Plume Diagrams

Plume diagrams, such as the one shown in Figure 1, are good means to display ensemble predictions system (EPS) data at a point over a specified time interval. They allow the user to quickly assess conditions and quick visualize the range of potential solutions. They do not contain statistical data that a box-and-whisker chart may contain and share

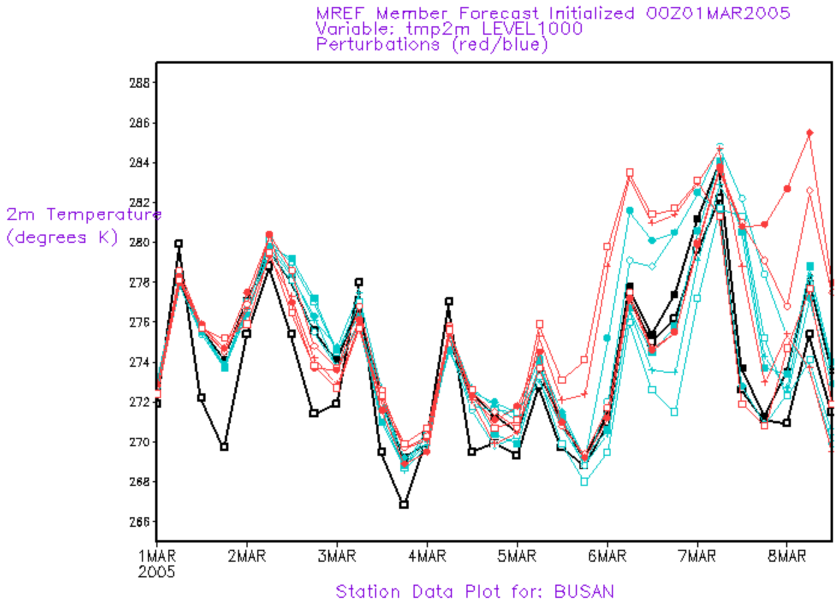

Figure 1 Plume diagram of 2m Temperatures (K) from the NCEP medium range ensemble forecast system (MREF) for Busan, Korea from forecasts initialized at 0000 UTC 1 March 2005. Black shows the high resolution run, blue shows the negatively perturbed members and read shows the positively perturbed members. The ordinate shows the value (K) in time along the abscissa.

many parallels to plan-view spaghetti charts. When displayed with the spread of each ensemble prediction system (EPS) member about the EPS mean, they are a spaghetti chart in time rather than space. This note will serve to explain the basic use of plume diagrams, the advantages and limitations of plume diagrams; and some simple forecast applications that plume diagrams perform well.

Plume diagrams of low-level temperature forecasts, such as the plume shown in Figure 1; allows the forecaster *to visually see the range of temperature forecasts.* It is left to the user to determine the degree of uncertainty or uncertainty in the forecast. The temperature plumes could have direct applications to precipitation type forecasting, timing a frontal passage, and forecasting daily temperature ranges. The data in Figure 1 are from the NCEP MREF forecasts of 2m temperatures at Busan, Korea from forecasts initialized at 0000 UTC 1 March 2005. These forecasts show each members 2m temperature forecasts in 6-hour intervals for the 7-day period. In this example, the high resolution control run is in black. Initially, all the perturbed members show a similar forecast which differs from

