Advancing intraseasonal climate forecasts through use of reforecasts

Dan Collins
NOAA Climate Prediction Center

Thanks to David Unger and Michelle L'Heureux of CPC and Tom Hamill of ESRL

Outline

1. Current state of intraseasonal prediction at CPC
2. Motivation & New model datasets – retrospective forecasts
3. Methods & Theory
4. Preliminary analysis
5. Skill improvement
6. Summary & Conclusions
7. Next Steps

CPC intraseasonal forecasts and models

Extended Range Forecasts:

- Subjectively combine dynamical model output from NCEP, ECMWF and CMC
- Legacy tools that specify surface variables from upper air circulation
- With improvement in model skill, increasingly depend on model derived surface variables and statistical correction of those variables to observations or reanalysis
- 6-10 day and week-2 probabilistic precipitation and temperature forecasts
- Examining forecast skill at weeks 2, 3 and 4 in NCEP Climate Forecast System version 2

North American Ensemble Forecast System (NAEFS)

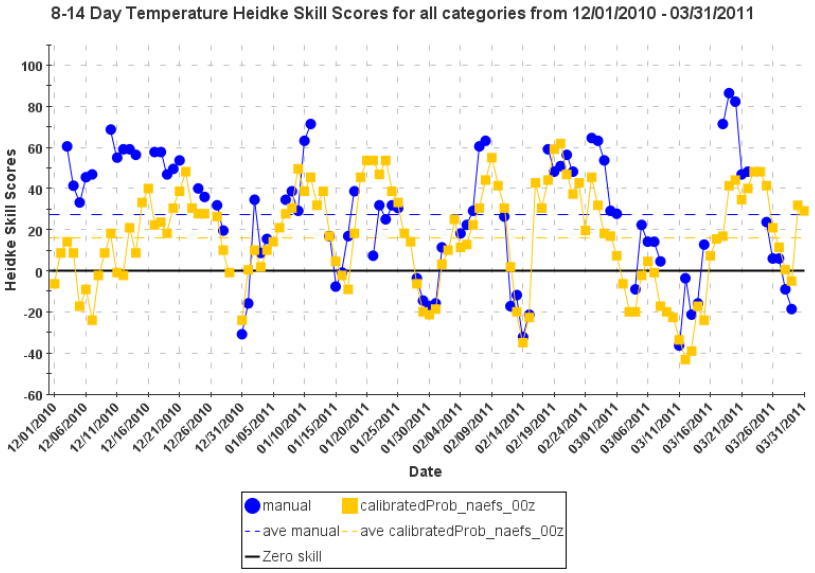
NAEFS Models:

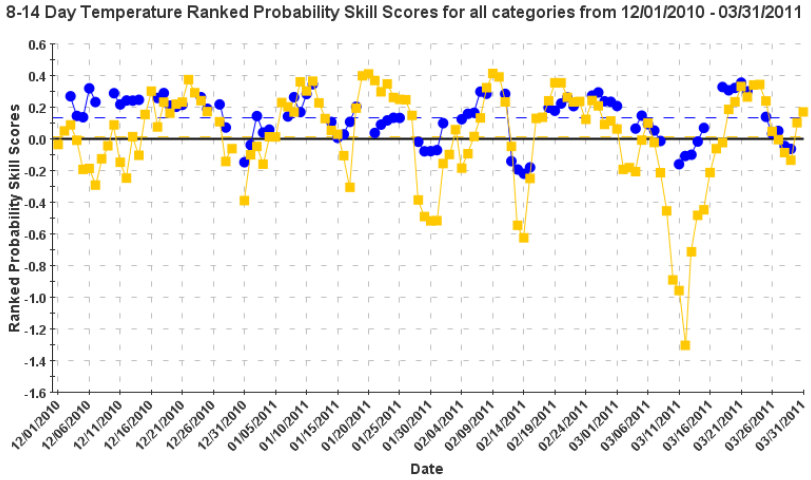
- NCEP Global Ensemble Forecast System (GEFS)
  - 20 members X 4 cycles per day
- Canadian Modeling Center ensemble prediction system (EPS)
  - 20 members X 2 cycles per day

NAEFS Forecast System:

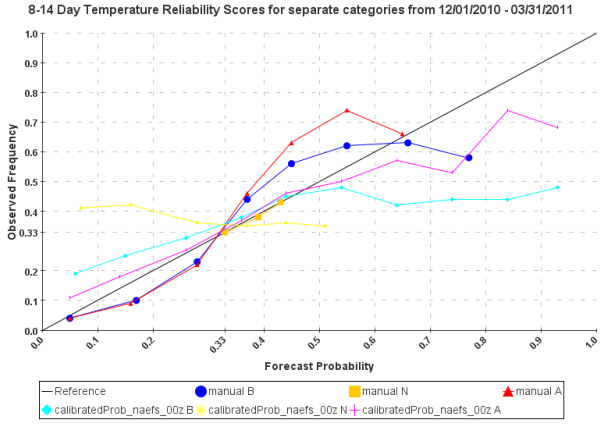
- Univariate bias correction of variables to model analysis
- Relatively short training data for adaptive system
- Bias adjustment can be spun up for model upgrades in relatively short time
- Bias = $\alpha\ (F_{-1} - O_{-1}) + (1 - \alpha\ )^{*}\ Bias_{-1}$

