Tendency for global ***climate synchrony and amplification*** *in fish populations*

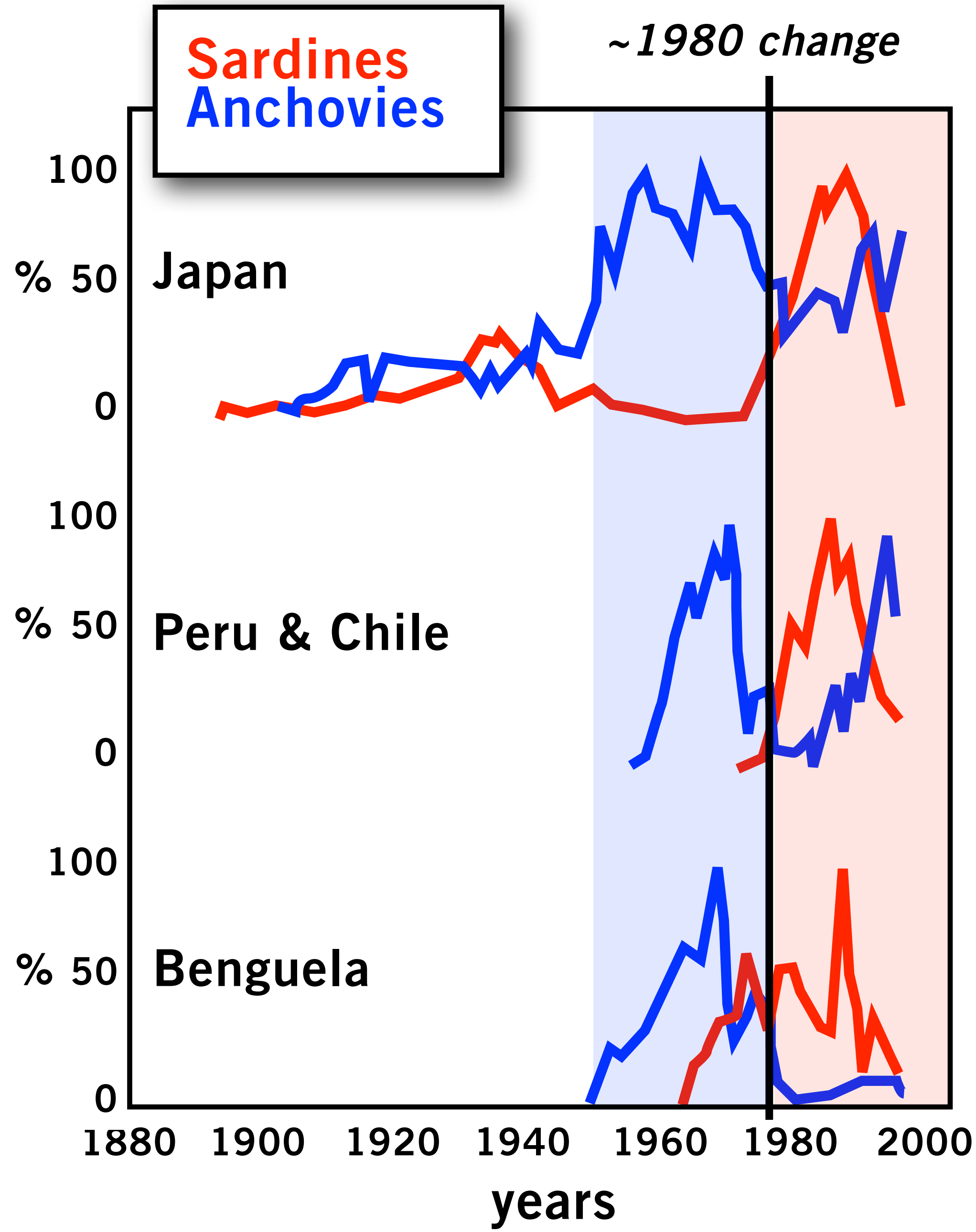
Emanuele Di Lorenzo, Mark D. Ohman, Salvador Lluch-Cota

& Ryan Rykaczewski

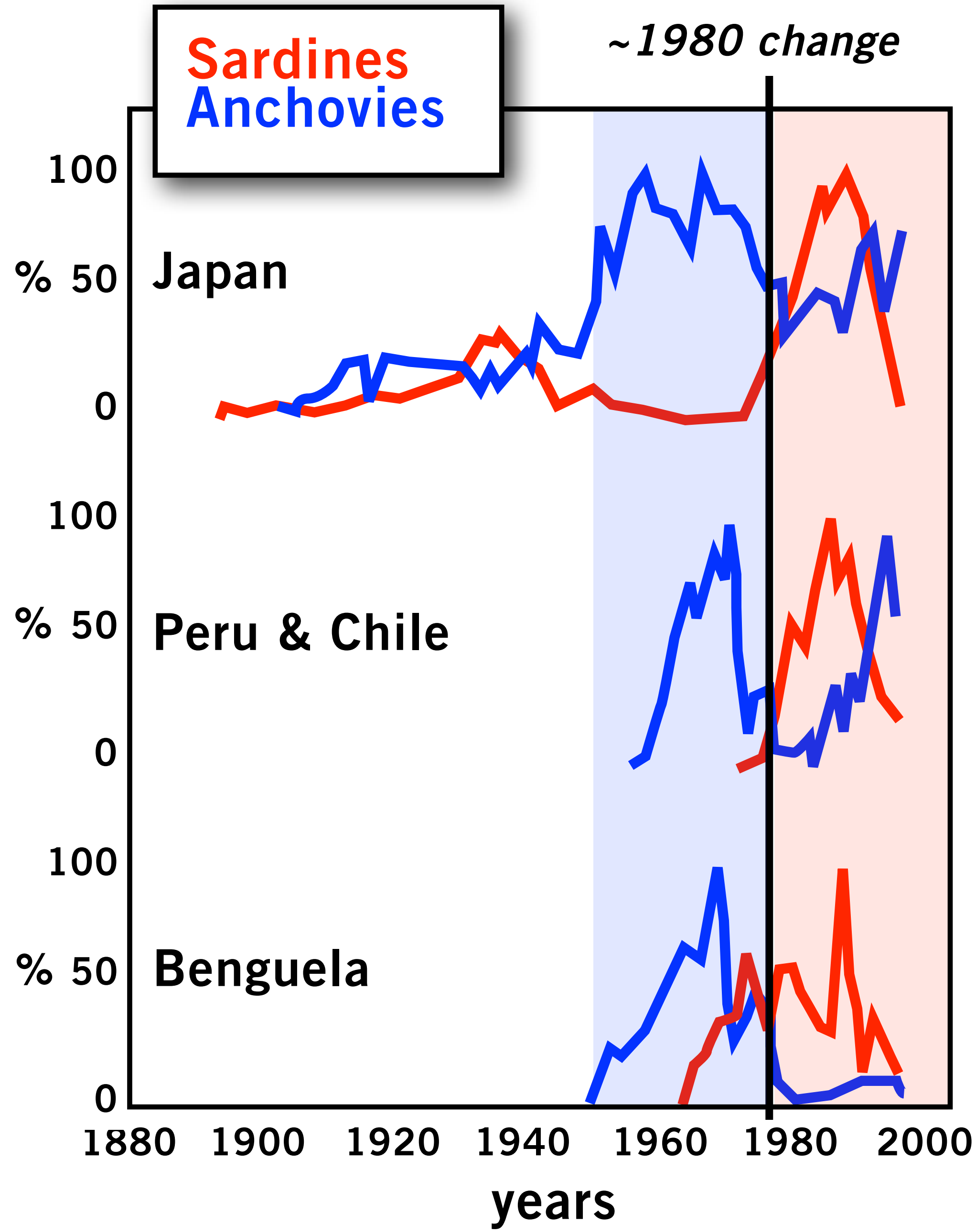
CCE-LTER

Georgia Tech | Ocean Science & Engineering

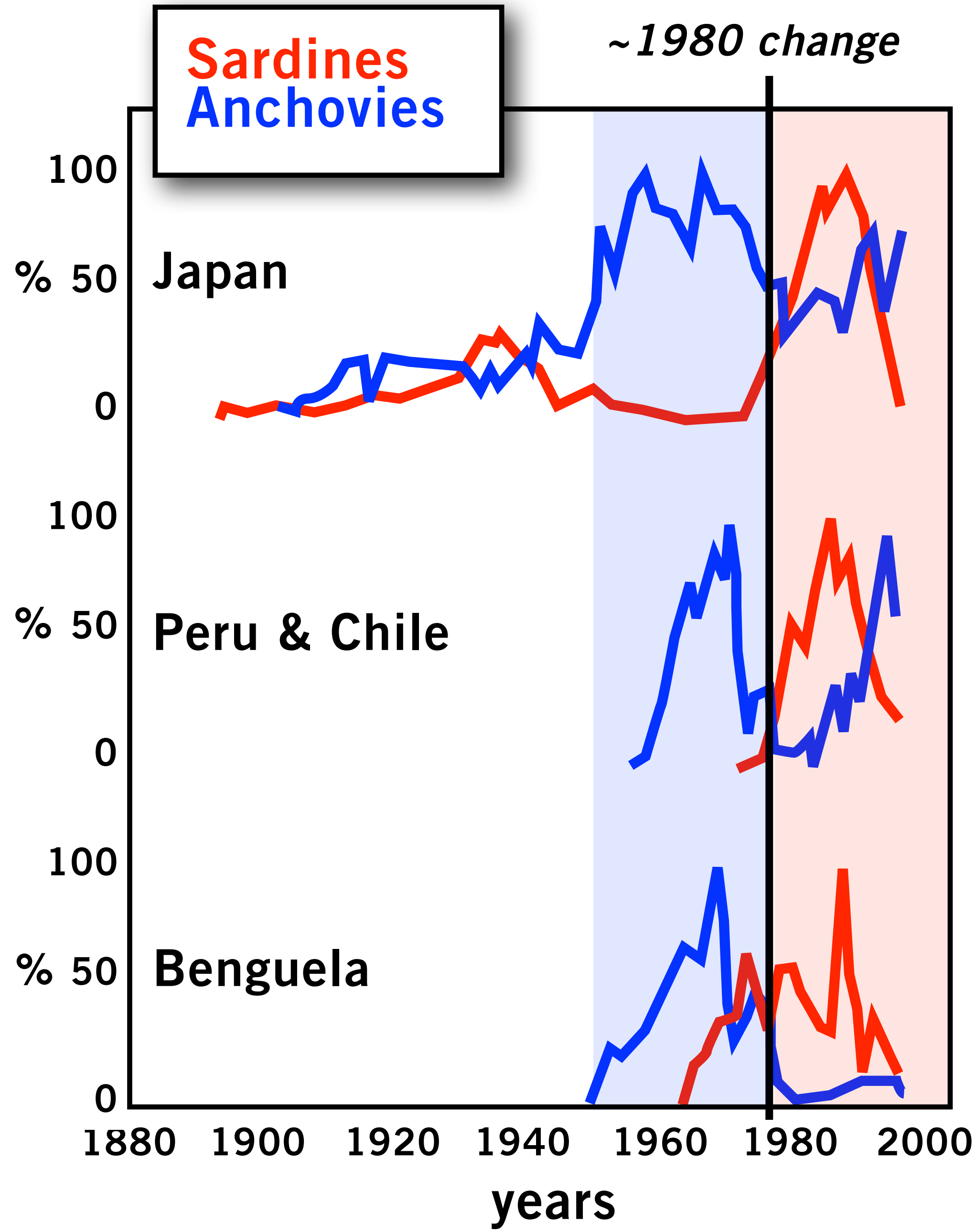
Victoria, Canada, March 2016


Sardines
Anchovies
~1980 change
100
% 50
0
Japan
Peru & Chile
Benguela
1880 1900 1920 1940 1960 1980 2000
years

Apparent Synchrony in Fish Populations



Apparent Synchrony in Fish Populations

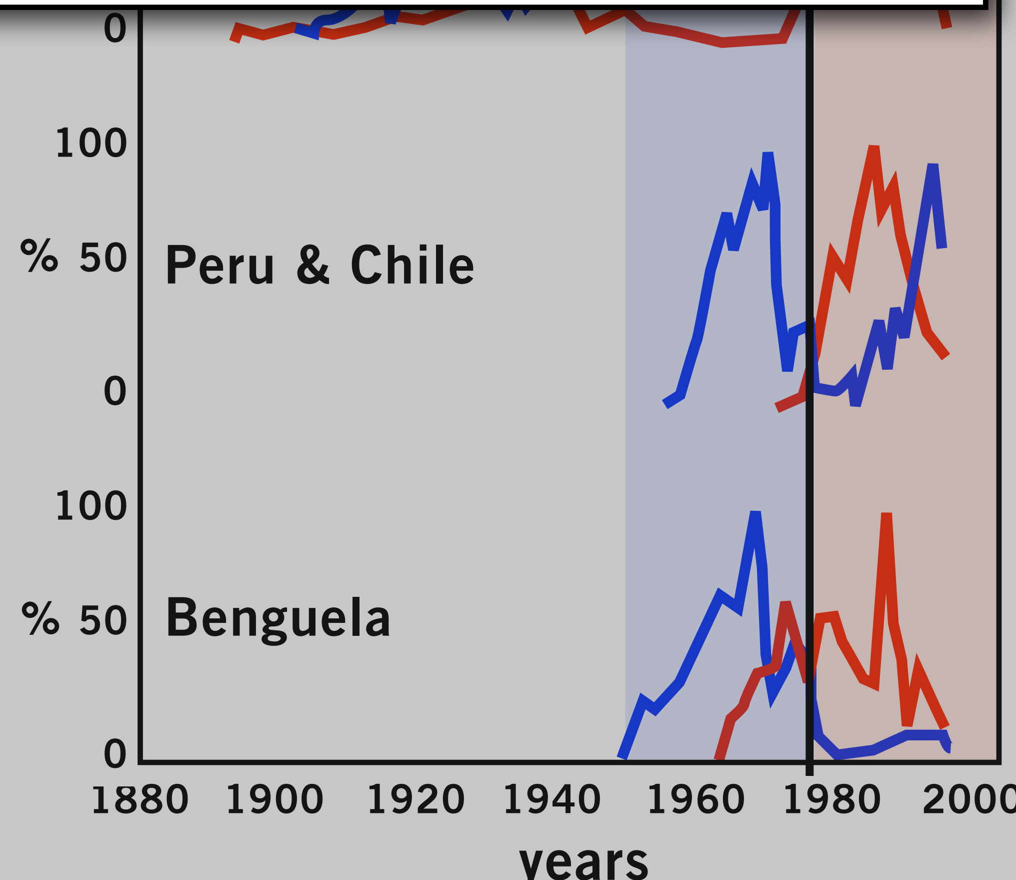


QUESTION:

Is there a mechanism?

<u>GOAL:</u>

Show that fish populations exhibit a natural tendency to **align with** and **amplify** the lowest frequency climate signals (e.g. AMO)



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Di Lorenzo and Ohman, PNAS, 2013

A *double integration hypothesis*
to explain ecosystem response to climate forcing

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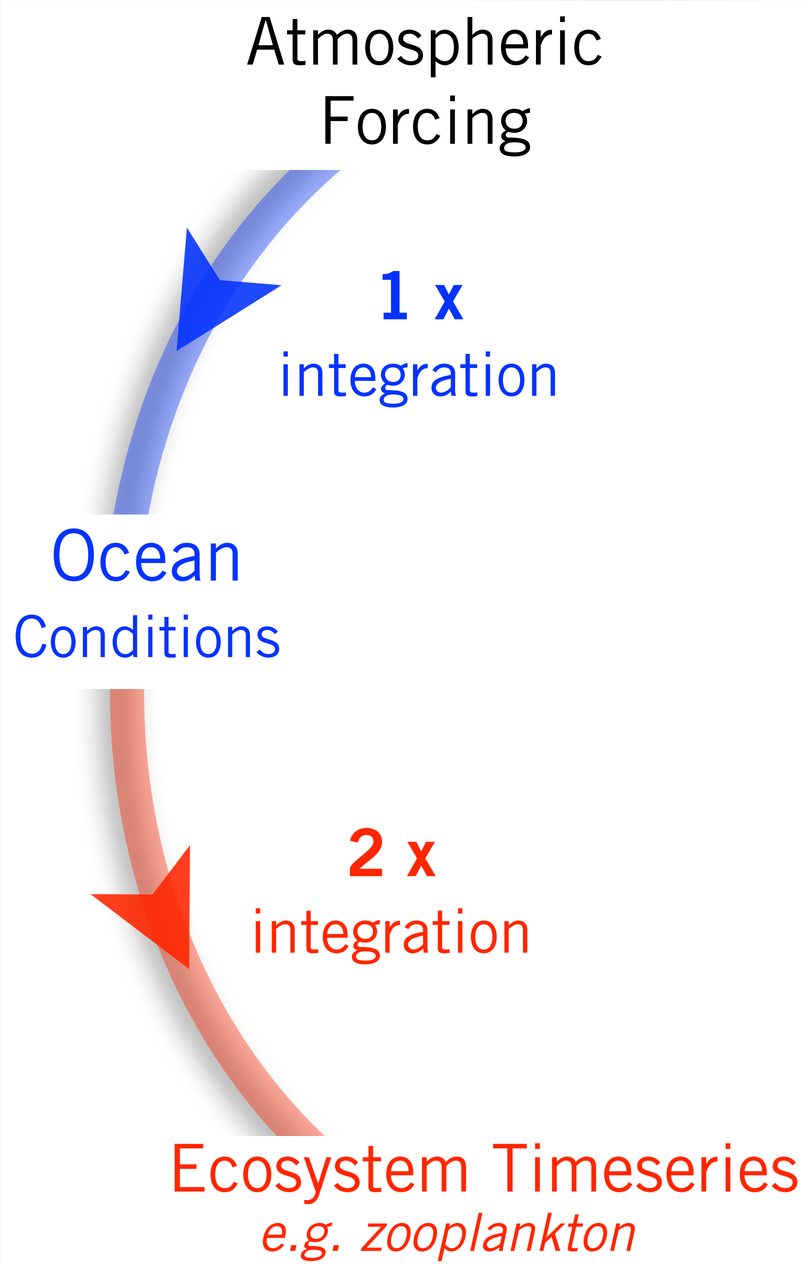

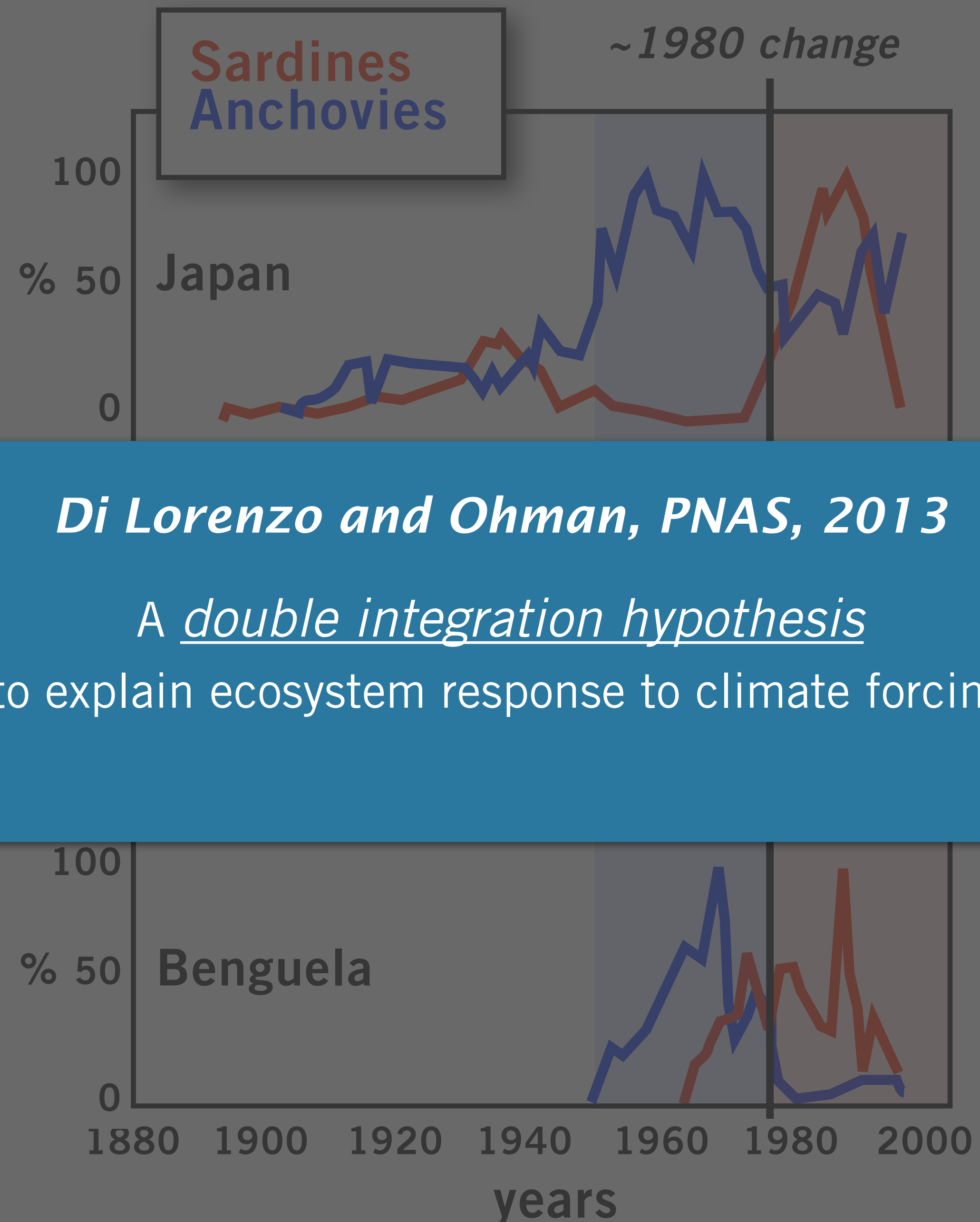

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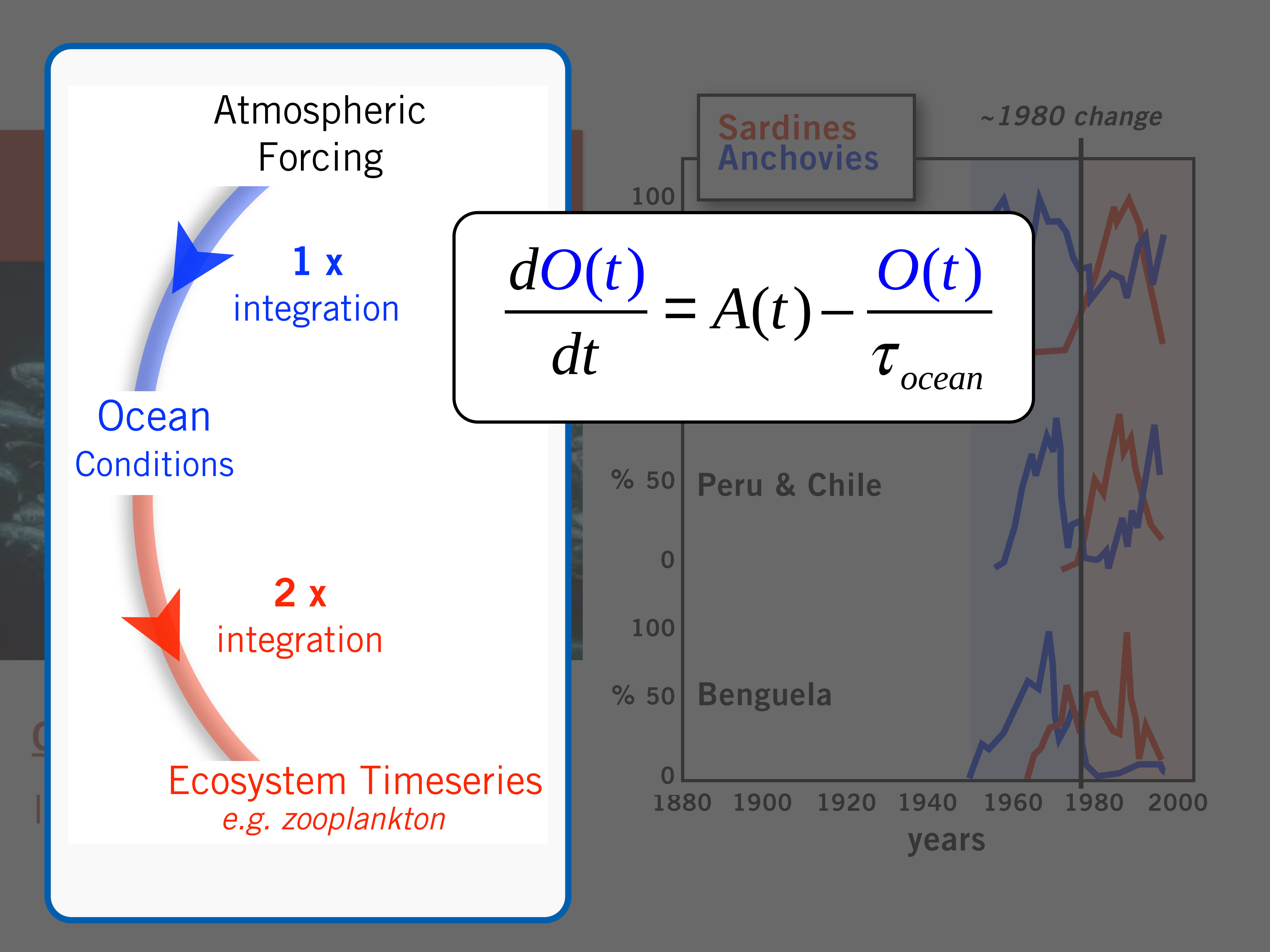

