

AN ATMOSPHERIC FORCING EXTENDING ENSO FORECAST HORIZON USING STATISTICAL MODELS

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KEY POINTS:

- ❑ A novel early ENSO predictor - **the Hawaiian index (HI)** - based on the February-March sea level pressure (SLP) is introduced
- ❑ Significant correlations of the predictor with the upcoming summer - next spring ENSO conditions are shown
- ❑ The predictor significantly improves the interseasonal forecast skills of the statistical Niño 3.4 index model

ABSTRACT

The loss of autocorrelations of tropical sea surface temperatures (SST) during late spring, also called the spring predictability barrier (SPB), is a factor that strongly limits the predictability of El Niño Southern Oscillation (ENSO), and especially the statistical SST based ENSO forecasts starting from the winter-spring season. Recent studies show that Pacific atmospheric circulation anomalies in winter-spring may have a long-term impact on the summer tropical climate via the SST footprint. Here, we infer an index based on sea level pressure (SLP) data from February-March in a single area surrounding Hawaii, and show that this area is the most informative part of the large SLP pattern initiating the SST footprinting mechanism. We then construct a statistically optimal linear model of the Nino 3.4 index taking this atmospheric index as a forcing. We find that this forcing efficiently lowers the SPB and provides significant improvements of interseasonal Niño 3.4 forecasts.

FINDING THE ATMOSPHERIC ENSO PREDICTOR

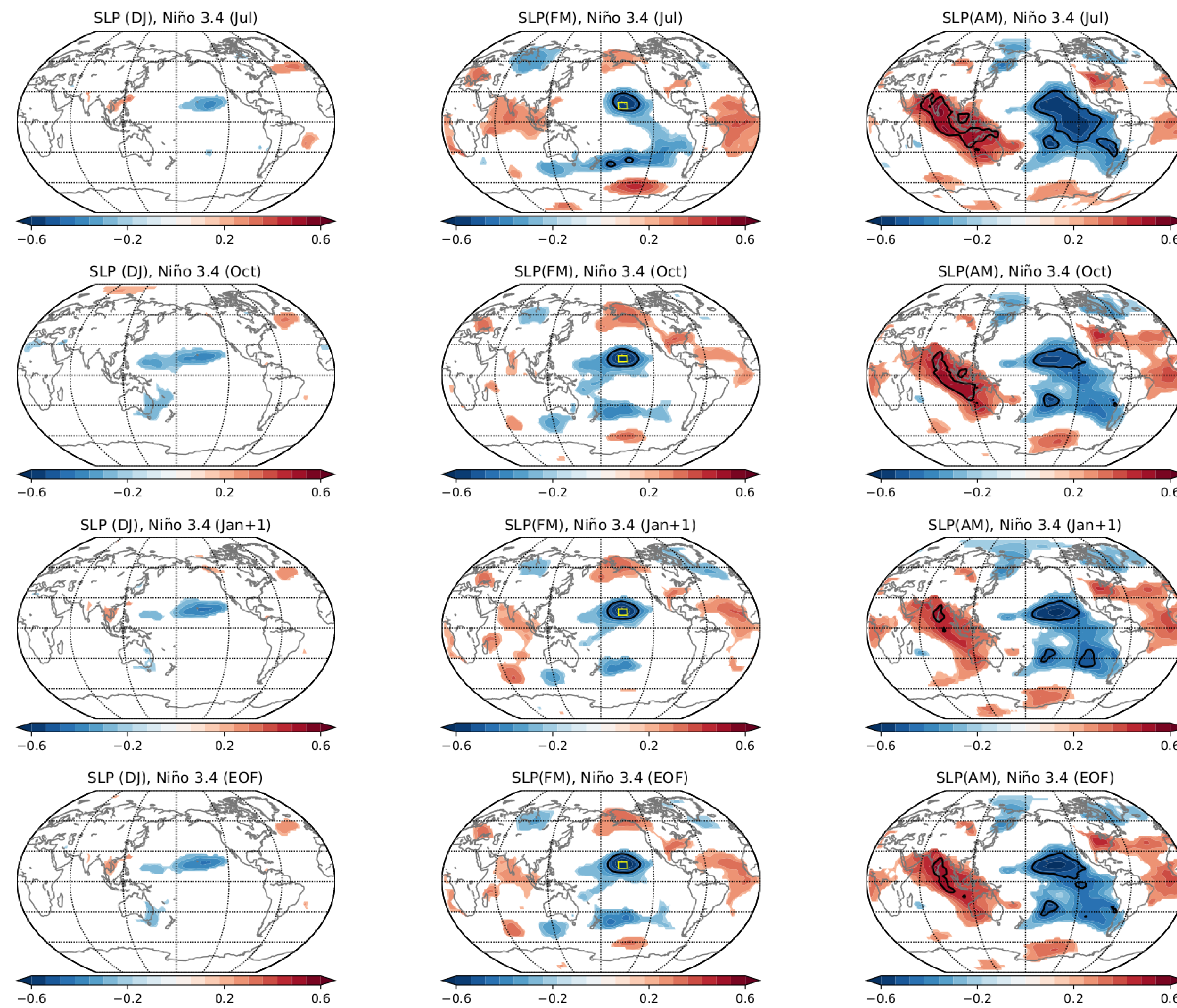
THE DATA:

- monthly 1959-2019 SLP dataset on a 144×73 global grid taken from NCEP-NCAR Reanalysis 1 (Kalnay et al., 1996). SLP anomalies (SLPAs) are obtained from this dataset by subtracting the periodic SLP annual climatology and then applying linear detrending at each grid point;
- monthly detrended 1960-2019 Niño 3.4 index is produced from the Extended Reconstructed SST (ERSST) dataset, version 5 (Huang et al., 2017a)

PREDICTOR SEARCH METHOD

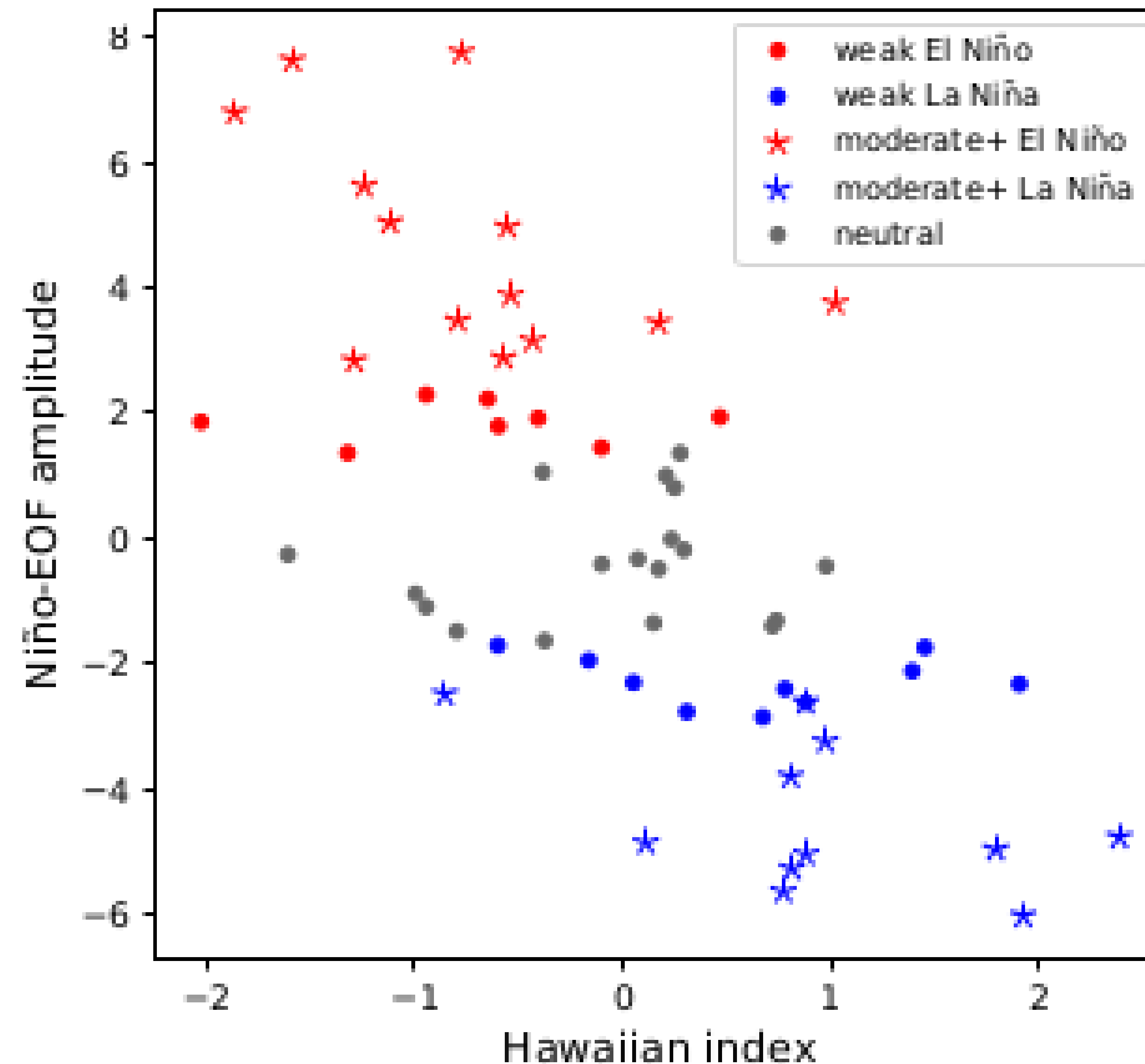
Analysis of the correlations of the SLP in the winter and spring seasons with the yearly Niño 3.4 index time series in each month of the upcoming ENSO cycle

