4.13 EVALUATING THE EFFECTIVENESS OF THE E.T.K.F. TARGETING METHOD FOR 3-6 DAY FORECASTS

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1. Introduction:

In recent years "targeted" observations have been deployed in data sparse regions in order to reduce errors in global forecast model initial conditions that may lead to the degradation of short-term (1-3 day) forecasts. One objective technique for identifying the regions where additional observations are most likely to produce the largest error reduction for 1-3 day forecasts of high impact winter weather is the Ensemble Transform Kalman Filter (ETKF) (Bishop et al, 2001; Majumdar et al, 2002). The ETKF makes a quantitative prediction of the likely impact of any feasible set of supplementary observations by estimating the "signal variance", where the signal is defined as the difference between a forecast that includes the targeted observations and one that does not. The signal variance is theoretically equal to the reduction in forecast error variance that would be imparted by the observations. The potential of the ETKF to predict the signal variance for 1-3 day forecasts and the relationship between signal variance and reduction in forecast error variance was demonstrated by Majumdar et al (2001). However the ability of targeted observations to influence forecasts in the medium range (3-6 days) and the effectiveness of the ETKF in predicting signal variance on these timescales has not yet been explored. Indications that targeting may have potential value beyond 3 days were found in the data from the 2005 Winter Storm Reconnaissance Program (WSR), which employs the ETKF. If the ETKF can be shown to have skill in predicting the signal variance beyond 3 days and if this signal variance can be related to a reduction in forecast error variance then we can expect targeted observations to be beneficial when a significant signal variance is predicted by the ETKF at these longer time scales.

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2. Issues in extending the ETKF beyond 3 days:

A number of difficulties may be expected to arise in the extension of the ETKF to longer time scales.

1) The linear assumptions inherent to the application of the ETKF to targeting may be compromised for time ranges as short as 24 hours (Gilmour et al, 2001).
2) The ETKF assumes the data assimilation statistics of an ensemble Kalman filter which is inconsistent with the operational 3-D-Var data assimilation scheme. This may result in predicted initial signals that are quite different in structure than those realized operationally.
3) The ETKF often produces spurious long distance correlations due to the limited size of the ensemble used to estimate the variances. This may lead to the indication of inappropriate target regions and large signal variances in areas not dynamically linked to the observation sites.
4) Local growth in highly baroclinic regions, in both the predicted and operational signals may obscure those signals that are associated with the observations.
5) The choice of verification regions is expected to be challenging at longer time ranges due to predictability limitations.

3. Research Strategy:

The effectiveness of the ETKF for 3-5 day forecasts is evaluated here using dropwindsonde data from the 2005 and 2006 Winter Storm Reconnaissance Programs. The ETKF's performance is evaluated based on its ability to

