12.2 Verification of a Real-Time System to Estimate Weather Conditions at High Resolution in the United States

Joseph P. Koval[1]
The Weather Channel, Atlanta, GA

Jeral G. Estupiñán
The Weather Channel, Atlanta, GA

Jim Staudinger
Weather Services International
Andover, MA

1. Introduction

The Weather Channel in Atlanta, Georgia (TWC) and Weather Services International Corporation in Andover, Massachusetts (WSI) jointly developed a system called HiRAD (**Hi**gh **R**esolution **A**ggregate **D**ata) that produces synthetic current conditions or surface weather conditions for any arbitrary point within the conterminous United States (CONUS).

The HiRAD system, described in detail by Neilley and Rose (2005), uses an interpolation scheme to estimate weather conditions at a large set of points via the following method:

1. An initial guess is produced at the interpolation site, as well as at several intelligently selected observation neighbors from hourly updated RUC analyses and short-term forecasts.
2. The initial guess is downscaled from the relatively coarse RUC grids to the interpolation and observation neighbors via computed deviations from a high-resolution climatological dataset.
3. Next, a correction to the first guess is applied at each of the neighbor sites based on the most recent observation at each site.
4. Then a punctual kriging (Cressie, 1990) scheme is applied to interpolate the corrections from the neighbor sites to the interpolation site, where the interpolated value, V is estimated from surrounding values P using:

$$V = \Sigma\lambda_i P_i$$

(λ are the interpolation weights used)

5. Finally, a corrected estimate at the interpolation site is computed by adding the interpolated correction to the climatologically adjusted first guess.

In addition to this basic interpolation method, a "manual kriging" is applied for some meteorological variables in cases where an interpolation point is co-located with an observation point. If an interpolation point is co-located with a METAR observing location, HiRAD will supplant, or "manually krig", the interpolated value at the interpolation site with the value reported in the METAR observation for a configurable METAR observation age and list of weather variables. Manual kriging is predicated upon the assumption that at METAR points, a METAR observation will be superior to a HiRAD report for most weather parameters, as long as the METAR report occurs close to the valid time of the HiRAD report.

2. Problem background

There is a need to quality control, or verify, the accuracy of the interpolation method used by HiRAD. This is only possible at points that are not collocated with METAR observations. At interpolation points collocated with a METAR observation, manual kriging generally ensures that the value output by HiRAD's estimation scheme is identical to the METAR observation.

Because of this behavior, another method was needed to facilitate verification of HiRAD's interpolation scheme.

3. Data Denial Concept and Application to HiRAD

Data denial is a concept that has been used to objectively measure the impact of individual inputs on numerical model accuracy for several years

[1]*Cooresponding author address:* Joseph P. Koval, The Weather Channel, 300 Interstate North Parkway, Atlanta, GA 30339.

(Cardinali et al. 2002, Benjamin et al. 2004). The concept assumes a control model run where an input, say X, is included in a modeling scheme. An experimental run is performed, identical to the control run with the exception that the input X is excluded from the analysis. Then, an error statistic for both the control run and the experimental run can be calculated. The difference in error between the control run and the experimental run is the impact of the experimental input on the model accuracy.

The concept can be applied to HiRAD, not in an attempt to determine the impact of a certain input on the interpolated output, but instead to verify objectively the skill of HiRAD's estimation of meteorological parameters. At HiRAD output sites that are collocated with a METAR observing station, the HiRAD output will be very similar, if not identical to that of a recent METAR observation as a result of kriging. However, at HiRAD output sites that are not collocated with a METAR observation, true interpolation takes place.

Data denial provides a method to take advantage of METAR observations as ground truth for calculating the skill of HiRAD's estimation techniques. If one assumes that a typical HiRAD run, with its kriging of METAR observations at collocated output sites is the control case, then a shadow version of HiRAD can run simultaneously that differs from the control version of HiRAD only in that input METAR observations are denied, or withheld, from the system when computing estimated meteorological values at collocated METAR sites. If a collocated METAR observation is denied as input when interpolating a set of meteorological variables at a given location, it is reasonable to assume that this is a proxy for HiRAD's full estimation techniques.

Then, an interpolation error can be calculated by differencing the data denial value and the control value at the interpolation location as shown in Figure 1. In the example, a typical calculation of a HiRAD surface temperature at KATL, the METAR observation from KATL is weighted 100% as a result of punctual kriging. Only if the METAR observation from KATL is missing or bad would a true interpolation of a temperature value at KATL take place (this situation is quite rare). Instead, the HiRAD output result IS the METAR's reported value of 84F.

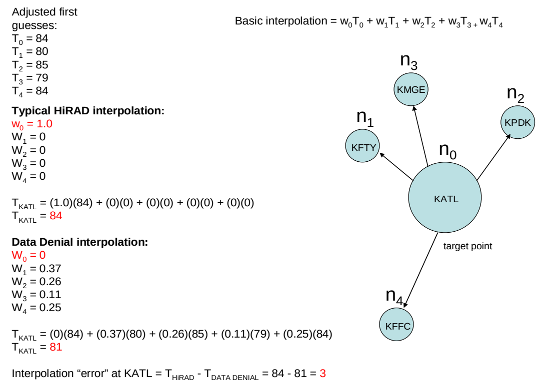

Figure 1. Example of typical HiRAD interpolation scheme and data denial interpolation scheme

In the data denial case, precisely the same analysis is run, though the weight of the METAR observation at the target point is set to zero. Now, an interpolation of the temperature at KATL using adjusted first guess data from the surrounding points occurs, and a weighted contribution to the estimated temperature at KATL is calculated. The weights applied to each neighbor point are a function of its magnitude of covariance with the interpolation point and its lack of covariance with the other neighbors. An interpolated or estimated temperature, known as the "data denial result", is calculated for KATL. Finally, an interpolation error is found by differencing the production HiRAD temperature and the data denial temperature.

