Oceanic Rossby Wave Predictability in ECMWF's S2S Model

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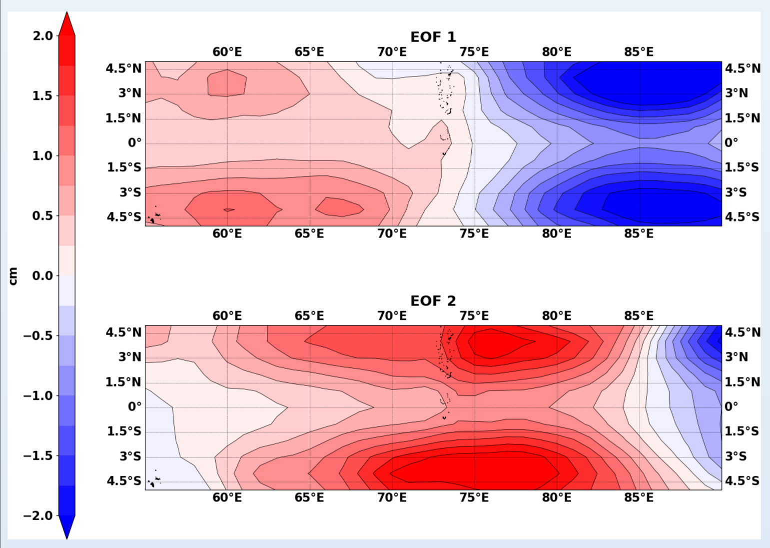
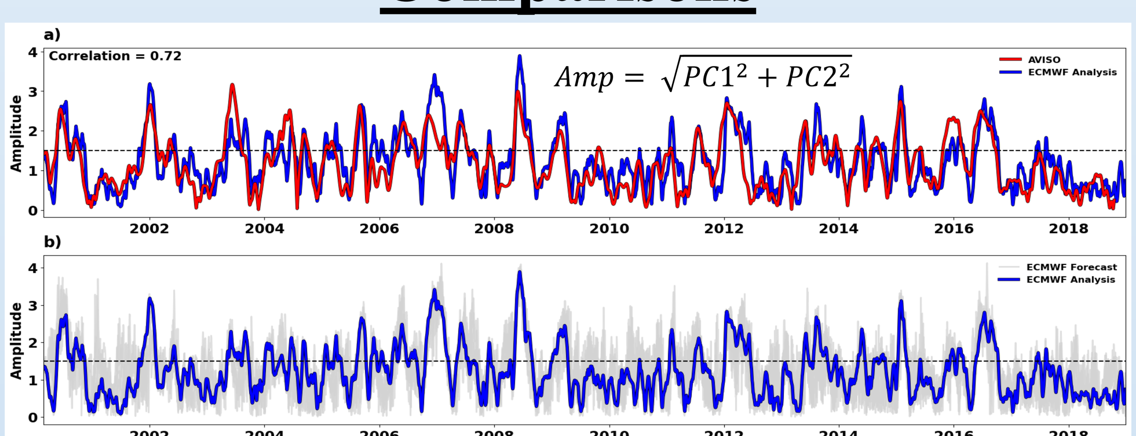
Methodology