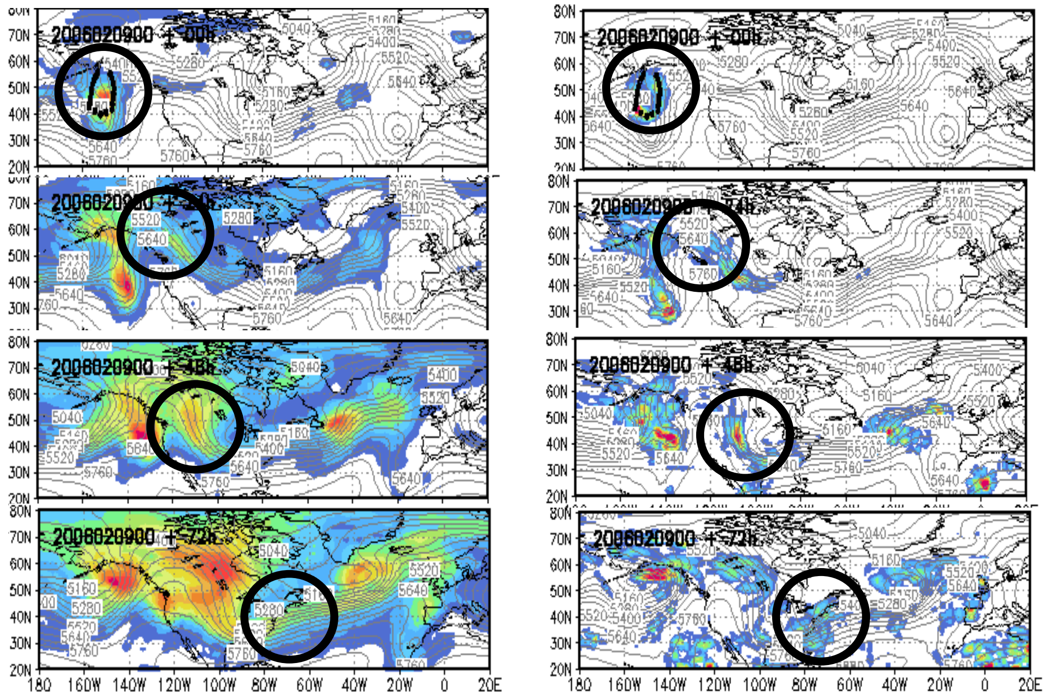

Figure 1: ETKF predicted signal variance (left) vs. squared MRF operational signal (right) at 24 hour intervals. The black dots in the top frames indicate the dropsonde locations. The verification regions are situated inside the circles.

predict the variance of forecast signals produced by these dropwindsonde data. The operational signals are computed using two operational NCEP Global Forecast System (GFS) model runs; one that includes the dropwindsonde data and one that does not. Forecast verification regions were selected subjectively by an examination of graphical representations of the predicted ETKF signal variance and the GFS squared signal realizations. Verification regions are placed where the ETKF predicts a large signal variance that can be dynamically linked to the observation site, either through advection by the mean flow or by wave packet propagation (Szunyogh et al, 2000, 2002). The verification norm used is “Total Energy” (Ehrendorfer, 2000) which includes wind and temperature at the 850mb, 500mb and 200mb atmospheric levels. The ETKF predicted signal variance and the variance of squared GFS signal realizations are compared using the method described in Majumdar et al (2001). This comparison is used to deduce whether a linear increasing relationship exists between the predicted and operational signal variances and whether there is a similar relationship between the predicted signal variance and the reduction in forecast error variance

4. Results:

The performance of the ETKF was evaluated for the WSR case of February 9, 2006, a case for which the ETKF predicted a significant signal variance beyond 3 days. A visual examination reveals a remarkable similarity between the ETKF predicted signal variance and squared GFS signal as shown in figure 1. The ETKF signal variance is shown on the left at 24 hour time increments and the squared GFS signal is on the right. The black dots in the uppermost frames indicate the dropsonde sites. Structural differences between the two quantities are evident at the observation time. The ETKF predicted signal variance is spread out along the upper-level trough feature while the NCEP, GFS signal realizations are localized about the dropsonde sites. Spurious long-distance correlations are possibly

