

Projected 21st century SSTs: Changes in the mean, variability and extremes

Michael Alexander

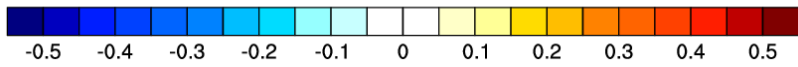
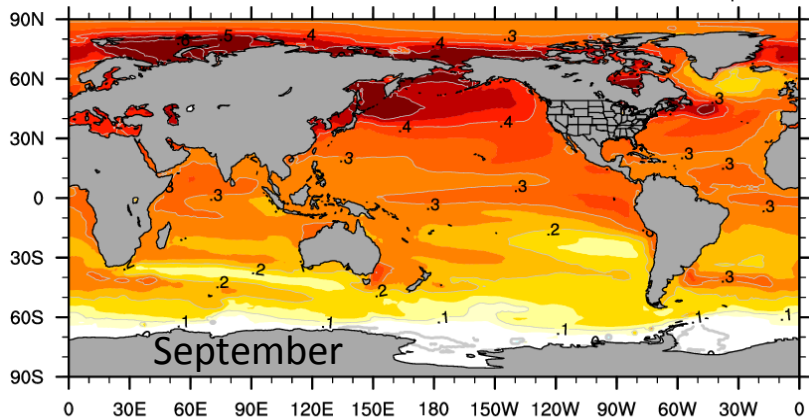
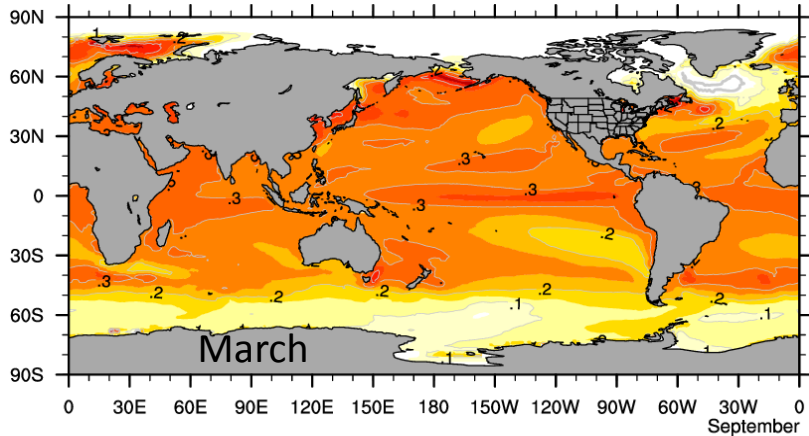
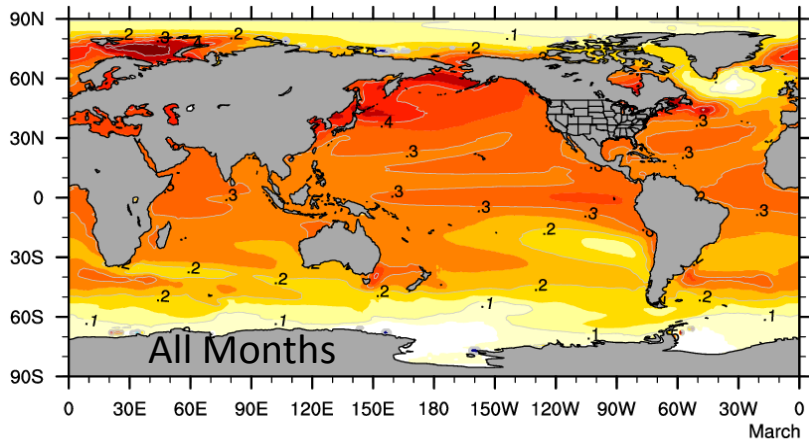
Jamie Scott

NOAA/Earth System Research Lab
Physical Science Division

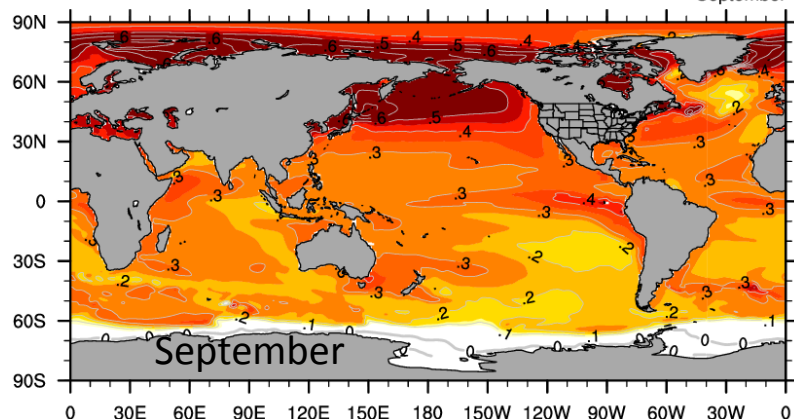
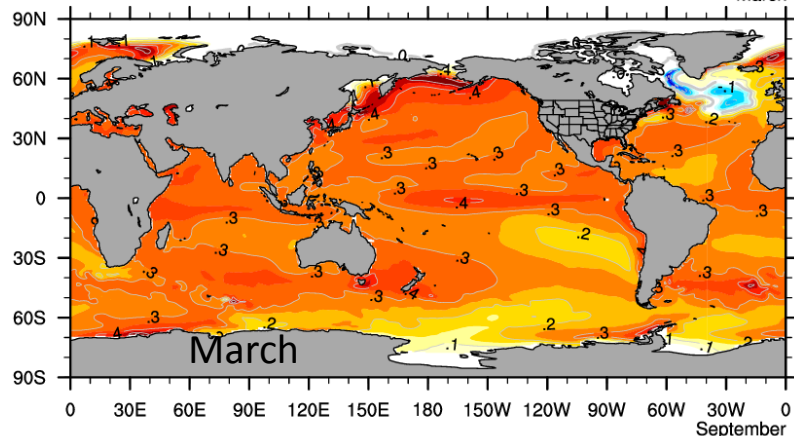
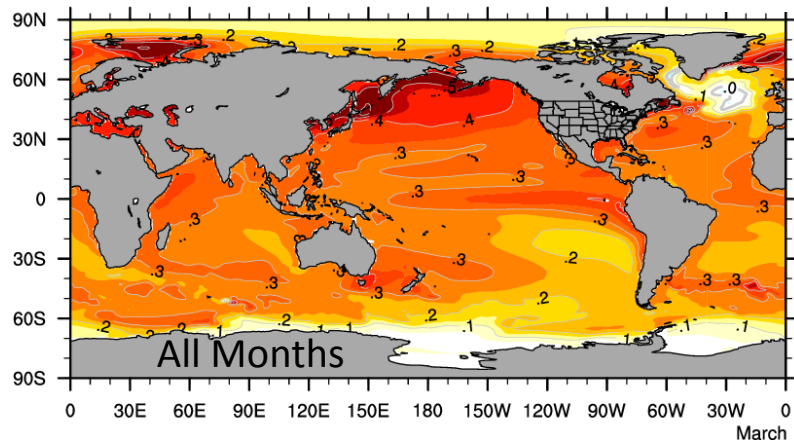
Motivation & Methods

- There is a great deal of interest in SST variability and change among marine ecologist and fishery scientists in addition to climate scientists.
 - General northward movement of fish populations with warming along the US east coast.
 - Concern now extends beyond just the change in the mean. Some notion that “All extremes are getting more extreme”.
 - Recent Research on ocean heat waves, e.g. (Mills et al., 2013 Pearce and Feng, 2013; Wernberg et al., 2013; Pershing et al. 2015; Scannell et al. 2016)
- Here we examine SST changes in a few different ways
 - Trends, including as a function of the seasonal cycle
 - Variance & Probability Distributions
 - Climate Departures (Diffenbaugh and Scherer 2011; Mora et al 2013)
time at which a future climate permanently departs from the climate of the past.
- Using
 - Global Maps
 - Large Marine Ecosystem (LMEs) regions - ocean areas generally along continental margins whose ecological systems are characterized by similarities in bathymetry, hydrography, and biological productivity” (Sherman and Alexander, 1986)

CMIP5 SST trends 1976-2099 ($^{\circ}\text{C}/\text{decade}$)

