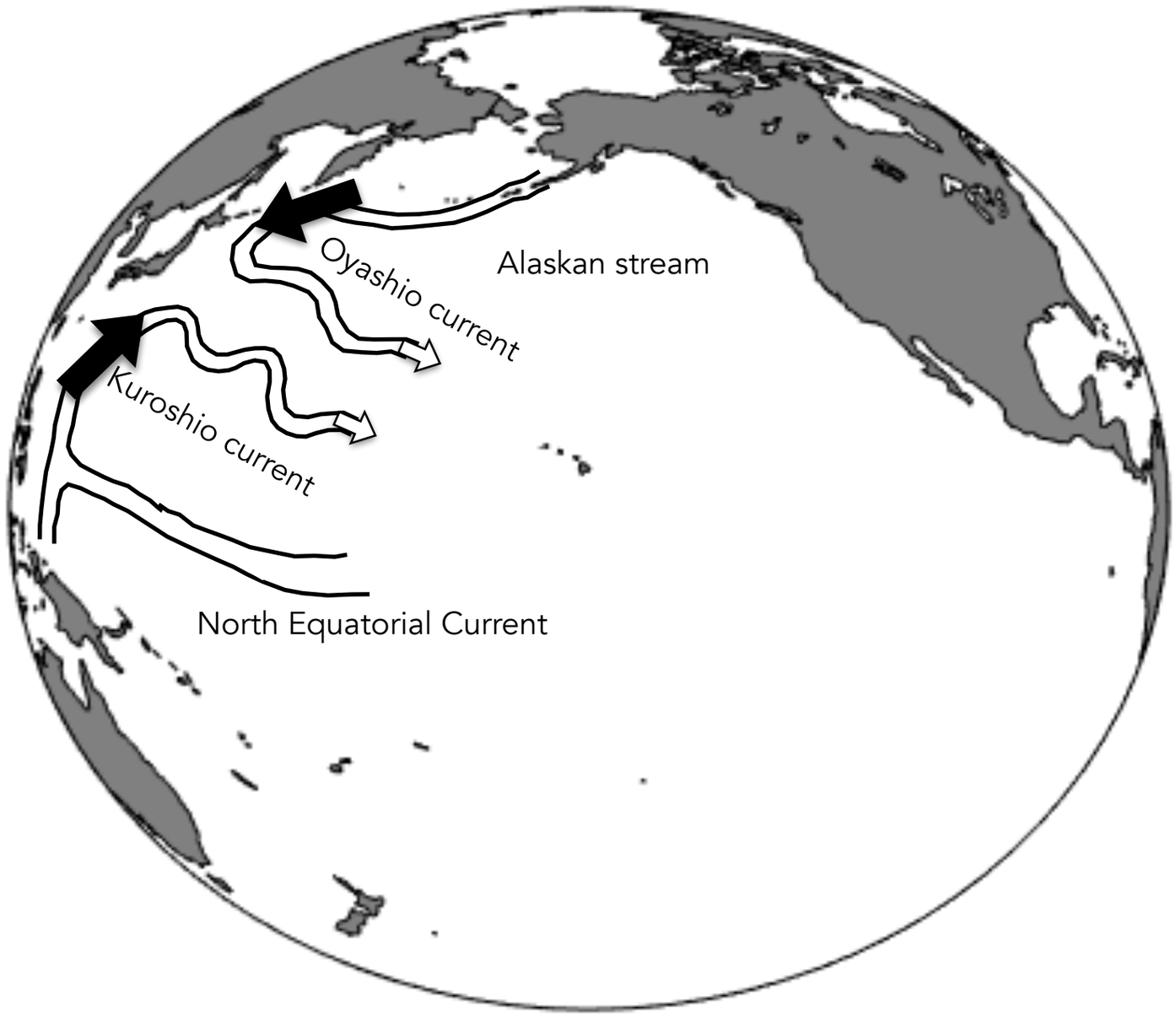
Interactions between Kuroshio extension system and Pacific meridional mode enhances a decadal peak in North Pacific Variability

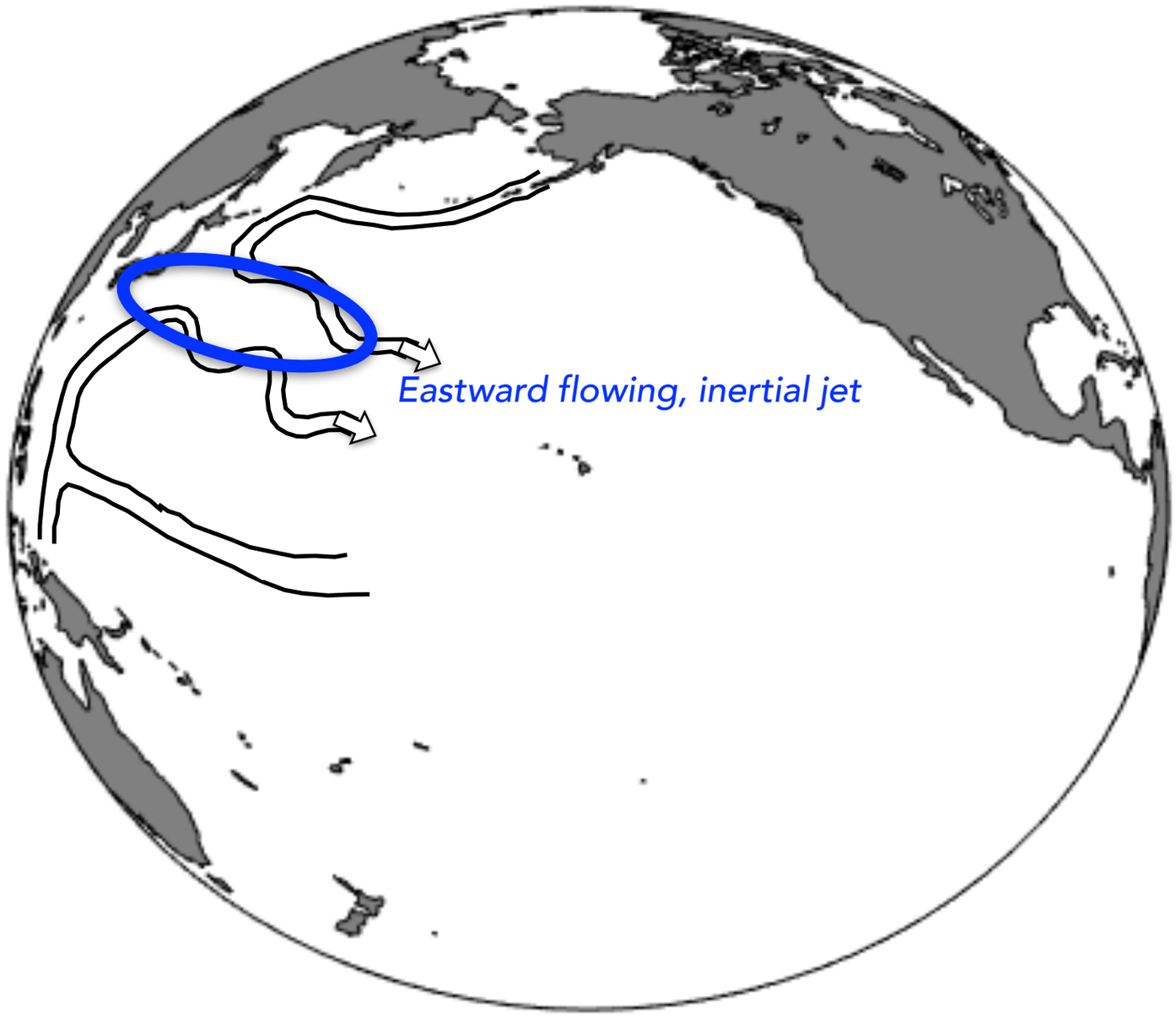
Youngji Joh* and Emanuele Di Lorenzo

School of Earth and Atmospheric Sciences, Georgia Institute of Technology

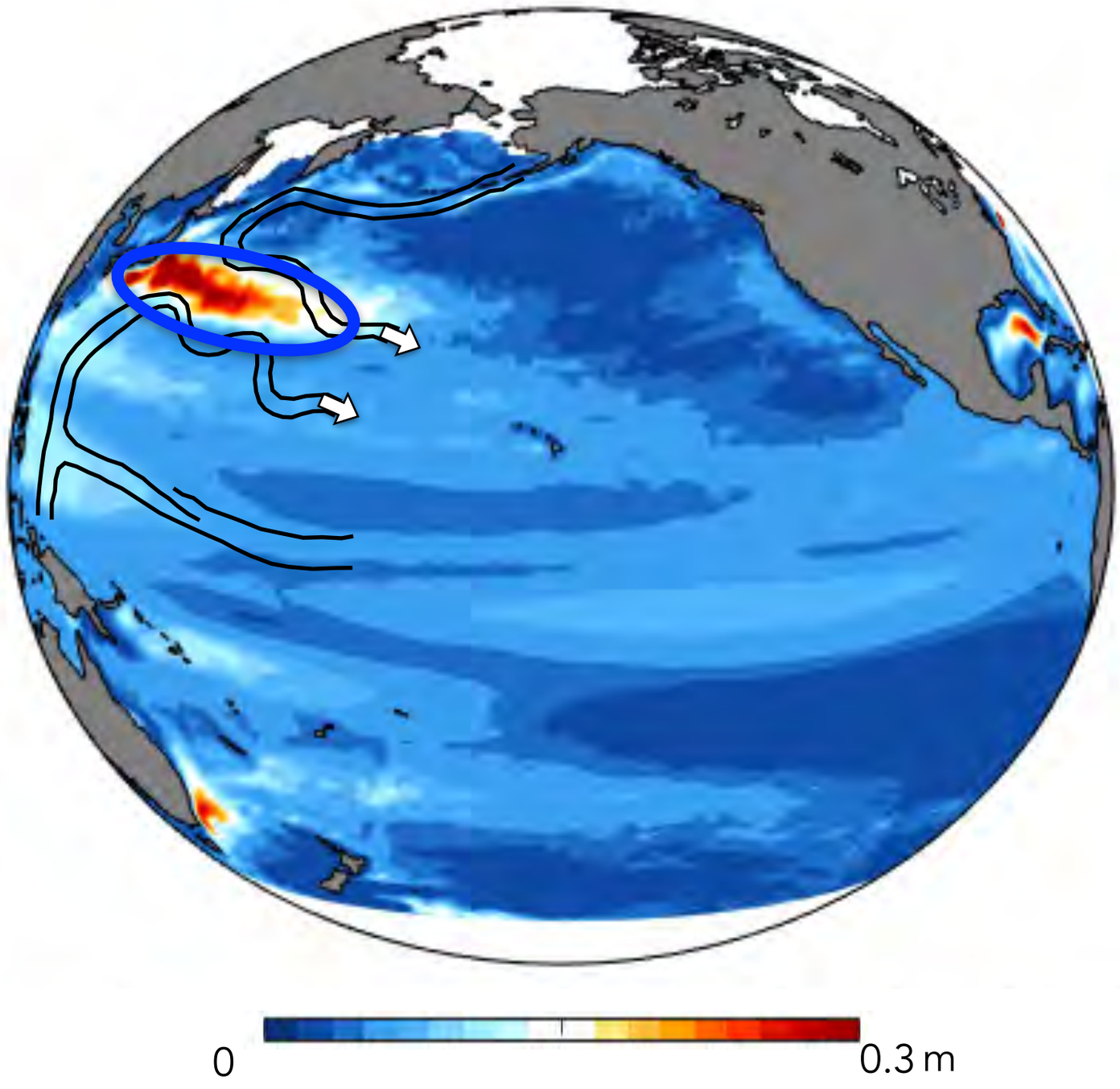
Western Boundary



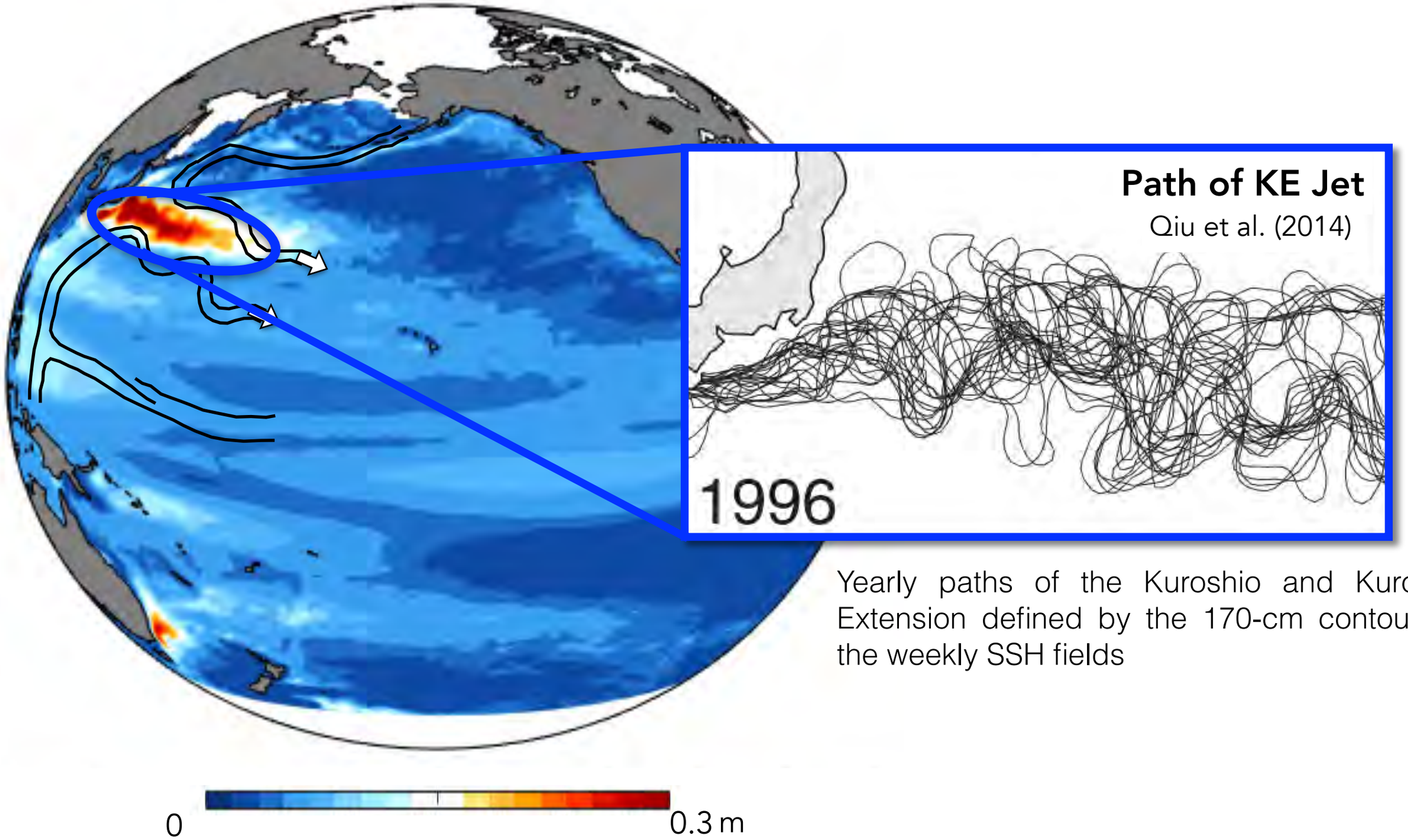
Kuroshio Extension (KE)



Standard deviation of SSHa

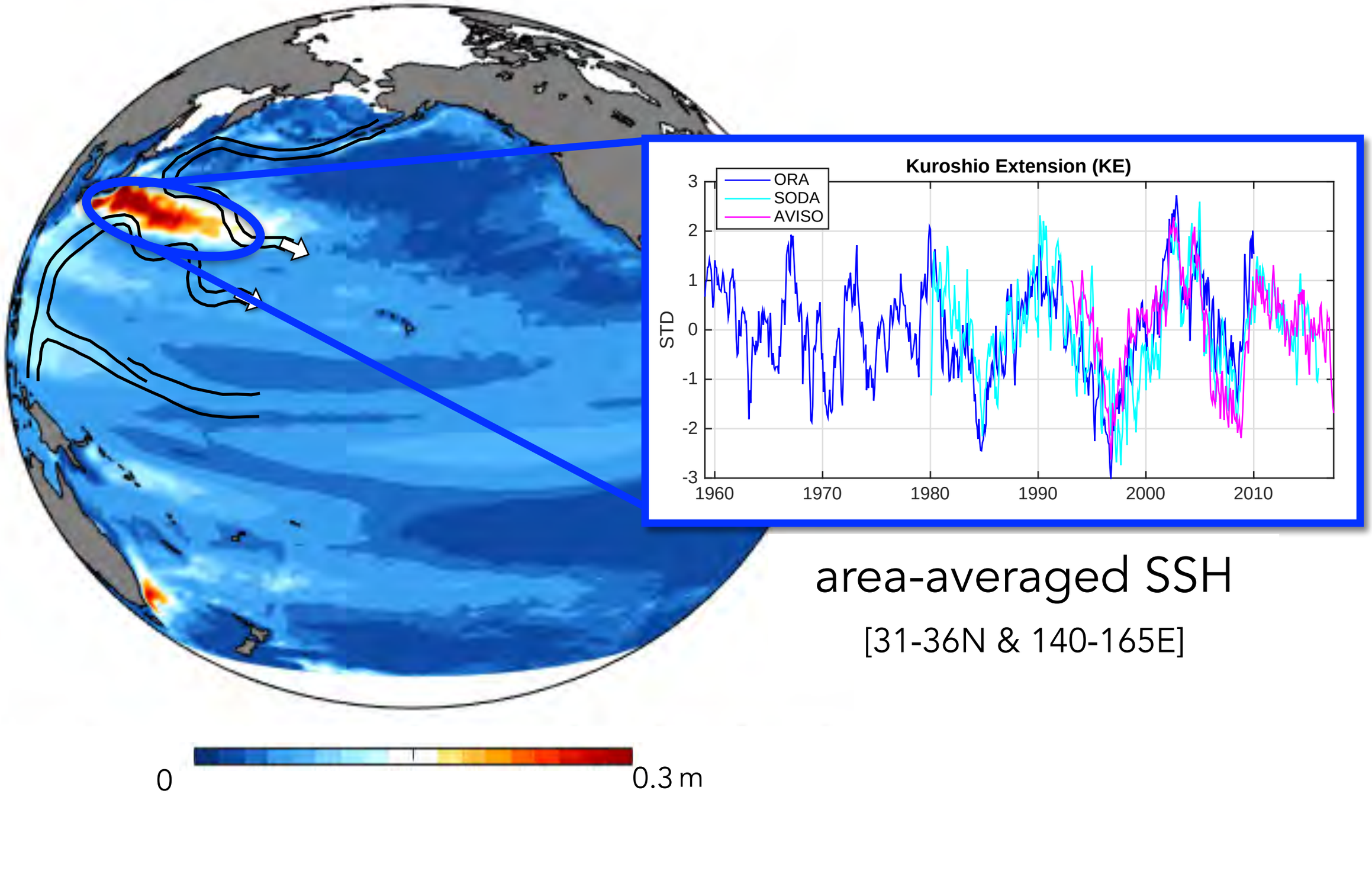


Standard deviation of SSHa



Yearly paths of the Kuroshio and Kuroshio Extension defined by the 170-cm contours in the weekly SSH fields

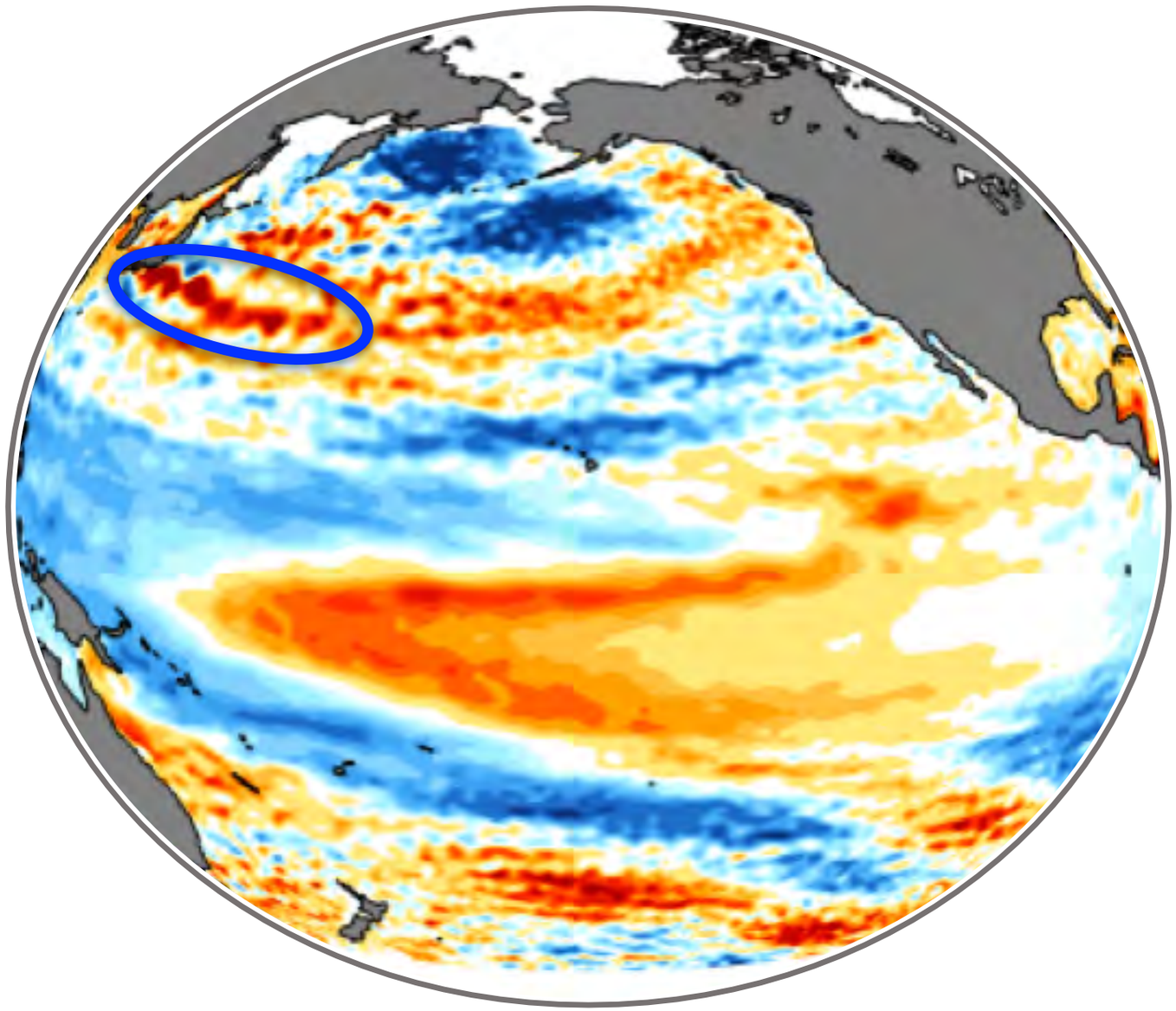
Standard deviation of SSHa

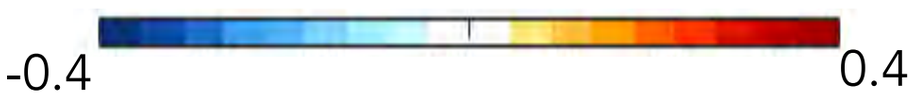


area-averaged SSH

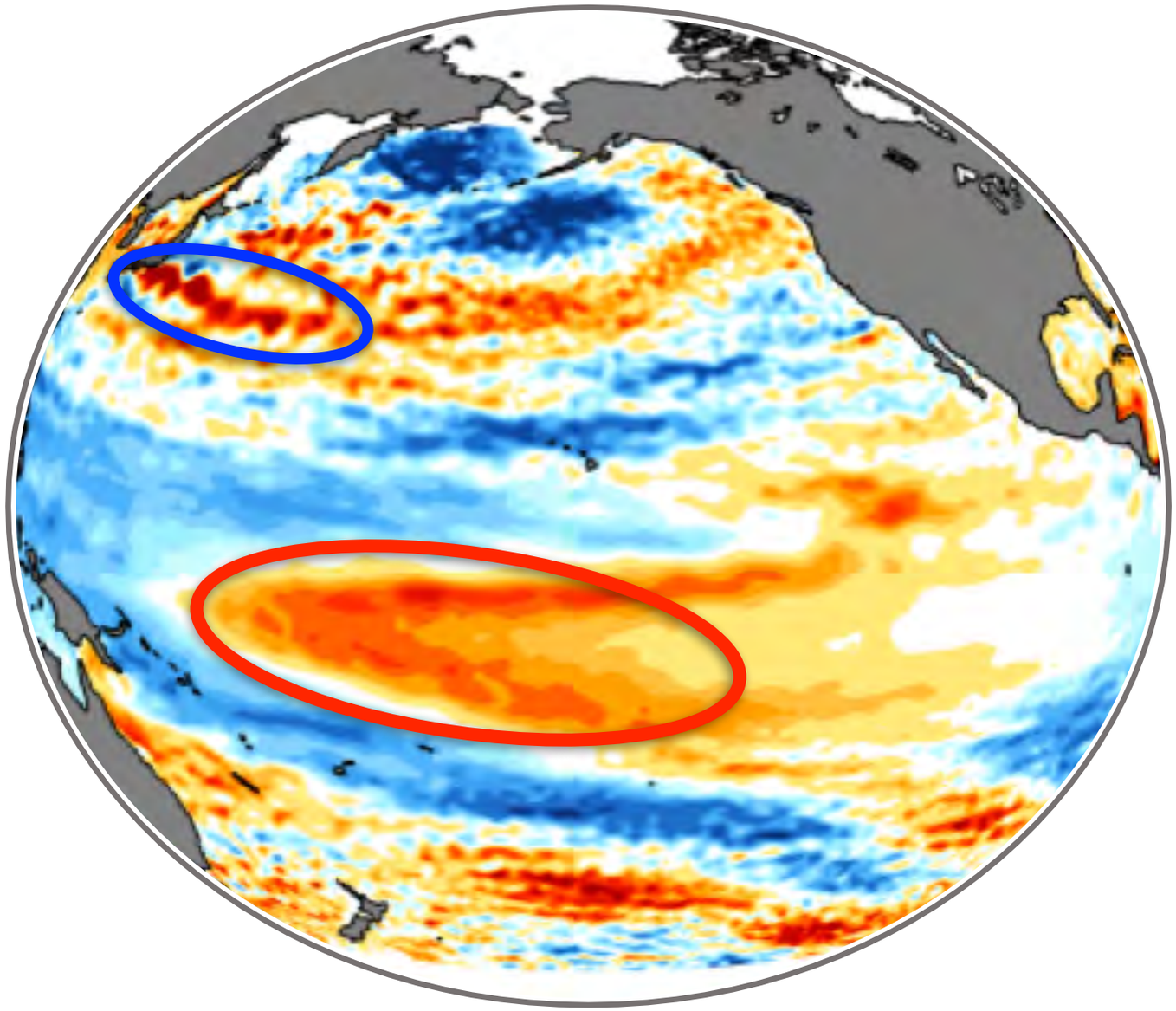
[31-36N & 140-165E]

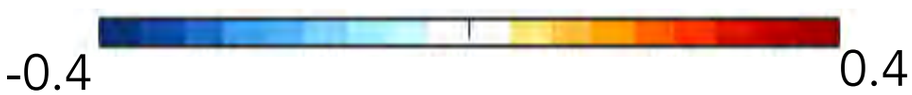
Correlated SSHa to KE



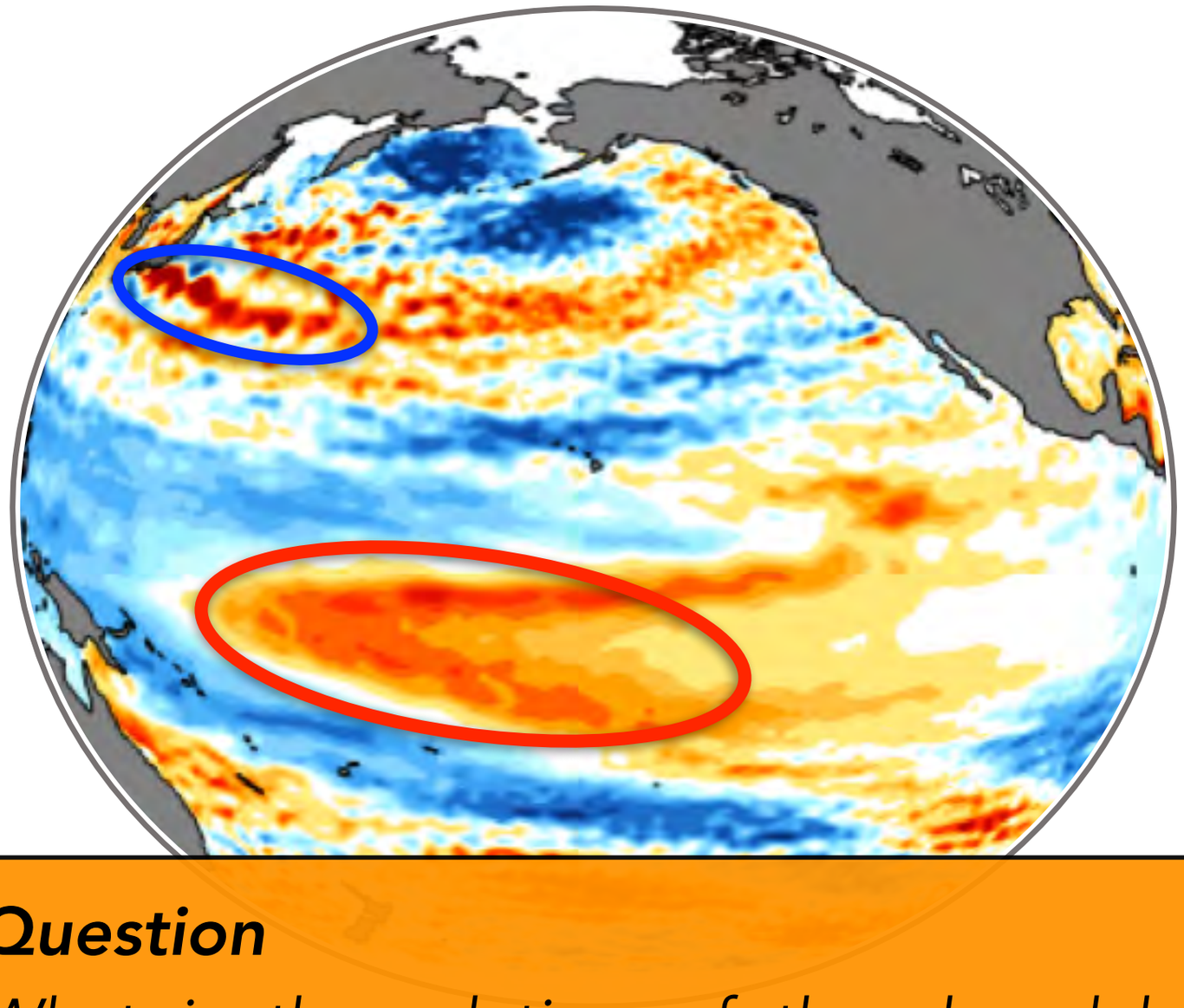


Correlated SSHa to KE





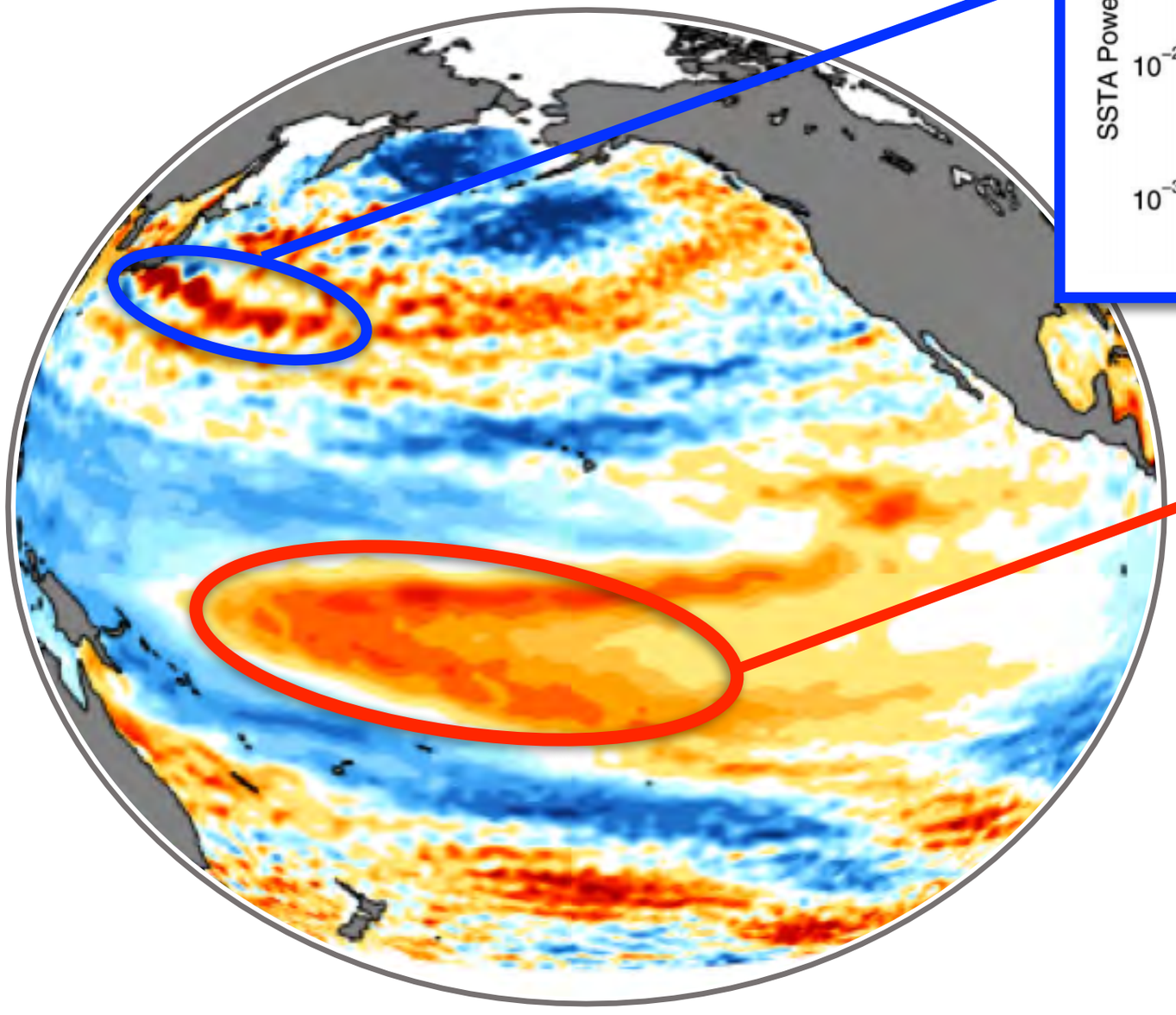
Correlated SSHa to KE



Question

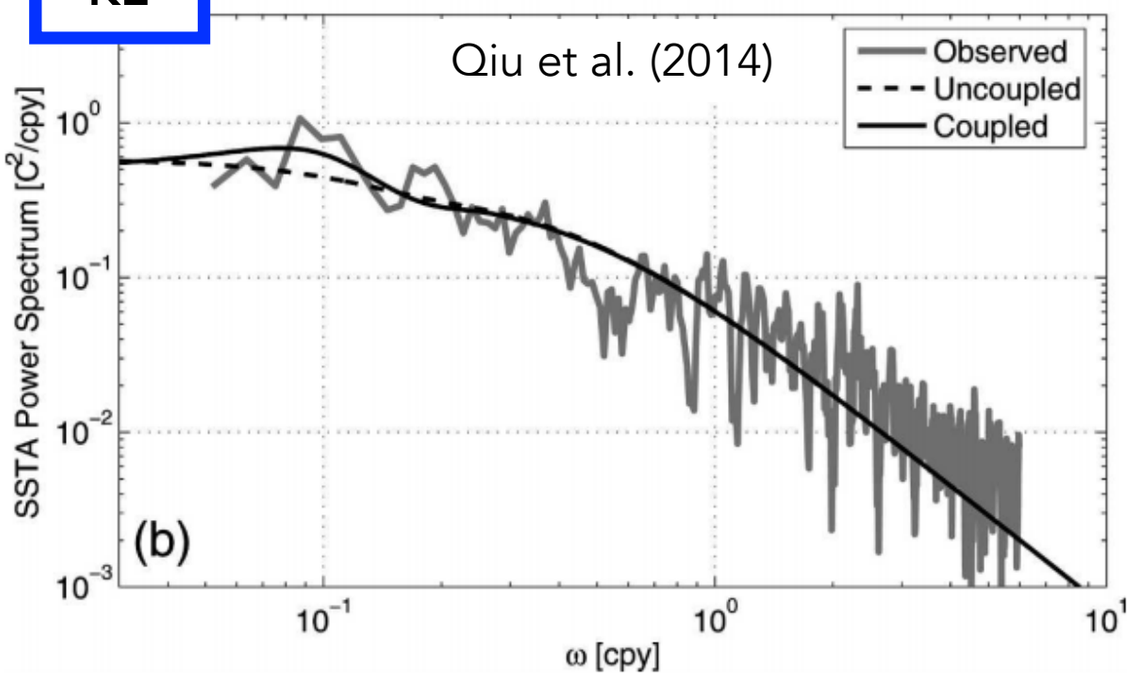
What is the relation of the decadal KE variability with a strong signature also in the tropics ?