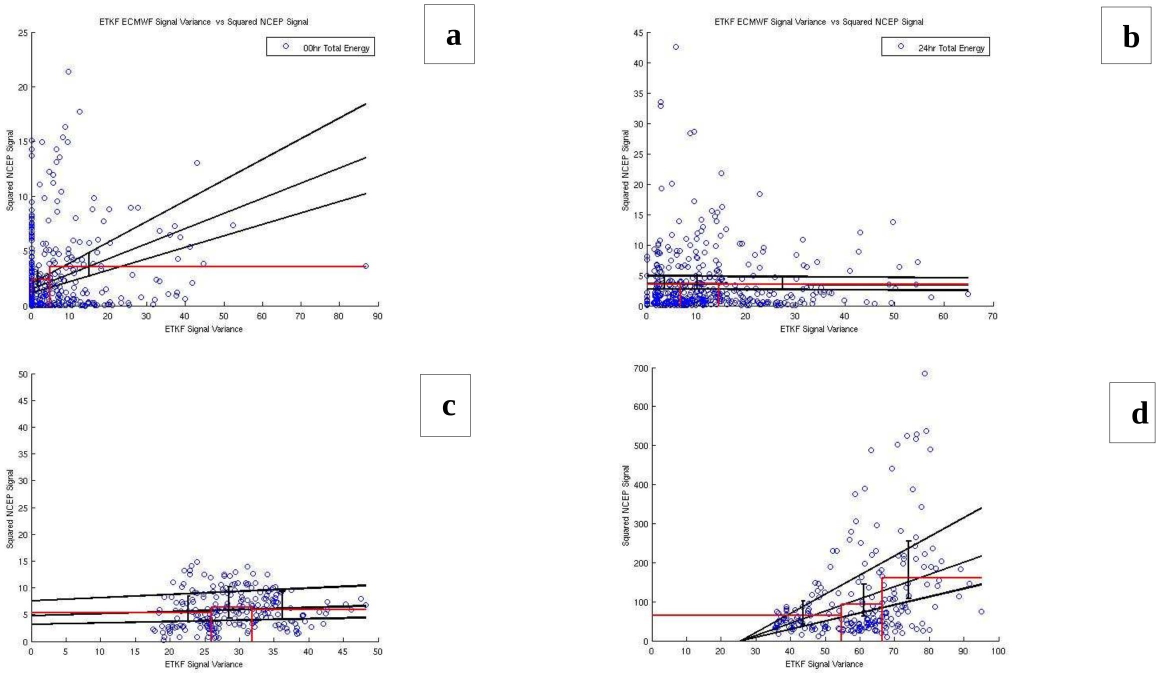

Figure 2: ETKF predicted vs. operational signal variance for all 2006 WSR cases combined at (a) observation time (b) 24 hours (c) 72 hours (d) 144 hours

responsible for the regions of large signal variance to the north of the sonde region and also in the central and northeast Atlantic Ocean. By 48 hours the predicted and operational signals both indicate signal growth in the central Atlantic that may or may not be related to the observations. The operational signal that spontaneously appears in the tropics can probably be attributed to local growth.

A quantitative comparison between the predicted and operational signal variance indicates a strong, linear increasing relationship at the observation time then an initial decay of the operational signal, which is consistent with previous findings (Majumdar et al, 2001; Szunyogh et al, 1999). For forecast times beyond three days the two quantities are well correlated and a linear increasing relationship between the predicted and operational signal variance can be inferred from the data. The ETKF's skill in general was then evaluated using the data from all the 2006 WSR cases. A linear increasing relationship was found between the predicted and operational signal variances at the observation time but at 24 hours the operational signal was found to decay in of verification variables in all the previously mentioned cases.

5. Conclusions and future work:

Preliminary results indicate that the ETKF may a similar manner as in the single case. For forecast periods between 24 and 72 hours no relationship between the predicted and operational signal could be inferred from the data, however for time periods 96 hours or longer a strong linear increasing relationship is indicated. A possible explanation for the lack of correlation at the earlier times may be random noise, similar in magnitude to the signals, that is produced by the perturbed initial conditions. Further analysis is necessary in order to reduce this noise and isolate the signal that is due to the observations.

One factor that is thought to influence the ability of the ETKF to predict signal variance is the prevailing flow regime (Szunyogh et al, 2000, 2002). The effect of flow regime was examined by comparing the predicted and realized signal variances for the 5 WSR 2006 cases with the most zonal synoptic pattern and the 5 cases where the flow was least zonal or blocked. At the observation time the ETKF was found to perform better for the zonal cases but at later times the ETKF was found to be equally proficient in predicting signal variance for both the zonal and non-zonal cases.

Similar results were obtained for a variety

have skill in predicting signal variance at time scales greater than 3 days. There is no indication that the ETKF's ability to predict signal variance is dependent on either flow regime of forecast verification variable. The next step is to determine whether the signal variance can be related to an actual reduction in forecast error variance. This relationship will be tested by computing the variances of the RMS error for the forecasts that include the targeted observations and those that do not and comparing the difference to the ETKF signal variance. More conclusive results should be obtained by reducing the noise in the signals. One approach that may prove useful is a wave packet analysis (Zimin et al, 2003). Identifying upper tropospheric Rossby wave packets would allow us to isolate the eastward propagating signal while filtering out the high frequency "noise. This method would also provide a robust means of selecting the verification regions from a dynamical standpoint. Stronger conclusions would be expected from a larger data set therefore the data from WSR 2005 will be included in the final analysis if it becomes available. A further examination of the effect of flow regime on the ETKF's performance is also in order. A better understanding of the strength and weaknesses of the ETKF will allow us to predict when targeted observations might be useful for medium-range forecasts, in addition to those instances when the deployment of supplementary observations would be likely to have minimal value.

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