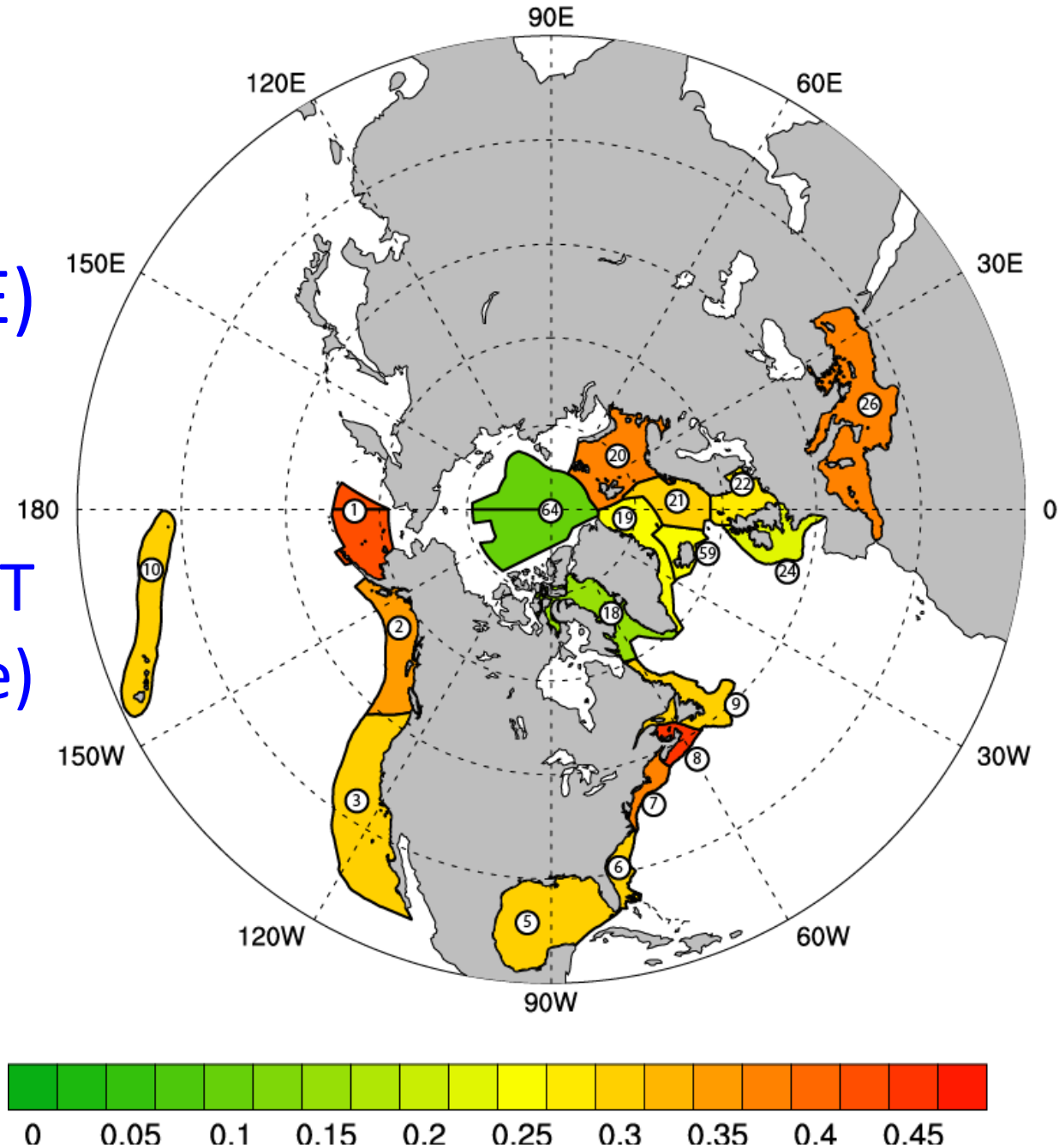


CESM-LENS SST trends 1976-2099 ($^{\circ}\text{C}/\text{decade}$)



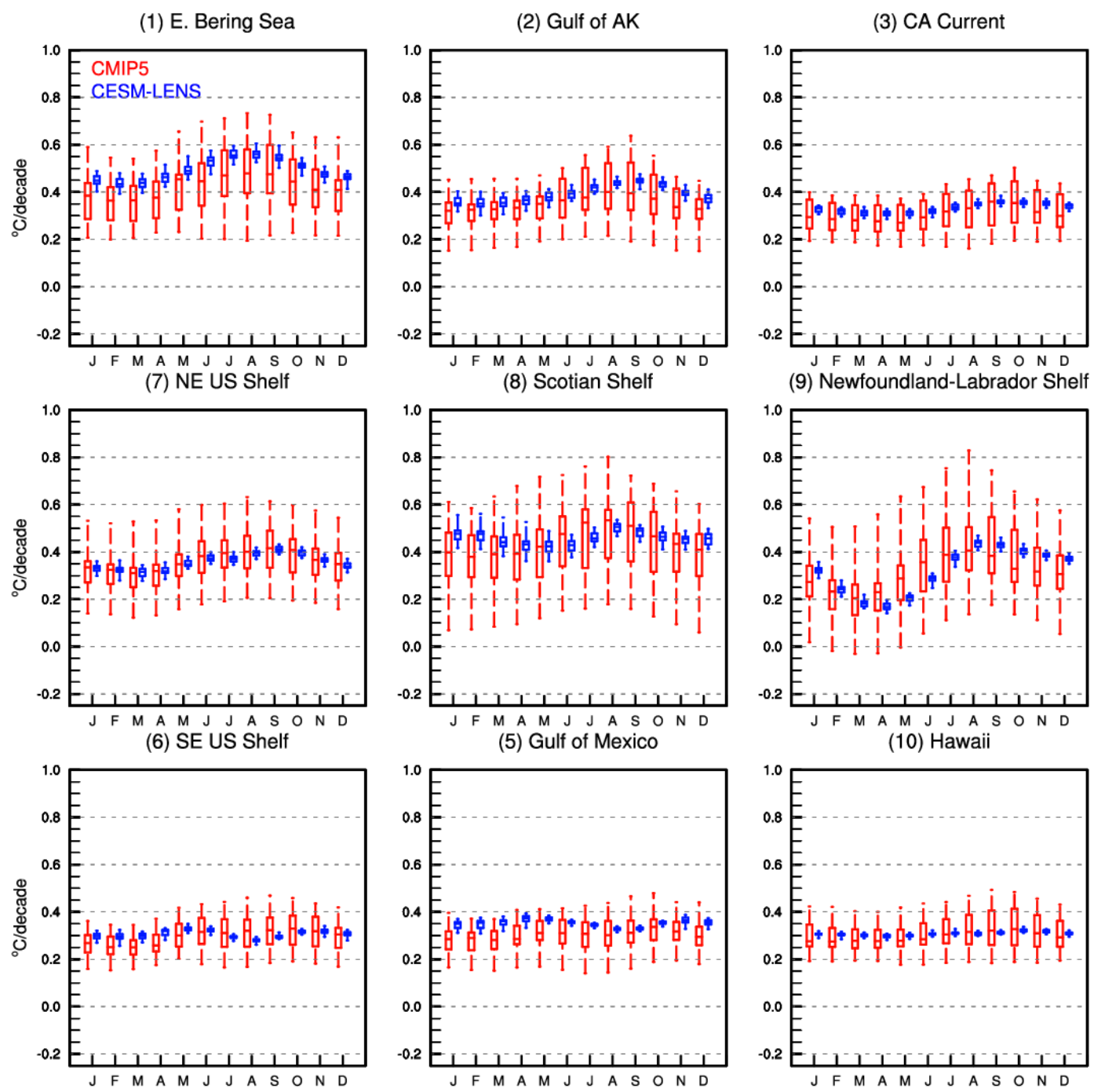
Large Marine Ecosystem (LME) regions

CMIP5 Median SST trends ($^{\circ}\text{C}/\text{decade}$)



SST CMIP5 & CESM-LENS RCP8.5 Monthly Trends 1975-2099 ($^{\circ}\text{C}/\text{decade}$)

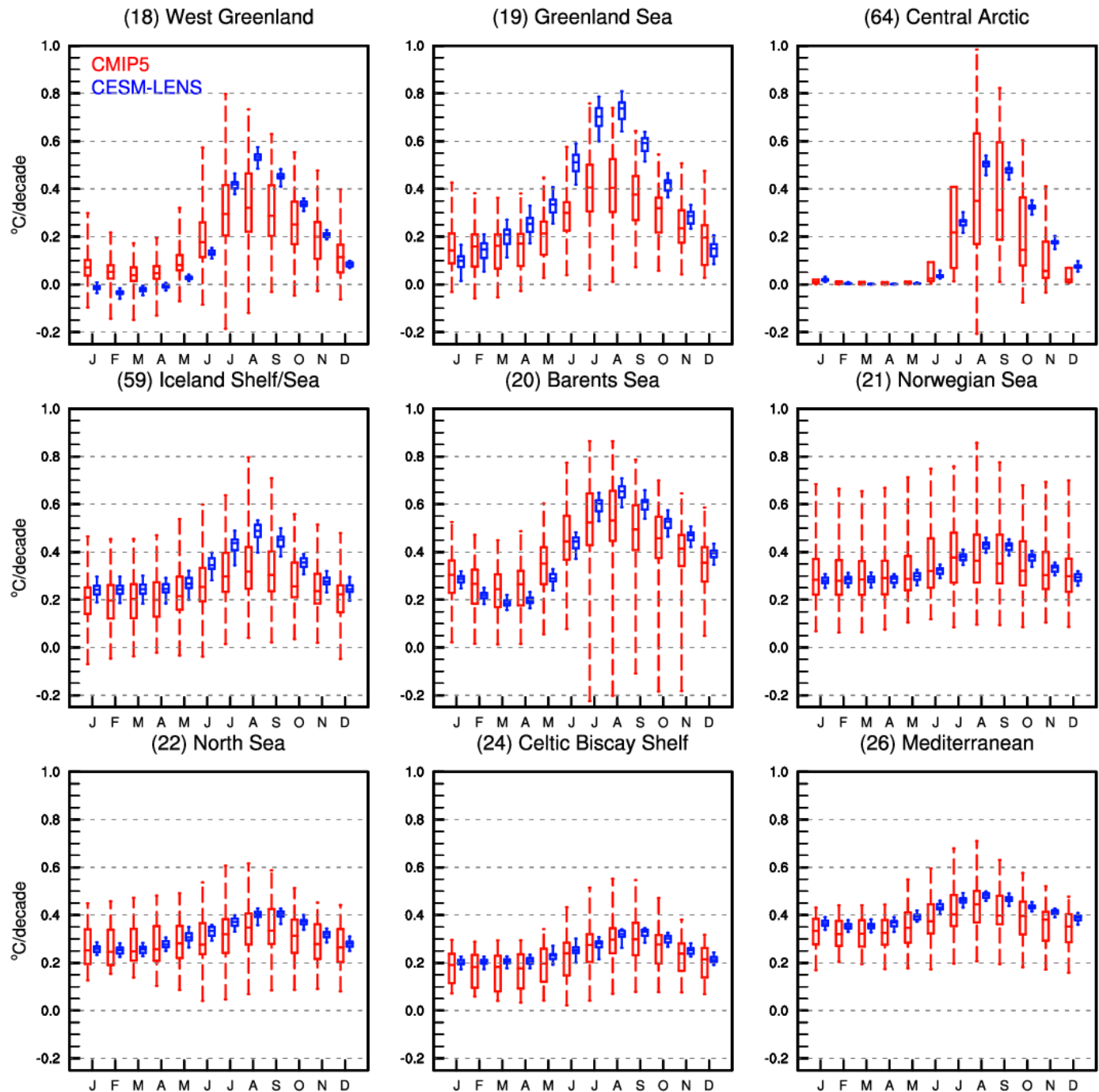
N. America
SST Trends
CMIP5 &
CESM-LENS
1976-2099
 $^{\circ}\text{C}/\text{decade}$
Box &
Whisker
low, 25%,
50%, 75%,
high



SST CMIP5 & CESM-LENS RCP8.5 Monthly Trends 1975-2099 (°C/decade)

