Prediction challenges associated with errors in linear trends of tropical Pacific sea surface temperature

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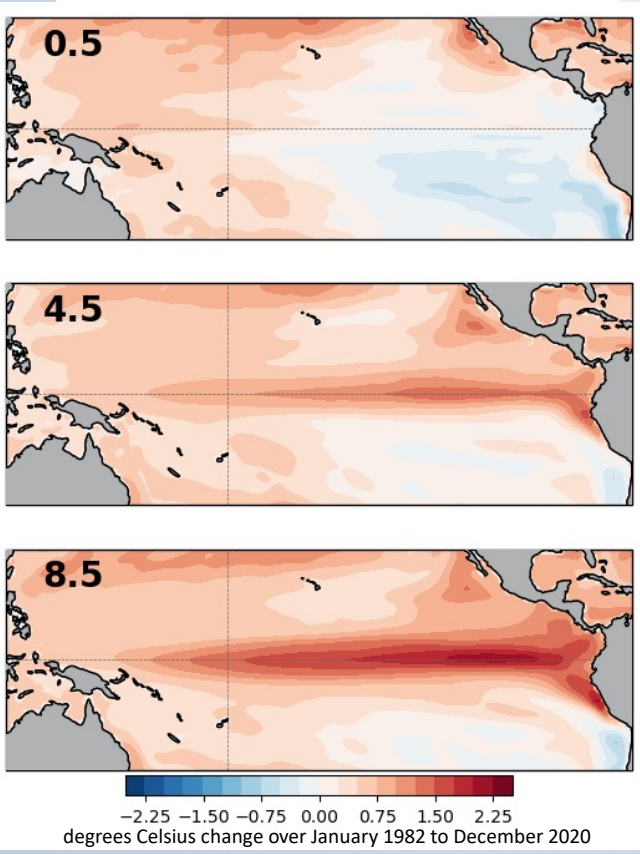
Key Take Away: SST trends in *initialized* climate model forecasts are **more positive** than observed trends across the tropical Pacific Ocean. This appears to be associated with an increase in El Niño False Alarms.

