WESTERN REGION TECHNICAL ATTACHMENT
NO. 99-06
MARCH 23, 1999

PRACTICAL USE OF UPPER-AIR MODEL DIAGNOSTIC GUIDANCE

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Introduction

Model diagnostics, using up-to-date comparisons between model forecasts and observations, have been produced at the Western Region Headquarters of the National Weather Service on a quasi-operational basis over the last six months. Upper-air forecasts from the ETA, AVN, and MRF models are compared to radiosonde observations on a daily basis with the intent of providing forecaster with current guidance on model performance. In a previous Technical Attachment (Cook, 1998), the goals and basic methods behind these diagnostics were presented as an introduction. This work is intended as an extension, focusing on the practical use of the upper-air diagnostics as well as an update on available products.

Methods

Operational forecasts from the ETA, AVN, and MRF models are compared to upper-air observations from sites located in the western United States. Model bias errors are calculated at each of the sites (on every 50 hPa level, where available) for both single forecasts as well as seven-day averages. A more detailed description of the parameters and data manipulation is provided by Cook (1998). A Barnes objective analysis (Barnes, 1964) of the model bias error fields has been added for both the single-forecast and period averaged diagnostics. Using the GEMPAK routine OABSND, objective analysis grids are created from the upper-air bias error fields on three levels (700, 500, and 300 hPa levels). Plots of upper-air model biases (both single forecast and seven-day average) are produced at each site in the form of a sounding, as well as a map-view of the objective analyses and actual model forecasts over the domain.

Single Forecast Upper-air Diagnostics

The single-forecast upper-air diagnostics are measures of model skill at each individual forecast hour with respect to the latest radiosonde observations. Model bias errors are plotted against pressure in the form of a sounding at each site for each parameter, allowing the forecaster to analyze in detail the vertical structure of the model biases at each sounding location (Cook, 1998). In order to analyze model skill on the larger scale, the forecaster may examine and compare bias profiles at many locations. However, this technique proves to be tedious and may have little reward with respect to diagnosing overall model performance. Consequently, a more efficient tool in evaluating this skill is needed.

The Barnes objective analyses of the ETA 500 hPa geopotential height bias errors valid on 990301, 1200 UTC are shown in Fig. 1A. The objective analyses of the model bias fields (in color) are projected over the forecasts (F000, F012, F024, F036 and F048) valid at 1200 UTC. In this case, a weak upper-level short-wave trough is moving into the Pacific Northwest while an upper-level ridge sits over the northern Rocky Mountains (Fig. 1A). The height bias errors grow more negative with forecast lead-time (F000 has little or no bias at this level), indicating an overall tendency to under-forecast the heights at this level. The more negative biases at the larger lead-times (F036 and F048) over northern California and Oregon appear to be associated with the upper-level trough, and highlight its slightly exaggerated magnitude. The Eta model appears to be overdoing the trough's magnitude, particularly at the later forecast hours. In addition, the model also seems to be under-forecasting the heights of the shortwave ridge to the east over Wyoming (again at the later forecast hours). The Barnes analysis of the 300 hPa u-component wind bias errors is shown in Fig. 1B. The objective analysis of the bias fields at each hour is shown as well as the actual forecasted total winds (wind barbs). Like the height biases, the u-component wind bias errors tend to grow with lead time. The 36-h and 48-h forecasts have biases more than $15 ms^{-1}$ too strong (positive) over Arizona and New Mexico and nearly as weak (negative) over Montana and northern Idaho. The larger positive biases over the southern part of the region and the larger negative biases over the northern portion of the region may indicate that the Eta model has the jet too far to the south in the forecasts with larger lead-times (F036 and F048). Again, as was seen in the geopotential height bias fields, the Eta appears to be overdoing the system as it moves onshore, particularly in the later forecast hours. The objective analyses of the 700 hPa temperature bias errors are shown in Fig. 2A. The cold air associated with the upper-level system in the Pacific Northwest is moving onshore into western Oregon and Washington with a baroclinic zone extending from northern California northeast into Idaho and Montana (Fig. 2A). Like the height fields, the Eta temperature bias errors tend to be more negative (cold) with lead-time, and for the most part, are associated with the baroclinic zone rather than with the coldest air connected to the system (Fig. 2A). In addition, the model biases for the 36-h and 48-h forecasts highlight the apparent incorrect magnitude of a thermal wave on the baroclinic zone over Wyoming and northern Colorado.

