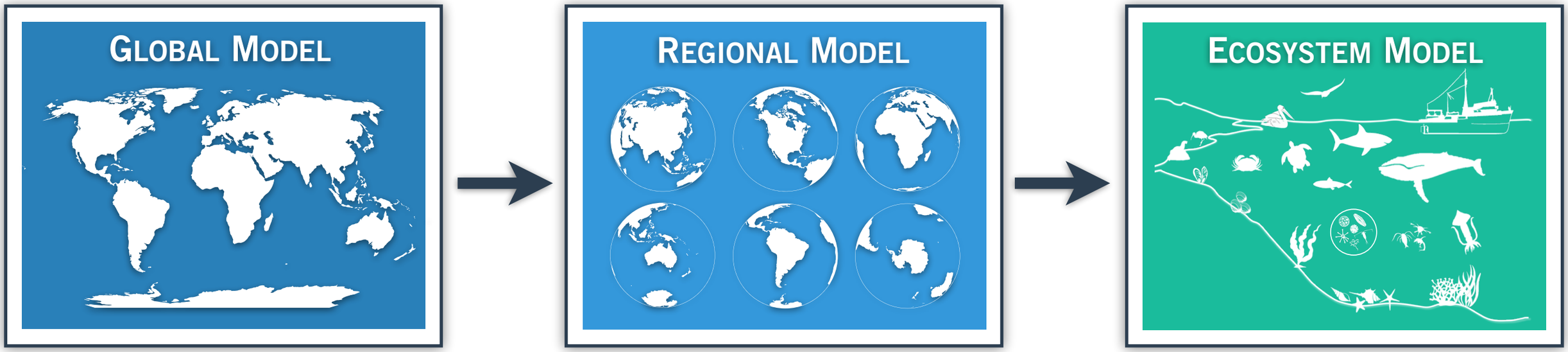
Seasonal- to Centennial-Scale Projections of the California Current System in Aid of Fisheries Management

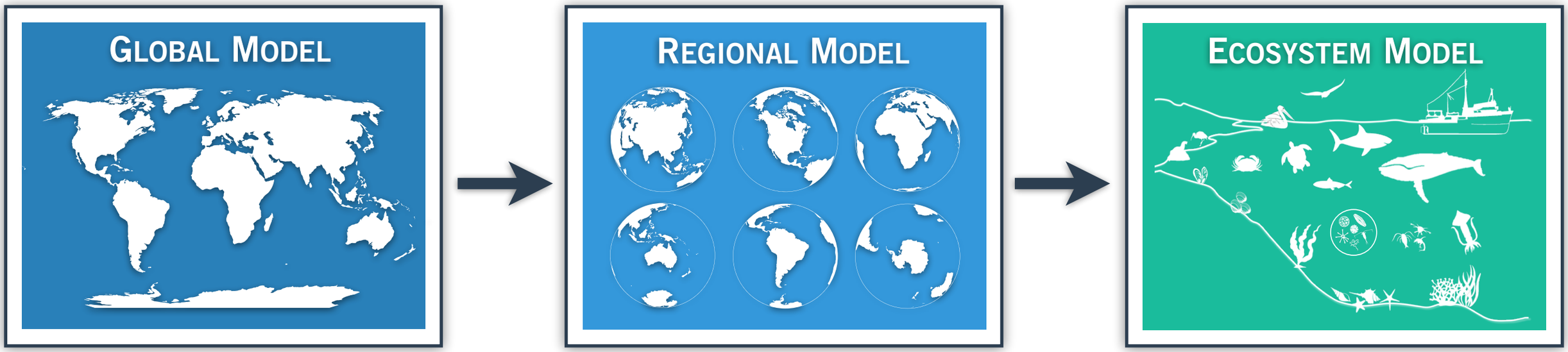
Mike Jacox

NOAA/NMFS Southwest Fisheries Science Center

with help from Mercedes Pozo Buil, Stephanie Brodie, and others

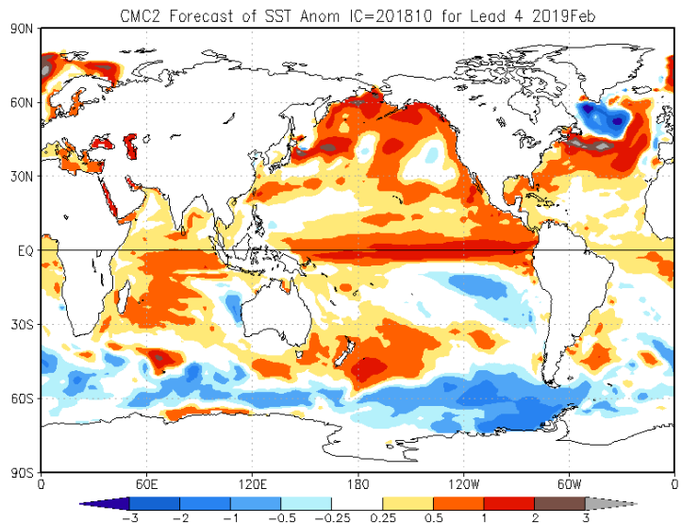
PICES Annual Meeting
Yokohama, Japan
October 29, 2018


Global Model
Regional Model
Ecosystem Model



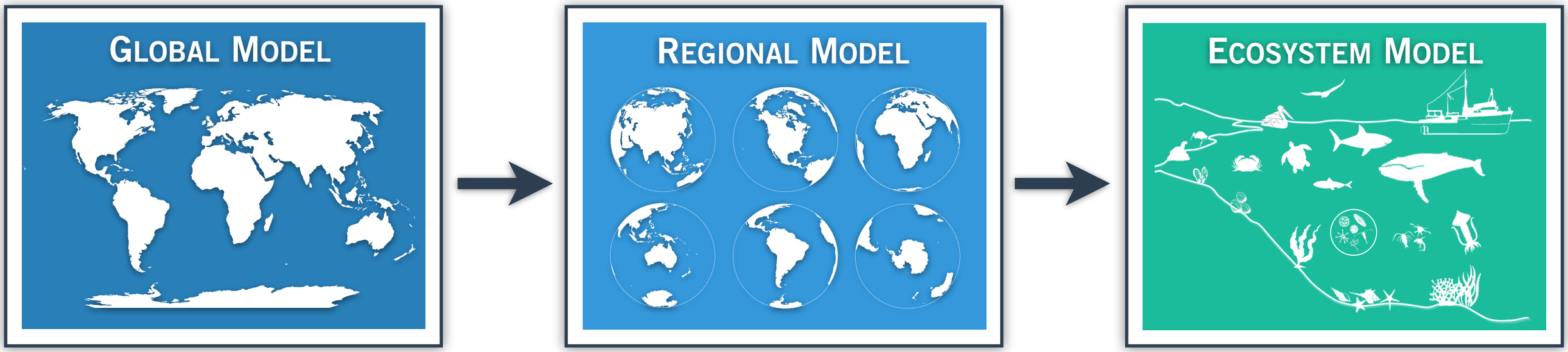
Global Model (CanCM4)

Oct. 2018 Forecast of Feb. 2019



SST Anomaly (˚C)

http://www.cpc.ncep.noaa.gov/products/NMME/



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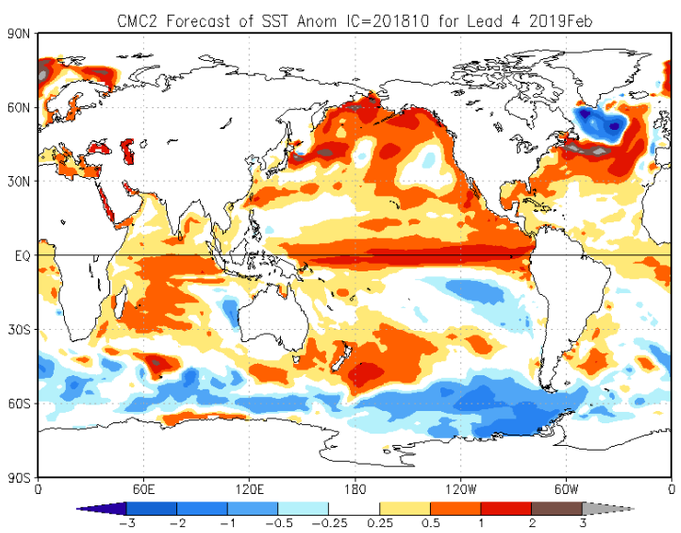
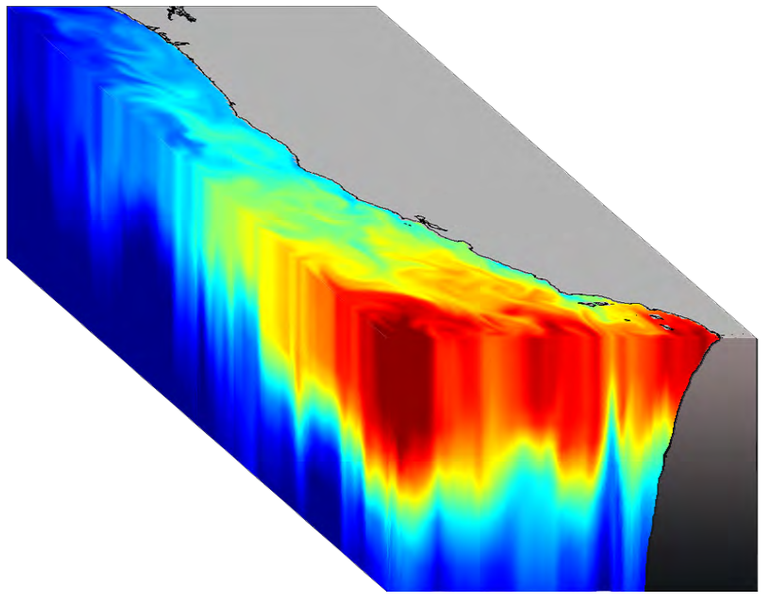


SST Anomaly (˚C)

Regional Ocean Modeling System
California Current System



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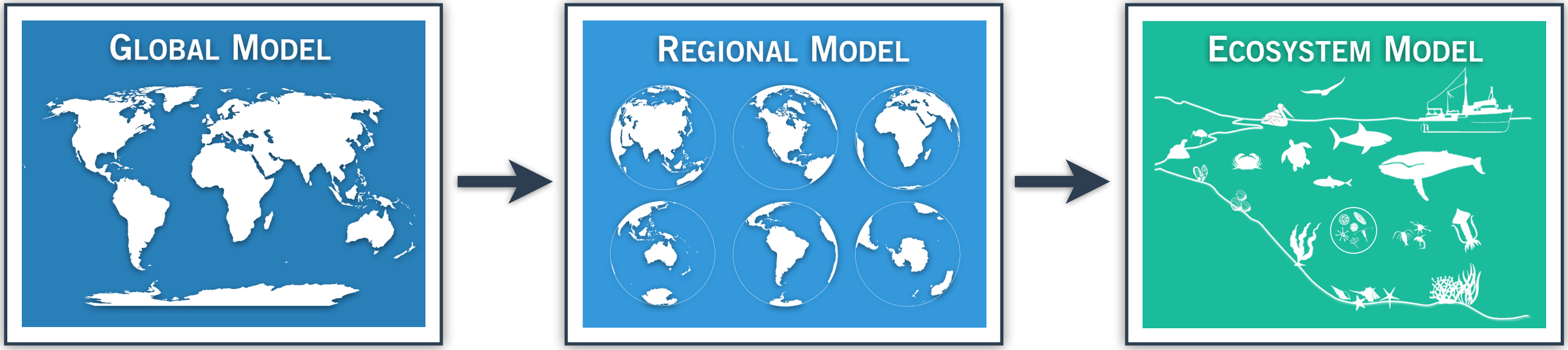

Global Model (CanCM4)
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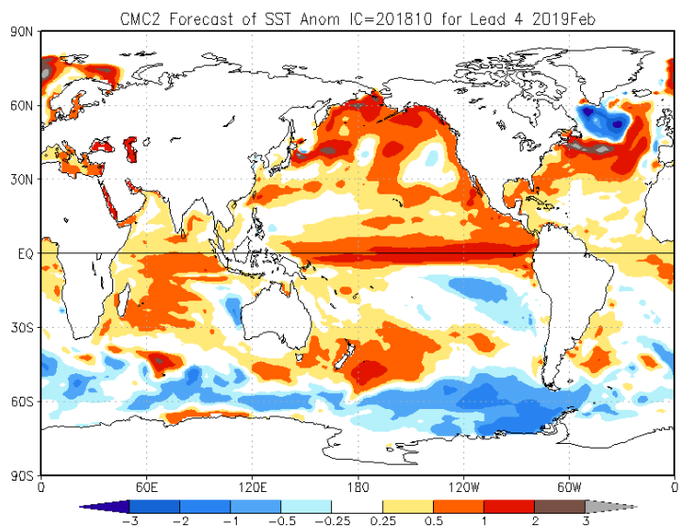

SST Anomaly (˚C)

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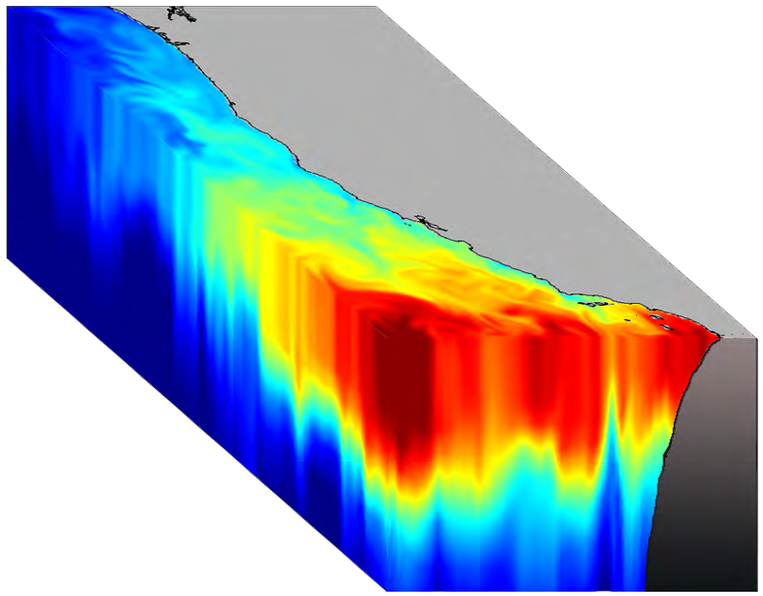

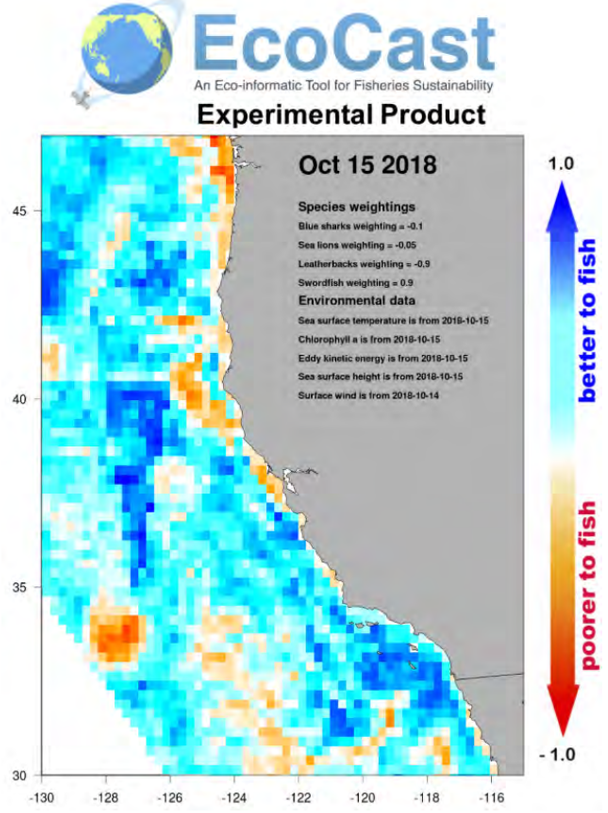

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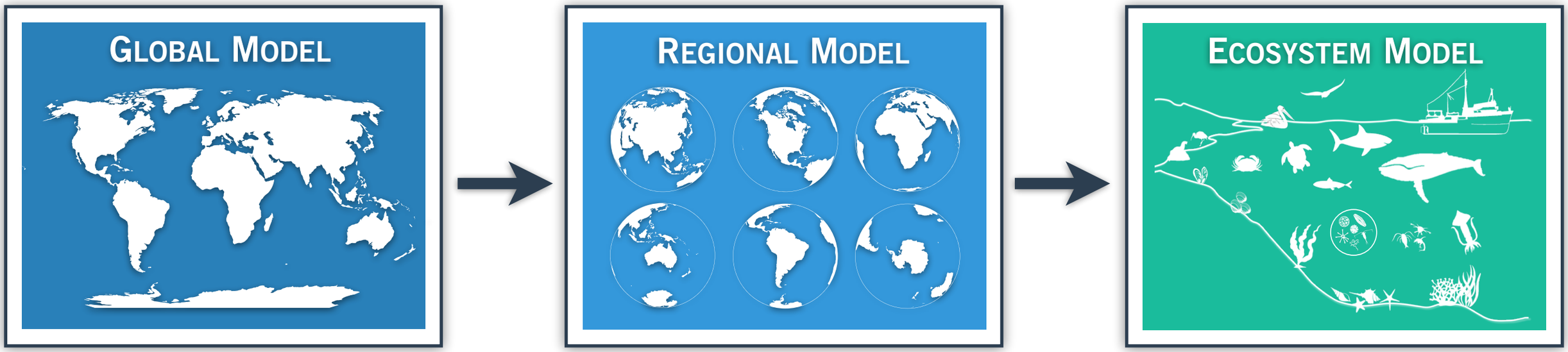
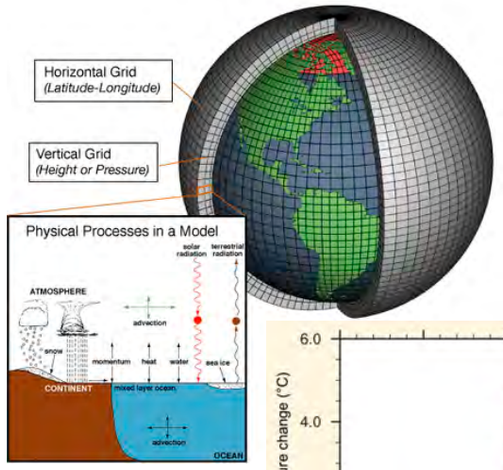
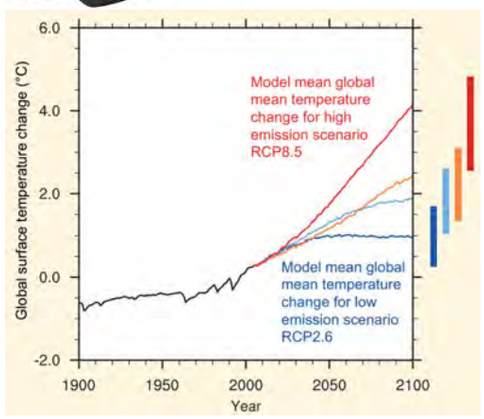
Hazen et al. (2018), Welch et al. (2018)