Trend in an NMME model

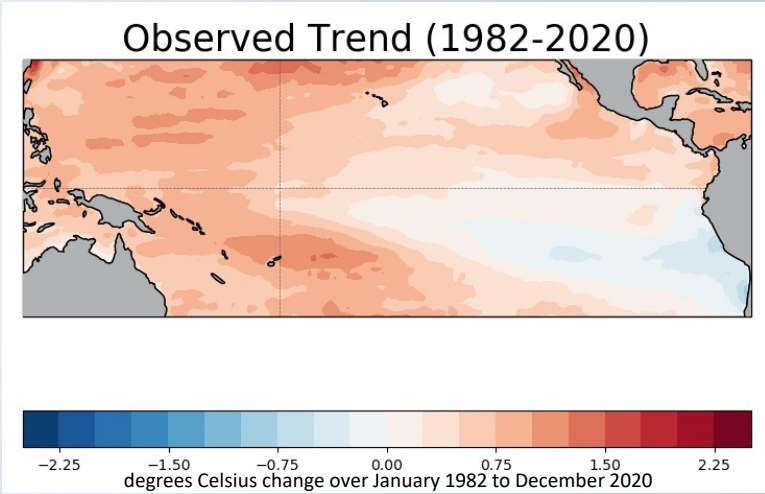
0.5-mth lead time

4.5-mth lead time

8.5-mth lead time



Should look like



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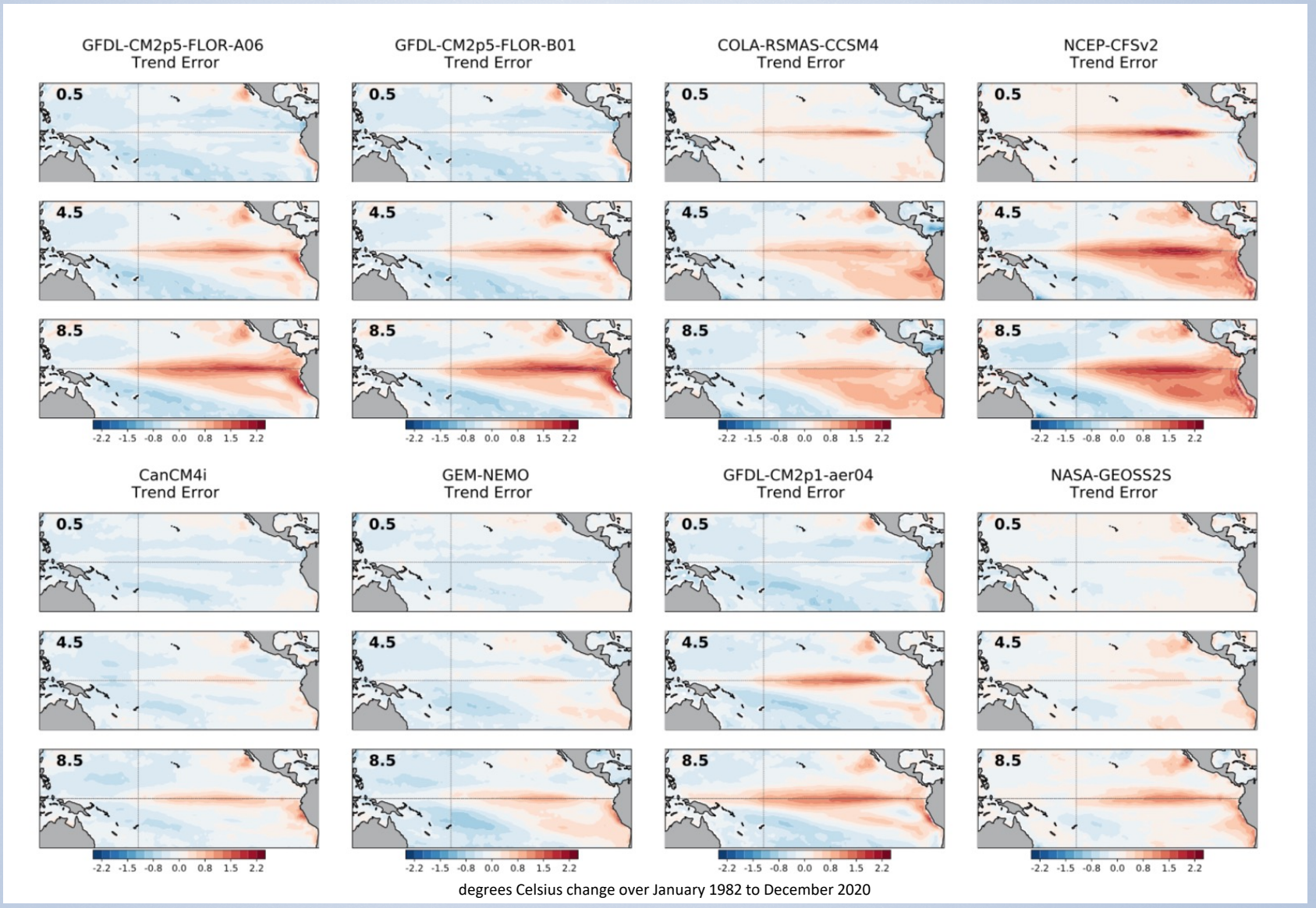
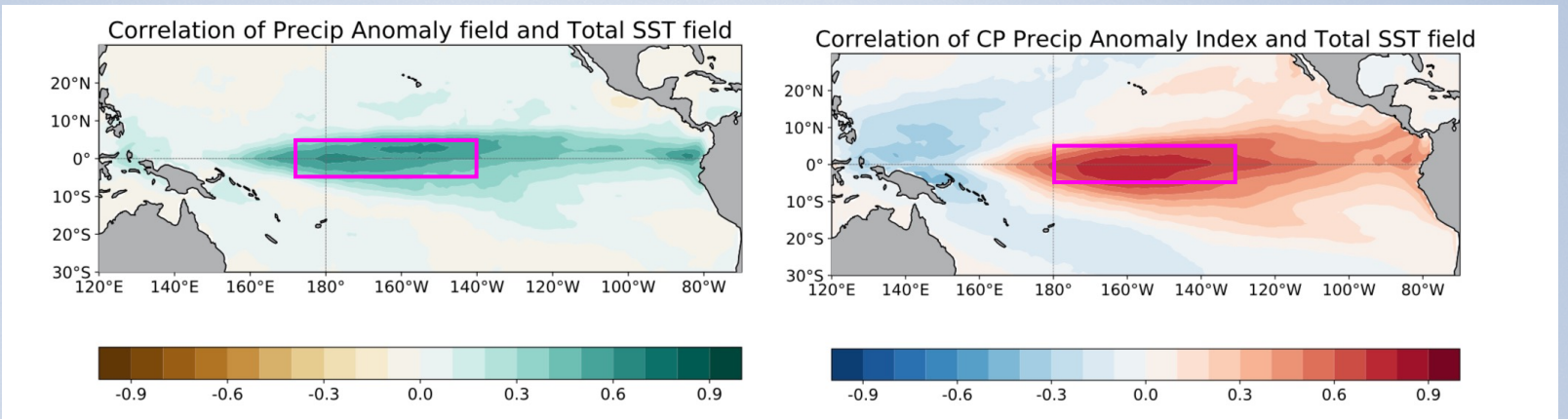
~40 year linear trend (1982-2020) computed separately for each forecast lead time and model in the North American Multi-Model Ensemble (NMME)
Linear Trend Error (forecast minus the observations) is too positive in the eastern Pacific Ocean. Most evident by the ~4.5-month lead and beyond.



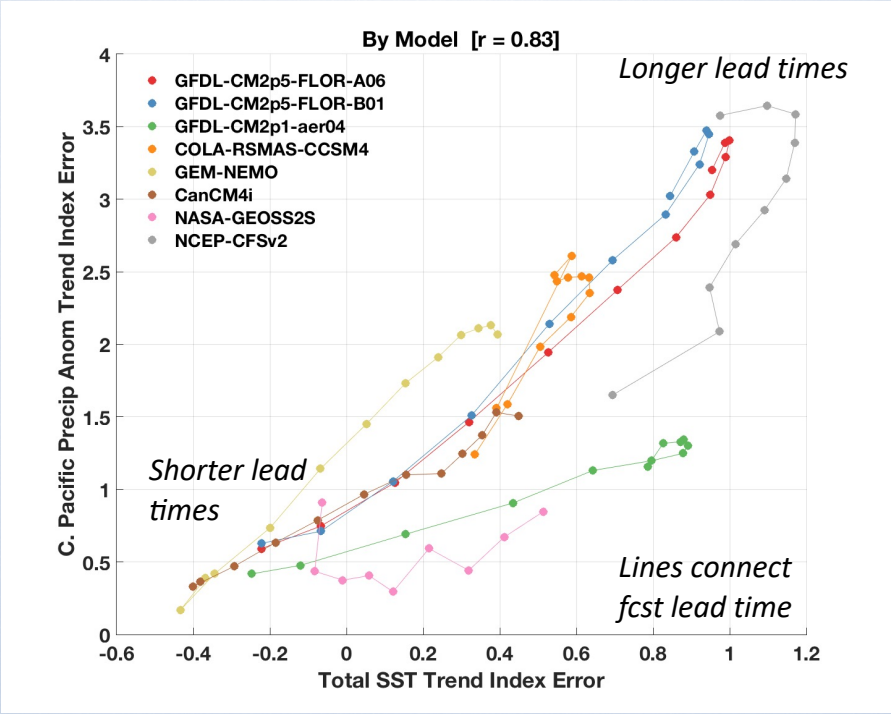
CFSv2 and CCSM4 have known initialization errors which manifest as SST trend error at short lead times (see 0.5-month).

