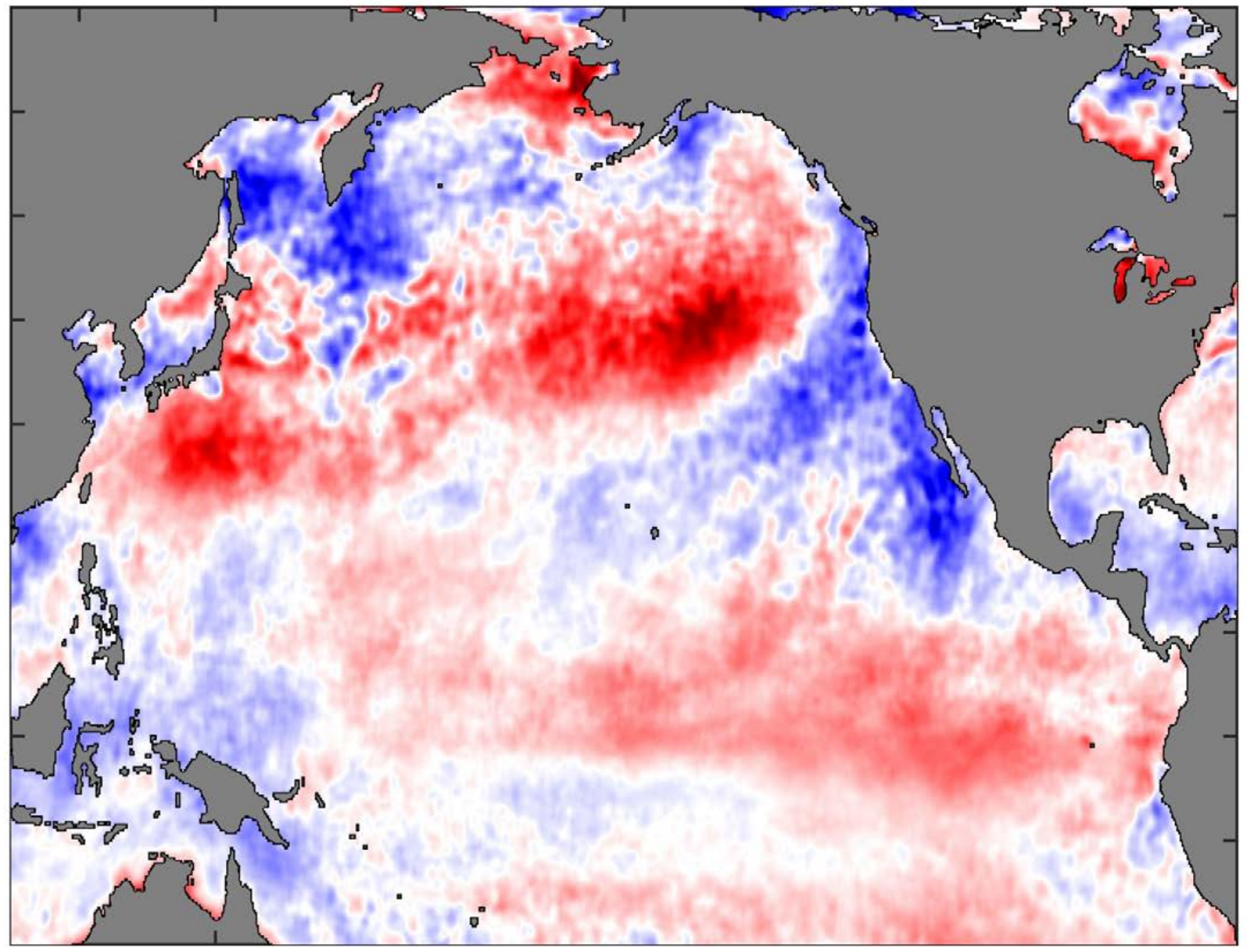
# Mechanisms Driving Seasonal Forecast Skill in the California Current System

Mike Jacox

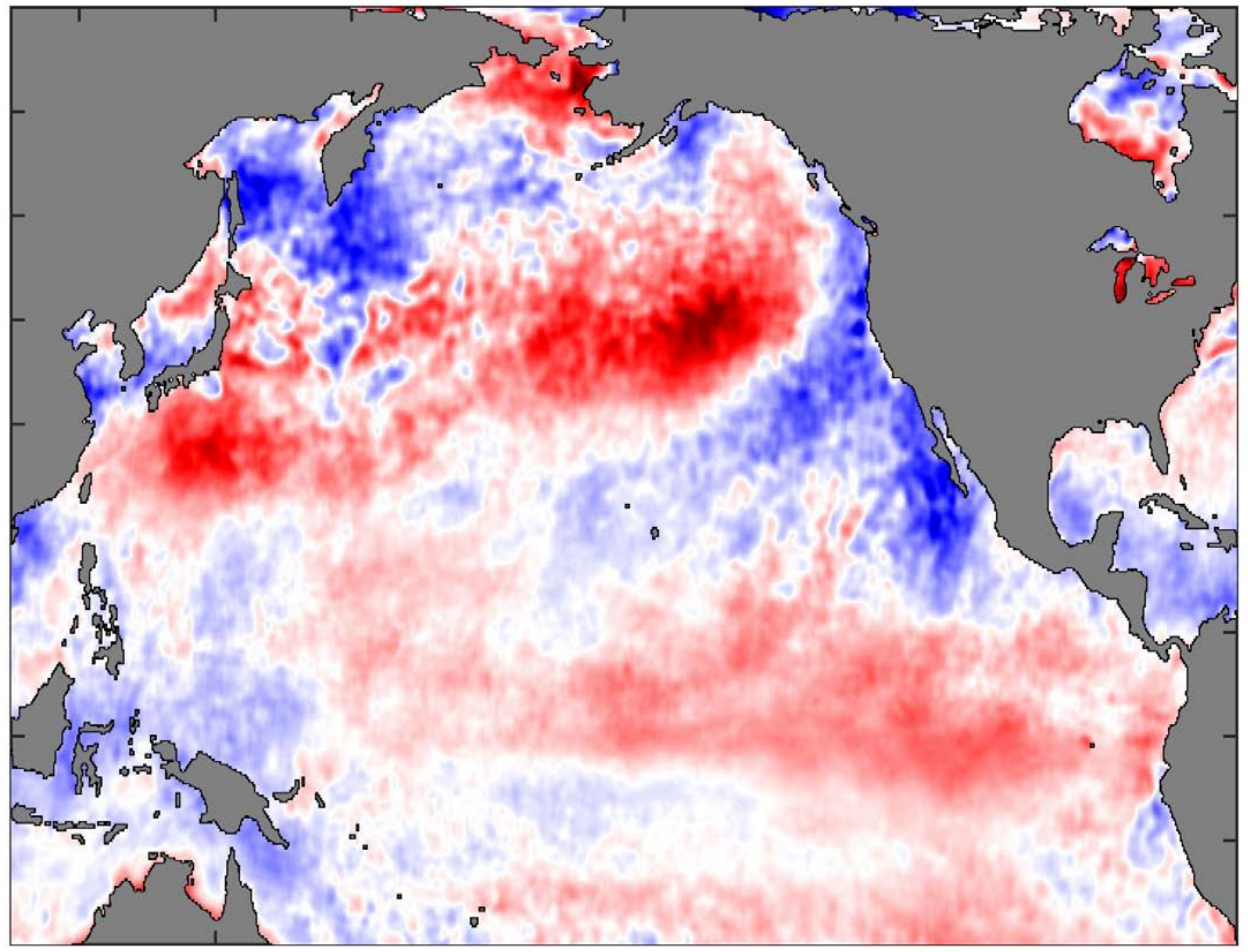
Symposium on the Effects of Climate Change on the World’s Oceans
June 7, 2018

Mike Alexander, Steven Bograd, Elliott Hazen, Gaelle Hervieux, Nate Mantua,
James Scott, Charlie Stock, Desiree Tommasi, Robin Webb, Cisco Werner

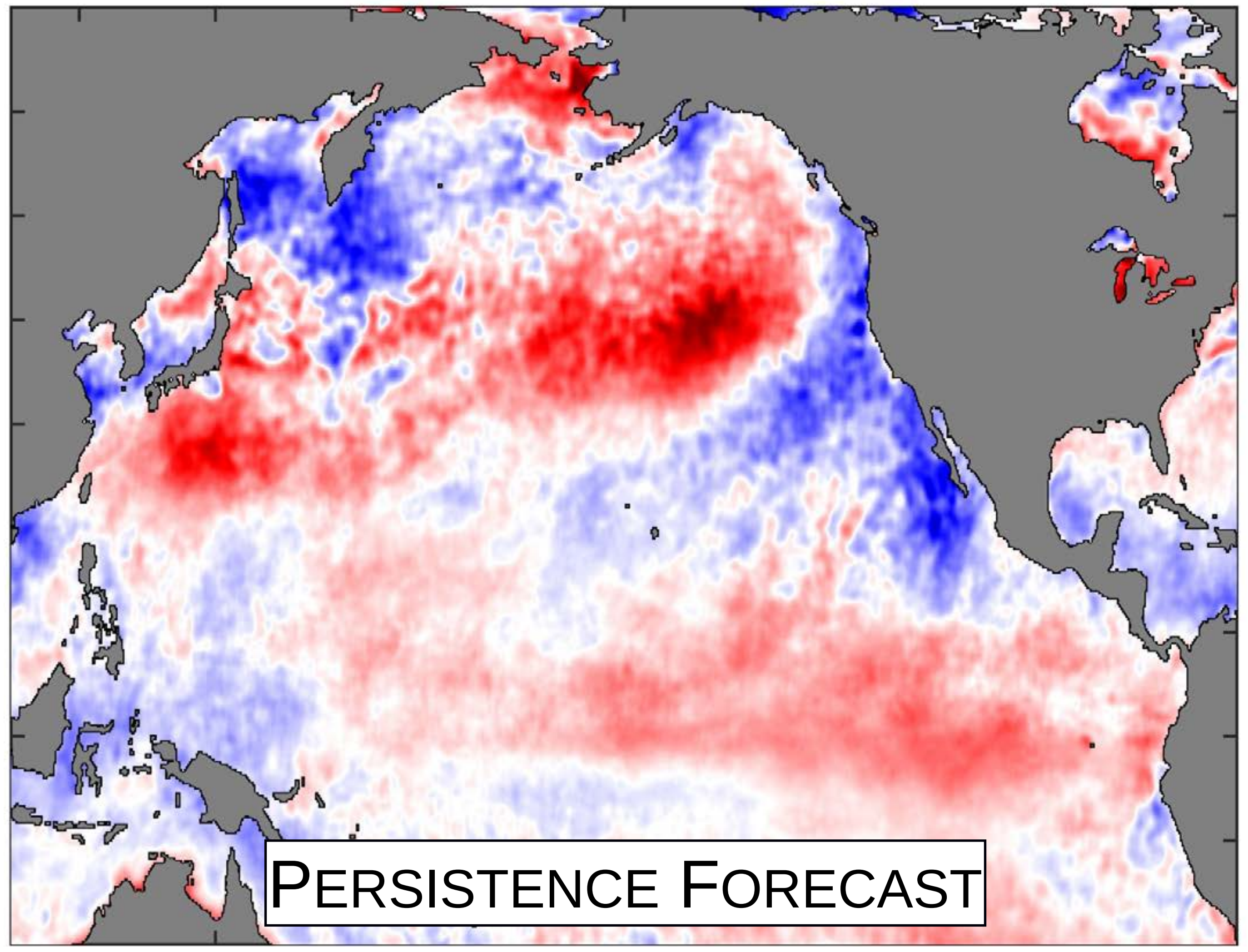
## August 1991 SST Anomaly



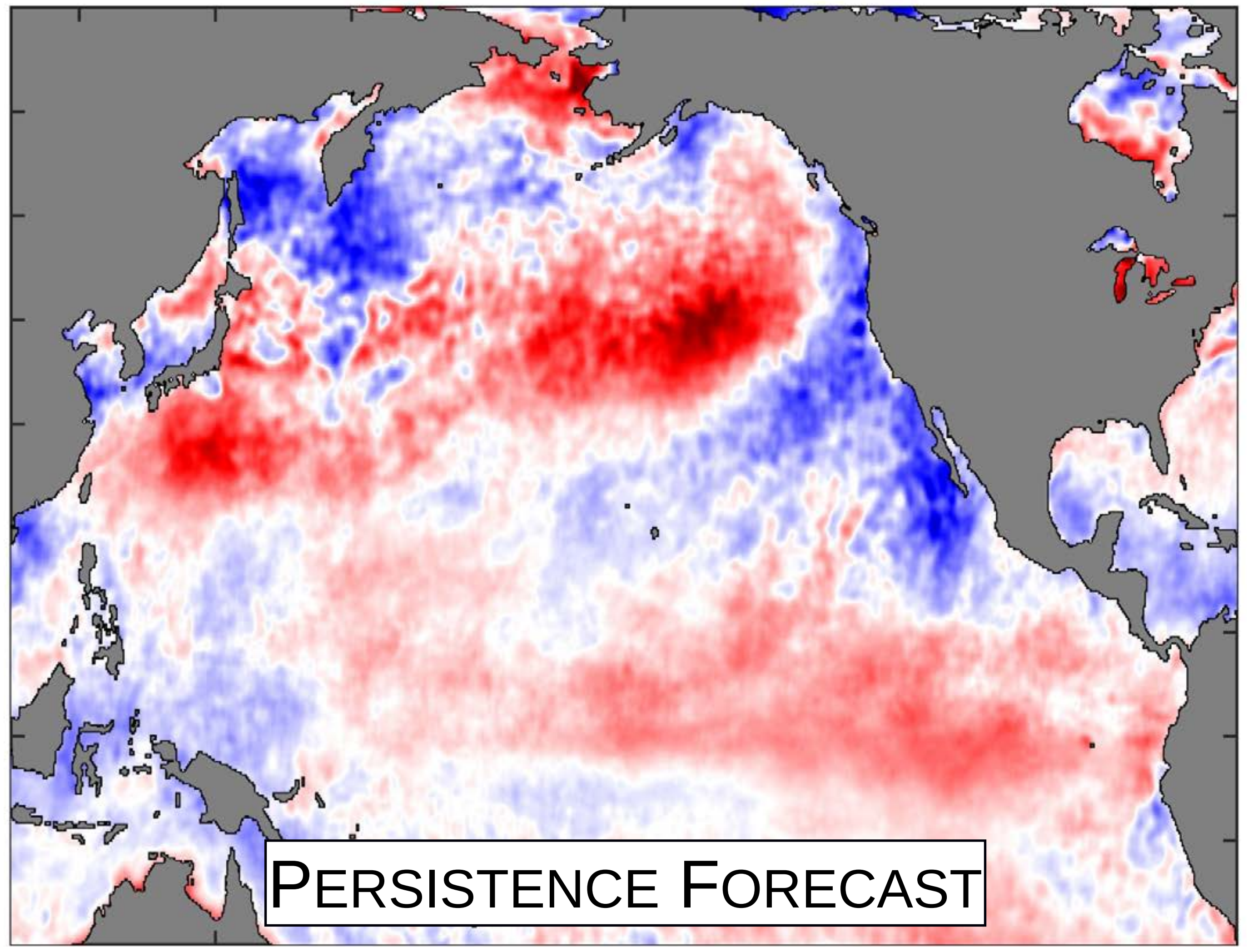
## August 1991 Forecast of November 1991

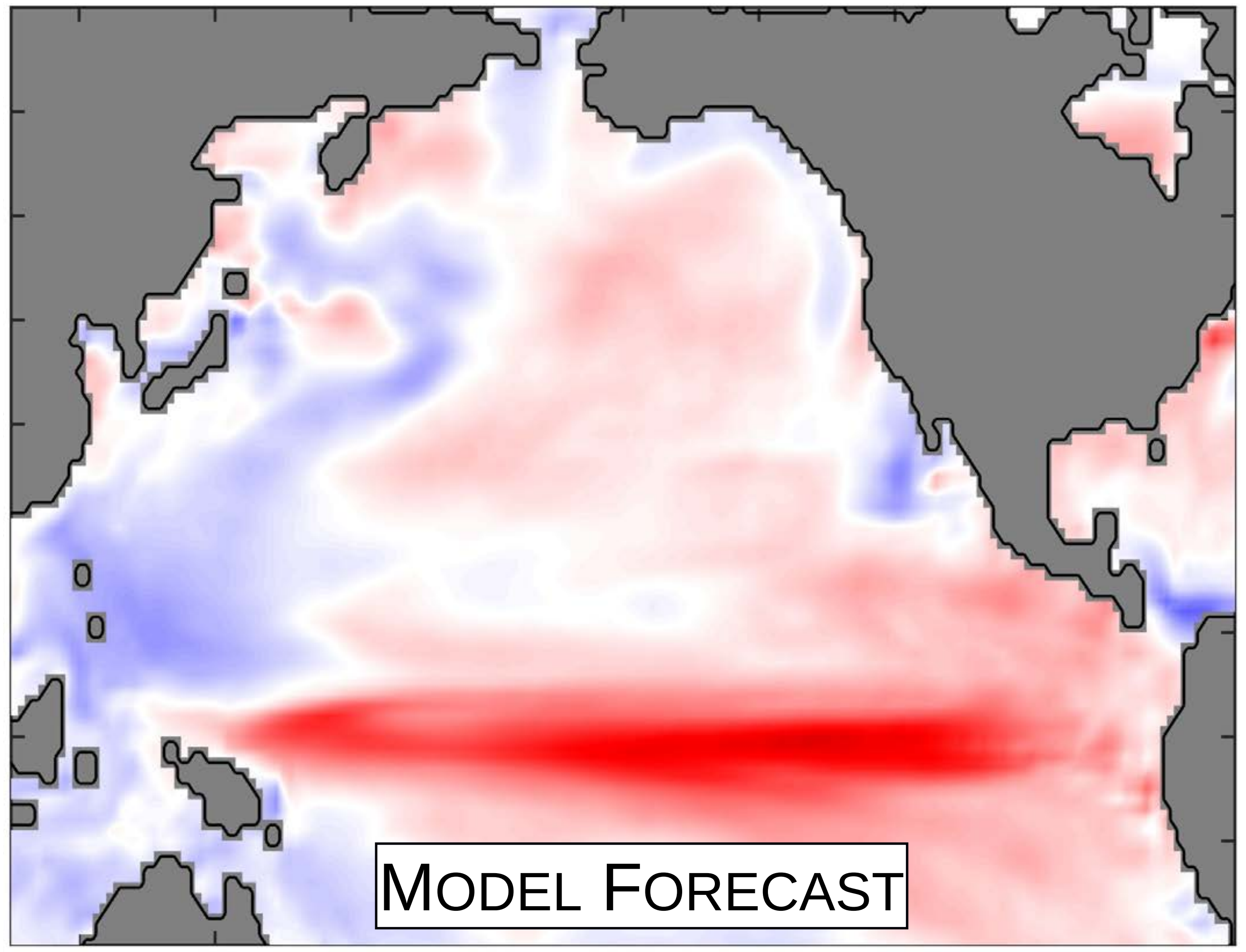


## August 1991 Forecast of November 1991



## AUGUST 1991 FORECAST OF NOVEMBER 1991



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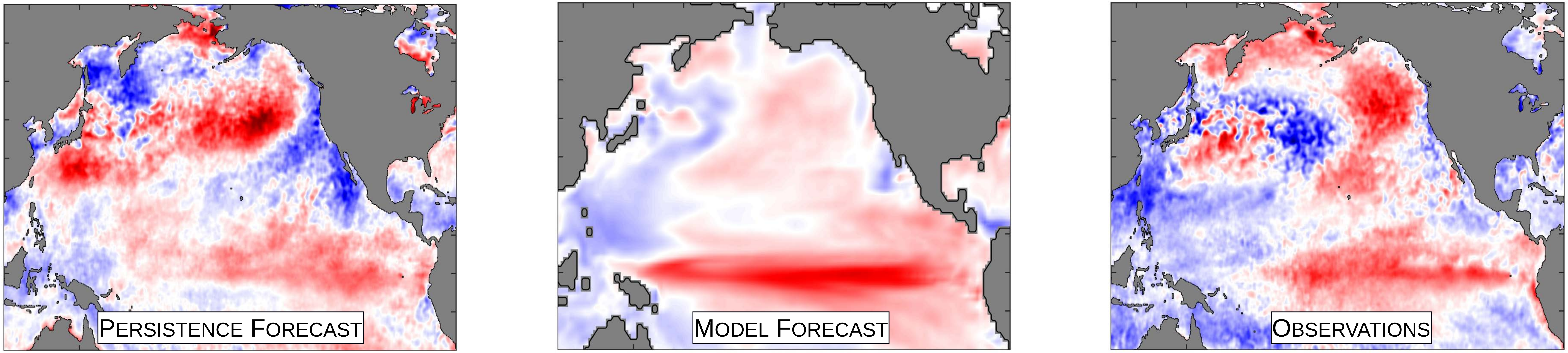

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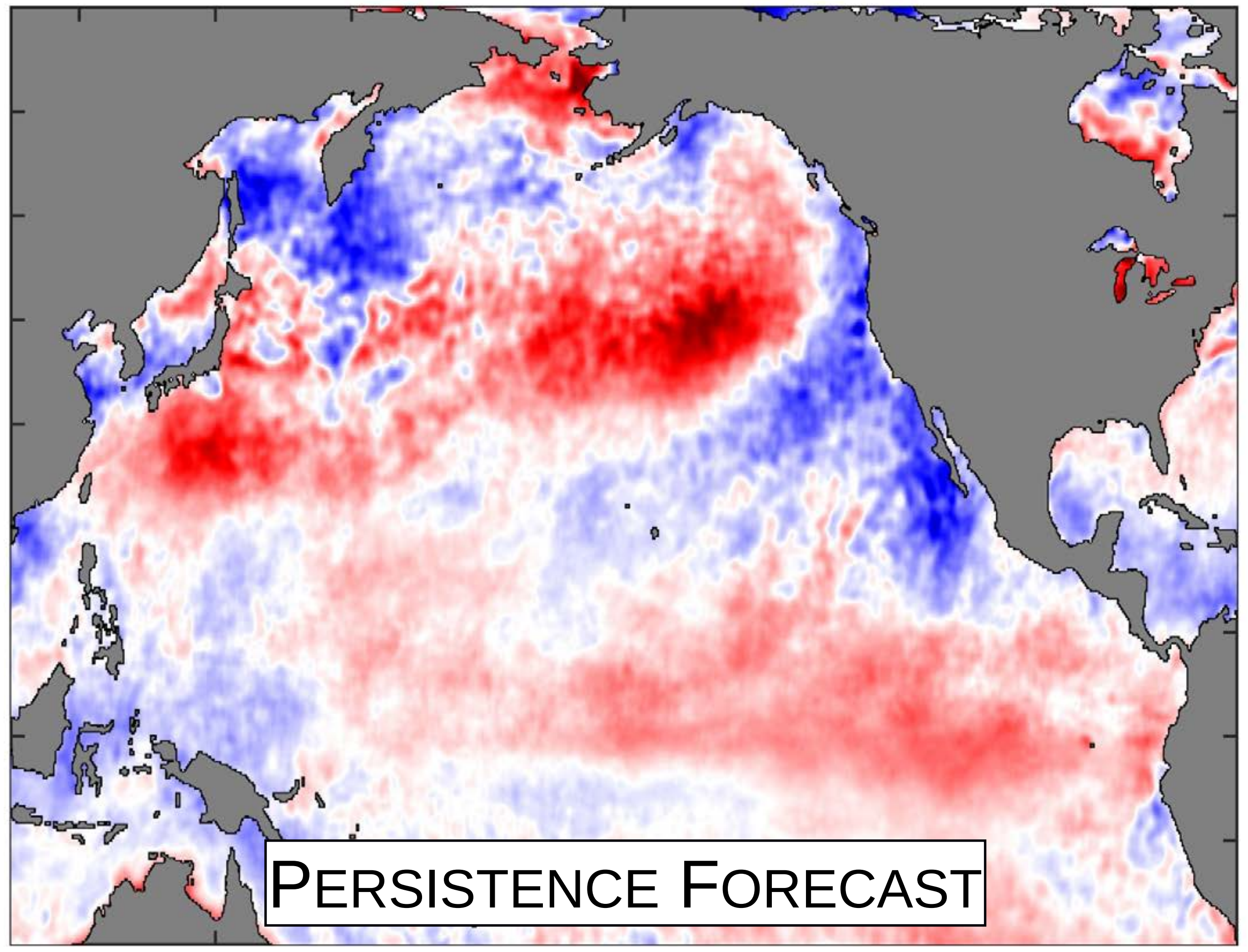
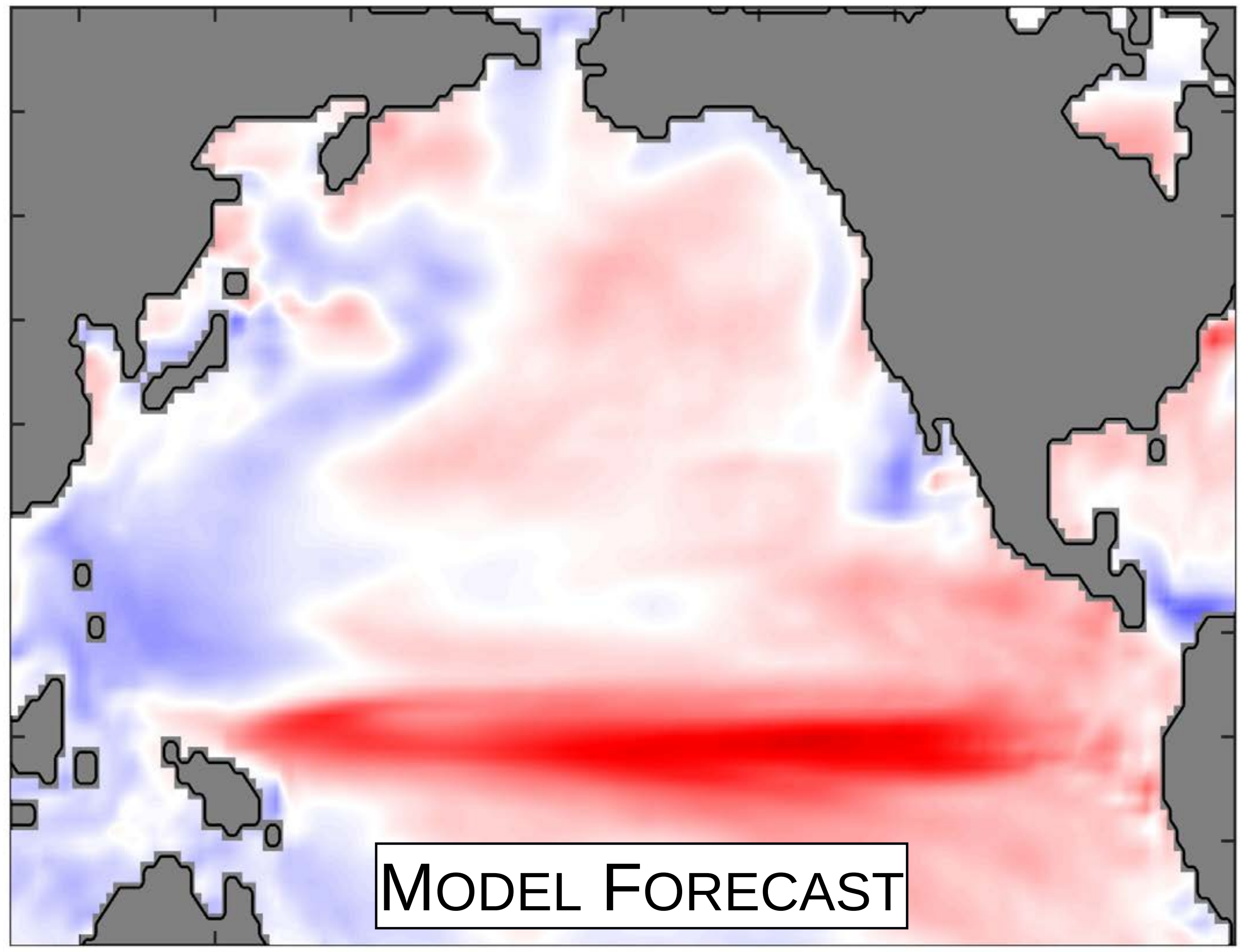
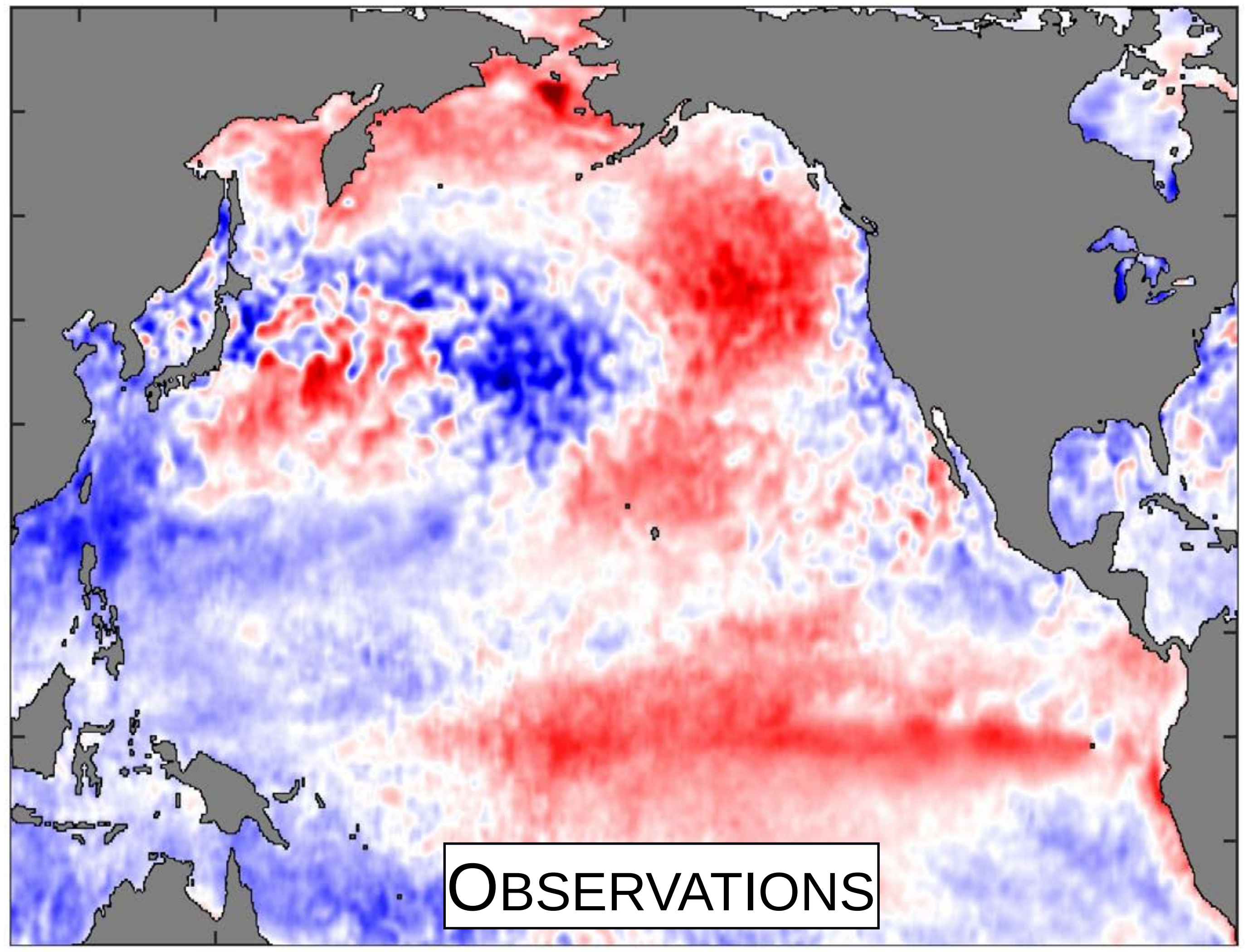
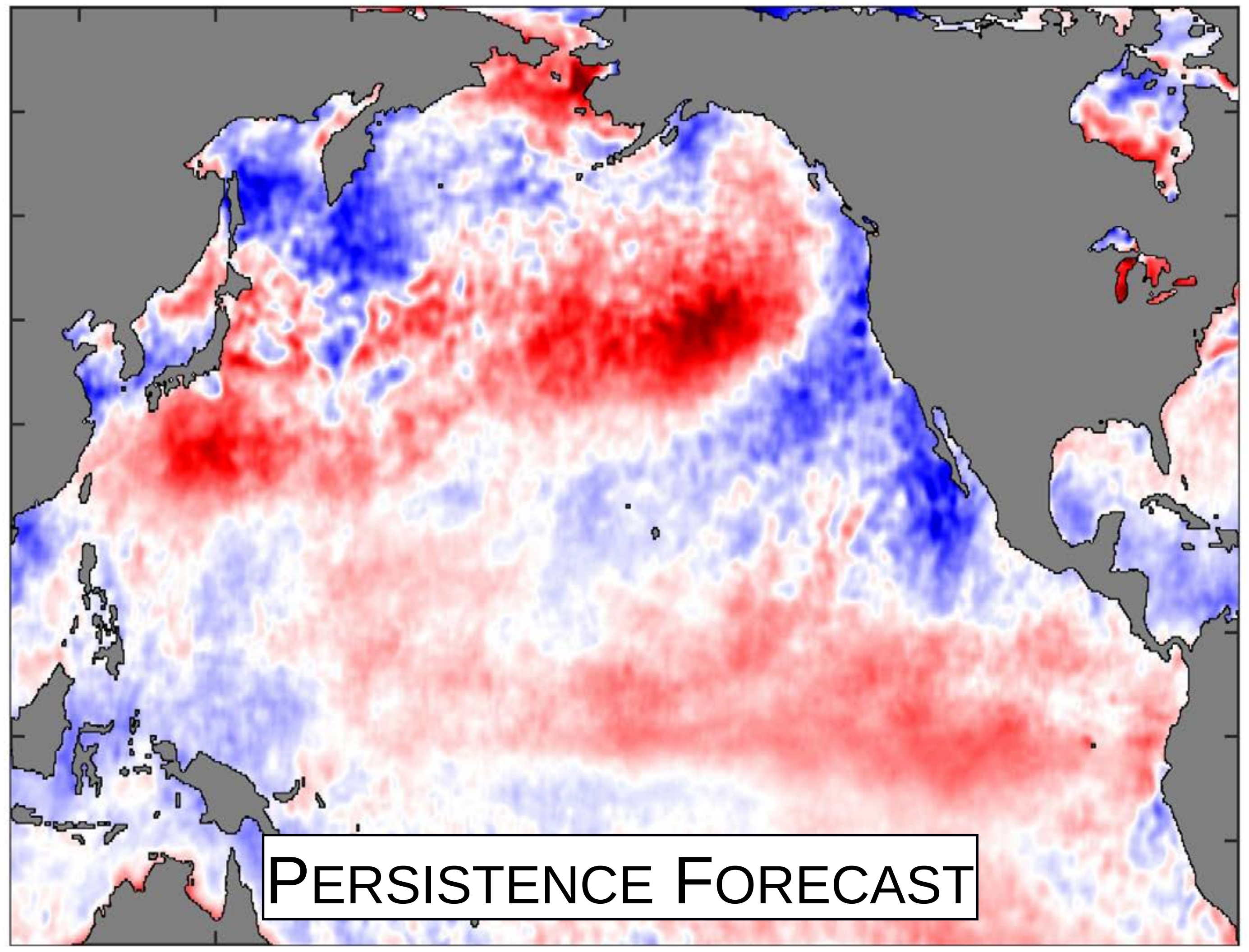