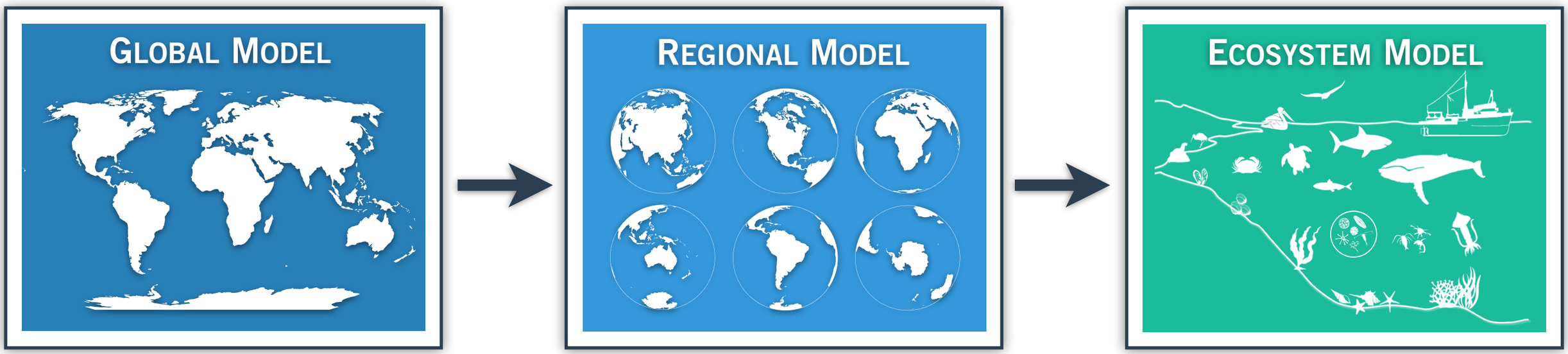


Coupled dynamics
Radiative forcing



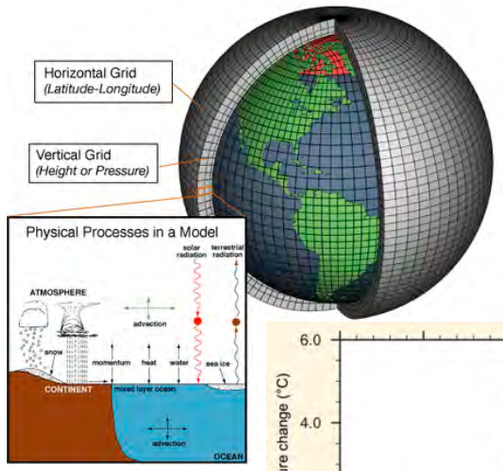


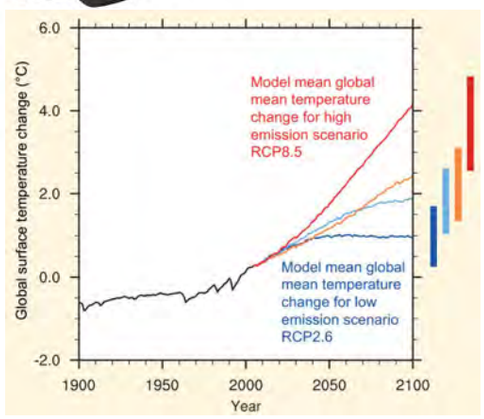
RCP 8.5 offers the largest “signal to noise”



Coupled dynamics
Radiative forcing

Better resolution of
fine-scale processes





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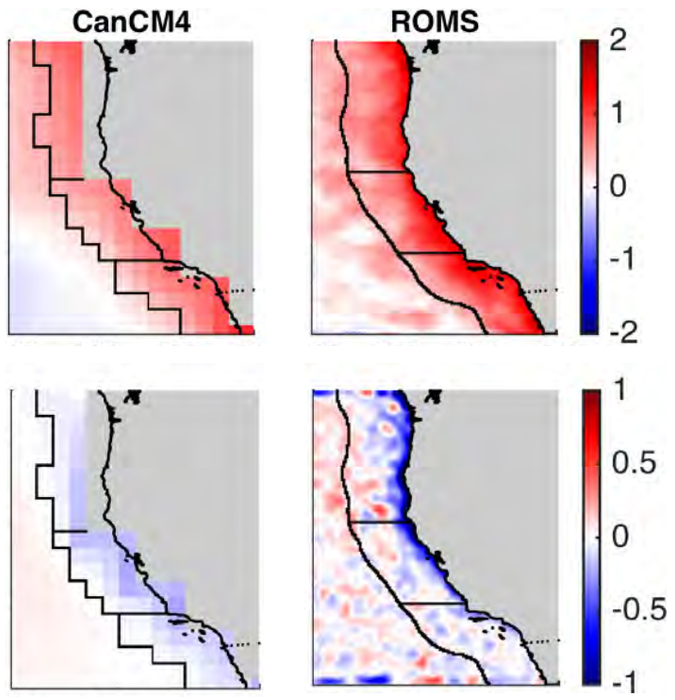
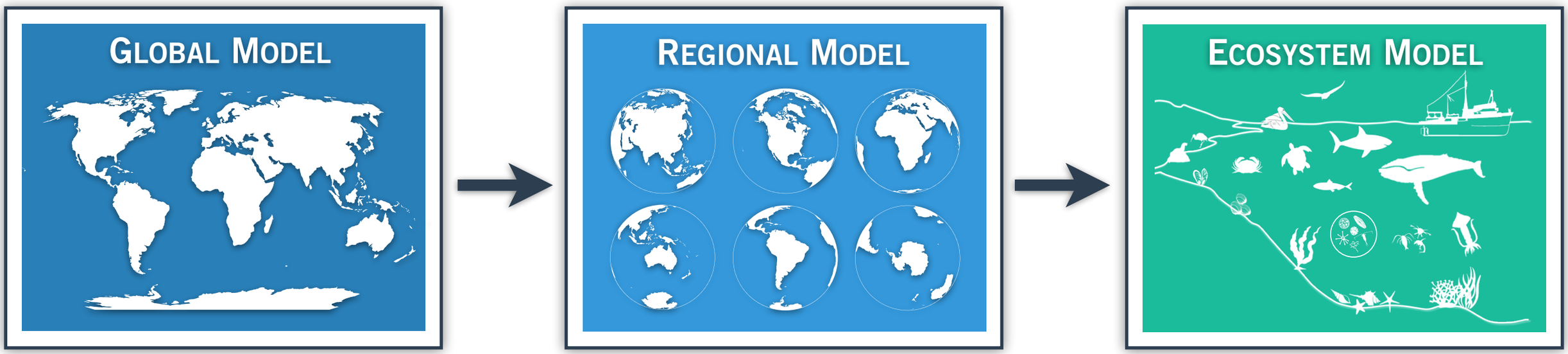


Jacox et al. (2017)



Coupled dynamics
Radiative forcing

Better resolution of
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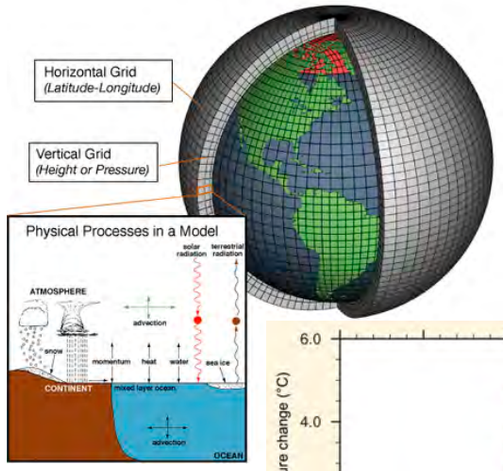
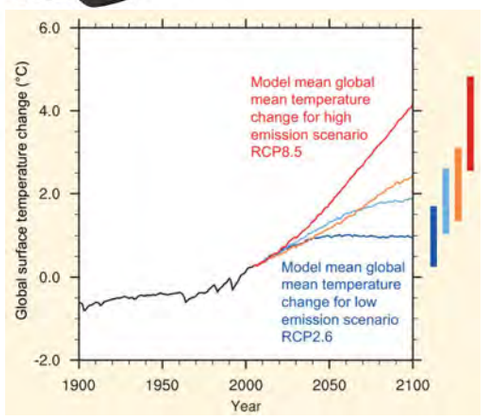
Exploit physical/biological
relationships





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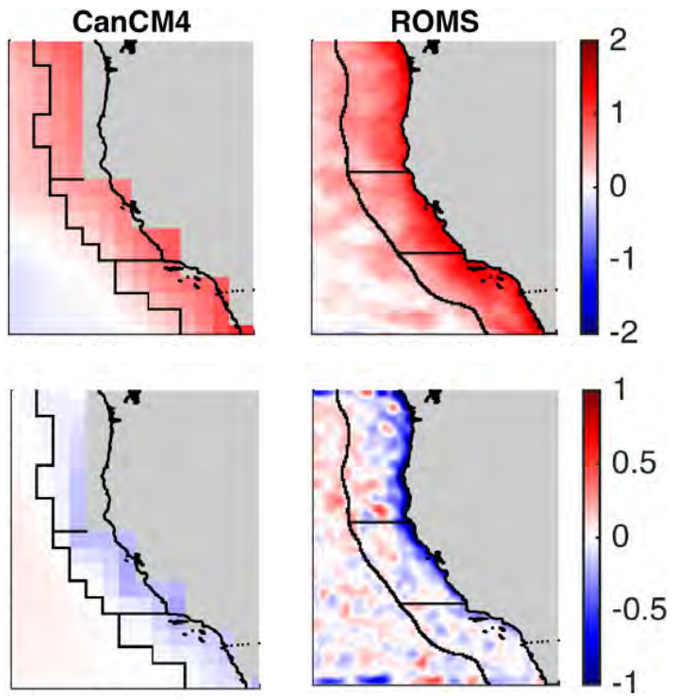

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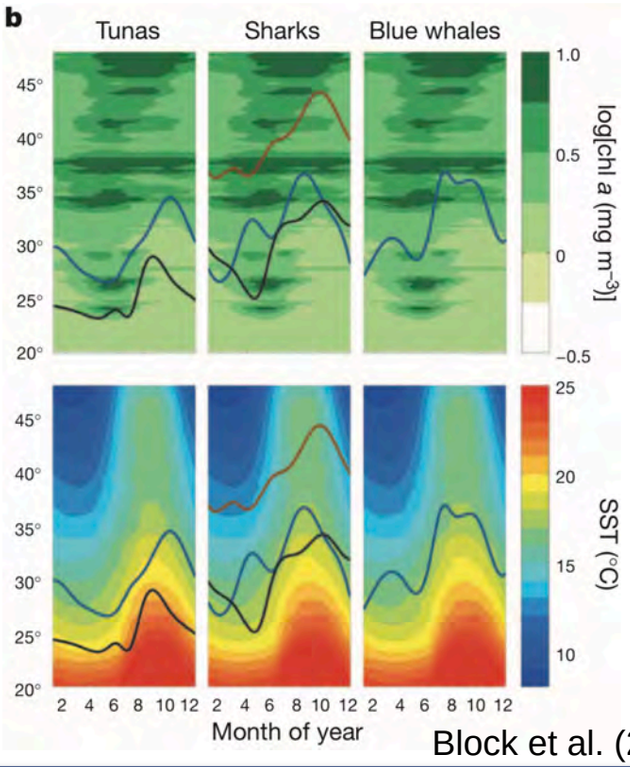
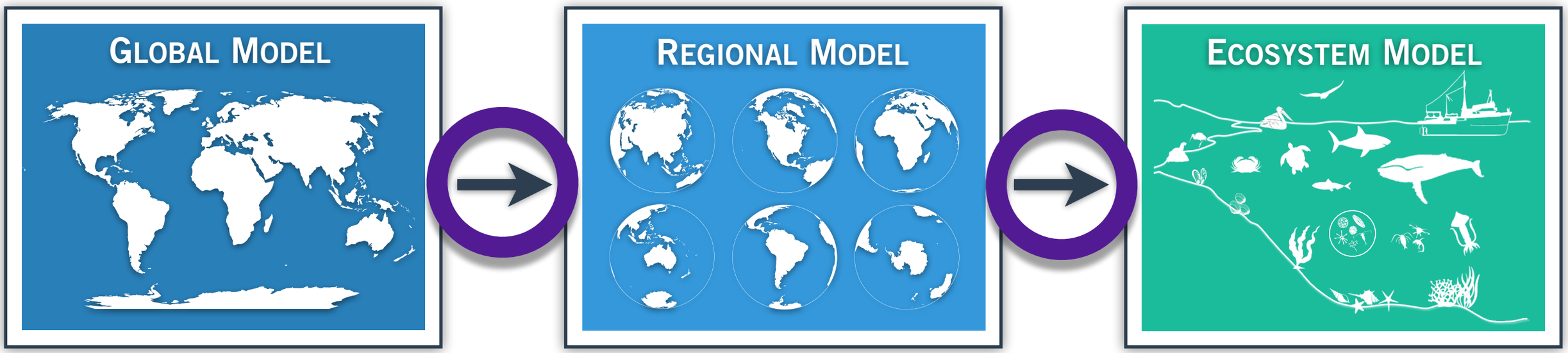


Block et al. (2011)



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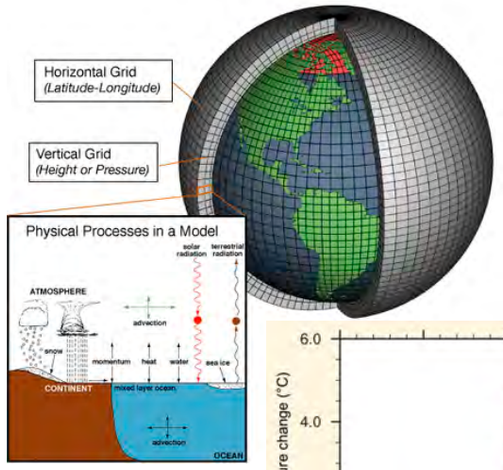

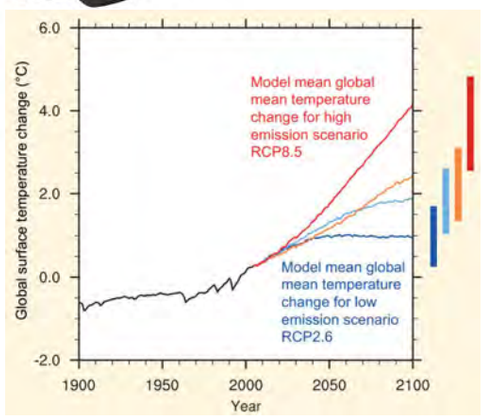

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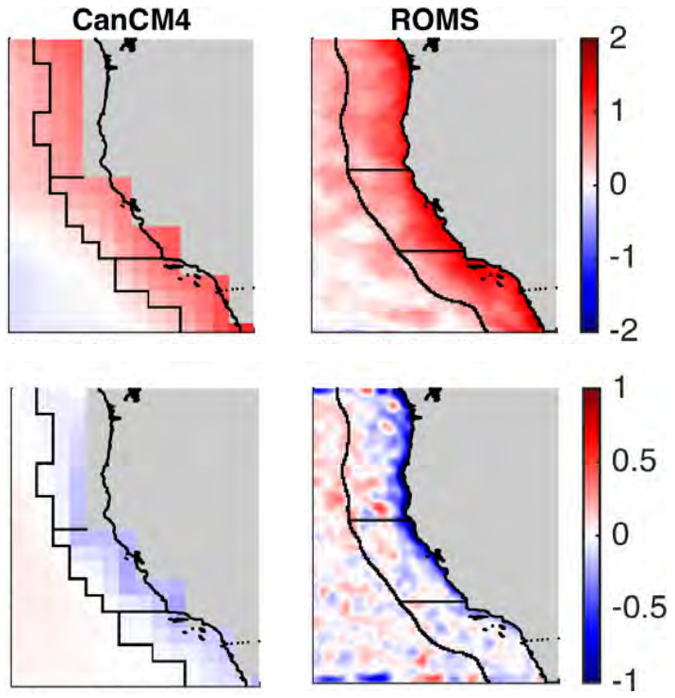

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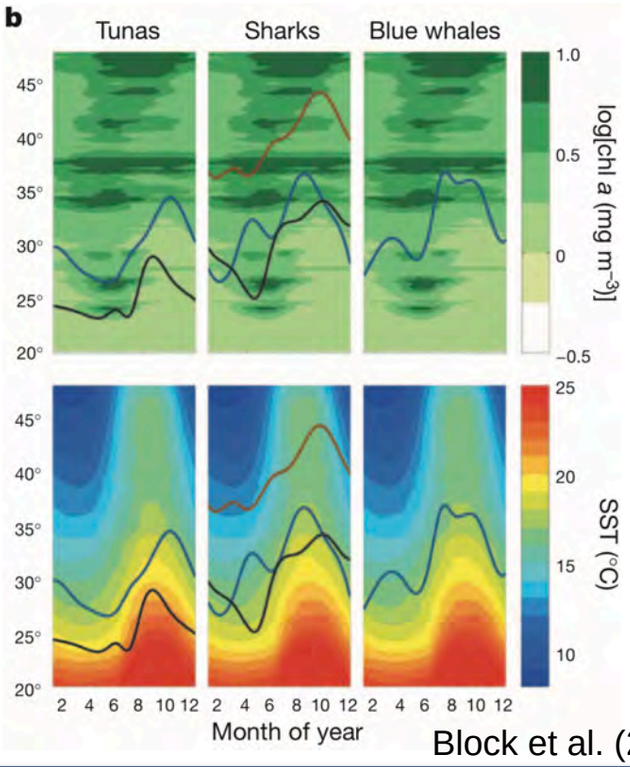

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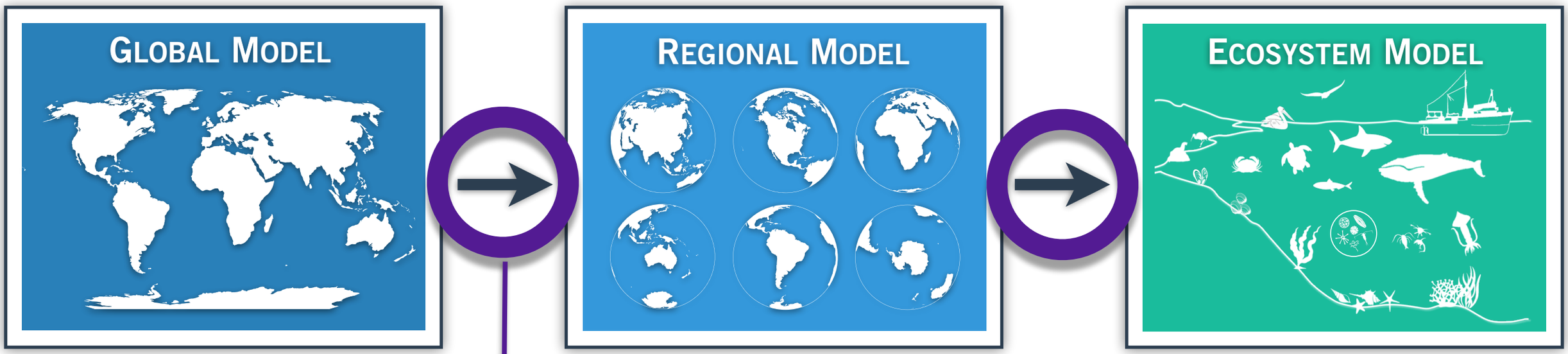
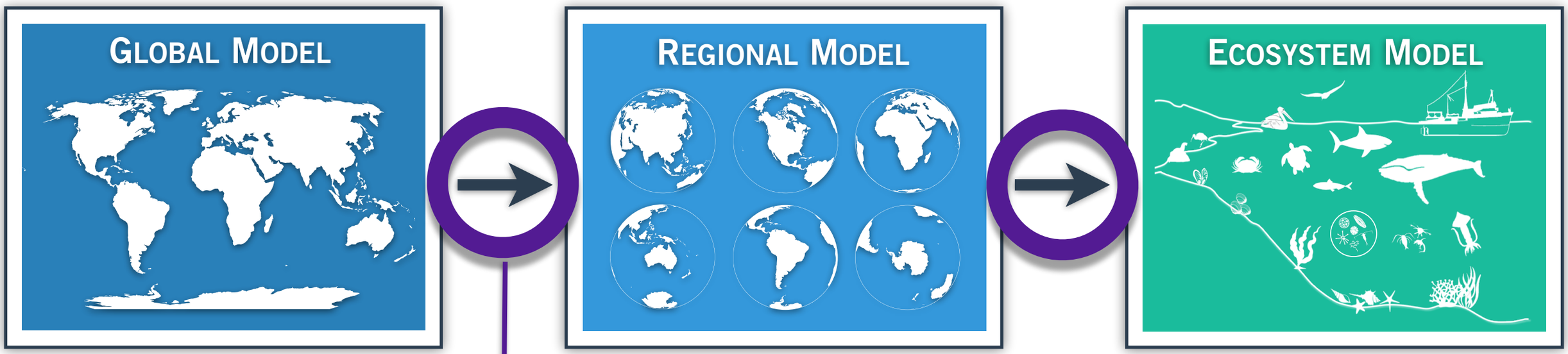


Which model(s)?



Which model(s)?

