

Medium-Range Fire Weather Forecasts

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Abstract. The forecast skill of the National Meteorological Center's medium range forecast (MRF) numerical forecasts of fire weather variables is assessed for the period June 1, 1988 to May 31, 1990. Near-surface virtual temperature, relative humidity, wind speed and a derived fire weather index (FWI) are forecast well by the MRF model. However, forecast relative humidity has a wet bias during the winter and a slight dry bias during the summer, which has noticeable impact on forecasts of the derived fire weather index. The FWI forecasts are also strongly affected by near-surface wind forecast errors. Still, skillful forecasts of the fire weather index as well as the other relevant fire weather variables are made out to about 10 days. These forecasts could be utilized more extensively by fire weather forecasters.

Key words: Fire weather; Forecasting; GCMs; Medium-range.

1. Introduction

In a recent article, Fosberg and Fujioka (1987) described the use of national weather forecasts at short to extended time ranges in planning for wildland fire management. Medium to extended range weather forecasts were cited for potential use in alerting, staging and deploying fire crews and equipment throughout the country. On a regional level, short to medium range weather forecasts can be used to alert air crews and to prepare equipment for deployment; deployment takes place when actual fire situations occur. On a local level, land managers can use short to medium range weather forecasts to determine optimal periods for setting prescribed silvicultural fires. Different scales of planning utilize different forecast horizons (Rios, 1989).

Fire weather forecasts are usually prepared from short-range weather forecasts (1-2.5 days) by the National Meteorological Center's (NMC's) nested grid model, statistical information from model output statistics, and human judgement. At weekly to monthly time

scales, forecasts for mean precipitation and surface temperature only are available from the Climate Analysis Center at NMC. The methodology used to make these extended range forecasts is described by Epstein (1988) and Wagner (1989). Basically, NMC's global medium range forecast (MRF) model forecasts are combined with persistence, statistical, and human forecasts to make an extended forecast of the 700 mb height. "Perfect prog" statistical models developed by Klein (1985) and Klein and Bloom (1987) are then used to predict surface virtual temperature and precipitation.

Medium and extended range fire weather forecasters and land managers, however, need more than just temperature and precipitation. For example, hot, dry, and windy conditions are times of extreme fire danger. Recently Klein and Whistler (1991) made extended range forecasts more relevant to fire weather by finding statistical relationships between the monthly averaged 700 mb height and monthly mean temperature, dewpoint, wind speed, and precipitation frequency (number of days in the period that precipitation exceeds 2.54 mm).

In a similar manner, we attempt here to make medium range forecasts (2-10 days) more relevant to fire weather forecasting by assessing the accuracy of NMC's MRF model forecasts of near surface fire weather elements such as virtual temperature, relative humidity, wind speed and a combination of these variables contained within the Fosberg (1978) fire weather index (FWI) to be described below. Medium range forecasts of these fire weather variables have not been heretofore scrutinized due to the presumed low model skill of near-surface fields.

2. Fire Weather Index

The physical aspects of wildland fire can be quantified in a variety of ways, e.g. rate of spread, rate of thermal energy production, fireline intensity, etc. Similarly, fire danger can be described by a variety of measures; in the United States, the most common measures are those of the

U.S. National Fire Danger Rating System (NFDRS; Deeming et al., 1977). For the most part, the indices that describe fire characteristics are based upon the work of Byram (1959), Rothermel (1972), and Albini (1976). The indices integrate the effects of weather, vegetation, and terrain. The information can be used, therefore, to determine suppression strategy.

By assuming constant fuel characteristics, Fosberg (1978) derived a simple fire weather index (FWI) based upon equilibrium moisture content (a function of virtual temperature and relative humidity) and wind speed. A subsequent study (Haines et al., 1983) showed that the FWI is highly correlated with fire occurrence in the Northeast. Therefore, as a first step in developing methods for medium range fire weather forecasting, we will undertake in this paper to examine how well we can predict the FWI as well as the primary meteorological variables that are used to derive the FWI.

The FWI is computed from the following expression given in Fujioka and Tsou (1985):

$$FWI = (1 + W^2)^{\frac{1}{2}}(1 - 2a + 1.5a^2 - 0.5a^3)/0.3002, \quad (1)$$

where W is the wind speed (in this formula W has units of statute mph) and the parameter a is the ratio of equilibrium moisture content to a moisture of extinction of 30. The second quantity in parentheses is called the moisture damping coefficient. The normalized equilibrium moisture content, a , is determined from dry-bulb virtual temperature, T (in the formulas below, T is in degrees Fahrenheit and is the absolute temperature rather than the virtual temperature of the NMC analysis to be discussed later), and relative humidity, R (in percent, see Simard, 1968), by the following relationships

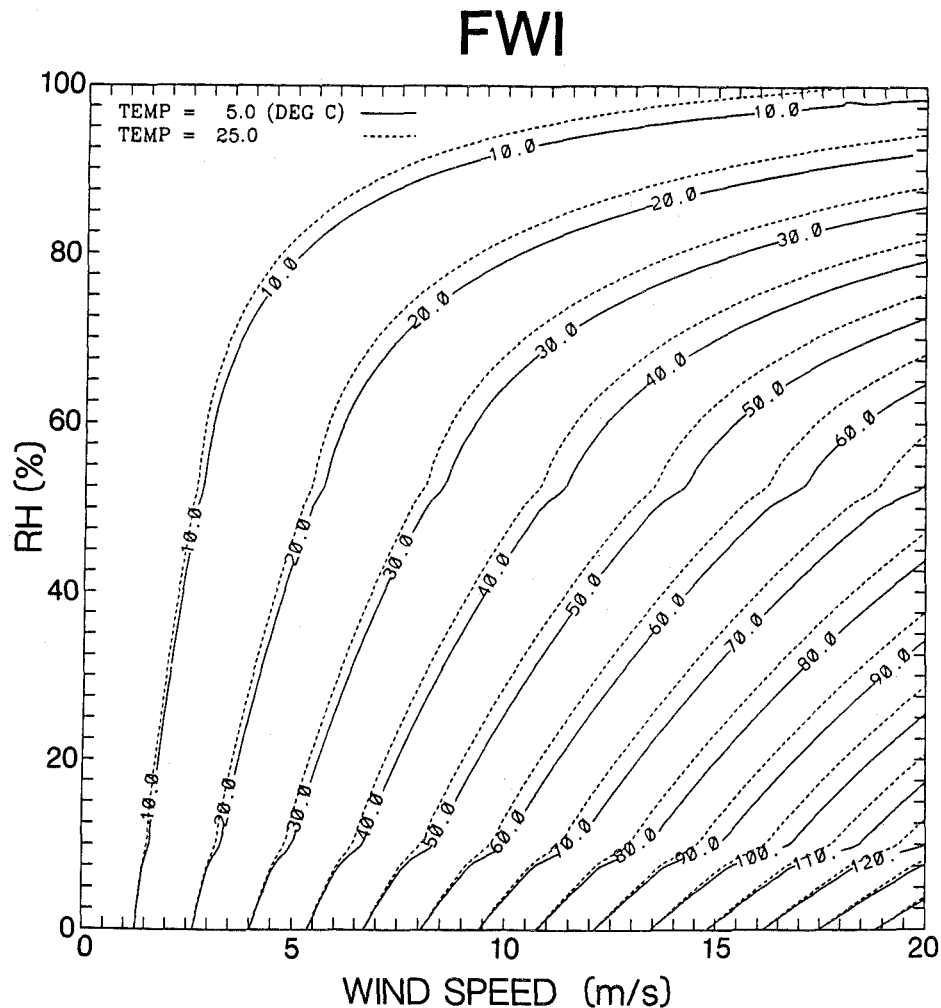


Figure 1. The FWI as a function of wind speed (abscissa) and relative humidity (ordinate) for virtual temperatures of 5 (solid) and 25 (dashed) degrees C.

$$a = m/30$$

$$m = 0.03229 + 0.281073R - 0.000578RT, R < 10\%$$

$$m = 2.22749 + 0.160107R - 0.014784T, 11 < R < 50\%$$

$$m = 21.0606 + 0.005565R^2 - 0.00035RT - 0.483199R, R > 50\%$$

Figure 1 shows the parameter dependence of the FWI on T (deg K), R (%), and W (m/s). The higher values of the FWI are supposed to represent a greater potential for fire activity. As may be seen, the temperature dependence is almost negligible. For increased temperature, the FWI increases only slightly. Much stronger variations in the FWI occur due to relative humidity and wind speed variations. As might be expected the FWI increases strongly for increased wind speed and decreased relative humidity. Basically, times of potential fire danger (as described by the above simplified FWI) are during windy, relatively dry, and to a lesser extent, warm conditions. Warm spells are also slightly more dangerous. The discontinuous slopes of the FWI are due to the slightly different parameter dependencies for the three relative humidity classes given above.

3. Data

Only large-scale meteorological data is used in this paper to describe the large-scale meteorological characteristics of the FWI and associated fire weather variables - relative humidity, wind speed, and virtual temperature. Similarly, we use NMC's large-scale global numerical weather prediction MRF model to describe how well we can forecast large scale deviations of this index and associated fire weather variables.