## AUGUST 1991 FORECAST OF MAY 1992



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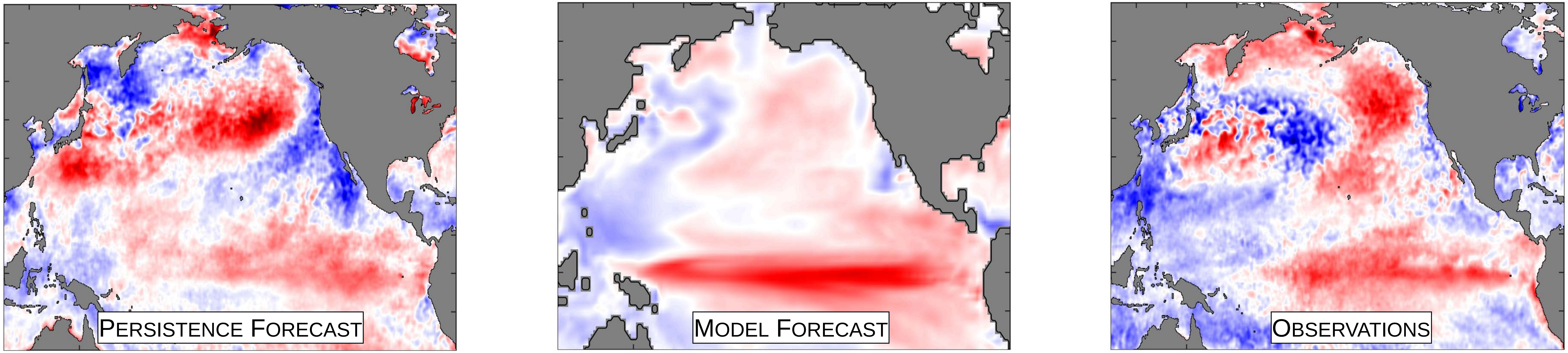


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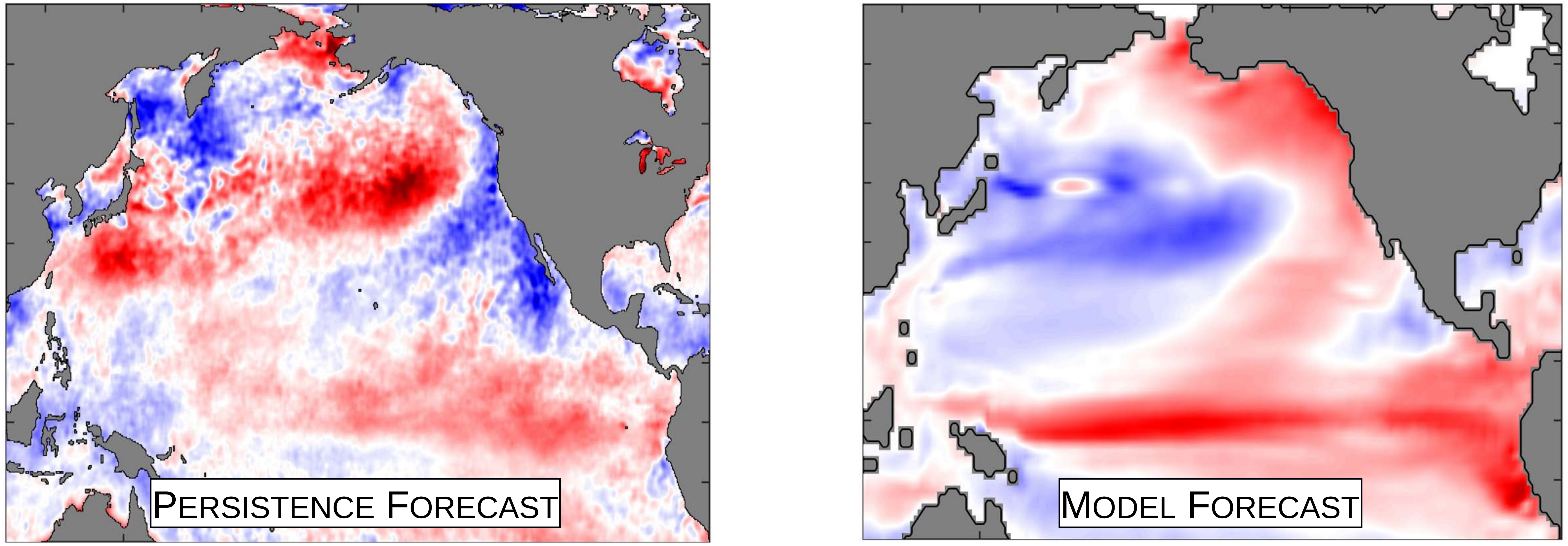

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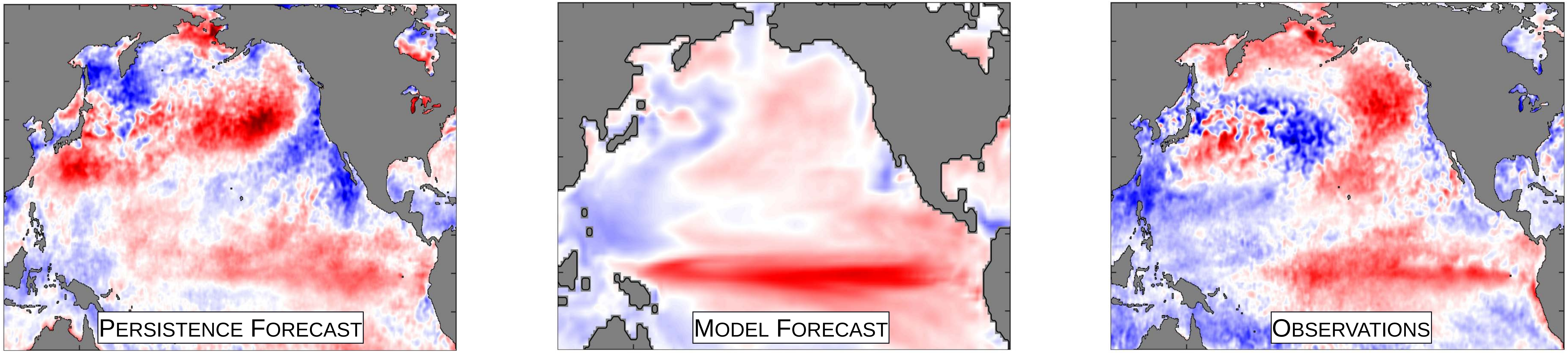


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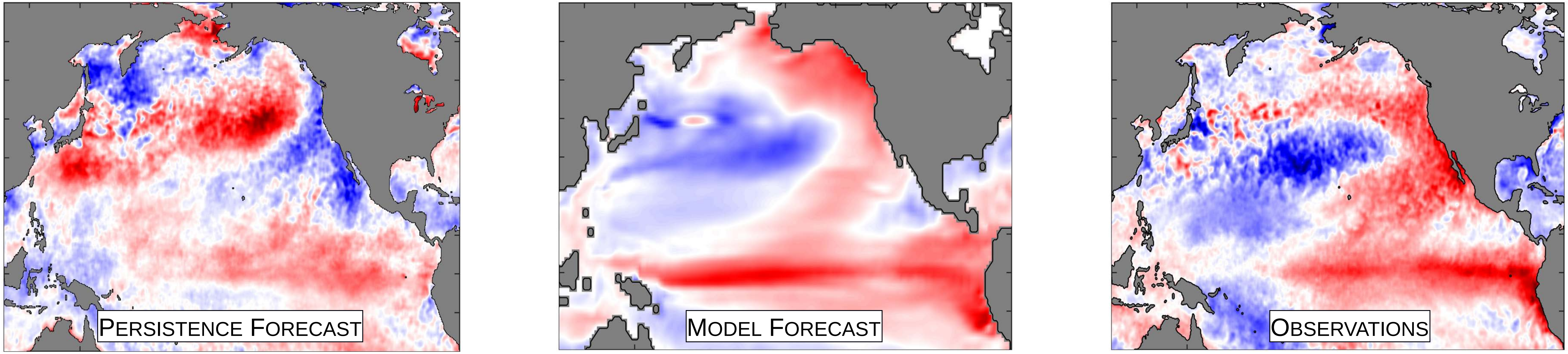
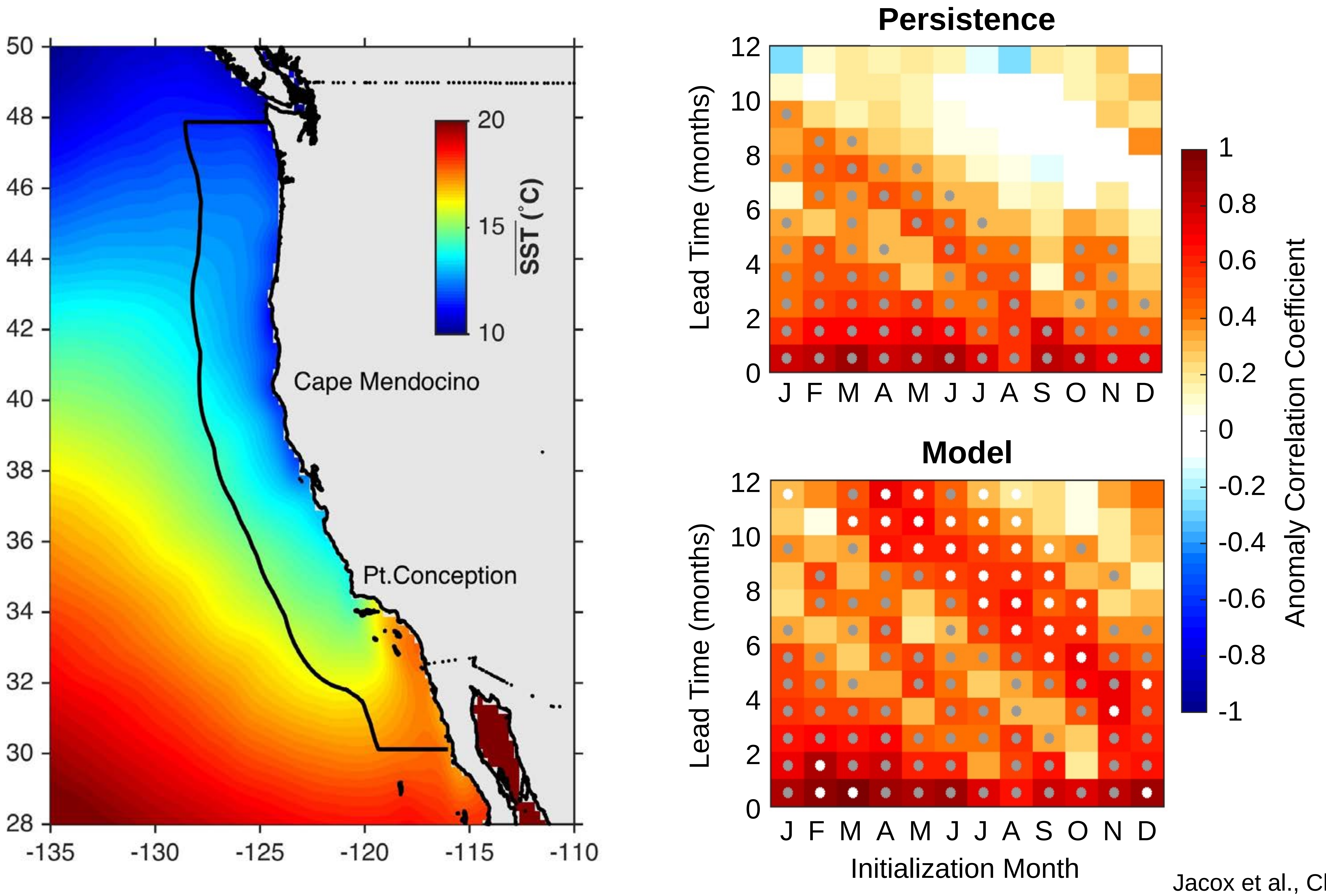
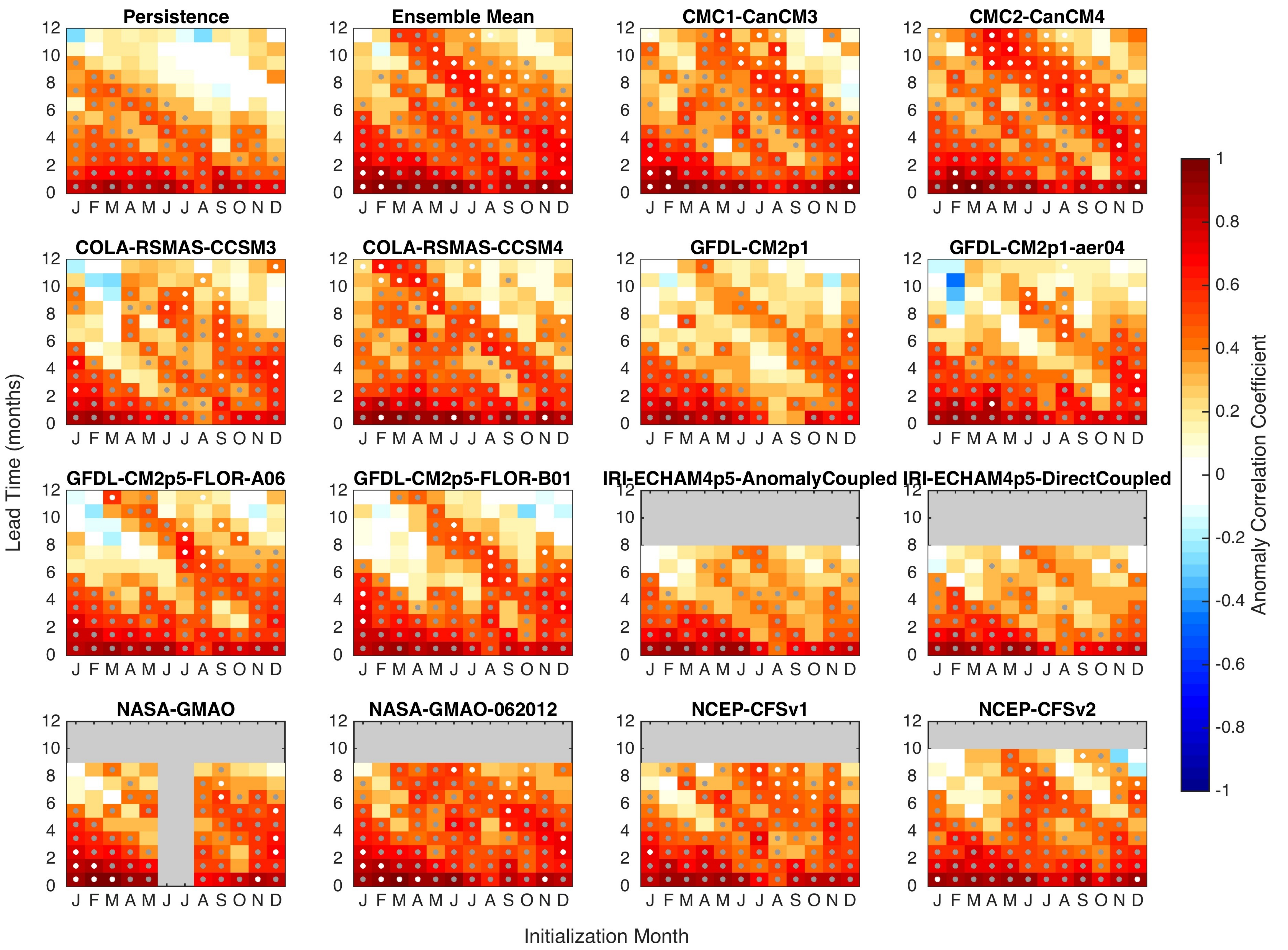


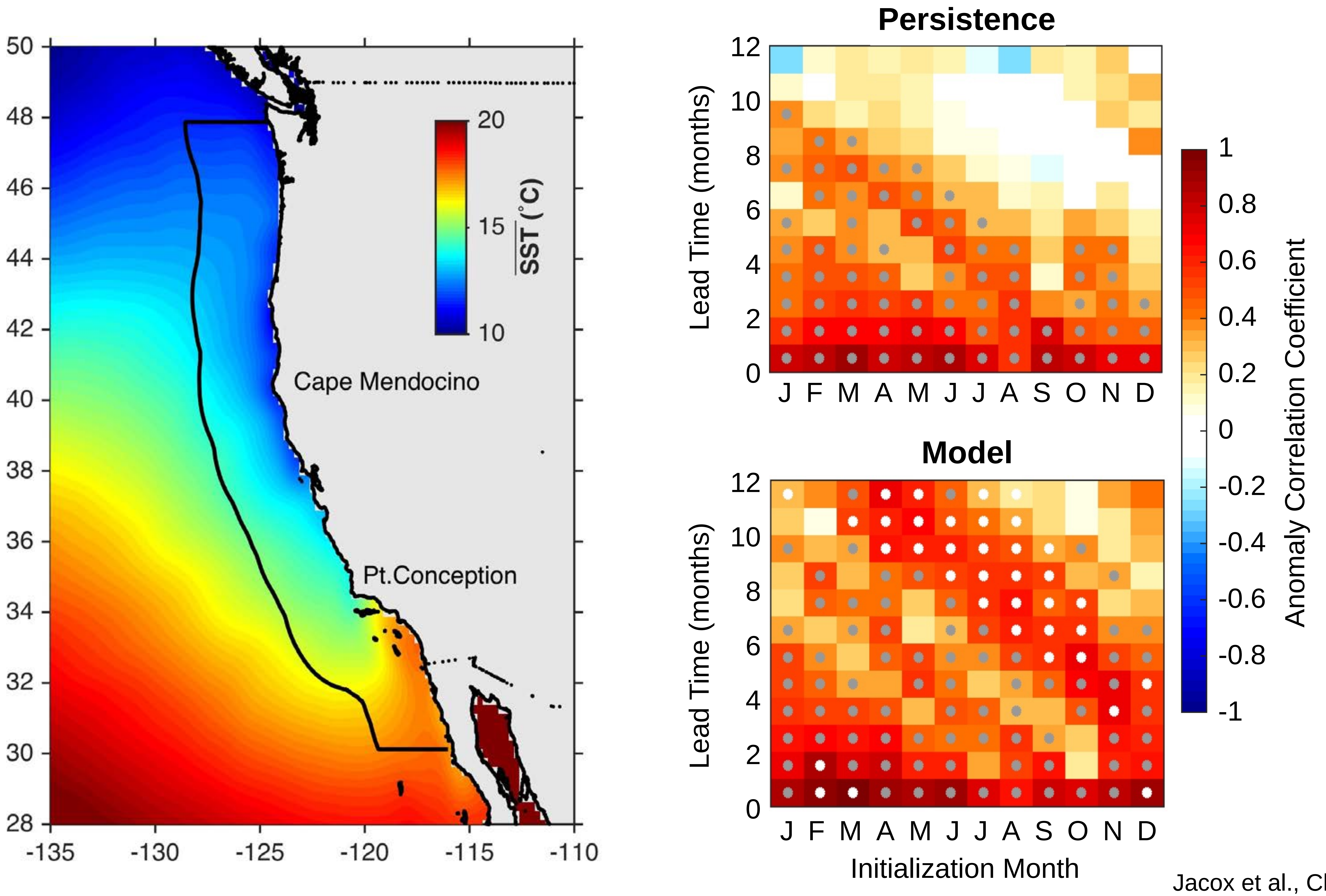



Jacox et al., Climate Dynamics (2017)

# NORTH AMERICAN MULTI-MODEL ENSEMBLE FORECASTS




Jacox et al., Climate Dynamics (2017)

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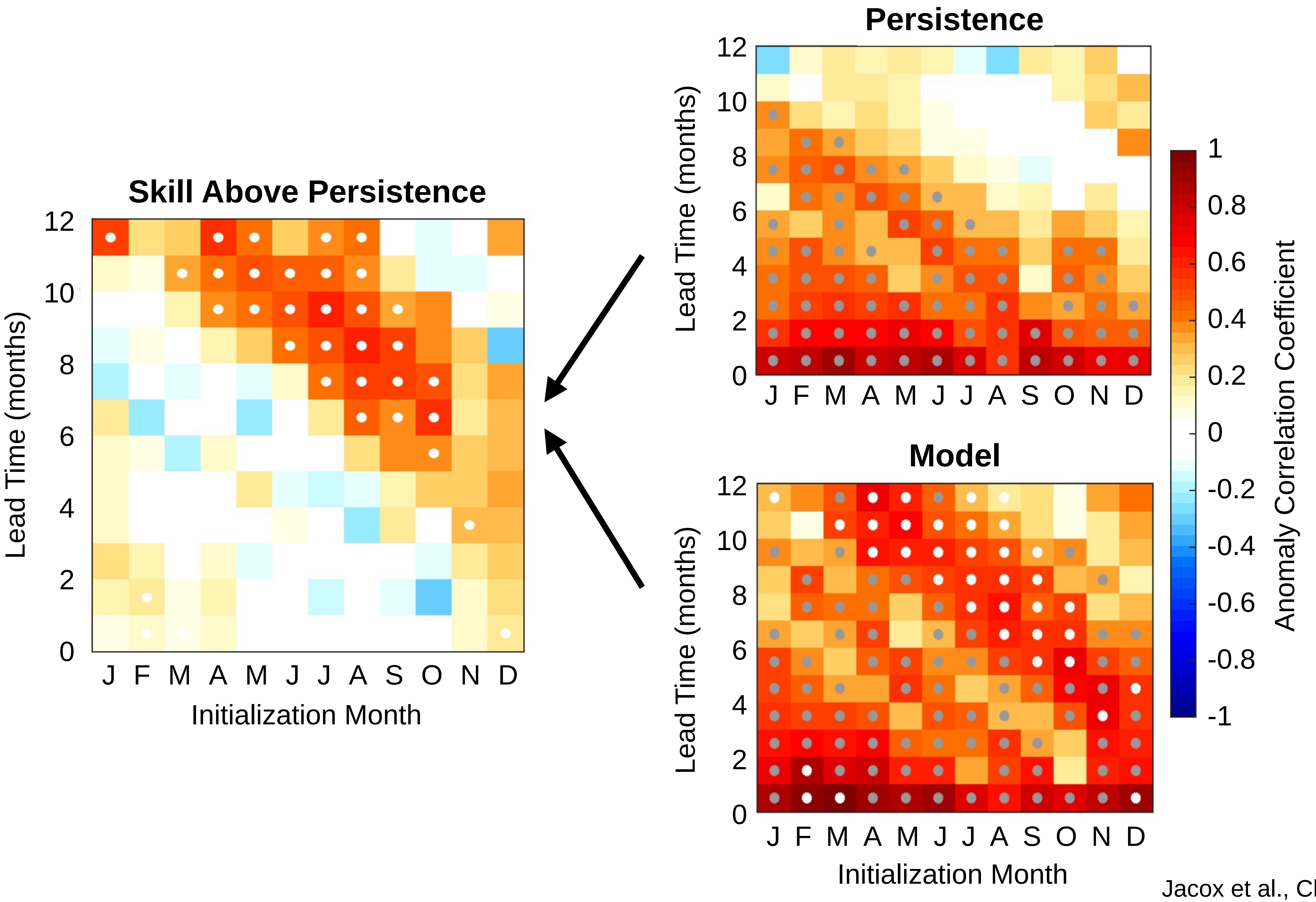
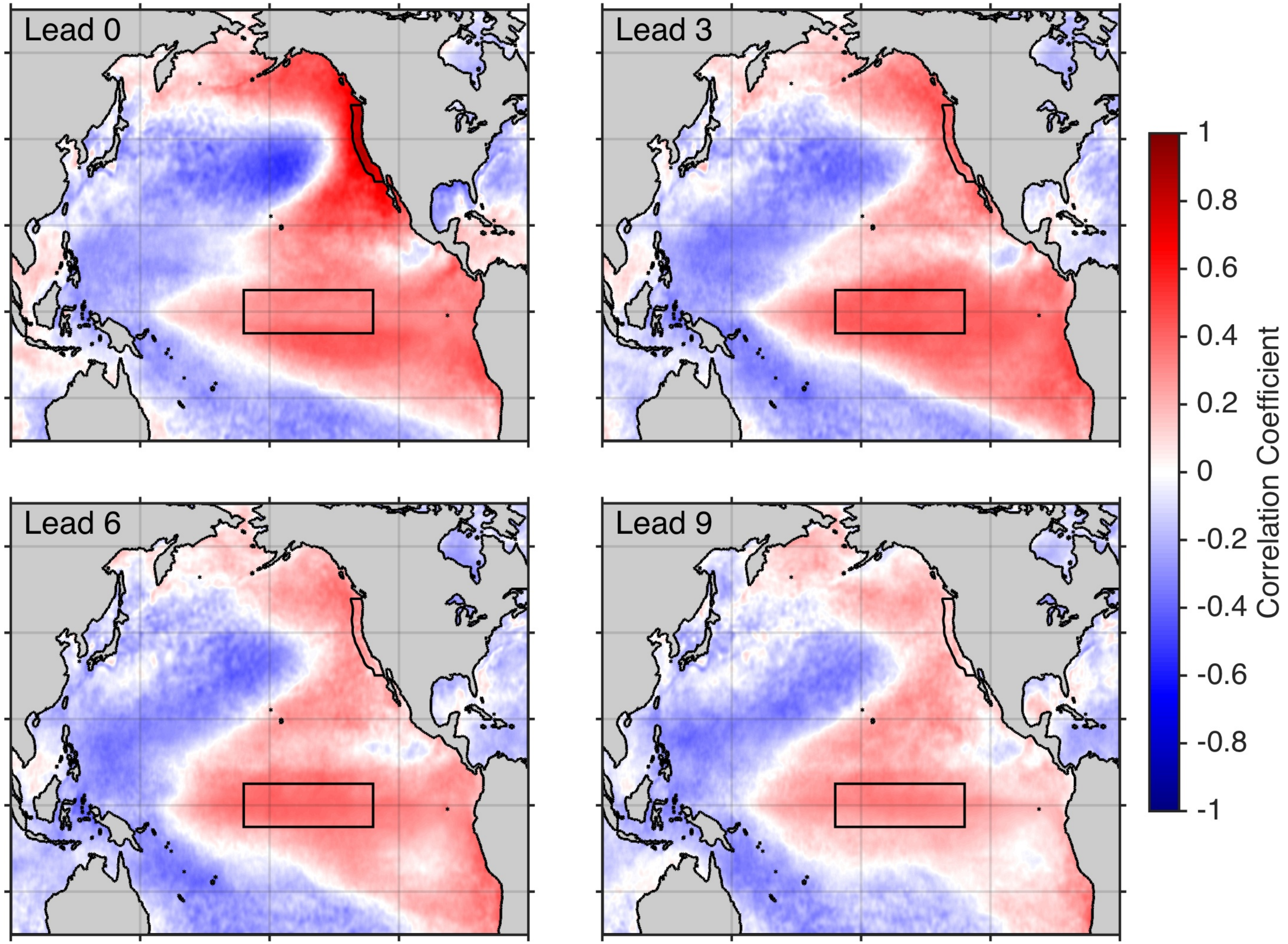
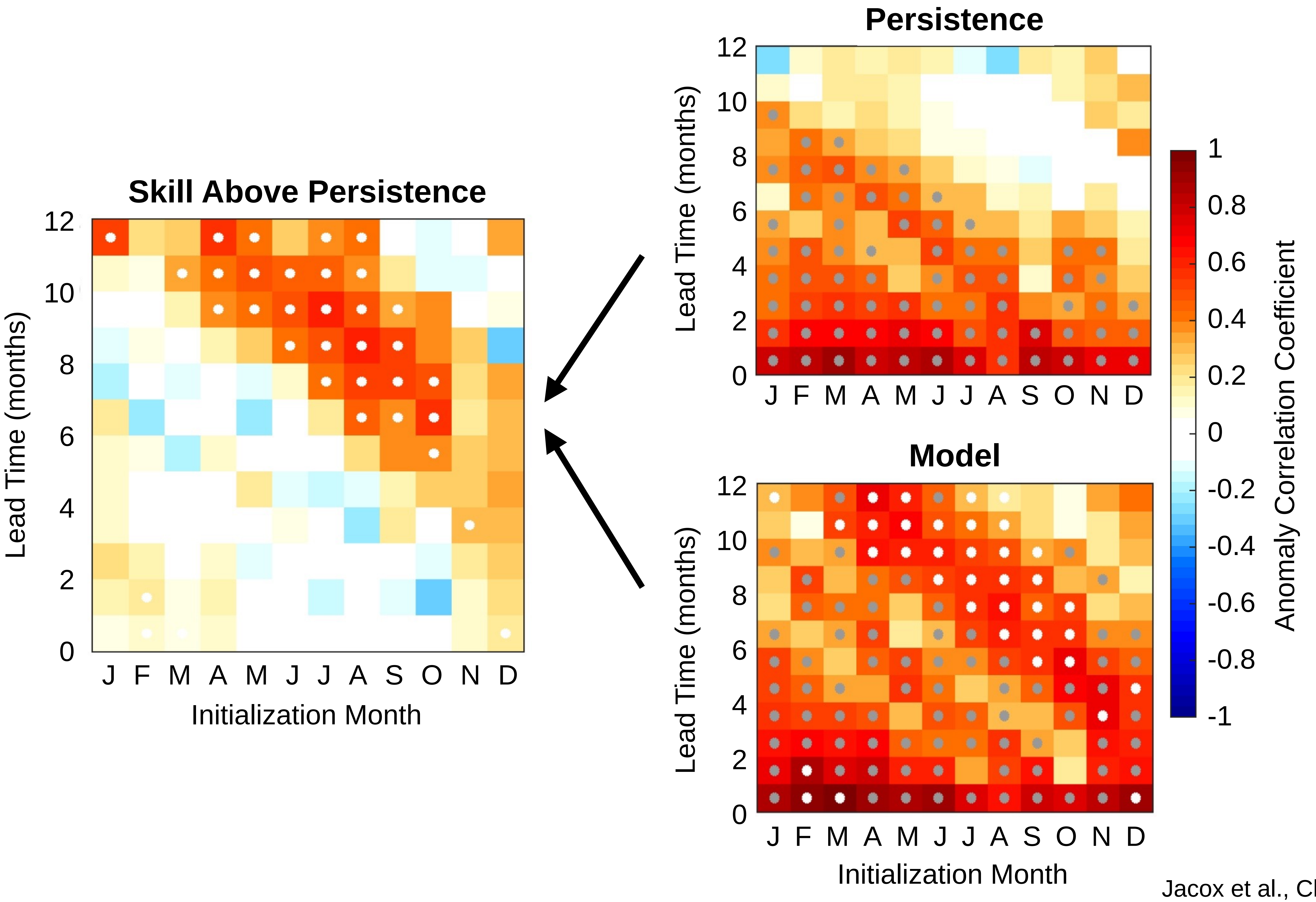