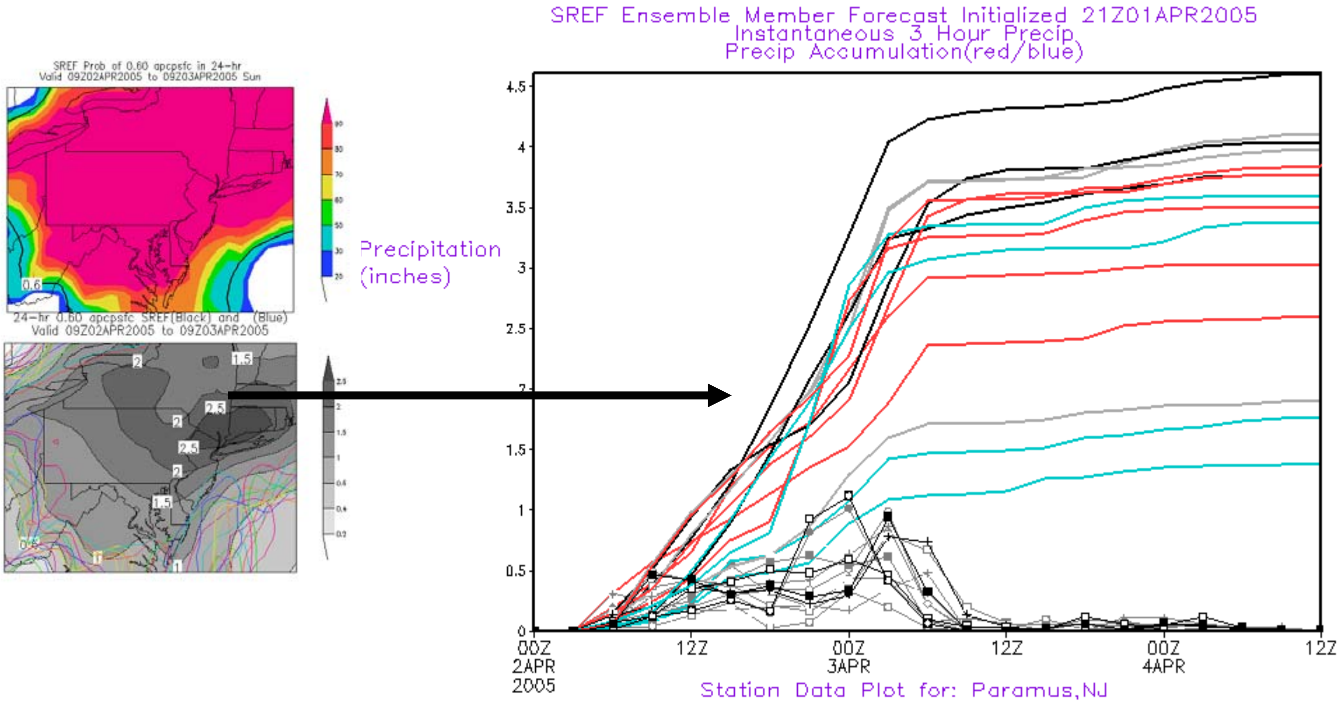

Figure 2 NCEP SREF QPF forecasts showing plan-view map of 0.60 inches probability and ensemble mean total QPF. The arrow shows the derived plume near the area of heaviest rainfall from the EPS. The accumulated precipitation plume shows each EPS members precipitation forecasts. The 3 SREF control members are drawn in black. The perturbations are drawn as shown in Figure 1. The diagram shows both total accumulated rainfall and in gray lines, each members 3 hour instantaneous precipitation.

the high resolution model run, which has colder low temperatures. This difference disappears around 4 March. After 6 March, there is a wide range of forecasts with clustering by perturbation. Note all the positively perturbed members are generally warmer than the negatively perturbed members from about 5 March through 7 March. This plume diagram shows the large amount of uncertainty from 5 March through 8 March. This uncertainty grows during this time. Note the unusually cold period focused around 4 March, on this date, Busan experienced a record and late season snowfall on 4 March 2005.

Plume diagrams allow the user to visualize the conditions at a point and visually inspect the differences between members. For point forecasting or computer worded forecast development applications they are potentially powerful forecast tools. However, the big limitation of these diagrams is there is no means to determine the context of the weather element, a feature better offered by plan view diagrams.

One forecast strategy using plume diagrams is to visualize the EPS data on a plan view diagram and then examine the plume diagrams. In areas of potentially heavy rainfall, plume diagrams of EPS quantitative precipitation near the region with a high probability of receiving heavy rains would allow the forecaster to see the uncertainty and the maximum rainfall by individual members. Ideally, a point and click option would be made available off the plan view to interrogate the QPFs. An example of such an application is shown in Figure 2. These data are from near the NCEP SREF region of 2-3 inches of QPF forecast for the 36-hour period ending at 0000 TC 3 April 2005. The plume diagram was derived by a point near the ensemble mean maximum QPF (see arrow). The plume shows the accumulated QPF over time. It clearly shows that the threat for in excess of 2.5 inches was present in more than 60% of the EPS members. No member forecast less than about 1.40 inches of QPF. The instantaneous 3-hour rainfall (gray lines) shows the onset time, time of heavy precipitation, and time the precipitation was forecast to end. Plume diagrams are valuable forecast tools in potential regions of heavy precipitation.