3.1 Observation

NMC's twice-daily (00 and 12 UTC) global analysis is available from the National Center for Atmospheric Research on a global 2.5 x 2.5 degree grid. The fields archived at the mandatory pressure levels (1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70 mb) are virtual temperature (which is only slightly higher than absolute temperature), wind velocity, and geopotential. Relative humidity is only archived at 300 mb and below. The analyzed surface pressure is also included. From these data we linearly interpolate the pressure level values to a surface value and then subsequently derive a windspeed and a fire weather index. This linear interpolation cannot take into account variations in the surface frictional

boundary layer and thus we will hereafter refer to these interpolated values as *near-surface* values that might apply to some near-surface anemometer level.

The northwestern hemisphere annual mean near-surface FWI for 00 UTC and 12 UTC for the period June 1, 1988 to May 31, 1990 is shown in Fig. 2. The geographical variations in the near-surface variables appear to be simply related to the underlying topography. The lowest virtual temperatures occur at the peak of the Rocky Mountains; the highest continental wind speeds occur in the lee of the Rocky mountains. The relative humidities are also relatively low in the mountains although the lowest relative humidities are found in the southwest deserts. The combination of the wind and relative humidity variations result in the greatest FWI in the windy lee-side belt and the dry southwest.

It can be readily discerned that late afternoon (00 UTC) FWI values are higher than early morning (12 UTC) values, mainly due to the higher early morning relative humidities shown in Fig 2b; the higher early morning relative humidities are caused by low early morning virtual temperatures, Fig. 2d. Another contribution to the greater late afternoon FWI is the greater wind speed over the U.S., as shown in Fig. 2c; the Texas panhandle region of the U.S. and the eastern subtropical Pacific, however, do have slightly higher winds in the early morning hours. Overall the 00 UTC values are quite similar to the 12 UTC values as well as the daily average.

For comparison to the available forecast data discussed below, we consider a 00 UTC T30 spherical harmonic spatially filtered version of the above data. This T30 filtered version truncates two-dimensional wave numbers greater than 30, which contribute to only the smallest scales. This filtered version was used originally to make the much larger forecast data set transfer and analysis feasible; nonetheless, a T30 truncation still captures most of the variance of the 2.5x2.5 degree final analysis. There is one additional approximation. The forecast data set did not have available the forecast surface pressure but did have the forecast geopotentials. We therefore used the Scripps topography to define the surface elevation and interpolated the forecasts to this surface rather than the surface defined by a more consistent analyzed surface pressure. The climatological averages for the period June 1, 1988 to May 31, 1990 for the 00 UTC T30 filtered and height interpolated observations are shown in the upper panels of Fig. 3.

The differences between the T30 filtered and height interpolated data set, seen by comparing the upper panels of Fig. 3 with the upper panels of Fig. 2, are noticeable but small. Consideration of individual stations would presumably show an even greater diversity. Nonetheless, we feel that consideration of the particular filtered

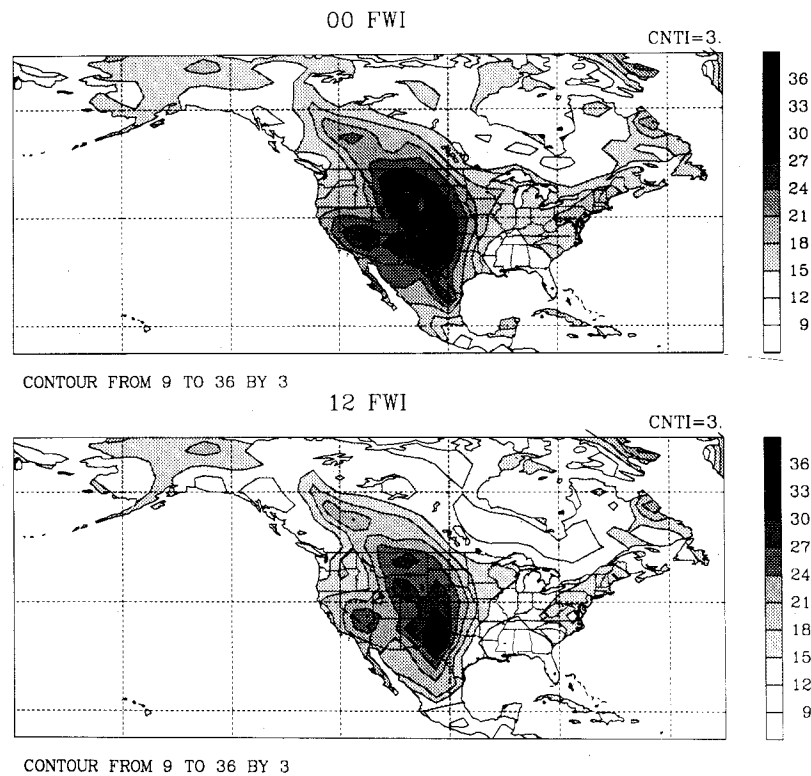


Figure 2. Annual N.A. near-surface FWI derived from the 2.5x2.5 degree twice daily NMC global analysis.

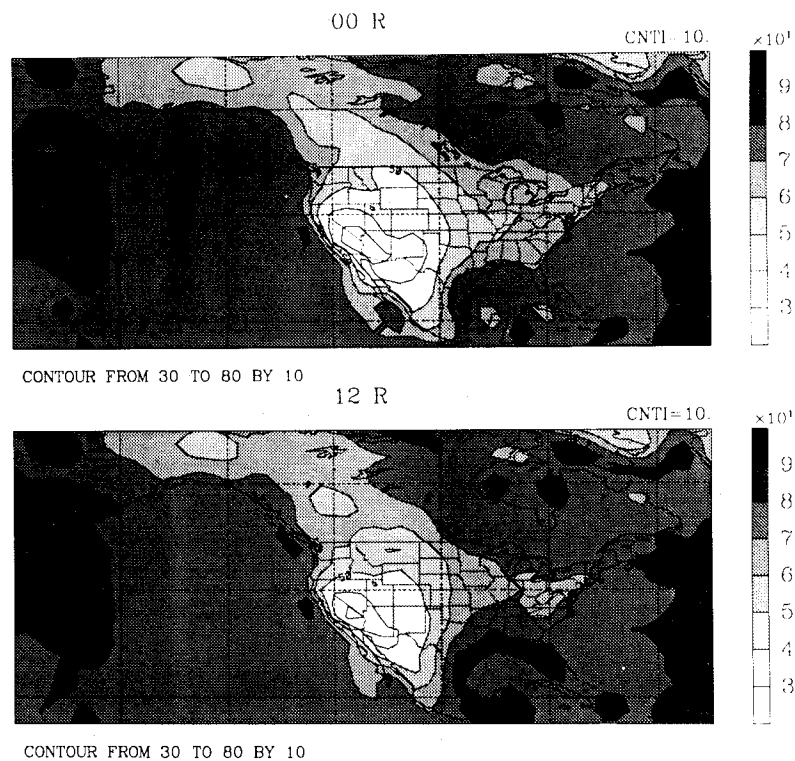


Figure 2b. Annual N.A. near-surface relative humidity derived from the 2.5x2.5 degree twice daily NMC global analysis.

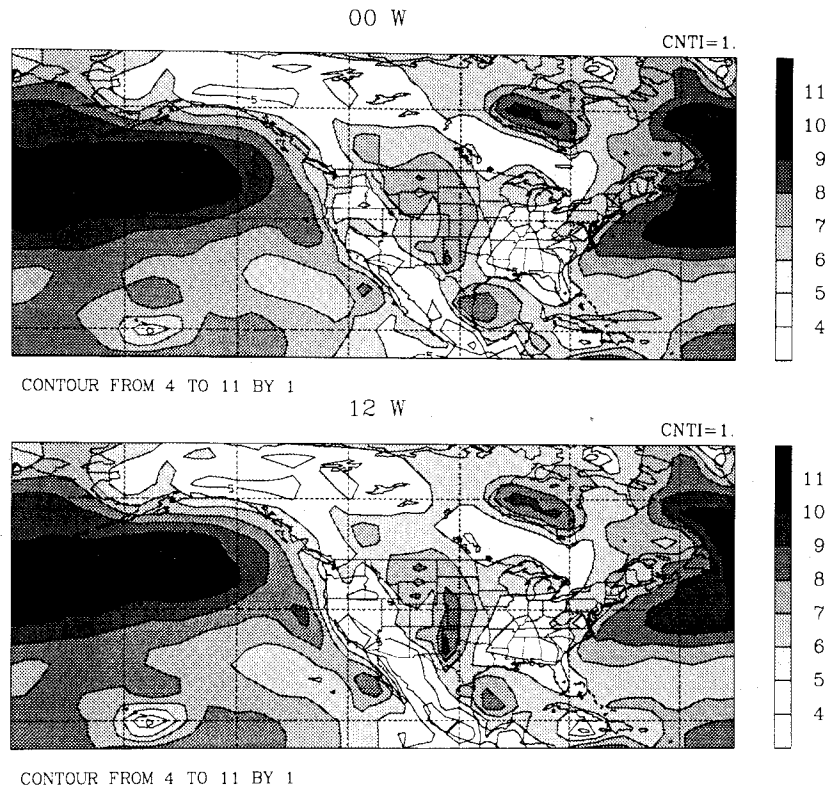


Figure 2c. Annual N.A. near-surface wind speed derived from the 2.5x2.5 degree twice daily NMC global analysis.

