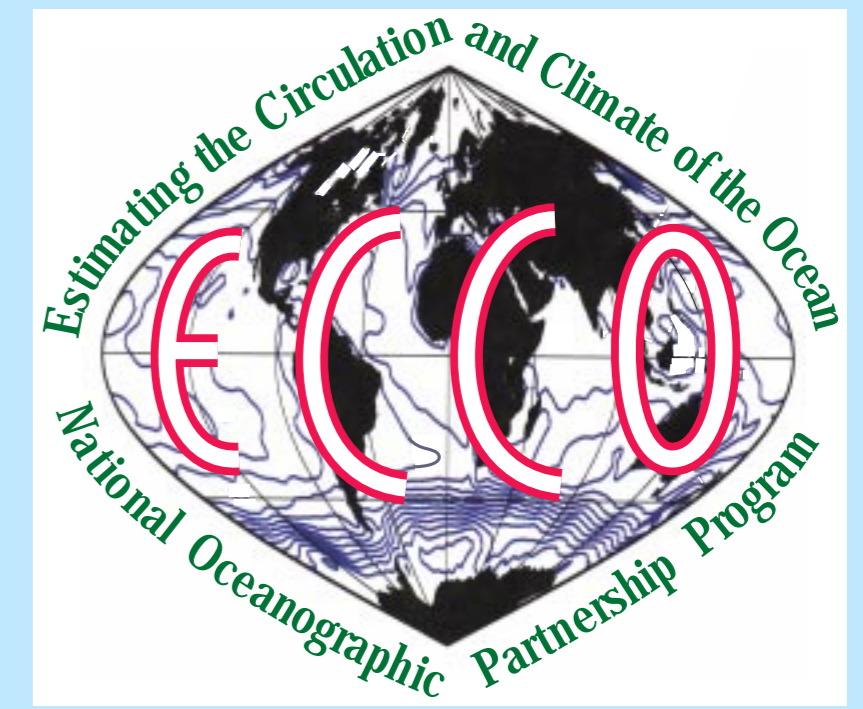


by

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Statistical limitations

The statistical atmosphere applied to the control hindcast run was derived from the years 1970 to 2000 using Reynolds SST fields and NCEP reanalysis wind stress fields. However, during the forecast we need to evaluate a new statistical relation between SST and windstress, but now using the simulated SST fields from the control hindcast. Those new statistics accounts for model biases on seasonal and longer timescales. For the optimization hindcast we can only use 9 years. The limitations that arise from this limited statistics is the subjected of this section.

Generally, any forecast skill using a statistical atmospheric model is effected by two limiting factors: a limited length of time over which the statistics for the SST-wind relation were derived from; and artificial skill arising from an overlap of training and forecast time interval. To demonstrate the sensitivity of the forecast skill to these two factors, Figure 7 shows three different control forecast results, that are based on different training periods. The skill of each control forecast setup is quantified in Figure 8 in terms of the RMS-error and the anomaly correlation of SST in the EQ-2 region. Each set of statistics is based on 21 forecasts, equally distributed over the time interval from 1993 to 1999. The RMS-error and the anomaly correlation is calculated relative to the simulated SST and not relative to the observed SST, to evaluate the skill of the forecast independent of the skill of the hindcast simulation.