Plume diagrams can also be valuable in forecasting severe weather. In areas of potential

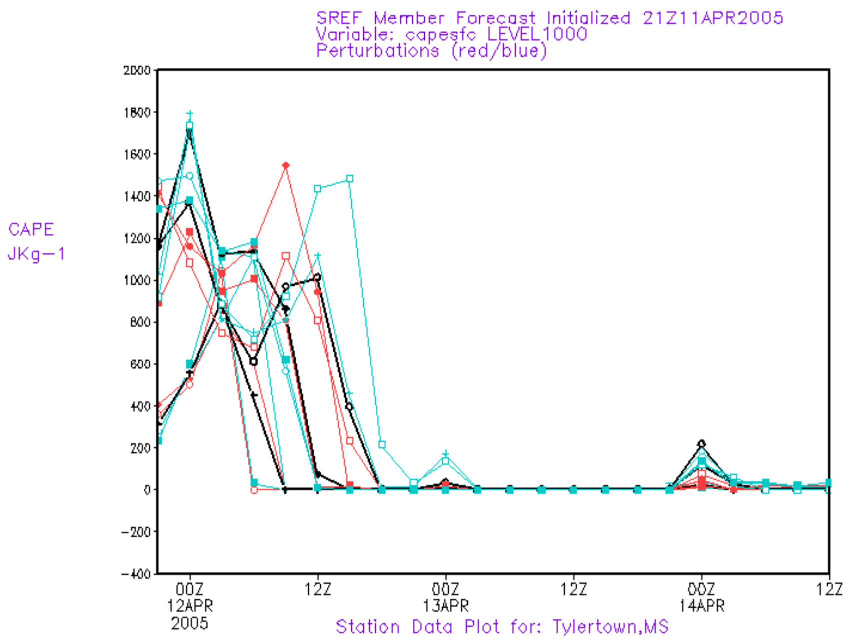

Figure 3 SREF CAPE forecasts initialized at 2100 UTC 11 April 2005. **Data show each SREF CAPE forecast with time along the ordinate.**

instability, convectively available potential energy (CAPE) plumes have a wide range of forecast applications. Figure 3 shows the NCEP SREF CAPE forecasts initialized at 2100 UTC 11 April 2005. Note the general instability, with CAPE in many SREF members in excess of $1000 JKg^{-1}$ around 0000 UTC 12 April 2005. Some EPS members showed instability lingering until 1200 UTC 12 April. This location and time was chosen due to the tornado observed in Tylertown, MS during the evening hours of 11 April 2005. Note how stable conditions become in all EPS members after 1500 UTC 12 April 2005.

Plume diagrams have several advantages:

1. *They allow the forecaster to assess a forecast element quickly at a point over a forecast range.*
2. *They allow the user to visualize the spread in the members at each time period. This facilitates "eyeballing the average" and seeing the range of solutions.*
3. *They are useful for timing the onset time range of rainfall, snowfall, and frontal passages.*
4. *They are useful in display accumulated precipitation.*
5. *Displaying the mean*[1] *and spread is not common, though achievable.*

Some plume diagram limitations include:

1. *They are for a point or an area averaged value, thus without access to plan-view displays, they provide no insights into the weather patterns.*
2. *They normally contain no statistical information which is contained in a box-and-whisker diagram.*
3. *They are often statically produced for pre-defined locations. The location of interest (maximum QPF) or a desired point may not be available.*

Currently, our plumes produced for pre-determined locations and for set variables. Plans include adding accumulated precipitation by type and an interface to pick the location of the plume. We encourage the use of plume diagrams in conjunction with plan-view maps whenever possible. A modification of plume diagrams is to compute them over a region rather than a point. This allows for averaging but creates problems with precipitation type forecasting. The Korean Meteorological Administration creates plume for South Korea. One advantage of aerial averaged plumes would be in hydrological forecasting where plumes for basin's and water sheds could be developed and used as inputs into hydrologic models.

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[1] Mean is now thick black on PSU/CTP WebPages and contols are thin black.