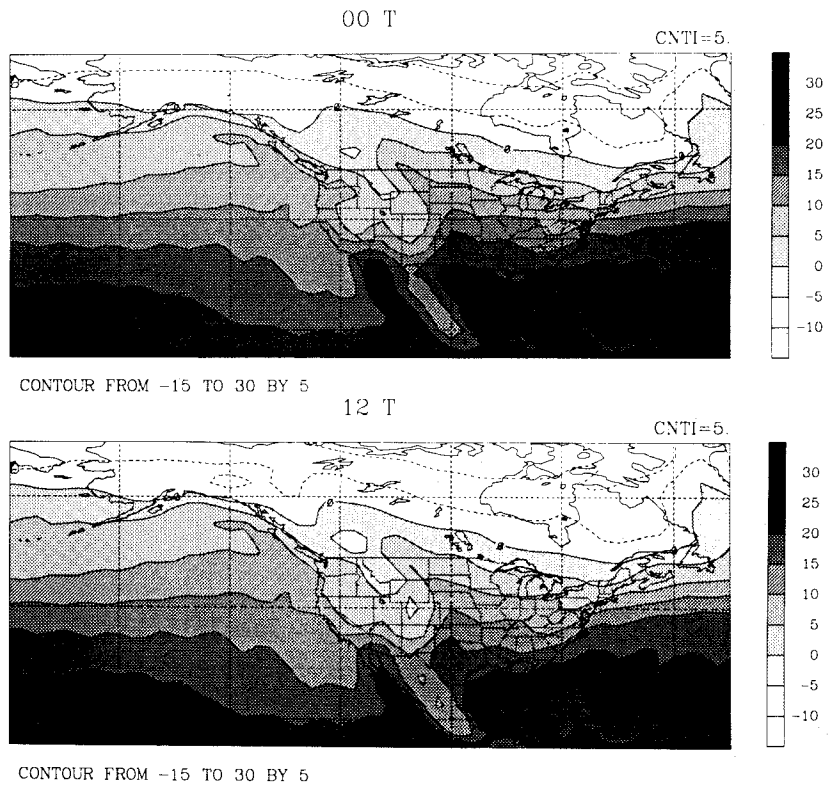


Figure 2d. Annual N.A. near-surface virtual temperature derived from the 2.5x2.5 degree twice daily NMC global analysis.

estimate for the large-scale surface fire weather variables. In the remainder of the paper we concentrate solely on observations and forecasts of this 00 UTC T30 height filtered data set.

3.2 Forecasts

The numerical forecasts available for this evaluation consist of 1-10 day 00 UTC MRF model forecasts of virtual temperature, relative humidity, geopotential, and zonal and meridional wind at the 12 mandatory pressure levels made by NMC's global spectral model (also known as the aviation, medium-range forecast or MRF model). These forecasts were archived by S. Saha of NMC in a set of spherical harmonics truncated at rhomboidal 30, and further truncated for transfer to T30. Exactly as is done for the T30 observations, we first convert the spherical harmonic coefficients to the 2.5×2.5 degree grid, interpolate in height to find near-surface values, and then calculate the near-surface wind speed and FWI.

The time period chosen for this evaluation was based on a preliminary analysis that showed a noticeable im-

provement in the relative humidity forecasts beginning in May of 1988. This forecast improvement is presumably due to the Pan (1990) modification to the surface evaporation in the MRF model. As discussed in Roads and Maisel (1990a), this improved surface evaporation parameterization also appeared to decrease the well known wet bias in the MRF model. From 1 June 1988 to present the forecast biases seemed relatively constant and thus we decided to limit our evaluation to the period June 1, 1988 to May 31, 1990.

4. Forecast Climatology

The annual values of the spatially filtered observations and 10-day forecasts of fire weather variables at 0000 UTC are compared in Fig. 3. Overall the comparison is good. The FWI has the appropriate geographical characteristics of the maximum in the southwest U.S. and the windy belt extending from Texas to Canada in the lee of the Rocky mountains. The 10-day forecast shows a slight negative bias but overall the comparison is good. This negative bias is related to the positive bias in the

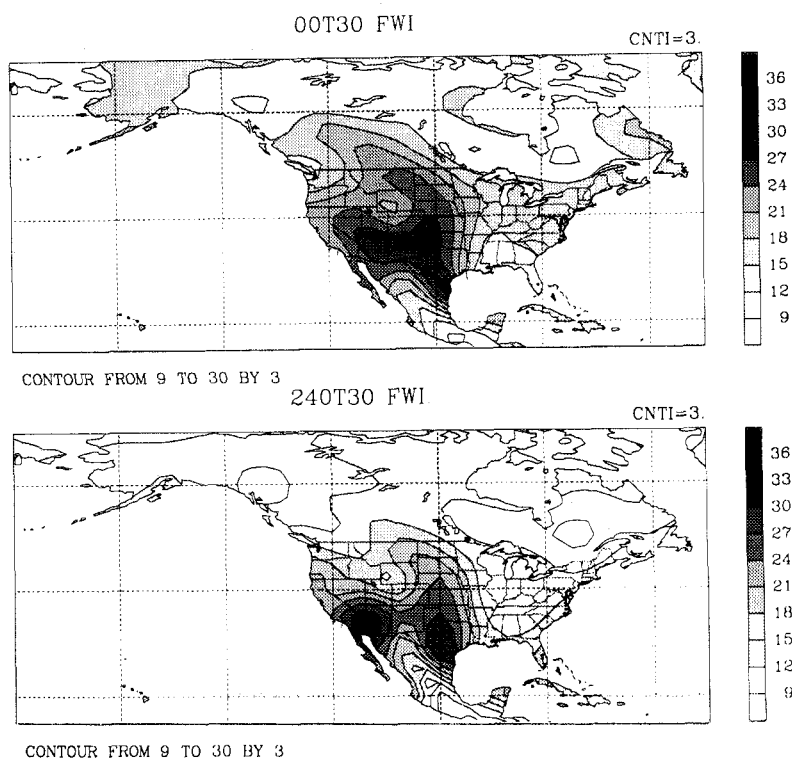


Figure 3a. (Upper panel) Annual N.A. near-surface FWI derived from the T30 filtered and height interpolated NMC global analysis at 00 UTC. (Lower panel) Annual N.A. 10 day forecast (240 hour forecast) FWI derived from the T30 filtered and height interpolated MRF model forecasts valid at 00 UTC.

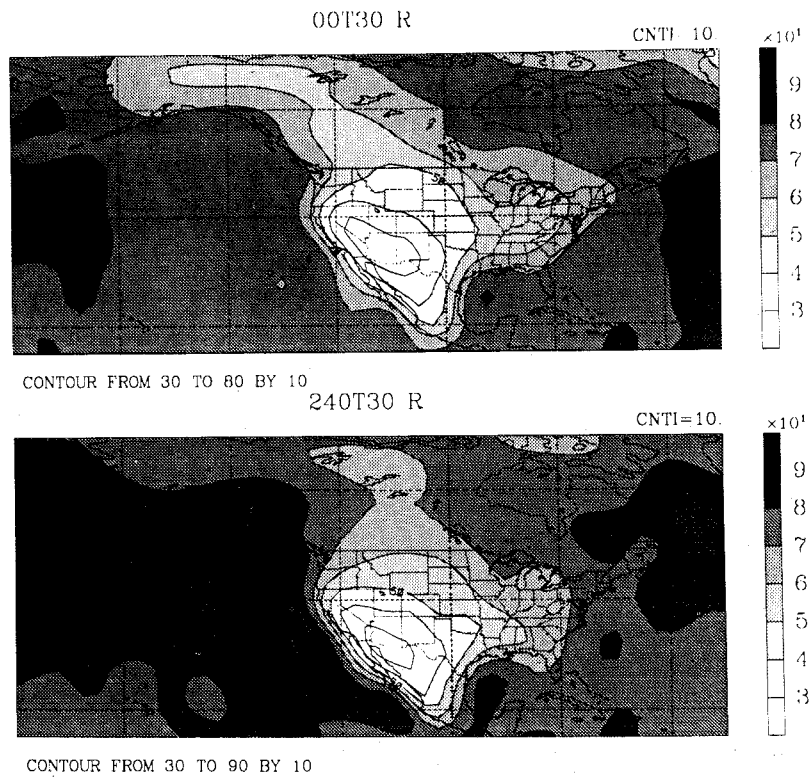


Figure 3b. (Upper panel) Annual N.A. near-surface relative humidity derived from the T30 filtered and height interpolated NMC global analysis at 00 UTC. (Lower panel) Annual N.A. 10 day forecast (240 hour forecast) relative humidity derived from the T30 filtered and height interpolated MRF model forecasts valid at 00 UTC.