Atmospheric Forcing
1 x integration
Ocean Conditions
2 x integration
Ecosystem Timeseries
e.g. zooplankton
$$\frac{dO(t)}{dt} = A(t) - \frac{O(t)}{\tau_{ocean}}$$
Sardines
Anchovies
~1980 change
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% 50
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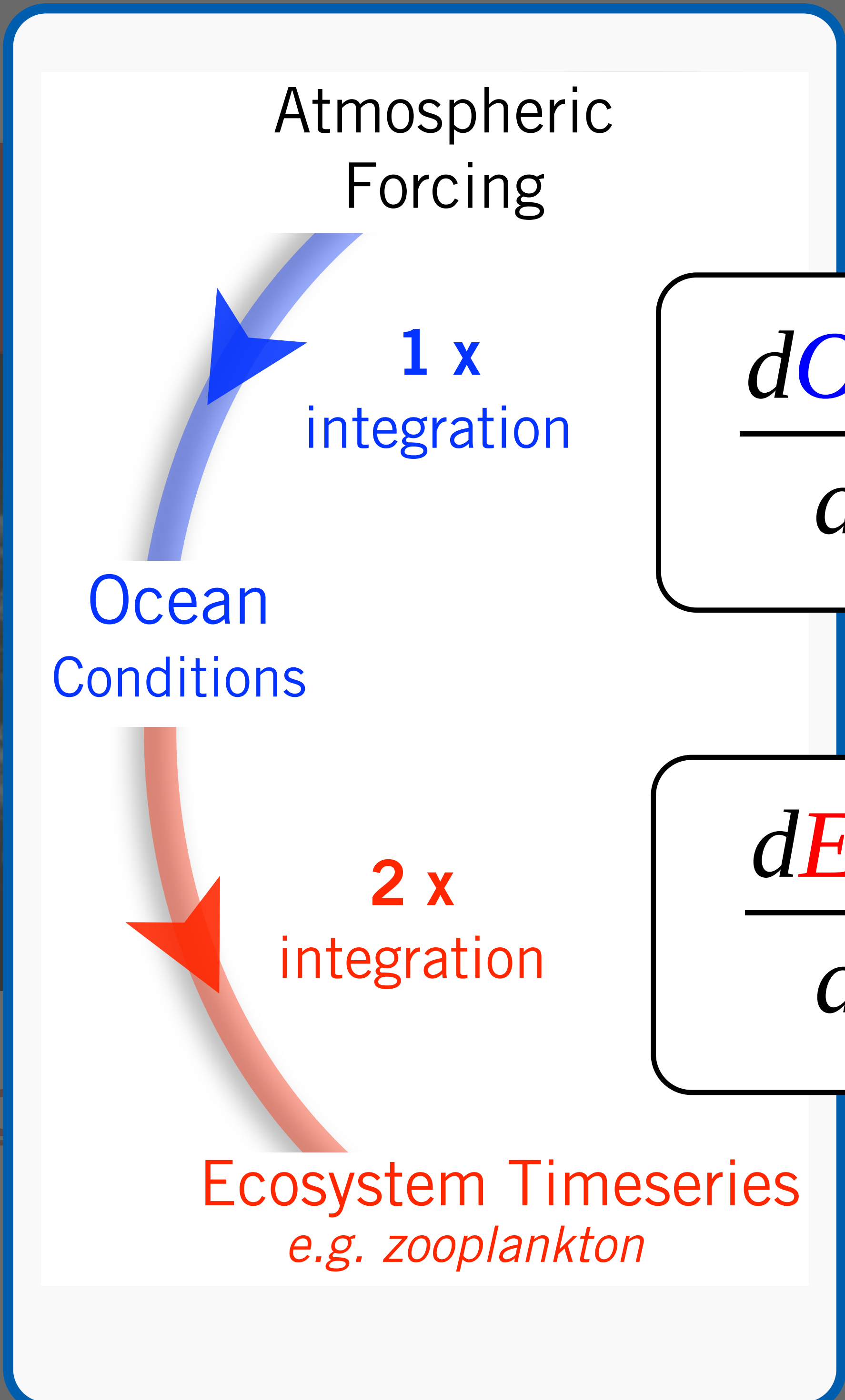
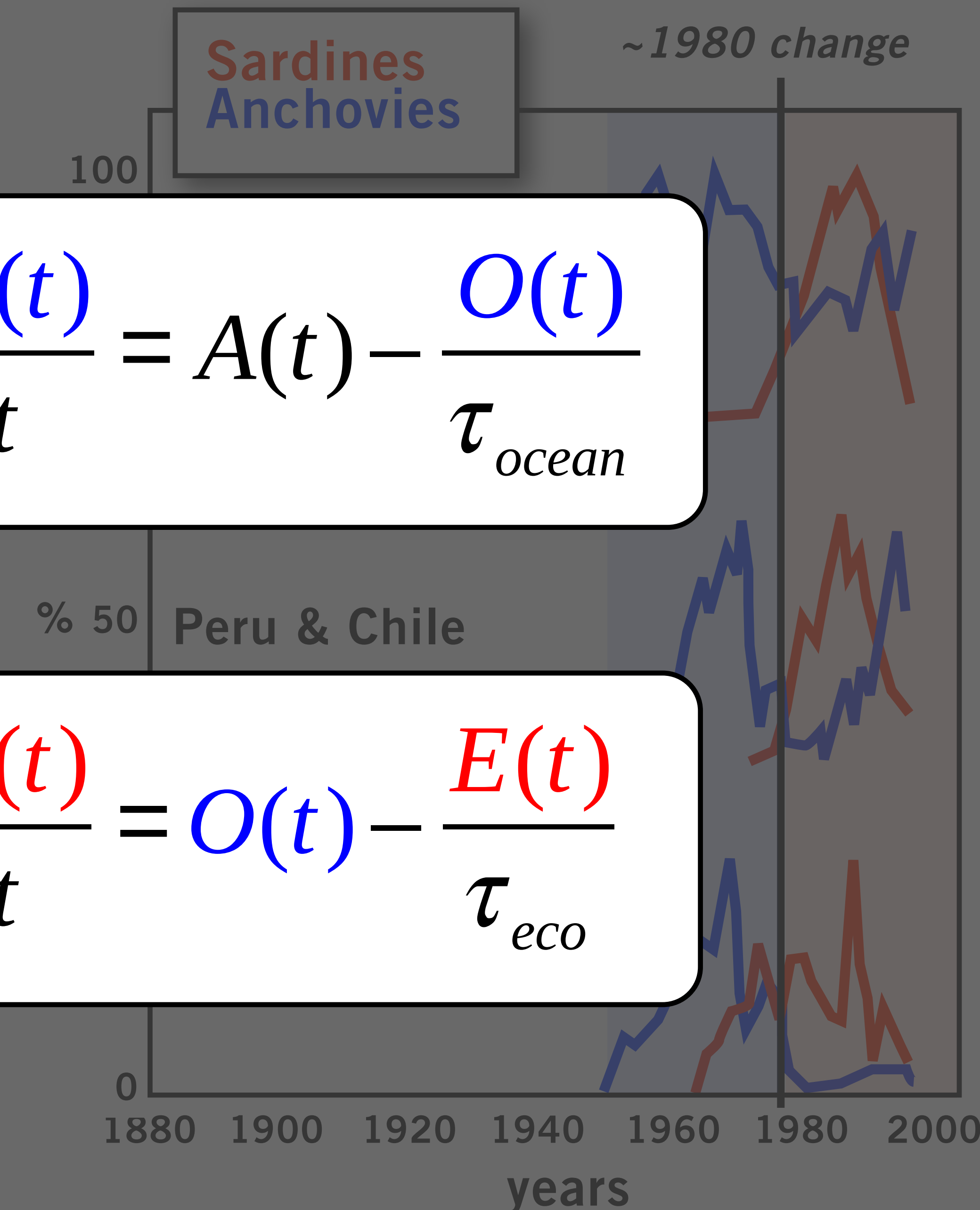
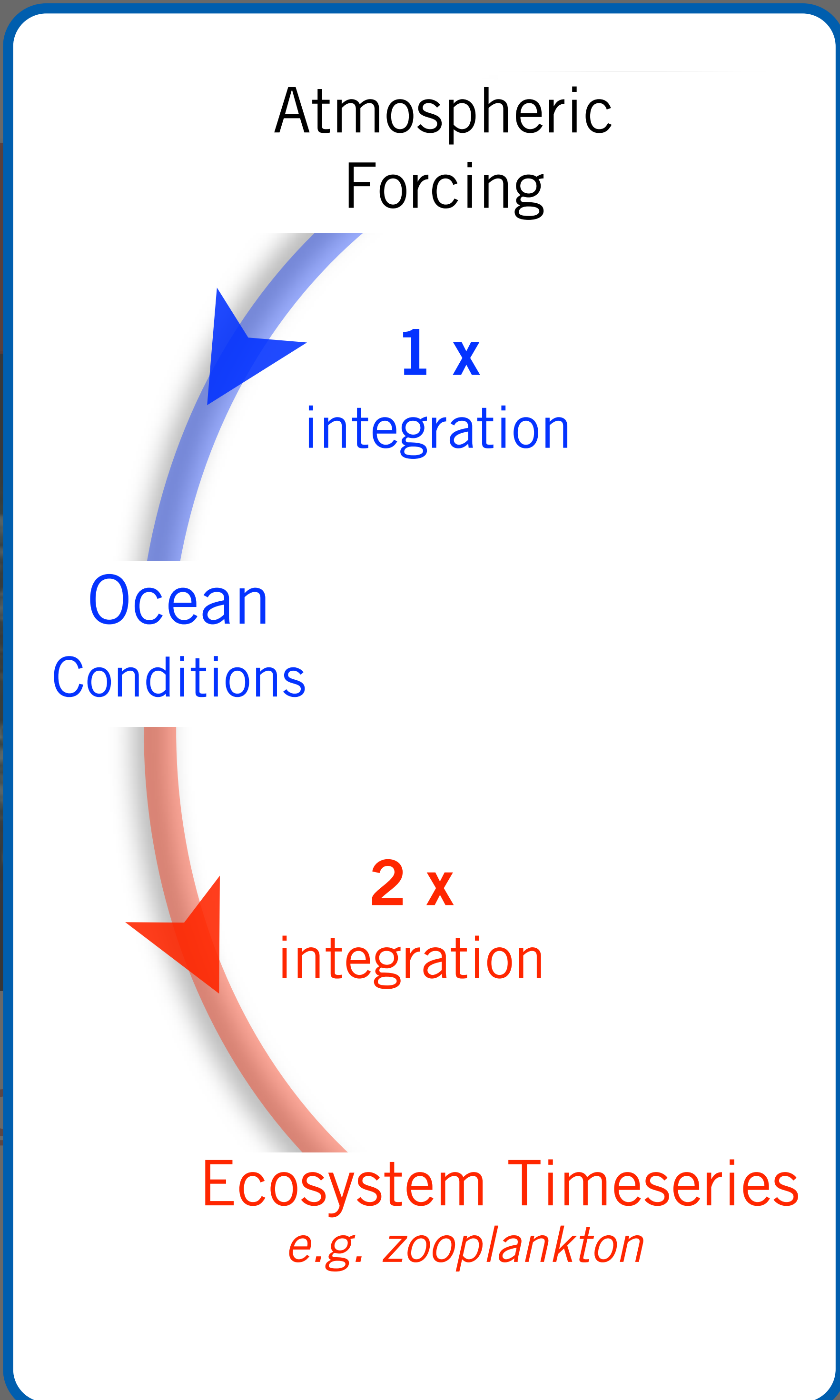


$$\frac{dO(t)}{dt} = A(t) - \frac{O(t)}{\tau_{ocean}}$$

$$\frac{dE(t)}{dt} = O(t) - \frac{E(t)}{\tau_{eco}}$$

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1 x
integration
Ocean
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2 x
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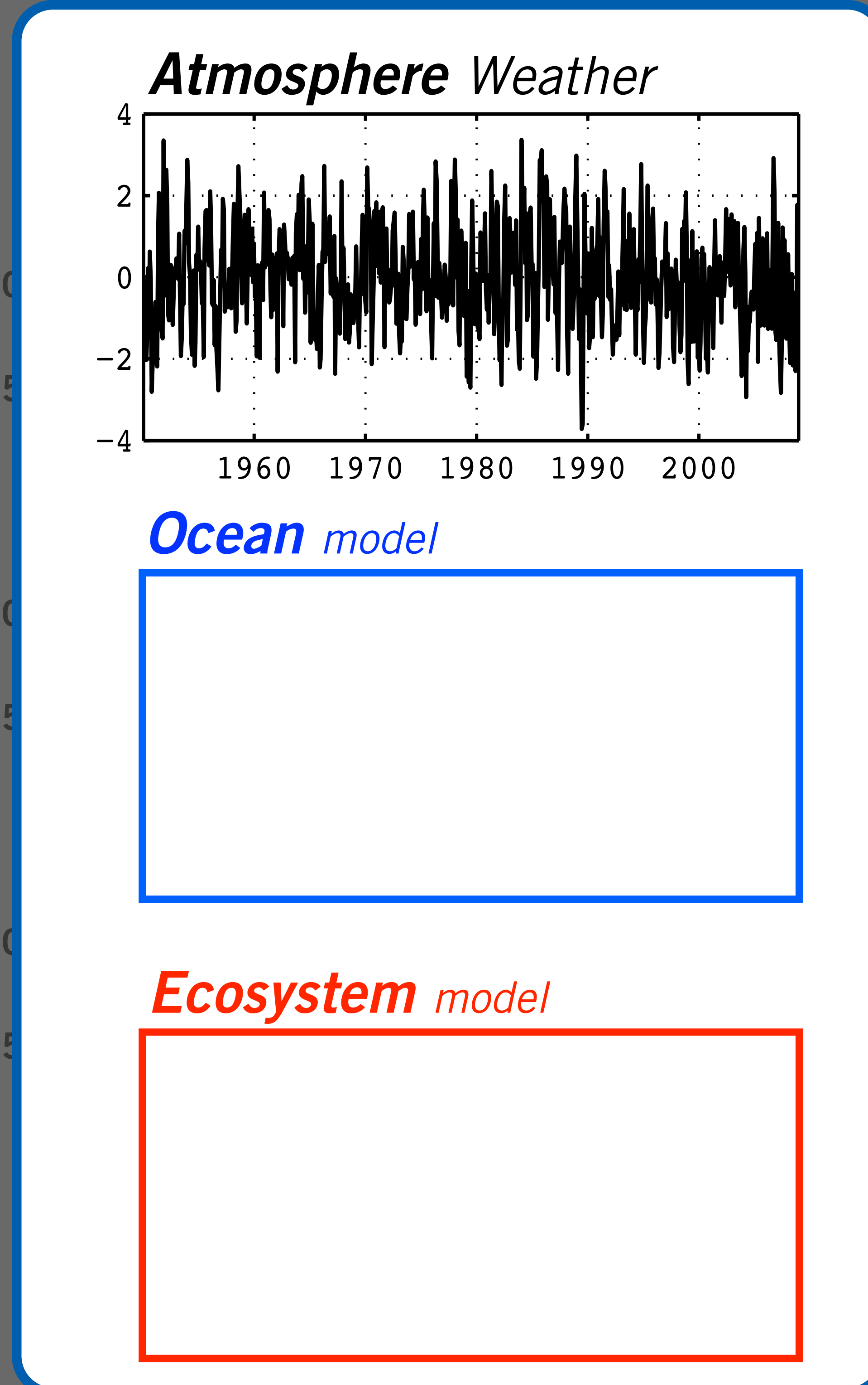
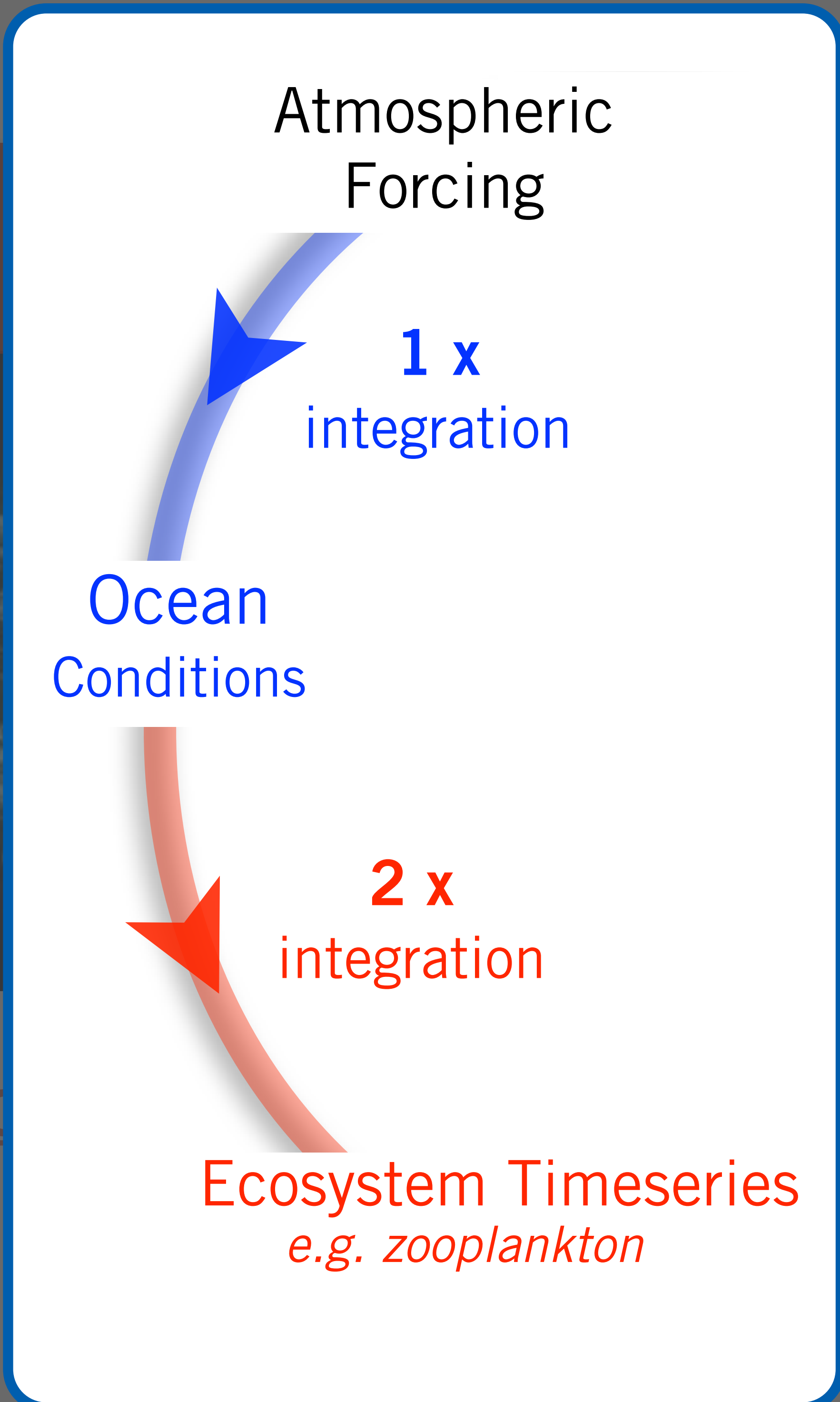
Ecosystem Timeseries
e.g. zooplankton


Atmosphere Weather
4
2
0
−2
−4
1960
1970
1980
1990
2000
Ocean model
Ecosystem model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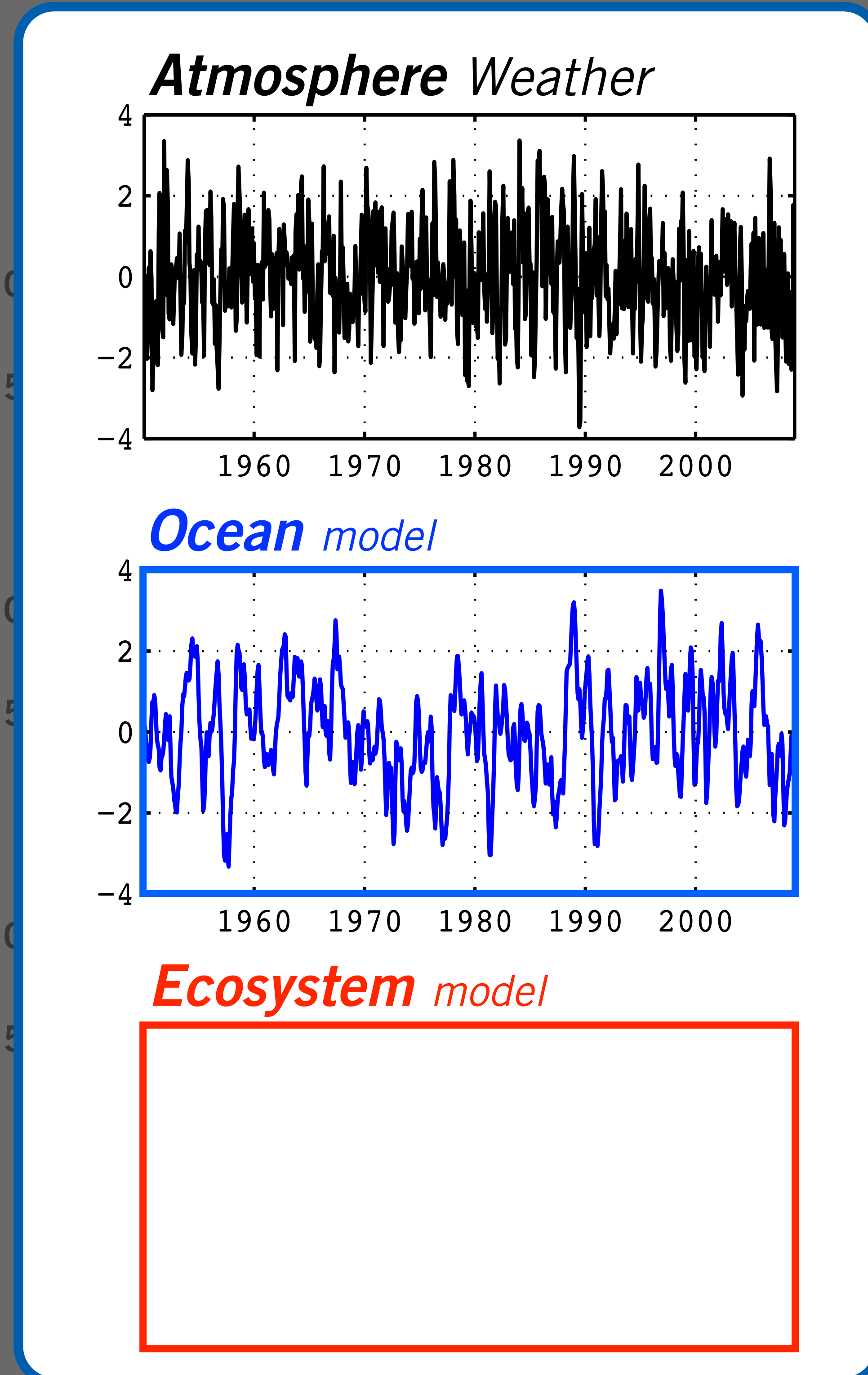
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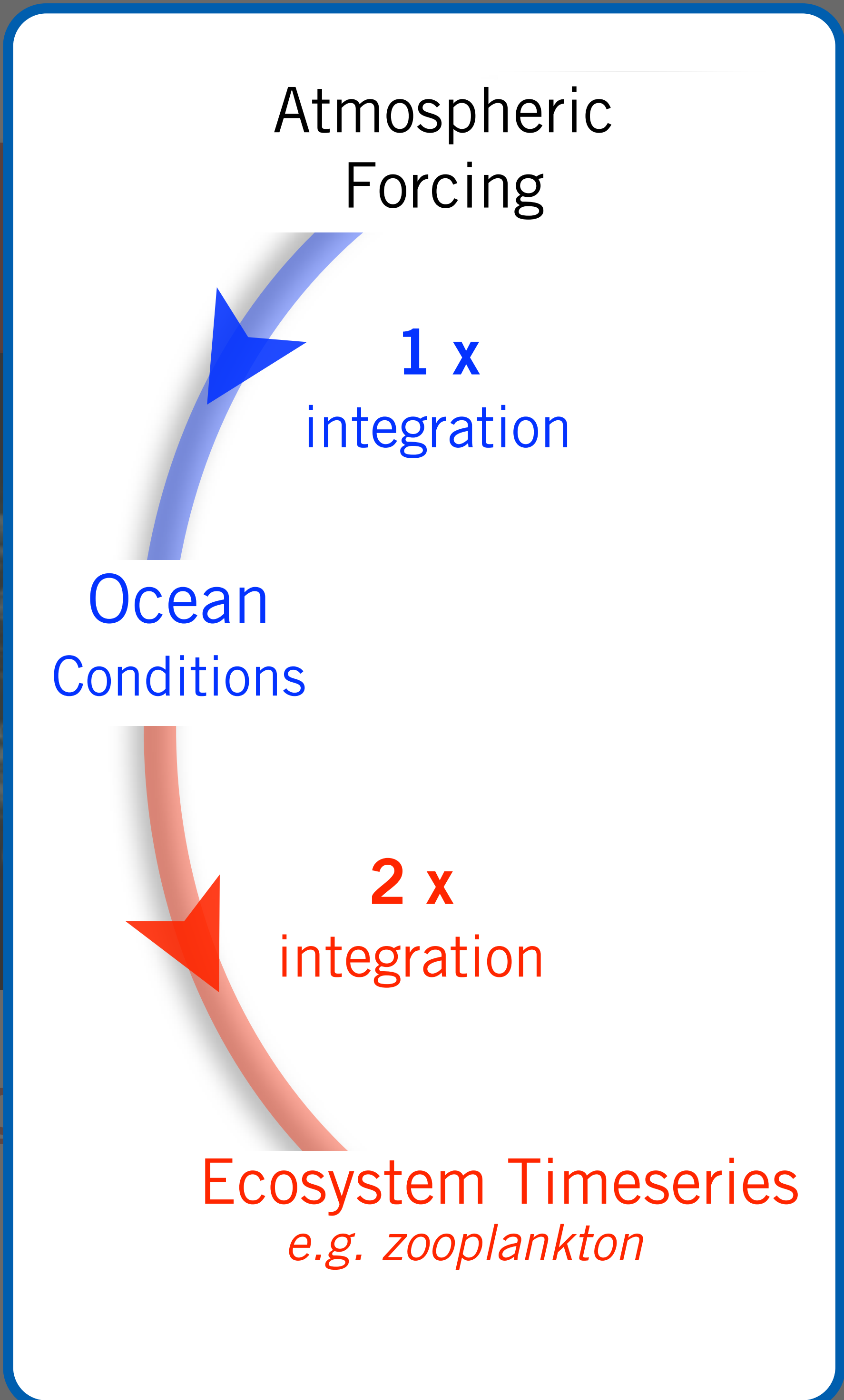
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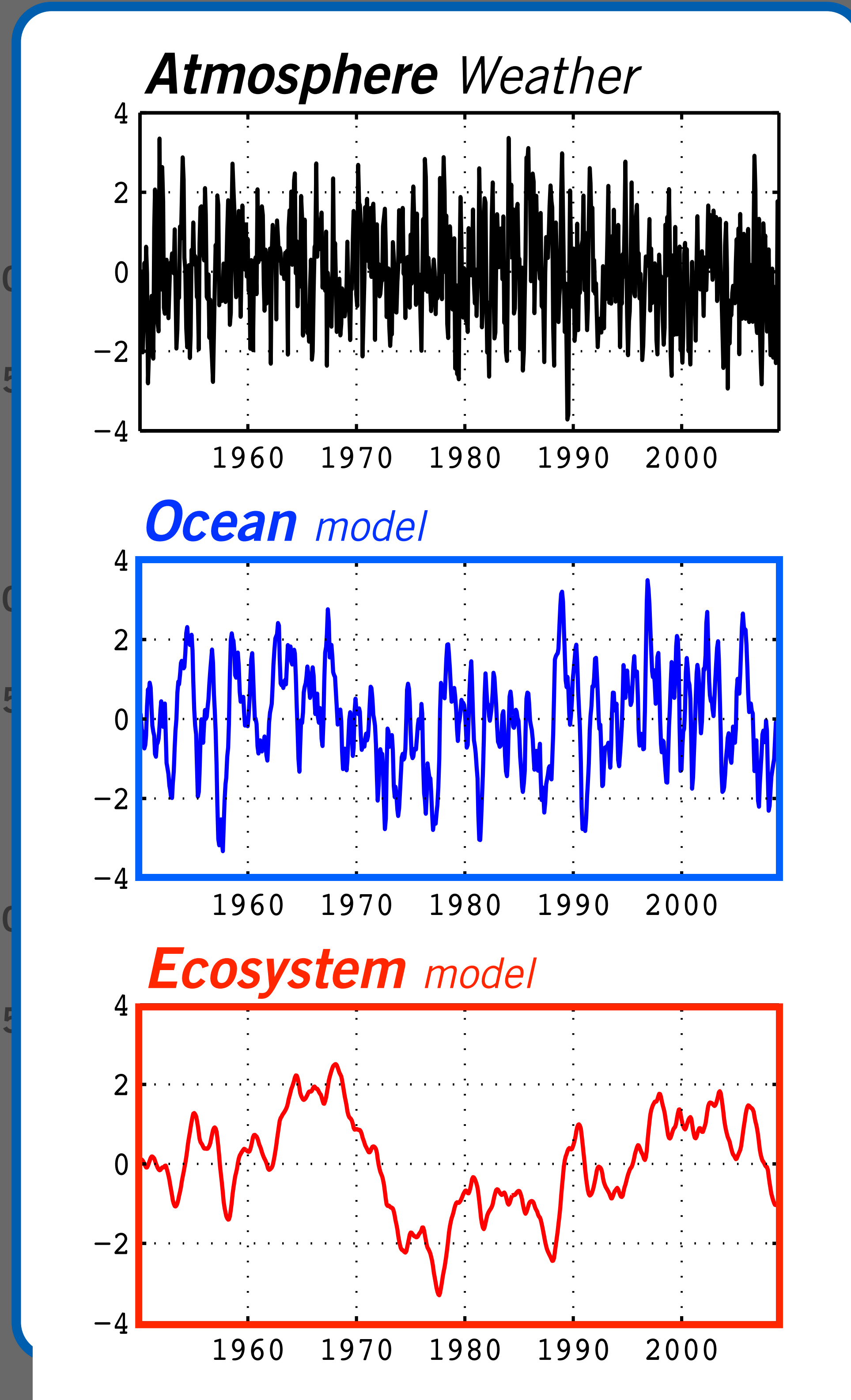
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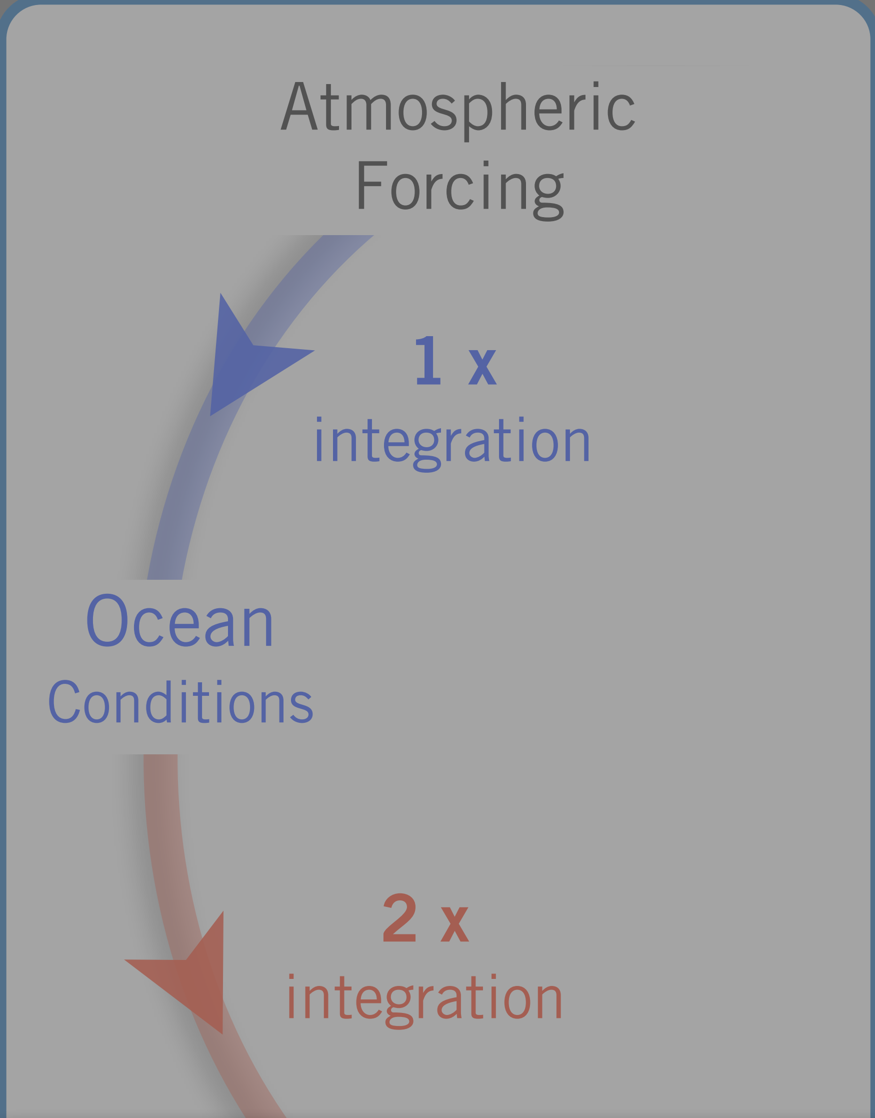
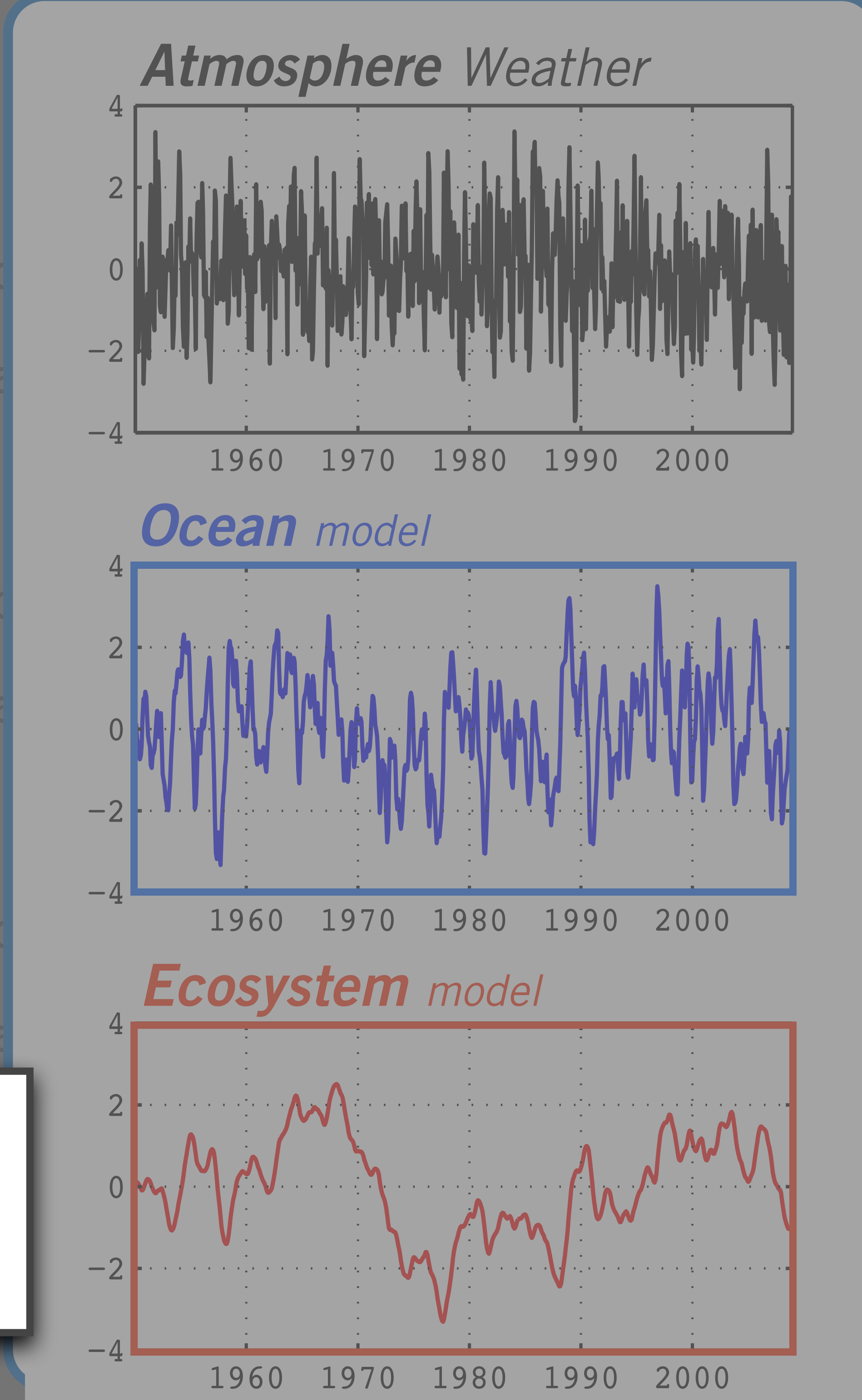
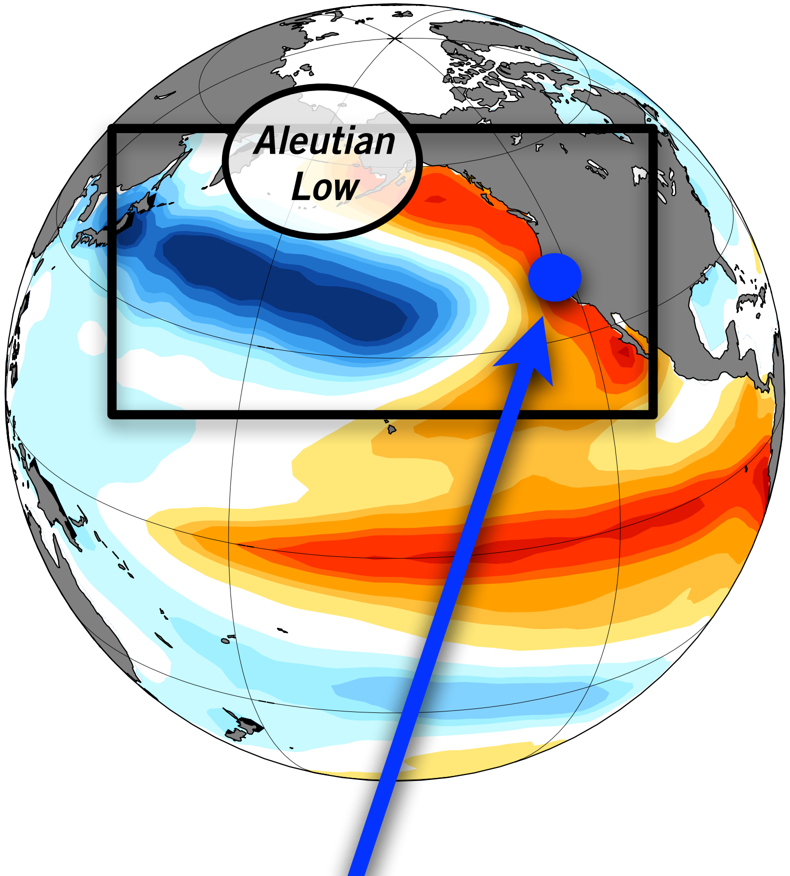




