3.2 THE UTILITY OF TAMDAR ON SHORT-RANGE FORECASTS OVER ALASKA

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1. INTRODUCTION AND MOTIVATION

Weather forecasting in Alaska is extremely challenging due to the rugged and topographically diverse terrain and a significant lack of observations. The upper-air observations, or radiosondes, are subject to large space time coverage gaps, which deteriorate to the west, thus making forecast adjustments based on observed upstream profiles more difficult. Additionally, the sparse data in this region has long plagued the success of numerical weather prediction in Alaska. The complex mountainous terrain and land-sea interface warrant specific tuning of model physics and parameterization to properly utilize the few available observations.

To mitigate the issue, the Alaska-based airline PenAir began equipping a fleet of 10 Saab 340s with Tropospheric Airborne Meteorological Data Reporting (TAMDAR) sensors in late summer 2007, and was fully deployed, calibrated, and reporting by the beginning of 2008. The sensor measures humidity, pressure, temperature, winds aloft, icing, and turbulence, along with the corresponding location, time, and altitude from built-in GPS. These observations are transmitted in real-time to a ground-based network operations center via a global satellite network.

Data-denial studies are carried out over this region using several data assimilations techniques into the NCAR Advanced Research WRF (ARW) and the MM5. Parallel 72-h experimental (control) simulations that include (withhold) the PenAir TAMDAR data are conducted. This study presents only one relatively short time period, and is seen as a snapshot of potential data-denial differences. It may, or may not, be representative of typical forecast skill. Case-specific and time-averaged forecast skill statistics, verified against conventional observing platforms (e.g., RAOBs, ASOS, etc.), are compiled and analyzed for the domain shown in Fig. 1 for the 12 day period from April 2 through April 14, but not including April 12, the model was initialized each day at 00 UTC or approximately 3 pm local time. TAMDAR accounted for approximately 25% of the observations in the experimental (EXP) run.

It should be noted that in locations across the continental U.S., this number of observations would not typically produce a noticeable difference in the forecast (Bengtsson et al. 2004; Liu et al. 2007); however, due to the extreme lack of observational data available over Alaska, even a small amount of additional data can have a significant impact.

2. METHODS AND MODEL CONFIGURATION

WRF-ARW is a fully compressible, nonhydrostatic mesoscale modeling system with a run-time hydrostatic option. WRF is conservative for scalar variables and uses a terrain following, hydrostatic pressure vertical coordinate with the top of the model being defined along a constant pressure surface. The WRF horizontal grid uses the Arakawa-C staggering definition. The time integration scheme in the model employs the third-order Runge-Kutta scheme, and the spatial discrimination includes 2nd to 6th order schemes. The current WRF-ARW release supports full physics, two-way, one-way and two-way moving nests as well as analysis and observation nudging.

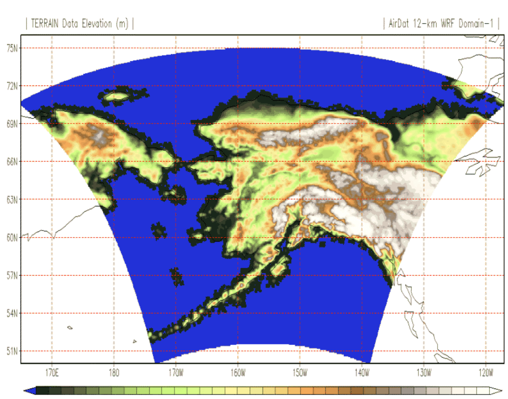

Fig. 1. The model domain of 220 X 220 with a grid spacing of 12 km is used in this study.

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The AirDat WRF-ARW Alaska model is designed to study the effects of TAMDAR data assimilation across Alaska. A domain measuring 220 x 220 grid points with horizontal grid spacing of 12 km is configured. Forty hybrid-sigma levels are used to specify the vertical atmosphere with the highest resolutions within the mixed layer and jet stream level. The model domain is shown in Fig. 1.

