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A MODIFICATION TO THE BRATSETH METHOD OF SUCCESSIVE CORRECTIONS FOR COMPLEX TERRAIN

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1. INTRODUCTION

Data assimilation over the complex terrain of the western United States is complicated by the irregular distribution of observations in the horizontal and vertical. For example, the method of successive corrections relies on isotropic weights that do not limit the spread horizontally of corrections to the background field through terrain. As a result, observations in one valley can influence the analysis in a neighboring data poor valley so long as they lie within the specified horizontal and vertical radii of influence (ROI). The propagation of corrections may be appropriate during situations when the boundary layer is well mixed; however under certain conditions (e.g., radiational inversions in valleys of differing elevations, cold air confined to one side of a mountain range), it may not be desirable for corrections to propagate through mountain ranges. To mitigate the effects of these problems, an anisotropic weight is proposed that limits the propagation of corrections through terrain. In addition, a land-water masking term has been implemented to limit the passage of corrections across coastlines and land-lake boundaries.

2. ANISOTROPIC MODIFICATIONS

This research relies upon high resolution (2.5 km) analyses over the western United States that are created at the Cooperative Institute for Regional Prediction (CIRP) at the University of Utah using the Advanced Regional Prediction System Data Assimilation System (ADAS). For the objective analysis, ADAS employs the Bratseth method of successive corrections (Bratseth 1986), an inexpensive analysis procedure that can be run in near-real time over a large horizontal domain (western United States) at high horizontal resolution. The background field used by ADAS is the 20 km version of the Rapid Update Cycle (RUC; Benjamin et al. 2002). ADAS typically incorporates over 2,000 surface weather observations each hour from Mesowest (Horel et al. 2002).

The anisotropic weighting terms described in section 1 have been added to the spatial correlation functions used in the Bratseth method. The modified functions are (see Lazarus et al. (2002) for full set of equations),

$$\rho_{ij} = \exp\left(\frac{-|r_{ij}|^2}{R^2}\right)\exp\left(\frac{-|\Delta z_{ij}|^2}{R_z^2}\right)\exp\left(\frac{-|z_o|^2}{R_B^2}\right)\exp(-\delta_{lw}), \qquad (1)$$

$$\rho_{xj} = \exp\left(\frac{-|r_{xj}|^2}{R^2}\right)\exp\left(\frac{-|\Delta z_{xj}|^2}{R_z^2}\right)\exp\left(\frac{-|z_x - T_x|^2}{R_T^2}\right)\exp\left(\frac{-|z_{og}|^2}{R_B^2}\right)\exp(-\delta_{lw}), \qquad (2)$$

where r_{ij} (r_{xj}) and Δz_{ij} (Δz_{xj}) are the horizontal and vertical distances between an observation-observation (observation-grid point) pair, z_x and T_x are the elevations of the grid point and terrain at location x, and z_o (z_{og}) is the magnitude of the terrain blockage between an observation-observation (observation-grid point) pair (see Fig. 1). The magnitude of the spatial correlation functions depend strongly upon the values specified for R, R_z, R_T, R_B and δ_{lw} which are the horizontal and vertical ROI, terrain factor (Lazarus et al. 2002), anisotropic factor and land-water mask term, respectively.

3. WASATCH FRONT EXAMPLE

To demonstrate the changes to an ADAS analysis resulting from the anisotropic terms, a case study is presented for a radiational inversion event that occurred at 1300 UTC 10 April 2003 over the mountain valleys of northern Utah. The topography of the region is shown in

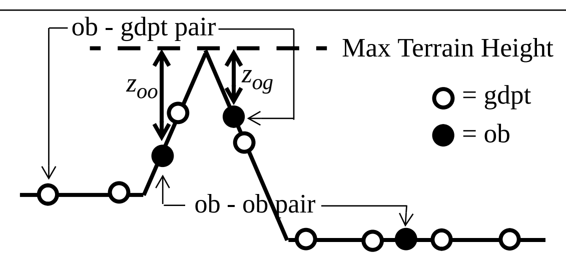

Figure 1. Schematic of analysis grid points (open circles) and observations (filled circles). The height of the intervening terrain for an ob-ob pair (z_o) and ob-gdpt pair (z_{og}) is shown.

