Errata - Replace first page only - incorrect version (#93-22) - corrected version (#93-23)

Western Region Technical Attachment
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USING THETA-E FOR MINIMUM TEMPERATURE GUIDANCE

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Introduction

Distribution of gridded data to National Weather Service (NWS) Forecast Offices encourages the use of analysis and forecast fields previously unavailable to the forecaster on Automation of Field Operations and Services (AFOS). One such field is the equivalent potential temperature, or Θ_e. Initial Θ_e conditions were once only available from the most recent upper air data, whereas Θ_e forecasts were completely unavailable. Θ_e calculations were either performed by hand on a thermodynamic diagram (see Remote Training Module MMFDC230, Skew-T, Log P Diagram), or by a limited number of AFOS applications programs (Tolleson, 1991). Now, with gridded data and PCGRIDS software, Θ_e is routinely analyzed and forecast through 48 h.

Θ_e is a conservative property relating both temperature and moisture, which allows for slow, fluid changes that can be followed over the course of time. Currently, Θ_e pattern recognition is most commonly used as an aid in identifying locations of convection and potential severe thunderstorms (Campbell, 1991; Chaston, 1992; Scofield, 1992).

Using a thermodynamic diagram, Θ_e is obtained by lifting an air parcel pseudoadiabatically from its condensation level until all the water vapor has been condensed out (when moist and dry adiabats become parallel to each other). The parcel is then compressed dry adiabatically down to its Θ_e at 1000 mb. Because this process converts latent heat of condensation into its equivalent in sensible heat, Θ_e will always be higher than the potential temperature whenever moisture is present (Taylor, 1954). Hence, Θ_e is a theoretical estimate of the *highest* possible temperature under saturated conditions. At this point, considerations of wind, cloud cover, and other factors are used to adjust the forecast minimum temperature downward.

In March, 1993, the Portland agricultural forecasters began diagnosing Θ_e forecasts in PCGRIDS to assess their usefulness in determining frost potential in an agricultural district just east of the Cascade Mountains. Previous studies of minimum temperatures in eastern Washington determined that fluctuations in cloud cover had a greater impact than did cold air mass advection (Hooker, 1991, 1992). It will be shown that model forecasts of low Θ_e air (cool, dry air) were useful in alerting a high frost potential in the forecast period. Conversely, forecasts of high Θ_e air over the district suggested warmer nights.

Case Studies

The Portland agricultural forecaster used Θ_e forecasts at 700 mb and 850 mb from the daily 1200 UTC runs of the NGM and "early" Eta models in PCGRIDS. The 24 h and 48 h model forecasts were used for first estimates of frost probability for the next two nights, since they both verified near the times when minimum temperatures most often occur. Selected examples of the Eta model guidance follow.

The first case was a cold night during which frost occurred (14 April 1993). Figures 1 and 2 show the 24 h forecast of Θ_e, and its verification, valid the morning of 14 April, for 700 mb and 850 mb, respectively. Generally speaking, the model correctly forecast an area of low Θ_e air pushing southward into Oregon. Based on these model forecasts, sub-freezing minimums were included in the preliminary forecast issued at noon Pacific Daylight Time (PDT). Other clues pointed to a cold night but were not available until the 0000 UTC 14 April Salem, OR, raob sounding, just prior to final forecast issuance. These clues included low 1000-500 mb thickness (5390 meters), an 850 mb temperature of 0°C, and weak surface pressure gradients. Minimum temperatures obtained from the district survey stations on the 14th ranged from 24° to 32°F.

Figures 3 and 4 show the same information as Figs. 1 and 2, respectively, but are valid for 17 April. The Eta model correctly indicated the Θ_e pattern which was a broad ridge of higher Θ_e air over much of Oregon. For that reason, the noon PDT preliminary forecast for the morning of 17 April called for cloudy, warm conditions in the district. Data used from the 0000 UTC 17 April Salem, Oregon (SLE) sounding also favored cloudy, warm weather. Again, this information became available very late in the forecast writing process. Minimum temperatures obtained from the district survey stations on 17 April were all at or above 40°F.