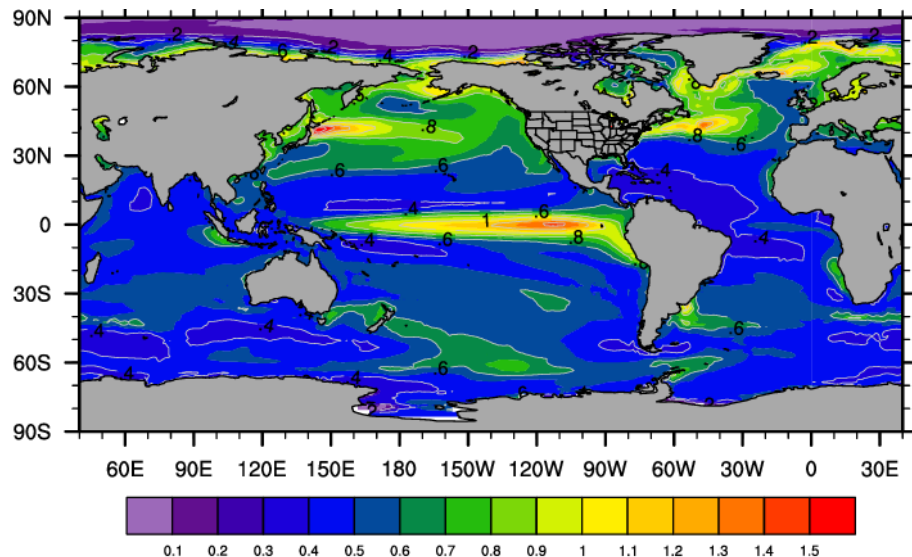
N Atlantic
SST Trends
CMIP5 &
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1976-2099
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low, 25%,
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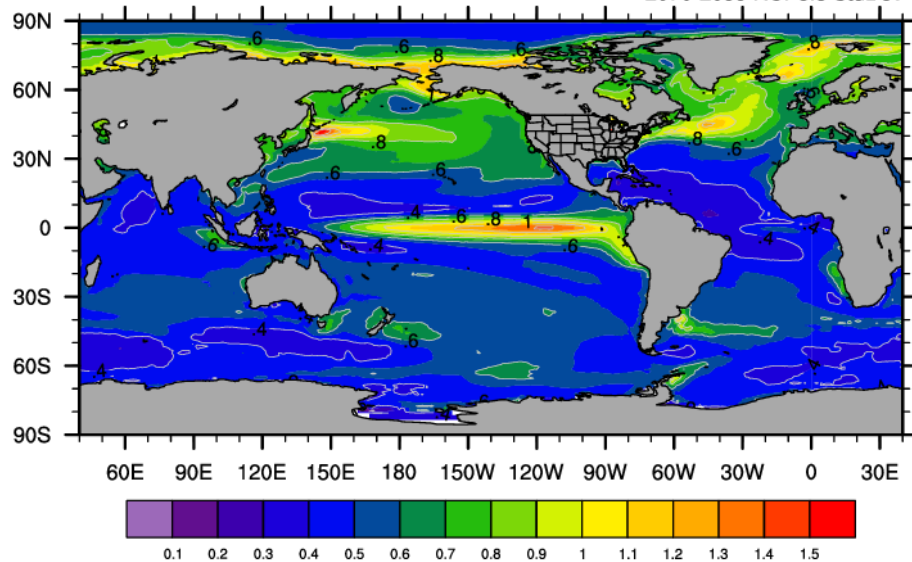


Detrended SST Variability in CMIP5

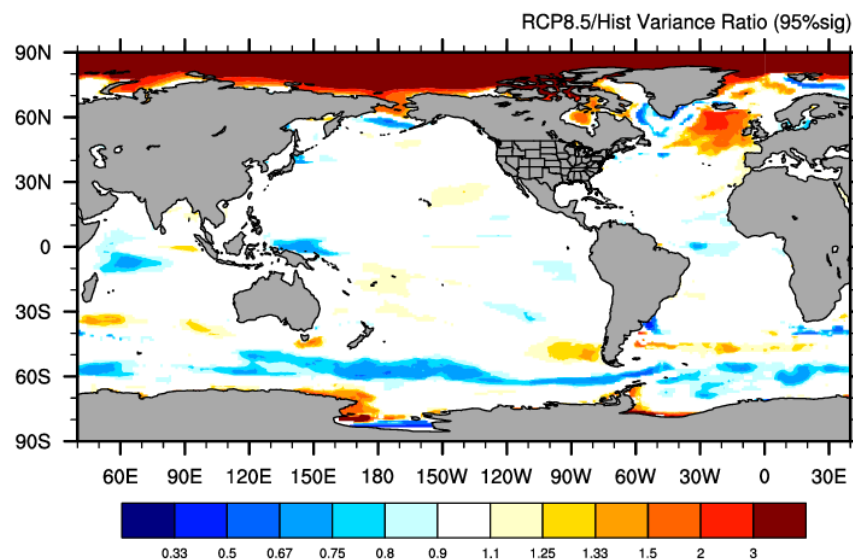
SST Std Dev 1976-2005



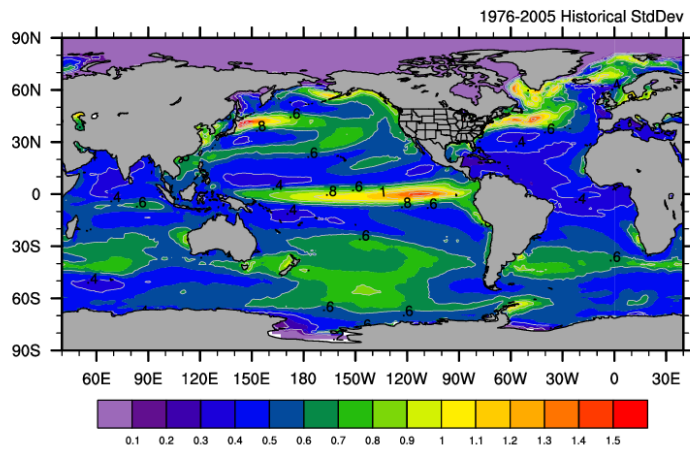
SST Std Dev 2070-2099 2070-2099 RCP8.5 StdDev



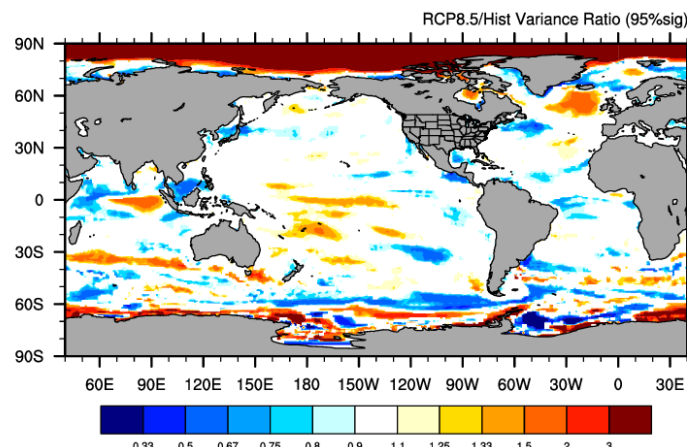
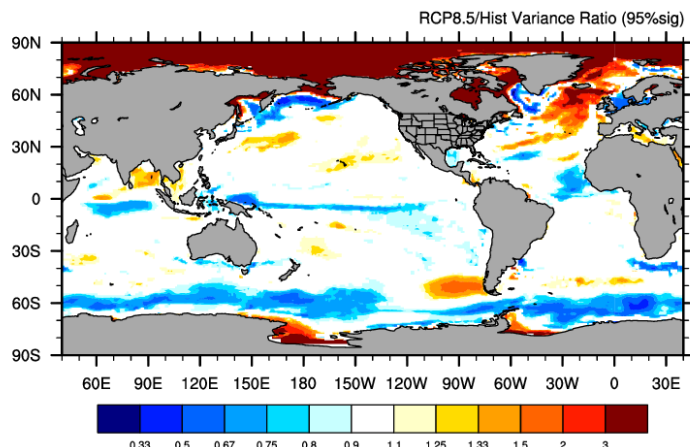
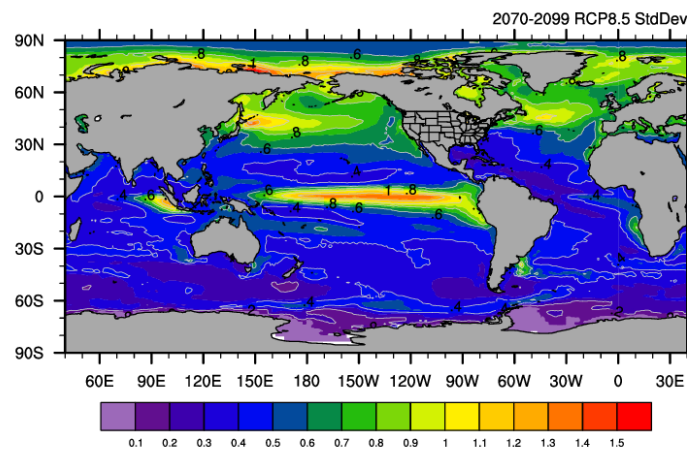
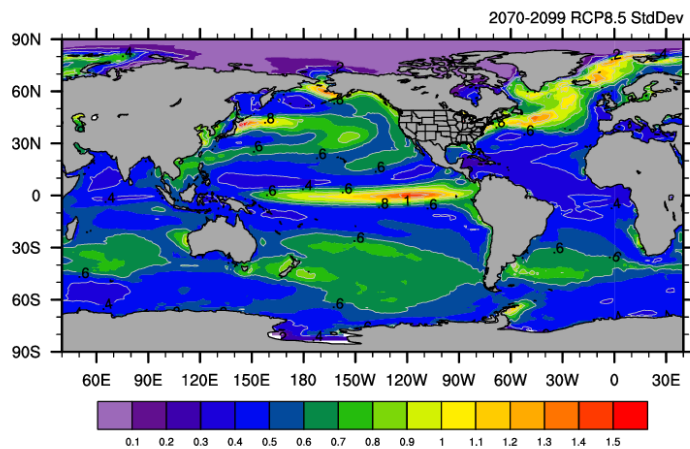
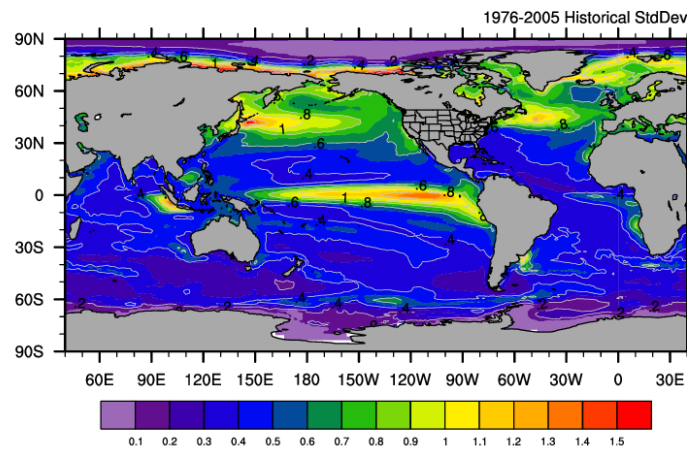
SST Variance ratio:
(2070-2099) / (1976-2005)