Winter (DJFM 2010-11) 8-14 day Temperature Forecast

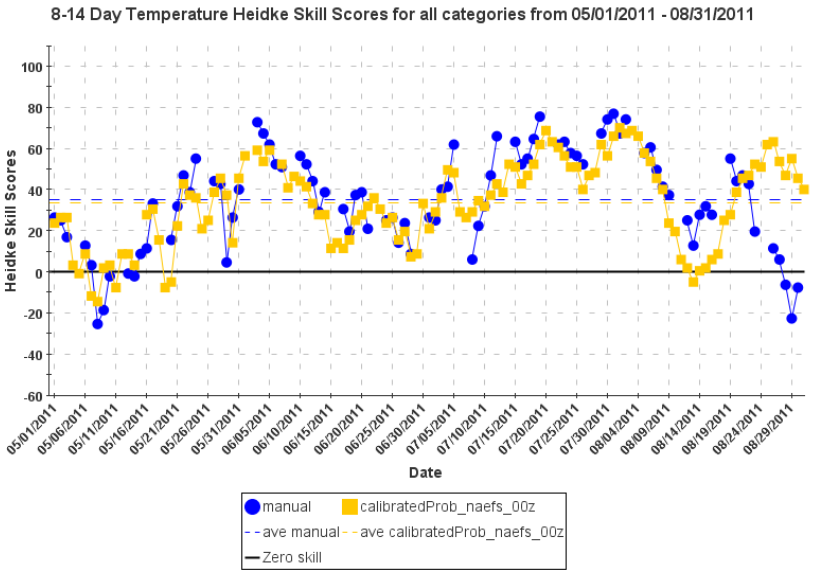


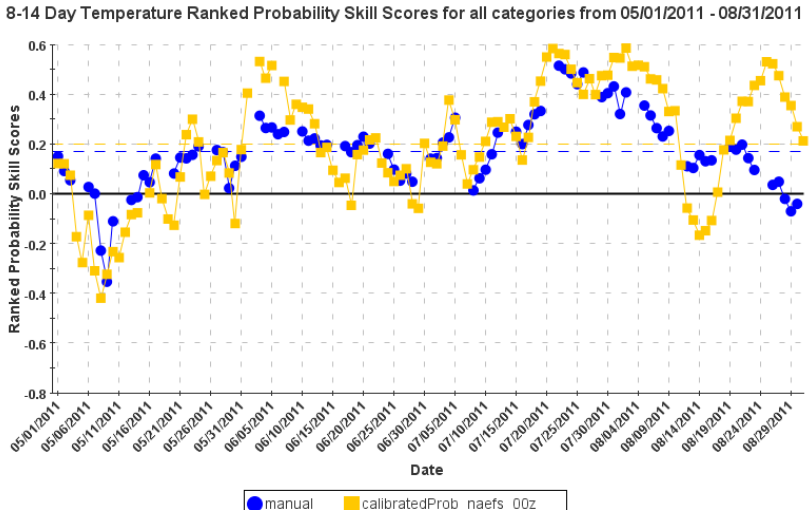


Temperature DJFM2011	8-14 day HSS	8-14 day RPSS
Manual	**27.1**	**.13**
NAEFS	**15.9**	**.01**