Jacox et al., Climate Dynamics (2017)




Jacox et al., Climate Dynamics (2017)

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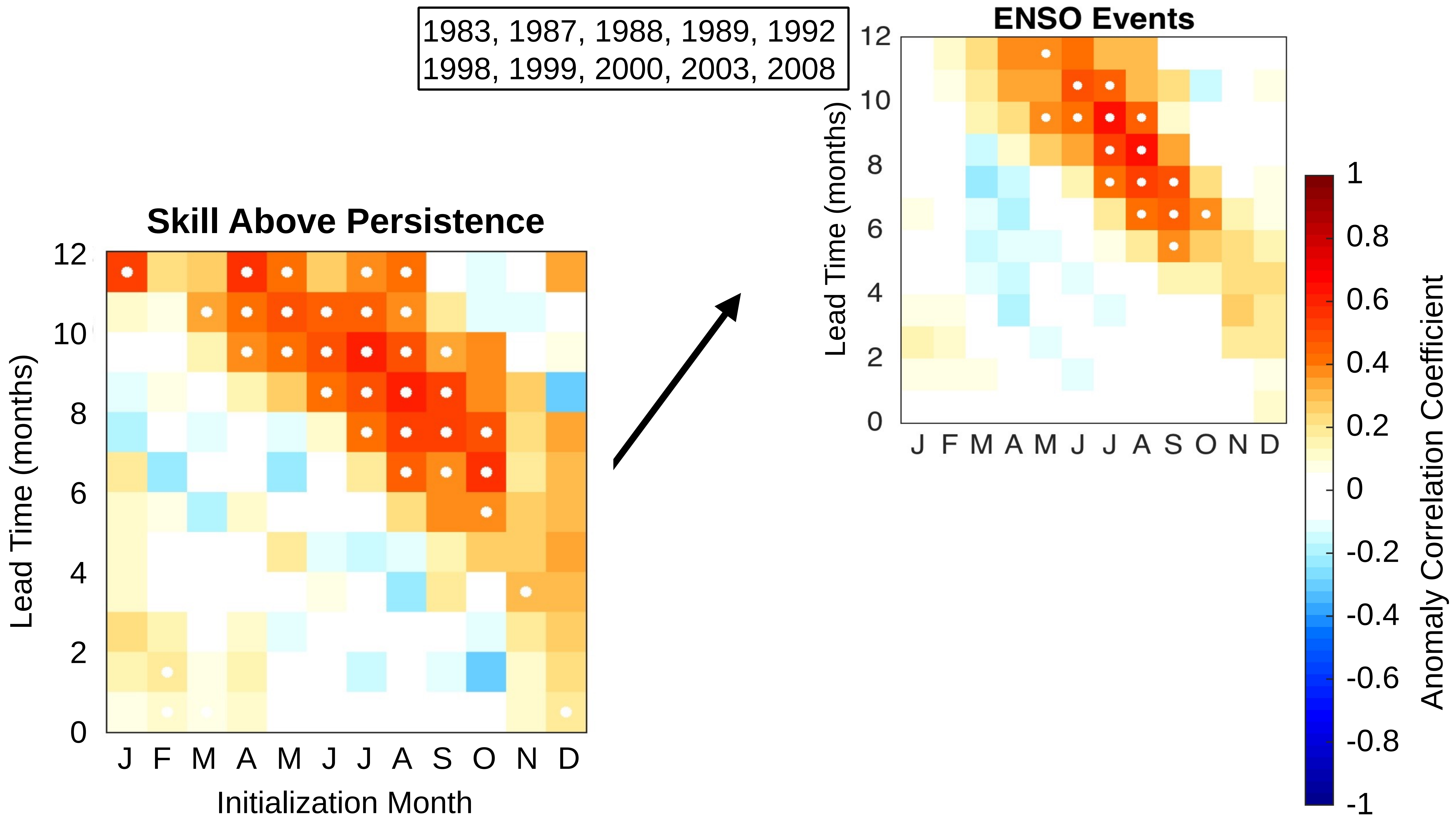
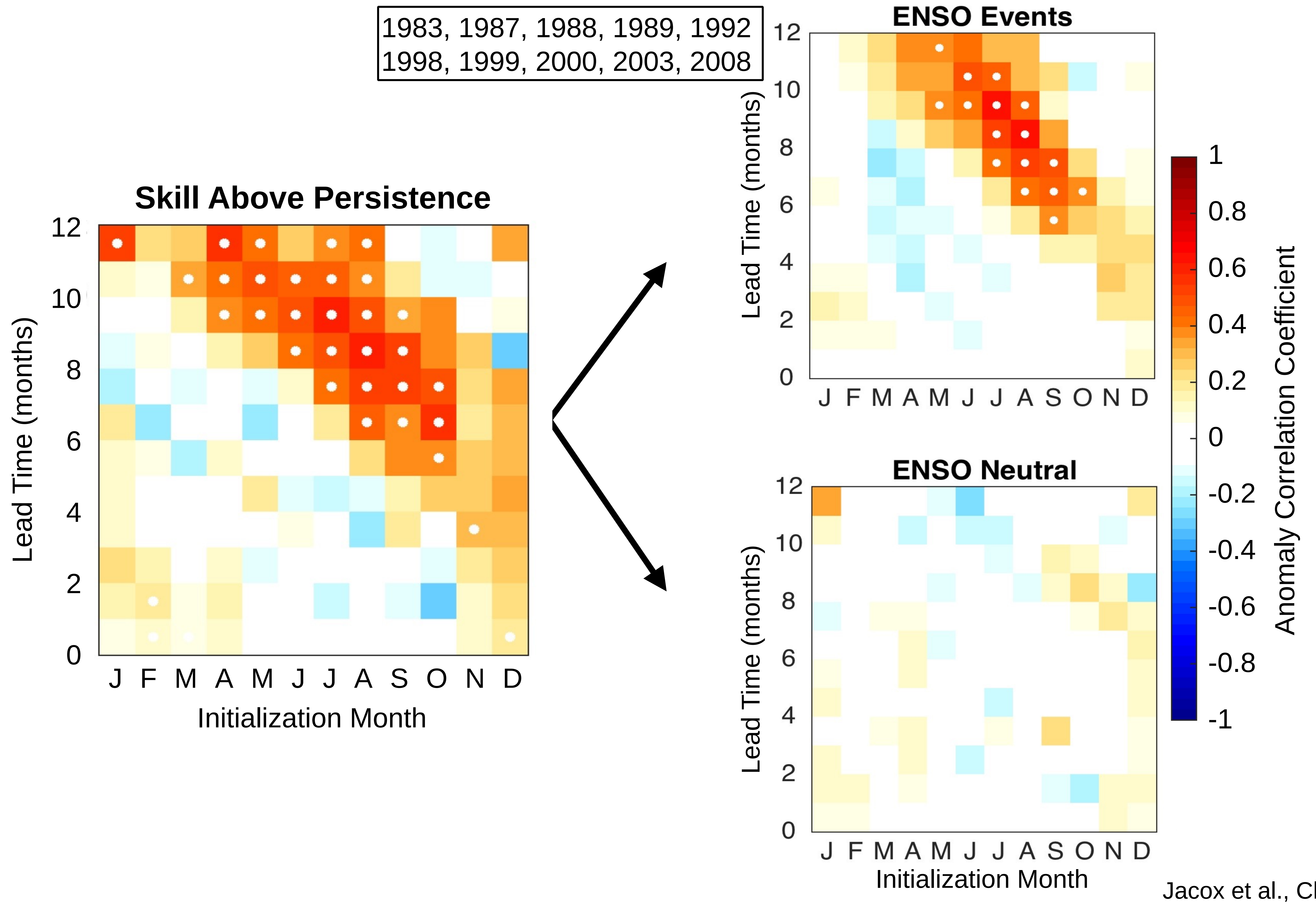



Jacox et al., Climate Dynamics (2017)



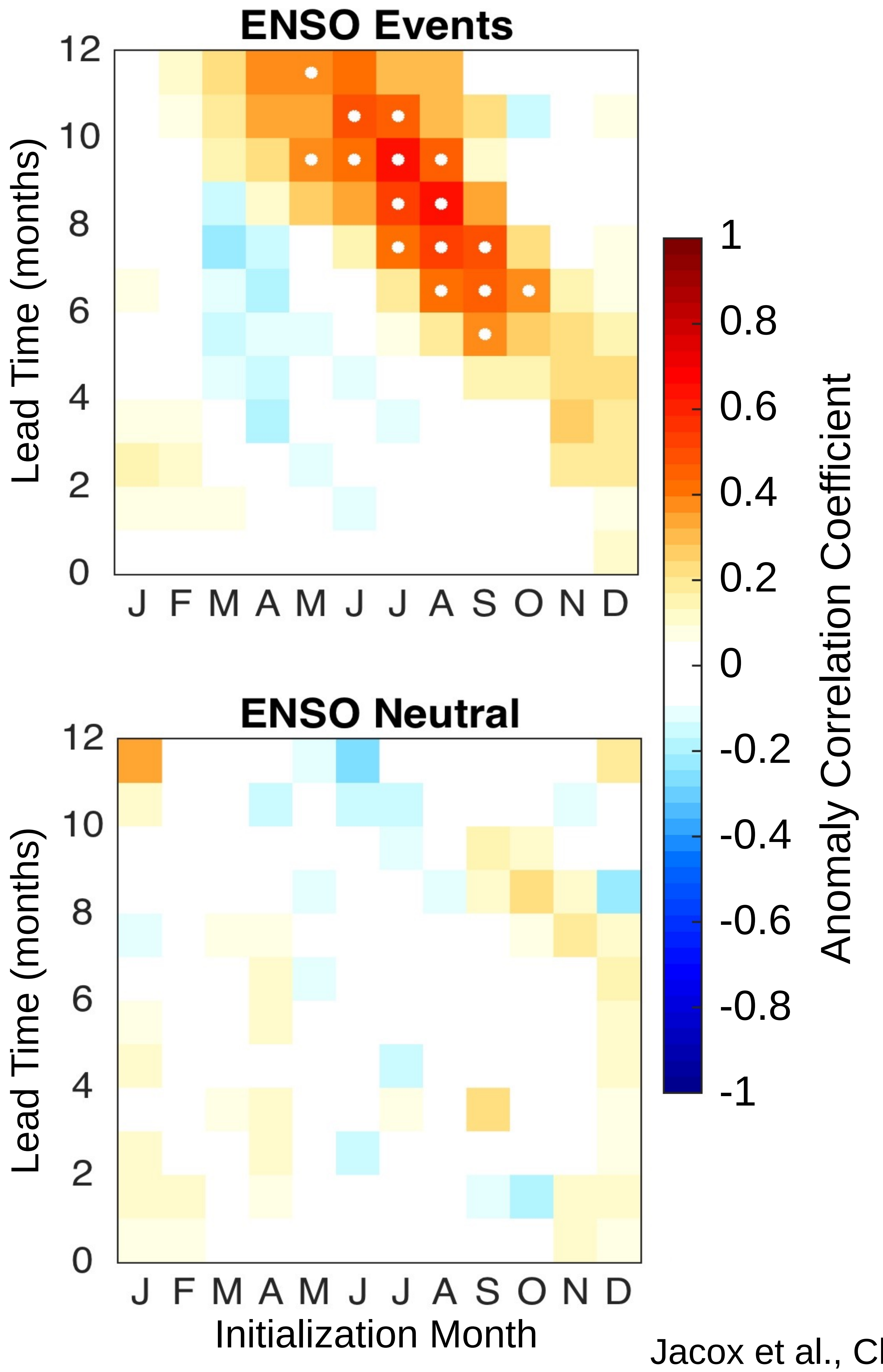

Jacox et al., Climate Dynamics (2017)

Possible forcing mechanisms

Surface heat flux

Wind stress

Coastal trapped waves




Jacox et al., Climate Dynamics (2017)

Possible forcing mechanisms

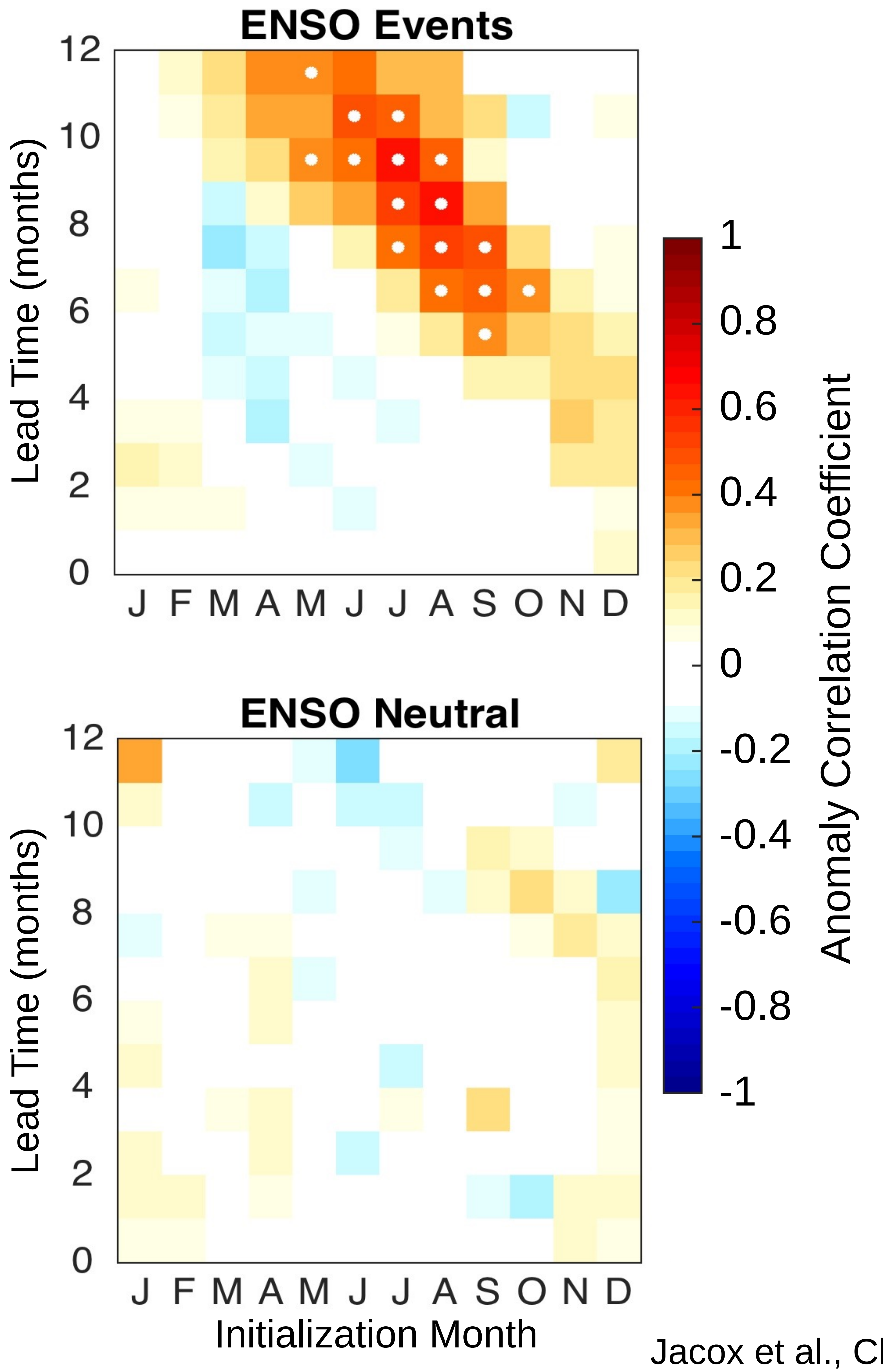
Surface heat flux

Wind stress

Coastal trapped waves

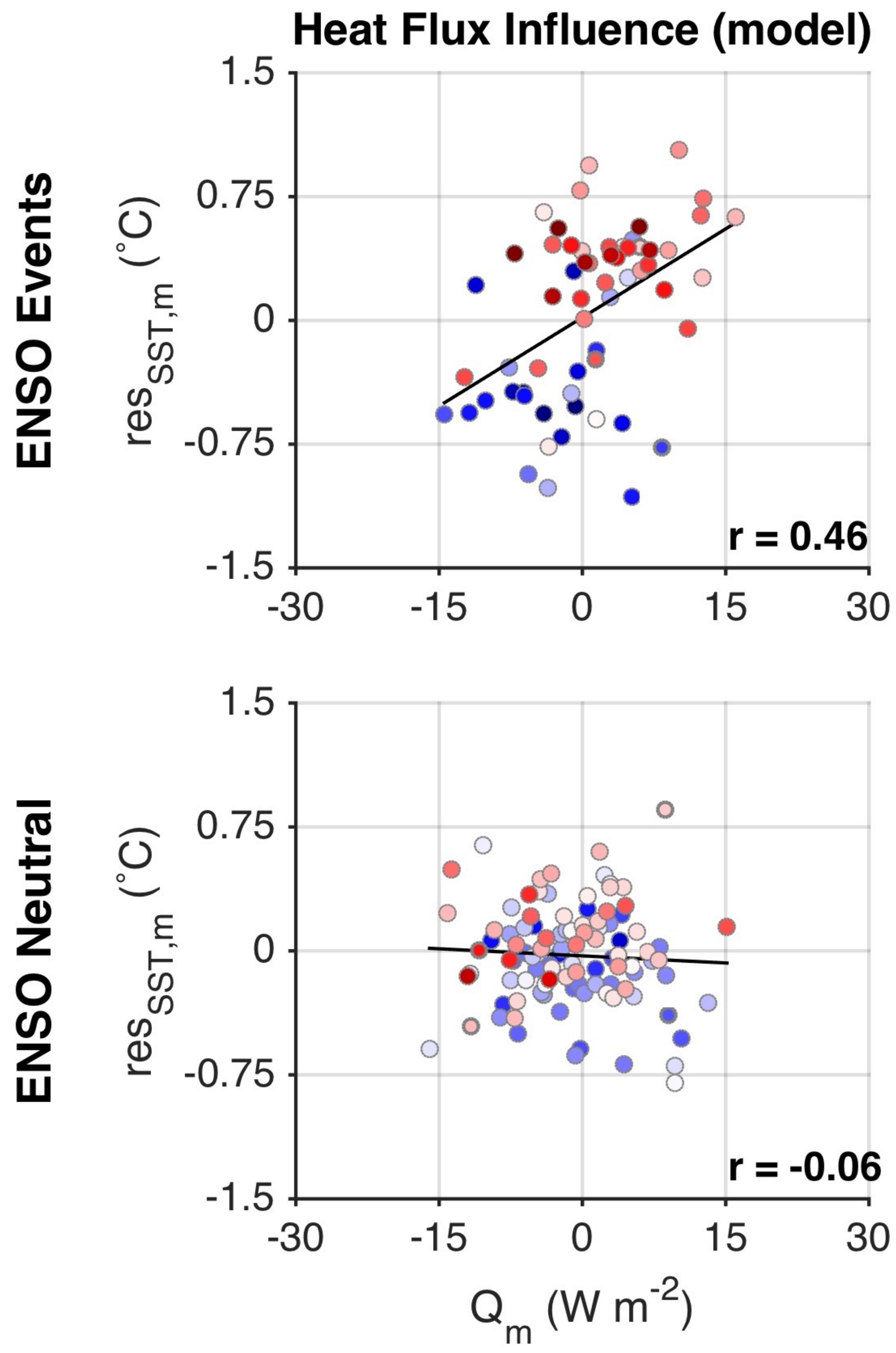
To generate SST predictability, forcing must:

1. Exert influence over SST in the model
2. Exert similar influence over SST in nature
3. Be predictable




Jacox et al., Climate Dynamics (2017)

# Heat Flux




Jacox et al., Climate Dynamics (2017)

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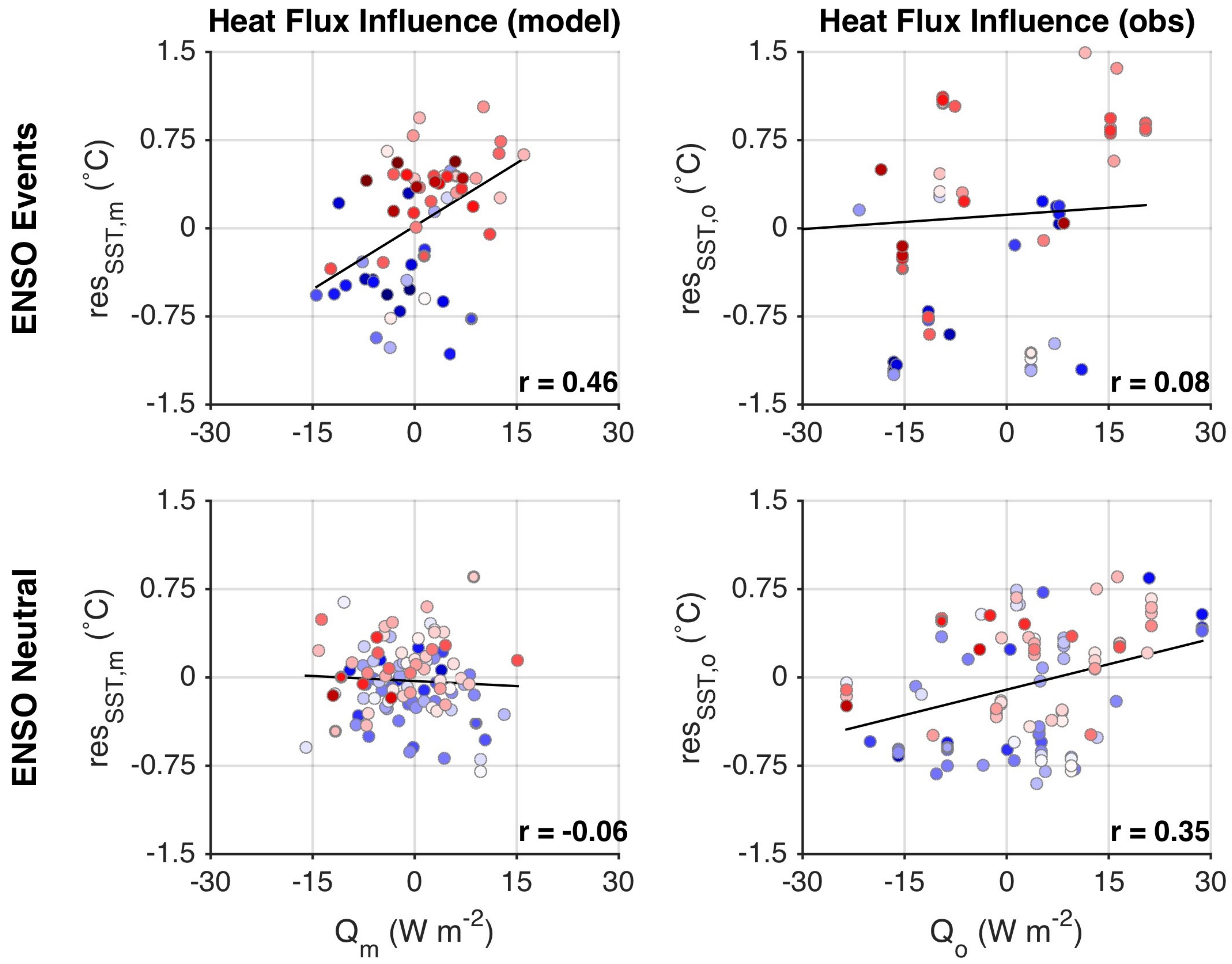


Jacox et al., Climate Dynamics (2017)

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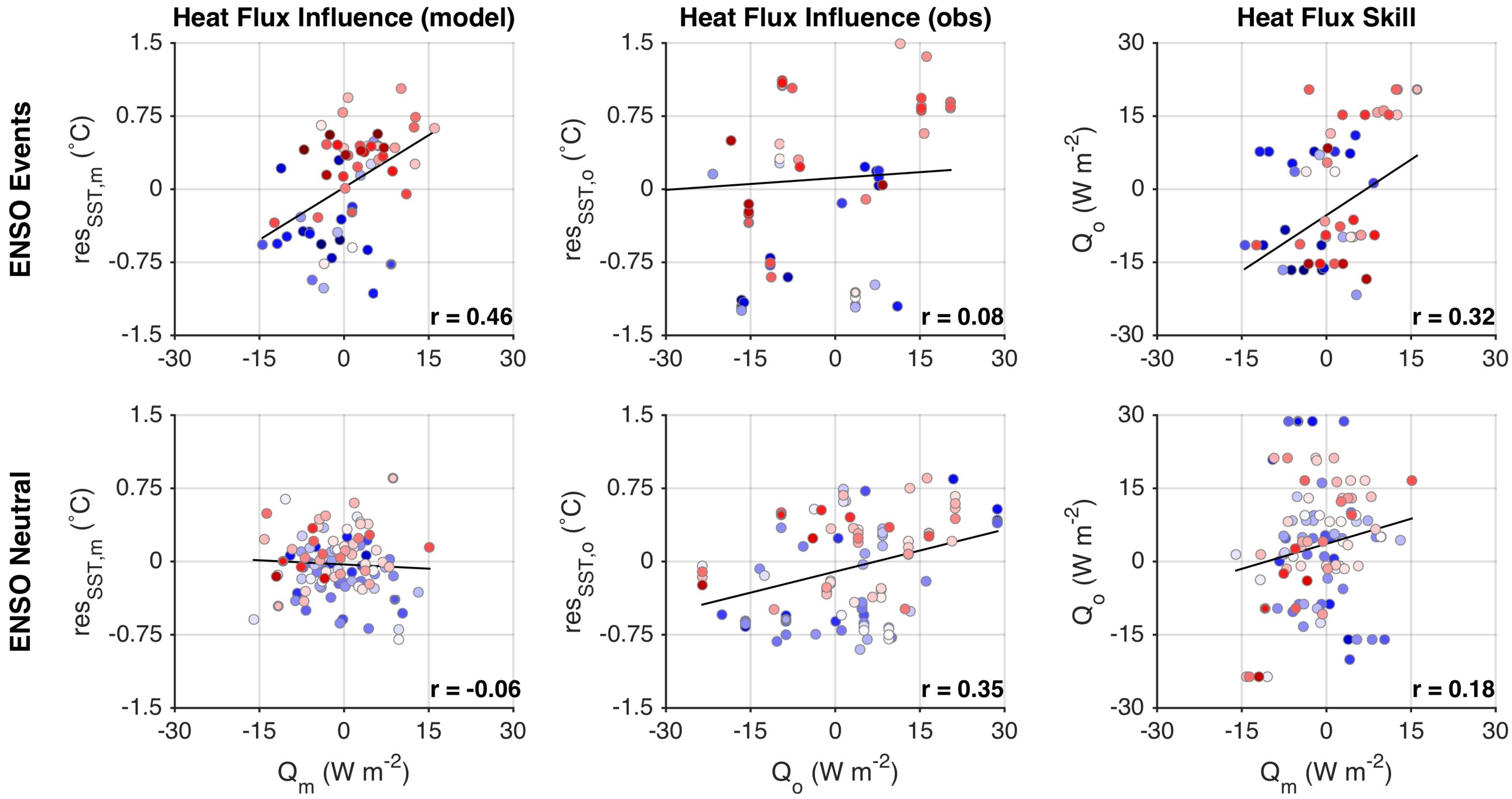
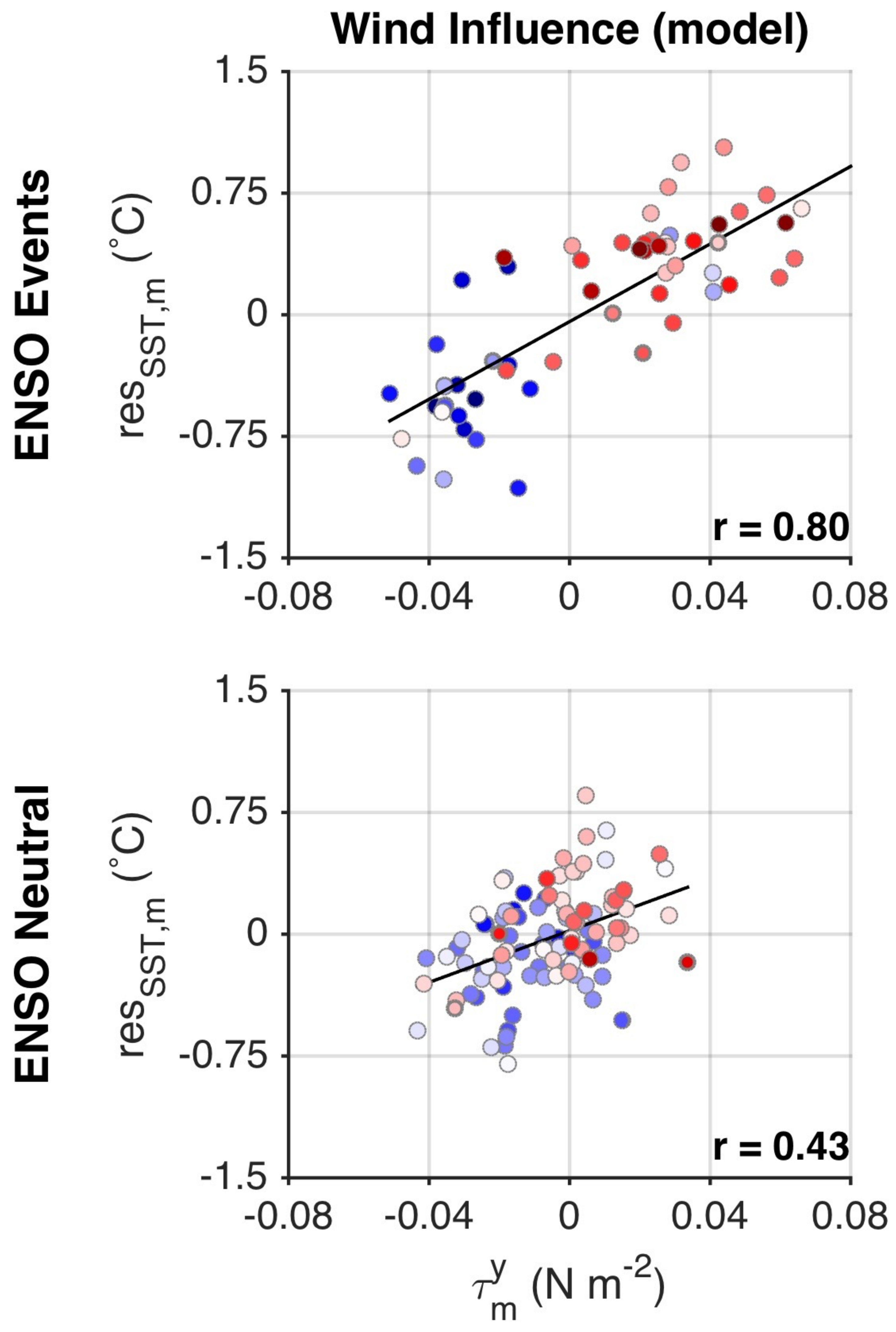



