GEOS seasonal forecast systems: ENSO prediction skill and biases. Two system versions, two time periods.

Anna Borovikov, Jelena Marshak, Andrea Molod, Robin Kovach

GMAO
Global Modeling & Assimilation Office

Motivation

This study aims to document, compare and contrast the differences in prediction skill of the GEOS seasonal forecast system over the two periods: 1982-1998 and 1999-2016. The systematic biases are different over these periods due to various factors, and properly accounting for them is important in estimating the forecast skill.

Model, data, experiment

The current version of the S2S forecast system (referred to as GEOS-S2S-2) is considered an interim system (while the new version 3 is being developed) is a significant upgrade from the previous system (GEOS-S2S-1, in service 06/2012-01/2018).

The ensemble of experiments for the seasonal forecasts were initialized on a fixed set of calendar dates for both systems. These dates begin on Jan 1, and are 5 days apart. All seasonal forecasts are initialized on the last 4 start dates of the month. For the retrospective seasonal forecasts, no additional ensemble members were generated for GEOS-S2S-2 with perturbed initial states. Thus only a lagged ensemble of 4 for any month was considered for this study for either system.

Initial conditions for the retrospective seasonal forecasts for GEOS-S2S-2 were generated using a suite of 5-day long coupled data assimilation runs using the GEOS-S2S-2 ODAS, initialized at 5 day intervals from the GEOS-S2S-1 coupled reanalysis initial states. Consequently the initial conditions for retrospective forecasts are fairly similar for both systems.

The major upgrades in GEOS-S2S-2 coupled model include post-MERRA-2 atmospheric component at 0.5° horizontal resolution (vs pre-MERRA-2 model at 1°) and MOM5.0 ocean component (vs MOM4.1).