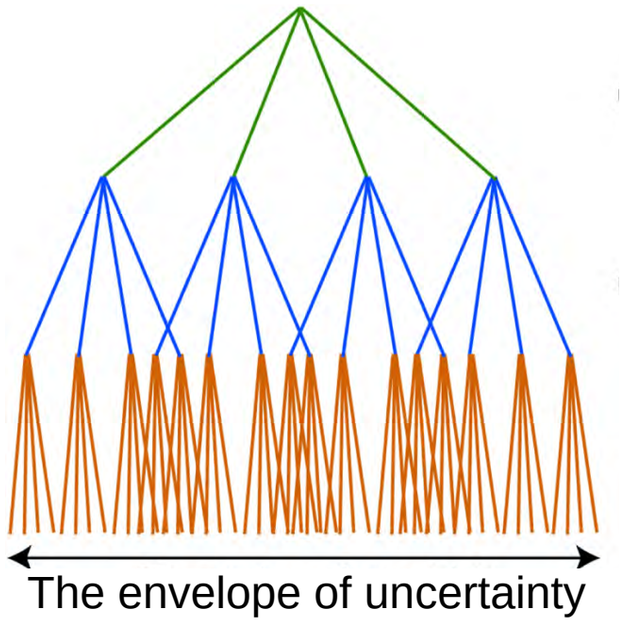
scenario uncertainty

vs.

model uncertainty

vs.

internal variability

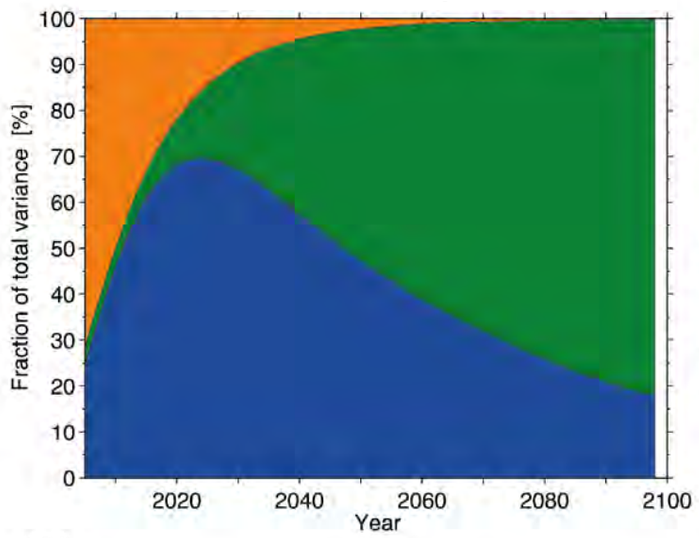


Scenario Uncertainty

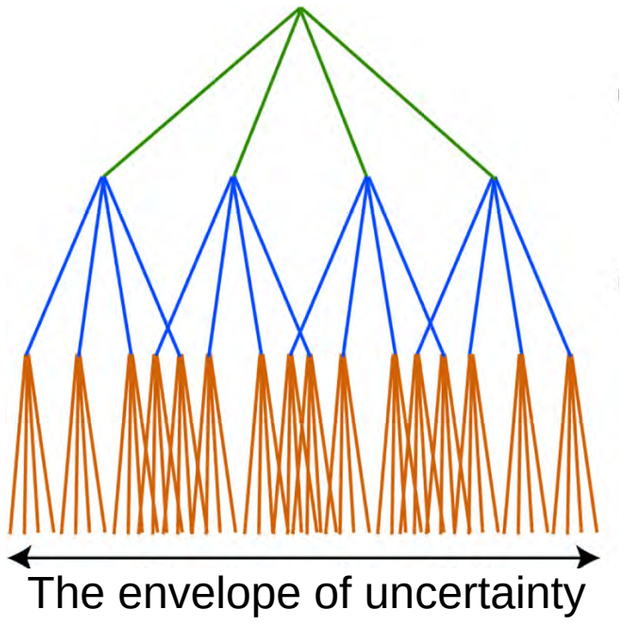
Model Uncertainty

Internal Variability

Global Air Temperature



Cheung et al. (2016); IPCC

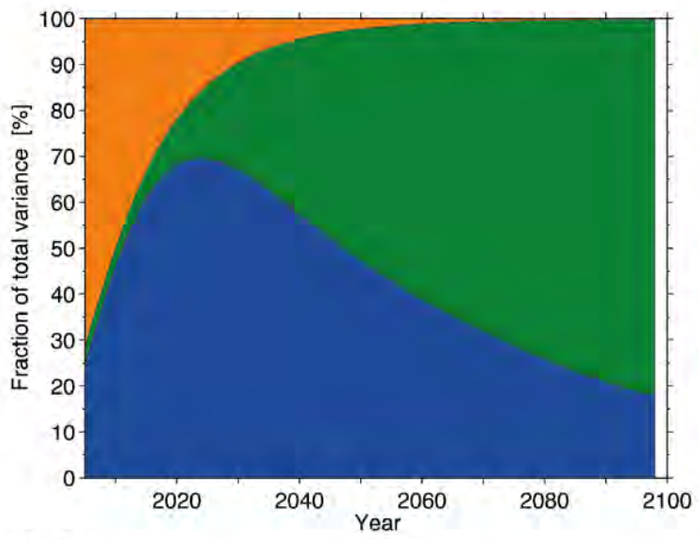


Scenario Uncertainty

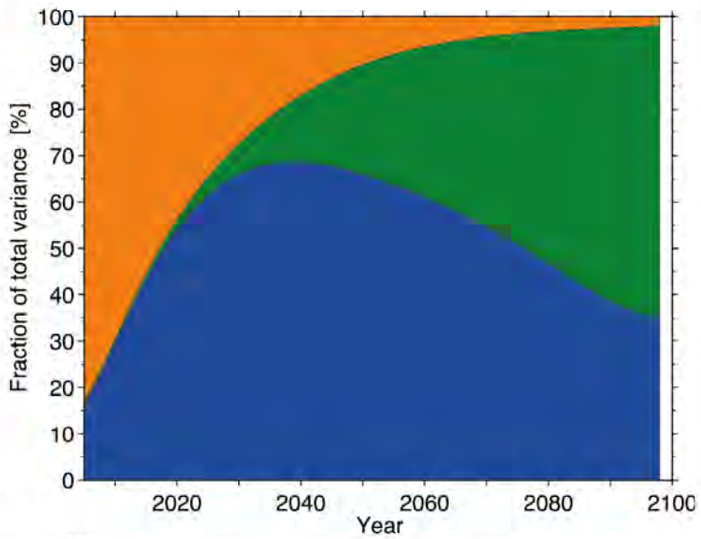
Model Uncertainty

Internal Variability

Global Air Temperature



Europe Winter Air Temperature



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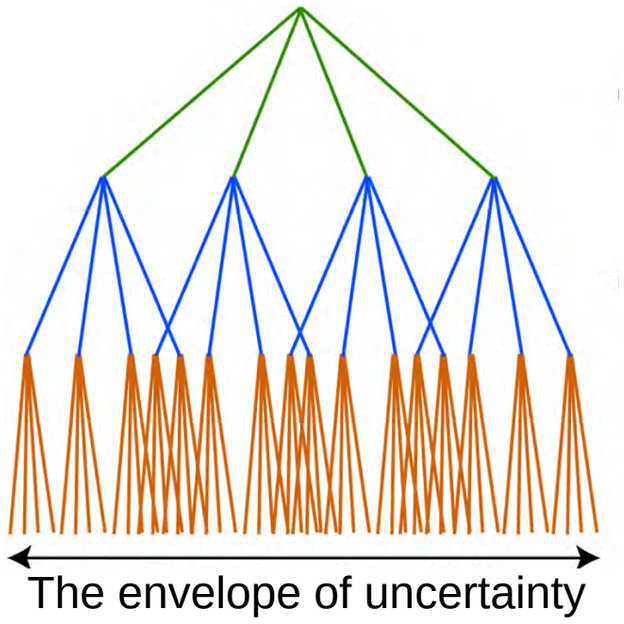

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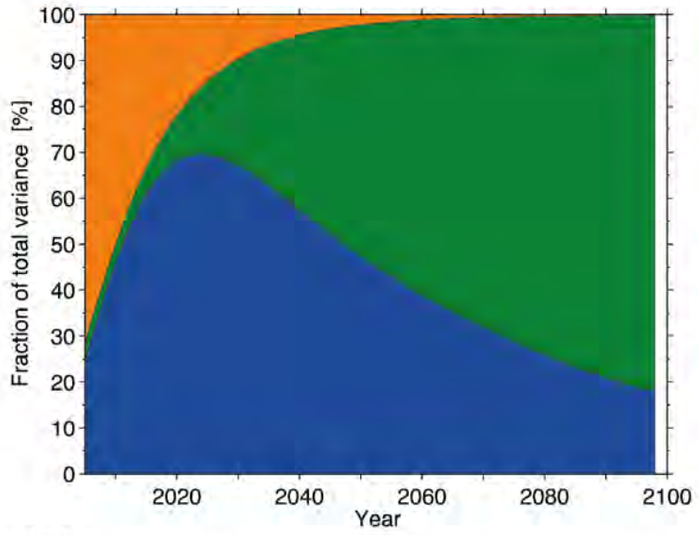

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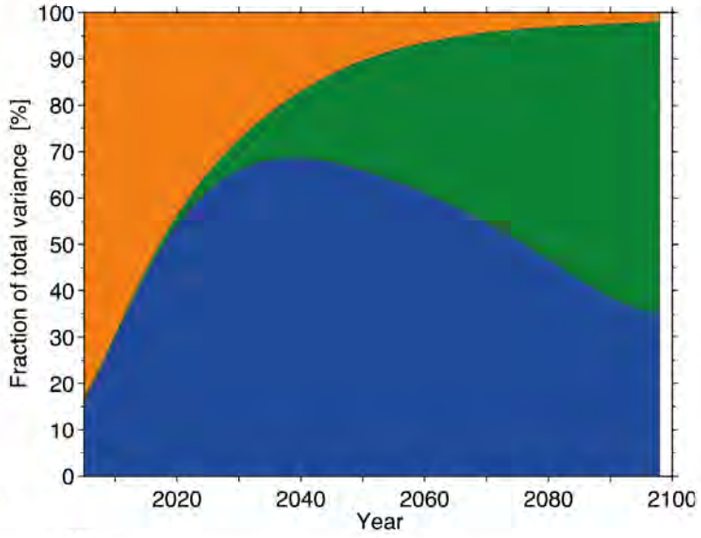
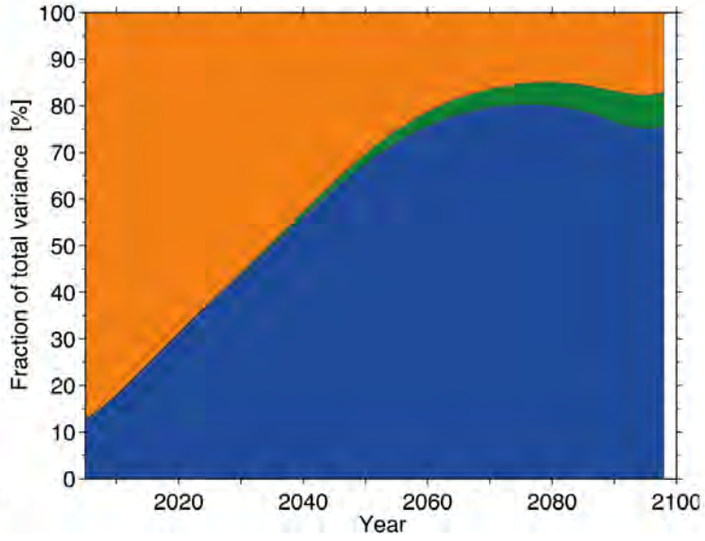


Europe Winter Precipitation



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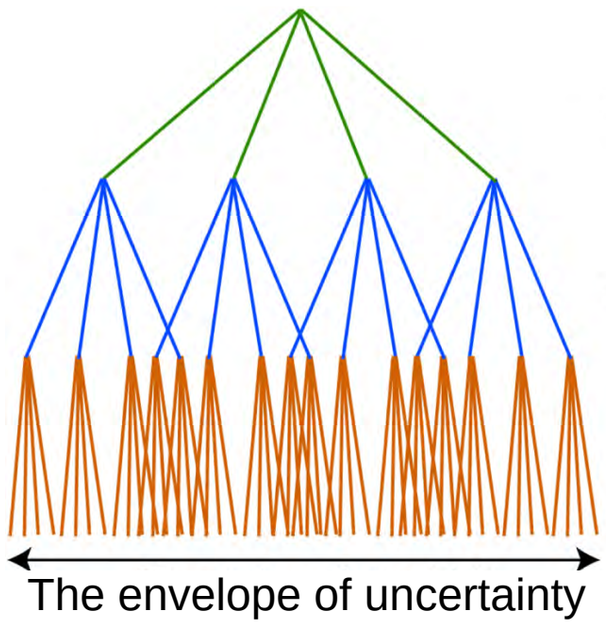
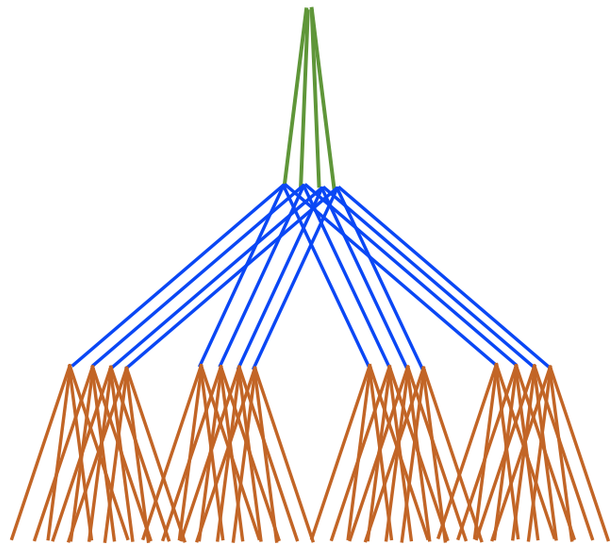


Scenario Uncertainty

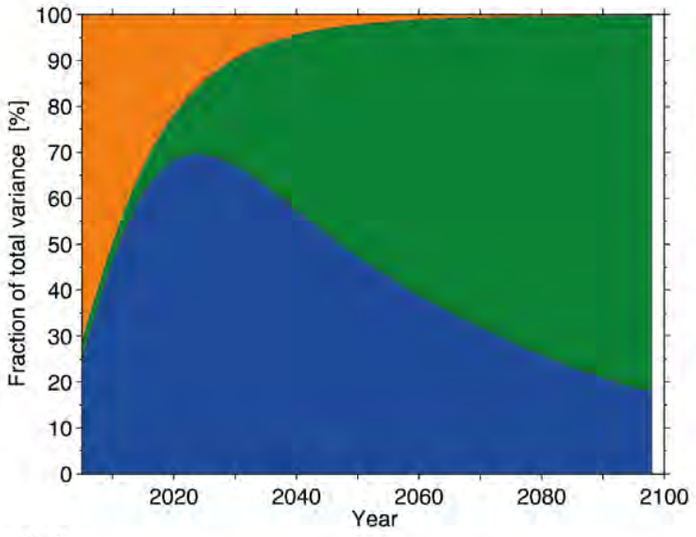
Model Uncertainty

Internal Variability

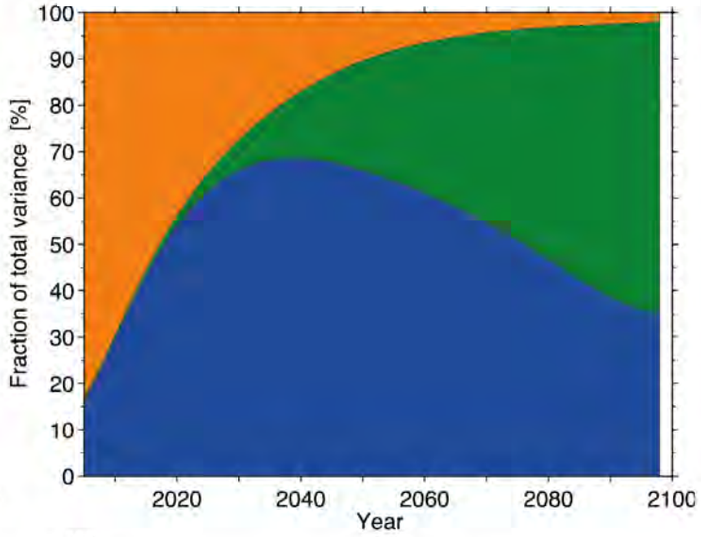


Scenario Uncertainty Dominates → **Model Uncertainty Dominates**

Global Air Temperature



Europe Winter Air Temperature



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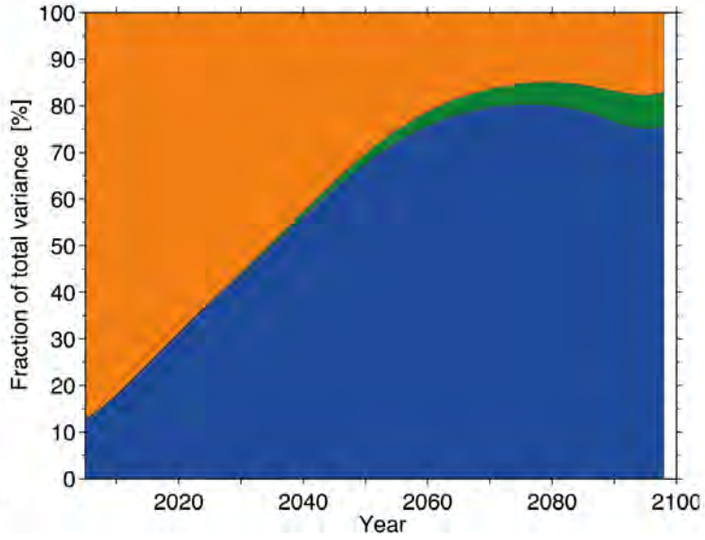

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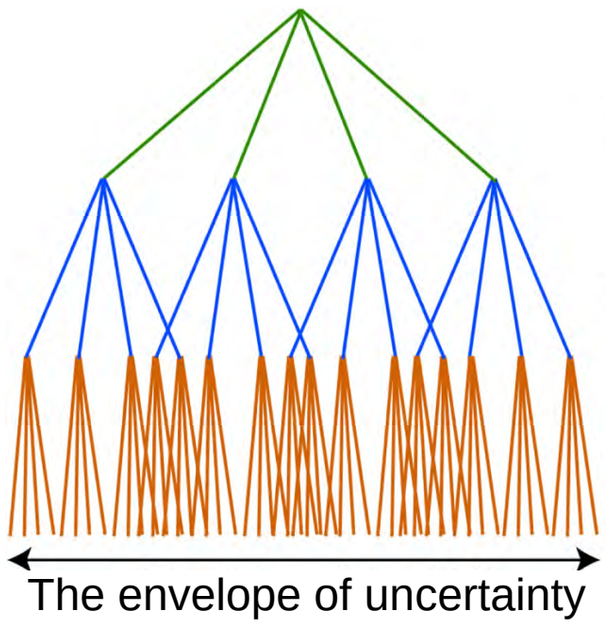
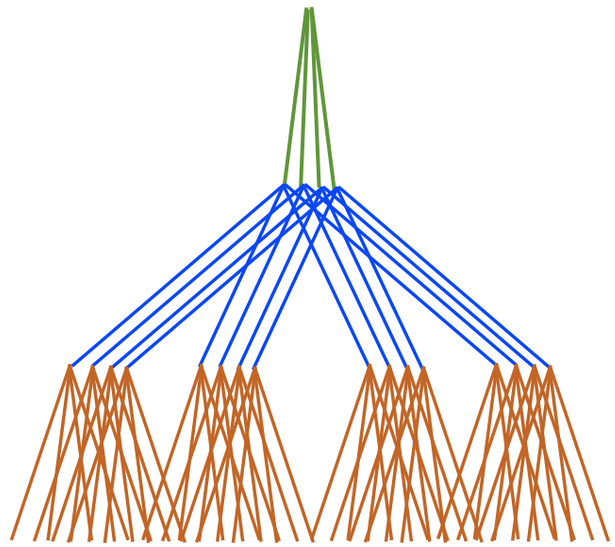