SST Detrended March Anomalies (26 models pooled)



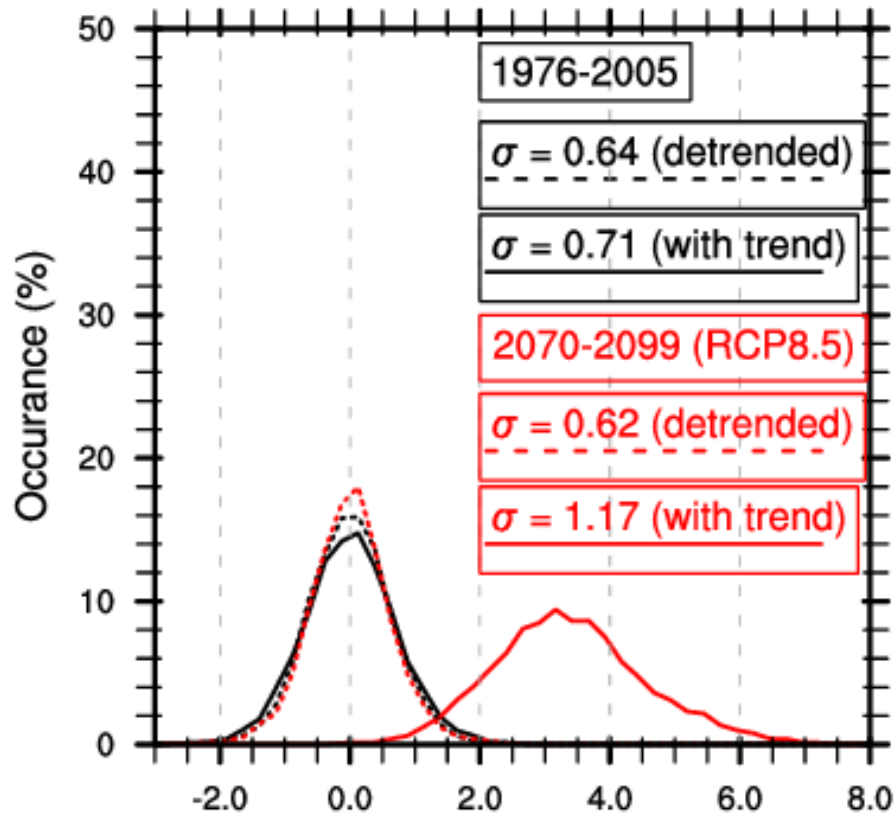
SST Detrended September Anomalies (26 models pooled)