Total Sea Surface Temperatures (SSTs) Relate To Precipitation Anomalies: Total SST and Central Pacific Precipitation Anomaly Indices

Indices are the average of the region inside the box



Total SST trend errors are associated with Central Pacific Precip. Anomaly trend errors



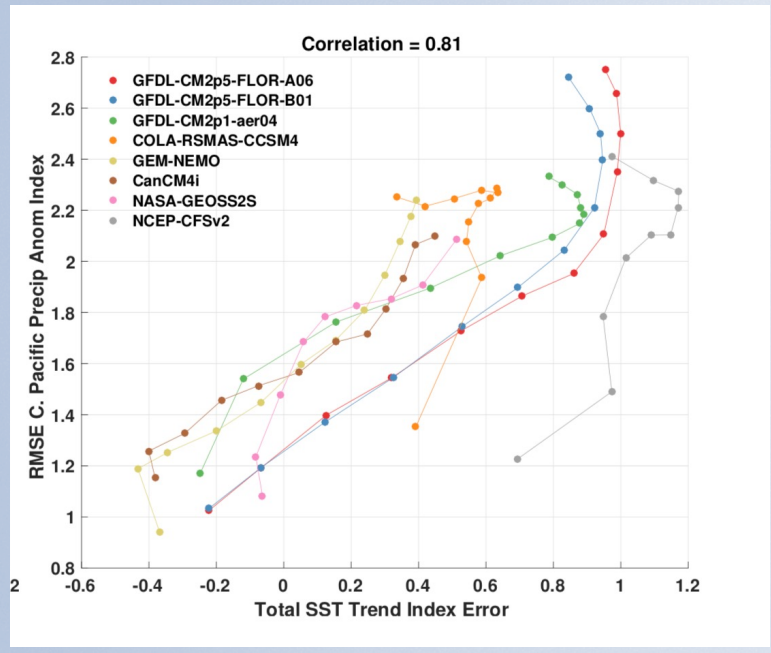
Too positive SSTs

↕

Too wet precipitation anomalies

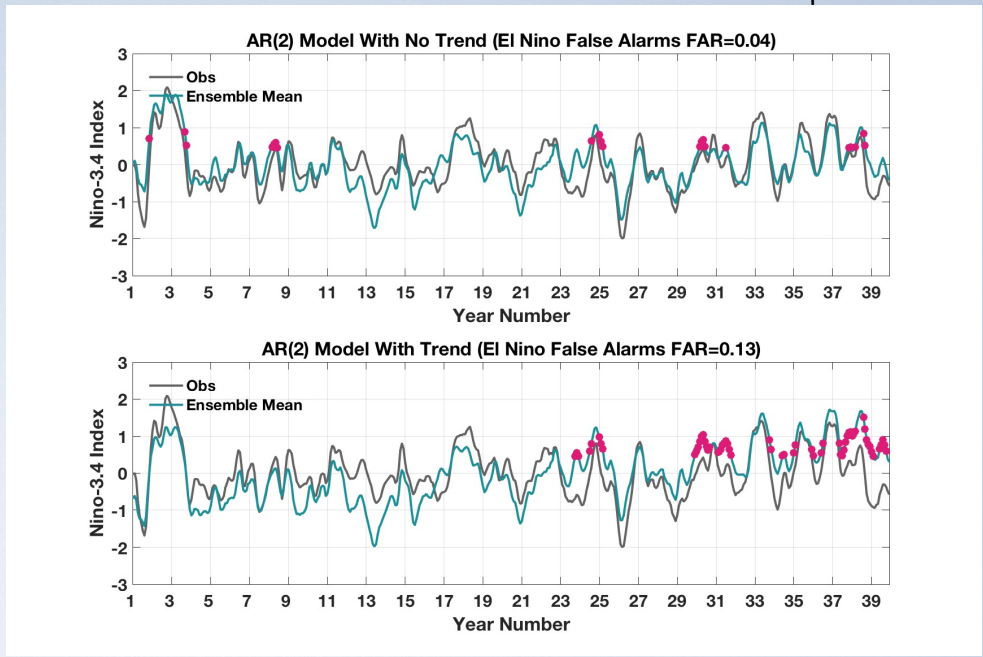
Errors in the SST trends relate to Errors in Precip. Anomalies

Root Mean Squared Error (RMSE) in mm/day



Typical precipitation anomalies in this region range from 3-5mm/day . These are relatively large errors.