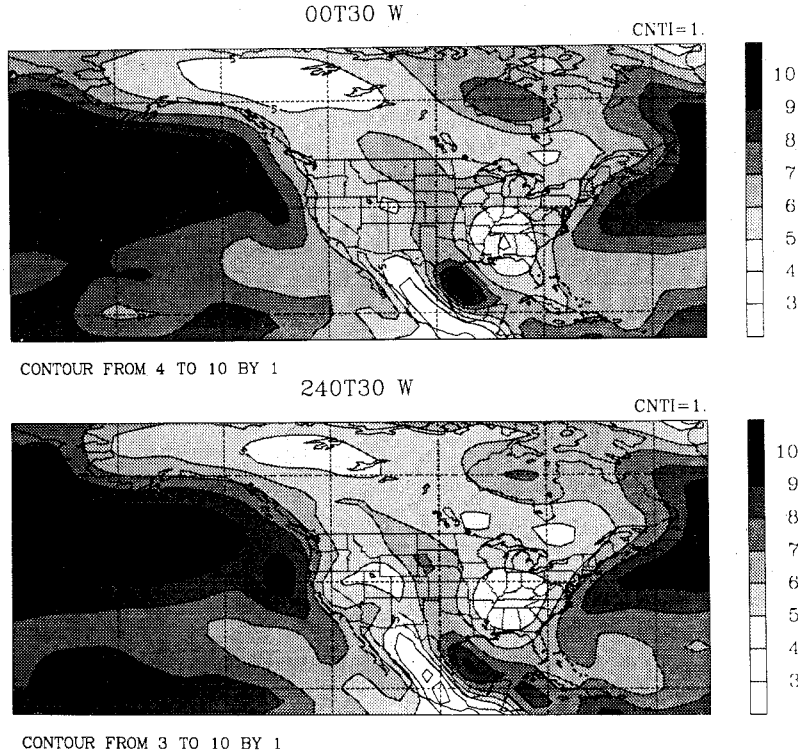


Figure 3c. (Upper panel) Annual N.A. near-surface wind speed derived from the T30 filtered and height interpolated NMC global analysis at 00 UTC. (Lower panel) Annual N.A. 10 day forecast (240 hour forecast) wind speed derived from the T30 filtered and height interpolated MRF model forecasts valid at 00 UTC.

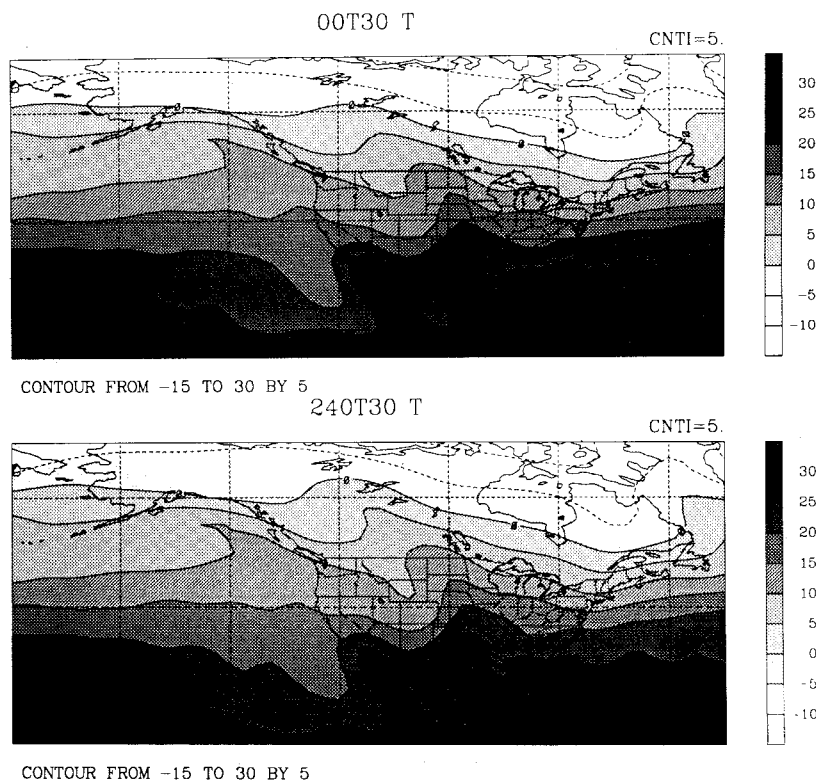


Figure 3d. (Upper panel) Annual N.A. near-surface virtual temperature derived from the T30 filtered and height interpolated NMC global analysis at 00 UTC. (Lower panel) Annual N.A. 10 day forecast (240 hour forecast) virtual temperature derived from the T30 filtered and height interpolated MRF model forecasts valid at 00 UTC.

relative humidity field. Interestingly, the 10 day forecast also shows a substantial wet bias over the ocean, which is a region where near-surface properties should be modelled the best. Counteracting the relative humidity bias is the slight positive bias in the wind field over the land. Over the North Pacific ocean the model appears to have a slight negative wind bias. Finally the virtual temperature forecast shows a slight negative bias.

Seasonal variations in the bias are shown in Fig. 4. Here we subtract the winter climatology (December, January, and February) from the summer climatology (June, July, and August). Note the much stronger variations in the forecast FWI, as shown in Fig. 4a. These strong variations are related in part to the stronger variations in the forecast relative humidity, Fig. 4b, which is too low during the summer and too high during the winter. The bias in the forecast wind variations, Fig. 4c, also contribute to the stronger forecast FWI variations. Seasonal virtual temperature variations, Fig. 4d., are forecast well, although, again, temperature does not have much influence upon the FWI.

To further examine these systematic biases, we show in Fig. 5, how the U.S. continental average of the model

drifts from the initial state toward the bias at 10 days. The annual bias is shown by the solid line labeled A and the summer minus winter difference divided by two is shown by the dashed line labeled (S-W)/2. To show the impact of these systematic biases on the MRF model's ultimate prediction, we also show by the solid line labeled sigma the continental U.S. average standard deviation of daily events.

As shown in Fig. 5, a major change occurs on the first day for all variables except virtual temperature which remains relatively constant the first forecast day. The strongest jump occurs in the relative humidity field, which on average jumps immediately to a wet state. During the summer time, however, the model jumps toward a dry state. The relative humidity bias is also comparable to the daily standard deviation, which indicates that this variable is relatively difficult to forecast. The FWI bias is relatively less, in part because the wind bias is relatively small. Of all the variables, virtual temperature appears to have the smallest relative bias and thus should probably be forecast the best. (It is.)

We can also examine the distributions to determine higher order errors. Here we examine the distributions

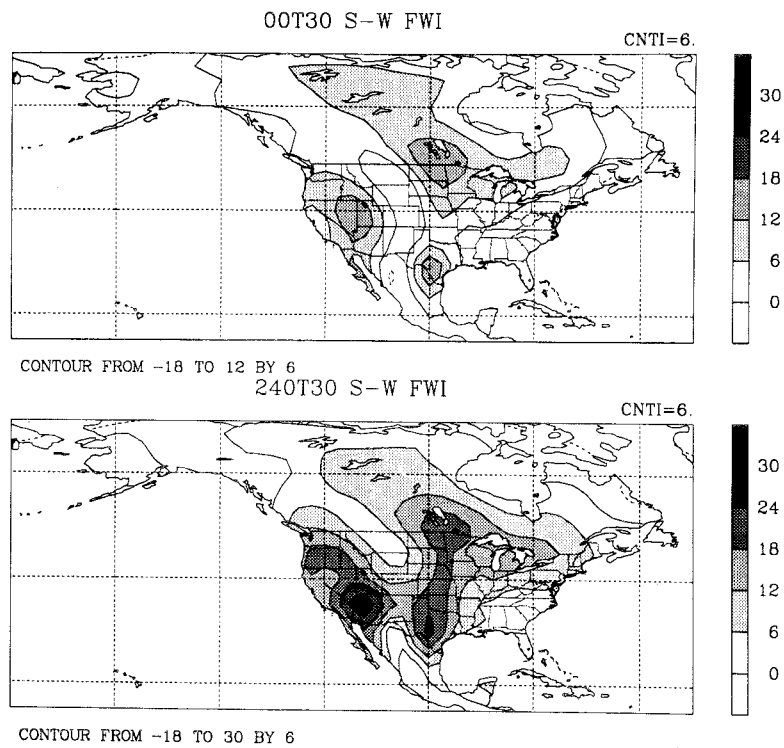


Figure 4a. (Upper panel) Summer minus winter N.A. near-surface FWI derived from the T30 filtered and height interpolated NMC global analysis at 00 UTC. (Lower panel) Summer minus winter N.A. 10 day forecast (240 hour forecast) FWI derived from the T30 filtered and height interpolated MRF model forecasts valid at 00 UTC.

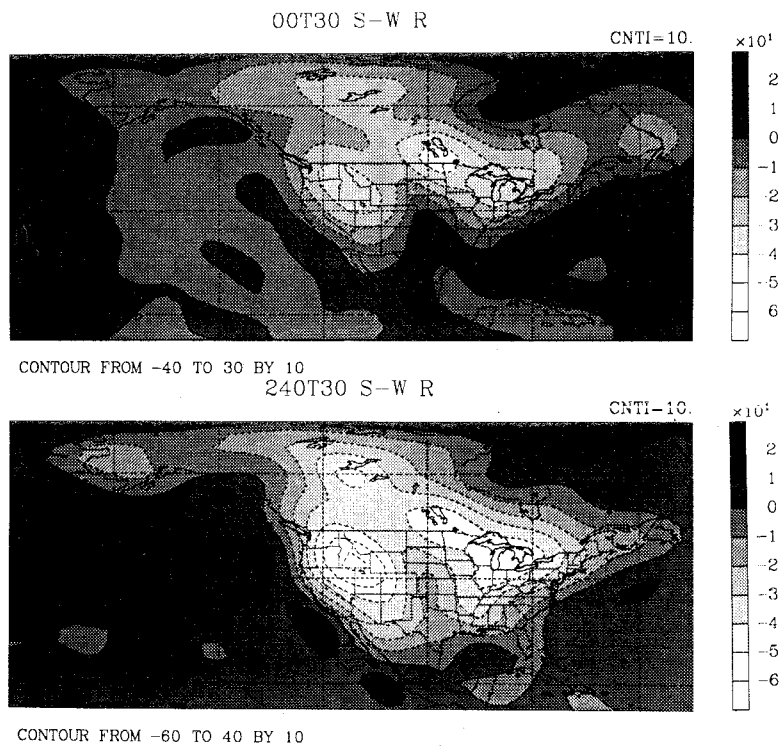


Figure 4b. (Upper panel) Summer minus winter N.A. near-surface relative humidity derived from the T30 filtered and height interpolated NMC global analysis at 00 UTC. (Lower panel) Summer minus winter N.A. 10 day forecast (240 hour forecast) relative humidity derived from the T30 filtered and height interpolated MRF model forecasts valid at 00 UTC.

