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Issues in identifying atmospheric and SST response to Oyashio Extension Front variability

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Ocean fronts are regions of strong sea-surface temperature and salinity gradients. These fronts are important regions of baroclinicity, anchoring the storm tracks, with shifts in the location of the front associated with storm track changes. It is therefore important to have confidence in the ability to identify the location of the front, and any shifts in the front. The Oyashio Extension (OE) Front lies to the east of Japan and together with the Kuroshio Extension Front is associated with the Pacific Western Boundary Currents.

Data and Methods

Three different high-resolution SST datasets:

- ERA5 reanalysis (Hersbach et al., 2020)
- NOAA OIv2 dataset (Reynolds et al., 2008)
- Group for High Resolution SST Multi-Product Ensemble (GMPE, Fiedler et al., 2015).

All available on a 0.25º resolution, monthly means calculated from daily data, for the common period September 1981–December 2016. Although they are not independent, the datasets are selected as typical of those used in analysis of air-sea interactions.

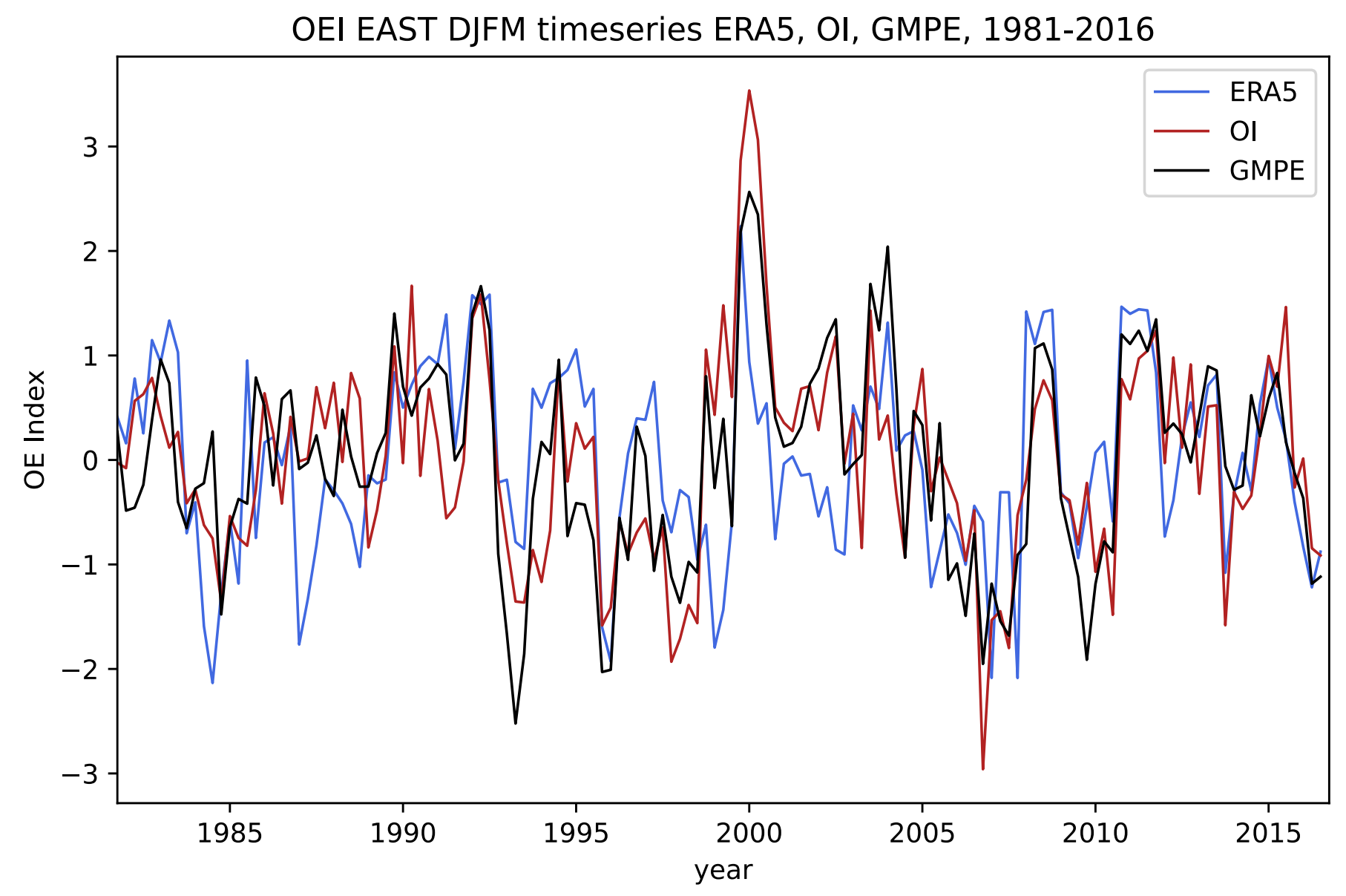

Figure 1. Timeseries of the OEI East derived from the three different SST datasets. Values are for December –March inclusive (DJFM), representing the extended winter season.

Identifying the OE Front

- calculate the latitude of the maximum meridional SST gradient at each longitude over the region 145-170º E, 35-47º North
- a cubic trend and the seasonal cycle is removed from the latitude of maximum SST gradient at each longitude
- the OE Index (OEI) is the first principal component (PC) of the latitude of the maximum meridional SST gradient at each longitude. (Frankignoul et al., 2011)