By using the objective analysis of the bias fields in conjunction with the actual forecasts, the forecaster is not only able to evaluate model biases over the whole domain, but to connect them to details in the forecasts themselves as well. At the very least, the objective analysis fields allow the forecaster to identify regions or situations of poor model performance that require further investigation. It is important to note that these products are based upon an objective analysis and consist of extrapolated data on a limited number of levels. The analysis is not necessarily "real", particularly in data void regions or along the domain boundary. Because it is also limited to three levels, it may not be resolving the total bias field. However, if used in conjunction with the bias error profiles in addition to other forms of both prognostic and observational data, the bias error objective analysis proves to be a valuable prognostic tool.

Seven-day Average Upper-air Diagnostics

The period upper-air diagnostics are measures of model skill for each forecast hour valid over a seven-day period with respect to radiosonde observations. The utility of the period diagnostic guidance lies in its use as a contemporary summary of model skill that is not necessarily dependent on specific weather regimes (Cook, 1998); for example, the November 3, 1998 change to the Eta post-processor, which allowed for the computation of relative humidity (RH) with respect to ice saturation. The Eta seven-day bias errors for the period ending on 981029, (prior to the change) are shown in Fig. 3. The RH biases for forecasts valid at Great Falls, Montana are small, with magnitudes no larger than 10% on any level (Fig. 3A). The objective analyses of the RH bias errors on the 300 hPa level over the entire domain are also small, with localized magnitudes no larger than 20%, indicating little or no problem with the model upper-level moisture at this time (Fig. 3B). The seven-day bias errors for forecasts valid during the period ending on 981115 are shown in Fig. 4. The profiles for RH forecasts valid at Great Falls exhibit bias errors at all forecast hours as large as a + 50% at upper-levels (Fig. 4A) for forecasts valid during the week period after the change. In addition, the objective analyses of the 300 hPa relative humidity bias fields exhibit values greater than +10% over the entire domain and are more than +30% for the northern portion of the region, indicating a gross tendency to over-forecast moisture at upper-levels. The change to the RH calculation in the Eta post-processor allowed for more moisture at upper levels, introducing a positive bias to the RH fields aloft that was easily recognized in the period averaged diagnostics. As a tool, the seven-day upper-air diagnostics provide the forecaster with a baseline knowledge of model performance, which is particularly important in the current environment of constant model evolution.

Summary

The upper-level diagnostics were designed with the intent of providing the forecaster with up-to-date guidance on model performance at all levels in the atmosphere. However, the traditional bias profiles at each individual site have proven to be inadequate in efficiently diagnosing overall model skill. With this in mind, the suites for both the single-forecast and period diagnostics were augmented with a Barnes objective analysis of the bias errors for each parameter on three levels (700, 500 and 300 hPa), allowing the forecaster to not only address model biases more efficiently over the whole domain, but to more importantly make connections to details in the actual forecasts. Both the single-forecast and period upper-air diagnostics continue to be valuable prognostic tools in addition to providing insight into current numerical weather prediction that is crucial in the present operational environment.

References

Barnes, S.L., 1964: A Technique for Maximizing Details in Numerical Weather Map Analysis. *J. Appl. Meteor.*, 3, 396-409.

Cook, L.K., 1998: Western Region Model Diagnostics. WR-Technical Attachment 98-39.

