The Influence of SST reemergence on marine stratiform cloud

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Andrew Geiss and Roger Marchand

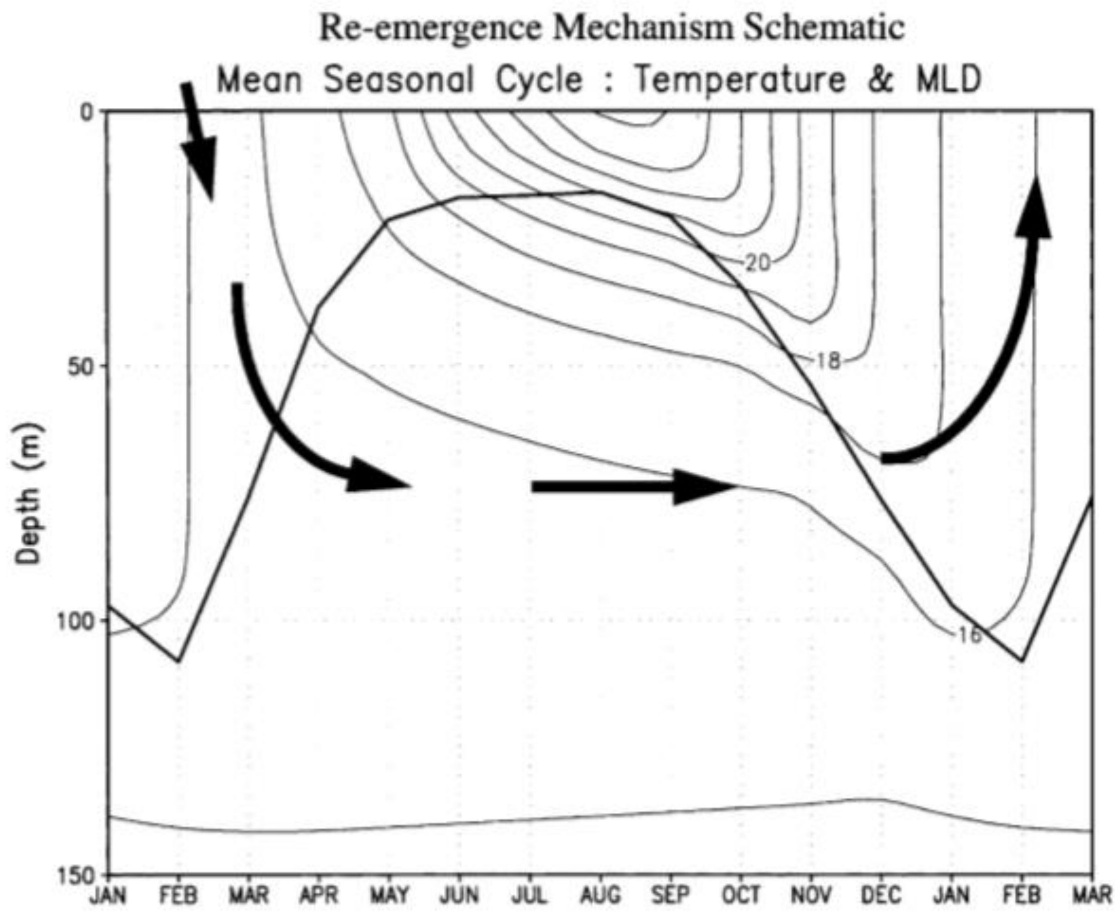
University of Washington – Dept. of Atmospheric Sciences

LuAnne Thompson

University of Washington – School of Oceanography

(contact: avgeiss@gmail.com)

Background: SST Reemergence



(Alexander et al. 2001)

Sea Surface Temperatures in the extratropics re-emerge between following winters

Driven by the seasonal heating of the ocean surface

Summertime heating shallows the mixed layer and wintertime temperature anomalies are stored underneath

(Namias and Born 1970)

Background: SST Reemergence

Reemergence primarily occurs in the sub-tropics and extratropics where there is a strong seasonal cycle of mixed layer depth

It can occur on 8-12 month time scales

It is typically identified in the literature by applying a threshold to the SST time-auto-correlation function