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Fig. 2. For these analyses, 4 iterations of the Bratseth method were used with the horizontal (vertical) ROI set to 75 km (375 m) for the first and second passes and 50 km (250 m) for the final two iterations. The RUC background field for the case (Fig. 3a) is warmer than the surface observations throughout the analysis and does not capture the inverted temperature structure along the valley sidewalls.

The ADAS analysis with isotropic weights is shown in Fig. 3b. The analysis is colder than the RUC and there is some evidence of the inverted temperature structure forming along the East Bench of the Salt Lake Valley. The analysis over the Great Salt Lake is not uniform because colder observations to the east are making negative corrections to grid points over the eastern side of the lake. The data sparse Skull Valley has a structure similar to its data dense neighbors to the east because corrections are propagating through the Stansbury Mountains.

The ADAS analysis with the anisotropic modifications is shown in Fig. 3c while the difference between the anisotropic and isotropic analyses is shown in Fig. 3d. The anisotropic term has reduced the propagation of negative (positive) observational corrections from the Rush and Tooele Valleys (Salt Lake Valley benches) to the benches of the Salt Lake Valley (the Rush and Tooele Valleys). As a result, the anisotropic analysis (Fig. 3c) has captured more of the inverted temperature structure along the East Bench. Along the West Slope, the difference plot (Fig. 3d) indicates the anisotropic term has resulted in a warmer analysis. The difference plot also indicates the anisotropic analysis is cooler over the Rush and Tooele Valleys.

The temperature structure over the Great Salt Lake is more uniform in the anisotropic analysis (Fig. 3c) because negative corrections from observations over land have been reduced. Over the data sparse Skull Valley, the analysis has warmed (Fig. 3d) towards the RUC background (Fig. 3a) because the anisotropic term and land-water mask have restricted the passage of corrections from almost all surrounding areas.

4. DISCUSSION

The effects of the anisotropic term and land-water mask upon the ADAS analyses varies from location to location. In a valley with abundant observations, the analysis is improved. Detailed structures (i.e. inverted temperature structures along the valley sidewalls) are more likely to be analyzed because observations within the valley receive more weight relative to those outside. In a data sparse valley, however, there is a greater dependence upon the background field because observational corrections from nearby valleys are reduced. This may be favorable if the background field is of high quality or during situations where the structure of adjacent valleys is different; however if the background field is poor or the boundary layer is well mixed, the spreading of corrections from one valley to another may be beneficial. Similar arguments can be posed regarding the land-water anisotropic mask. Improvement is evident in analyses with observations located over both land and water. However, in areas where observations are only present over land, the quality of the analysis over water is strongly tied to the background field.

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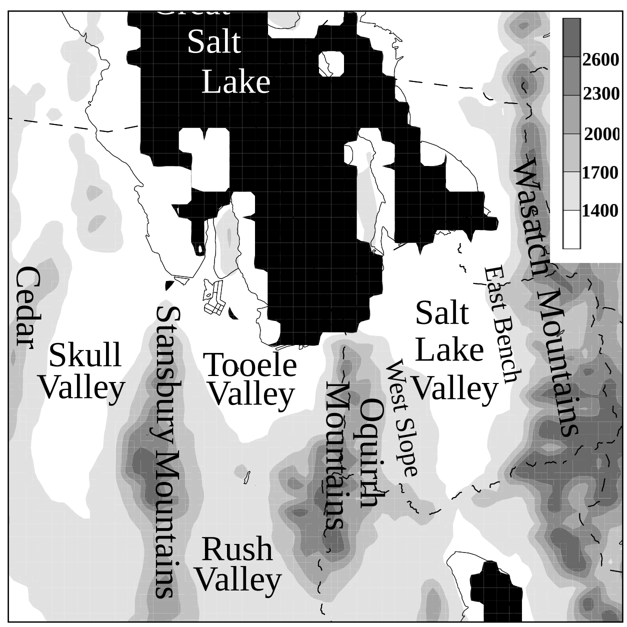

Figure 2. Surface terrain (m) for the Wasatch Front at 2.5 km resolution. Terrain considered water in the land-water masking is shaded black.