4. Technical Background

Data denial is performed by running a special version of HiRAD in which same-site METAR observations are excluded as input. Care is taken to ensure that precisely the same input data are used with the sole exception of the denial of co-located METAR information to interpolation sites.

HiRAD is currently run operationally three times per hour at :05, :25, :45 minutes after each hour. A data denial run that shadows the :05 run, using its identical inputs, occurs at :08 minutes after the hour. The results of the :05 HiRAD and :08 data denial runs are differenced to produce the data denial "error" field.

Gross statistics for the entire sample of METAR sites are calculated for each run of data denial. Statistics include sample Mean Absolute Error, Median Absolute Error, Bias, and proportion of points with errors exceeding certain thresholds (usually 3 degrees F). These statistics have been collected and archived since March 2005. Additionally, a tracking system has been developed to consistently monitor HiRAD performance based on the accumulated data denial results (Figure 2) for temperature, dewpoint, and wind speed at approximately 1400 METAR locations within CONUS via an HTML-based user interface.

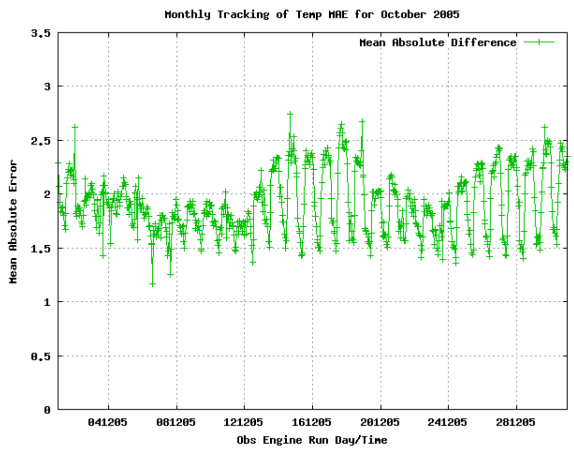

Figure 2. Sample monthly tracking graph showing diurnal range of data denial MAE of all CONUS METAR points.

5. Findings and Consequences

Analysis of the compiled results presents some interesting trends in the data denial statistics. A diurnal variation in Mean Absolute Error (MAE) of the sample is evident; the data denial results are lowest, and therefore most skillful, in the late afternoon hours. Skill reaches a minimum in the early morning hours. The magnitude of the diurnal variation also increases with increasing continentality of the air mass in the CONUS. It is also evident that the data denial statistics exhibit lowest error in areas of minimal elevational and microclimatological gradients. This is an expected result for an interpolation scheme - the interpolation will be most accurate in areas where elevation and microclimates vary least, and where numerous nearby neighbor sites are available for the interpolation. Interpolation skill will decrease as microclimatological and elevational gradients increase, and density of neighbor locations decrease.

Another intriguing (and initially unintended) result is that the data denial analysis has allowed for the frequent identification of METAR reports of poor quality. When a bad METAR observation is used in HiRAD's typical interpolation scheme, it IS the HiRAD output result at this interpolation point, and therefore becomes the "verification" value in the data denial comparison. In the data denial run, the bad observation is unknown to the interpolation scheme, so the result is a reasonable interpolation of the meteorological variable. When the interpolation error is calculated for the point, the resultant error will be very large as a result of the bad METAR observation. The data denial comparison's ability to highlight potentially poor METAR observations has allowed for the development of a process to trap and filter such METAR observations (Rose, et al. 2005).

From the lengthy archive of data denial results for each station we have also developed a quality control system for METAR observations, Data Denial Enhance Quality Control (DDEQC), that uses the data denial results in concert with the modified first guess from the RUC to perform real-time quality control of METAR observations from the HiRAD analyses (Rose et al. 2005).

6. Limitations and Conclusions

We are confident that the data denial system provides a good proxy for estimating the skill of HiRAD's interpolation scheme. However, there is some uncertainty introduced since we are removing an observation that would normally be available to HiRAD, intentionally degrading its quality. This limitation is especially true at METAR locations that are in remote areas and are significantly different from nearest neighbors in elevation. For example, when calculating data denial results for Mt. Washington (KMWN), we are significantly hampering HiRAD's interpolation scheme when we remove one of the METAR reporting stations in northern New England. When the "production" version of HiRAD runs, the Mt. Washington observation weighs heavily in estimating weather variables at high elevation points in the area, so the data denial results may be a bit pessimistic compared to reality. Still, there are mountain ranges without METAR observations for which HiRAD must estimate current conditions and the data denial results may ultimately prove to be quite representative.

The data denial study has enabled us to find and address issues with HiRAD's interpolation scheme, leading to refinements in the analysis methods and improvement in the results. We plan to continue to support the data denial system to track HiRAD performance, support DDEQC, and make improvements to the HiRAD system.

7. References

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