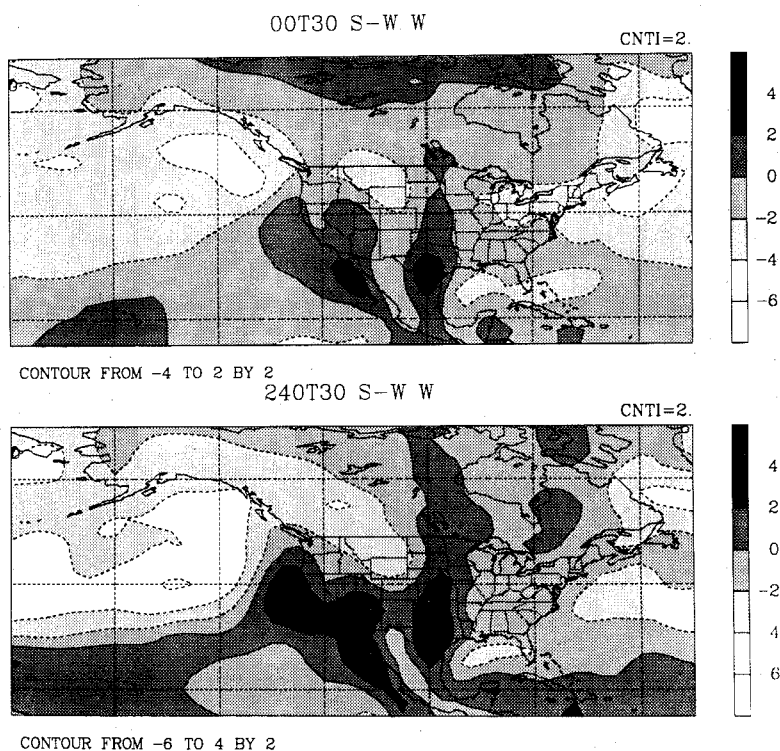


Figure 4c. (Upper panel) Summer minus winter N.A. near-surface wind speed derived from the T30 filtered and height interpolated NMC global analysis at 00 UTC. (Lower panel) Summer minus winter N.A. 10 day forecast (240 hour forecast) wind speed derived from the T30 filtered and height interpolated MRF

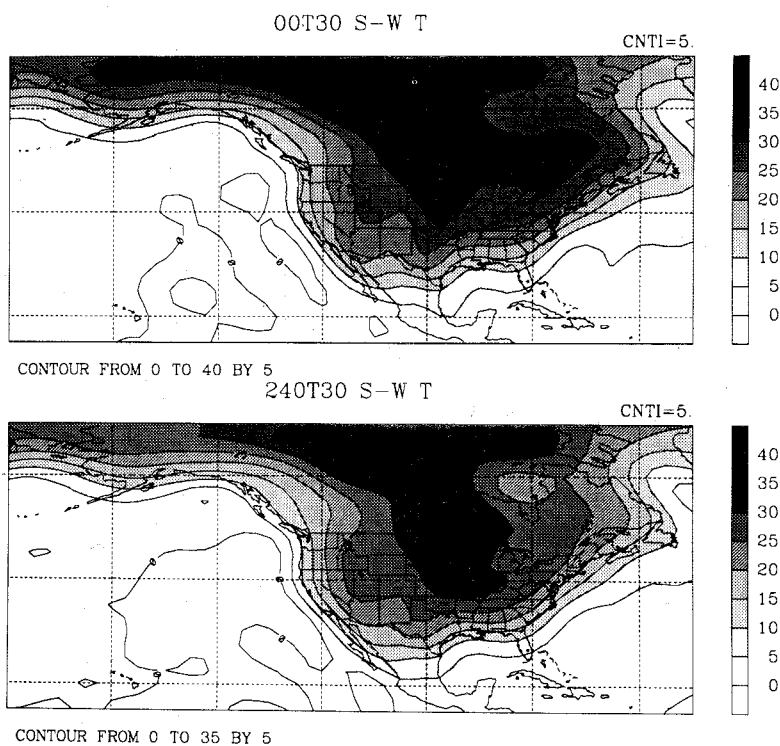


Figure 4d. (Upper panel) Summer minus winter N.A. near-surface virtual temperature derived from the T30 filtered and height interpolated NMC global analysis at 00 UTC. (Lower panel) Summer minus winter N.A. 10 day forecast (240 hour forecast) virtual temperature derived from the T30 filtered and height interpolated MRF model forecasts valid at 00 UTC.

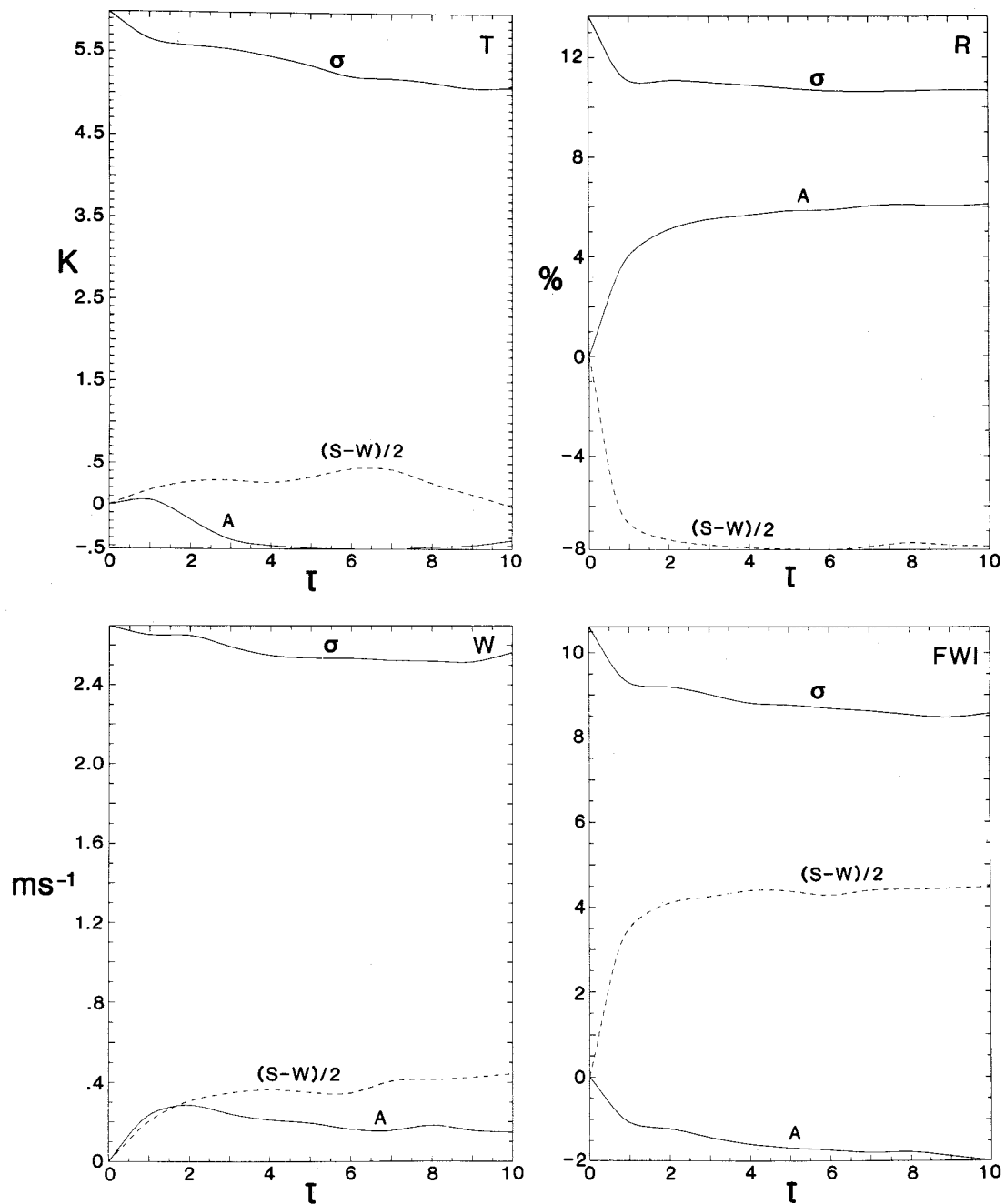


Figure 5. Annual (A), [summer-winter]/2 ((S-W)/2), bias or systematic error in comparison to the U.S. standard deviation of daily anomalies, sigma. virtual temperature, T, relative humidity, R, wind speed, W, and the FWI values are shown in the corresponding panels.