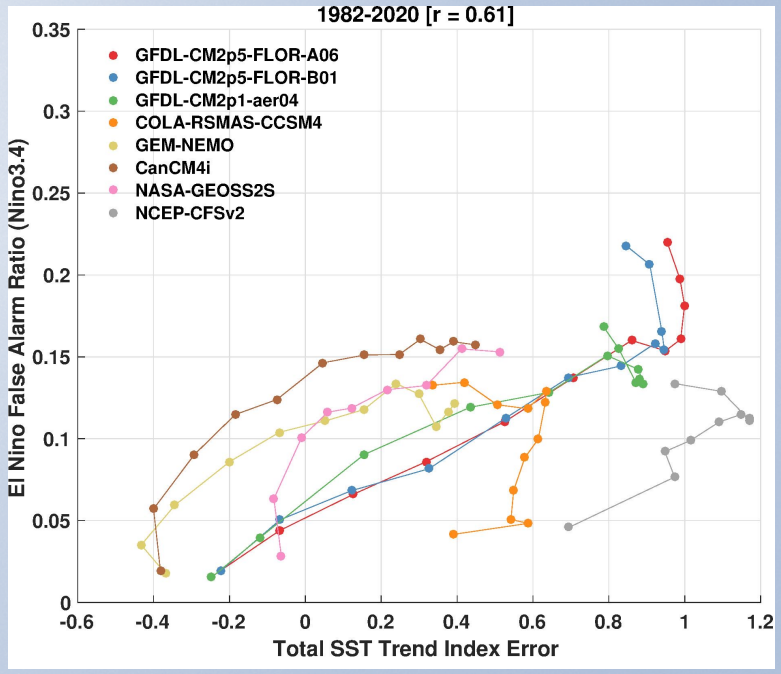
"Perfect" 100 member AR(2) simulation of Niño-3.4 index with a linear trend added to the ensemble mean in the bottom panel.



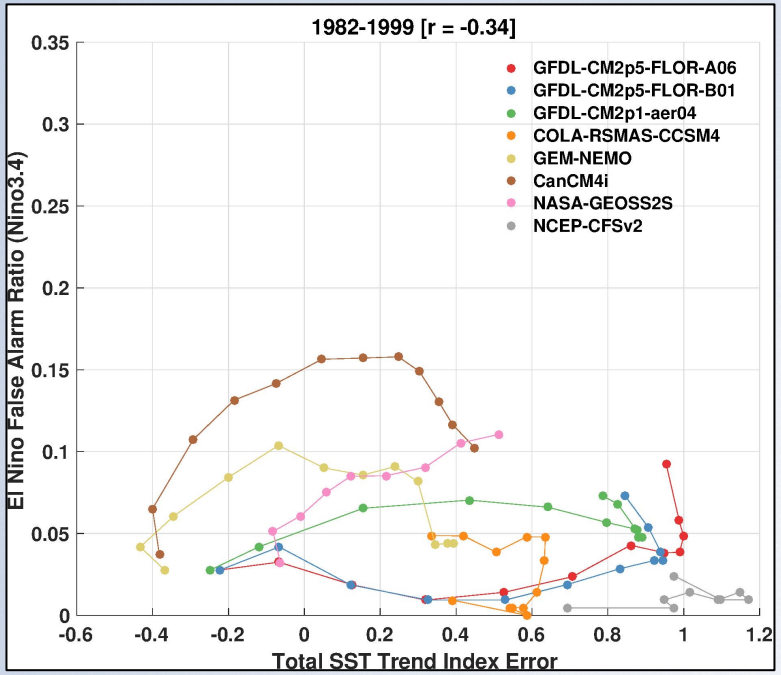
Positive SST trends increase the frequency of El Niño False Alarms (pink dots) especially in the last half of the record.

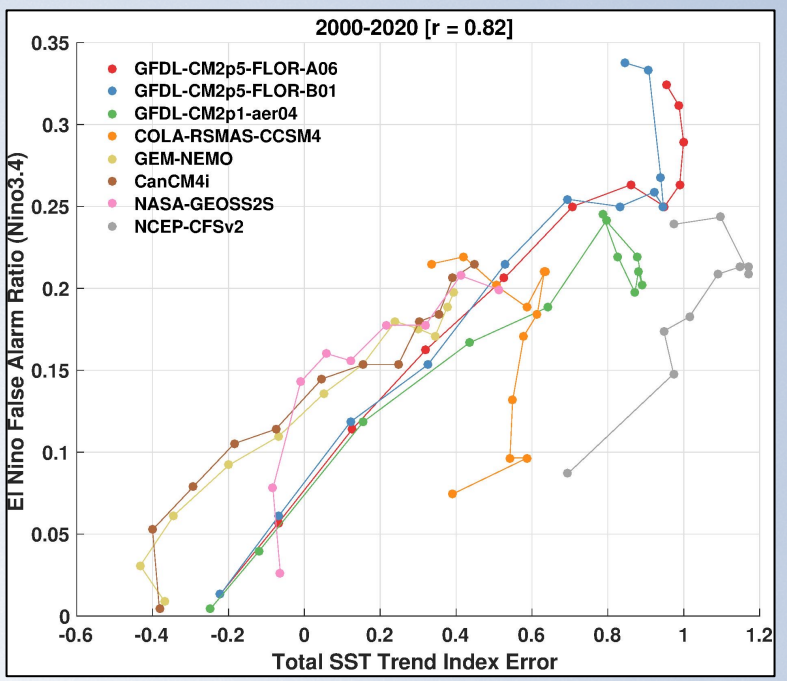
In NMME predictions, El Niño False Alarm ratio increases with larger SST trend index errors.

Has this ratio changed from the first half of the record to the last half?