QUESTION:

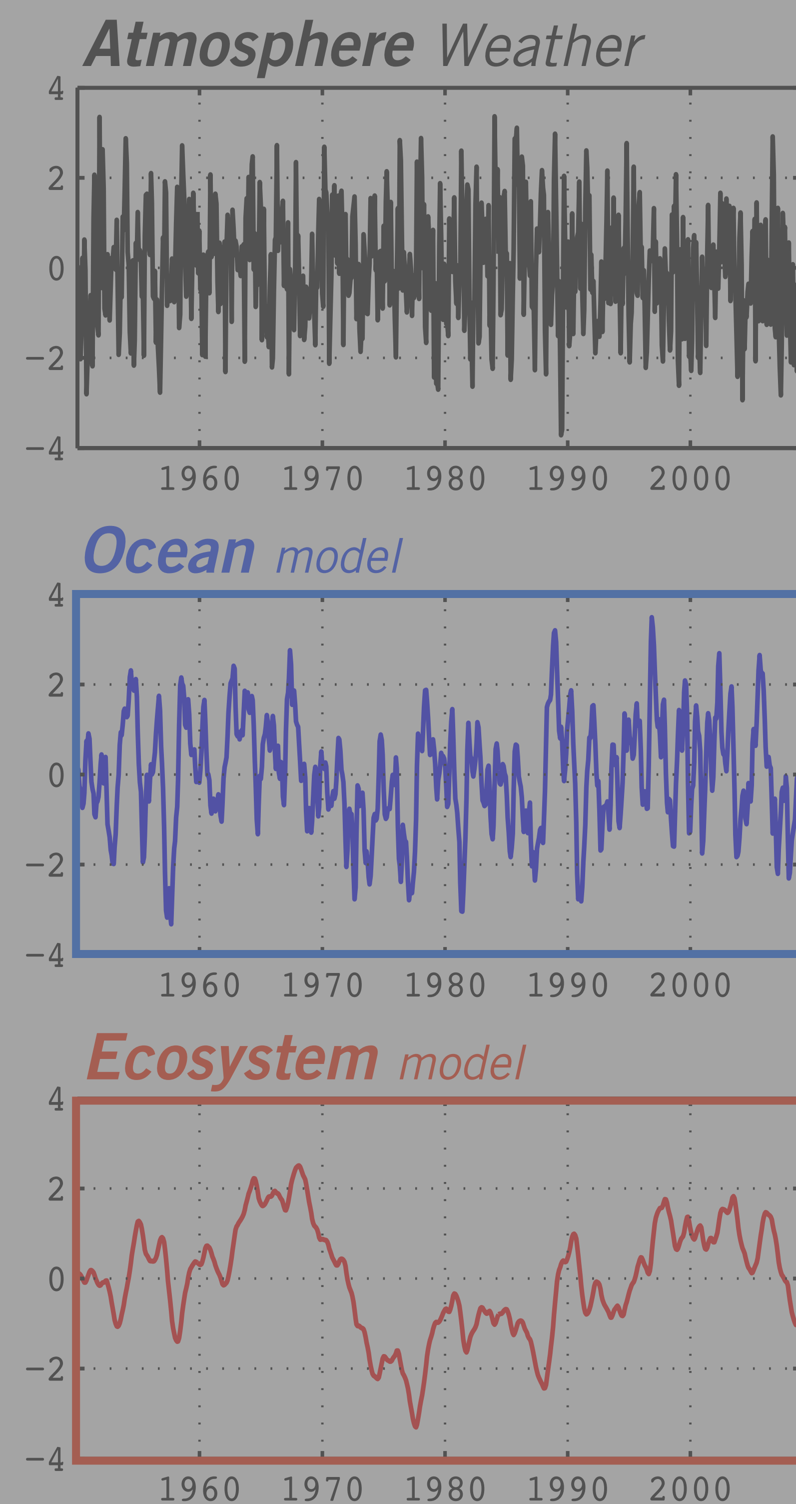
Does this model work in nature?

Pacific Decadal Oscillation (PDO)



Zooplankton California Current

Di Lorenzo and Ohman, 2013



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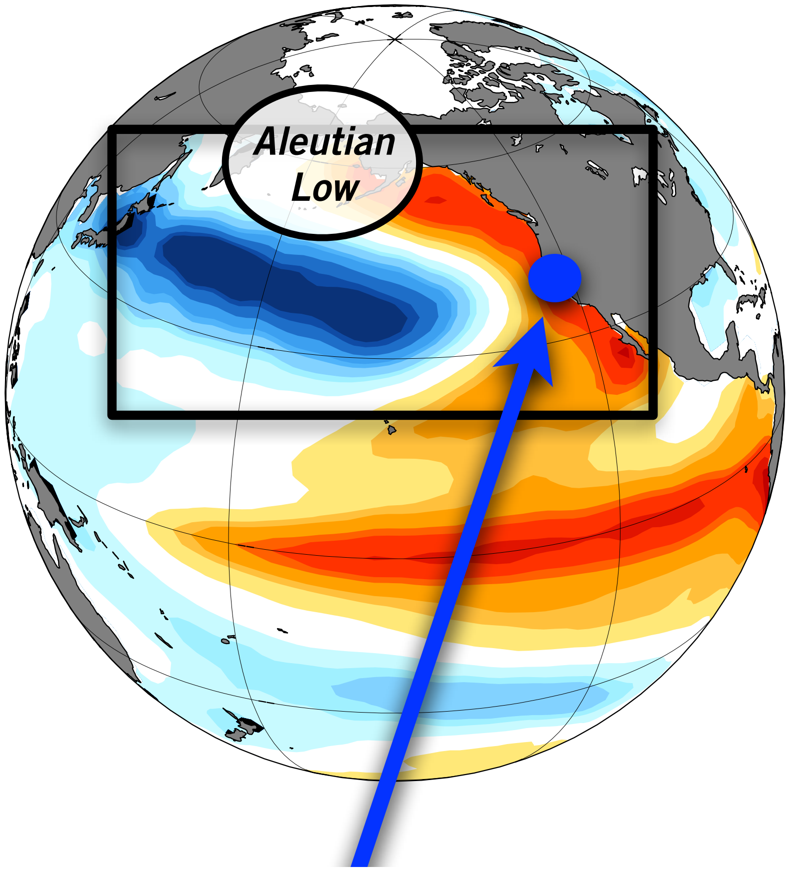


Zooplankton California Current

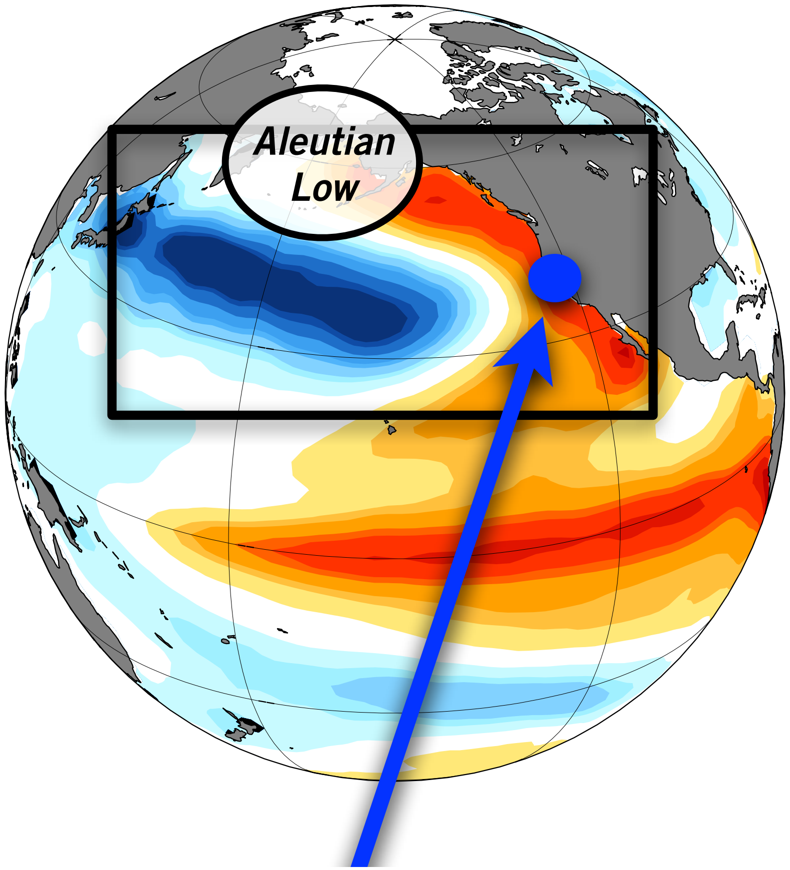
Di Lorenzo and Ohman, 2013

Atmosphere *Weather*

Ocean *model*

Ecosystem *model*

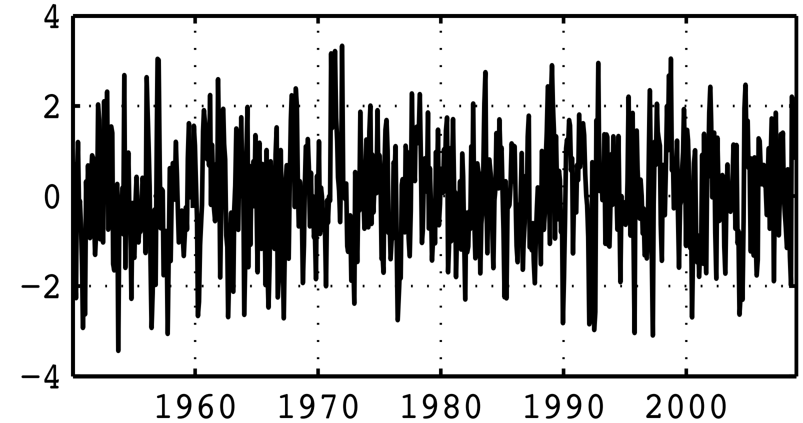
Pacific Decadal Oscillation (PDO)



Zooplankton California Current

Di Lorenzo and Ohman, 2013

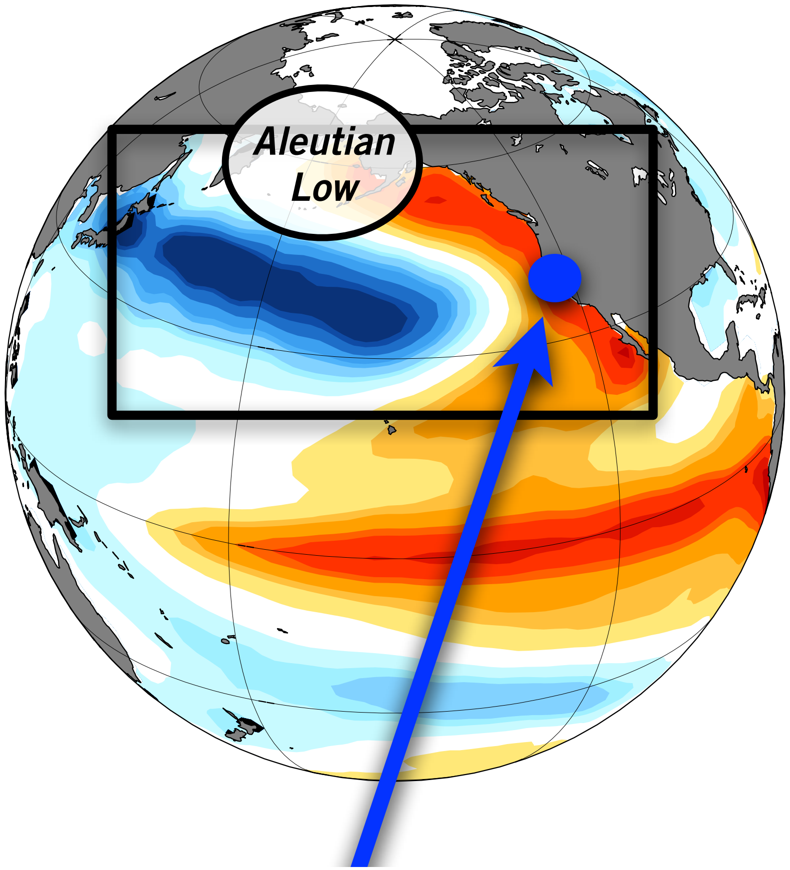
Aleutian Low Index



Ocean *model*

Ecosystem *model*

Pacific Decadal Oscillation (PDO)



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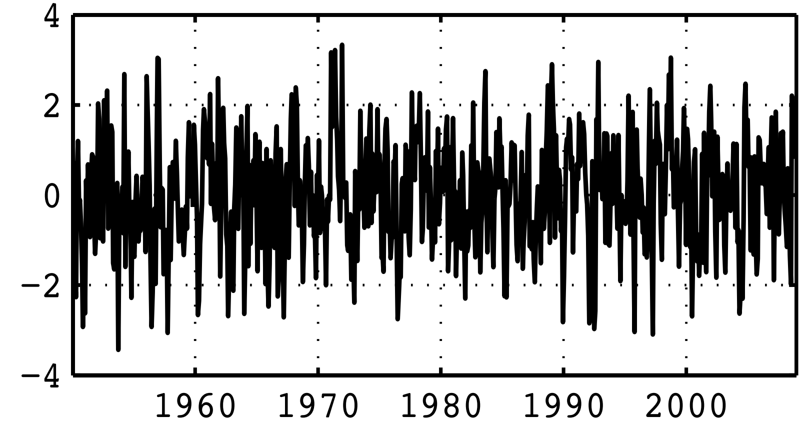
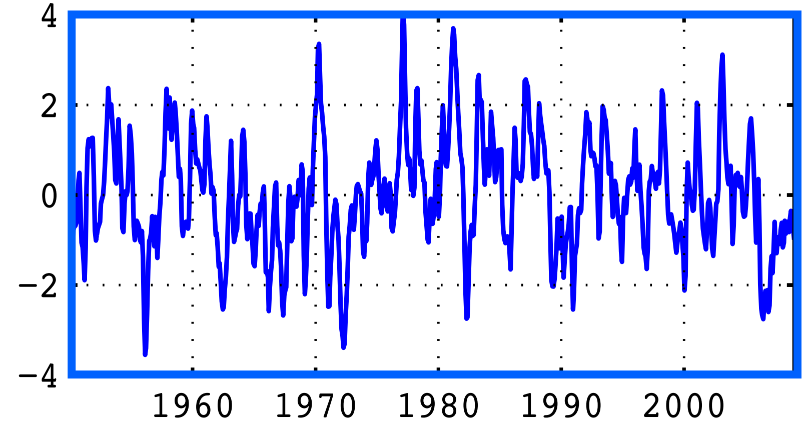
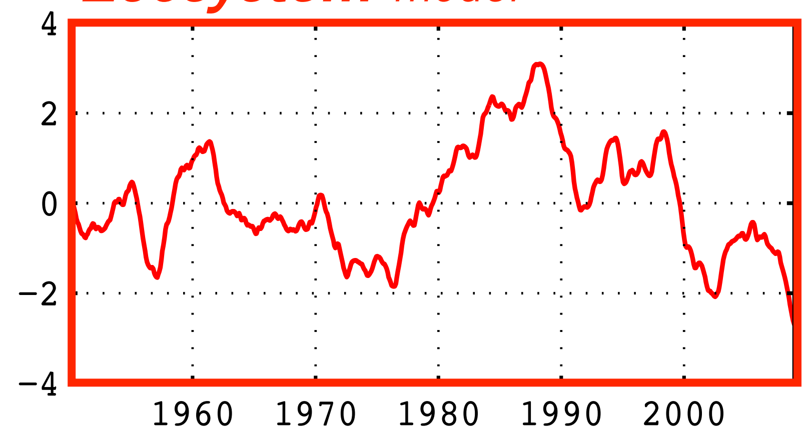


Ocean *model*



Ecosystem *model*



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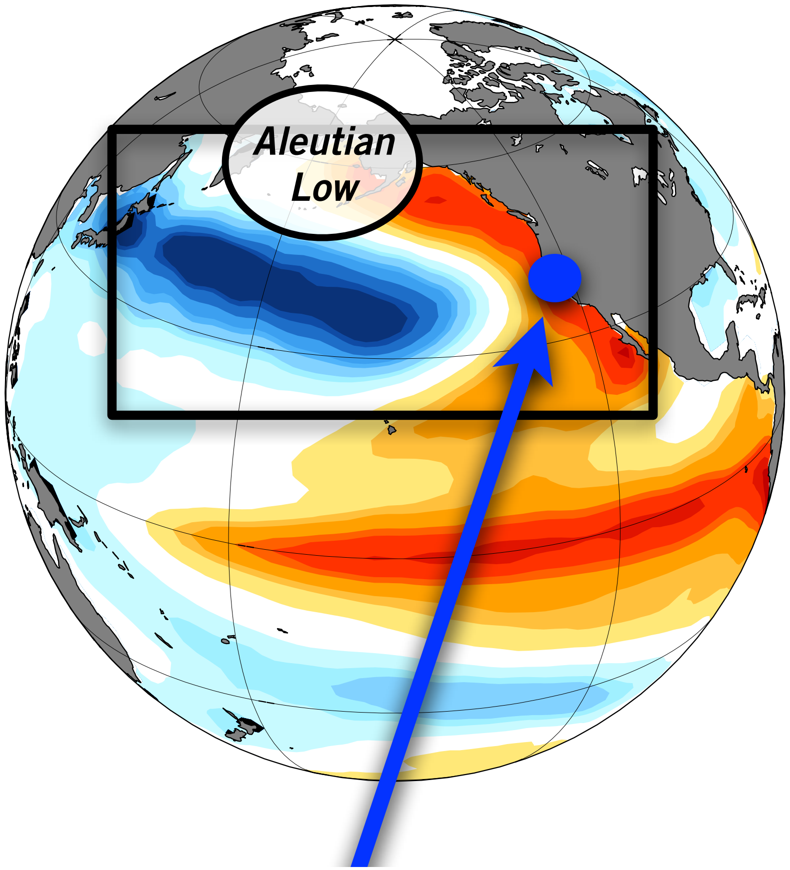
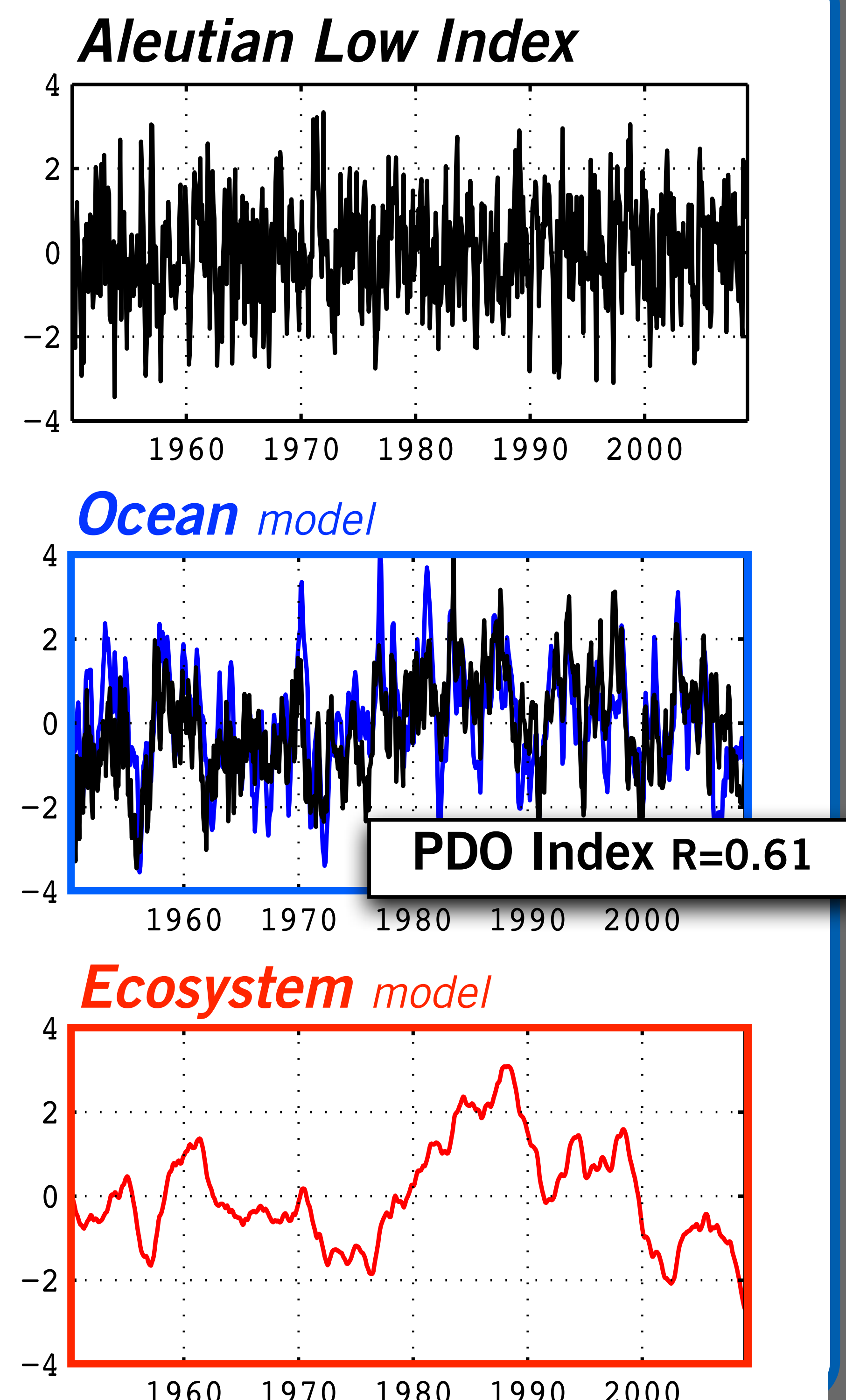


Zooplankton California Current

Di Lorenzo and Ohman, 2013



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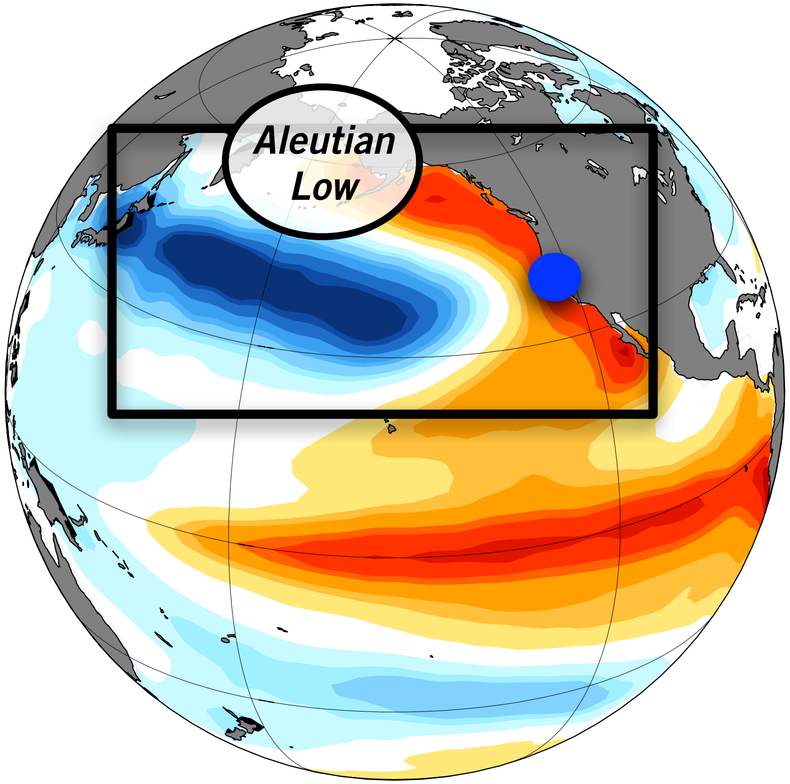
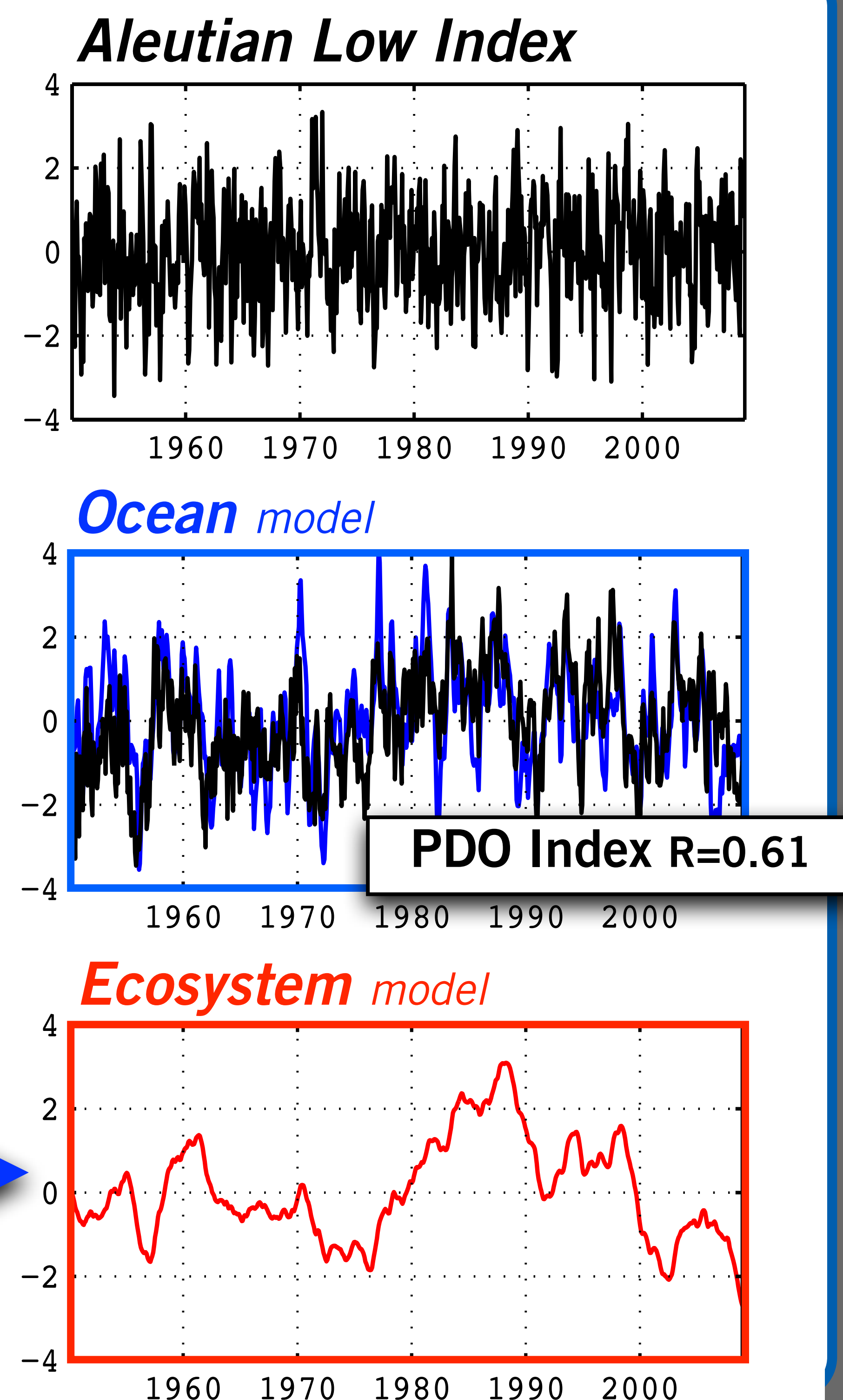
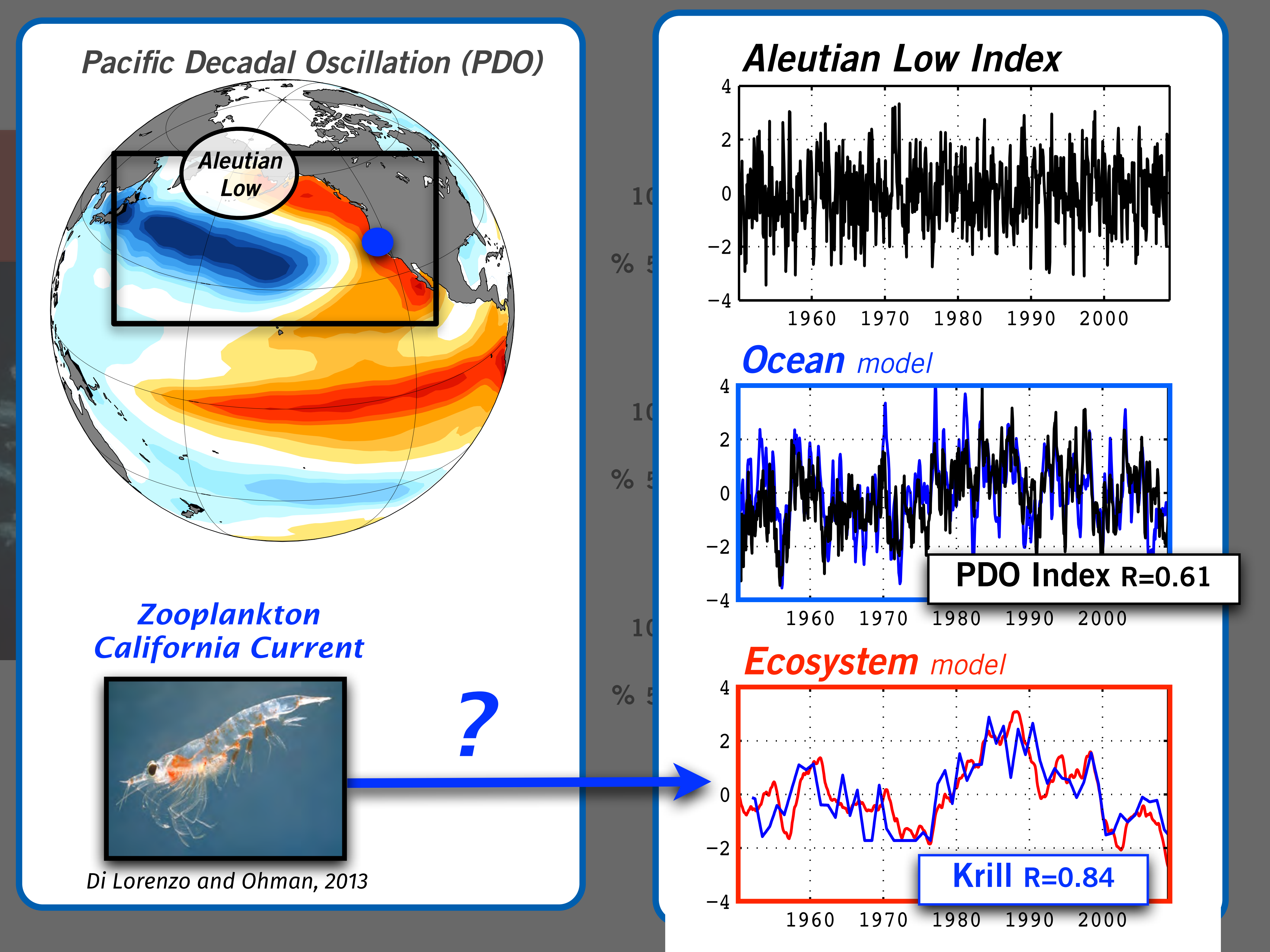


Zooplankton California Current

Di Lorenzo and Ohman, 2013

?