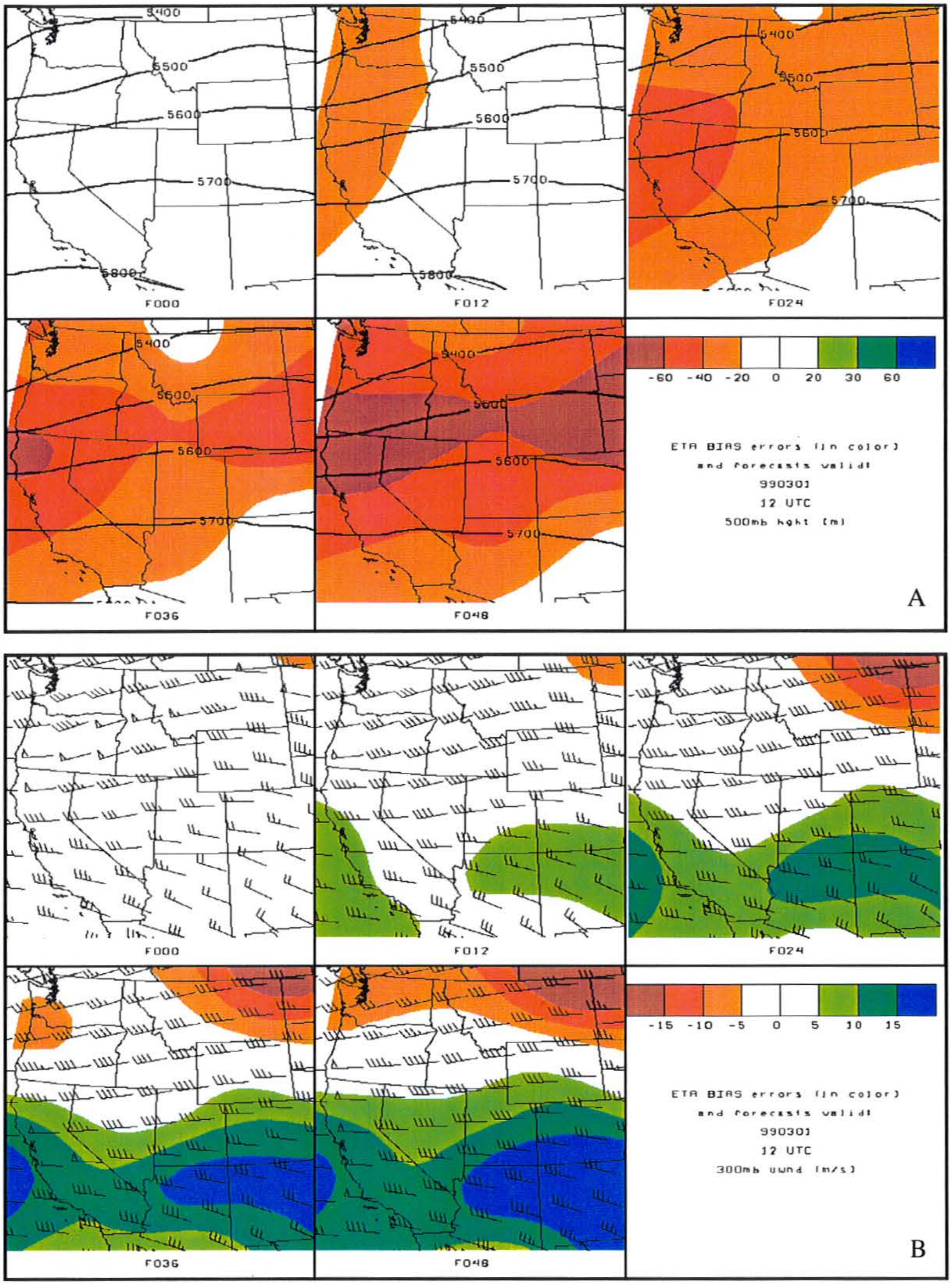

Figure 1. Barnes objective analysis of ETA A) 500 hPa geopotential height (m) and B) 300 hPa u-component wind (ms^{-1}) bias errors overlaid on actual forecasts valid on 990222, 1200 UTC. The objective analysis of the bias fields are shown in color.

