CAPS Research Note

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Update to ADAS to account for variations in terrain for surface and near-surface data

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Investigators in Utah found that surface data at higher elevations were having too strong an effect on the analysis at points at the same height above sea level but more distant from the surface. This was affecting the development of mountain-valley flows in the model. The Utahans introduced an additional term to the correlation equations that was only applied to surface data (Lazarus et al., 2002):.

$$\rho_{xj} = \exp\left(\frac{-\left|\vec{r}_{xj}\right|^2}{R^2}\right)\exp\left(\frac{-\left|\Delta z_{xj}\right|^2}{R_z^2}\right)\exp\left(\frac{-\left|z_j - T_x\right|^2}{R_T^2}\right), \tag{1}$$

where r_{xj} is the horizontal distance between observation j and grid point x, Δz is the vertical distance between the observation and grid point. z_j is the height above sea level of the surface observation and T_x is the height of the terrain at point x. R, R_x, and R_T are the horizontal, vertical, and terrain error correlation ranges, respectively.

While this solved the problem for their observation arrays, it was inconsistent for general use because the same terms are not applied to sounding data at the same locations, and in that case a method is needed to gradually reduce the effect as data AGL height increases.

Proposed solution: introduce a different term in the correlation equations that accounts for the variation in terrain. This will decrease the correlation of points that are at different heights AGL and are near the surface, but will not affect points or observations that are distant from the surface.

$$\rho_{xj} = \exp\left(\frac{-\left|\vec{r}_{xj}\right|^2}{R^2}\right)\exp\left(\frac{-\left|\Delta z_{xj}\right|^2}{R_z^2}\right)\exp\left(\frac{-\left|T_j - T_x\right|^2}{R_t^2\left(\bar{h} + h_t\right)^2}\right), \tag{2}$$

where $\bar{h}$ is the average height above ground level of the observation and the grid point, and h_t is a constant, needed primarily to avoid division by zero in the case $\bar{h}$ is very small. R_t is a non-dimensional correlation parameter.

In the proposed scheme, in regions of flat terrain or where the grid or observation are far above the terrain, the resultant correlation is the same as in the original ADAS formulation.

Estimating the Parameters

Say the correlation of variables should decrease to exp(-2) for a 500 m change in terrain near the surface, and you would like h_t to be 50 m.
Then

$$\exp(-2) = \exp\left(\frac{-500^2}{R_t^2(250+50)^2}\right),\ 2R_t^2 = \frac{500^2}{300^2},$$

$$R_t^2 = 1.2$$

We now explore the effect of varying the parameters around this first guess.

Figure1 shows a west-to-east cross-section taken of the Salt Lake Valley, and shows the spread of a hypothetical observation with a 5.0 potential temperature perturbation from the background, with a single pass of the Bratseth scheme, The observing site is near a peak on the Oquirrh Mountains on the west side of the valley. For this analysis the horizontal correlation range is set to 80 km and vertical correlation range is 500 m. The effect of the observation is spread above the valleys to the east and west of the ridge. If the temperature perturbation were due to solar insolation on the ridge, its actual influence over the valley would be affected by prevailing large-scale winds and the mountain-valley circulation. The Utah investigators found that this horizontal spread of the potential temperature perturbations limited the formation of the mountain-valley circulation.

Figure 2 is the same situation as depicted in Fig. 1, except with the new algorithm, R_t = 1.2 and h_t = 50 m. The influence of the observation is now limited to a smaller area near the observing location and is spread only to the neighboring ridges where the terrain is nearly the same as at the observation location.

Increasing R_t increases the horizontal spread of this observation in this terrain. Figure 3 is the result with R_t increased to one-and-a-half that in Fig. 2, with R_t = 1.8 and h_t = 50 m. Decreasing R_t reduces the horizontal spread of this observation in this terrain. Figure 4 is the result with R_t reduced to one-half of that in Fig. 2, with R_t = 0.6 and h_t = 50 m.

Increasing h_t has the effect of diluting the effect of a fixed R_t by increasing the denominator; so increasing h_t increases the horizontal spread of this observation, with a greater effect near the surface. Figure 5 is the result with h_t increased to double that in Fig. 2, with R_t = 1.2 and h_t = 100 m. Decreasing h_t has the opposite effect. Figure 6 is the result with h_t reduced to 10 m.