CORRELATIONS OF THE SEASONAL SLP MEANS DURING DIFFERENT COUPLE OF MONTHS WITH THE NIÑO 3.4 INDEX IN THE FOLLOWING MONTHS.



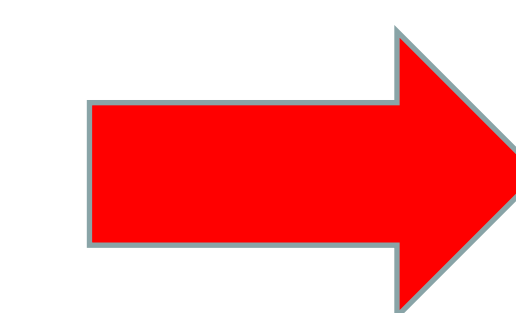
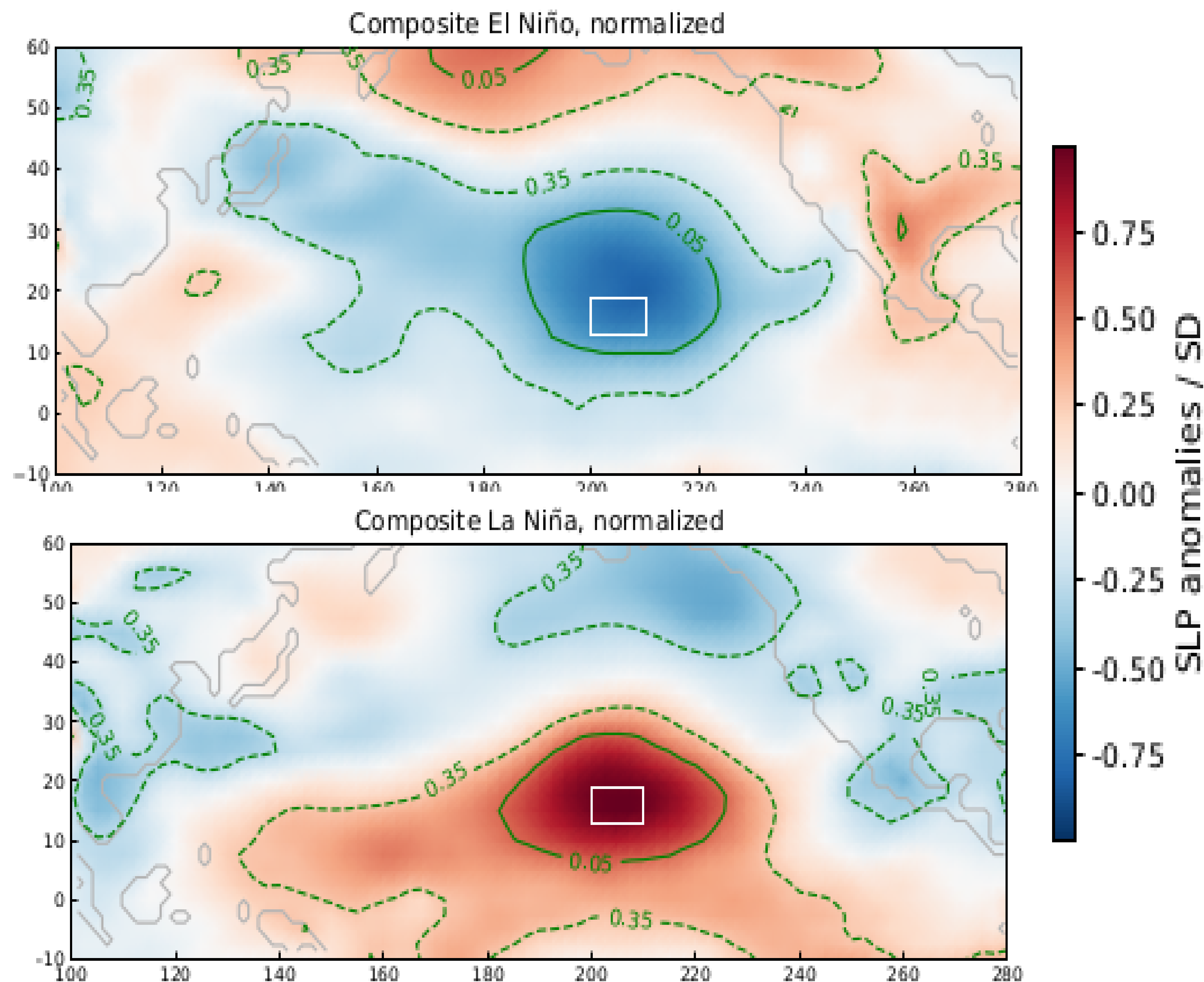
The three upper rows show the correlations with the Niño 3.4 index in July, October and January. The bottom row shows the correlations with the Niño-EOF time series characterizing the whole ENSO cycle following the considered SLP seasons. Only significant correlations (0.1 significance level) are plotted in accordance with the AR1 surrogate test applied to absolute values of the correlations in each grid point separately. The black contours correspond to the 0.1 significance level of the stronger test based on globally distributed SLPA surrogates). The yellow rectangles mark the area used for the HI.