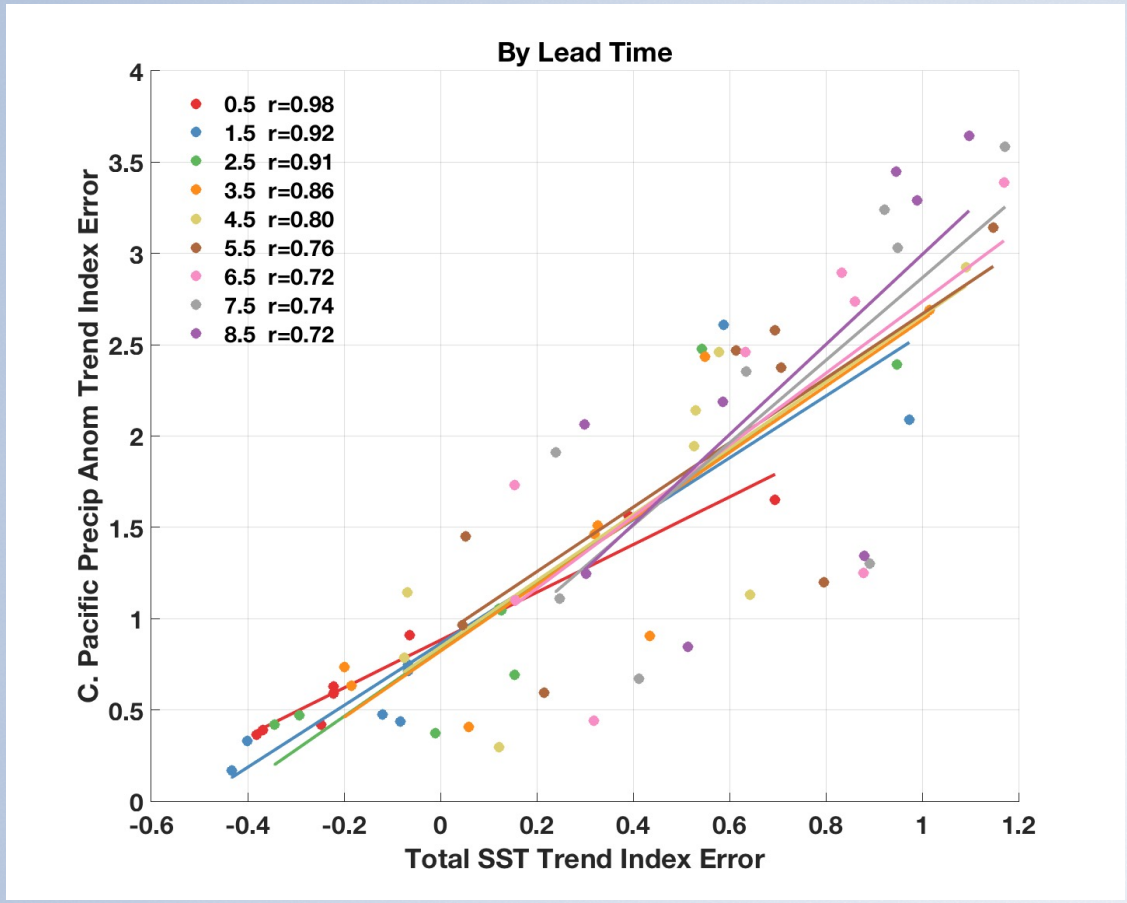
El Niño False Alarm Ratio increased in the last half of the record. SST trend errors have an influence on seasonal ENSO predictions.