E-mail: anna.borovikov@nasa.gov | *Web:* gmao.gsfc.nasa.gov

Telephone number: +1-301-614-6030

Observed SST 1982-1998 vs 1999-2016

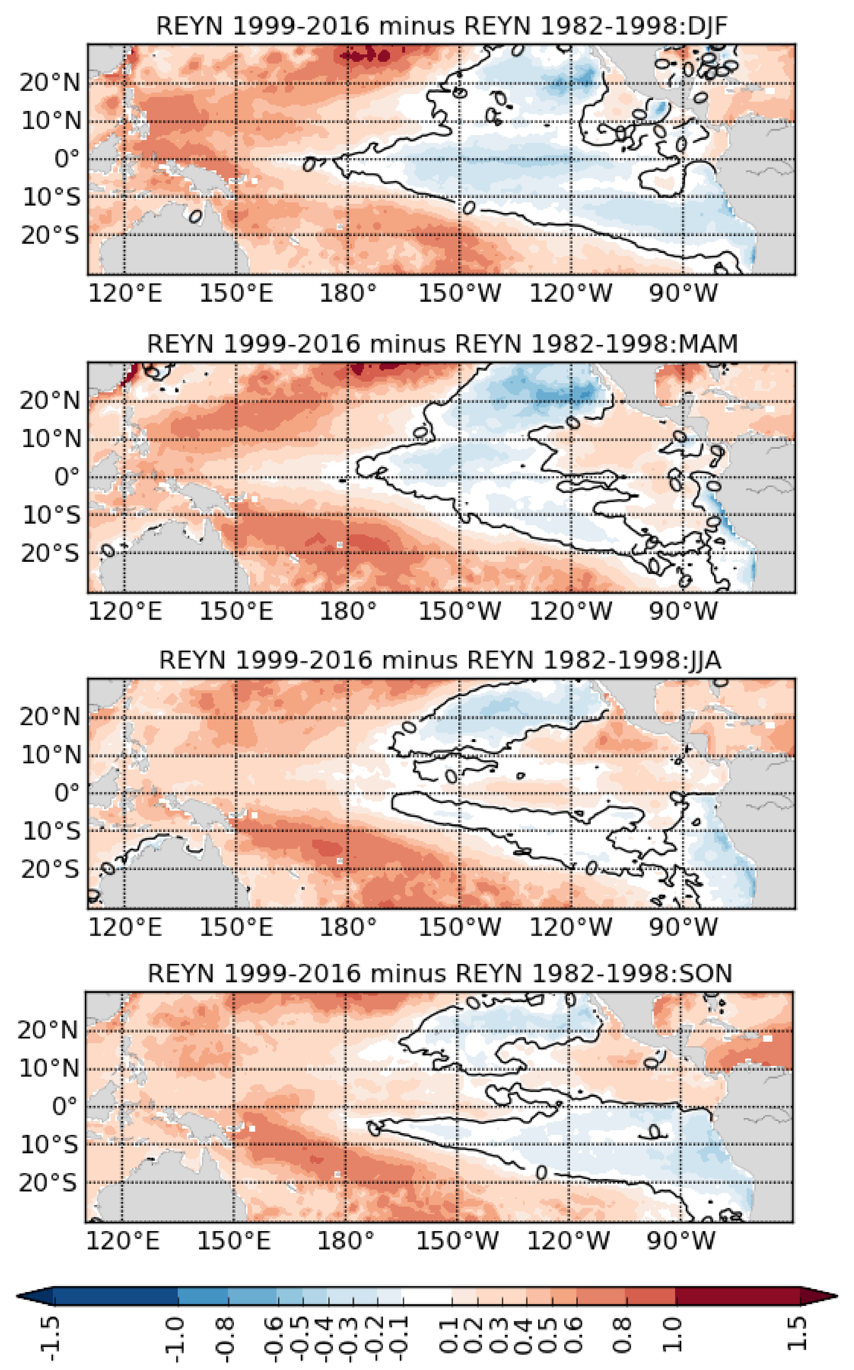


Figure 1: Reynolds SST used as ODAS observations for the initialization of the seasonal hindcasts/forecasts, and as SST validation. Shown here is the difference between the mean tropical Pacific Ocean SST values over 1999-2016 and 1982-1998 periods for four seasons.

Tropical Pacific Ocean SST observations show a warming trend from the earlier to the most recent period, although the spatial pattern of the warming is not uniform with greater values in the western equatorial region and off the equator in the western and central regions. The Niño 3.4 region exhibits mixed tendencies: slight cooling in the boreal winter and spring and slight warming along the equator in summer and autumn, while the off-equatorial areas east of 160°W are cooler in the mean during the later period.

