

AN ANALYSIS OF A COLD FRONTAL PASSAGE OVER COMPLEX TERRAIN IN NORTHWEST UTAH

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1. INTRODUCTION

The Oklahoma Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS) is used to analyze the passage of a strong cold front across northwest Utah. The ADAS analyses capture the uneven progression of the front as it impinges upon the mountain ranges of northwest Utah.

ADAS analyses are generated routinely at 1 h intervals over northwest Utah for nowcasting and research applications. Graphical displays derived from these analyses are available over the Internet at <http://www.met.utah.edu/mesonet>.

2. ANALYSIS DOMAIN

The ADAS domain covers a 218 km X 218 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. Most of the Great Salt Lake lies in 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.

3. ANALYSIS TECHNIQUE

The ADAS analysis (Brewster et al. 1995) uses the National Centers for Environmental Prediction Rapid Update Cycle Version 2 (RUC2) 40-km analysis for the initial background field. Local data are interpolated onto the grid using the Bratseth technique (Bratseth, 1986), an iterative interpolation scheme that converges to optimal interpolation. This technique is less sensitive to variations in local data density and accounts for relative background-to-observation error.

Surface observations are obtained from the Utah Mesonet, a collection of weather observing networks managed by federal, state and local agencies, and private firms. Upper air soundings are

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available at 00 and 12 UTC from the SLC NWSFO. Radial velocity and reflectivity are obtained from the WSR-88D radar located at Promontory Point, Utah (KMTX in Fig. 1). Aircraft reports of temperature and wind are available, especially near the Salt Lake City airport during peak commercial travel periods.

A separate cloud analysis package is a recent addition to ADAS. The cloud analysis starts with a 3-D background cloud fraction obtained from the ADAS relative humidity. The 3-dimensional cloud field is then modified by the inclusion of visible and infrared satellite data and radar reflectivity.

4. ANALYSIS MODIFICATIONS

Surface air and dew point temperature from a 3-dimensional linear regression/Barnes analysis are used to replace the RUC2 first guess fields at the surface. This step improves the specification of the background field by incorporating current surface conditions and local terrain features.

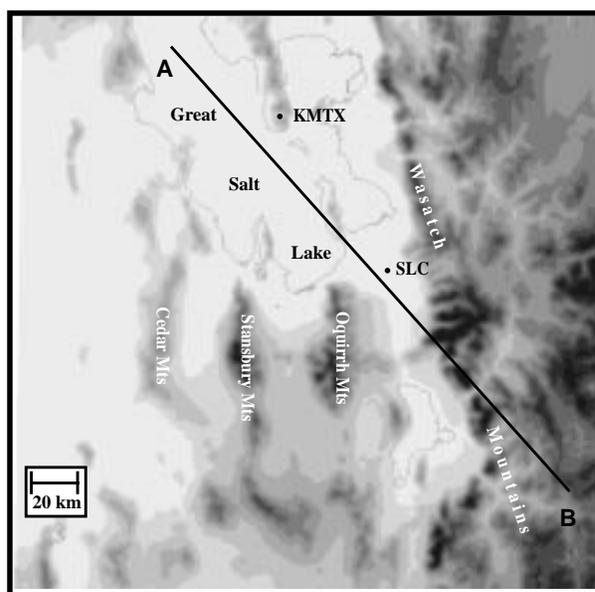


Figure 1. Domain of the ADAS analyses over northwest Utah. Darker shading denotes higher terrain. The cross-section in Figs. 2 and 3 follow the diagonal line A-B.

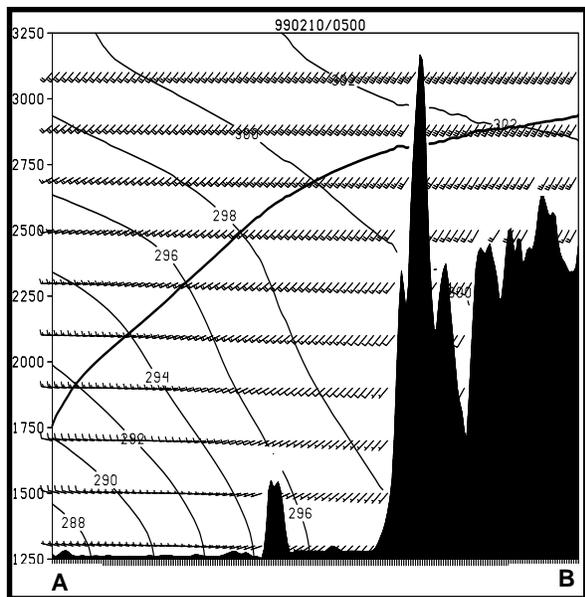


Figure 2. Vertical cross section of potential temperature in K, the 0 °C isotherm (heavy line) and horizontal wind in m s^{-1} at 0500 UTC 10 February. Analysis based on the RUC2 first guess only. The path of the cross section is shown in Figure 1.