Correlated SSHa to KE

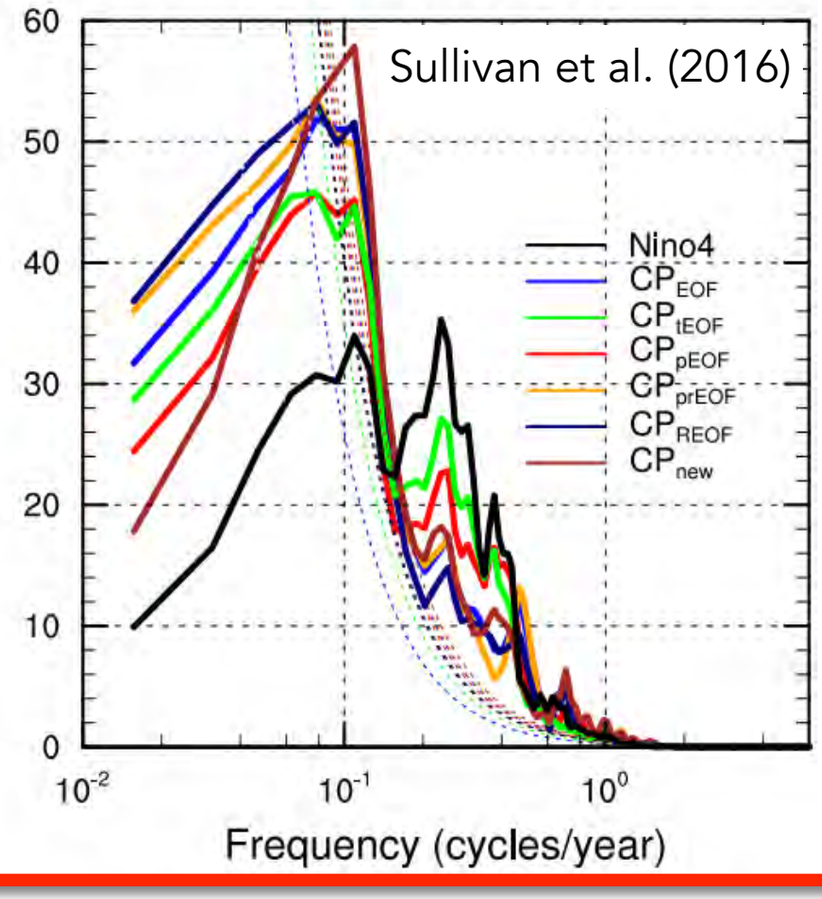


-0.4 0.4

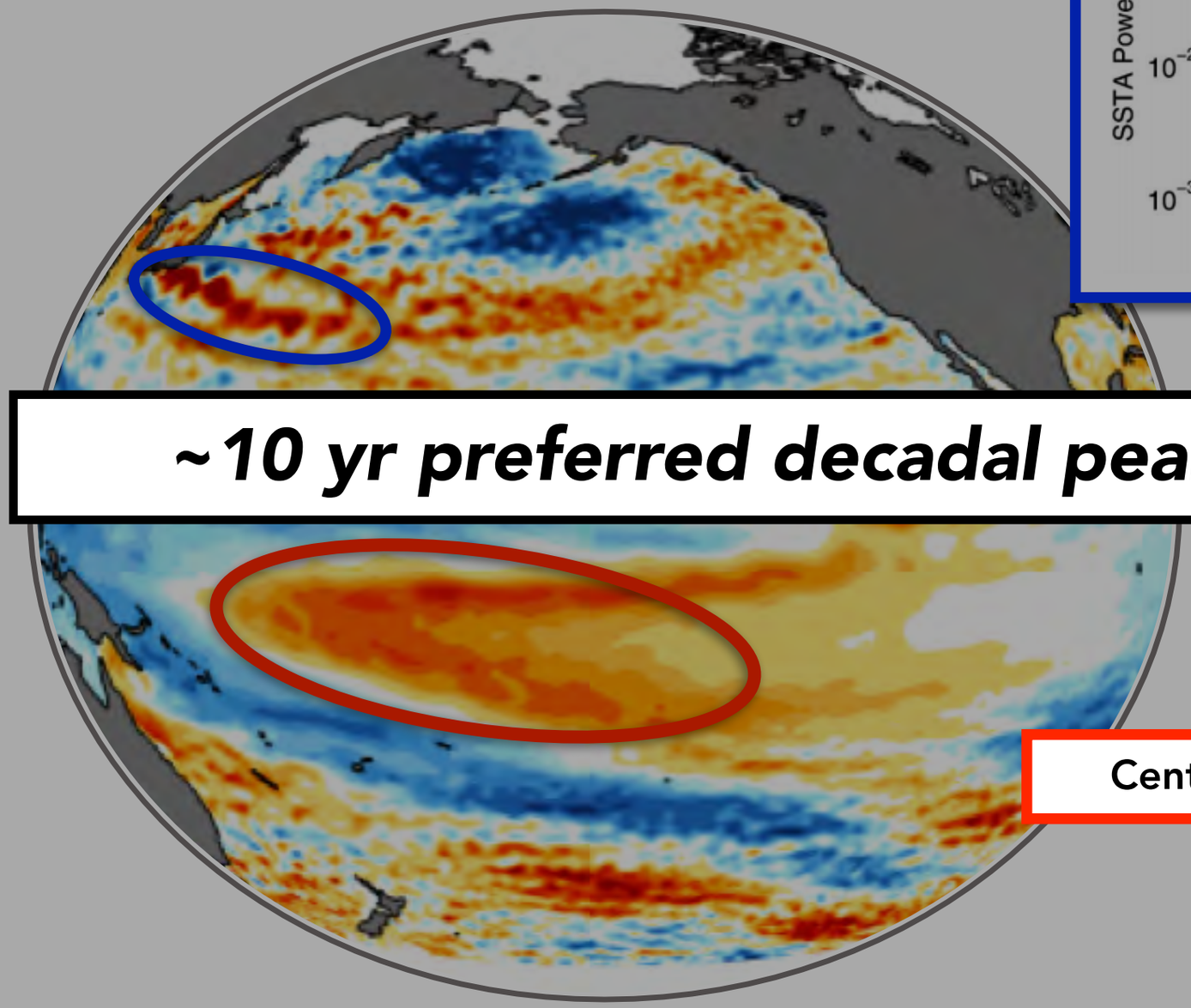
KE



Central Pacific ENSO



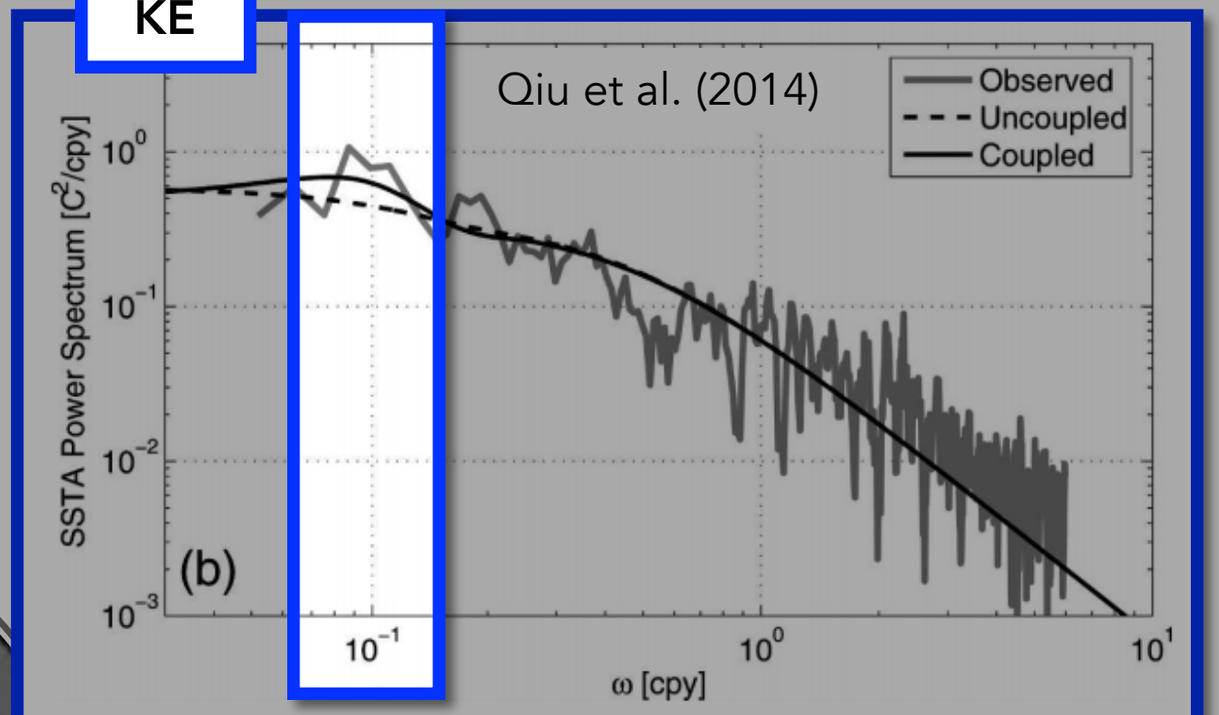
Correlated SSHa to KE



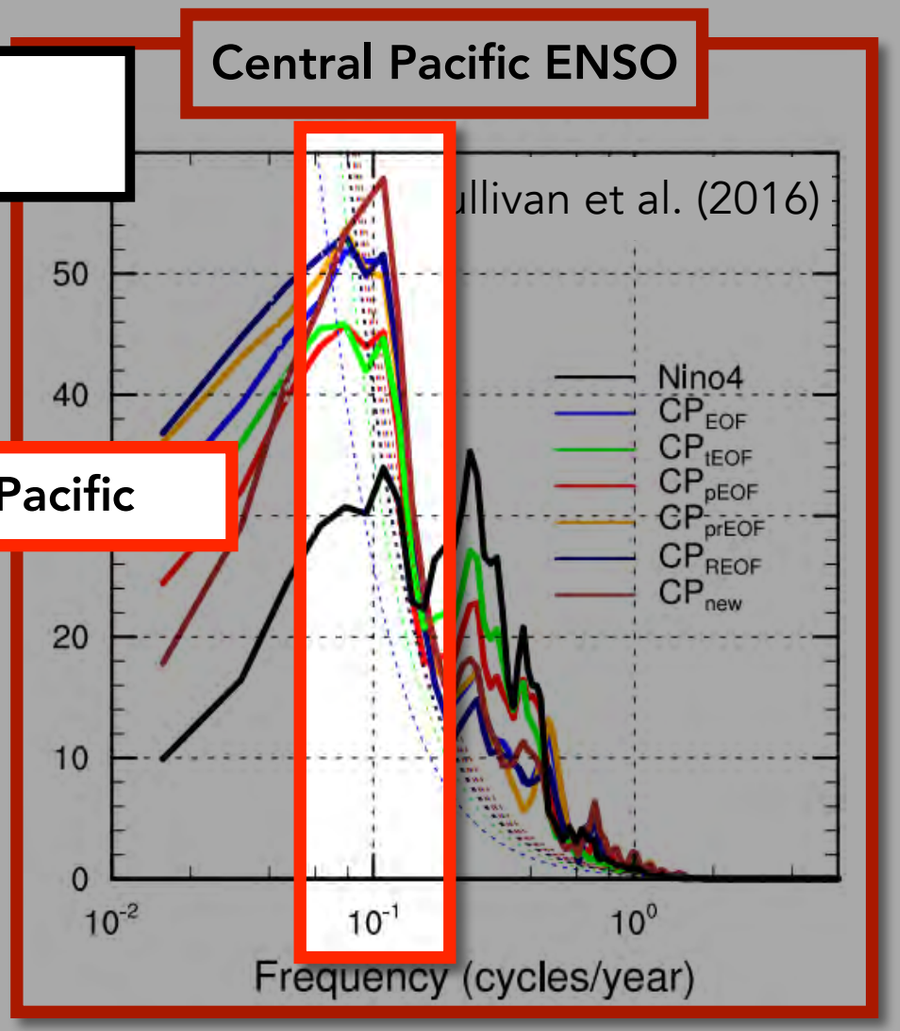
-0.4 0.4

~10 yr preferred decadal peak

KE

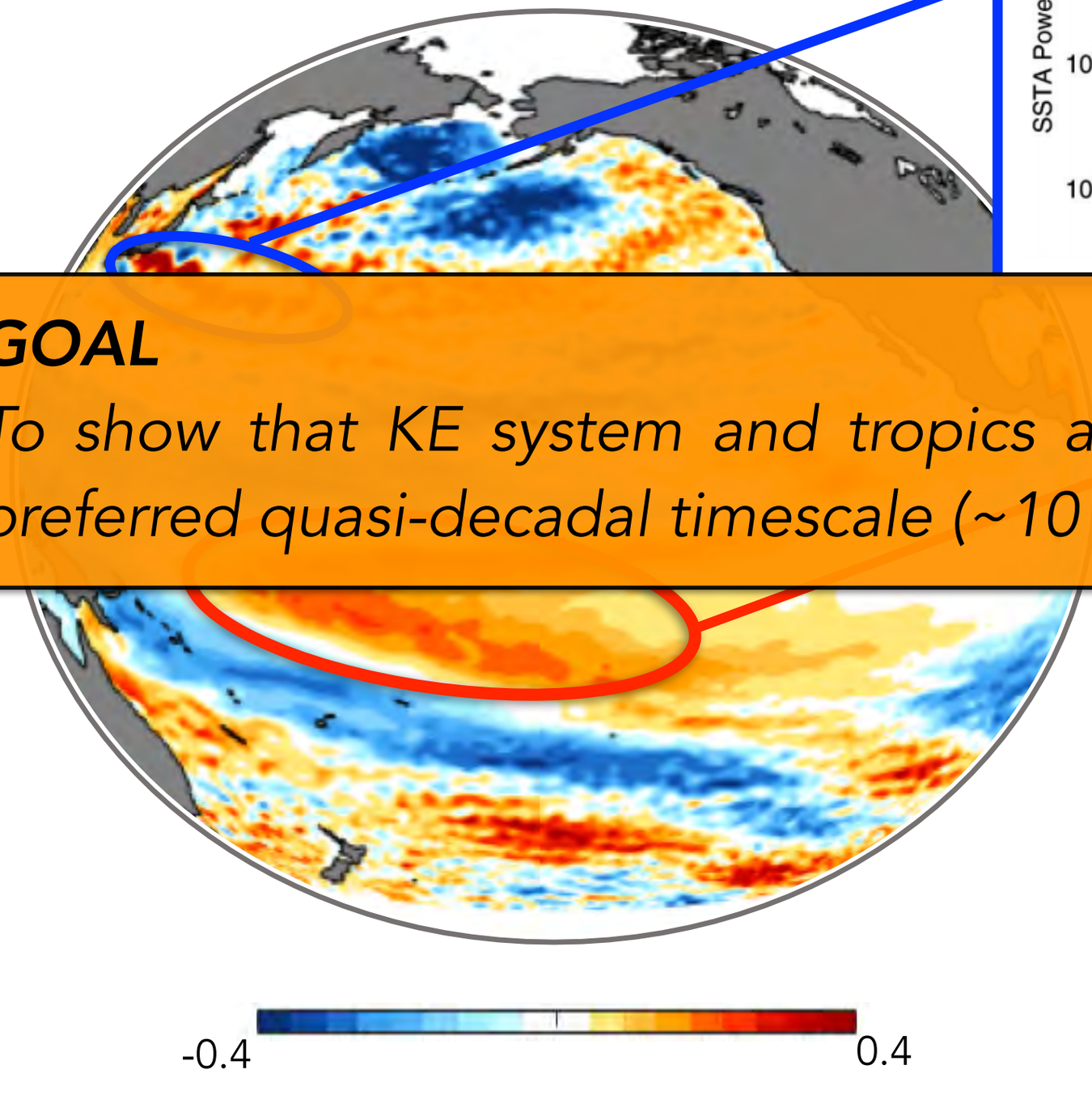


Central Pacific ENSO

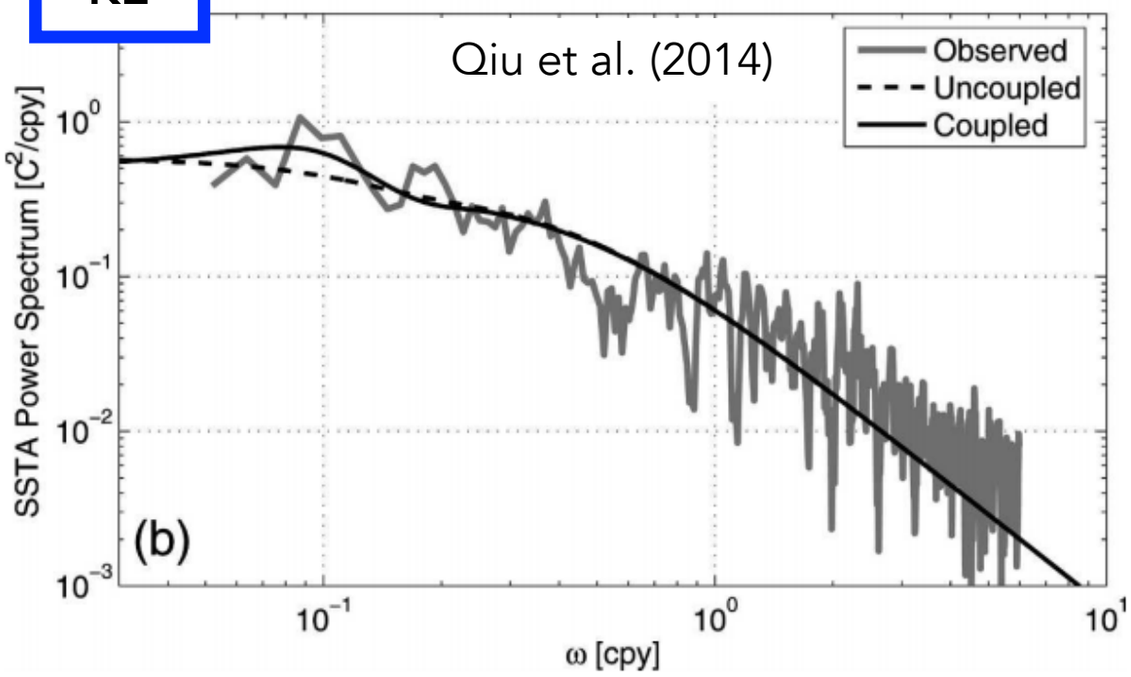


Central Pacific

Correlated SSHa to KE



KE

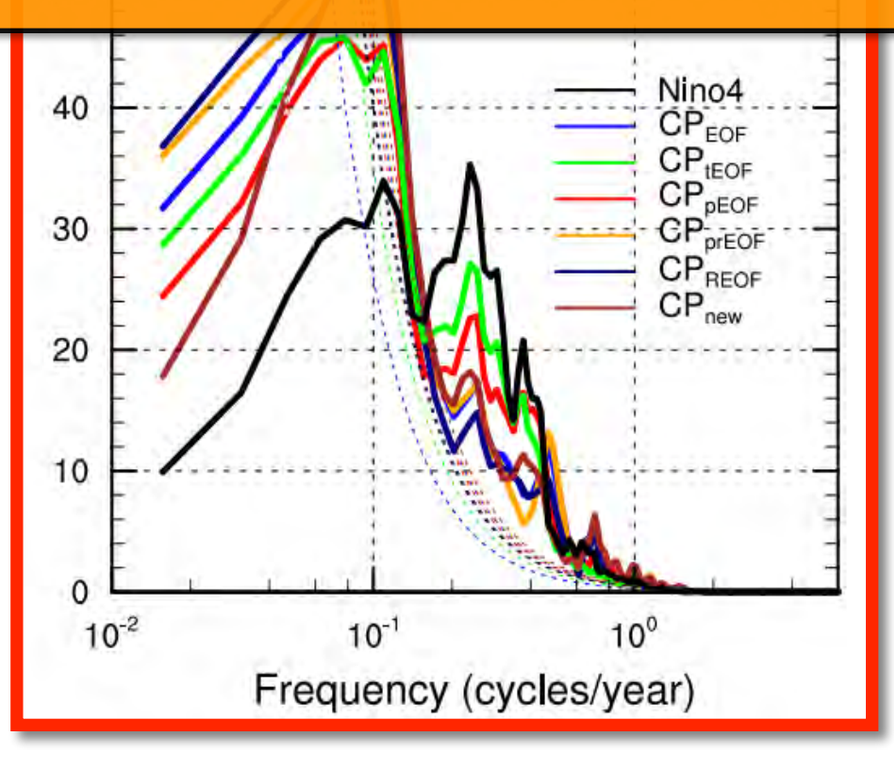


GOAL

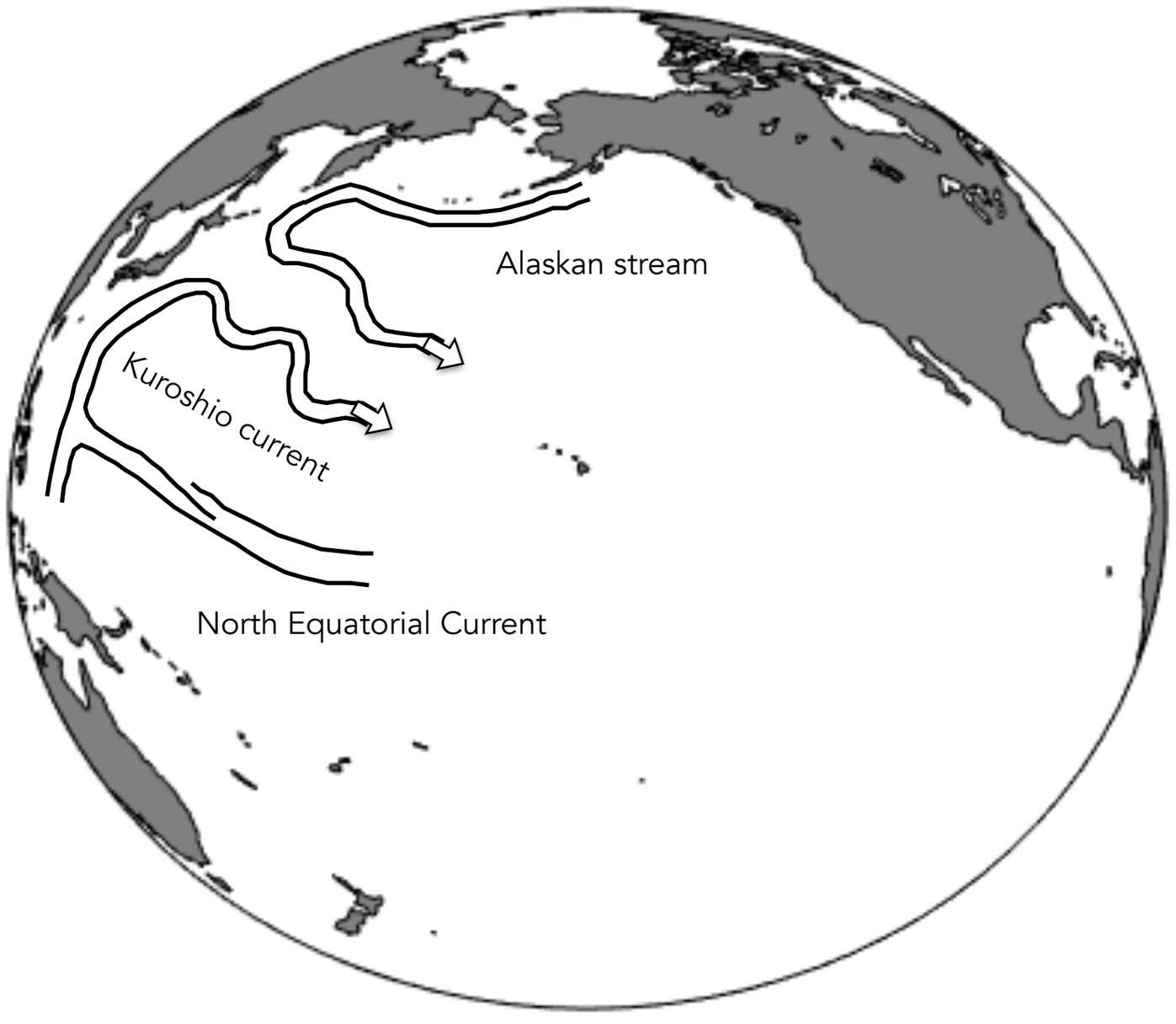
To show that KE system and tropics are linked and give raise to a preferred quasi-decadal timescale (~10 yr).

Central Pacific ENSO

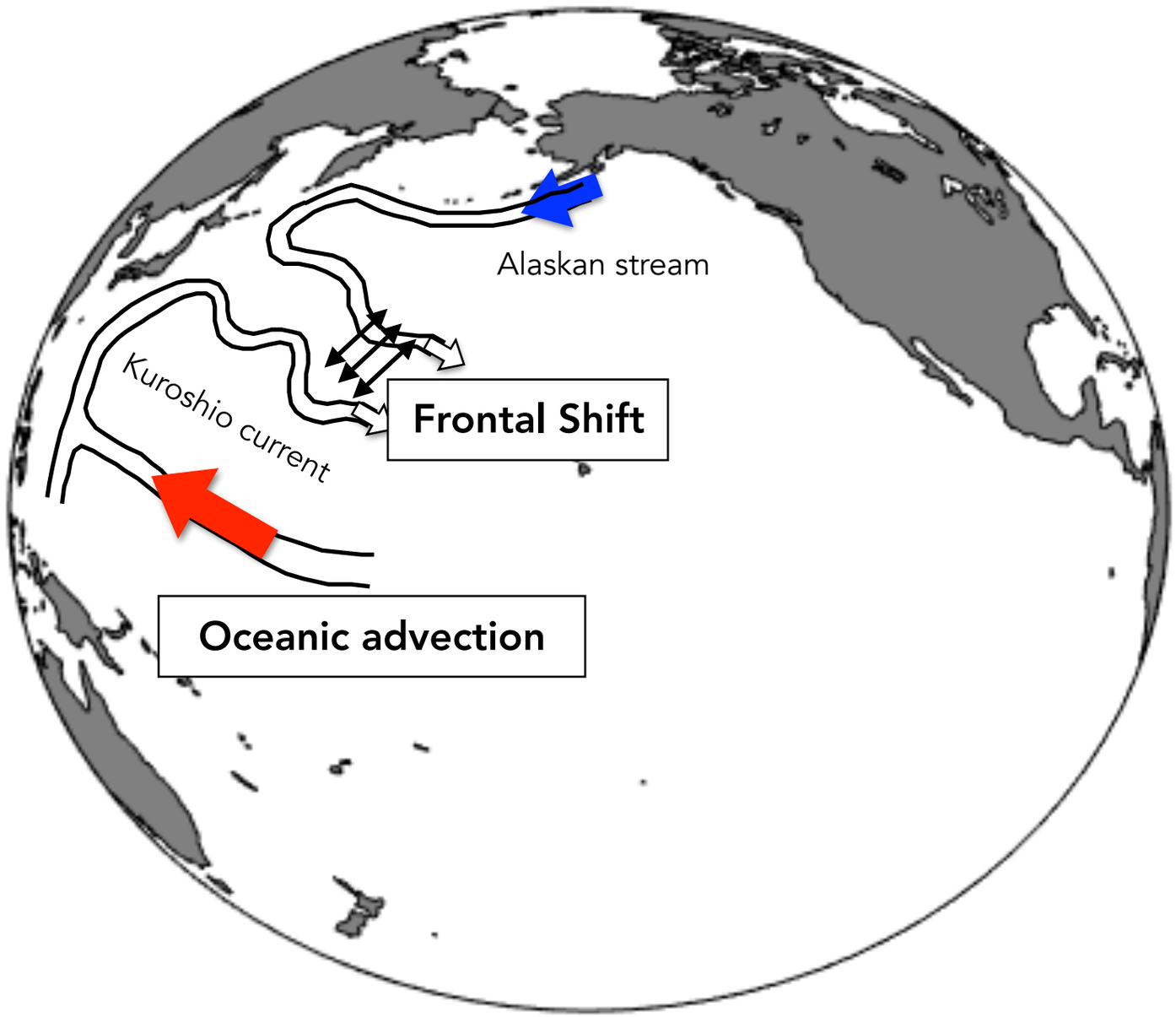
Sullivan et al. (2016)



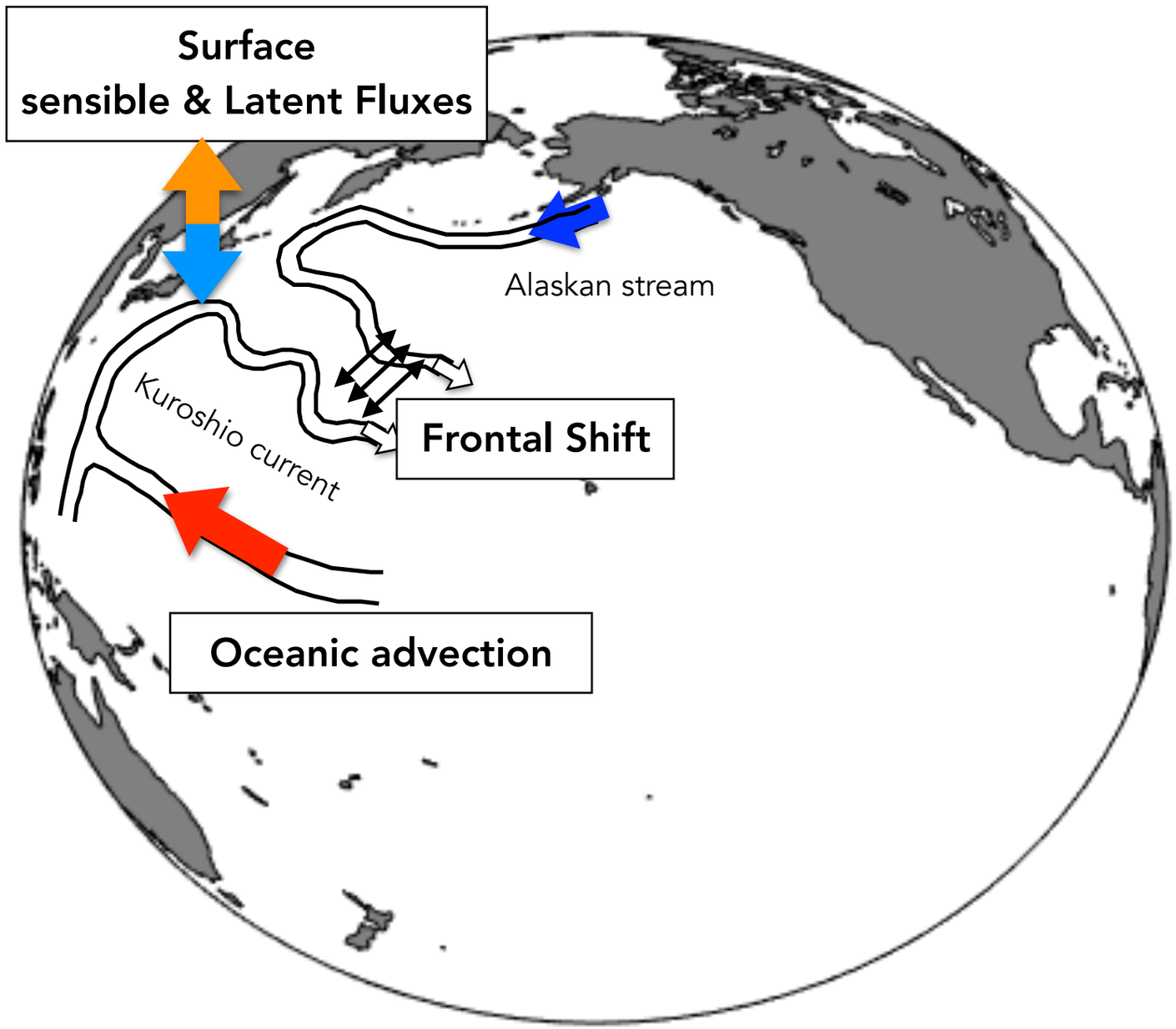
Forcing and Response



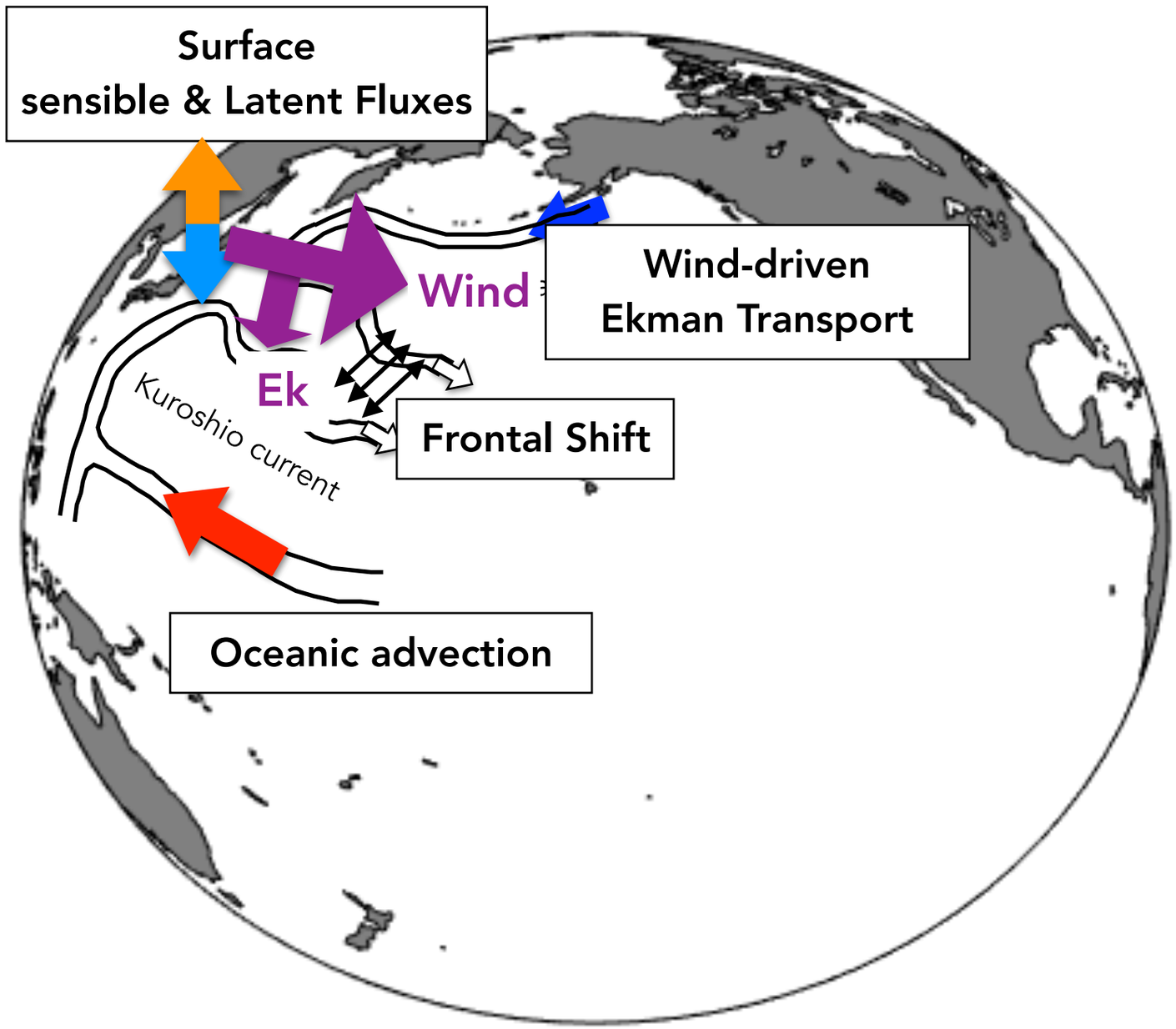
Forcing


Alaskan stream
Kuroshio current
Frontal Shift
Oceanic advection

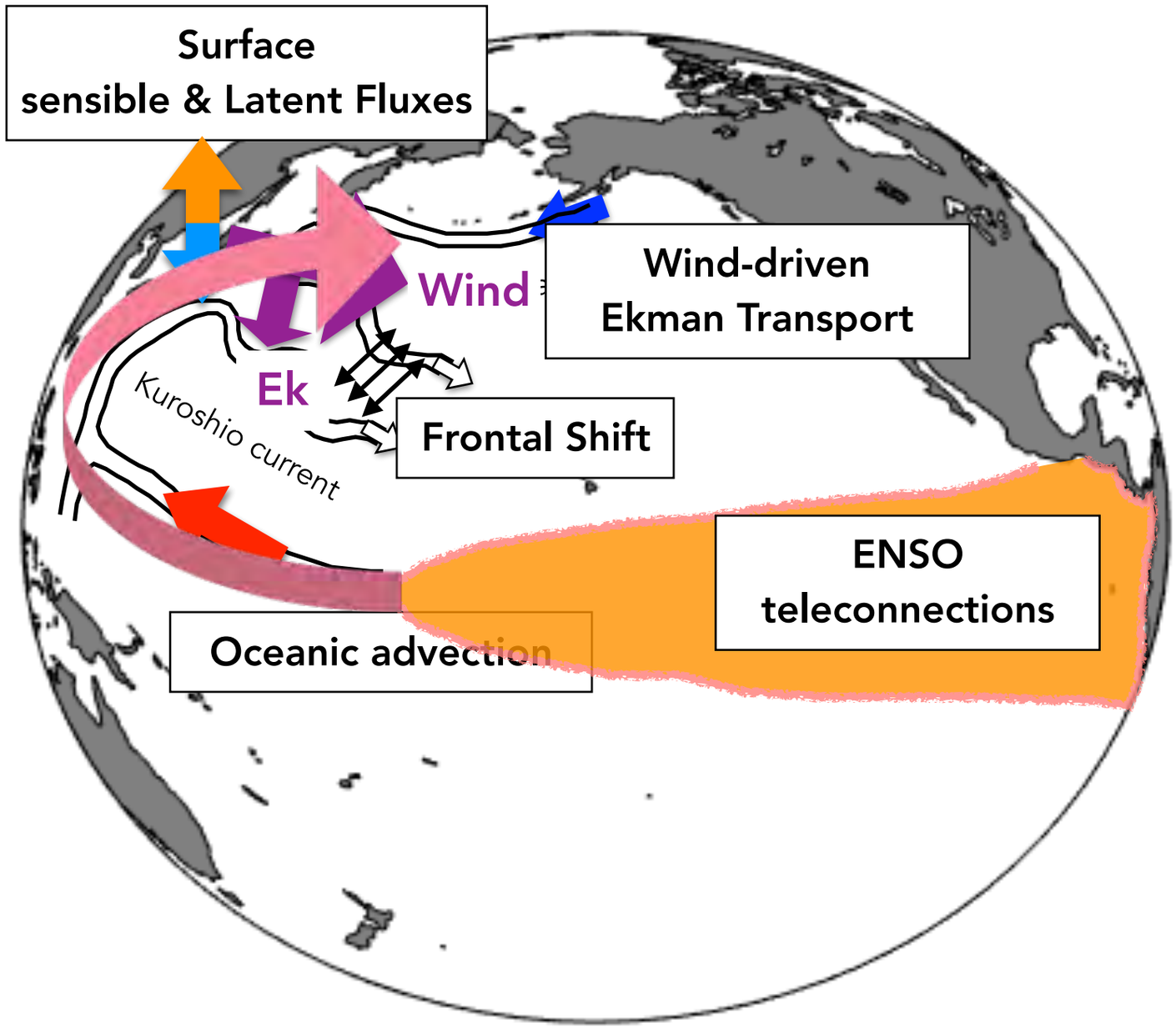
Forcing


Surface
sensible & Latent Fluxes
Alaskan stream
Kuroshio current
Frontal Shift
Oceanic advection

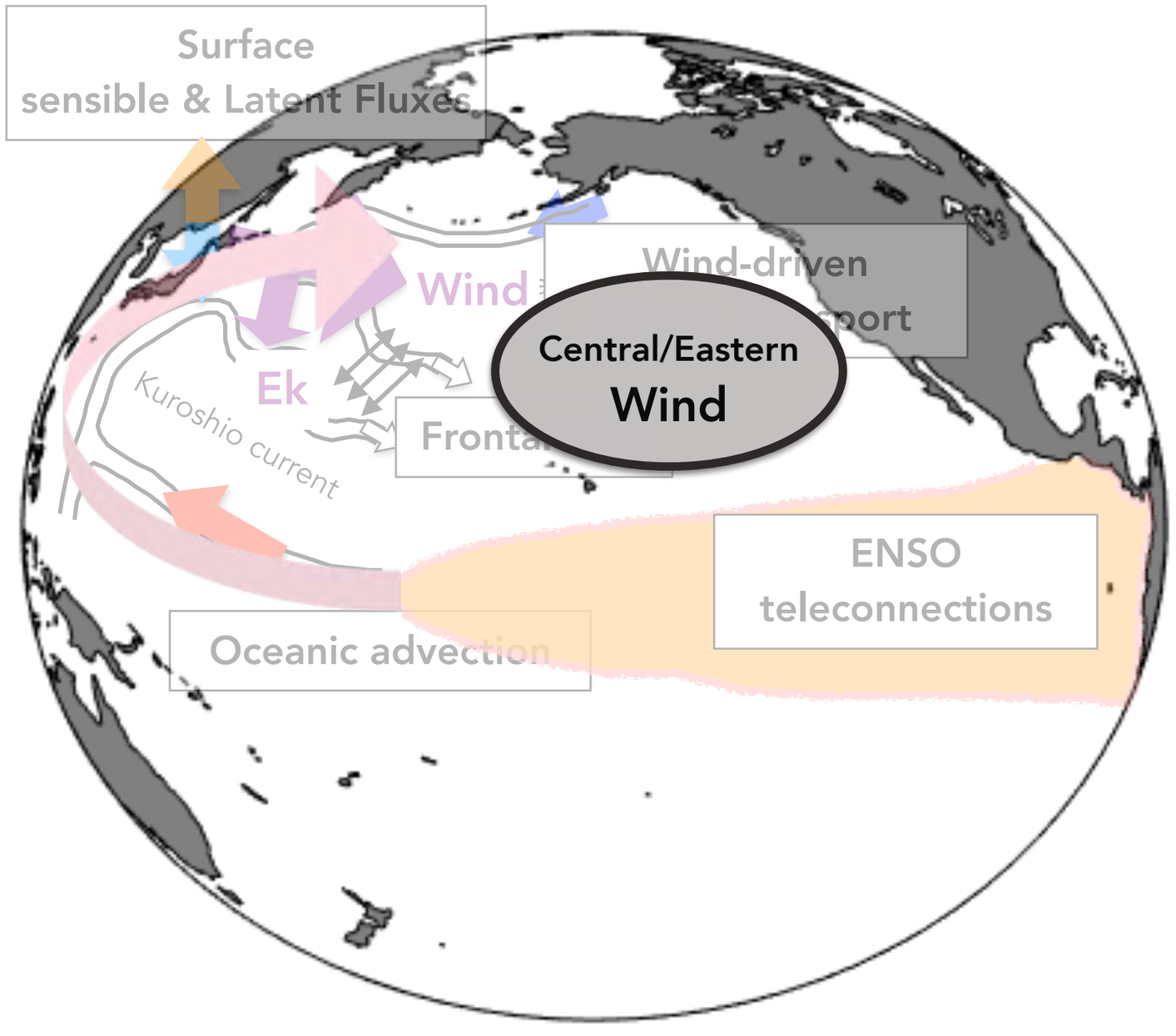
Forcing


Surface
sensible & Latent Fluxes
Wind
Wind-driven
Ekman Transport
Ek
Kuroshio current
Frontal Shift
Oceanic advection

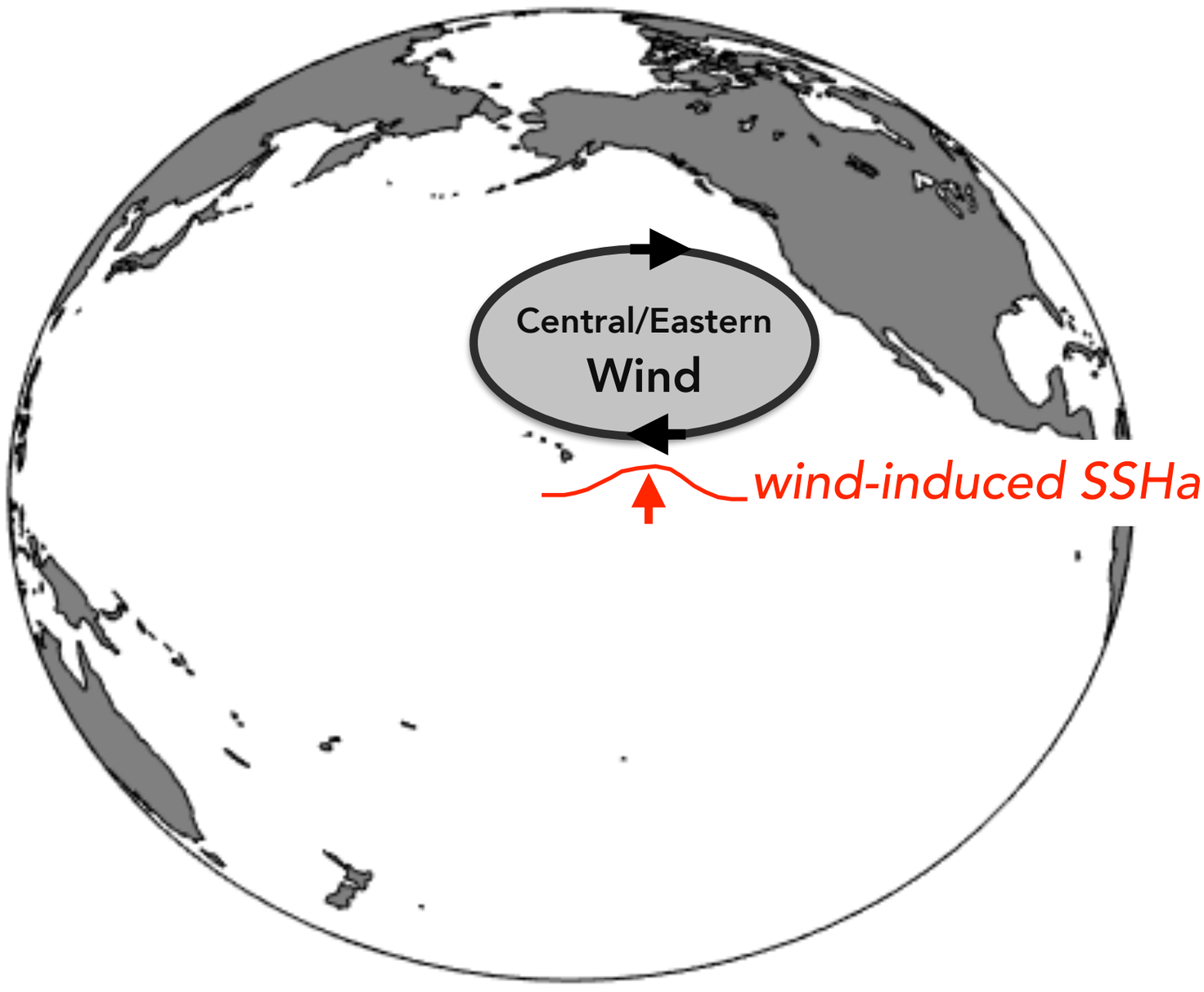
Forcing


Surface
sensible & Latent Fluxes
Wind
Wind-driven
Ekman Transport
Ek
Kuroshio current
Frontal Shift
ENSO
teleconnections
Oceanic advection

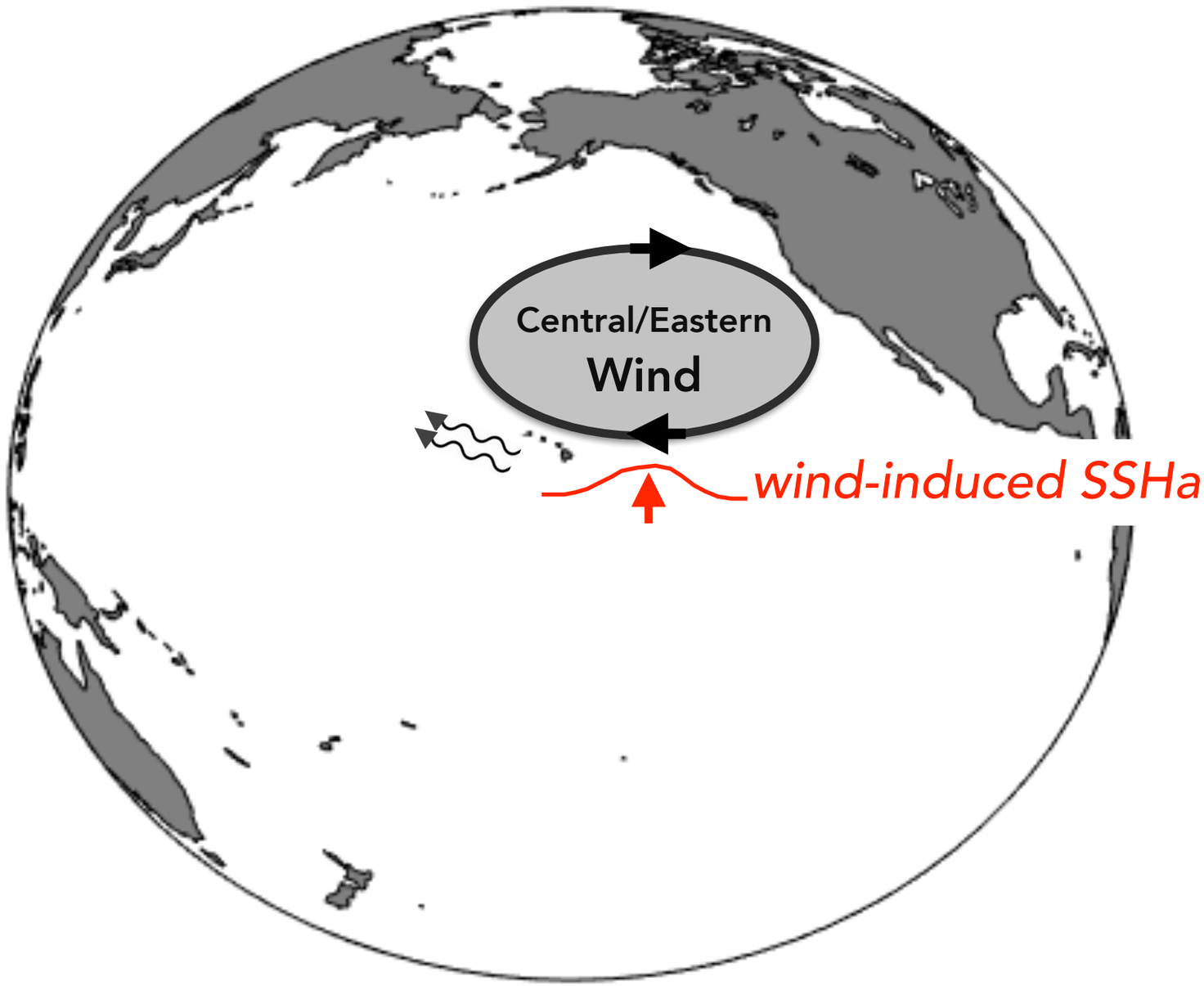
Forcing


Surface
sensible & Latent Fluxes
Wind
Ek
Kuroshio current
Wind-driven
Central/Eastern
Wind
ENSO
teleconnections
Oceanic advection

