundancy between sonde and aircraft observations.
- Denying wind data from sondes and aircraft results in a large deterioration of forecast quality.
- Denying temperature data from sondes and aircraft has a smaller impact than denying wind data.
- The largest impact is obtained when denying both wind and temperature data.
- A considerable part of the impact is due to the observations taken north of 53°N
- Not using data from the North American continent leads to considerable analyses differences in other data void areas, thus demonstrating the uncertainties in our knowledge of the state of the atmosphere.
- The regions around Hudson Bay, Novia Scotia, Buffin Bay and Northern Canada have been identified as sensitive areas, where initial analyses uncertainties are important.

As the experiments were only performed for one period, it is not possible to draw general conclusions, as the results might depend on the flow itself. The OSEs need to be extended to cover different seasons and different years.

The results discussed in the present paper form the first part of a more extensive investigation on the potential benefit of a wind lidar in space. A companion paper will address the question to what extent (simulated) wind profiles from a lidar instrument can help to reduce the initial analyses differences caused by the denial of wind observations as described in the present study. These experiments can be interpreted as ‘Observing System Replacement Experiments (OSRE)’, where the lidar data are taken as substitute for the wind data from sondes and aircraft.

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