(again only over the continental U.S.) with the climatology of the observations and each forecast day (annual mean, annual cycle and semi-annual cycle) removed, Fig. 6. Note that the limits of the forecasts are smaller than the observed limits. The model is less likely to show the strong deviations of the initial conditions. As can be seen in Fig. 5, this narrower distribution is also reflected

in a systematic decrease in variance of the model, almost as if the forecast model is losing variance or energy. Another feature of interest is that many of the variables have medians different from zero, indicating skewed distributions. For example, once the average is removed the median anomalous wind speed is about -1 m/s. This negative median of the anomalous distributions is due to

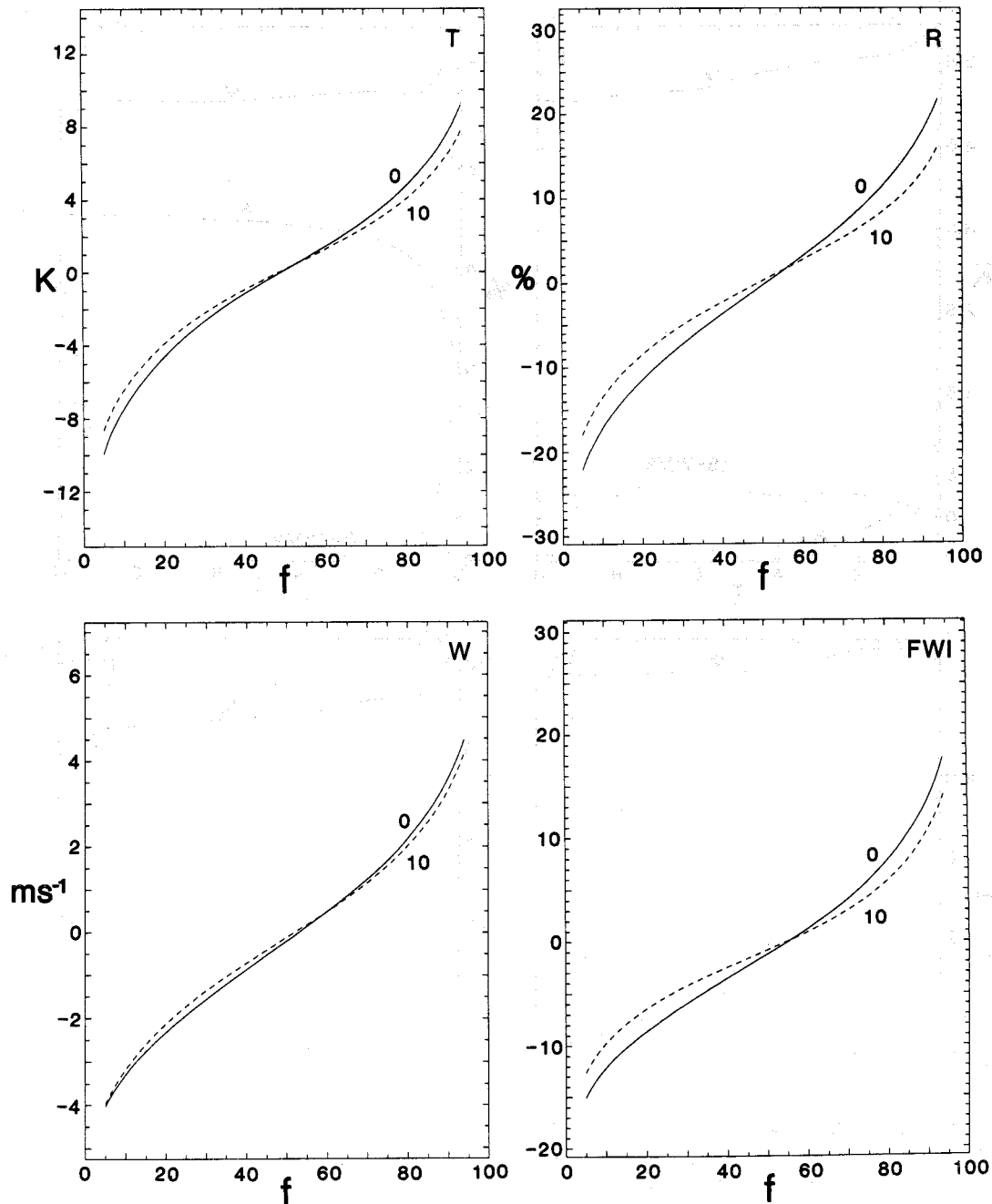


Figure 6. Cumulative frequency, f , distributions for anomalous T, R, W, and FWI. Observations are shown by solid lines, 10 day forecasts by dashed lines. The median of the distribution corresponds to the values at $f=50$.

the climatological average being larger than the median. This feature is characteristic of positively skewed distributions.

5. Forecast Skill

We use the distributions described in Fig. 6 to evaluate individual MRF model forecasts. For simplicity, we

assess the skill of forecasting deviations from climatology within pre-set class limits. For example, in a two class system we would separate, by anomalous median described above, high and low values of observed and forecast variables. Even higher resolution assessments (e.g. 3 and 5 class systems) can be made. A normalized measure of the number of times that the forecast class matches the observed class is given by the Heidke skill score (Brier, 1951)

$$S = \left\{ \frac{\frac{N_c}{N_f} - \epsilon}{1 - \epsilon} \right\}$$

where N_f = number of forecast events, N_c = number of correct forecast events, and epsilon = the probability of making a correct forecast by chance.

The probability of making correct forecasts simply by chance is the sum of the joint probabilities that an observation or forecast falls within the same category. For example, in a three equal class system,

$$\epsilon = \sum_{i=1}^3 \left(\frac{1}{3}\right)^2 = \frac{1}{3}$$

We shall describe the forecast skill mostly with this three equal class system.

Besides comparing the MRF model forecast skill of fire weather variables to chance, the skill of the numerical forecasts are also assessed by comparing the numerical forecast skill to three other forecast methods:

(1) Persistence forecasts use only the initial day as a predictor; numerical forecasts also use the initial day to initialize the model and thus a comparison of the numerical forecast to persistence yields the value-added skill of the forecast model.

(2) Climatological forecasts are essentially null forecasts since we are really only interested in evaluating the skill of forecasting anomalous deviations from a presumably well known climatology. The climatology (which is not necessarily well known) is approximated here by an annual mean and two annual harmonics derived from two years of data. If the appropriate climatology has not been removed, then these null forecasts will show skill. (A major caveat is that if the appropriate climatology is over-specified then we risk showing too little skill. As stated in Roads (1989), it is not always certain just exactly what we know and what we do not know in *a posteriori* skill evaluations.) As in Roads and Maisel (1990b) climatological forecasts are made by using as a predictor the same day of the year as would be used by a persistence forecast, but for a different year. In particular, climatological forecasts for the period June 1, 1988-May 31, 1989 are made from the period June 1, 1989-May 31, 1990; climatological forecasts for the period June 1, 1989-May 31, 1990 are made from the period June 1, 1988-May 31, 1989.

(3) Finally, predictability or perfect model estimates are made by comparing forecast day 1 with forecast day 2, forecast day 2 with forecast day 3, and so on, as suggested by Lorenz (1982). This model intra-comparison attempts to describe the potential model skill that arises from a perfect model but with an initial error equal to a

1-day forecast error. The major reason for evaluating the model in comparison to itself is that we would like to know whether we can hope to improve forecasts by improving the model as well as the estimate of the initial state.

An intercomparison of persistence, P, climatological, C, and predictability, L, skill to the numerical forecast, F, skill for a three class system evaluated over the continental U.S. (169 grid points) is shown for a three equal class system in Fig. 7a. Separate evaluations were also made for each grid point but only minor differences were found. Two and five class systems were also evaluated but are not shown, since the results are quite similar to the three class system evaluated here. Basically, the apparent skill at which we can forecast fire weather variables depends in part upon how much information we need. For example, the skill is greater when we ask only whether a particular forecast is likely to be above or below normal. If we want a lot more information, such as discriminating forecasts within a 5 class system, then we are much less skillful at making this kind of forecast. The greatest impact of the number of classes in the forecast evaluation system occurs at the initial time when the skill is largest; at later times when little accuracy is present, forecast skill is comparable for all class limits.

Each year (June 1, 1988 - May 31, 1989 and June 1, 1989 - May 31, 1990) was evaluated separately in Fig. 7a and although the difference is almost negligible, the second year is forecast better at short range (1-4 days) for all variables. This difference cannot however be attributed solely to forecast model improvement since persistence and climatological forecasts show similar year to year variability. We also evaluated each season separately and found almost negligible differences in skill. However, the MRF model skill is almost always higher during the wintertime for all the variables. Interestingly, persistence skill is slightly lower during the wintertime.