Scenario Uncertainty

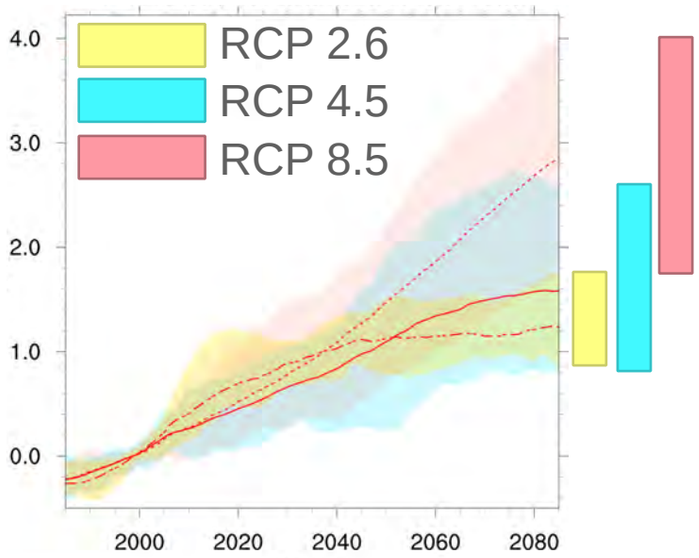
Model Uncertainty

Internal Variability



Scenario Uncertainty Dominates → **Model Uncertainty Dominates**

California Current Large Marine Ecosystem
Sea Surface Temperature



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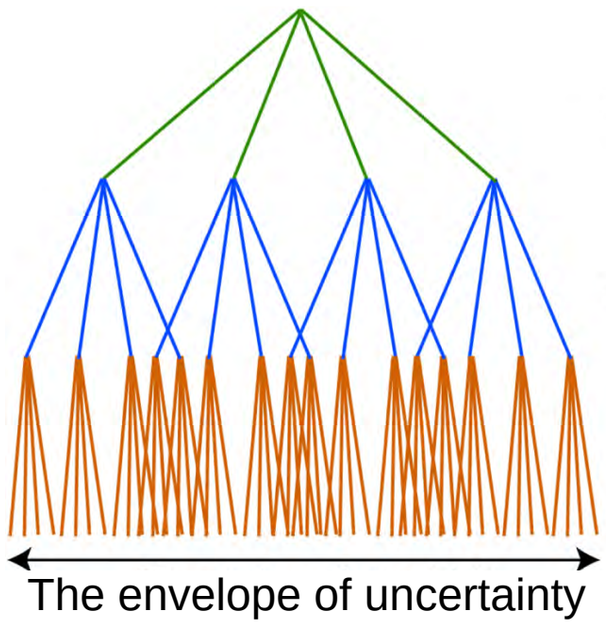
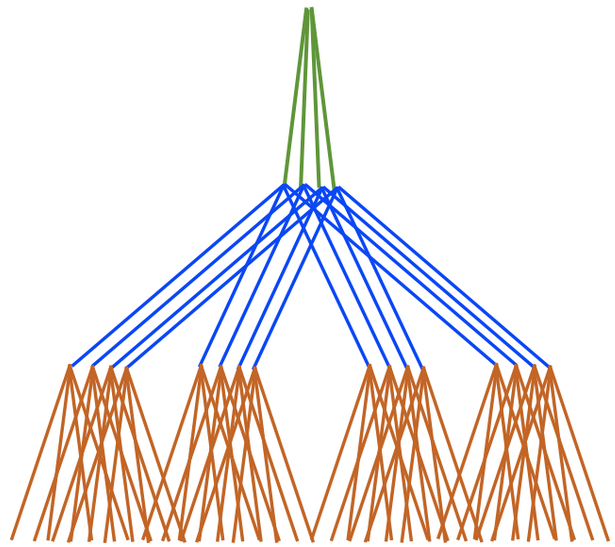


Scenario Uncertainty

Model Uncertainty

Internal Variability



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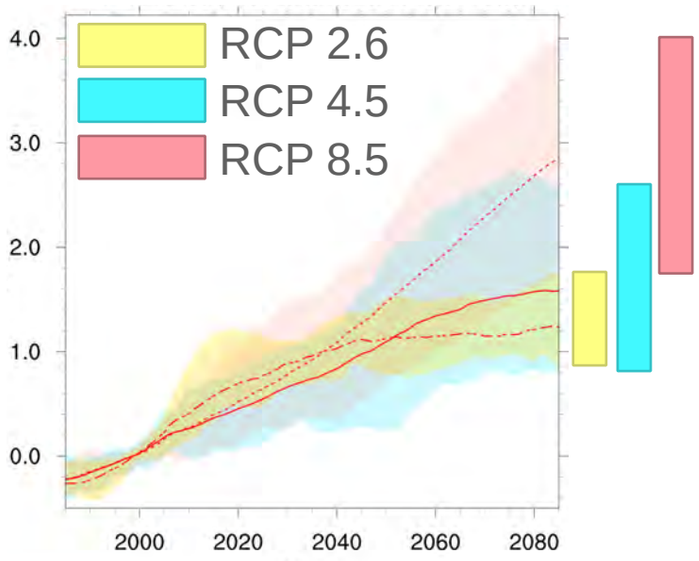
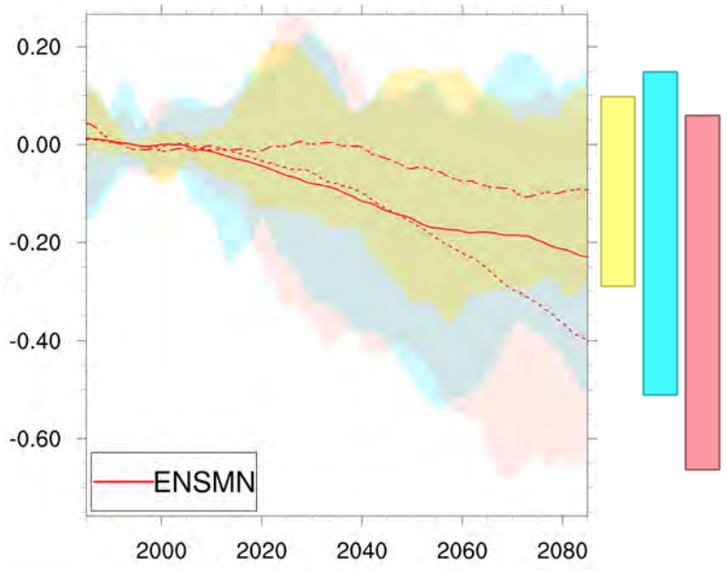
California Current Large Marine Ecosystem

Sea Surface Temperature



Sea Surface Salinity



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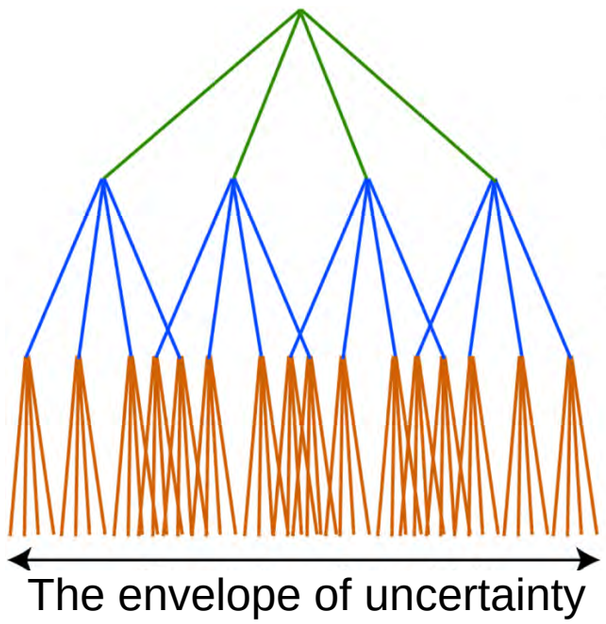

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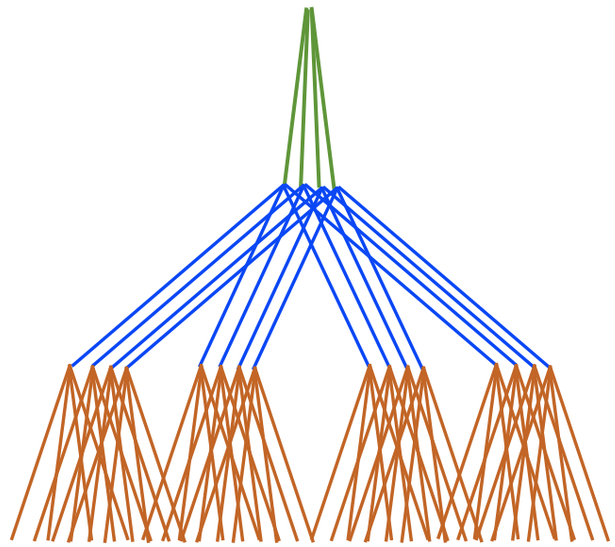

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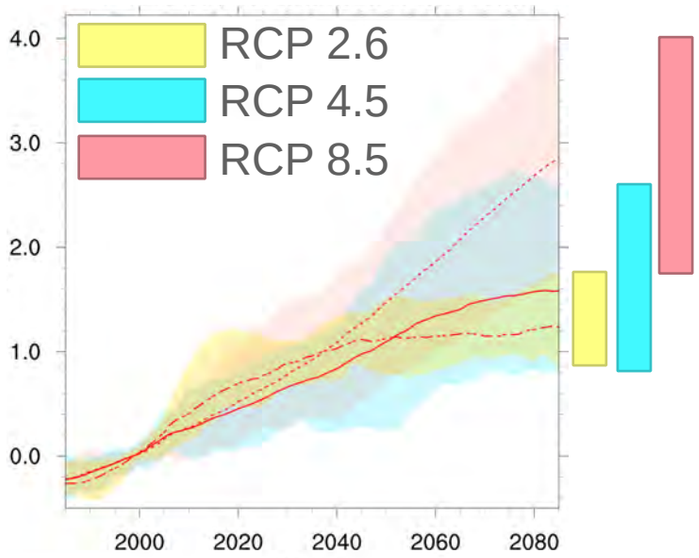

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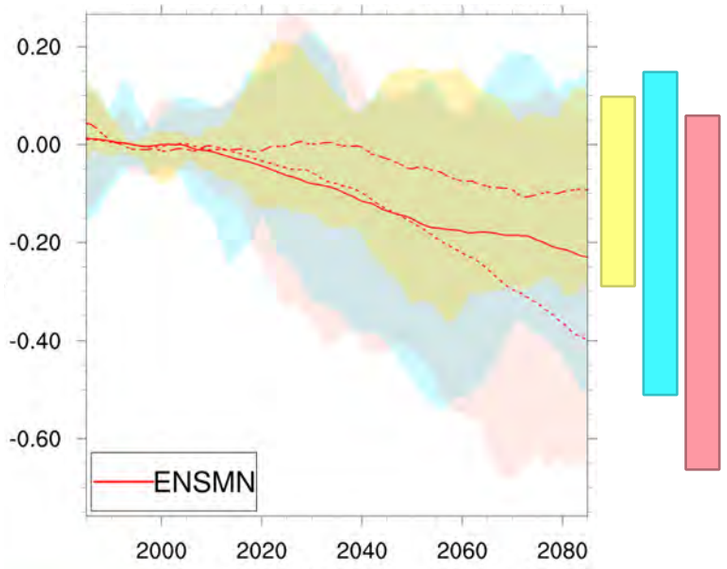
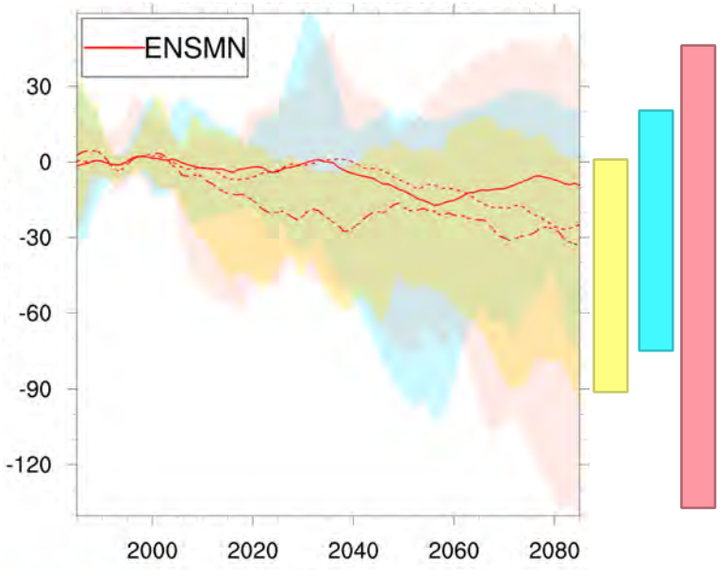
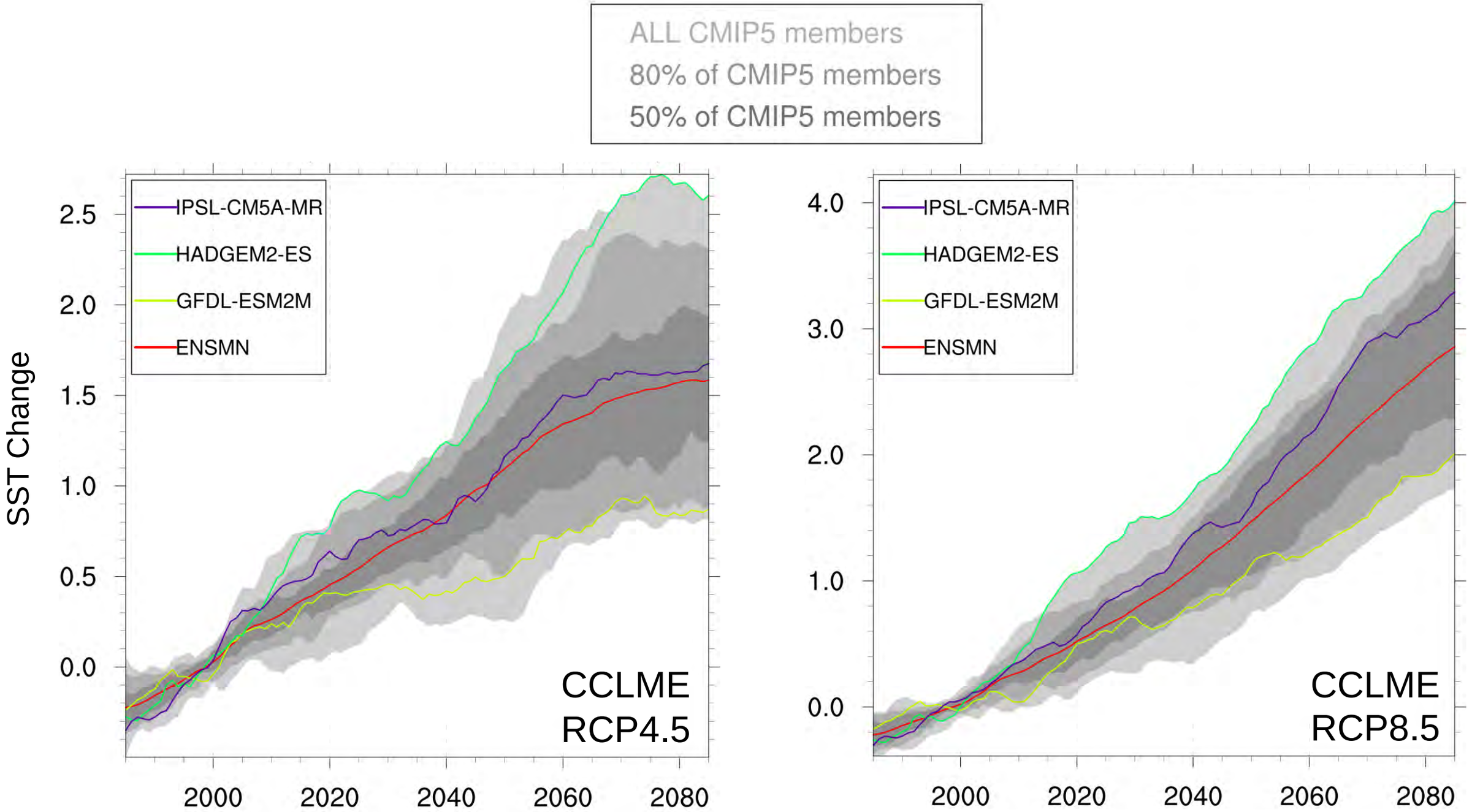