Of note is that where the terrain is quite variable, the horizontal range parameter may need to be increased from what might be appropriate in the case of flat terrain, because it now represents the correlation if the terrain had been flat, with the terrain variability now acting to account for reduction in the horizontal correlation due to terrain variability.

Testing with actual observations will be needed to gauge whether the range of variables explored here is appropriate for ADAS.

References

Lazarus, S.M., C.M. Ciliberti, J.D. Horel, and K.A. Brewster, 2002: Near-real time applications of a mesoscale analysis system to complex terrain. *Wea. and Forecasting*, **17**, 971-1000.

Figures

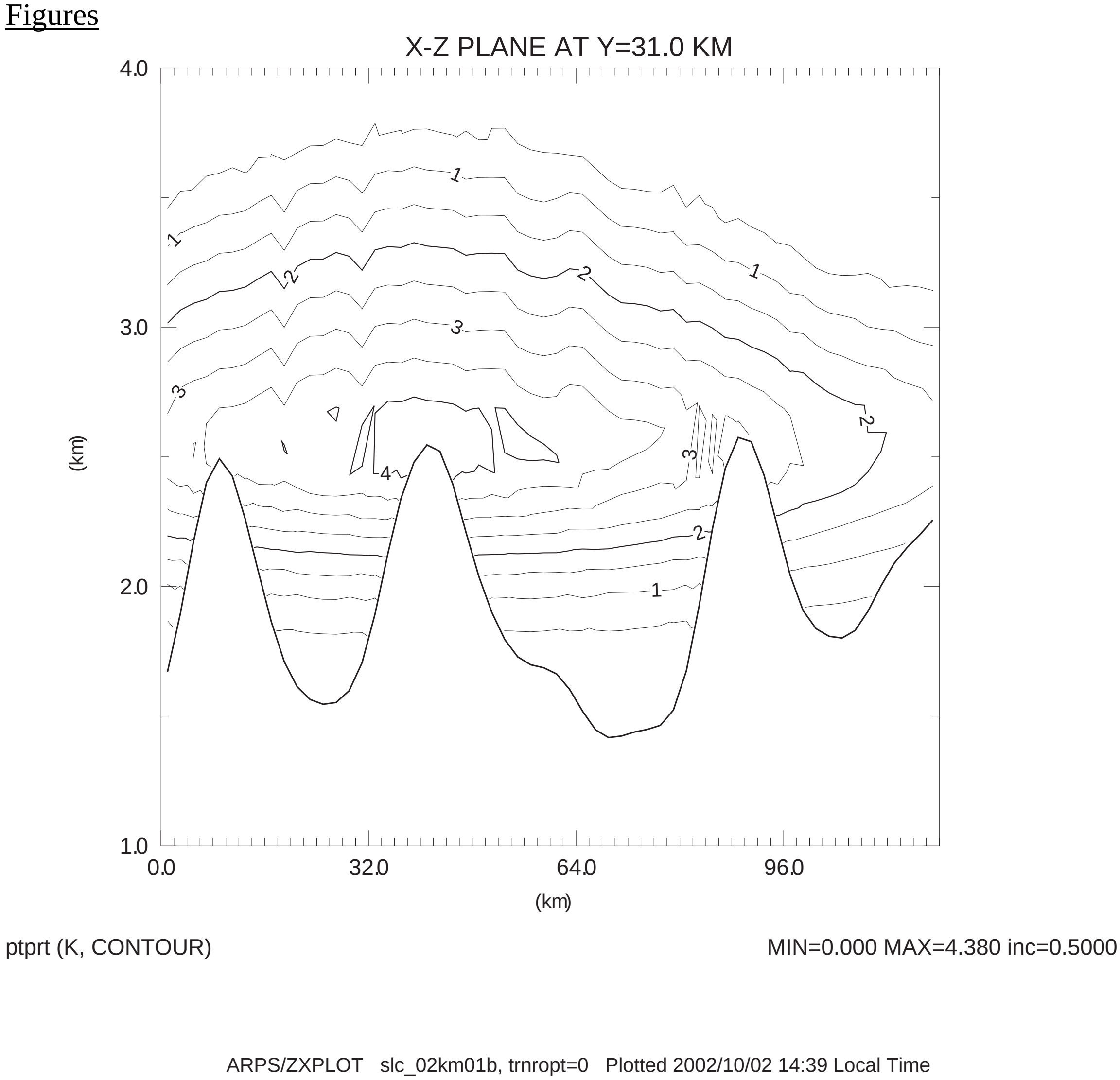

FIG 1. West-to-east cross-section through Salt Lake Valley. Analyzed potential temperature perturbation, degrees K. Original ADAS correlation formulation.

