JP 1.2 STATUS OF AWIPS VALIDATION EFFORT AT COMET

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1. INTRODUCTION

In March of 1999, the Cooperative Program for Operational Meteorology, Education, and Training (COMET®) was tasked by the National Weather Service (NWS) to conduct the Advanced Weather Information Processing System (AWIPS) Validation Effort (AVE). Work to date has encompassed three phases.

Phase 1 was designed to support the commissioning of AWIPS version 4.2 by conducting qualitative assessments of displayed basic model fields such as temperature, winds, and moisture parameters. Phase 2 began a more quantitative evaluation of AWIPS model derived fields that use techniques such as mathematical differencing or integration, non-standard conversions, and empirically derived formulas. In both phases AWIPS displays of the Eta and AVN model fields have been compared with those from the General Meteorological Package (GEMPAK). The third and final phase started in April 2001 examined the 'Sounding' view of the AWIPS Volume Browser. AWIPS model sounding fields are compared to plots from the NSHARP software.

Any discrepancies found in any phase have been jointly investigated with the Forecast Systems Laboratory (FSL). Those discrepancies that are deemed significant are submitted to the Systems Engineering Center, Development Branch (SEC/DB, formerly AWIPS Program Office or APO) as an official discrepancy report (DR). Documentation of discrepancies have been posted on-line monthly for forecasters to view at *http://meted.comet.ucar.edu/awips/validate*. Forecasters also are able to send discrepancy reports to the COMET Program via the AVE Web site. A description of the validation procedure and results for all phases is presented in the following sections.

2. PHASE 1

Phase 1 of AVE began in March of 1999 and continued for approximately four months. The method of investigation for Phase 1 included displaying model plan views side-by-side using the AWIPS Volume Browser and GEMPAK, and then visually inspecting for any significant qualitative differences. Phase 1 also examined spatial cross sections to verify that the procedure used to obtain the two-dimensional "slice" of data from the three-dimensional model grid was correct.

The data used to compare AWIPS and GEMPAK displays of model fields came from the case study for 9 November 1998 prepared by COMET staff. This case study includes a major winter storm that extended from the northern plains to the upper Great Lakes and an outbreak of severe weather in the southern plains and lower Mississippi Valley. This provided a wide range of meteorological environments in order to do the comparison. A limited number of basic fields were examined. These included temperature, wind, relative humidity, geopotential height, and mean-sea-level pressure. Only the Eta and AVN models were used during the validation since we assume that the model data is not corrupt and that we are validating how AWIPS ingests, displays, and manipulates the model data. If a discrepancy is found in either of the displays of these models, then the NGM, MRF, or RUC model will likely have the same problem in its plot of the field.

During Phase 1 the validation team was looking for various types of errors. These included grid transformation errors, consistency in meteorological constants used in computations, differences in plotting style between AWIPS and GEMPAK, error due to display scale chosen, and noting where fields are generated in a different manner based on models.

Only minor differences were found between the GEMPAK and AWIPS displays of meteorological model fields, and no serious discrepancies were observed.

The geopotential height and mean sea-level pressure fields are smoothed in GEMPAK by default, using a nine-point smoothing routine. An example of smoothed and unsmoothed geopotential height at 850 mb is shown in Figure 1a. It is apparent that the smoothing causes values in low and high centers and the gradients near them to be diminished. Figure. 1b shows a qualitative comparison with AWIPS, which does

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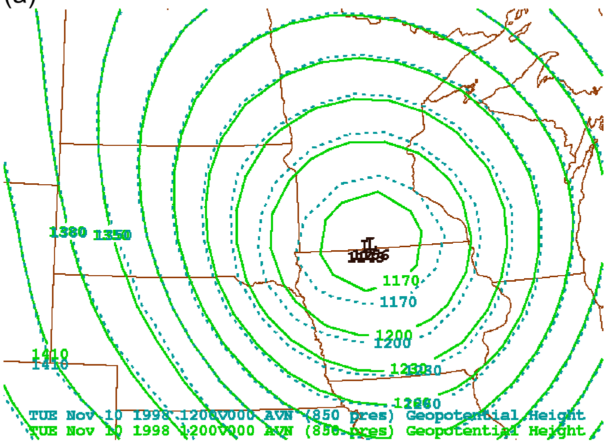
not smooth the data and is nearly identical to that of the GEMPAK unsmoothed height field.