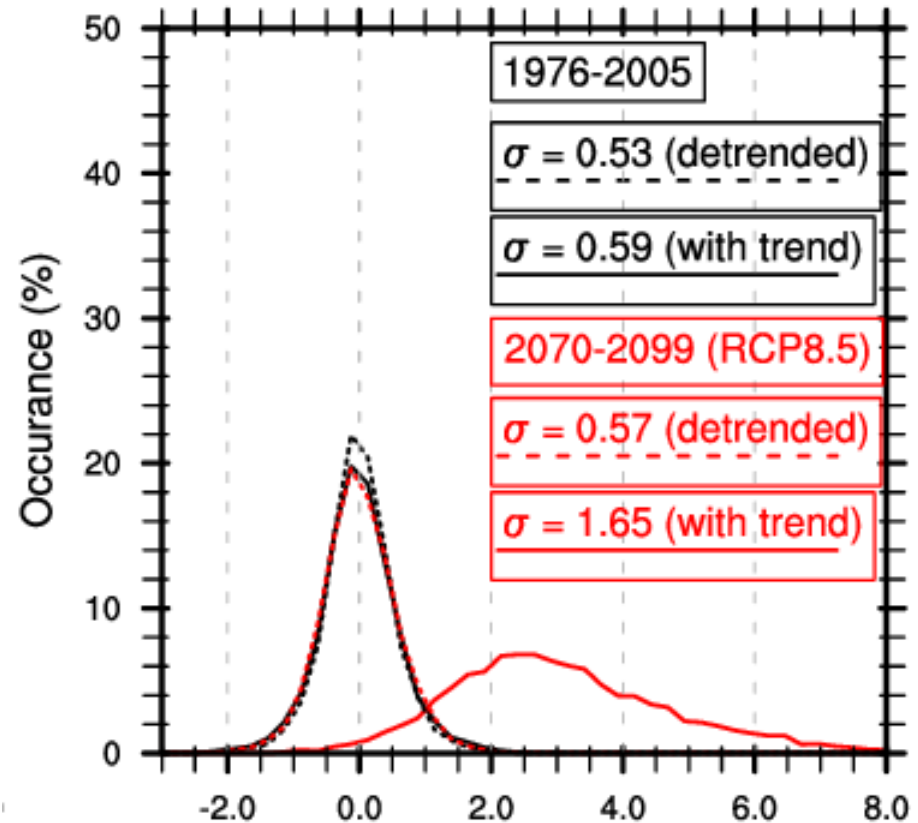
Example CMIP5 SST PDFs & Std Dev

1976-2005 & 2070-2099

(7) NE US Shelf

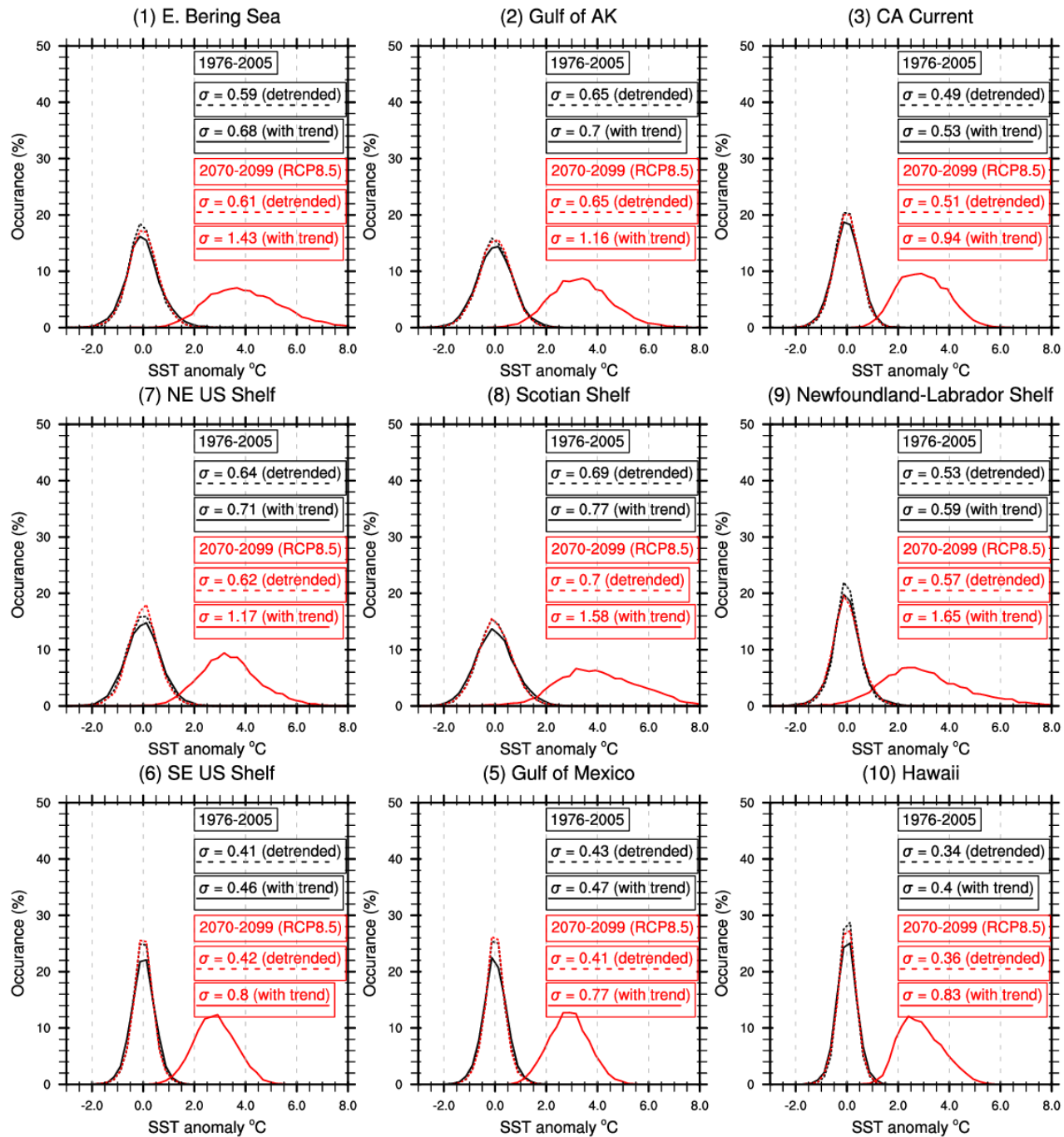


(9) Newfoundland-Labrador Shelf

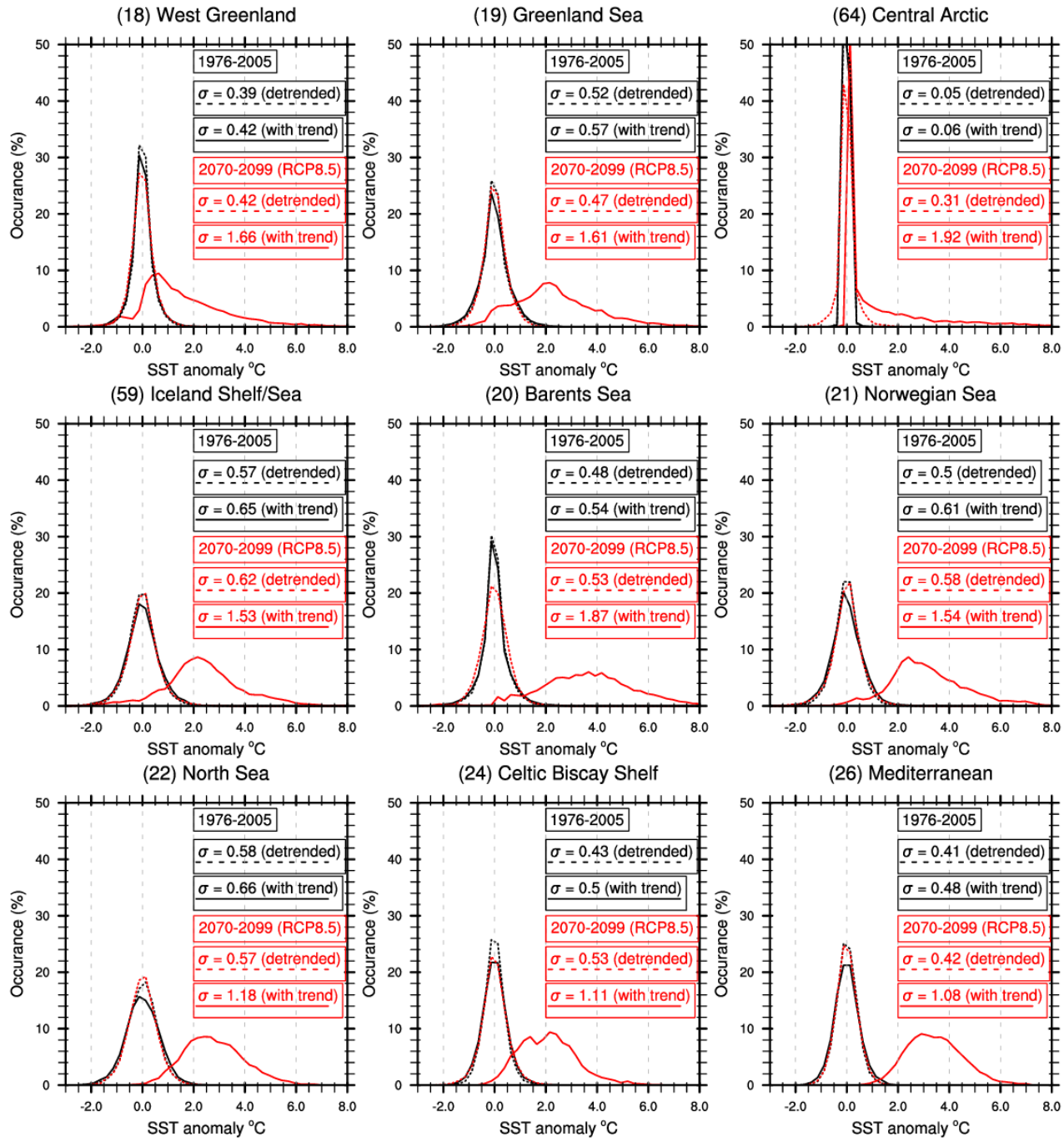


Solid full anomalies; dashed - detrended

SST PDF All CMIP5 Monthly Anom (1976-2005 clim)



SST PDF All CMIP5 Monthly Anom (1976-2005 clim)

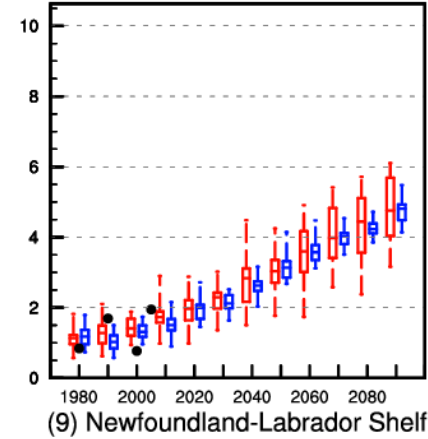
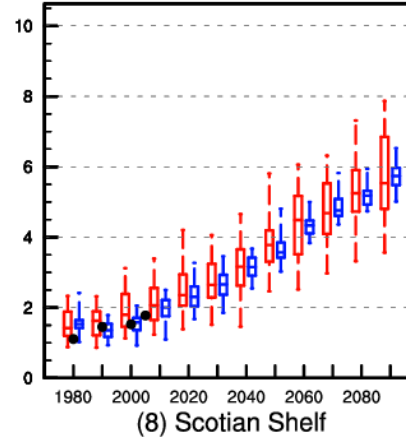
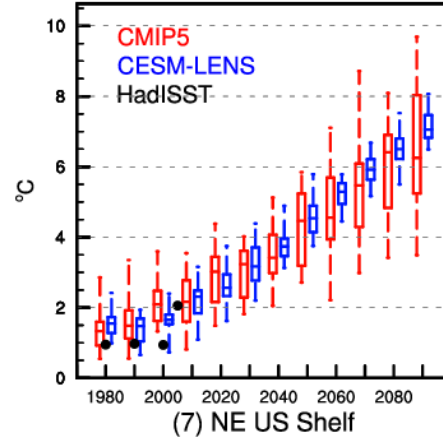


SST LME RCP8.5 Decadal Max Anom CMIP5 & CESM-LENS Spread

(1) E. Bering Sea

(2) Gulf of AK

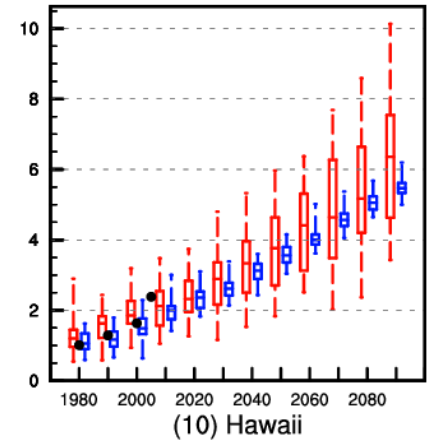
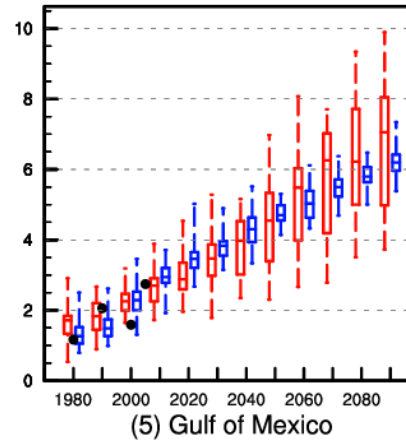
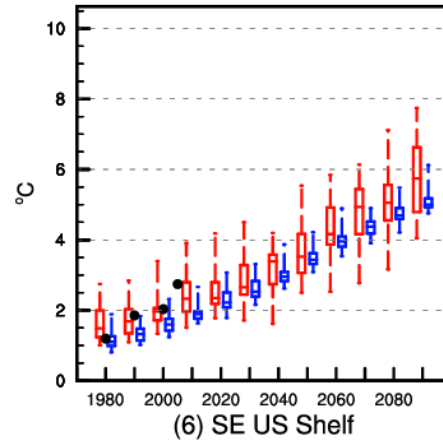
(3) CA Current



(7) NE US Shelf

(8) Scotian Shelf

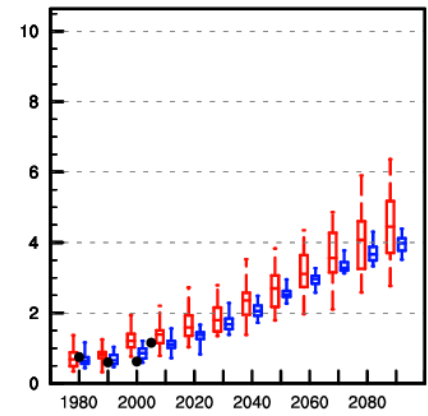
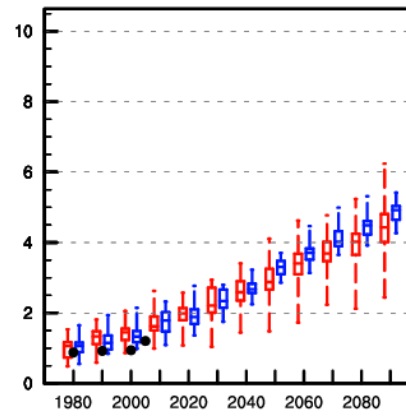
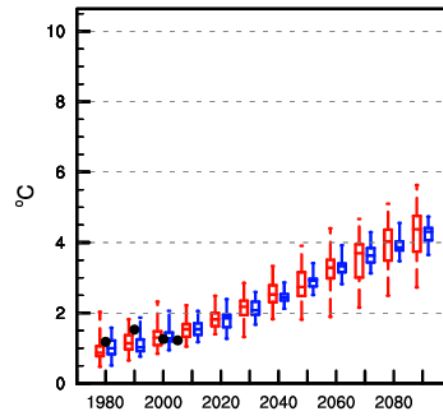
(9) Newfoundland-Labrador Shelf



(6) SE US Shelf

(5) Gulf of Mexico

(10) Hawaii



N. America
Maximum
Monthly SST
anomaly
(relative to
1976-2005
average)
per decade
CMIP5
CESM-LENS
Observations

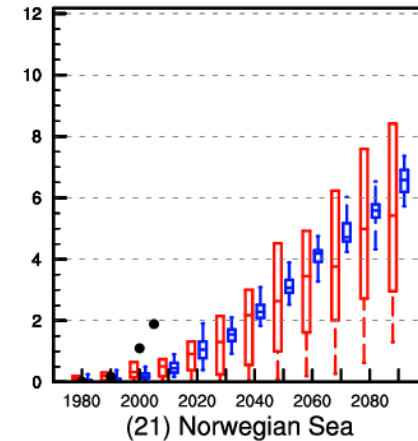
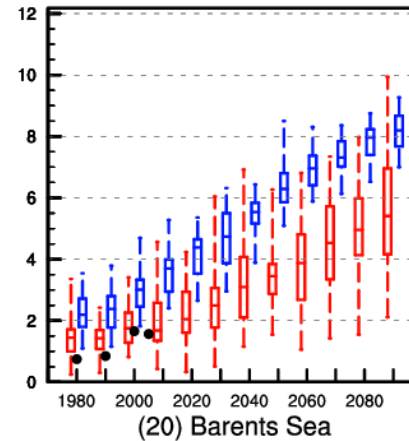
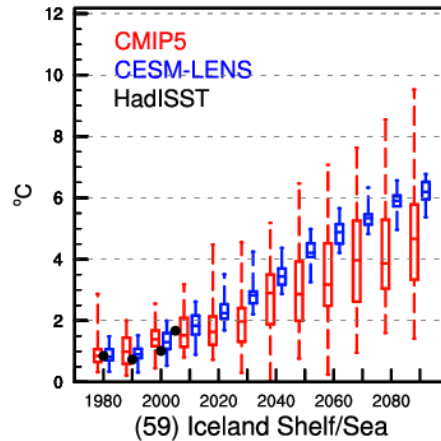
SST LME RCP8.5 Decadal Max Anom CMIP5 & CESM-LENS Spread

