Ensemble Kalman Filter Analysis, and its Application to Reanalysis using only Surface Pressure Observations

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Climate variability and global change studies are increasingly focused on understanding and predicting regional changes of daily weather statistics. Assessing the evidence for such variations over the last hundred years requires a daily tropospheric circulation dataset. The only dataset available for the early 20th century consists of error-ridden hand-drawn analyses of the mean sea level pressure field over the Northern Hemisphere. Modern data assimilation systems have the potential to improve upon these maps, but prior to 1948, few digitized upper-air sounding observations are available for such a reanalysis. We investigate the possibility that the additional number of newly recovered surface pressure observations is sufficient to generate useful weather maps of the lower-tropospheric extratropical circulation back to 1890 over the Northern Hemisphere, and back to 1930 over the Southern Hemisphere. Surprisingly, we find that using an advanced data assimilation system based on an ensemble Kalman filter (Whitaker and Hamill, 2002), it would be feasible to produce high-quality maps of even the upper troposphere using only surface pressure observations. For the beginning of the 20th century, the errors of such upper-air circulation maps over the Northern Hemisphere in winter would be comparable to the two to three day errors of modern weather forecasts (e.g., 500 hPa geopotential height spatial correlations of ~0.95, rms errors ~35-40m).

Encouraged by these results, we have developed a capability to produce high-quality daily reanalyses for the troposphere from surface pressure observations alone (Compo et al. 2006) using this Ensemble Filter. The combination of the Global Climate Observing System International Surface Pressure Databank of improved surface observational records together with this data assimilation method provides a new opportunity to extend the existing reanalyses back in time, perhaps providing for the first time a reanalysis data set of a century or longer (the other alternative, to wait for another 50 years of observations, is less appealing). **Figure 1** illustrates a pilot reanalysis, showing the degree to which the principal mid-tropospheric features for the famous "post-Christmas Snowstorm" of December 1947 (Kocin and Uccellini 2004) are present in a map from a reanalysis using surface pressure observations and the Ensemble Filter (left panel) compared to the features seen in maps from the Air Weather Service (middle panel) and a reanalysis using the full NCEP assimilation system (middle panel). Our feasibility and pilot results suggest that a reanalysis spanning the entire 20th century can be produced using currently available observations and advanced data assimilation methods.

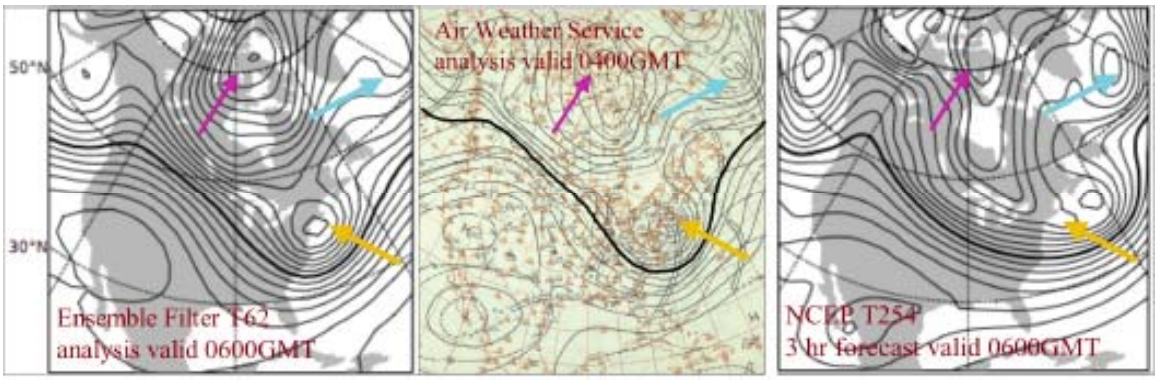

Figure 1 The 500 hPa height analysis of 27 December 2004 06GMT from the Ensemble Filter data assimilation system using only surface pressure observations (left) and from the experimental NCEP T254 analysis using all available surface and upper air observations (right). An Air Weather Service map drawn in near-real time is also shown (middle). Colored arrows illustrate the same features in all three maps.

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