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SENSITIVITY EXPERIMENTS WITH A HIGH RESOLUTION DATA ASSIMILATION SCHEME

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1. INTRODUCTION

The Oklahoma Advanced Regional Prediction System Data Analysis System (ADAS) is being used to develop and assess methods to perform data assimilation in complex terrain. In order to test the ADAS system under a variety of weather conditions, local 3-dimensional analyses are being produced hourly over northern Utah. Images are available at *www.met. utah.edu/mesowest*.

Optimal configurations for data assimilation over complex terrain remain under investigation. Data from the Intermountain Precipitation Experiment (IPEX) during February 2000 are used to investigate the sensitivity of the analysis system to available data resources.

2. ANALYSIS DOMAIN

The ADAS Wasatch Front domain covers a 118 km X 118 km area over northwest Utah, centered near Salt Lake City (Fig.1). From west to east the domain includes the Cedar, Stansbury, Oquirrh and Wasatch Mountains. The Great Salt Lake lies in the northern half of the analysis domain. The grid spacing is 1 km in the horizontal and stretched in the vertical, varying from 9 m near the surface to 600 m at the domain top. The topography within the domain varies from 1245 m near the western edge of the domain to above 3300 m in the Wasatch Mountains.

3. ANALYSIS TECHNIQUE

The ADAS analysis uses the National Center for Environmental Prediction Rapid Update Cycle Version 2 (RUC2) 40-km resolution analysis for the initial background field. Local data are interpolated onto the grid using the Bratseth technique (Bratseth 1986), a successive correction scheme that converges to optimal interpolation. The Bratseth technique is computationally inexpensive, includes both observation and background field error statistics, and is relatively insensitive to variations in local data density.

The cloud analysis starts with a three-dimensional fractional cloud cover field obtained from the ADAS relative humidity. The 3-dimensional cloud field is then modified using a Barnes scheme to analyze visible and infrared satellite data and radar reflectivity.

The vertical weights in the Bratseth analysis were modified to compensate for the strong terrain gradients within the domain. The weights used in the observation to grid point analysis are reduced for grid points that are far above the surface. This approach allows for observations at high elevation to influence data-void locations in nearby mountain ranges while limiting their effect on the free atmosphere adjacent to the mountains. A simple dry convective adjustment scheme was added to eliminate super adiabatic lapse rates. The pressure reduction technique developed by Messenger and Treadon (1995) is used to calculate sea level pressure.

4. LOCAL DATA

The ADAS analysis system is currently run on a near-real time basis, with local analyses produced each hour. The data commonly available for assimilation include: surface observations obtained from MesoWest, a collection of weather observing networks managed by government agencies and private firms in the western United States; upper air soundings at 00 and 12 UTC from the Salt Lake City NWSFO, wind profiles from the U.S. Army Dugway Proving Grounds, and radial velocity and reflectivity in NIDS format from the WSR-88D radar located at Promontory Point, Utah (KMTX in Fig. 1). Aircraft reports of temperature and wind are also assimilated.

The IPEX field experiment, conducted during February 2000, provides additional data for analysis over northwest Utah. IPEX focussed on the kinematic and microphysical structure of orographic

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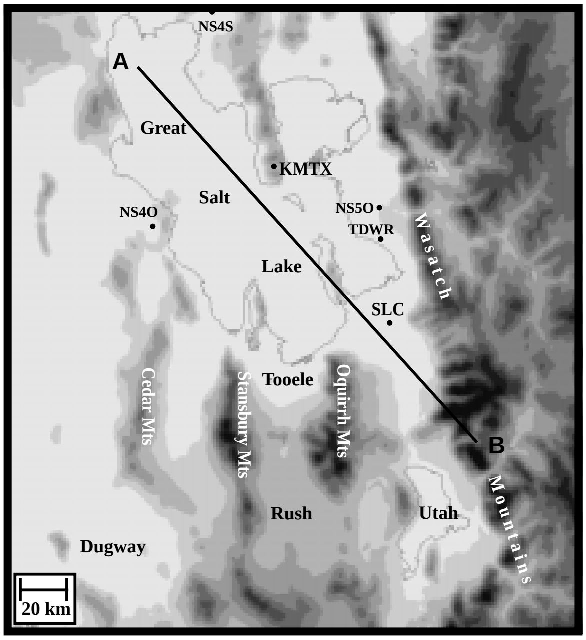

Figure 1. Domain of the ADAS analyses over northwest Utah. Darker shading denotes higher terrain. The cross-section in Fig. 4 follows the diagonal line.