(a)



(b)

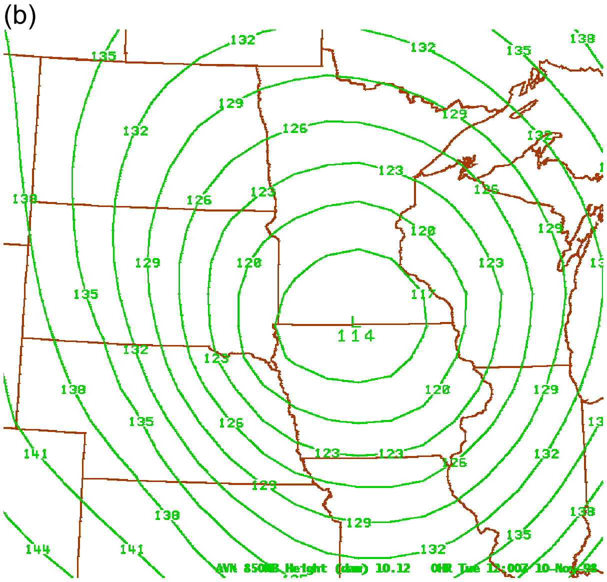


Figure 1. 850-mb geopotential height contours from the AVN model at 1200 UTC on 10 Nov 1998. (a) GEMPAK display showing smoothed (solid) and non-smoothed (dashed) display. (b) AWIPS display for the same time.

It was found that the AVN gridded data was scale dependent. For example, the AWIPS North American scale will use the 202 grid while finer scales use data from the 211 grid. This can create some small differences in the contouring of the displays, as well as the location and magnitude of wind barbs, when compared to the GEMPAK display of Aviation model data. At the COMET Program and various field offices GEMPAK defaults to use the 202 gridded data for all AVN scales. This problem does not appear in the Eta displays.

There is also a difference in the display of some cross-section fields. GEMPAK does not extrapolate data below the surface, and therefore contours will abruptly end at the lowest level of available data. However, AWIPS uses various methods, depending on the model chosen, to bring the contours to the model terrain. This is more apparent in the AVN, since the Eta sigma coordinate is just above the model surface. The AWIPS display uses boundary-layer temperature data to create a pseudo-surface temperature for the contours. Forecasters should be made aware that these extrapolation methods may or may not represent the actual profile near the surface.

Lastly, AWIPS and GEMPAK have a slight difference in the display of light winds. When the winds are below 2.5 knots, GEMPAK will draw a staff without a wind barb, while AWIPS draws a circle at the grid point. GEMPAK and AWIPS both display calm winds as circles.

3. PHASE 2

Phase 2 of the COMET AVE examines more complex derived fields, to include mathematical differencing, integration techniques, and non-standard conversions. Early stages of Phase 2 used the same qualitative validation procedure as in Phase 1, although real-time model data was used instead of the COMET case study. Initially, a select group of thermodynamic and other common fields were chosen for validation based on model product usage statistics provided by Patrice Kucera of FSL.

In January of 2000 the AVE team began a more quantitative evaluation of AWIPS derived fields. This included not only the side-by-side comparison, but also examination of the programming code (provided by FSL) used to perform the calculation of the field. As the more quantitative evaluation in Phase 2 began, the COMET Program was directed to validate all fields in the ‘Plan view’ of the Volume Browser that were available for AWIPS including any remaining ingested model fields not examined in Phase 1. Also during Phase 2, inquiries regarding AWIPS model displays were sent to the COMET Program by forecasters via the AVE Web site. These inquiries were investigated individually, and when necessary, resolutions were posted to the ‘Latest Issues’ section of the AVE Web site. Monthly updates of the AVE Web site were announced to the Science and Operations Officers (SOO) via e-mail messages.