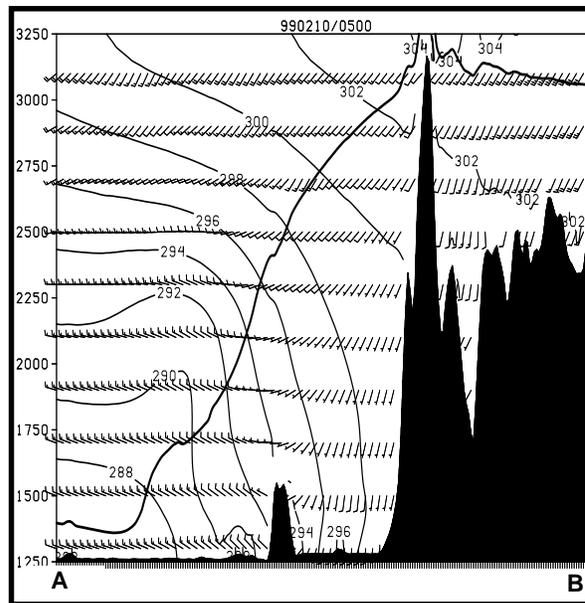


Figure 3. As in Fig. 2 except for the ADAS analysis.

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 gridpoint interpolation are reduced for grid points that are far above the surface. This approach allows for observations at high elevations to influence data-void locations in nearby mountain ranges while limiting their effect on the free atmosphere adjacent to the mountains. Additionally, dry convective adjustment was added to eliminate superadiabatic lapse rates.

5. MESOSCALE ANALYSIS

A vigorous cold front moved through the Salt Lake area on 9-10 February 1999. The front was preceded by hurricane force wind gusts along mountain crests with record warm temperatures in the pre-frontal environment. The cold frontal passage was accompanied by thunderstorms and widespread, heavy snowfall. The Wasatch Mountains on the east side of the domain received 15-21" of snow, with up to 12" recorded in some Salt Lake Valley locations.

The cold front passed through the ADAS domain between 04 to 07 UTC 10 February. Figure 2 shows a cross section of potential temperature and vector wind at 0500 UTC 10 February along the

path defined in Fig. 1 as determined from the RUC2 first guess only. This analysis was performed with no supplementary radar, satellite, upper air or surface observations. The RUC2 analysis depicts a broad baroclinic zone with winds changing gradually from southwesterly to westerly across the frontal zone.

The cross section along the path AB in Fig. 1 based upon the ADAS analysis is shown in Fig. 3. Prefrontal southerly flow and postfrontal northwesterly flow are evident below 2000 m MSL with southwesterly flow near the 700 mb (3000 m) level. The above-surface wind structure of the cold front is determined from the RUC2 first guess (Fig. 2) and modified by radial velocity from the KMTX radar; no rawinsonde or aircraft observations were available at this time.

A well-mixed boundary layer precedes the front while strong static stability follows in the ADAS analysis (Fig. 3). The melting level (0 °C isotherm) in the ADAS analysis varies from near the ridge-top of the Wasatch Mountains to near the surface of the Great Salt Lake. The distinct thermodynamic structure of the cold front in the ADAS analysis results from the availability of surface observations to more accurately define the horizontal scale of the baroclinic zone.

Surface air temperature and streamlines at 05

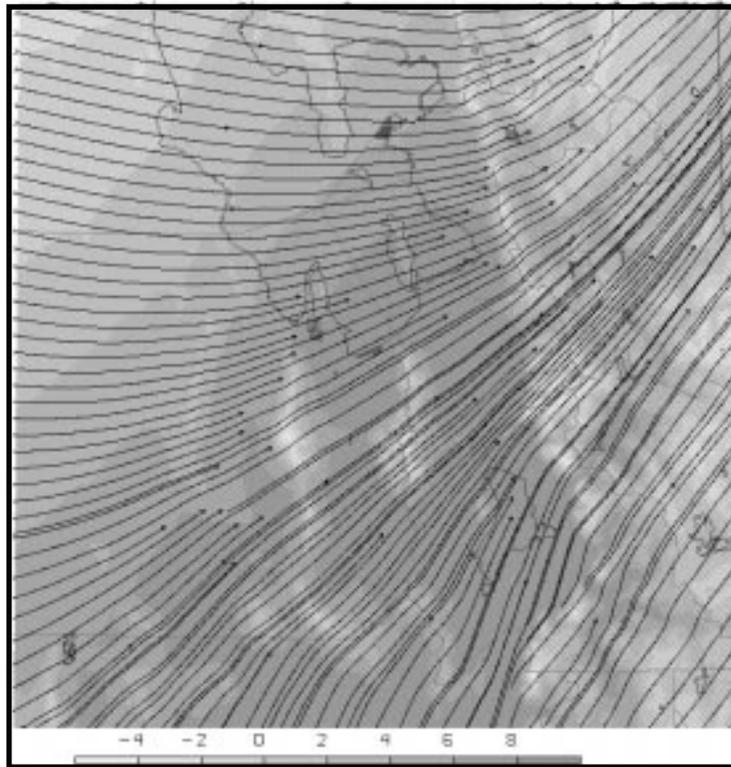


Figure 4. Surface air temperature in $^{\circ}\text{C}$ (shaded according to the scale at the bottom) and streamlines of 10 m wind at 0500 UTC 10 February. Analysis based on RUC2 first guess only.