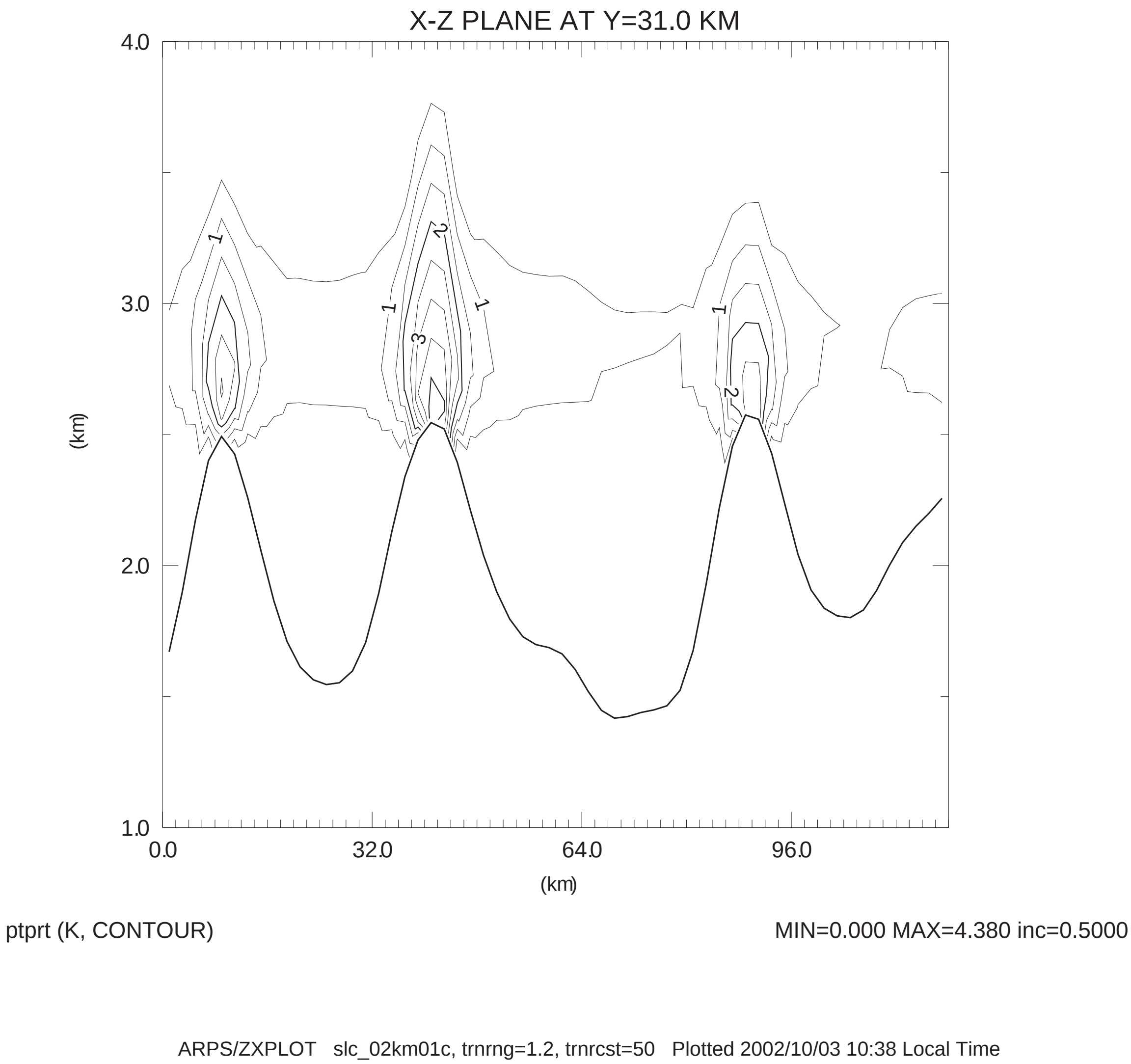

FIG 2. West-to-east cross-section through Salt Lake Valley. Analyzed potential temperature perturbation, degrees K. ADAS with proposed terrain correlation adjustment. R_t = 1.2 and h_t = 50 m.