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Aleutian Low
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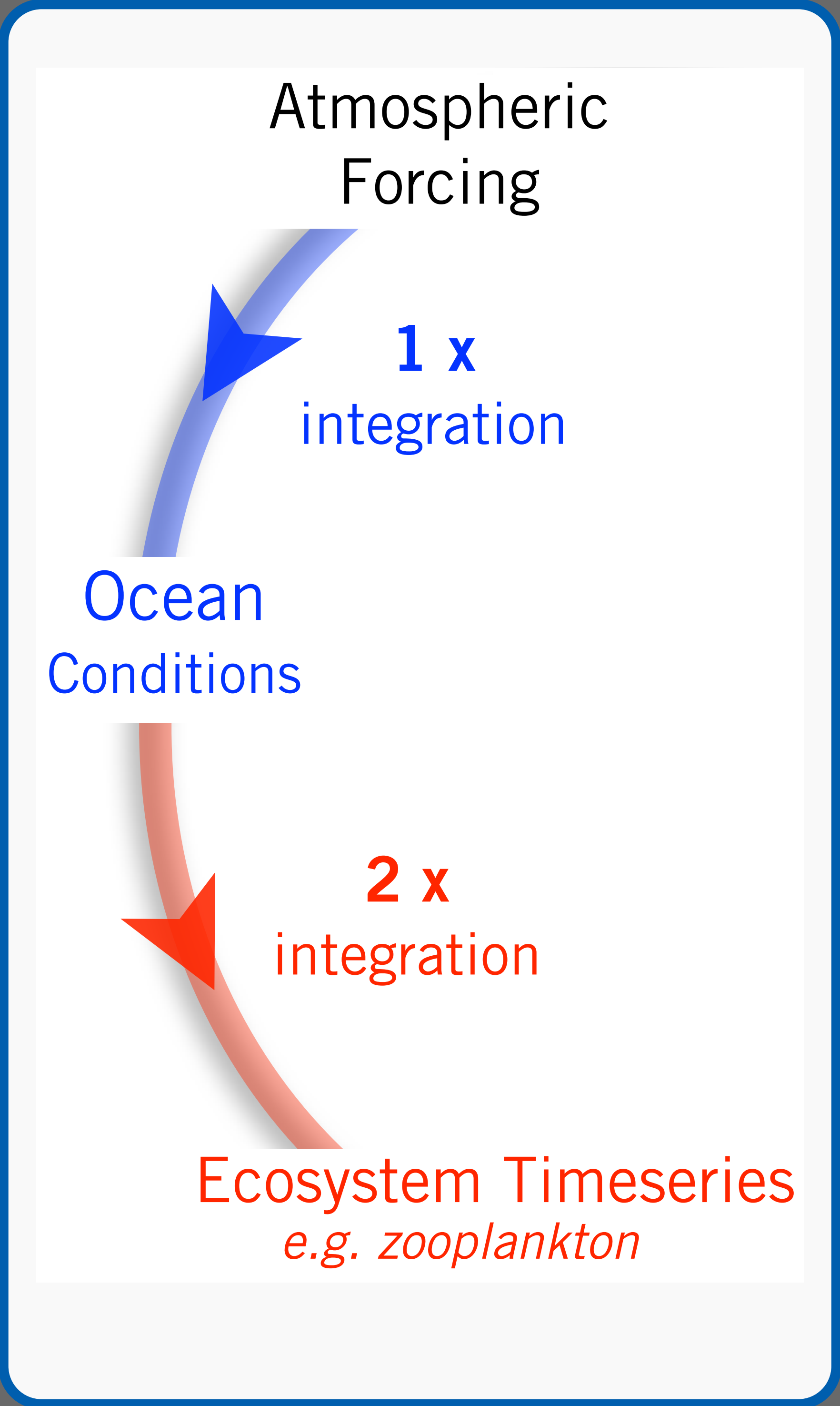
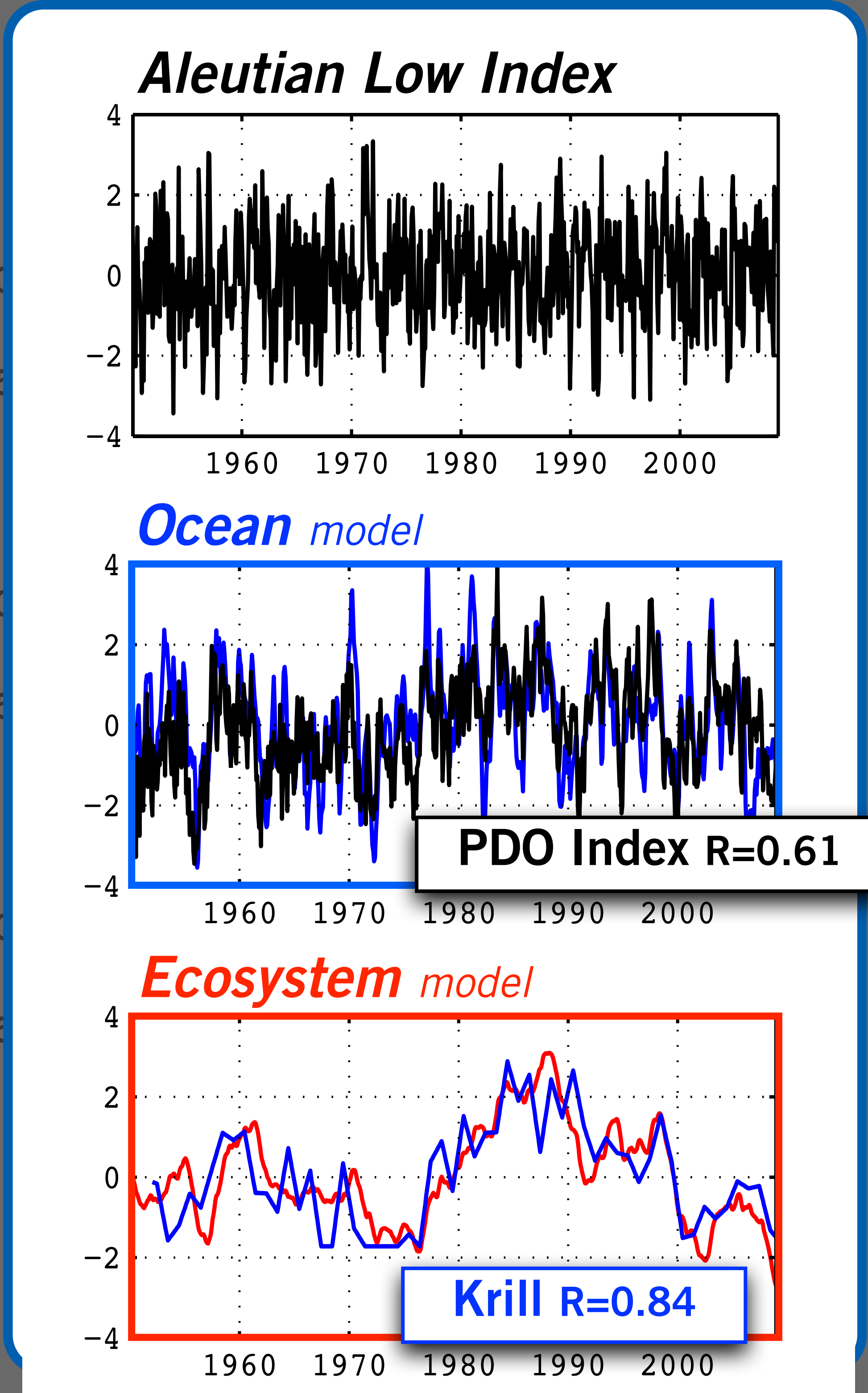
Di Lorenzo and Ohman, 2013
?
Aleutian Low Index
4
2
0
−2
−4
1960
1970
1980
1990
2000
Ocean model
PDO Index R=0.61
Ecosystem model
Krill R=0.84



Atmospheric Forcing
1 x integration
Ocean Conditions
2 x integration
Ecosystem Timeseries
e.g. zooplankton



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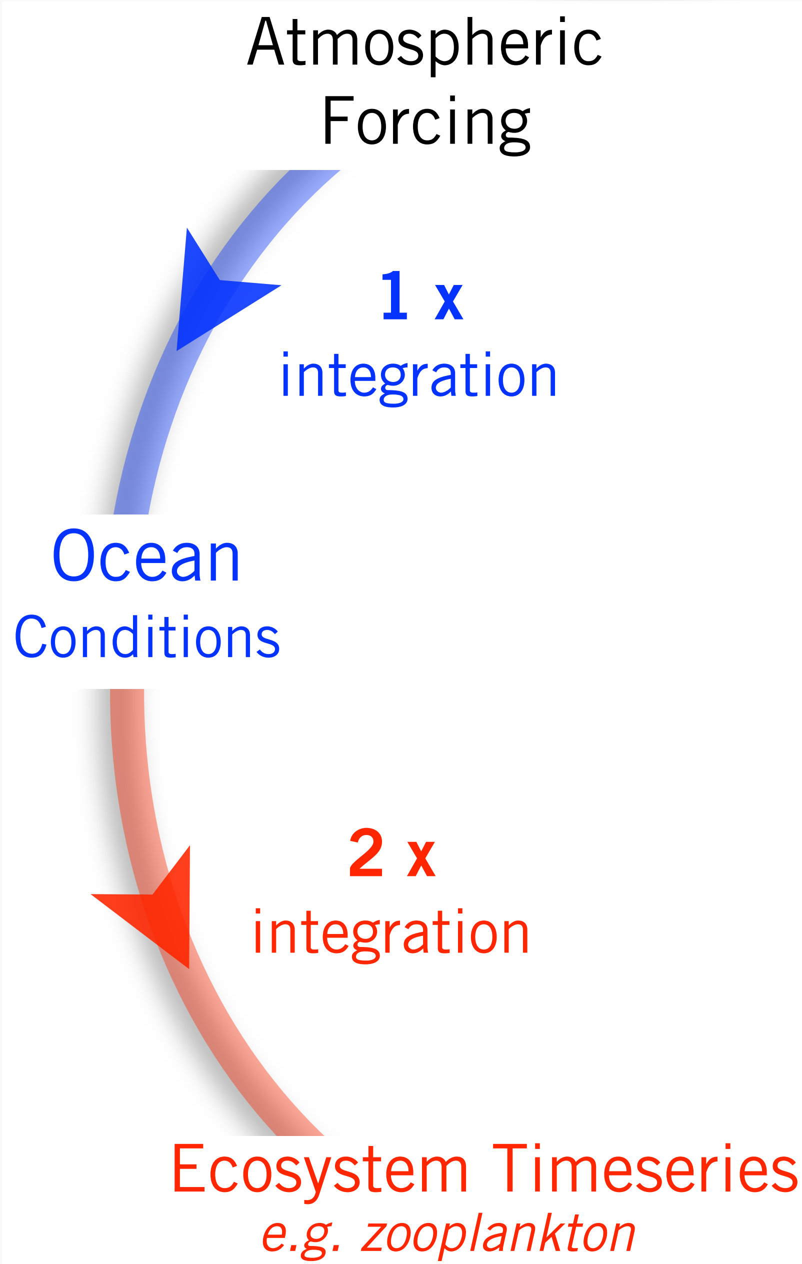
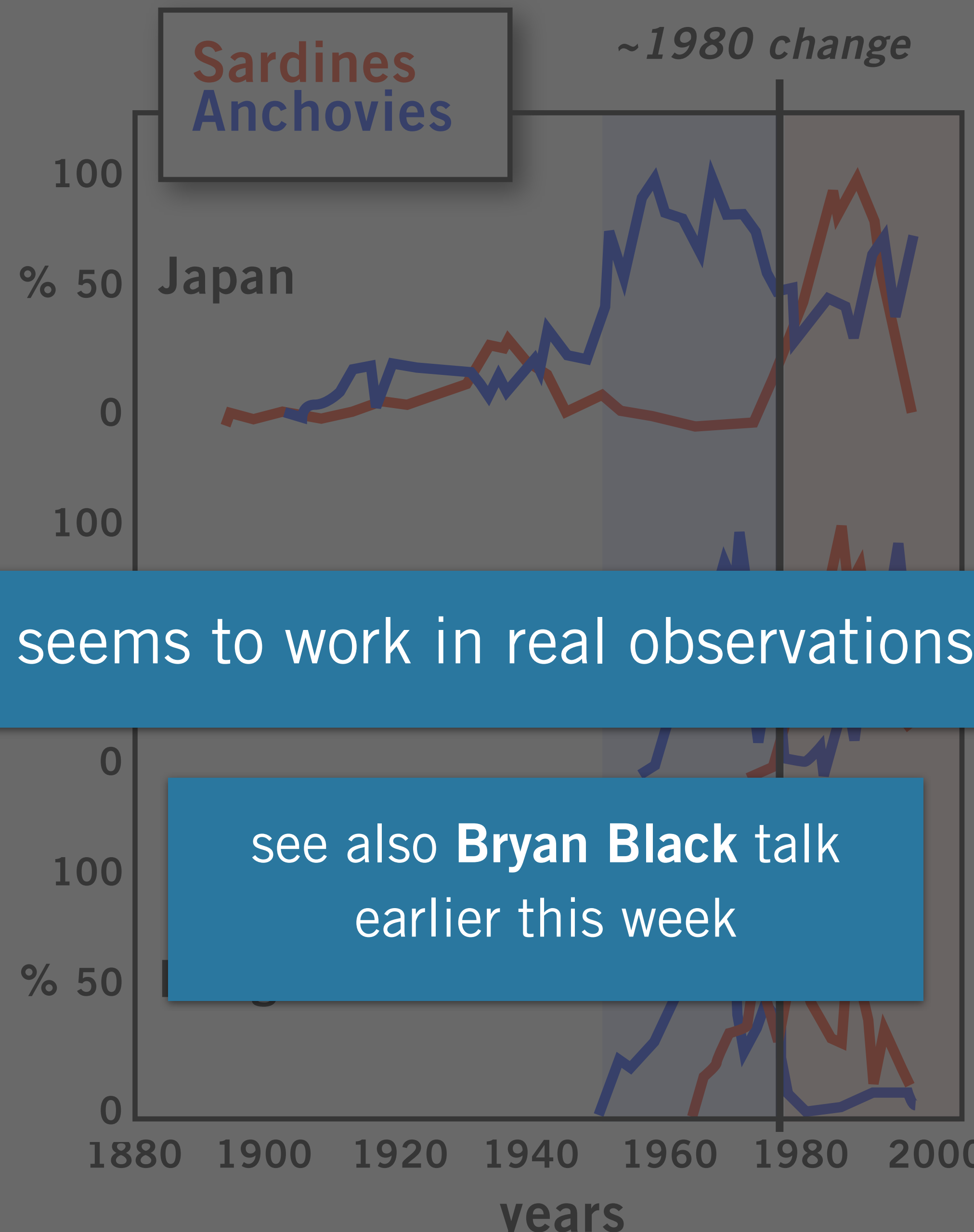
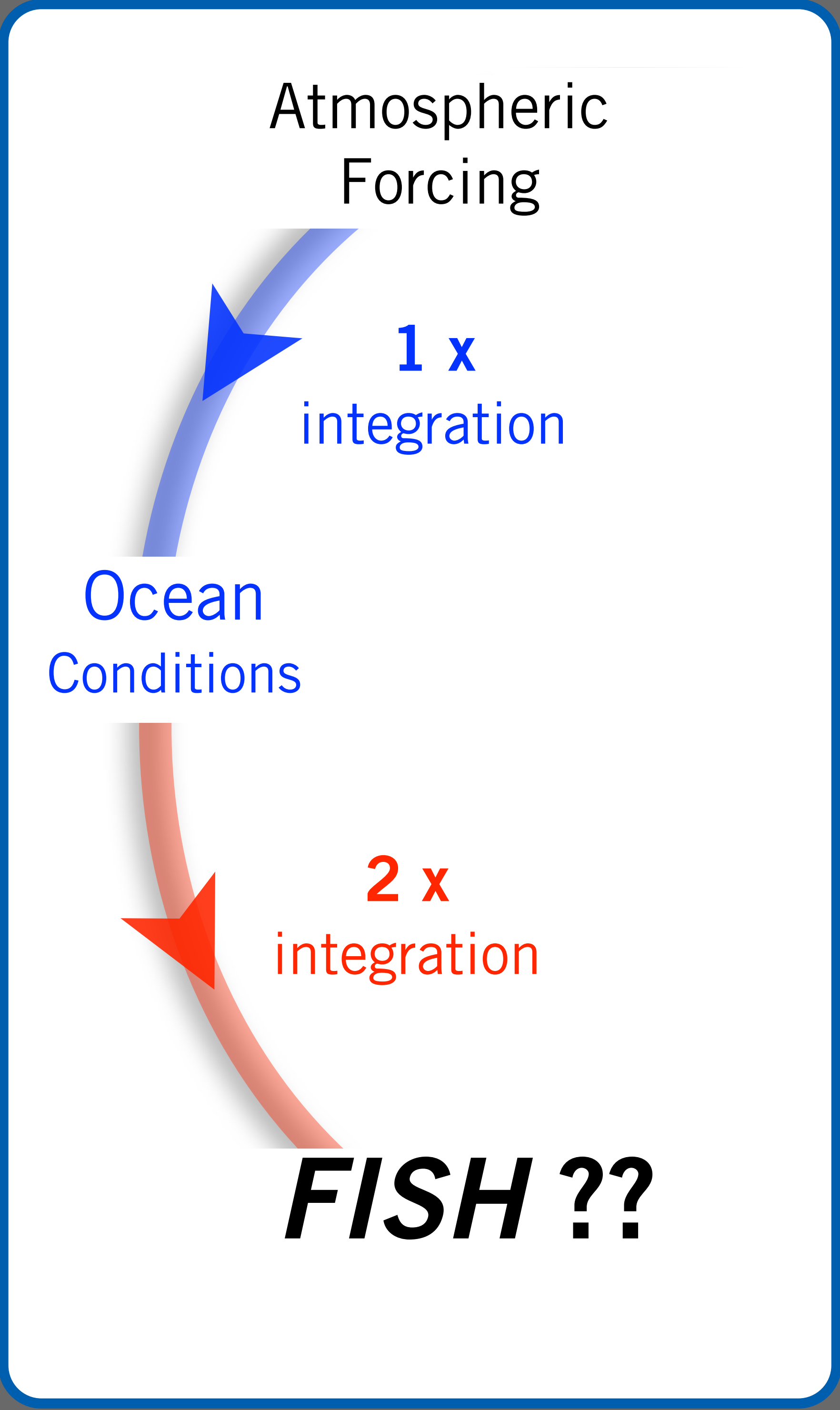
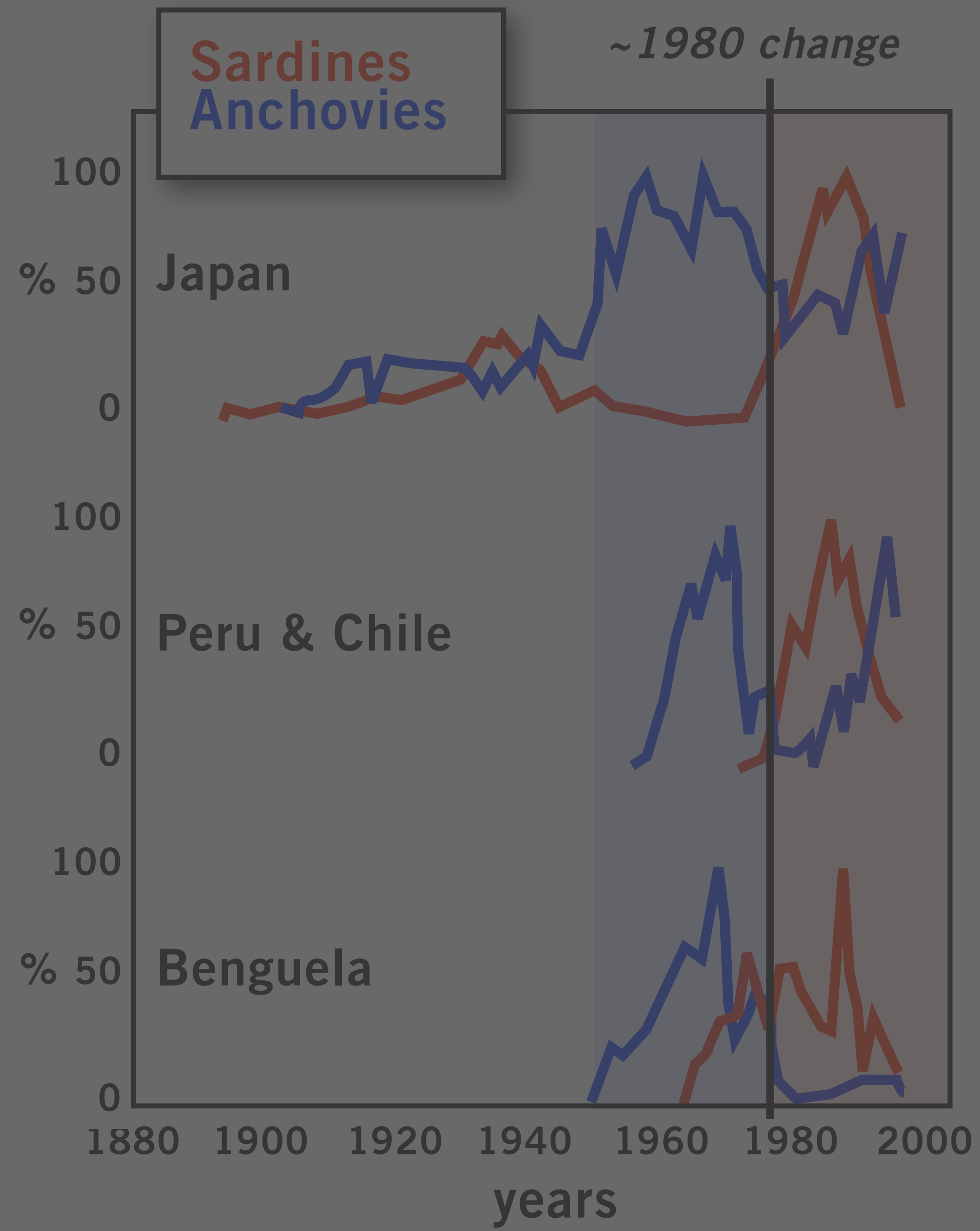




seems to work in real observations!