As is clearly shown in Fig. 7a, the MRF model provides 1-10 day forecasts of all fire weather variables that are better than persistence or climatological forecasts. Fire weather forecasters would benefit immediately from having available the MRF model forecasts of at least the FWI. However, of all the fire weather variables, the MRF model forecasts the FWI the worst, initially due to the low skill of the relative humidity forecasts and a few days later due to the fast decaying skill of the wind forecasts. Virtual temperature is forecast the best, but temperature has the smallest influence on the FWI. According to the predictability estimates, we cannot hope to predict virtual temperature much better than we do at present (unless the initial error can be reduced); however there is still quite a bit of improvement that could be done for the forecast relative humid-

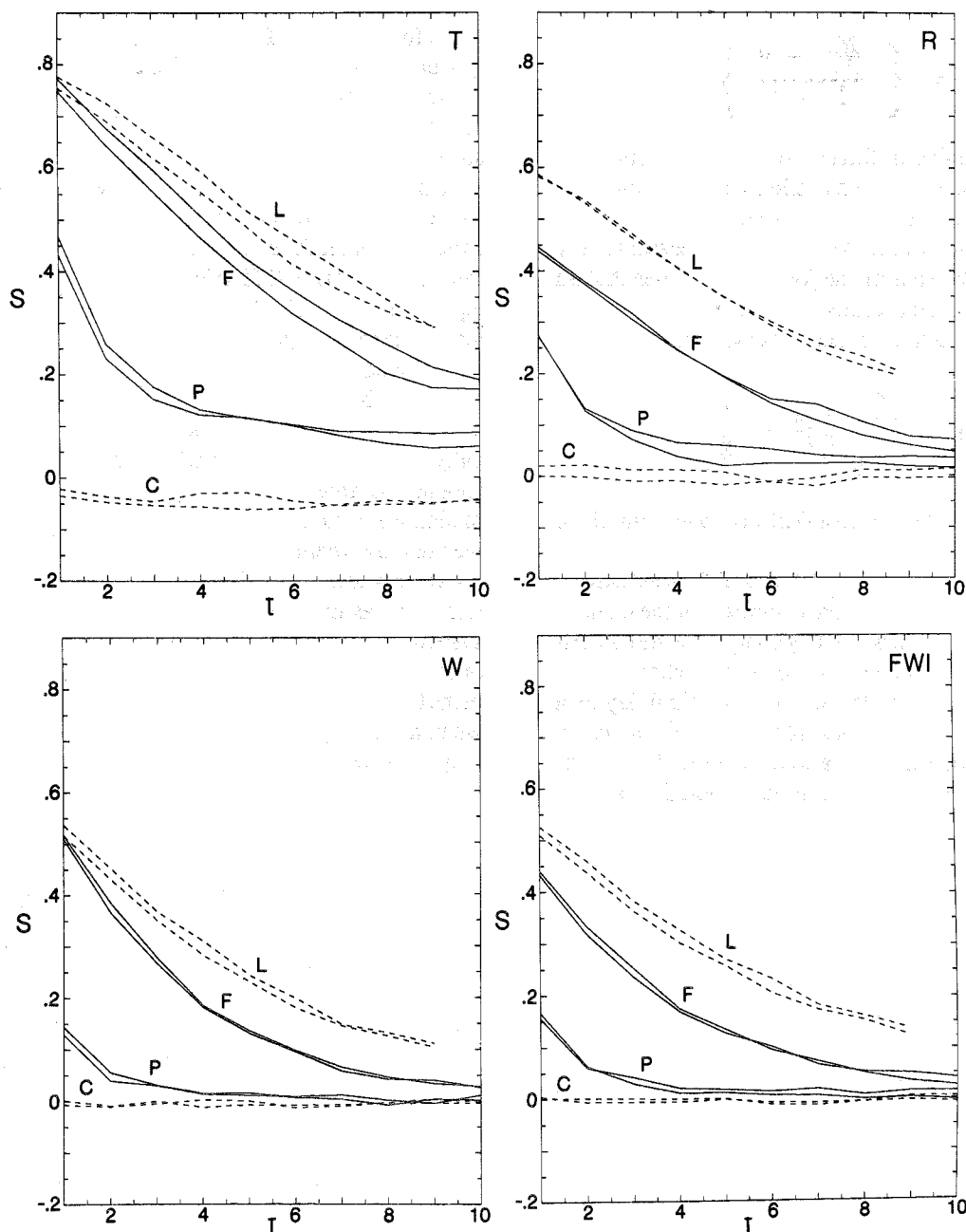


Figure 7a. MRF model forecast skill, F, in comparison to persistence skill, P, climatological skill, C, and predictability skill, L, in a three class system. The two curves represent the skill in the first and second year. The second year is almost always slightly more skillful.

ity fields which would then provide considerable increase in forecast accuracy of the FWI.

Although a seasonal bias correction was implicitly made by removing a seasonally varying climatology dependent upon forecast time, we do not necessarily need to know the bias in the model in order to make a good forecast. Fig. 7b shows the skill of forecasts when the forecasts are treated like the observations. That is, the climatology removed is the observed climatology and

the class limits are defined from the observed distributions. Only minor differences occur in most variables except for the relative humidity. Clearly this field needs a strong seasonal bias correction in order to achieve reasonable forecasts. This bias effect is less noticeable for the fire weather index which is also influenced greatly by the wind speed; the wind speed has much less of a forecast bias. It should also be noted that the predictability appears to be overestimated when the