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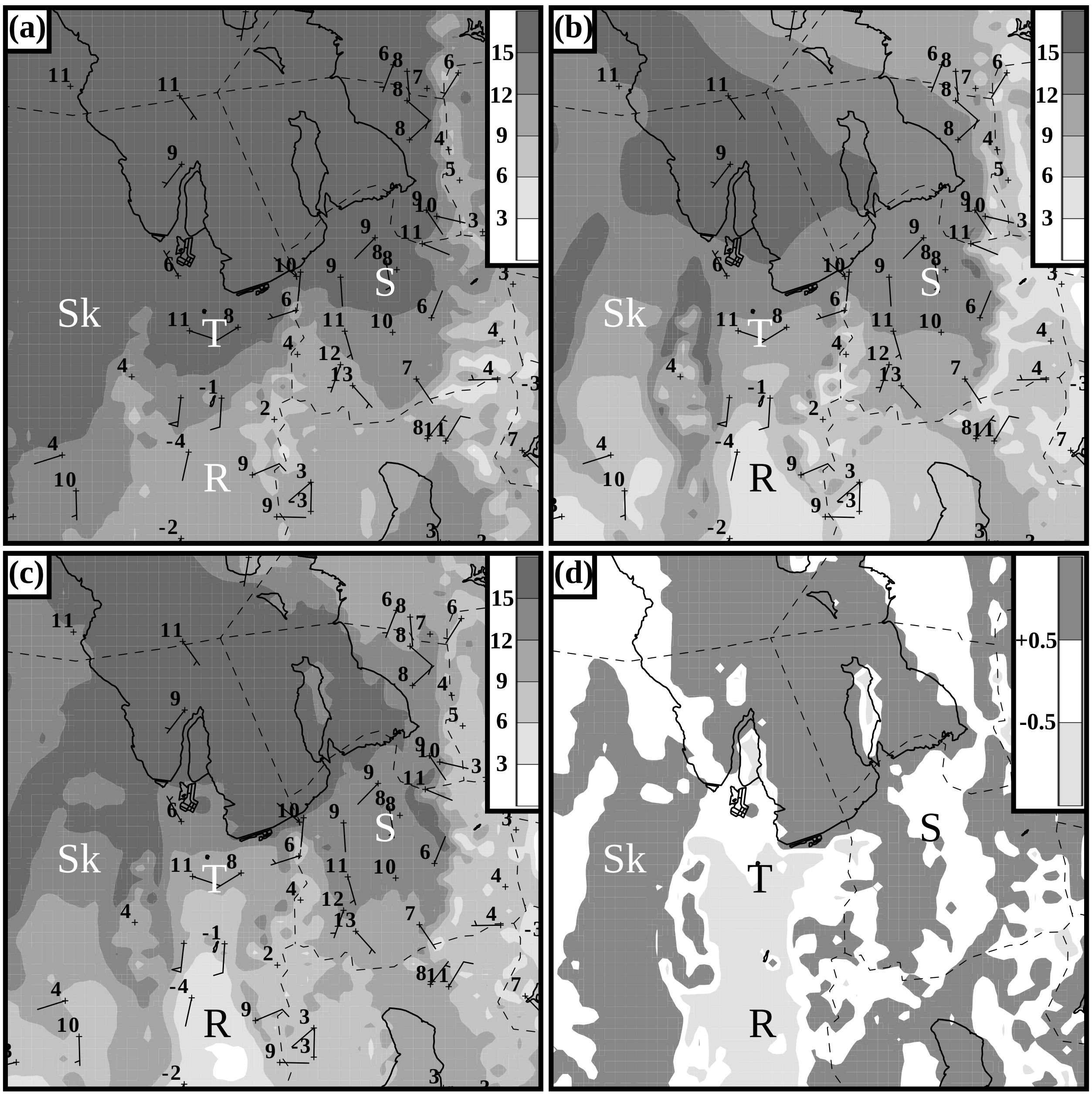

Figure 3. Wasatch Front (a) RUC, (b) isotropic ADAS and (c) anisotropic ADAS analyses of temperature (°C) for 1300 UTC 10 April 2003. (d) Difference in temperature (°C) between anisotropic (c) and isotropic (b) ADAS analyses. Surface stations (indicated by + symbols) are annotated with observations of temperature (°C) and winds [full (half) barb denote 10 (5) ms^{-1}]. The locations of the Rush, Salt Lake, Skull and Tooele Valleys are indicated by R, S, Sk and T, respectively.