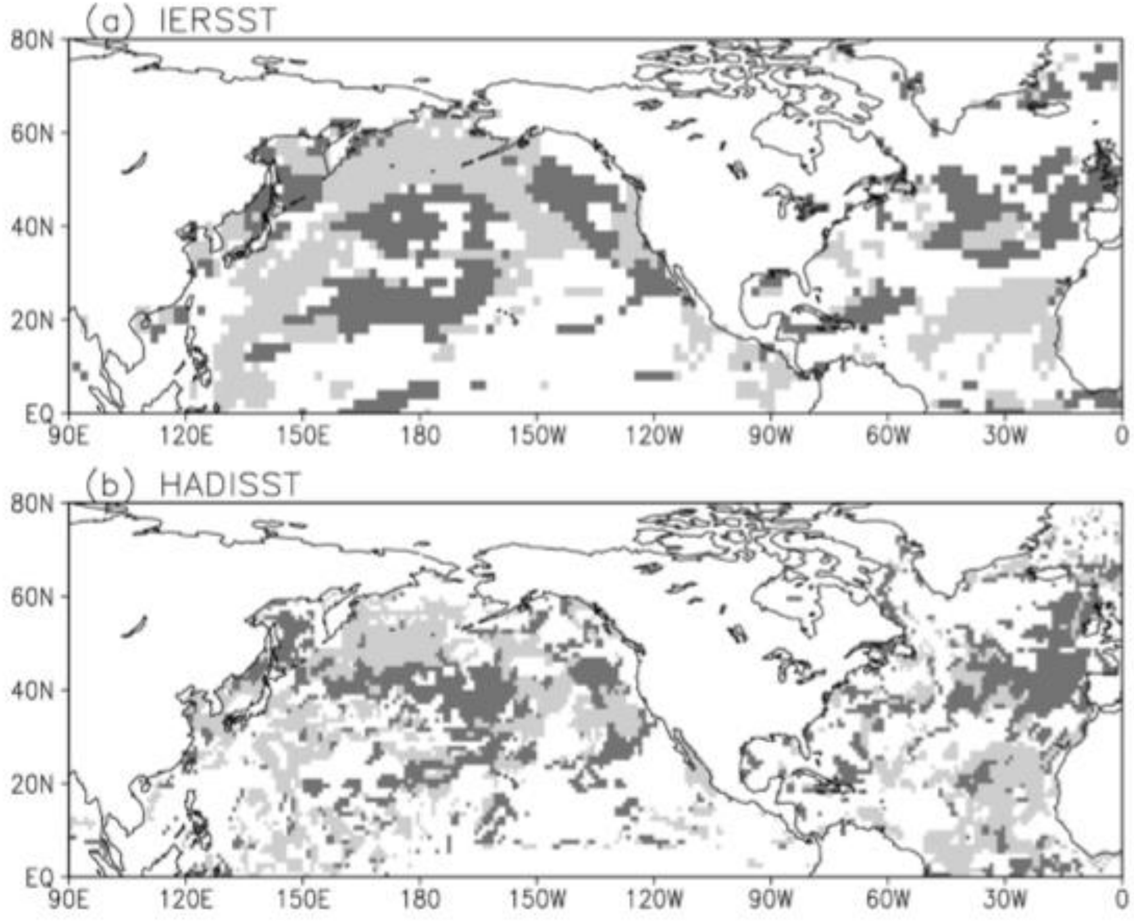


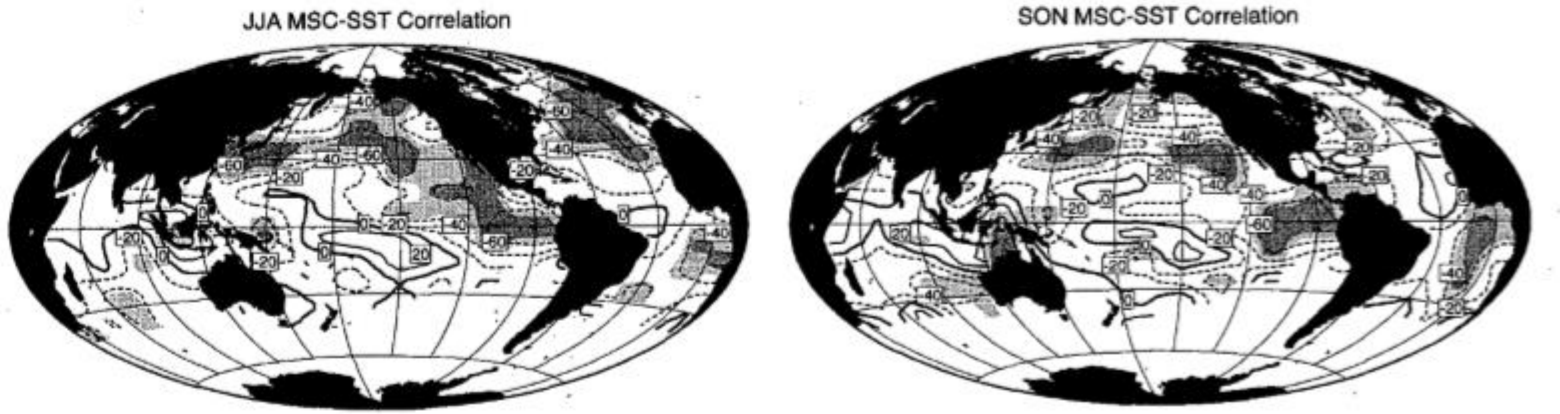
FIG. 2. Spatiotemporal distribution of the SSTA WWR in the NH for the starting month of February from (a) IERSST and (b) HADISST datasets. Dark (light) shading indicates the recurrence timing is in winter (fall).

(Zhao and Li 2009)

Background: SST Controls on LCF

Low cloud occurrence is strongly linked to SST particularly in the subtropical eastern boundary regions

Lower SSTs are generally associated with increased low cloud fraction



(Norris and Leovy 1994)

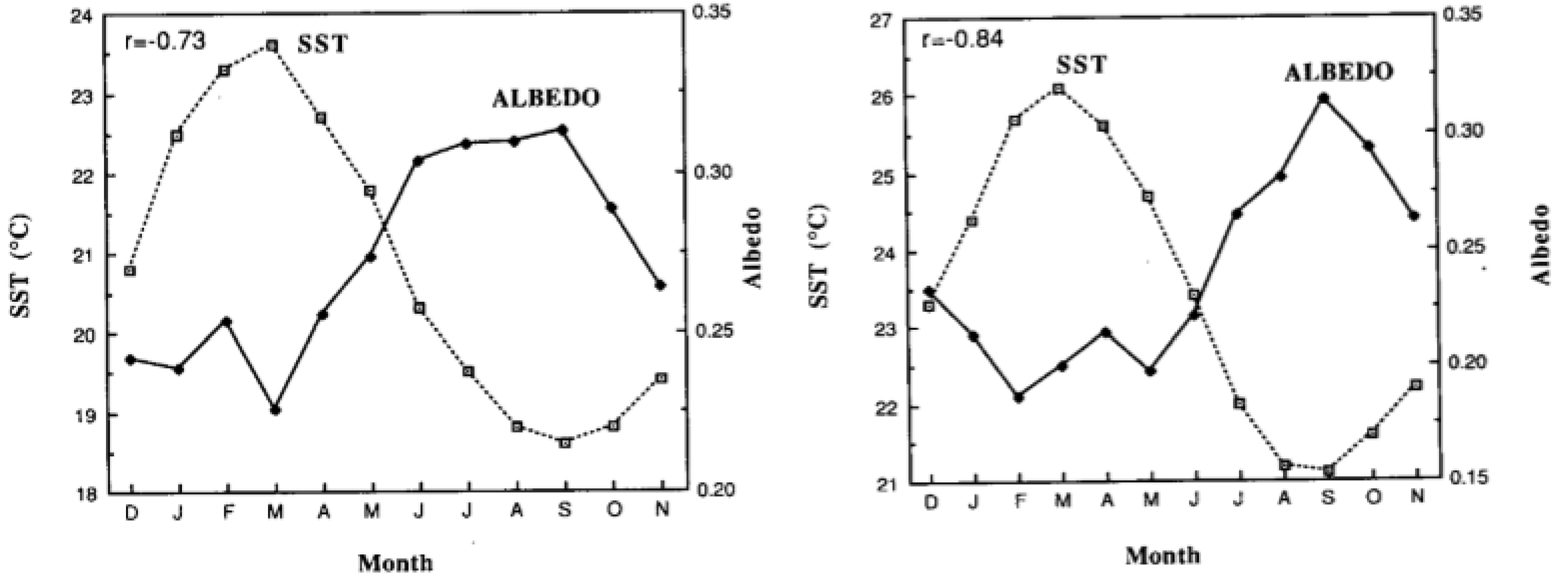
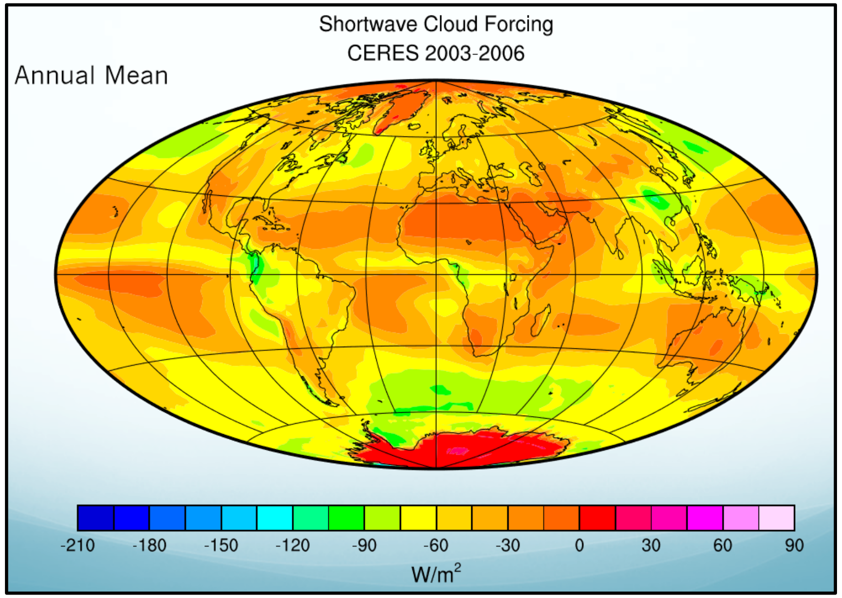