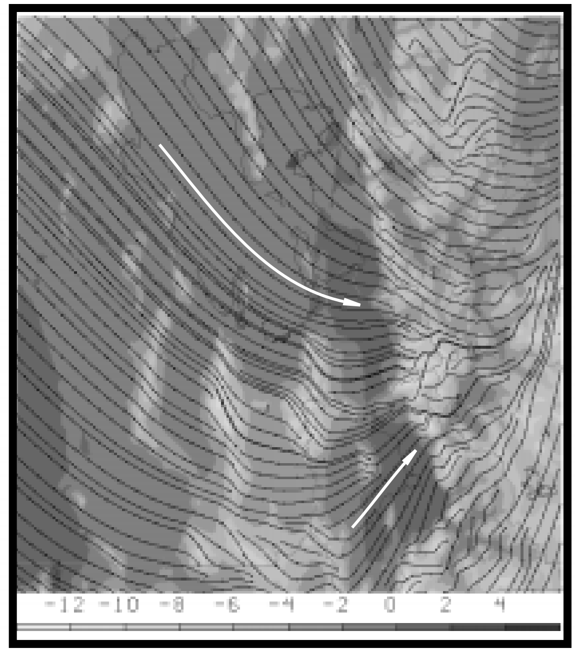

Figure 2. ADAS analysis of surface temperature (in $^{\circ}$C according to the scale at the bottom) and surface wind streamlines at 1800 UTC 24 February. Observations of surface air temperature in $^{\circ}$C and vector wind in m s^{-1} are also shown for selected sites.

precipitation associated with the Wasatch Mountains. The supplementary IPEX data used in this study include KMTX Level II radar data, soundings at 3 locations within the domain, and additional surface observations in the vicinity of the Great Salt Lake. Additional data sets available for analysis include radar scans from the NOAA P-3 research aircraft, two University of Oklahoma Doppler on Wheels (DOW) radars, and the FAA Terminal Doppler Weather radar (TDWR in Fig. 1).

5. ANALYSIS

ADAS sensitivity experiments have been conducted on IPEX Intensive Observing Period (IOP) 7, during 24 February 2000. During IOP 7, a complex weather system, including a slow-moving cold front, passed through northwest Utah and produced heavy orographic snowfall over the Wasatch Mountains during both the pre- and post-frontal periods. Snowfall was limited to the post-frontal period in the valleys. The surface front had moved into the Salt Lake Valley past the Salt Lake City Airport (SLC in Fig. 1) by 1800 UTC, accompanied by the onset of heavy precipitation.

Figure 2 shows an analysis of surface temperature and wind at 1km resolution based solely on the initial RUC2 background field (i.e., no local data are used in the analysis). The RUC2 analysis provides a very good initial field at this time, aided in part by a special sounding at SLC at 1800 UTC that was incorporated into the national-scale analysis. (ACARS data in the vicinity of the SLC airport and a few aviation surface observations were also assimilated by the RUC2.) Relatively warm temperatures are found immediately to the west of the Wasatch Mountains while westerly and northwesterly winds are found over much of the domain. These conditions suggest that the front is in the vicinity of the Wasatch Mountains at the analysis time.

Figure 3 shows MesoWest observations of surface temperature and wind, and the ADAS analysis of those fields at 1800 UTC, 24 February 2000. This analysis uses all available data resources. While the initial background field provided by the RUC2 captured many of the large-scale features of the wind and temperature fields, many significant local terrain-flow interactions are absent. For example, both the observations and the analysis in Fig. 3 depict post-frontal northerly flow over the northern half of the Great Salt Lake. The front has pushed much further south over the relatively flat desert terrain in the western third of the domain.The MesoWest surface temperature observations and the ADAS analysis depict a ribbon of warm air trapped