3.1 Phase 2 Validation Procedure

The validation method used during Phase 2 had a qualitative aspect, just as in Phase 1, but it also had a quantitative aspect. To provide a first look at how well the AWIPS calculation compared with that of GEMPAK, a qualitative comparison was made between the AWIPS and GEMPAK plan view (2D) plots for the Eta and AVN models. Again, it was assumed that other models (NGM, MRF, RUC, etc.) would have the same display characteristics in AWIPS, but if a model-specific inquiry from the field was received, that particular model was examined. Again, plots were examined side-by-side with identical plot properties, such as contour interval and area. Real-time data was used to validate the fields, so that the AVE team was looking at the same data that forecasters were using operationally. A set of the images used during the comparison was posted in the documentation with a description of any noted discrepancies or biases.

Second, the AWIPS source code that is used to calculate derived fields was examined, and the procedures and equations found in the code were documented. If the qualitative comparison of the plots showed a discrepancy, the GEMPAK calculation code was also examined and compared to that found in AWIPS. When a discrepancy was found, AWIPS developers at FSL were notified. The AVE team worked with the developers to resolve the difference between the two systems, and then documented the cause of the difference on the AVE Web site. Developers and COMET staff reviewed much of the documentation for correctness and clarity before posting to the Web. Some AWIPS algorithms were created by outside experts who were also consulted when needed.

Third, a basic definition of each field was included with the documentation for completeness. If possible, a journal article or COMET educational material was referenced with the definition so that the reader can find additional information on the significance and use of that field.

Once all the documentation was assembled onto a single Web page, the field was added to a table in either the ‘Ingested Fields’ or the ‘Derived Fields’ section of the AVE Web site. This table provides forecasters with a quick “at-a-glance” view of all validated fields. Color-coded checkmarks in the table indicate which fields compare well to GEMAK, which have small discrepancies, and which have larger differences. This allows the forecaster to easily identify critical information he/she might want to read regarding a particular field.

3.2 Phase 2 Results – Minor Discrepancies

The majority of AWIPS fields examined in the early stages of Phase 2, before the quantitative validation aspect was included, were found to be nearly identical to displays of GEMPAK. This was partially due to the fact that the initial fields were relatively simple and many were directly ingested from the model. However, equivalent potential temperature, computed lifted index, and some skew-T parameters were observed to have differences with GEMPAK. As Phase 2 became more quantitative and the fields more complex, further discrepancies were found. Also, quantitative examination of equivalent potential temperature showed that it had more than a minor discrepancy with GEMPAK. This will be discussed later.

In Phase 2 of AVE, 52 fields that were available for the Eta or AVN models from the Volume Browser were examined. Of these, about six were found to have minor discrepancies and several forecaster inquiries warranted documentation of our investigation. Note that during the validation effort AWIPS switched from version 4.2 to 4.3, but this did not have a large impact on the validation of model fields. Below are brief descriptions of these discrepancies with GEMPAK and the other minor issues. Also note that this does not imply that AWIPS is wrong in every one of these cases; it merely indicates that AWIPS is slightly different from GEMPAK.

3.2.1 Wet Bulb Temperature

On the COMET systems, there were two fields in GEMPAK that displayed wet bulb temperature, but only the "Wet Bulb Temperature (deg F)" field compares with AWIPS. Examination of the code revealed that the calculation method is the same for AWIPS and the GEMPAK FORTRAN program used for "Wet Bulb Temperature (deg F)". Like AWIPS, GEMPAK uses an iterative process (Newton's method) to solve a transcendental equation that includes wet bulb temperature. COMET staff informed UNIDATA that the "Scalar-HAS" menu in GEMPAK included a second field, "WetbulbT_C", that needed to be removed from the GARP (i.e. GEMPAK interface) software distribution so that future releases will not include this variable as a choice in the menus.