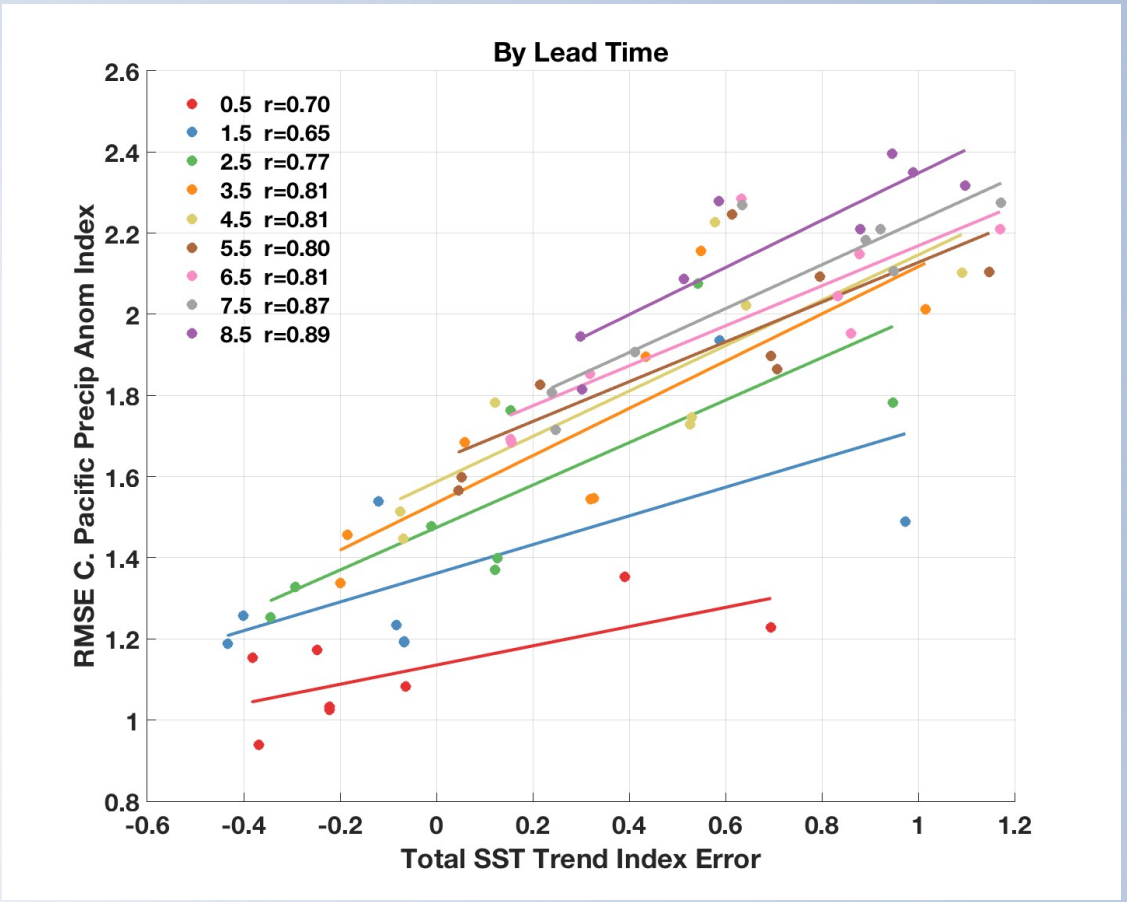


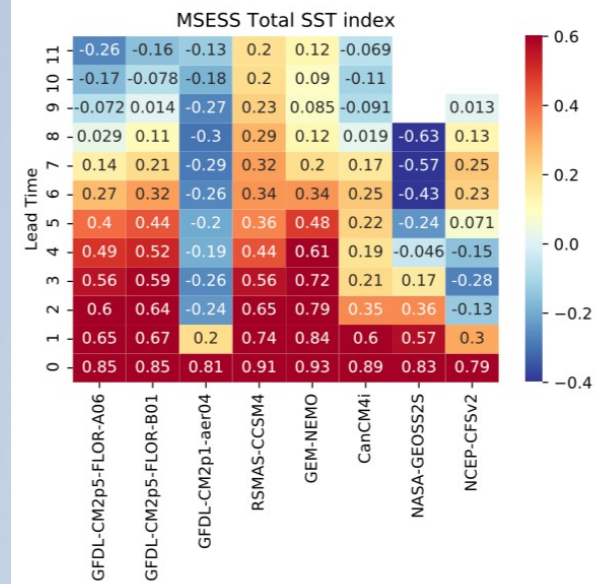


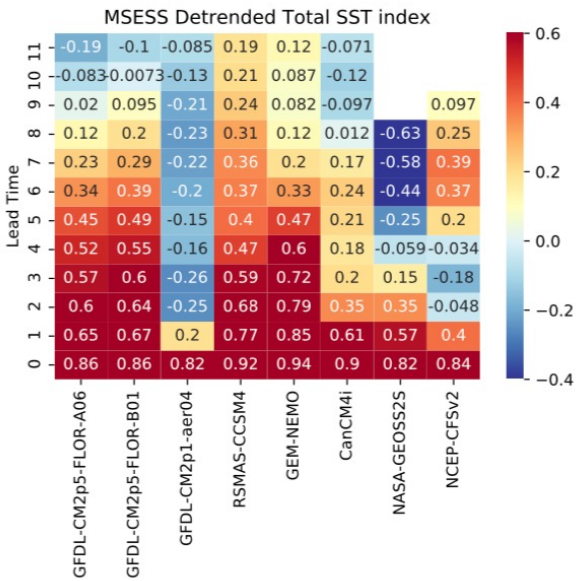
- Implication that understanding the “Pattern Effect” is tied to improving seasonal climate predictions.
- Motivates the bridging of modeling efforts associated with initialized climate predictions and efforts associated with uninitialized CMIP-style simulations.
- Community may want to consider recommending the creation of large-ensembles that stem from initialized models (e.g. GFDL-SPEAR) that would allow researchers to understand how errors in the short term (*which can be verified against observations)* may result in biases in longer term projections.