see also **Bryan Black** talk earlier this week


Atmospheric Forcing
1 x integration
Ocean Conditions
2 x integration
FISH ??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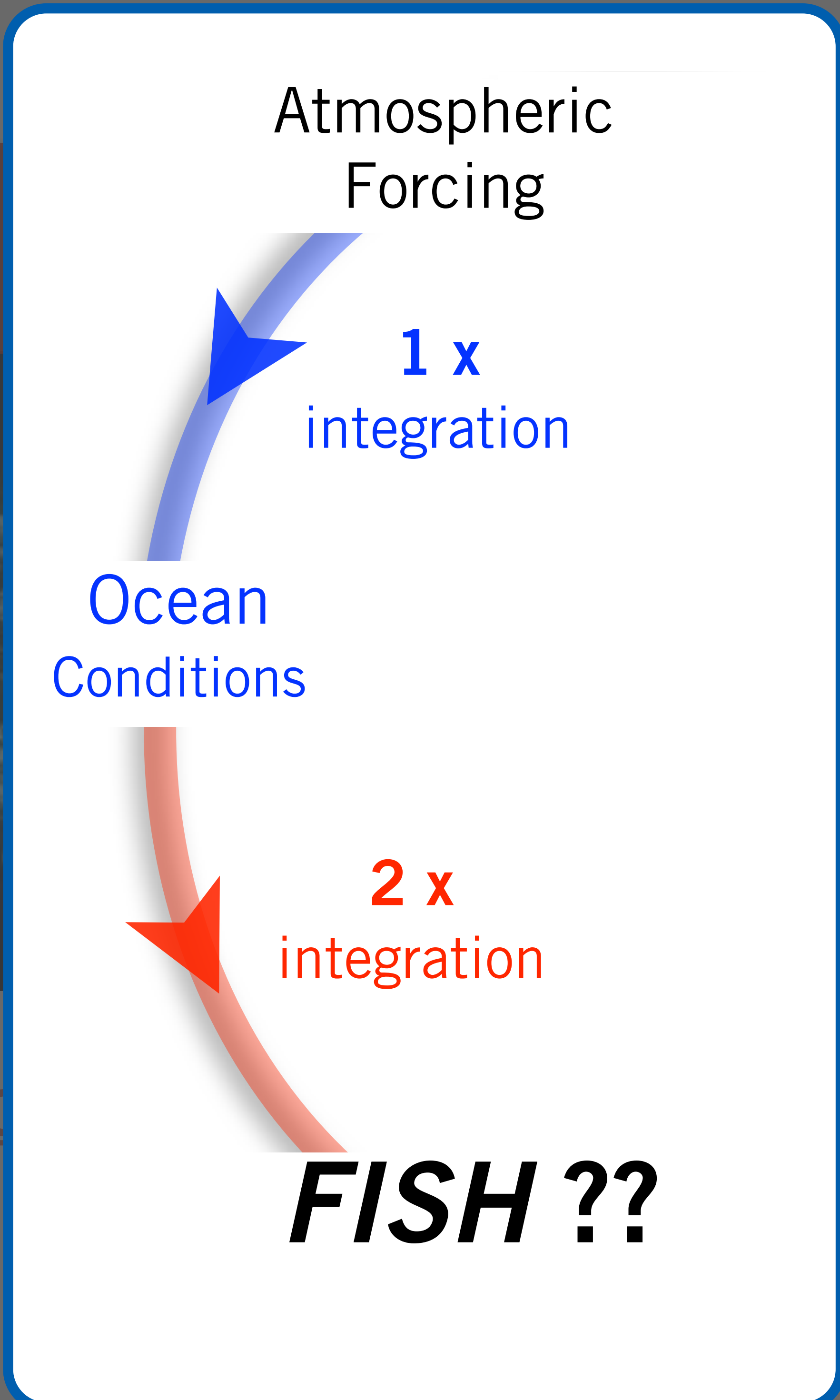
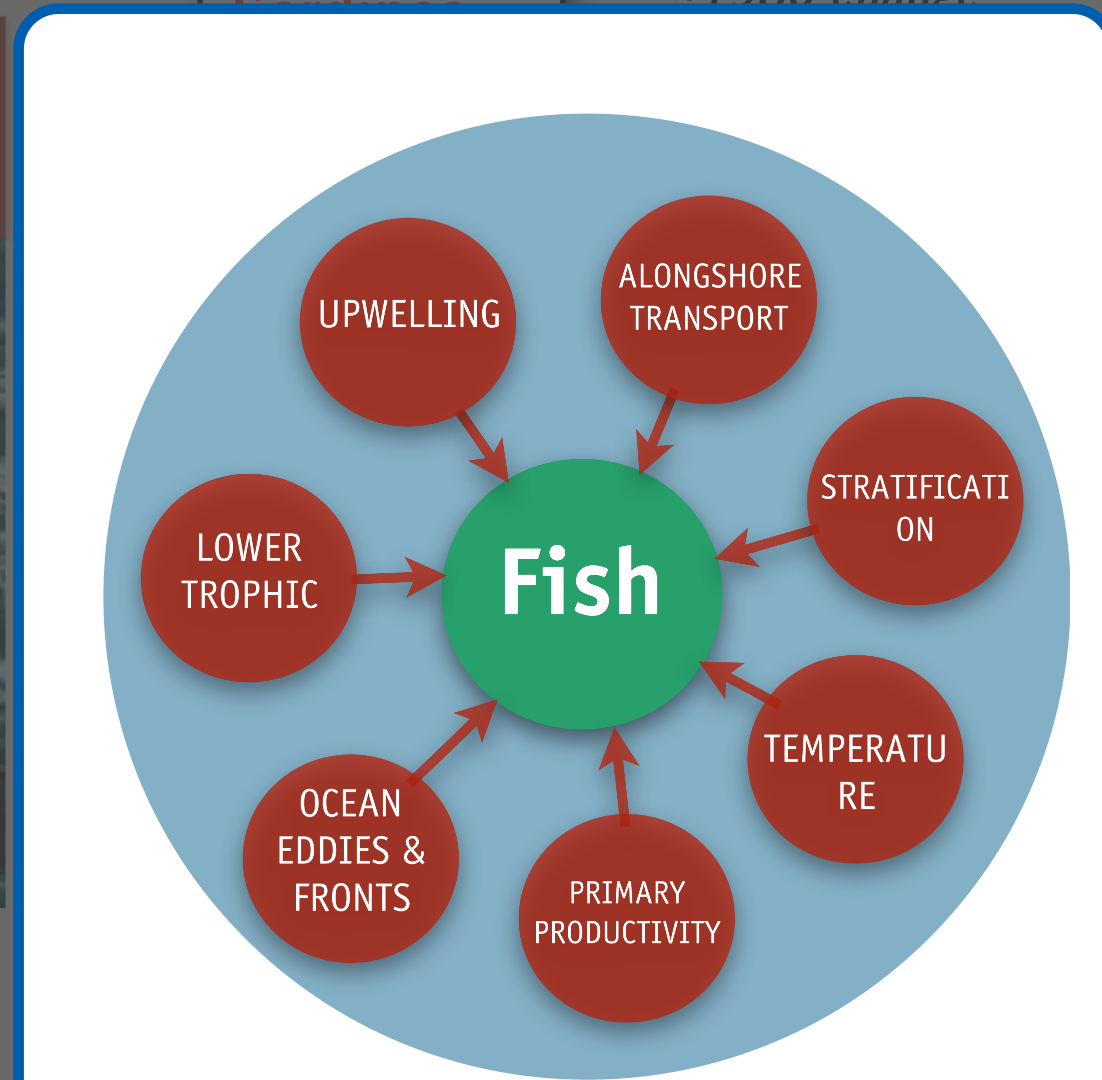
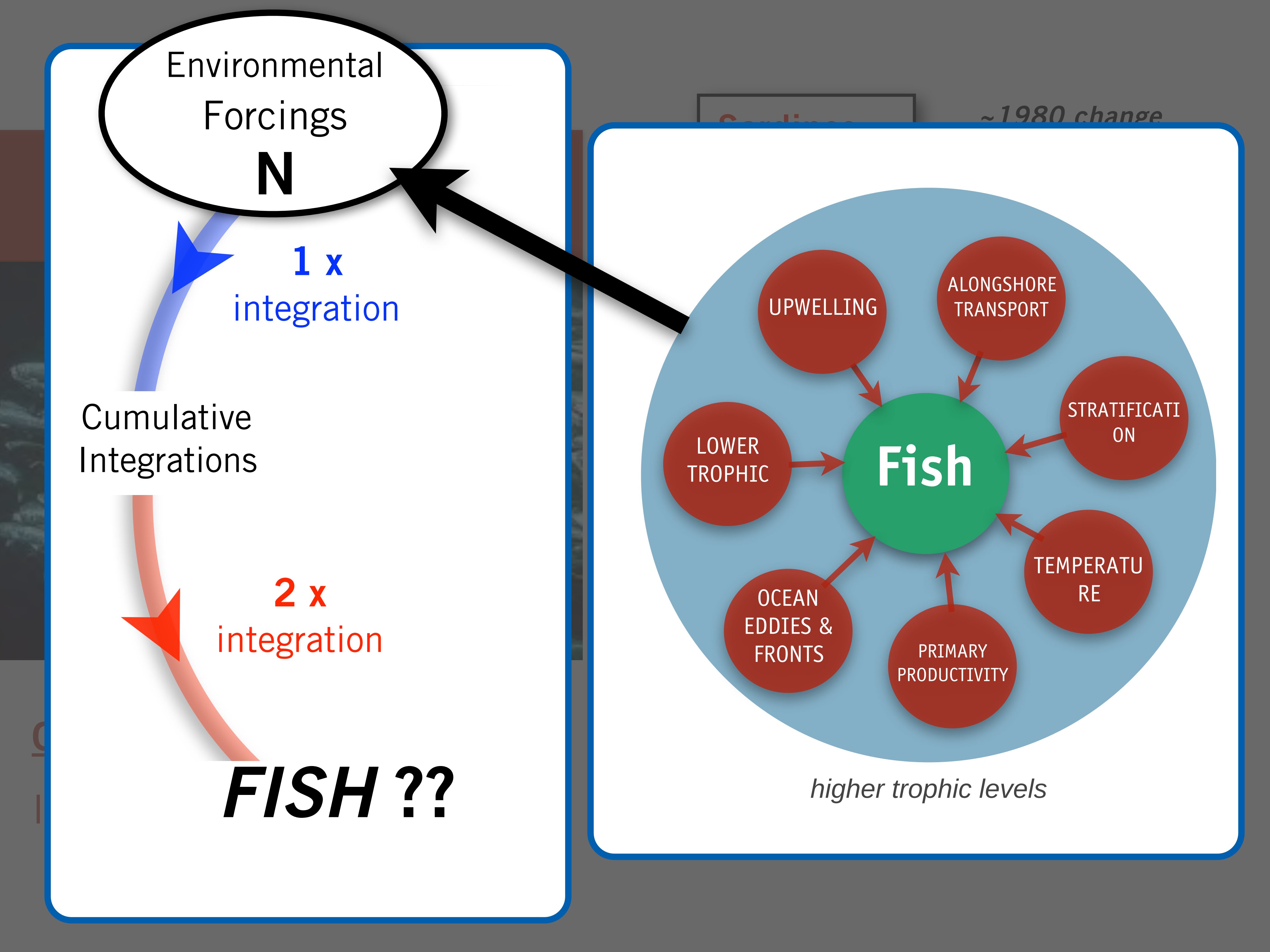
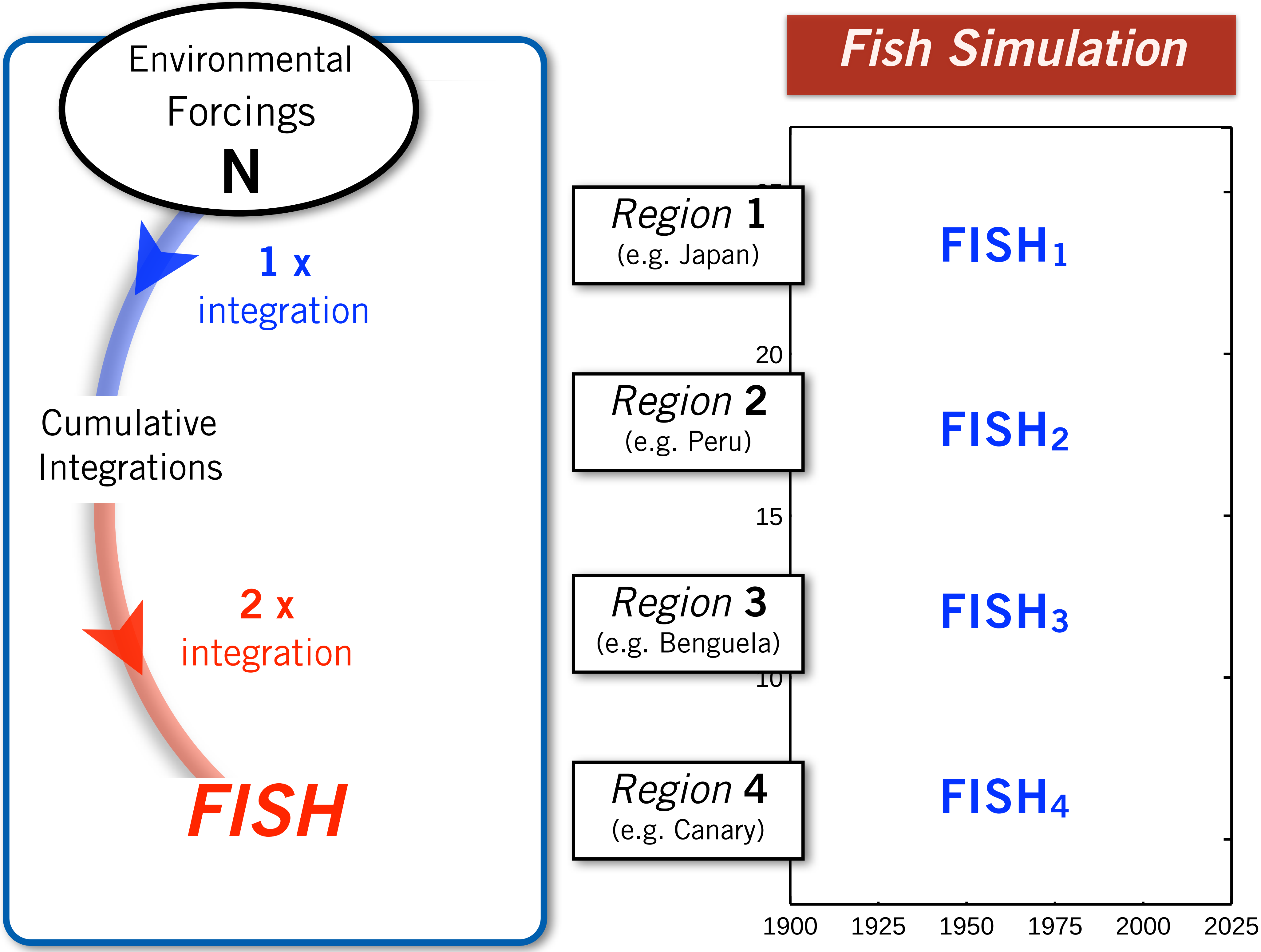


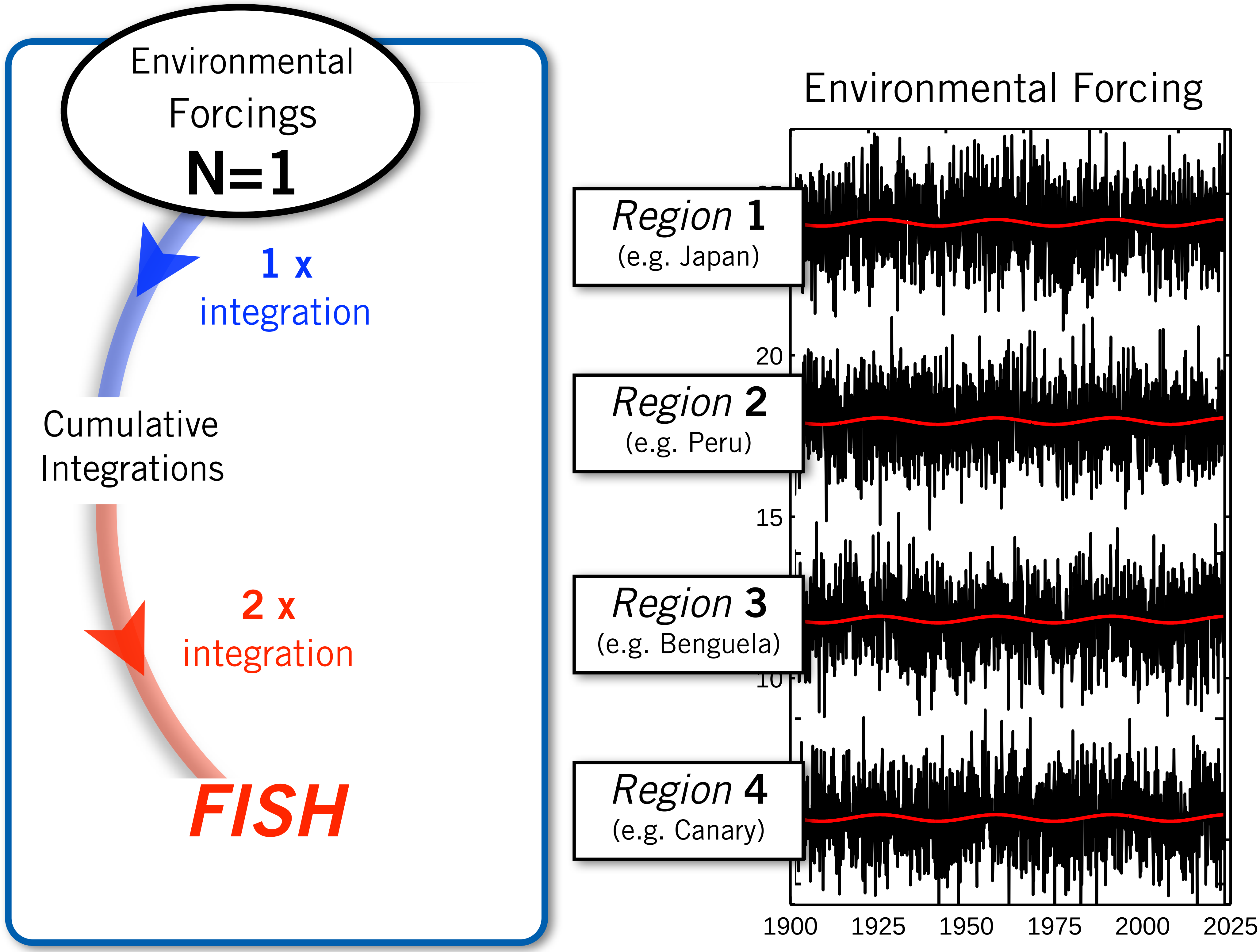


higher trophic levels


Environmental
Forcings
N
1 x
integration
Cumulative
Integrations
2 x
integration
FISH ??
UPWELLING
ALONGSHORE
TRANSPORT
LOWER
TROPHIC
Fish
STRATIFICATI
ON
TEMPERATU
RE
OCEAN
EDDIES &
FRONTS
PRIMARY
PRODUCTIVITY
higher trophic levels



Fish Simulation
Environmental Forcings
N
1 x integration
Cumulative Integrations
2 x integration
FISH
Region 1 (e.g. Japan)
Region 2 (e.g. Peru)
Region 3 (e.g. Benguela)
Region 4 (e.g. Canary)
FISH1
FISH2
FISH3
FISH4
20
15
10
1900
1925
1950
1975
2000
2025



Environmental Forcings
N=1
1 x integration
Cumulative Integrations
2 x integration
FISH
Environmental Forcing
Region 1 (e.g. Japan)
Region 2 (e.g. Peru)
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20
15
10
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1975
2000
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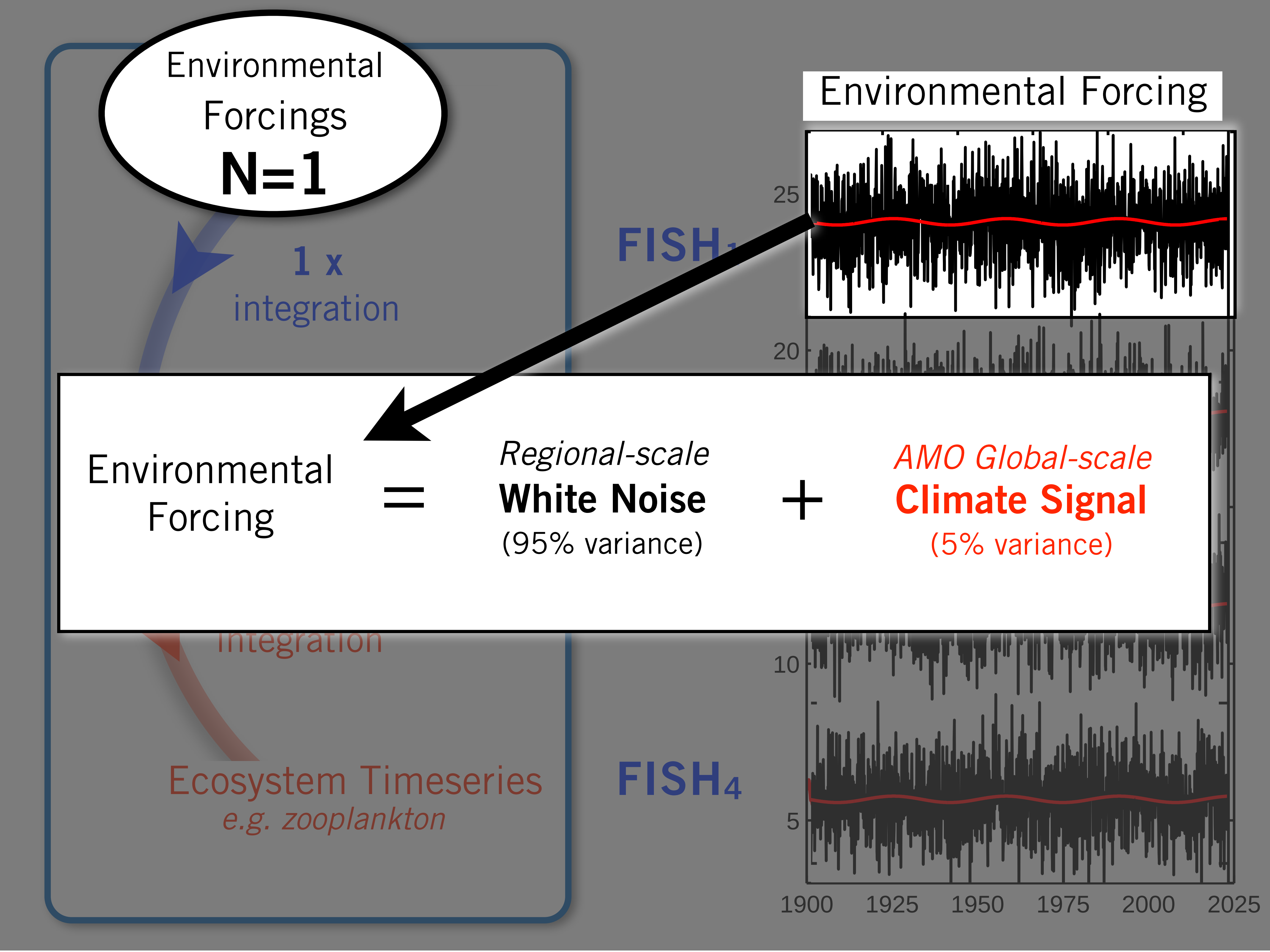
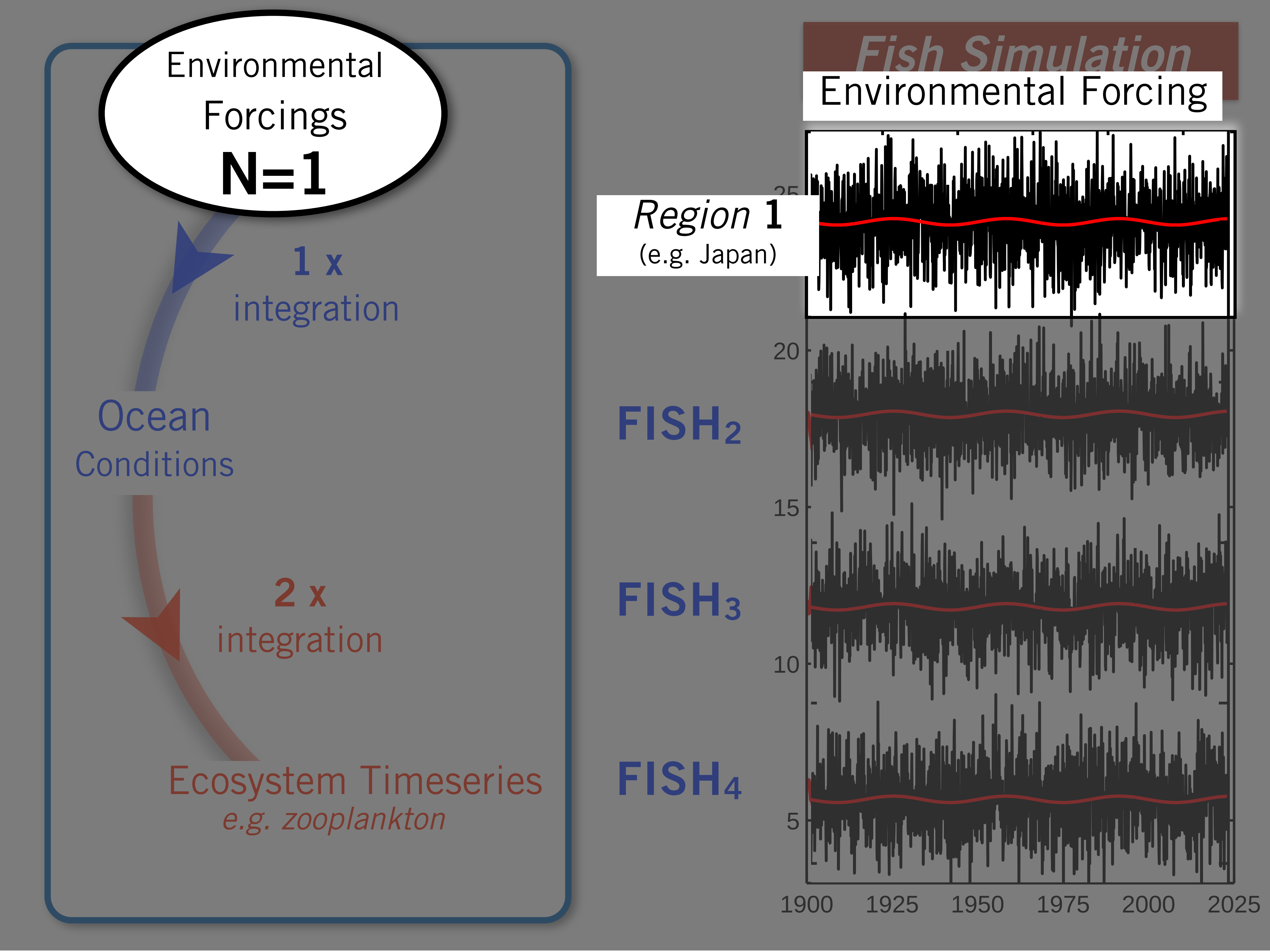


Environmental
Forcings
N=1
1 x
integration
FISH1
FISH4
integration
Ecosystem Timeseries
e.g. zooplankton
Environmental Forcing
25
20
10
5
1900
1925
1950
1975
2000
2025
Environmental Forcing
=
Regional-scale
White Noise
(95% variance)
+
AMO Global-scale
Climate Signal
(5% variance)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Fish Simulation
Environmental Forcing
Region 1
(e.g. Japan)
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FISH3
FISH4
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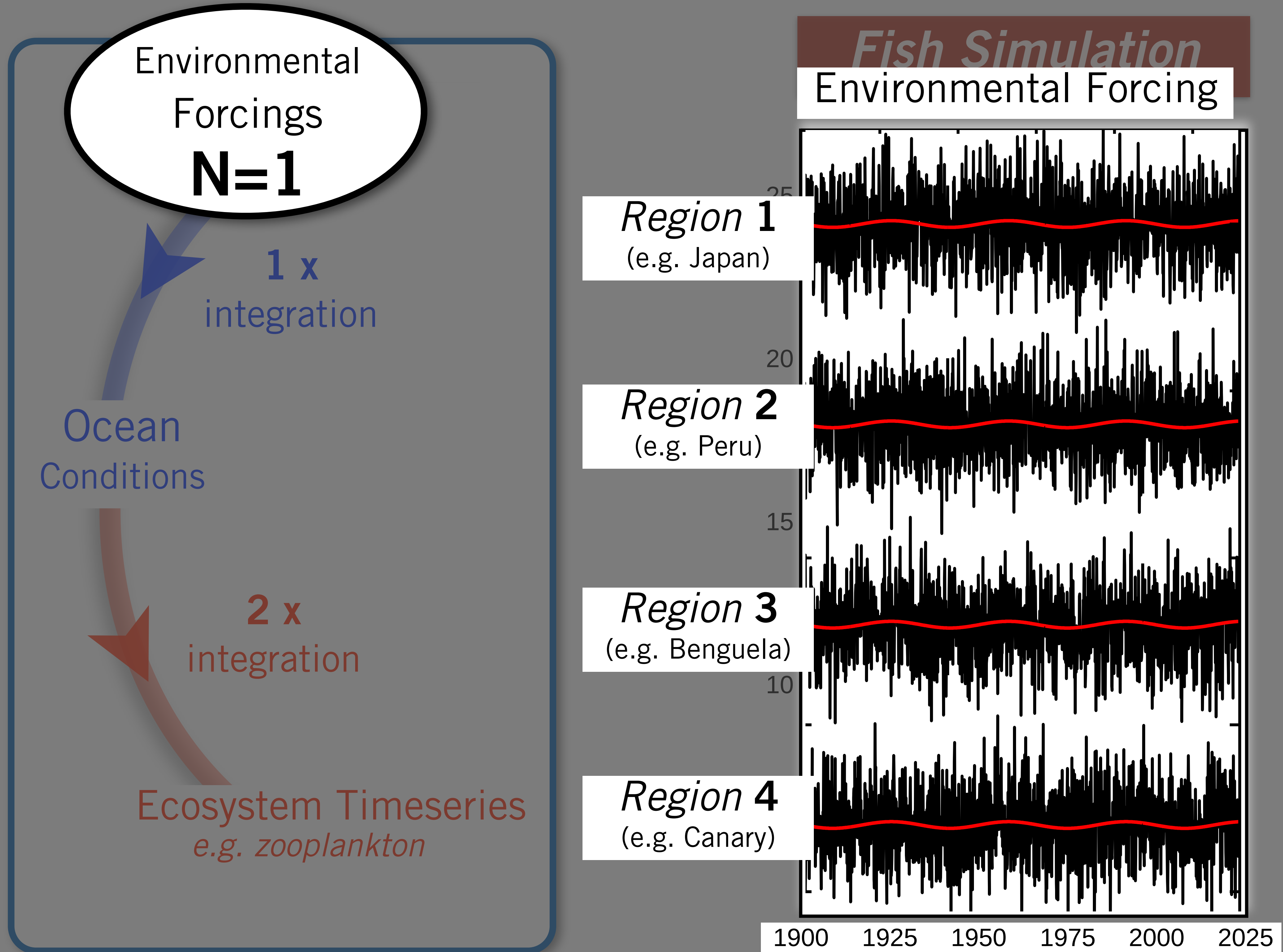