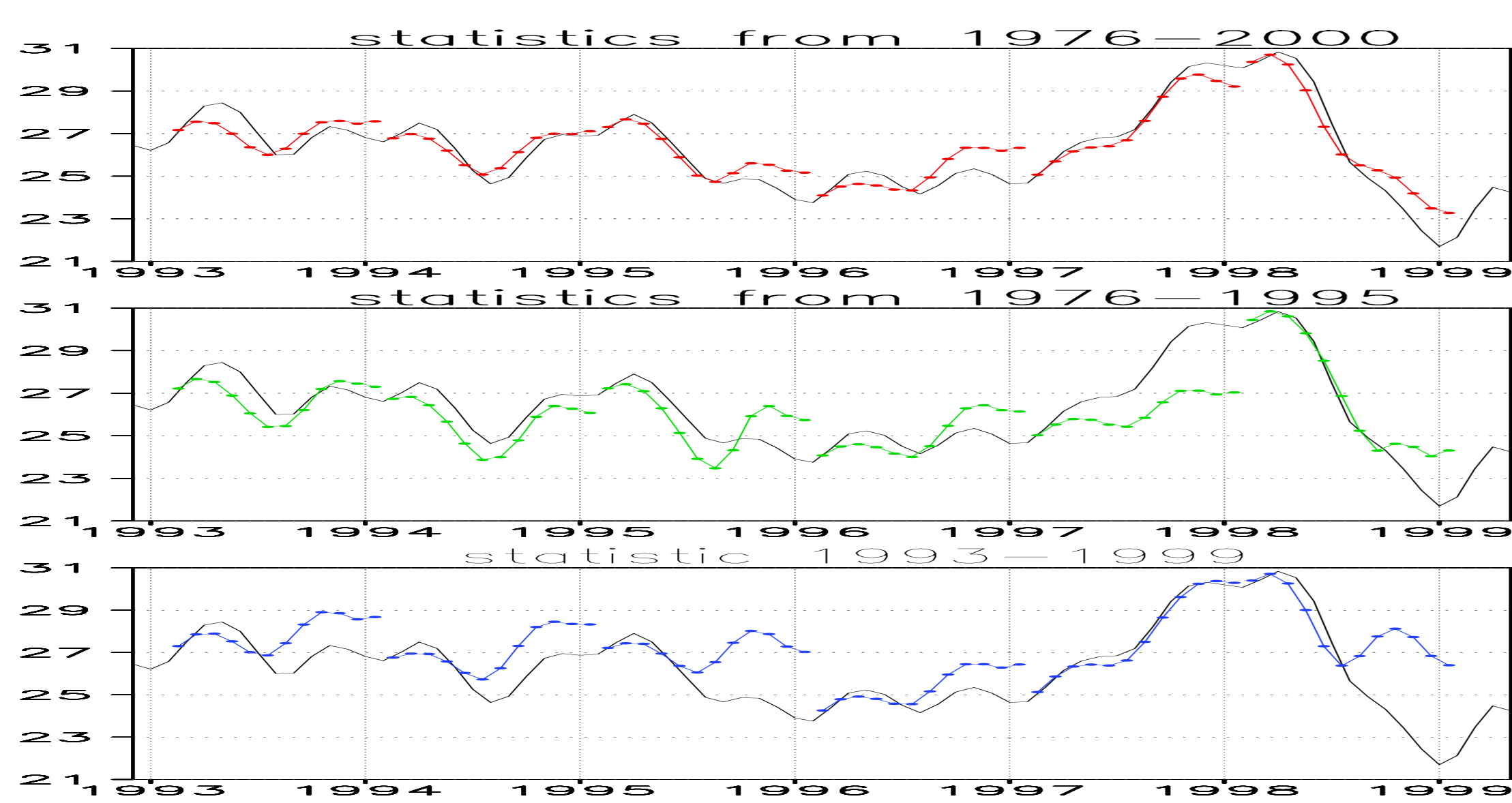


Figure 7: The time series of several control forecasts and the control hindcast in the EQ2 region are shown for different statistical atmosphere models. In the upper panel the statistics from 1976 - 2000 are used, in the middle 1976 - 1995 and in the lower panel the statistics from 1992-1999 are used. Values are in degree Celsius.