These successful uses of the Θ_e model forecasts by no means imply other relevant data can be ignored. For example, there is not a one-to-one relationship between Θ_e temperature and actual minimum temperature. On the morning of 19 April, the Θ_e forecast from the Eta model correctly verified with values lower that those observed on 14 April (Fig. 5, Fig. 1, and Fig. 2). In addition, the 850 mb temperature at 0000 UTC 19 April was colder and the 1000-500 mb thickness value was 130 meters lower than those observed on 14 April. Frost occurred, but the survey stations were 3° to 5°F warmer on 19 April, with more than one station not falling below freezing. A review of the situation revealed stronger surface pressure gradients and a steady wind resulted in better mixing and the higher minimum temperatures.

Conclusions

The gridded data sets available from the NGM and Eta model runs via PCGRIDS are an asset to NWS forecasters. Early results from a relatively small data set (daily March through May) show that a subjective analysis of the Θ_e model forecasts can be a helpful supplement to existing temperature forecast techniques, such as MOS guidance and thickness fields. There is not a direct relationship between Θ_e values and actual minimum temperatures. However, the data may indicate the potential for a cold night up to 48 h (two nights) ahead of time. This is an improvement over existing Θ_e applications which merely reflect the conditions as of the last available upper air report. Future studies could include more extensive comparisons of Θ_e forecasts with other temperature/ moisture products such as thickness, layer relative humidity fields, and Model-Output-Statistics (MOS) output.

References

Campbell, Mike, 1991: Equivalent Potential Temperature Applications, Western Region Technical Attachment No. 91-37.

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Scofield, Roderick, 1992: Satellite Applications/National Meteorological Center Material, National Weather Service Training Center Flash Flood Forecasting Course.

Taylor, George F., 1954: Elementary Meteorology, Prentice-Hall, Inc., pg. 99.

Tolleson, Paul D., 1991: Equivalent Potential Temperature Program for AFOS - EQP, Western Region Programming Note No. 93.

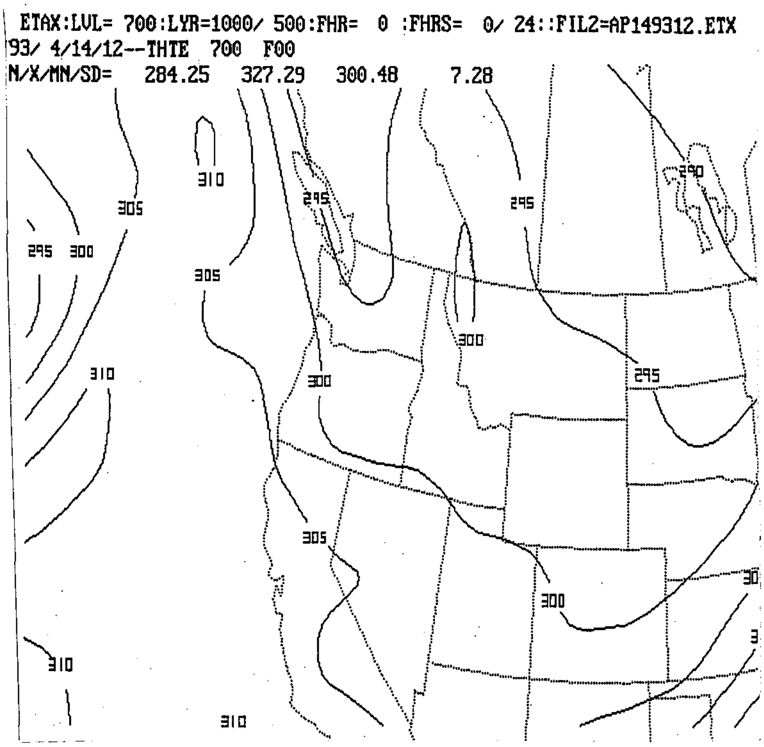


Fig. 1. 24 h Eta forecast (left) and verification (right) of 700 mb θ_e, valid 1200 UTC 14 April, 1993.