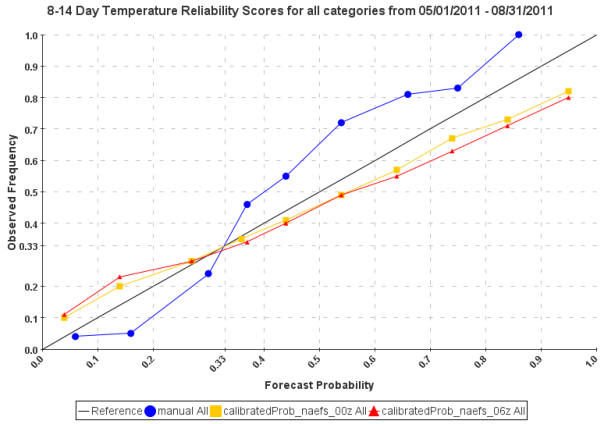


Summer (MJJA 2011) 8-14 day Temperature Forecast

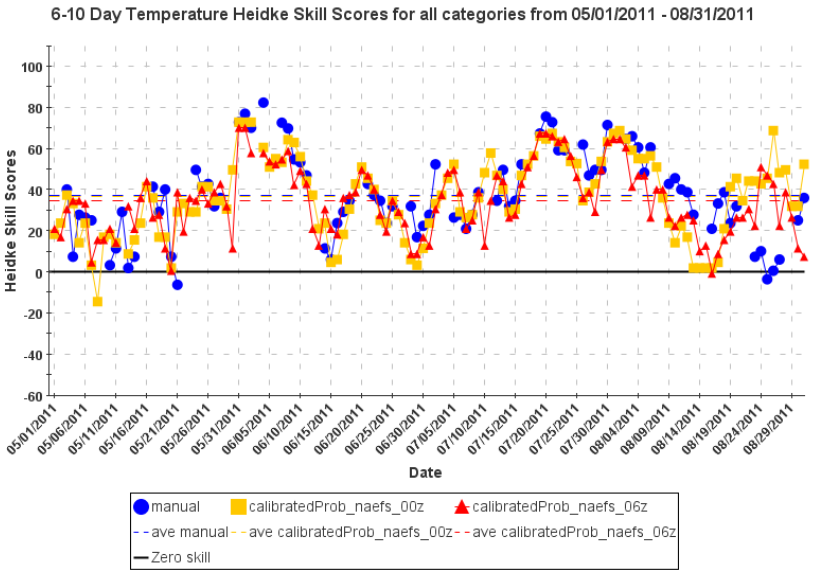


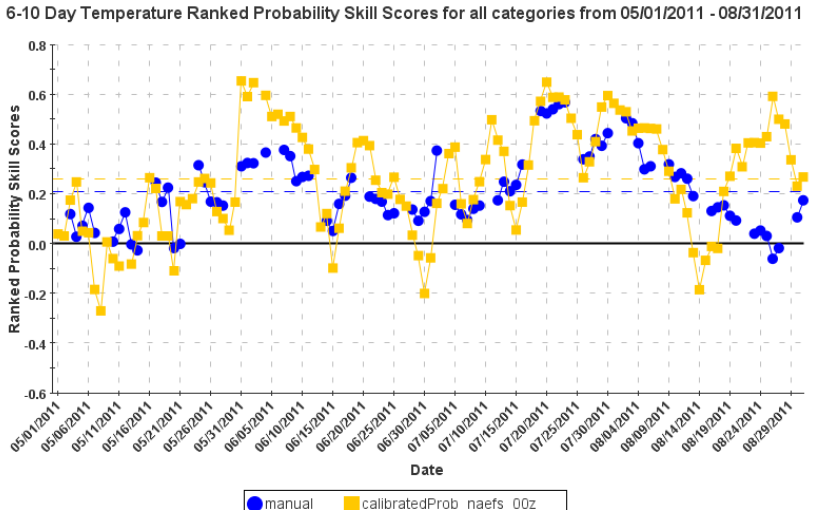


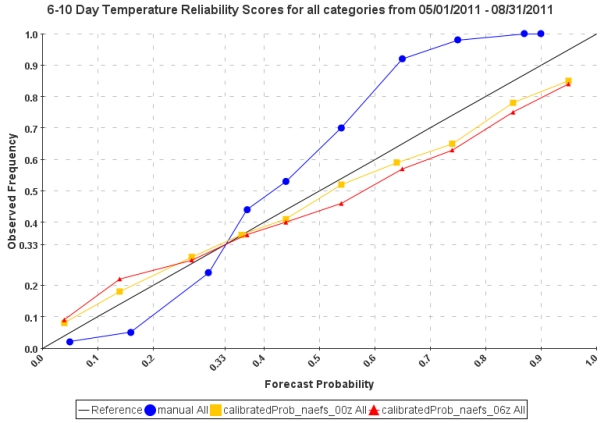
Temperature MJJA2011	8-14 day HSS	8-14 day RPSS
Manual	**35.1**	**.17**
NAEFS	**33.3**	**.20**
GEFS 06Z	**30.8**	**.17**



Summer (MJJA 2011) 6-10 day Temperature Forecast



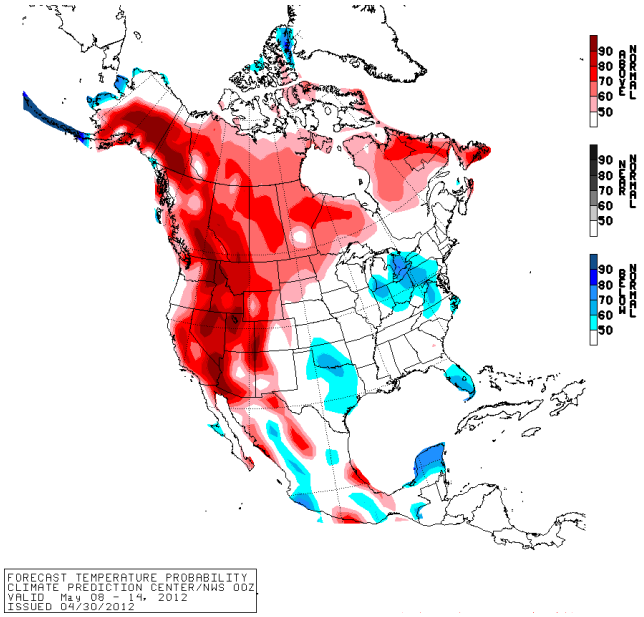




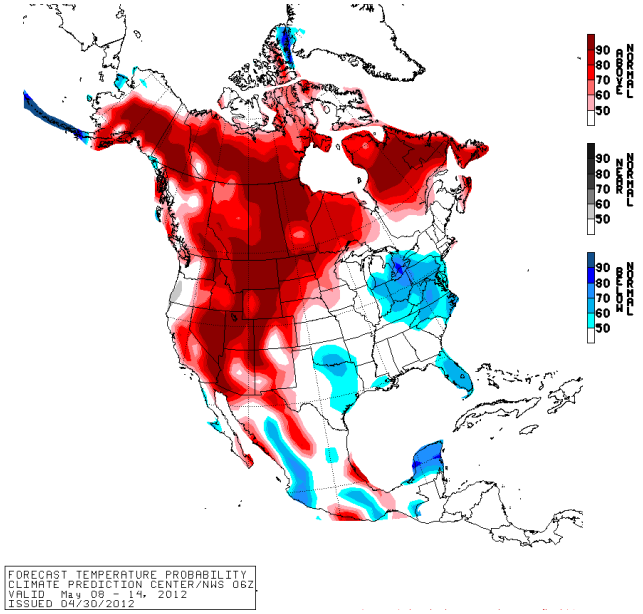
Temperature MJJA2011	6-10 day HSS	6-10 day RPSS
Manual	**37.2**	**.21**
NAEFS	**36.5**	**.26**
GEFS 06Z	**34.4**	**.23**

Week 2 Temperature using 2 Models or 1 model

Probability of Above, Near (gray) and Below Normal



00Z NCEP + Environment Canada



06Z NCEP Only (Note greater probabilities)

Motivation for using new retrospective forecasts

- First generation CDC/ESRL forecast tool still in use at CPC for extended range, running model more than 10-years old
- Shorter training data unable to fully capture model statistics and calibrate forecasts
  - Forecast reliability remains over-confident with under-dispersive ensembles and residual bias
- Bias estimate is always lagged from real-time forecasts, which can lead to seasonal cycle errors
- Limited independent cases for forecast-observation comparison of intraseasonal timescale variability

Potential use of new retrospective forecasts

Next generation NOAA GEFS reforecasts created by ESRL:

- Current operational NCEP Global Ensemble Forecast System (GEFS) as of 2012
- T254L42 (about ½ degree grid spacing) in week 1 and T190L42 (about ¾-degree) in week 2
- 10 perturbation ensemble members + control
- 1985-2010 (2011 to be added)
- Using Climate Forecast System Reanalysis initial conditions (now GDAS)
- Currently nine variables are archived at CPC
- Complete data available by ftp from ESRL

Comparison to CFSv2:

- T126L64
- 4 members x 4 cycles per day to 45-days lead in real time
- 4 members per day reforecasts
- 1999-2011

Methods

1. Ensemble Regression

- Currently used in CPC seasonal forecasts
- Regression statistics calculated from the ensemble mean apply to individual members after accounting for the ensemble spread
- Calculate statistics for 1985-2004 reforecasts:

  Y_{mean}, $Y_{variance}$, E_{spread}, R_{XY}, X_{mean}, $X_{variance}$

- $\sigma^2_{\text{Error variance}} = \sigma^2_{\text{Observed}} (1 - R^2)$

- $R_{\text{best member}} = R^2_{\text{mean}} / R_{\text{individual members}}$

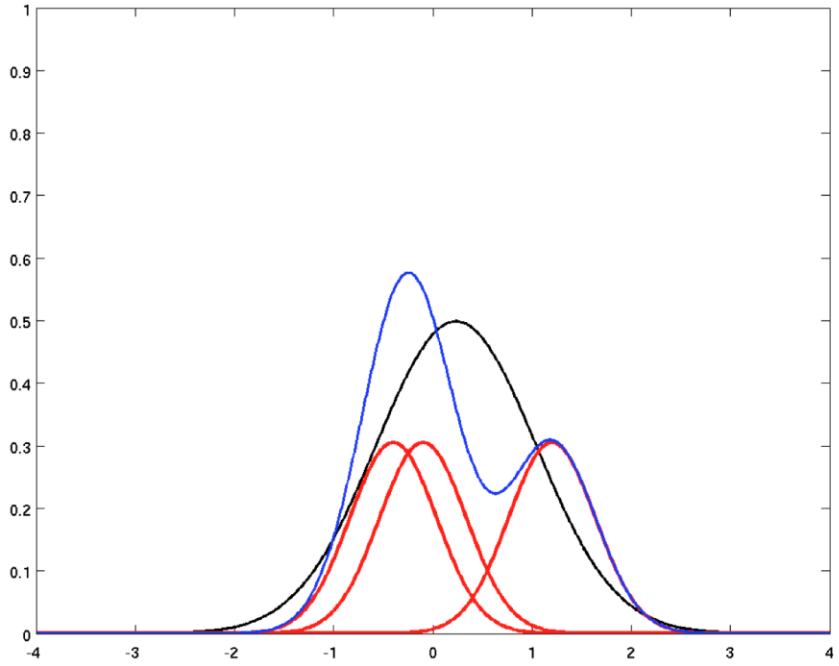
- Initial model fields are used as observation
  - Reduces issues in matching climatologies of forecasts and observations

Methods

1. Regression of ensemble mean
2. PDF correction using reforecast climatological mean and variance
3. Count-based ensemble derived PDF with kernel smoothing based on sample size

4. Climatology

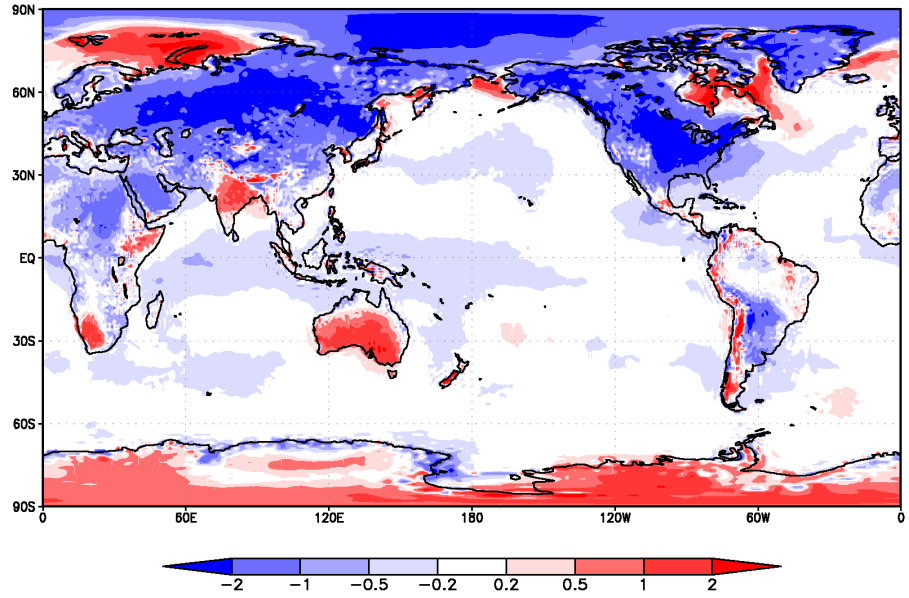
Example: Probability density functions based on linear regression