The AirDat WRF-ARW-Alaska configuration employs the latest physics packages. The WSM 6- class graupel scheme is employed to define grid scale precipitation, while the Kain-Fritsch cumulus scheme is used to define the subgrid scale water cycle. The Rapid Radiative Transfer Model (RRTM) scheme is used to specify long wave radiation, while the Dudhia scheme is employed for short-wave radiative processes. The Mellor-Yamada-Janjic boundary layer scheme is used to account for mixing layer fluxes and turbulence, while the NOAH model is employed for land-surface physics.

The WRF-VAR system is used to assimilate various data platforms into the AirDat WRF-ARW model. The goal of any variational data assimilation system is to determine an optimal estimate of the current atmosphere. This is achieved through the iterative solution of a prescribed cost function. The WRF-VAR assimilation system uses an incremental formulation, in model space, for the variational problem. Previous forecasts, observations and physical laws are combined to produce an analysis increment which is added to the first guess to provide an updated analysis (Barker et al. 2004). Following the assimilation of all of the observational data, an analysis is produced which must be merged with the existing lateral boundary conditions before the WRF forecast can begin.

Several improvements have been made to the latest WRF-VAR system to better assimilate various observation platforms, including asynoptic aircraft data provided by TAMDAR. The previous version of the WRF-VAR system used height interpolation for all observation operators. For example, if an observation is reported as a function of pressure, then height is approximated using the hydrostatic relation. This introduces an unnecessary source of error. The new WRF-VAR system uses a vertical interpolation in terms of the original observed coordinate, height or pressure. In addition, a First Guess at Appropriate Time (FGAT) package has been introduced in the WRF-VAR system (Lee et al. 2004). This procedure allows for a more accurate calculation of innovation vectors. This allows for a more optimal use of observations when their valid time differs from that of the analysis, which happens frequently with TAMDAR data.

Two WRF-ARW forecasts were run operationally at AirDat for a 12 day period in April 2008 to study the impact of TAMDAR data on forecast quality over the domain presented in Fig. 1 for a 72 hour period. The 12 day average will help determine if TAMDAR forecasts are consistently improved over non-TAMDAR. The first run, the Control (CTL), included the full MADIS data feed, but withheld all TAMDAR data. The second run the Experimental (EXP) included the full MADIS and TAMDAR data streams. All other modeling parameters were identical between the CTL and EXP forecasts.

3. PRELIMINARY RESULTS

Due to the lack of verification data over Alaska, the CTL and EXP runs will primarily be verified using North American Regional Reanalysis (NARR; Kalnay et al. 1990; Mesinger et al. 2006), RAOB observations, and limited surface observations. The NARR was obtained from NCDC's NOMADS archive. It uses the high resolution NCEP Eta Model (32km/45 layer) together with the Regional Data Assimilation System (RDAS).

For this study, the model-generated soundings were verified against RAOB observations when available (i.e., 00 and 12 UTC); otherwise, moisture, temperature and wind profiles were obtained from the NARR. The RH value is derived from the RAOB temperature and dewpoint using the calculation outlined in Bolton (1980), and the NARR-based RH value is derived from specific humidity, temperature, and pressure following Rogers and Yau (1989).

The 12-day average RAOB data for Anchorage for variables including temperature and winds were compared to the average forecasted variables for the same time period. The average absolute value of the difference from actual temperature (CTL=AVG|RAOB-CTL|) is shown in Fig. 2. The difference from actual temperature indicates an improvement in the 700-1000 hPa level of 0.15^{o}C, or a 13% reduction in error. The EXP and CTL are nearly identical from about 700 to 400 hPa, however above 400 hPa the CTL is slightly improved over the EXP. The average difference from 200-700 hPa is 0.03^{o}C which equates to a 3.08% increase in error. This could be in part due to the fact most of the TAMDAR equipped planes