3.2.2 Vorticity Advection (VA) and Differential VA

Once relative vorticity is substituted into the advection equation and expanded, four terms exist:

$$\textbf{vorticity adv.} \quad \underset{①}{-u\frac{\partial v}{\partial x^2}} \; \underset{②}{+u\frac{\partial u}{\partial y\,\partial x}} \; \underset{③}{-v\frac{\partial v}{\partial y\,\partial x}} \; \underset{④}{+v\frac{\partial u}{\partial y^2}}$$

To perform the finite difference, imagine using the grid below to calculate the vorticity advection at the number "5".

1	2	3
4	5	6
7	8	9

An error was found in the calculation in term four:

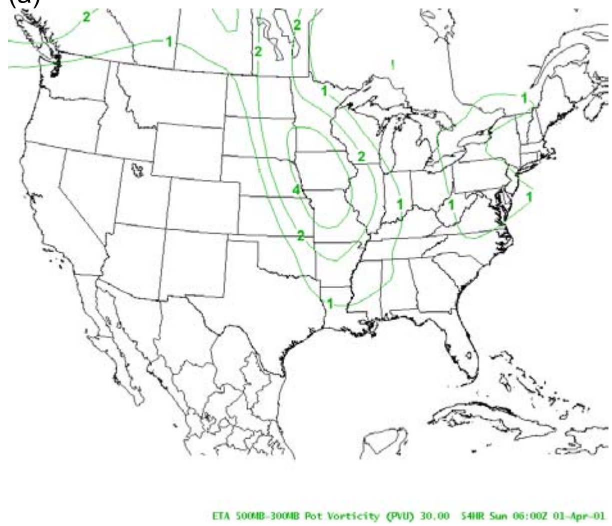
$$④ = v_5\left[\frac{u_2+u_8-2u_5}{\partial y^2}\right]$$

Instead of using the u-wind at points #2 and #8, AWIPS was using the u-wind at points #4 and #6. A fix was made at FSL and implemented in AWIPS version 5.0. Another reason for the difference is that AWIPS does the calculation of relative vorticity and advection all at once, which means that grid point #5 is affected by grid points within plus or minus one grid spacing. However, GEMPAK does the calculation in a two-step process where the vorticity is first calculated at all the grid points, and then it is advected. This causes the GEMPAK calculation of vorticity advection at a point to be affected by grid points within plus or minus two grid spaces, and therefore the GEMPAK plot is slightly smoother than the AWIPS plot. This same error affects differential vorticity advection.

3.2.3 Potential Vorticity (PV) and Equivalent PV

Potential vorticity is always calculated using a layer even if you just choose the 500 mb level in the 'Planes' section of the Volume Browser. For potential vorticity on a pressure surface or isentropic surface, AWIPS will use the next level above the requested level to form the layer. When plotting potential vorticity with AWIPS in a pressure layer (i.e., 500-300 mb), an error in the calculation method was found (see Figure 2). The potential vorticity of the upper level (i.e., 300 mb) of the requested layer was correctly calculated using itself and the next higher available level.

(a)



(b)

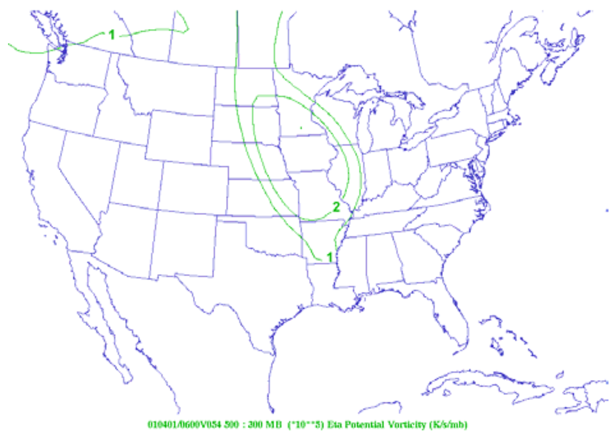


Figure 2. Plots of Eta potential vorticity in a layer from (a) AWIPS and (b) GEMPAK. Although the contour shapes are similar, the error in the AWIPS layer calculation caused higher AWIPS values.