THE ORIGIN OF THE HI FACTOR



ENSO cycle amplitudes vs. the HI. These amplitudes are the projections of June-May Niño 3.4 windows to the Niño-EOF. Cycles corresponding moderate and strong, weak and neutral ENSO events are plotted by stars, colored circles and black circles, respectively. Red and blue denote El Niño and La Niña phases, respectively.

COMPOSITE PATTERNS AS THE FEBRUARY-MARCH SLP AVERAGED SEPARATELY OVER 170 THE YEARS OF EL NIÑO AND LA NIÑA ONSET



The El Niño and La Niña composites resemble the negative and positive patterns, respectively, of the North Pacific Oscillation (NPO)

The composites are normalized by the standard deviation (SD) of the FM SLP anomalies in each grid point. The green contours bound the significant values for significance levels of 0.05 and 0.35). The rectangle marks the HI area.

NIÑO 3.4 LONG-TERM FORECAST USING HI FORCED AR MODEL

The basic form of the model:

$$x_{ni} = a_1^i x_{ni}^{-1} + a_2^i x_{ni}^{-2} + \dots + a_l^i x_{ni}^{-l} + b^i h_n + \xi_{ni}$$

x_{ni} is the Niño 3.4 index in the i -th month of the n -th ENSO cycle, x_{ni}^{-j} is the index j months before x_{ni} , h_n is the HI value preceding the n -th ENSO cycle, and l is the lag (model memory depth).