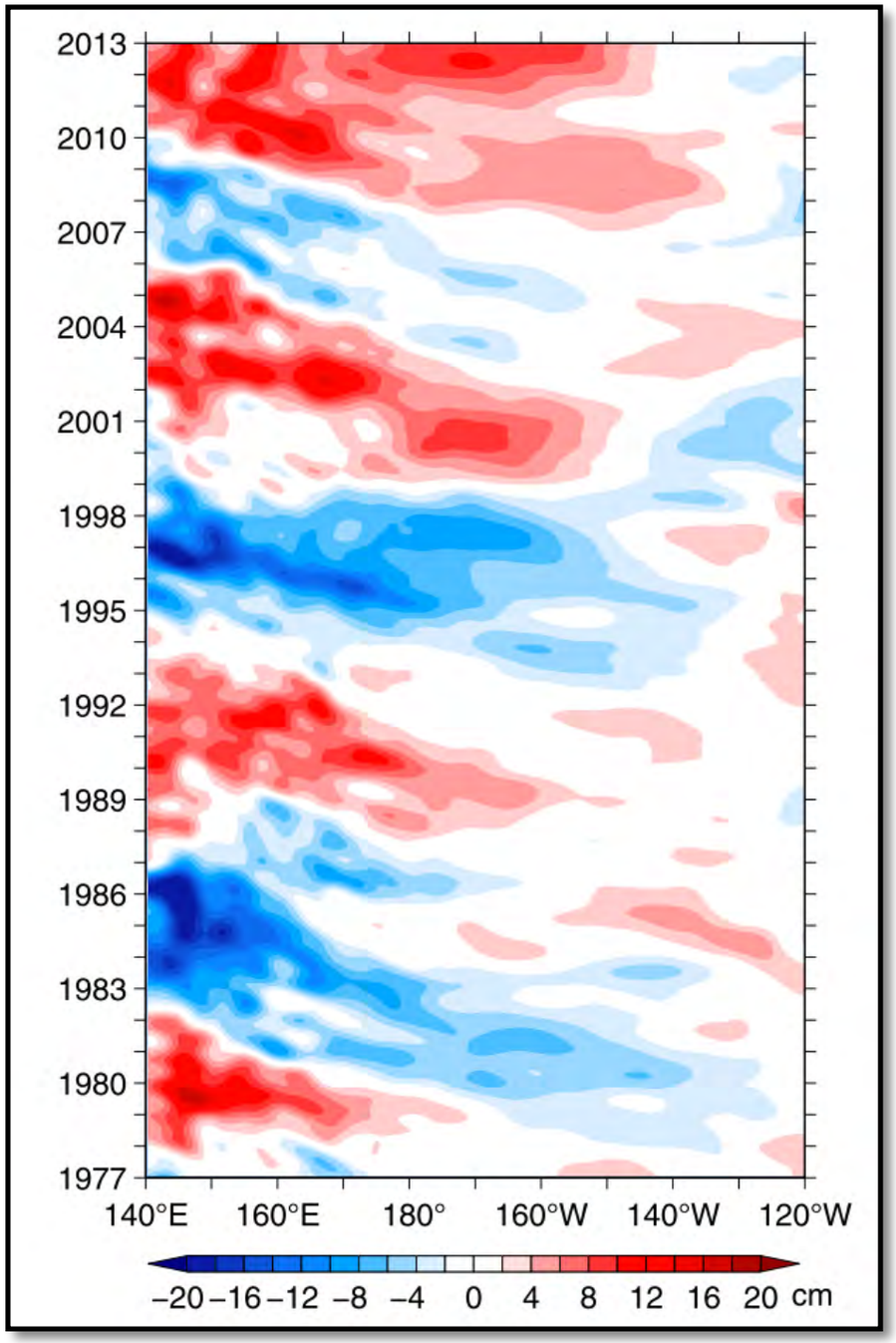
Forcing



Forcing

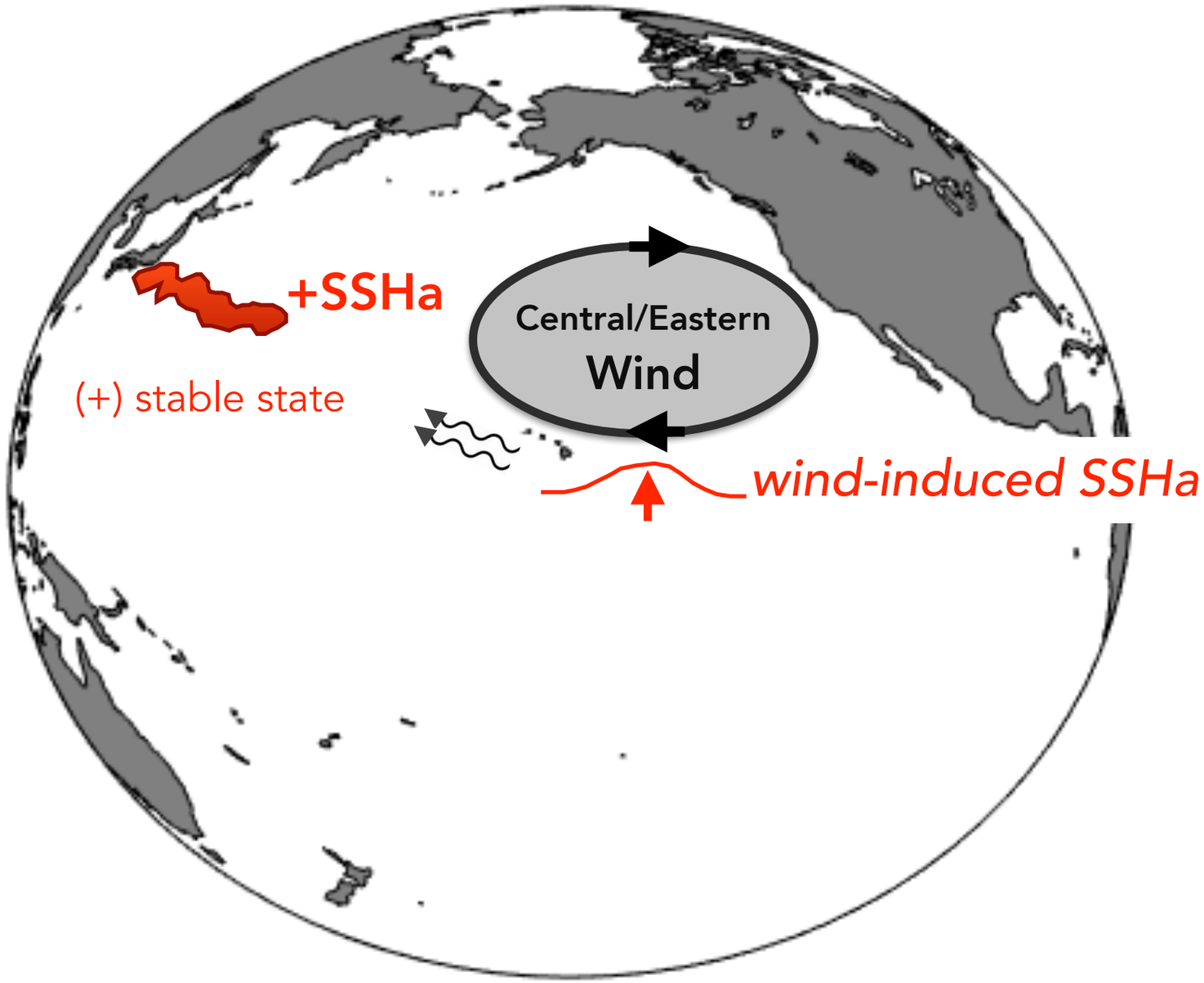


Low-pass filtered SSHa along the KE band

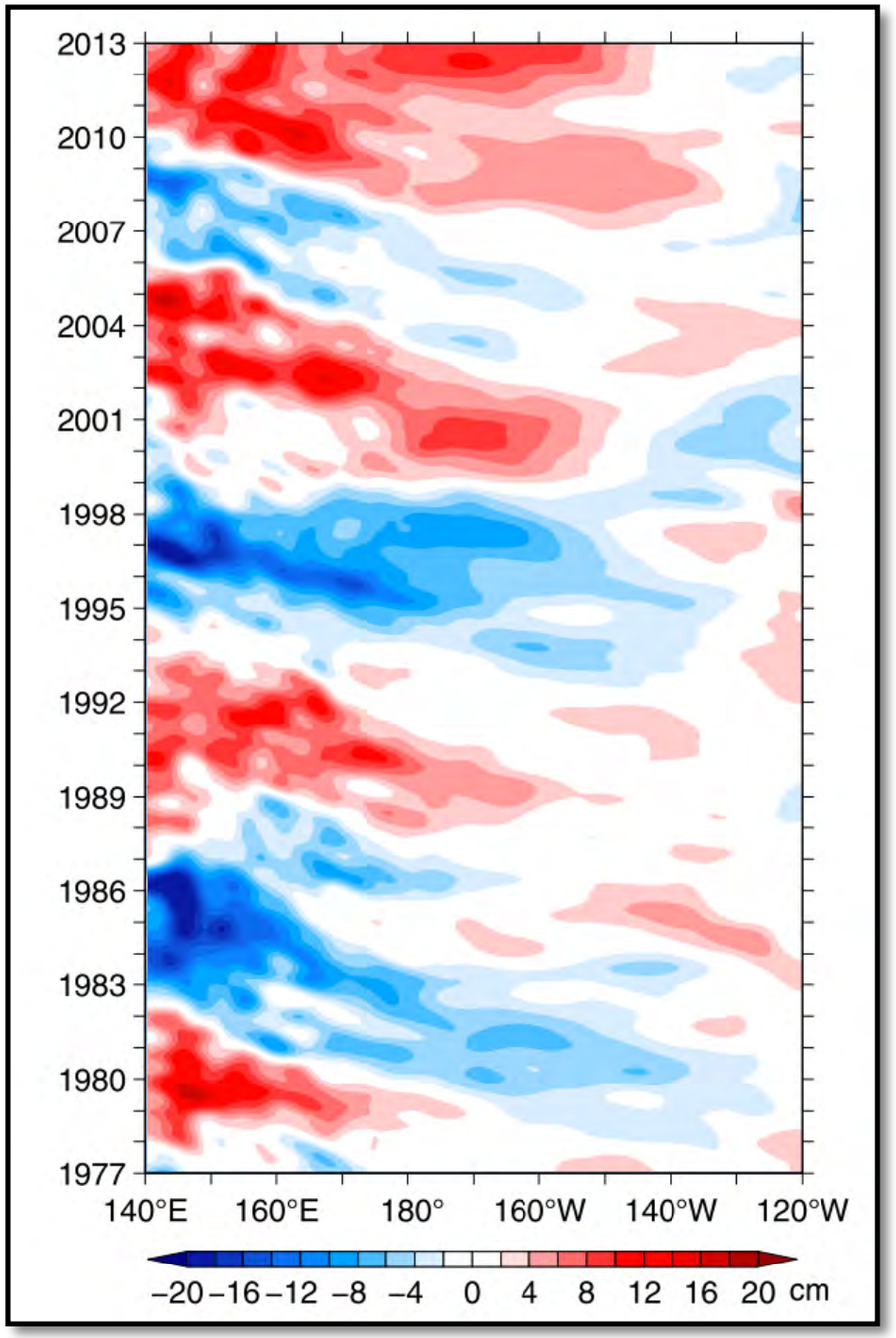


Qiu et al. (2014)

Forcing

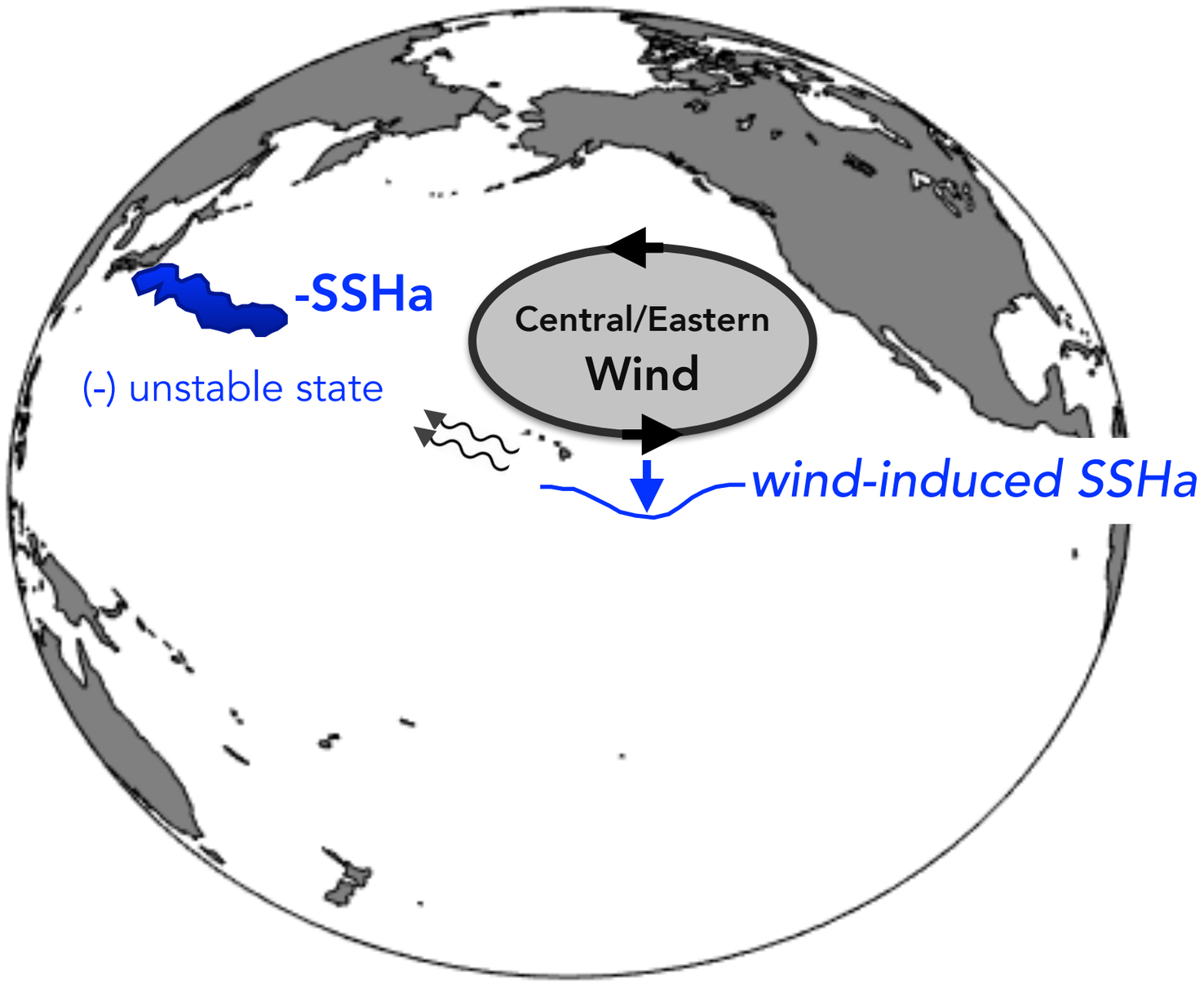


Low-pass filtered SSHa along the KE band

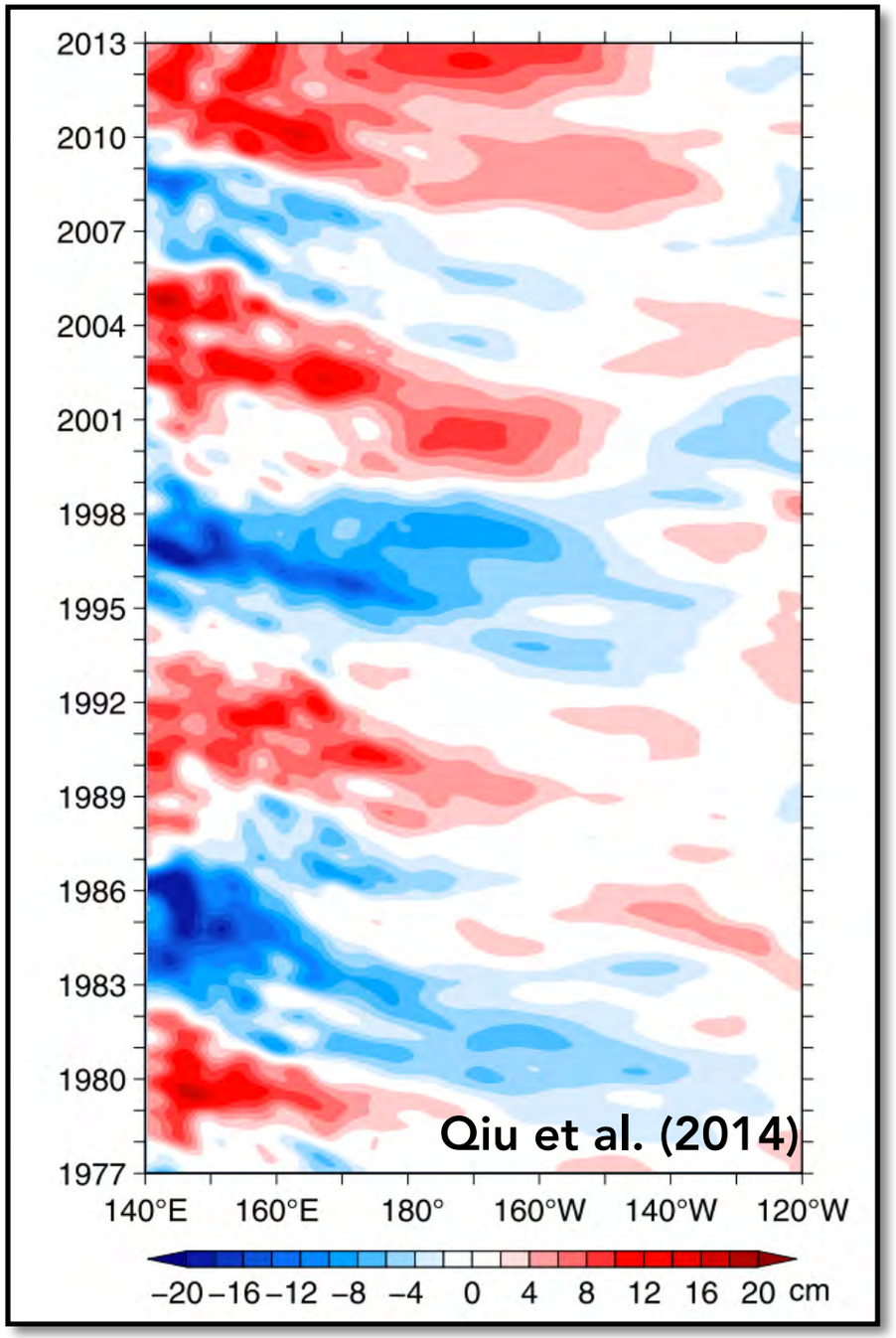


Qiu et al. (2014)

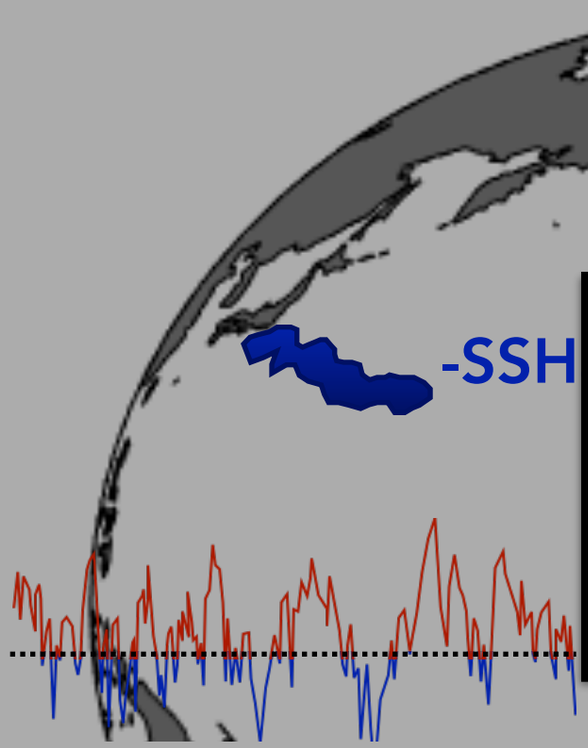
Forcing

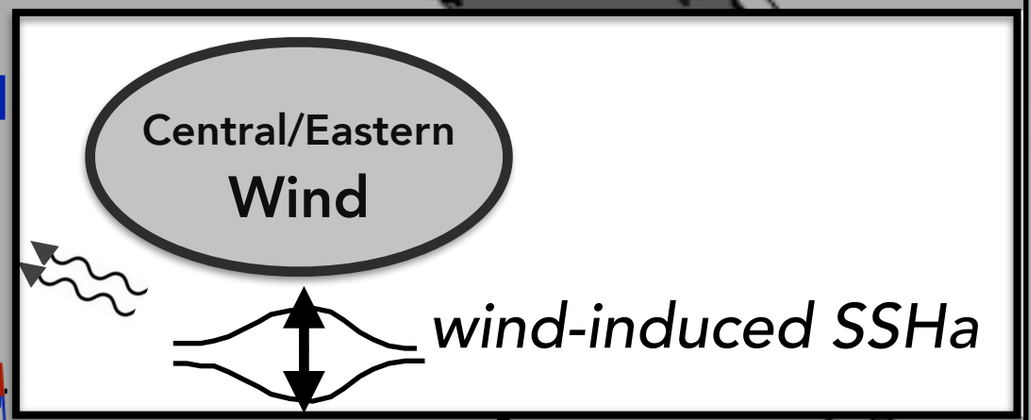


Low-pass filtered SSHa along the KE band

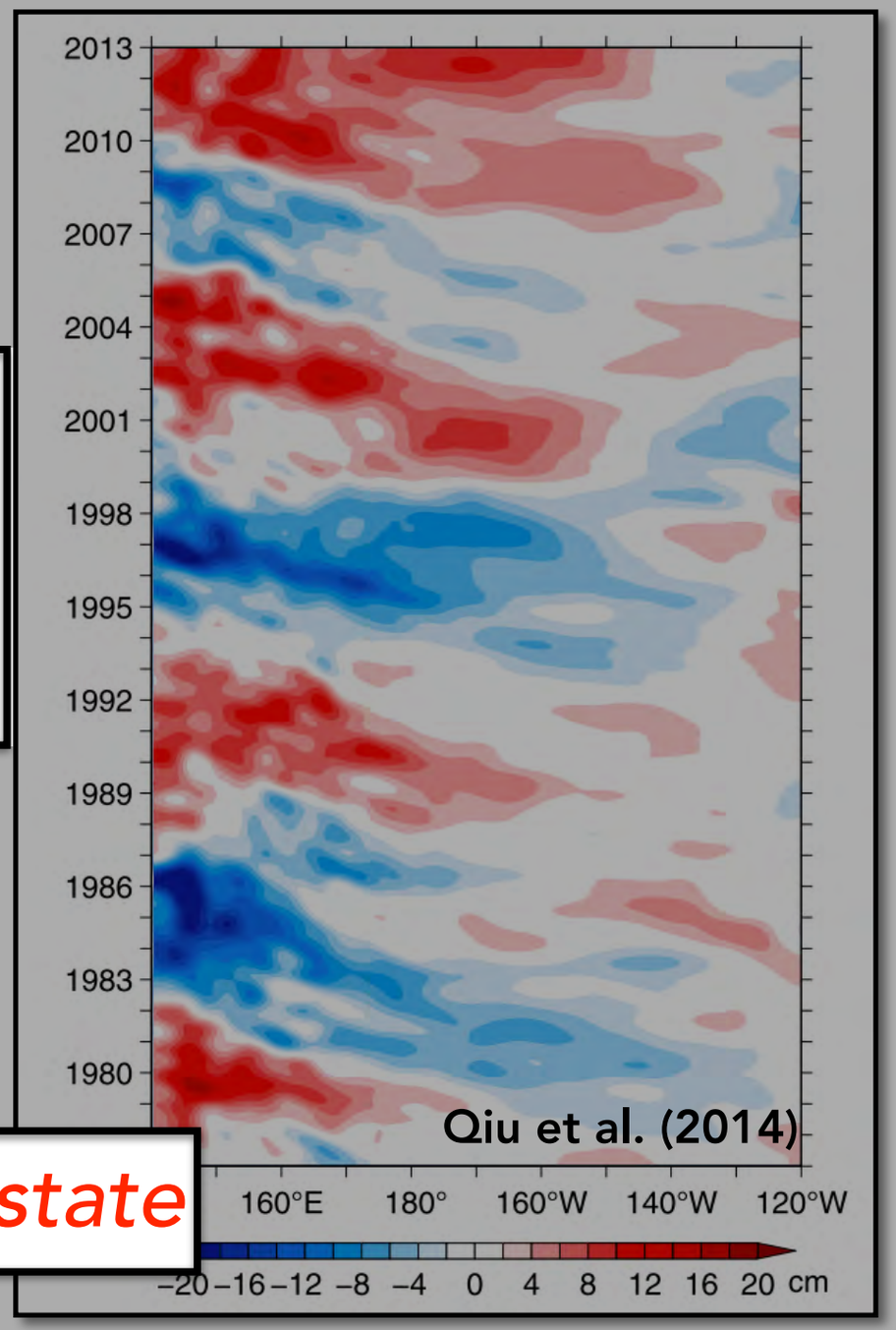


Forcing



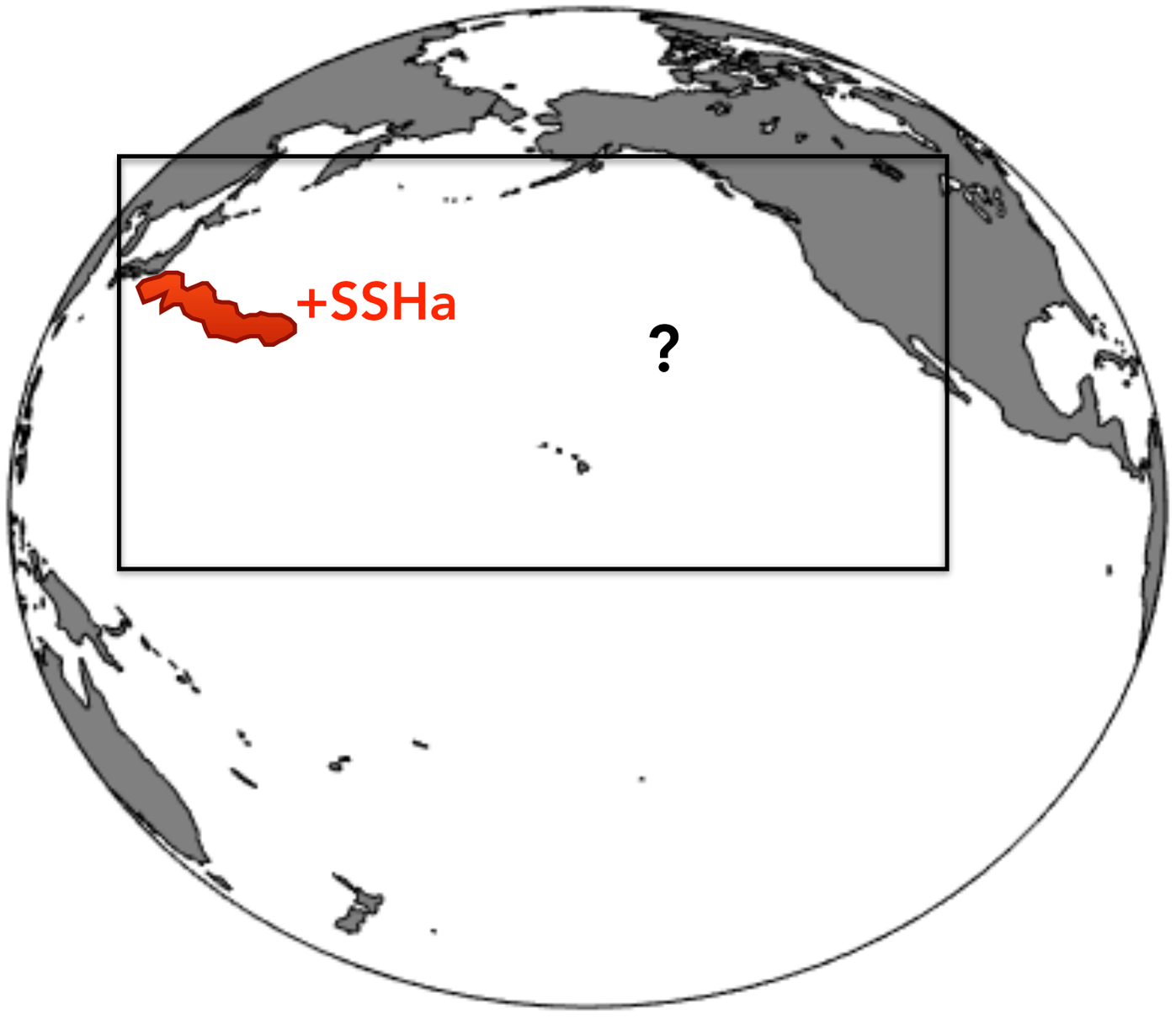


Low-pass filtered SSHa along the KE band

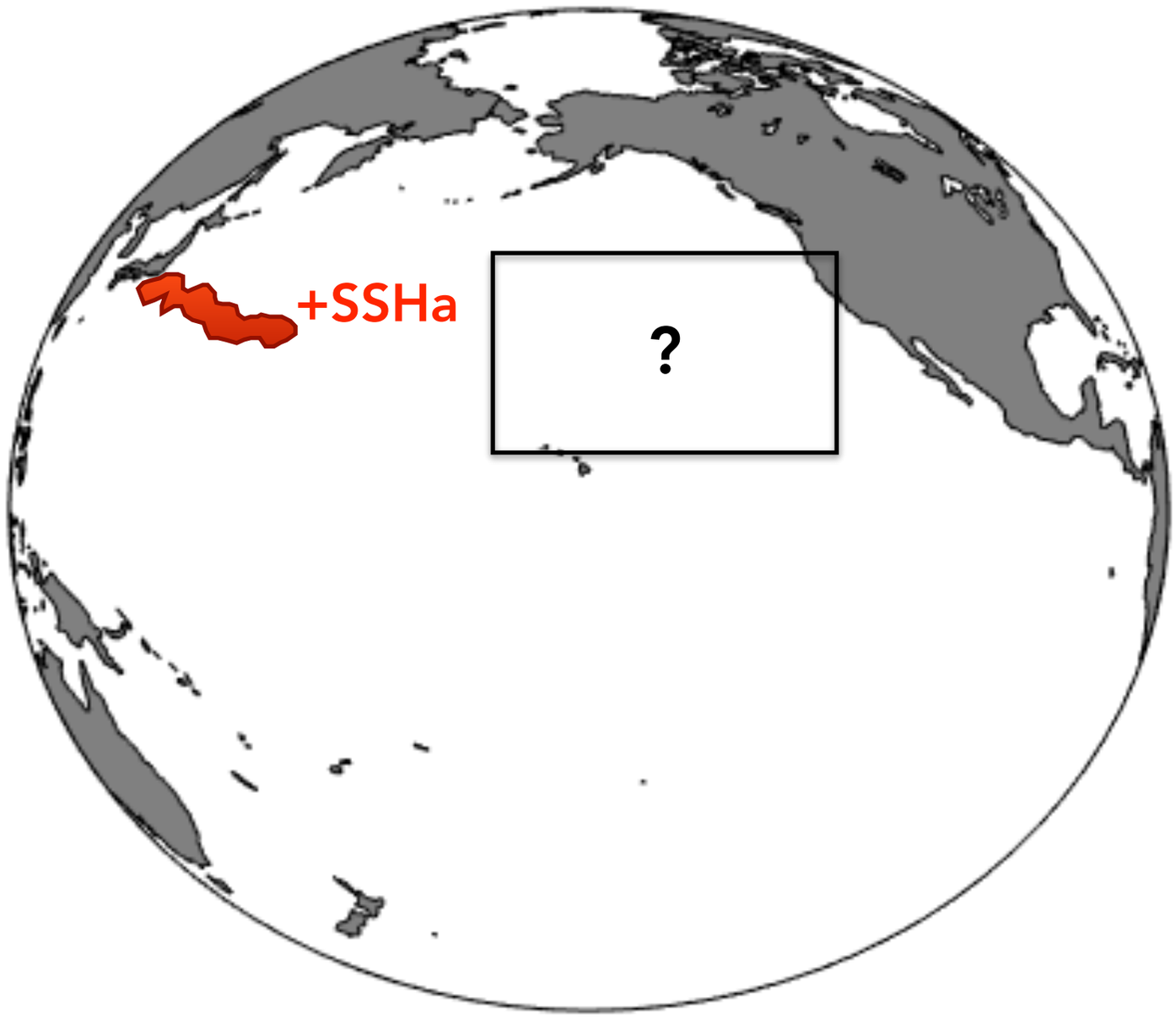


Decadal transition of KE dynamic state

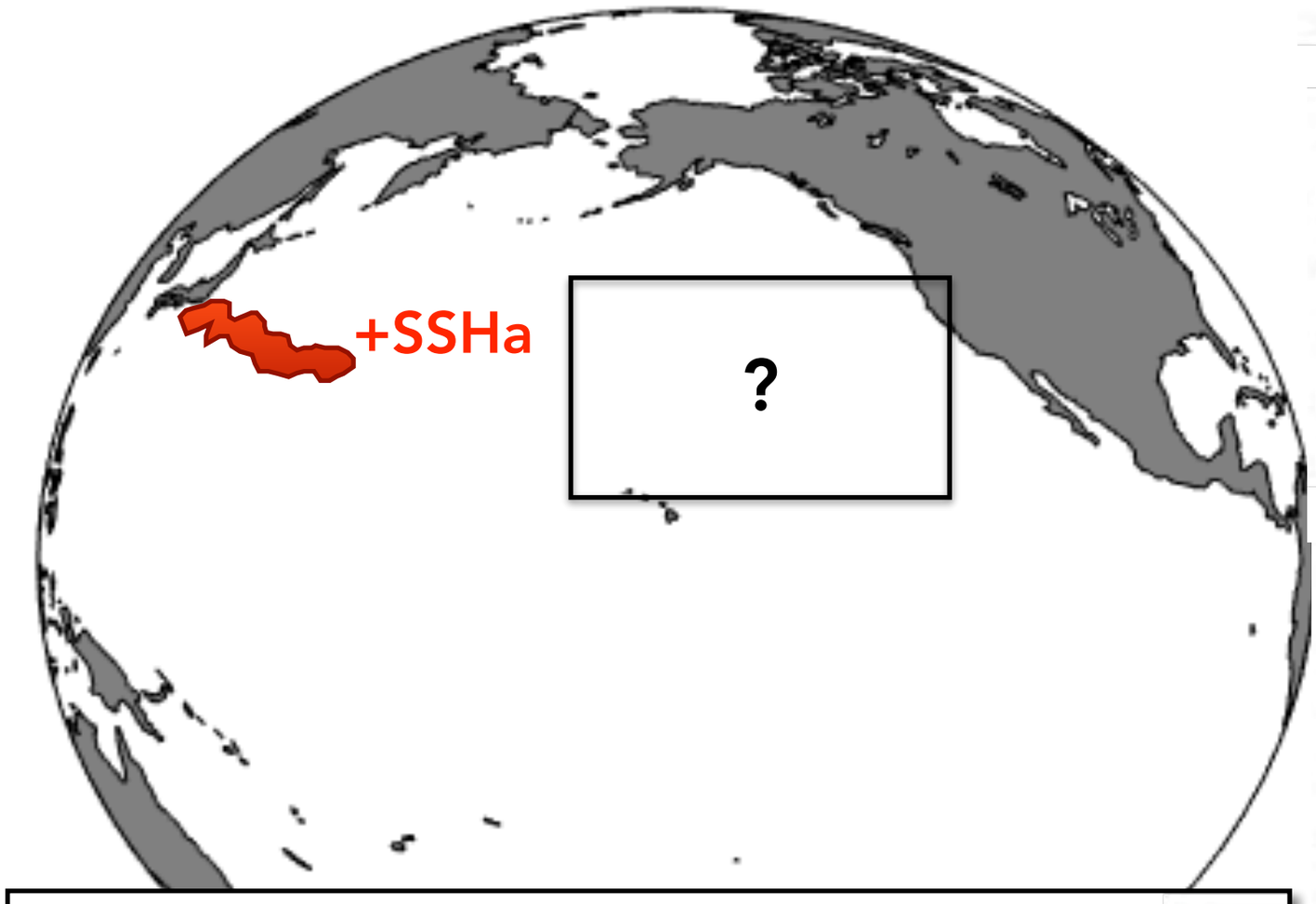
Response



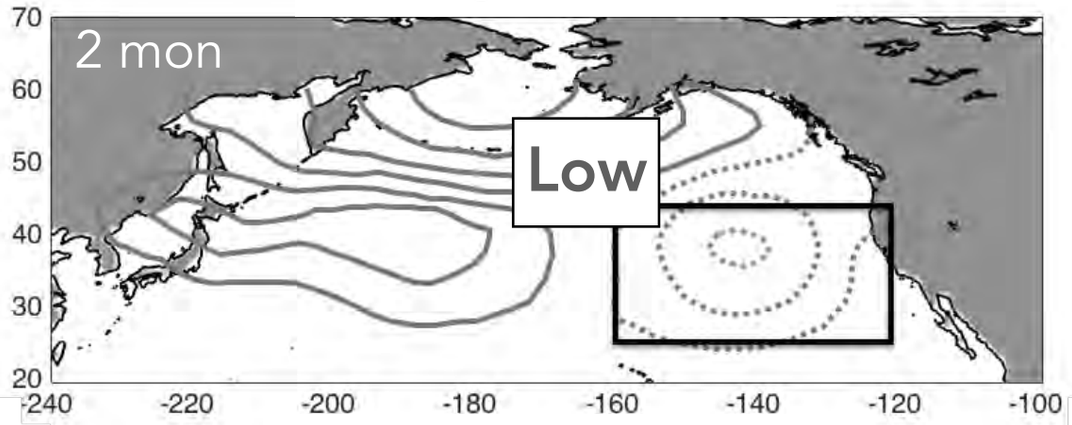
Response



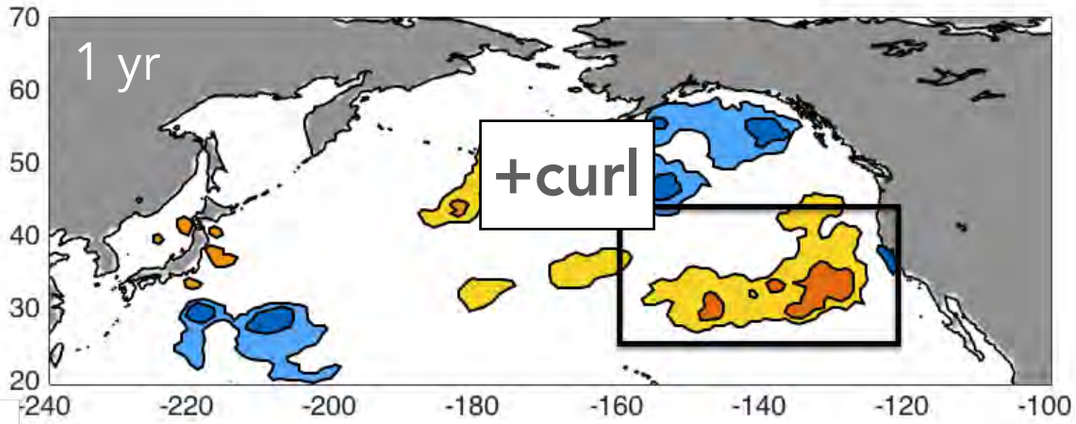
Response



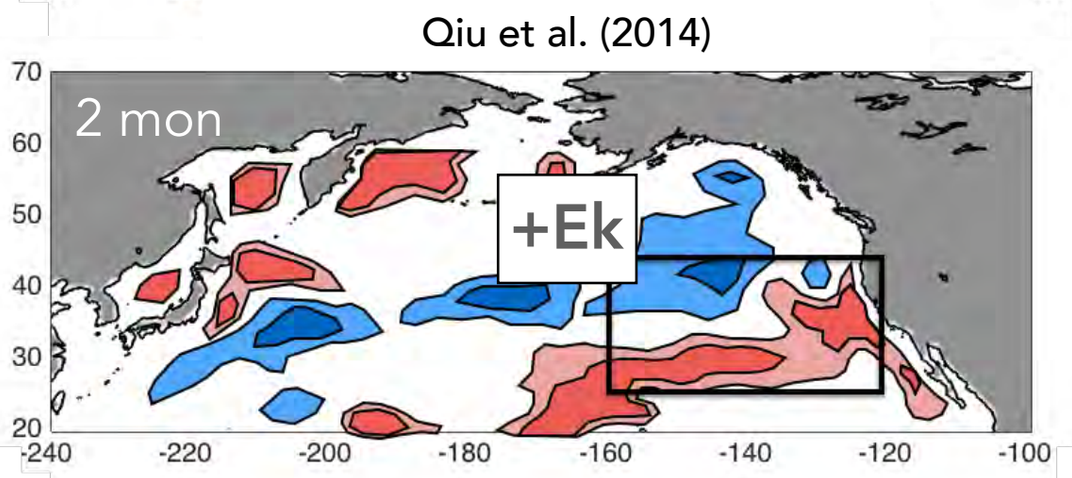
Frankignoul et al. 2010

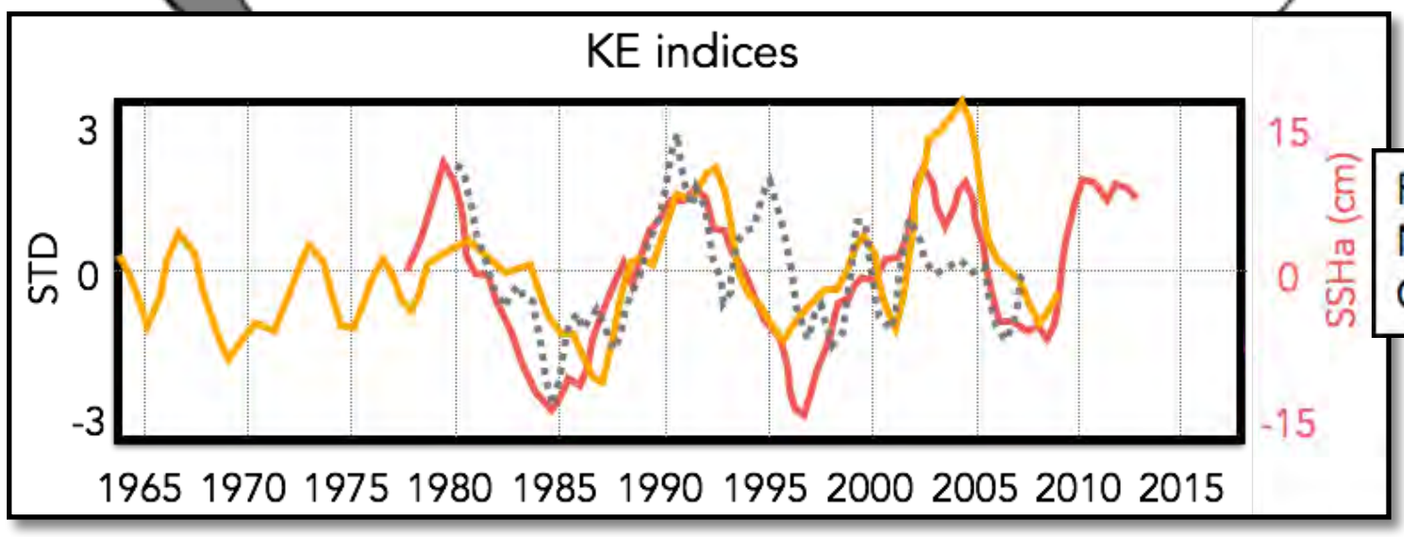


Na et al. (2018)

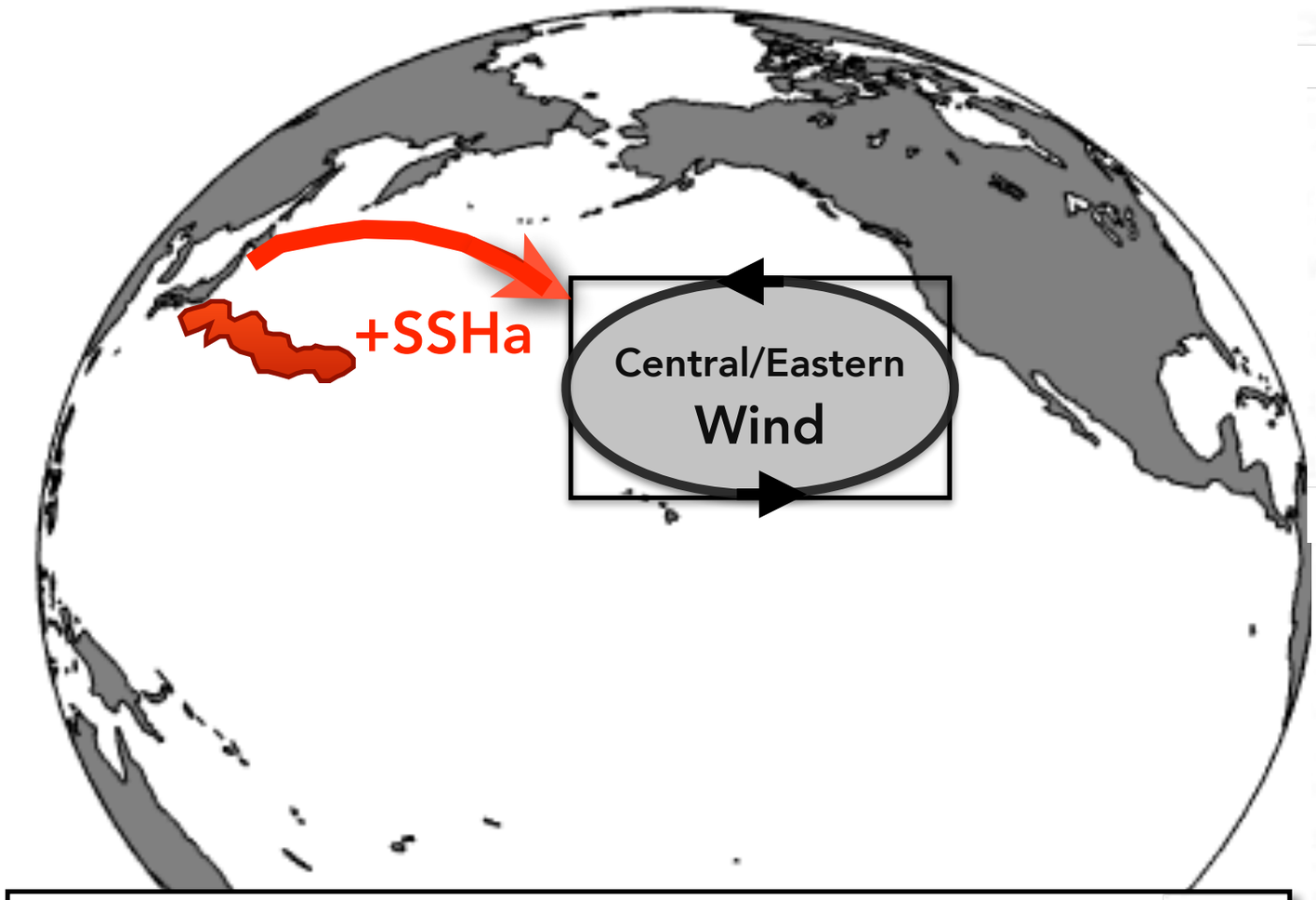


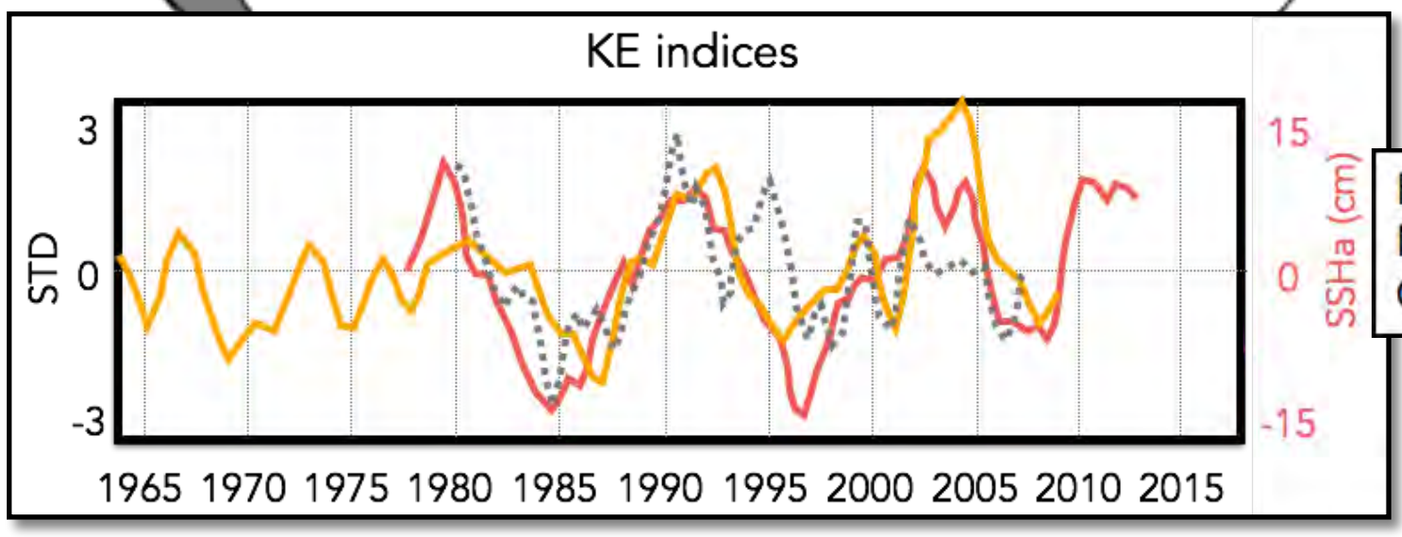
Qiu et al. (2014)