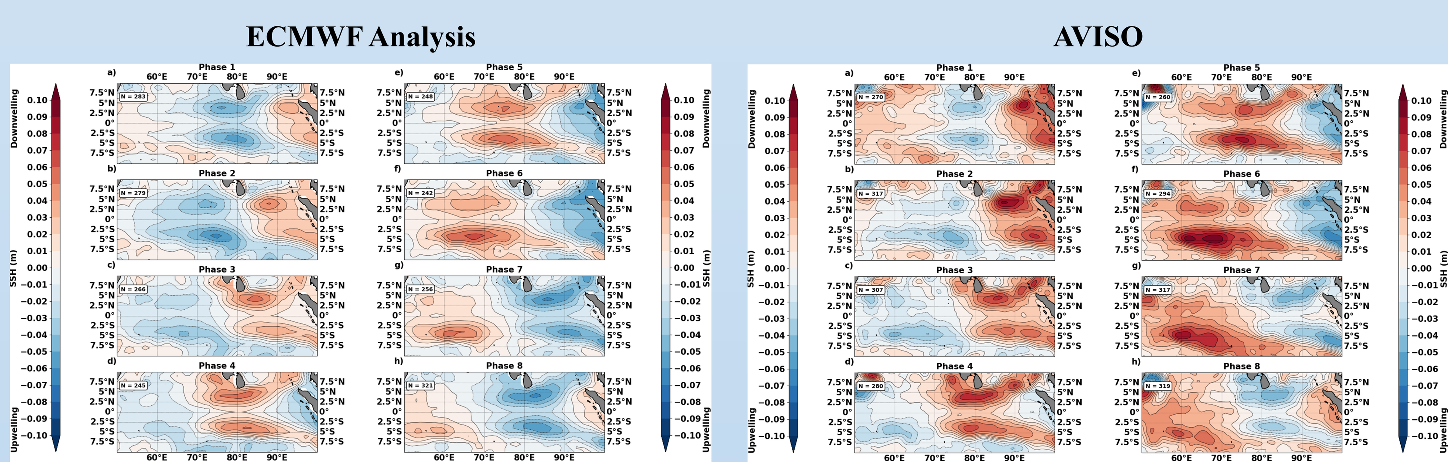


- Equatorial Rossby waves (ERWs) are determined using methodology developed in Rydbeck et al. (2021).
- Empirical orthogonal functions (EOFs) are computed from AVISO SSH anomaly fields along 6°S - 6°N.
- Associated principal components (PCs) are used to determine phase and amplitude of the ERWs.

Comparisons



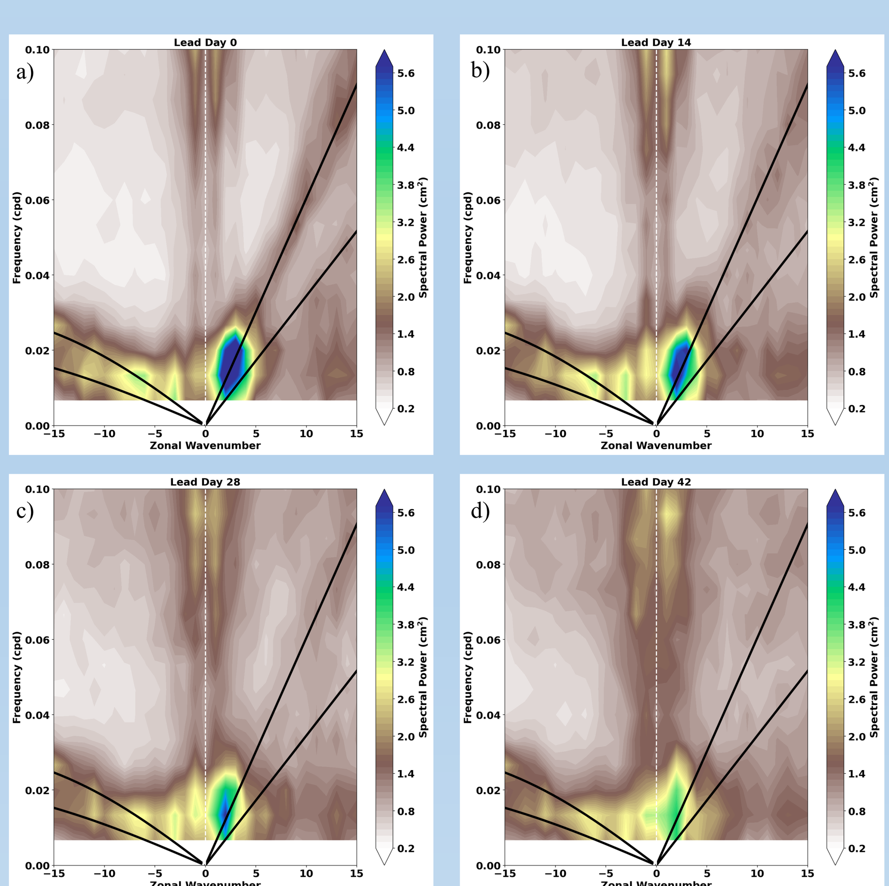
Daily amplitude time series are constructed for lead days 0, 7, 14, 21, 28, 35, and 42 to see how the model forecast degrades in time. A relatively high correlation (0.72) between the AVISO and ECMWF analysis exists partially due to the assimilation of AVISO SSH into ECMWF. Disagreement amongst the forecast members exists when compared with AVISO.