Niño 3.4 forecast bias

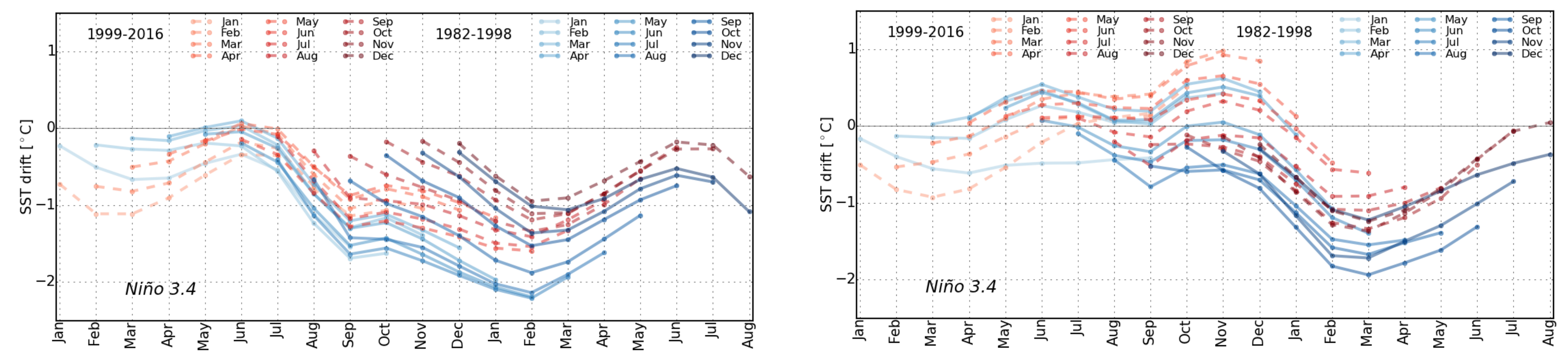


Figure 3: GEOS-S2S-1 on the left, GEOS-S2S-2 on the right

GEOS-S2S-1 is biased cold throughout the year. The GEOS-S2S-2 mean forecast error varies seasonally about zero, especially during the later period.
A common feature to both GEOS-S2S-1 and GEOS-S2S-2 is a large cold bias during the Jan-Feb-Mar season, particularly exaggerated in the earlier period. This bias shows faster initial growth during the later period, but its maximum amplitude is still smaller even at long leads.

Forecast Skill

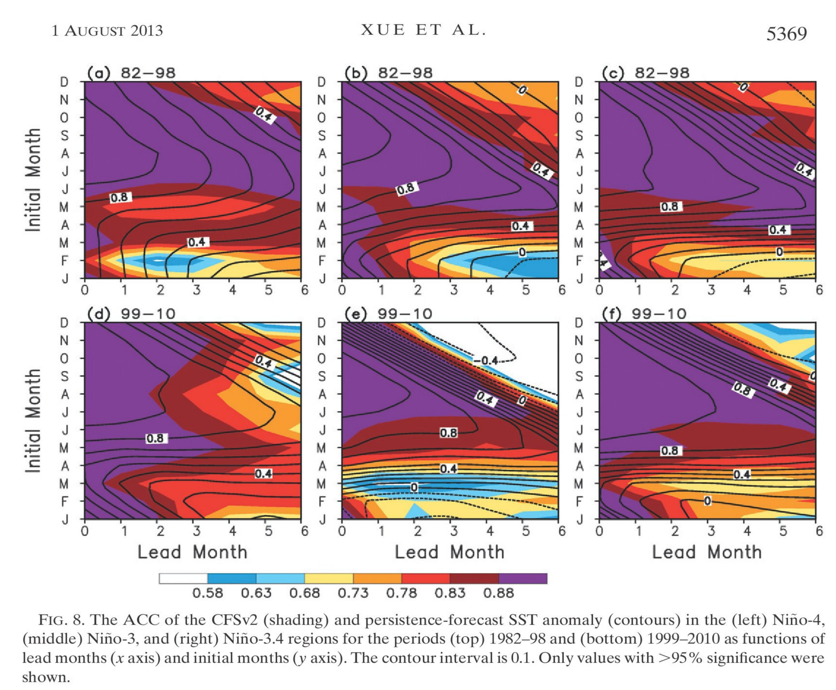
Anomaly Correlation Coefficient (ACC) is used as a measure of potential skill and Mean Square Skill Score (MSSS) as a measure of actual skill. MSSS is computed with respect to climatology.

$$MSSS_{clim}=\frac{MSE_{clim}-MSE_{fcst}}{MSE_{clim}},\ where\ MSE_{\substack{fcst\\ [clim]}}=\frac{1}{n}\sum_{i=1}^{n}\left(T_{\substack{fcst\\ [clim]}}(i)-T_{obs}(i)\right)^2$$

Here $T_{fcst}(i)$ is the temperature anomaly of the *i*-th hindcast and $T_{clim}(i)\equiv 0.$

Potential predictability P computed as the anomaly correlation for a case of one of the ensemble members treated as observations, averaged over all possible combinations of ensemble members.

$$P=\langle AC(T_i,\langle T_{N\setminus i}\rangle)\rangle \qquad ACC=\langle AC(\langle T_N\rangle ,T_{obs})\rangle$$



The paper by Xue et al. (2013) was an inspiration for this study. Similar characteristics of ACC skill were found for the CFSv2 and GEOS-S2S-1 and S2S-2 SST forecasts.