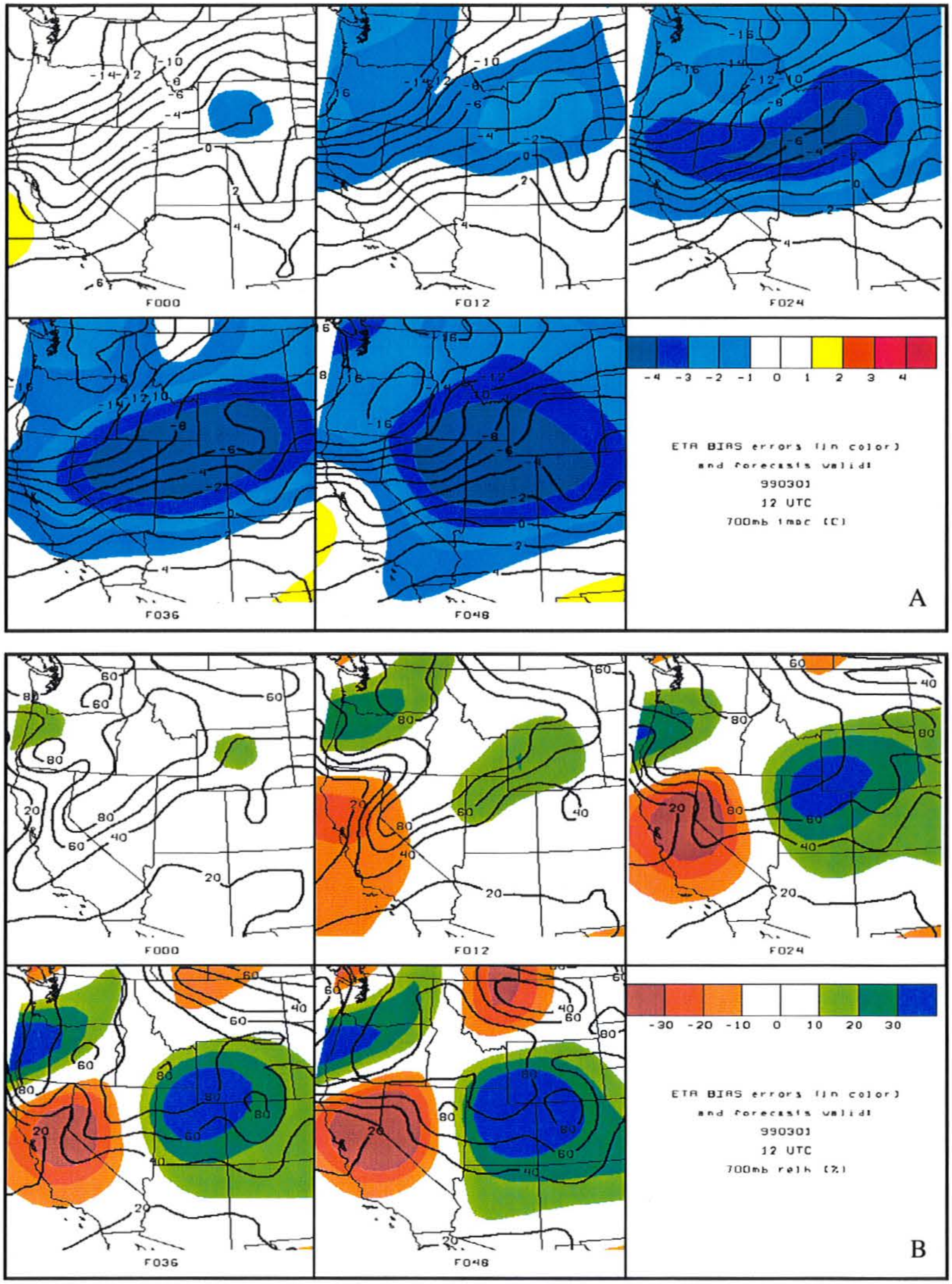

Figure 2. Barnes objective analysis of Eta 700 hPa A) temperature (˚C) and B) relative humidity (%) bias errors overlaid on actual forecasts valid on 990222, 1200 UTC. The objective analysis of the bias fields are shown in color.