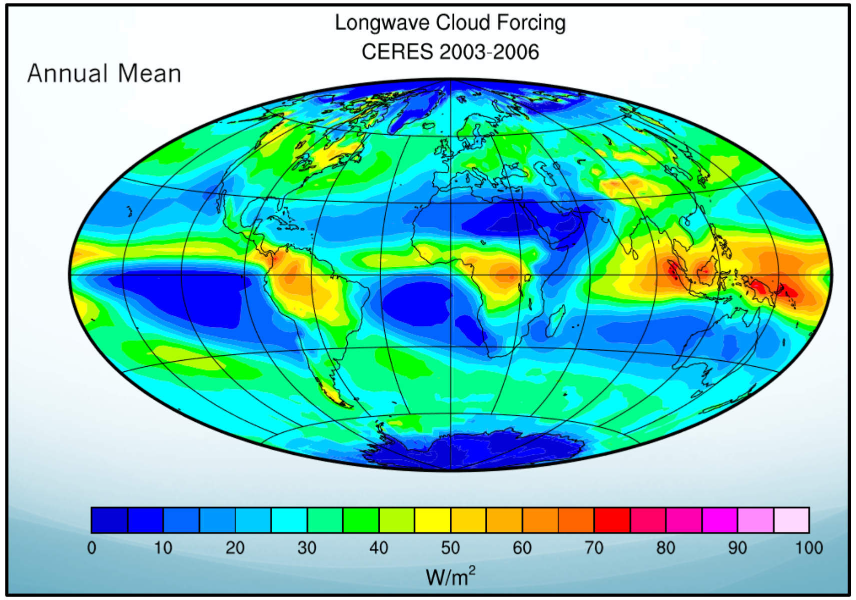
FIG. 2. Annual cycle of spatially averaged SST (dashed) and albedo (solid) and coefficient of linear regression from 60 monthly averages (Dec84–Nov89) for Region 1 (left) and Region 2 (right).

(Oreopoulos and Davies 1993)

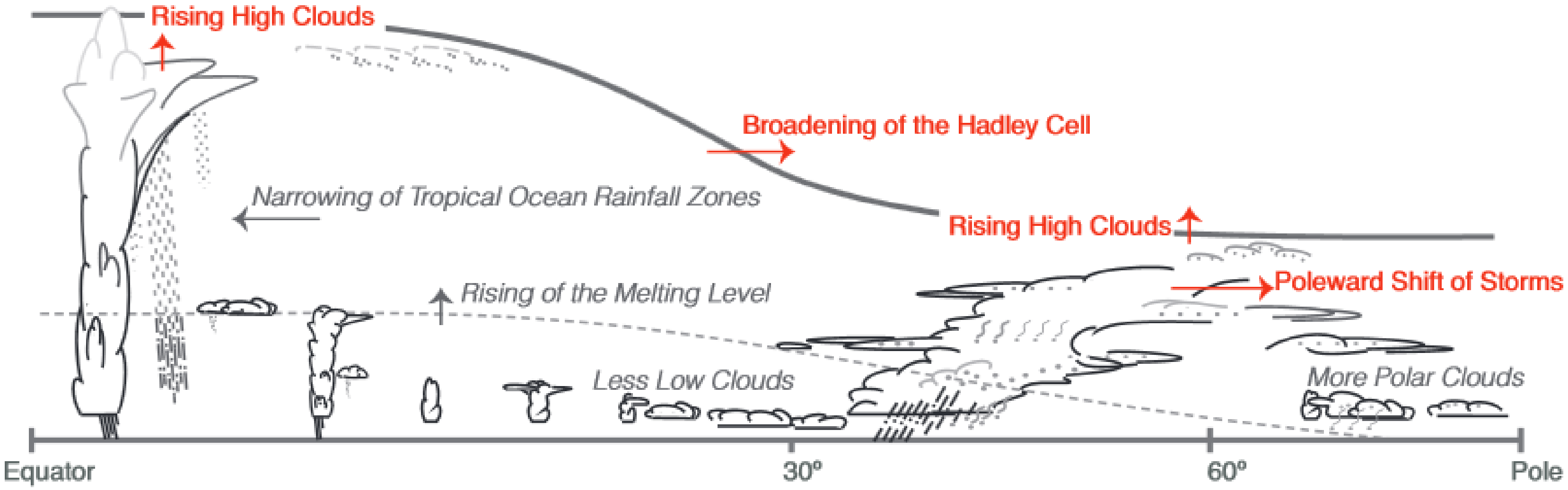
Motivation

Clouds (subtropical low cloud in particular) play a significant role in Earth's radiative budget.





(Hartmann, 2014)



(IPCC AR5, 2013)

Low cloud responds to changes in SST, but changes in low cloud under global warming are still uncertain

Motivation

Additionally, recent work has shown that low cloud may play a significant role in magnifying modes of climate variability (the AMO)