- OEI represents north-south fluctuations in the location of the front, positive values - northward shift
- calculate extended winter seasonal mean values (DJFM) and a subseasonal anomaly timeseries, where the mean anomaly for each DJFM season is subtracted from the anomaly for each month in the season, showing the month-by-month variability from the seasonal mean.

The OEI is frequently subdivided into western (141-153ºE) and eastern (153-173ºE) sections as there is no significant synchronous correlation between the two, they have different drivers and the eastern section has the main impact on large-scale air-ocean interactions (Qiu et al., 2017). We focus on the eastern section and calculate the index separately for each dataset.

We use linear regression to show the association between the different OEI and detrended SST over the Pacific region.

Results

For some timesteps the OEI Index is well-constrained (Figure 1), and there is broad agreement on multi-annual timescales. However at certain times the match appears to be less good. Correlations range from 0.58 (ERA5-OI) to 0.79 (OI-GMPE). The correlations between seasonal anomalies (Table 1) are much weaker than those for seasonal means (not shown).

DJFM anomalies	OI	GMPE
ERA5	0.35	0.42
OI		0.55

Table 1. OEI correlations for extended winter (DJFM) seasonal anomalies.

Low correlations on subseasonal timescales are a cause for concern if air-sea interactions are to be examined at this scale, as there may be significant differences between indices derived from different datasets. In addition, correlations between ERA5 and OI indices are low in February and March (Figure 2), which is important as wintertime air-sea interactions are commonly studied for this region.