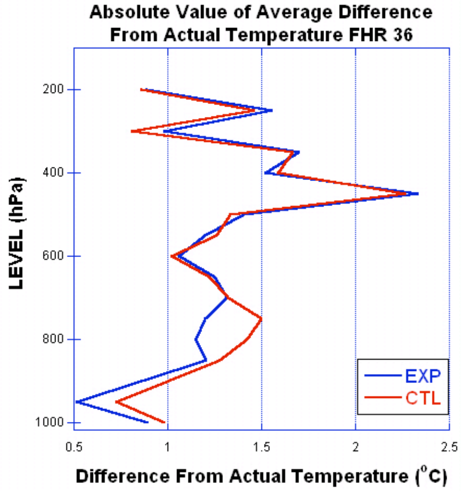

Fig. 2 Difference from actual temperature over PANC

in Alaska are likely flying below 300 hPa, so the EXP would not have any additional data to have a positive impact on the EXP compared to the CTL. A time series of the difference from actual temperature at both 500 hPa and 850 hPa for Anchorage (Fig. 3) indicates that at 500 hPa, the differences are fairly similar, however the EXP is consistently slightly improved over the CTL, at forecast hour 12 there is a 8.09% reduction in error, while at forecast hour 60 there is a 6.79% reduction in error. At 850 hPa the EXP is slightly

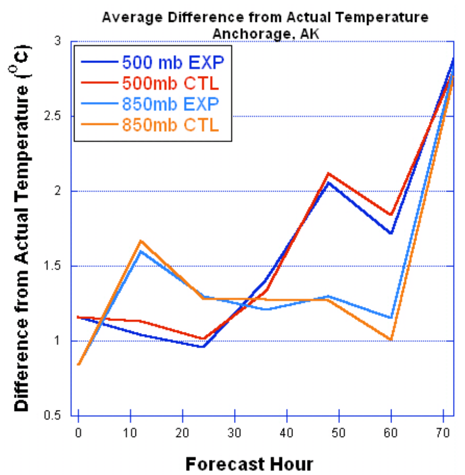

Fig. 3 Average difference from actual temperature over PANC

more accurate compared to the CTL until forecast hour 50, the greatest improvement occurs around forecast hour 12 where there is a 4.34% reduction in error.

The 12 day average difference for winds is shown in Fig. 4, the largest improvement occurs between 400-700 hPa where a 7% reduction in error occurs.

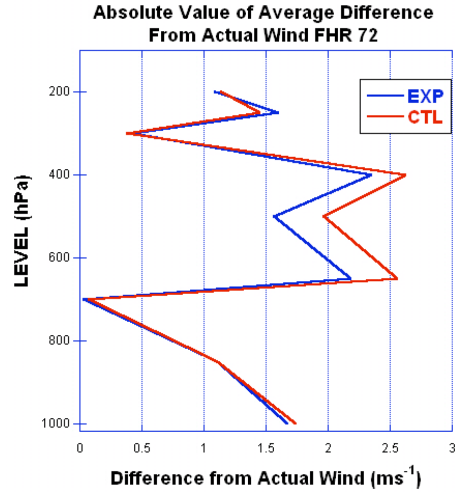

Fig. 4. Wind error at forecast hour 72.

To further verify the influence of TAMDAR data, we examined a single day from the 12 day period. Figure 5 shows the temperature difference from the actual value at 500 and 850 hPa for April 2, 2008 in Anchorage, AK. At 500 hPa the average temperature improvement was

