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This report documents our accomplishments during the period 1 May 2011 - 30 April 2012 in pursuit of the research goals stated in the proposal titled "Incorporating Scale and Predictability Information in Multi-model Ensemble Climate Predictions."

The purpose of this research project was to develop new and improved strategies for combining seasonal forecasts from different operational forecast centers. In the first year, we developed a rigorous test for deciding whether a multi-model combination based on unequal weights has significantly smaller errors than that based on equal weights. The proposed test is rigorous and expected to be of wide interest. This work has been accepted for publication by the *Quarterly Journal of the Royal Meteorological Society* (DelSole et al., 2012).

In the second phase of this research, we developed a new approach to consolidating multimodels based on *regularized* least squares. The basic idea is to find weights that minimize the mean square error, while simultaneously constraining the weights to satisfy certain smoothness conditions. We call the resulting technique *scale-selective ridge regression*. When the constraint is invariant to spatial scale and translational transformations, then the technique reduces to standard ridge regression, which has previously been proposed for multimodel consolidation by van den Dool and Rukhovets (1994). The new methodology was developed and tested using the ENSEMBLES data set (Weisheimer et al., 2009). The weights produced by scale-selective ridge regression are shown in fig. 1. For comparison, we show the weights produced by standard ridge regression in fig. 2. Comparison between figs. 1 and 2 shows that the weights are very similar to each other. This similarity is remarkable given that standard ridge regression is applied independently and individually at each grid point, and therefore is 'unaware' of the neighboring weights. The skill of the two multi-model consolidations are nearly the same, and multivariate tests reveal that it is difficult to reject the hypothesis that the errors of one consolidation are smaller than that of the other. This result implies that the differences in weights are not significant, at least in regards to their impact on prediction errors. **This result shows that standard ridge regression gives multimodel consolidations that are just as good as more sophisticated, scale selective regularizations, a result that was completely unanticipated.**

References

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Weisheimer, A., et al., 2009: ENSEMBLES: A new multi-model ensemble for seasonal-to-annual prediction– skill and progress beyond DEMETER forecasting tropical Pacific SSTs. *Geophys. Res. Lett.*, **36**, L21 711.