Environmental Forcings
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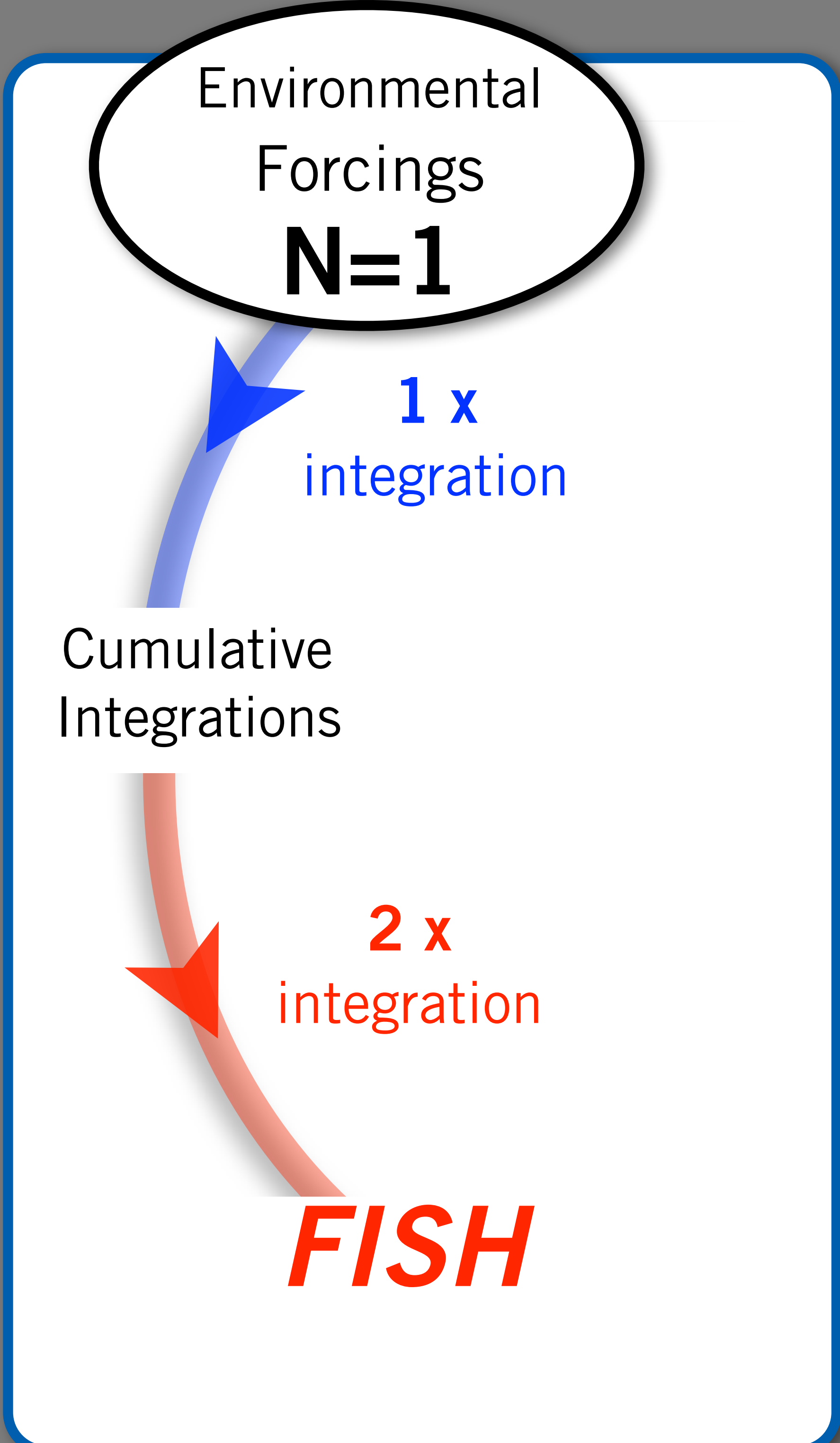
Environmental
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1 x
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Cumulative
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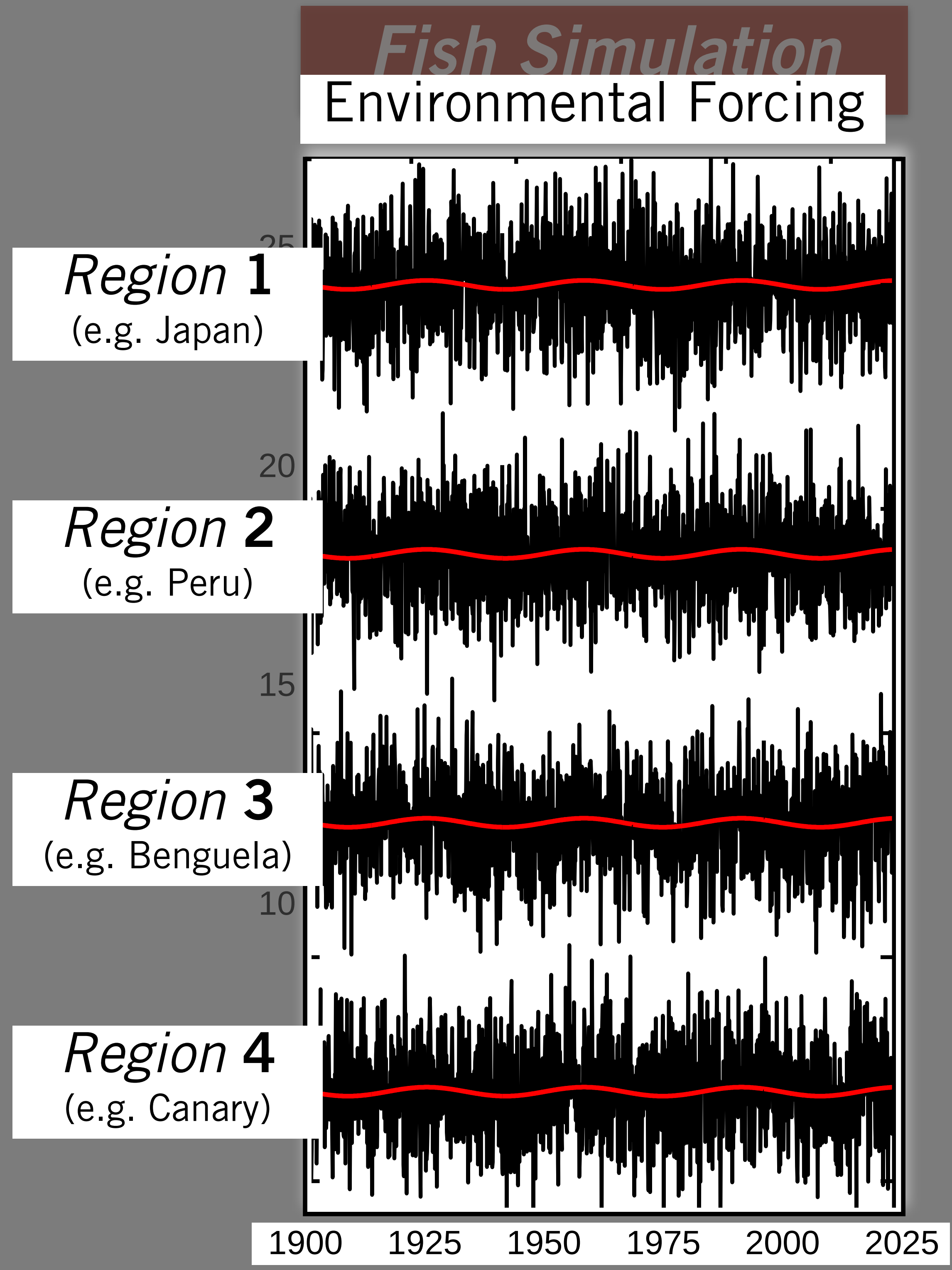
FISH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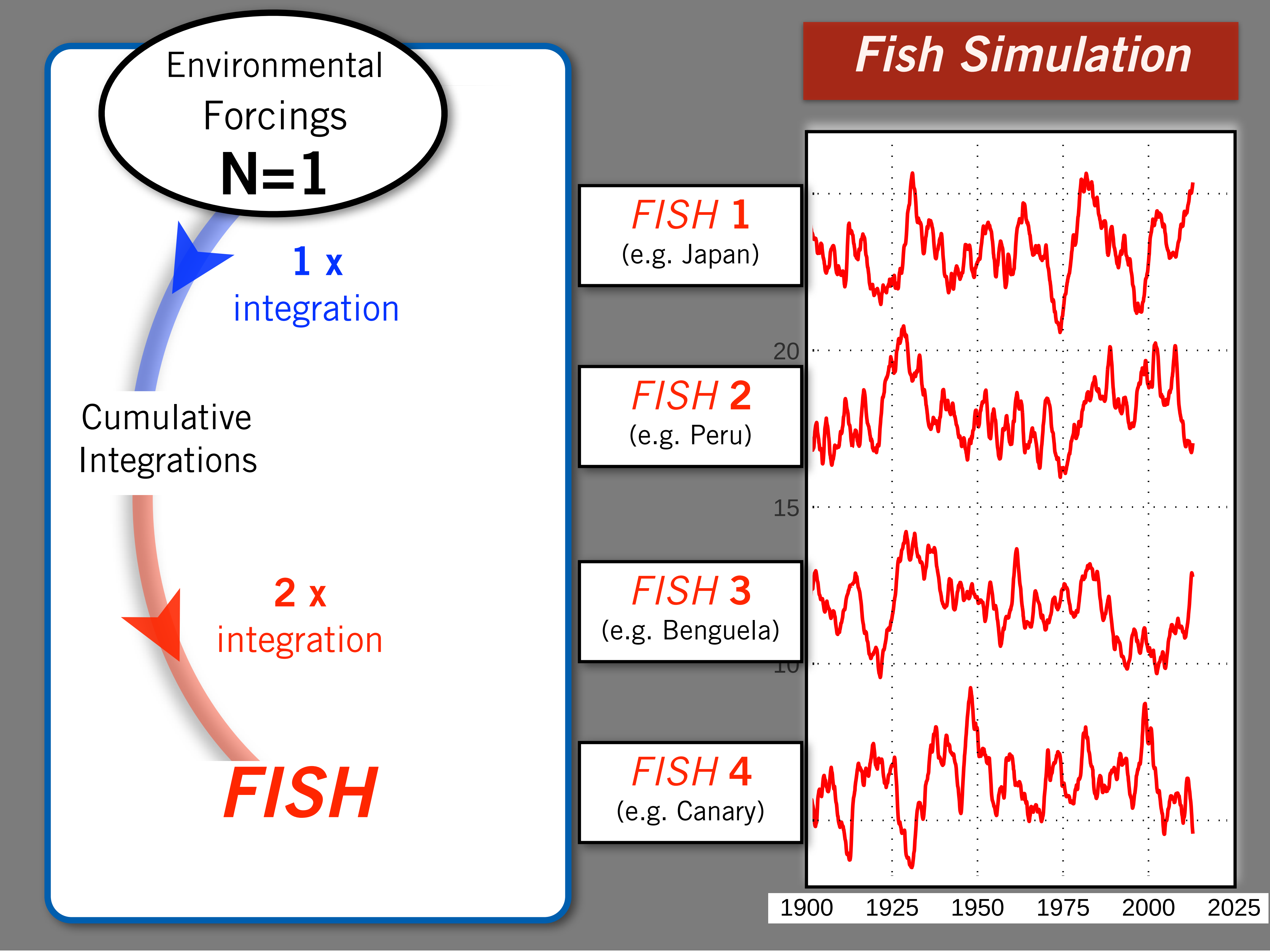

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FISH 4
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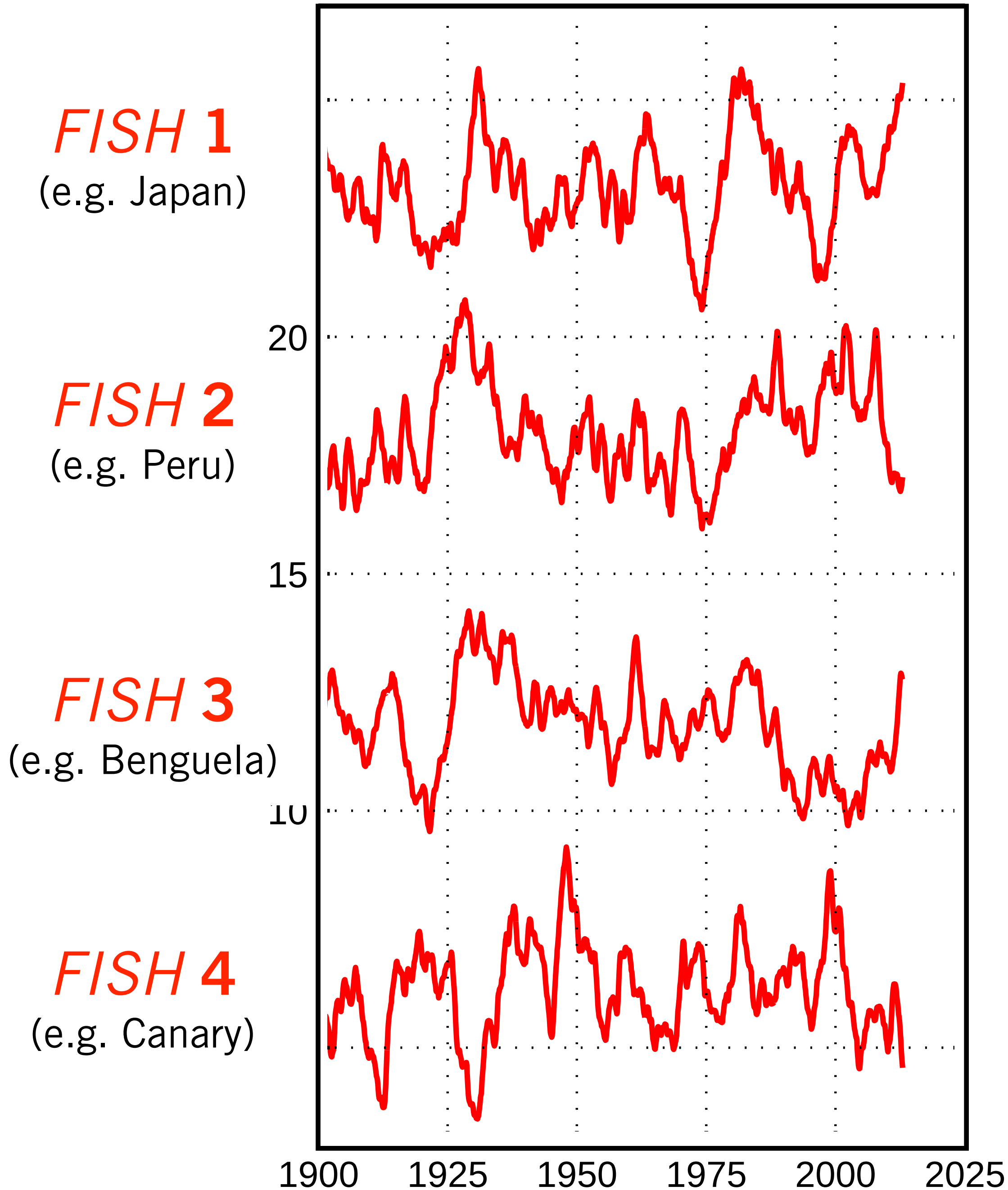
20
15
1900
1925
1950
1975
2000
2025

Environmental Forcings

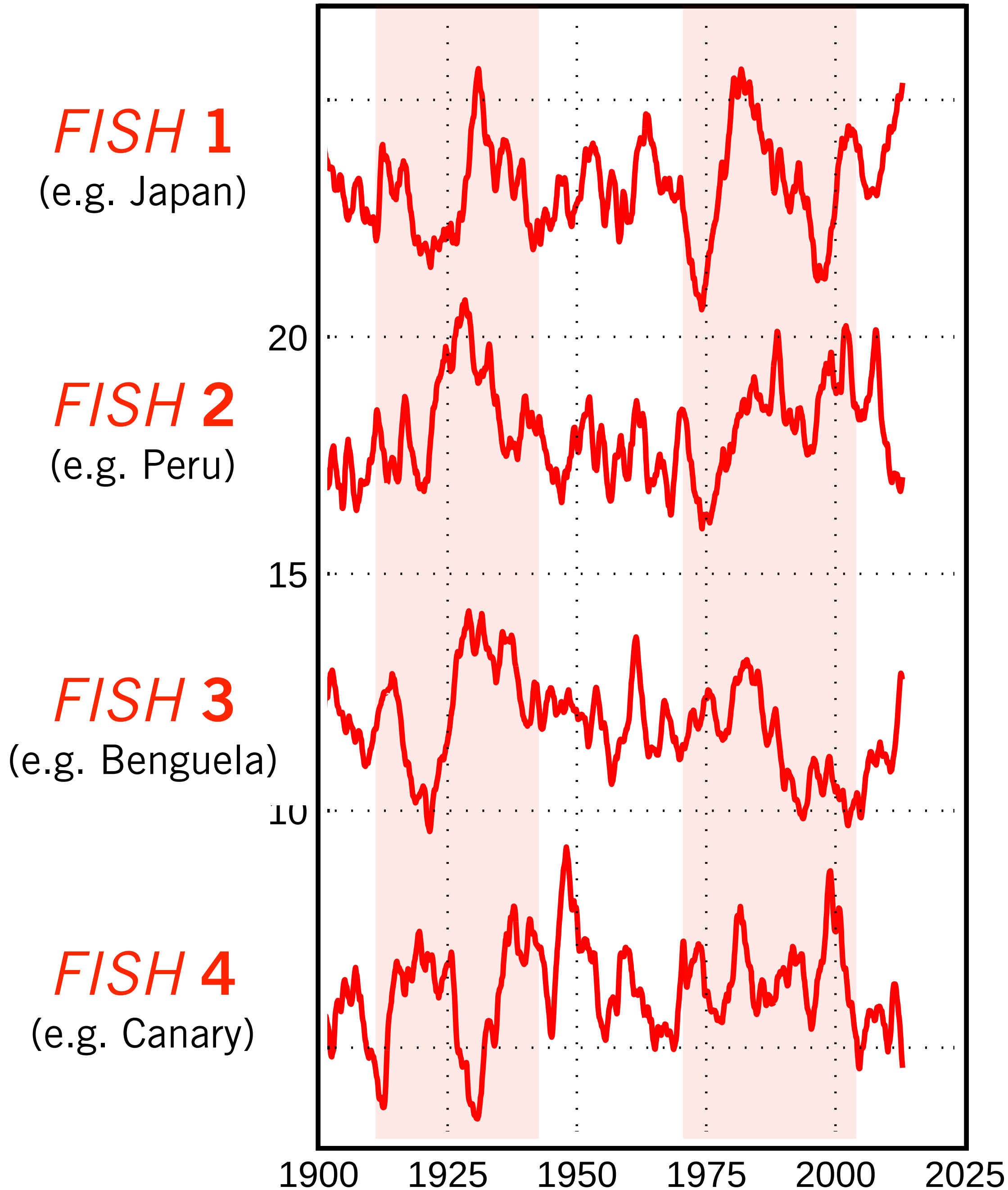
N=1

Fish Simulation



Environmental Forcings
N=1

Fish Simulation

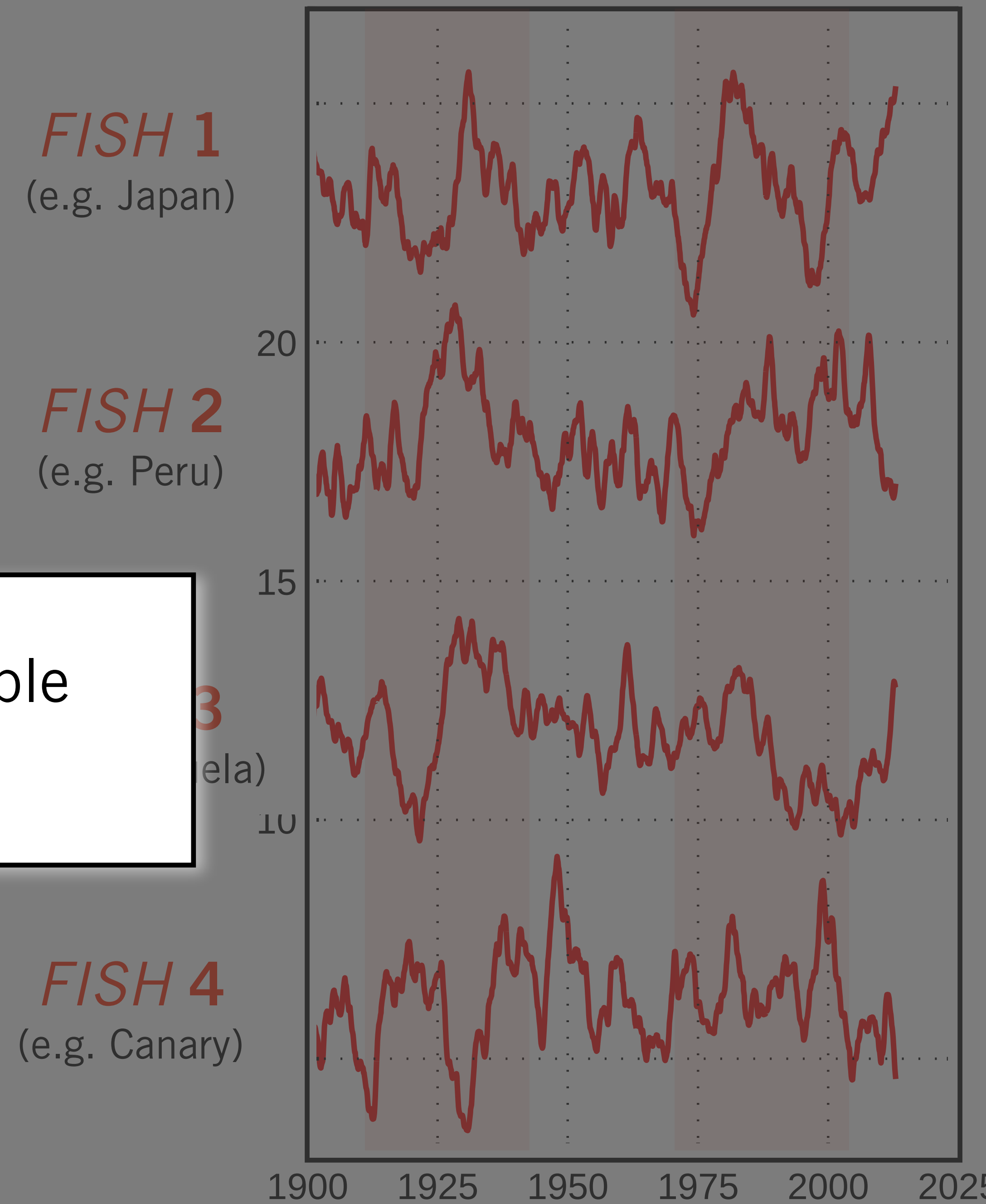


Environmental Forcings

N=1

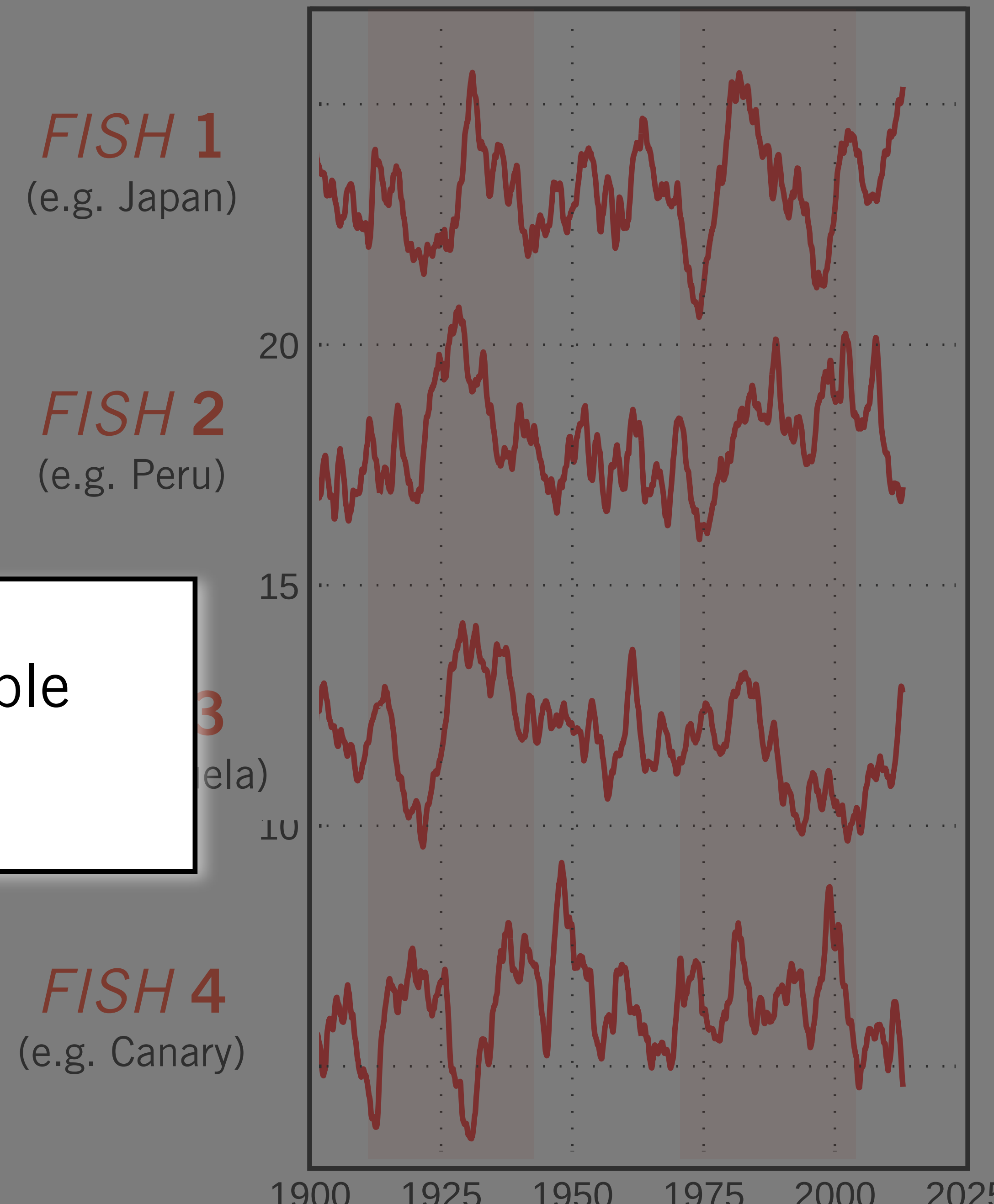
FISH are sensitive to multiple environmental stressors