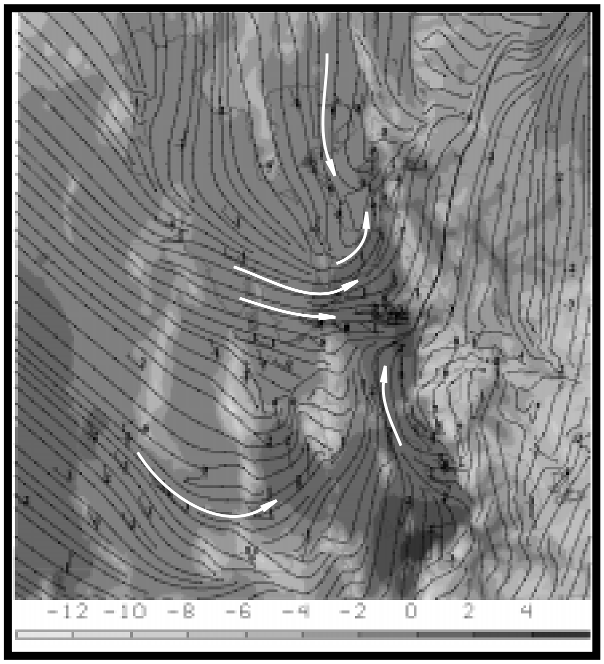

Figure 3. As in Fig. 2 except for the analysis based on the RUC2 initial background field only.

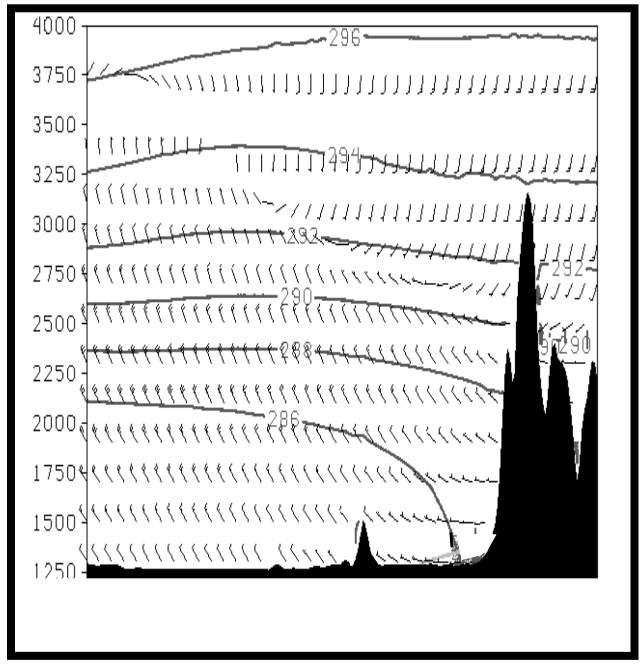

Figure 4. Vertical cross section (along path A-B in Fig. 1) of potential temperature (in K), the 0 °C isotherm (gray, heavy line) and horizontal wind in m s^{-1} at 1800 UTC 24 February. Analysis based on the RUC2 first guess only.

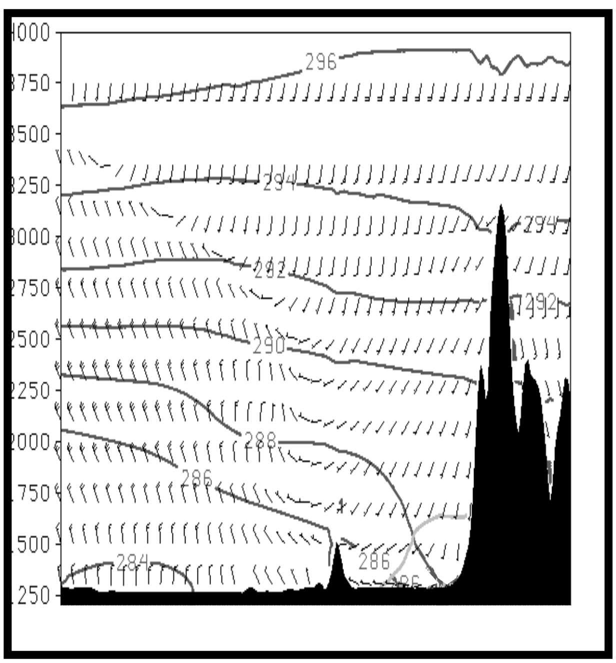

Figure 5. As in Fig. 4 except the analysis was completed using the RUC2 first guess plus all available local data sources except radial velocity from the KMTX radar.