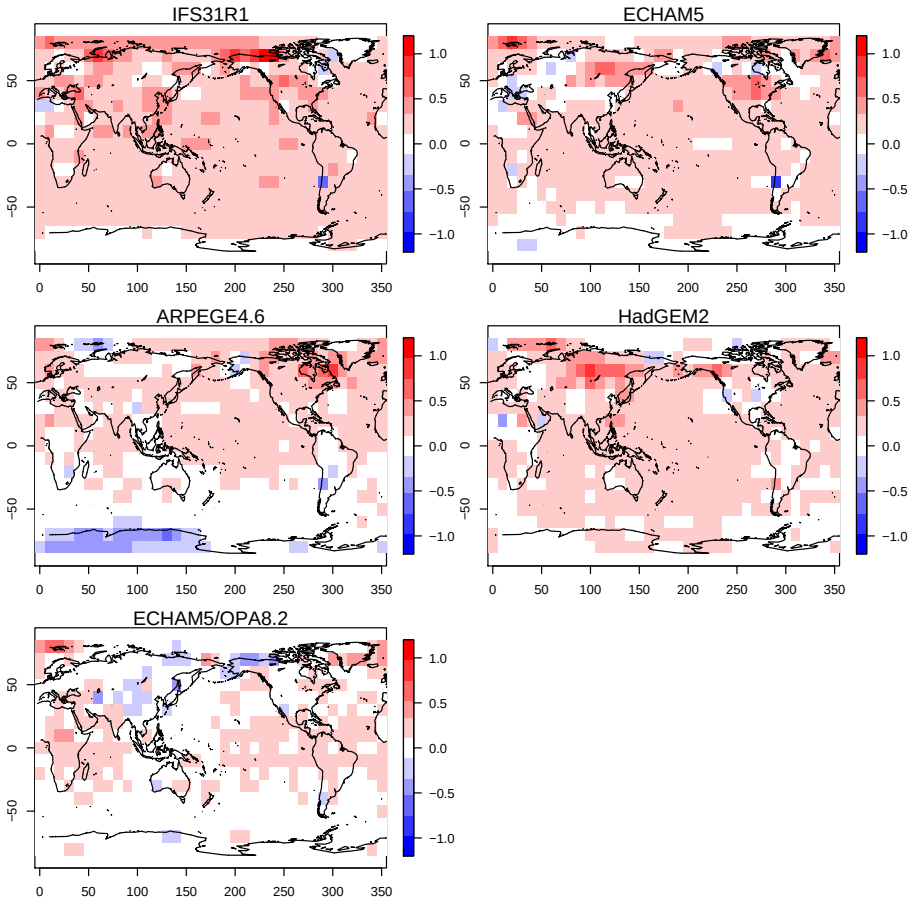

Figure 1: Weights derived from scale-selective ridge regression, when applied to November-January 2m-temperature hindcasts from the ENSEMBLES data set during the 46-year period 1960-2005. The hindcasts were initialized in November of each year with nine member ensembles. The NCEP/NCAR Reanalysis is used for verification.

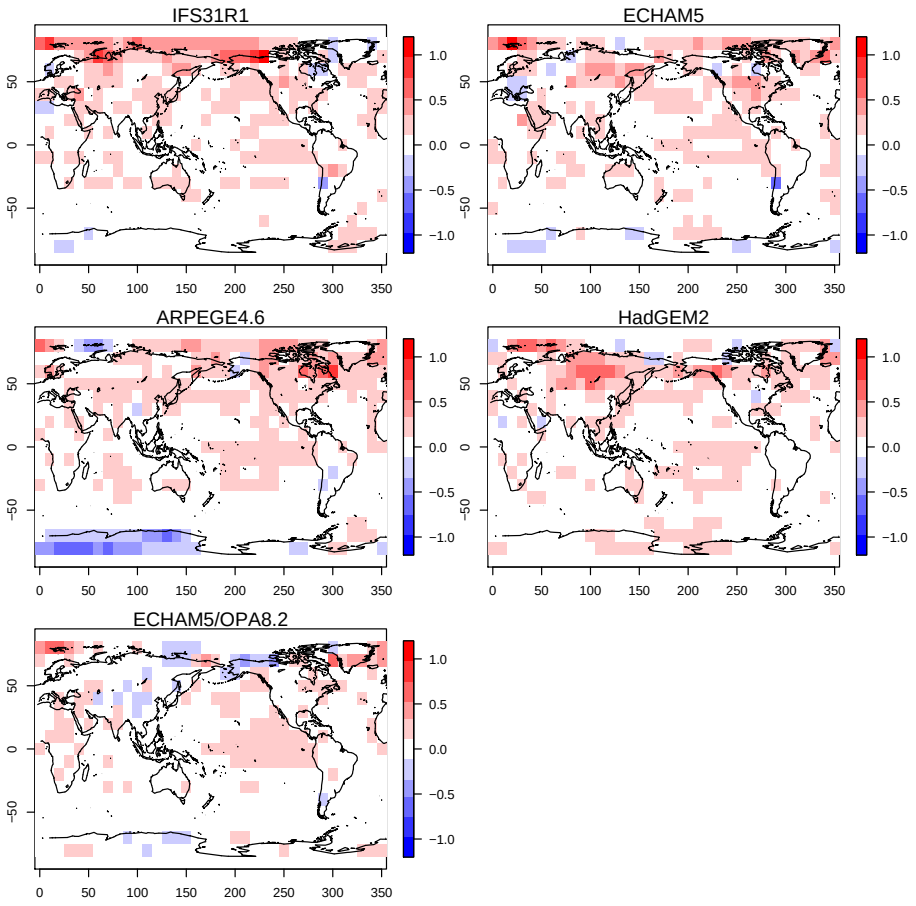

Figure 2: Weights derived from standard ridge regression, when applied to November-January 2m-temperature hindcasts from the ENSEMBLES data set during the 46-year period 1960-2005. The hindcasts were initialized in November of each year with nine member ensembles. The NCEP/NCAR Reanalysis is used for verification.