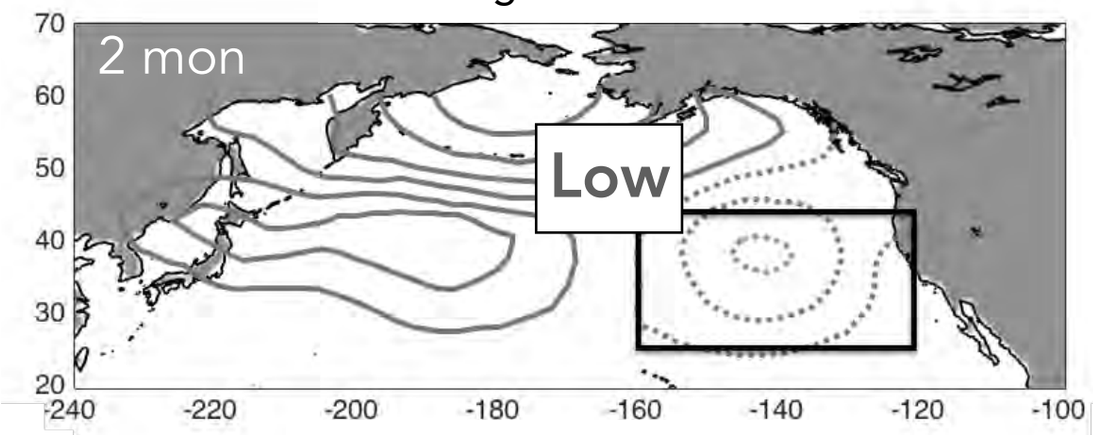


Response

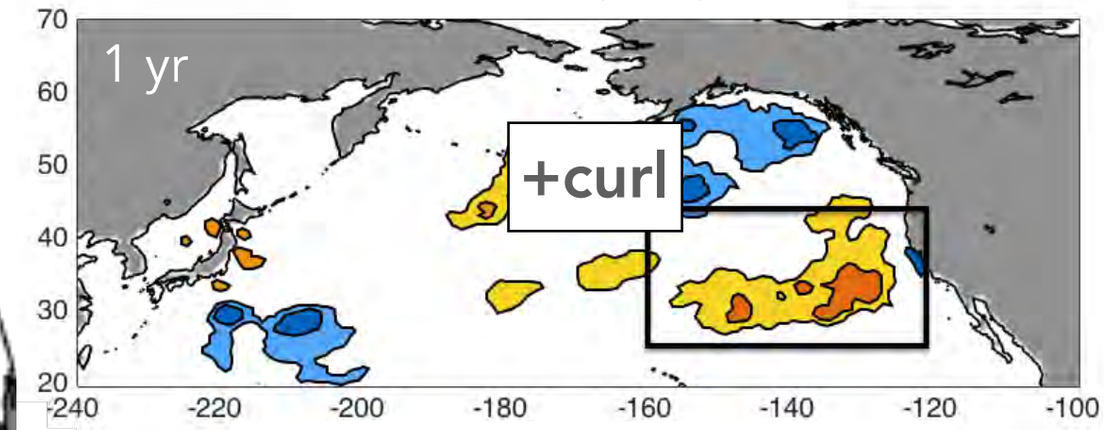




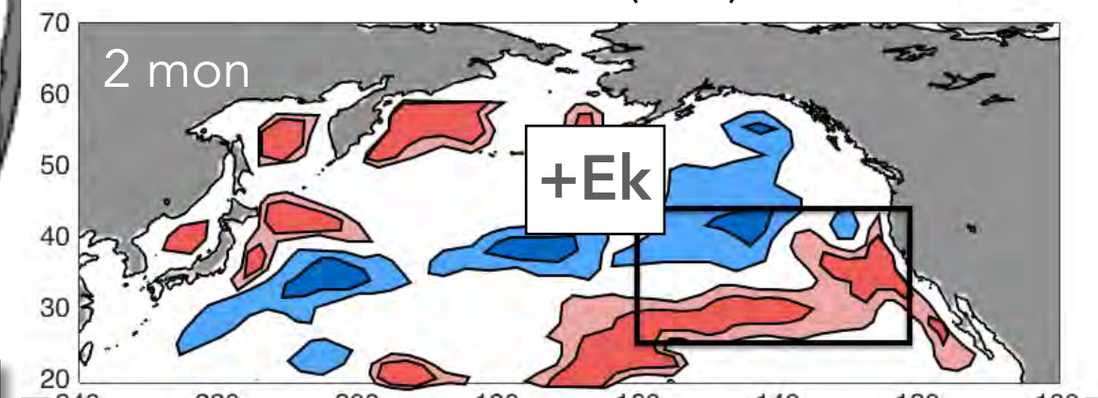
Frankignoul et al. 2010



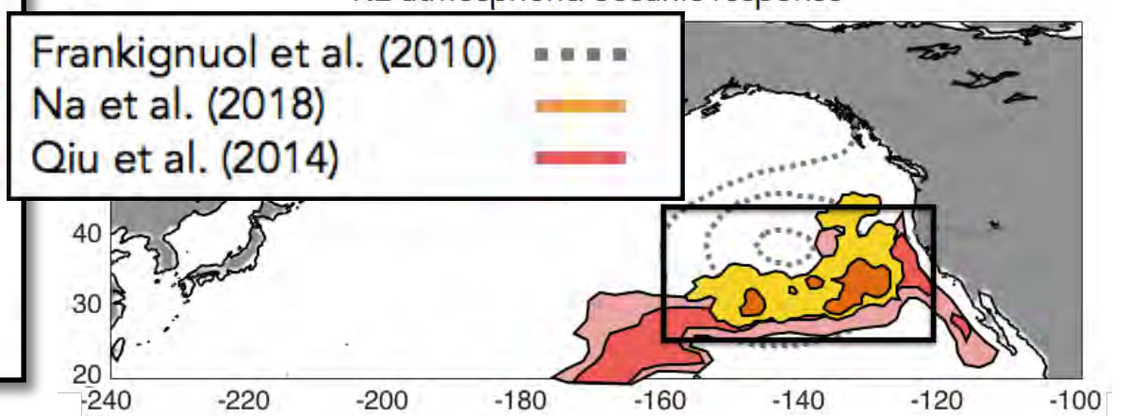
Na et al. (2018)



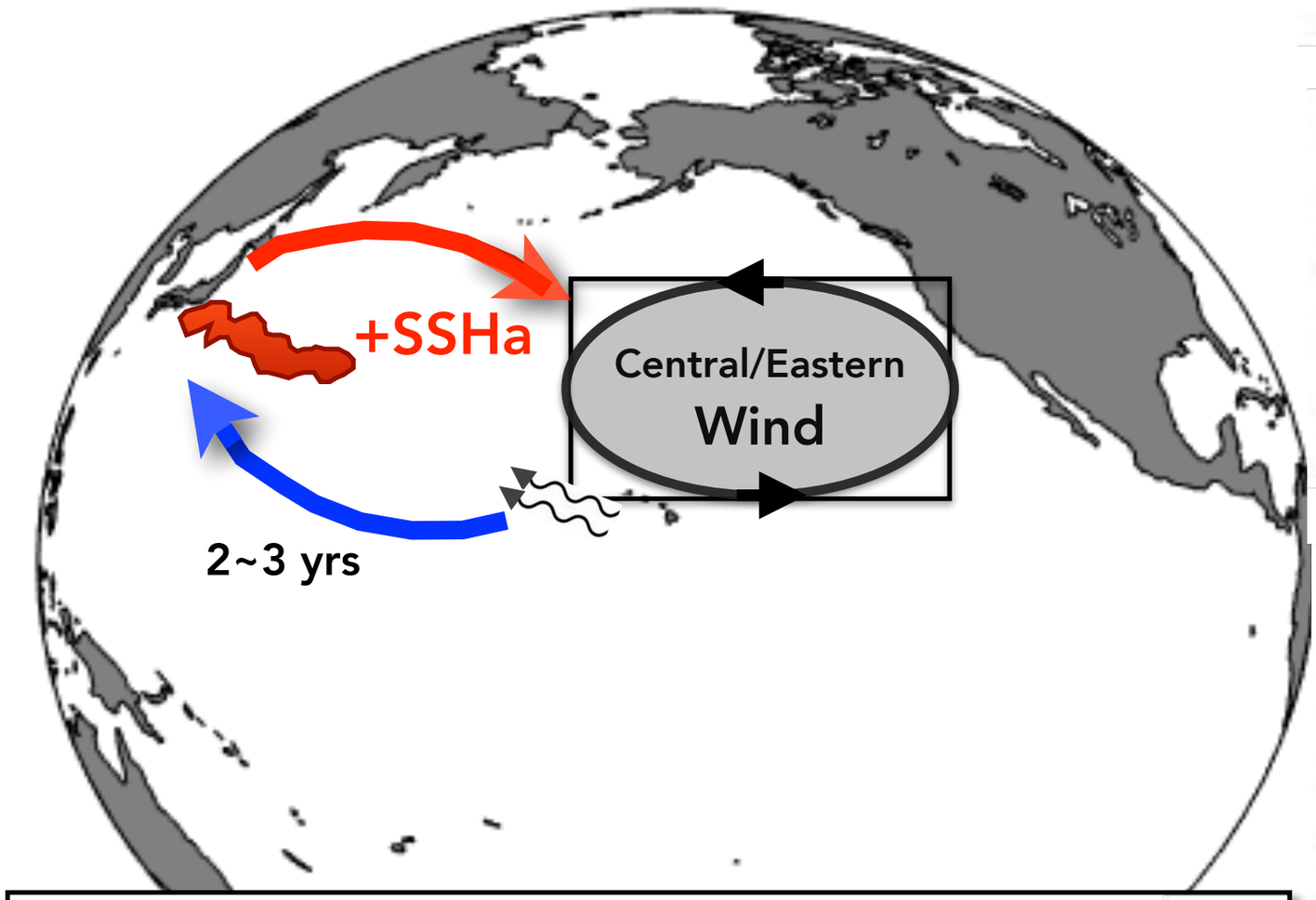
Qiu et al. (2014)



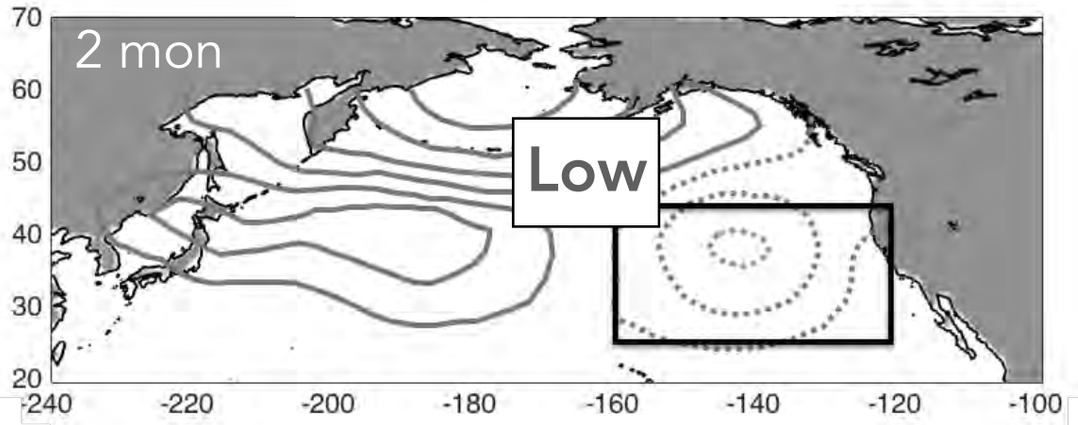
KE atmospheric/oceanic response



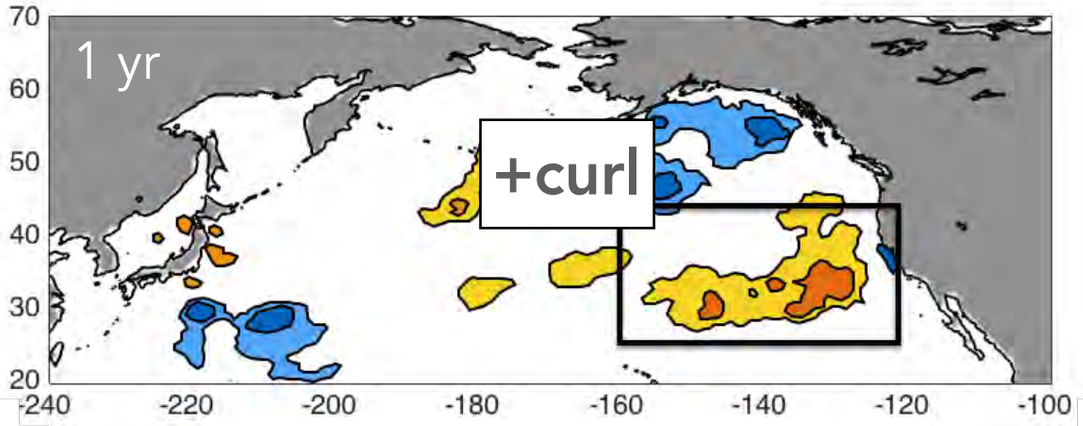
Response



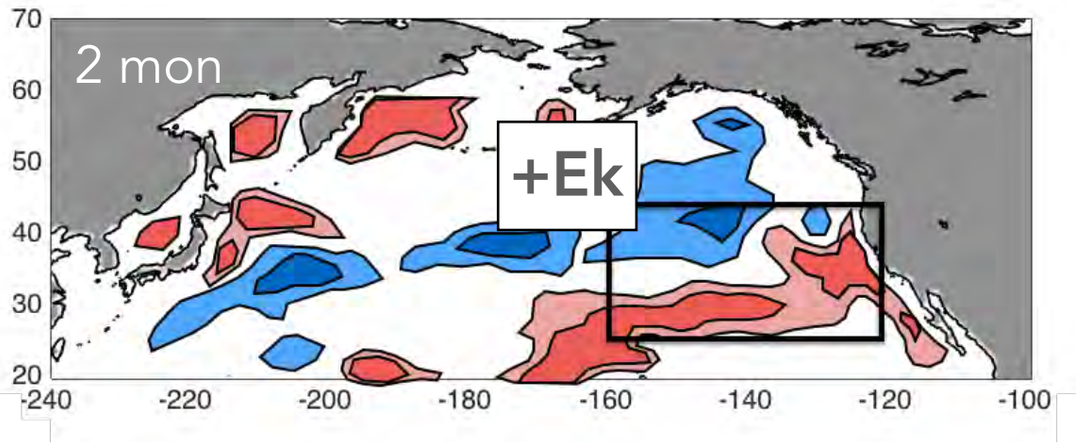
Frankignoul et al. 2010

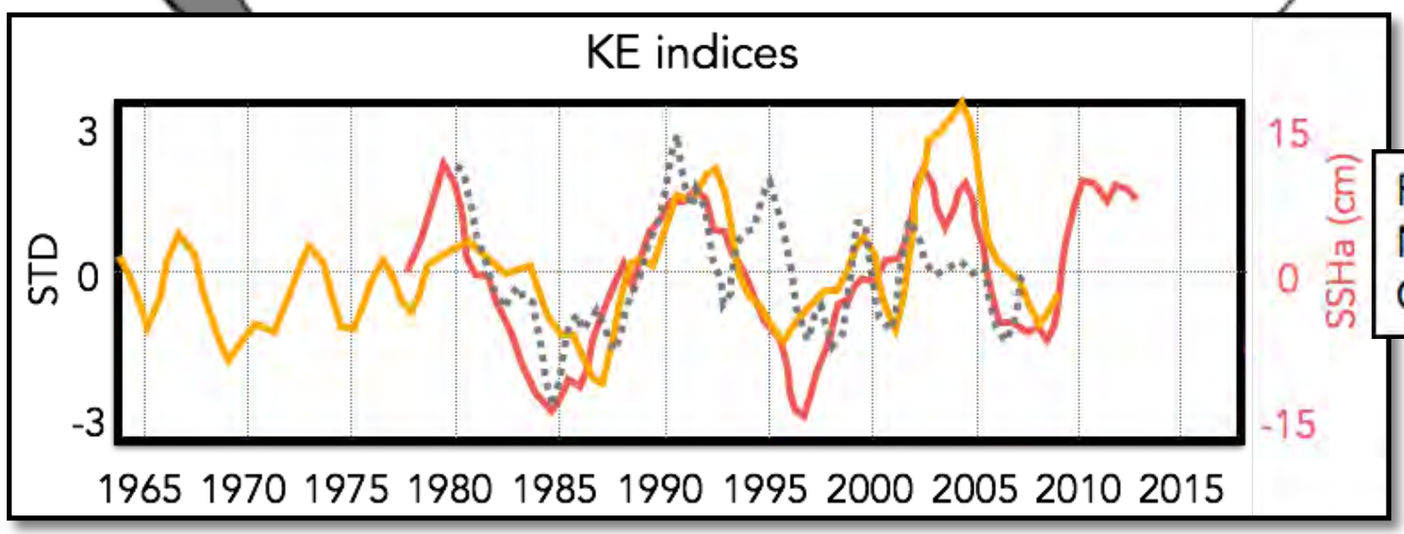


Na et al. (2018)

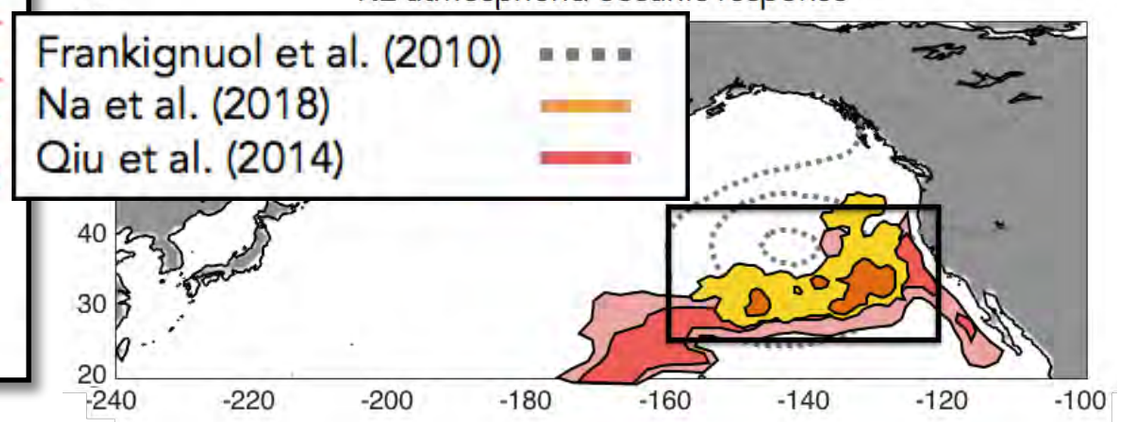


Qiu et al. (2014)

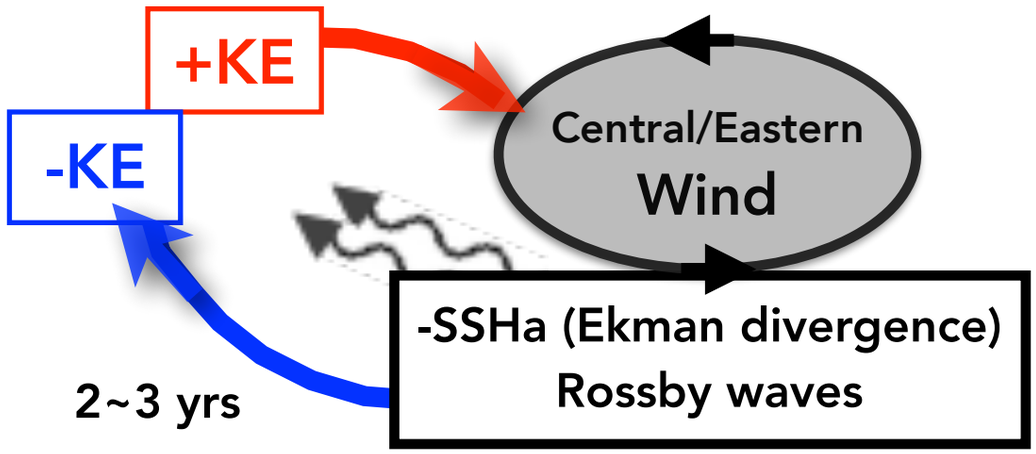




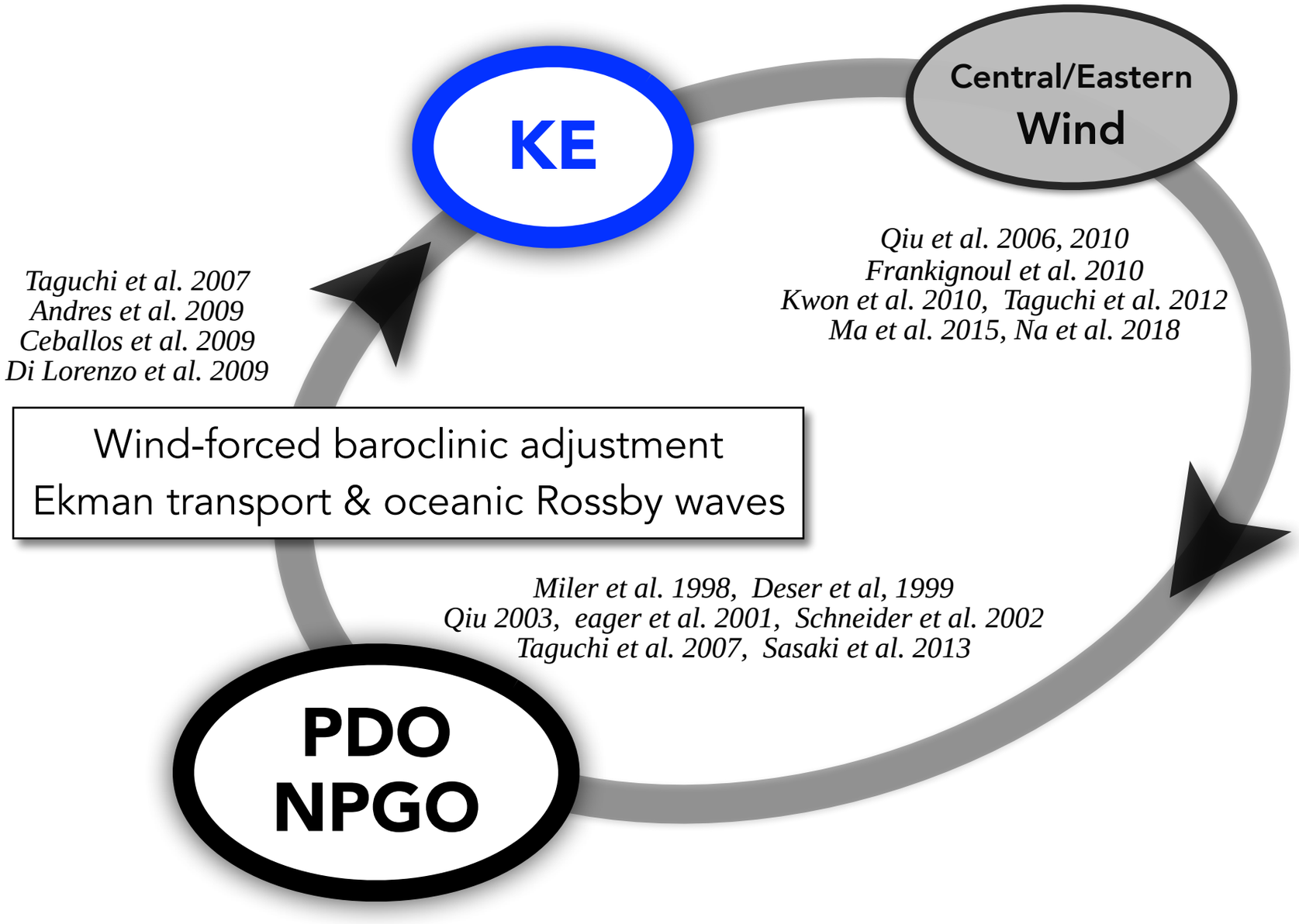
KE atmospheric/oceanic response



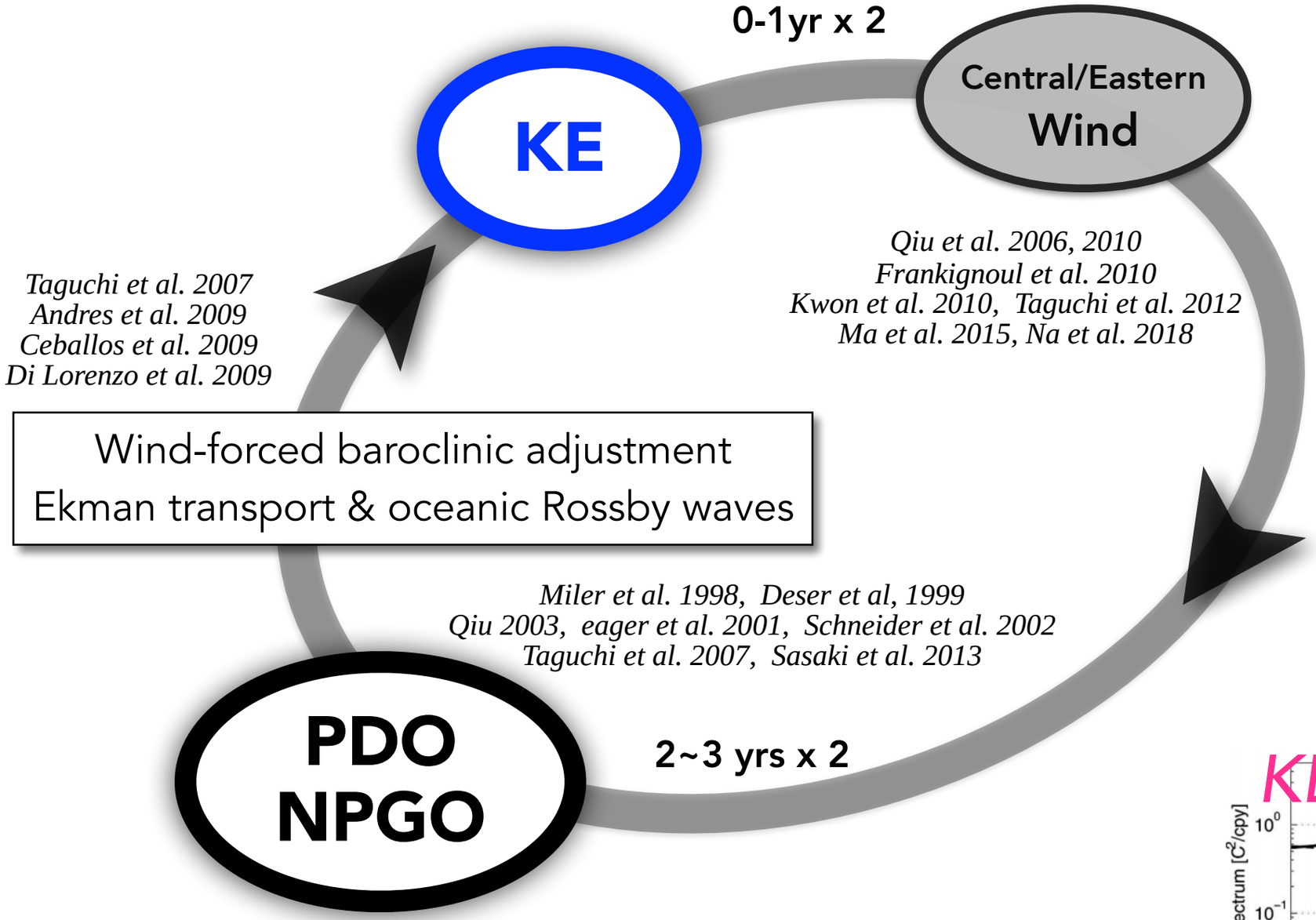
Forcing & Response

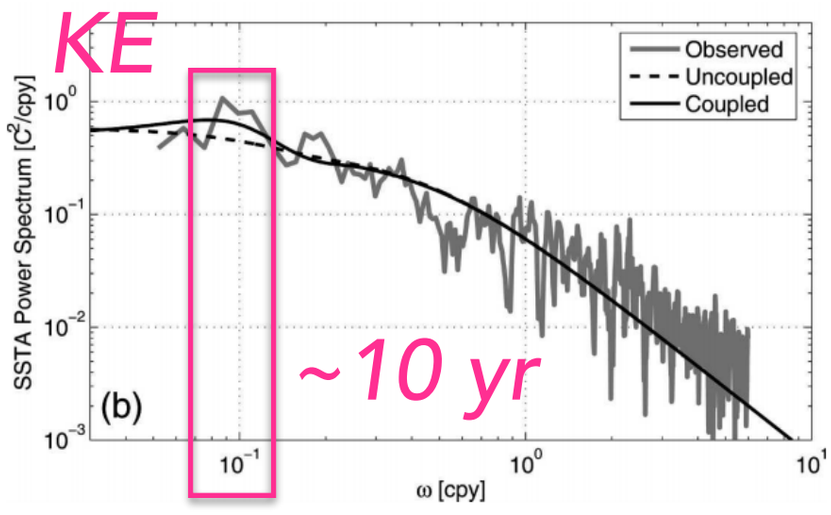


Proposed hypothesis



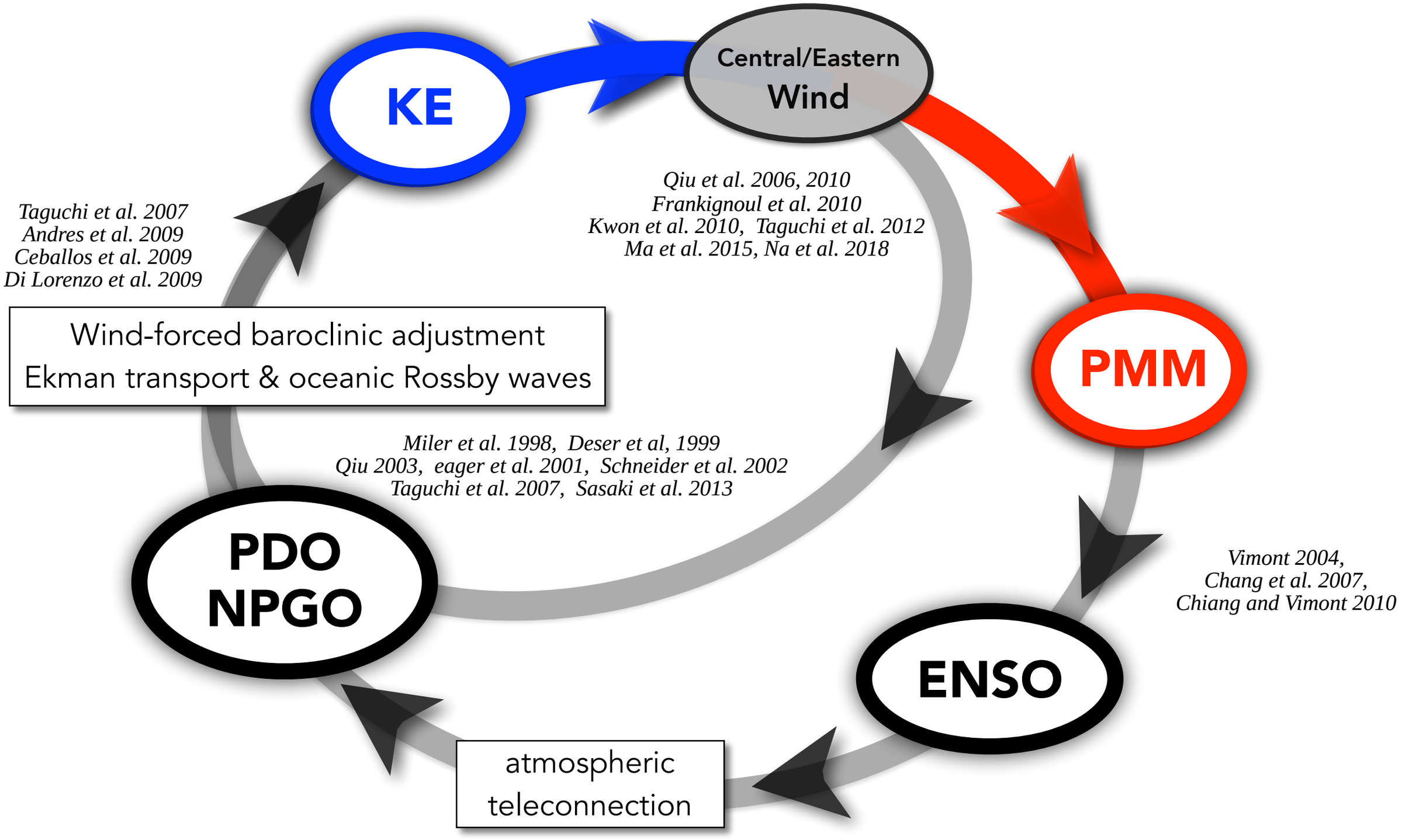
Proposed hypothesis





Proposed hypothesis

Expanded hypothesis



Proposed hypothesis

Expanded hypothesis

KE

Central/Eastern Wind

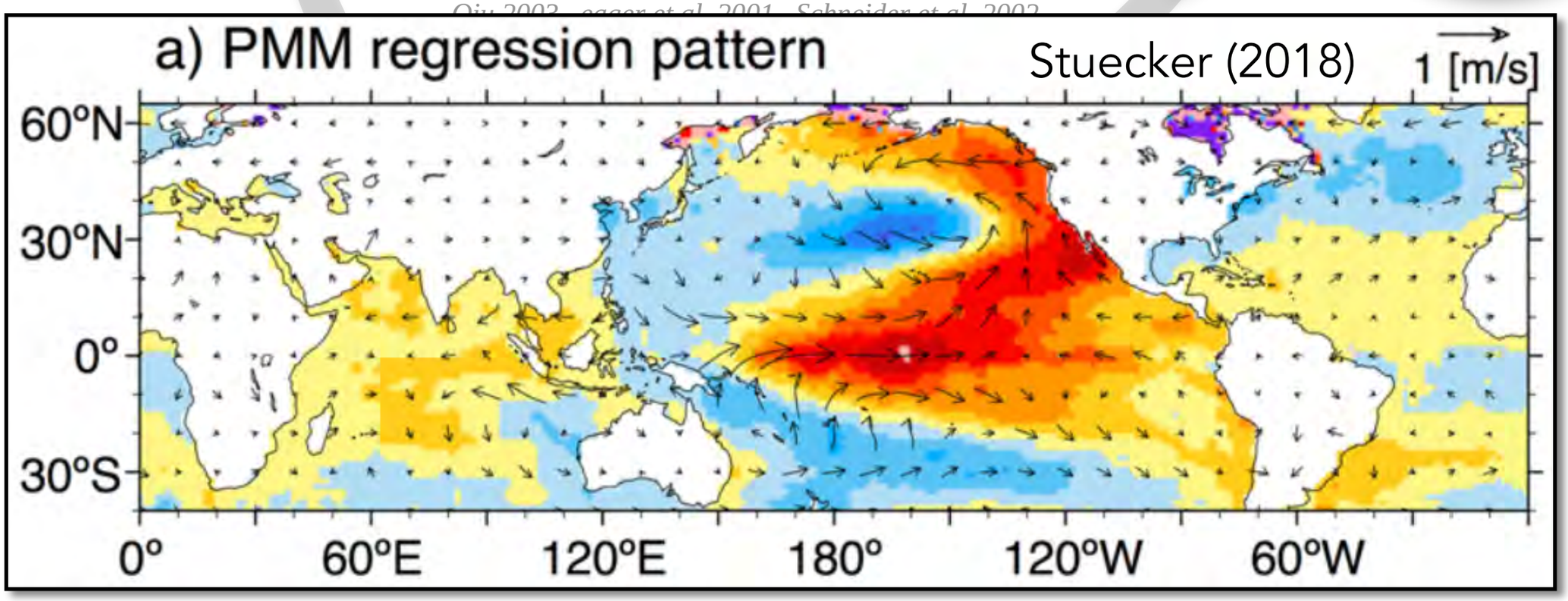
PMM

Qiu et al. 2006, 2010
Frankignoul et al. 2010
Kwon et al. 2010, Taguchi et al. 2012
Ma et al. 2015, Na et al. 2018

Taguchi et al. 2007
Andres et al. 2009
Ceballos et al. 2009
Di Lorenzo et al. 2009

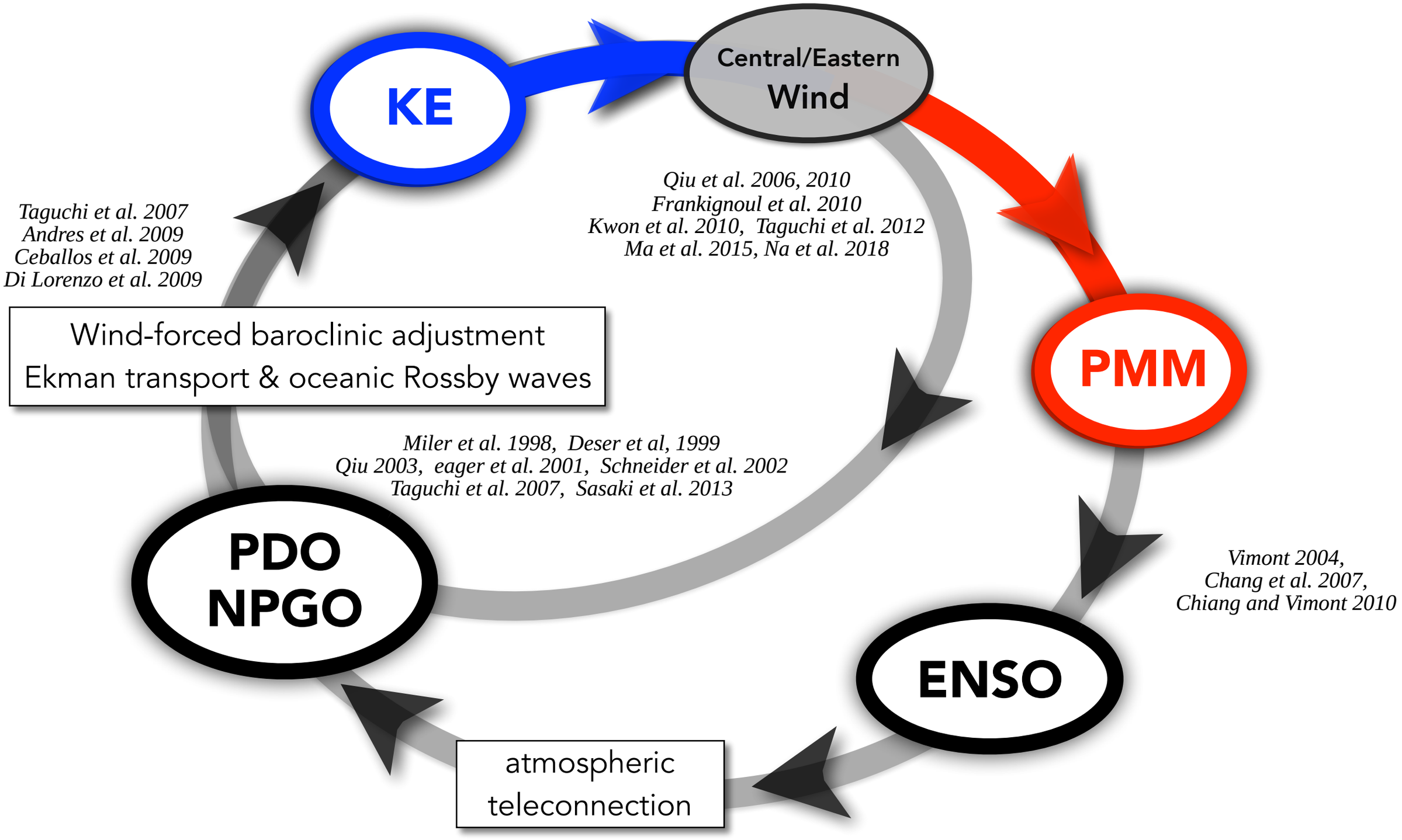
Wind-forced baroclinic adjustment
Ekman transport & oceanic Rossby waves

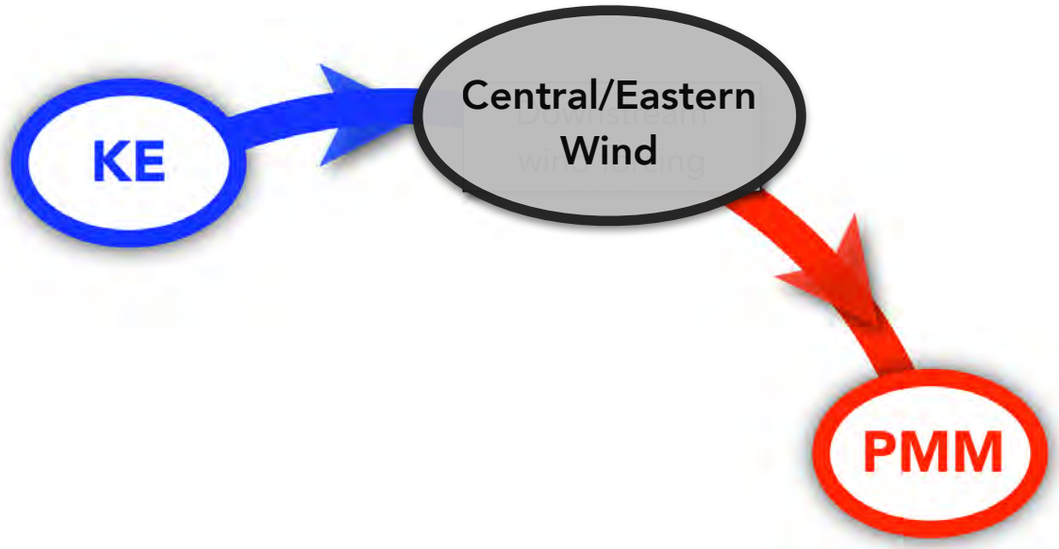
Miler et al. 1998, Deser et al, 1999
Qiu 2003, eager et al. 2001, Schneider et al. 2002