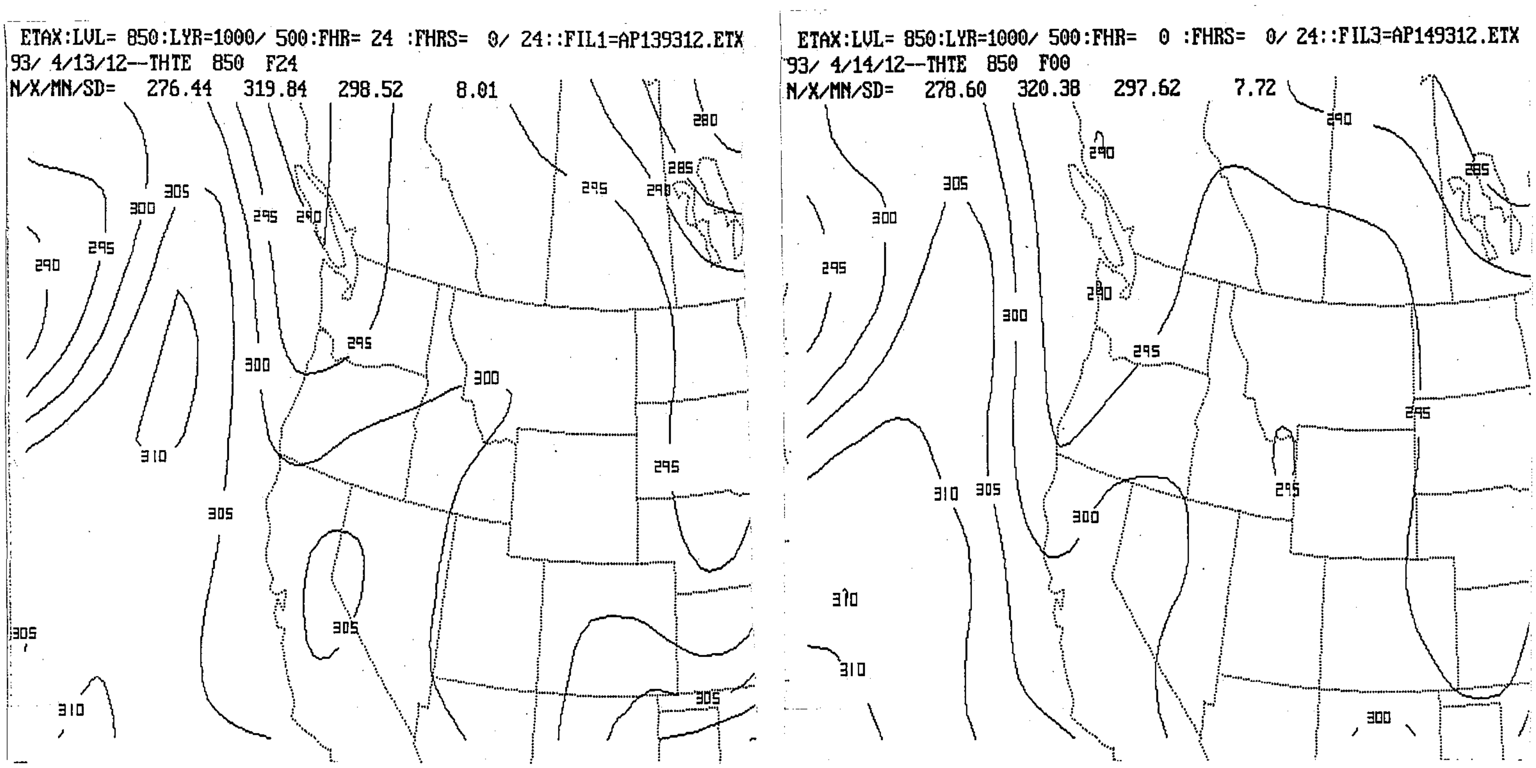


Fig. 2. 24 h Eta forecast (left) and verification (right) of 850 mb θ_e, valid 1200 UTC 14 April, 1993.

