The Influence of SST Reemergence on Marine Stratiform Cloud

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1. Background

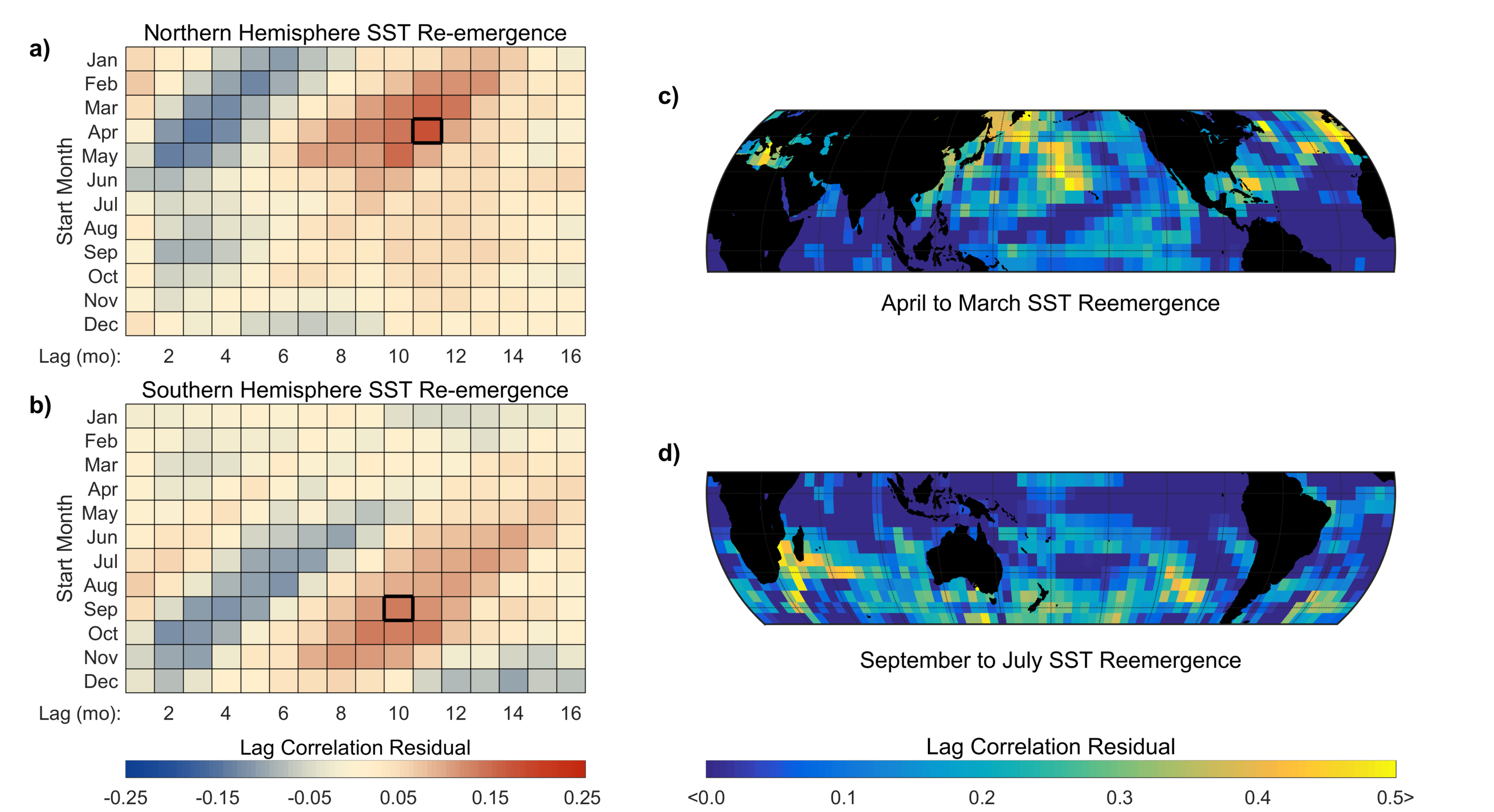
In the extratropics, sea surface temperature (SST) anomalies undergo a winter to winter reemergence process. During the summer, the ocean mixed layer rapidly shallows, which results in wintertime temperature anomalies being stored underneath and mixed back to the surface when the mixed layer deepens the following winter. Marine stratiform cloud occurrence is strongly influenced by SST, particularly in the subtropics and eastern boundaries of the world's ocean basins. We examine the global distribution of SST reemergence and SST controls on cloud amount using satellite data, and identify a region in the north-east Pacific Ocean where wintertime SSTs are correlated with occurrence of marine stratiform cloud the following winter. We hypothesize that through this reemergence mechanism marine stratus cloud amount, and thus shortwave cloud radiative forcing, in the north-eastern Pacific exhibits memory on inter-seasonal and even multi-year time-scales, and may play a non-negligible role in intra-annual sea surface temperature variability.