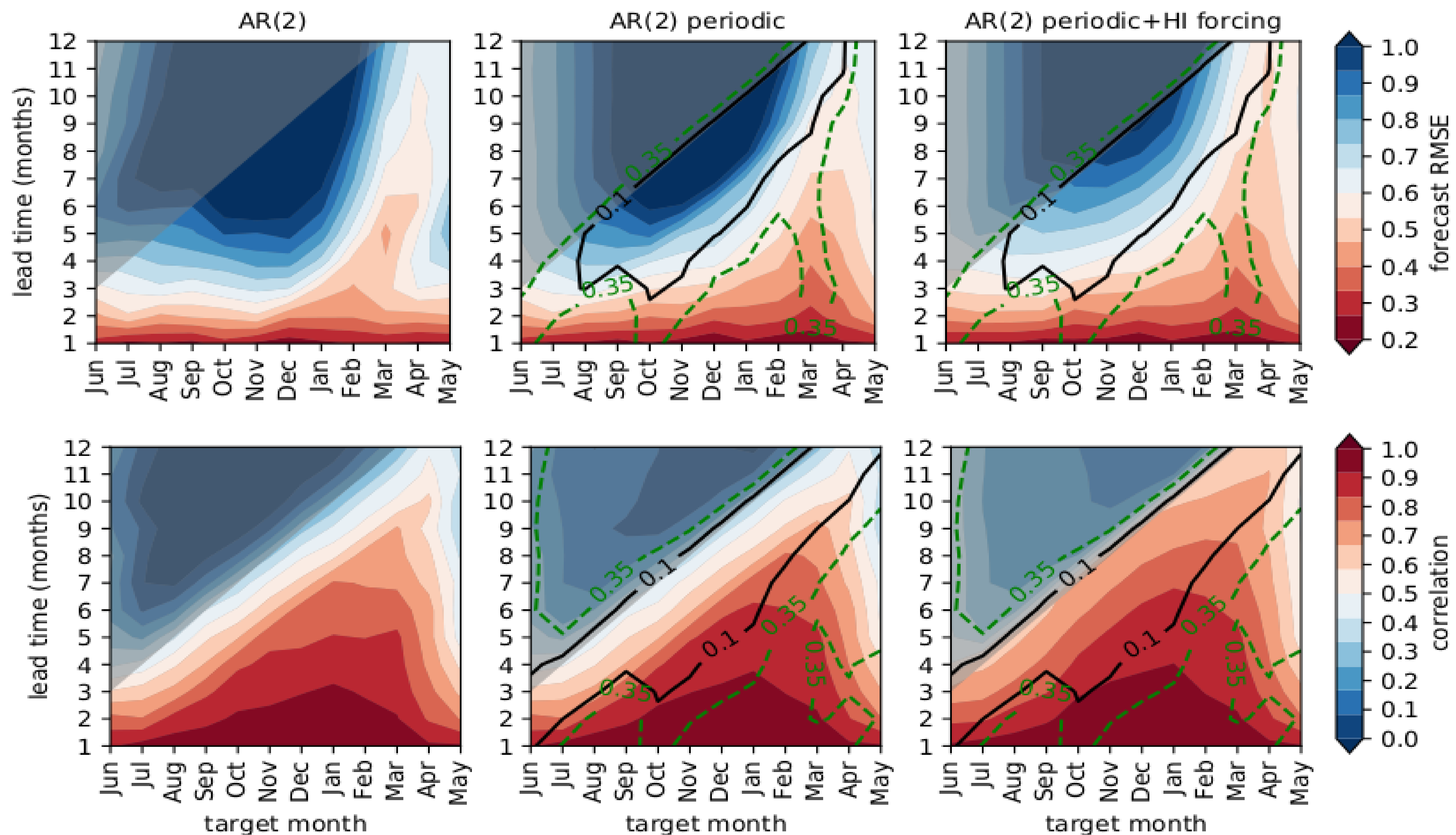
A discrete Fourier representation for the periodic series of the model coefficients

$$k^i = (a_1^i, \dots, a_l^i, b^i)$$

$$k^i = k_0 + \sum_{n=1}^q \left(c_n \cos \frac{2\pi}{12} ni + s_n \sin \frac{2\pi}{12} ni \right)$$

We use the Bayesian criterion of optimality to find the most probable values of the structural parameters l and q . Result of optimization: the lag $l=2$ AR model forced by both the seasonal parameter forcing and the yearly HI forcing is the best Niño 3.4 index, and the optimal truncation of the seasonal forcing corresponds to $q = 1$

PREDICTION SKILLS OF THREE STATISTICAL MODELS OF THE NIÑO 3.4 INDEX



From left to right: the AR model without forcing with the optimal lag $l = 2$, the AR model with the seasonal forcing with the optimal structural parameters $l = 2$ and $q = 1$, and the optimal AR model ($l = 2$) with the combined seasonal ($q = 1$) and HI forcing. The r.m.s. forecast error (RMSE) (normalized to the r.m.s. deviation of the detrended Niño 3.4 index, upper panels) and the correlations r (bottom panels) are shown in different target months for lead times from 1 to 12 months. The area where the HI forcing is unavailable is overlain by a transparent matte mask; The contours in the right panels bound the areas of significant improvements of the optimal HI-forced model prediction skills relative to the AR(2) model with the seasonal forcing alone.

CONCLUSION

The HI derived from the SLP in February-March is shown to hold important information for the upcoming ENSO cycle lasting from summer to spring of the next year. This information reflects the impacts of the spring patterns of atmospheric circulation anomalies on the summer tropical ocean-atmosphere system due to the SST footprinting mechanism. Thus, the HI can serve as an early predictor for ENSO across the spring predictability barrier .

We demonstrate that the statistical AR model of the Niño 3.4 index taking the HI as a forcing is better in the Bayesian sense and delivers significantly better multimonth predictions. In fact, the HI forcing in the model substantially lowers the SPB and hence increases the predictability of the whole June-May ENSO cycle for forecasts starting in spring.

Please see for details:

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