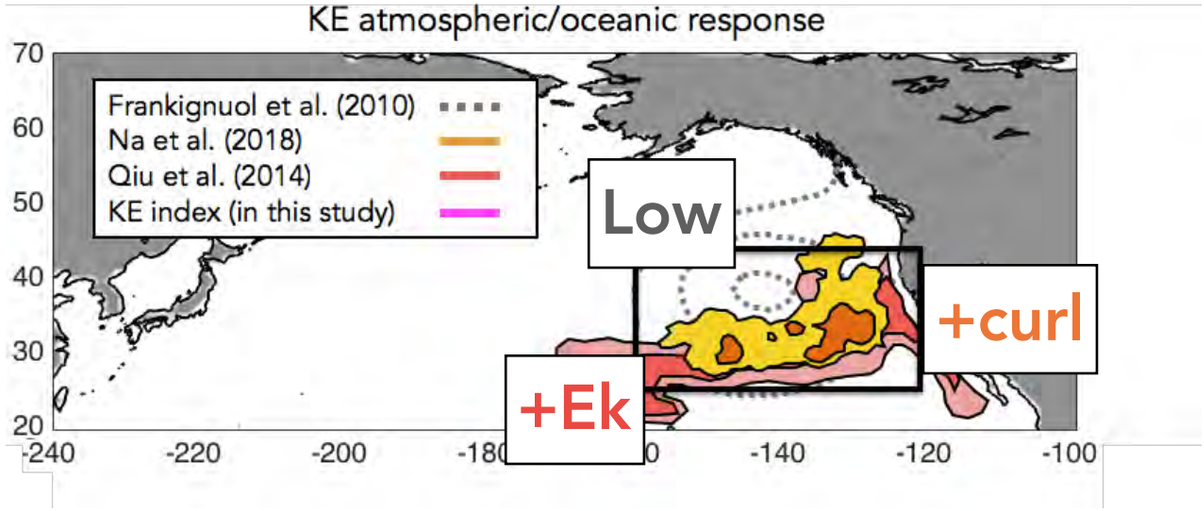


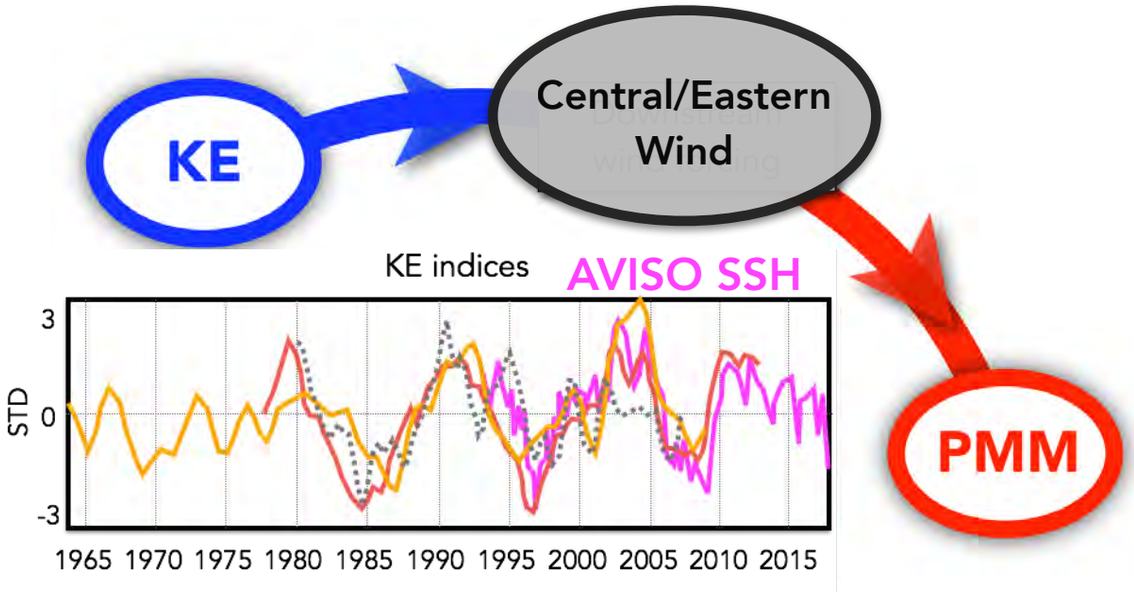
Proposed hypothesis

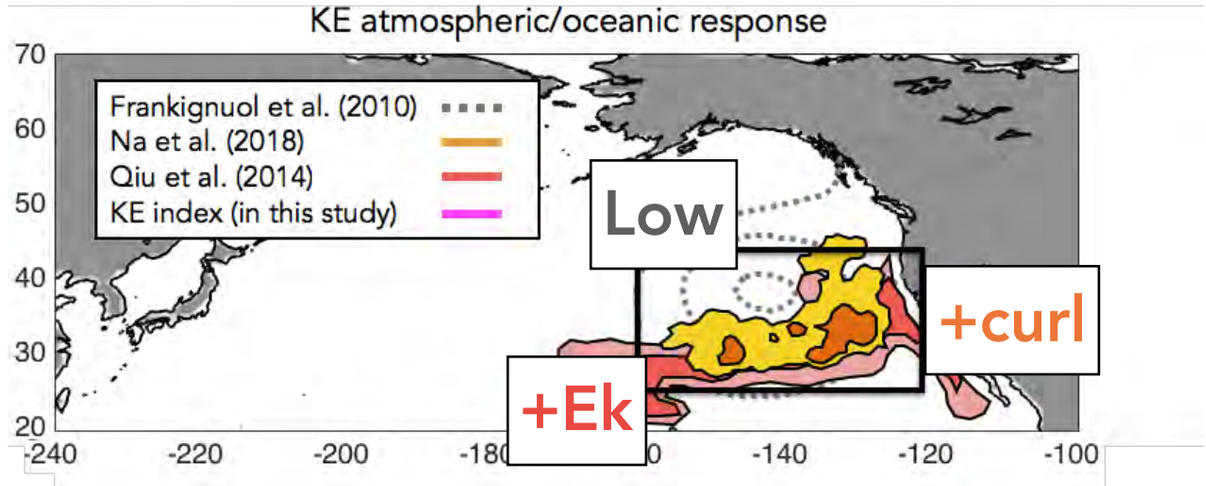
Expanded hypothesis



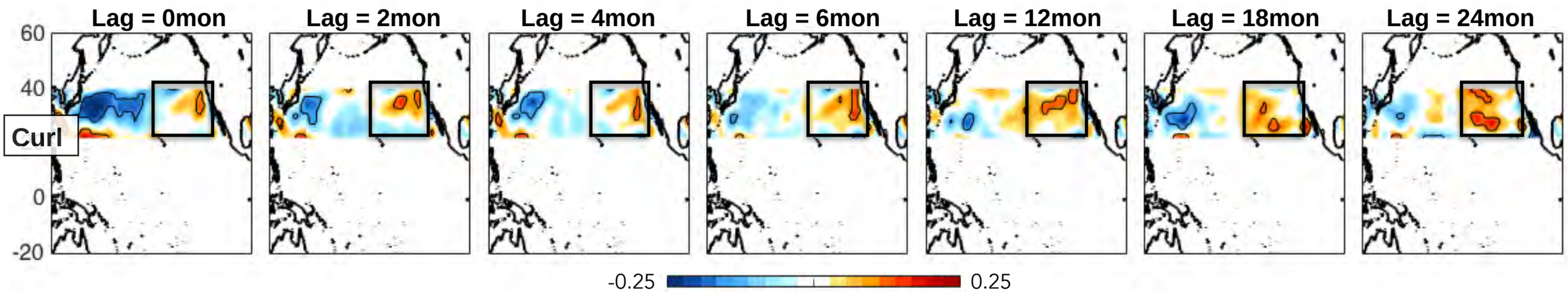

KE
Central/Eastern
Wind
PMM

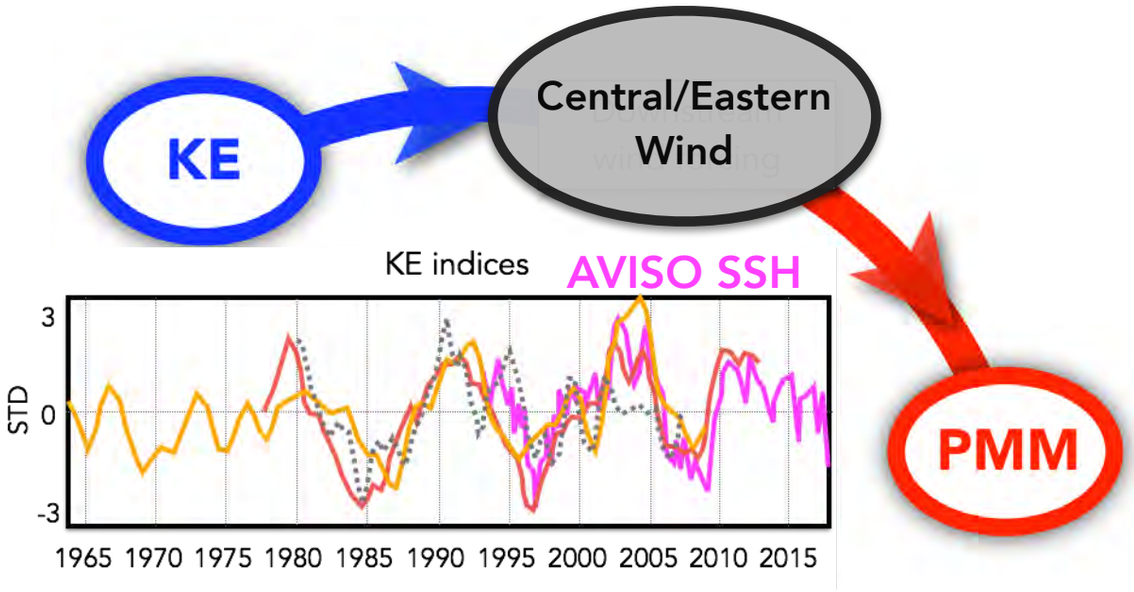

KE atmospheric/oceanic response
Frankignuol et al. (2010)
Na et al. (2018)
Qiu et al. (2014)
KE index (in this study)
Low
+curl
+Ek
70
60
50
40
30
20
-240
-220
-200
-140
-120
-100

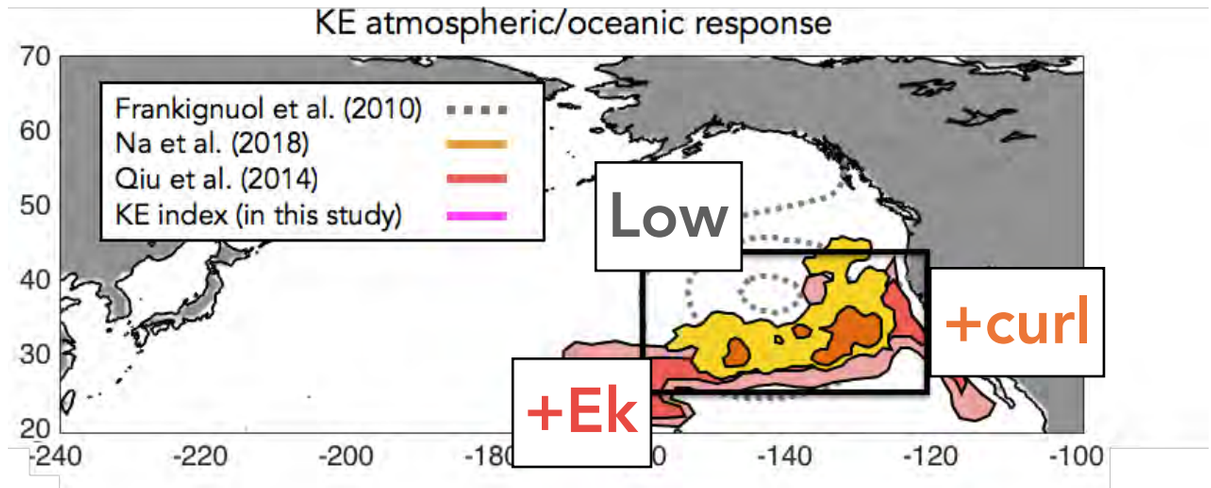




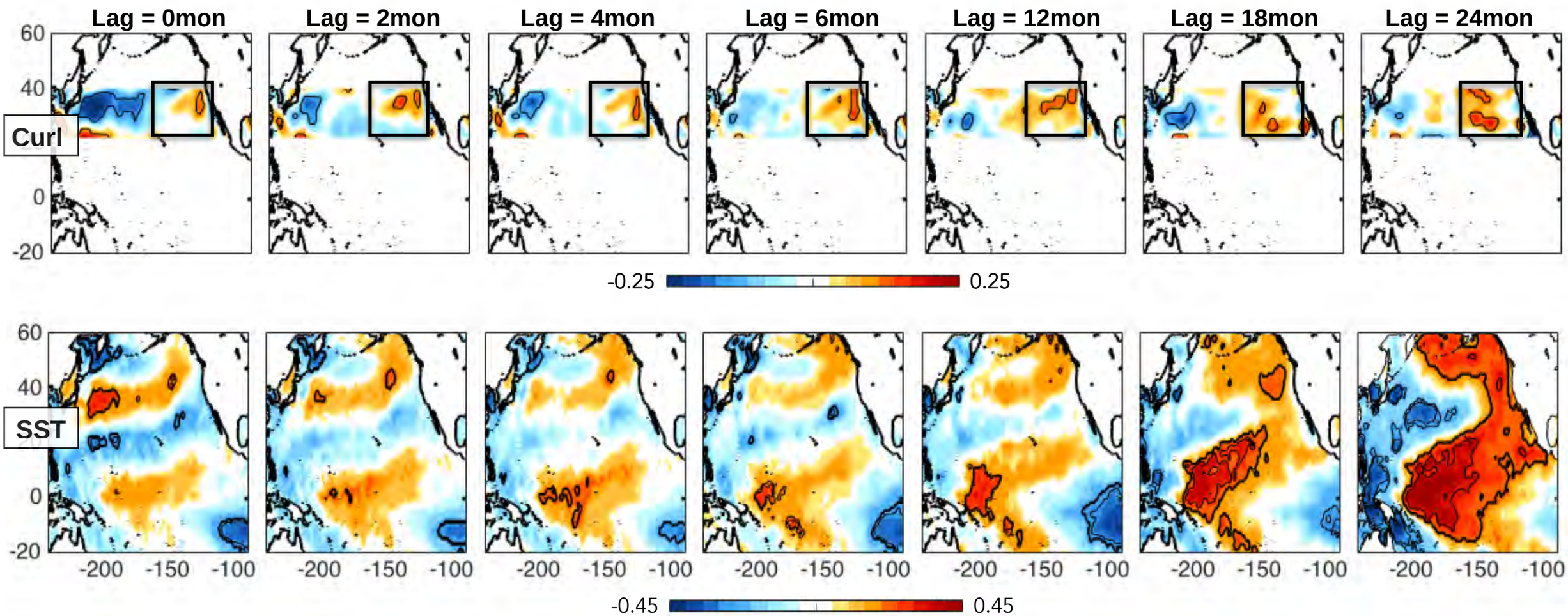
Correlation map to KE index

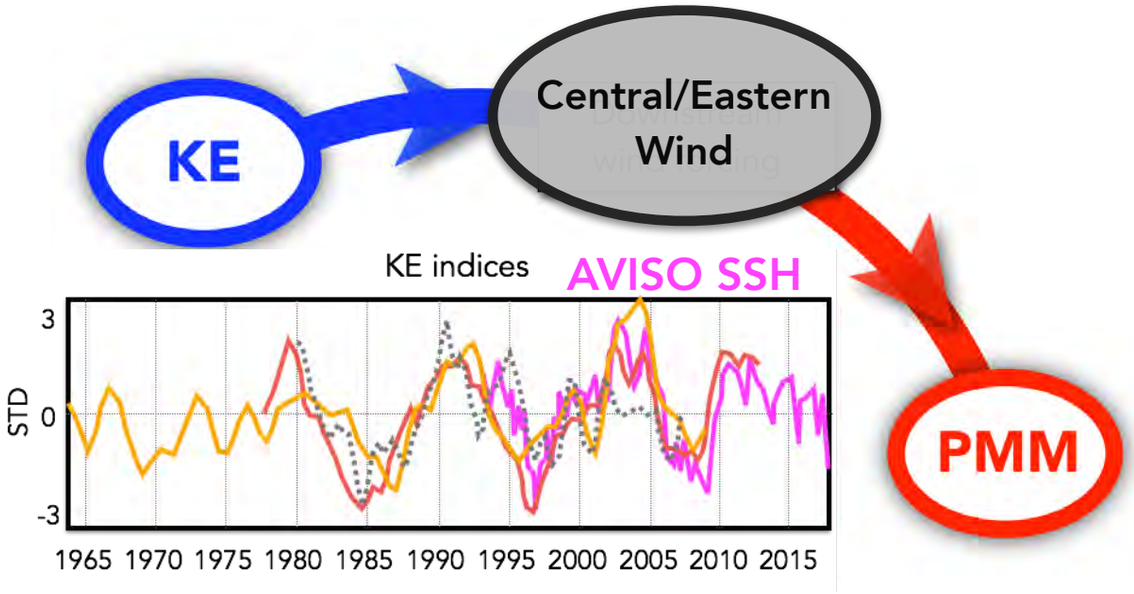


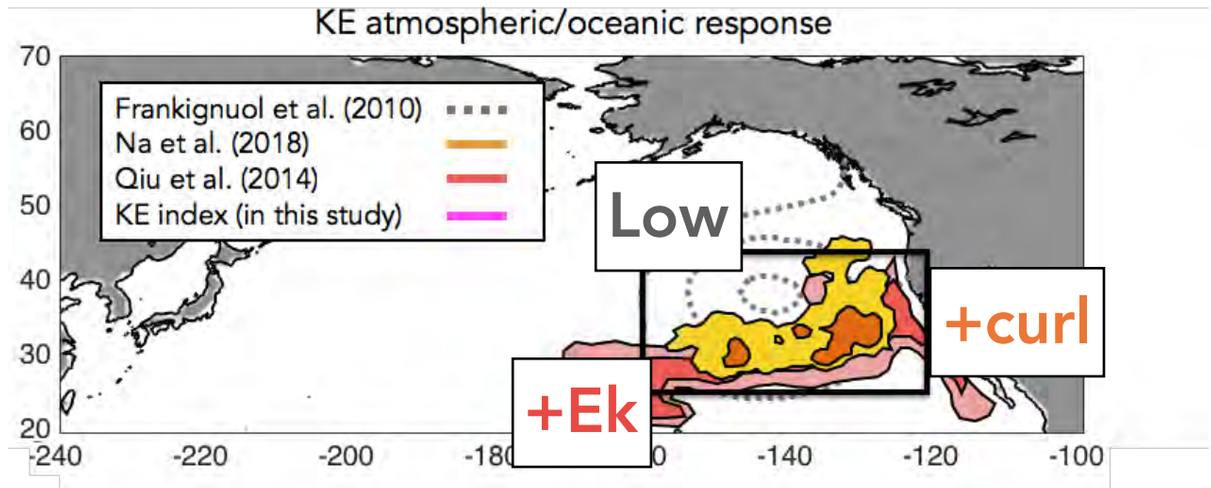


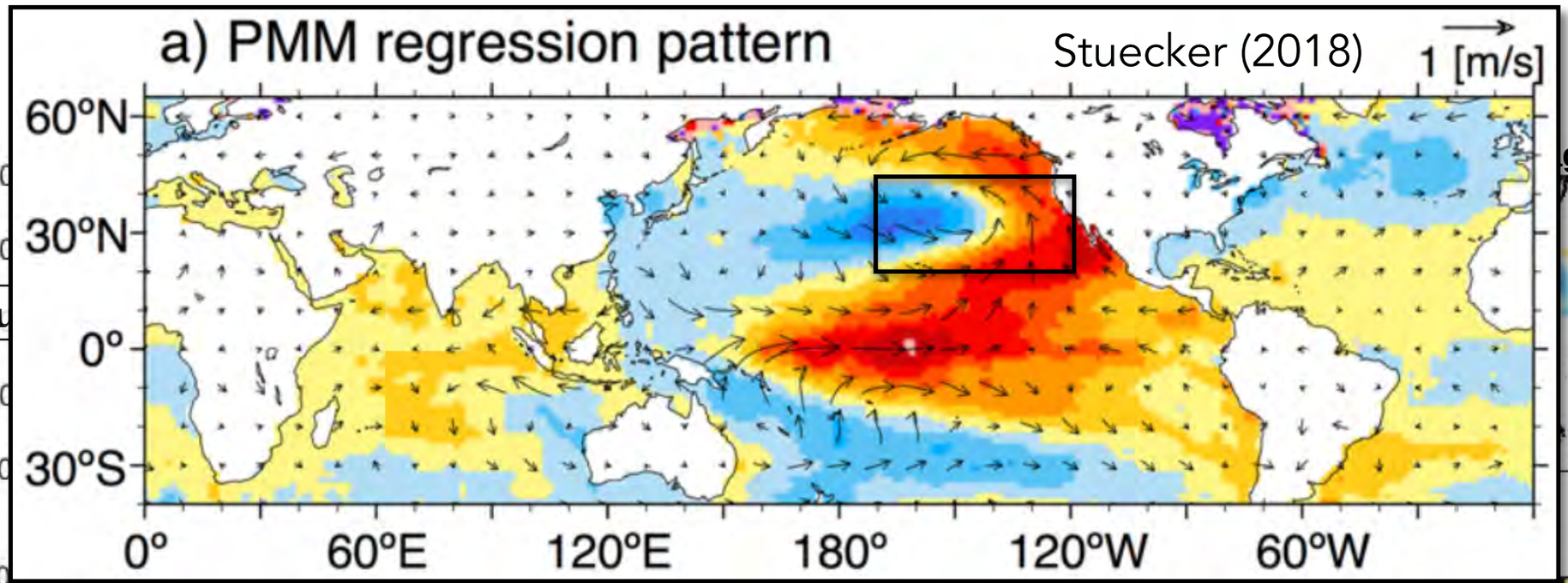


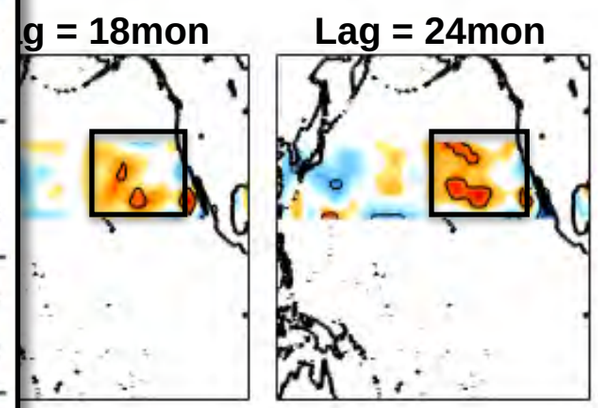
Correlation map to KE index

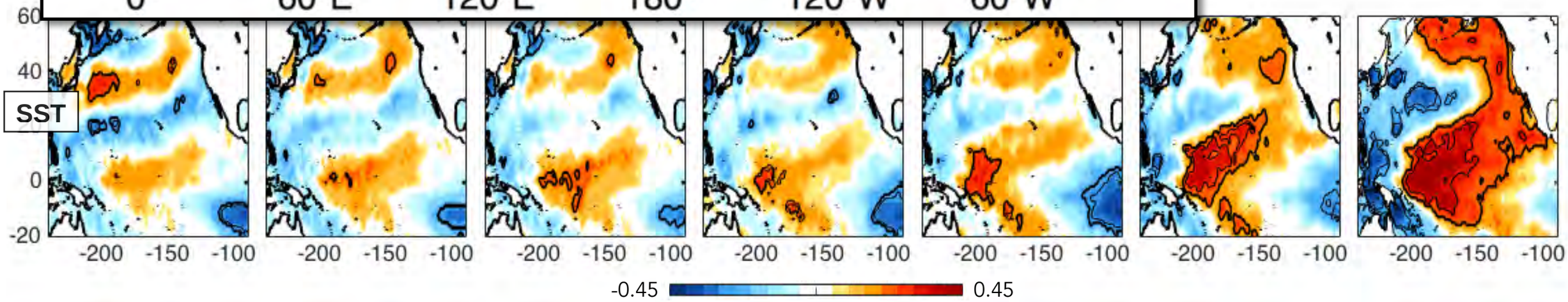


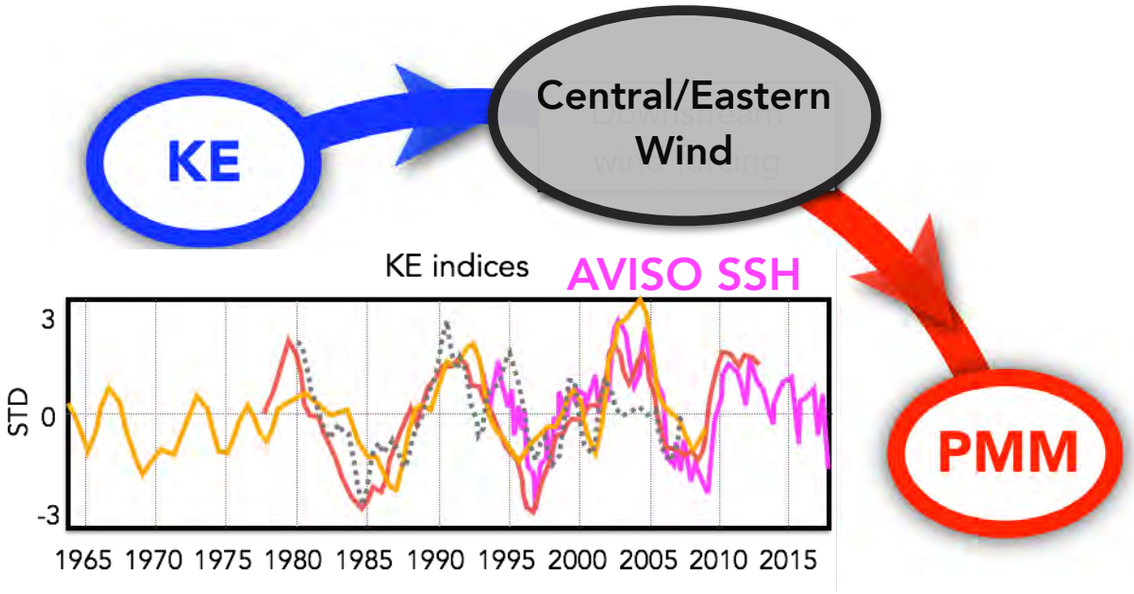

KE
Central/Eastern Wind
PMM
KE indices
AVISO SSH
STD
3
0
-3
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015

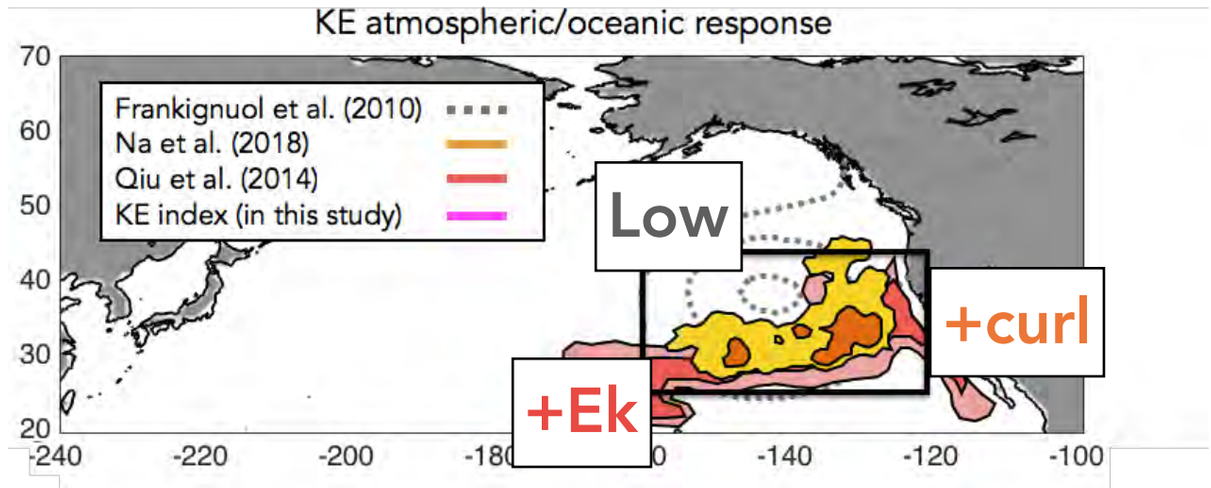

KE atmospheric/oceanic response
Frankignuol et al. (2010)
Na et al. (2018)
Qiu et al. (2014)
KE index (in this study)
Low
+curl
+Ek
70
60
50
40
30
20
-240
-220
-200
-140
-120
-100


a) PMM regression pattern
Stuecker (2018)
1 [m/s]
60°N
30°N
0°
30°S
0°
60°E
120°E
180°
120°W
60°W

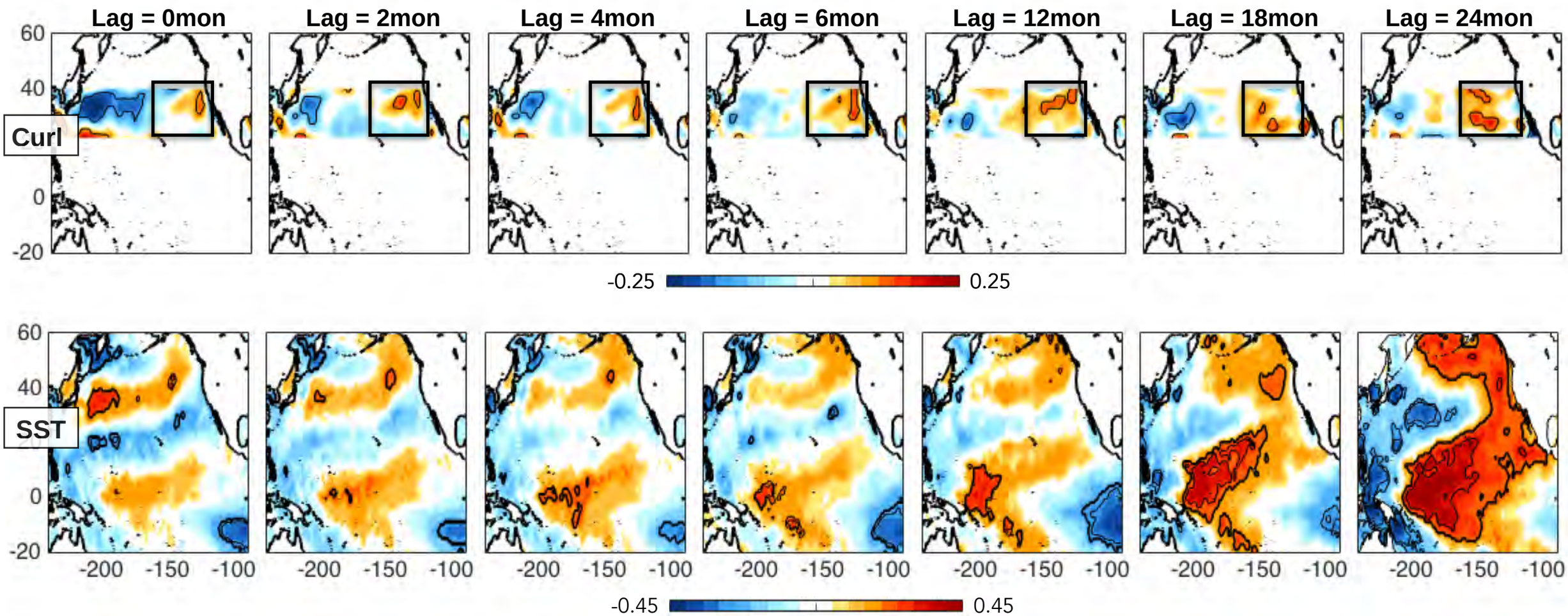

Lag = 18mon
Lag = 24mon

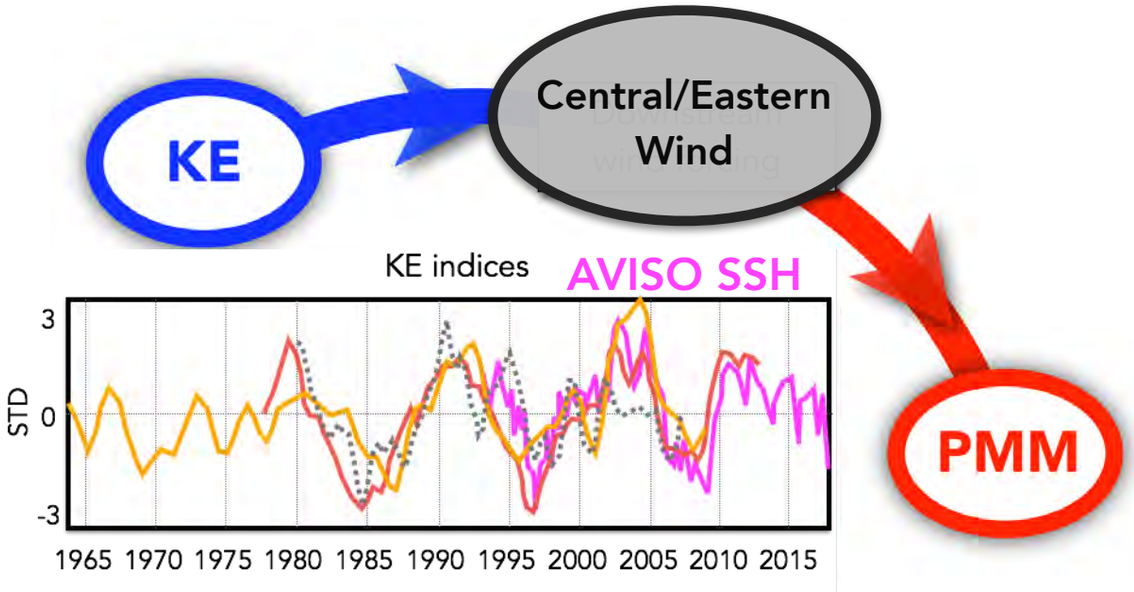

Cu
SST
60
40
0
-20
-200
-150
-100
-0.45
0.45

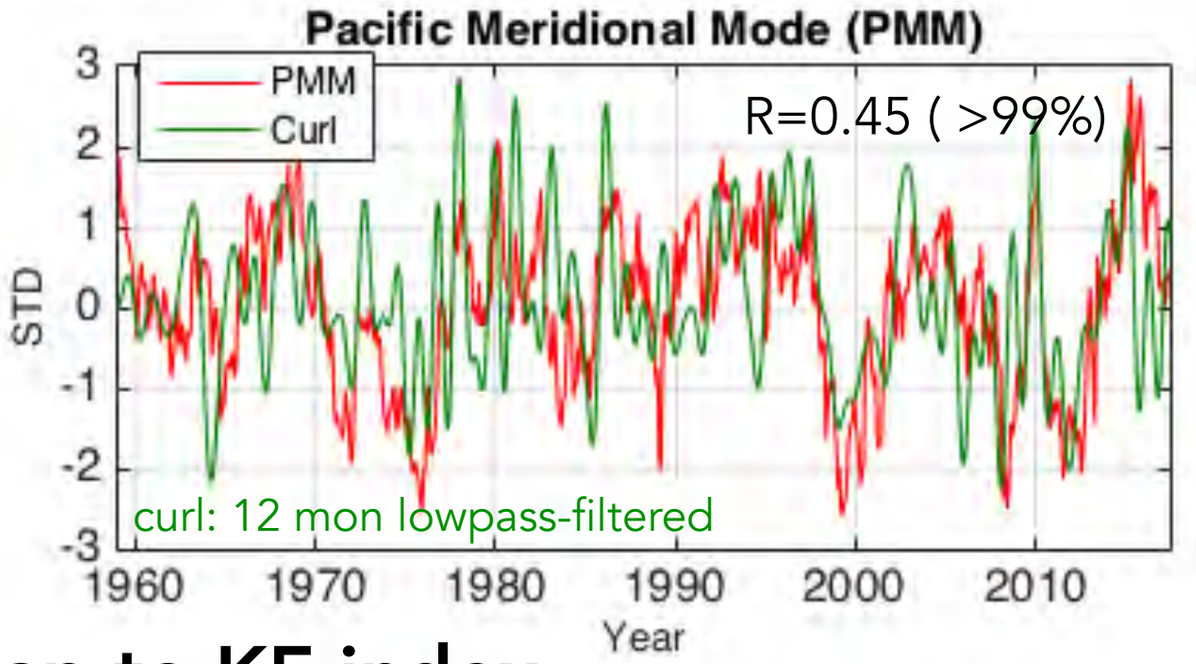




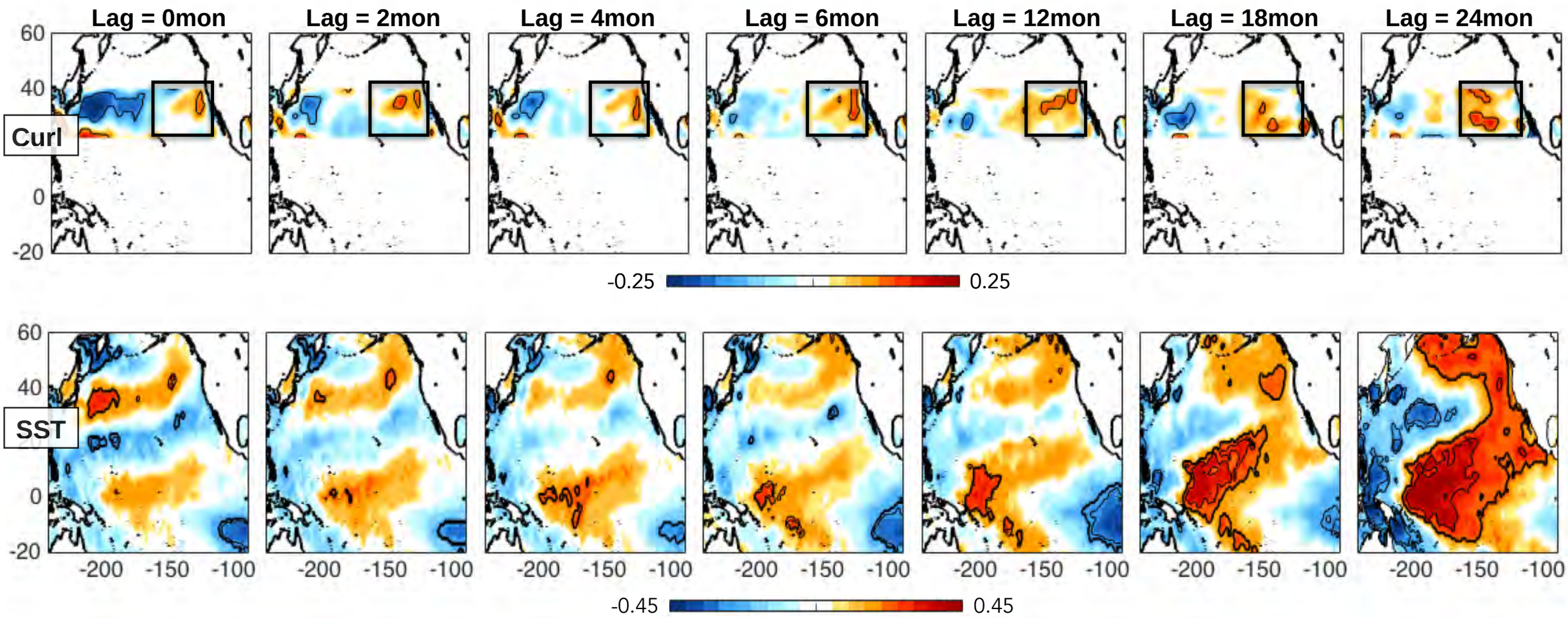
Correlation map to KE index

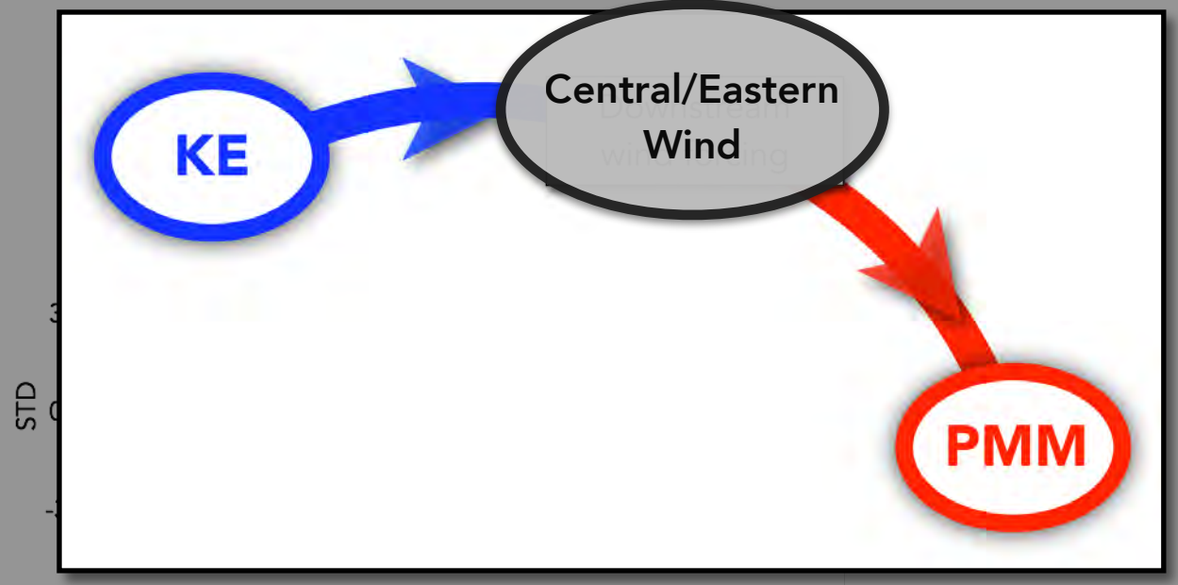


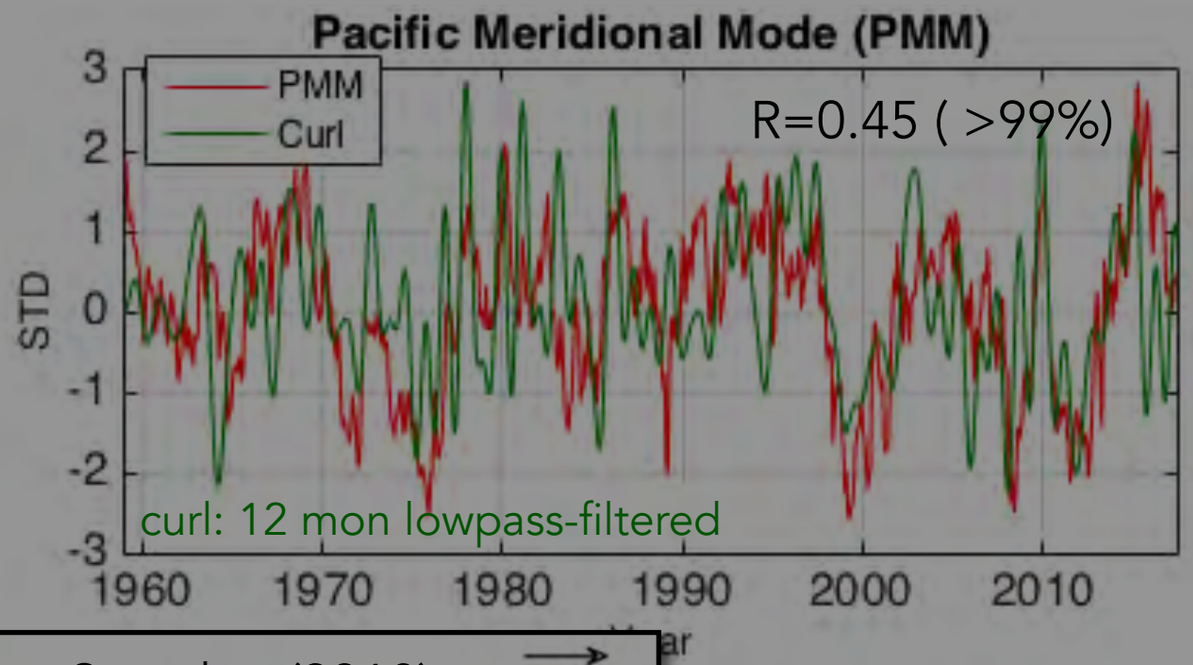


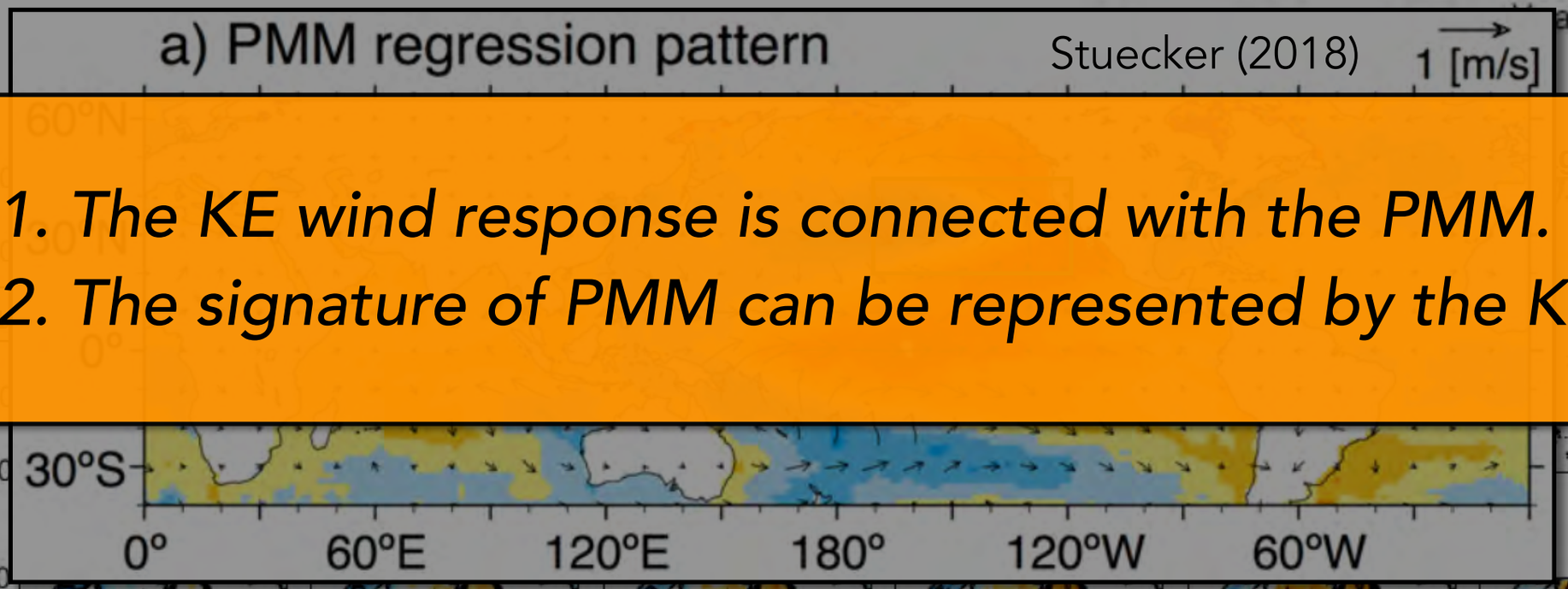


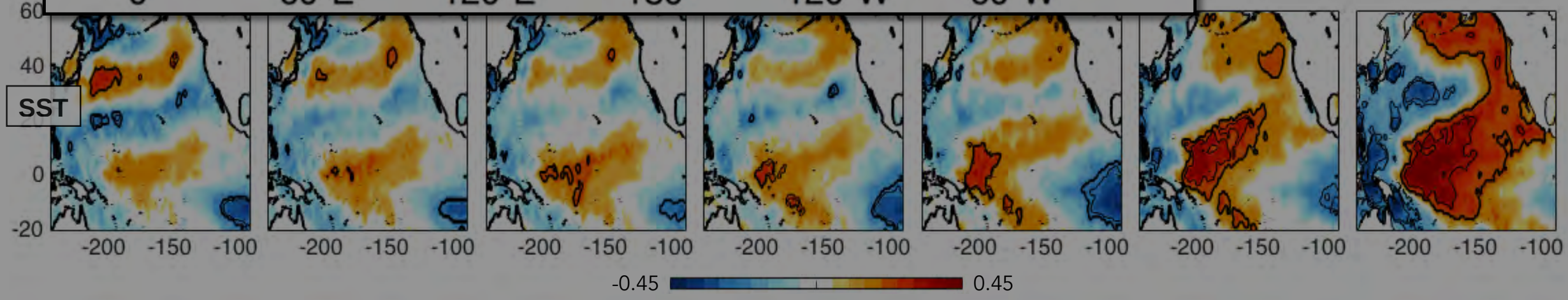
Correlation map to KE index









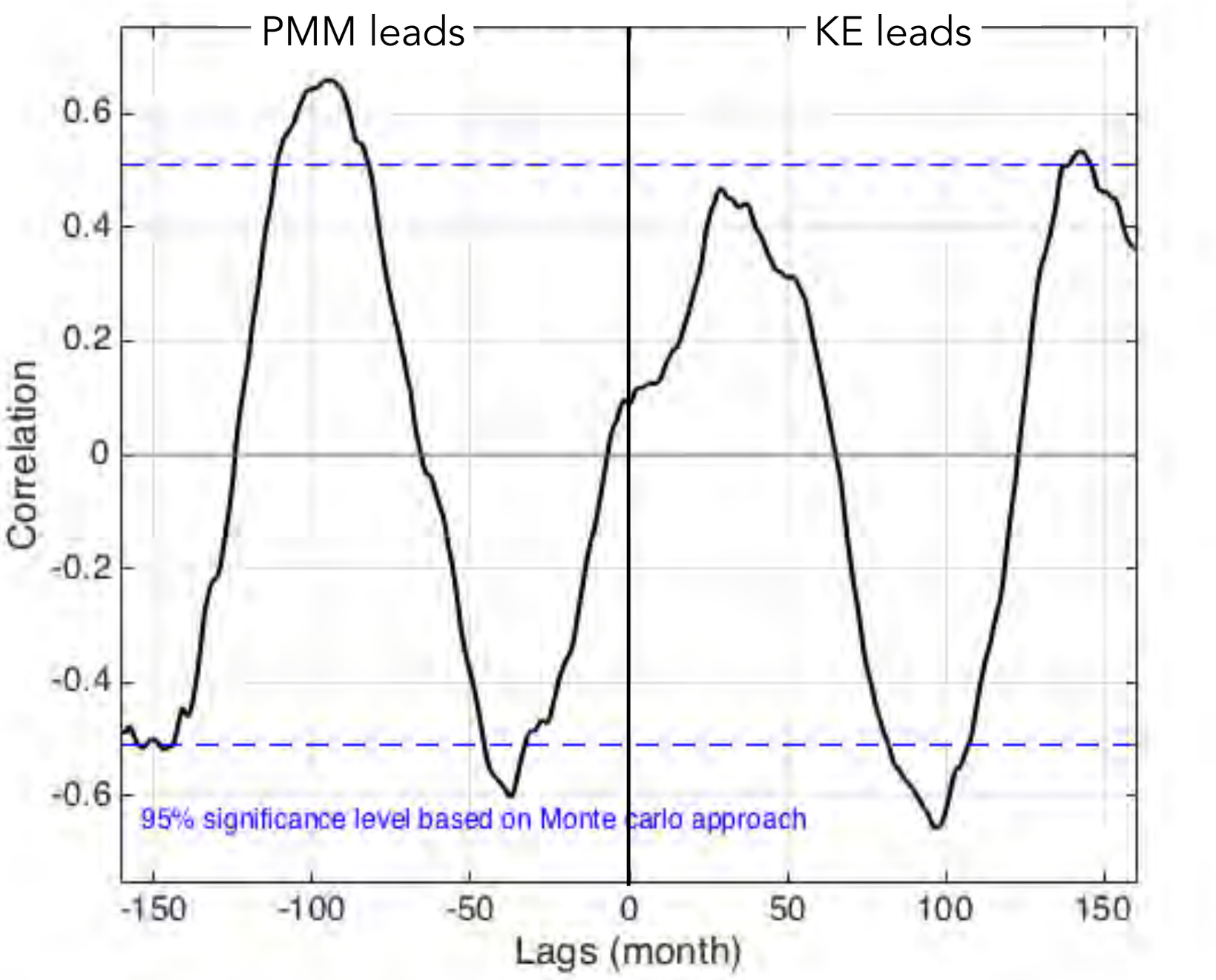


1. The KE wind response is connected with the PMM.

2. The signature of PMM can be represented by the KE variability

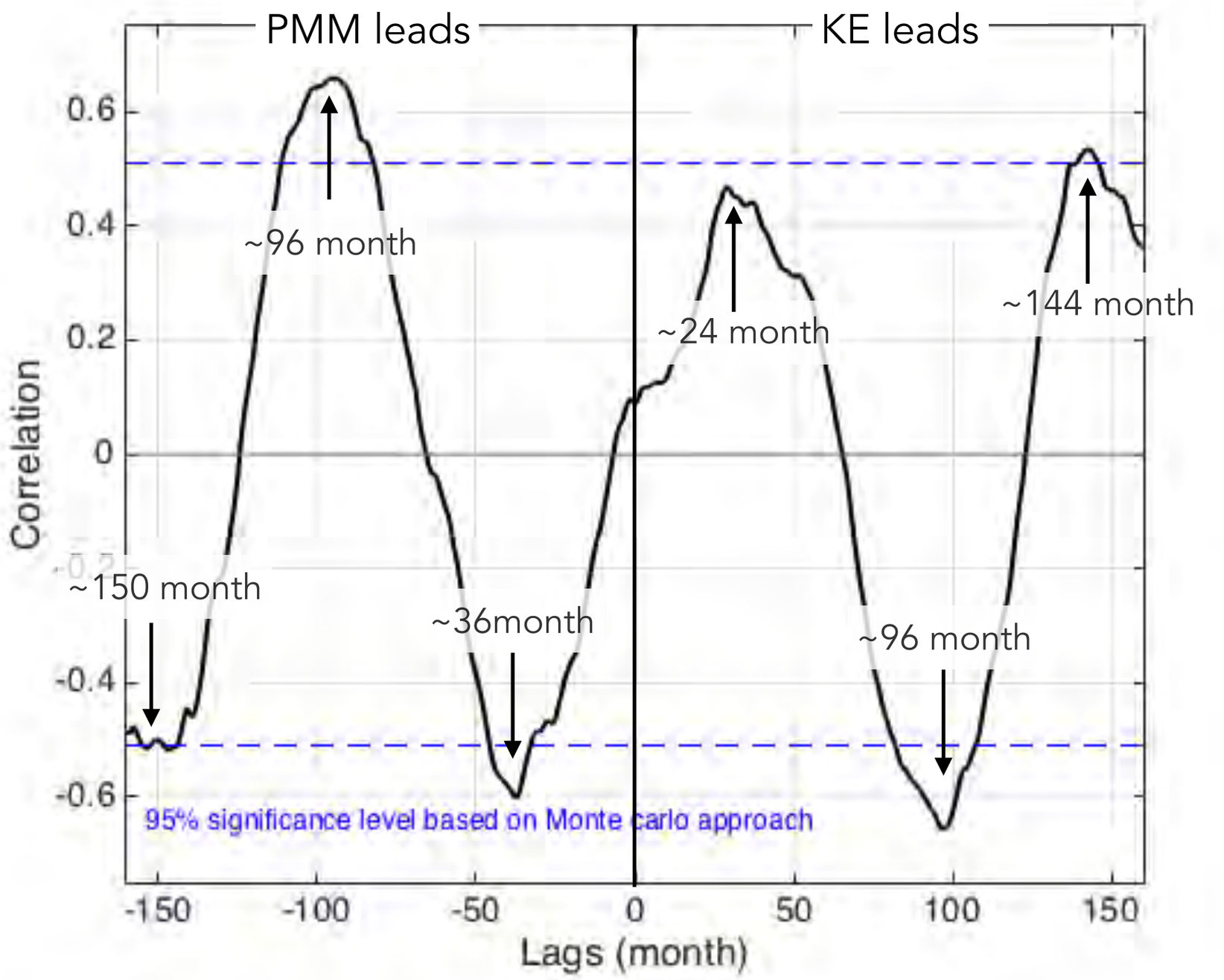
temporal lead/lag relationship between the KE and PMM?