2. Data

MISR Cloud – The Multi-angle Imaging Spectro-Radiometer retrieves cloud top height and optical depth using multi-angle imaging. We use 5-degree gridded monthly global cloud fraction joint histograms between 2000-2015. The joint histograms bin cloud occurrence with respect to cloud optical depth and cloud top height.

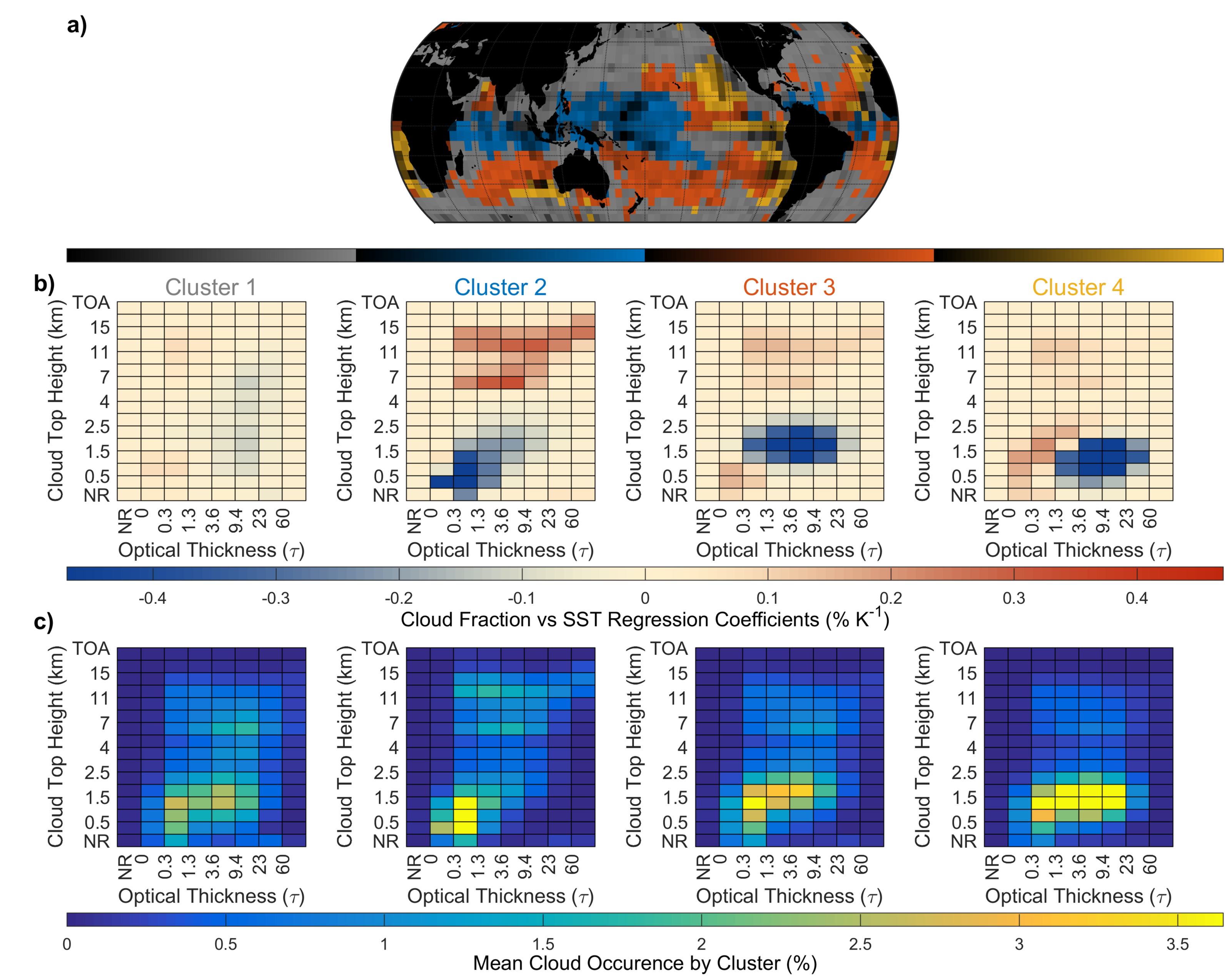
OISST – We use NOAA's Optimum Interpolation Sea Surface Temperature dataset. This is a blended SST product that uses optimum interpolation to combine and grid SST observations from ships, buoys, and the Advanced Very High Resolution Radiometer. Here, 5-degree gridded monthly means of SST from 1982 to 2015 are used.