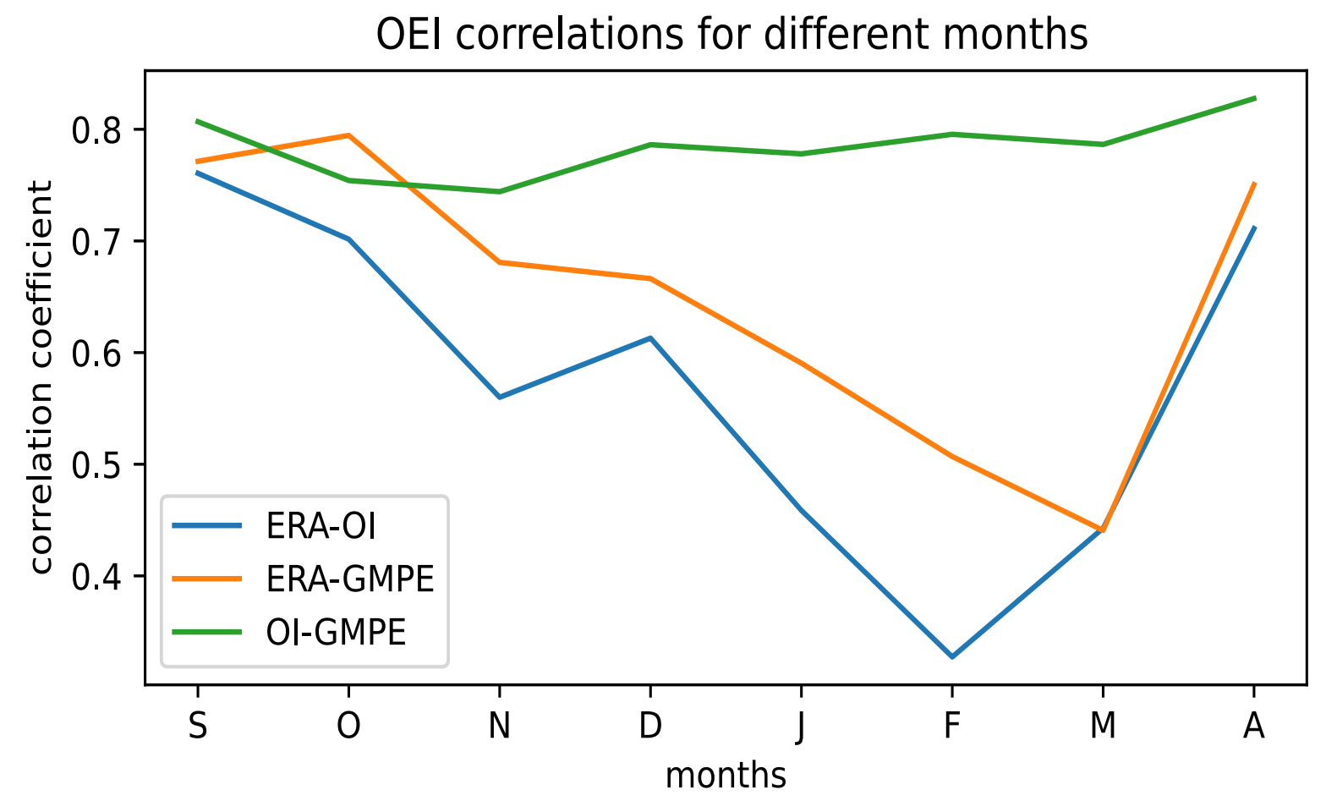

Figure 2. Correlations between OEI timeseries for each month from September-April. All correlations are significant (p<0.05) with the exception of the ERA5-OI February correlation

Regressions of OEI against SST are presented for ERA5 and OI (Figure 3). While there are some similarities, there are also important differences:

- positive SST values are shifted northwards in ERA5 relative to OI
- significant negative SST values are more extensive and extend further west in OI
- SST signal local to the OE region is stronger in ERA5.
- even greater discrepancies arise when regressing the OEI against atmospheric fields such as sea-level pressure, heat fluxes and storm track metrics, at different leads and lags.

This means that results obtained from the use of a single SST dataset to derive the OEI could be open to misinterpretation.