Jacox et al., Climate Dynamics (2017)

# WIND STRESS




Jacox et al., Climate Dynamics (2017)

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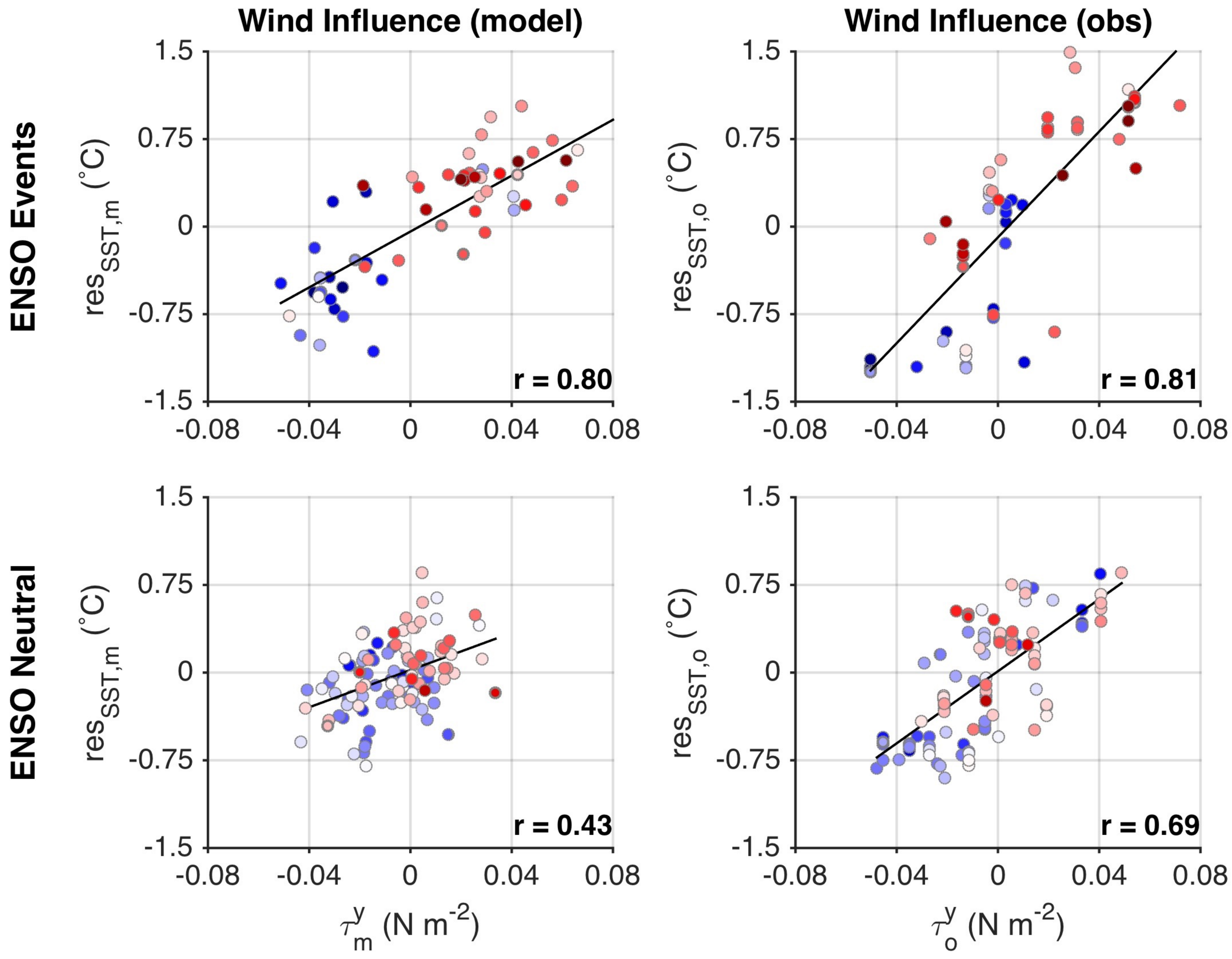


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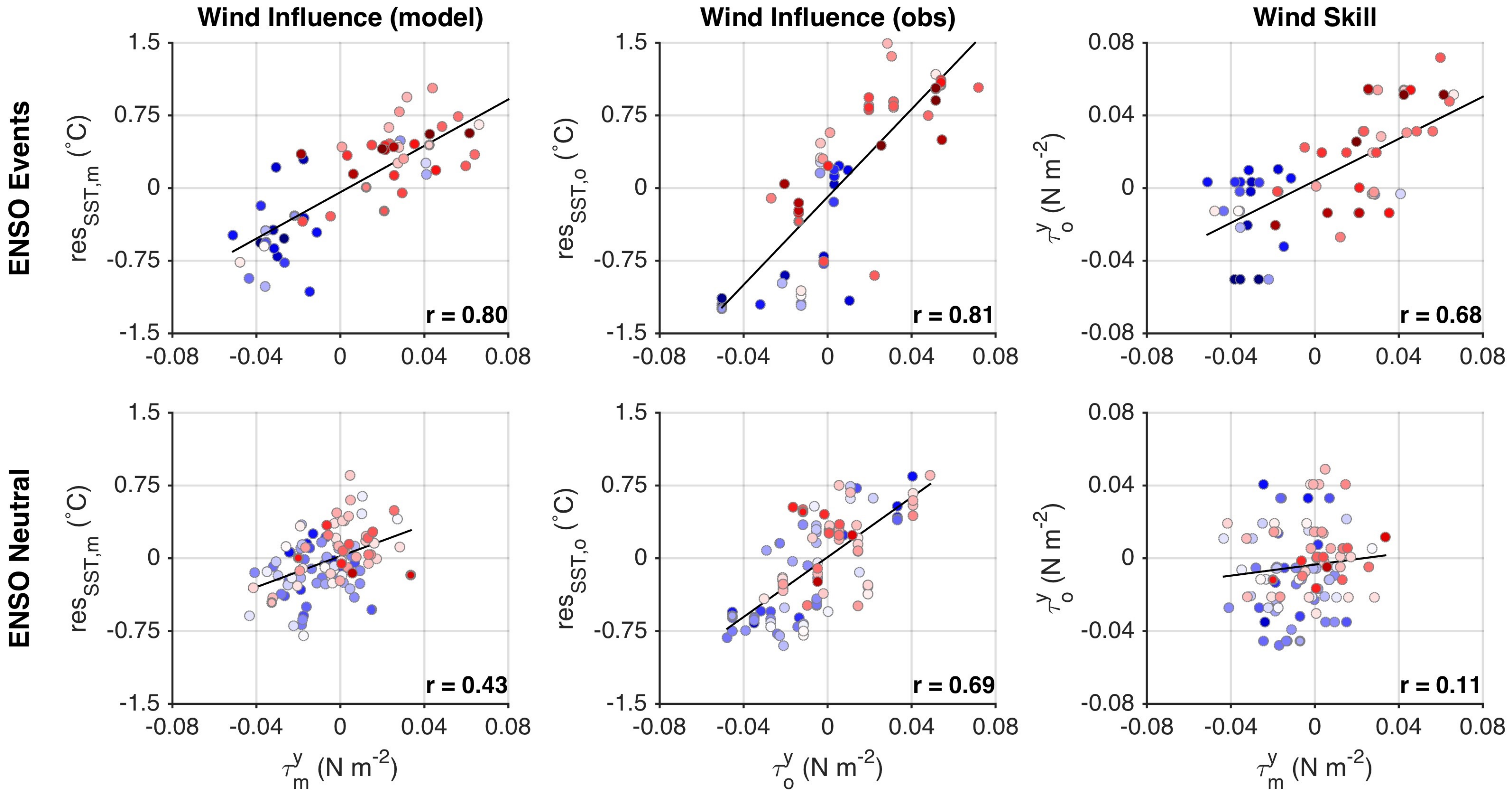
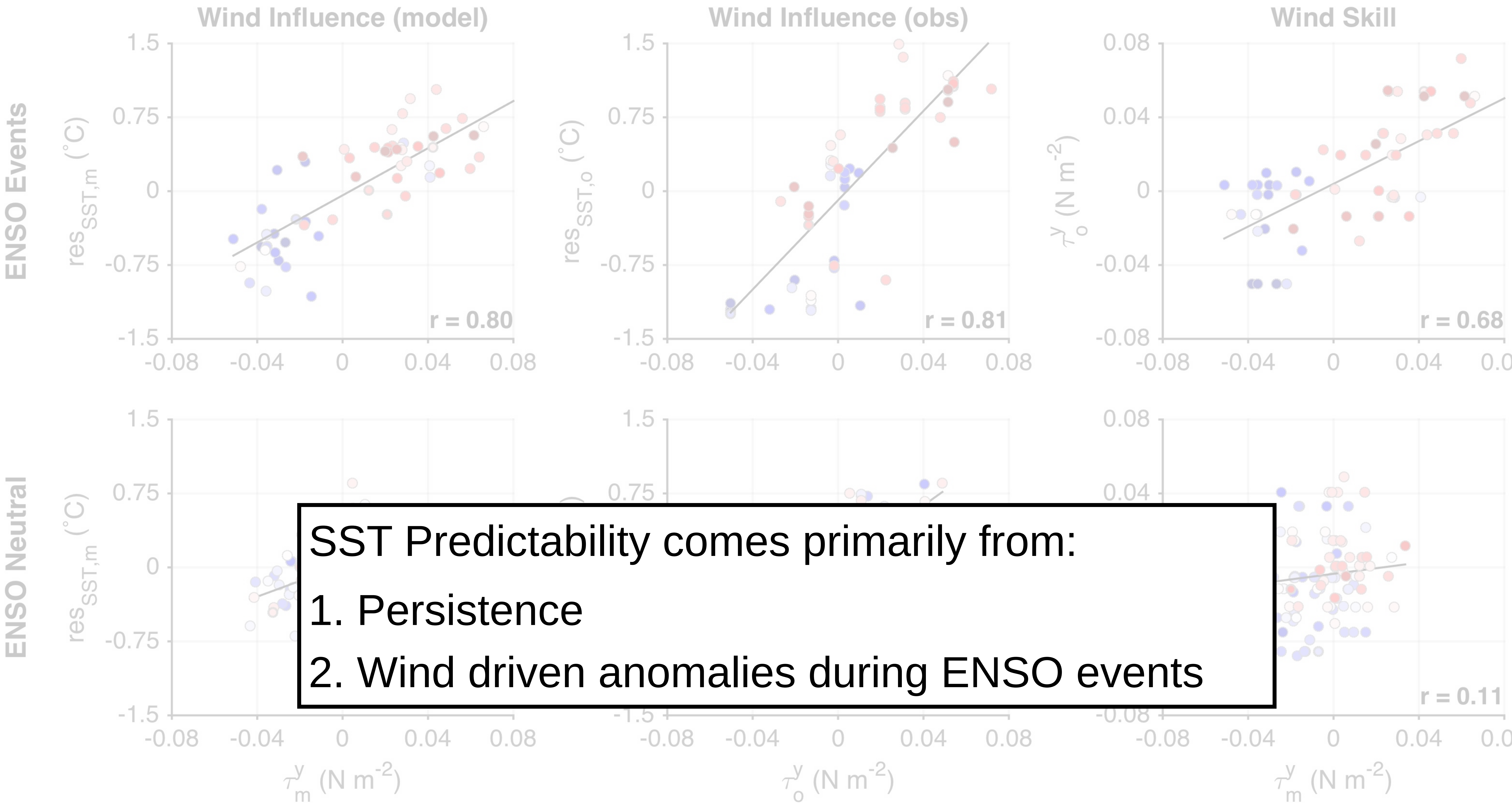
# Wind Stress




Jacox et al., Climate Dynamics (2017)

# Wind Stress

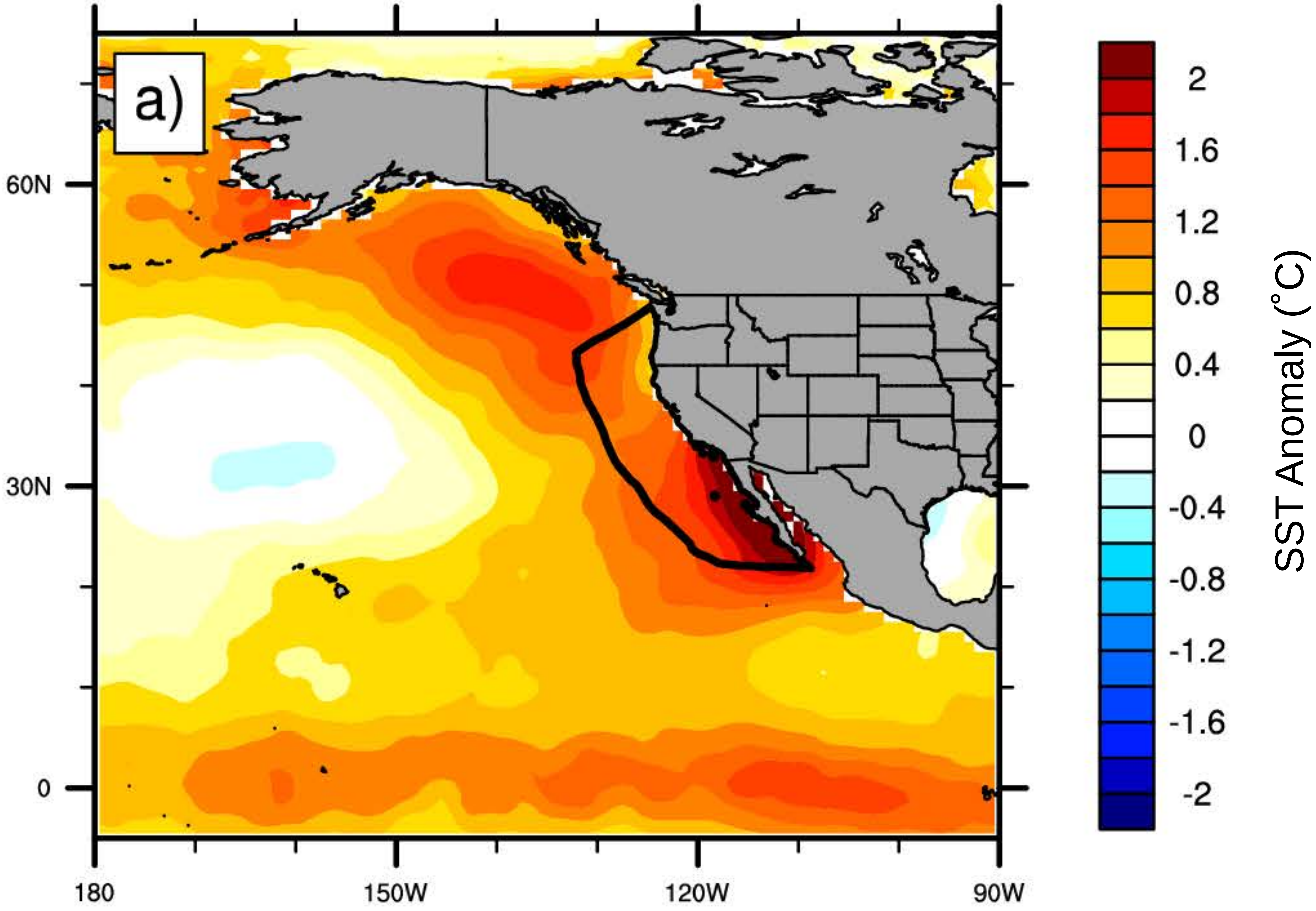


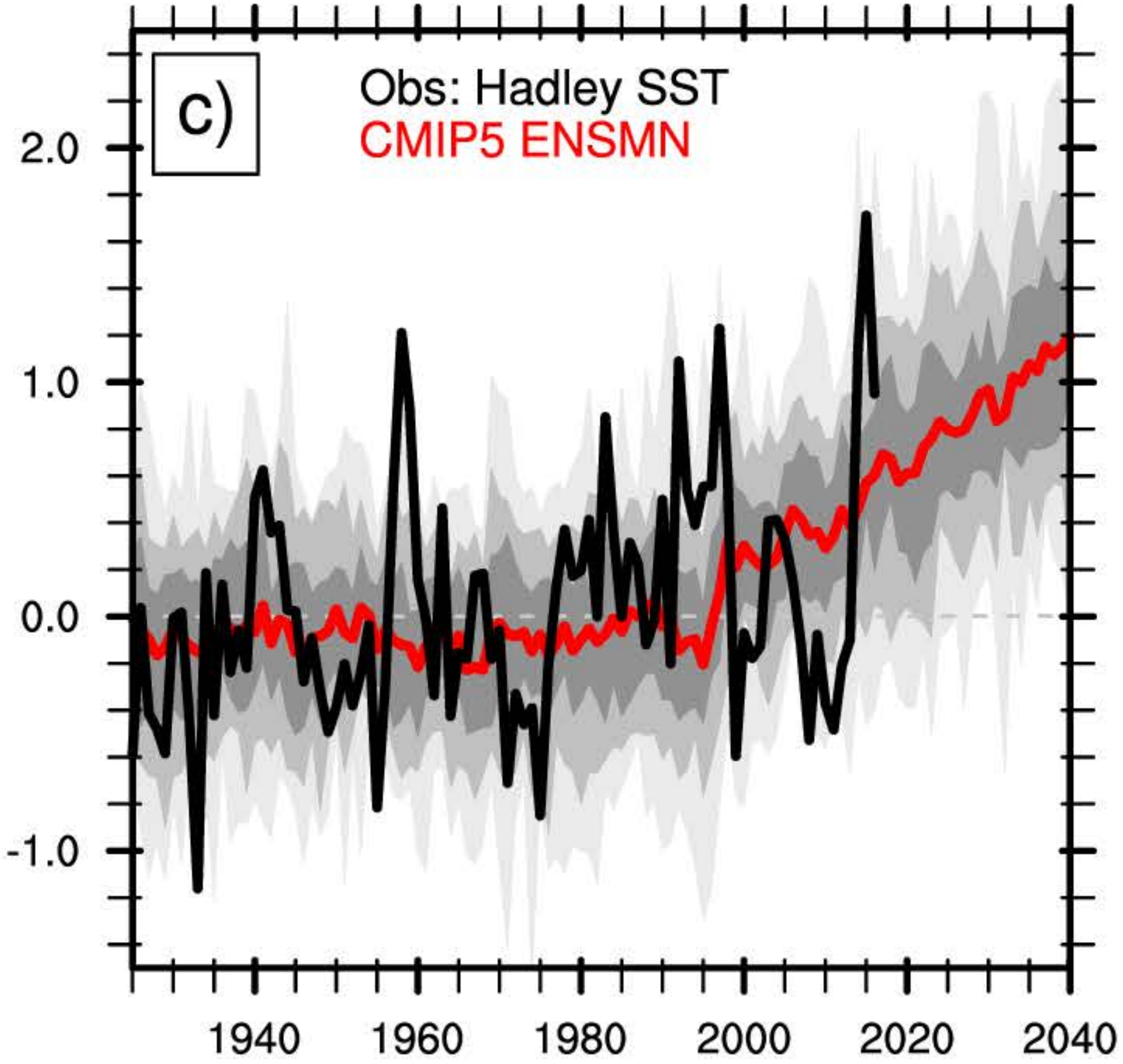

SST Predictability comes primarily from:

1. Persistence
2. Wind driven anomalies during ENSO events

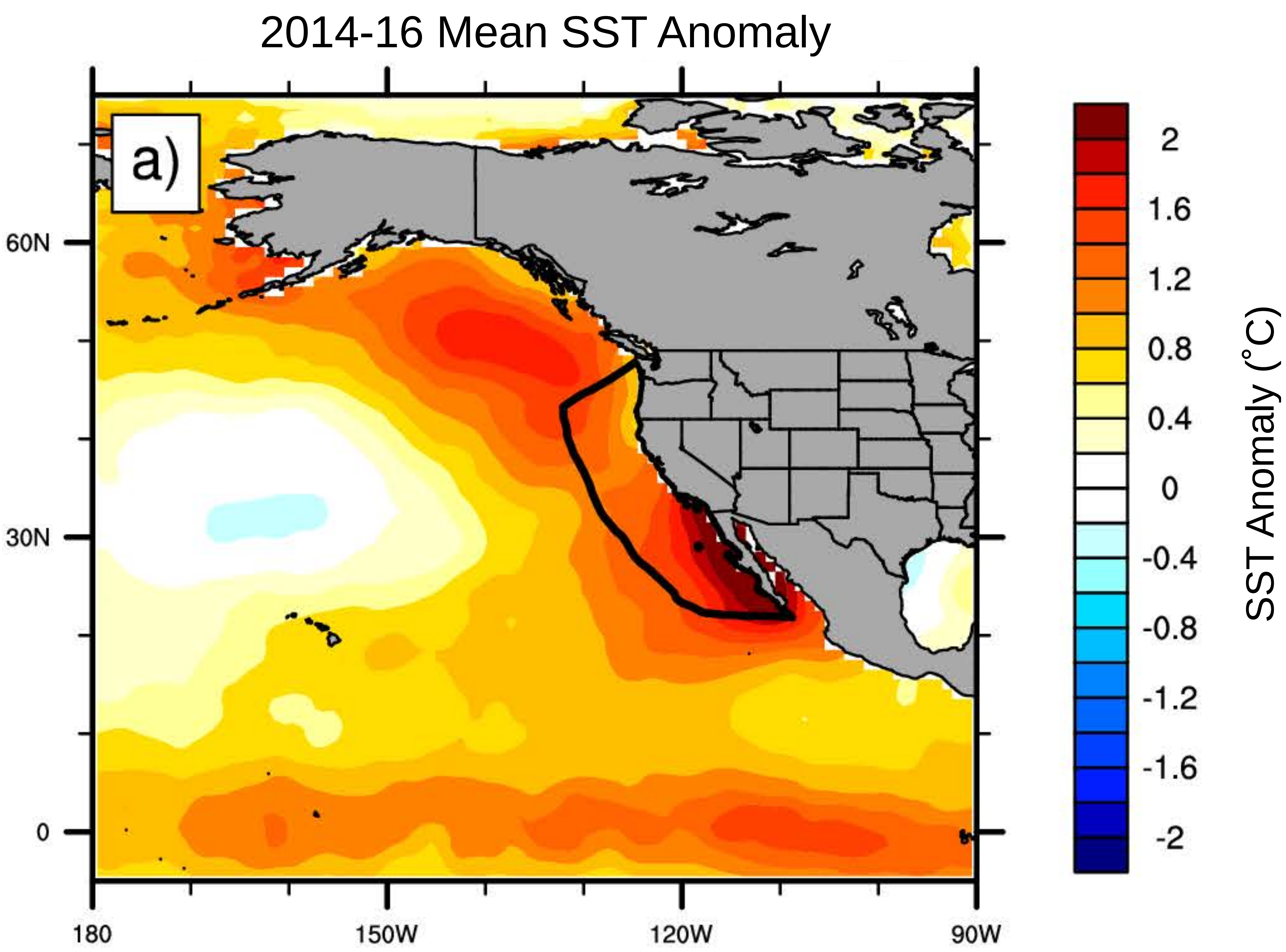
Jacox et al., Climate Dynamics (2017)

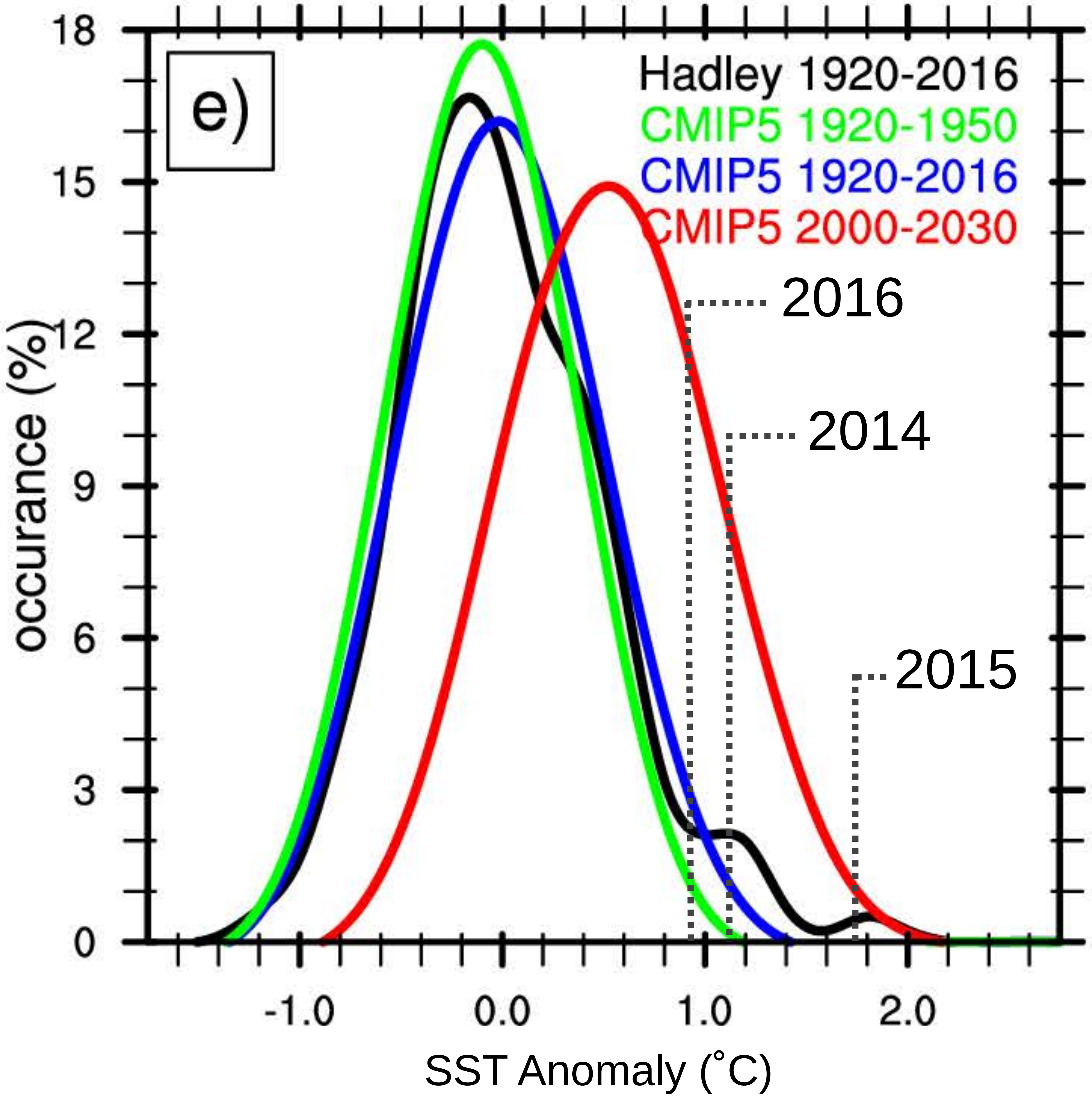
2014-16 Mean SST Anomaly



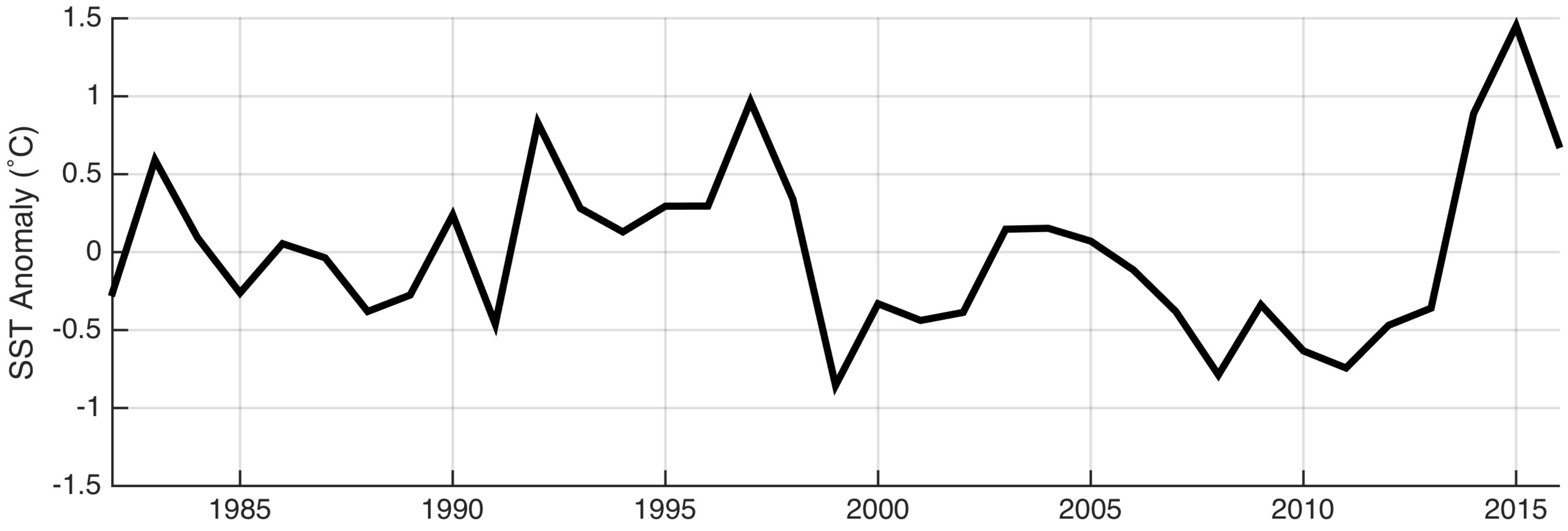




Jacox et al., BAMS (2017)




Jacox et al., BAMS (2017)

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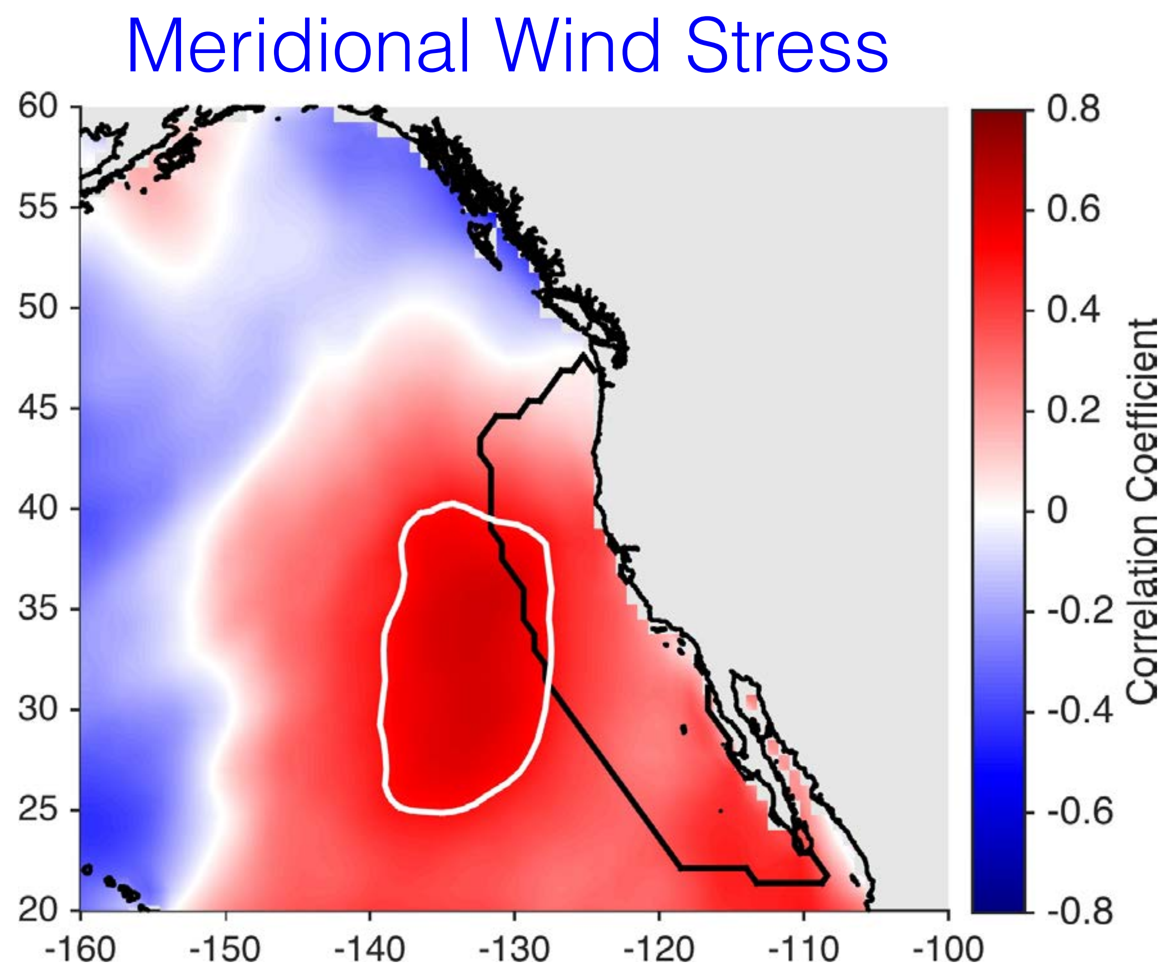