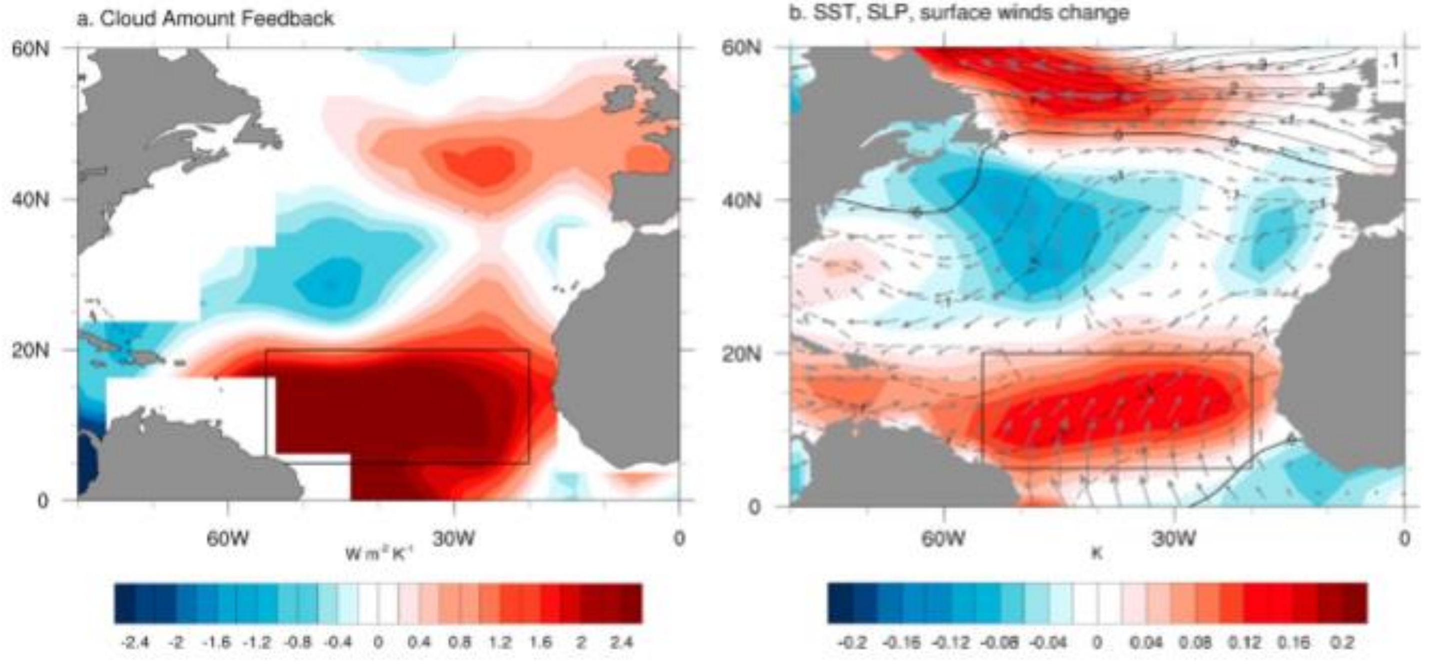


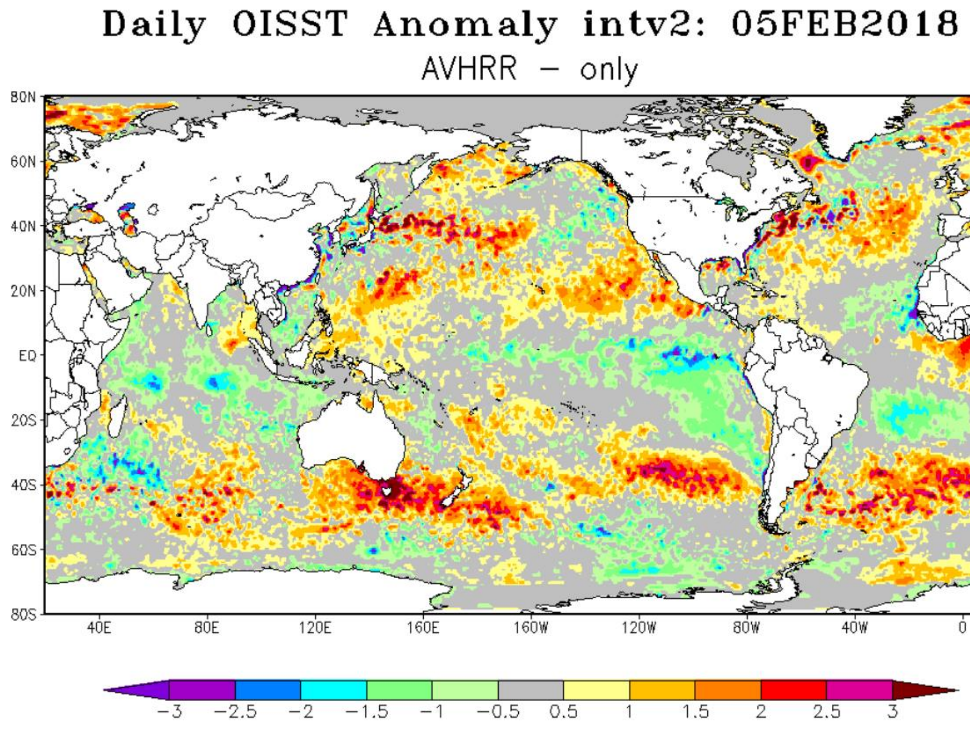
Figure 3. Cloud amount feedback. (a) Observational estimate of cloud amount feedback computed as cloud amount radiative kernel (Figure S3) multiplied by the regression of cloud amount on the NASST index (Figure 1b). Units are $W m^{-2} K^{-1}$. (b) Change in mean SST (shaded), SLP (contours), and surface winds (vectors) due to the imposed cloud amount feedback in the slab-ocean model experiment. Units are of kelvin (SST), hPa (SLP), and ms^{-1} (surface winds). Contours range from −0.2 hPa to 0.2 hPa with intervals of 0.02 hPa.

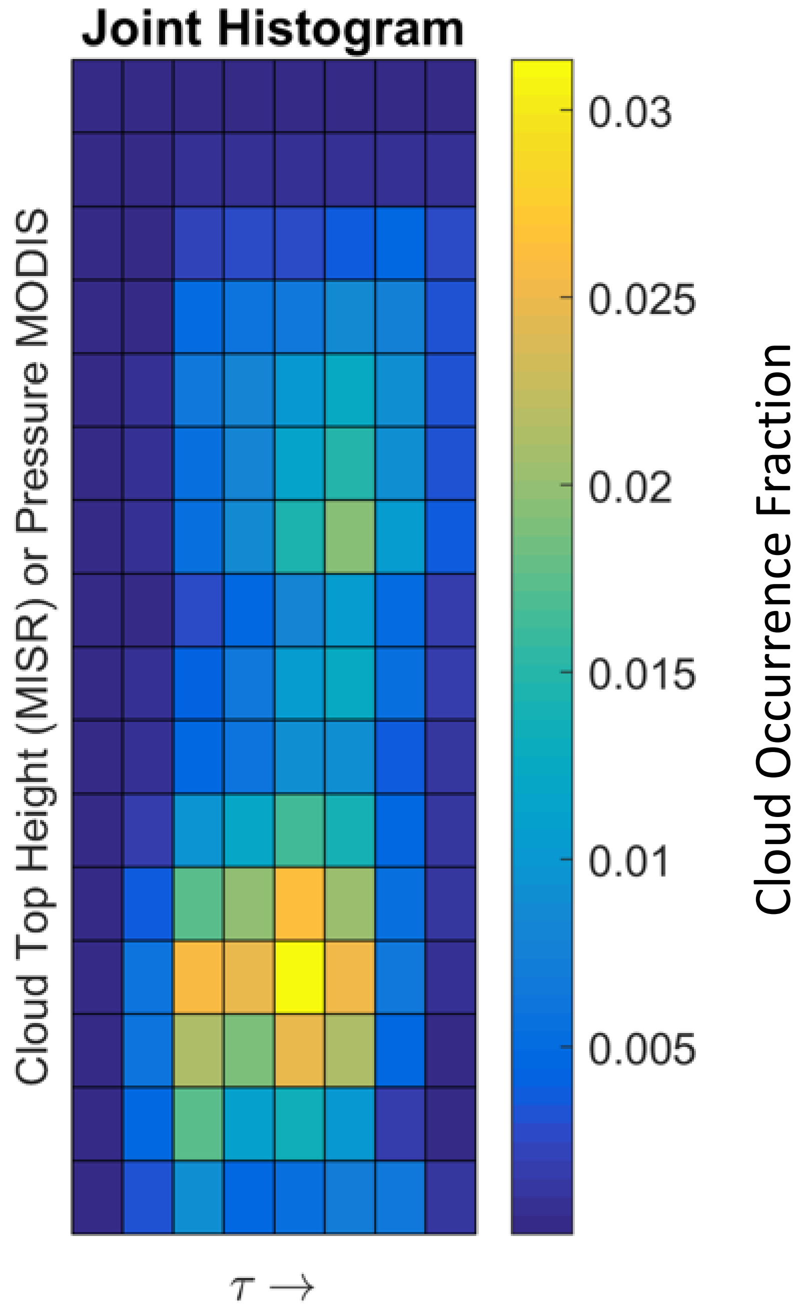
Bellomo et al. 2016

Data

Monthly 5-degree gridded Optimally Interpolated SST (OISST) from 2000-2016

Monthly MISR 5-degree gridded cloud fraction joint histograms from 2000-2016





Method

Approach:

1) Catalog cloud responses to SST over the duration of the MISR mission

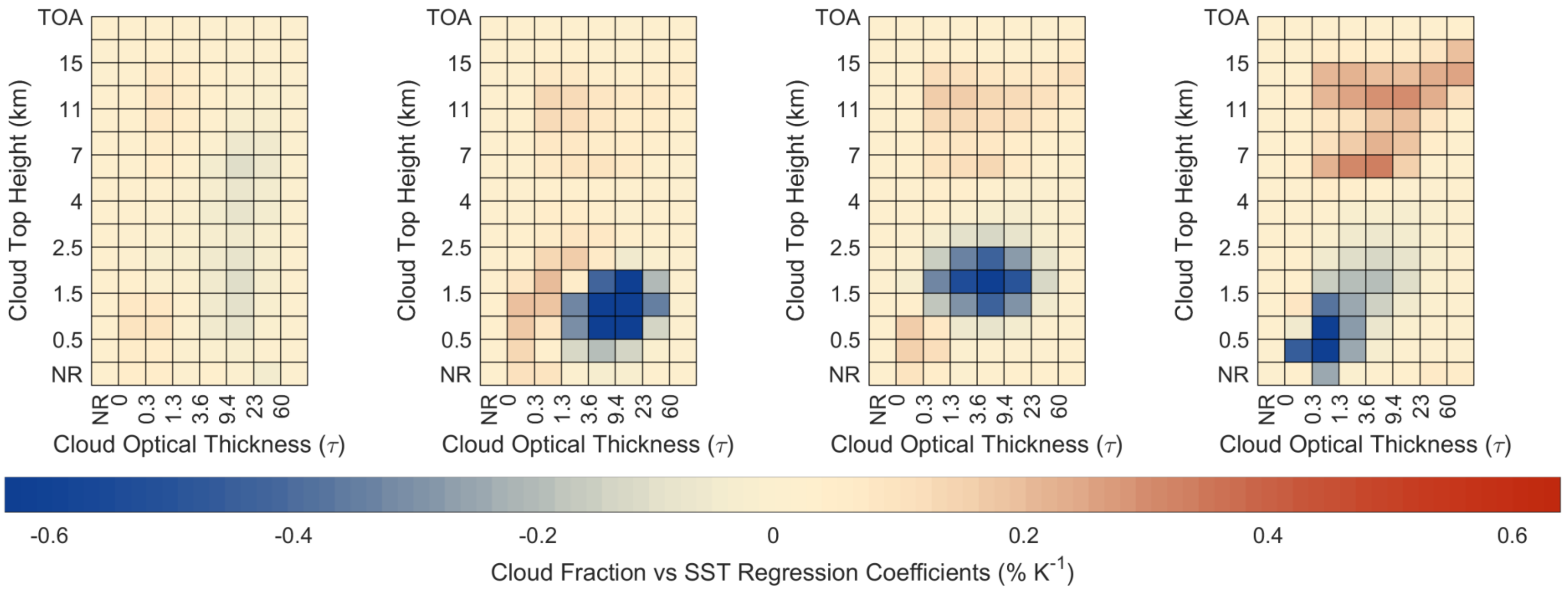
2) Identify locations where SST reemergence occurs

3) Identify any locations where cloud amount is influenced by the reemergence

Results: MISR Cloud-SST Relationship

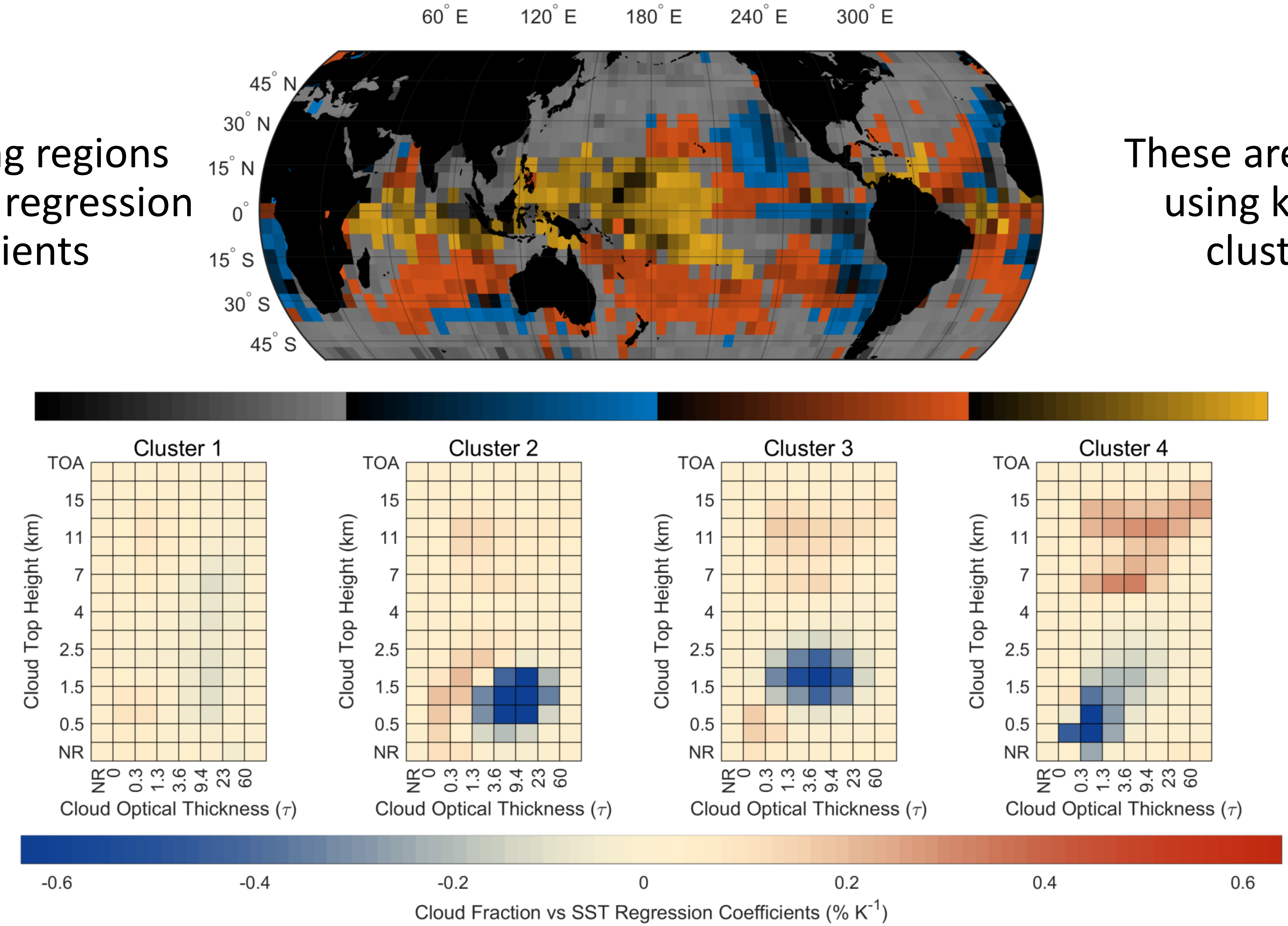
To catalog cloud-SST relationships on a global scale I regress detrended, de-seasonalized, cloud fraction anomalies on to SST

This is done for every 5x5 degree box and for every bin in the MISR cloud occurrence joint histograms. Below are some examples.