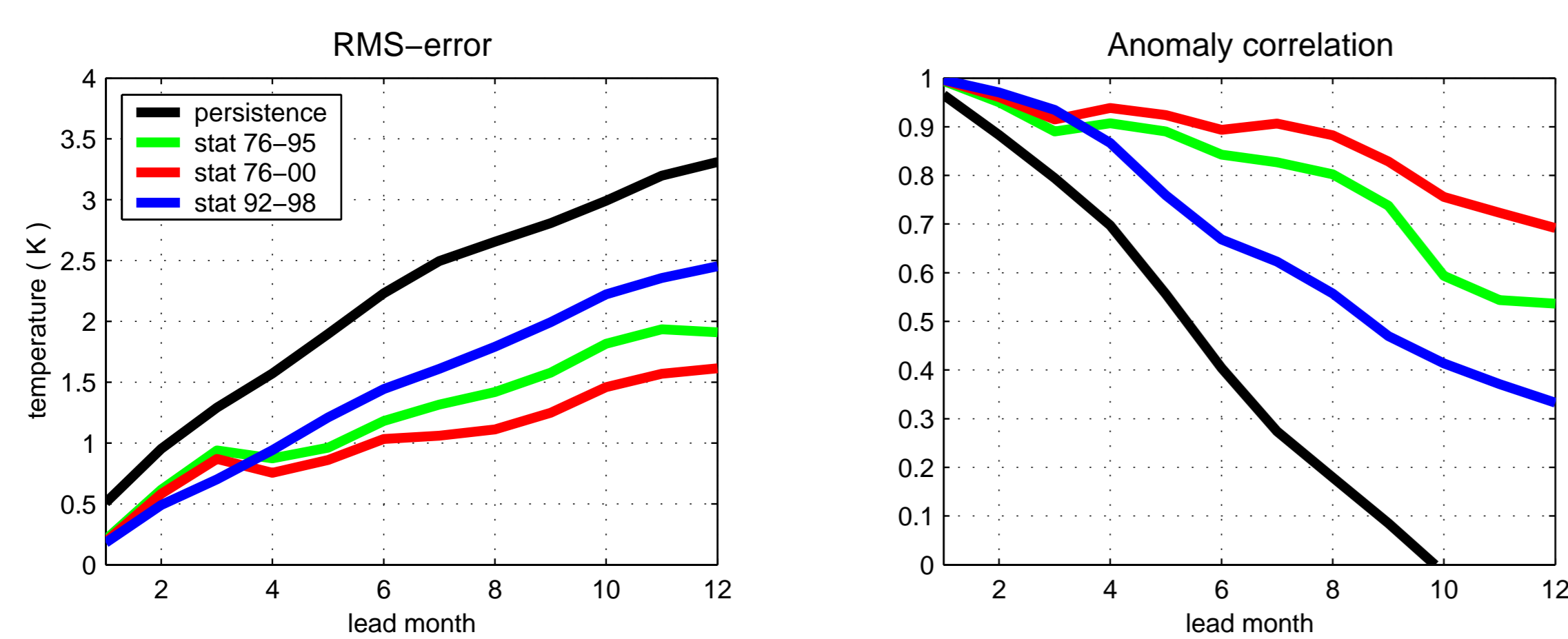


Figure 8: The skills of 21 control forecasts in the EQ2 region is shown for three different statistical atmosphere models. On the left the RMS-error is shown and on the right the anomaly correlation. Both skill values are relative to the hindcast. The RMS-error is in Kelvin.

We note that the skill of our control hind/forecast system based on longer atmospheric statistics is comparable to state-of-the-art skills, e.g., as published by *Ji and Leetmaa* (1997) and *Segsneider et al.* (2000). Our results agree especially with *Barnett et al.* (1993) who used the same method as done in our control run. However, the forecast based on the limited statistics from 1992 - 1998 shows a significant degradation with strong tendencies towards an El Niño, i.e., SST forecasts are biased warm, clearly indicating that feedbacks between the wind stress and the SST are badly represented in this statistical atmospheric model (see Figure 7).

Forecast

The skill of a seasonal-to-interannual forecast is usually quantified by a comparison of the predicted SST with observations. However, simulated and predicted SST usually deviates from observations in a systematic way. To remedy this bias would require a statistical correction, e.g., estimated from the difference between simulated and observed SST over a long (25-50 year) period. Because such long simulations are not available at present from optimized solutions, we will instead quantify the skill of the forecast here by comparing its SST with those from the hindcast. We anticipate that the skill relative to the observed SST would be similar once a proper statistical correction is available from longer estimation runs.