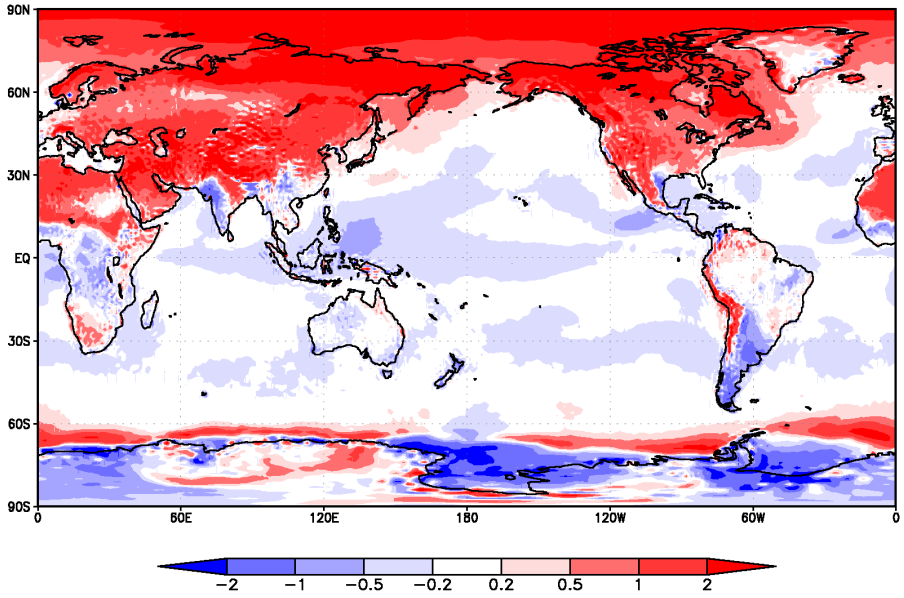
- Ensemble member forecasts
- Ensemble regression PDF
- Regression of ensemble mean