Fish Simulation



Fish Simulation

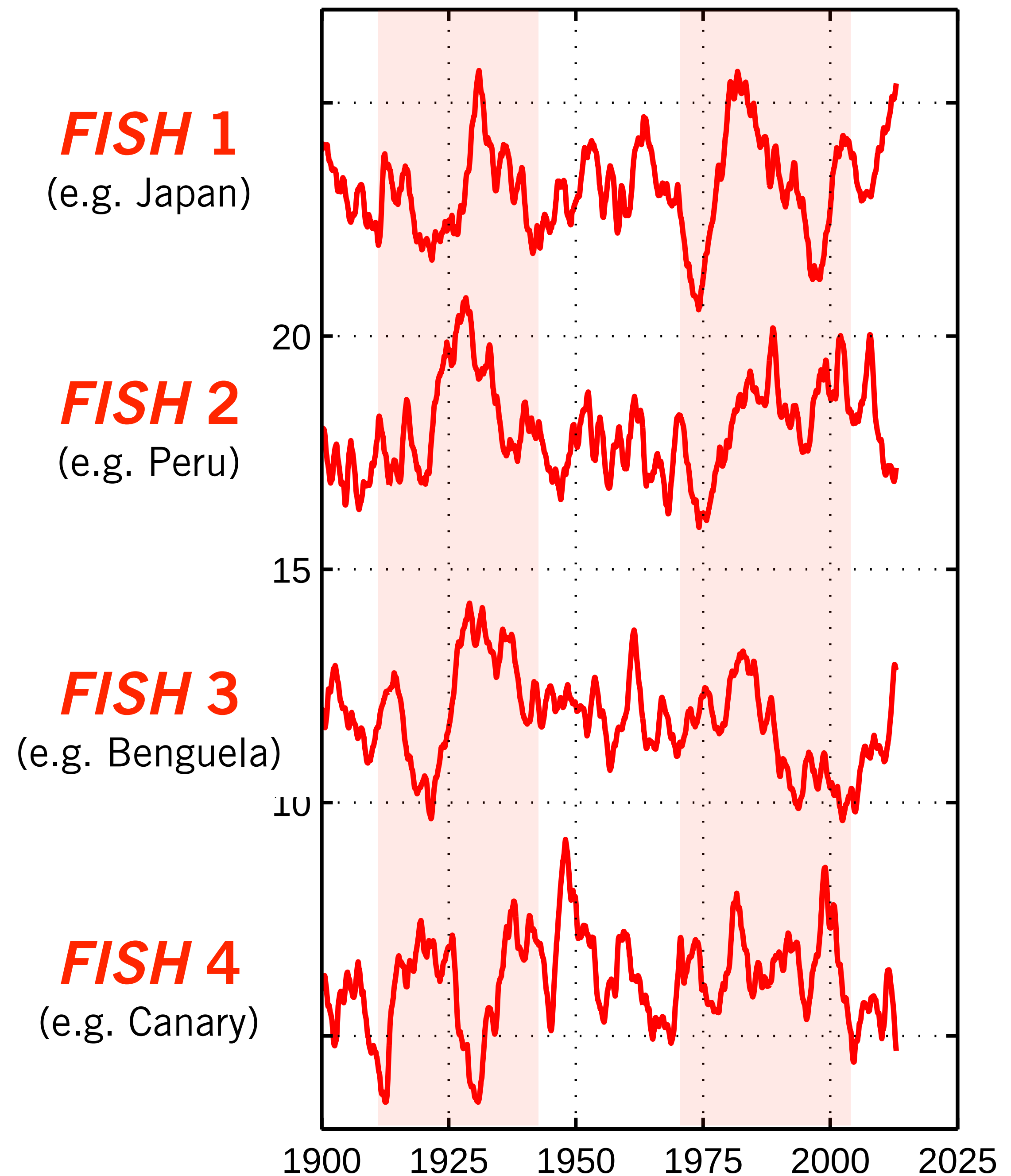
Environmental Forcings
N=2



FISH are sensitive to multiple environmental stressors

Fish Simulation

Environmental Forcings
N=2

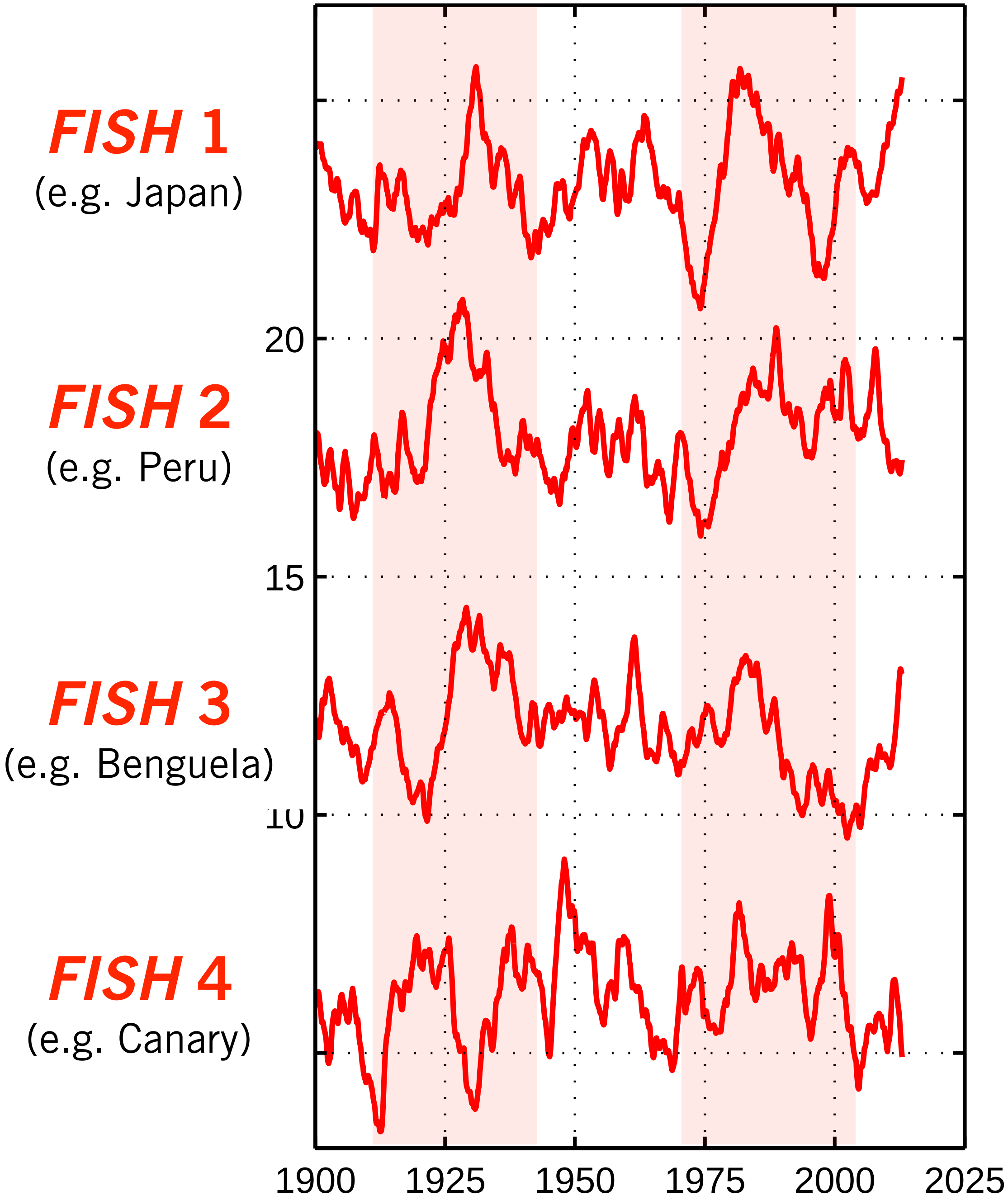


Pairwise Correlation
R=0.01

Environmental Forcings

N=4

Fish Simulation



Pairwise Correlation

R=0.2

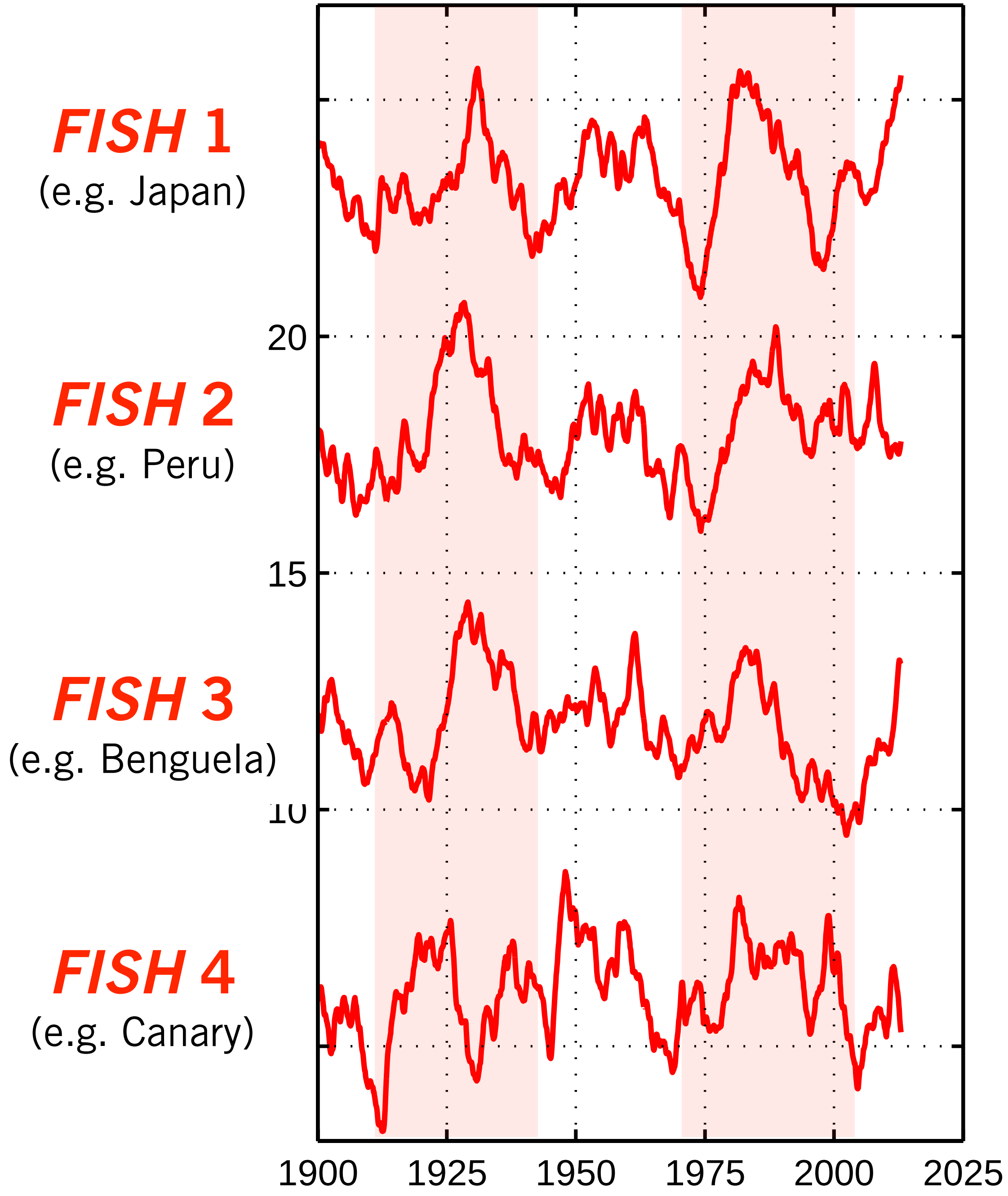
Environmental Forcings

N=7

Pairwise Correlation

R=0.3

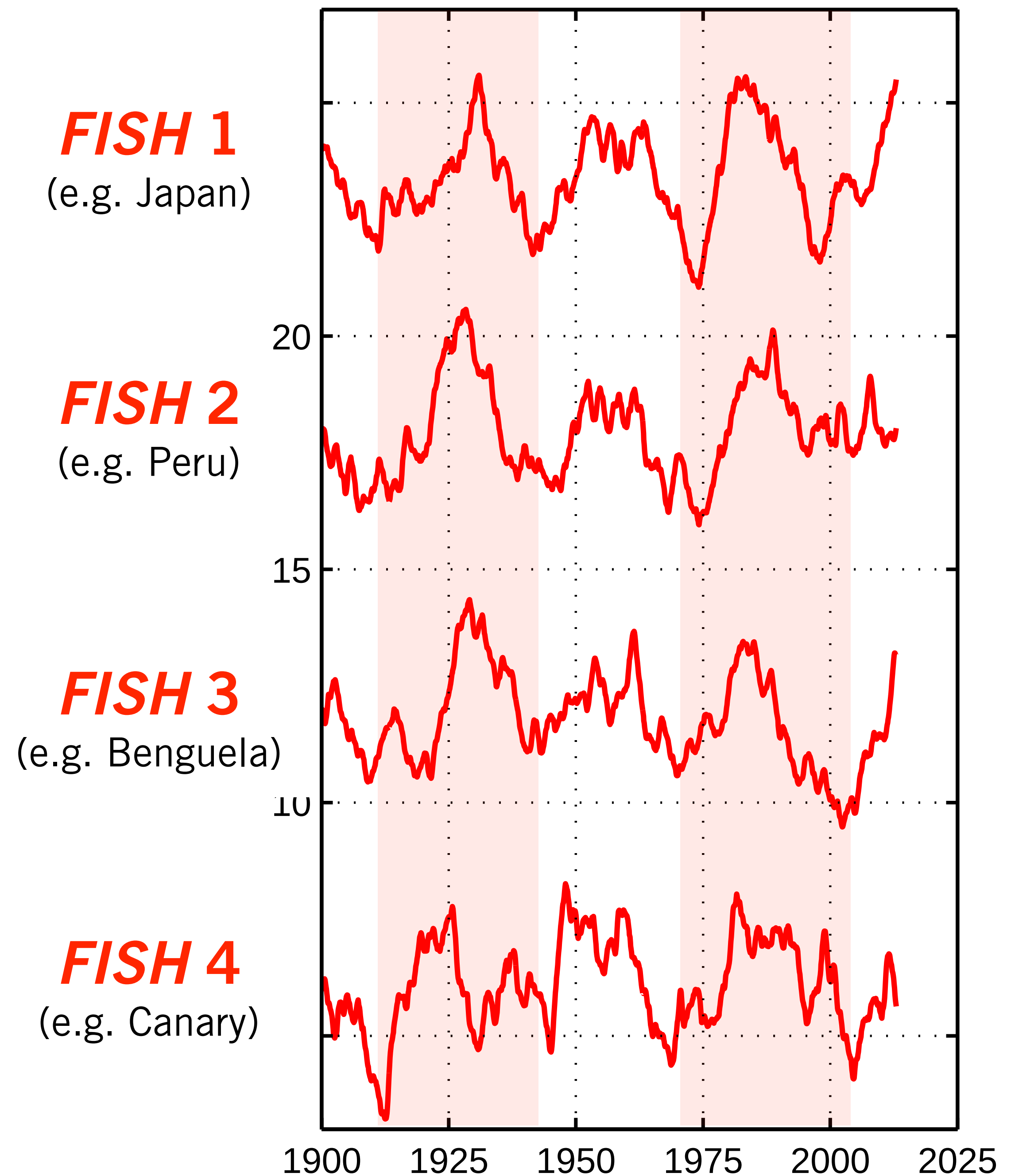
Fish Simulation



Environmental Forcings
N=10

Pairwise Correlation
R=0.45

Fish Simulation



Fish Simulation

Environmental
Forcings
N=10

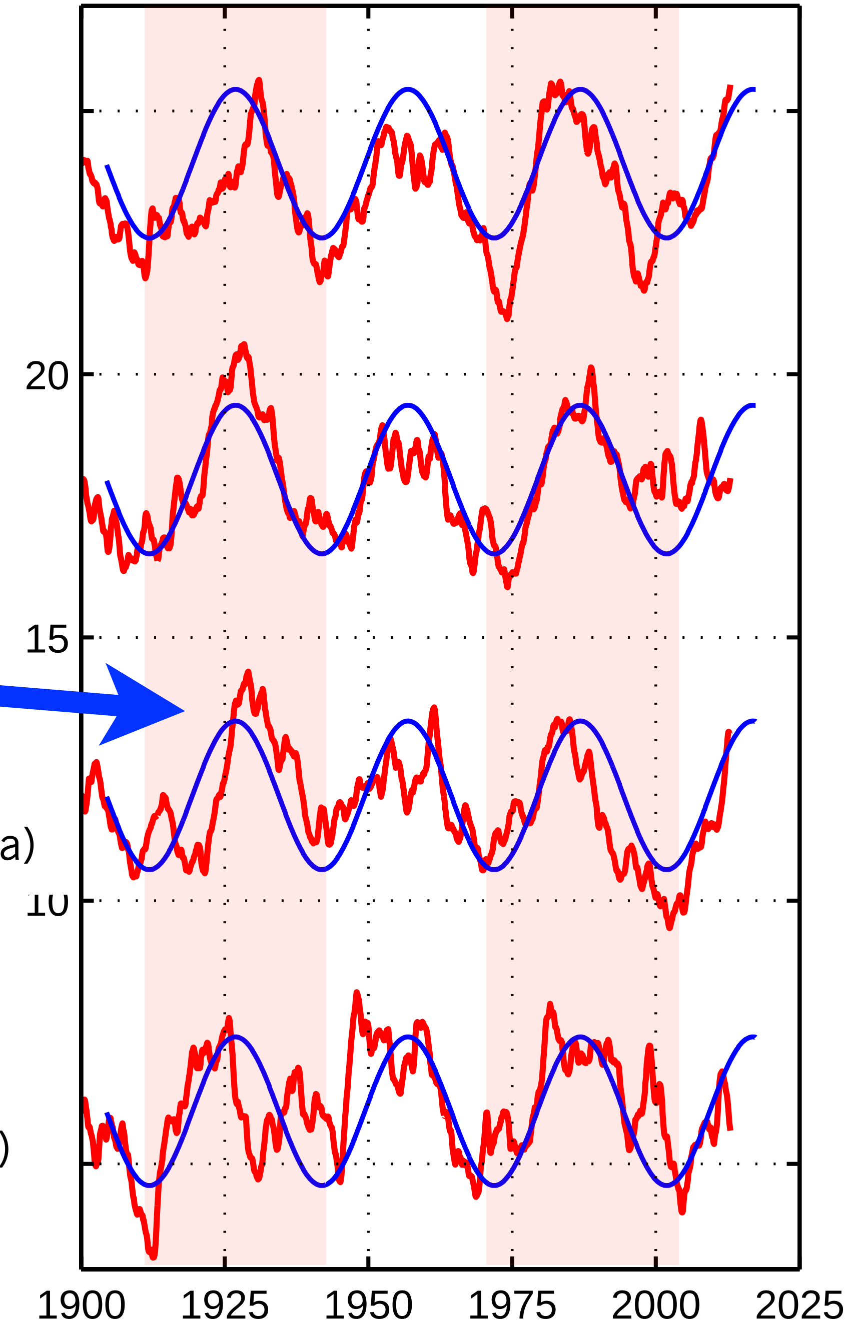
AMO
Global-scale
Climate Signal
(5% variance)

FISH 1
(e.g. Japan)

FISH 2
(e.g. Peru)

FISH 3
(e.g. Benguela)

FISH 4
(e.g. Canary)

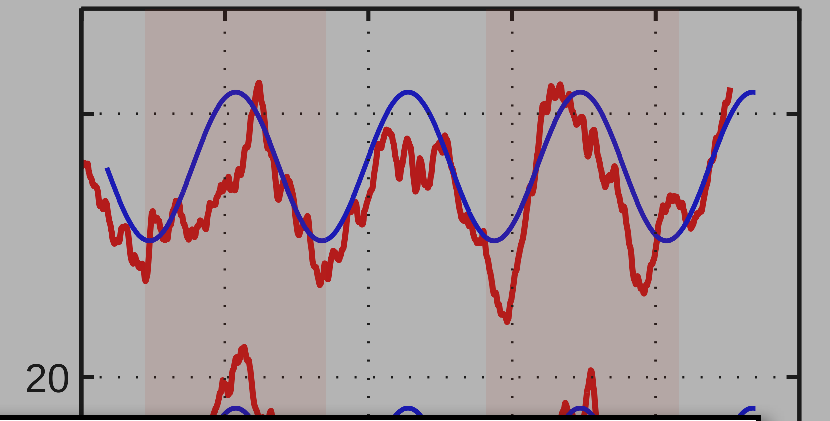


Environmental Forcings

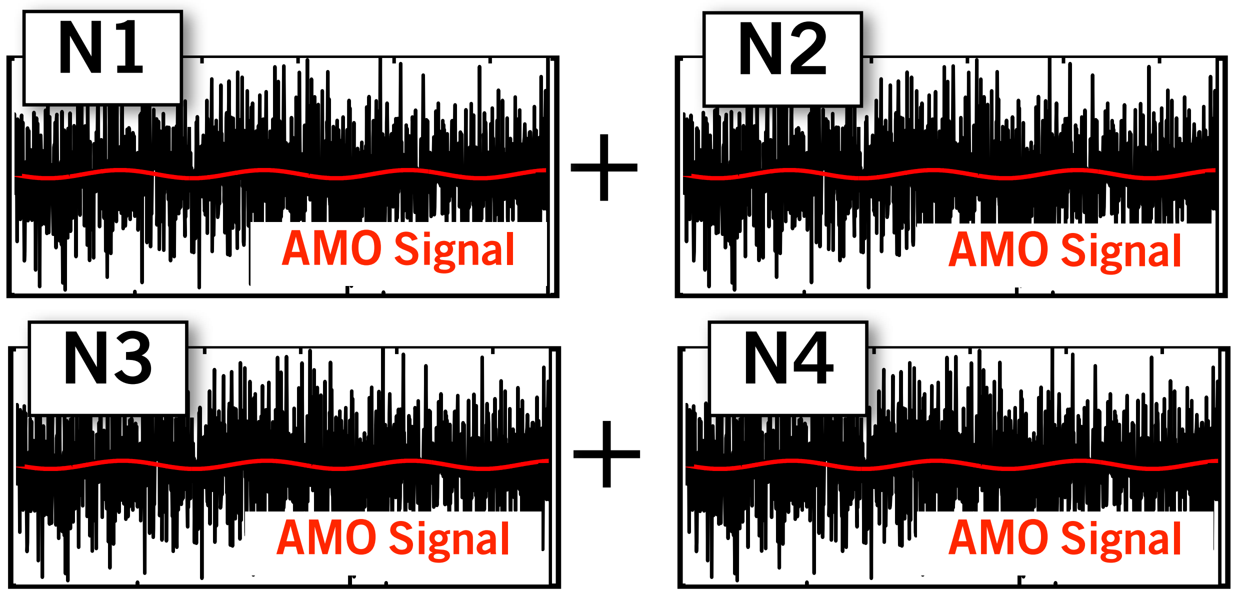
N=10

Fish Simulation

FISH 1
(e.g. Japan)



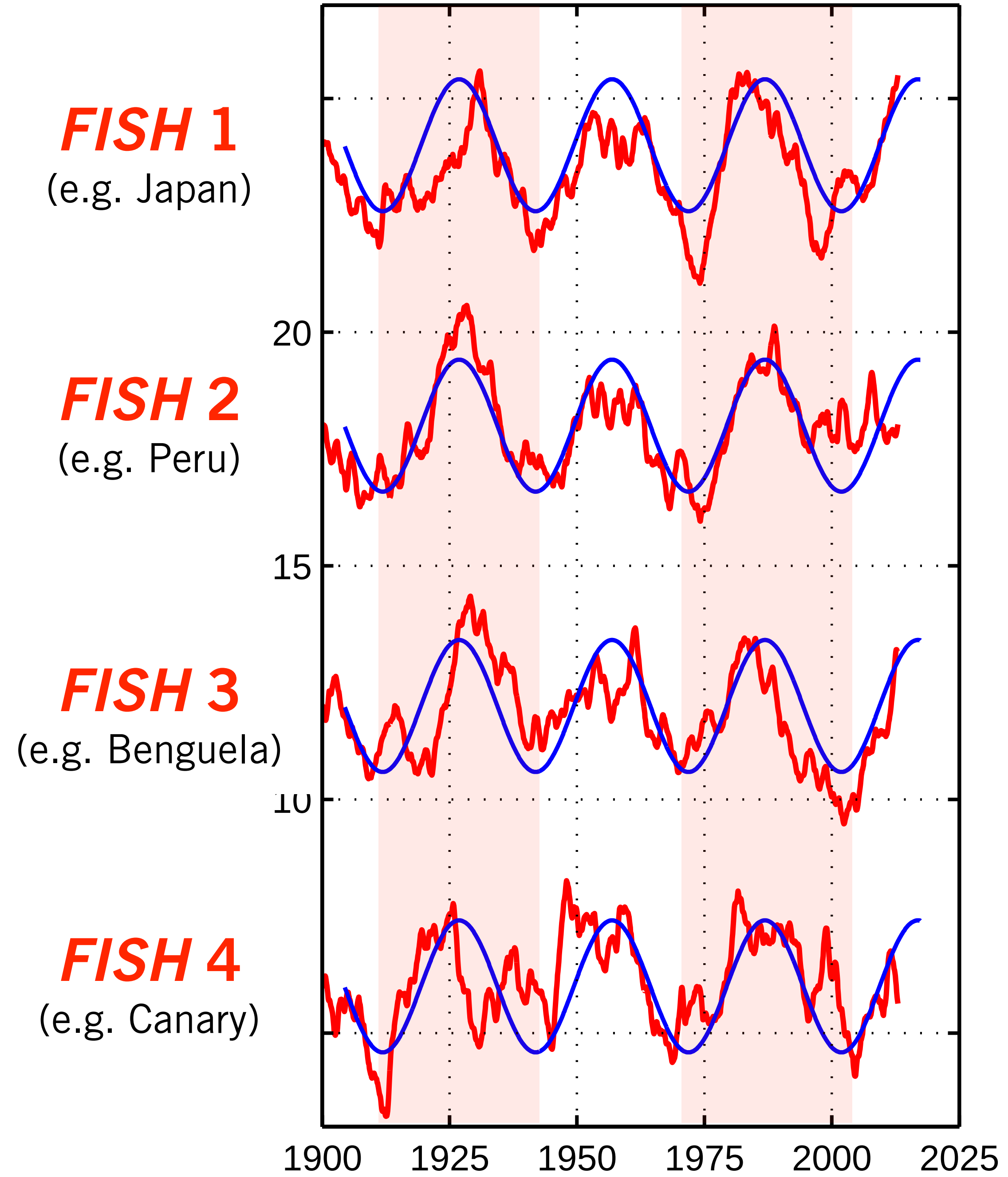
Environmental Forcings = N1 + N2 + N3 + N4 + ...



Environmental Forcings

N=10

Fish Simulation

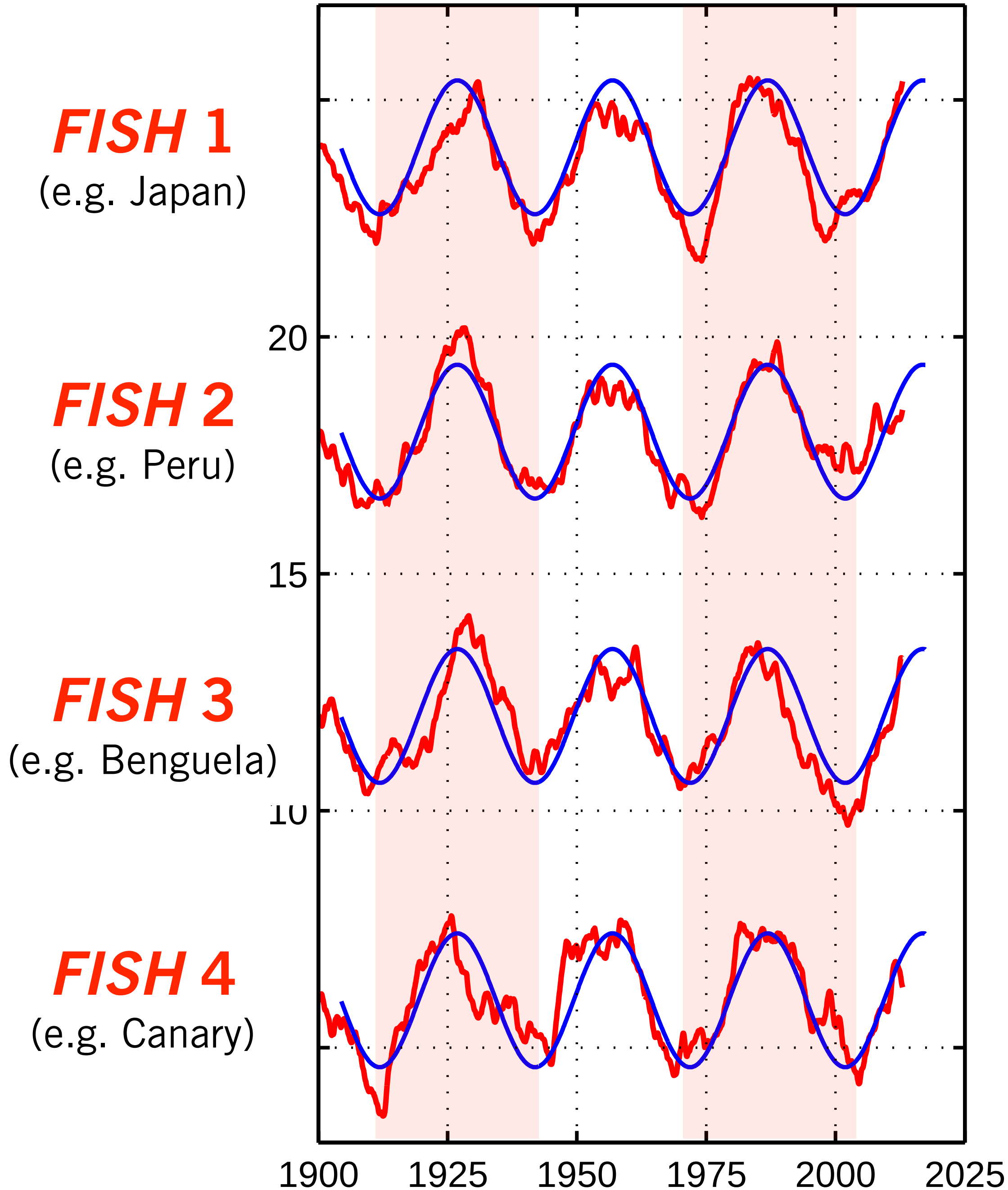


Pairwise Correlation

R=0.45

Environmental Forcings
N=20

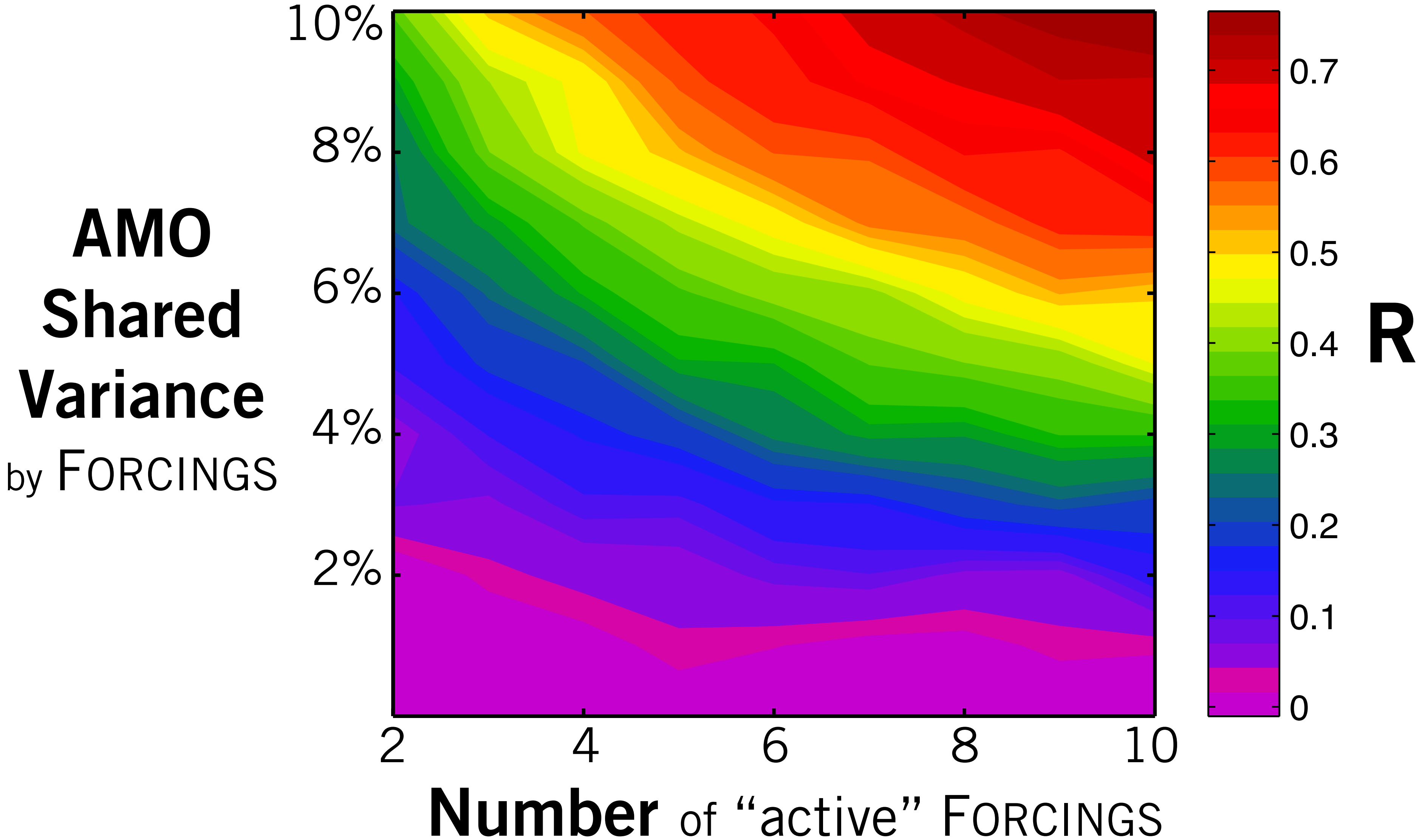
Fish Simulation

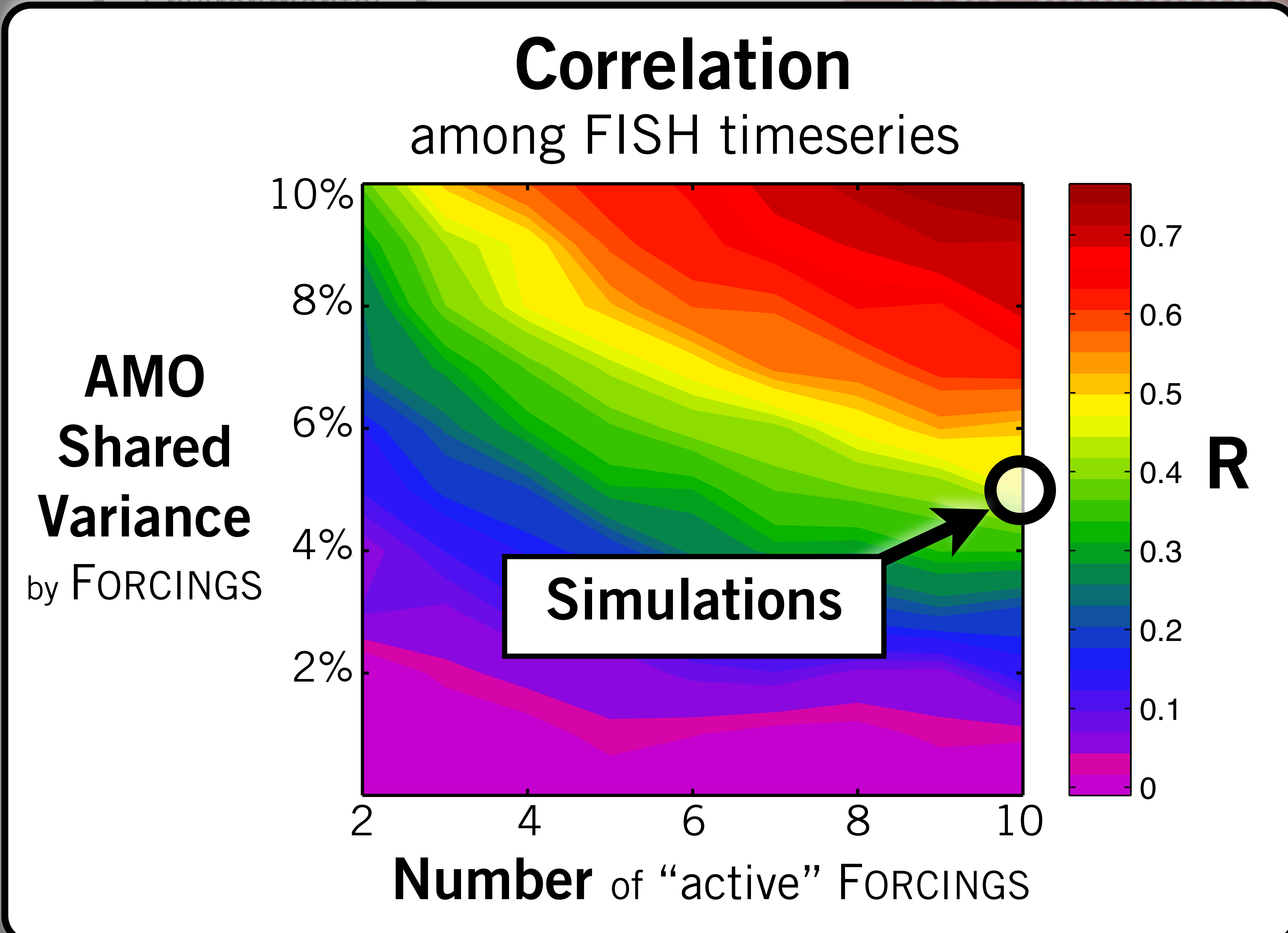


Pairwise Correlation
R=0.85

Correlation

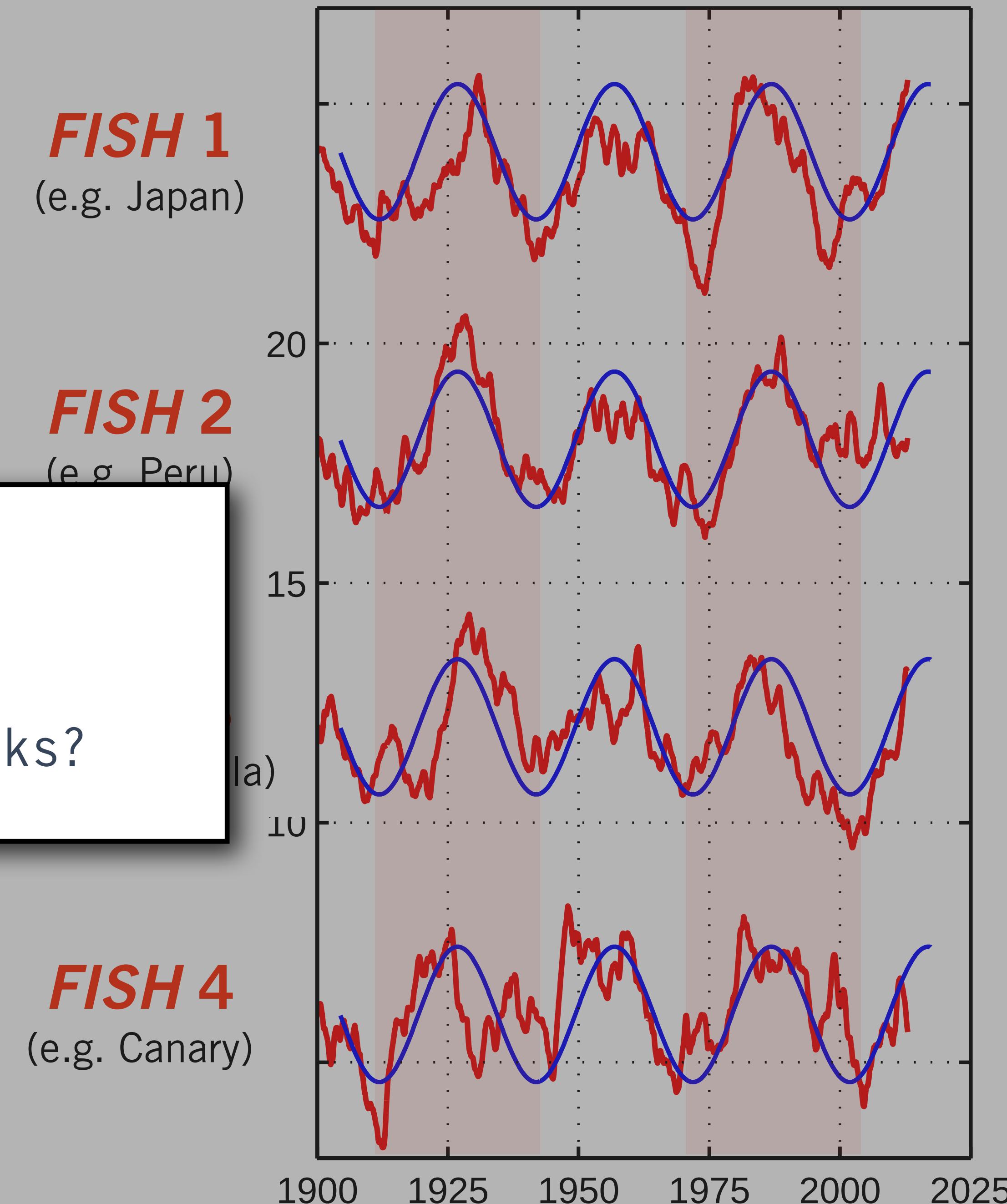
among FISH timeseries





Correlation
among FISH timeseries
AMO
Shared
Variance
by FORCINGS
10%
8%
6%
4%
2%
2
4
6
8
10
Number of "active" FORCINGS
Simulations
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
R

Fish Simulation



QUESTION:

Is there evidence for climate synchrony in global fish stocks?