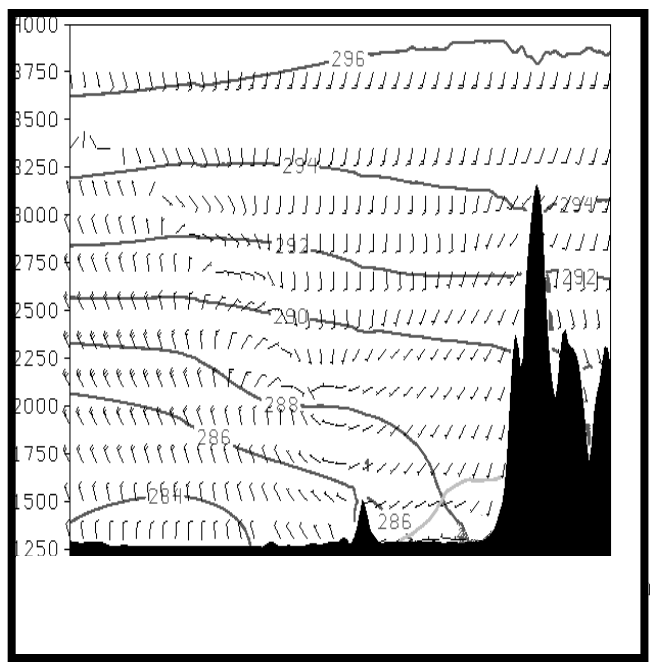

Figure 6. As in Fig. 4, except the analysis was completed with all available observations, including Level II radar data from the KMTX radar.

in the valleys immediately west of the Wasatch Mountains. This ribbon is fed by a southerly along-barrier flow channeled by the high terrain to the east. The barrier flow extends northward towards Ogden (NS5O in Fig. 1).

At 1800 UTC, the surface front is advancing towards the metropolitan regions of Ogden, Salt Lake City, and Provo from several directions. In the north, the front has travelled southward towards Ogden. In the vicinity of Salt Lake City the front has penetrated into the Salt Lake Valley, leading to a well defined wind shift that demarcates its leading edge. Between Ogden and Salt Lake City, the westerly push of the front coupled with the residual barrier flow led to the development of a well-defined cyclonic circulation. Over the central portion of the domain, the westward progression of the front is retarded by the Stansbury and Oquirrh Mountains. The front has just begun to penetrate into the Tooele Valley by 1800 UTC. The faster progression of the front over the western deserts has led to its extension towards the Rush Valley from the west.

The supplementary surface observations available during IPEX and the ADAS analyses based upon them provide an unique opportunity to document the surface flow interactions with the local terrain in northern Utah. The sensitivity of the ADAS analyses to the availability of local data has been examined in a series of experiments of which only one will be presented here.

Figure 4 shows a cross-section along the line A-B in Fig. 1 from an analysis completed using only the RUC2 background field. The RUC2 analysis suggests that the front is in the vicinity of the Wasatch Mountains at this time, with west-northwesterly flow below 2500 m. The ADAS analysis completed with all available local data except the level II data from the KMTX radar is presented in Fig. 5. These local data help to define a sharper baroclinic zone with colder air evident over the Great Salt Lake. Ahead of the front, southerly along-barrier flow is evident within the boundary layer. The vertical structure of the wind field depicts a much more steeply sloped front.

An analysis completed using all available data including the level II data from the KMTX radar is shown in Fig. 6. Since the base elevation of the radar is at 2100 m, the radial velocity data only adjusts the wind field above that level. Additional structure is now analyzed along the wind shift line over the Great Salt Lake with easterly flow evident at the 2100 m level, and at crest level of the Wasatch Mountains (3000 m).

6. SUMMARY

The original ADAS configuration was modified in order to account for the strong variations in temperature, moisture and wind in the free atmosphere and those found near the surface. The large variations in surface elevation within the analysis domain present a challenge to any analysis procedure. The accuracy of the model's analysis depends strongly on its horizontal and vertical resolution. Errors introduced by the differences between the model terrain and station elevation are reduced in analyses run at 1 km resolution, compared to those run at lower resolution.

A slow-moving cold front approaching the Wasatch Mountains is used to illustrate terrain-flow interactions and the sensitivity of ADAS to the inclusion of local data in regions of complex terrain. The IPEX field program provided additional surface and upper air data to define the 3-dimensional structure of the cold front. The local data allows for local and mesoscale structure to be analyzed within the larger scale synoptic features. Data from the NOAA P-3 aircraft and DOW radars deployed during IPEX will be contrasted to the ADAS analyses for further validation.

In order to quantitatively estimate the accuracy of the ADAS analyses, work is in progress to rerun the analysis system withholding selected local data. Analysis variables may then be interpolated to the withheld data locations and errors assessed as the root-mean squared deviations of interpolated minus observed data values.

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