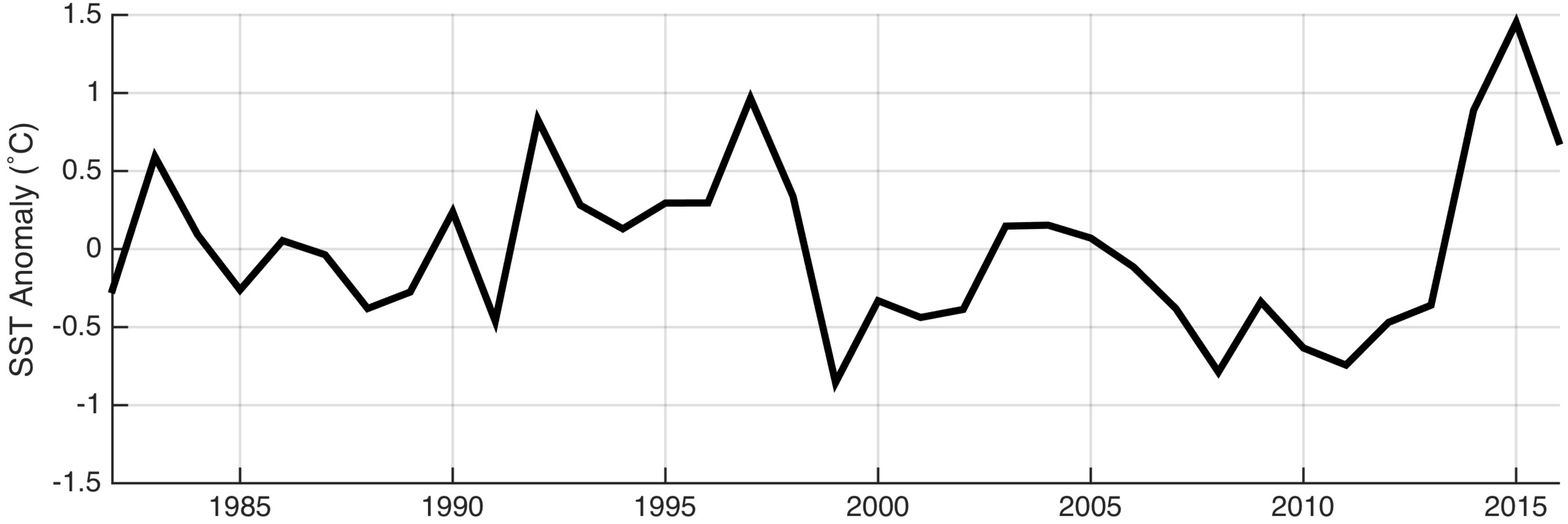


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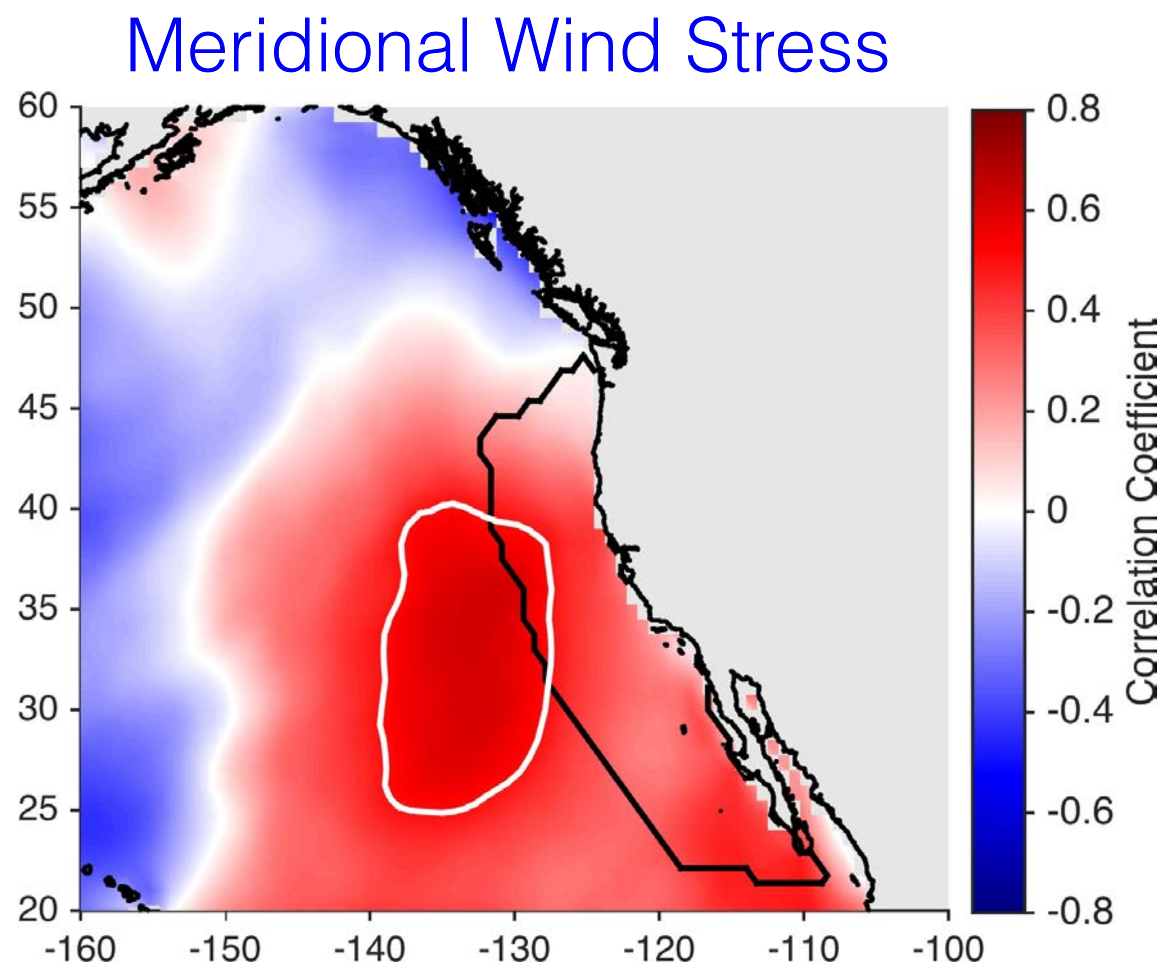
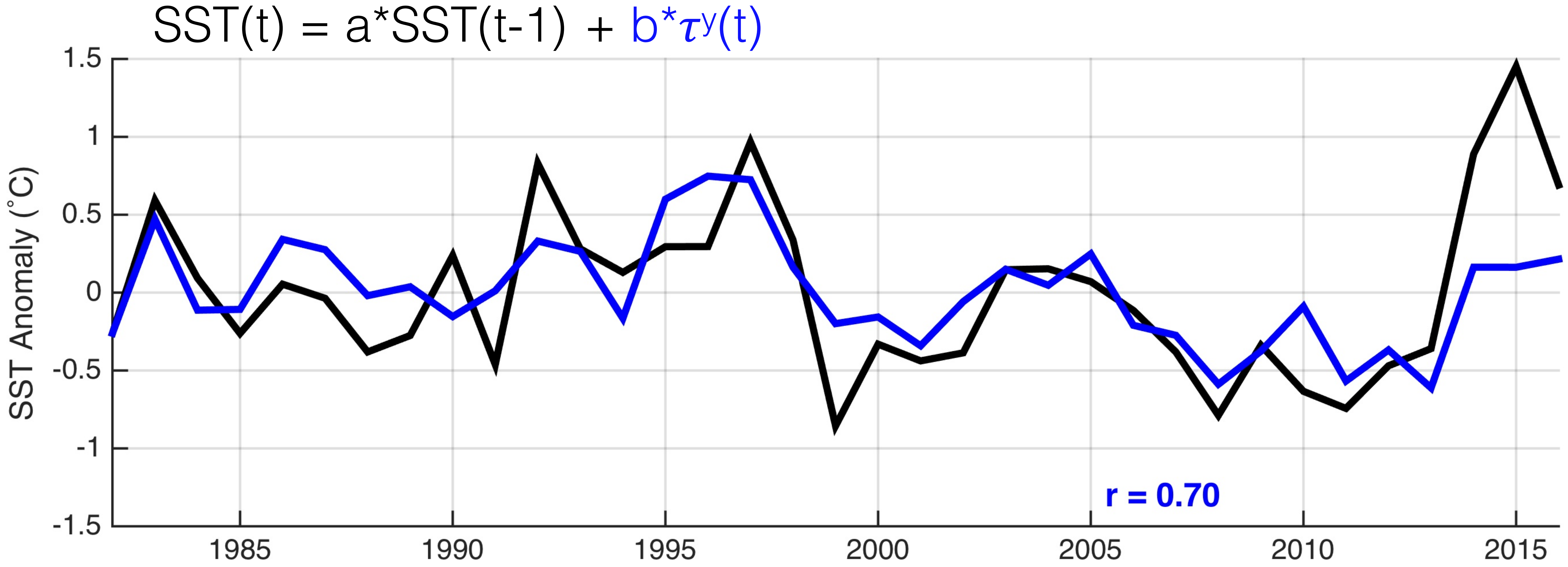
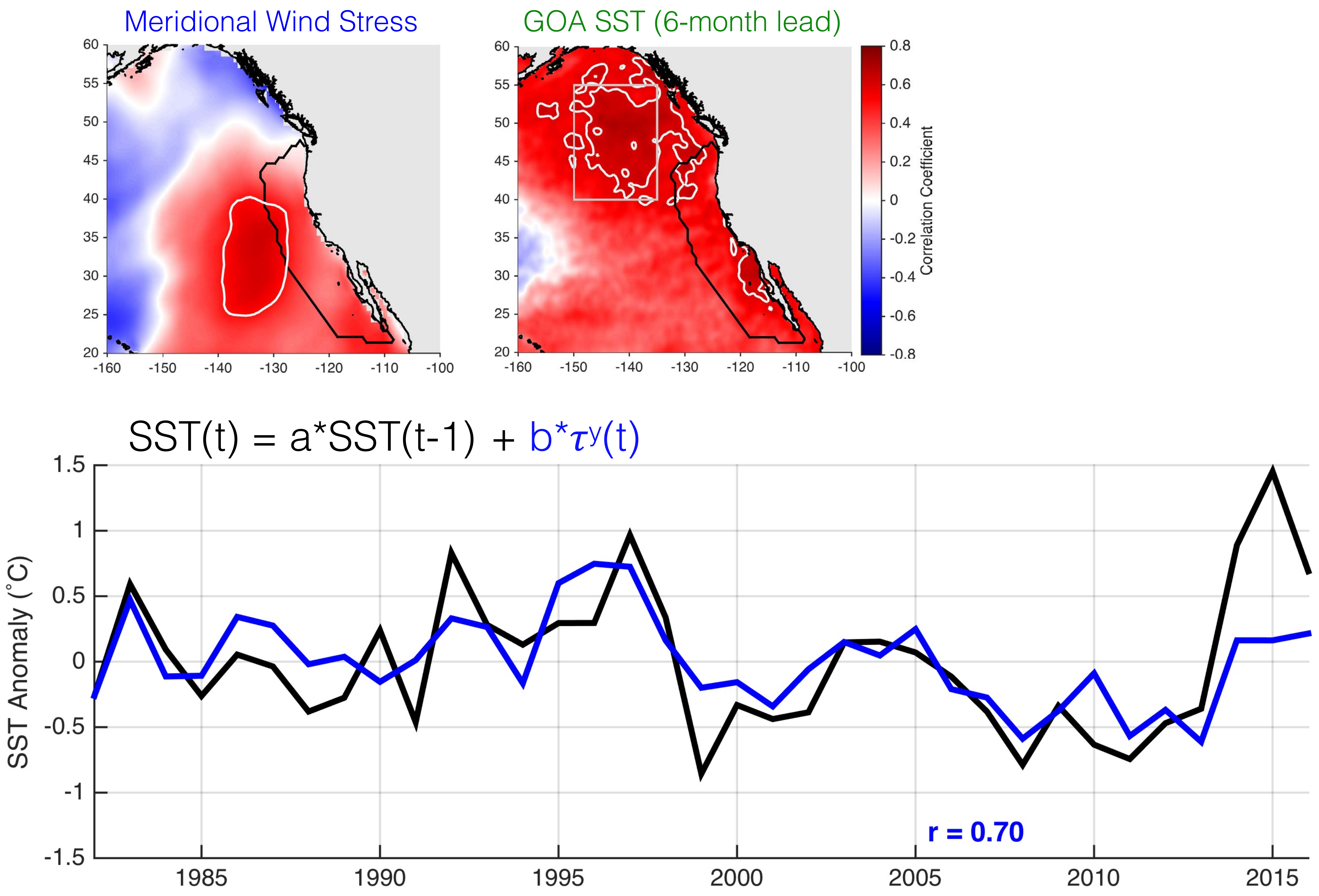



Jacox et al., BAMS (2017)

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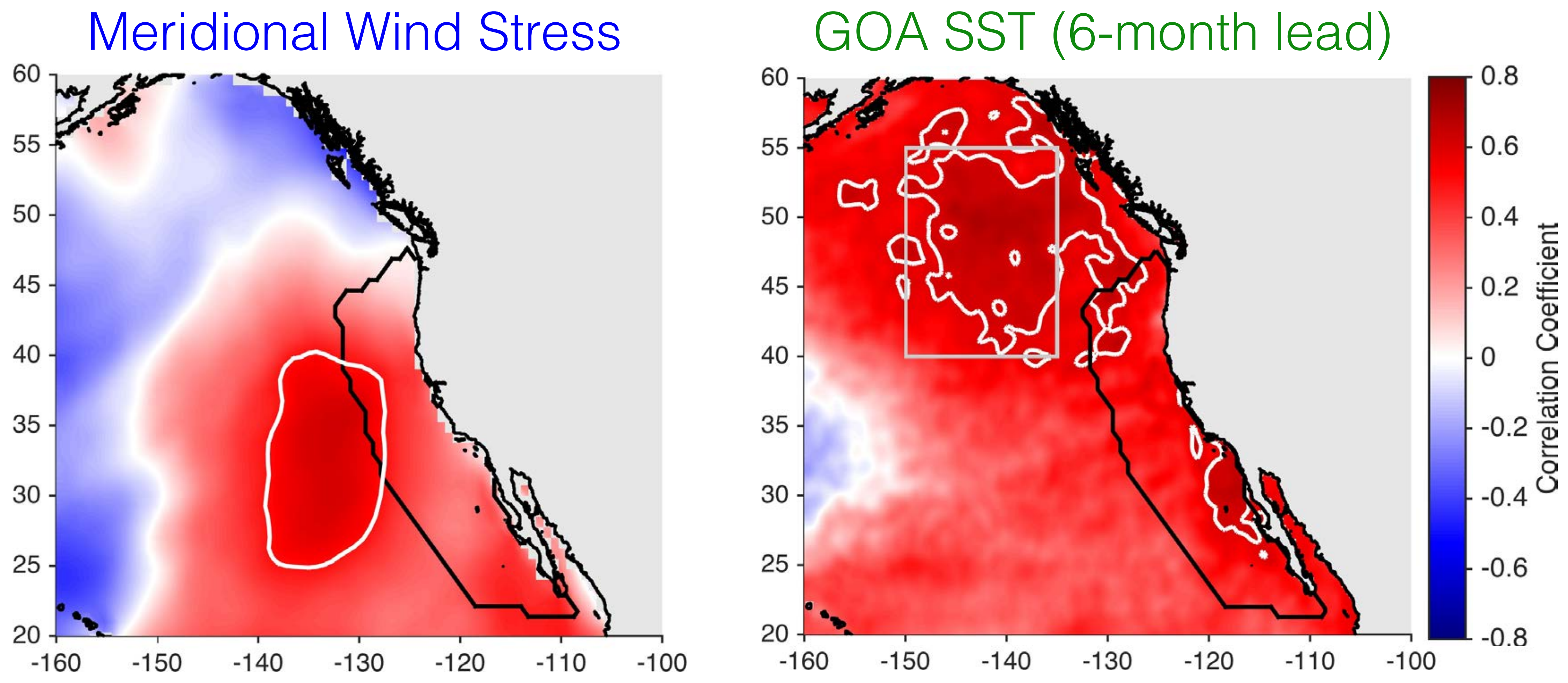
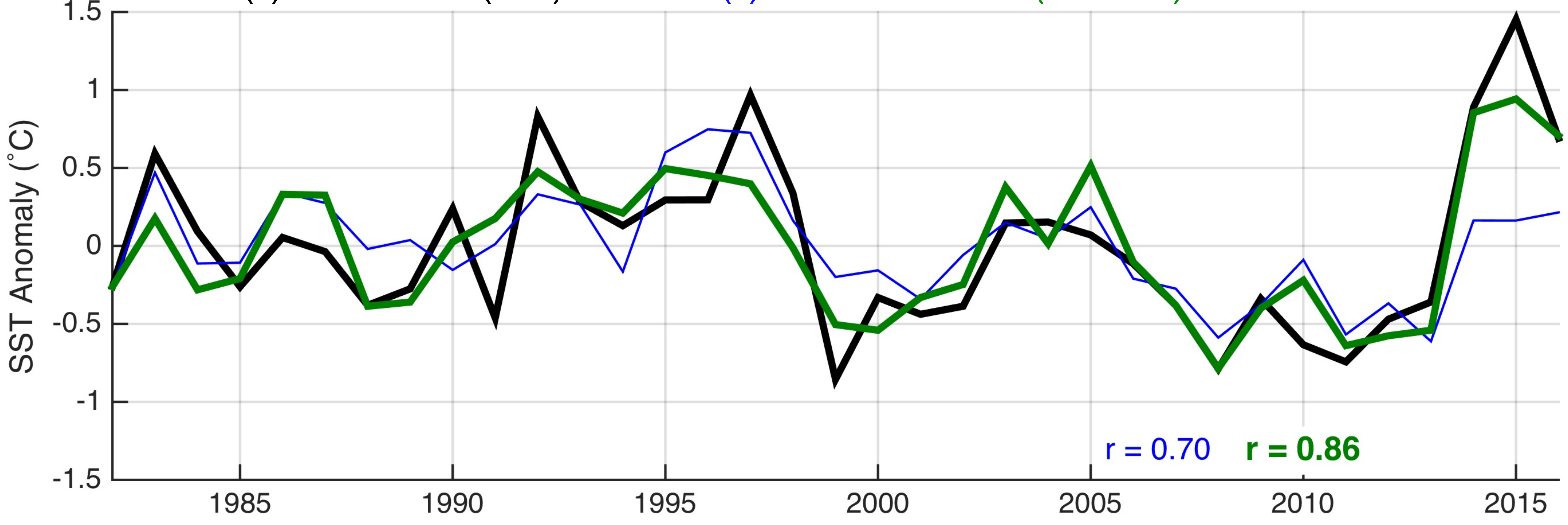



$$SST(t) = a{*}SST(t-1) + b{*}\tau^{y}(t) + c{*}SST_{GOA}(t - 0.5)$$

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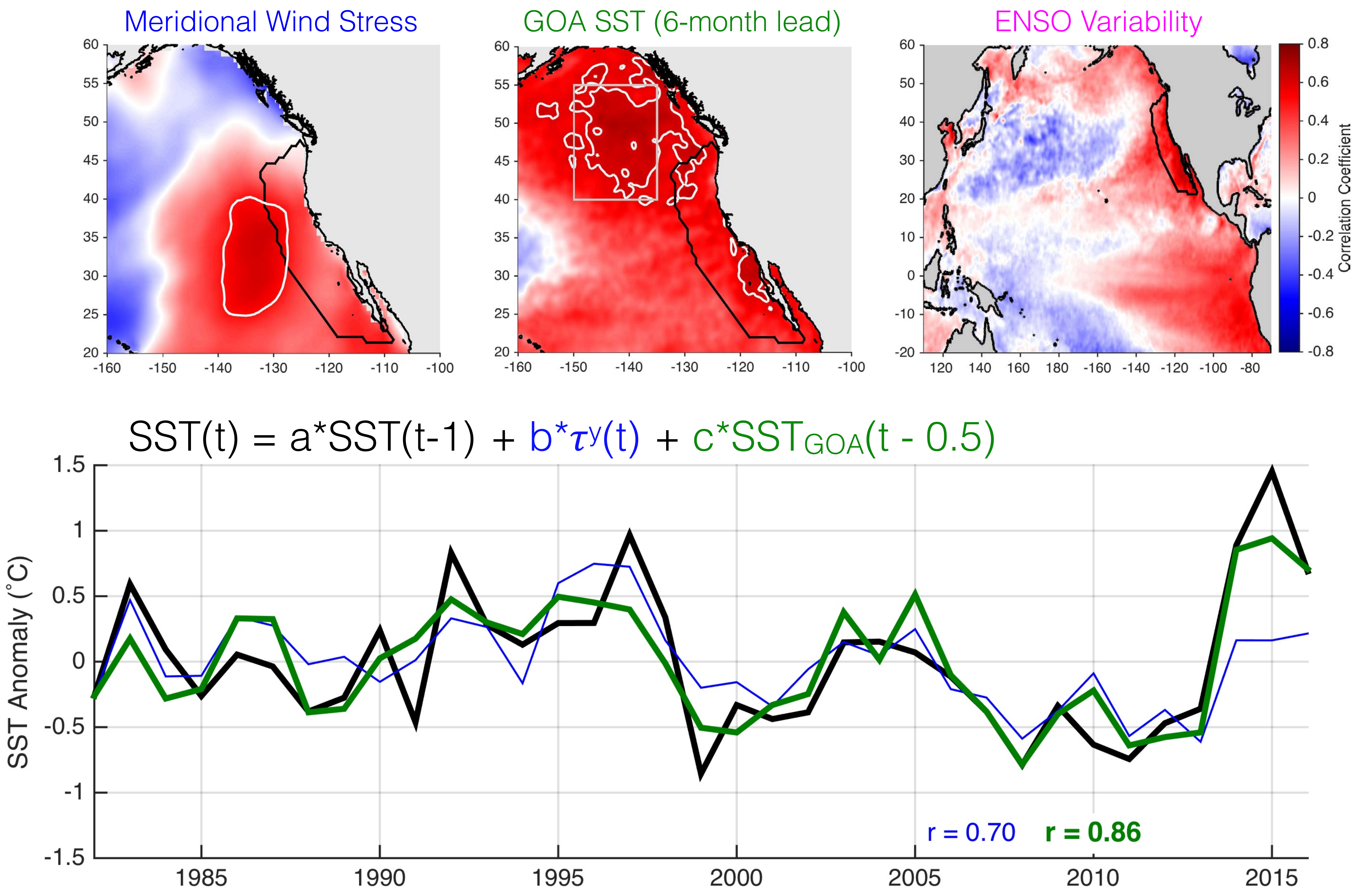


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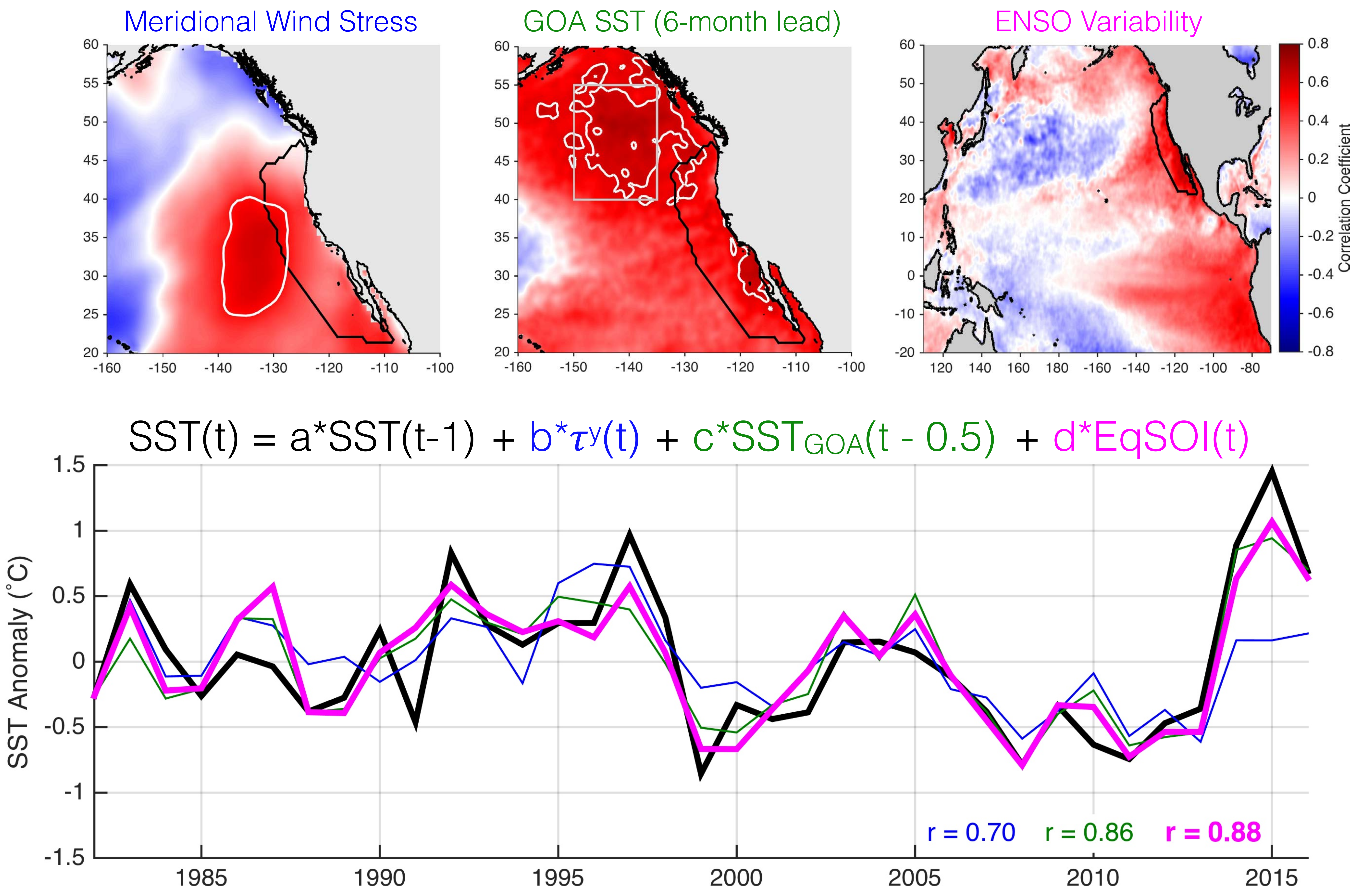


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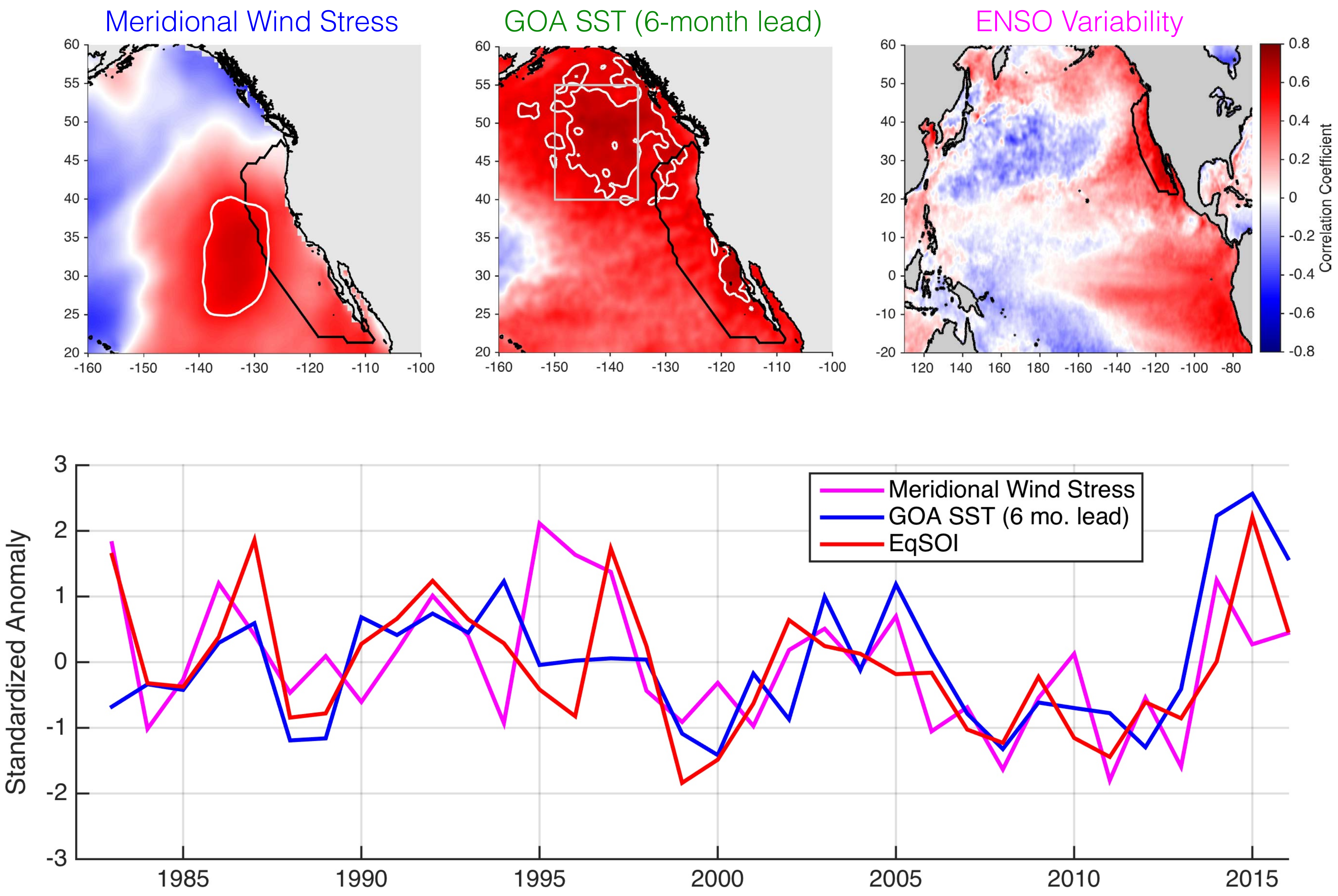