Cross-correlation function



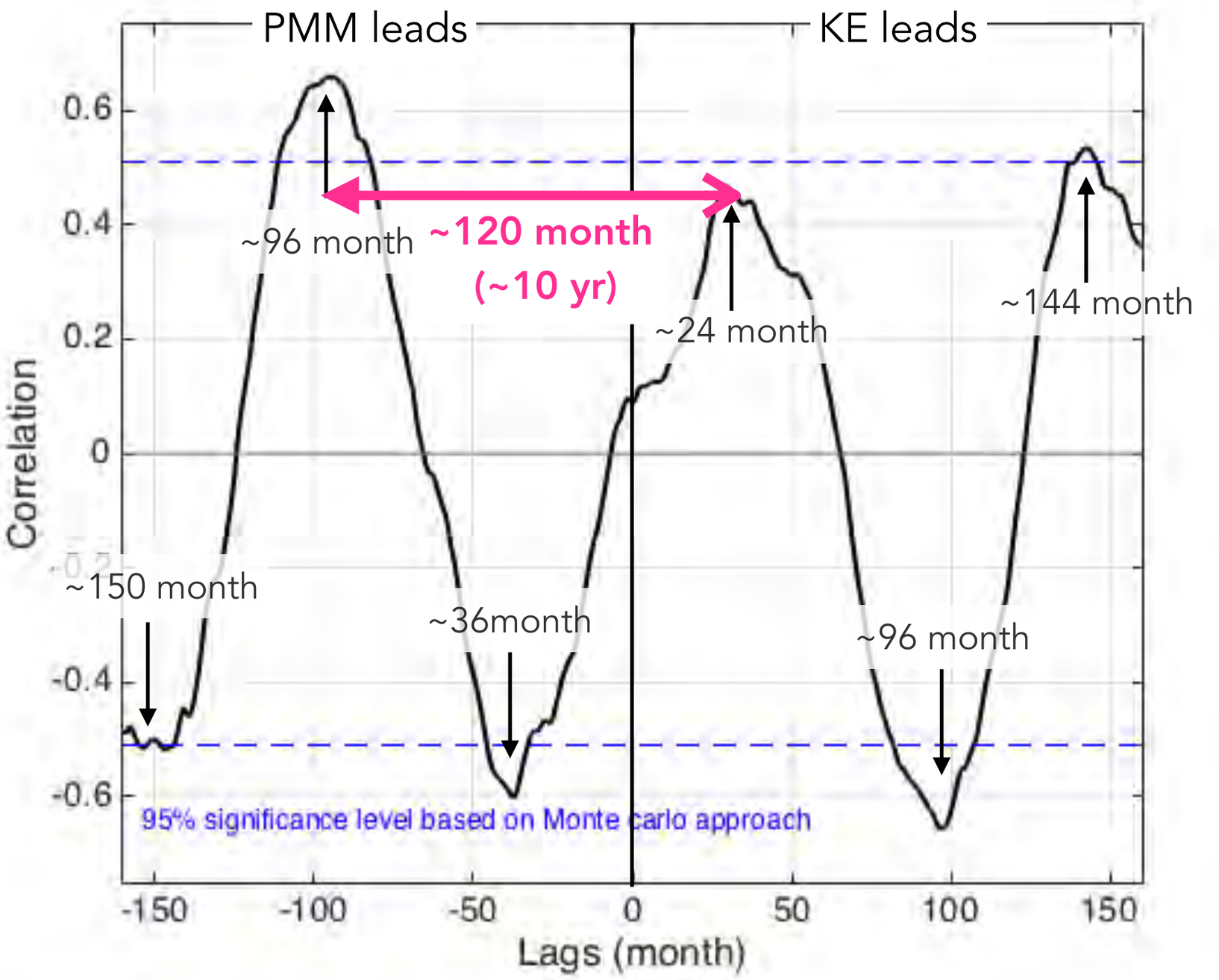
temporal lead/lag relationship between the KE and PMM?

Cross-correlation function



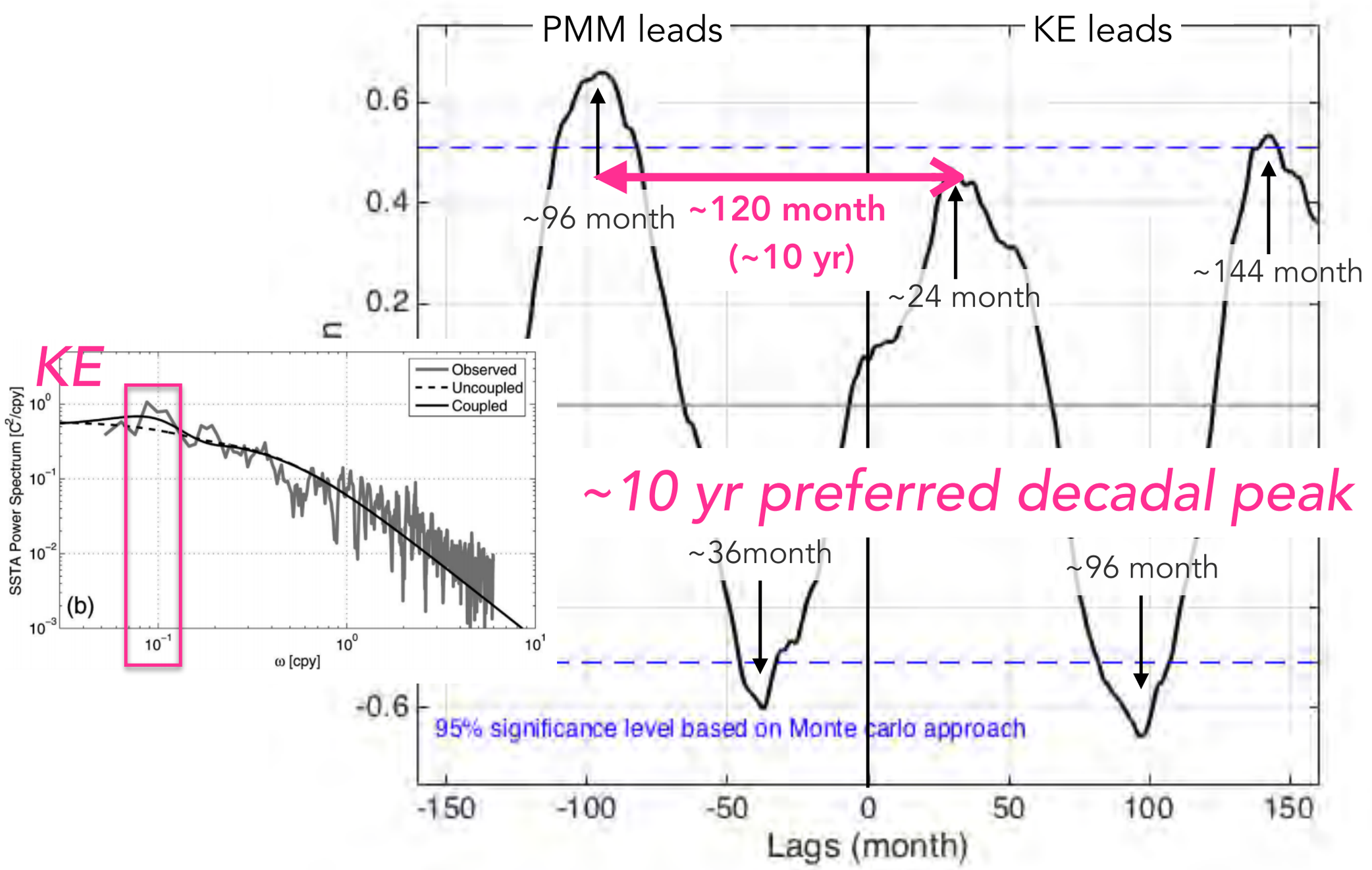
temporal lead/lag relationship between the KE and PMM?

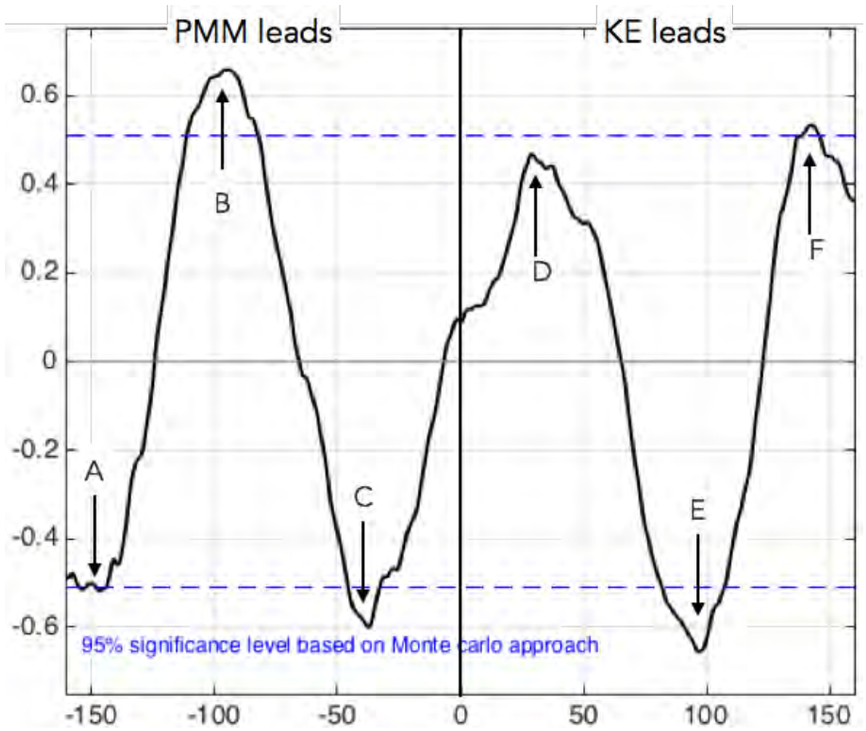
Cross-correlation function



temporal lead/lag relationship between the KE and PMM?

Cross-correlation function





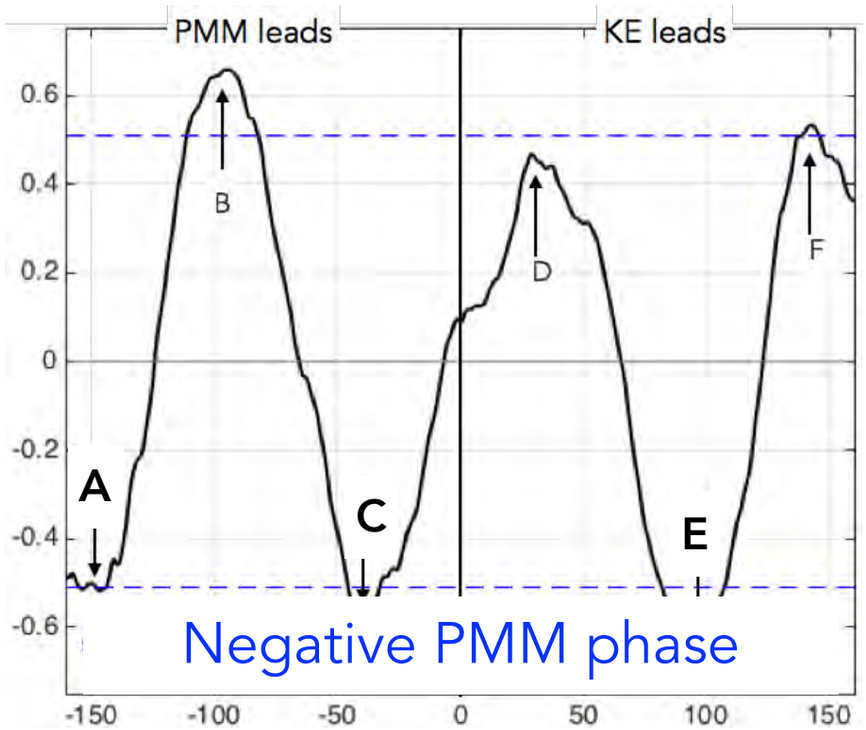
Correlation map to KE index

SST

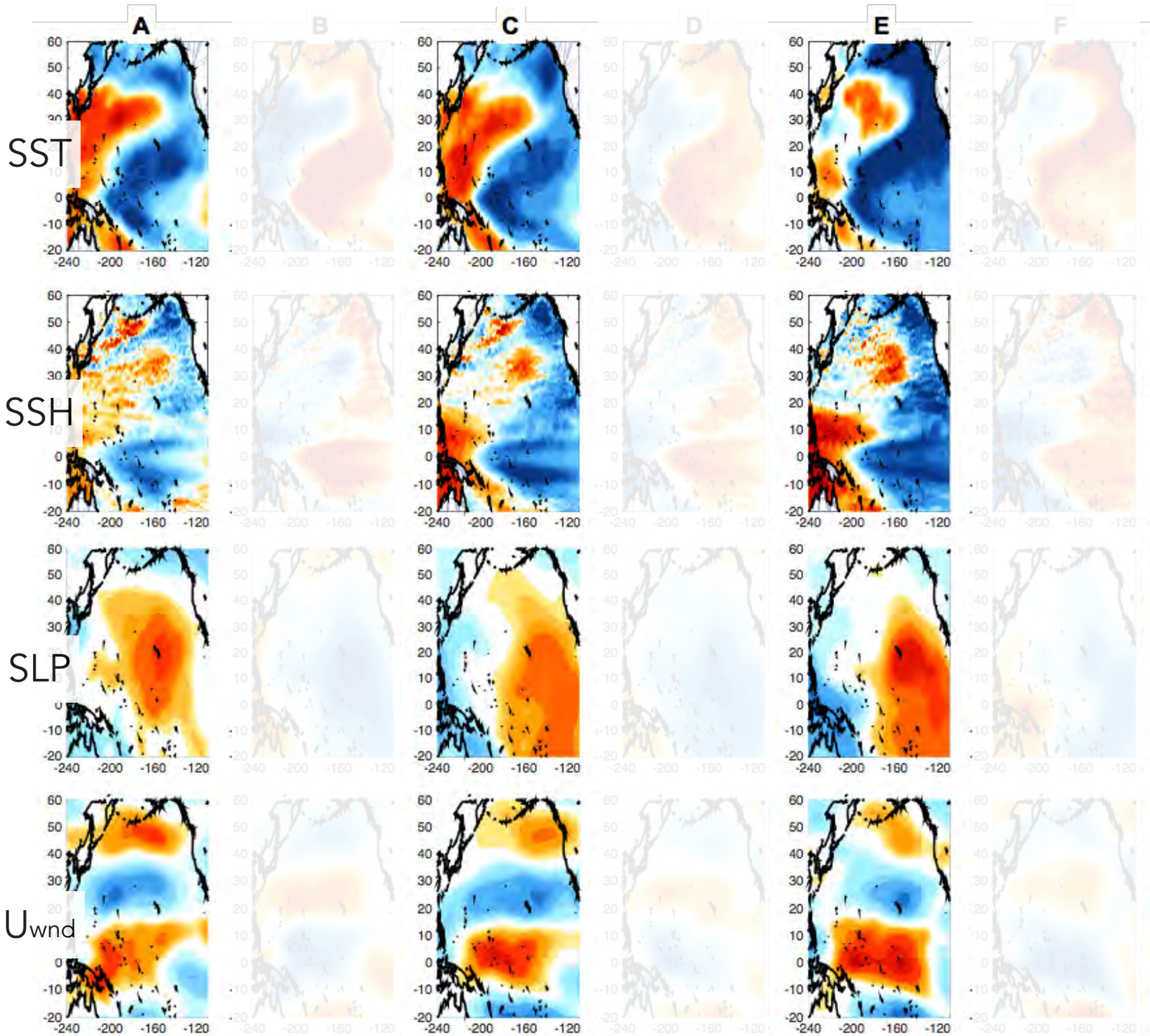
SSH

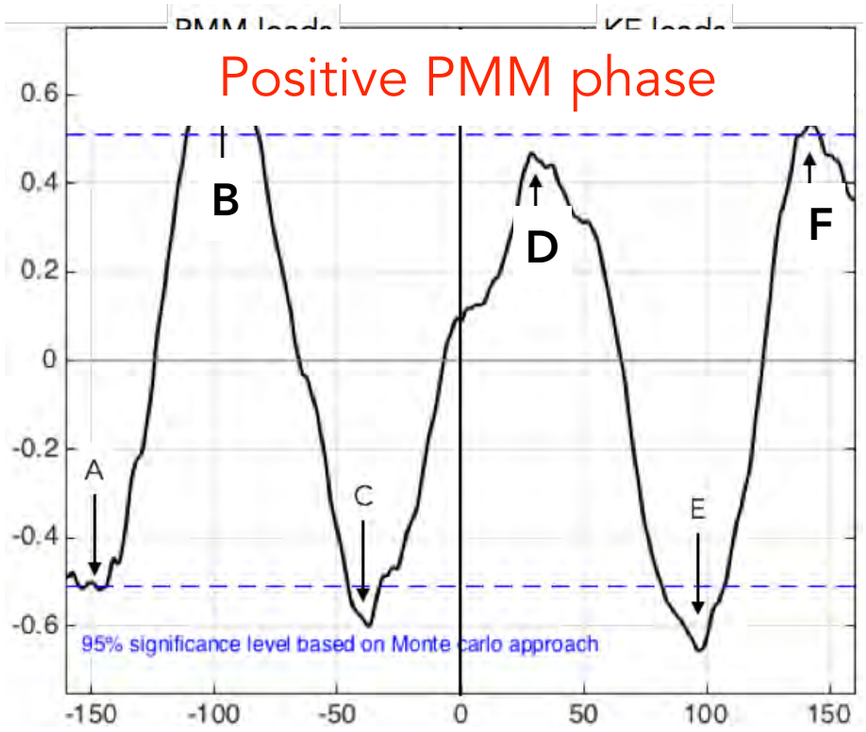
SLP

Uwnd

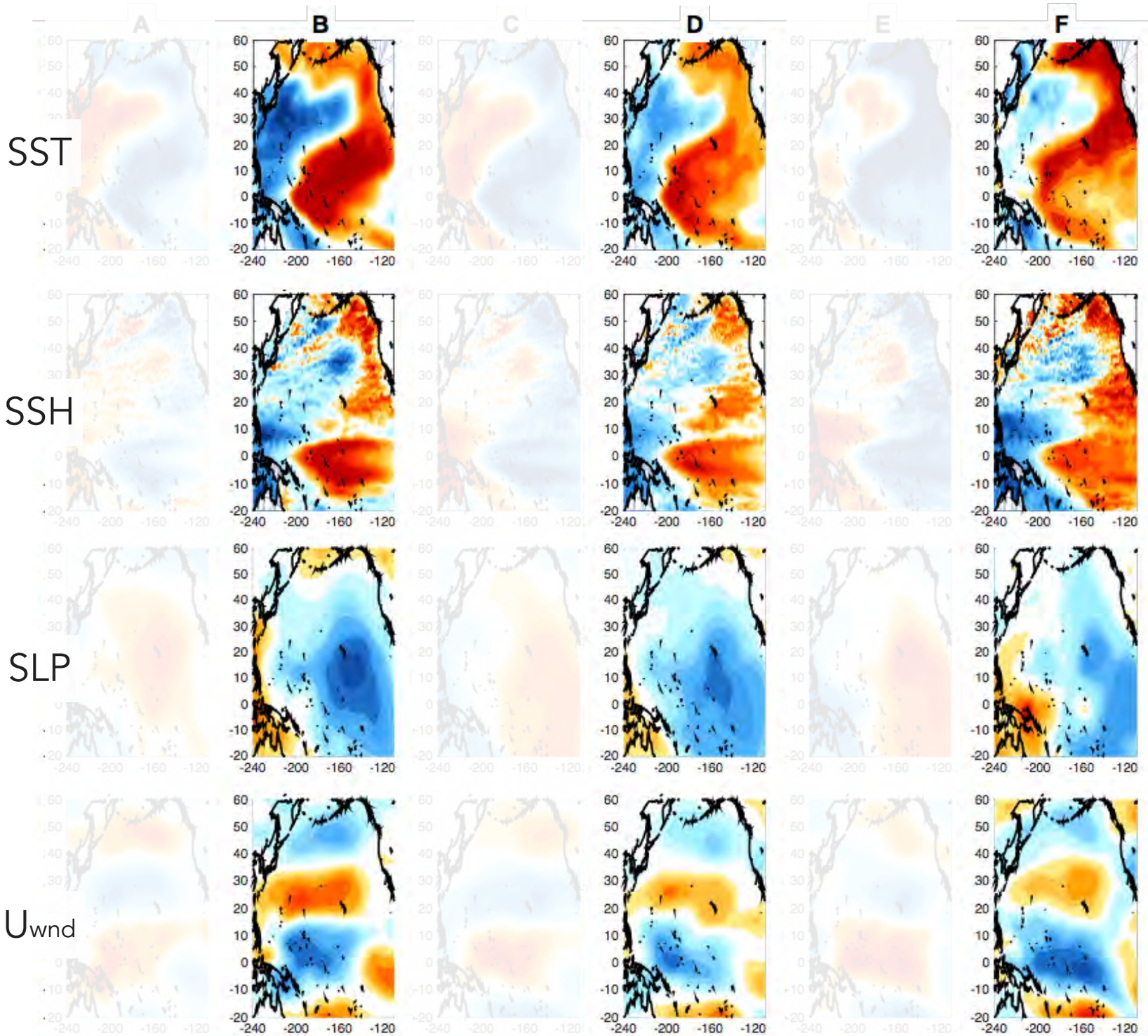


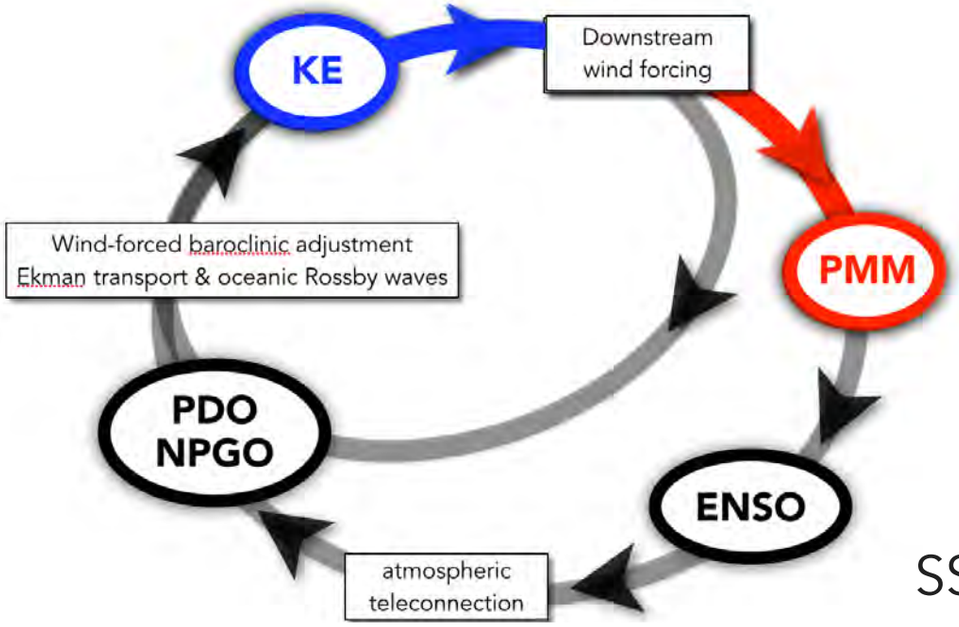
Correlation map to KE index



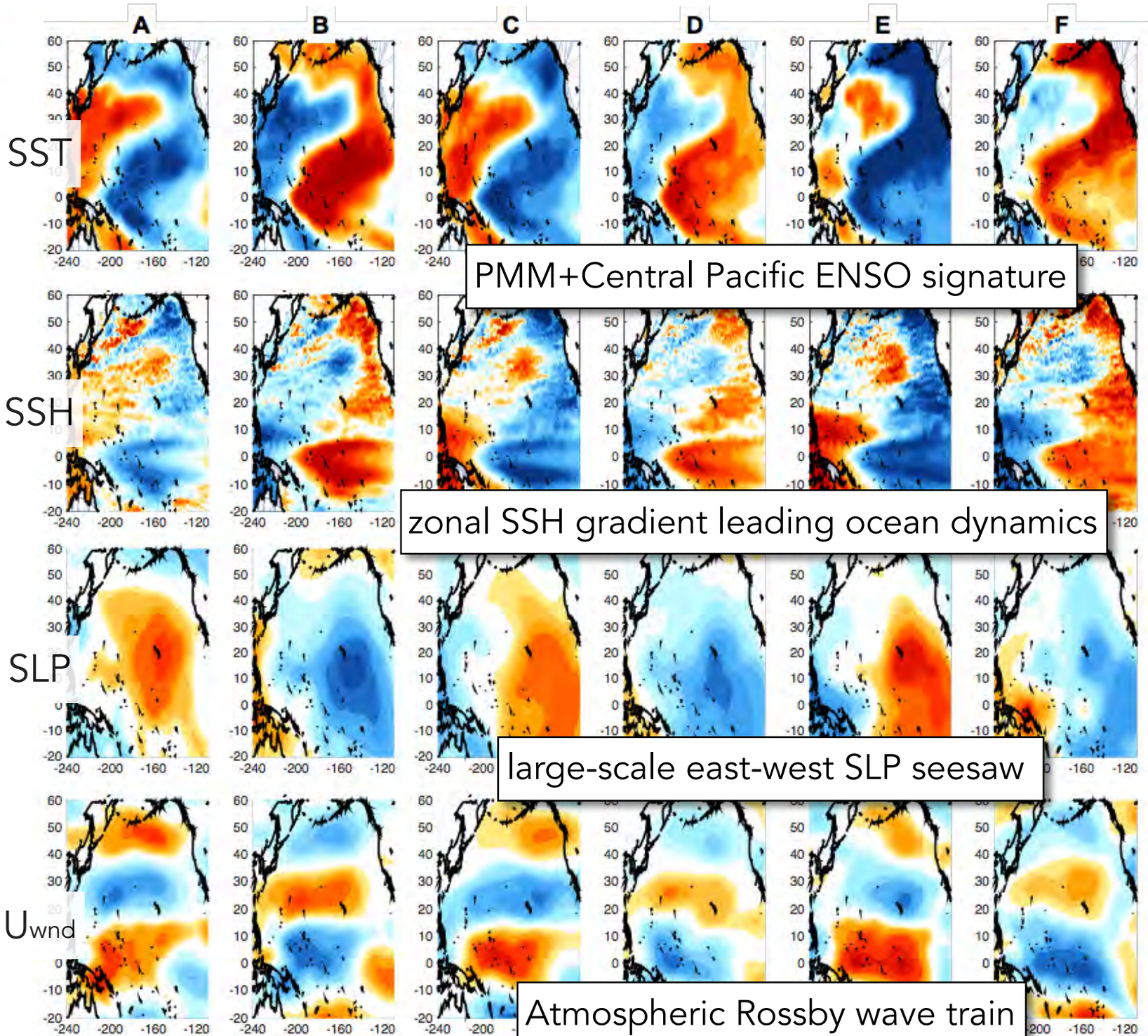


Correlation map to KE index

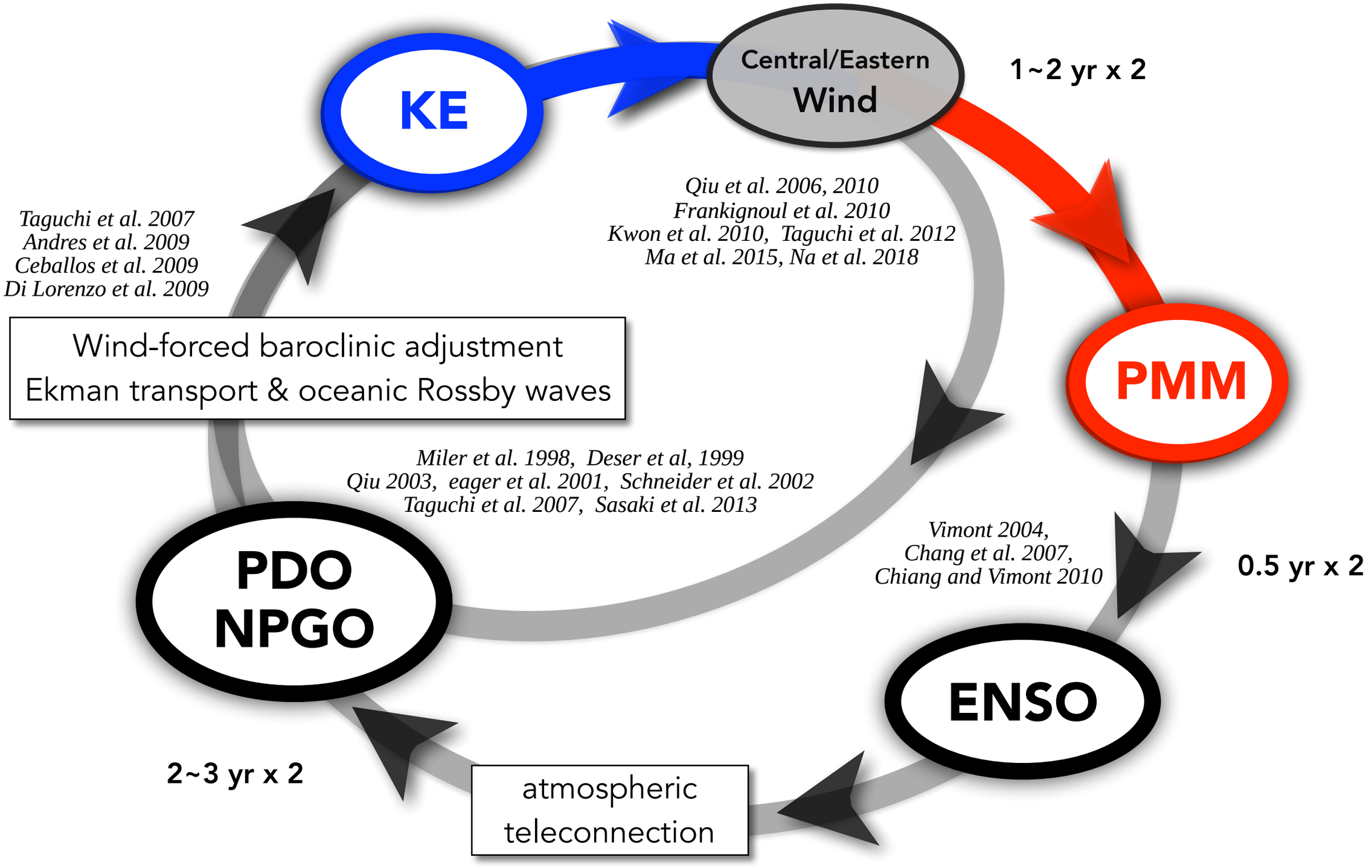




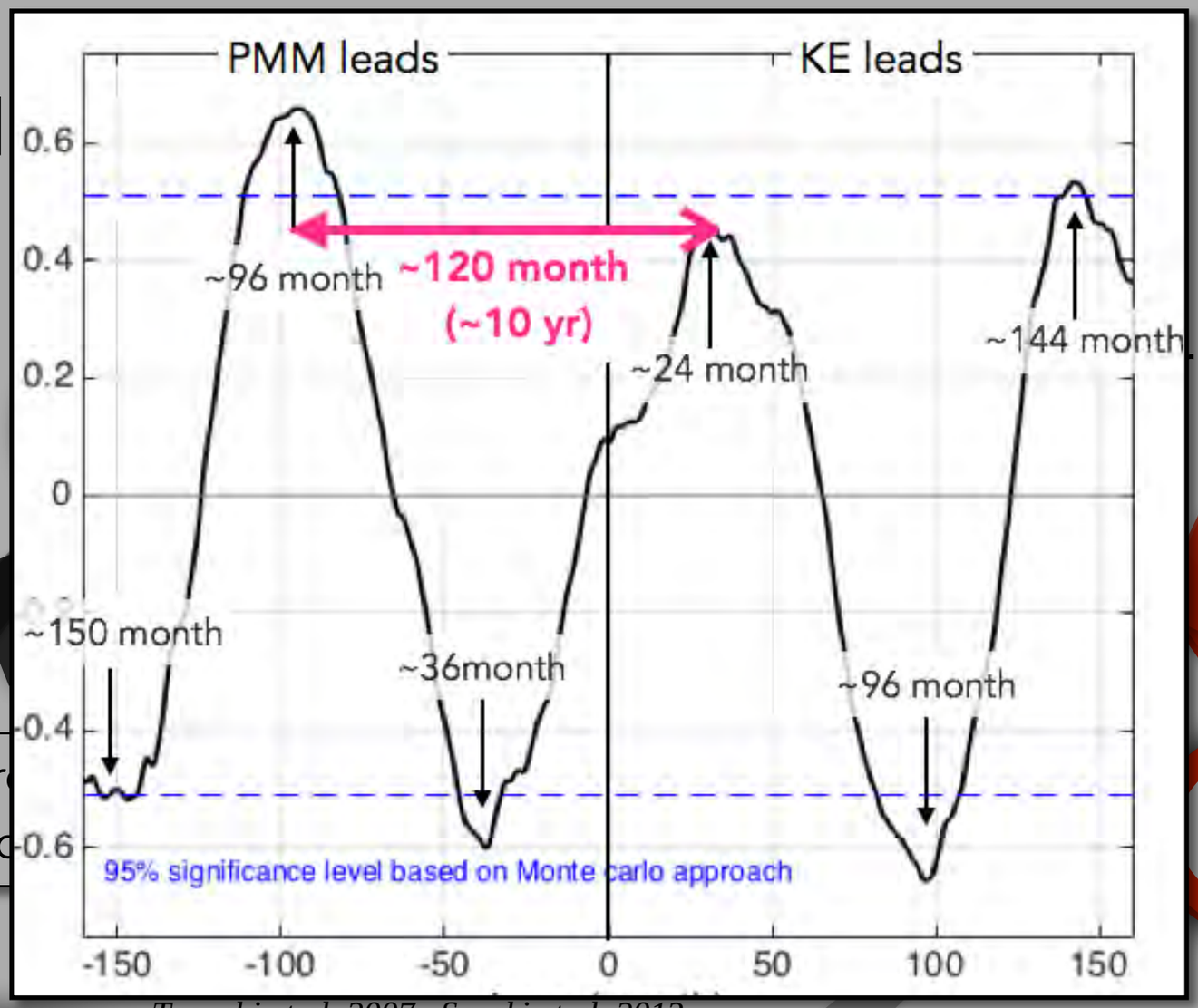
Correlation map to KE index



Suggested Hypothesis



Suggested



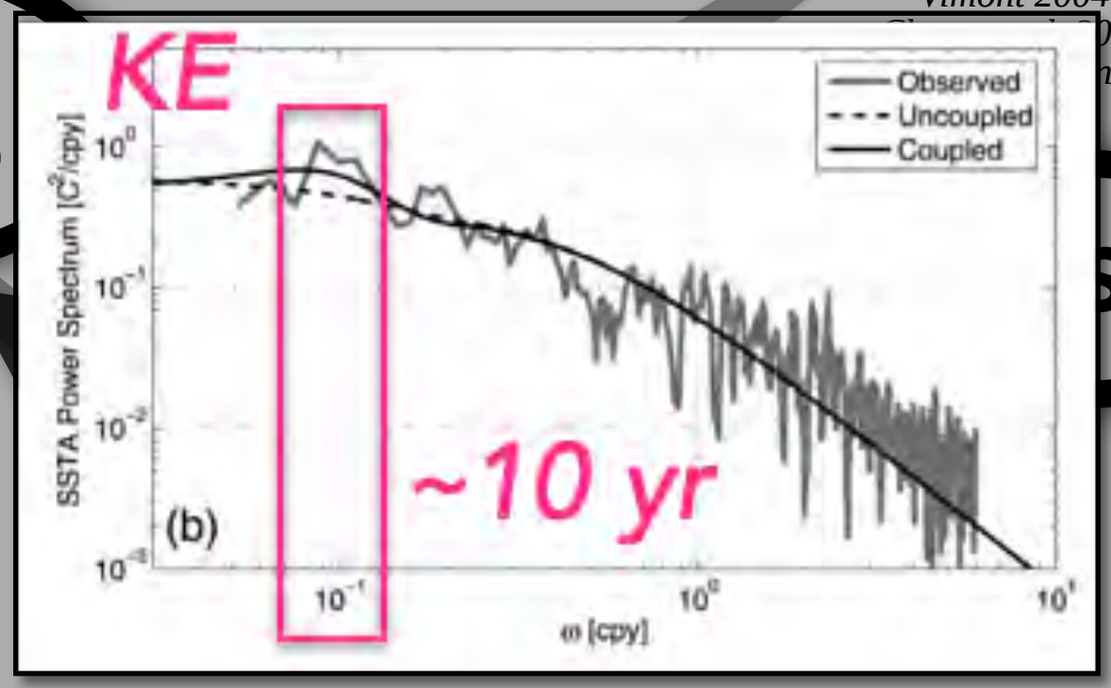
Taguchi et al. 2007, Sasaki et al. 2013

Taguchi et al. 2007
Andres et al. 2009
Ceballos et al. 2009
Di Lorenzo et al. 2009

Wind-forced bar
Ekman transport & c

PDO
NPGO

2~3 yr x 2



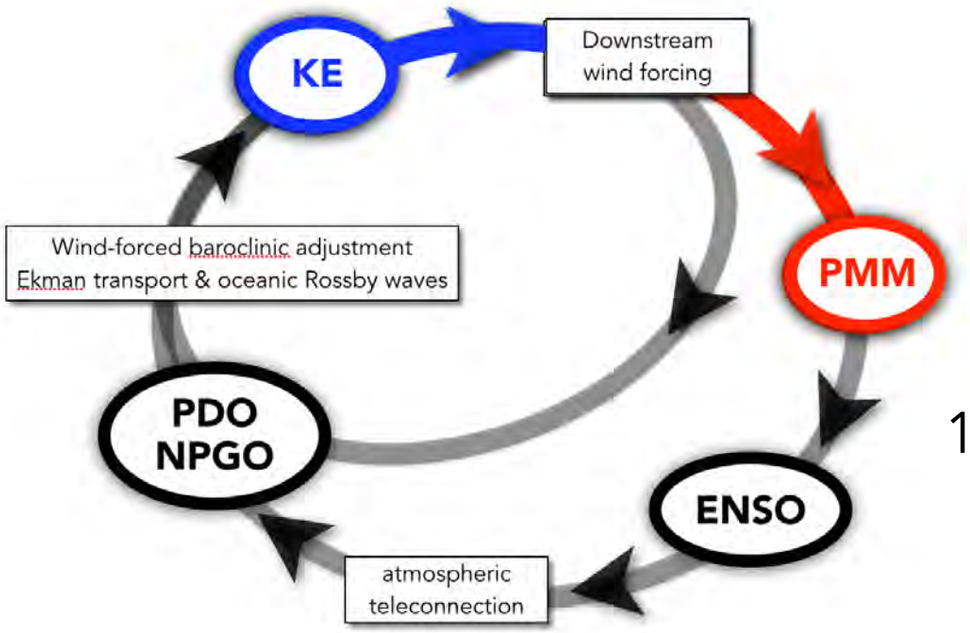
Vimont 2004,
…007,
…nt 2010

PMM

0.5 yr x 2

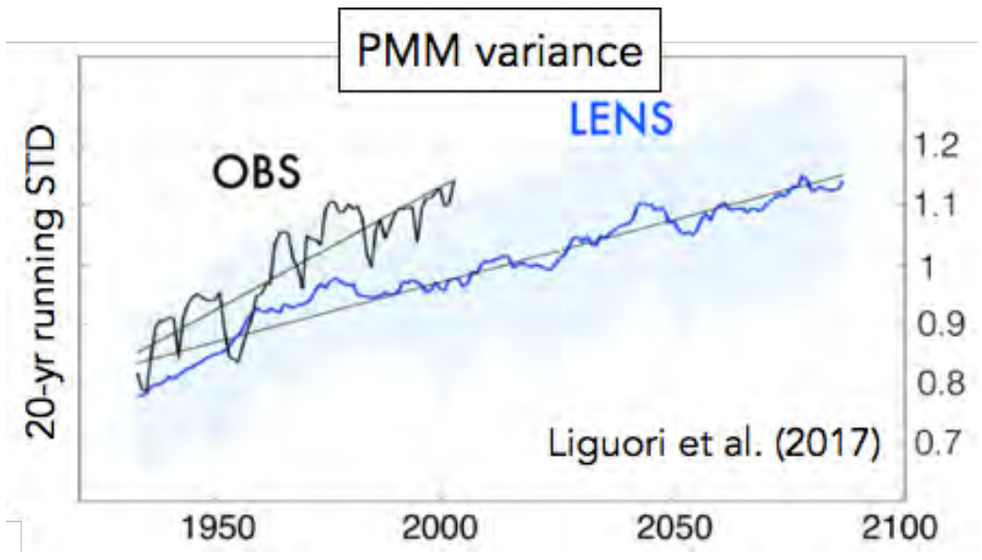
…SO

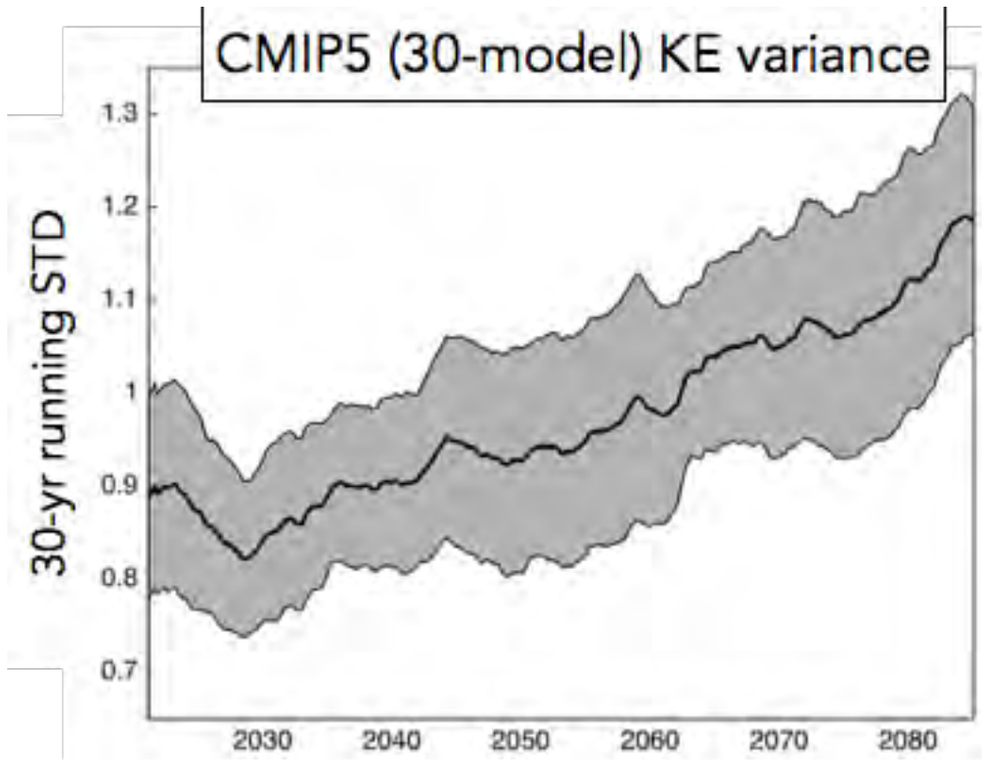
x 2



Ecological responses to climate changes and their applicability to ecosystem predictions?