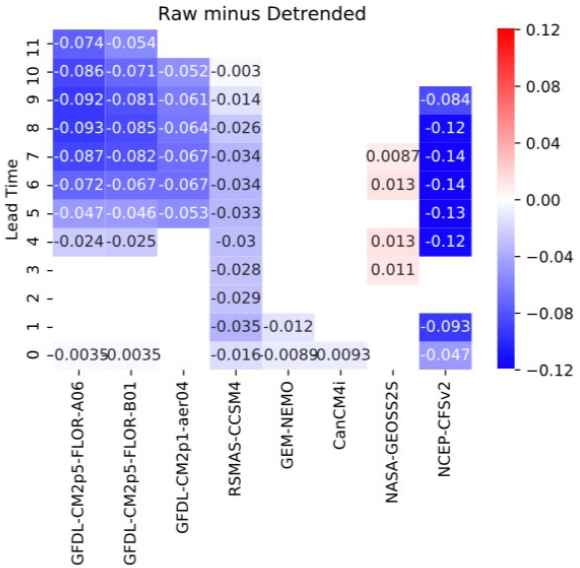
Extra Slides

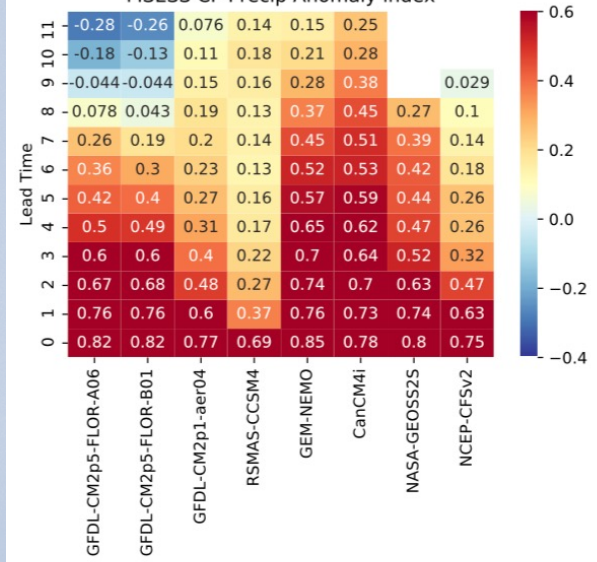

By Lead Time
0.5 r=0.98
1.5 r=0.92
2.5 r=0.91
3.5 r=0.86
4.5 r=0.80
5.5 r=0.76
6.5 r=0.72
7.5 r=0.74
8.5 r=0.72
C. Pacific Precip Anom Trend Index Error
Total SST Trend Index Error
0
0.5
1
1.5
2
2.5
3
3.5
4
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2

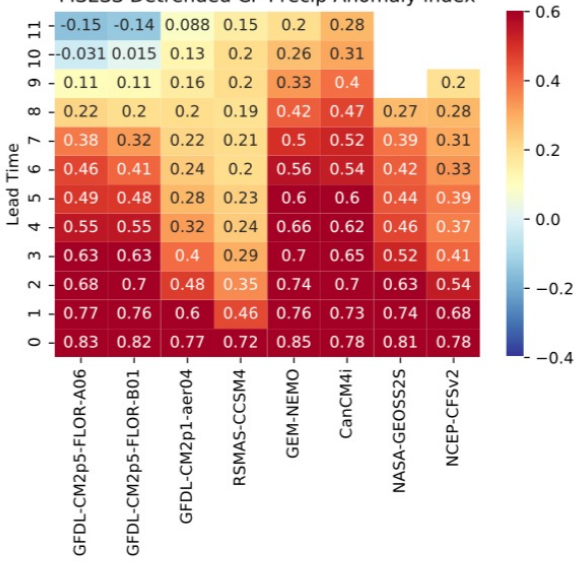

By Lead Time
0.5 r=0.70
1.5 r=0.65
2.5 r=0.77
3.5 r=0.81
4.5 r=0.81
5.5 r=0.80
6.5 r=0.81
7.5 r=0.87
8.5 r=0.89
RMSE C. Pacific Precip Anom Index
Total SST Trend Index Error
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2

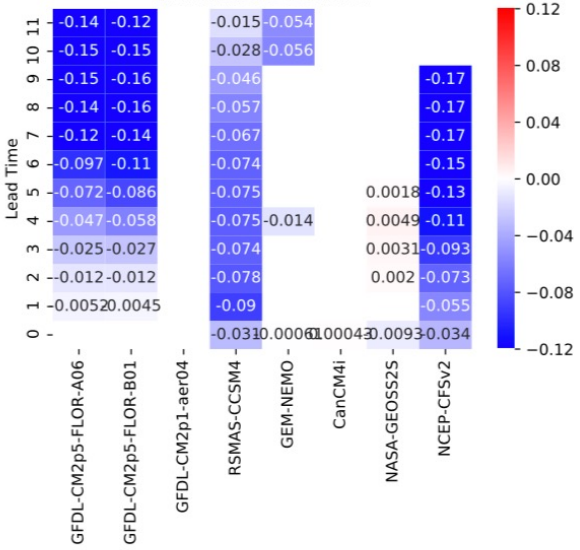

MSESS Total SST index
Lead Time
0 1 2 3 4 5 6 7 8 9 10 11
-0.26 -0.16 -0.13 0.2 0.12 -0.069
-0.17 -0.078 -0.18 0.2 0.09 -0.11
-0.072 0.014 -0.27 0.23 0.085 -0.091 0.013
0.029 0.11 -0.3 0.29 0.12 0.019 -0.63 0.13
0.14 0.21 -0.29 0.32 0.2 0.17 -0.57 0.25
0.27 0.32 -0.26 0.34 0.34 0.25 -0.43 0.23
0.4 0.44 -0.2 0.36 0.48 0.22 -0.24 0.071
0.49 0.52 -0.19 0.44 0.61 0.19 -0.046 -0.15
0.56 0.59 -0.26 0.56 0.72 0.21 0.17 -0.28
0.6 0.64 -0.24 0.65 0.79 0.35 0.36 -0.13
0.65 0.67 0.2 0.74 0.84 0.6 0.57 0.3
0.85 0.85 0.81 0.91 0.93 0.89 0.83 0.79
GFDL-CM2p5-FLOR-A06
GFDL-CM2p5-FLOR-B01
GFDL-CM2p1-aer04
RSMAS-CCSM4
GEM-NEMO
CanCM4i
NASA-GEOSS2S
NCEP-CFSv2
0.6 0.4 0.2 0.0 −0.2 −0.4


MSESS Detrended Total SST index
Lead Time
0 1 2 3 4 5 6 7 8 9 10 11
-0.19 -0.1 -0.085 0.19 0.12 -0.071
-0.083 -0.0073 -0.13 0.21 0.087 -0.12
0.02 0.095 -0.21 0.24 0.082 -0.097 0.097
0.12 0.2 -0.23 0.31 0.12 0.012 -0.63 0.25
0.23 0.29 -0.22 0.36 0.2 0.17 -0.58 0.39
0.34 0.39 -0.2 0.37 0.33 0.24 -0.44 0.37
0.45 0.49 -0.15 0.4 0.47 0.21 -0.25 0.2
0.52 0.55 -0.16 0.47 0.6 0.18 -0.059 -0.034
0.57 0.6 -0.26 0.59 0.72 0.2 0.15 -0.18
0.6 0.64 -0.25 0.68 0.79 0.35 0.35 -0.048
0.65 0.67 0.2 0.77 0.85 0.61 0.57 0.4
0.86 0.86 0.82 0.92 0.94 0.9 0.82 0.84
GFDL-CM2p5-FLOR-A06
GFDL-CM2p5-FLOR-B01
GFDL-CM2p1-aer04
RSMAS-CCSM4
GEM-NEMO
CanCM4i
NASA-GEOSS2S
NCEP-CFSv2
0.6 0.4 0.2 0.0 −0.2 −0.4