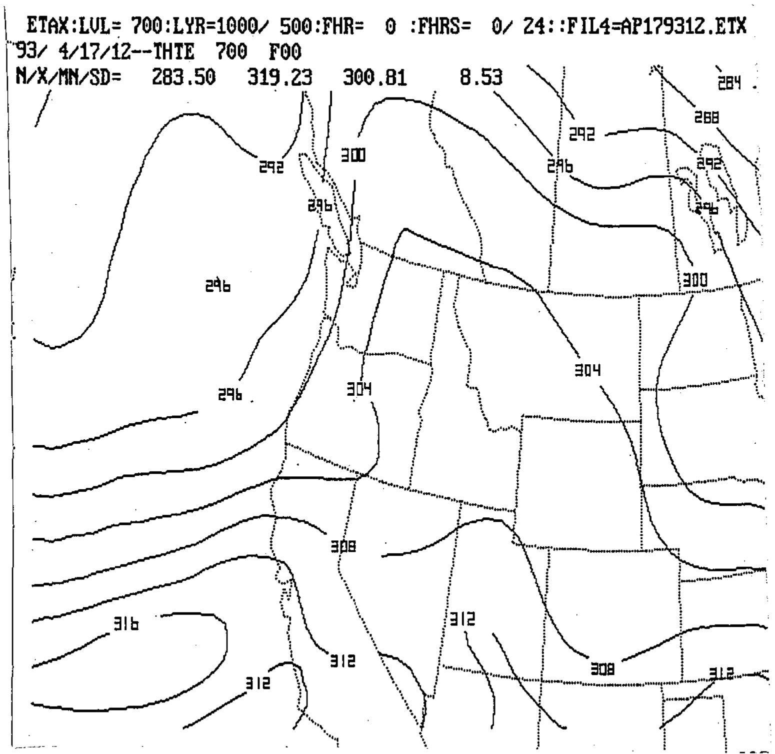


Fig. 3. Same as Fig. 1, valid 1200 UTC 17 April 1993.