However, the potential vorticity at the lower level (i.e., 500 mb) of the layer was being calculated with an average wind and average potential temperature that were derived from the entire 500-300 mb layer instead of the 500 mb layer and the next available layer above it. The values found for the top and bottom of the layer were then averaged. This "hybrid" average will give an incorrect value. AWIPS developers at FSL were able to make a fix to their local system, which was implemented in AWIPS version 5.0. This error also affects equivalent potential vorticity calculations in a layer.

3.2.4 Eta Snow Accumulation

AWIPS and GEMPAK do not use the same method of calculation for snow accumulation. GEMPAK simply assumes a snow/rain ratio and multiplies it by the precipitation accumulation without regard for the thickness or elevation at each grid point. The empirical formula for the snow/rain ratio used by AWIPS was developed by FSL using a linear fit. Steve Albers of FSL indicated that the empirical formula should work fairly well for most of the continental U.S. except the West Coast where advection of low-level air over warm waters can still cause rain even when the thickness is normally considered cold enough for snow. Geoff Dimego of the National Centers for Environmental Prediction (NCEP) also sent an announcement indicating that the Eta snow accumulation product in AWIPS is not an explicit output field from the Eta and that he would work with AWIPS developers to include the explicit field in the future.

3.2.5 Other Issues Submitted by Forecasters

There have been a number of inquiries submitted to the AVE team by field forecasters. The following is a very brief description of some of the issues documented on the AVE Web site.

A direct comparison of computed lifted index with GEMPAK is not possible because it is not available in GEMPAK. However, it should be noted that computed lifted index in AWIPS is based on a fairly standard procedure, but results may vary from direct model output of lifted index due to the input values used.

An error was found in the portion of code that determines the parcel parameters used in the skew-T thermodynamic calculations. The AWIPS algorithm should have used a layer-averaged dewpoint for the 12Z sounding and the surface dewpoint for the 00Z sounding. However, this was reversed, causing more convectively active thermodynamic skew-T parameters at 12Z.

When displaying MRF image data on the CONUS scale, the MRF 202 grid is remapped from its default polar stereographic map projection to the CONUS scale map projection that is based on a Lambert Conic Conformal. This can cause small differences between the contours and image. Therefore, the cursor readout of the image will seem to not agree exactly with the contours. Because the AVN and Eta gridded data are on the same projection as the CONUS scale, cursor readout differences are not an issue.

Convective inhibition, or CIN, was being underestimated by the calculations in the ‘Sounding’ view of the Volume Browser. If there is a mid-tropospheric inversion that causes a double level of free convection (LFC) to occur the second area of CIN is not examined. The error is that after the first LFC is found, the method of calculation does not continue to look for a second possible LFC and hence another area of CIN.

There have also been short-term discrepancies related to “bugs” in the AWIPS software or changes in the way model output is interpolated to output grids. However, details on these issues will not be discussed here.

3.3 Phase 2 – Significant Discrepancies

Of the 52 fields validated in Phase 2, only one has been deemed to have a significant discrepancy. Again, as with the minor issues, it is important to note that this does not necessarily imply that AWIPS is wrong in all cases; it merely indicates that the field is more than slightly different from GEMPAK in either its display or calculation method.

3.3.1 Equivalent Potential Temperature (theta-e)

AWIPS values for theta-e appear several degrees Celsius lower than values given in GEMPAK plots. This is especially noticeable in areas of higher moisture (Figure 3). The procedure and equations used by the two systems to perform the calculation differs significantly. Qualitatively, the AWIPS method of calculation for theta-e differs from the GEMPAK method in two ways. First, GEMPAK lifts the parcel to determine latent heat release while AWIPS does not. Second, GEMPAK equations make adjustments to the specific heat of dry air at constant pressure and the latent heat of vaporization as the temperature, pressure, and moisture content of the parcel change while AWIPS equations hold these values constant. Essentially, AWIPS used the isobaric method of calculation while GEMPAK used an adiabatic method. The SEC/DB was notified of this discrepancy and it was decided to switch AWIPS to the adiabatic method of computing equivalent potential temperature in version 5.0.

