1. Header

Project title: Best Practices for Estimating Forecast Uncertainty in Seasonal-to-Decadal Predictions

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2. Results and accomplishments

We have developed an extended family of recalibration methods for seasonal-to-decadal ensemble forecasts. The extended family incorporates simultaneous adjustment for a discrepancy in trend between forecasts and observations. We have developed robust and efficient methods for fitting recalibration frameworks in the chosen family that address sensitivity to initial conditions when numerical optimization is required. We have developed new cross-validation methodologies that enable the comparison of training periods of different lengths, and varying frequency of hindcast start dates, using limited data. We have developed additional crossvalidation methodologies specifically for forecasts with a range greater than 12 months, where overlap between forecast periods must be considered.

We have developed a systematic methodology for determining the optimal recalibration method and training period for an existing forecast system using hindcast data. We have applied this methodology to near-surface temperature forecasts on seasonal time scales for the CCCMa CanSIPS, ECMWF System4 and MOHC GloSea5 forecast systems, and on decadal timescales for the CCCMa CanCM4, MOHC HadCM3 and NOAA GFDL-CM2.1 models. Results indicate the importance of correcting conditional biases in the forecast mean on all time-scales, and of correcting linear trends on seasonal time-scales. The optimal training period is around 25-30 years in most cases. In regions where forecasts are skilful after recalibration, skill can be improved further using longer training periods, but the improvement is limited. We have also investigated the effects of varying hindcast start frequency and ensemble size by subsampling existing hindcast experiments. At the grid box level, hindcast frequency has a greater effect on skill than ensemble size. However, ensemble size can have a greater effect for spatially aggregated variables.

All but the simplest approaches to synthesizing probability from ensemble forecasts involve making parametric assumptions about the forecast distribution. The parameters of the forecast distribution must be estimated and are themselves uncertain. This component of uncertainty is routinely neglected when issuing probability forecasts. We demonstrate that this leads to overconfident forecasts and propose two methods of accounting for parametric uncertainty.

On seasonal timescales, we have demonstrated the difficulty of forecasting “normal” weather and climate conditions. We show that there are two important mathematical properties of the normal category in a three-category climatologically equi-probable forecast system, used in most forecast products, which affect the scores for this category. Firstly, the normal category can achieve the highest probability less frequently than the outer categories, and far less frequently in contexts of weak to moderate skill. Secondly, the upper limits of the probability for the normal category are related to, and thus constrained by, the correlation skill of the forecast system.

A PhD-level graduate seminar was developed and delivered in the Fall 2014 Semester in the Department of Earth and Environmental Sciences at Columbia University. Students were exposed to the issues of sampling in the number of hindcasts (i.e. length of history for past forecasts) and ensemble size; downloaded and processed forecast data from IPCC decadal hindcasts and realtime seasonal forecasts; and examined the robustness of mean an conditional bias estimates as a function of data quantity, which are central topics to this project.

Results from the project were presented at the following 13 conferences and workshops.

1. CliMathNet Conference (3 July 2013, Exeter, UK)
2. 13th European Meteorological Society Annual Meeting and 11th European Conference on Applications of Meteorology (10 September 2013, Reading, UK)
3. 6th International Verification Methods Workshop (18 March 2014, New Delhi,India)
4. World Weather Open Science Conference (18 August 2014, Montreal, Canada)
5. NOAA Virtual Workshop on Bias Corrections in Seasonal to Interannual Predictions (30 September - 2 October 2014)
6. MAPP Webinar series on “Opportunities for Predictions and Prediction Research” (29 October 2014). As a result of this webinar, PI Goddard was invited to meet personally with Fern Gibbons in Washington D.C. to discuss research priorities for the senate’s weather and climate bill.
7. Joint meeting of the MiKlip and SPECS seasonal-todecadal forecasting projects (23 - 25 February 2015, Offenbach am Main, Germany)
8. CliMathNet Conference (10 July 2015, Bath, UK)
9. Past Earth Network Conference (3 September 2015, Crewe, UK)
10. Royal Statistical Society Annual Conference (9 September 2015, Exeter, UK)
11. WCRP workshop on understanding, modelling and predicting weather and climate extremes (6 October 2015, Oslo, Norway)

12. Workshop on stochastic modelling, data assimilation and non-equilibrium phenomena (2 November 2015, London, UK)
13. ECMWF workshop on forecast verification (2 March 2016, Reading, UK)

3. Highlights of accomplishments

* New ways of measuring the performance of ensemble forecasts
* New framework for recalibrating seasonal-to-decadal ensemble forecasts
* New methodology for determining the optimal recalibration strategy
* New methods of accounting for parameter uncertainty in probability forecasts
* Mathematical justification for the confidence limits on probabilities for the 'near-normal' category in seasonal climate forecasts
* PI Ferro was awarded the Royal Meteorological Society's L. F. Richardson Prize for 2015 for his paper "Fair scores for ensemble forecasts", based on work conducted as part of the project.

4. Publications from the project

Ferro C.A.T., 2014: Fair scores for ensemble forecasts. Quarterly Journal of the Royal Meteorological Society, 140, 1917-1923, DOI: 10.1002/qj.2270.

Mason, S. J., Ferro, C.A.T., Landman, W.A., 2016: Forecasts of “Normal”. Monthly Weather Review. Accepted.

Sansom P.G., Ferro C.A.T., Stephenson D.B., Goddard L., Mason S.J., 2016: Best practices for post-processing ensemble climate forecasts, Part I: Selecting appropriate recalibration methods. Journal of Climate, 29, 7247-7264. DOI: 10.1175/JCLI-D-15-0868.1.

Sansom P.G., Ferro C.A.T., Stephenson D.B., Goddard L., Mason S.J., 2016: Best practices for post-processing ensemble climate forecasts, Part II: Designing hindcast experiments. In preparation.

Siegert S., Sansom P.G., Williams R.M., 2016: Parameter uncertainty in forecast recalibration. Quarterly Journal of the Royal Meteorological Society, 142, 1213-1221. DOI: 10.1002/qj.2716.

5. PI contact information

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