Objective Analysis Schemes to Monitor Atmospheric Radiation Measurement Data in Near Real-Time

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Recent work in this area by Charles Wade (1987) lays out the groundwork for monitoring data quality for projects with large networks of instruments such as the Atmospheric Radiation Measurement (ARM) Program. Wade generated objectively analyzed fields of meteorological variables (temperature, pressure, humidity, and wind) and then compared the objectively analyzed value at the sensor location with the value produced by the sensor. Wade used a Barne's objective analysis scheme to produce objective data values for a given meteorological variable (q) in two-dimensional space. The objectively analyzed value should be comparable to the actual sensor value if 1) the variable q is appropriate for this type of objective analysis; 2) the data quality of the sensors is good; and 3) there are a significant number of sensors on which to base the objective analysis. If conditions 1 and 3 are satisfied, the objective values can be compared with the actual values to provide an estimate of the data quality.

Investigation of Pressure Data Quality

The outright objective analysis of surface pressure data over a network of sensors spanning hundreds of kilometers is not considered appropriate. The variations in pressure would be dominated by vertical variations in pressure as a result of topography. An objective analysis on a two-dimensional plane requires that the pressure data from each sensor be extrapolated to a common level. ARM surface pressure data have been extrapolated via the hypsometric equation to the elevation of the ARM Central Facility.

The difference between the actual pressure and the objectively analyzed pressure has been shown by Wade to be an effective tool in determining sensor drift and other marked changes in sensor performance. Similar analysis of ARM surface pressure data is being conducted by the Site Scientist Team (SST). The SST objective analysis includes the 30-minute average data from both the energy balance Bowen ratio (EBBR) and the surface meteorological observation system (SMOS) pressure sensors (total of 15 sensors). When the data quality is low, data could be replaced by reasonable estimates provided by this objective analysis technique. The data quality of the recovered data will be a function of the bias of the objective analysis scheme.

ARM Surface Temperature Data

The objective analysis technique applied to the ARM surface pressure data has also been tested by the SST on the 30-minute average surface temperature data. The temperature data were not extrapolated to a common height as was done with pressure, but potential temperature could be used in the analysis if deemed necessary. Figure 1 shows the time series of the difference between objective and actual values for the SMOS temperature sensors. Since the temperature data are fairly noisy, a running average of 250 points was applied to help visually identify trends.

Figure 2 is a histogram of the temperature differences at Coldwater, Kansas, using the objective analysis values that exclude the data from the Coldwater sensor. The objective analysis (without the data from Coldwater) provides an estimate that is generally within ± 1 degree Celsius of the actual value.

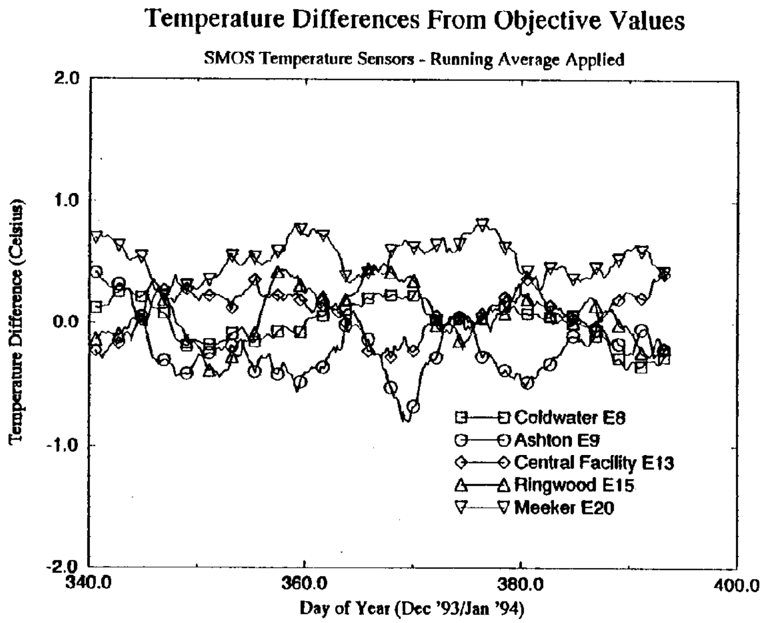

Figure 1. The difference between the objectively analyzed and the actual temperatures for the ARM SMOS temperature sensors.