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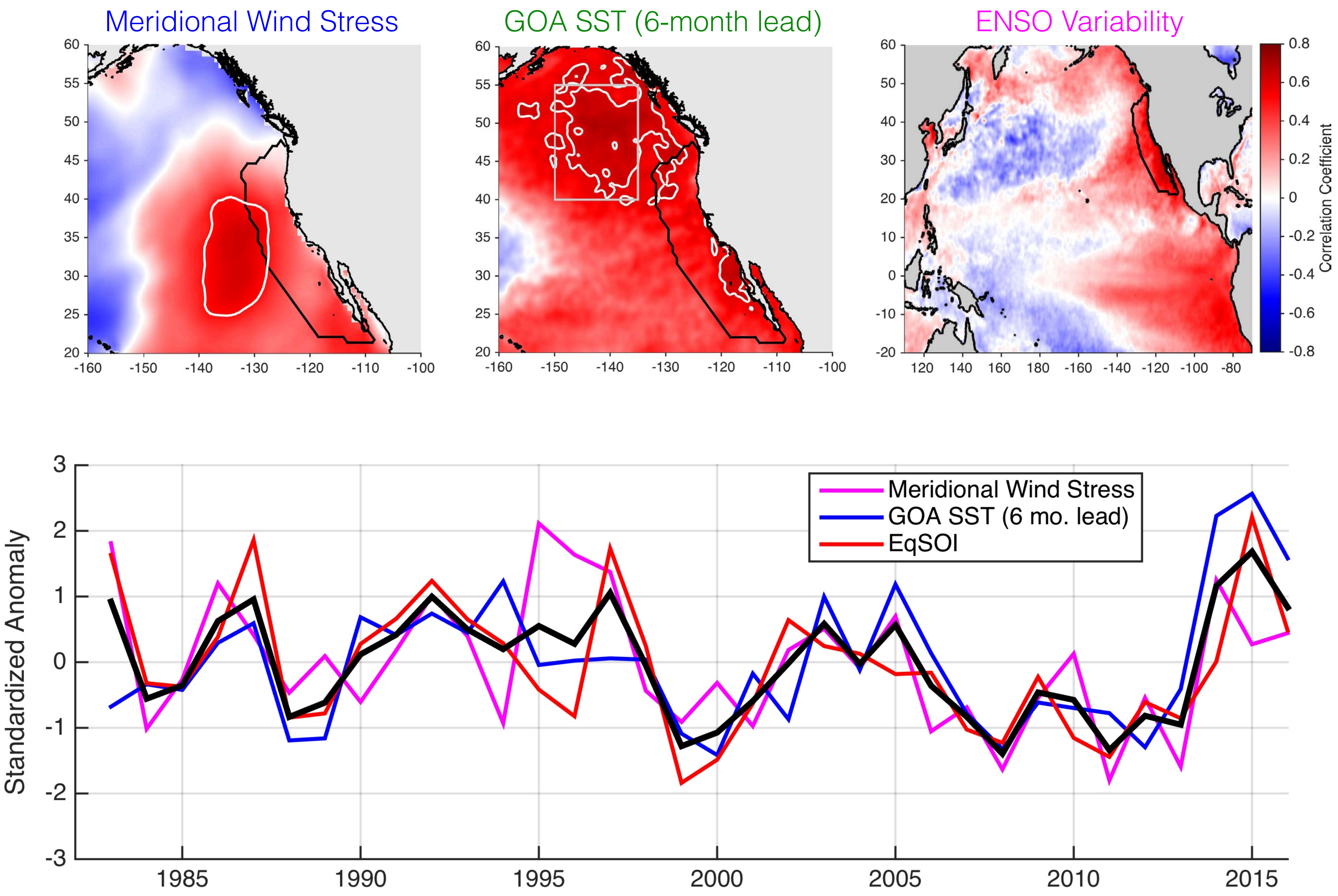


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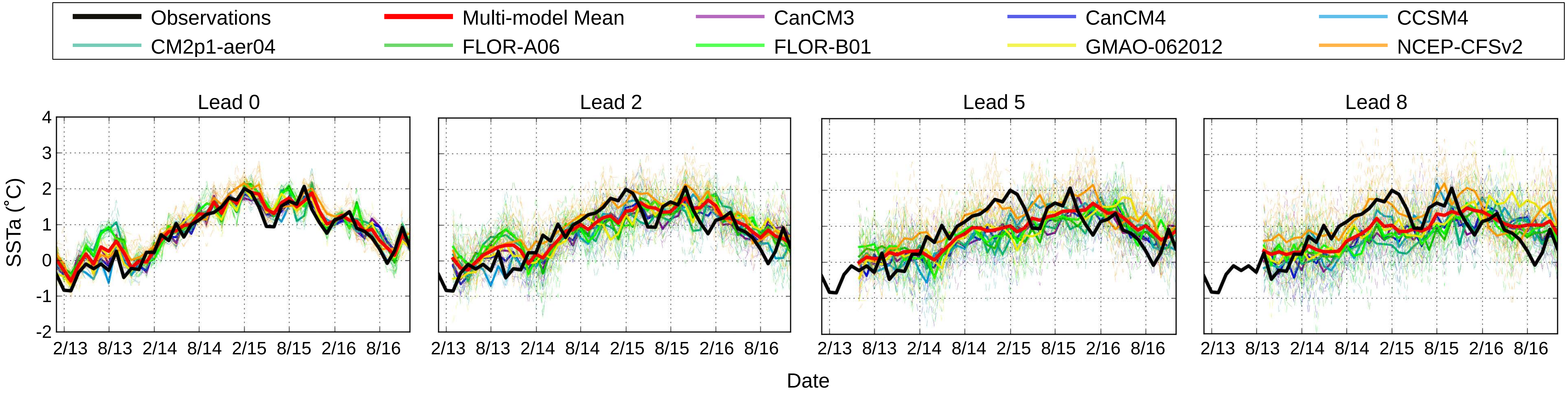
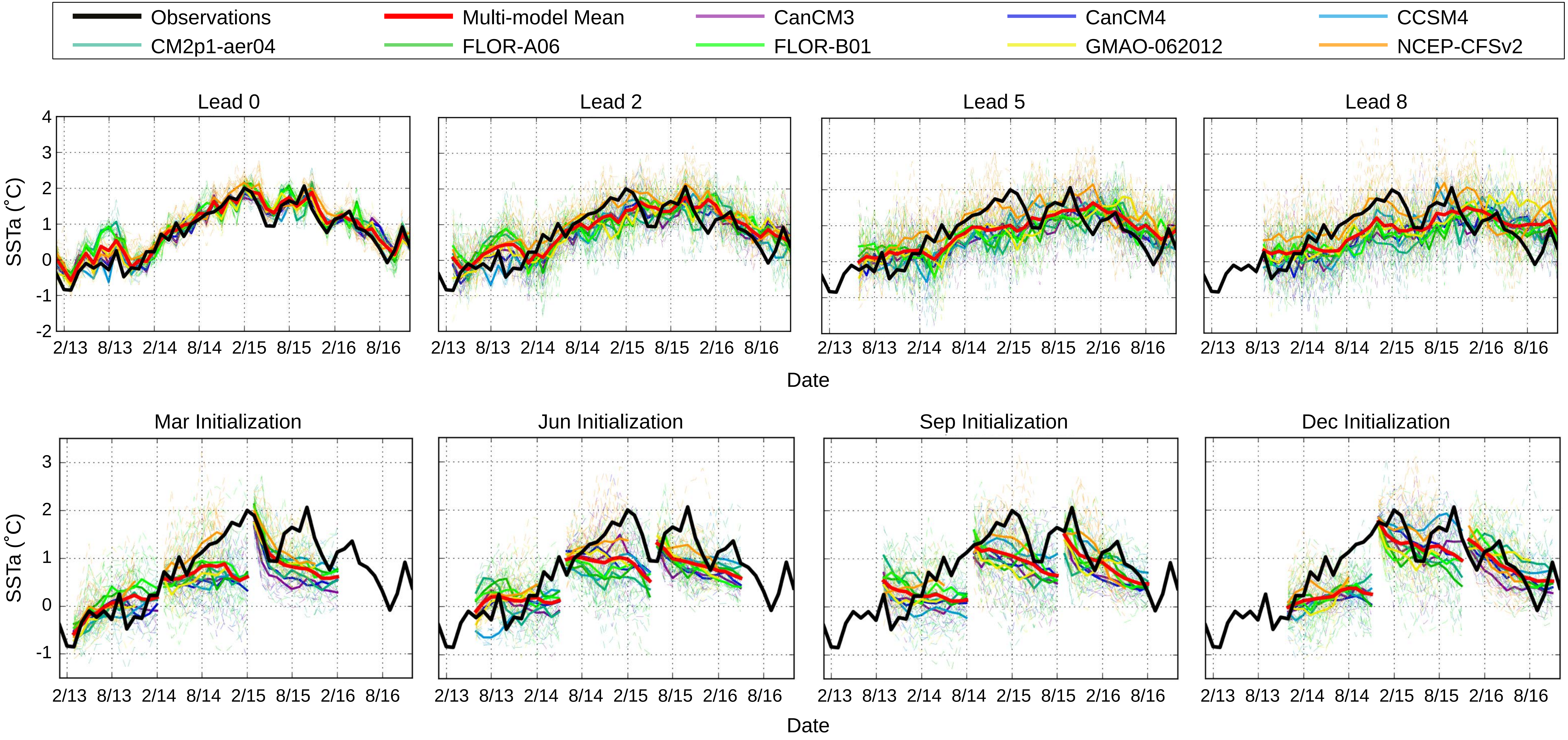


Observations
Multi-model Mean
CanCM3
CanCM4
CCSM4
CM2p1-aer04
FLOR-A06
FLOR-B01
GMAO-062012
NCEP-CFSv2
Lead 0
Lead 2
Lead 5
Lead 8
SSTa (°C)
4
3
2
1
0
-1
-2
2/13
8/13
2/14
8/14
2/15
8/15
2/16
8/16
Date



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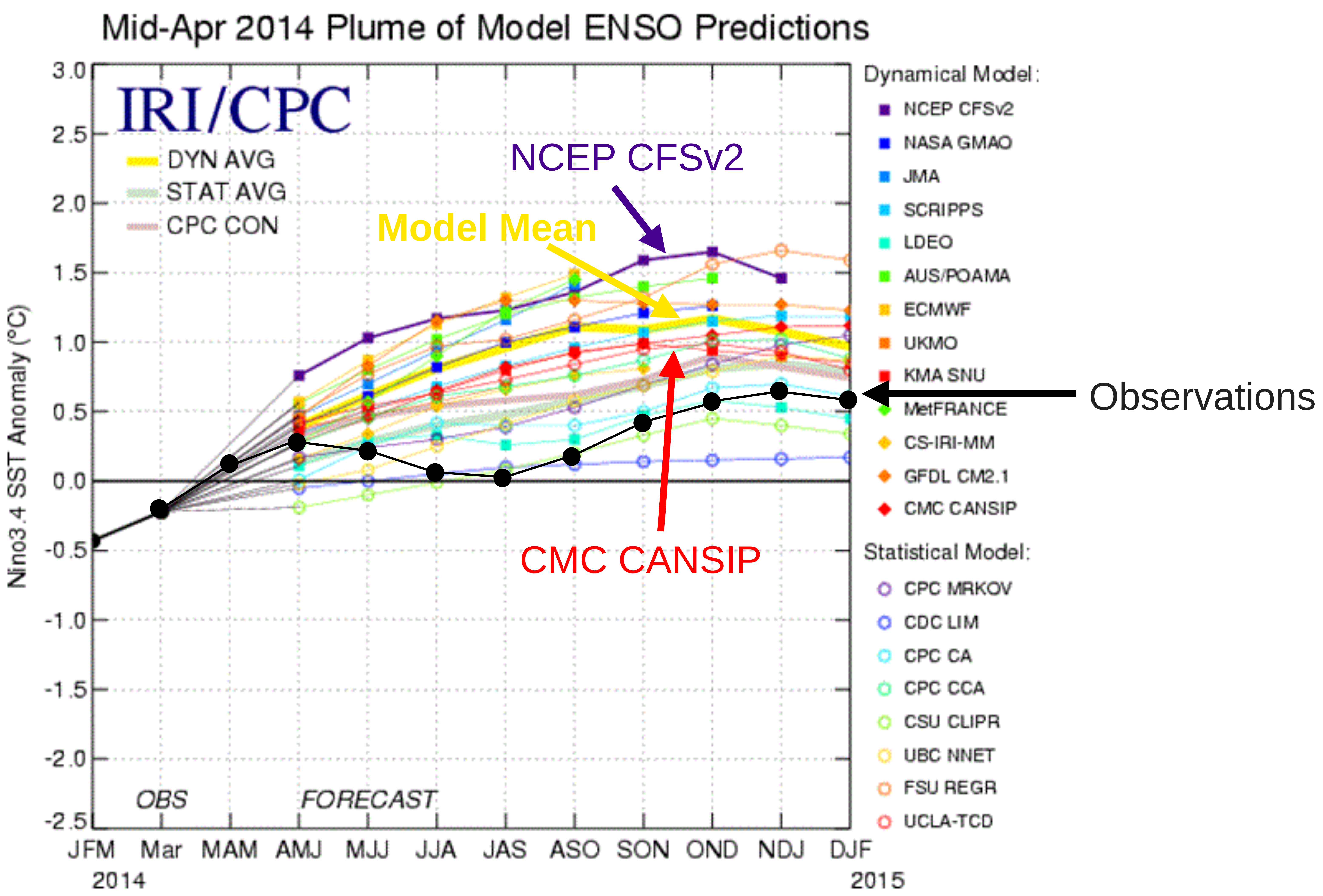
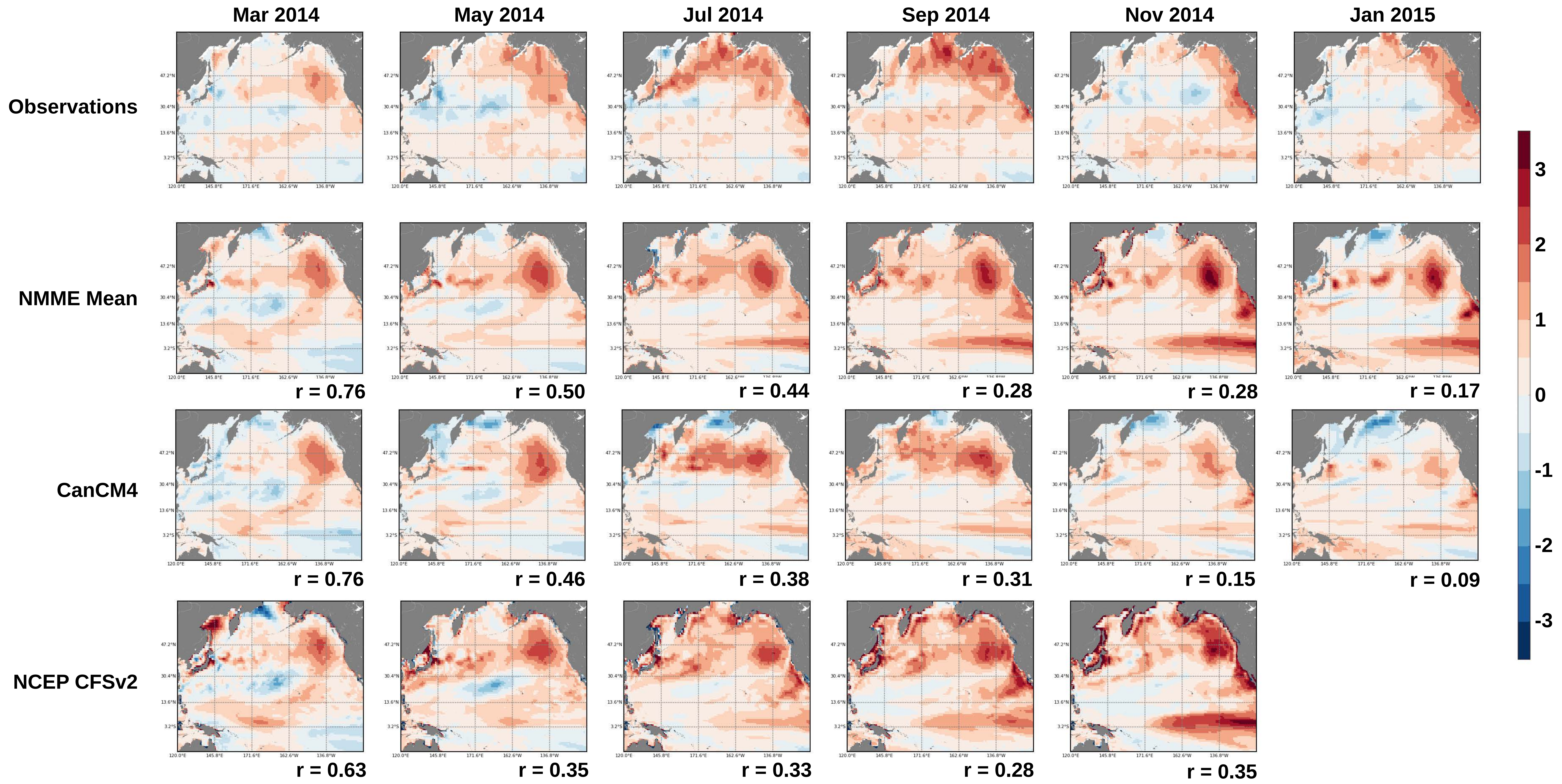
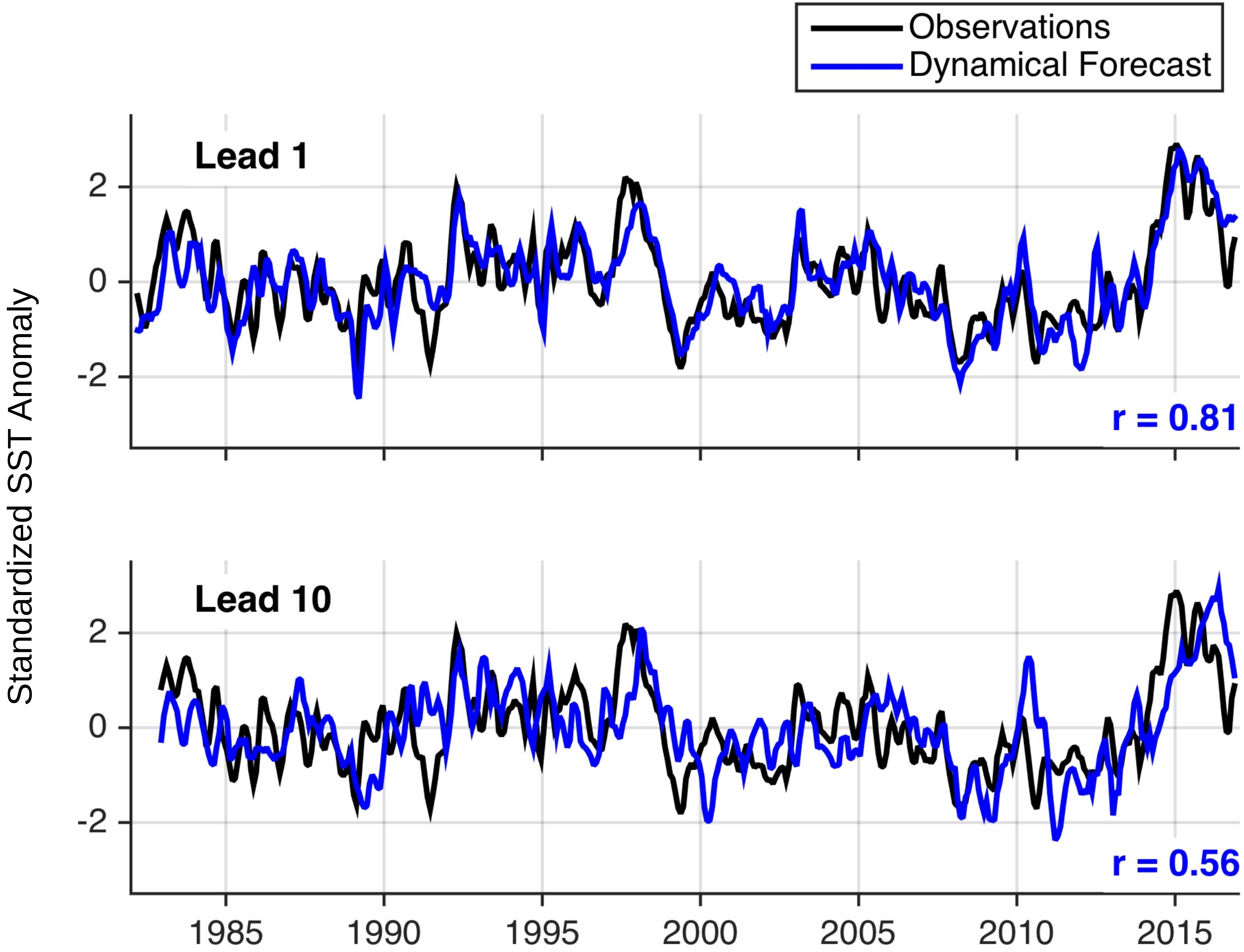
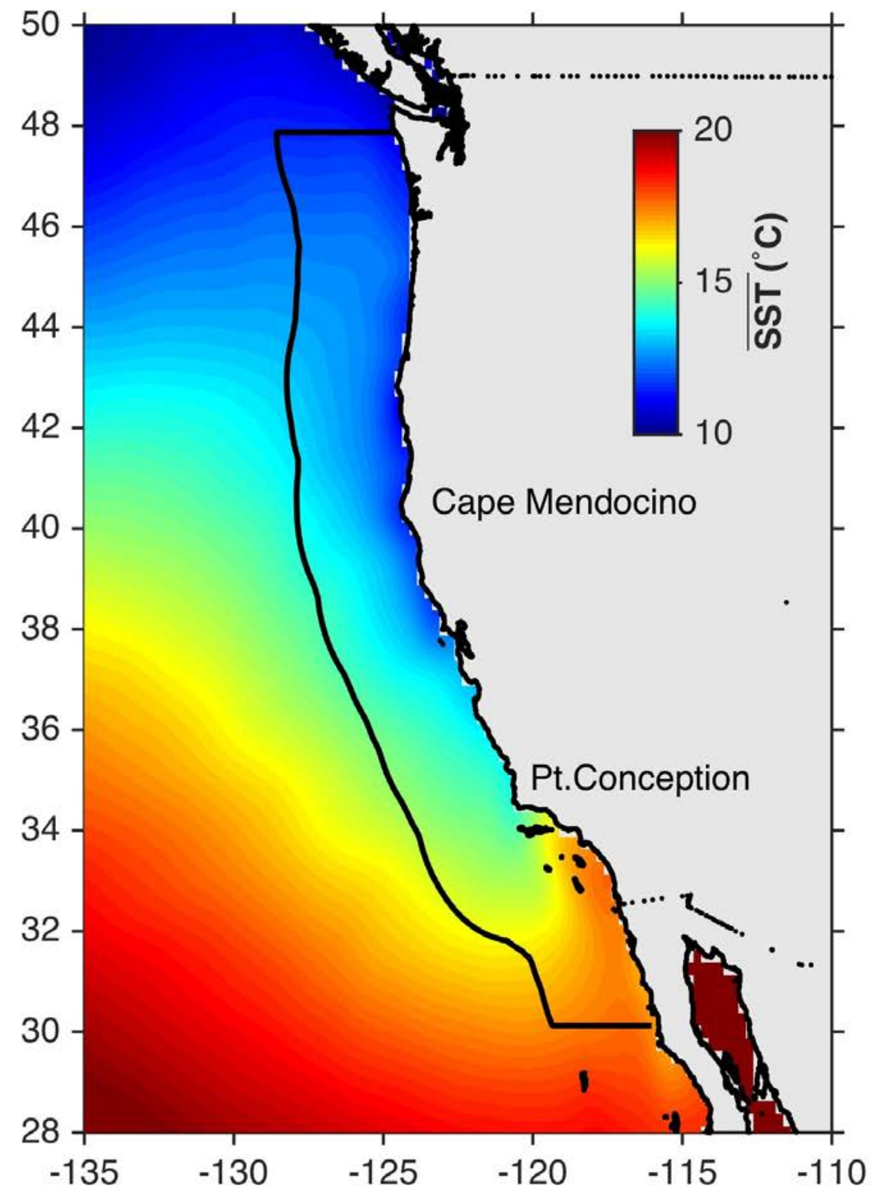
Multi-model Mean
CanCM3
CanCM4
CCSM4
CM2p1-aer04
FLOR-A06
FLOR-B01
GMAO-062012
NCEP-CFSv2
Lead 0
Lead 2
Lead 5
Lead 8
SSTa (°C)
2/13 8/13 2/14 8/14 2/15 8/15 2/16 8/16
Date
Mar Initialization
Jun Initialization
Sep Initialization
Dec Initialization

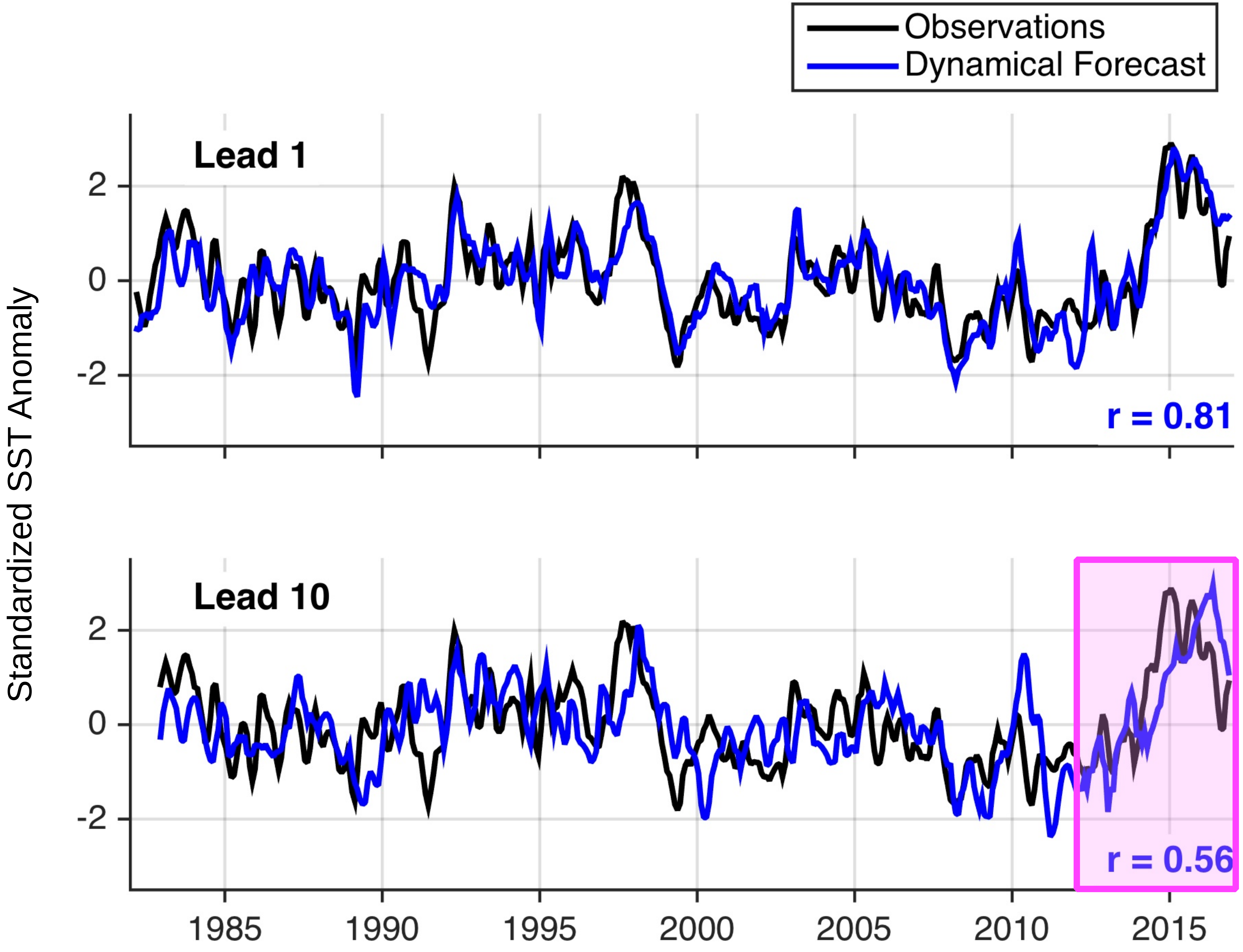

Mid-Apr 2014 Plume of Model ENSO Predictions
IRI/CPC
DYN AVG
STAT AVG
CPC CON
NCEP CFSv2
Model Mean
CMC CANSIP
Observations
Nino3.4 SST Anomaly (°C)
OBS
FORECAST
JFM Mar MAM AMJ MJJ JJA JAS ASO SON OND NDJ DJF
2014
2015
Dynamical Model:
NCEP CFSv2
NASA GMAO
JMA
SCRIPPS
LDEO
AUS/POAMA
ECMWF
UKMO
KMA SNU
MetFRANCE
CS-IRI-MM
GFDL CM2.1
CMC CANSIP
Statistical Model:
CPC MRKOV
CDC LIM
CPC CA
CPC CCA
CSU CLIPR
UBC NNET
FSU REGR
UCLA-TCD

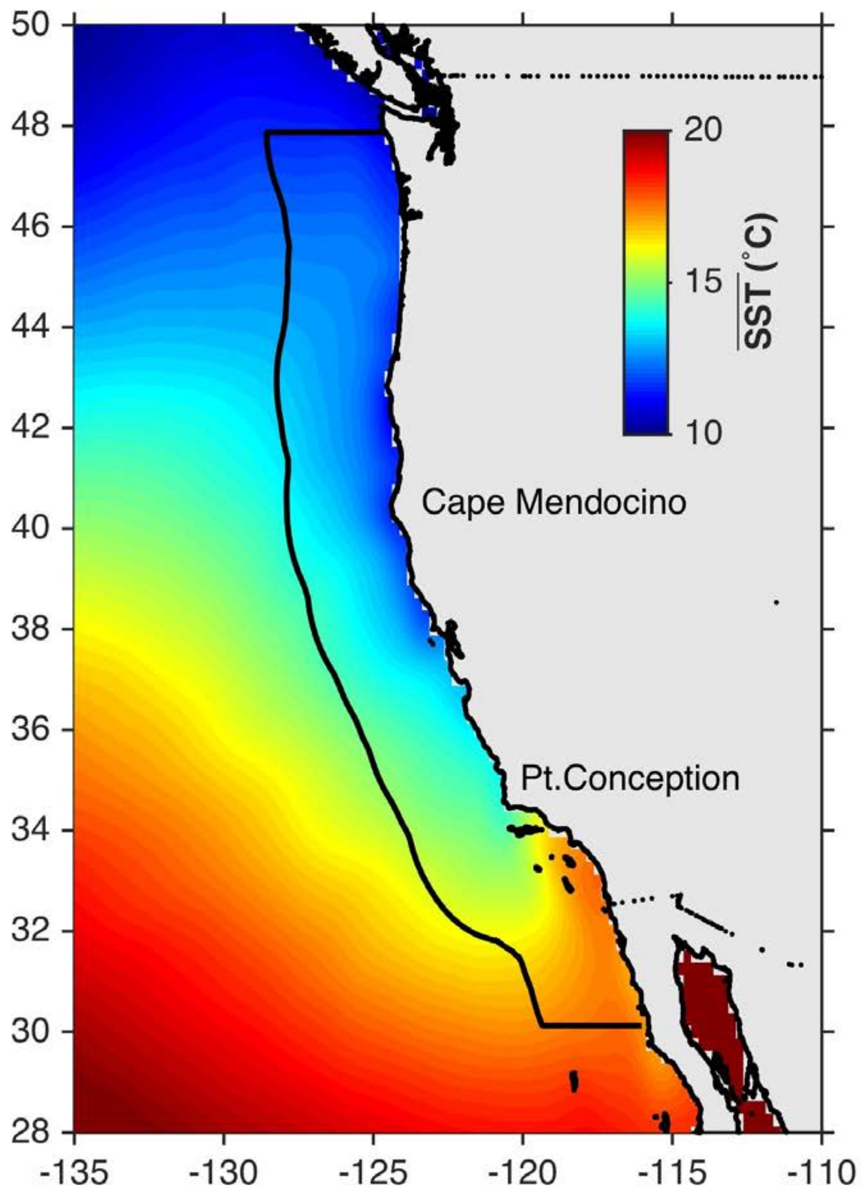


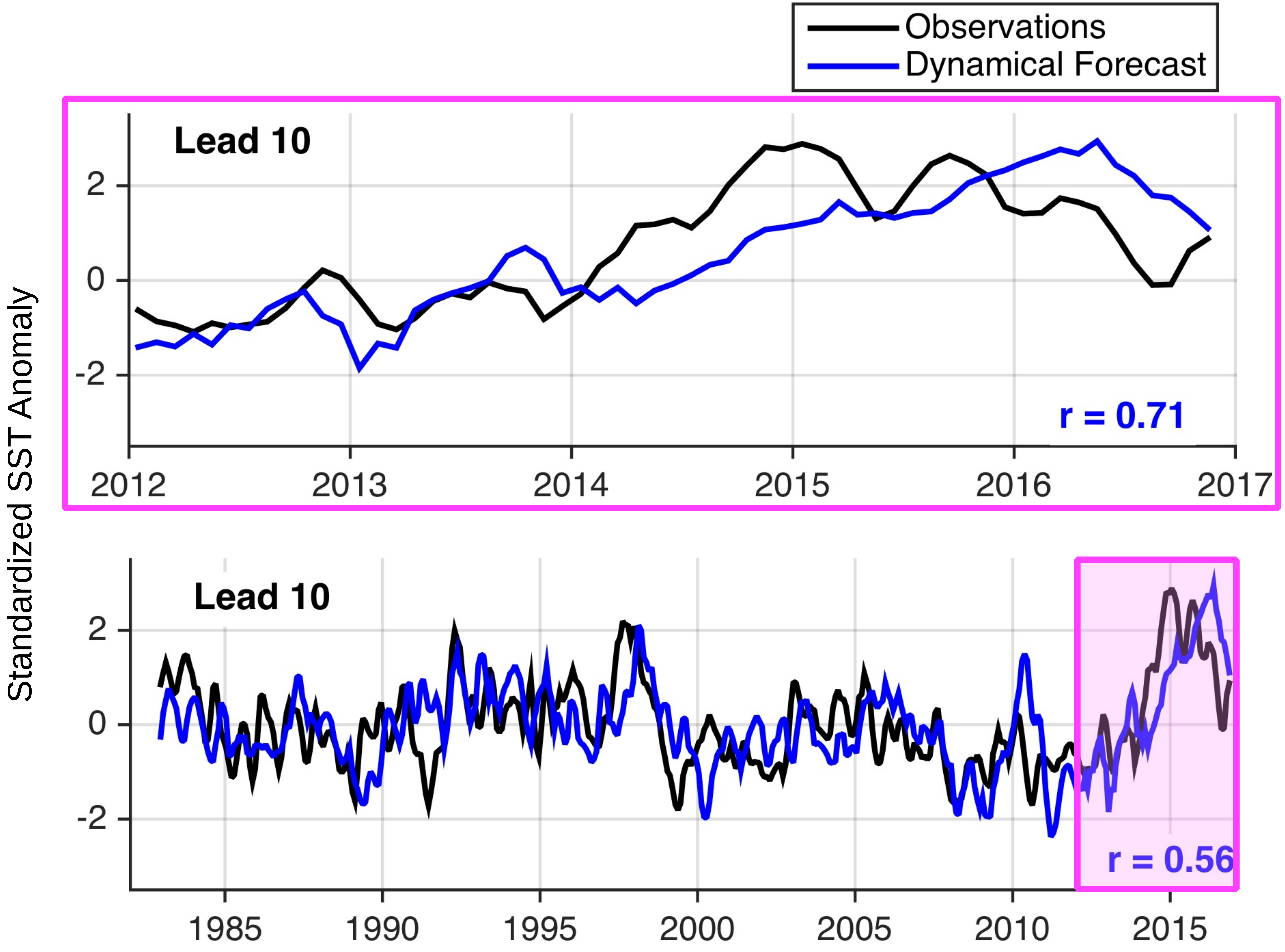
Mar 2014
May 2014
Jul 2014
Sep 2014
Nov 2014
Jan 2015
Observations
NMME Mean
CanCM4
NCEP CFSv2
r = 0.76
r = 0.50
r = 0.44
r = 0.28
r = 0.28
r = 0.17
r = 0.76
r = 0.46
r = 0.38
r = 0.31
r = 0.15
r = 0.09
r = 0.63
r = 0.35
r = 0.33
r = 0.28
r = 0.35
3
2
1
0
-1
-2
-3