Niño 3.4 ACC, MSSS, predictability skills

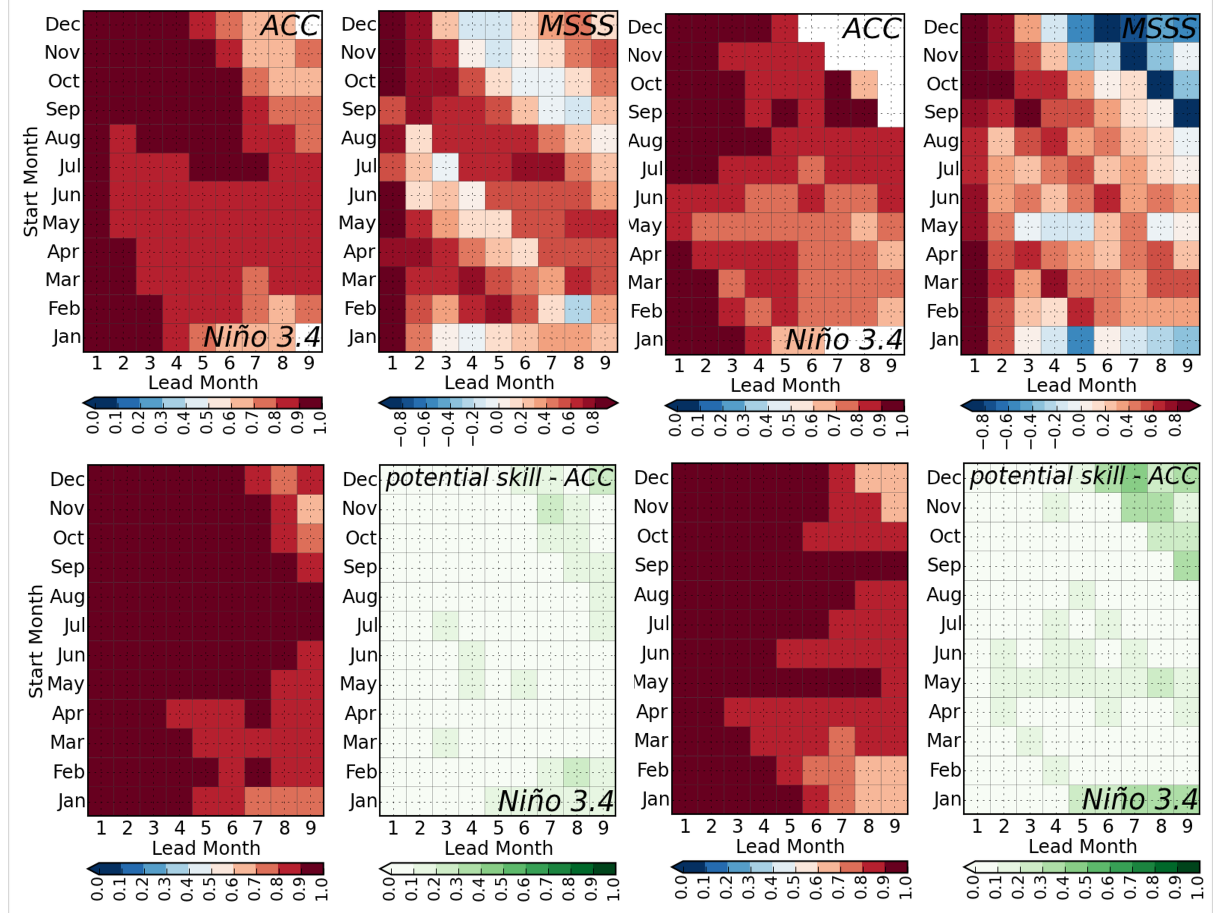


Figure 4: DEOS-S2S-1 Left: 1982-1998 and right: 1999-2016 periods.