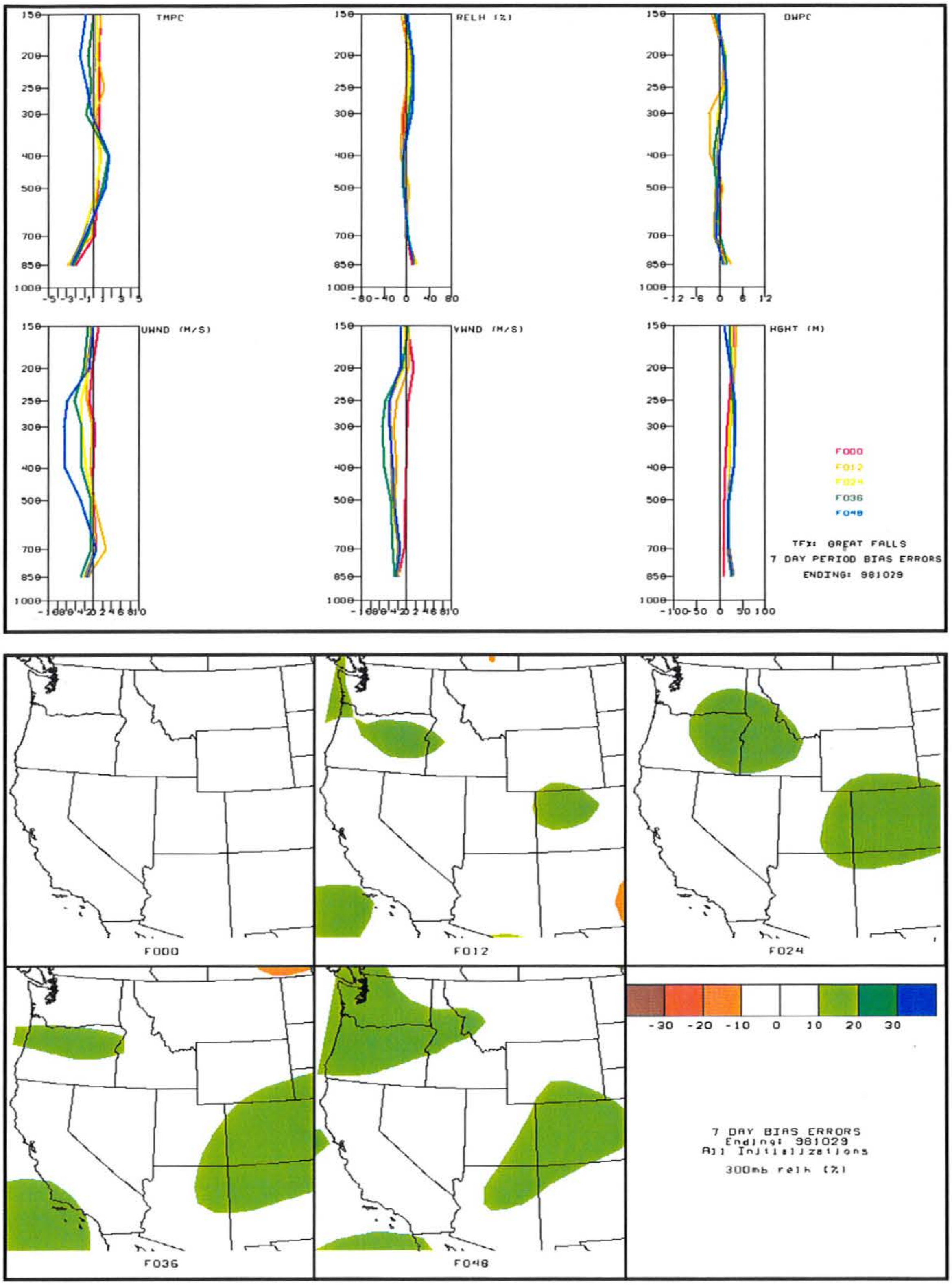

Figure 3. Eta 7-day average bias errors in the form of A) the upper-air profile for Great Falls, MT. (TFX) and B) the Barnes objective analysis of the RH (%) fields over the whole domain for the period ending on 981029.