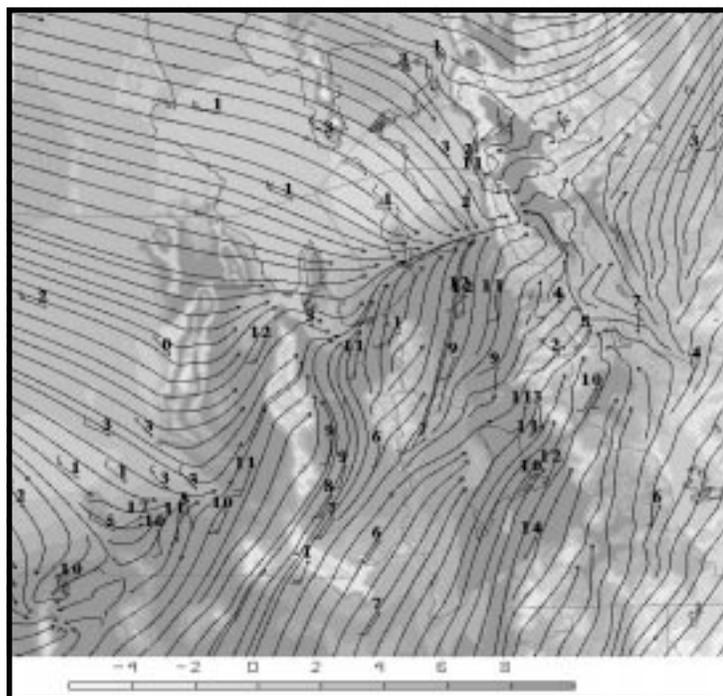


Figure 5. As in Fig. 4 except for the ADAS analysis. Surface observations of surface air temperature in $^{\circ}\text{C}$ and vector wind in m s^{-1} from the Utah Mesonet.

UTC from the RUC2 first guess are shown in Fig 4. A broad baroclinic zone extends across the northern half of the domain. The 1km resolution of the analysis terrain leads to the lower surface temperatures over the mountains.

The ADAS analysis of the cold front is shown in Fig. 5. The surface observations help to define the location of the cold front near the southern edge of the Great Salt Lake. Effects of the terrain are evident: the front has progressed further south over the desert to the west of the Cedar Mountains while the front's movement eastward is retarded by the Wasatch Mountains. Southerly winds are channeled through the valleys to the south of the cold front with northwesterly flow behind the front.

Analysis inaccuracies are evident in data-void regions. For example, the ADAS analysis maintains high temperatures behind the cold front to the north of the Cedar Mountains and along the northwestern boundary of the analysis domain. Temperature in these areas are specified primarily from the linear regression/Barnes analysis that fills the data void regions with information from surface observations to the south of the front or to the west of the analysis boundary.

6. SUMMARY AND FUTURE WORK

A strong cold front is used to illustrate the ability of the ADAS system to analyze current weather conditions over northwestern Utah. The front progressed further to the south over the west desert of Utah and was retarded near the Wasatch Mountains. The ADAS analysis at 1 km horizontal resolution defines the wind and temperature structure of the front in greater, and more realistic, detail than an analysis at the same horizontal resolution based on the RUC2 only.

The standard ADAS configuration was modified to diagnose as accurately as possible both 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. Horizontal spacing of 1 km was found to provide a better analysis compared to analyses performed at 2 km spacing; errors introduced due to differences between the model's terrain and station elevation are significantly larger at the coarser resolution.

The amount and quality of local data available for use in the analysis is also very important. Sur-

face observations from the Utah Mesonet combined with the use of the linear regression/Barnes analysis help to define the surface air and dew point temperature fields. Analysis quality also depends strongly on the availability of additional upper air observations, e.g., rawinsondes, radar wind and reflectivity, and satellite information.

The analysis system is run hourly and graphics are posted on the Internet. Processing of KMTX base reflectivity and radial velocity data on cloudy days is quite time consuming as thousands of vertical profiles must be handled separately by the Bratseth technique. Direct replacement of the radial component of the wind in the ADAS analysis by the radar data is required in order to complete the analysis in 30 minutes or less on a single Sun E10000 processor.

Additional data will be assimilated into the ADAS analyses during the next several months, including: Level II digital radar data from the KMTX radar; velocity returns from the Federal Aviation Authority Terminal Doppler Weather Radar located at Layton, Utah, and a wind profiler located at the Dugway Army Proving Grounds. Preliminary studies have begun to use the ADAS analyses to initialize the Advanced Regional Prediction System in order to obtain high resolution (1 km), short term (0-3h) forecasts over northwestern Utah. Computational resources are insufficient at the present time to complete such model runs operationally.

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7. REFERENCES

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- Brewster, K., F. Carr, N. Lin, J. Straka, and J. Krause 1995: A local analysis system for initializing real-time convective-scale models, *Preprints, 10th Conf. on Numerical Weather Prediction*, Norman, OK, Amer. Meteor. Soc., 596-598.