The phase diagram features the lifecycle of the Rossby waves. The ECMWF analysis and AVISO phases compare well in terms of placement of maxima/minima within the Rossby wave lobes. There is a noticeable difference in the magnitude, however.

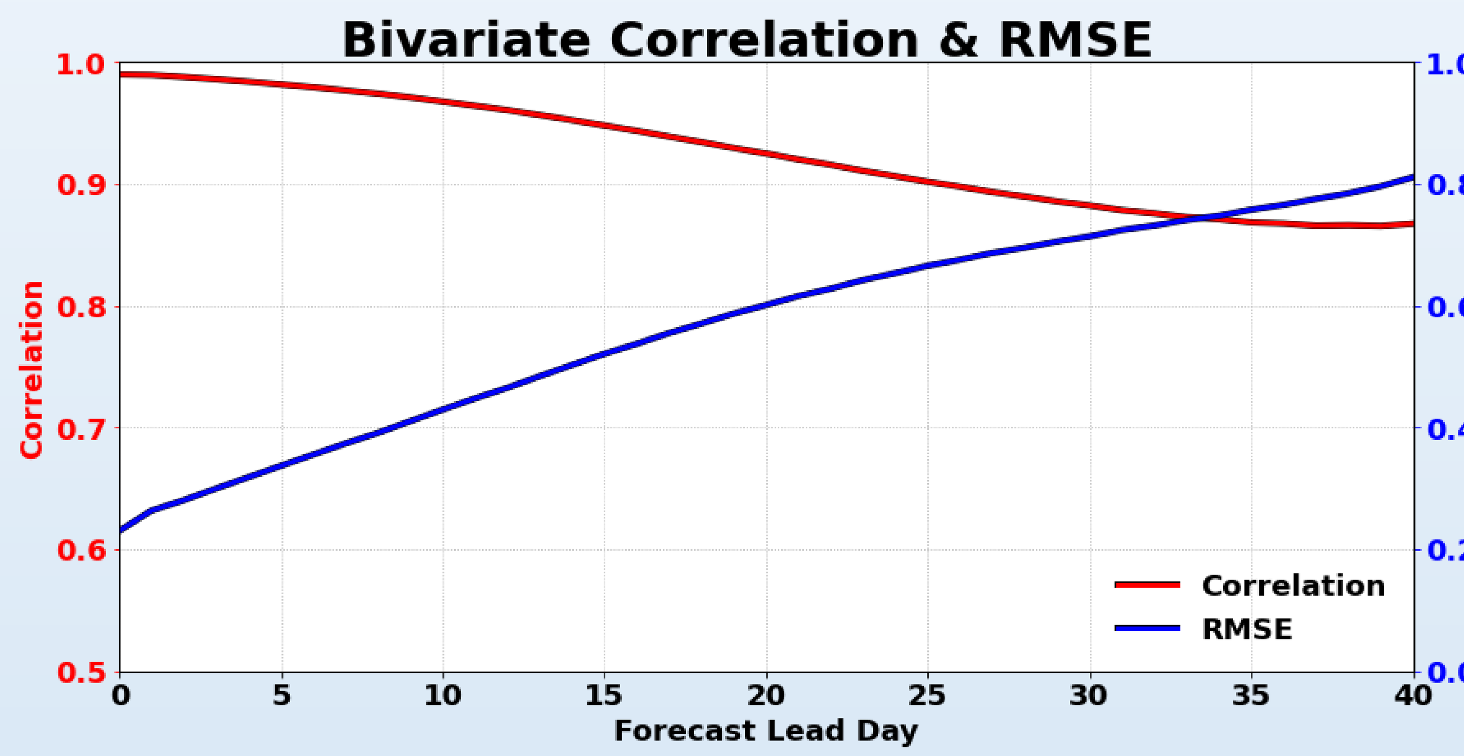
Sources of Error

- Wavenumber-frequency spectral decomposition of for the IO basin shows strong energy in the Kelvin wave regime and more moderate values in the Rossby wave regime.
- Over the course of the forecast period (analysis time (a) to day 42 (d)) we see diminishing spectral power in both regimes.
- Kelvin waves are driven primarily by eastward winds associated with the convective phase of the ISO.



- A misrepresentation of winds in the forecast model would manifest as weakening Kelvin waves as seen here. Therefore, weakening Kelvin waves implies weakening Rossby waves due to weakening reflective energy off of Sumatra.