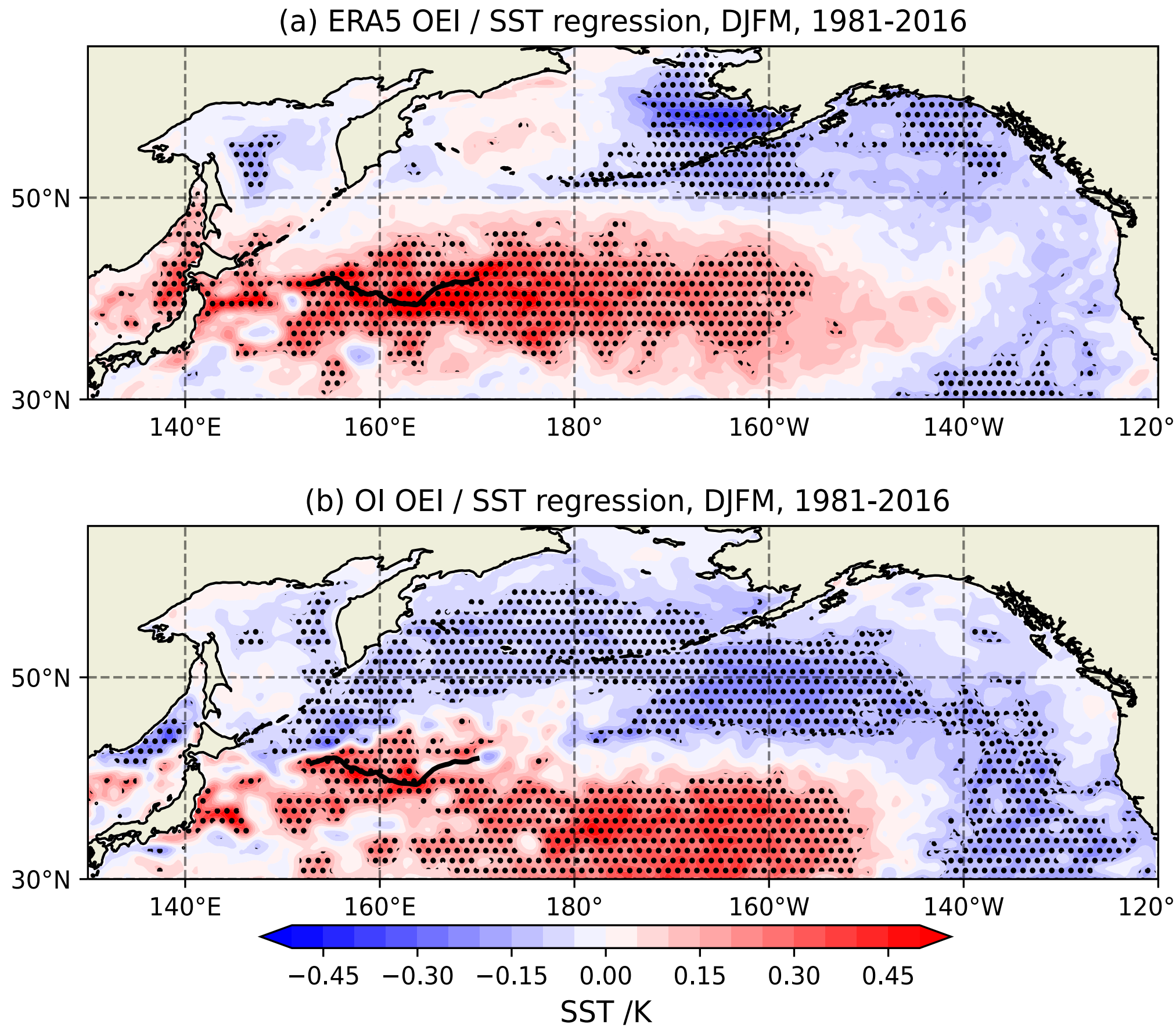

Figure 3. Maps of the regression of OEI against SST for ERA5 (top) and OI(bottom). Stippling shows areas of significance (p<0.05) with p-values adjusted for multiple testing and spatial autocorrelation using the False Discovery Rate (Benjamini and Hochberg,1995).The black bold line shows the mean position of the OE Front.