1. provides ***a basis for decadal predictability of biophysical environment*** since the KE and PMM both exert significant influences on SST and regional water mass formation and transformation processes in the North Pacific.

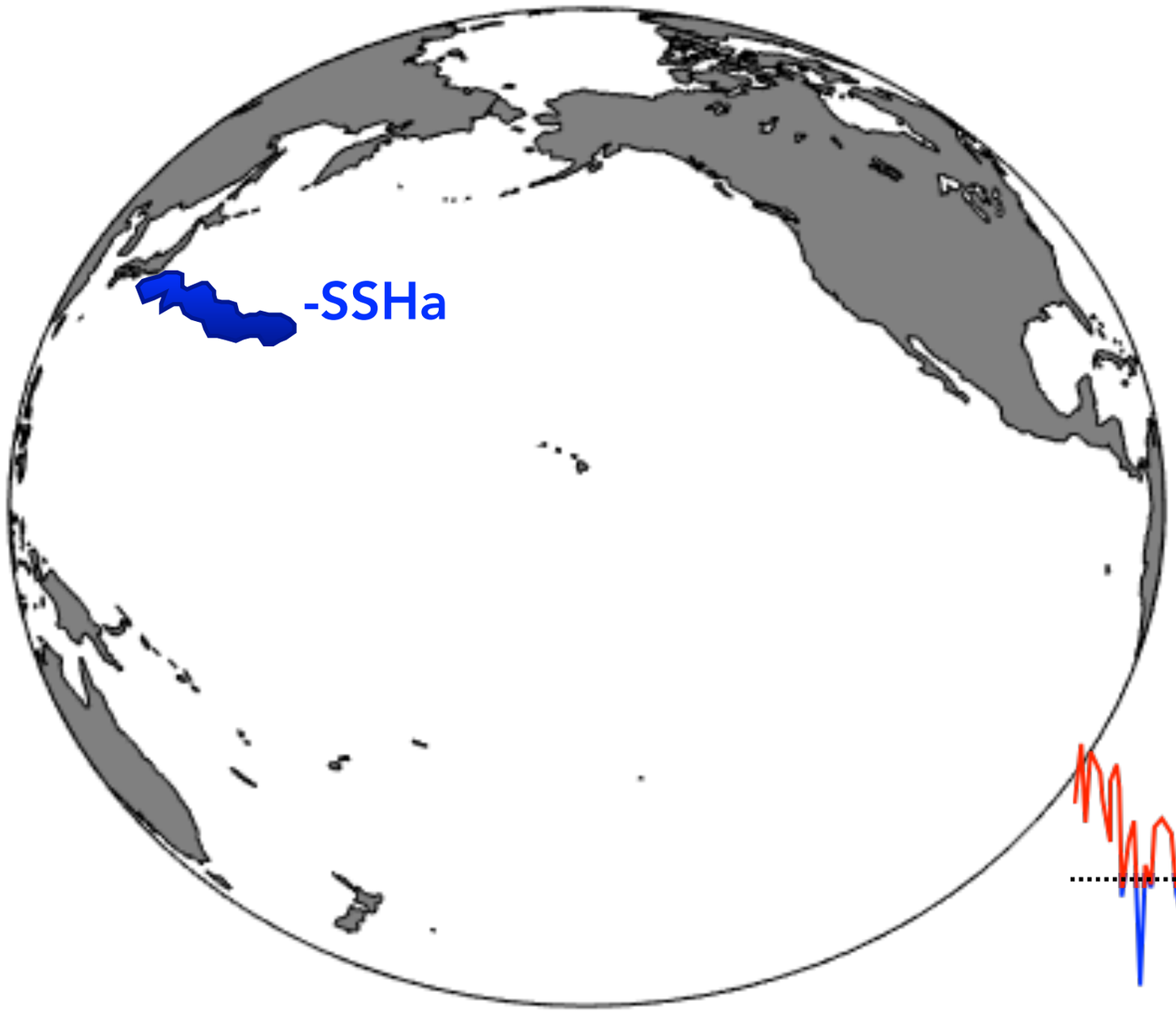


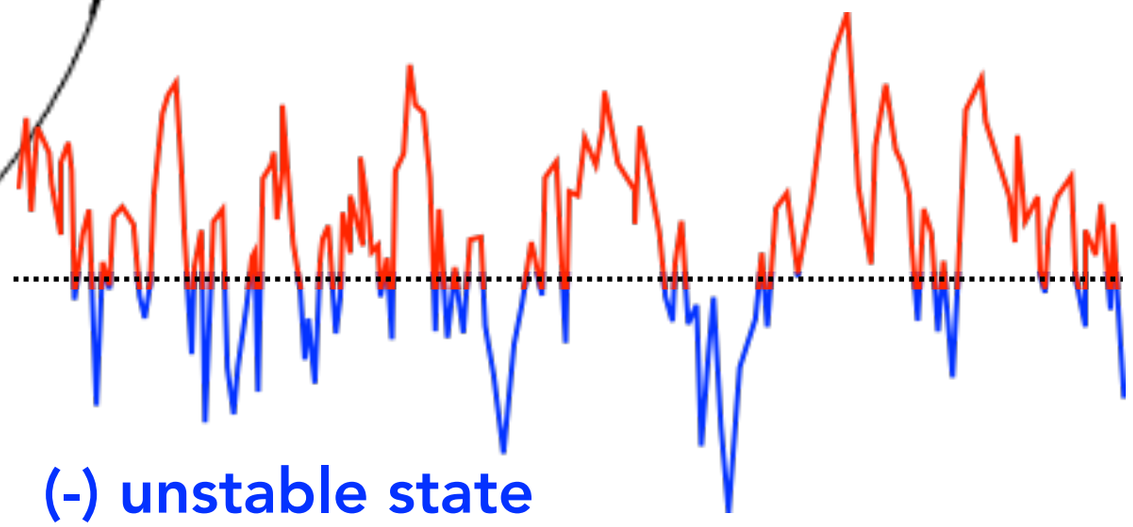


2. suggests ***the amplified linkage between KE-PMM under anthropogenic forcing*** that leads to stronger decadal fluctuations of biophysical quantities (e.g., salinity, oxygen, chlorophyll-A) in the North Pacific

Supplemental Figures

KE dynamic state



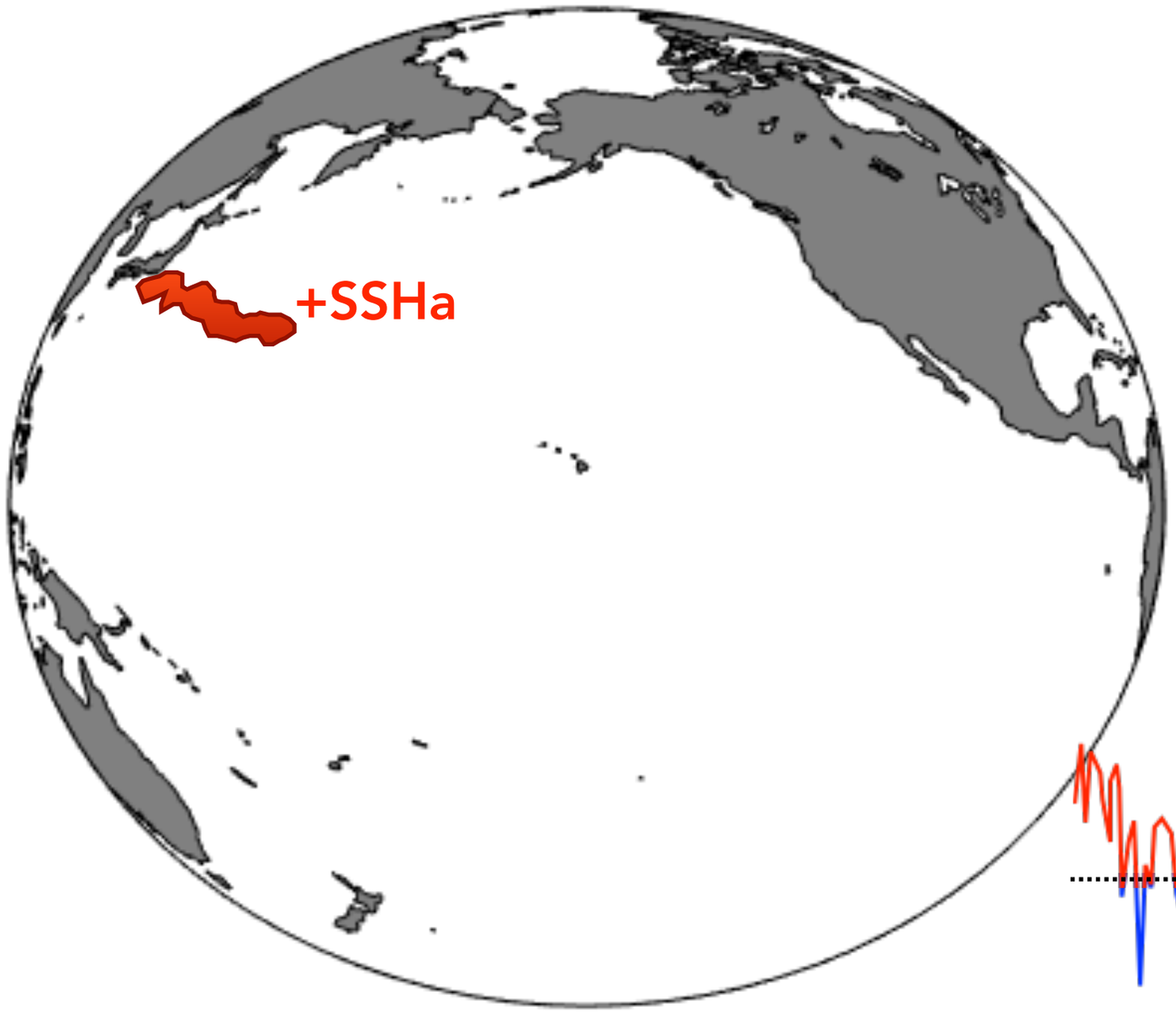


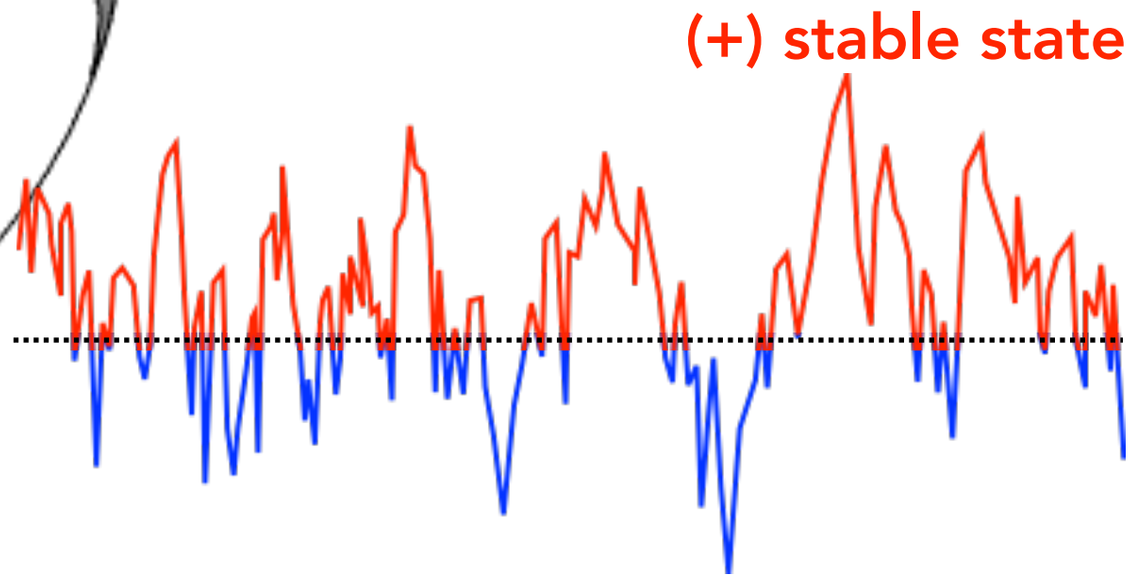
(-) unstable state

Qiu et al. (2014)

*Note that the terminology ‘’stable’’ versus ‘‘unstable’’ is to indicate the dynamic state of the KE system, doesn’t necessary mean the condition for instability of the KE jet.

KE dynamic state

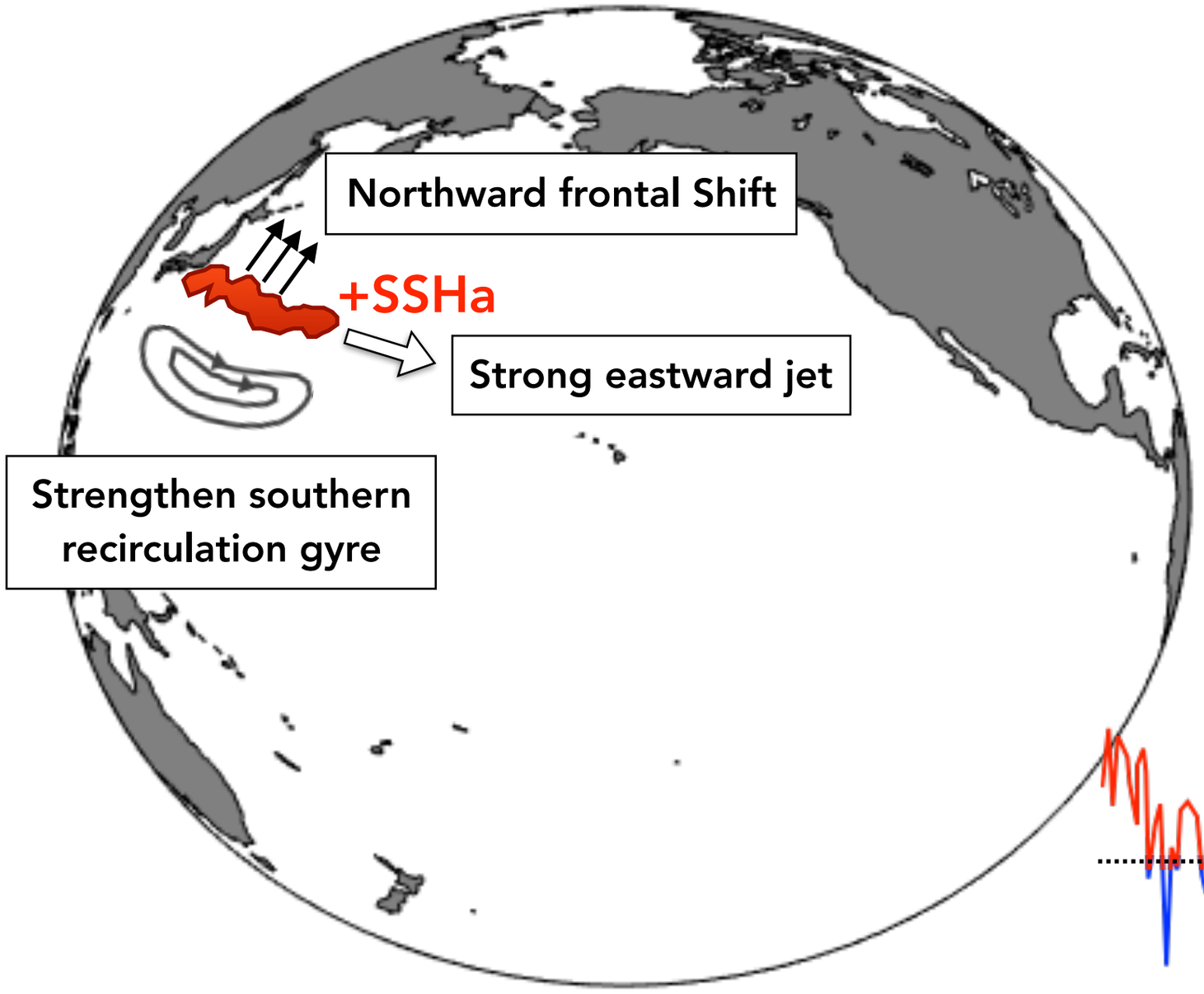


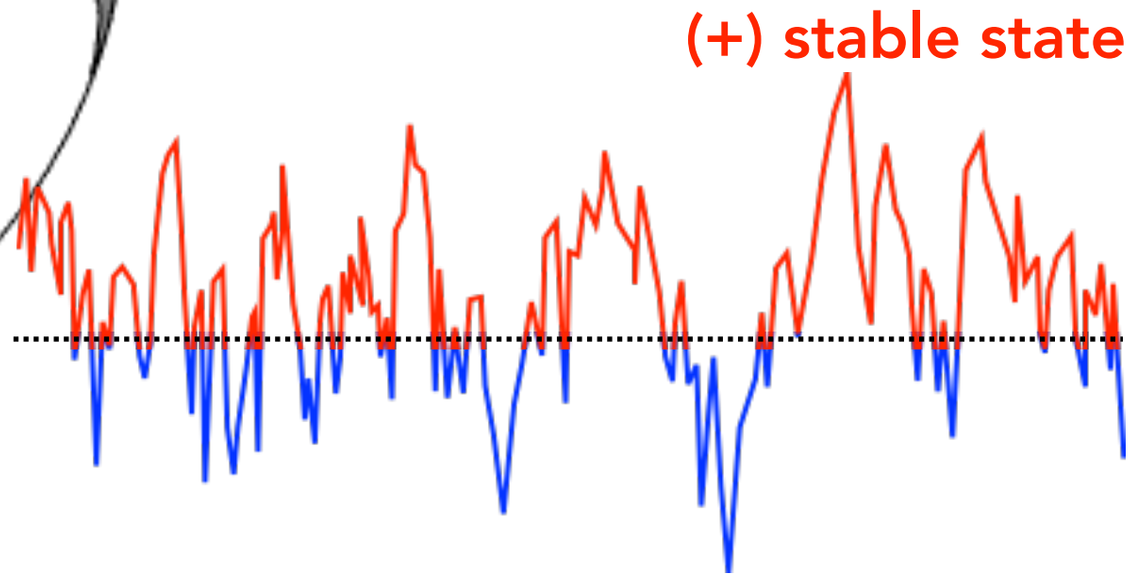


Qiu et al. (2014)

*Note that the terminology ‘’stable’’ versus ‘‘unstable’’ is to indicate the dynamic state of the KE system, doesn’t necessary mean the condition for instability of the KE jet.

KE dynamic state

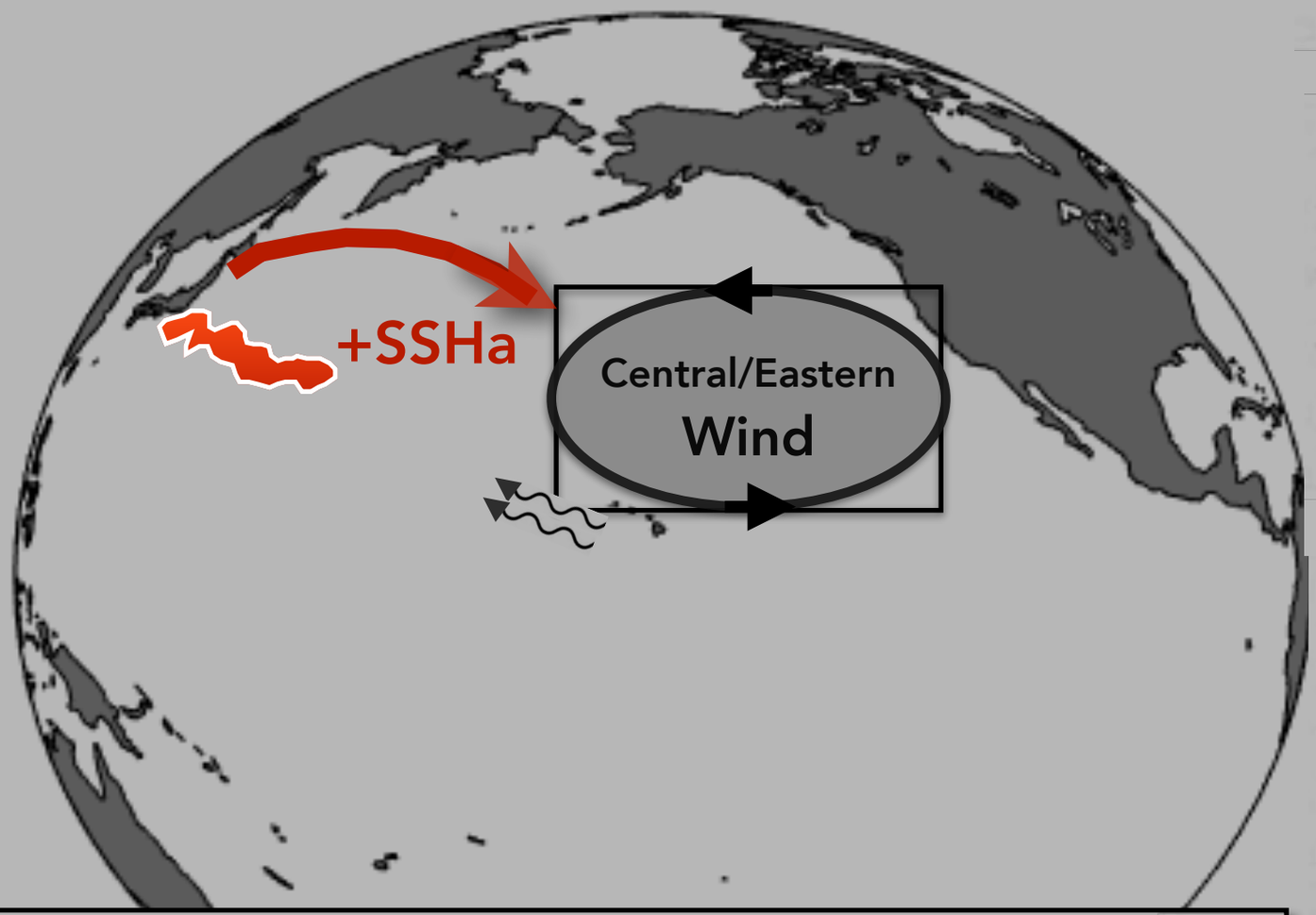




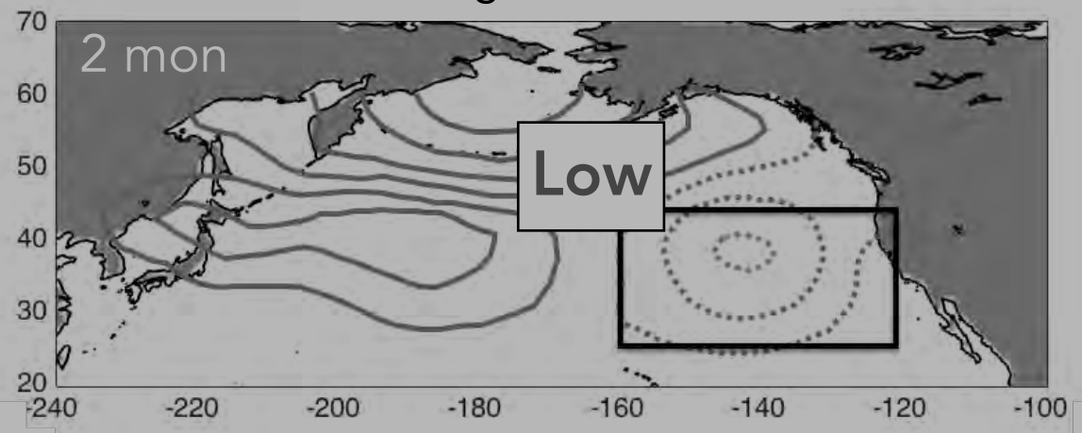
Qiu et al. (2014)

*Note that the terminology ‘’stable’’ versus ‘‘unstable’’ is to indicate the dynamic state of the KE system, doesn’t necessary mean the condition for instability of the KE jet.

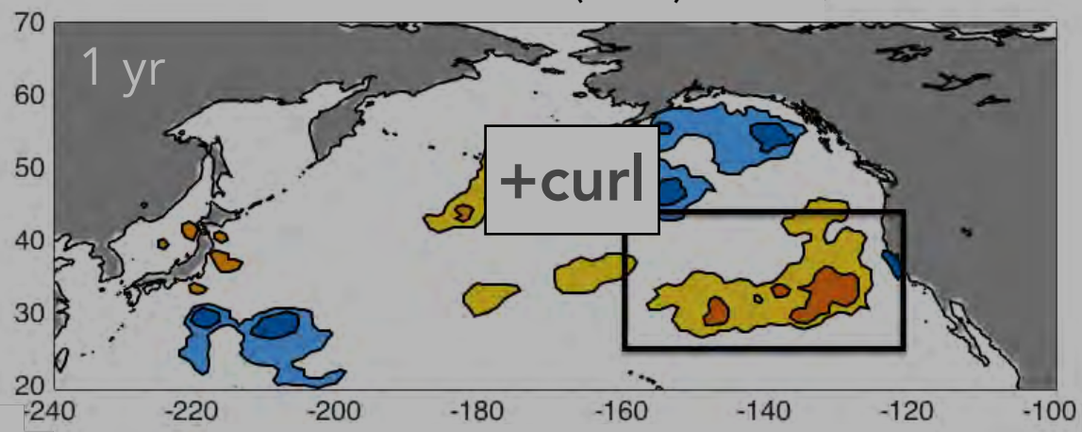
KE atm/ocean response



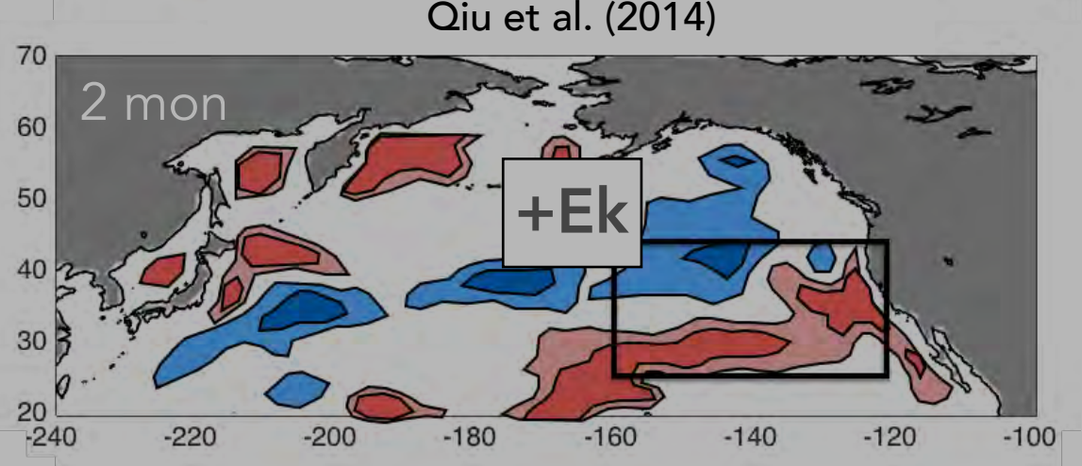
Frankignoul et al. 2010

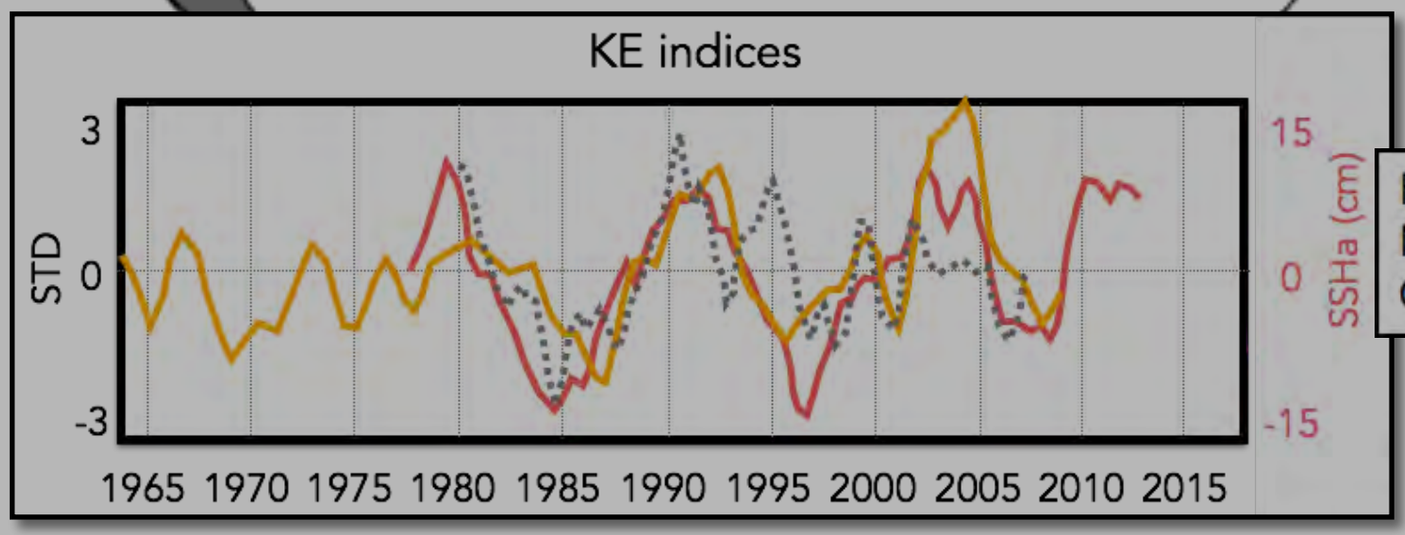


Na et al. (2018)

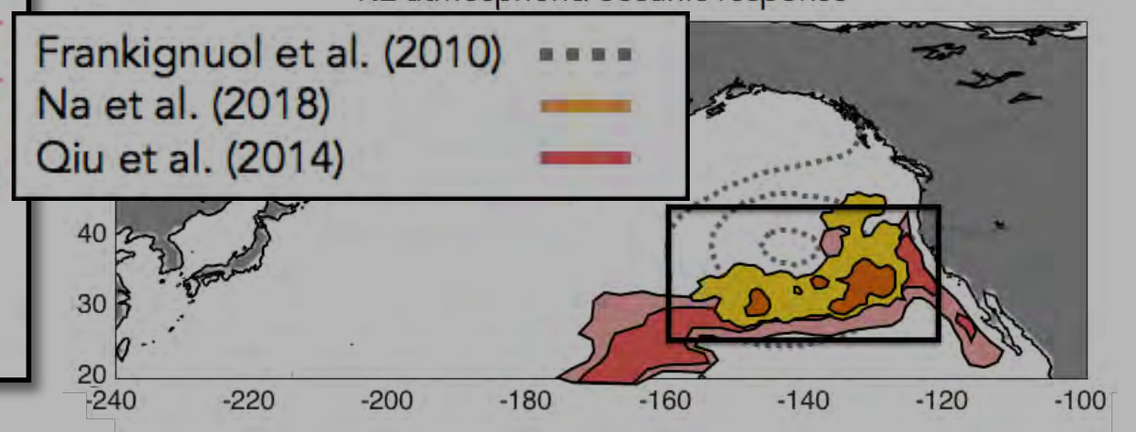


Qiu et al. (2014)

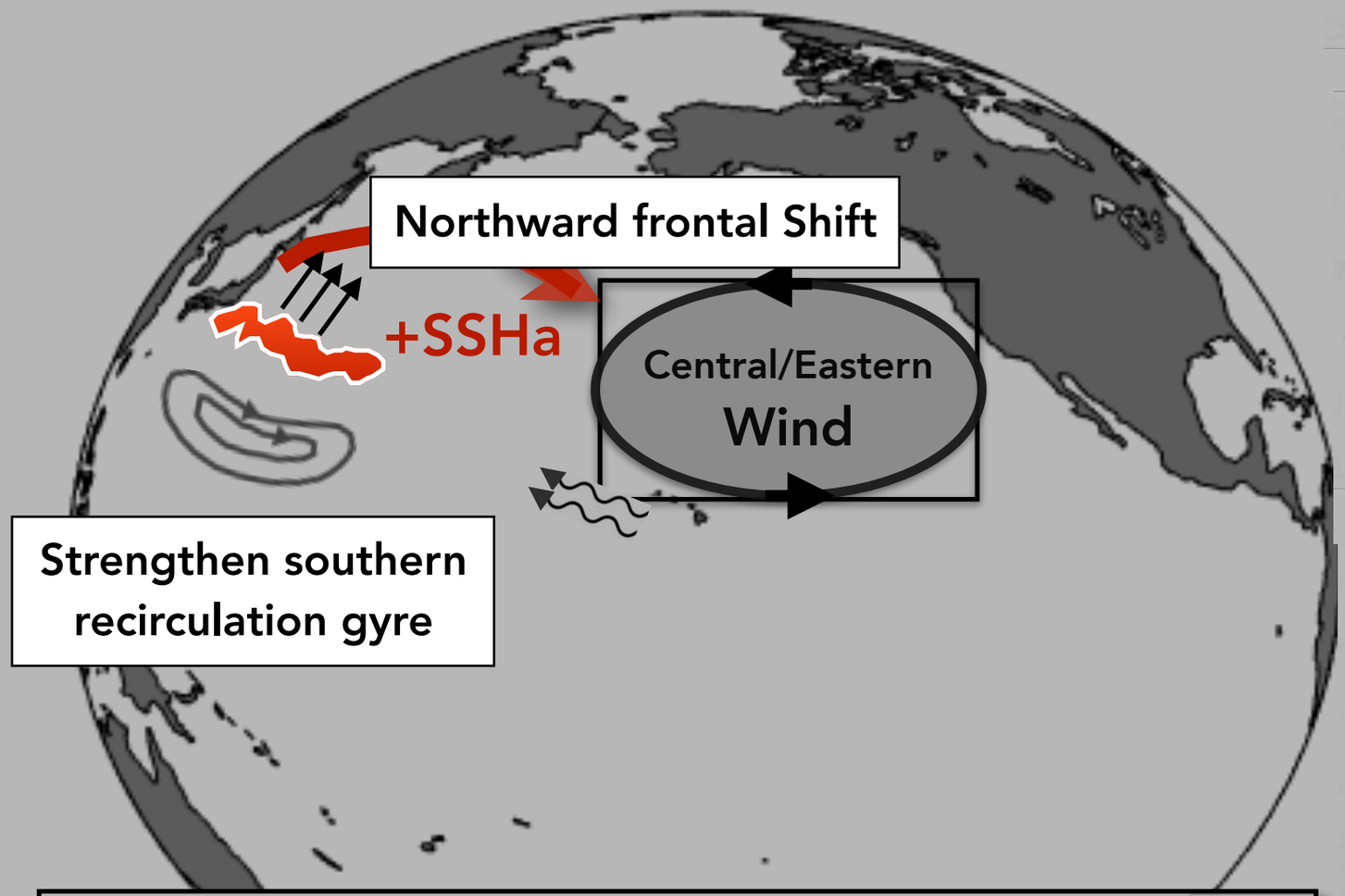




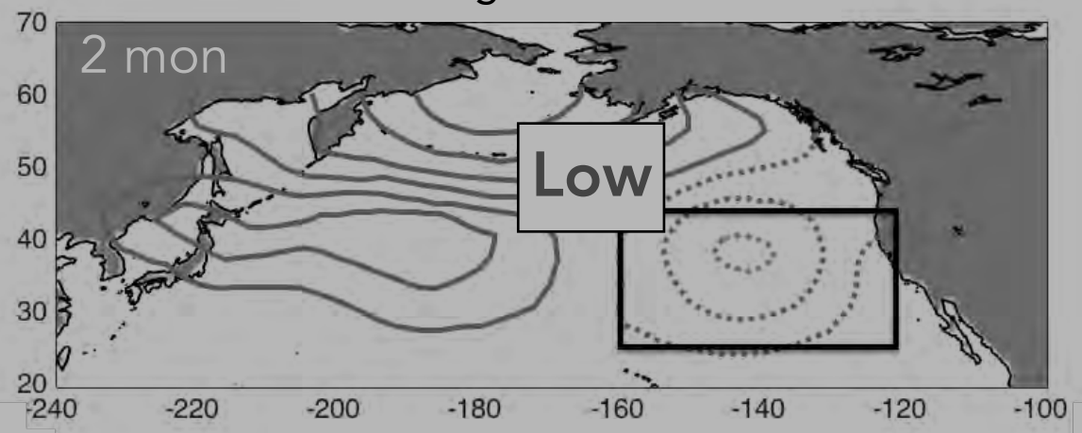
KE atmospheric/oceanic response



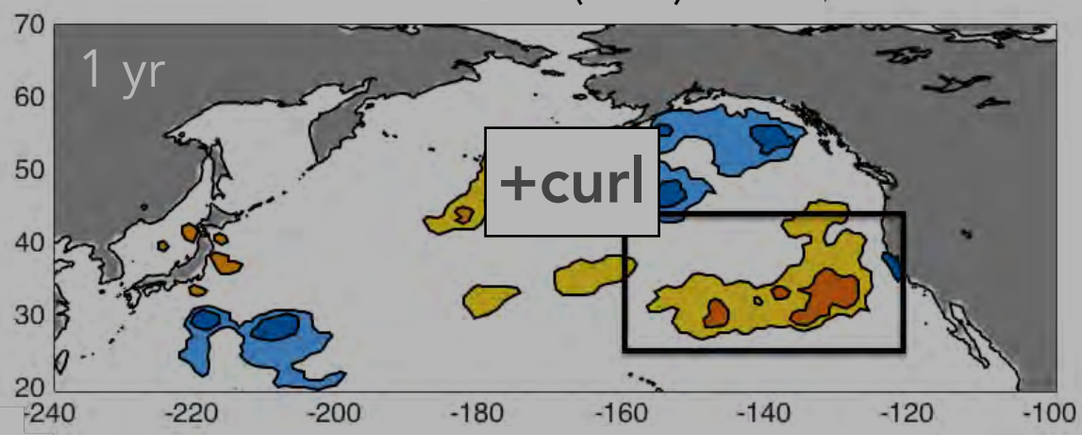
KE atm/ocean response



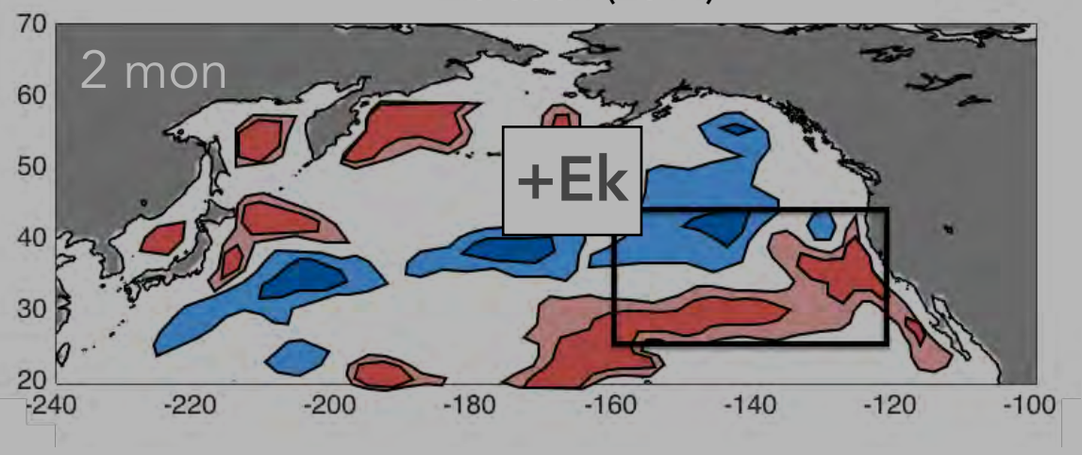
Frankignoul et al. 2010

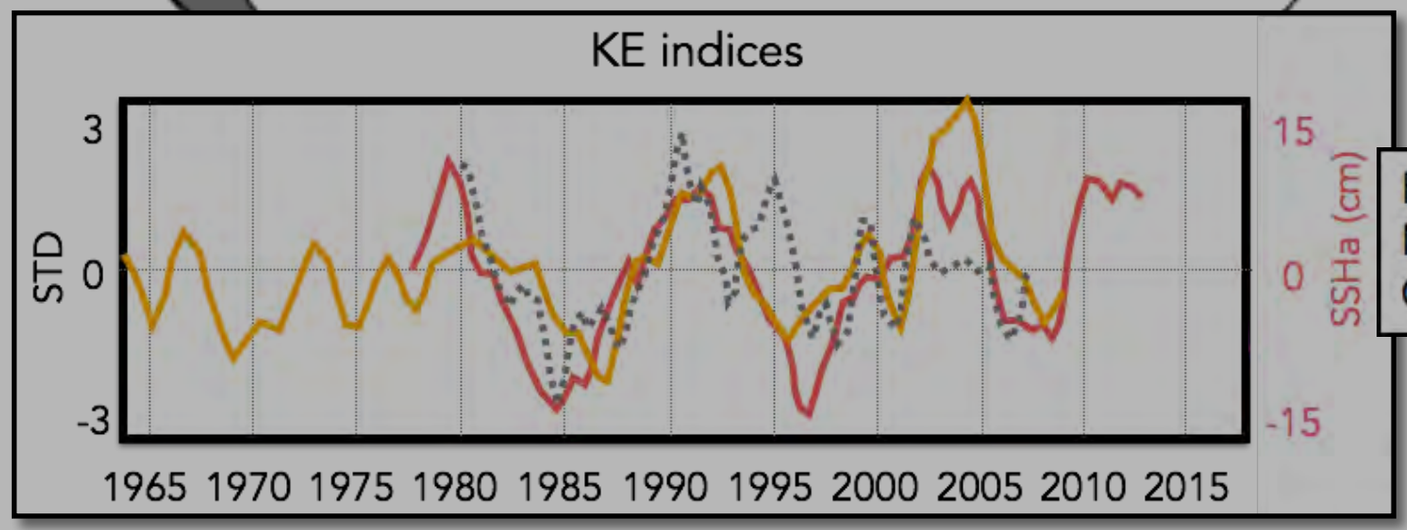


Na et al. (2018)

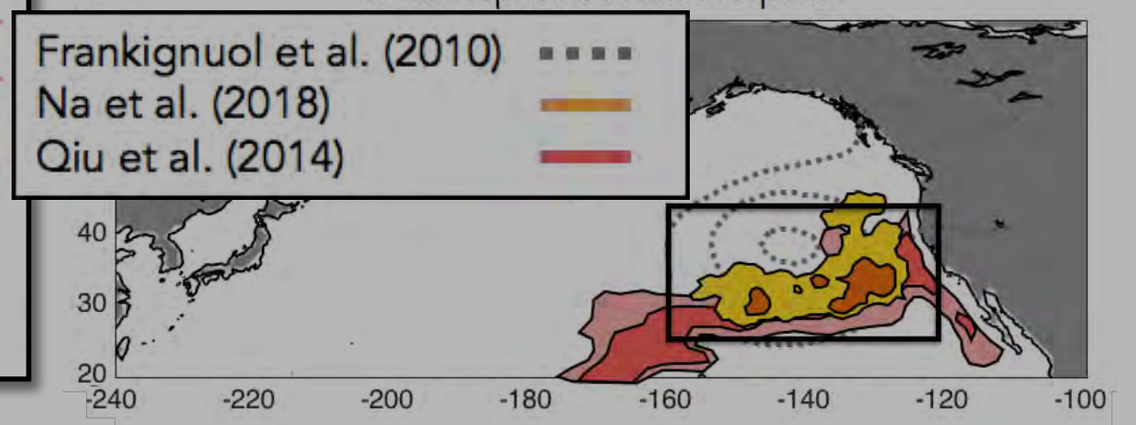


Qiu et al. (2014)