(a)
(b)

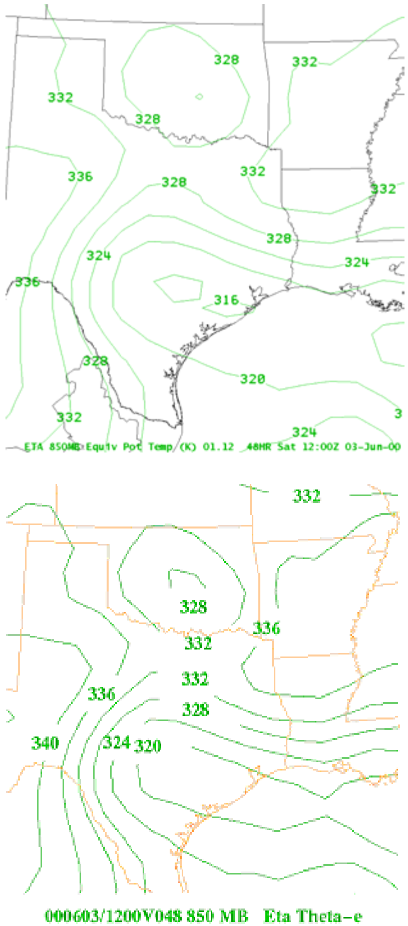


Figure 3. Plots of Eta equivalent potential temperature for (a) AWIPS and (b) GEMPAK. Areas of high moisture were affected most. The contour shapes are very similar but the AWIPS values are lower.

4. PHASE 3

AVE began a third phase in March of 2001. In this phase the sounding view of the AWIPS Volume Browser is compared to that of the SkewT Hodograph Analysis and Research Program (NSHARP). Four model fields were examined before AVE work was postponed. These include CAPE, CIN, LI, and forecast maximum temperature. The initial parcel conditions (temperature, dewpoint, pressure) for AWIPS were matched to the values given in the NSHARP lifted parcel level (LPL) data section. However, NSHARP applies a virtual temperature correction to the parcel path and environmental temperature trace to account for the effect of moisture on air density (buoyancy). This slightly increases the temperature of the parcel and the environment in moist low levels. Also, when lifting the parcel, it does not exactly follow the wet adiabatic lapse rate since the skew-T wet adiabats have typically been constructed using temperature and not virtual temperature. This causes CIN values to generally be less than AWIPS, and CAPE and LI values to be greater than AWIPS, although the difference is usually not significant. The AWIPS forecast maximum temperature field compared well to NSHARP.

The documentation in Phase 3 is slightly different from phase 2. Several different times and locations of model data are compared since we are looking more at point data rather than an entire grid of values. Therefore, a table is used to show the comparisons between AWIPS and NSHARP. There are three sections to the documentation: a ‘Validation Notes’ section describes our observations during the investigation, a ‘Calculation’ section documents the equations used or any conditions to the calculation, and a reference section provides resources to more detailed information.

At present, AVE Phase 3 work has been postponed to later in the 2002 fiscal year. However, COMET will continue to answer questions and investigate forecaster inquiries regarding AWIPS display of model data.

5. CONCLUSION

The AVE team has examined 62 fields overall, not including fields examined due to forecaster inquiries regarding skew-T calculations. The majority of the AWIPS model fields have compared well with the same fields in GEMPAK and NSHARP. The main goal of the AWIPS Validation Effort is to provide confidence to the forecasters that the products they use operationally are correct, and to provide an avenue for them to submit questions and concerns. At the same time, the on-line documentation provides all parties with previously unavailable basic knowledge of AWIPS calculation methods.

6. ACKNOWLEDGEMENTS

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