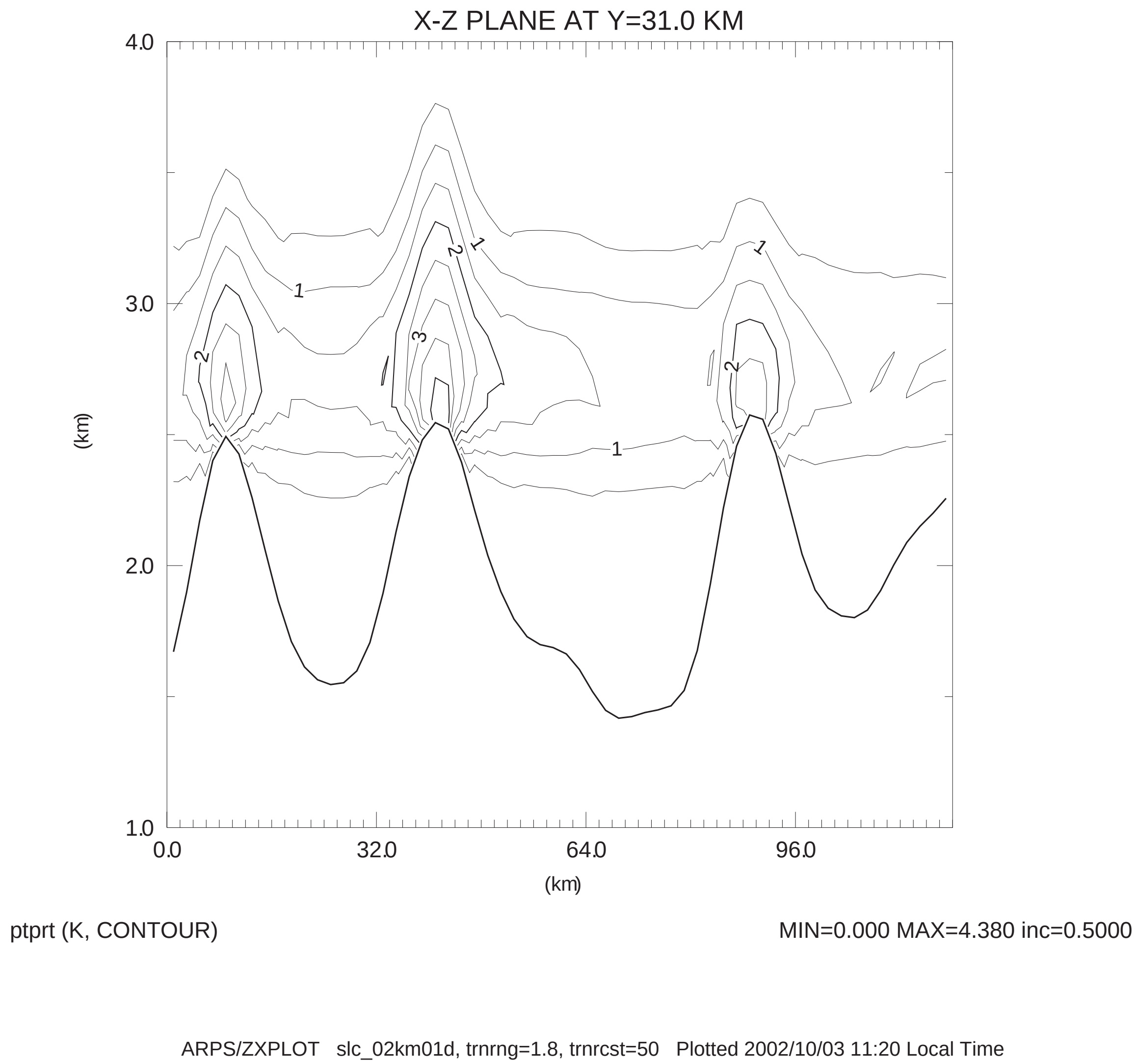

FIG 3. West-to-east cross-section through Salt Lake Valley. Analyzed potential temperature perturbation, degrees K. ADAS with proposed terrain correlation adjustment. R_t = 1.8 and h_t = 50 m.