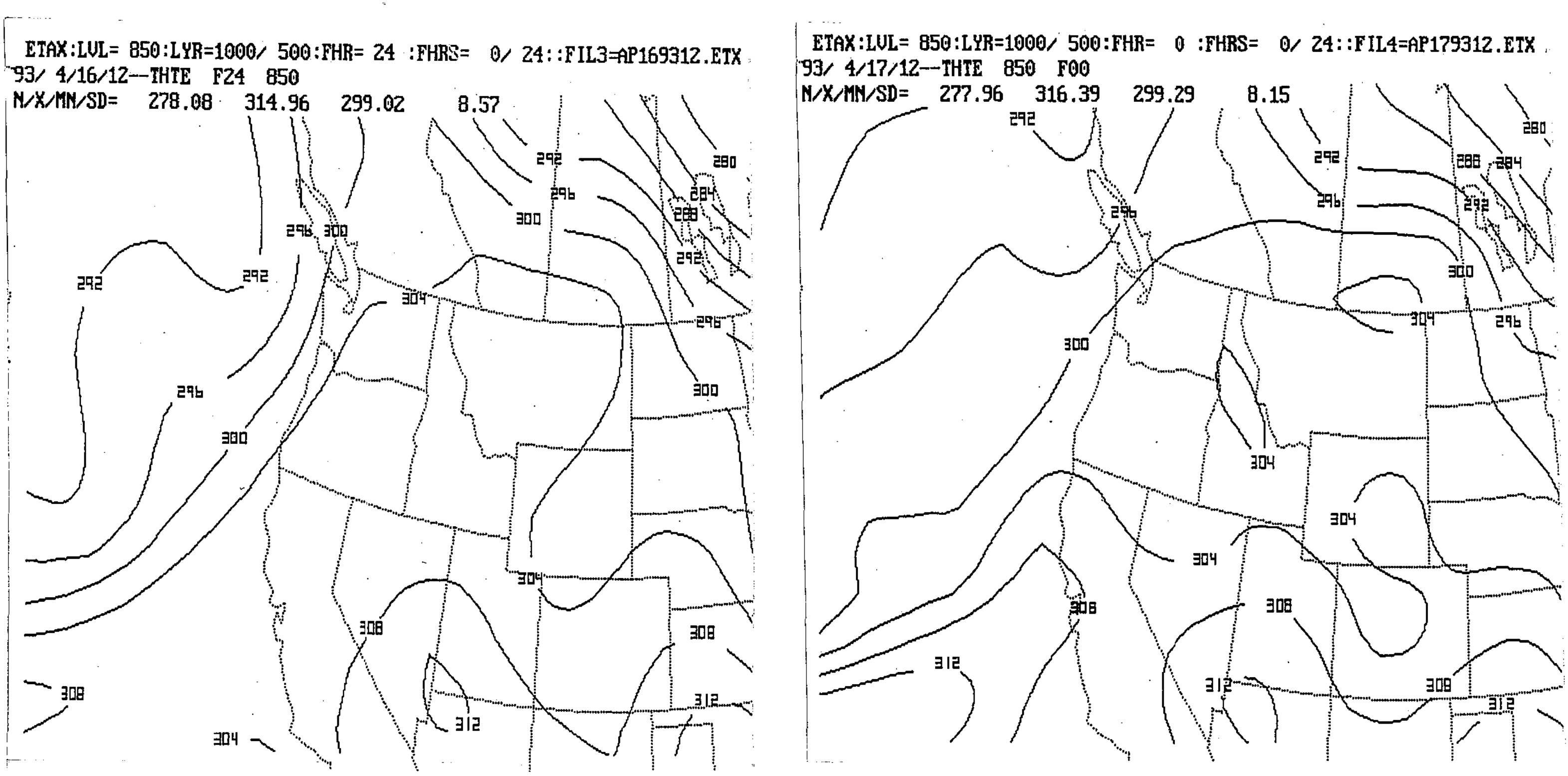


Fig. 4. Same as Fig. 2, valid 1200 UTC 17 April 1993.