Primary Production



https://www.esrl.noaa.gov/psd/ipcc/

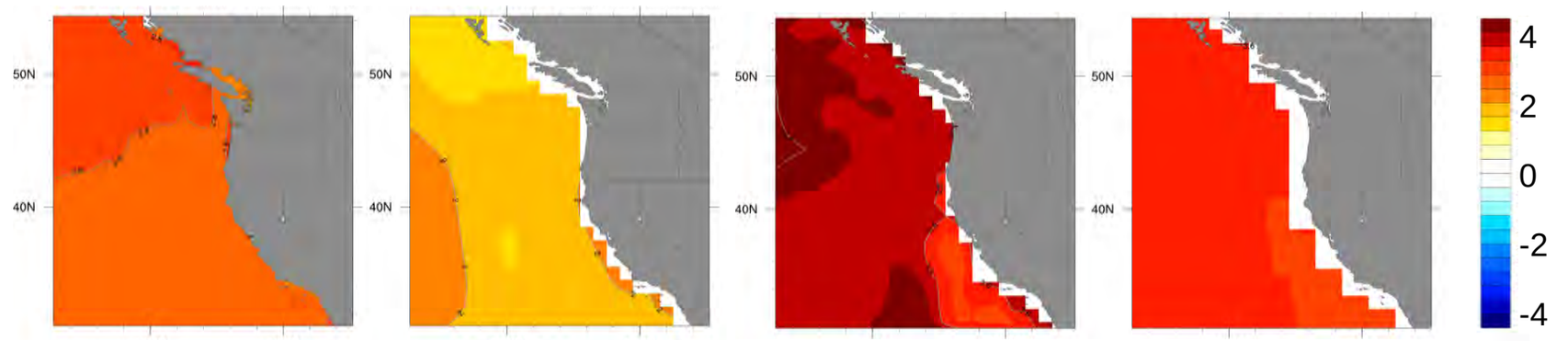


https://www.esrl.noaa.gov/psd/ipcc/

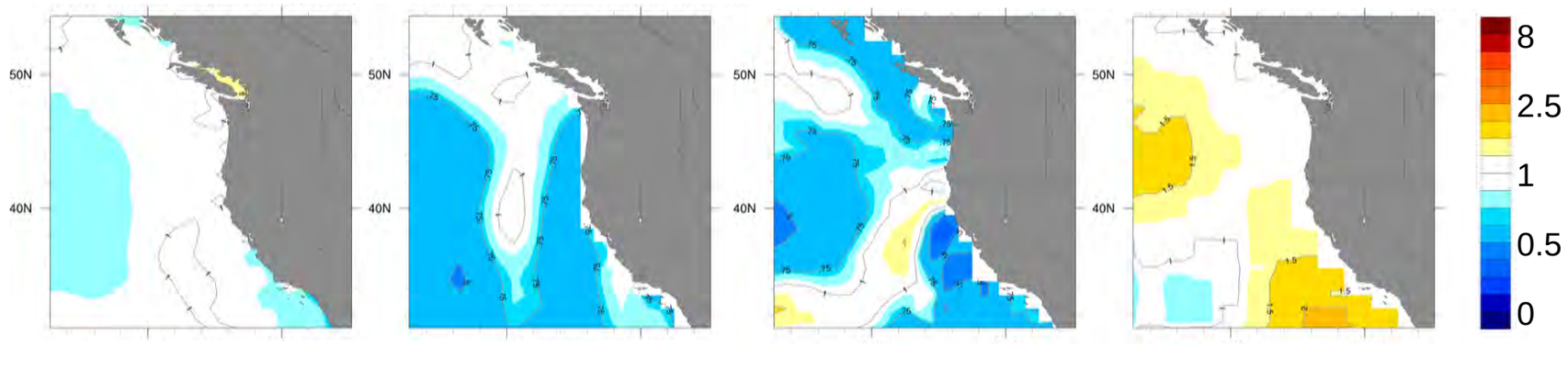
2050-2099 vs. **1956-2005**

CMIP5 Ensemble | GFDL ESM2M | HADGEM2-ES | IPSL-CM5A-MR

SST Mean Change

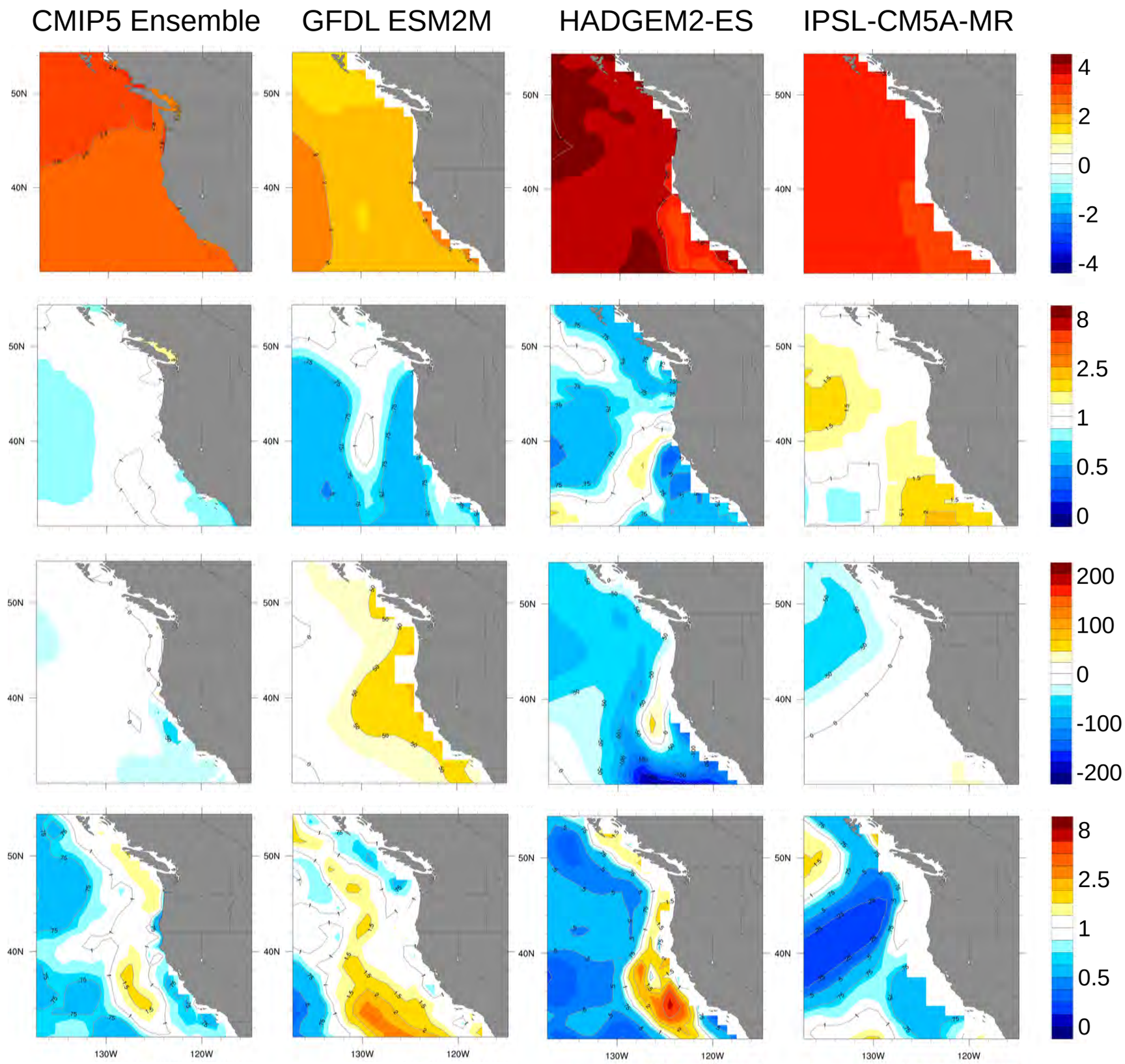


SST Variance Ratio

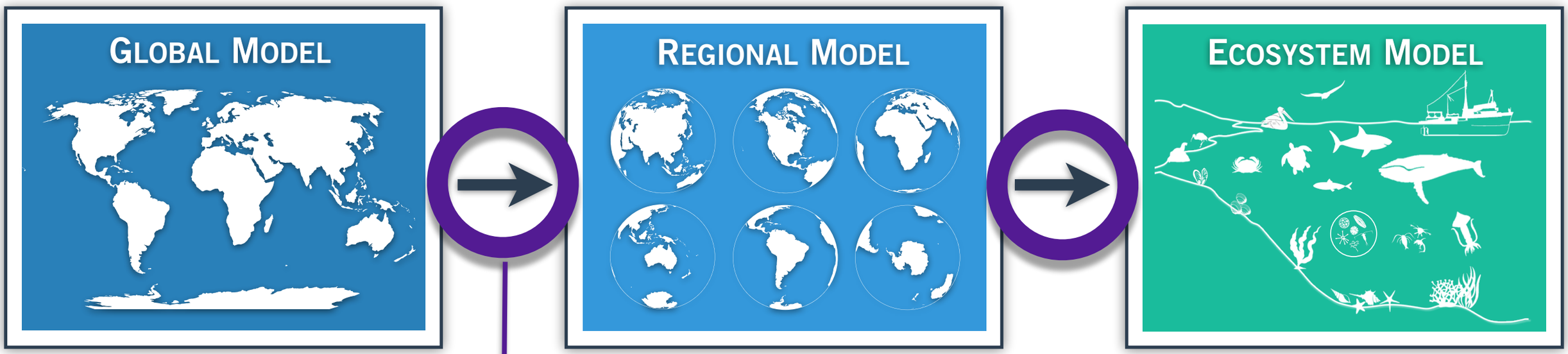


www.esrl.noaa.gov/psd/ipcc/

2050-2099 vs. 1956-2005



www.esrl.noaa.gov/psd/ipcc/



Which model(s)?

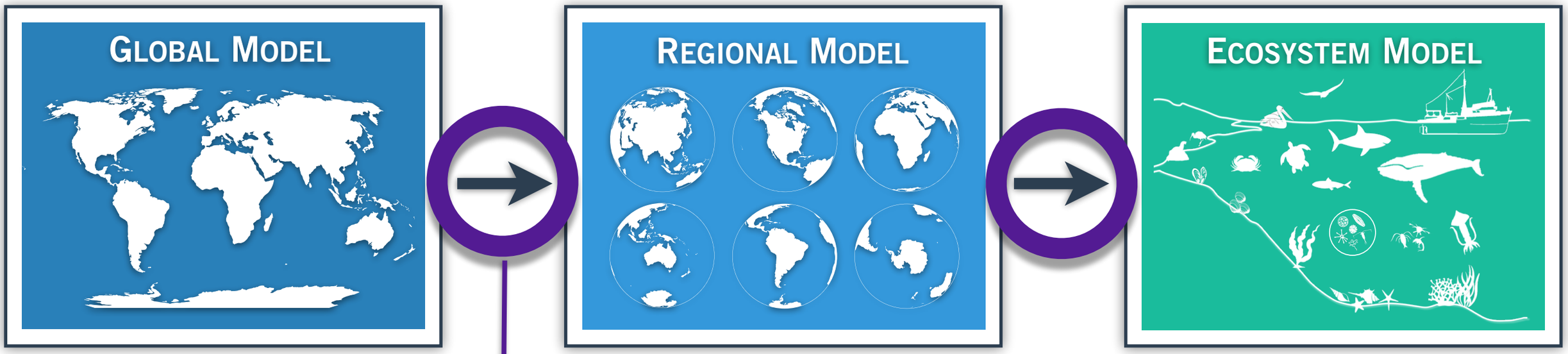
scenario uncertainty

vs.

model uncertainty

vs.

internal variability



Which model(s)?

scenario uncertainty

vs.

model uncertainty

vs.

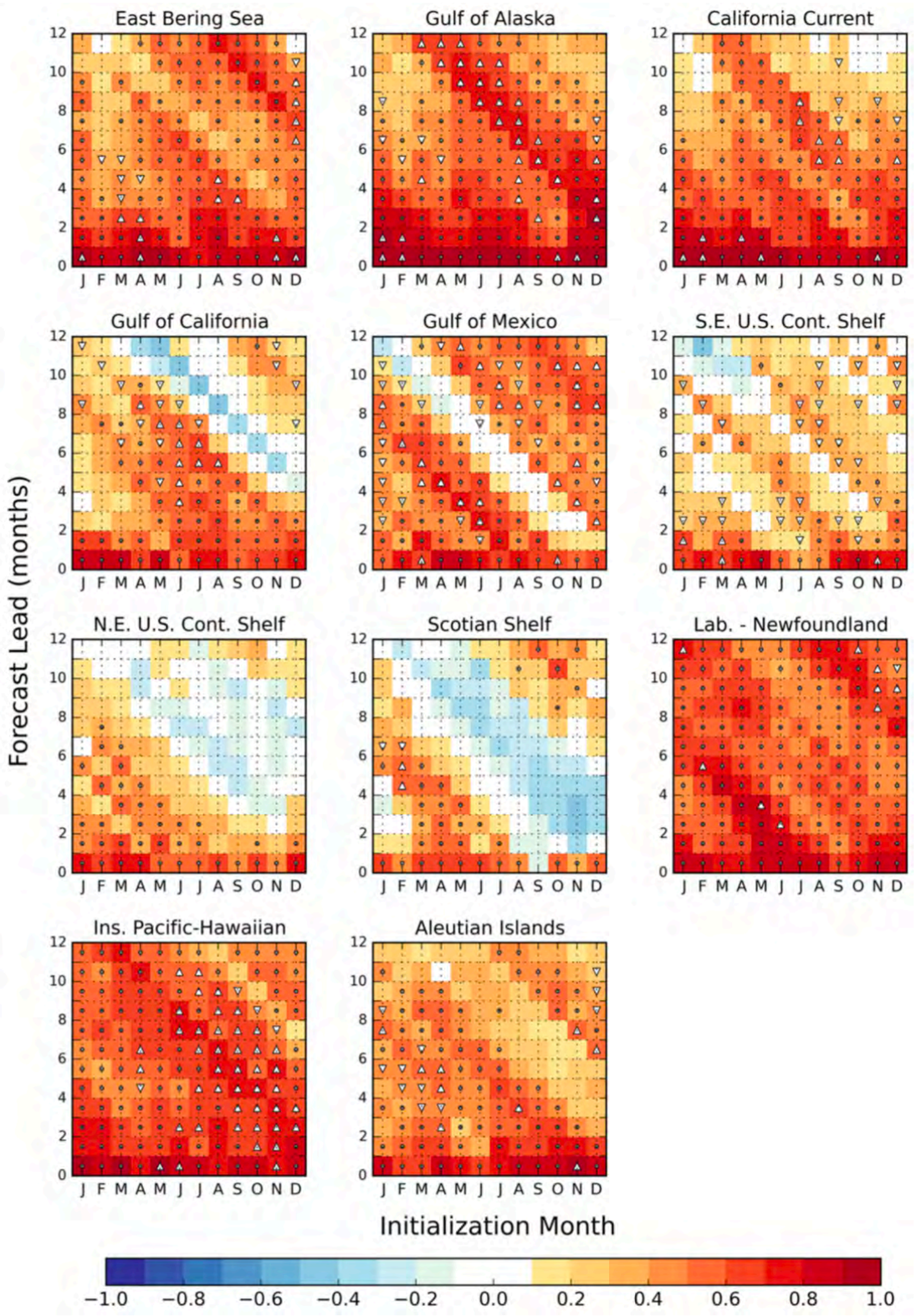
internal variability

Ensemble size

NMME 4-month lead SST Forecast Skill

http://www.cpc.ncep.noaa.gov/products/NMME/

NMME SST Forecast Skill for North American LMEs

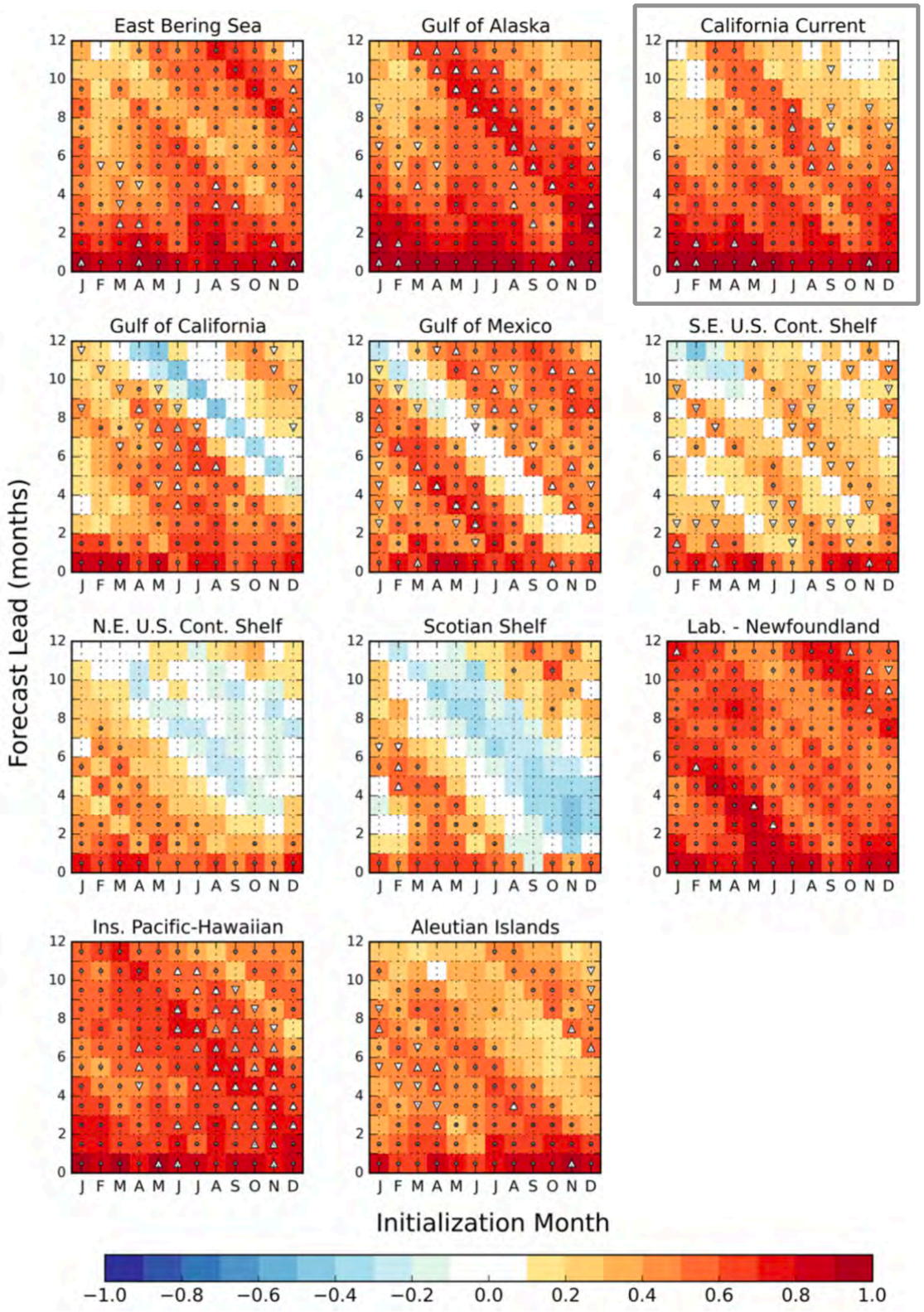


Hervieux et al. (2017

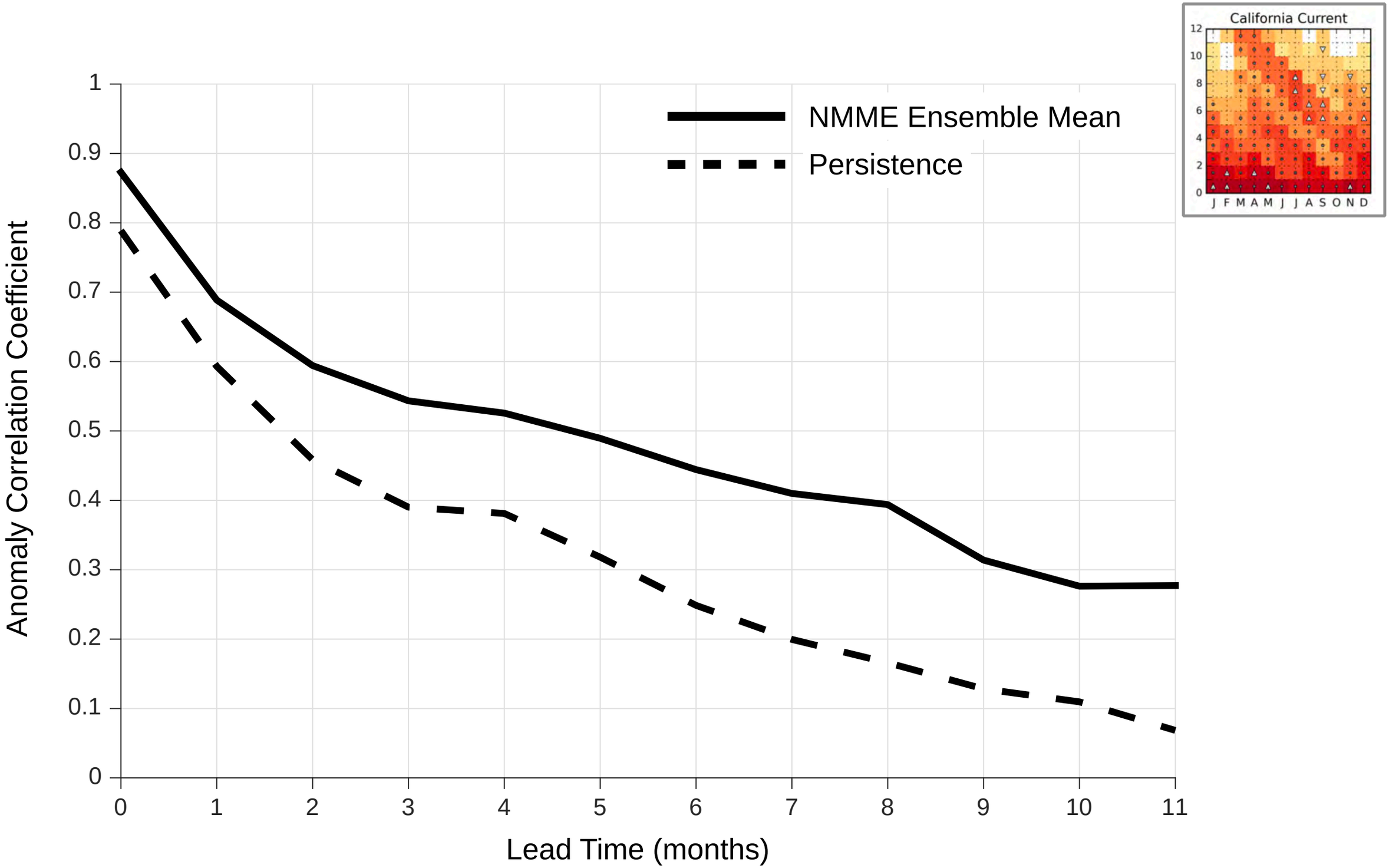
NMME 4-month lead SST Forecast Skill

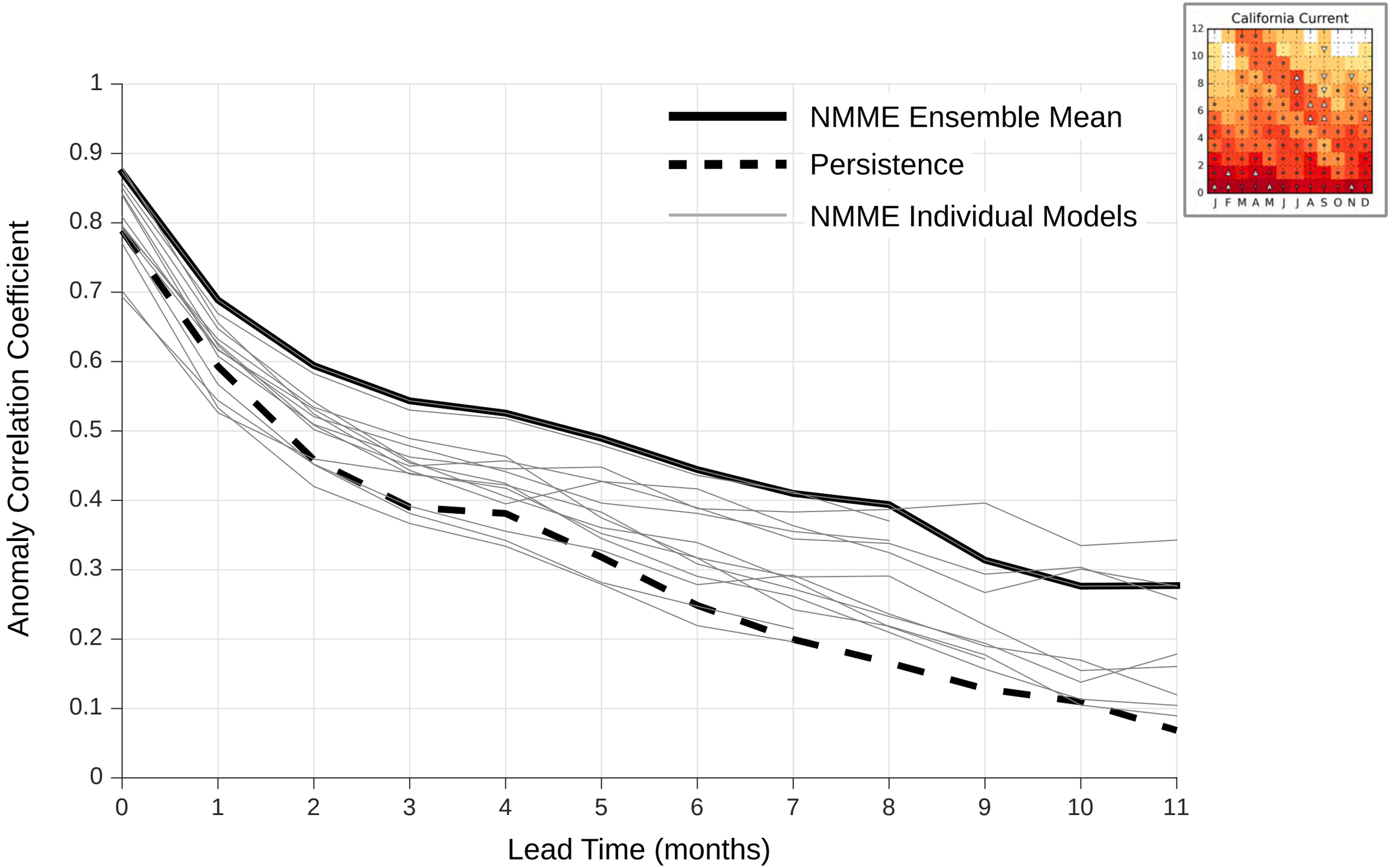
http://www.cpc.ncep.noaa.gov/products/NMME/