Raw minus Detrended
Lead Time
0 1 2 3 4 5 6 7 8 9 10 11
-0.074 -0.054
-0.086 -0.071 -0.052 -0.003
-0.092 -0.081 -0.061 -0.014 -0.084
-0.093 -0.085 -0.064 -0.026 -0.12
-0.087 -0.082 -0.067 -0.034 0.0087 -0.14
-0.072 -0.067 -0.067 -0.034 0.013 -0.14
-0.047 -0.046 -0.053 -0.033 -0.13
-0.024 -0.025 -0.03 0.013 -0.12
-0.028 0.011
-0.029
-0.035 -0.012 -0.093
-0.0035 0.0035 -0.016 -0.0089 0.0093 -0.047
GFDL-CM2p5-FLOR-A06
GFDL-CM2p5-FLOR-B01
GFDL-CM2p1-aer04
RSMAS-CCSM4
GEM-NEMO
CanCM4i
NASA-GEOSS2S
NCEP-CFSv2
0.12 0.08 0.04 0.00 −0.04 −0.08 −0.12


MSESS CP Precip Anomaly index
Lead Time
0 1 2 3 4 5 6 7 8 9 10 11
-0.28 -0.26 0.076 0.14 0.15 0.25
-0.18 -0.13 0.11 0.18 0.21 0.28
-0.044 -0.044 0.15 0.16 0.28 0.38 0.029
0.078 0.043 0.19 0.13 0.37 0.45 0.27 0.1
0.26 0.19 0.2 0.14 0.45 0.51 0.39 0.14
0.36 0.3 0.23 0.13 0.52 0.53 0.42 0.18
0.42 0.4 0.27 0.16 0.57 0.59 0.44 0.26
0.5 0.49 0.31 0.17 0.65 0.62 0.47 0.26
0.6 0.6 0.4 0.22 0.7 0.64 0.52 0.32
0.67 0.68 0.48 0.27 0.74 0.7 0.63 0.47
0.76 0.76 0.6 0.37 0.76 0.73 0.74 0.63
0.82 0.82 0.77 0.69 0.85 0.78 0.8 0.75
GFDL-CM2p5-FLOR-A06
GFDL-CM2p5-FLOR-B01
GFDL-CM2p1-aer04
RSMAS-CCSM4
GEM-NEMO
CanCM4i
NASA-GEOSS2S
NCEP-CFSv2
0.6 0.4 0.2 0.0 −0.2 −0.4


MSESS Detrended CP Precip Anomaly index
Lead Time
0 1 2 3 4 5 6 7 8 9 10 11
-0.15 -0.14 0.088 0.15 0.2 0.28
-0.031 0.015 0.13 0.2 0.26 0.31
0.11 0.11 0.16 0.2 0.33 0.4 0.2
0.22 0.2 0.2 0.19 0.42 0.47 0.27 0.28
0.38 0.32 0.22 0.21 0.5 0.52 0.39 0.31
0.46 0.41 0.24 0.2 0.56 0.54 0.42 0.33
0.49 0.48 0.28 0.23 0.6 0.6 0.44 0.39
0.55 0.55 0.32 0.24 0.66 0.62 0.46 0.37
0.63 0.63 0.4 0.29 0.7 0.65 0.52 0.41
0.68 0.7 0.48 0.35 0.74 0.7 0.63 0.54
0.77 0.76 0.6 0.46 0.76 0.73 0.74 0.68
0.83 0.82 0.77 0.72 0.85 0.78 0.81 0.78
GFDL-CM2p5-FLOR-A06
GFDL-CM2p5-FLOR-B01
GFDL-CM2p1-aer04
RSMAS-CCSM4
GEM-NEMO
CanCM4i
NASA-GEOSS2S
NCEP-CFSv2
0.6 0.4 0.2 0.0 −0.2 −0.4


Raw minus Detrended
Lead Time
0 1 2 3 4 5 6 7 8 9 10 11
-0.14 -0.12 -0.015 -0.054
-0.15 -0.15 -0.028 -0.056
-0.15 -0.16 -0.046 -0.17
-0.14 -0.16 -0.057 -0.17
-0.12 -0.14 -0.067 -0.17
-0.097 -0.11 -0.074 -0.15
-0.072 -0.086 -0.075 0.0018 -0.13
-0.047 -0.058 -0.075 -0.014 0.0049 -0.11
-0.025 -0.027 -0.074 0.0031 -0.093
-0.012 -0.012 -0.078 0.002 -0.073
-0.0052 0.0045 -0.09 -0.055
-0.031 -0.00061 -0.00043 -0.0093 -0.034
GFDL-CM2p5-FLOR-A06
GFDL-CM2p5-FLOR-B01
GFDL-CM2p1-aer04
RSMAS-CCSM4
GEM-NEMO
CanCM4i
NASA-GEOSS2S
NCEP-CFSv2
0.12 0.08 0.04 0.00 −0.04 −0.08 −0.12