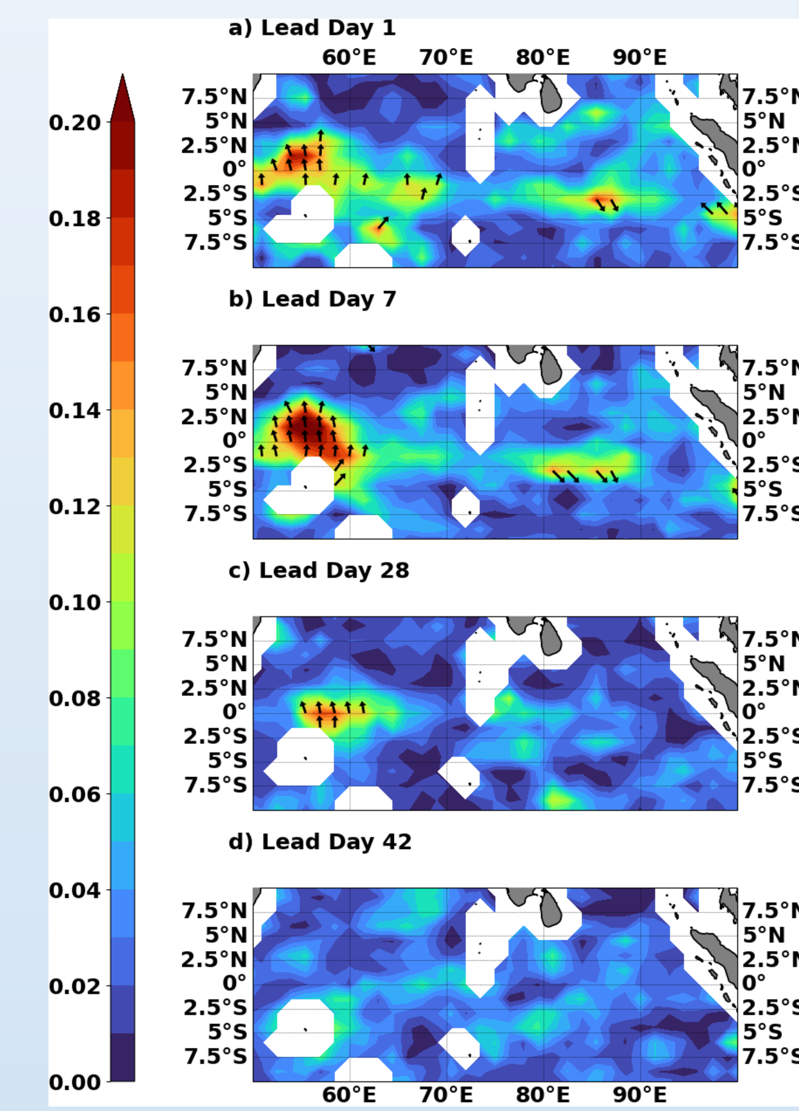
Forecast Skill



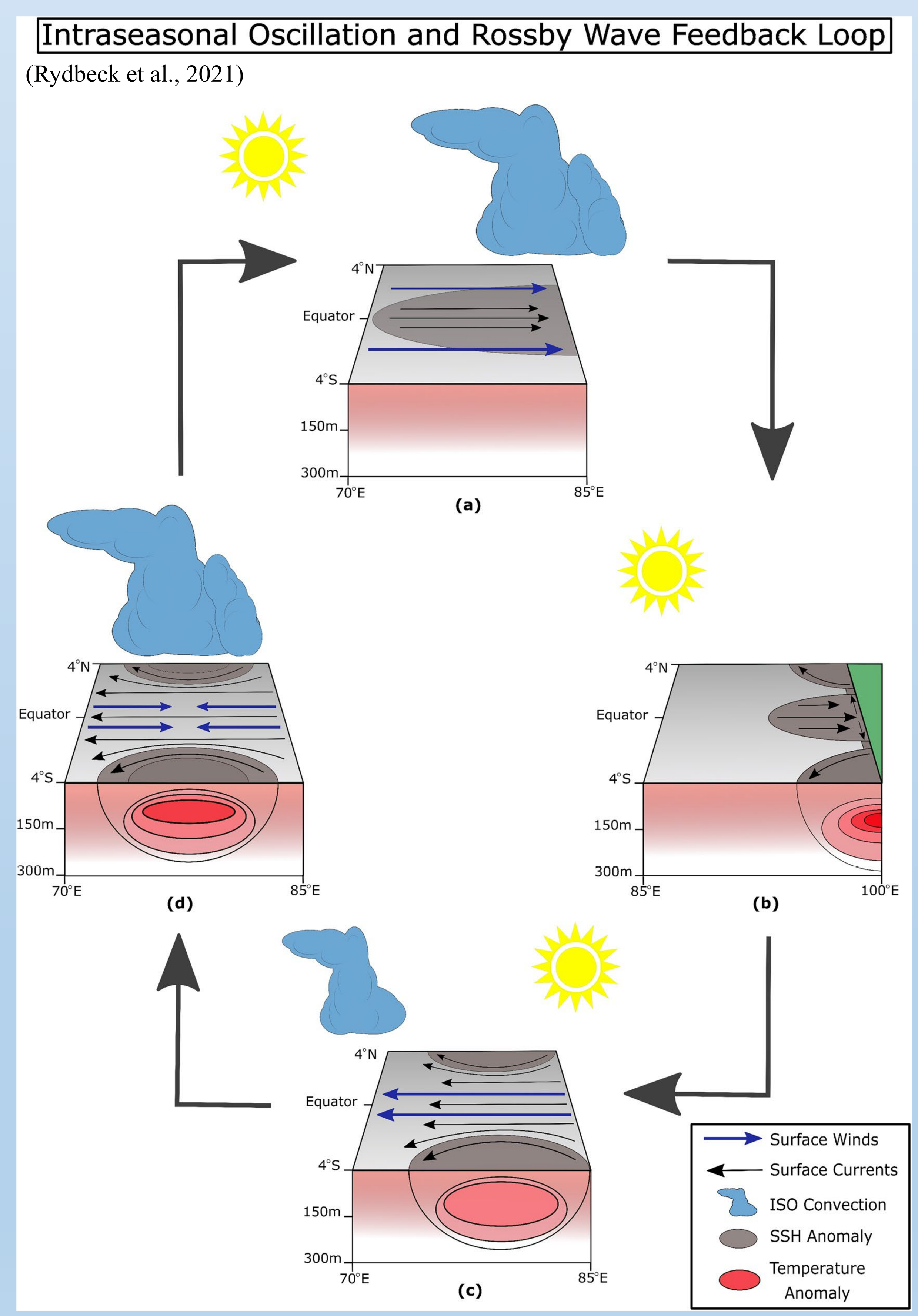
- 110 days of analysis SSH are padded to front of each forecast datetime group (DTG) dataset in order to properly remove a 110-day running average. 90-day zero-padding occurs at the back of forecasts
- Wavenumber-filtering occurs after the removal of the first three harmonics of the seasonal cycle as well as the 110-day running mean
- Filtered SSH is projected onto the AVISO EOF spatial patterns to obtain PC1 and PC2, which are used to define the amplitude and phase