(18) West Greenland

(19) Greenland Sea

(64) Central Arctic

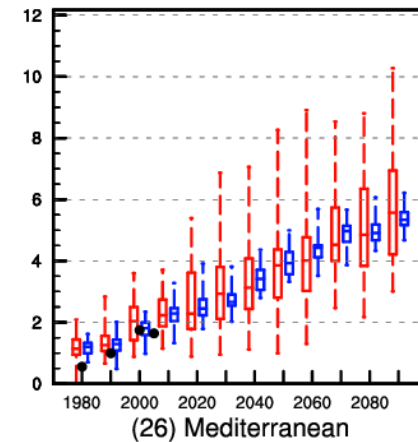
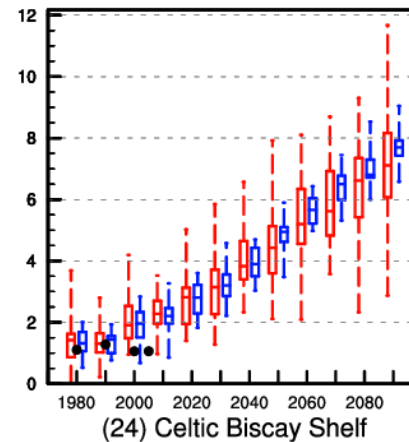
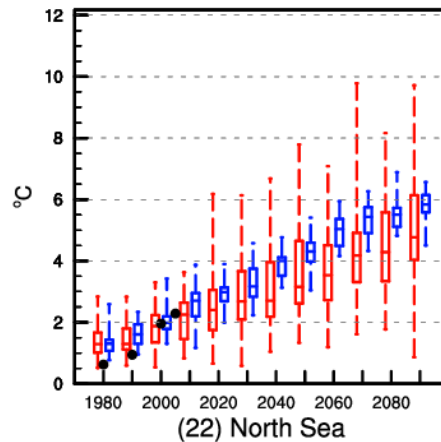
N Atlantic
Maximum
Monthly SST
anomaly
(relative to
1976-2005
average)
per decade



(59) Iceland Shelf/Sea

(20) Barents Sea

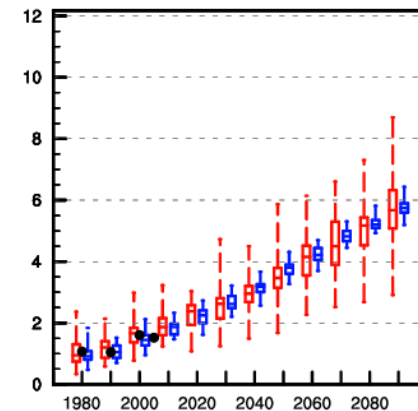
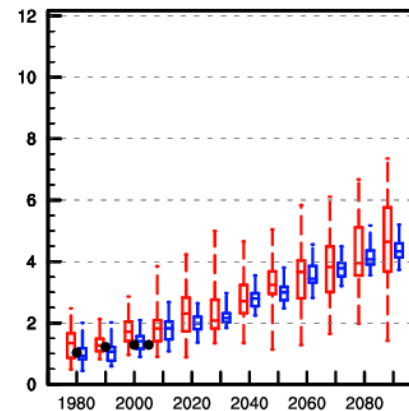
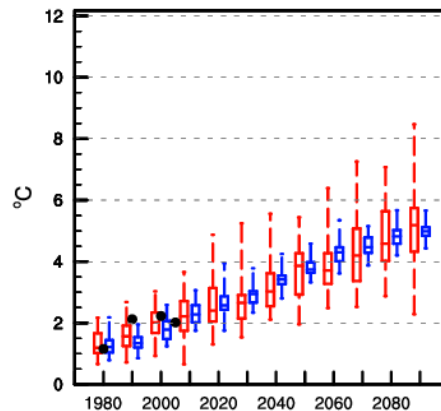
(21) Norwegian Sea