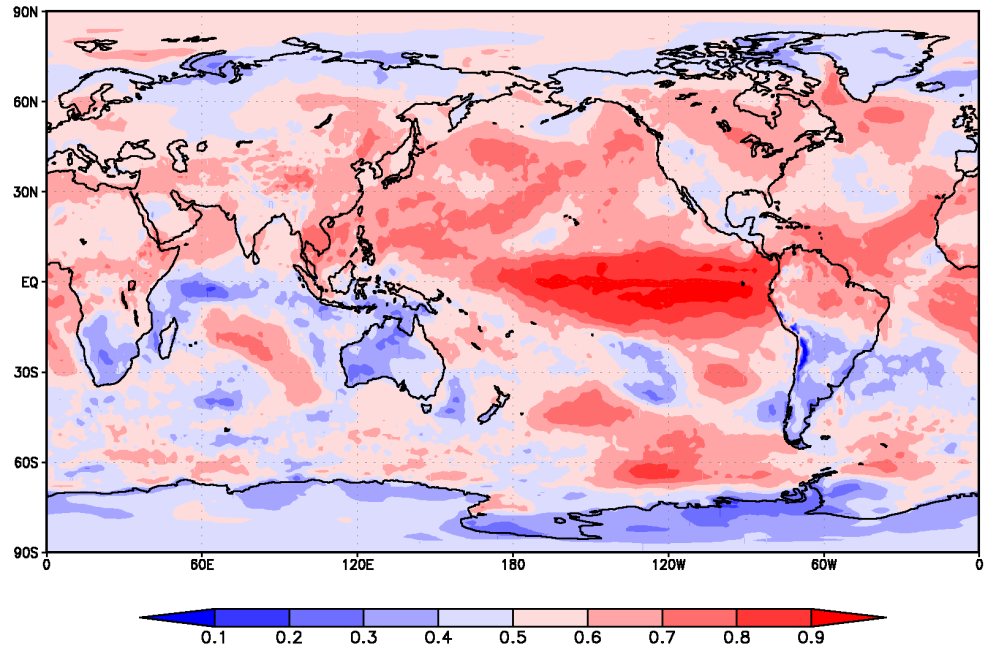
Mean bias

Winter



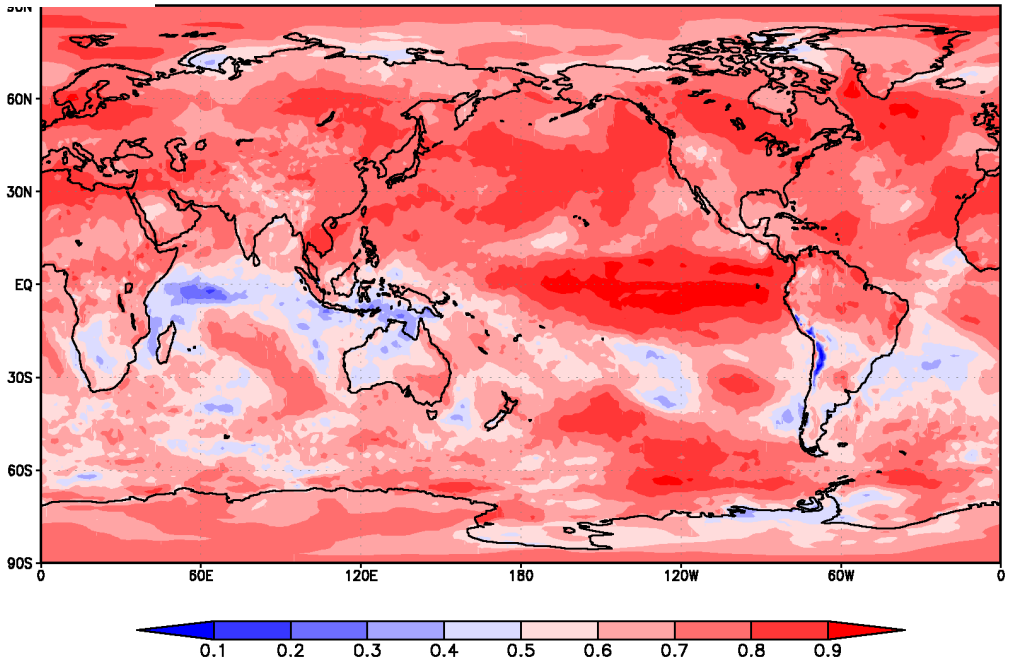
Summer



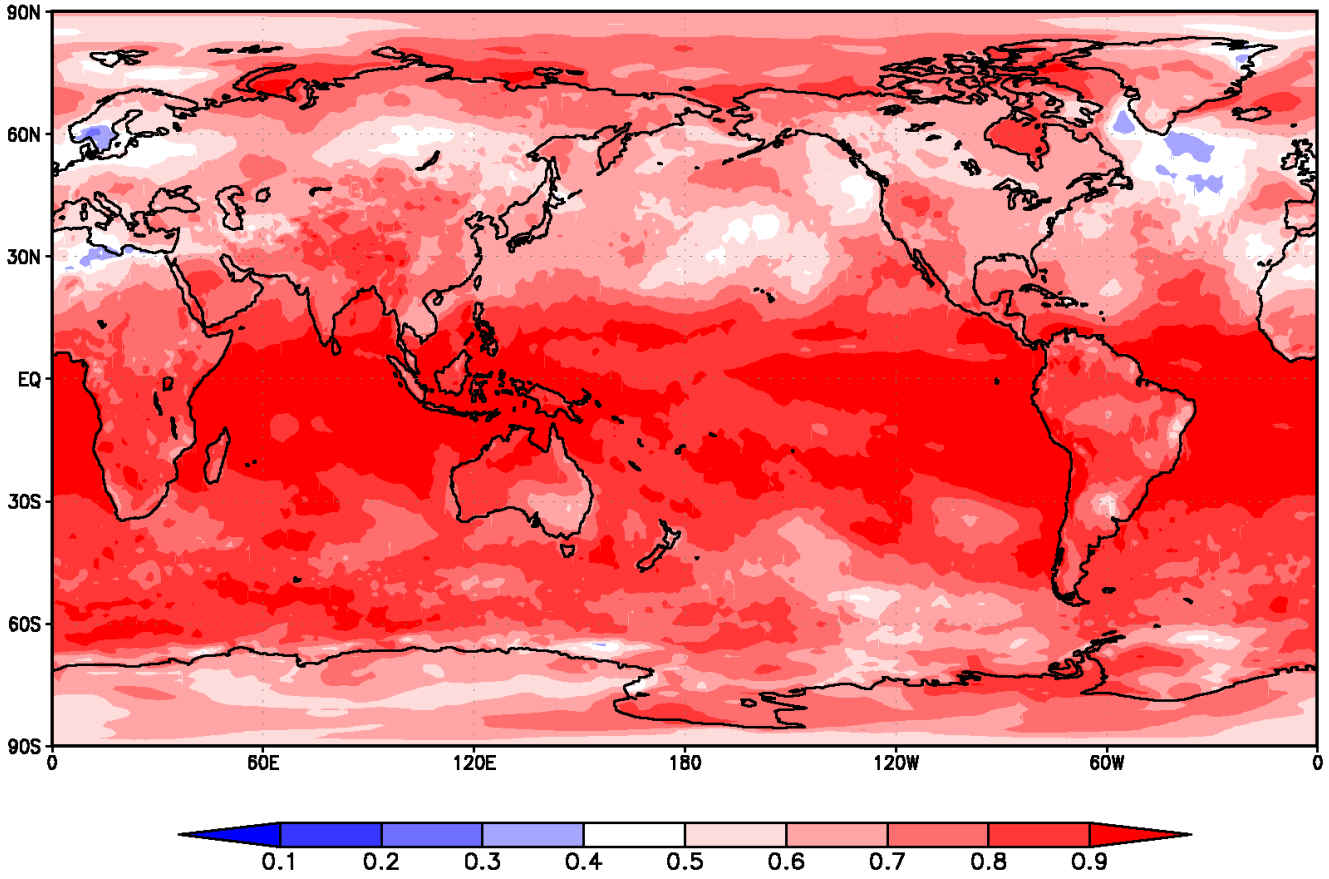


Mean Correlation