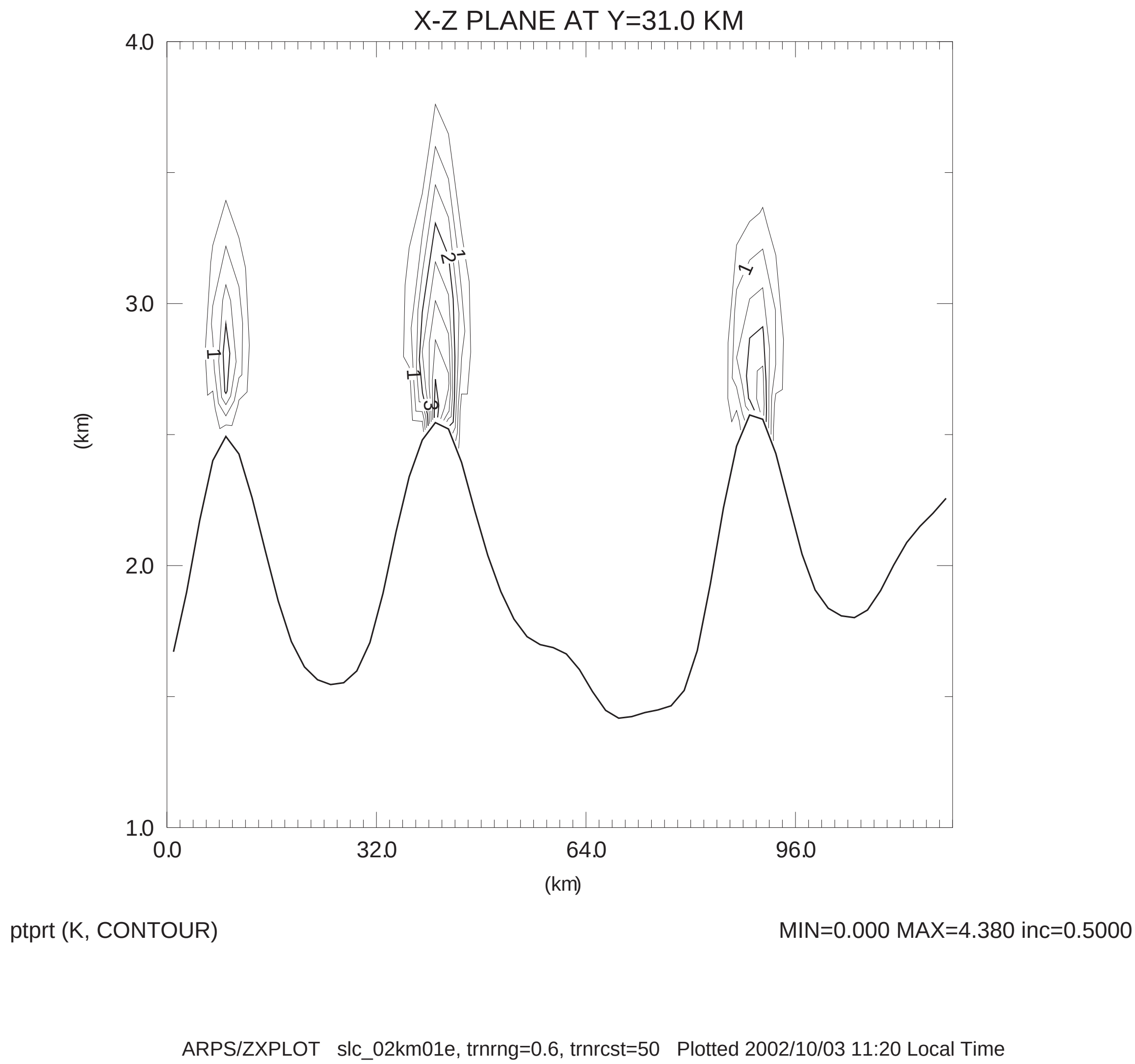

FIG 4. West-to-east cross-section through Salt Lake Valley. Analyzed potential temperature perturbation, degrees K. ADAS with proposed terrain correlation adjustment. R_t = 0.6 and h_t = 50 m.