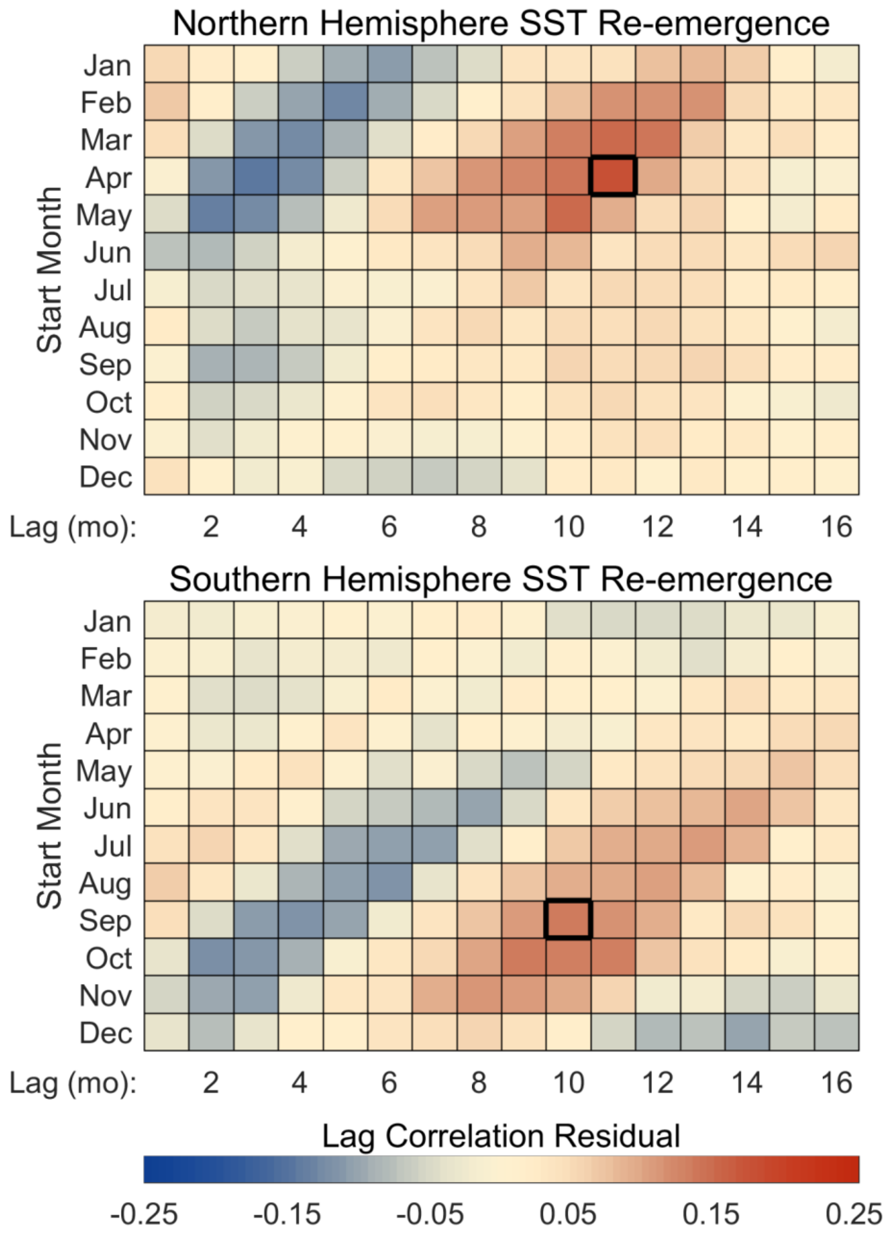
Results: MISR Cloud-SST Relationship

Neighboring regions have similar regression coefficients



These are grouped using k-means clustering

Results: SST Reemergence



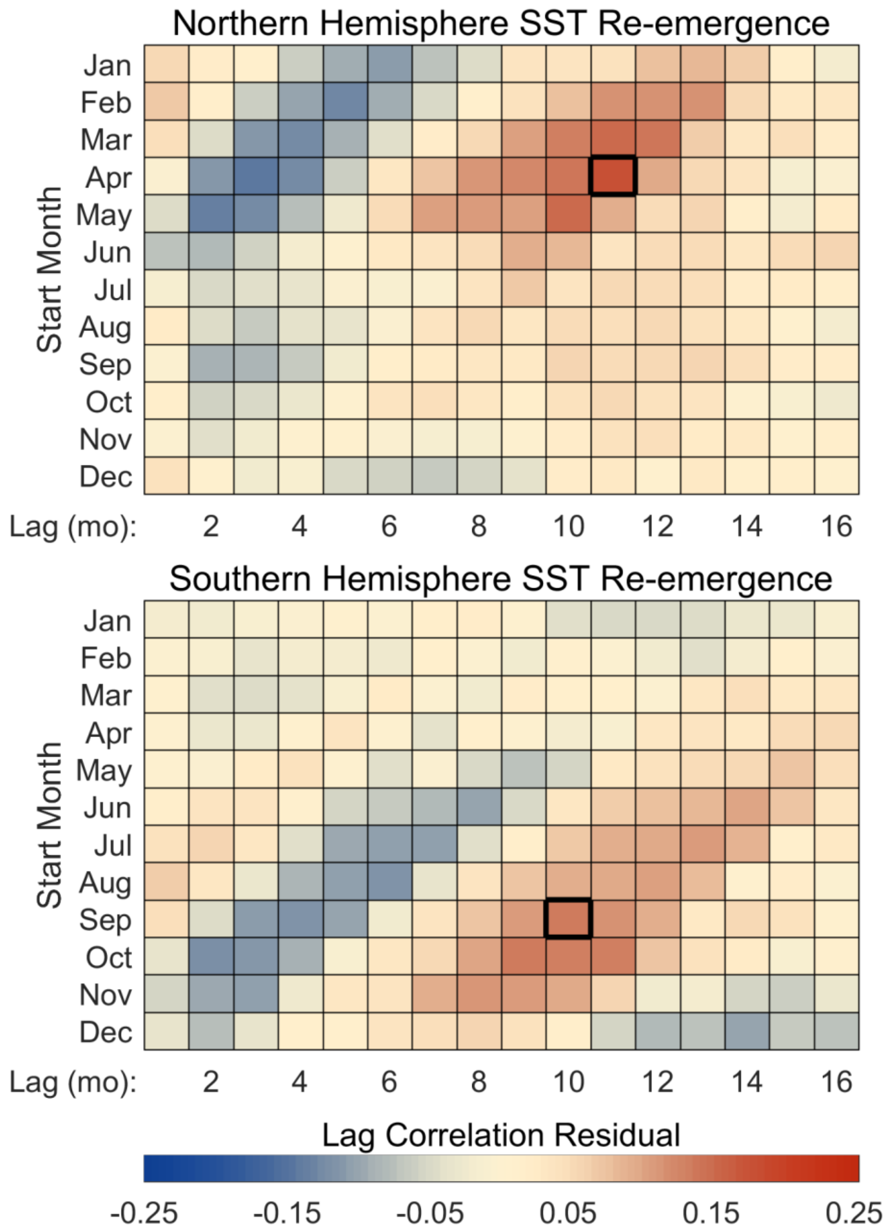
Cataloging SST reemergence approach:

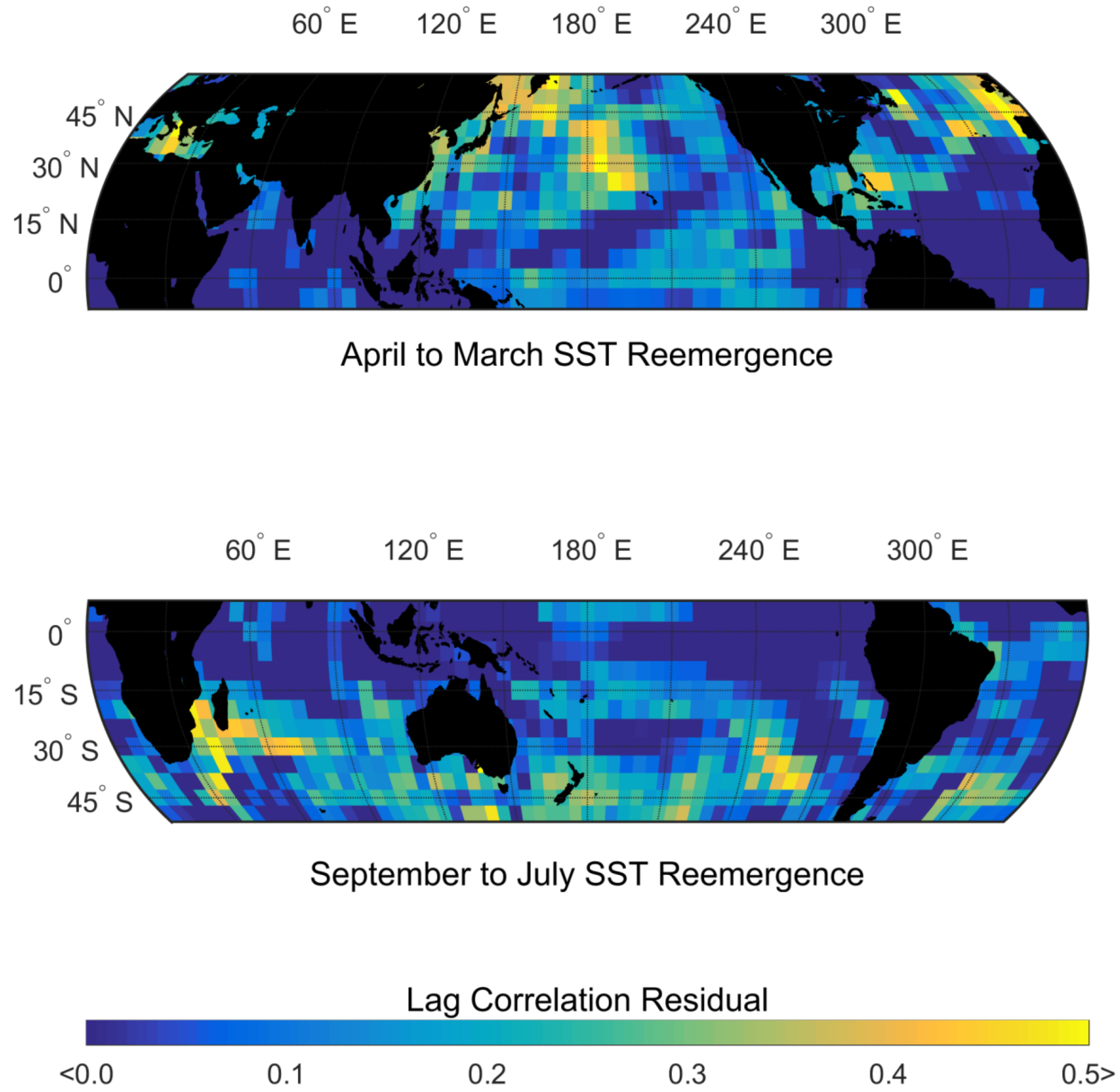
Assume SST behaves like an autoregressive-1 process (only has memory of the previous month)

Best fit a time-autocorrelation function for an AR1 process (exponential decay) to the SST time-autocorrelation function

If there is a large positive deviation from this curve, then SST must have memory on longer time-scales