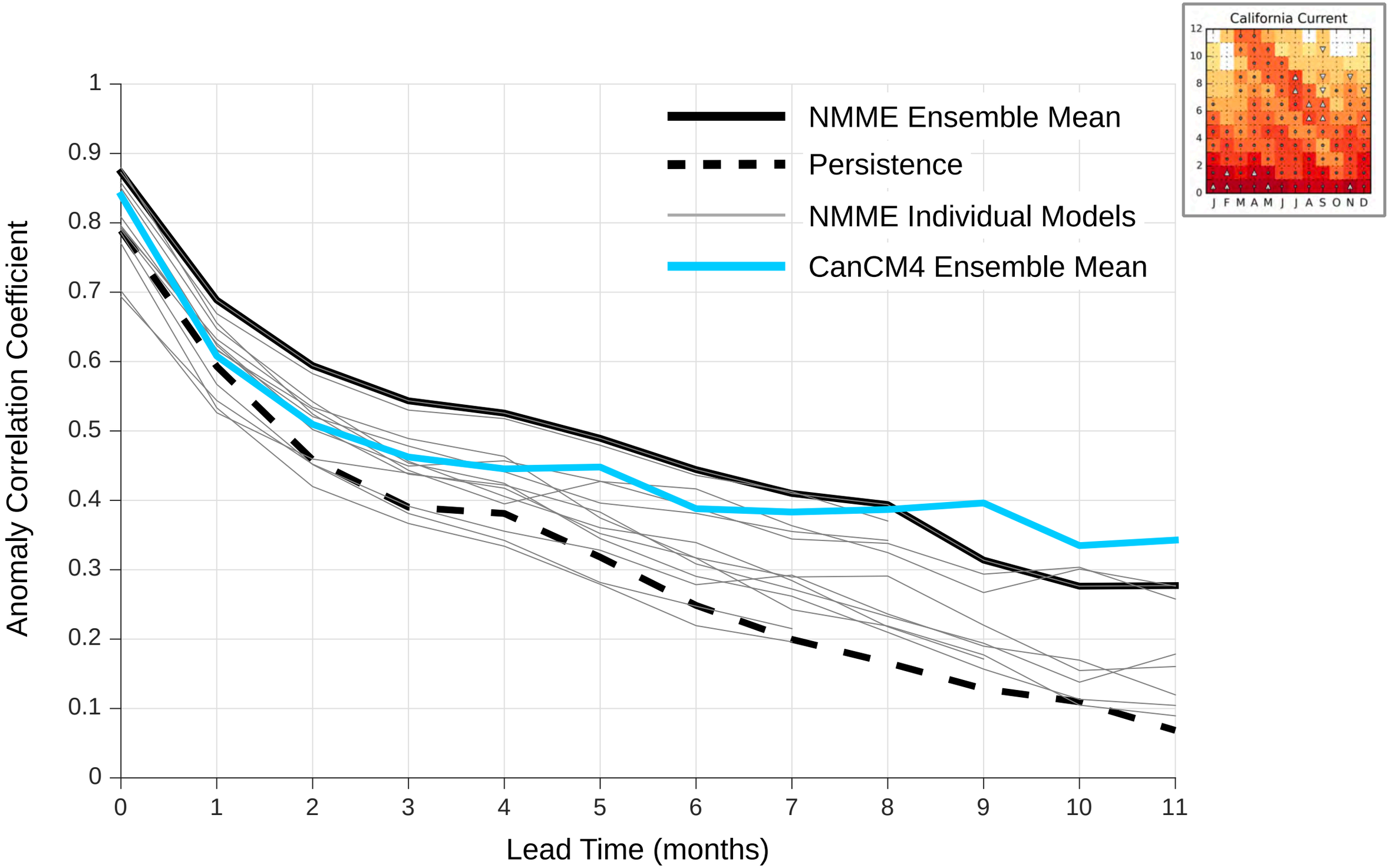
NMME SST Forecast Skill for North American LMEs

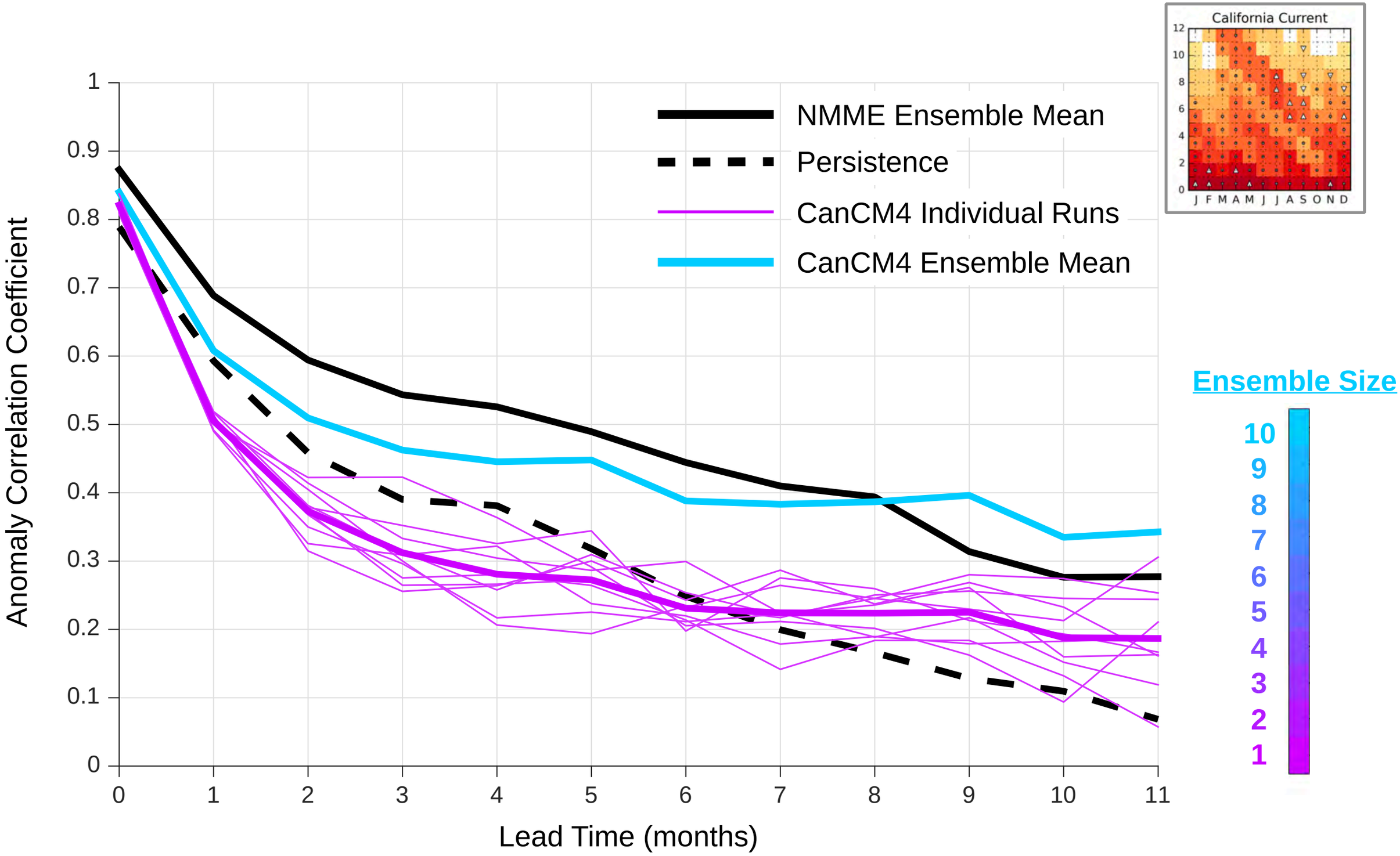


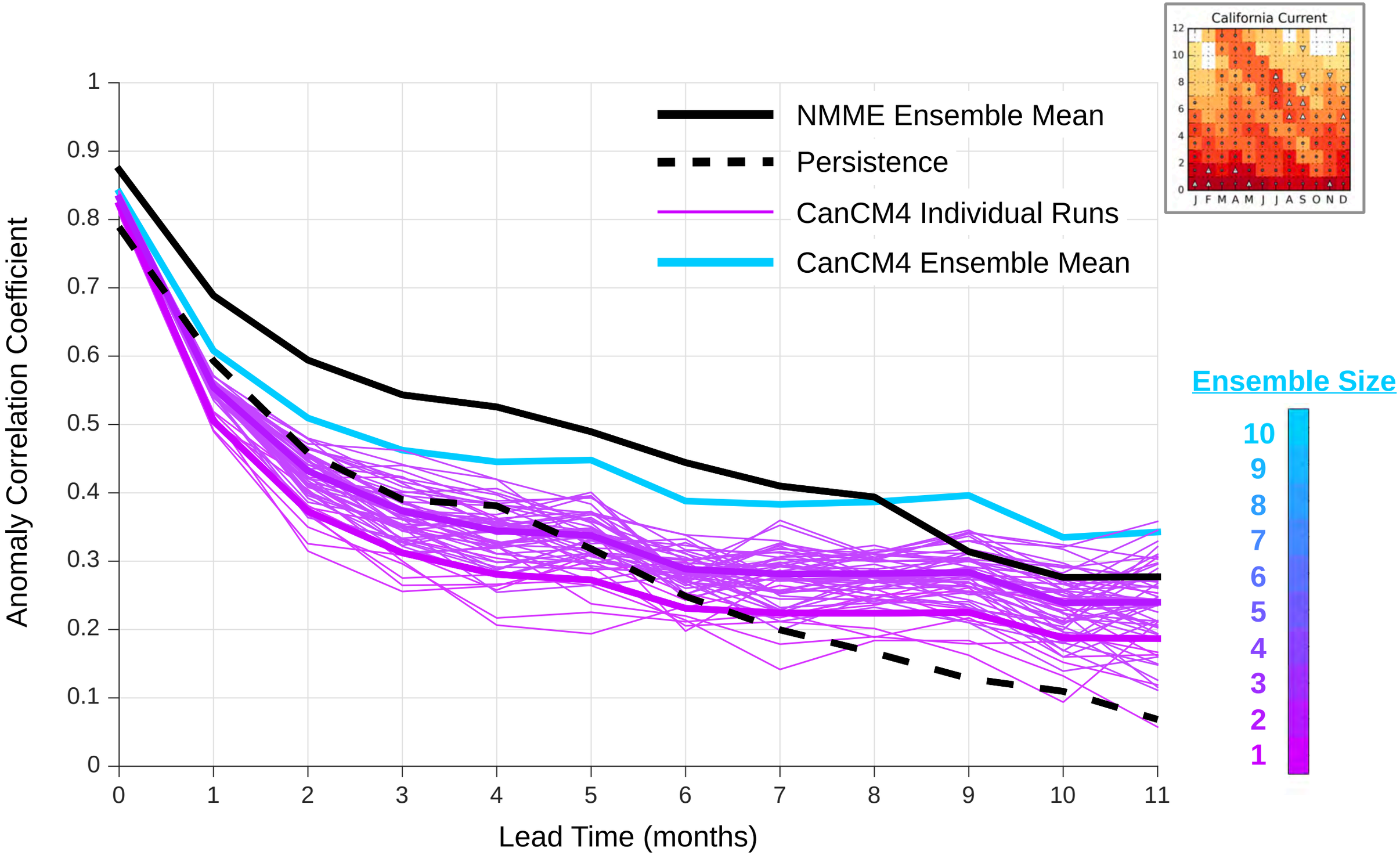
Hervieux et al. (2017


NMME Ensemble Mean
Persistence
Anomaly Correlation Coefficient
Lead Time (months)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
1
2
3
4
5
6
7
8
9
10
11
California Current
J F M A M J J A S O N D


California Current
12
10
8
6
4
2
0
J F M A M J J A S O N D
NMME Ensemble Mean
Persistence
NMME Individual Models
Anomaly Correlation Coefficient
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10 11
Lead Time (months)


California Current
12
10
8
6
4
2
0
J F M A M J J A S O N D
NMME Ensemble Mean
Persistence
NMME Individual Models
CanCM4 Ensemble Mean
Anomaly Correlation Coefficient
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10 11
Lead Time (months)


California Current
J F M A M J J A S O N D
NMME Ensemble Mean
Persistence
CanCM4 Individual Runs
CanCM4 Ensemble Mean
Ensemble Size
10
9
8
7
6
5
4
3
2
1
Anomaly Correlation Coefficient
Lead Time (months)


California Current
12
10
8
6
4
2
0
J F M A M J J A S O N D
NMME Ensemble Mean
Persistence
CanCM4 Individual Runs
CanCM4 Ensemble Mean
Ensemble Size
10
9
8
7
6
5
4
3
2
1
Anomaly Correlation Coefficient
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
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4
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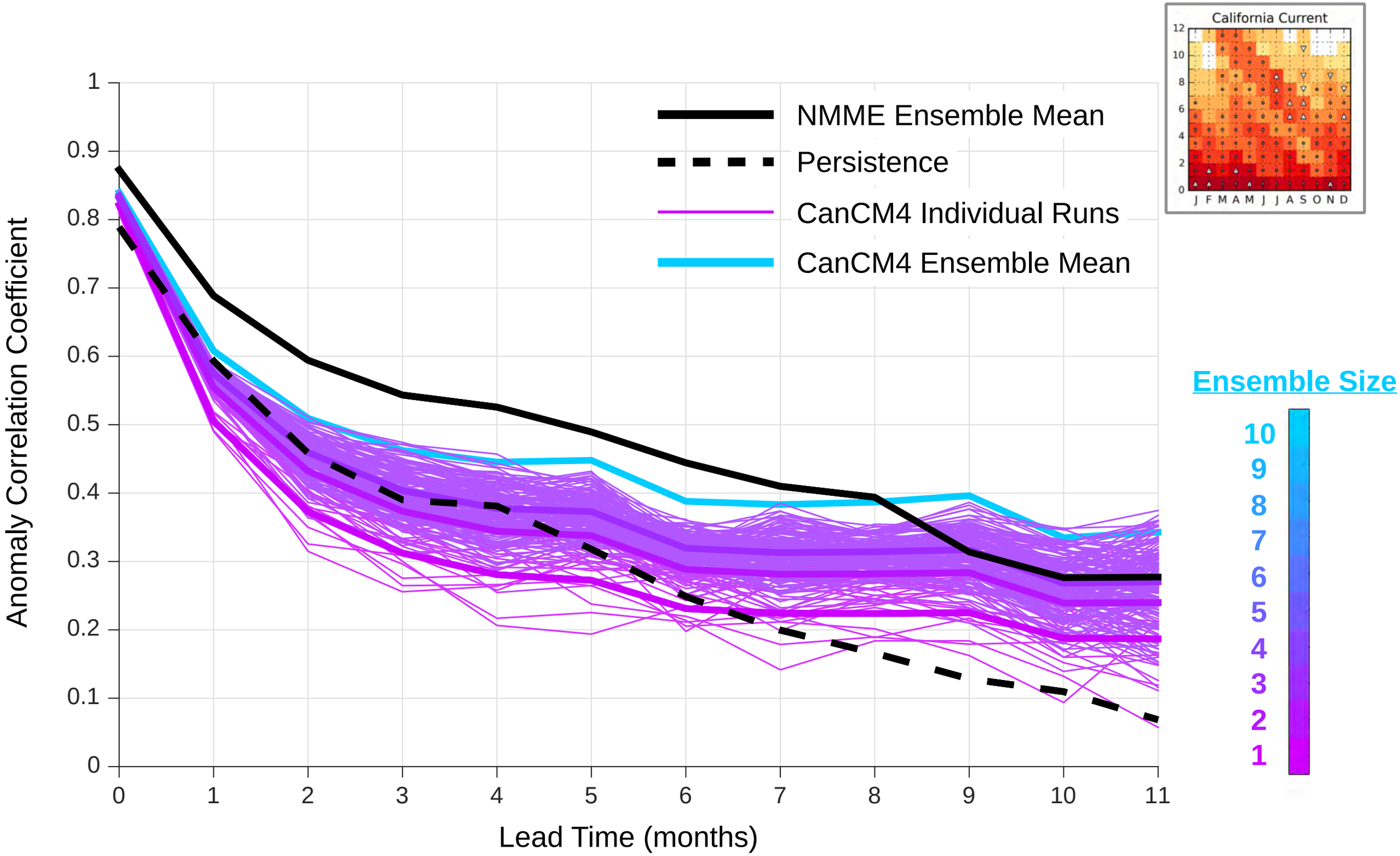
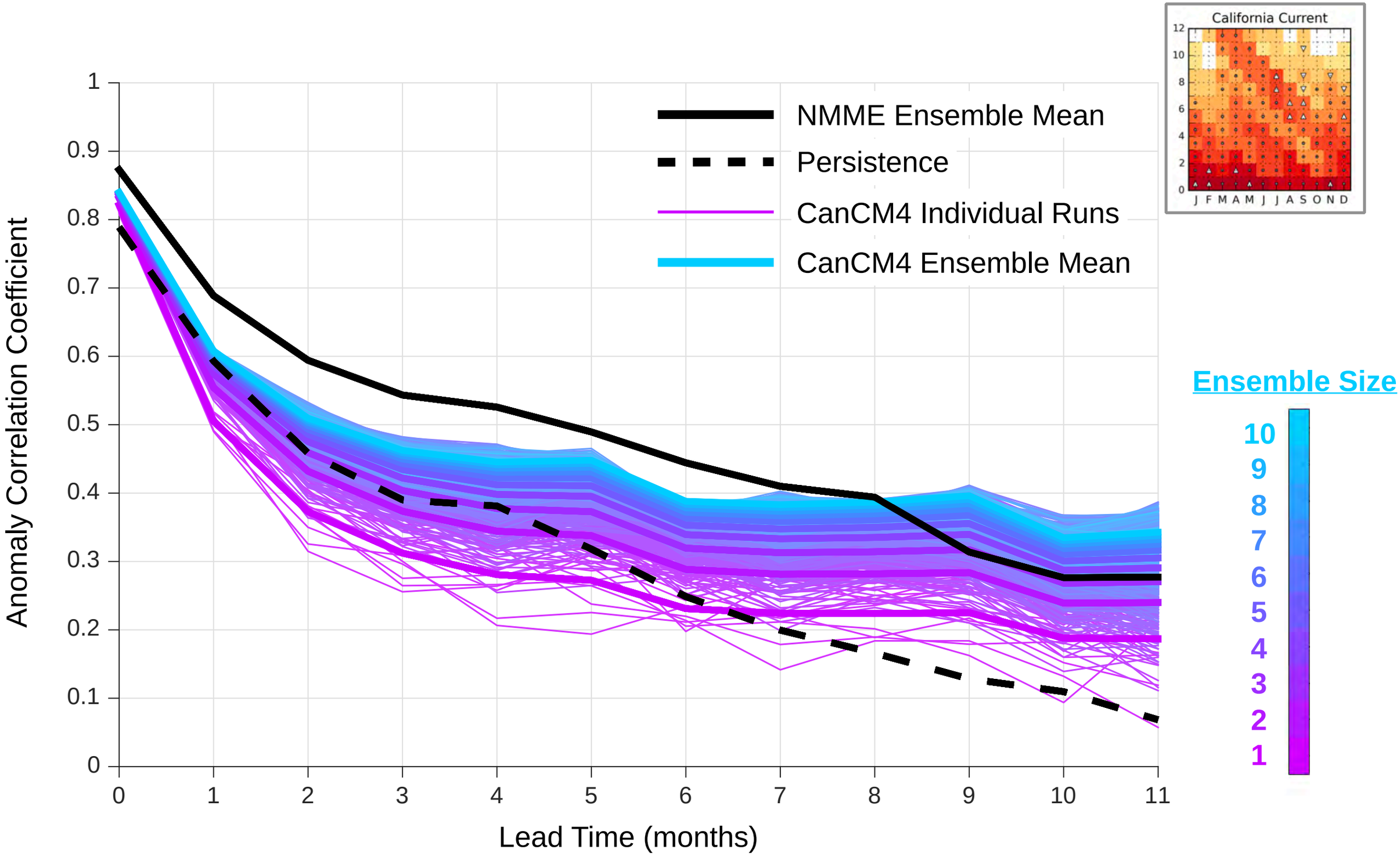
8
9
10
11
Lead Time (months)