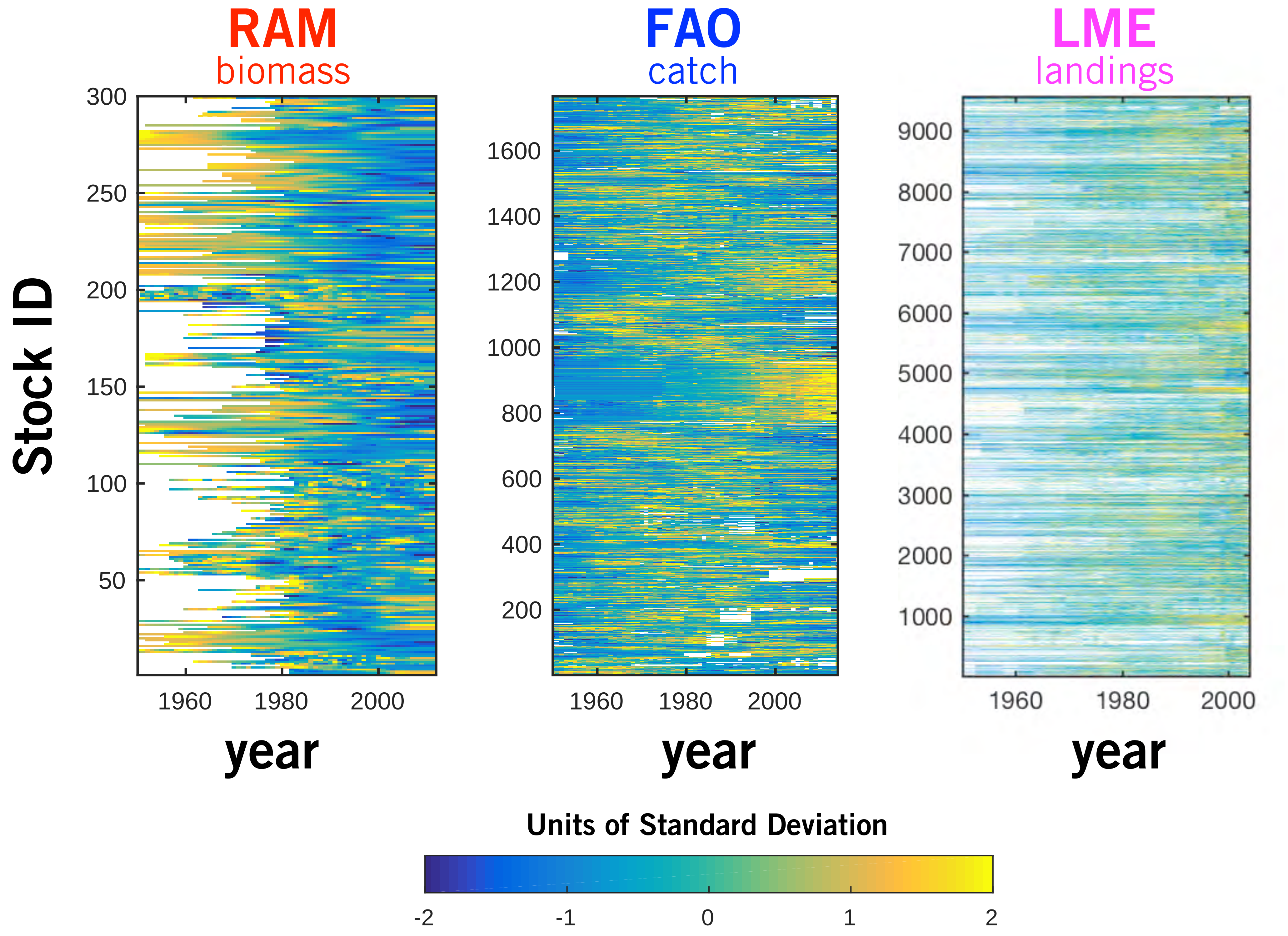
RAM
biomass

FAO
catch

LME
landings

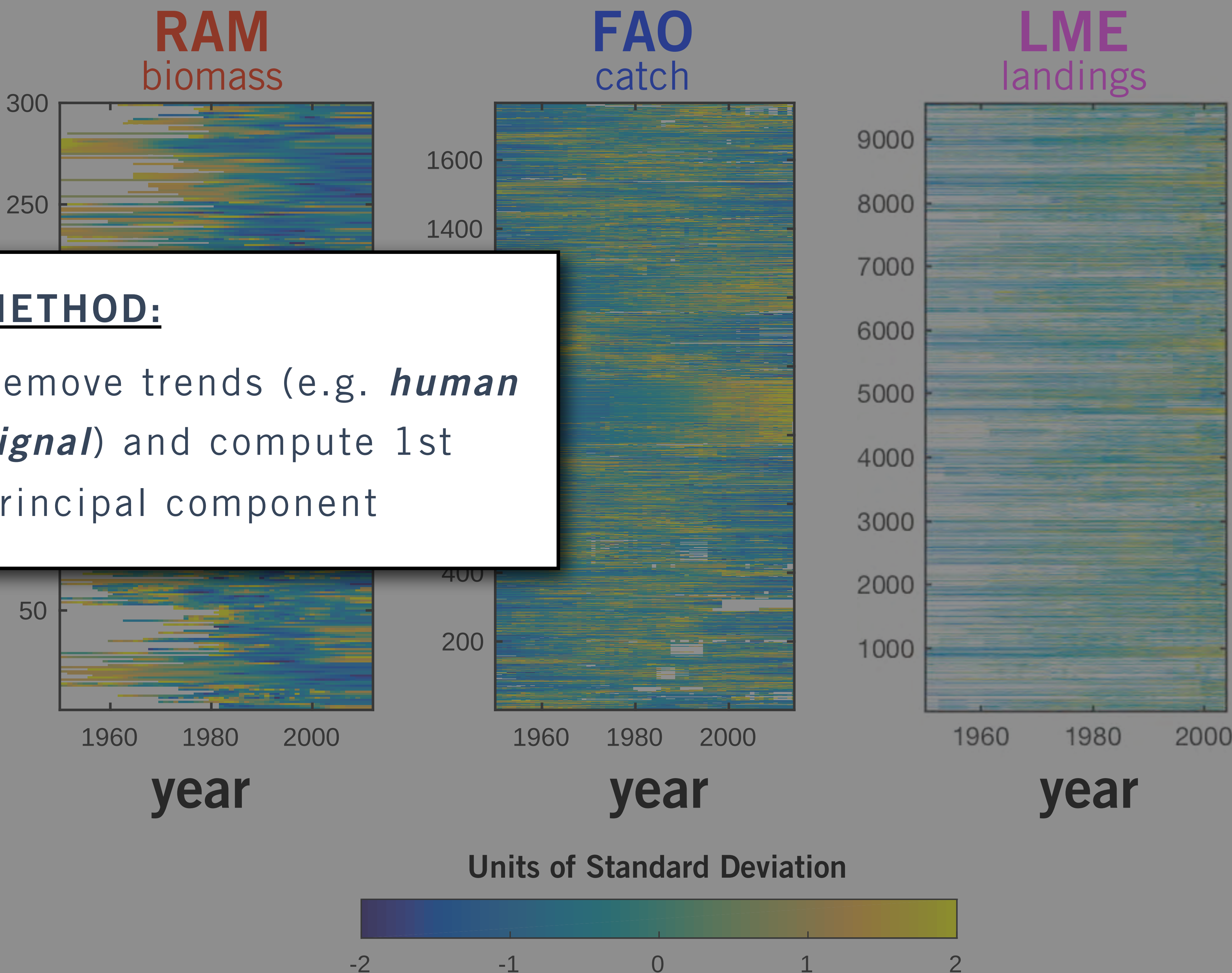
QUESTION:

Is there evidence for climate synchrony in global fish stocks?


RAM
biomass
FAO
catch
LME
landings
Stock ID
300
250
200
150
100
50
1600
1400
1200
1000
800
600
400
200
9000
8000
7000
6000
5000
4000
3000
2000
1000
1960
1980
2000
year
year
year
Units of Standard Deviation
-2
-1
0
1
2

METHOD:

Remove trends (e.g. ***human signal***) and compute 1st principal component



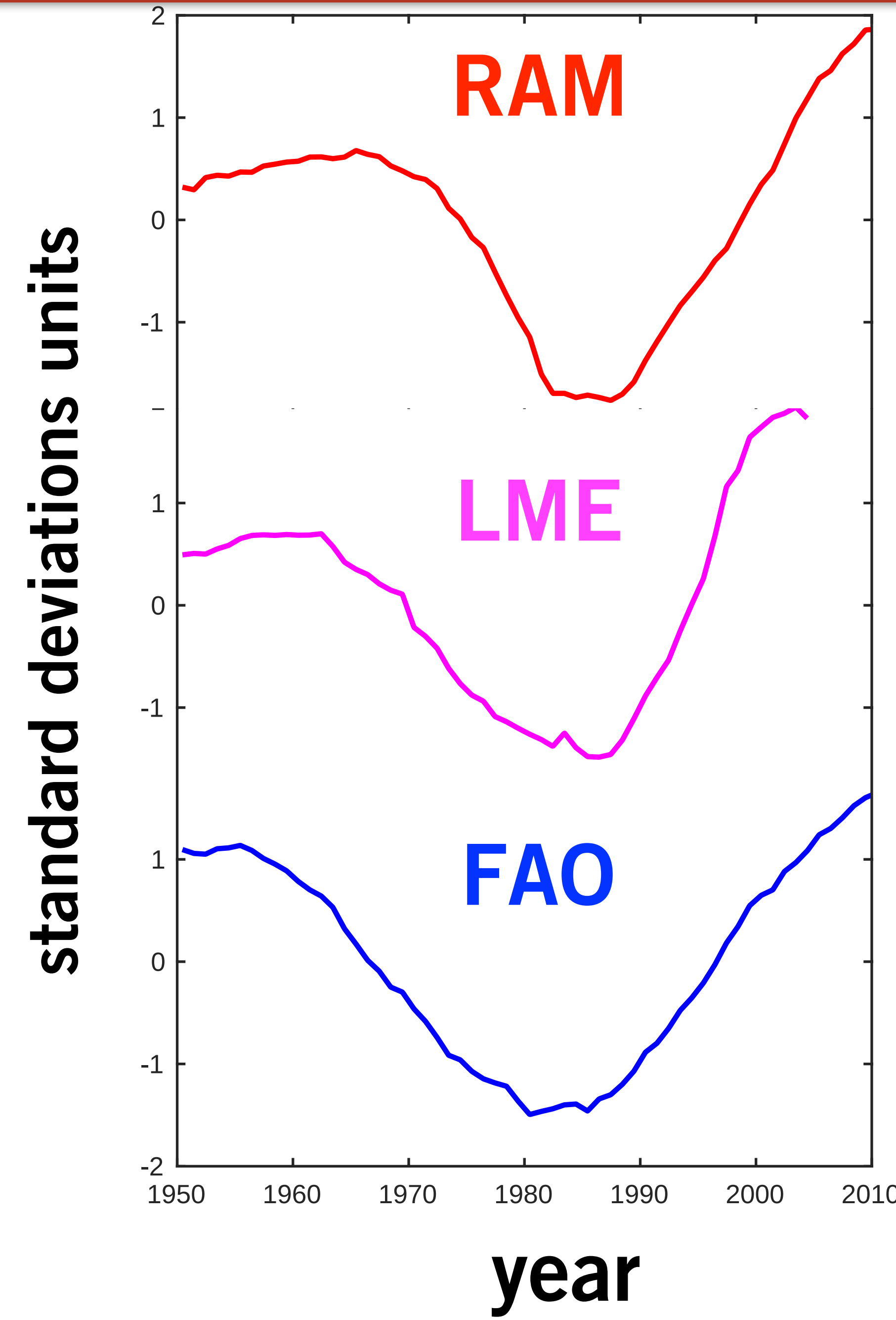
Fish Principal Components (PCs)

METHOD:

Remove trends (e.g. ***human signal***) and compute 1st principal component

15-30% of variance

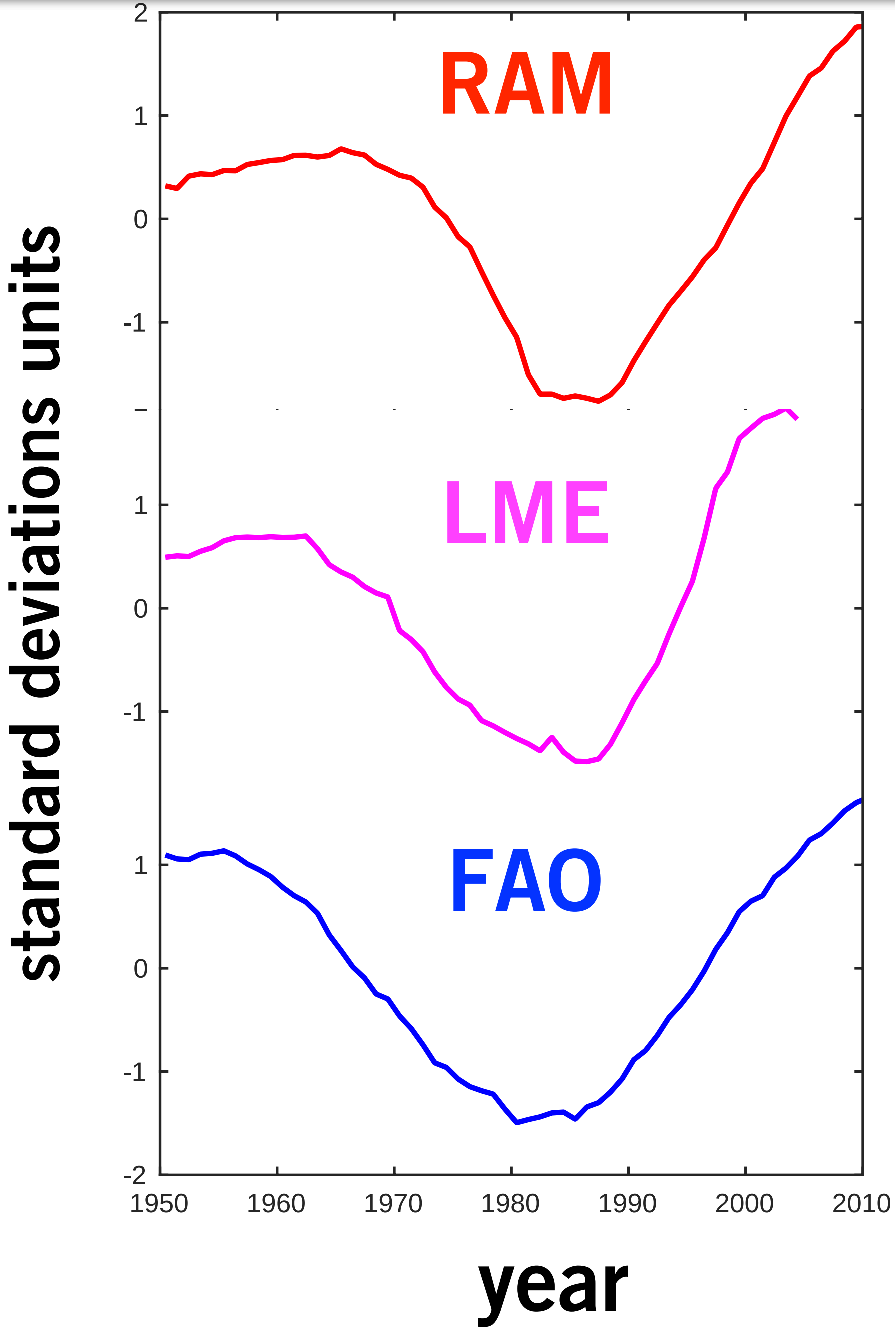
R~ 0.4 - 0.6



Fish Principal Components (PCs)

QUESTION:

Are they correlated with AMO?

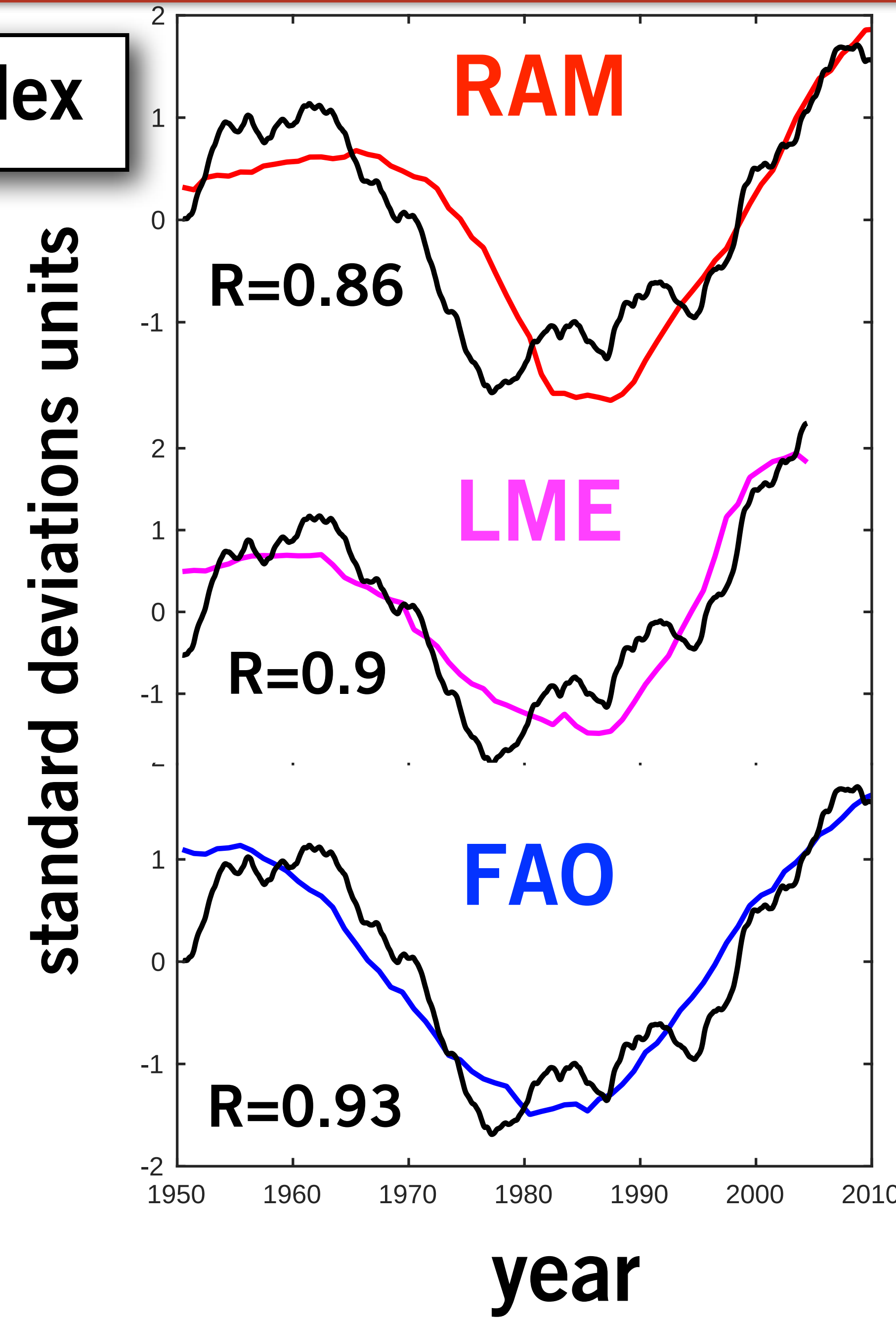


Fish Principal Components (PCs)

AMO Index

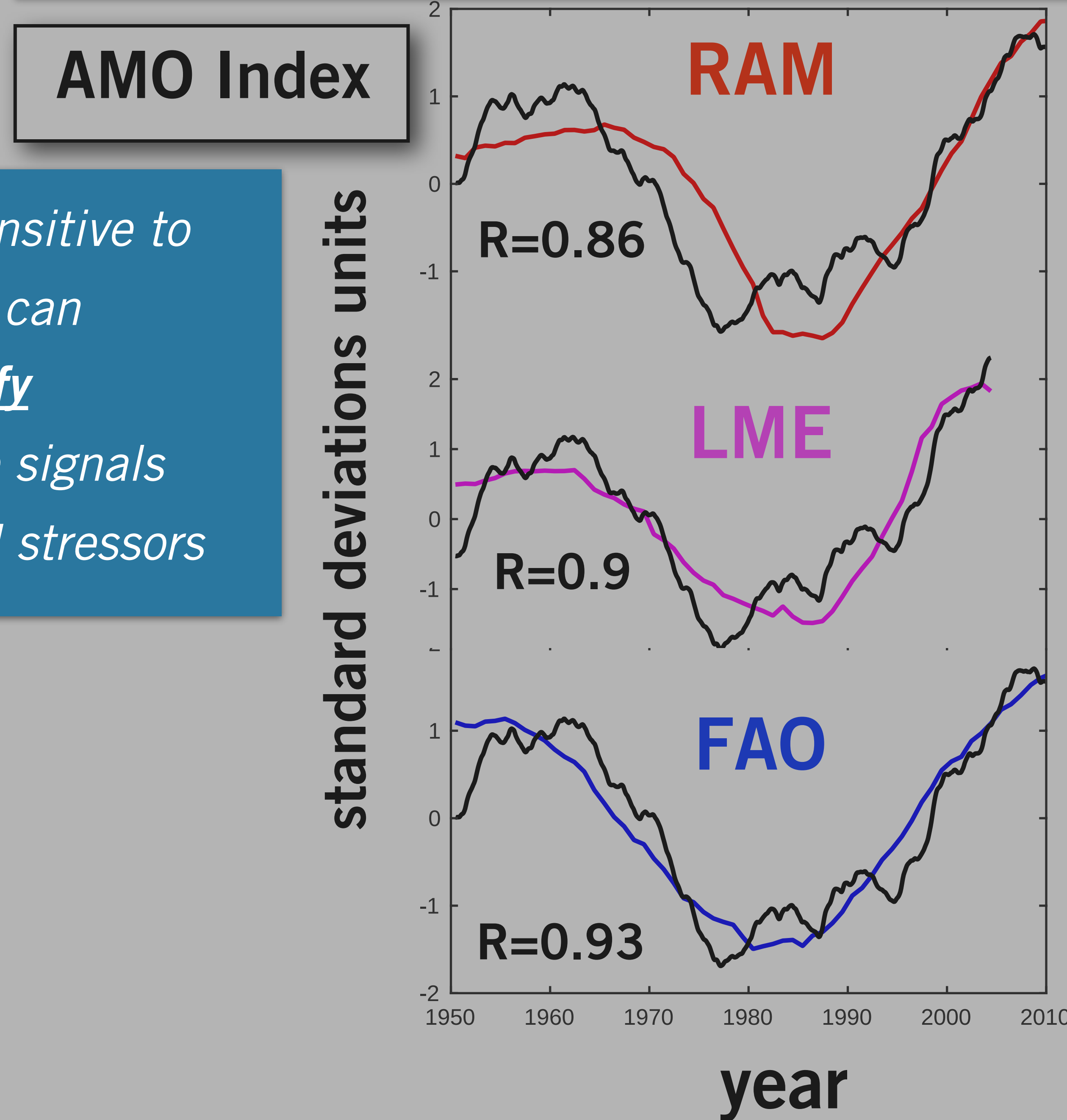
QUESTION:

Are they correlated with AMO?



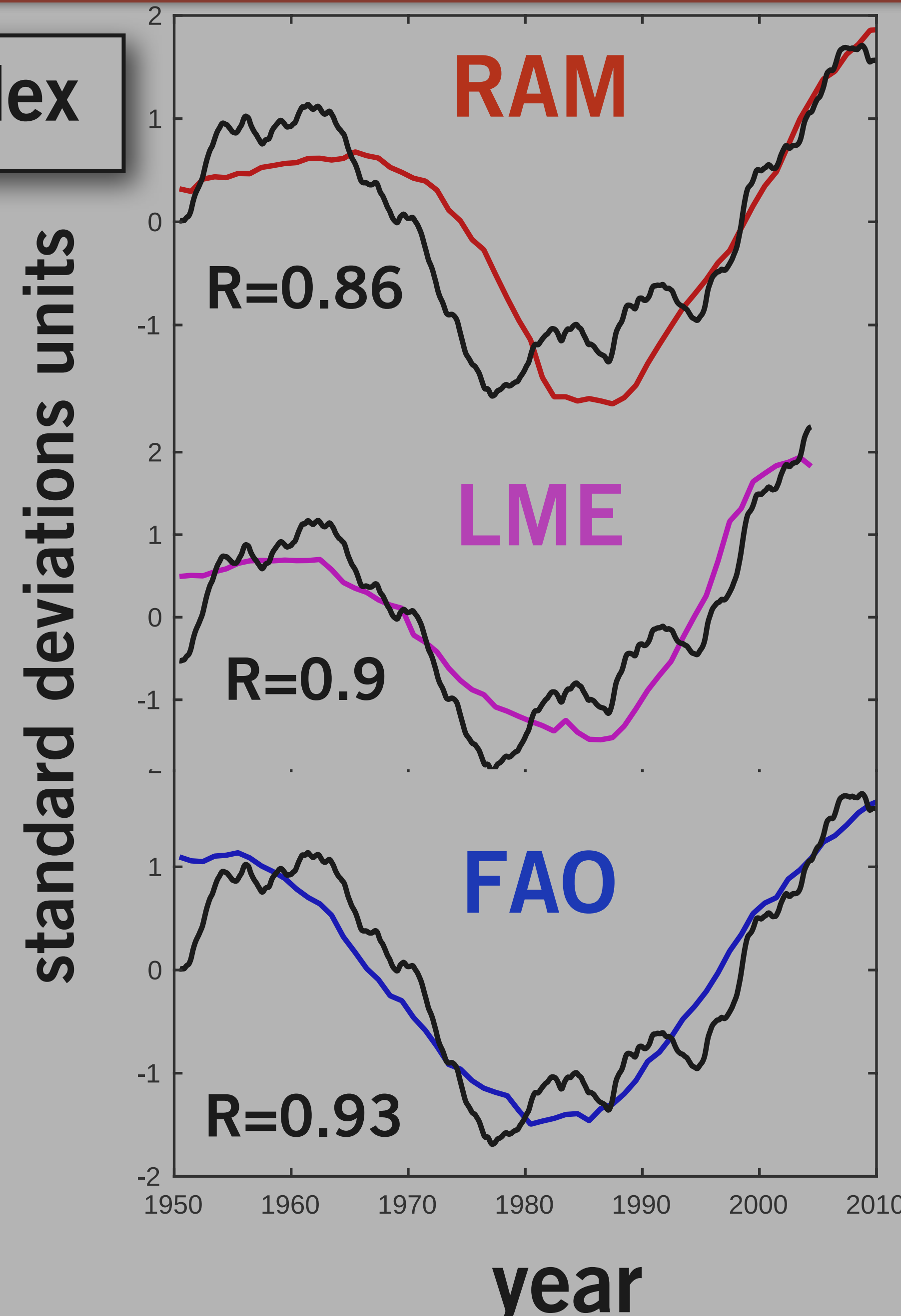
Fish Principal Components (PCs)

FISH POPULATIONS *sensitive to*
multiple stressors *can*
filter and amplify
low-frequency climate signals
present in their regional stressors



Fish Principal Components (PCs)

AMO Index



FISH POPULATIONS *sensitive to* ***multiple stressors*** *can* ***filter*** ***and*** ***amplify*** *low-frequency climate signals present in their regional stressors*

tend to ***align*** *to* ***global-scale*** *climate signals (e.g. AMO)*

END of presentation