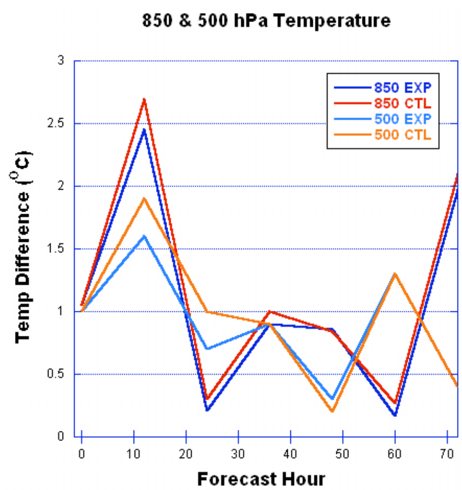

Fig 5 20080402 00Z Temperature difference in Anchorage, AK

0.07°C or a 4.4% reduction in error, this increased at 850 hPa to 0.10° C or a 12.75% reduction in error. A very important variable to examine in Alaska is winds, we generated soundings for the experimental and control runs and compared this to the actual sounding from April 2 at 12 UTC.

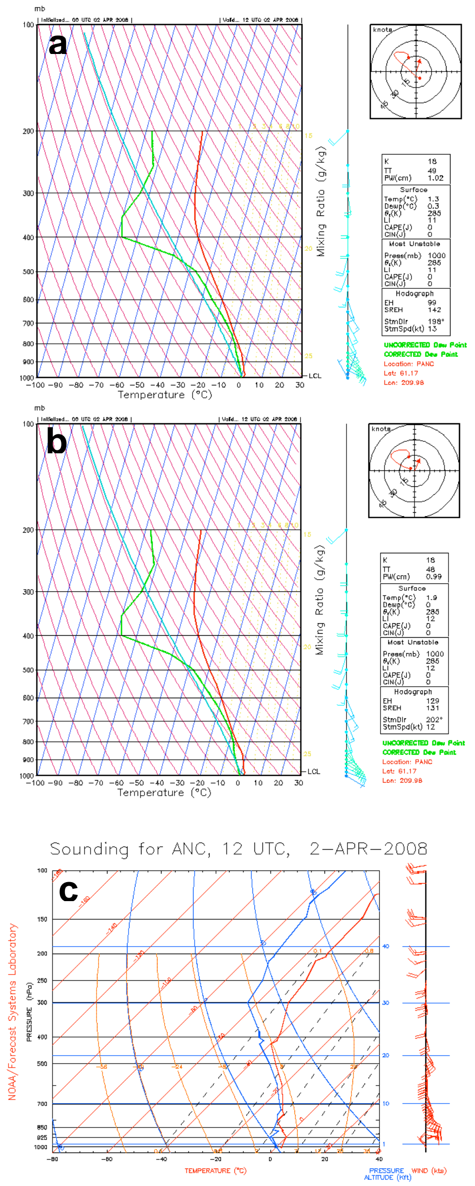

Fig. 6 Soundings for April 2, 2008 12 UTC (a) model generated sounding for EXP, (b) model generated sounding for CTL, (c) actual sounding.

Notice the difference in low level winds between the experimental and control runs, the actual and experimental runs shows a northwest wind at the surface, while the control run does not capture this low level feature and shows a southeast wind from 1000-700 hPa.

4. SUMMARY AND CONCLUSIONS

This is a limited study with only one time period examined, and a small dataset of additional TAMDAR data assimilated to the EXP run. Despite this limited quantity, the data produced encouraging results that demonstrate the potential impact additional TAMDAR observations may have over such a data-sparse region like Alaska.

Unfortunately, this can also serve as a disadvantage because with so few observations, the potential for a single observation to swing the analysis is very large. Thus, if the observation is of utmost quality and accuracy, the forecast skill can increase greatly; however, with even a small amount of error, the same observation can induce large model errors. This is likely the reason for such erratic differences between the EXP and CTL throughout the analysis field. The bottom line is the observations must be quality controlled to a degree higher than typical CONUS observations. This brings up another hurdle in that one of the best methods of quality control, buddy checking, is limited by the lack of asynoptic observations.

We are in the initial stages of exploring what impacts a high resolution data set can have on a region such as Alaska. More case studies need to be conducted to better understand degrees of impact and limitations. Long-term statistical analysis is underway to isolate trends from the noise of day-by-day cases. Much will be learned in the following year, and results will be made available throughout the ongoing study.

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