GMAO Seasonal Forecast Ensemble Exploration

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Model, data, experiment

The GMAO coupled global seasonal forecast system S2S version 1 has been in service from June 2012 through January 2018 (Borovikov et al. 2017). The S2S version 2 came into production in December 2017. For 35 years, every 5 days, a 9-month coupled seasonal hindcast has been run for both versions, allowing for evaluation of the forecast skill and a study of various characteristics of the ensemble forecasts in particular.

The AGCM component of version 1 is Fortuna-2.5 (at 1° × 1¼° horizontal resolution). For version 2 the AGCM is Heracles-5_4_p3 (at ½° horizontal resolution), both at 72 hybrid vertical levels. The OGCM component has been upgraded from Modular Ocean Model version 4 (MOM4) for version 1 to MOM5 (Griffies, 2012) for version 2, both at ½° horizontal resolution with a meridional equatorial refinement to ¼° and 40 vertical levels.

Motivation

Studying the characteristic of an ensemble forecast system we attempt to answer several questions:

- Consistency: do the observations statistically belong to the distributions of the forecast ensembles?
- Is the ensemble spread an indicator of forecast uncertainty?
- To what extent is the ensemble spread related to the model's climatological variability and is that variability realistic?

Rank Histogram as a measure of ensemble consistency

For the computations described here we assembled a sample of 135 instances of 4-member ensembles by combining all winter forecasts for 35 years.

Fig. 1.Rank Histogram helps to answer the "consistency" question. The closer the ensemble distribution to the perfect flat histogram, the more consistent is the ensemble. Shown here are rank histograms for Niño4, Niño3.4, Niño3 and Niño1+2 SST indices winter hindcasts for leads 1,3 and 6 months.

Mean intra-ensemble standard deviation vs the standard error of the estimate *(SEE)* as a measure of forecast uncertainty

Let SDy be the standard deviation of the observation *(y)*, cor_{xy}^2 the squared correlation between the ensemble mean forecast *(x)* and the observation, *σ* the standard deviation of the intra-ensemble spread, then $SEE = SDy\sqrt{1-cor_{xy}^2}$ and *R = σ/SEE*, which should be close to 1 for a perfect model:

if *R < 1* the model is under dispersive

if *R > 1* model is over dispersive

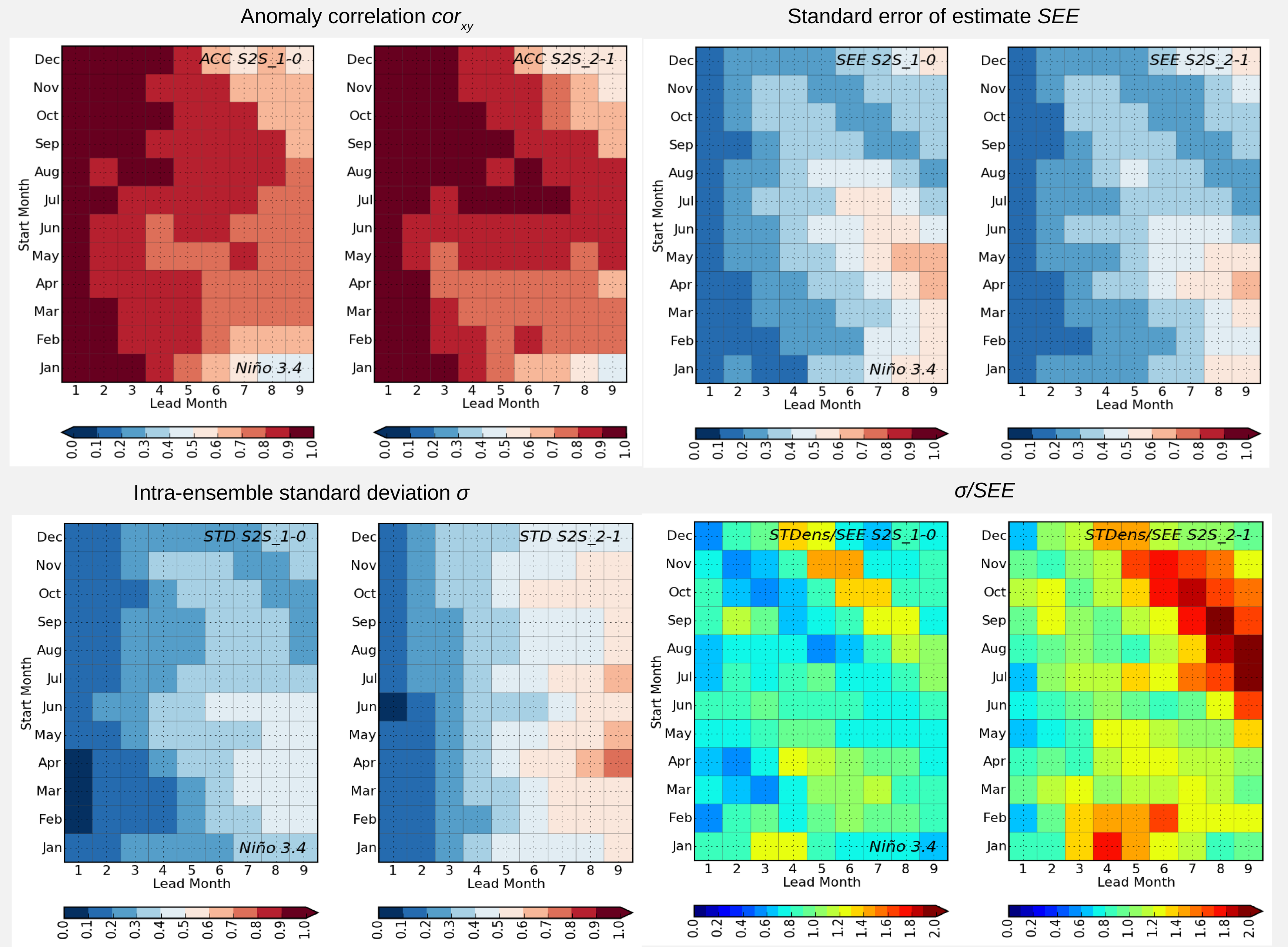

Fig. 2. Shown here are the four quantities described above for both forecast system versions for for Niño3.4 SST, all initial months, all leads.