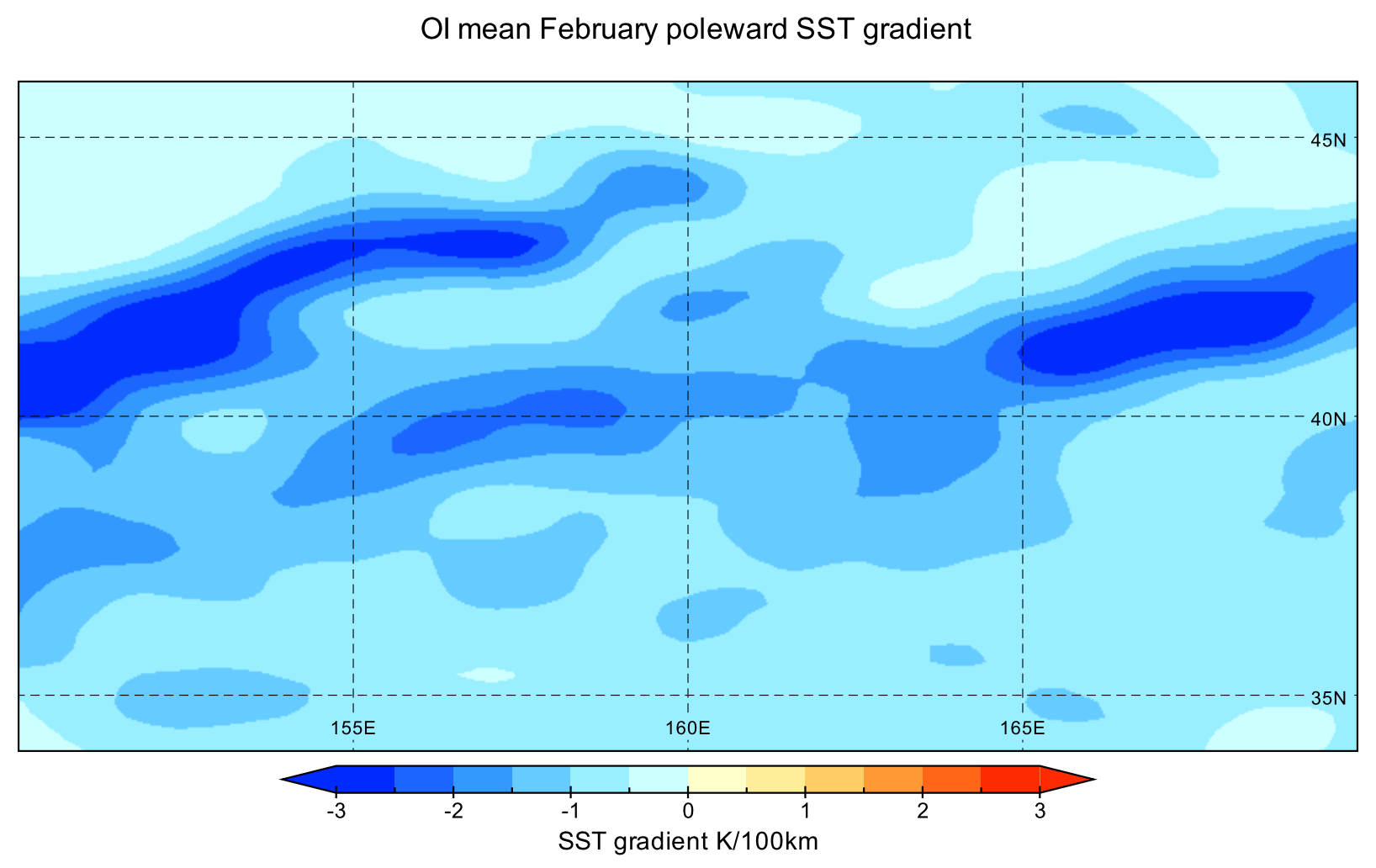

Figure 4. Mean poleward SST gradient for February in the OI dataset.

The SST gradient pattern in the OE region is quite complex (Figure 4), and all three datasets show a similar pattern. To the east (165-170ºE) and west (150-155ºE) there are clearly defined fronts with sharp gradients. However in the central section fronts are either less-defined (160-165ºE) or there are parallel fronts (155-160ºE). Slight differences in gradient strength in the datasets mean that the OE front will be identified at different latitudes at those longitudes where there is greater ambiguity. For example slight changes in the relative strengths of the parallel fronts means that the front detection algorithm may be sampling from different fronts depending on the dataset used.

Key Points

- the OE Front is frequently identified using SST gradients
- the OE indices calculated from a range of high-resolution SST datasets show some important differences
- these differences are particularly noticeable at subseasonal timescales and during winter
- when indices are regressed against SST and atmospheric variables, there are significant differences in spatial structure
- regression differences can lead to misinterpretation of results when a single SST dataset is used, which hinders the understanding of air-sea interactions
- differences in indices arise due to complexities in the spatial structure of the OEF

Next Steps

Common features are seen in regression maps, so an ensemble approach will help to identify robust features that are important in developing understanding of air-sea interactions. Alternatively, different OE indices can be constructed using zonal means or medians of the maximum gradient. The different indices show the greatest agreement in regression for GMPE, suggesting that indices derived from the GMPE are more capable of identifying significant features of air-sea interaction. The three indices derived from other datasets show greater differences in regression analysis.

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