(22) North Sea

(24) Celtic Biscay Shelf

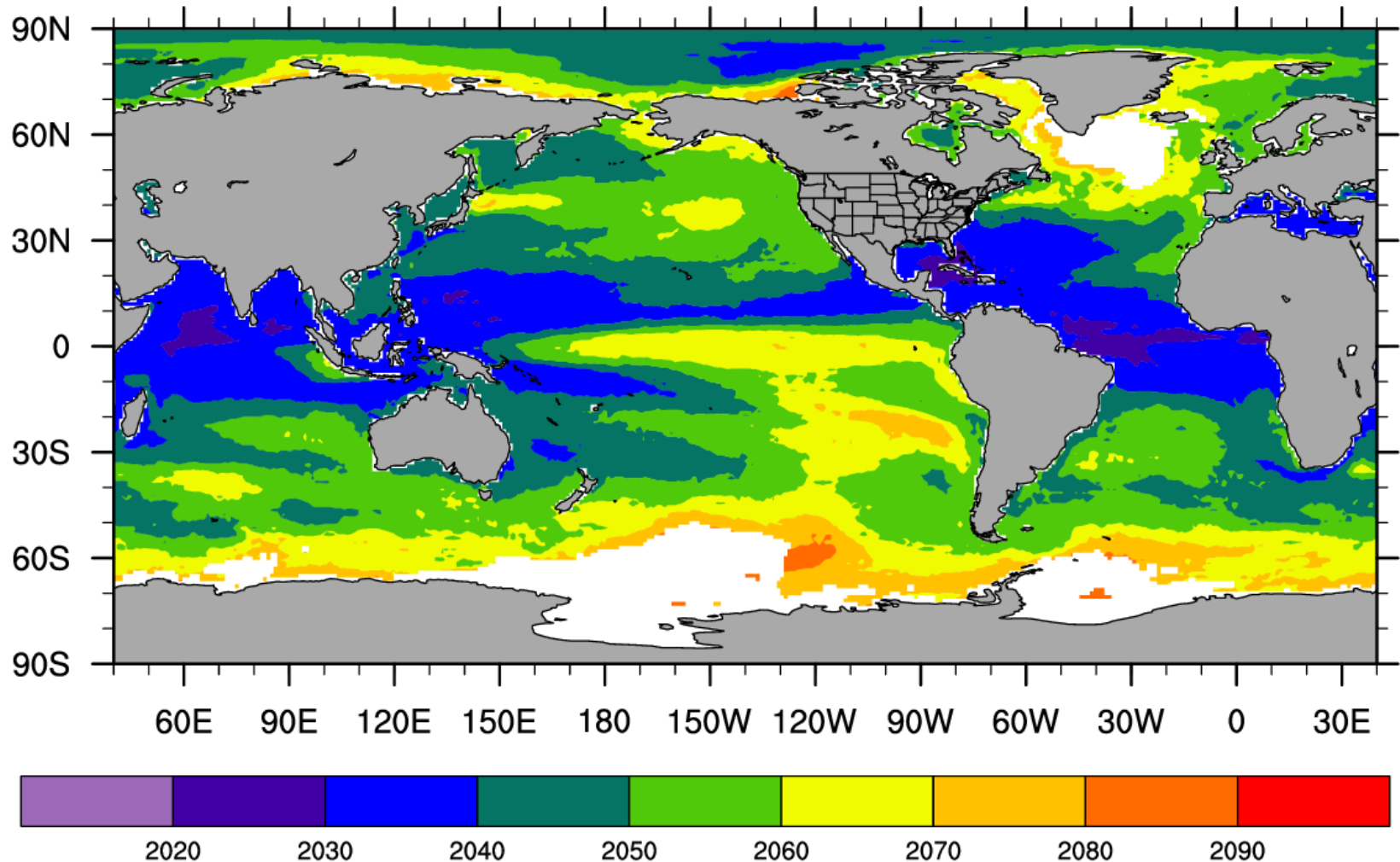
(26) Mediterranean



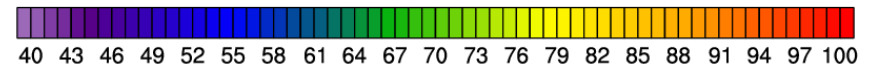
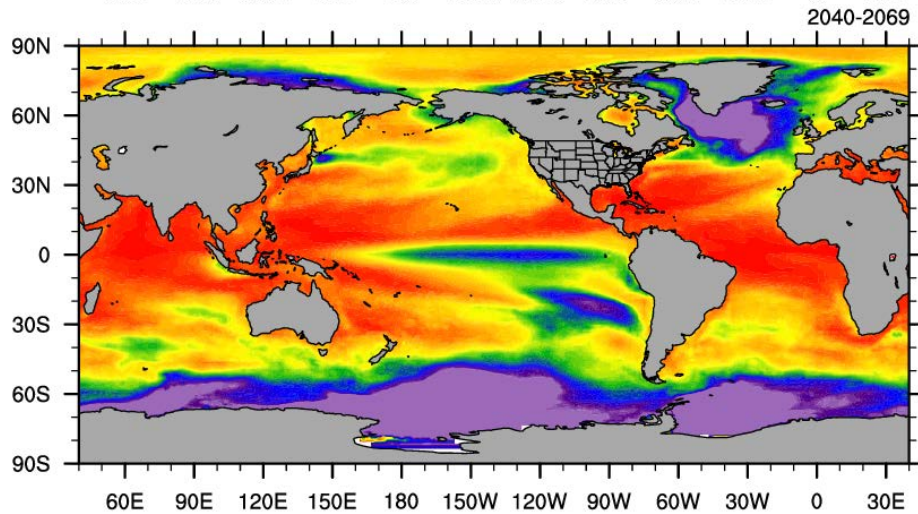
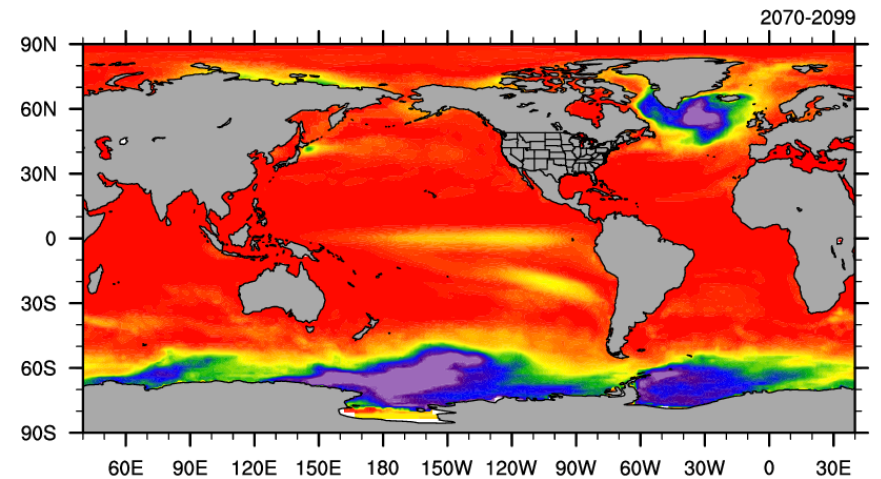
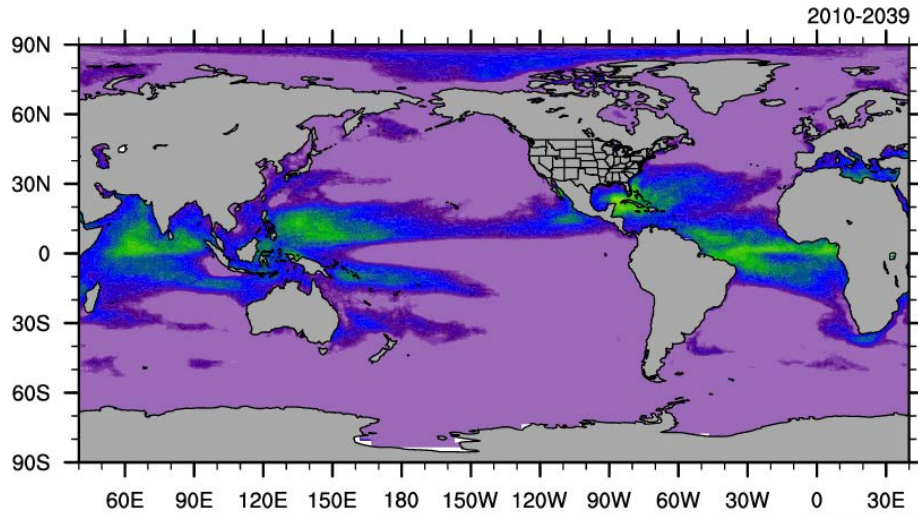
CMIP5
CESM-LENS
Observations

Climate Departures

Year when annual mean SST permanently exceeds maximum in 1976-2005

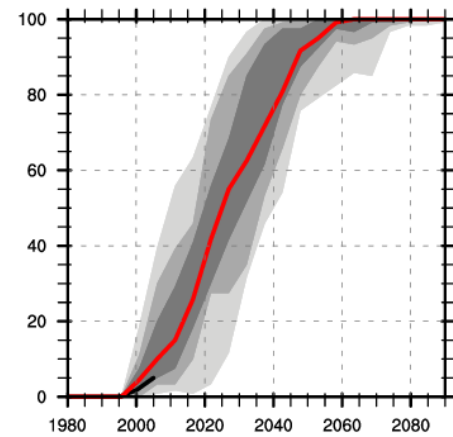
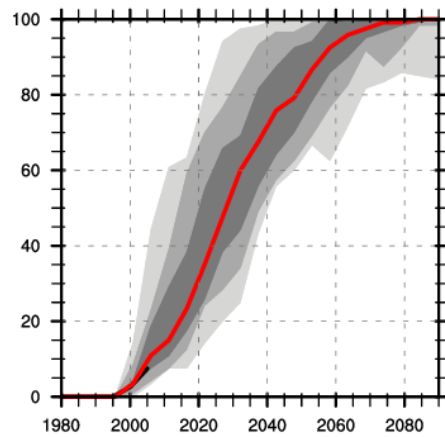
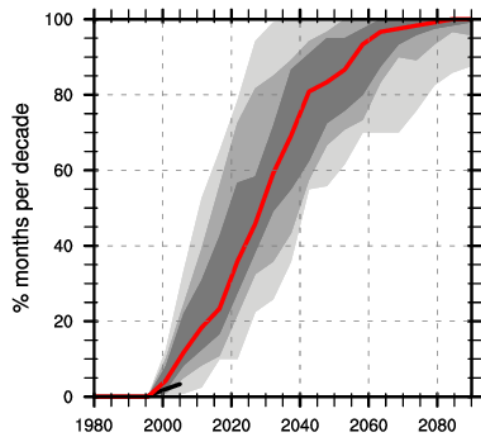
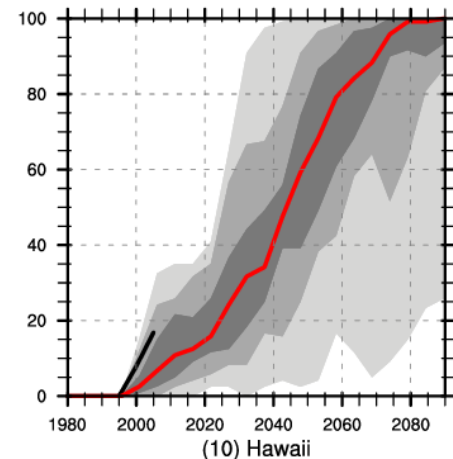
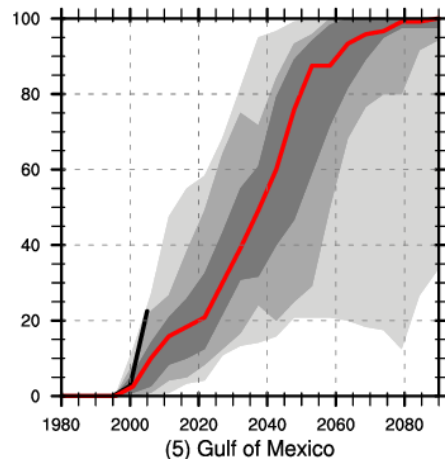
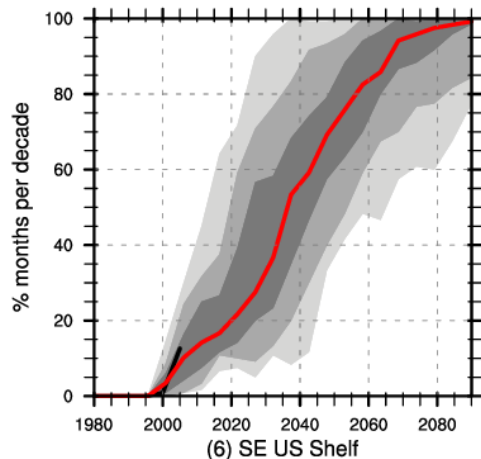
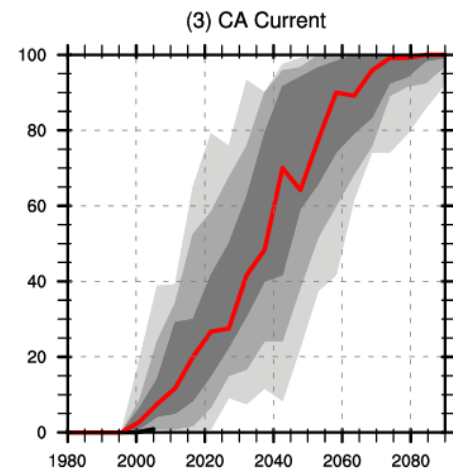
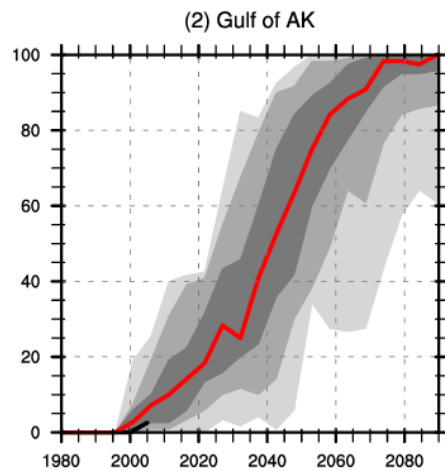
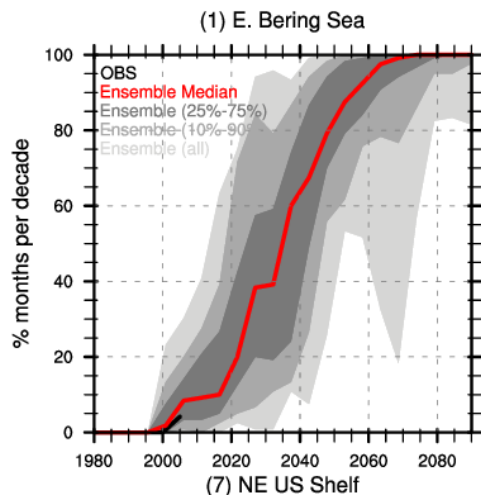