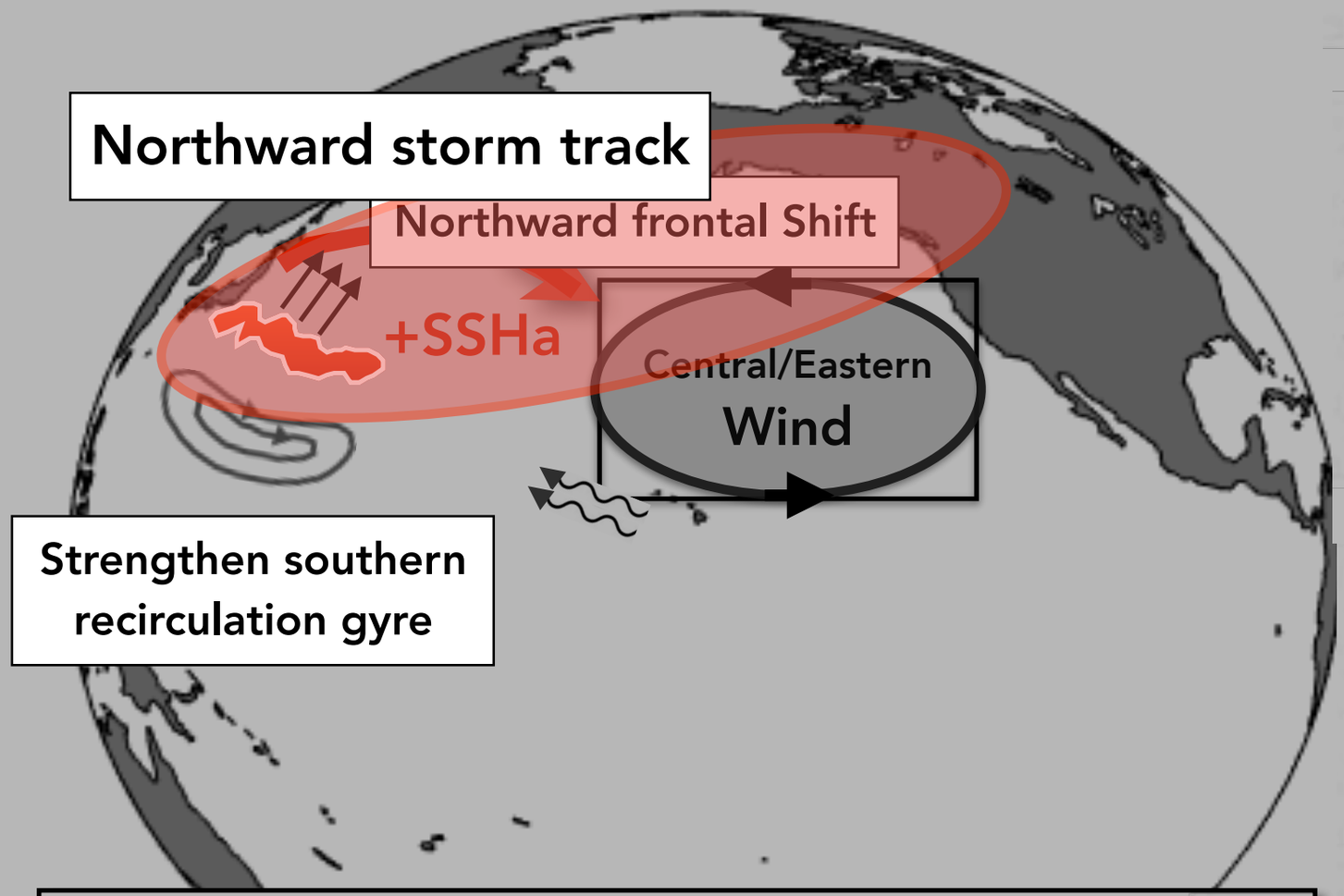




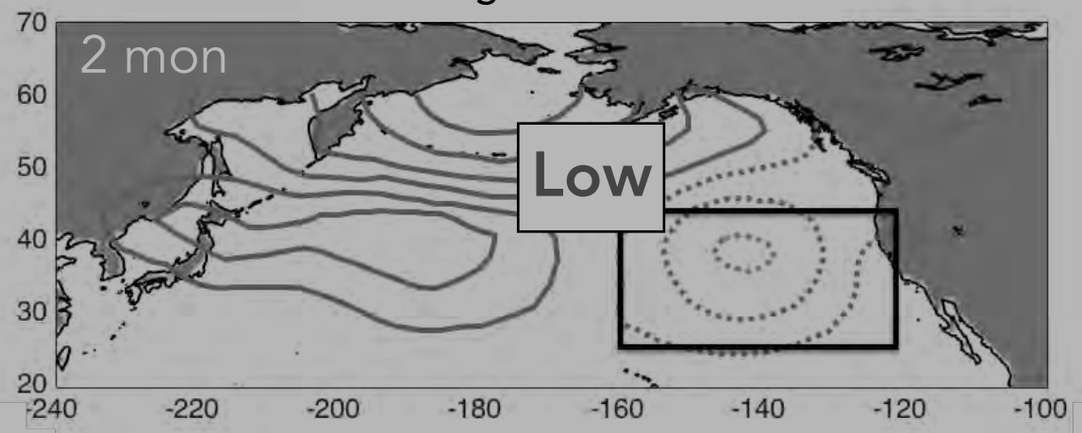
KE atmospheric/oceanic response



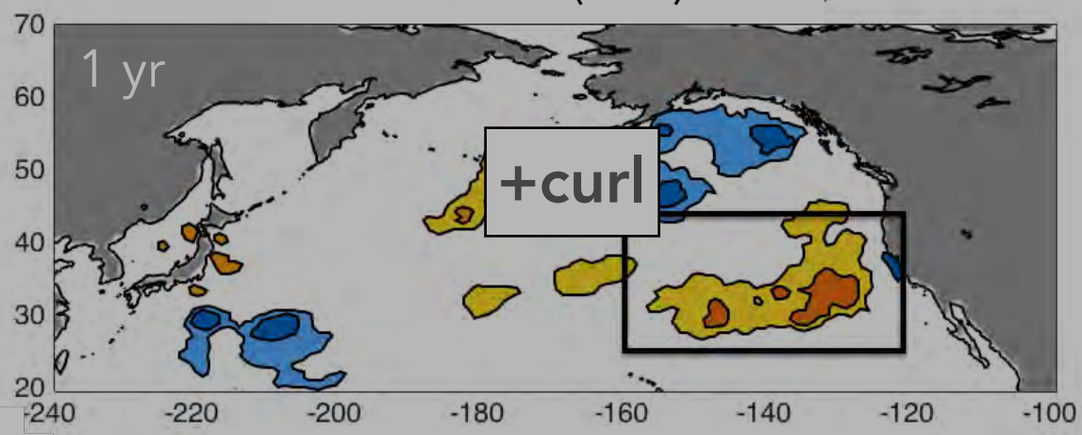
KE atm/ocean response



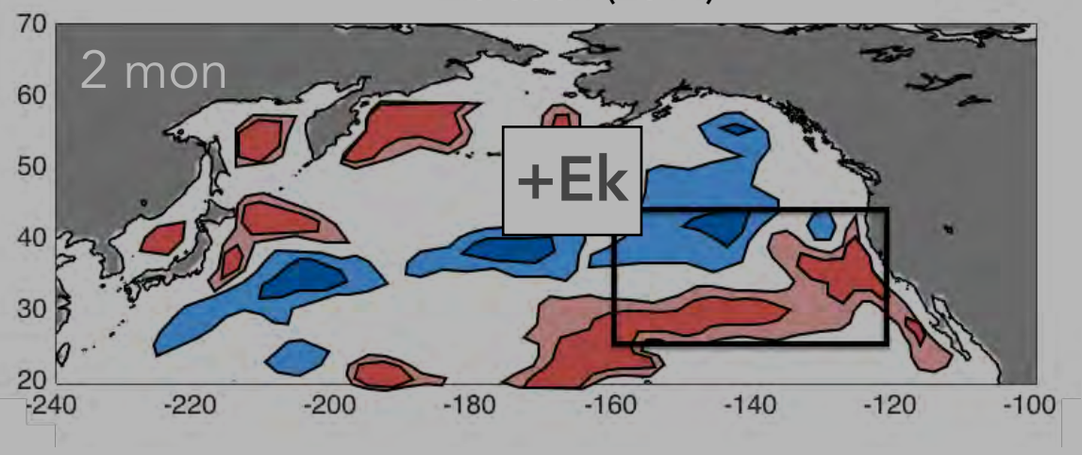
Frankignoul et al. 2010

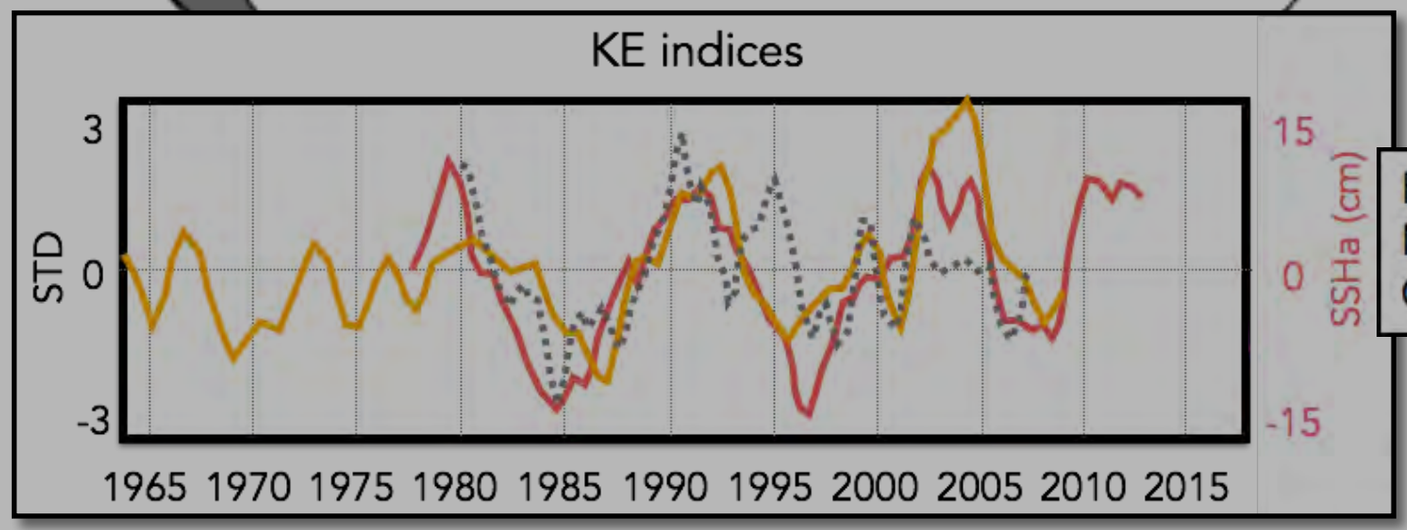


Na et al. (2018)

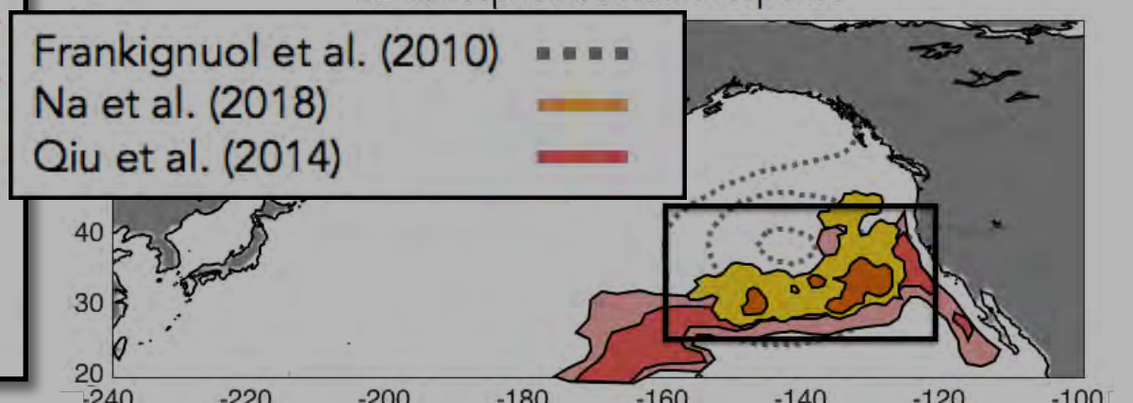


Qiu et al. (2014)

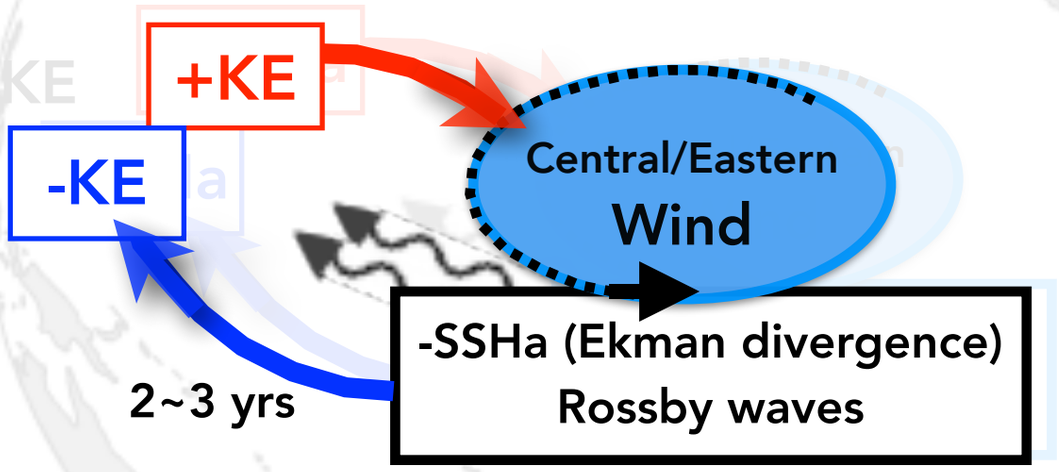


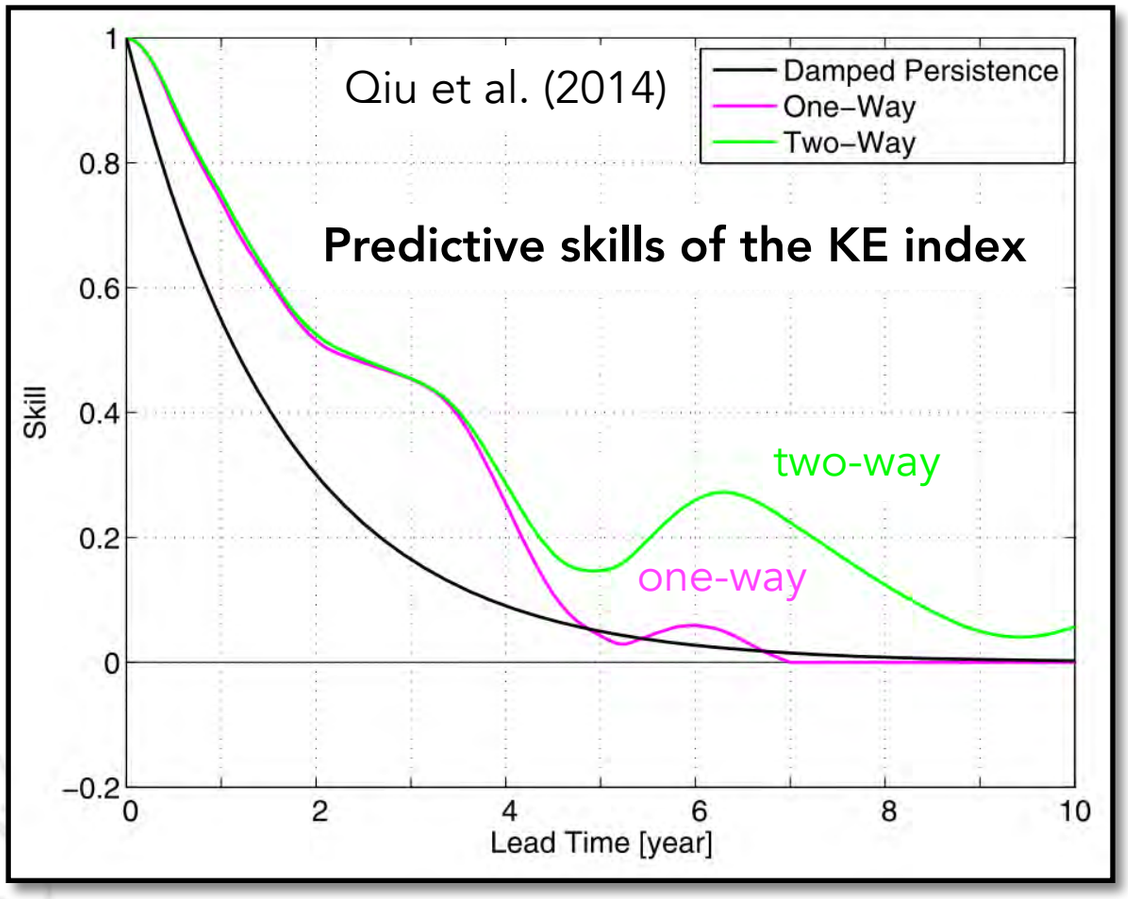


KE atmospheric/oceanic response

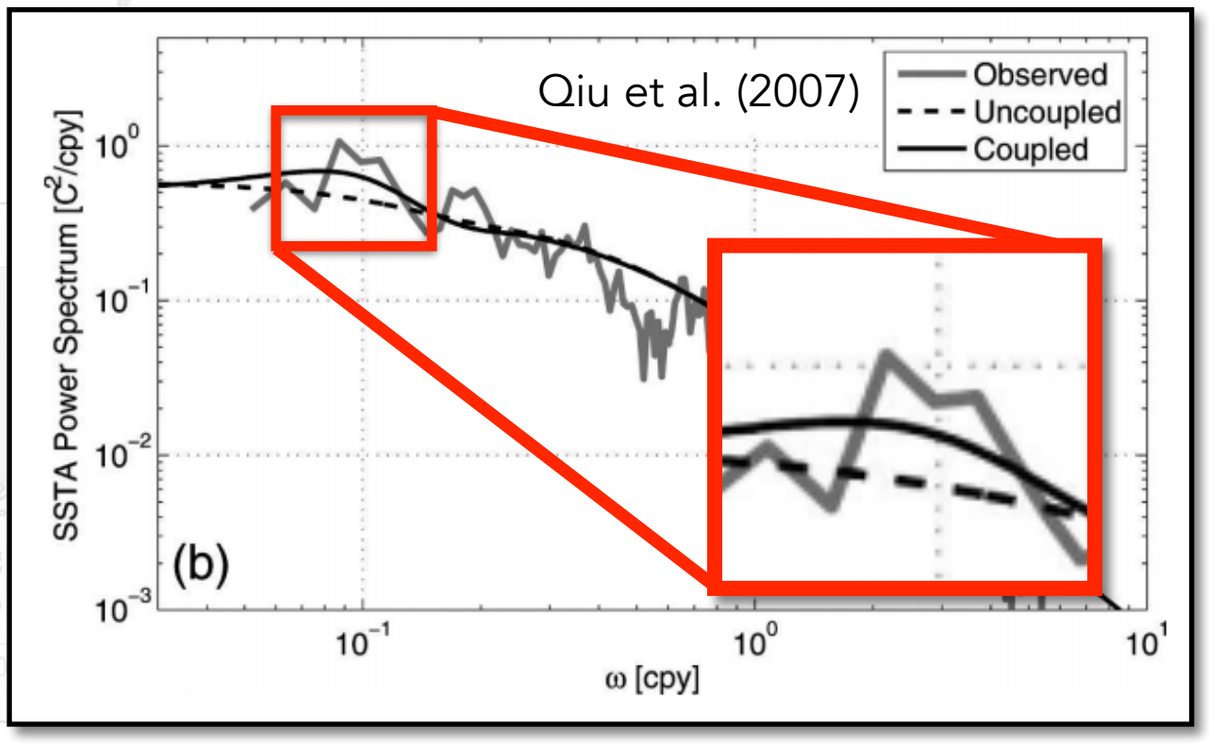


Forcing & Response

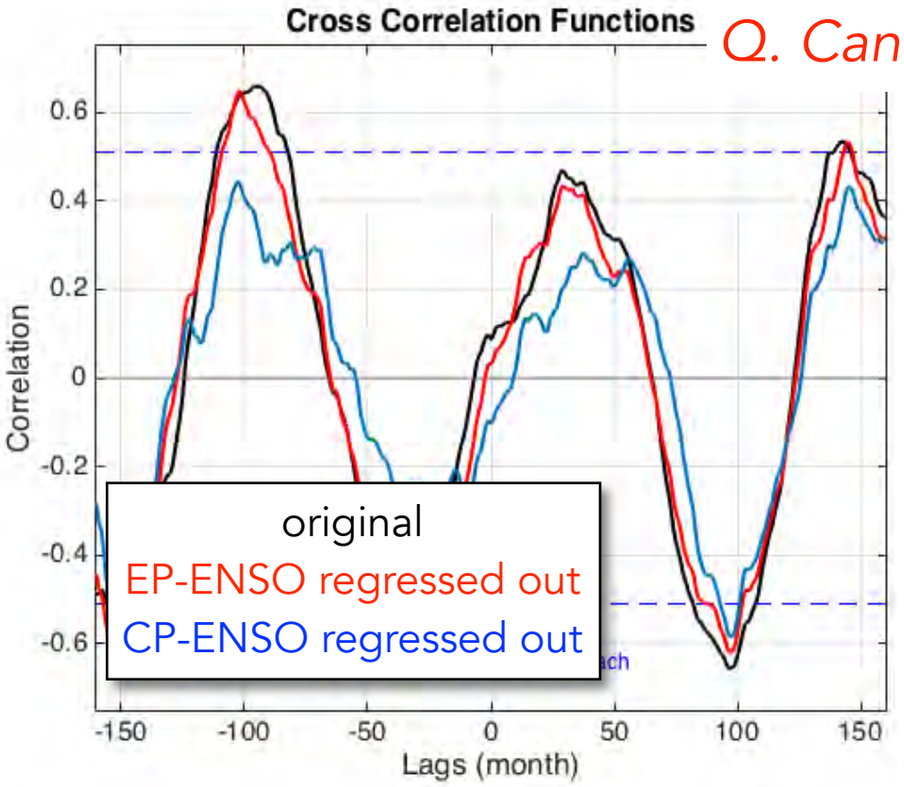




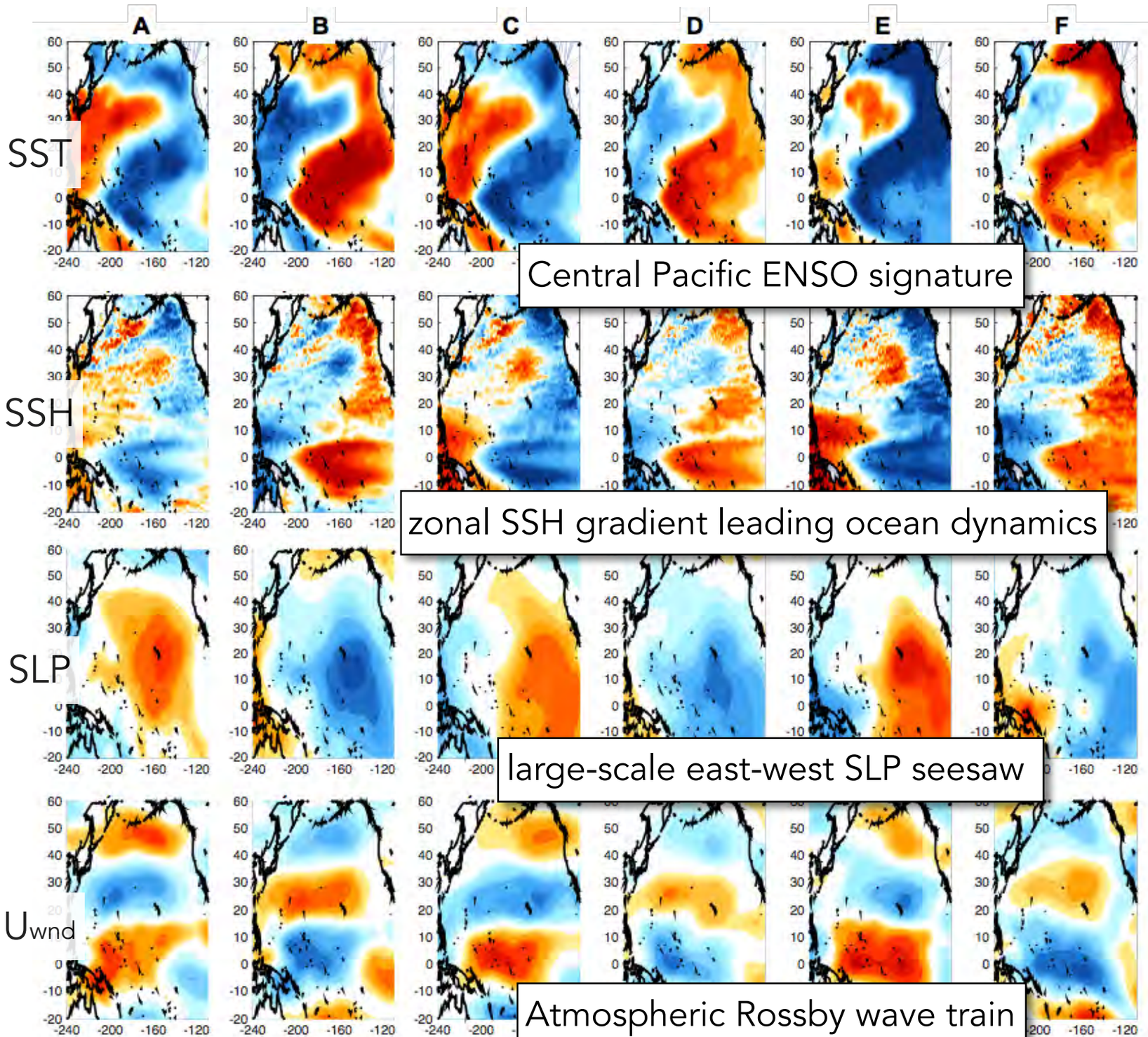
damped persistence
Rossby waves adjustment
Rossby waves adjustment+wind feedback



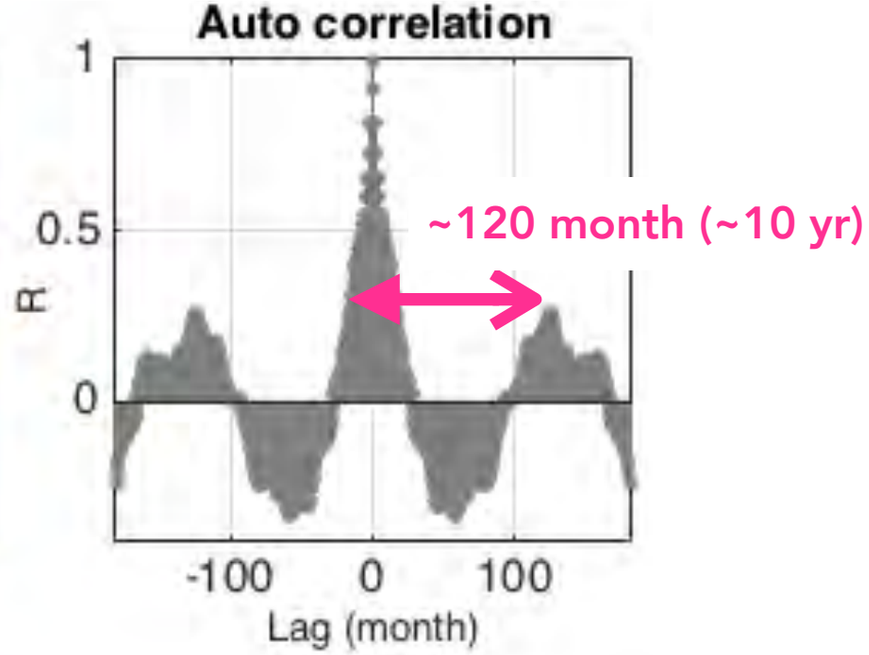
Q. Can the transition of PMM be reconstructed by the KE modulation?



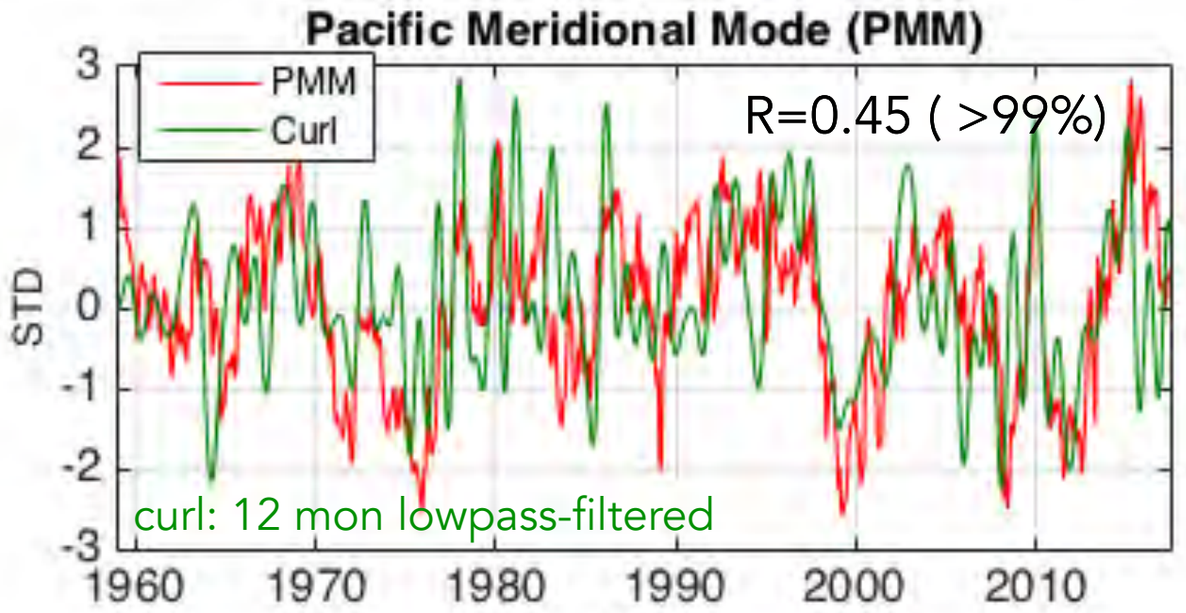
Correlation map to KE index



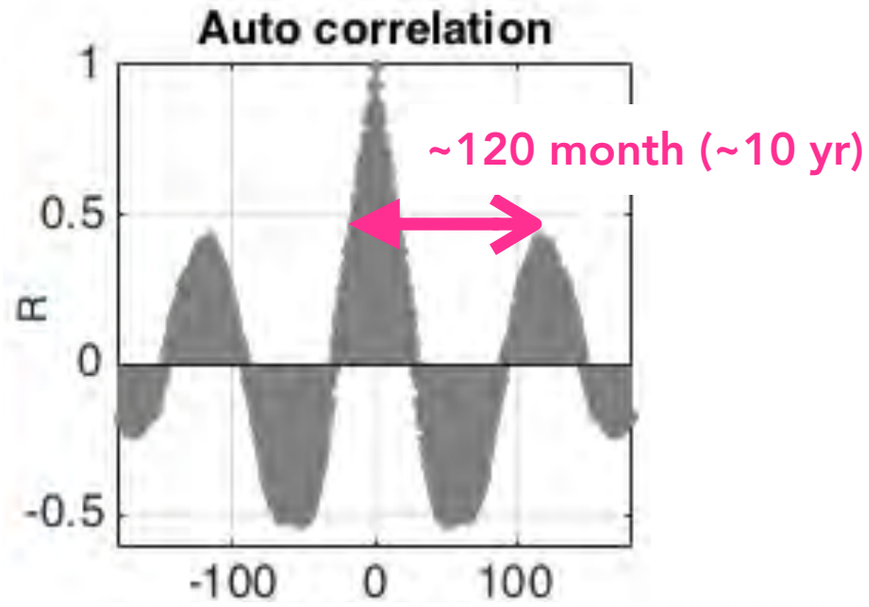
PMM



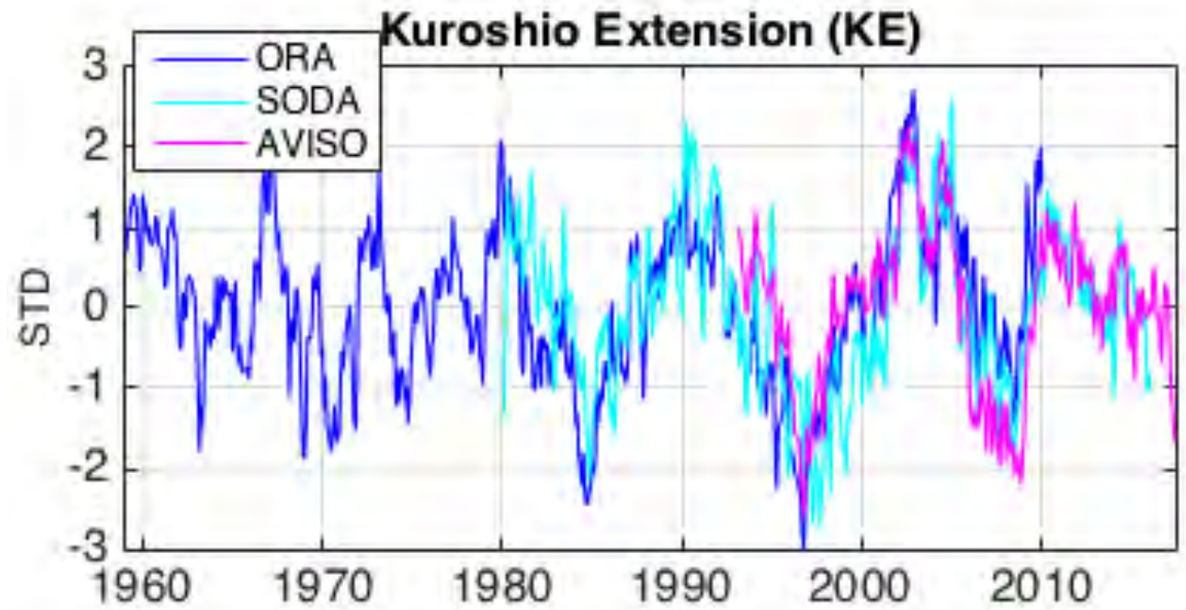
~120 month (~10 yr)

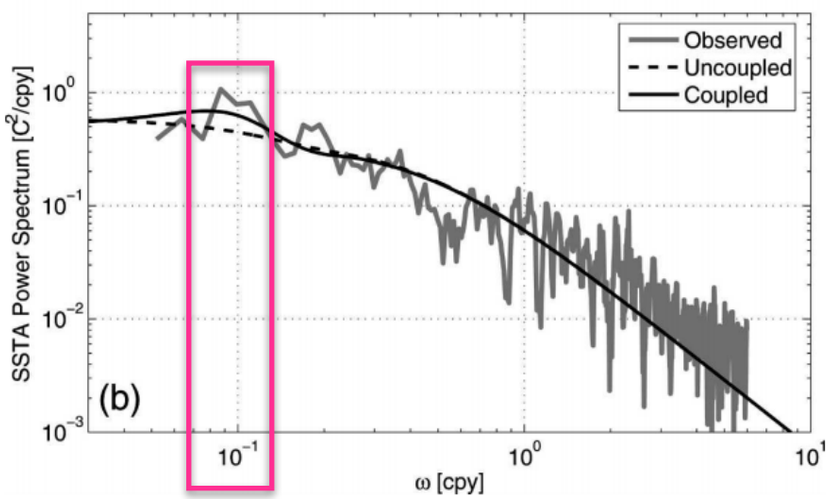


KE

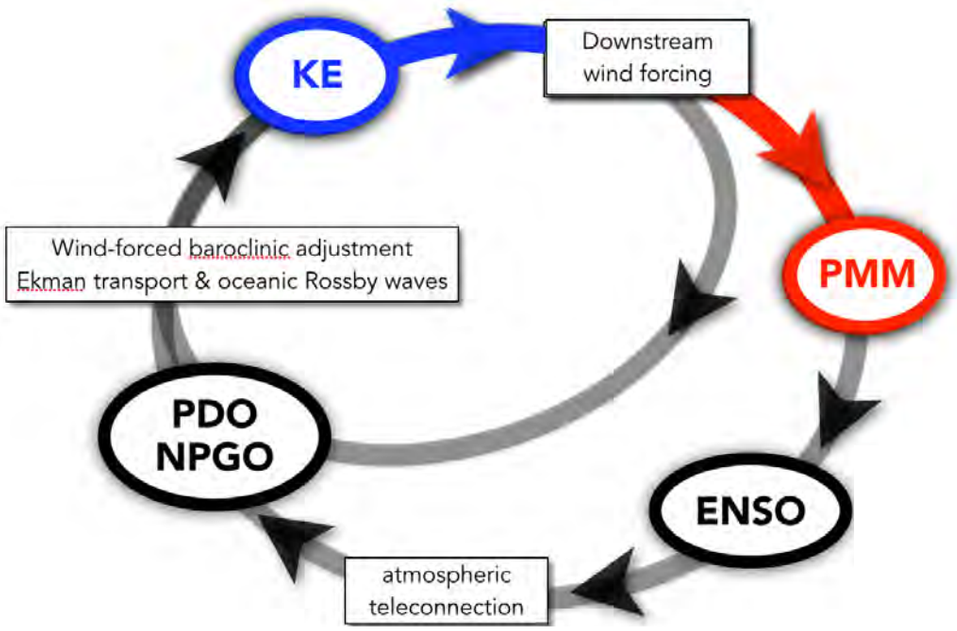


~120 month (~10 yr)

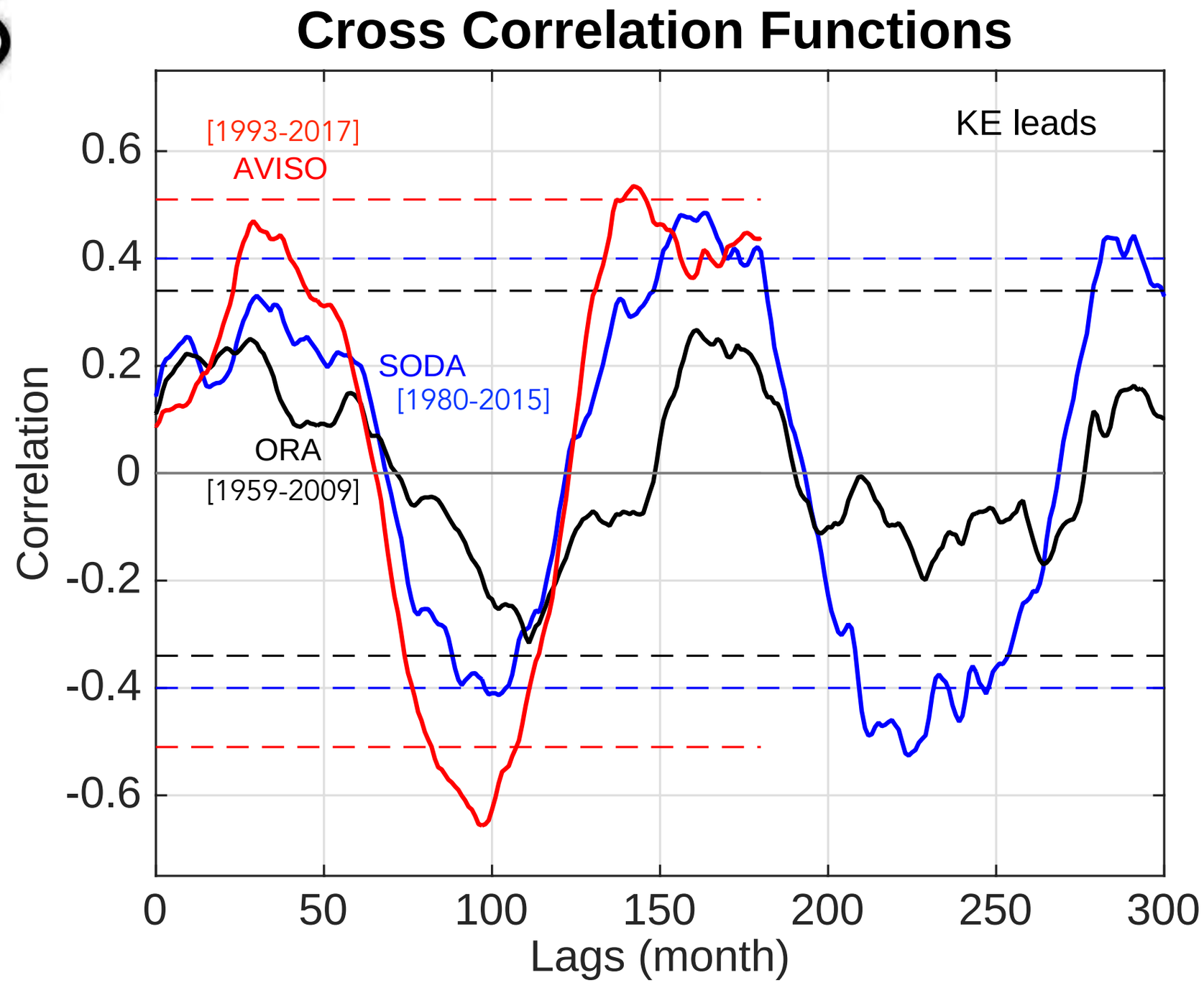


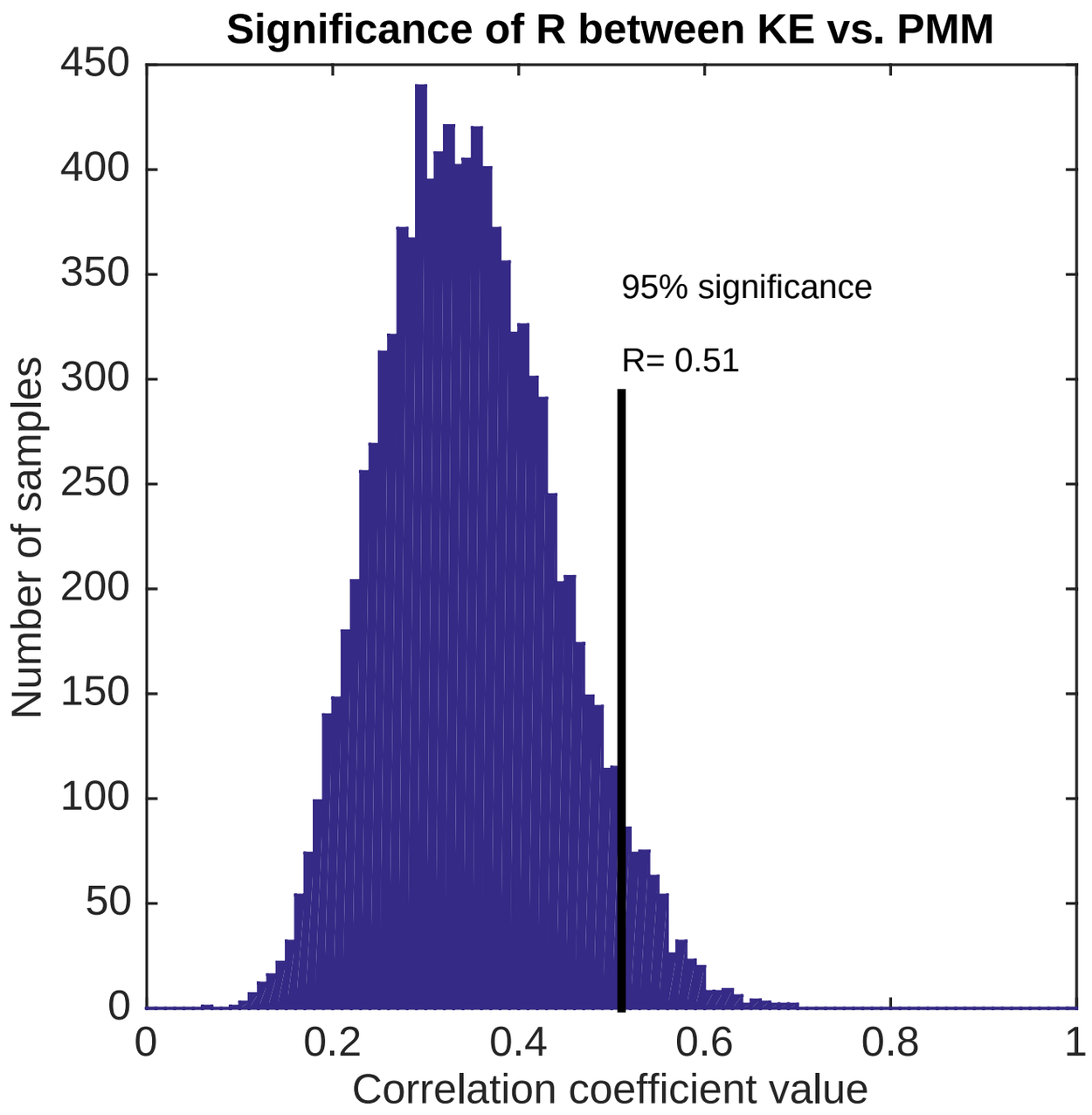


~10 yr preferred decadal peak



Question
The interaction of KE-PMM with different period?




Significance of R between KE vs. PMM
95% significance
R= 0.51
Number of samples
Correlation coefficient value
0
50
100
150
200
250
300
350
400
450
0
0.2
0.4
0.6
0.8
1