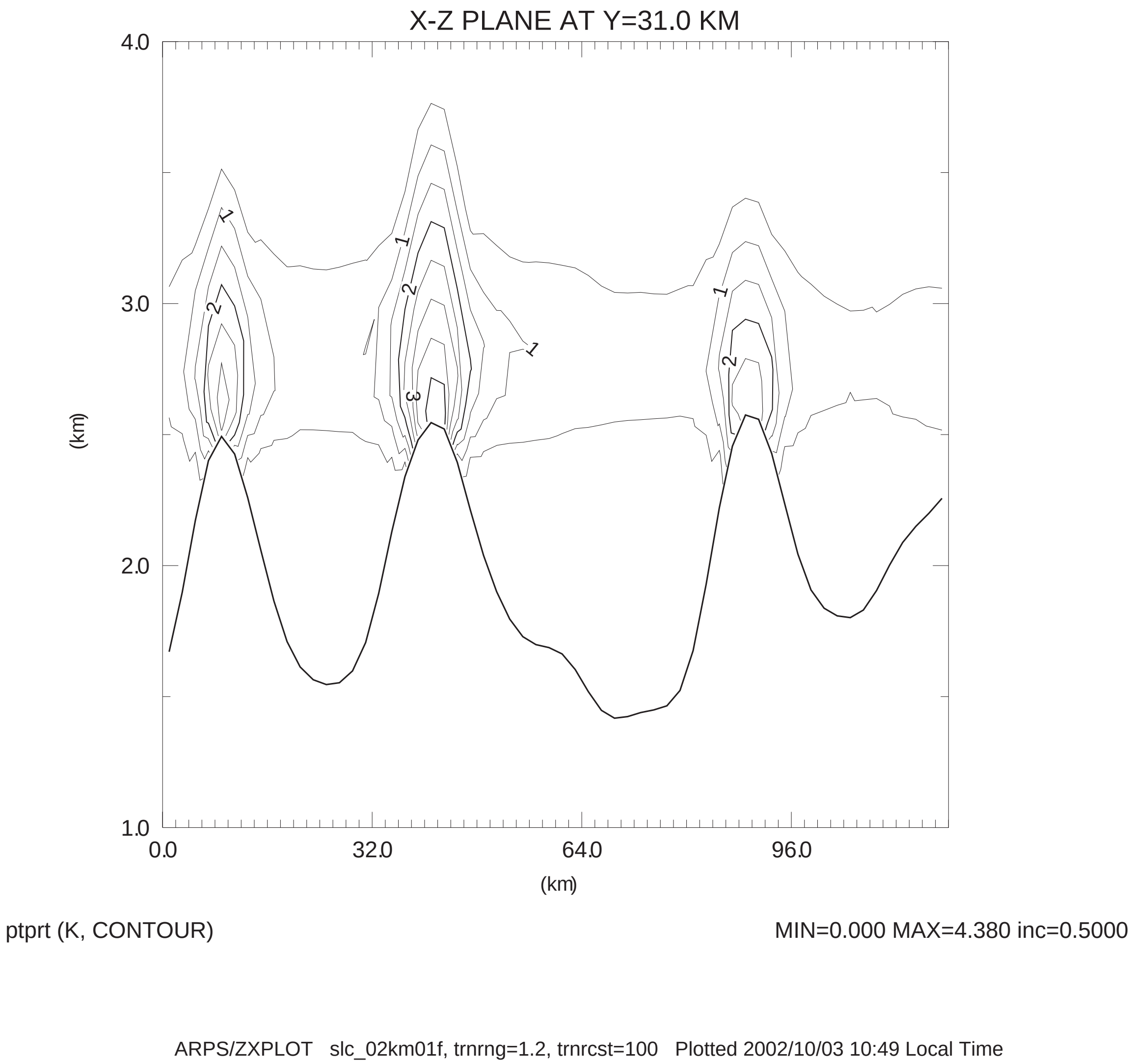

FIG 5. West-to-east cross-section through Salt Lake Valley. Analyzed potential temperature perturbation, degrees K. ADAS with proposed terrain correlation adjustment. R_t = 1.2 and h_t = 100 m.