Climatological variability represented by the ensemble spread

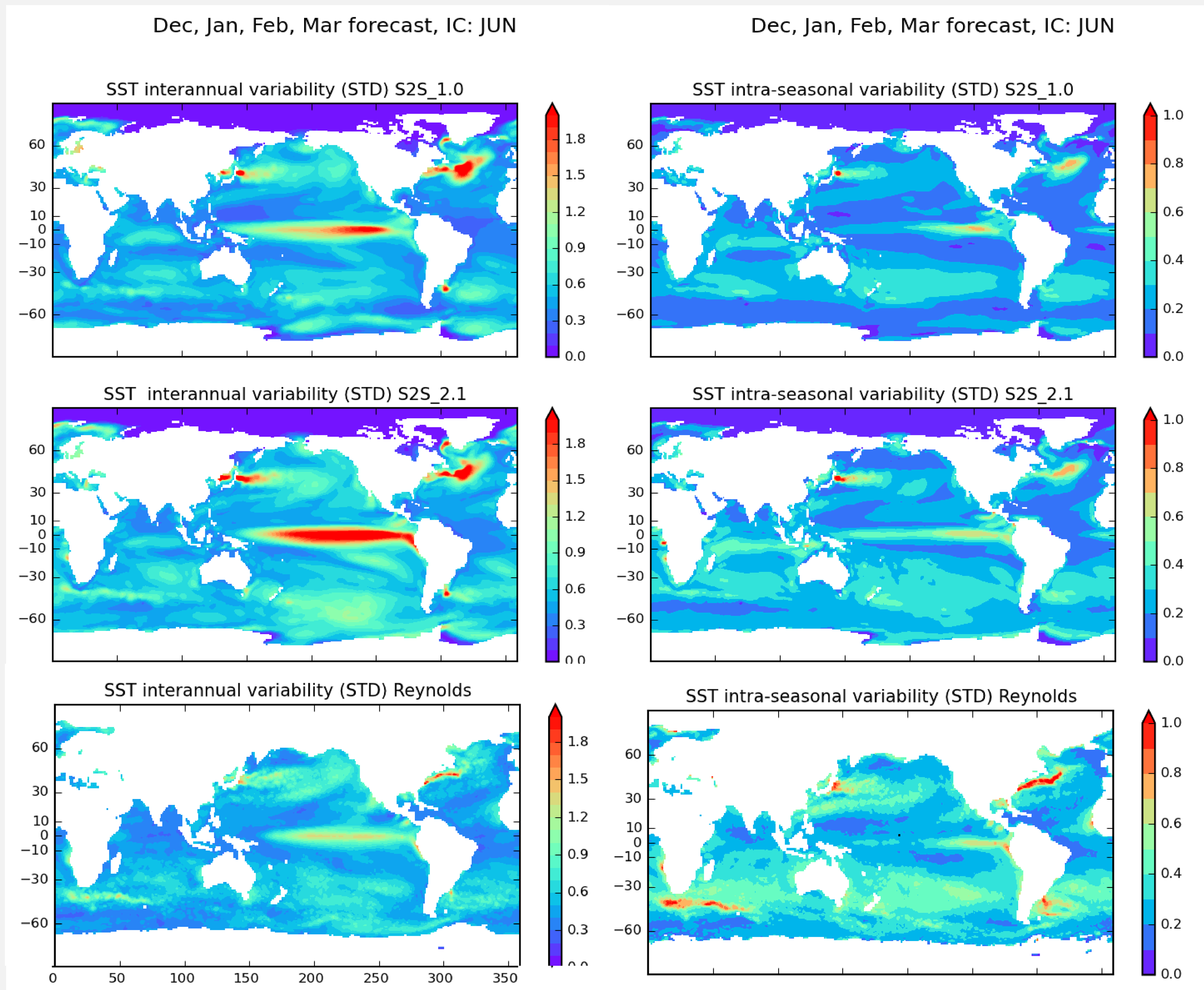

Fig.3. Focusing on the extended cold season December-March, we show interannual (left) and intra-seasonal (right) variability from the ensemble of hindcasts initialized in June for version 1 (top), version 2 (middle row) and compare it to the observed variability computed using Reynolds SST (bottom).

Conclusions

While the results are based on a small ensemble size, all indications are that the version 2 model has increased dispersion (intra-ensemble spread) compared to version 1.

- The marked reduction in the forecast bias in the version 2 (indicated by the rank histogram) for the eastern equatorial Pacific SST can be attributed to the new AGCM cloud physics.
- The version 2 system appears to be over-dispersive in Niño3.4 SST index when comparing with the forecast error at long leads verifying in spring (possibly linked to excessive ENSO variability in spring when observations show reduced variability).
- The version 2 system tends to be slightly under-dispersive at short (1 month) leads, though still better than version 1 – perhaps an indication that the initial errors are too small or don't project sufficiently on the growing modes of SST.
- The DJFM intra-seasonal SST variability appears to be more realistic (greater) in version 2, consistent with the increased dispersion in this system.
- The version 2 system has excessive interannual SST variability especially over the tropical Pacific (possibly linked to strong or overactive ENSO).

References

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