Forecast Skill

The connection between OHC anomalies and precipitation (shading) show strong in-phase (northward-pointing arrows; only shown for the upper 95th percentile confidence level and above) coherence values in the western IO out to 3 weeks where we see strong diminishing coherence. By the end of the forecast period (day 42) no significant coherence is present. This highlights the degradation of reciprocity between OHC and precipitation as described in Rydbeck et al. (2021).

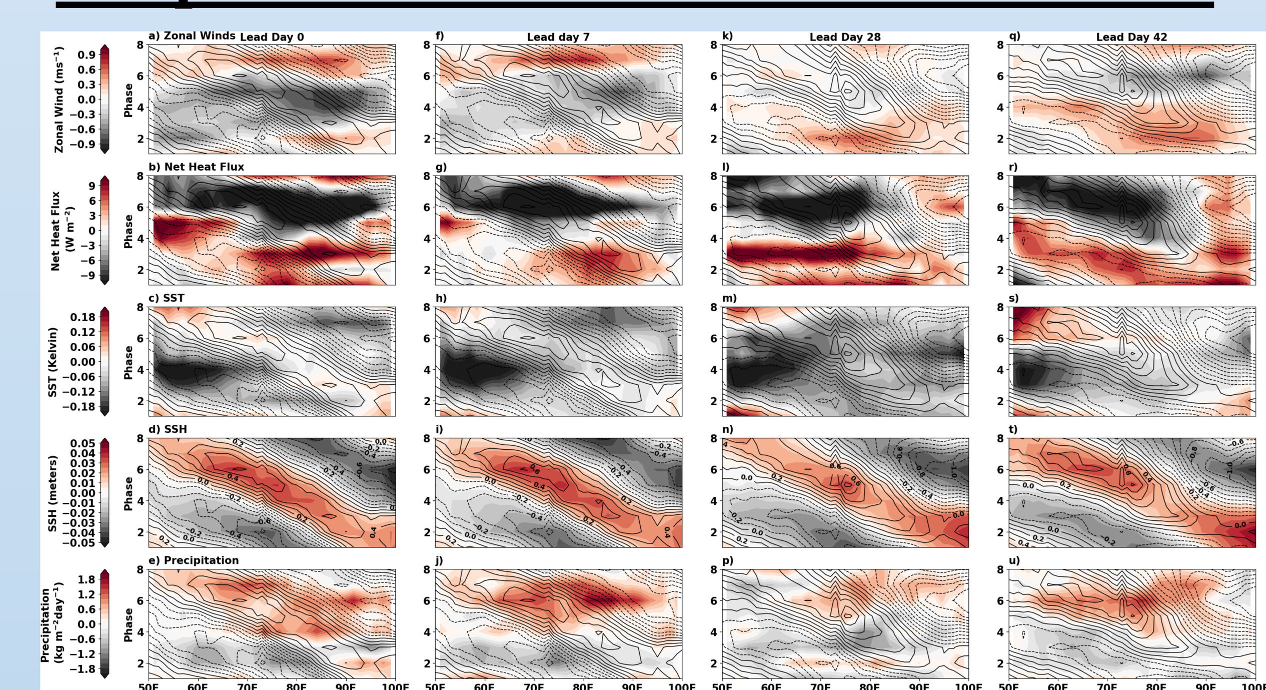


Feedback Processes



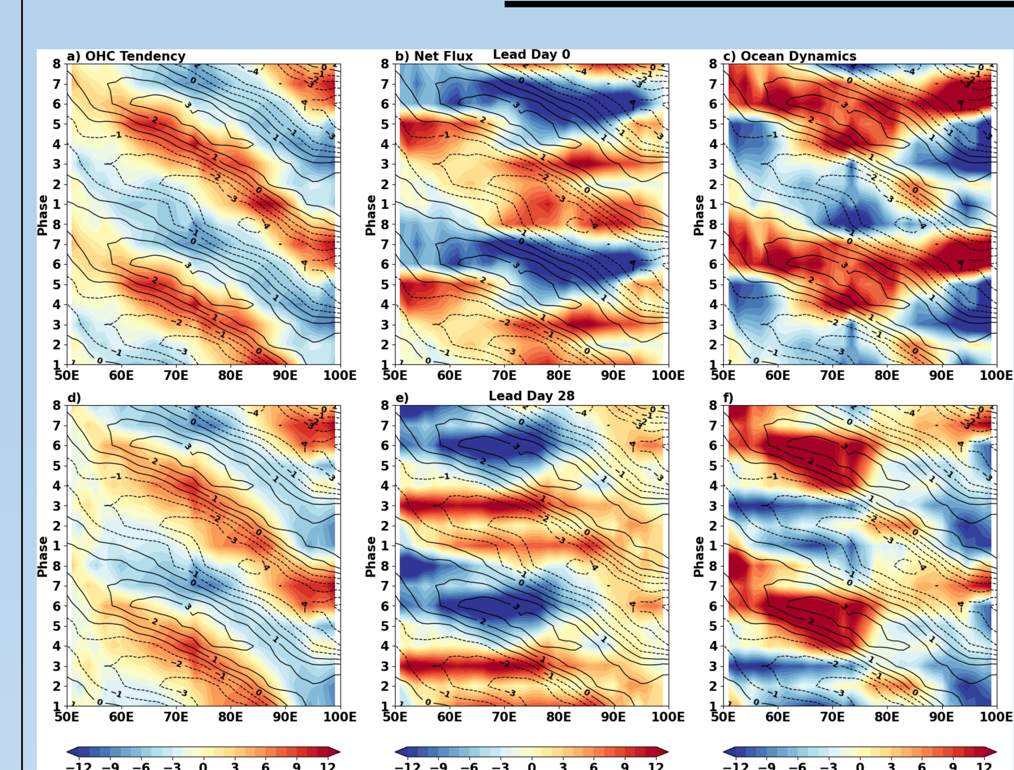
Feedback processes between the ocean heat content and the intraseasonal oscillation are depicted in this schematic from Rydbeck et al. (2021). Westerlies originating from the convective phase of the ISO pile warm water towards the east via oceanic Kelvin waves (a). This produces a westward-oriented pressure gradient and when combined with easterly winds associated with the passage of the ISO envelope sets off a downwelling Rossby wave (b). Maximum wave amplitude occurs in the central Indian Ocean and results in a maximum suppression of isotherms, which increases OHC (c). The passage of the convective phase of succeeding ISO amplifies due to the increase in OHC in the central IO (d), thereby producing strong westerlies and repeating the process (a).

Coupled Processes in the Forecast Model



Hovmöllers of various atmospheric and oceanic fields shown from time series constructed from different forecast lead times (analysis, day 7, day 28, and day 42). Shifting locations of the westerlies (red shading in figures a, f, k, and q) support the hypothesis that incorrect placement and magnitude of westerlies are responsible for weakening Kelvin/Rossby waves as seen in the spectral plots. Note that these composites are based off of strong OERW amplitudes (amplitudes ≥ 1.5) and do not show this weakening signal.

OHC Maintenance



- Strong negative heat flux (positive downward) in phase 6 during lead day 0 (figure b) associated with MJO westerlies.
- Displacement of net heat flux by day 28 (figure e) supports the hypothesis of a displacement of the westerlies, which corroborates weakening Rossby waves.
- Ocean dynamics, however, remain quite robust and aid in sustaining the OHC tendency despite the incorrect placement of winds.