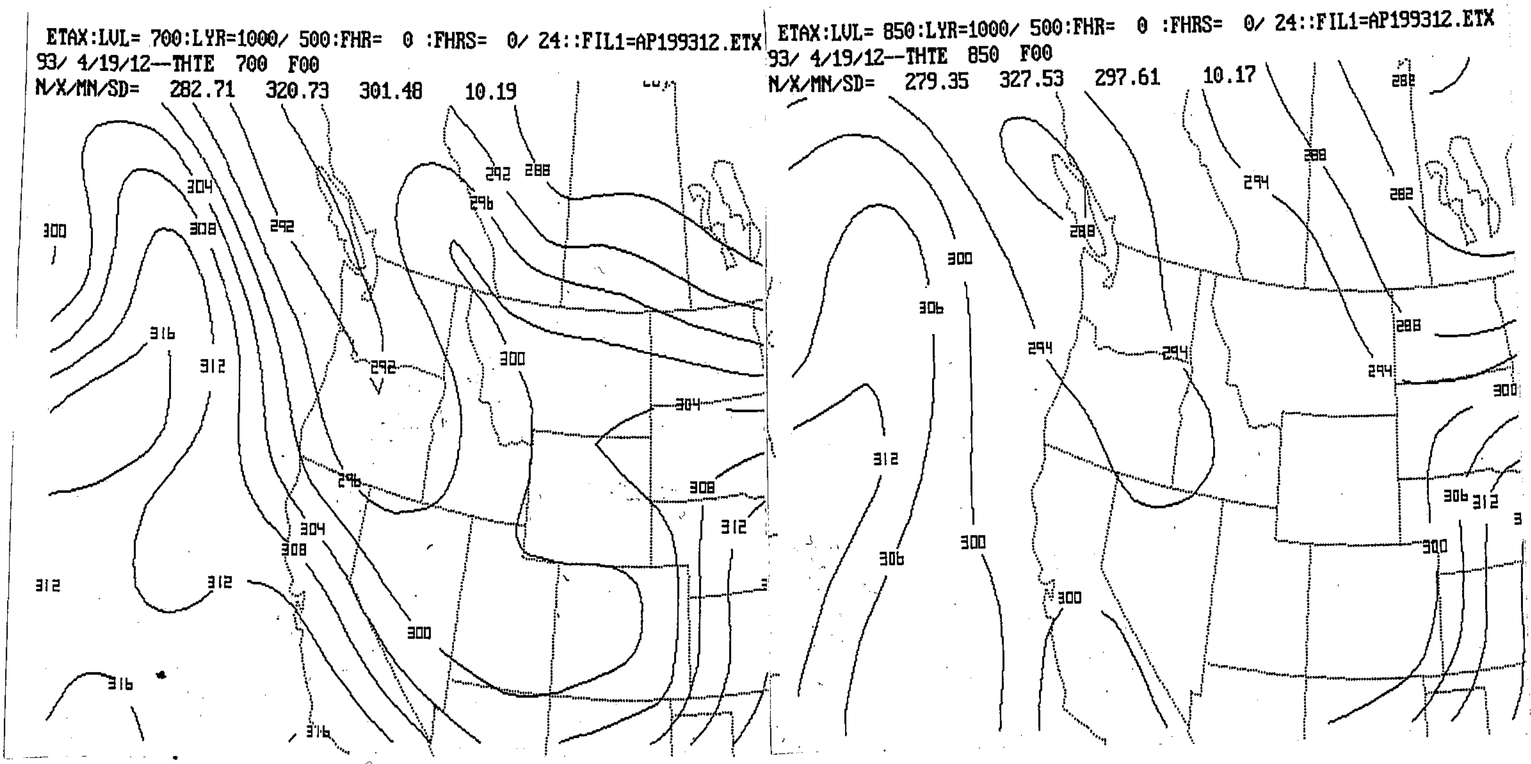