Percent of Years Exceeding Maximum SST Anomaly in 1976-2005

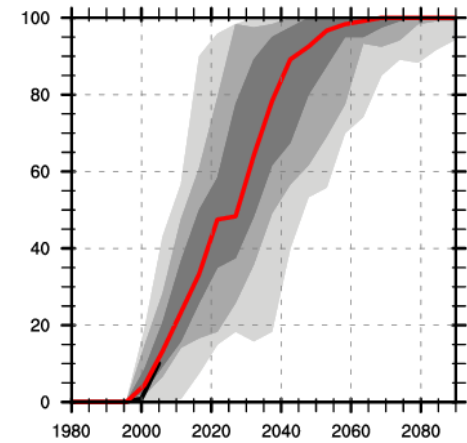
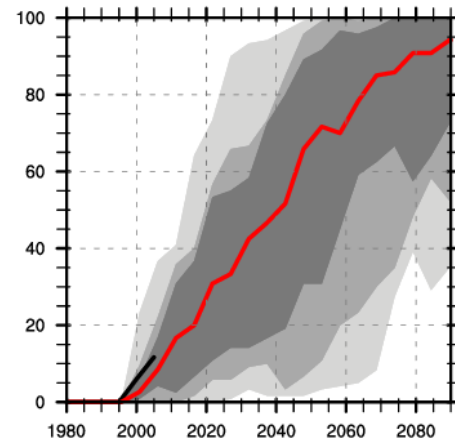
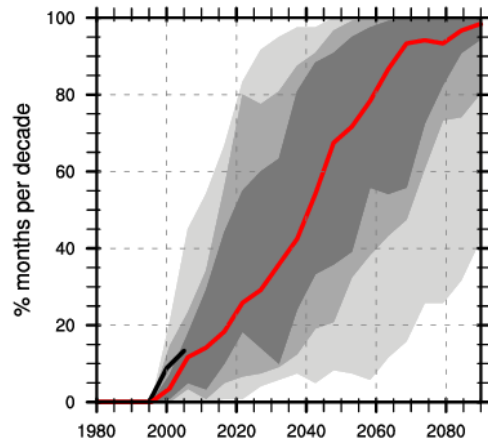
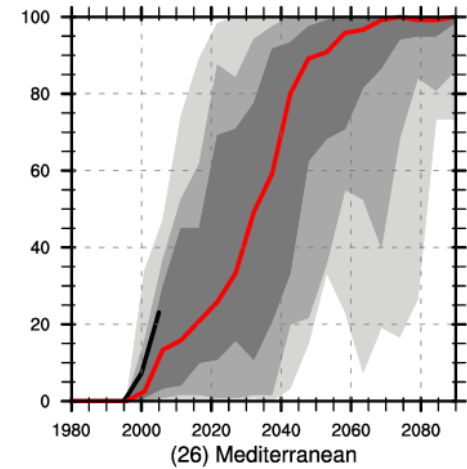
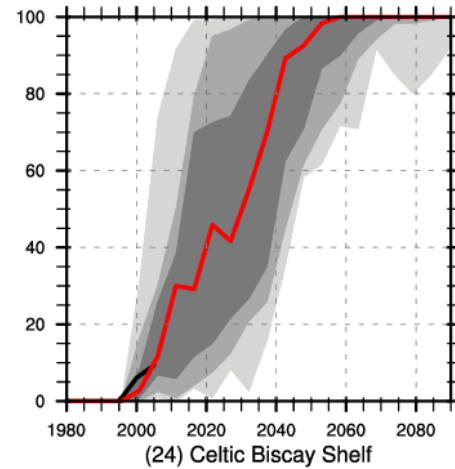
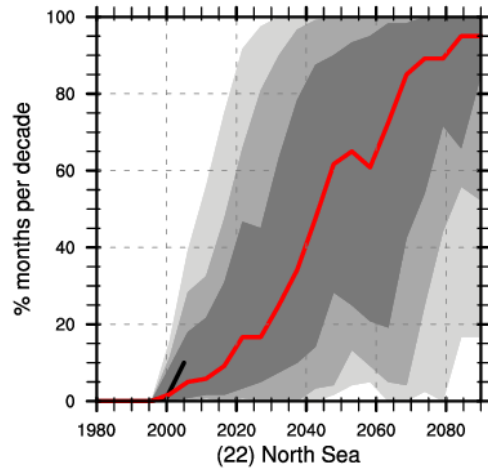
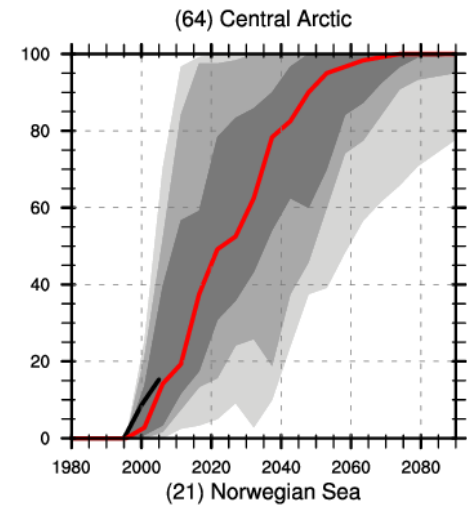
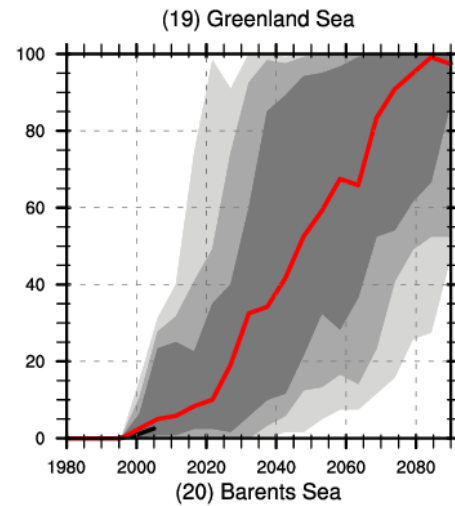
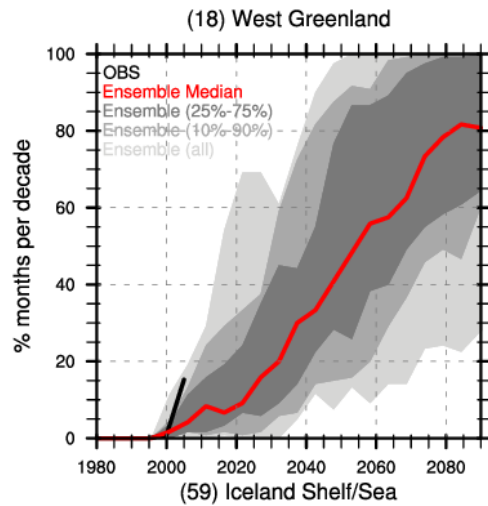


N. America

Percent of months in a decade warmer than the 1976-2005 calendar month maximum in CMIP5 models



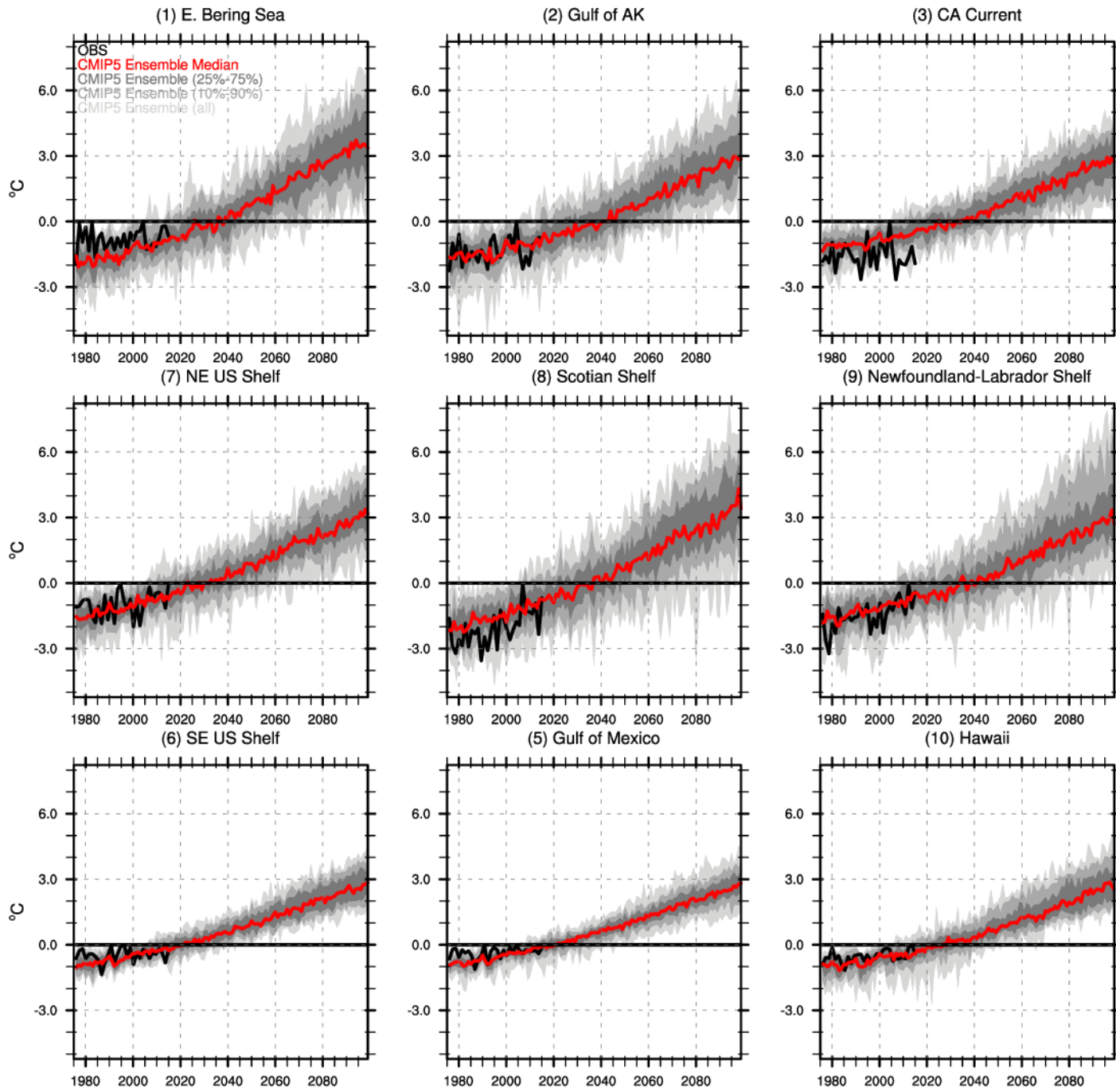
N. Atlantic
Percent of
months in
a decade
warmer
than the
1976-2005
monthly
maximum
in CMIP5
models



Summary

- Upward trends over the 21st century nearly all of the globe
 - Spread in trends much greater in CMIP5 than in CESM-LENS: difference in physics more important than in natural variability for generating SST variability
 - Trends greater in summer than in winter in mid and high latitudes
 - Due to seasonal cycle in MLD?
 - If ice present suppresses SST variability
- Modest changes in variability after detrending
- Climate Departure
 - earlier in tropics
 - more uniform across CMIP5 in subtropical than mid and high latitude regions even though changes larger there

SST CMIP5 RCP8.5 SEP Anomalies Relative to 1975-2005 Max



SST CMIP5 RCP8.5 SEP Anomalies Relative to 1975-2005 Max