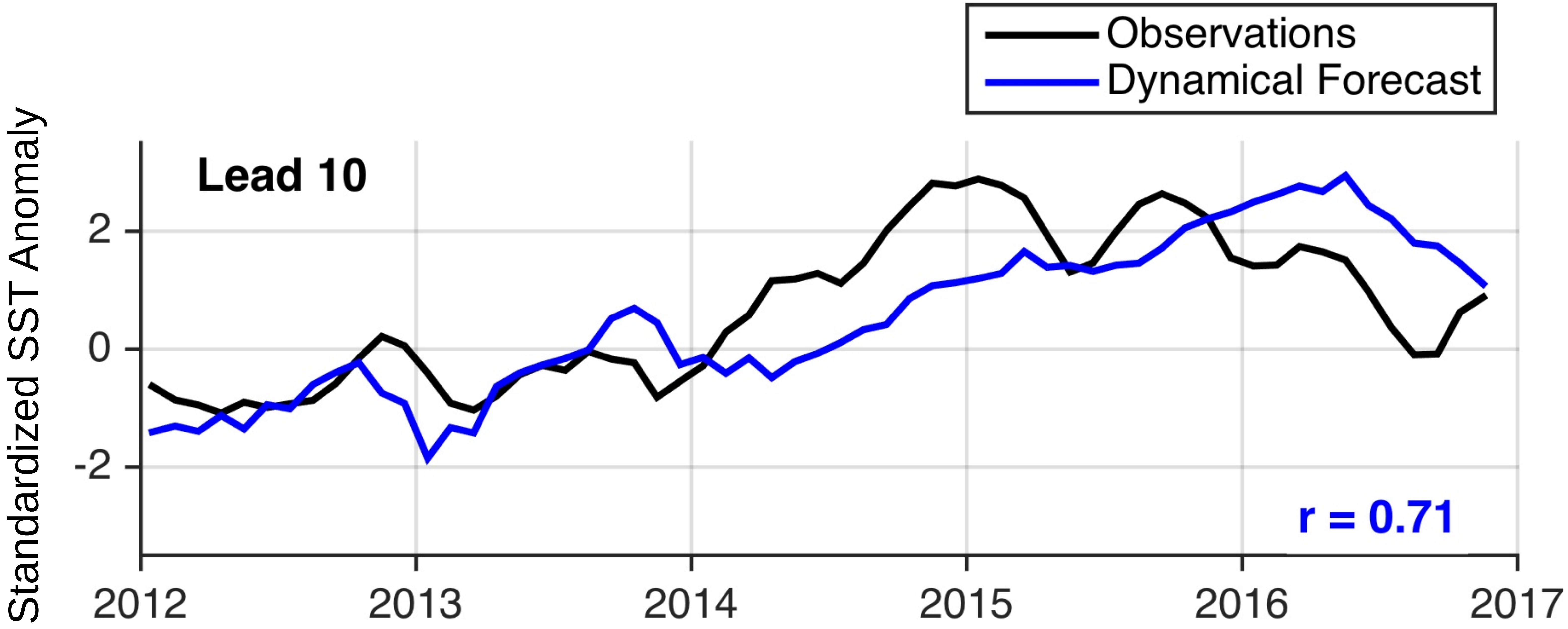

Observations
Dynamical Forecast
Lead 1
r = 0.81
Lead 10
r = 0.56
Standardized SST Anomaly
2
0
-2
1985
1990
1995
2000
2005
2010
2015


Cape Mendocino
Pt.Conception
SST (°C)
20
15
10
50
48
46
44
42
40
38
36
34
32
30
28
-135
-130
-125
-120
-115
-110

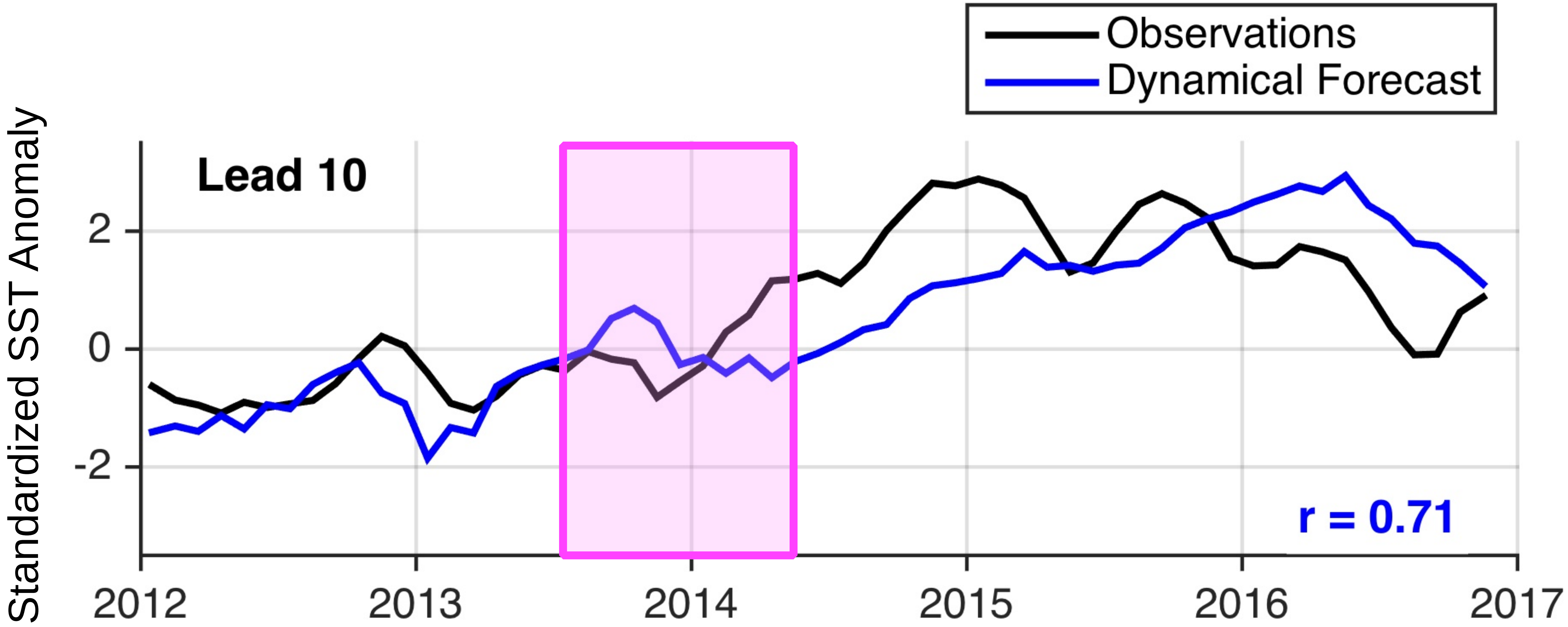

Observations
Dynamical Forecast
Lead 1
r = 0.81
Lead 10
r = 0.56
Standardized SST Anomaly
2
0
-2
1985
1990
1995
2000
2005
2010
2015


Cape Mendocino
Pt.Conception
SST (°C)
20
15
10
50
48
46
44
42
40
38
36
34
32
30
28
-135
-130
-125
-120
-115
-110

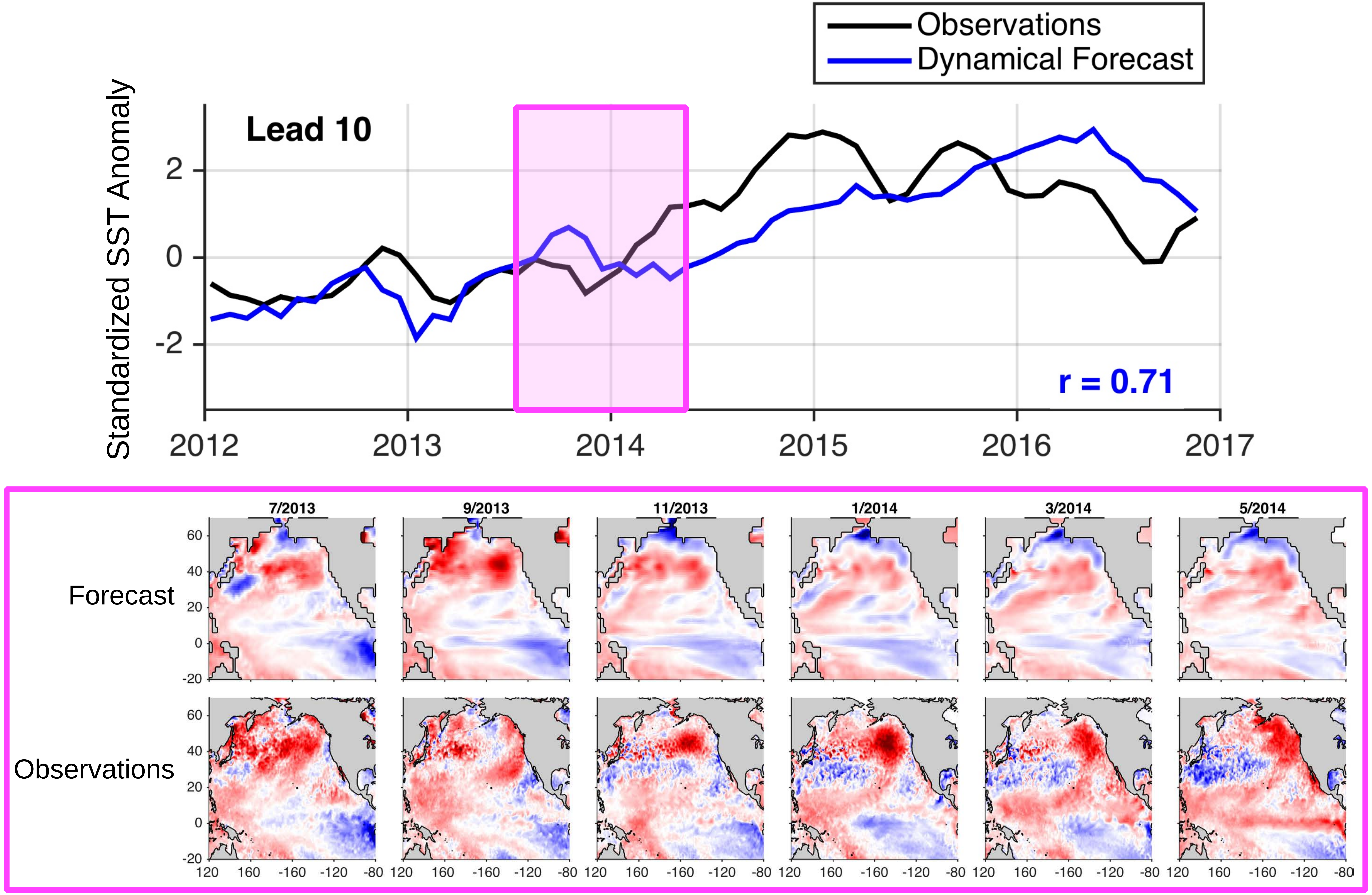

Observations
Dynamical Forecast
Lead 10
2
0
-2
r = 0.71
2012
2013
2014
2015
2016
2017
Standardized SST Anomaly
Lead 10
2
0
-2
r = 0.56
1985
1990
1995
2000
2005
2010
2015

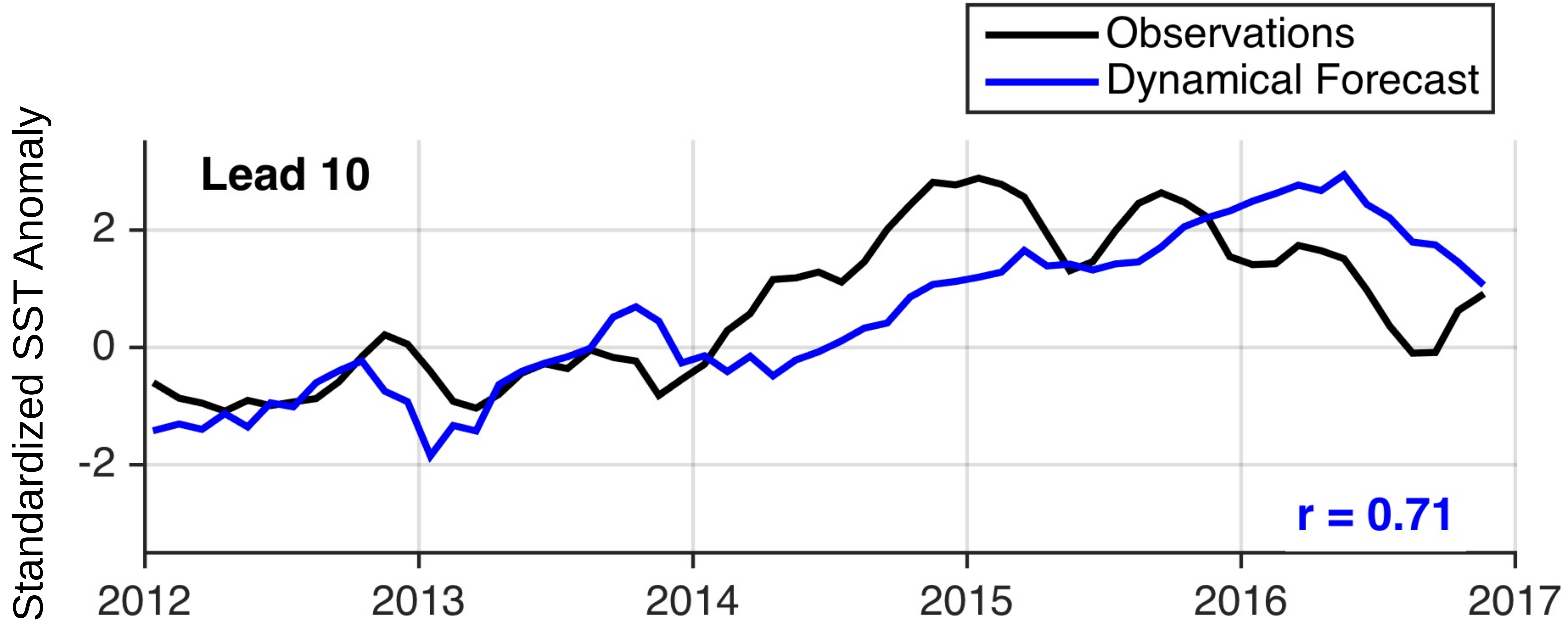


Observations
Dynamical Forecast
Lead 10
Standardized SST Anomaly
2
0
-2
2012
2013
2014
2015
2016
2017
r = 0.71



Observations
Dynamical Forecast
Lead 10
Standardized SST Anomaly
2
0
-2
r = 0.71
2012
2013
2014
2015
2016
2017


Observations
Dynamical Forecast
Lead 10
Standardized SST Anomaly
2
0
-2
r = 0.71
2012
2013
2014
2015
2016
2017
7/2013
9/2013
11/2013
1/2014
3/2014
5/2014
Forecast
Observations
60
40
20
0
-20
120
160
-160
-120
-80


Observations
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Lead 10
Standardized SST Anomaly
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2014
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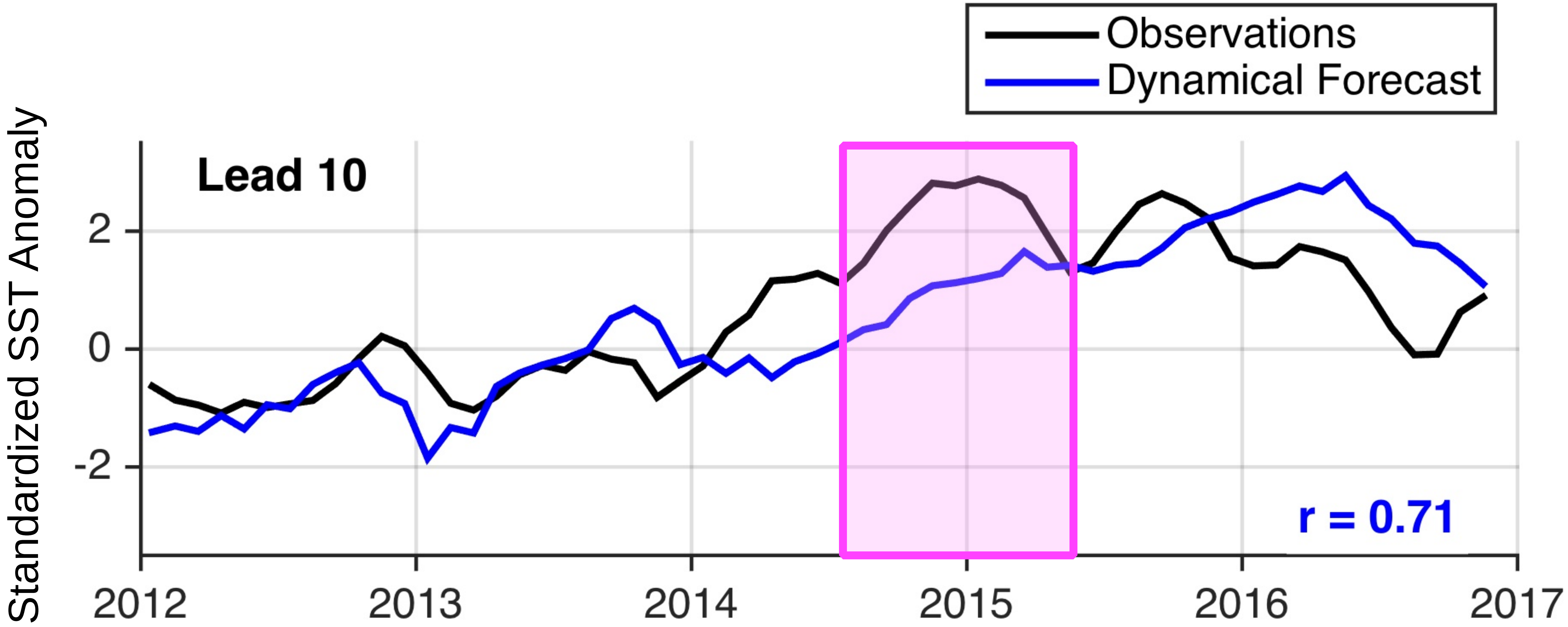

Observations
Dynamical Forecast
Lead 10
Standardized SST Anomaly
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-2
r = 0.71
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2013
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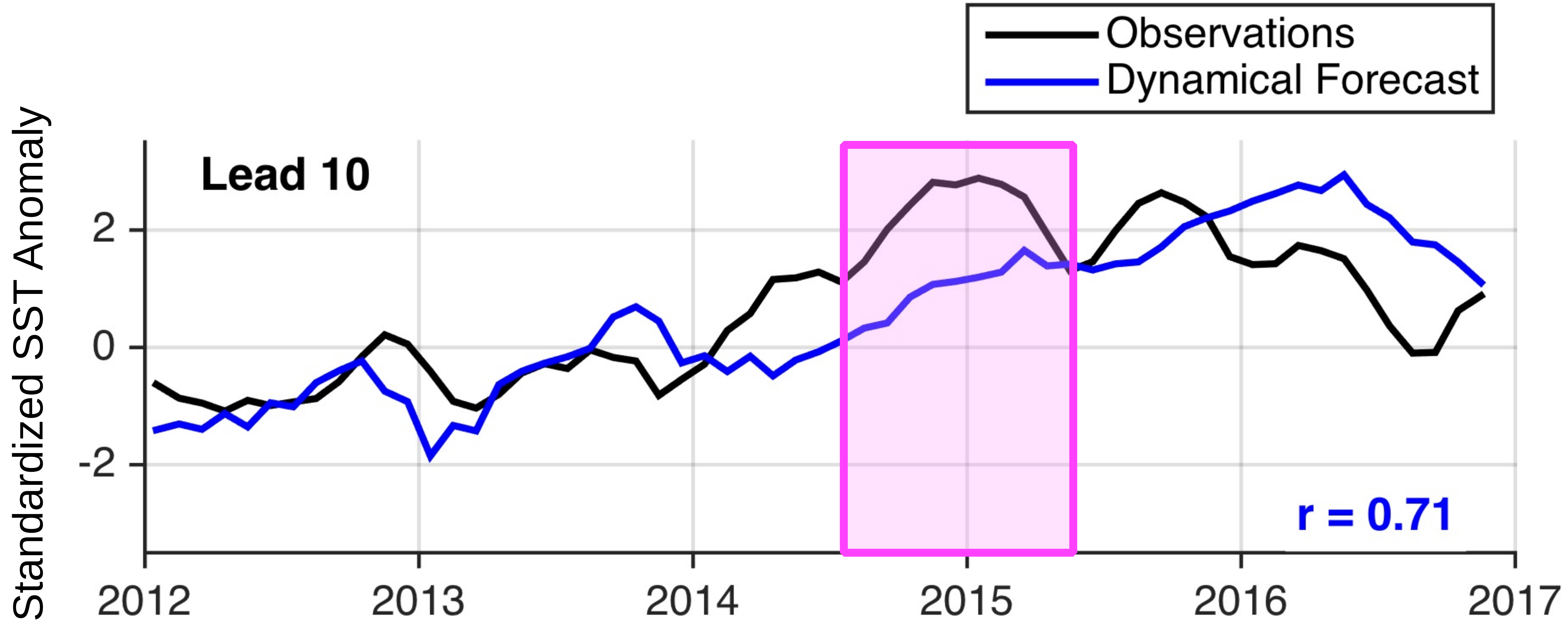
2015
2016
2017


Observations
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-2
r = 0.71
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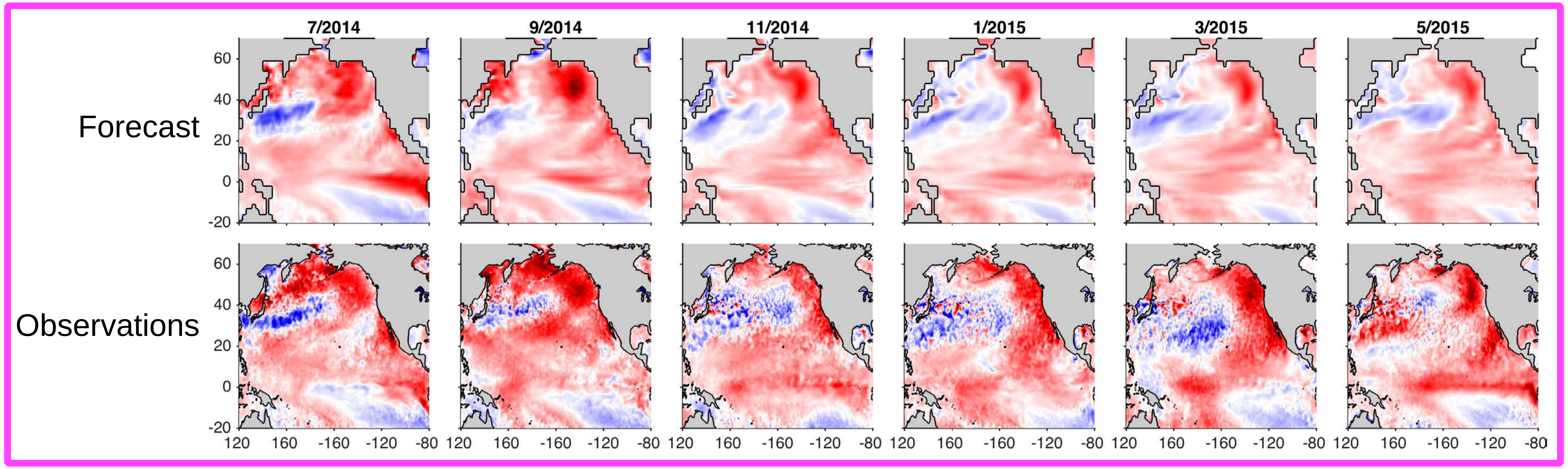
2017


7/2014
9/2014
11/2014
1/2015
3/2015
5/2015
Forecast
Observations
60
40
20
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-20
120
160
-160
-120
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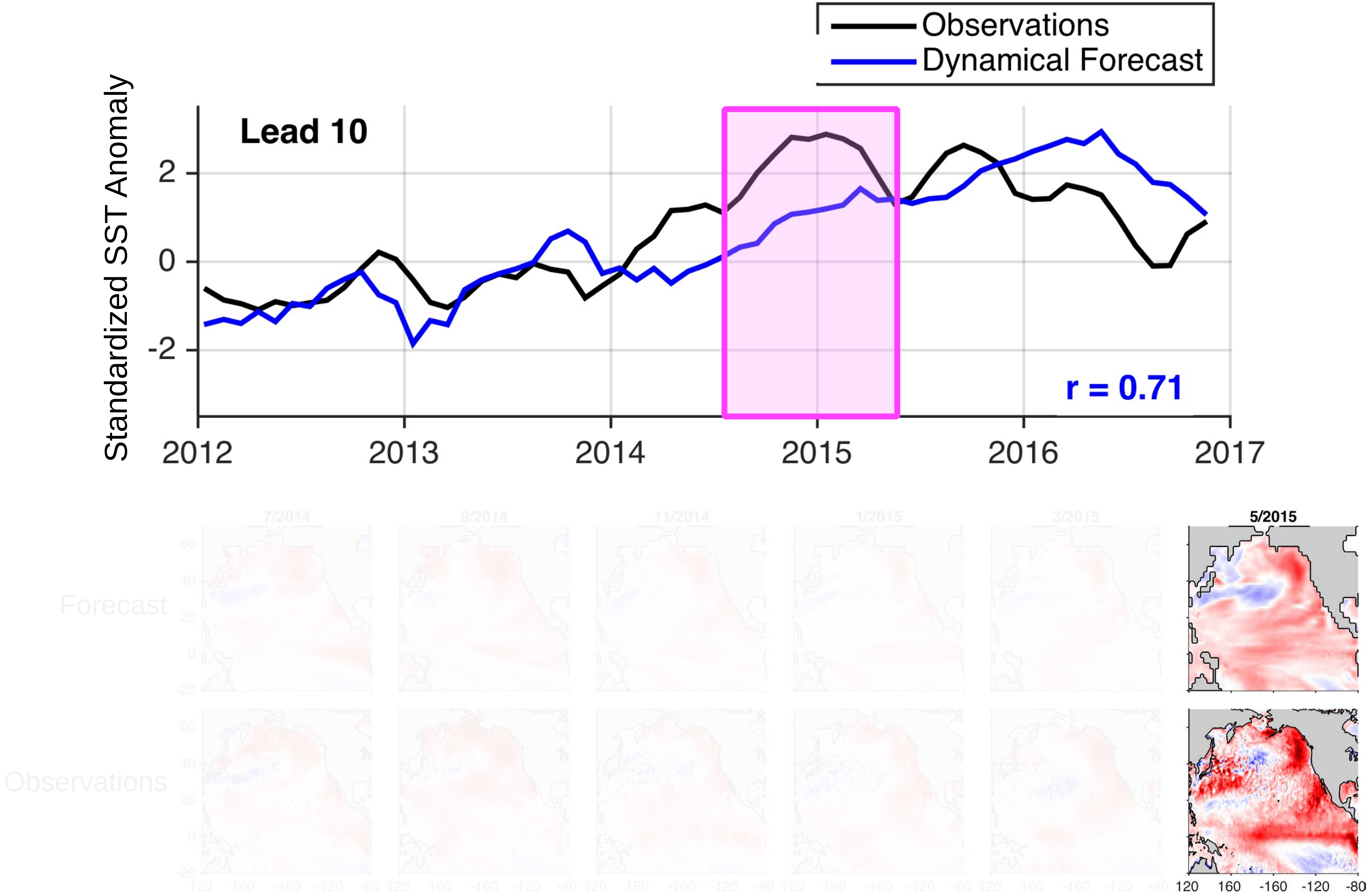
Observations
Dynamical Forecast
Lead 10
Standardized SST Anomaly
2
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-2
r = 0.71
2012
2013
2014
2015
2016
2017
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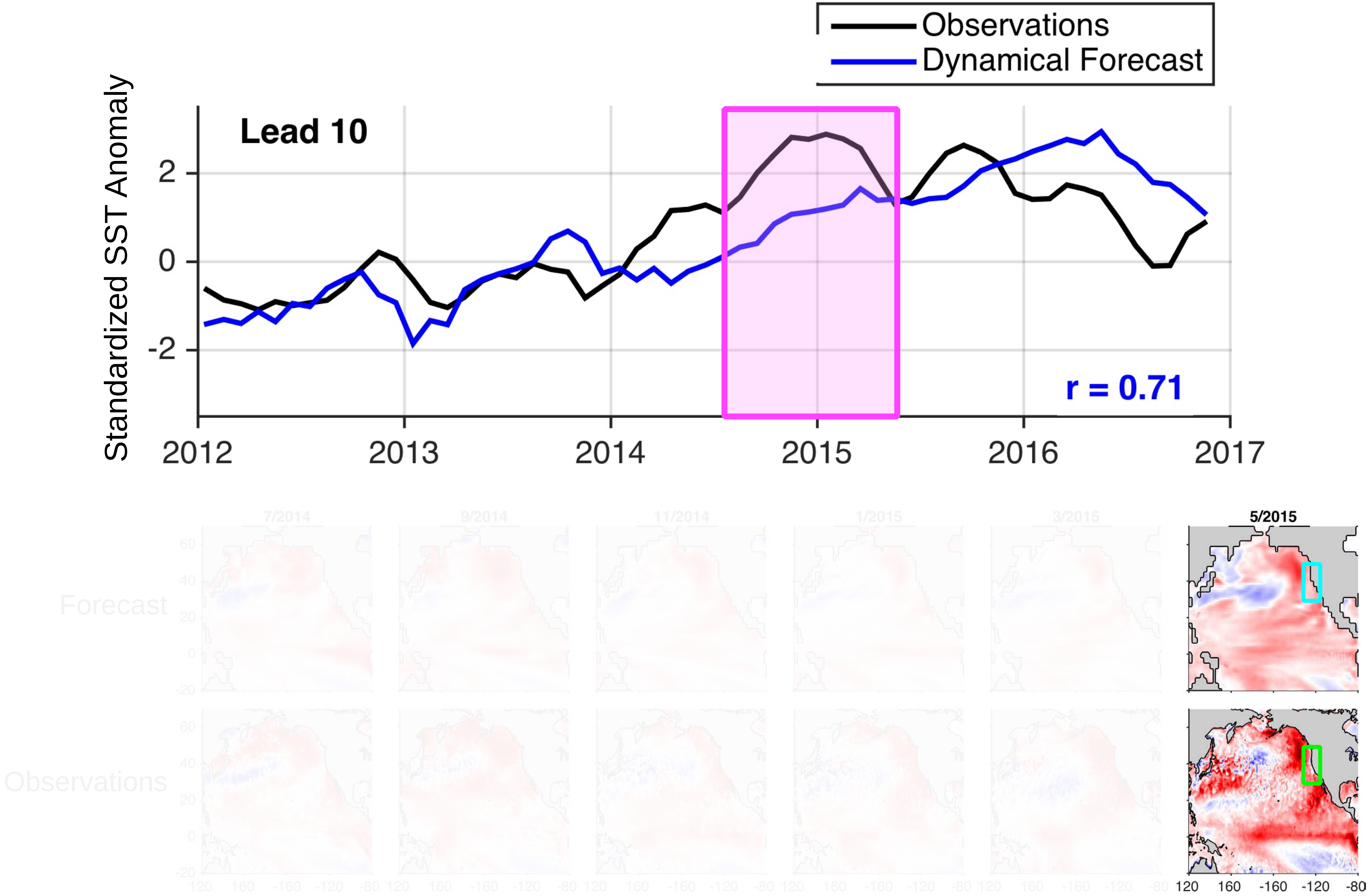
-160
-120
-80