3. SST Reemergence



We characterize SST reemergence globally by computing residual correlation coefficients obtained by subtracting the autocorrelation expected from a red noise process from the true SST autocorrelation function. Panels a) and b) display northern (25 to 65N) and southern (-65 to -25 S) hemisphere averaged reemergence respectively. These are seasonal correlations for lags (horizontal axis) following specific start months (vertical axis). The negative values around 3-6 month lag, followed by positive values around 9-12 month lag, are evidence of the reemergence mechanism in the hemispheric mean. The reemergence is strongest following the spring (of each hemisphere, respectively), and the month and lag with the largest residual are boxed (thick black lines). Panels c) and d) show the spatial distribution of lag correlation residuals corresponding to the boxed month and lag in the neighboring left panel.

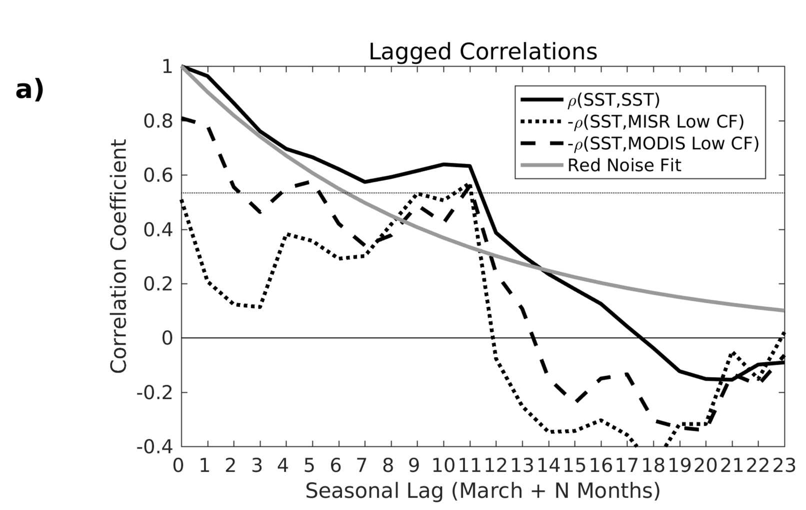
4. Cloud/SST Interactions

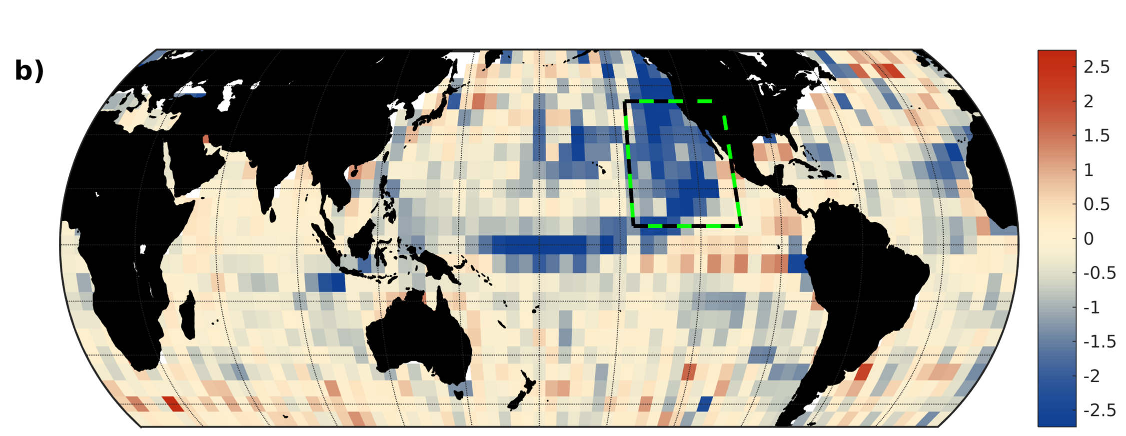


Above is a global analysis of SST-cloud interaction. We first compute instantaneous regression coefficients globally for each bin in the MISR cloud fraction joint histograms. Then we apply k-means clustering to identify regions with similar SST-cloud relationships. Color in panel a) denotes cluster assignments and shading represents normalized distance from the corresponding cluster center. Row b) shows 4 cluster centers, computed from SST-cloud fraction regression coefficients, that describe how monthly SST anomalies interact with cloud fraction. Row c) shows the climatological mean cloud occurrence for the regions associated with each cluster.