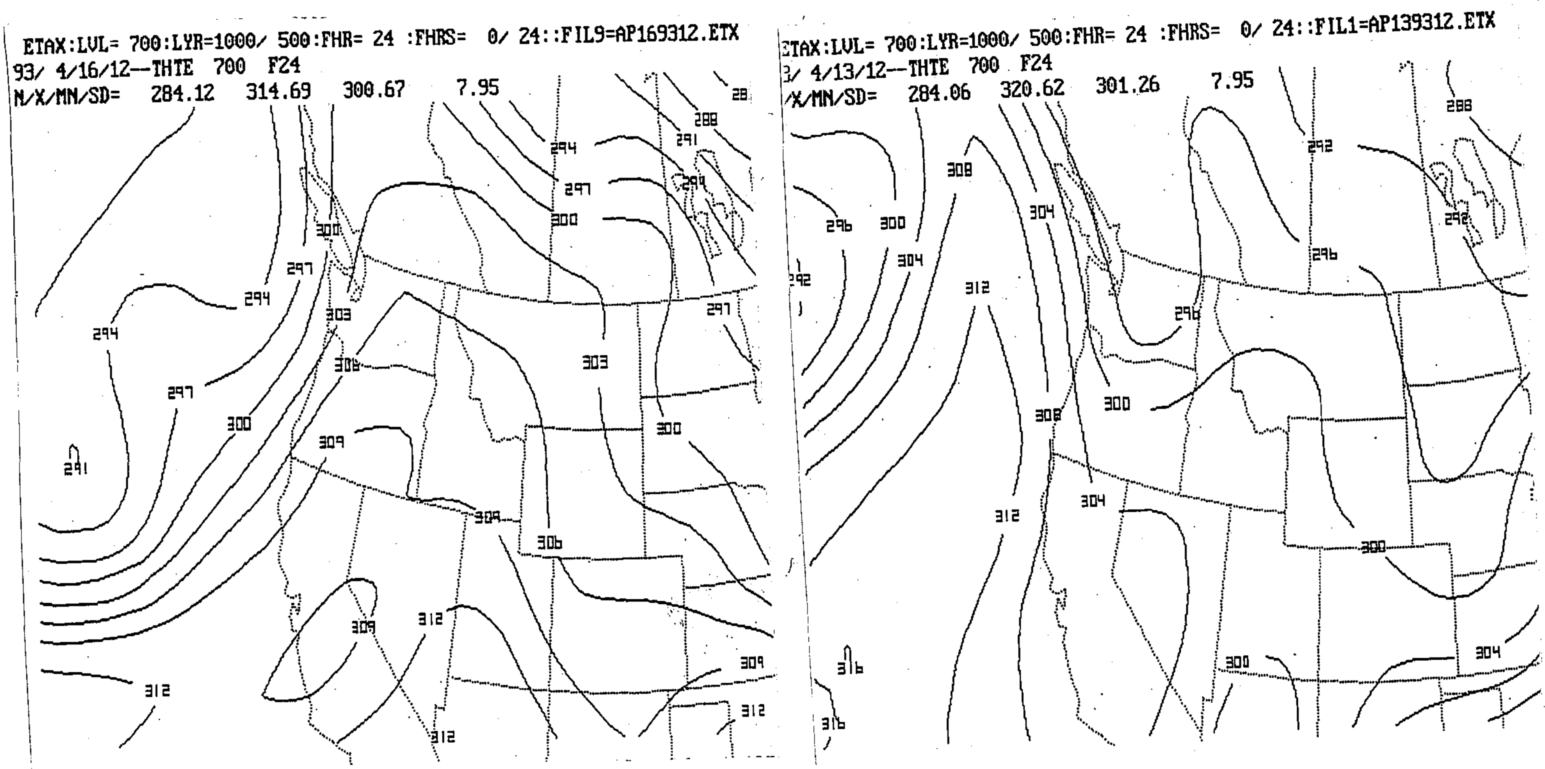


