A Conditional Skill Mask for Improved Seasonal Predictions

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What is a Skill Mask?

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CFSv2 T2M Forecast

CFSv2 Forecast w/Skill Mask Applied

- Skill Mask is Determined from Re-forecasts
- Average anomaly correlation skill over 1982-2009
- Function of initial month and lead-time
- Average AC skill < 0.3 is considered not skillful

Skill mask is a simple model to forecast forecast skill

From NOAA/NWS/NCEP/CPC (http://www.cpc.ncep.noaa.gov/products/people/wwang/cfsv2fcst/)
Forecast Skill Varies From Year-to-Year Due to ENSO

Can we improve seasonal forecasts by creating a skill mask that is conditional upon ENSO?
Data & Methodology

Data

• CFSv2 Re-forecasts (24 ensemble members per month, 1982-2009)
• 0, 3, 6-month leads
• U.S. 2m Temperature & Precipitation

Perfect Model Approach

• Withhold one ensemble member as “truth” and determine forecast using the other 23 members. Repeat for all members.

• Expected Conditional (year-to-year) Anomaly Correlation for a given lead-time, based on the signal-to-noise ratio ($S$) and number of ensemble members:

\[
\begin{align*}
\rho_n(t) &= \frac{S^2(t)}{S^2(t) + 1} \left( S^2(t) + \frac{1}{n} \right)^{1/2} \\
S &= \frac{\|\text{ensemble mean anomaly}\|}{\|\text{ensemble spread}\|}
\end{align*}
\]
“Unconditional” or Average Correlation Skill
0-month lead CFSv2 Perfect Model Forecasts (1982-2009)
2m Temperature
Conditional (Year-to-Year) Perfect Model Skill: 0-lead, 2m Temperature

**Conditional**

**Unconditional**

**Ratio of Conditional to Unconditional**
Is Nino3.4 a good predictor of Forecast Skill?

Regression model of Perfect Model Conditional Forecast Skill with Nino3.4 as a predictor:

\[ y_{i,j,l}(\text{seas, year}) = m_{i,j,l}(\text{seas}) \times x_l(\text{seas, year}) + b_{i,j,l}(\text{seas}) \]

\(i=\text{lons}, \ j=\text{lats}, \ l=\text{lead-time}\)

\(Y=\text{Perfect Model Forecast Skill (Anomaly Correlation)}\)

\(X=\text{ABS(Nino3.4)}; \ \text{simultaneous ensemble mean forecast}\)
Regression between Conditional Skill and ABS(NINO34) (units: correlation/std)

0-month lead; 2m Temperature
Is There a Better Predictor?

Variance Explained (%)

PC1
- 50%
- 25%
- 0%

PC2
- 50%
- 25%
- 0%

PC3
- 50%
- 25%
- 0%

EOFs Dec-Jan-Feb

PC Timeseries

Dec-Jan-Feb
Mar-Apr-May
Jan-Jul-Aug
Sep-Oct-Nov
Is PC1 a good predictor of Forecast Skill?

Regression model of Perfect Model Conditional Forecast Skill with PC1 as a predictor:

\[ y_{i,j,l}(\text{seas}, \text{year}) = m_{i,j,l}(\text{seas}) \times x_{i,j,l}(\text{seas}, \text{year}) + b_{i,j,l}(\text{seas}) \]

\[ i=\text{lons}, \; j=\text{lats}, \; l=\text{lead-time (0-month lead)} \]

\( Y= \text{Perfect Model Forecast Skill (Anomaly Correlation) } \)

\( X= \text{ABS(PC1); simultaneous ensemble mean forecast} \)
Regression between Conditional Skill and ABS(PC1) (units: correlation/\text{std})
0-month lead; 2m Temperature
Signal vs. Noise

ENSO

Temperature

Non-ENSO

Temperature

Precipitation

Regression Coefficient

| -0.2 | -0.15 | -0.1 | -0.05 | 0.05 | 0.1 | 0.15 | 0.2 |
Regression Model RMSE Fit

Temperature (deg C)  Precipitation (mm/day)

0-month Lead

3-month Lead

6-month Lead

Initial Month

- Average
- Nino34
- PC1
- PC1+PC2
- PC1+PC2+PC
Regression Model Cross-Validated Skill

Temperature (deg C)

Precipitation (mm/day)

0-month Lead

3-month Lead

6-month Lead

Initial Month

Average
Nino34
PC1
PC1+2
Perfect Model Tercile Seasonal Forecasts (T2M)
Non-EC Heidke Skill Score (shaded)
Percent of Forecasts that are EC (contours)
Real World Tercile Seasonal Forecasts (T2M)

Non-EC Heidke Skill Score (shaded)
Percent of Forecasts that are EC (contours)
Perfect Model Tercile Seasonal Forecasts (Precip)

Non-EC Heidke Skill Score (shaded)
Percent of Forecasts that are EC (contours)
Real World Tercile Seasonal Forecasts (Precip)

Non-EC Heidke Skill Score (shaded)
Percent of Forecasts that are EC (contours)
Conclusions

1. Nino3.4 does not appear to be an ideal predictor of forecast skill for T2M because it cannot capture growing and decaying states of ENSO.

2. A seasonal EOF-based ENSO predictor is slightly better than Nino3.4 at predicting T2M and Precip perfect model skill for some seasons.

3. An average model is as good as or better than an ENSO-based regression model in predicting perfect model forecast skill.

4. Including higher PCs does not improve the regression model’s ability to forecast forecast skill.

1. When the average and conditional masks are applied to probabilistic seasonal tercile forecasts the ENSO-based skill masks appear to offer some benefit over an average skill mask, although this varies with lead-time and region (and maybe season?).

2. At longer leads the ENSO-based masks have regions of both large forecast skill improvement and large forecast busts when compared to the average skill mask. It is not clear if this would be beneficial in an operational forecast environment.