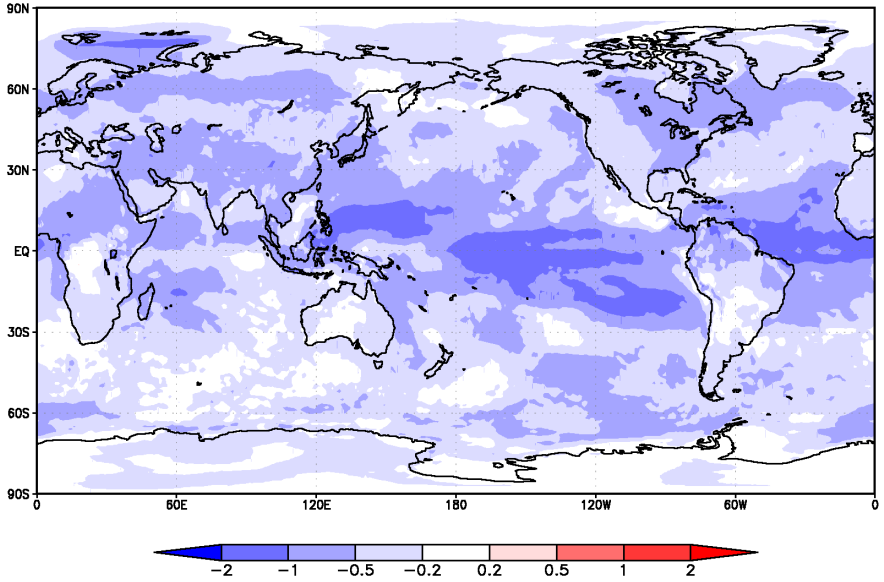
Best Member Correlation



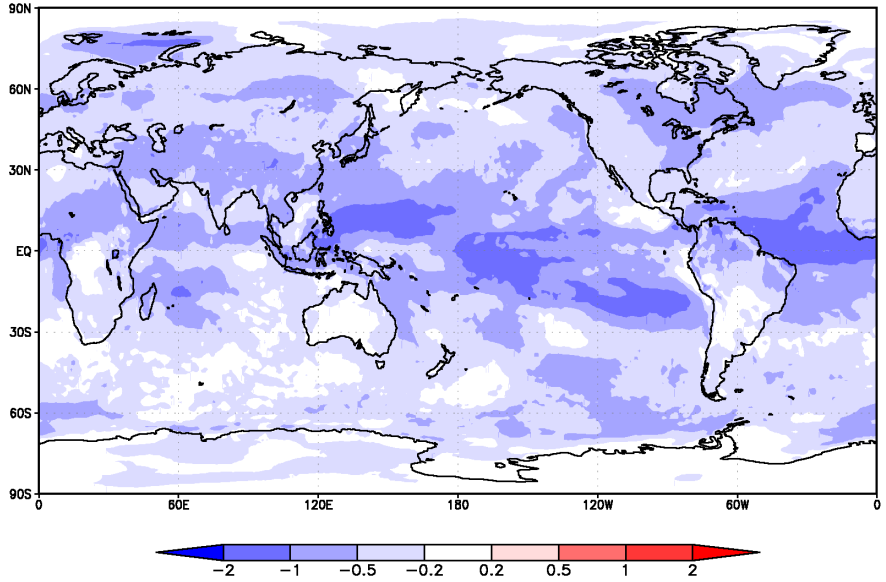
Ratio best member kernel width to mean error