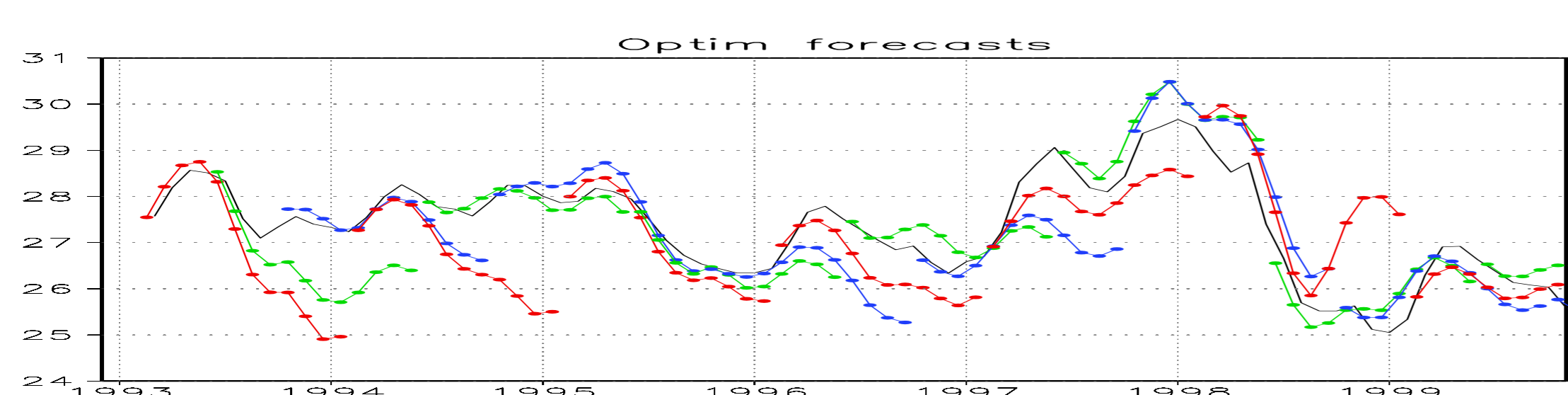


Figure 9: The time series of the SST in the EQ2 region of 21 forecasts and the optimization hindcast are shown. Each forecast is 12 month long and the values are degree Celsius.