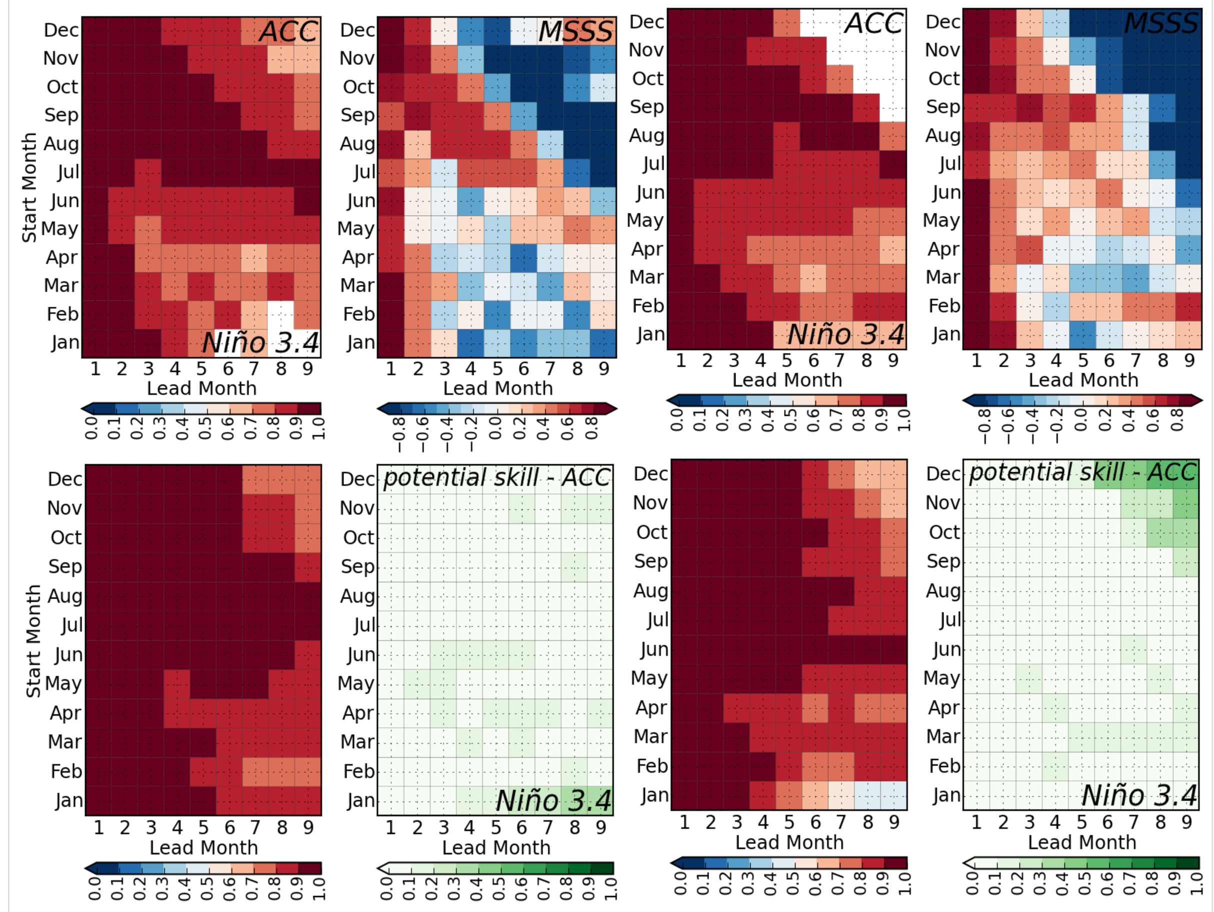


Figure 4a: GEOS-S2S-2 Left: 1982-1998 and right: 1999-2016 periods. Figures 4 and 4a show SST ACC and MSSS for the Niño 3.4 index at the top row. The Pearson correlation significance test with p-value at 0.01 is applied to the ACC. Bottom row: potential predictability P, and the difference with the ACC, shown shown just above it.
The left columns are for the 1982-1998 period, the right for the 1999-2016. Forecast start months are along the y-axis and lead months are along the x-axis.

References

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Conclusions

Both versions of the GEOS S2S systems show reduction in ENSO ACC skill during 1999-2016 compared to 1982-1998 with the spring barrier being even more pronounced during the later period than during the earlier period. The difference between potential skill and ACC leaves room for improvement.

Acknowledgement

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