California Current
J F M A M J J A S O N D
NMME Ensemble Mean
Persistence
CanCM4 Individual Runs
CanCM4 Ensemble Mean
Ensemble Size
10
9
8
7
6
5
4
3
2
1
Anomaly Correlation Coefficient
Lead Time (months)


California Current
12
10
8
6
4
2
0
J F M A M J J A S O N D
NMME Ensemble Mean
Persistence
CanCM4 Individual Runs
CanCM4 Ensemble Mean
Ensemble Size
10
9
8
7
6
5
4
3
2
1
Anomaly Correlation Coefficient
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
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6
7
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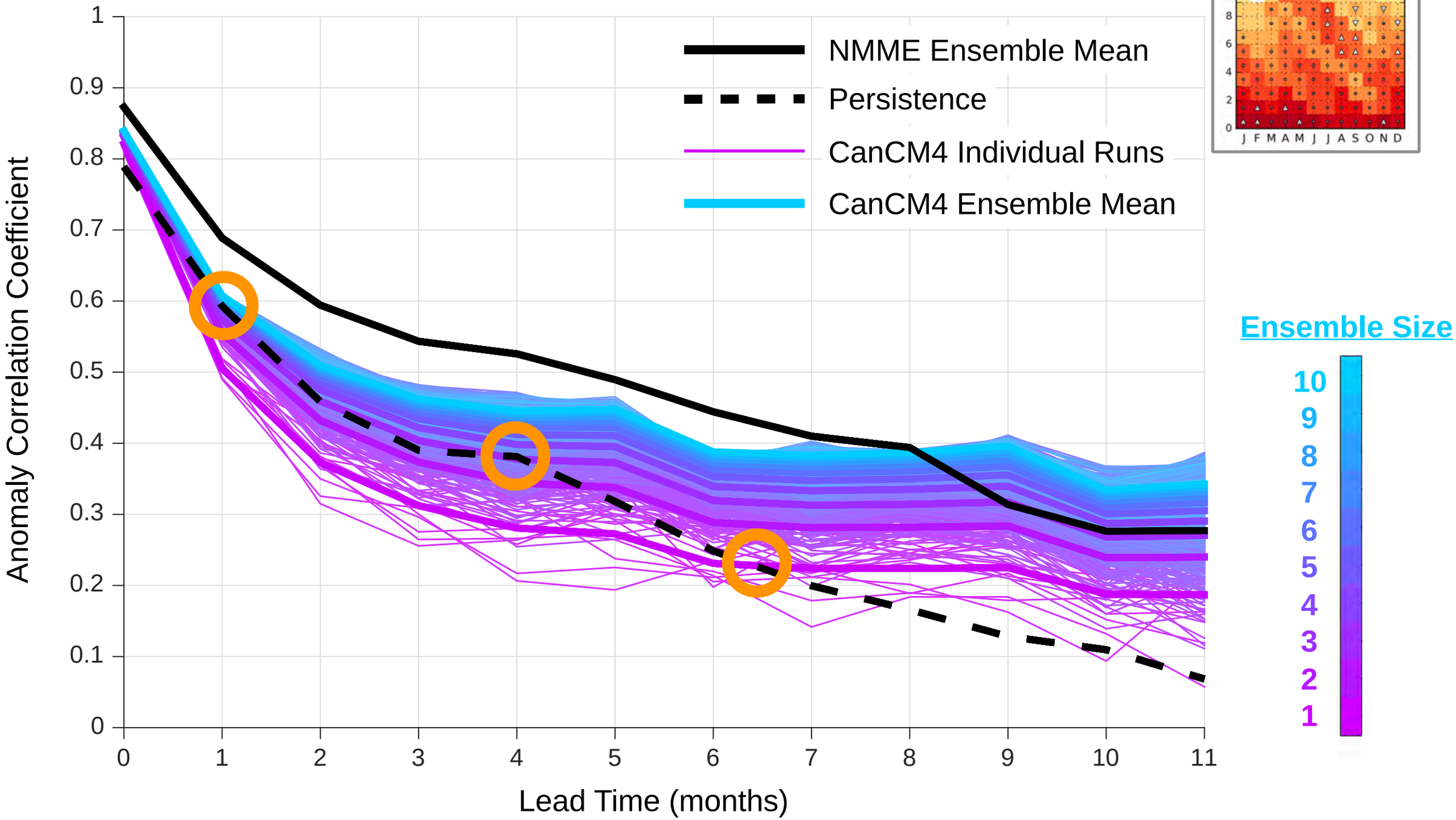
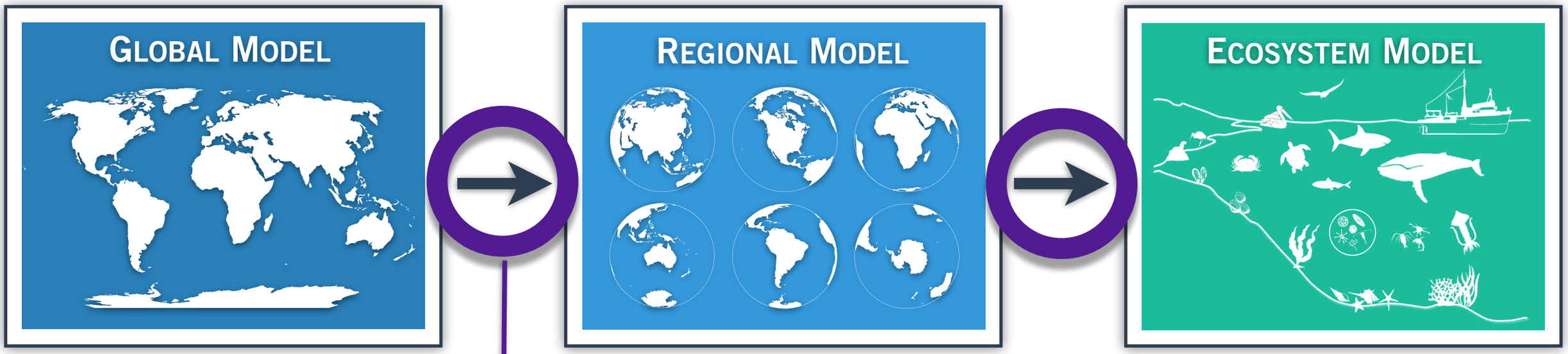
10
11
Lead Time (months)


California Current
12
10
8
6
4
2
0
J F M A M J J A S O N D
NMME Ensemble Mean
Persistence
CanCM4 Individual Runs
CanCM4 Ensemble Mean
Ensemble Size
10
9
8
7
6
5
4
3
2
1
Anomaly Correlation Coefficient
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
8
9
10
11
Lead Time (months)



Which model(s)?

scenario uncertainty

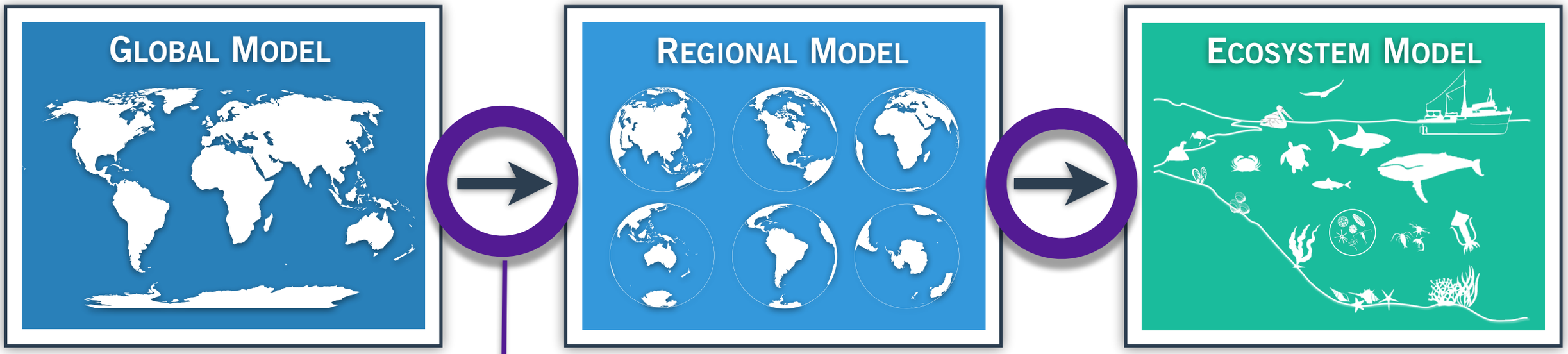
vs.

model uncertainty

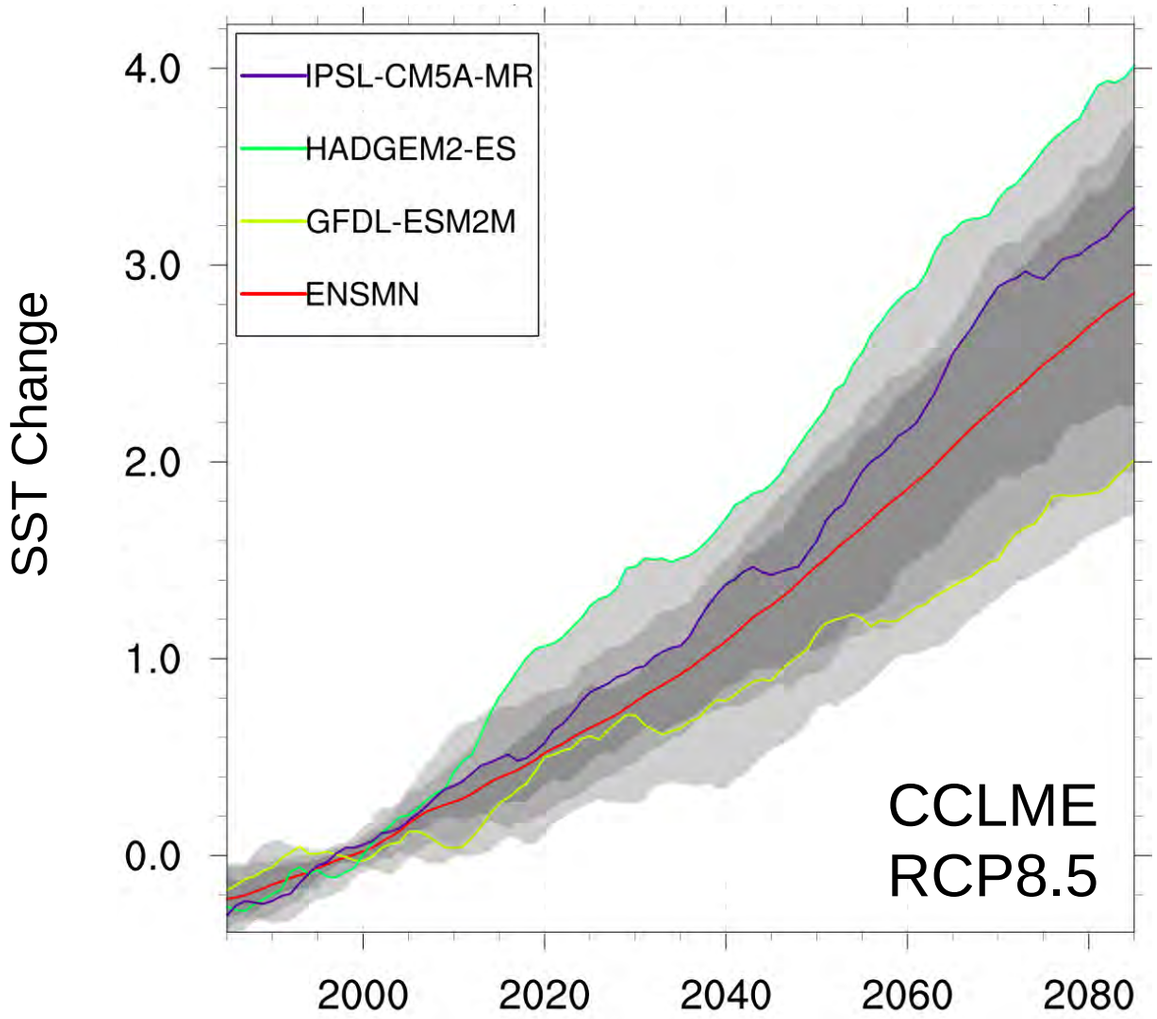
vs.

internal variability

Ensemble size

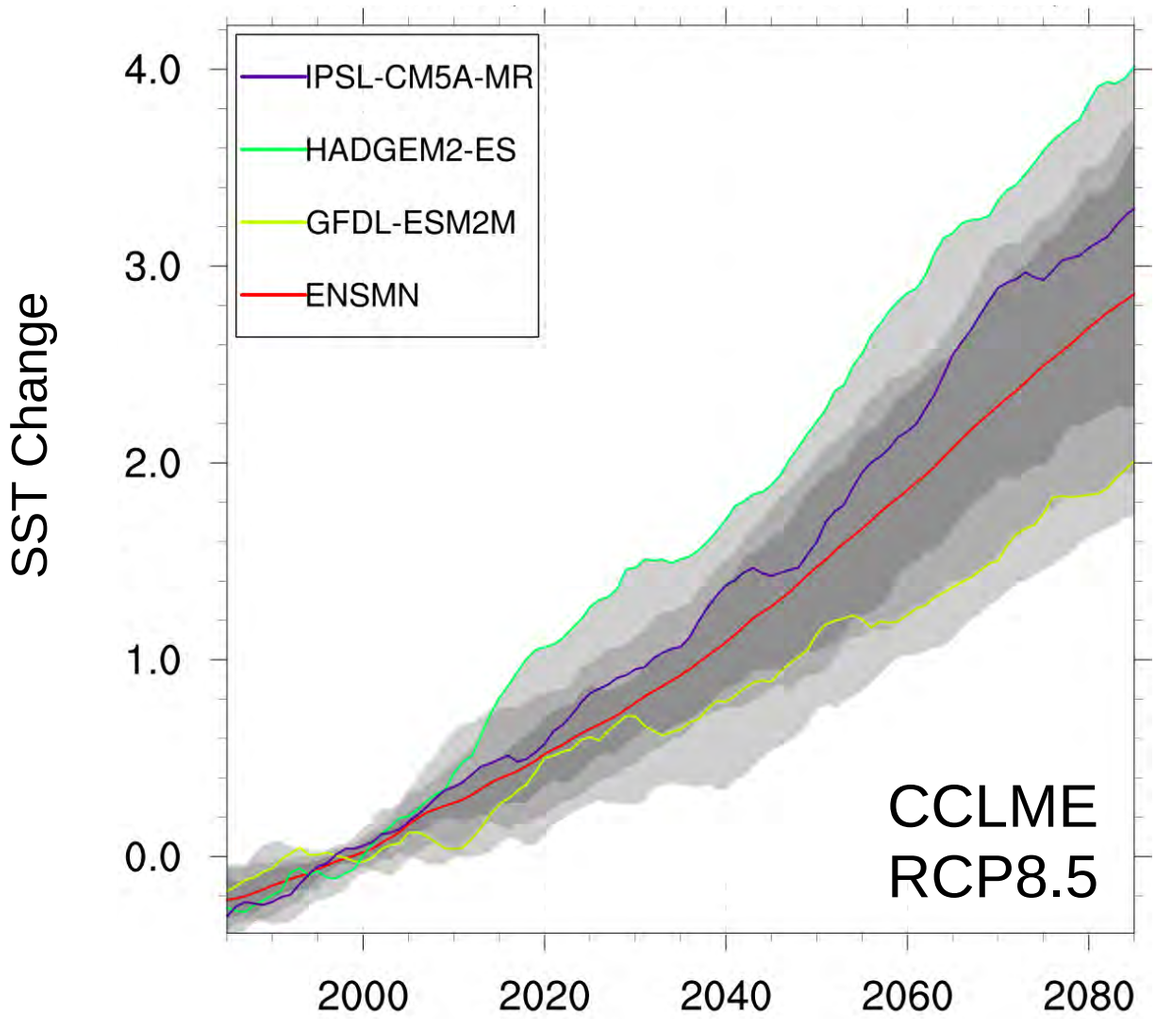


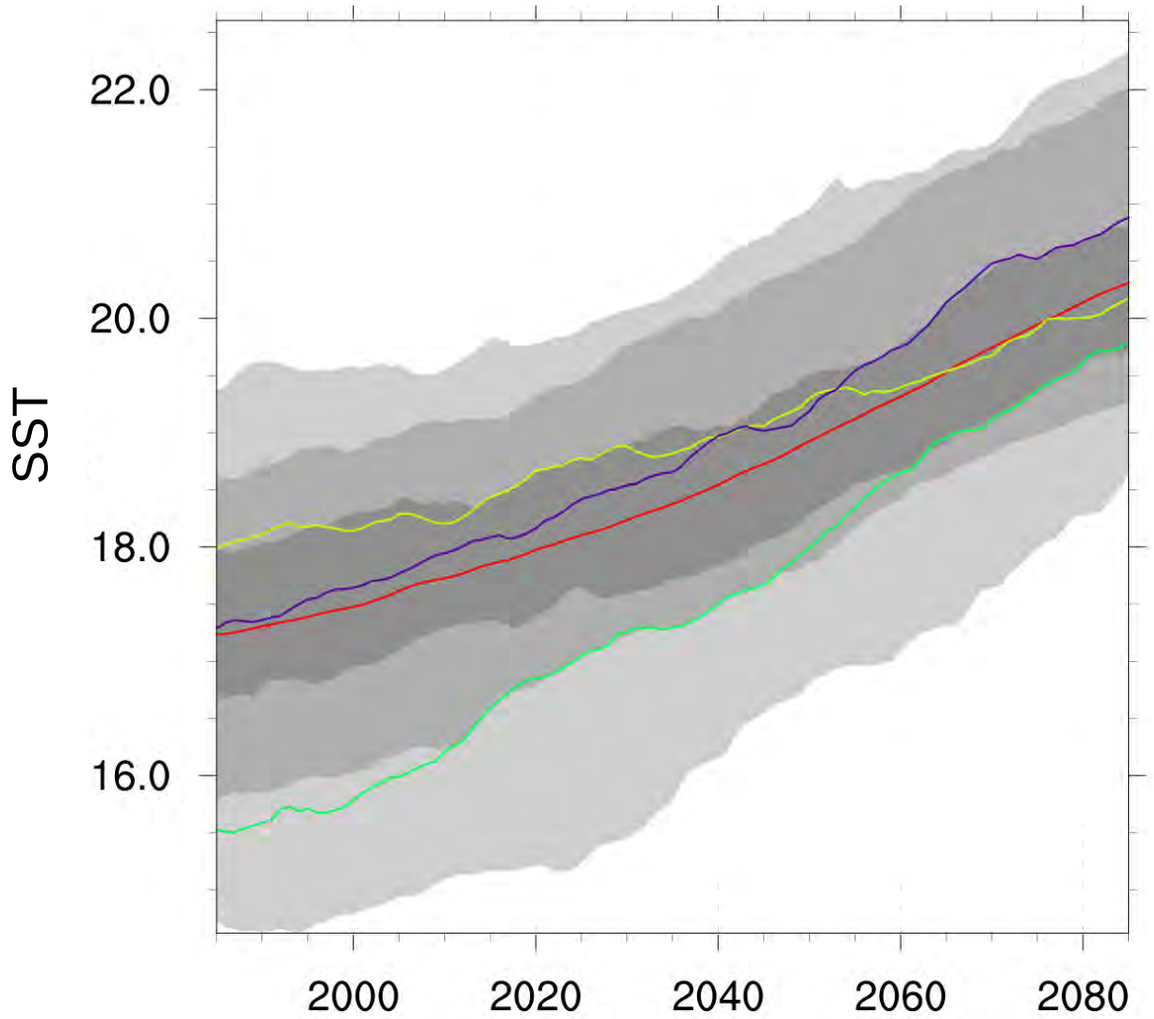
- Which model(s)?
  - scenario uncertainty
  - vs.
  - model uncertainty
  - vs.
  - internal variability
- Ensemble size
- Model Bias