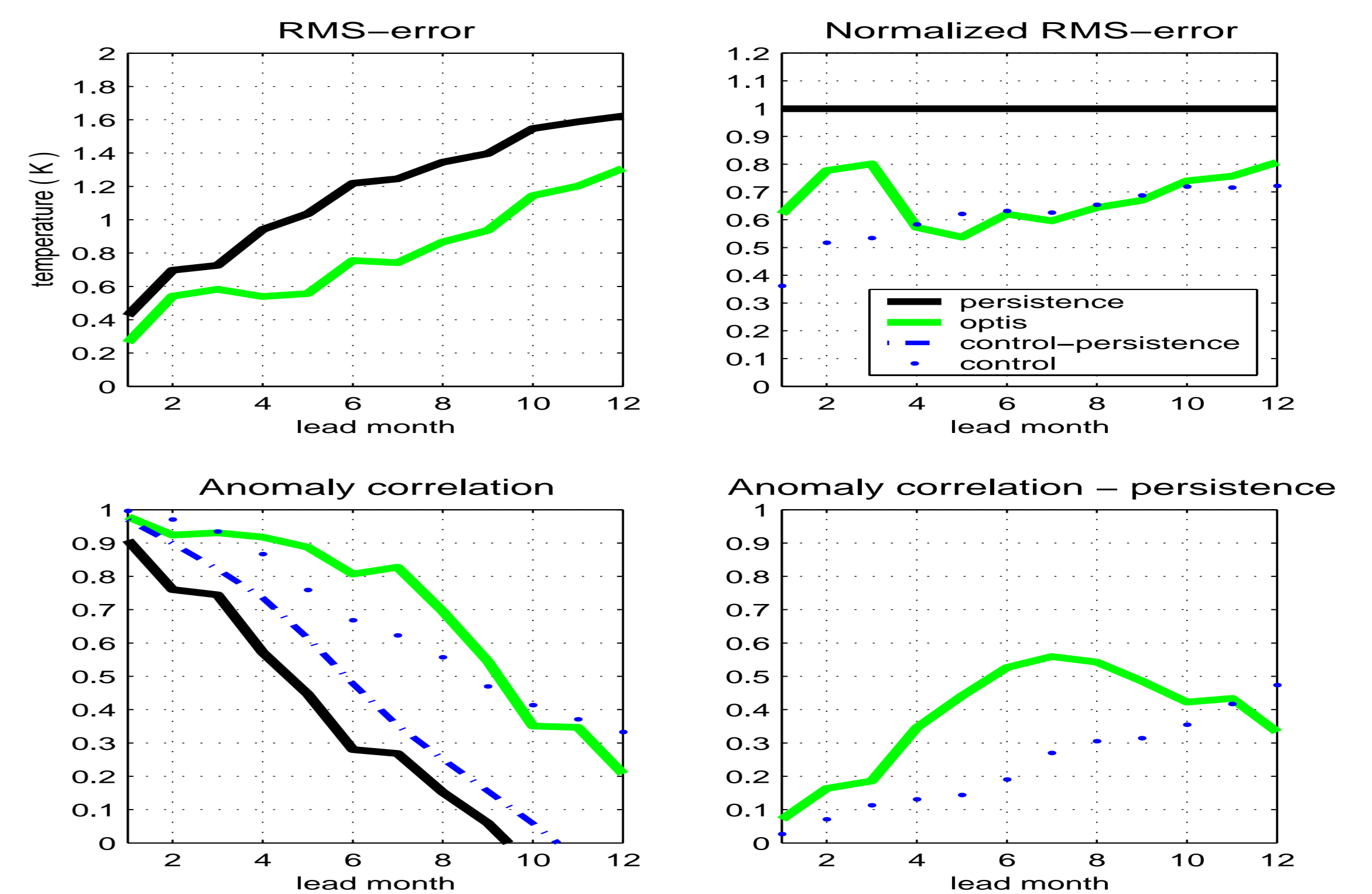


Figure 10: The RMS-error (upper panels) and anomaly correlation (lower) are shown for the optimization and control (with the limited statistical atmosphere) forecasts. In the upper right panel the RMS-error has been normalized by the RMS-error of the hindcast persistence. All skill values are relative to the hindcast.