Most of the mid-high latitudes show no strong interaction between SST and cloud fraction on monthly timescales (cluster 1). The third and fourth cluster show the well documented negative correlation between SST and subtropical low cloud. The second cluster likely results from modes of tropical variability (e.g. El Nino). For low cloud (CTH < 2.5km) cluster 2 gives: -5.4 $\%K^{-1}$, cluster 3: -4.5$\%K^{-1}$, cluster 4: -5.7$\%K^{-1}$.

5. Cloud Reemergence

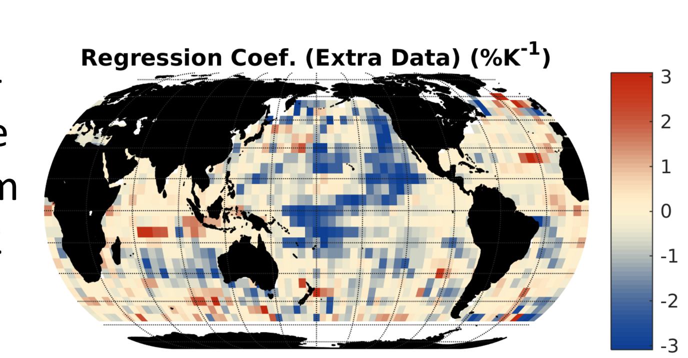


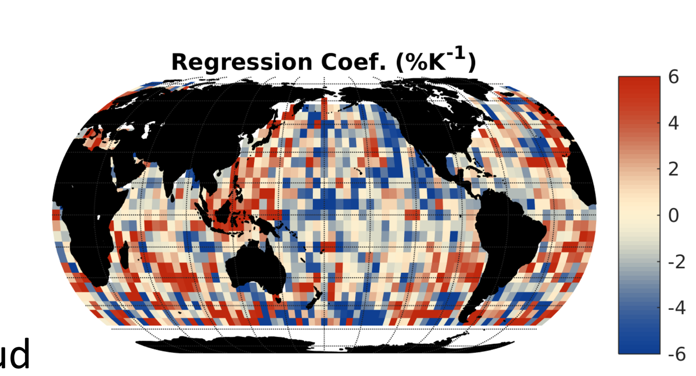


Winter-Winter SST-Low CF Lagged Covariance (%K)

Left – Panel a): lag correlations between winter SST anomaly and future SST, MODIS low cloud, and MISR low cloud amount averaged over the boxed region in the lower panel. The sign of the SST to low-cloud-fraction lag correlations is flipped for easier comparison to the SST autocorrelation curve. The deviation (of the solid black line) from the red-noise autocorrelation function (solid gray line) around 10-12 months lag results from the SST reemergence mechanism. Panel b): lagged covariance between late-winter / early-spring (MAM in the northern hemisphere and ASO in the southern hemisphere) SST and following winter (FMA in the northern hemisphere and JJA in the southern hemisphere) low cloud fraction (MISR: cloud top height <2.5km, MODIS: cloud top pressure >680hPa). The strongest lag covariances occur in the North-East Pacific Ocean.

Right – Winter-winter lagged regression coefficients between cloud and SST (bottom). We note that with such a short time-series (15 years) these regression coefficients are very noisy. When estimated using 33 years of SST reemergence data and instantaneous SST–cloud fraction regression coefficients (top) the same pattern in the NE Pacific seen in the lagged covariance is apparent.





6. Conclusions

- We characterize the global distribution of SST reemergence (panel 3) which mostly occurs in the extratropics, and cloud-SST interaction (panel 4) which is strongest in the tropics and subtropics.
- Both effects occur in the subtropical North-East Pacific Ocean, where there is very large winter-winter lagged covariance between the two fields (panel 5).
- Regionally averaged winter time low cloud occurrence is correlated with SST anomalies from the previous winter the North East Pacific (panel 5). The fields have larger lagged correlations then expected from a red noise process, so winter low cloud anomalies are likely being influenced by SST reemergence.
- Regression between March-May averaged SSTA and February-April averaged low cloud fraction anomaly the following year for the region selected in panel 5 gives a regression coefficient of -5.2$\%K^{-1}$. Further understanding this relationship can potentially provide insight into SST-low cloud feedbacks.

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