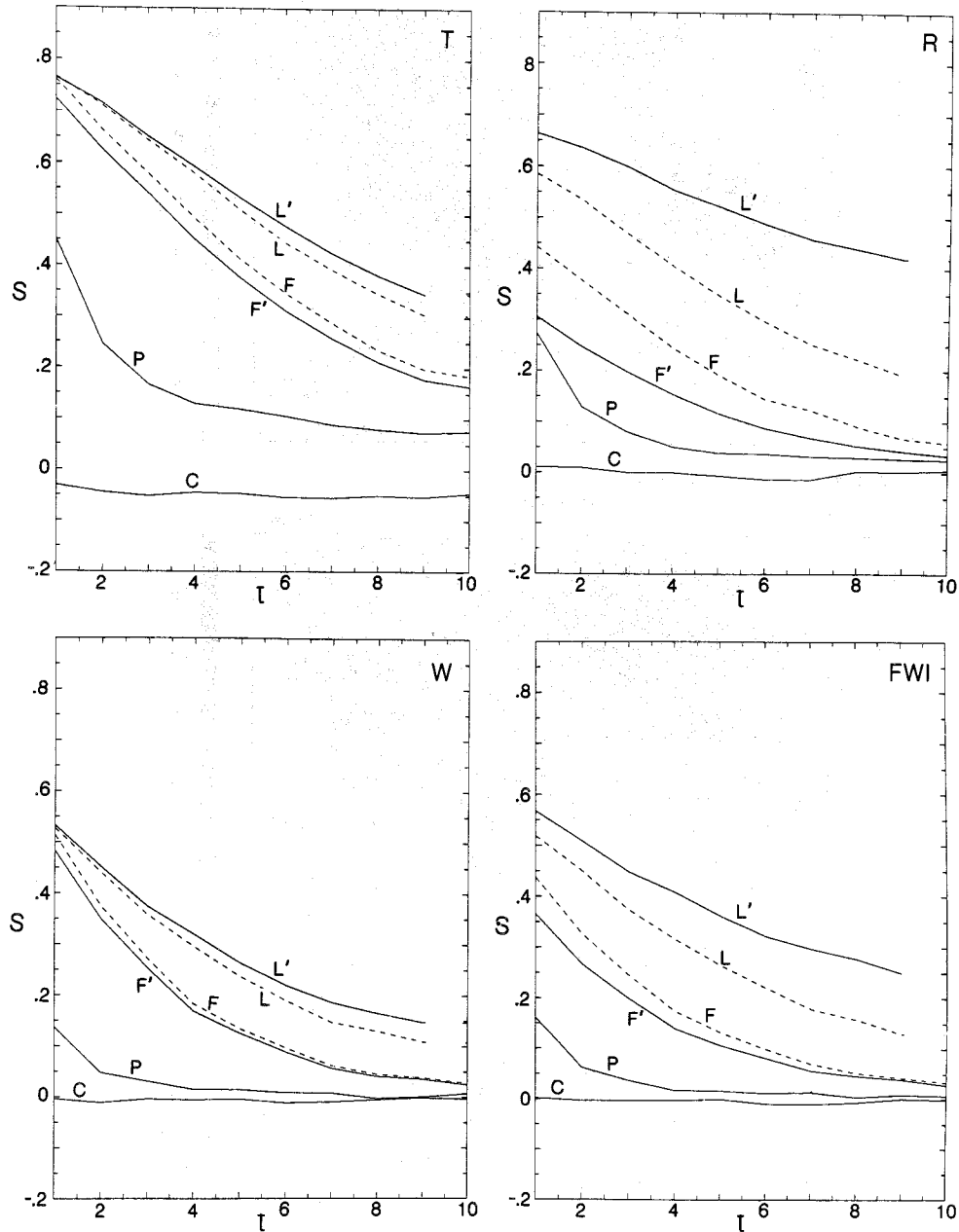


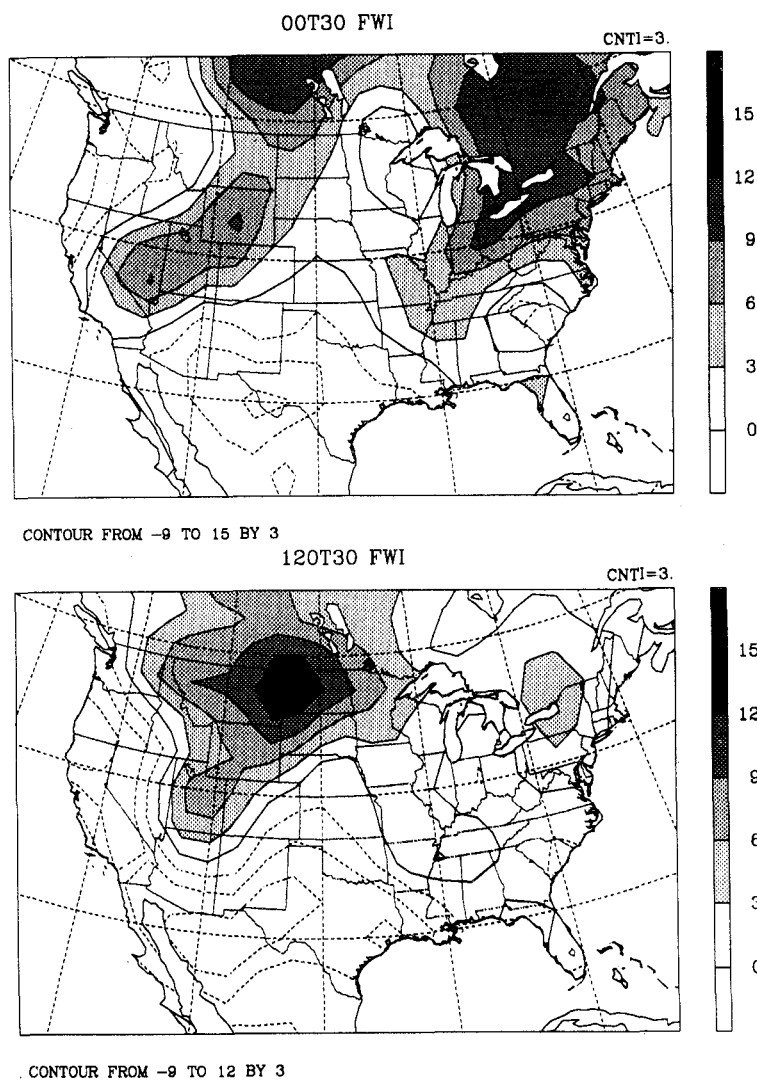
Figure 7b. Skill when the numerical MRF model forecasts are untreated for systematic and distribution errors. Dashed lines represent the forecasts with the seasonal bias removed; solid lines do not remove the seasonal bias.

seasonally varying bias is omitted. This is related to the forecasts being biased either high or low during parts of the seasonal cycle; comparing biased forecasts with each other can result in apparent but deceptive skill.

6. Specific Examples

So far we have described the overall climatology,

distributions, and forecast skill of the large-scale observations and forecasts. In this section we describe specific situations that might be encountered by a fire weather forecaster making use of the MRF model products. One of the specific cases shown here in Fig. 8a is at the beginning of the forecast evaluation period (June 1-10, 1988). For comparison, we also show the period (June 1-10, 1989) in Fig. 8b. For brevity, we show only the 10 day observed average and 10 day average of the 5



8a

Figure 8a. (Upper panel) Observed June 1-10, 1988 U.S. FWI anomalies derived from the T30 filtered and height interpolated NMC global analysis at 00 UTC. (Lower panel) Mean 5 day FWI forecast anomalies, verifying for the period June 1-10, 1988 and derived from the T30 filtered and height interpolated MRF model forecasts. The climatology is defined from the observations; that is, we do not correct here for the systematic bias.

day forecasts verifying on the individual days (June 1-10). For simplicity we only show the anomalies. An indication of the anomalies required to give forecasts of above normal or much above normal etc. are left to the individual fire weather forecaster at specific geographical locations; however typical values can be discerned from the distributions shown in Fig. 4.

During the 1988 period, as shown in Fig. 8, there was a large FWI over the North Central and North Eastern portions of the U.S. The western FWI extreme was related to the dry and windy air in the cooler air following a major cold front. All of the features of the synoptic fire weather system appear to have been captured to a certain

extent by the MRF model (not shown). Major discrepancies of the western extreme were that the model was too dry and the major wind anomaly did not extend far enough to the south. The virtual temperature anomaly appears to have been forecast the best.

In contrast, as shown in Fig. 8b, the FWI was negative over this same region in the first part of June of 1989. The largest FWI now appears on the Northwest and Southwest coasts with moderate amounts extending across the Gulf coast and deep south. This FWI extreme was again reflected in the relative humidity and wind fields. Again, virtual temperature was forecast best and had little influence upon the FWI.

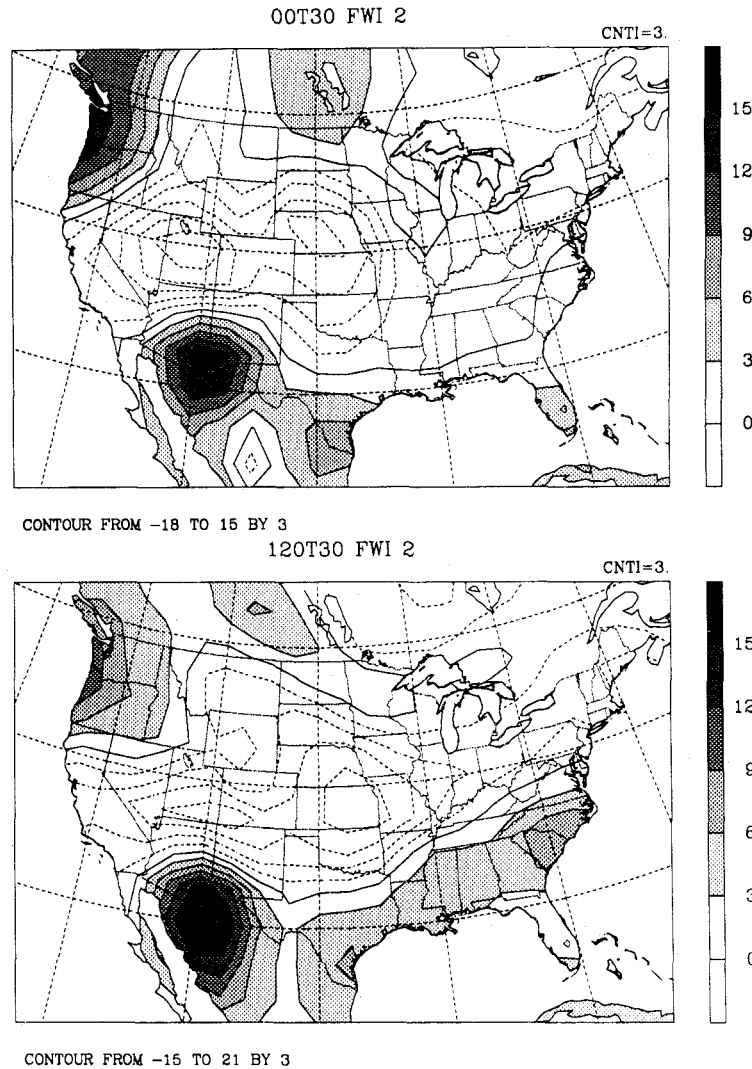


Figure 8b. (Upper panel) Observed June 1-10, 1989 U.S. FWI anomalies derived from the T30 filtered and height interpolated NMC global analysis at 00 UTC. (Lower panel) Mean 5 day FWI forecast anomalies, verifying for the period June 1-10, 1989 and derived from the T30 filtered and height interpolated MRF model forecasts. The climatology is defined from the observations; that is, we do not attempt to correct here for the systematic bias.

7. Conclusions

Medium range forecasts by NMC's MRF model of near surface fire weather elements, T, R, W and FWI were evaluated in this paper for the period June 1, 1988-May 31, 1990. Medium range forecasts of these fire weather variables have not been heretofore scrutinized due to the presumed low MRF model forecast skill of near-surface fields. This presumption does not appear to be correct with the current version of the MRF model.

Forecasts of all fire weather elements are skillful and significantly better than chance, climatology, and persistence forecasts out to at least 10 days. Surface virtual

temperature is forecast best and the FWI is forecast worst, mainly due to the low forecast skill of the surface relative humidity. Improvements in the MRF model near surface relative humidity would have the greatest impact upon improving medium range forecasts of FWI.

Still, skillful MRF model forecasts of surface fire weather elements are now available and could provide additional useful guidance to fire weather forecasters. Basically, these MRF forecasts could provide guidance at medium ranges to supplement the temporally and spatially coarser monthly averages of the extended range forecasts; these medium range forecasts could then set the stage for more continuous (6 hourly) and higher

spatial resolution forecast data currently available to fire weather forecasters at shorter time scales.

A major caveat to the work reported on here is that we have not yet ascertained whether the FWI used here to guide this investigation is in fact related well to the initiation and extent of fires. Again, the FWI provides a simplified indication of present weather conditions. Additional information is gained from knowledge of the virtual temperature, relative humidity and windspeed. More knowledge about potential fire danger would be gained by also knowing the available fuel and its current environmental state. We also suspect that additional small-scale information will be required at the station scale. Therefore, we will only conclude for the moment that the large-scale MRF model forecasts of near-surface fire weather elements provide an additional tool that could be better used by fire weather forecasters.

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