Fig. 5. Verification of Eta Θ_e forecast valid 19 April 1993 700 mb (left) and 850 mb (right).



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RADIOSONDE DATA PROCESSING CHANGES

On September 1, 1993, several changes will be implemented in the Micro-ART software. These changes will affect the accuracy, quality, and homogeneity of radiosonde measurements from both an archive and an operational standpoint. The changes being implemented are:

1. The gravity constant used in the calculation of geopotential heights will change from 9.8 m s^{-2} to 9.80665 m s^{-2} to conform with the international standard.

2. The relative humidity (RH) equation will change to reflect a resistor change in the radiosonde instrument from 1.2 megohm to 1.0 megohm.

3. RH will be reported over a broader range of values; when the RH is below 20%, or when the ambient temperature is less than -40°C.

Gravity constant change

The gravity constant change will slightly lower all geopotential height fields. Figure 1 shows the difference between the new calculations and the old calculations.

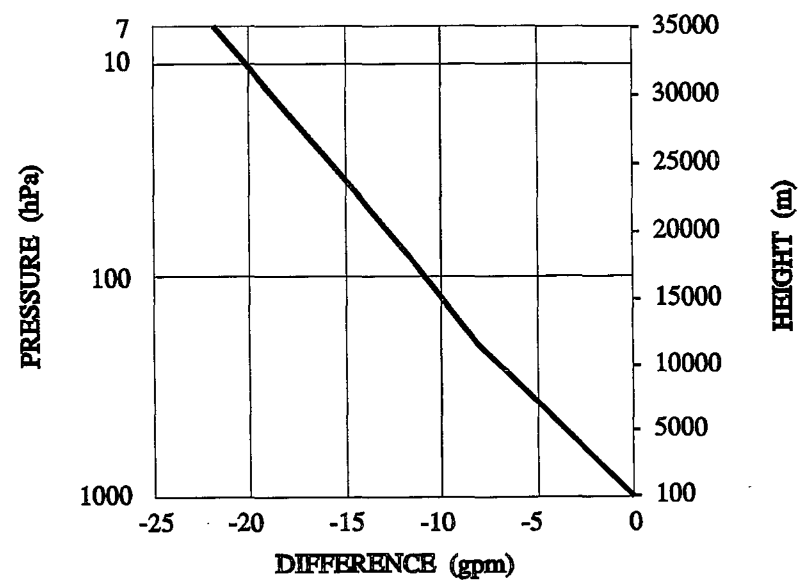

Figure 1 - Mean differences in height of the geopotential height calculations using the new value of g (9.80665 m s^{-2}) minus the old value of g (9.8 m s^{-2}).

Estimates are that the virtual temperatures calculated from geopotential heights will decrease by 0.17, 0.15 and 0.13°C for the 850-300mb layer, the 300-100mb layer, and the 100-50mb layer, respectively. As shown in Figure 1, near 500mb the geopotential heights will average about 5 geopotential meters less using the new gravity constant.

Relative humidity calculation changes

The change in the RH equation will increase the values of the higher humidity observations. Maximum in-cloud RH measurements are expected to increase from 94.4% using the old resistor values to 97.6% using the new resistor values. In-cloud RH will still fall short of 100%. Figure 2 depicts the mean difference in RH using the new equation. As can be seen in Figure 2, the effect of this change is negligible for RH values below 80%.

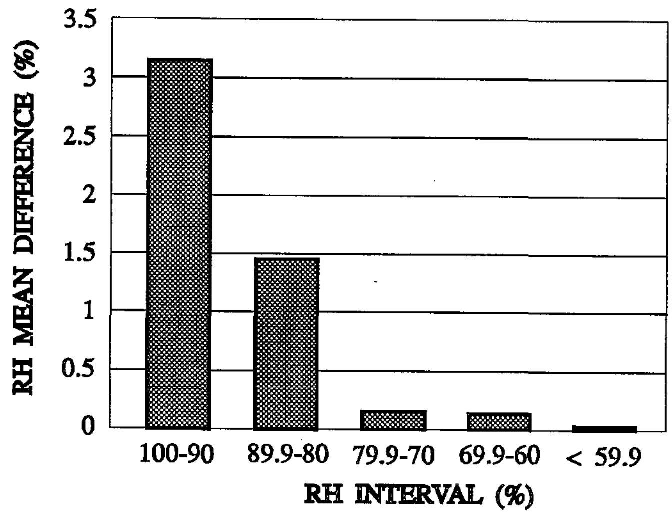

Figure 2 - The mean difference in RH, new resistor values minus old resistor values for selected RH ranges.

Relative humidity reporting changes

The practice of not reporting humidities when: (1) less than 20%, and (2) air temperature is less than -40°C will be discontinued. The 20% RH threshold has been in effect since 1973. Up to this time, RH has never been reported when the temperature was less than -40°C. This change will introduce an apparent drying of the atmosphere in already dry locations. In 20 NWS test flights, the RH did go below 20%, but values did not go below 12%. Expectations are that a moist bias will still remain in the observations.

The net effect of the resistor value and reporting procedure changes is to increase the variance of the distribution at the endpoints. Thus, high RH observations become higher and low RH observations become lower.

References

NOAA Data Quality and Continuity Program, 1993: Upper Air Processing Changes, Issues and Status, Vol. 1 No. 2, July.