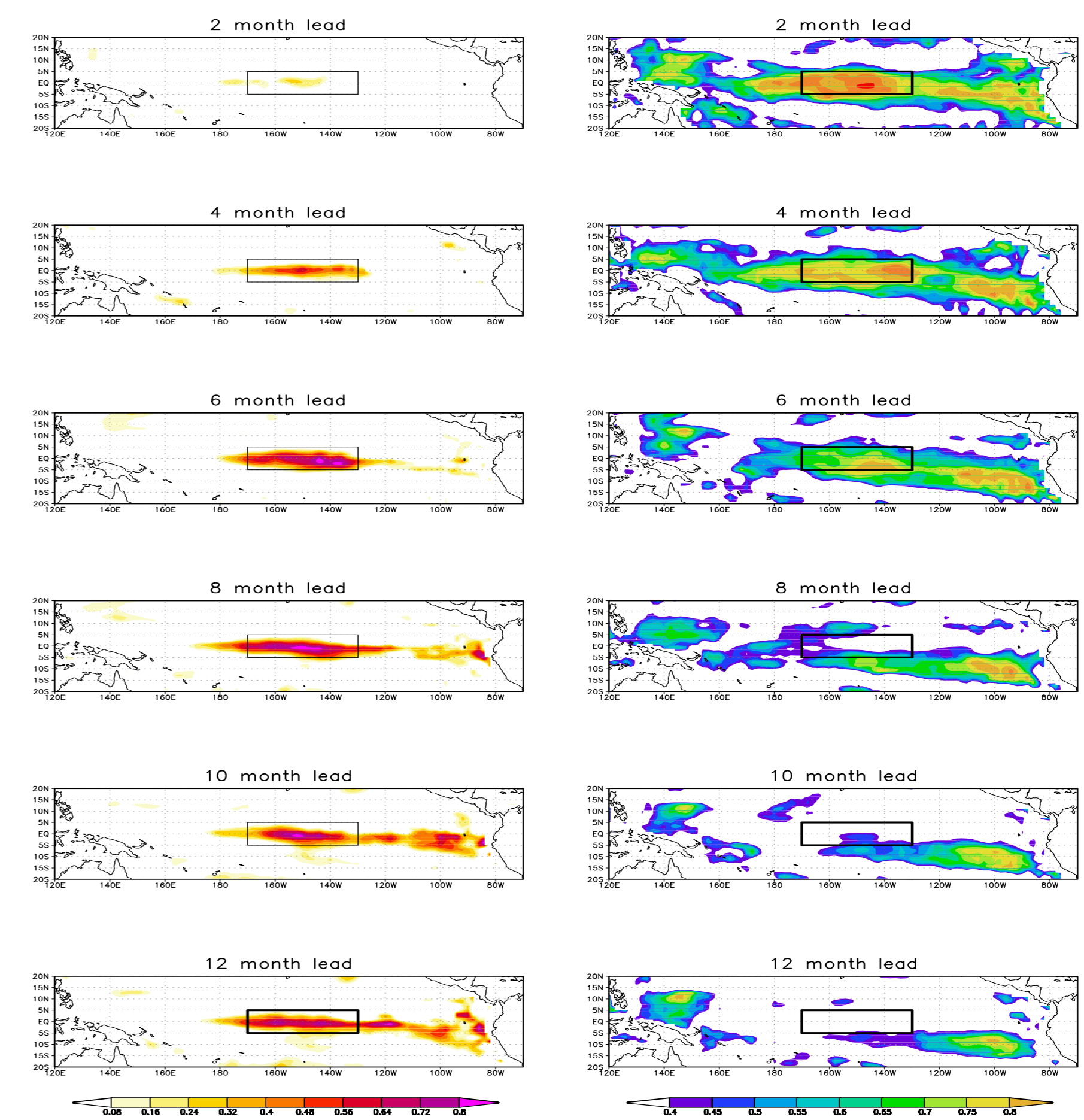


Figure 11: The RMS error of the observed SST persistence minus the RMS-error of the optimizations forecast is shown for different lead times (left panels). The right panels show the anomaly correlation of the optimizations forecast. Units are in Kelvin (left) and none-dimensional (right).

Summary and conclusions

Our analysis had the focus of evaluating the feasibility of using results from an ocean state estimation procedure to improve the skill of seasonal ENSO forecast system that is based on an ocean model coupled to a statistical atmosphere. The adjusted surface forcing makes it necessary to infer a statistical atmosphere model from relatively short estimation results that in addition overlap with the forecast period. The limited statistics and the deviation of the smooth statistical atmosphere lead to a degradation of the forecasts, a problem that precludes a clear demonstration here that ocean state estimation can indeed improve the predictive skill of coupled models. From our results it is clear that until 50-year long optimization efforts are under way, the largest limitation in using existing optimized output for ENSO predictions is in the limited quality of the statistical atmosphere model. Despite all those difficulties we can see in Figure 8 some small indications of an improvement in the predictive skill of the optimized and dynamically balanced run through higher anomaly correlations than can be found from the control approach (Figure 10). Moreover Figure 11 shows that the optimization leads to sensible results that in contrast to the control run have validity also outside the tropical region. Both findings suggest, that ocean state estimation may benefit not just seasonal predictions in low latitude, but could also be used for off-equatorial seasonal forecast of SST.

To improve the presently marginal benefits of optimization results for improving seasonal forecasts, two advances are required: Firstly, it will be necessary to constrain a simple coupled model which consist of the ocean component and a simple atmospheric boundary layer. Instead of correcting the observed forcing during the hindcast and do an anomaly coupling to the atmosphere model during the forecast, one could do the hind- and forecast with the anomaly coupled atmosphere model, in which the anomaly coupling would be optimized by correcting the regression matrix of the boundary forcing coupling during the hindcast optimization. Equally important is to extend the estimation period to several decades.

Respective efforts are being pursued now, with the goal to provide ocean estimates over the last 50 years. It can be anticipated that both improvements together will significantly advance our ability in initializing coupled ocean-atmosphere models for forecast purposes.

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