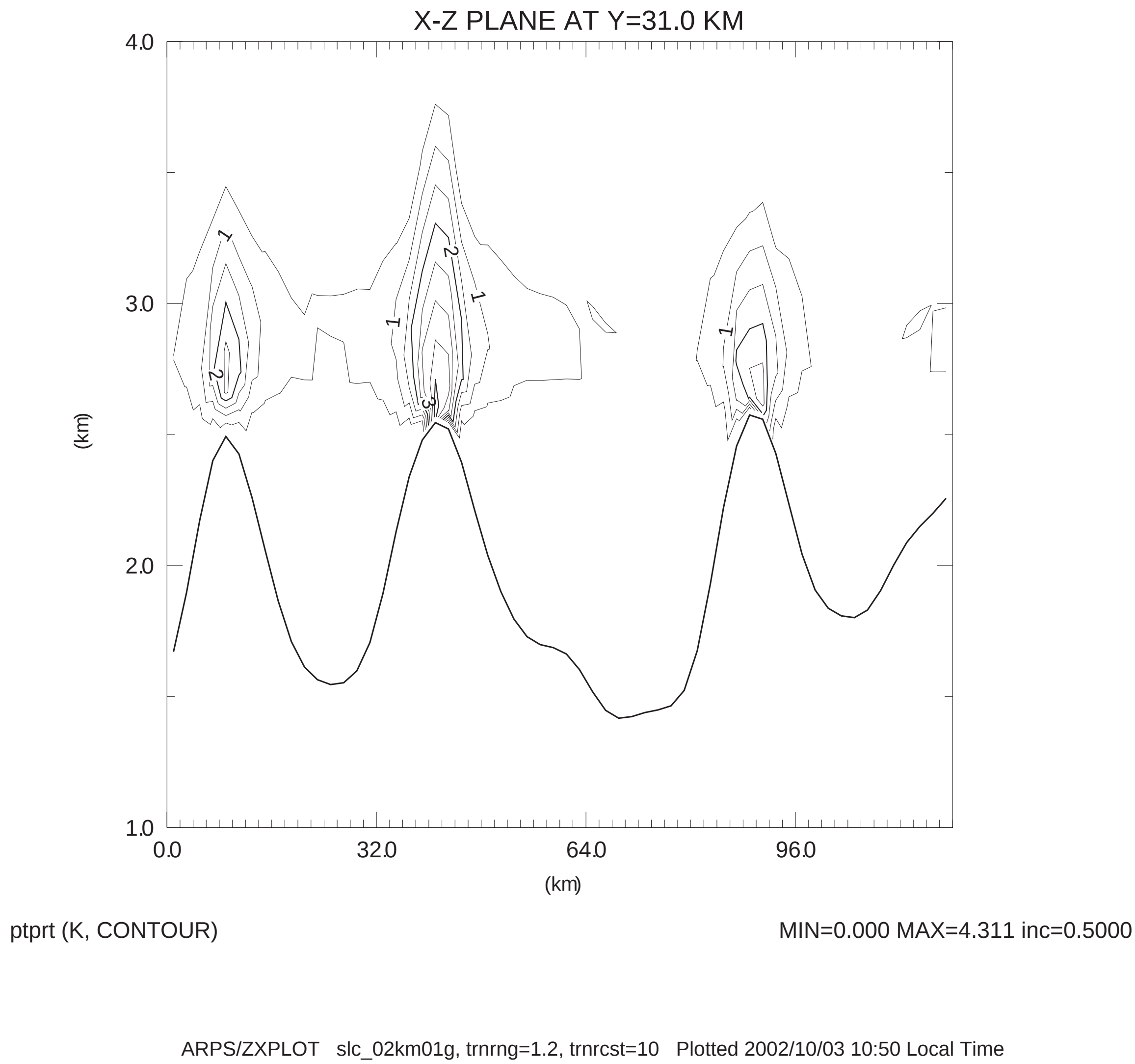

FIG 6. West-to-east cross-section through Salt Lake Valley. Analyzed potential temperature perturbation, degrees K. ADAS with proposed terrain correlation adjustment. R_t = 1.2 and h_t = 10 m.