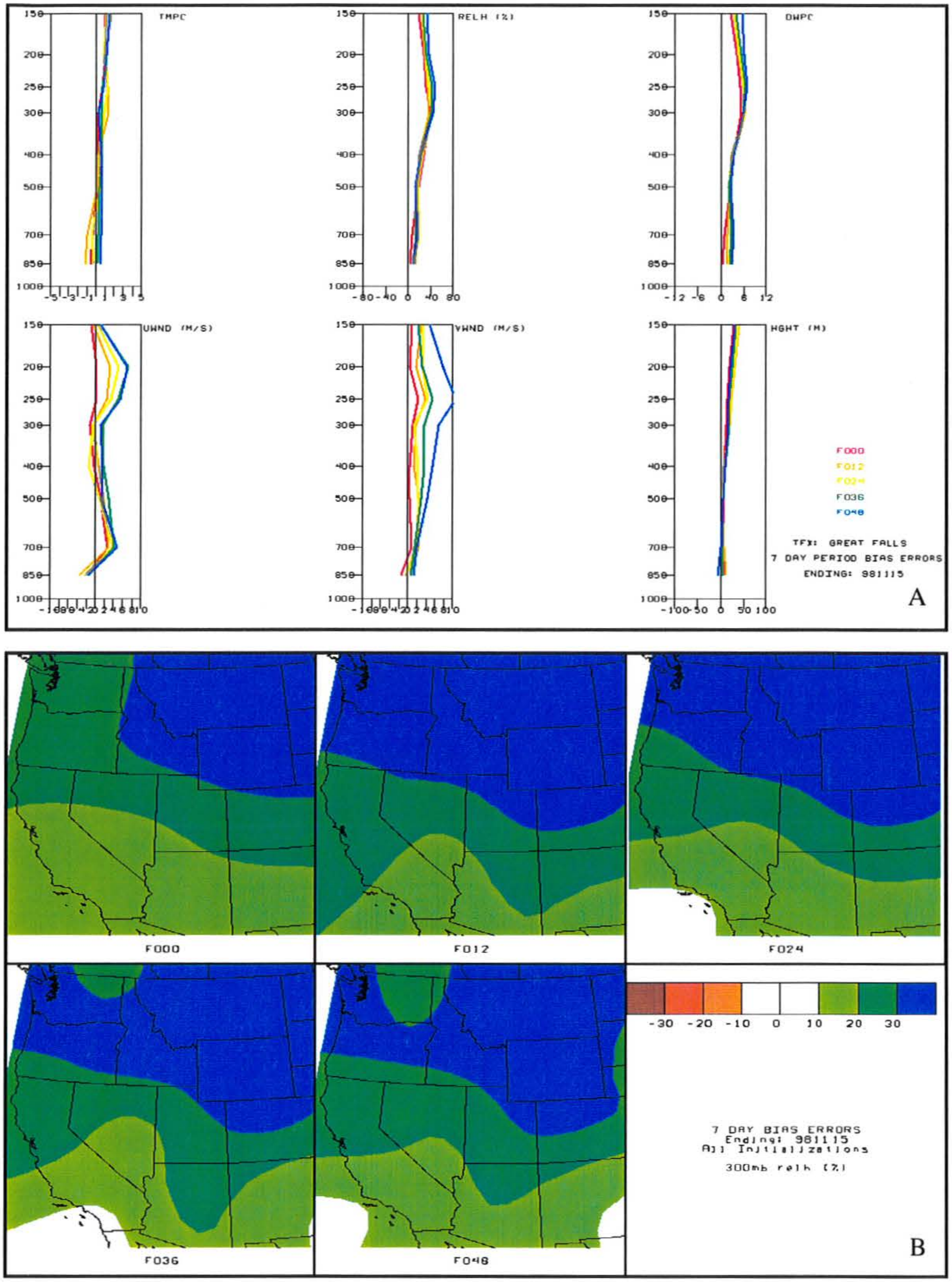

Figure 4. Eta 7-day average bias errors in the form of A) the upper-air profile for Great Falls, MT. (TFX) and B) the Barnes objective analysis of the RH (%) fields over the whole domain for the period ending on 981115.