Results: SST Reemergence

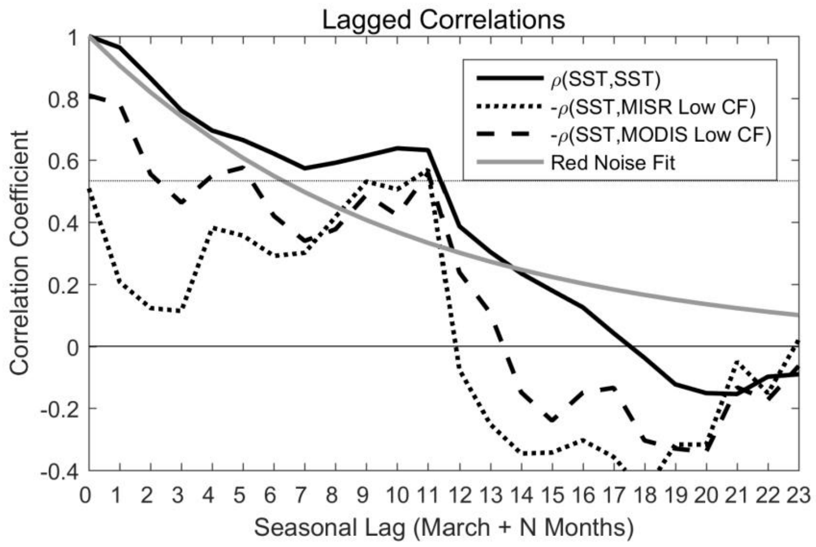


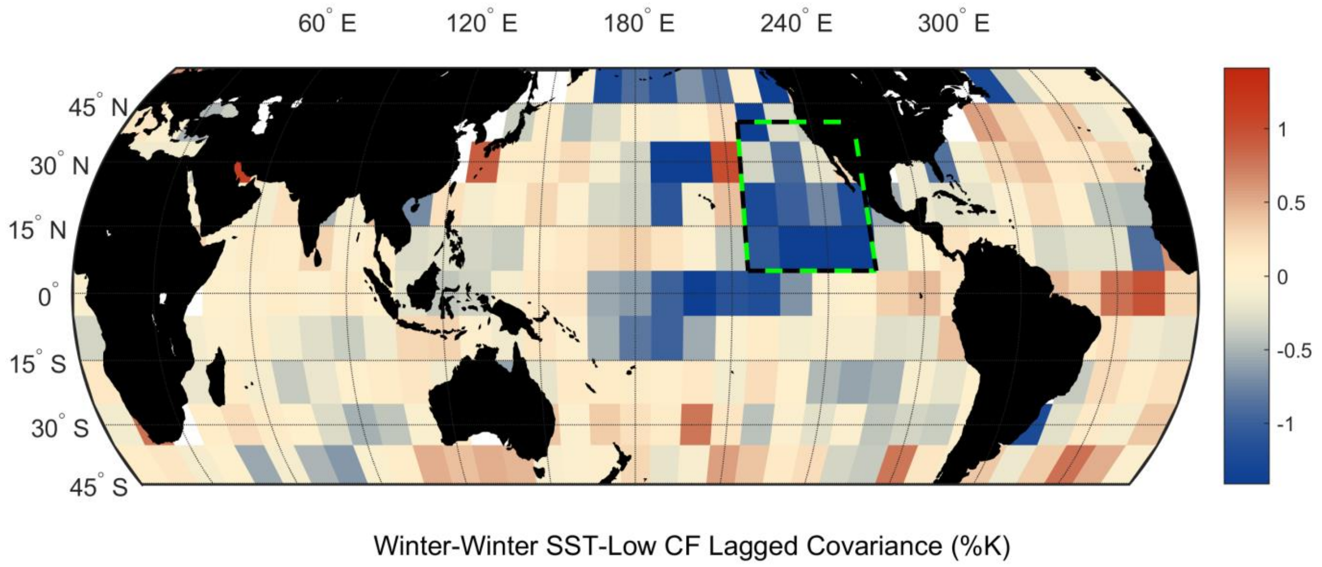


April to March SST Reemergence

September to July SST Reemergence

Results: LCF Reemergence



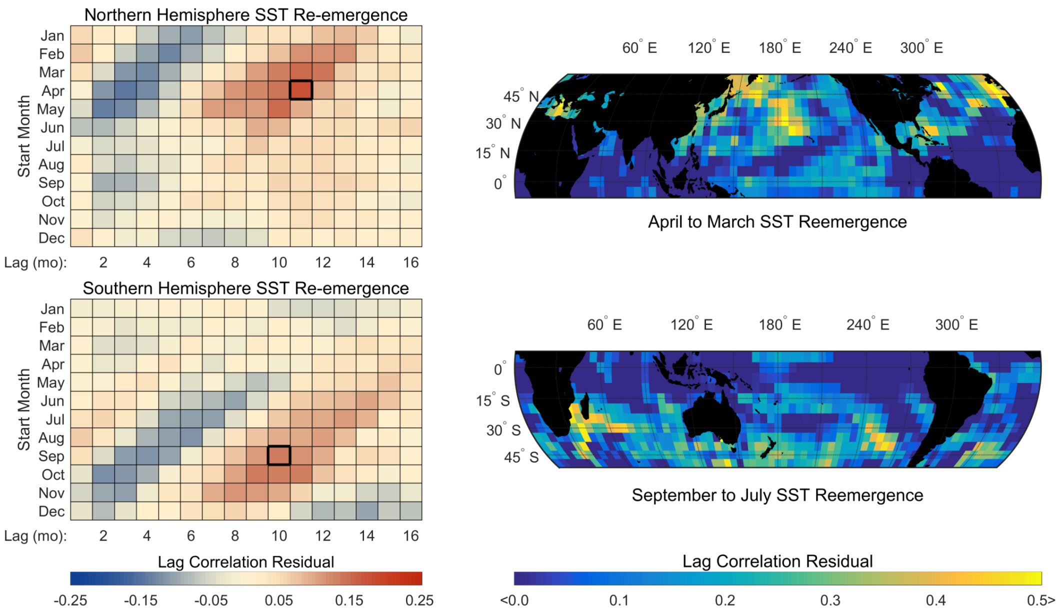


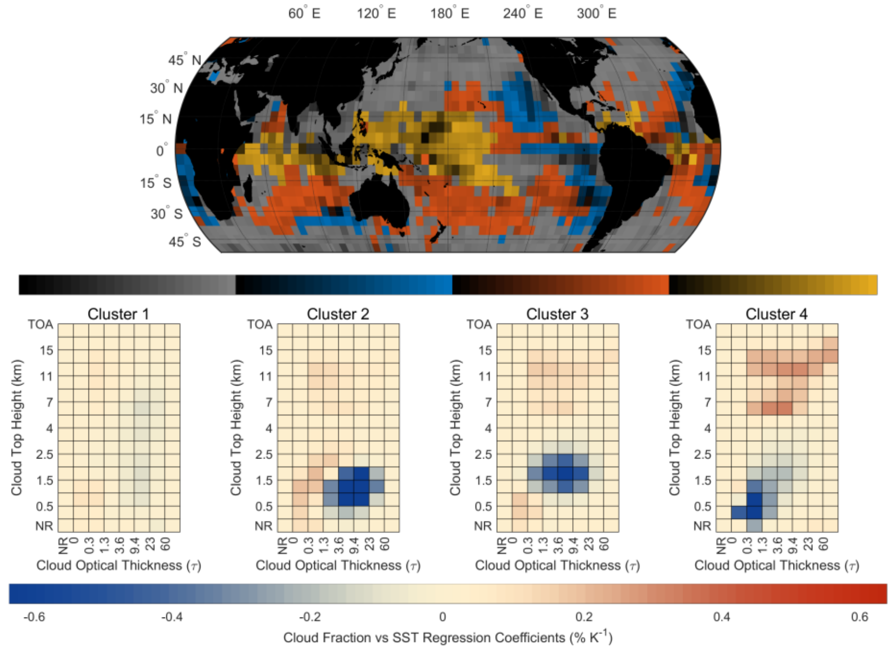
The NE Pacific is the one region where both effects overlap

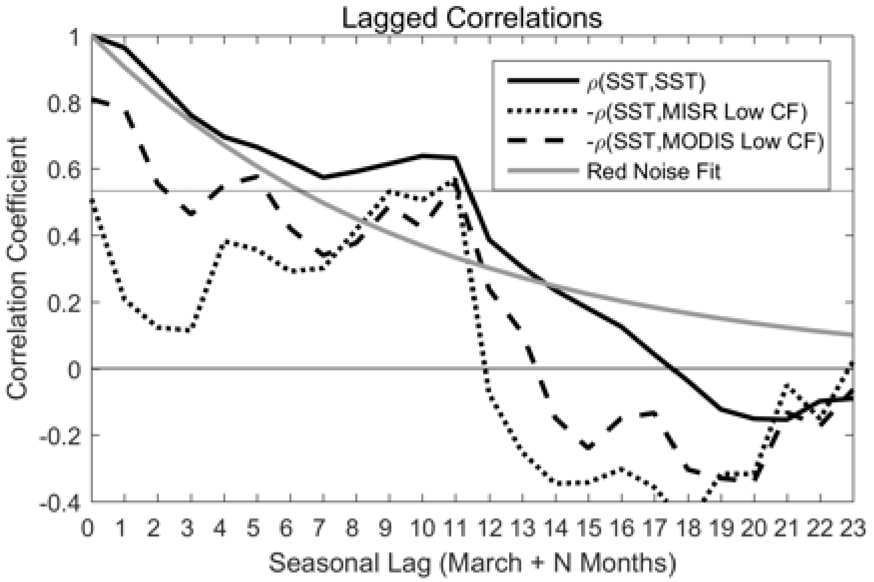
There is a re-emergence signal in LCF at 8-12 months after boreal winter

Can this signal improve understanding of low cloud-SST feedbacks?

Questions?


Northern Hemisphere SST Re-emergence
Start Month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Lag (mo):
2
4
6
8
10
12
14
16
Southern Hemisphere SST Re-emergence
Lag Correlation Residual
-0.25
-0.15
-0.05
0.05
0.15
0.25
60° E
120° E
180° E
240° E
300° E
45° N
30° N
15° N
0°
April to March SST Reemergence
15° S
30° S
45° S
September to July SST Reemergence
Lag Correlation Residual
<0.0
0.1
0.2
0.3
0.4
0.5>


60° E
120° E
180° E
240° E
300° E
45° N
30° N
15° N
0°
15° S
30° S
45° S
Cluster 1
Cluster 2
Cluster 3
Cluster 4
Cloud Top Height (km)
TOA
15
11
7
4
2.5
1.5
0.5
NR
NR 0 0.3 1.3 3.6 9.4 23 60
Cloud Optical Thickness (τ)
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Cloud Fraction vs SST Regression Coefficients (% K⁻¹)


Lagged Correlations
ρ(SST,SST)
-ρ(SST,MISR Low CF)
-ρ(SST,MODIS Low CF)
Red Noise Fit
Correlation Coefficient
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Seasonal Lag (March + N Months)