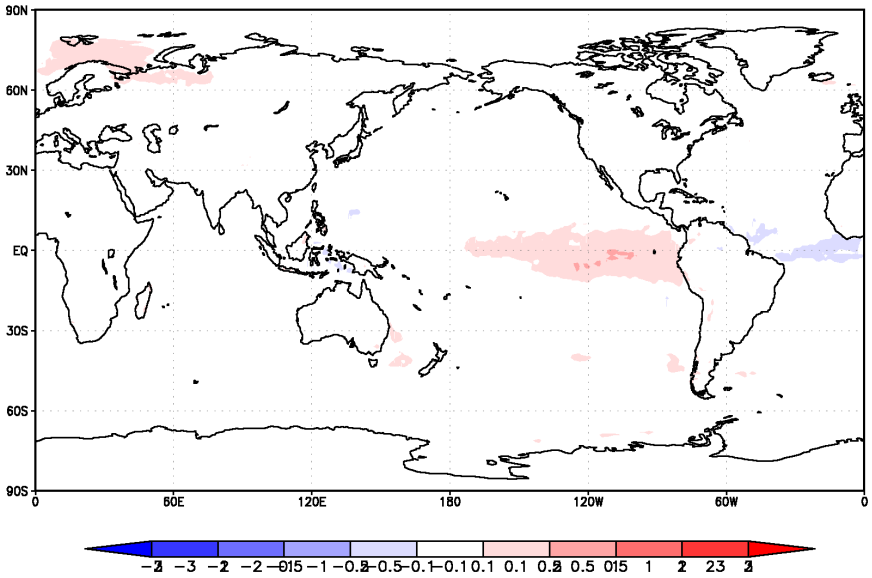
$CRPS_{mean} - CRPS_{clim}$



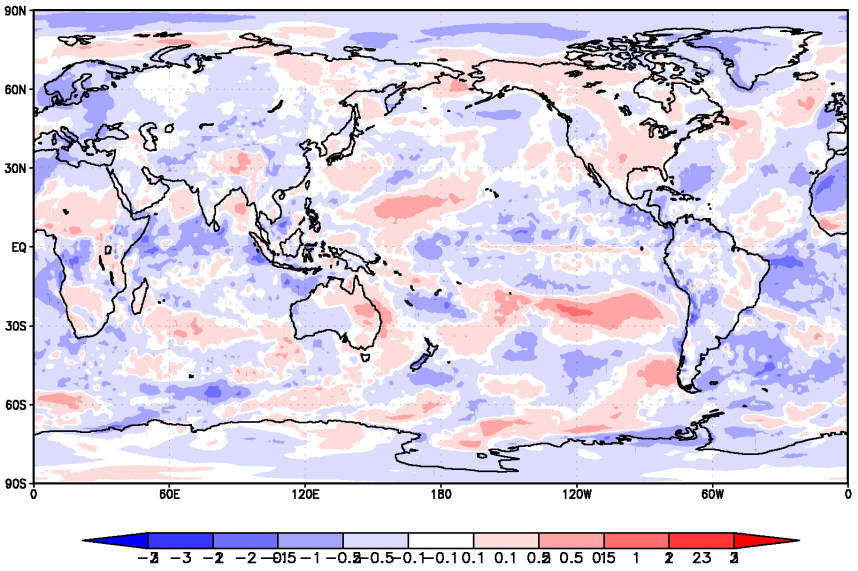
$CRPS_{ens\ reg} - CRPS_{clim}$



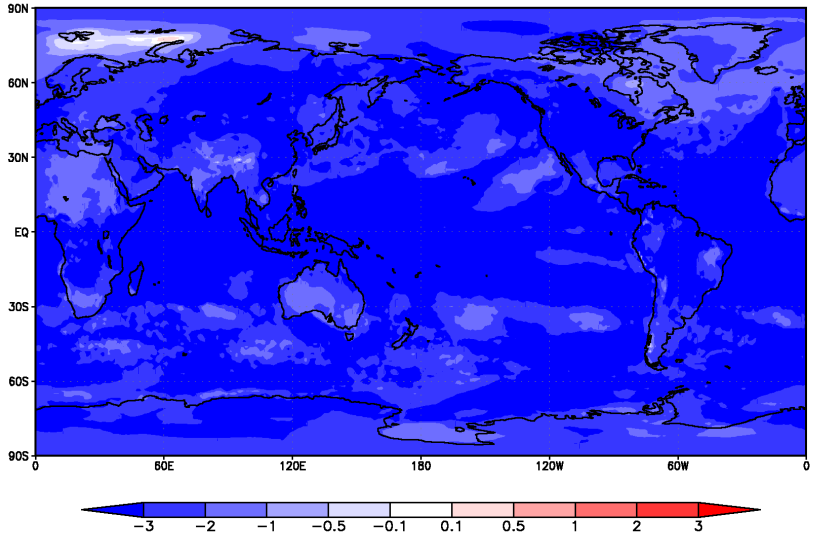
CRPS $_{ens\ reg}$ – CRPS $_{mean}$



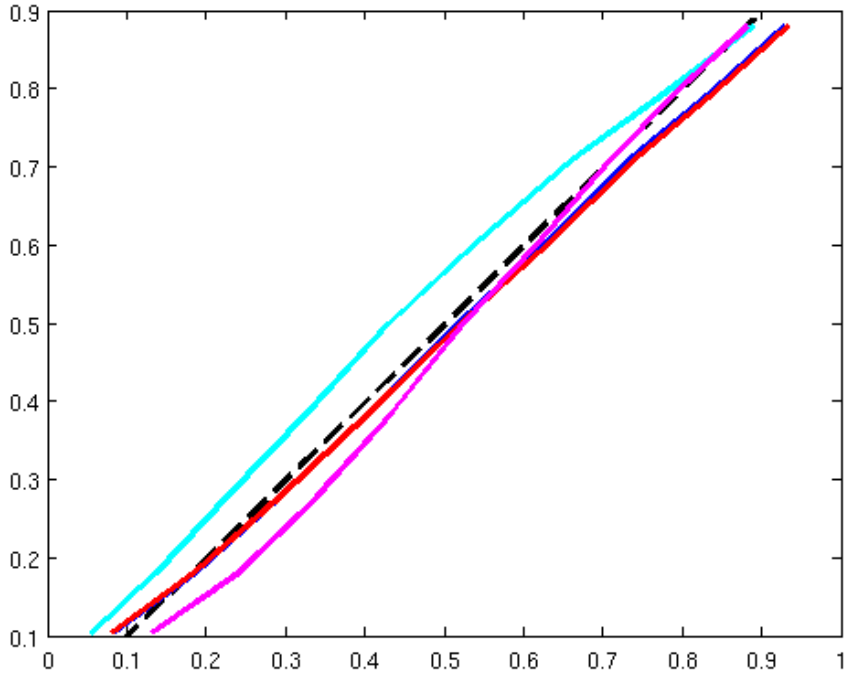
CRPS $_{ens\ reg}$ – CRPS $_{PDFcor}$



CRPS $_{ens\ reg}$ – CRPS $_{count}$

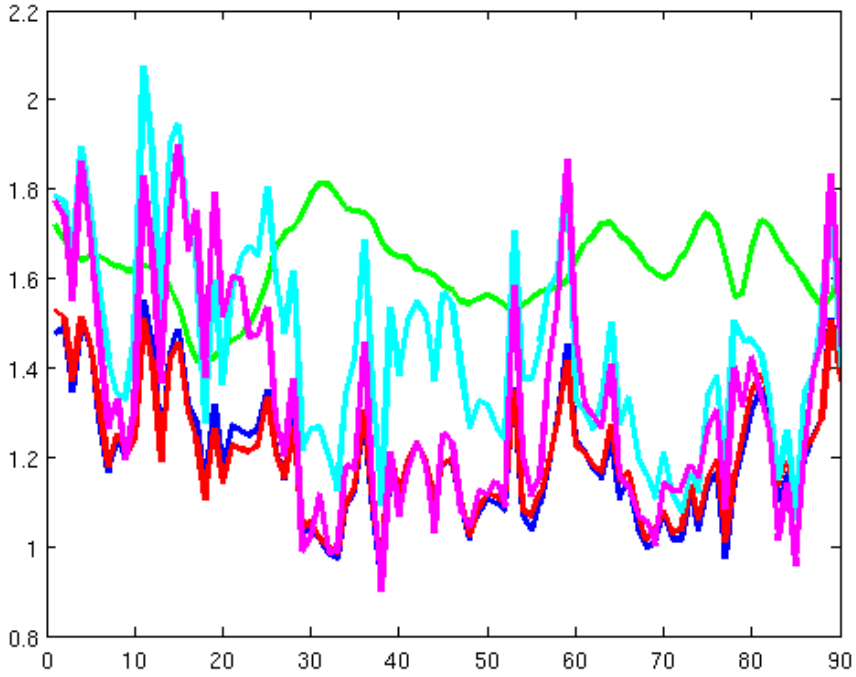


Reliability of percentiles of distribution



- Ensemble regression
- Regression of ensemble mean
- PDF correction of mean and variance
- Count based PDF with kernel sampling correction

CRPS time series for DJF 2005



- Climatological PDF forecast
- Ensemble regression
- Regression of ensemble mean
- PDF correction of mean and variance
- Count based PDF with kernel sampling correction

Conclusions

- Correction of week 2 temperature using the NOAA GEFS reforecasts shows large gains in skill over uncorrected model ensemble PDF
- Analysis of full PDF CRPS and reliability does not indicate any advantage of using individual members in ensemble regression over regression of the ensemble mean
  - Perhaps extremes and other variables may be different
- Regression has some advantage over a simple correction of model mean and variance biases

Next Steps

- Examine robustness of results to changes in the reforecast system: Fewer years or ensemble members
- Examine other variables and extremes
- Extensive data set will allow analysis of skill in relationship to climate modes, such as MJO