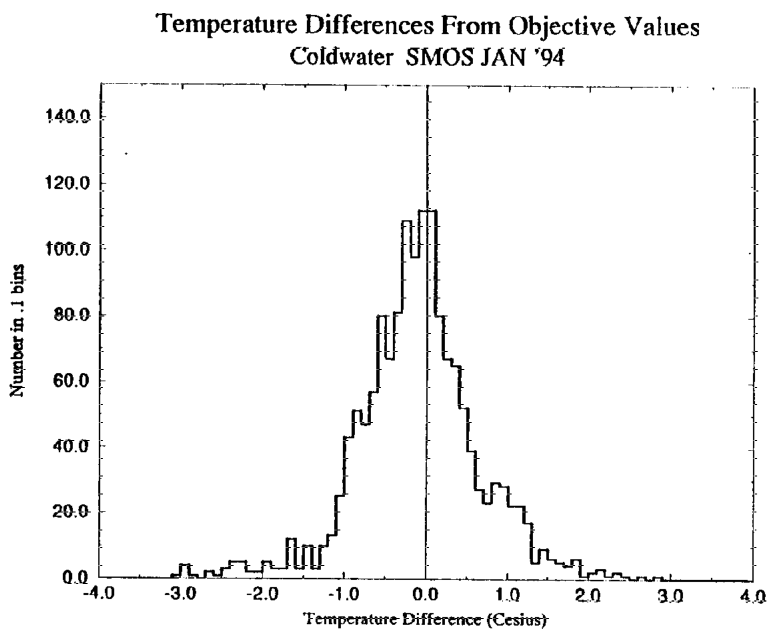

Figure 2. Histogram for the difference between the objectively analyzed temperature at Coldwater (without using the Coldwater data) and the actual temperature at Coldwater. Verifies the utility of using the objective values for replacing missing data.

ARM Surface Wind Data

The use of the objective analysis technique on the ARM surface wind data is also being tested by the SST. Winds need special treatment because the two "surface" wind-sensing systems (EBBR and SMOS) have their respective sensors at two separate levels (3.4 m and 10.0 m AGL). The SST has used a logarithmic wind profile with a surface roughness length of 3.5 cm to increase the EBBR wind speed to a value that would be expected at 10.0 m AGL. The objective analysis was applied after the wind speeds were adjusted to the common level of 10 m. Errors in vane orientation and biases in the wind direction due to terrain influences can be detected from this type of analysis.

Extension to Other ARM Data Streams

Wade's analysis scheme was also used to evaluate the quality of specific humidity data, which could be included in an array of ARM data streams that are evaluated in the same manner. Other variables from the EBBR systems, such as soil temperature, latent heat flux, and sensible heat flux, could have these techniques applied. Integrated liquid water from the array of microwave radiometers and the balloon-borne sounding system could be combined into an analysis.

The objective analysis technique which has been applied to variables in the x,y plane could be as easily applied to two- or three-dimensional space. The time dimension could be included in the objective analysis as well (see Doswell 1977) and would be especially useful for an instrument like the profiler which produces data in the z,t domain.

The traditional meteorological variables lend themselves to this type of analysis. The methods may also have use in monitoring the quality of ARM radiation measurements. The solar and infrared radiation observation stations (SIROS) network is a variation of the objective analysis in the x,y domain.

The analysis of the SIROS data may be difficult during partly cloudy conditions but may provide useful data quality evaluations during the periodic clear sky conditions. Other radiation instruments such as the broadband filter on the multi-filter rotating shadowband radiometer (MFRSR) could potentially be included in an analysis of SIROS data.

Incorporation of External Data Sets

One of the limiting factors of the objective analysis techniques tested by the SST is the density of the instruments in the spatial domain. The data set Wade analyzed comprised two different mesonet systems with a total of 123 automated stations. Analysis of ARM data will be enhanced as more facilities come on line, but the use of Oklahoma Mesonet data would greatly enhance the significance of the analysis within Oklahoma. The Oklahoma Mesonet has 111 stations operating. Other external data sources may be available, but may not be as easy to mesh with the ARM data as is the Mesonet data.

Implementation of Objective Analysis Schemes

The SST will be working with the Experiment Support Team to incorporate these types of analyses into the overall quality assurance programs of ARM. Implementation of the schemes to provide real-time checks of data quality and the use of objective data as replacements for missing data will be the focus of the work. Further testing will be needed to optimize the selection of a radius of influence for each of the data streams.

References

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Wade, C.G. 1987. A Quality Control Program for Surface Meteorological Data. *J. Atmos. Ocean. Techn*. **4**:435-453.