Observations
Dynamical Forecast
Lead 10
Standardized SST Anomaly
2
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-2
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2013
2014
2015
2016
2017
r = 0.71
Forecast
Observations
5/2015
120
160
-160
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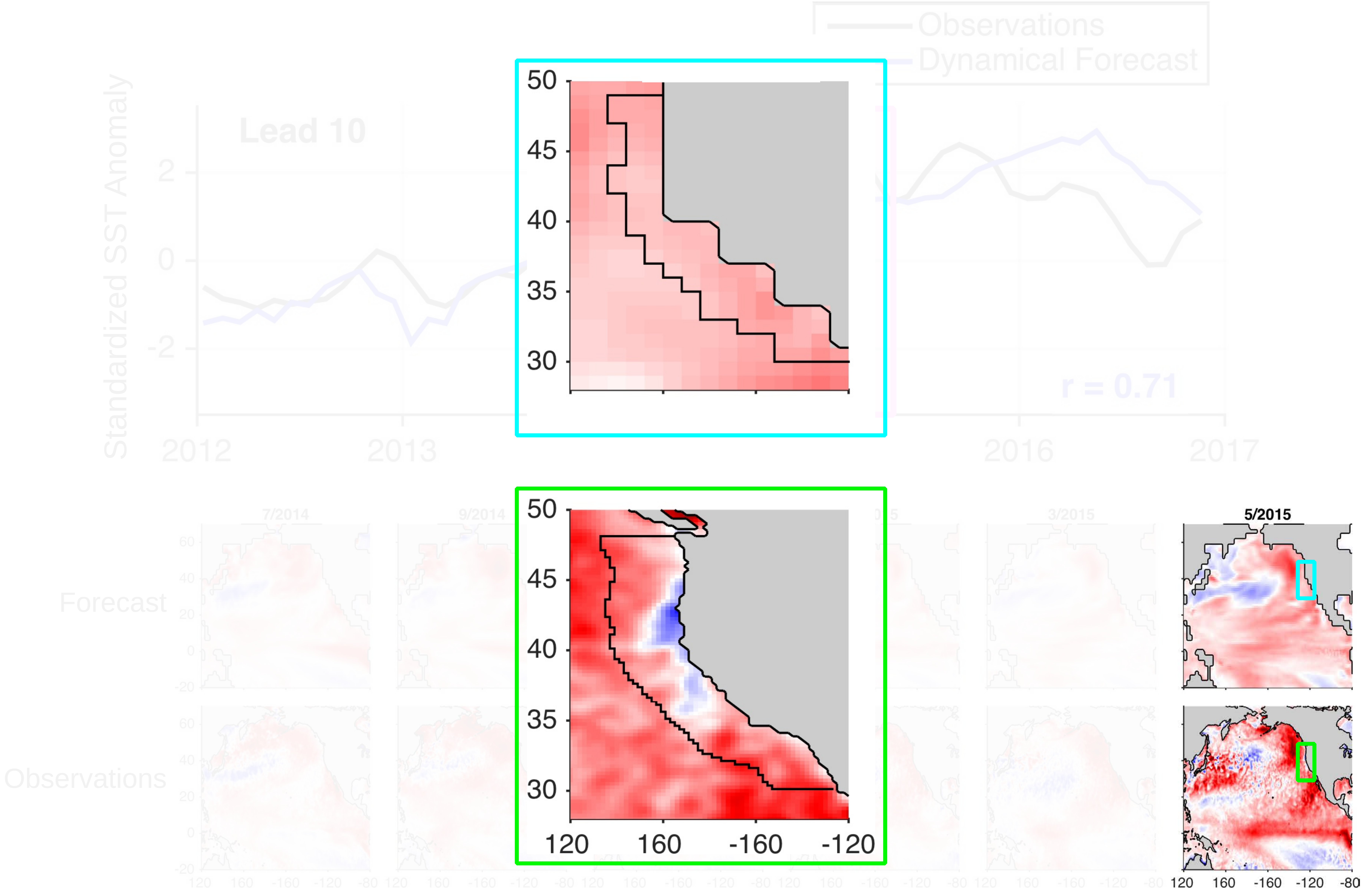
-80


Observations
Dynamical Forecast
Standardized SST Anomaly
Lead 10
r = 0.71
2012
2013
2016
2017
50
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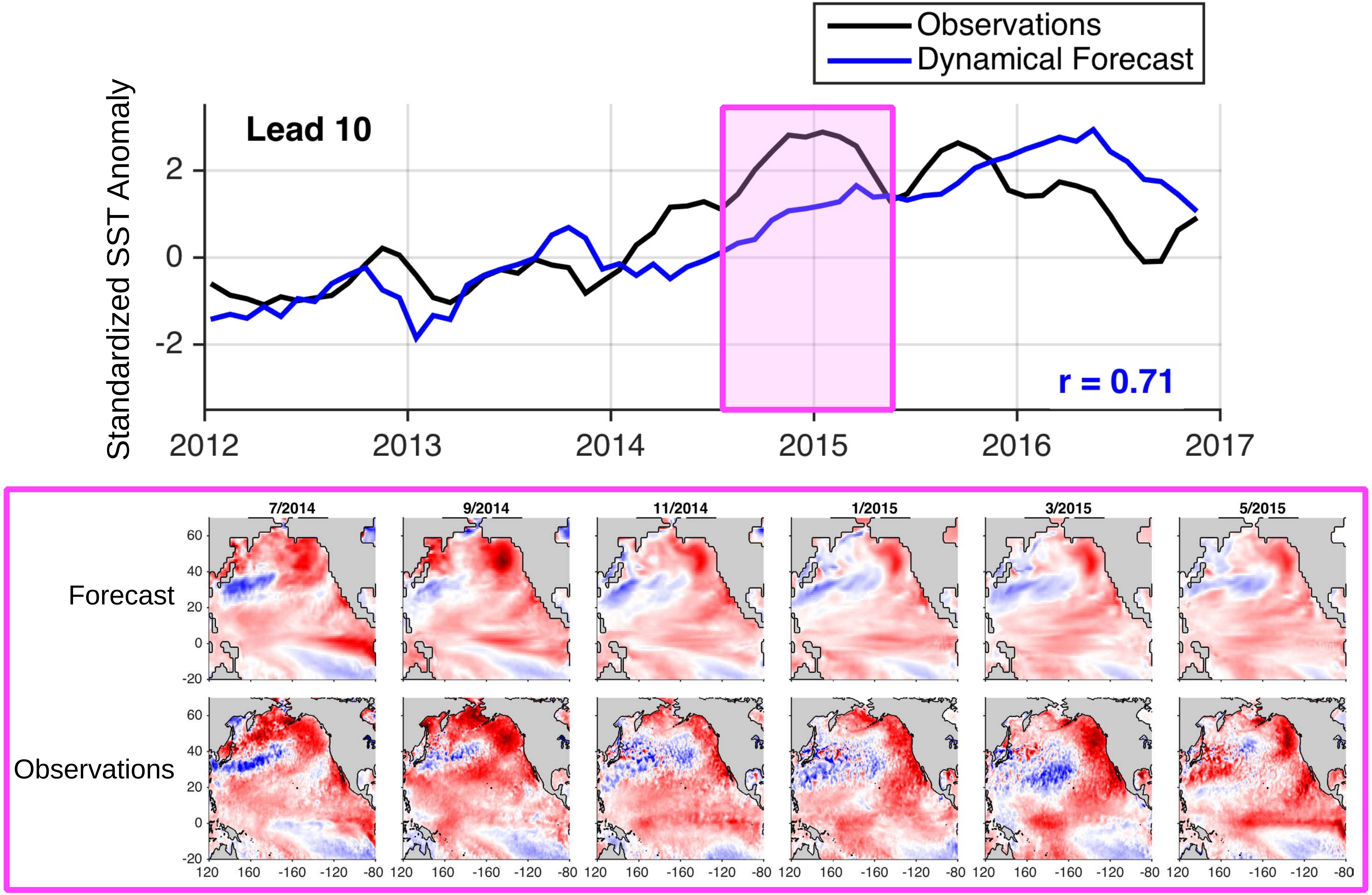
30
120
160
-160
-120
Forecast
Observations
7/2014
9/2014
3/2015
5/2015
-80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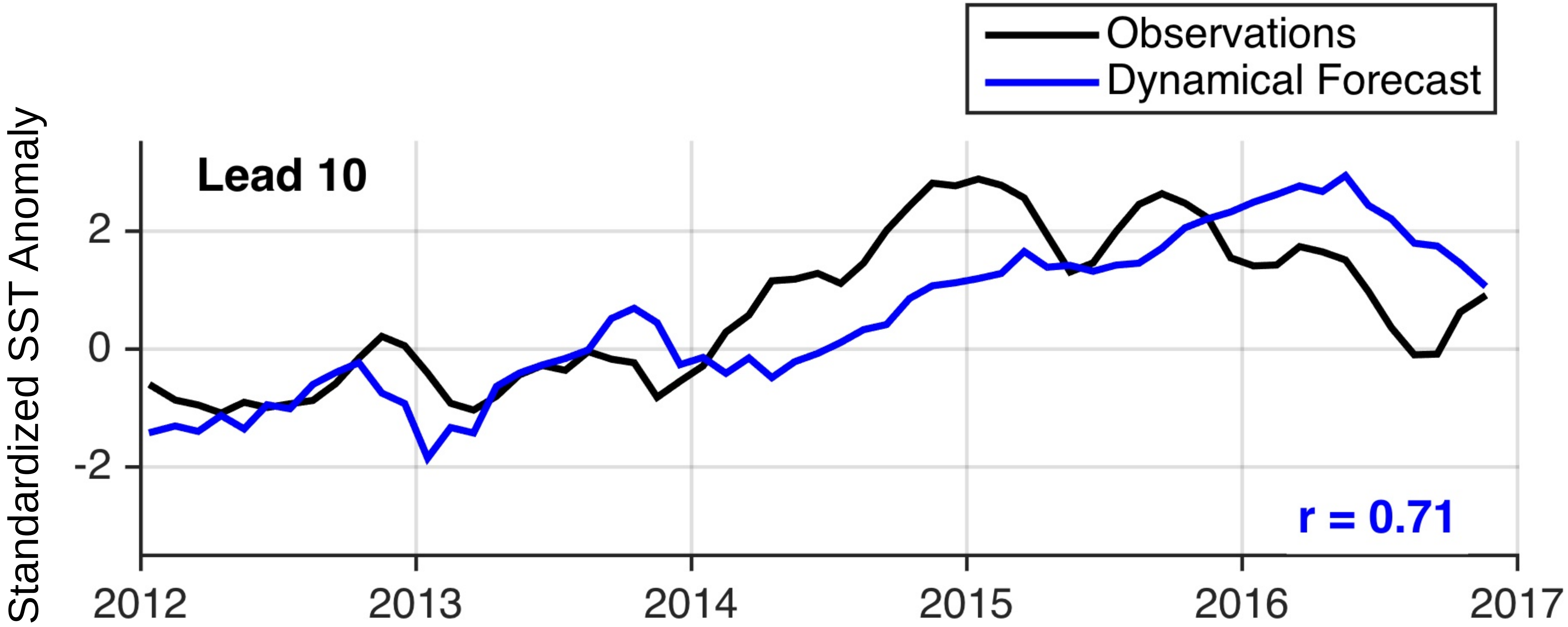
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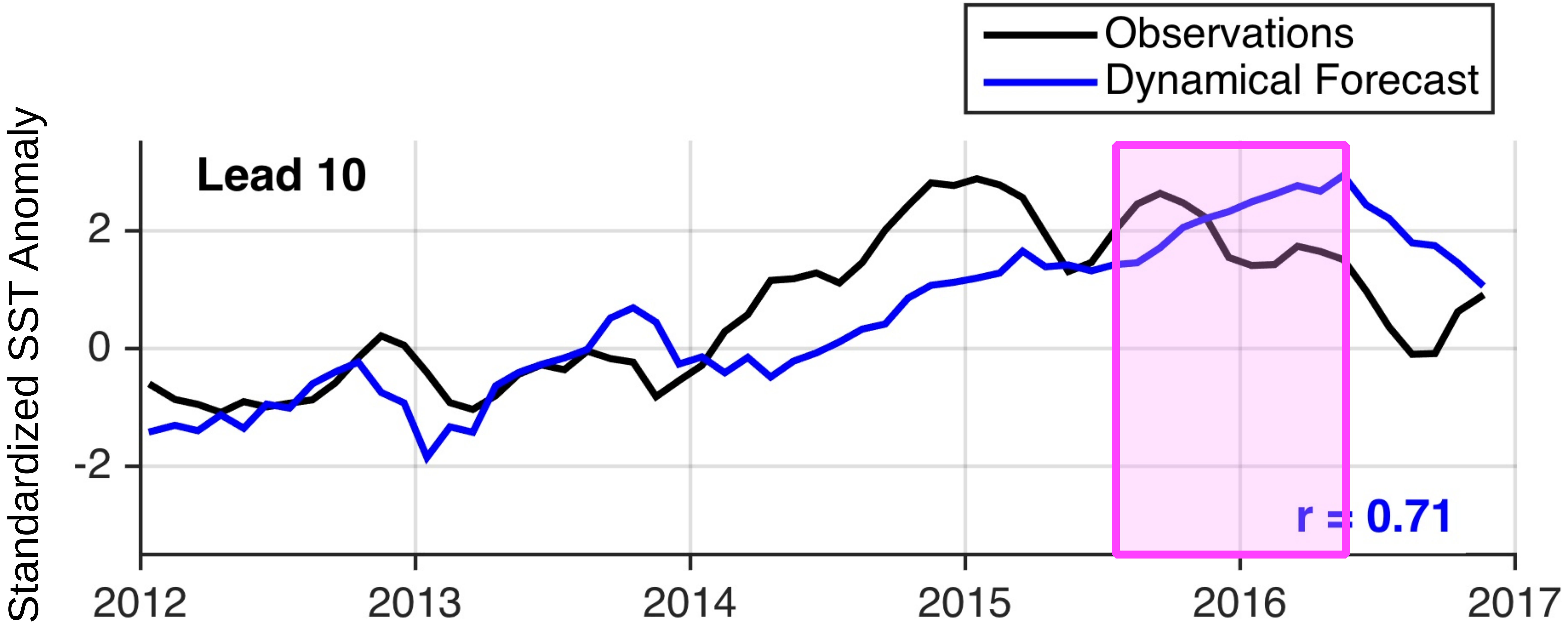
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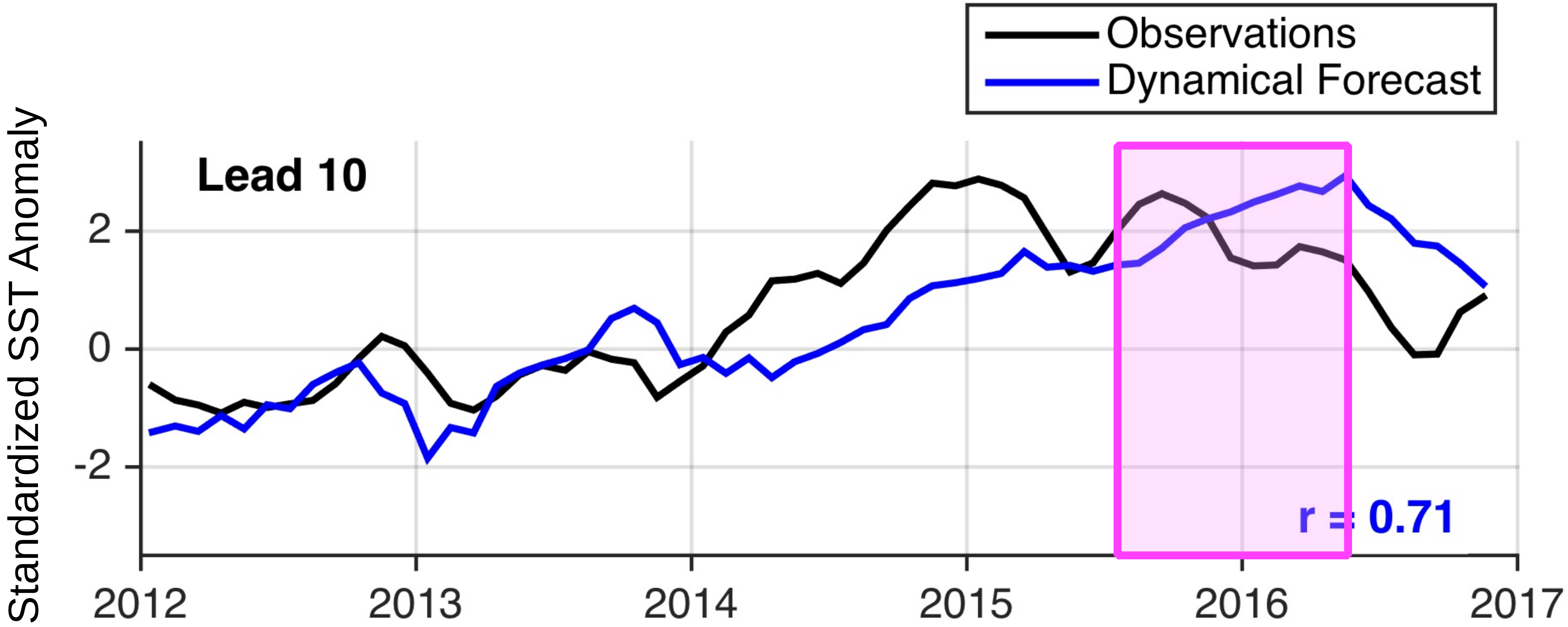

Observations
Dynamical Forecast
Lead 10
Standardized SST Anomaly
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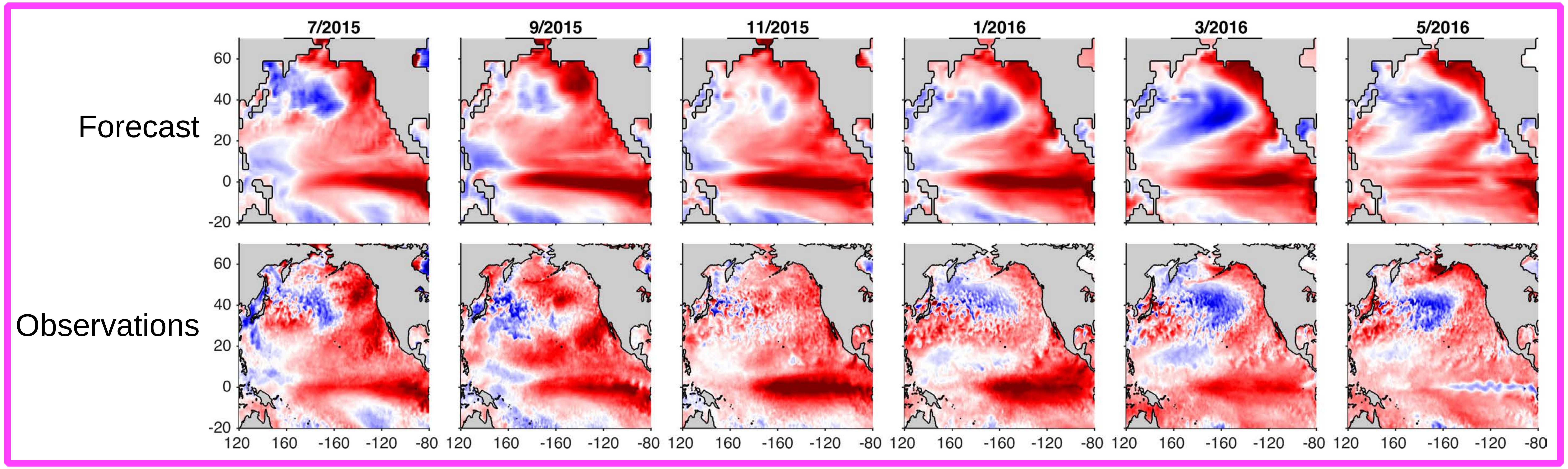

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11/2015
1/2016
3/2016
5/2016
Forecast
Observations
60
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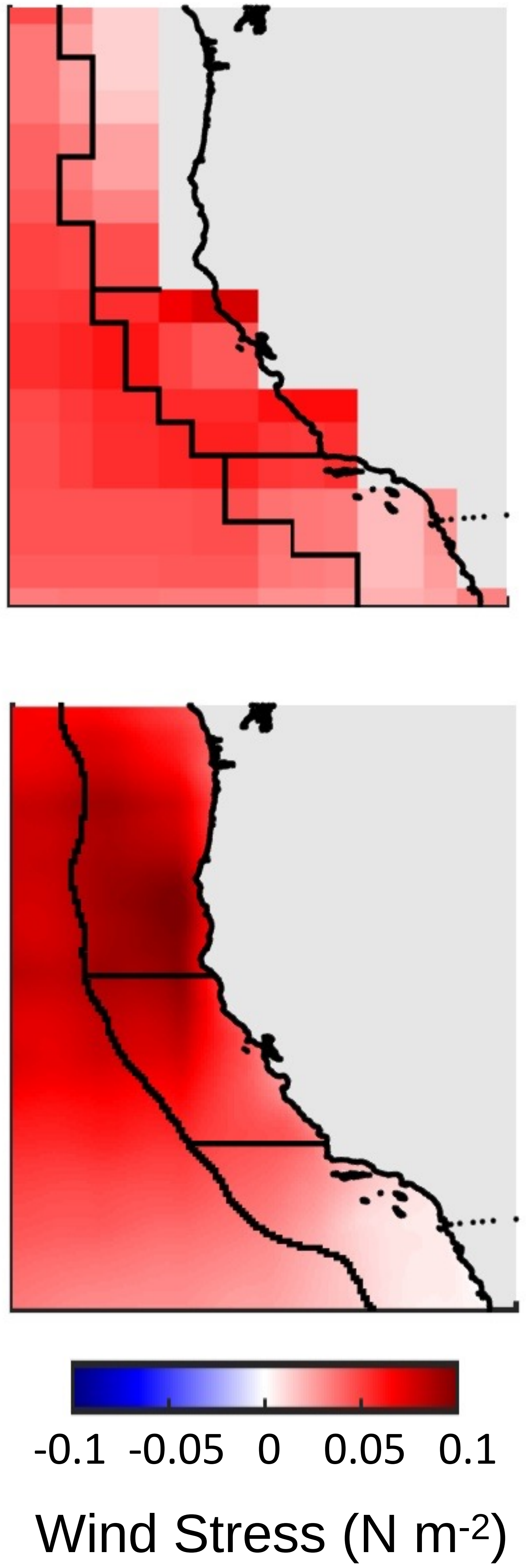
-80

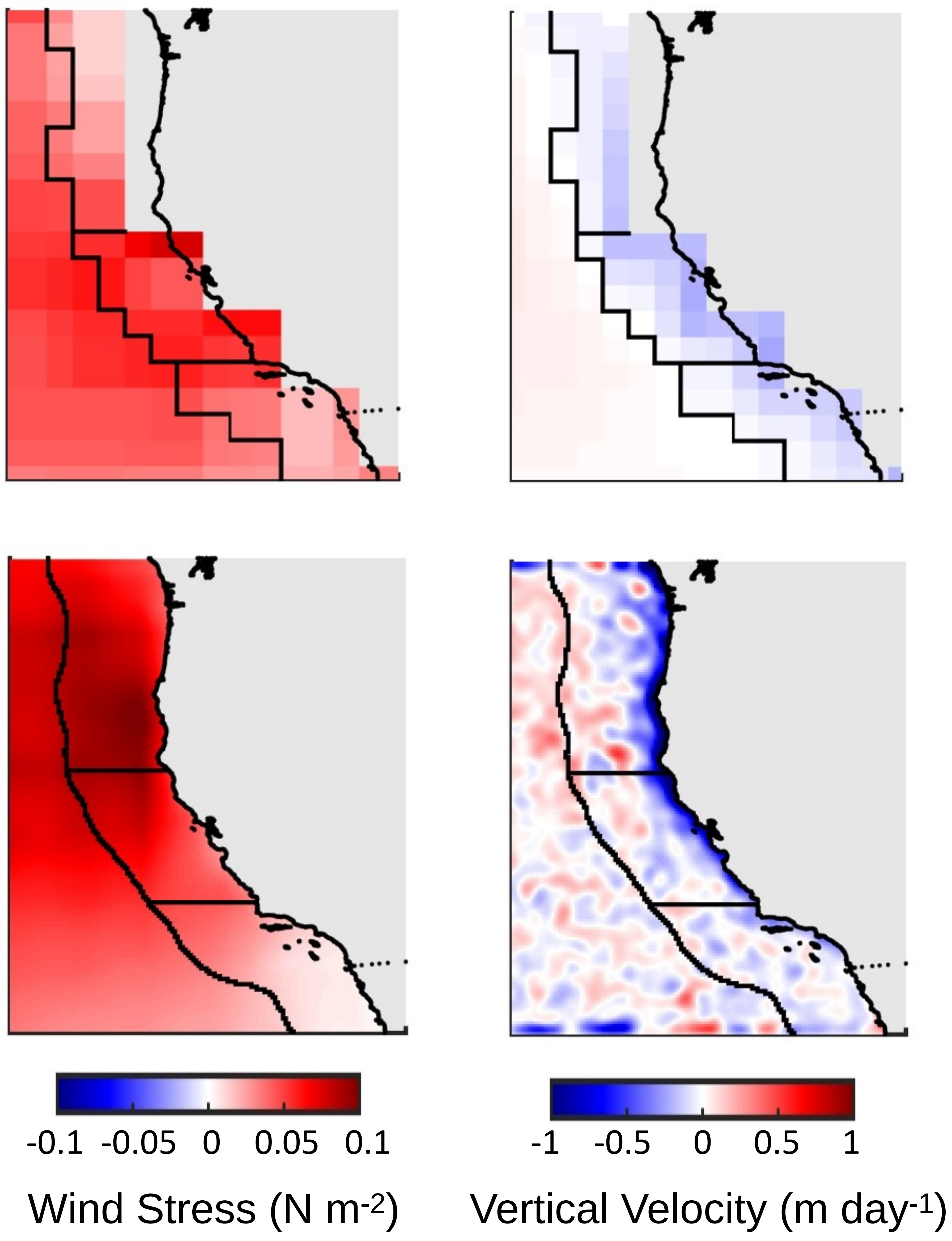
Global Forecast
(CanCM4)

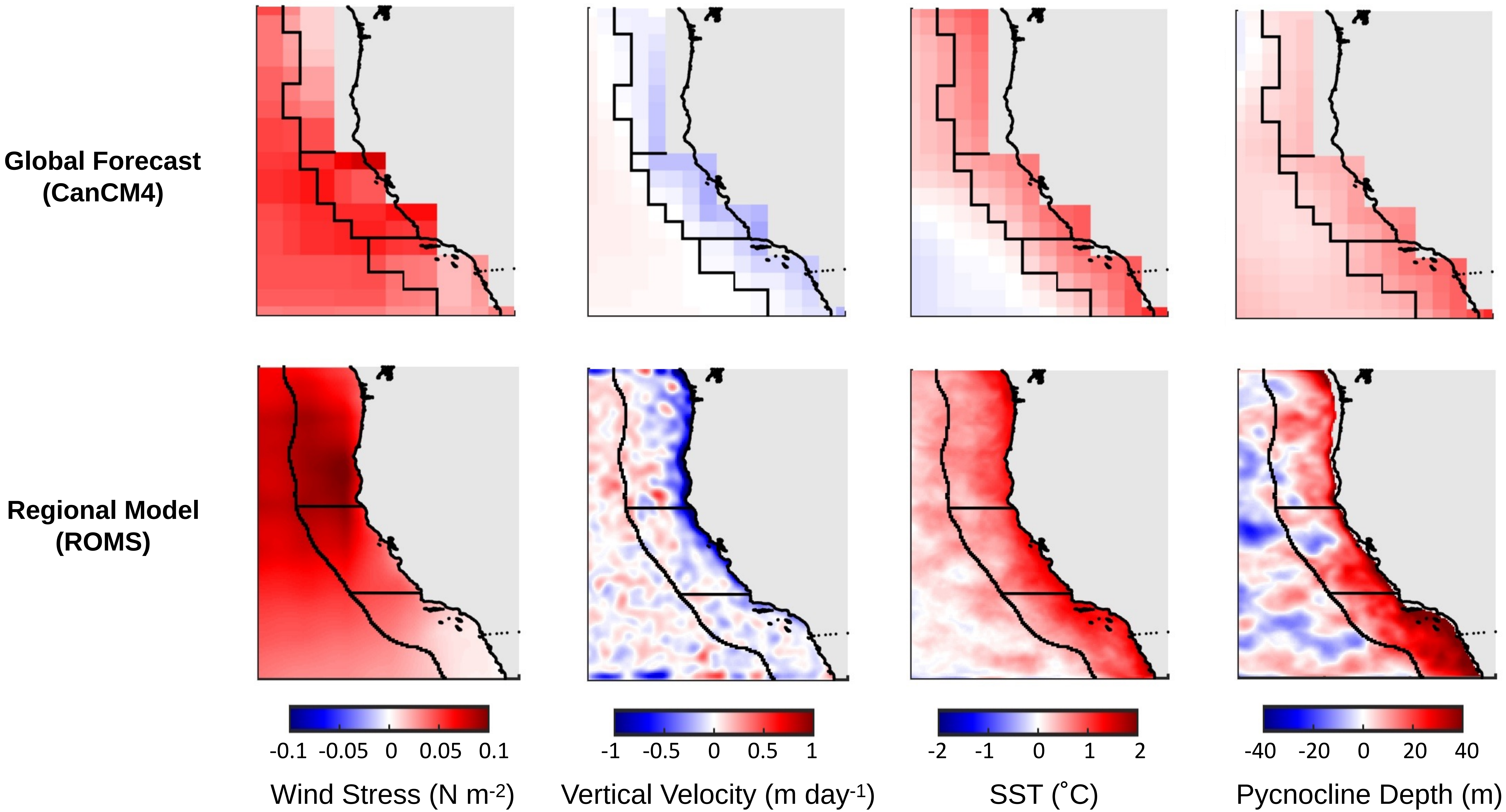
Regional Model
(ROMS)



Global Forecast (CanCM4)

Regional Model (ROMS)





Global Forecast
(CanCM4)
Regional Model
(ROMS)
-0.1 -0.05 0 0.05 0.1
Wind Stress (N m-2)
-1 -0.5 0 0.5 1
Vertical Velocity (m day-1)
-2 -1 0 1 2
SST (˚C)
-40 -20 0 20 40
Pycnocline Depth (m)