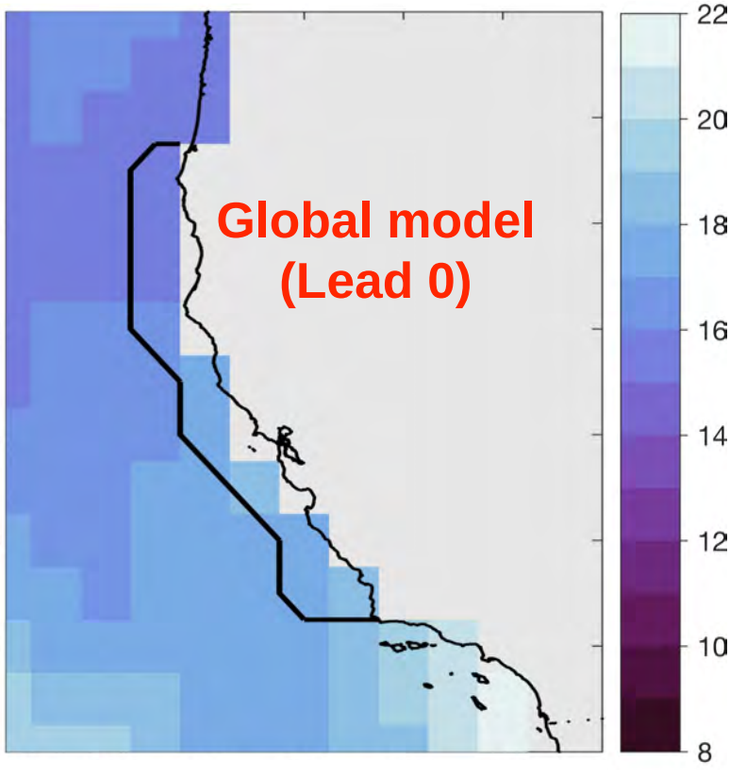
https://www.esrl.noaa.gov/psd/ipcc/

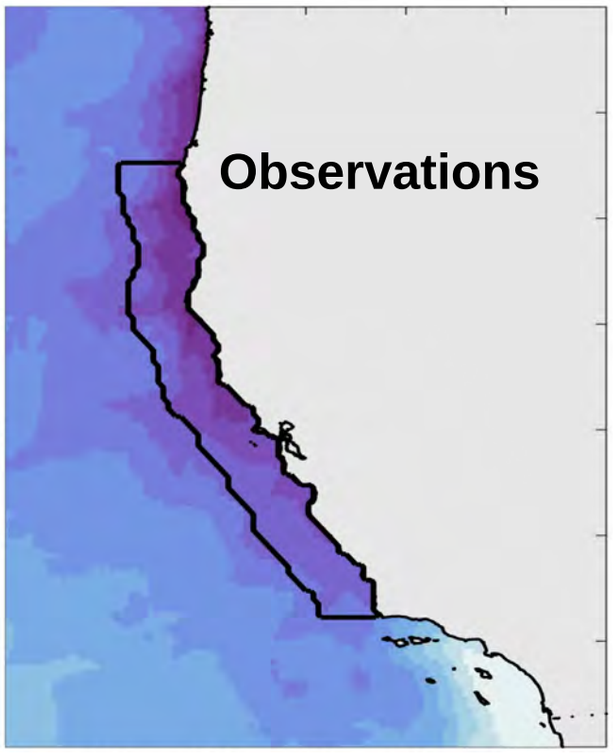
ALL CMIP5 members
80% of CMIP5 members
50% of CMIP5 members

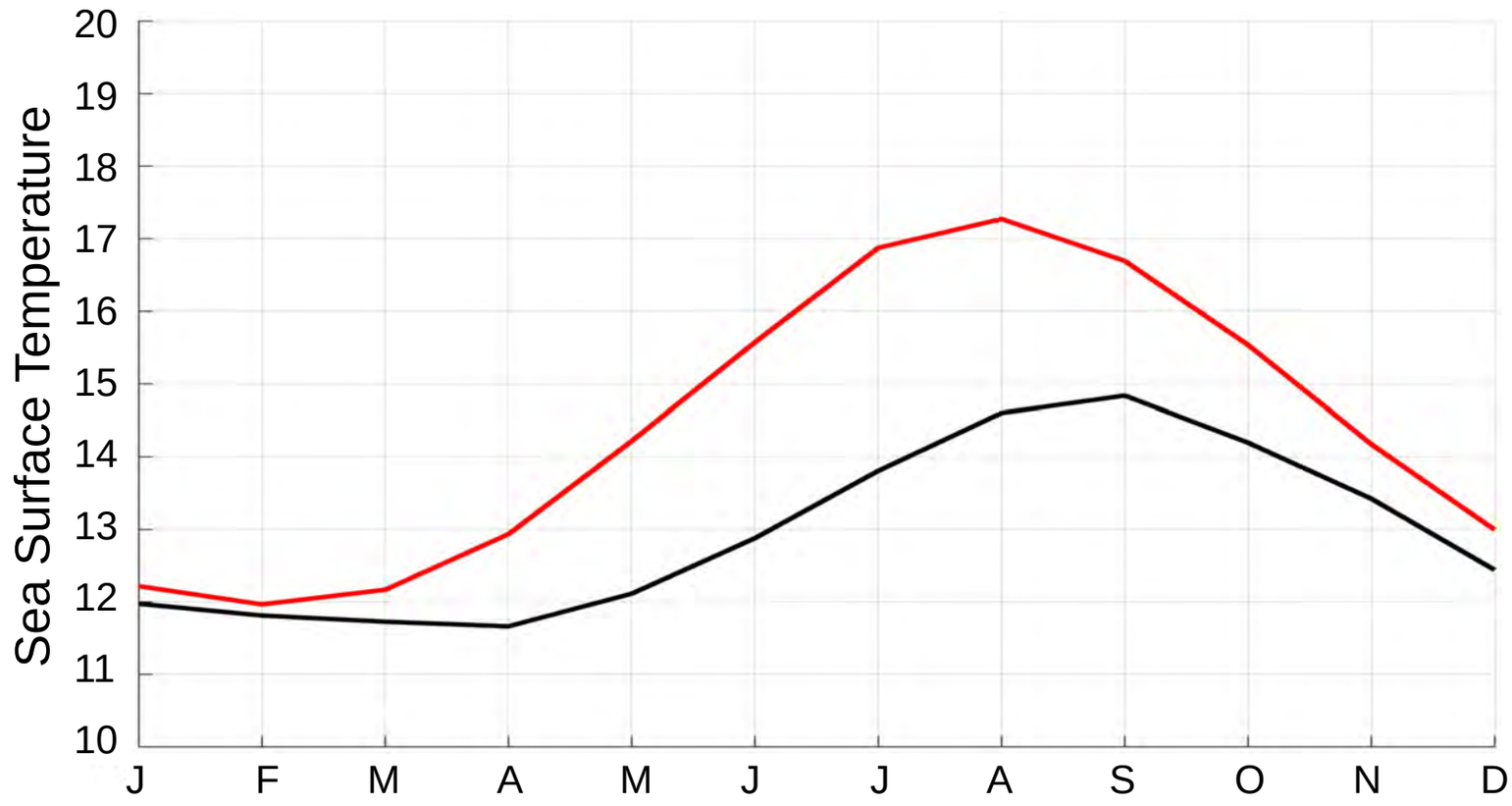


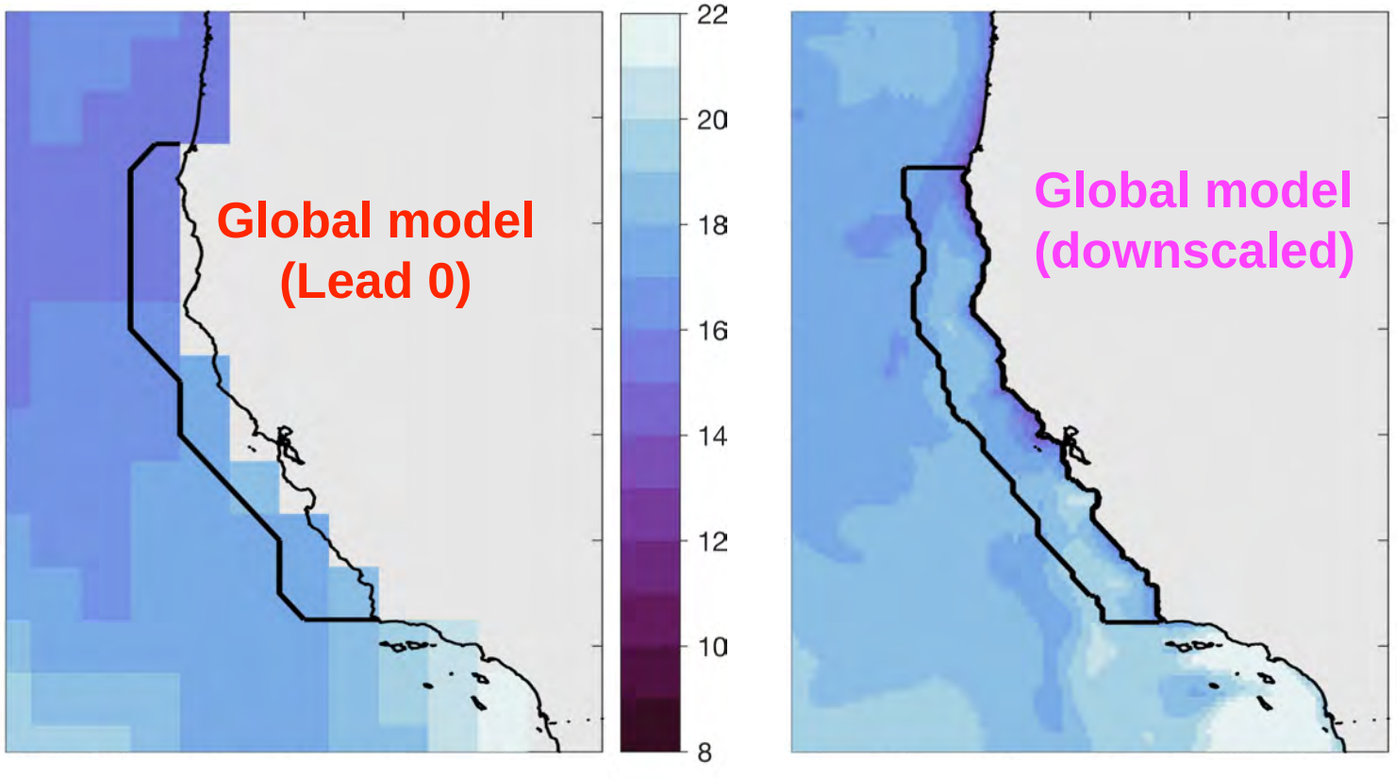


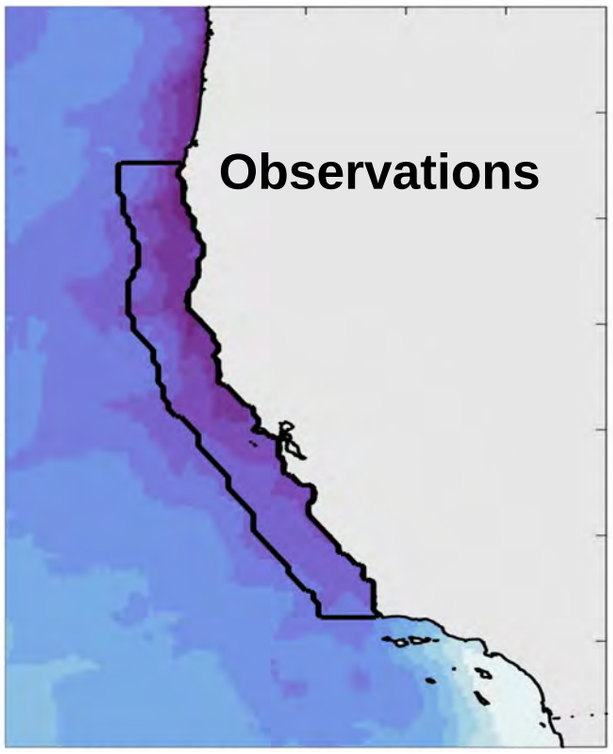
https://www.esrl.noaa.gov/psd/ipcc/

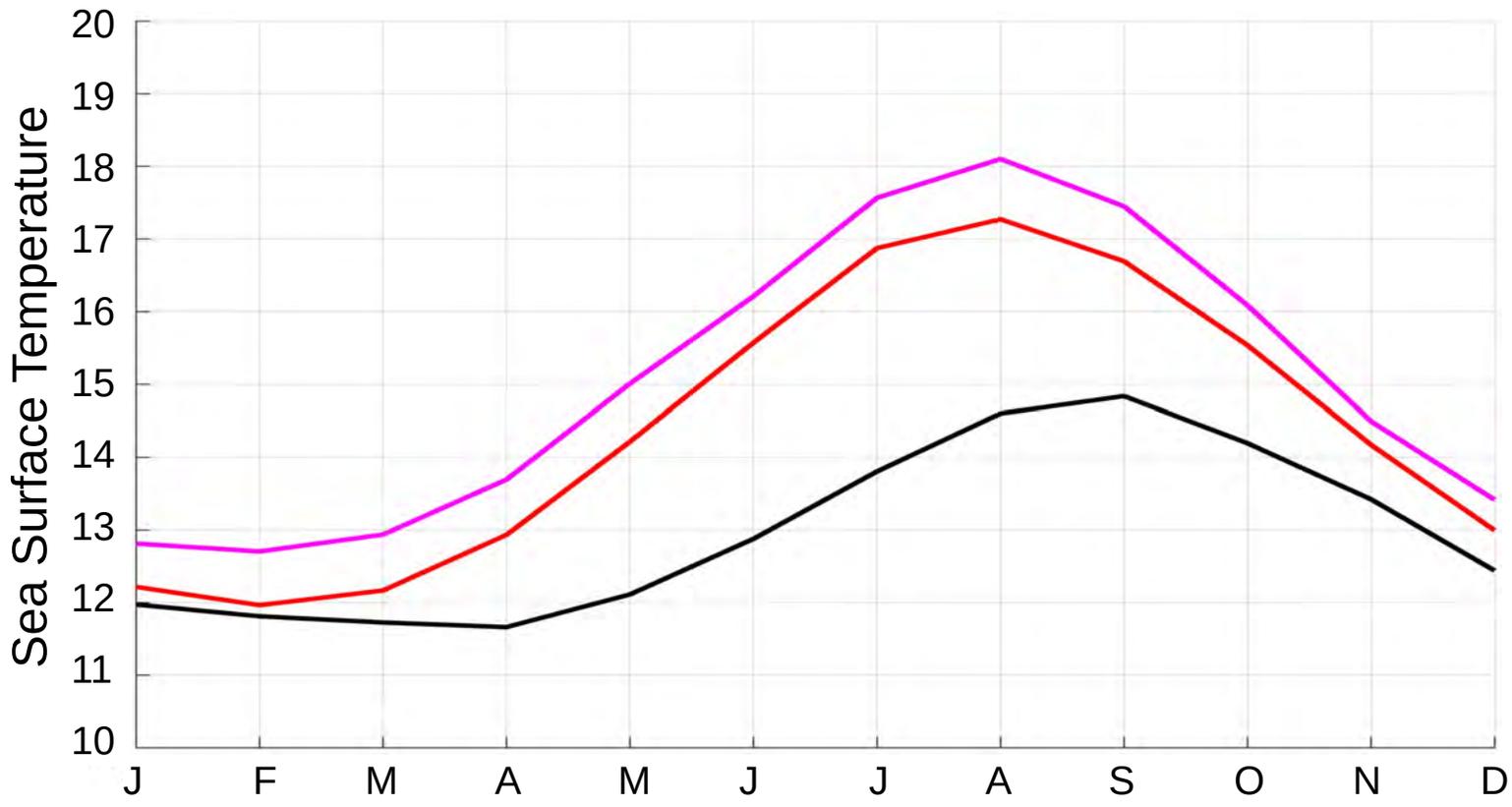

Global model
(Lead 0)
22
20
18
16
14
12
10
8


Observations


Sea Surface Temperature
20
19
18
17
16
15
14
13
12
11
10
J
F
M
A
M
J
J
A
S
O
N
D


Global model
(Lead 0)
22
20
18
16
14
12
10
8
Global model
(downscaled)


Observations


Sea Surface Temperature
20
19
18
17
16
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J
F
M
A
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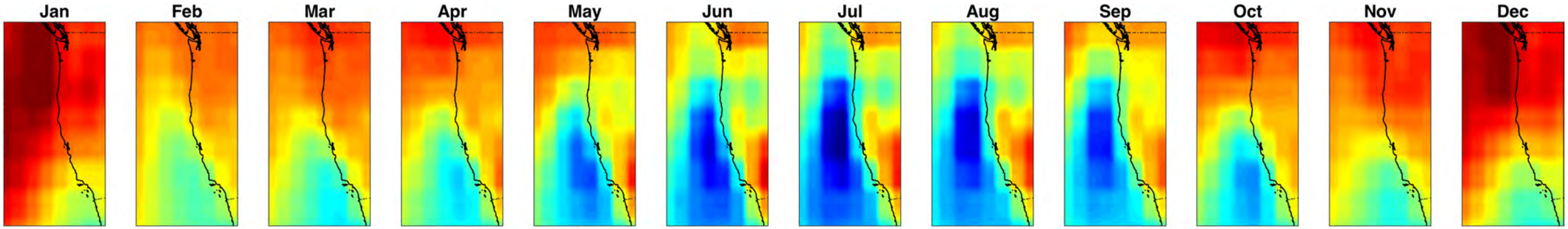
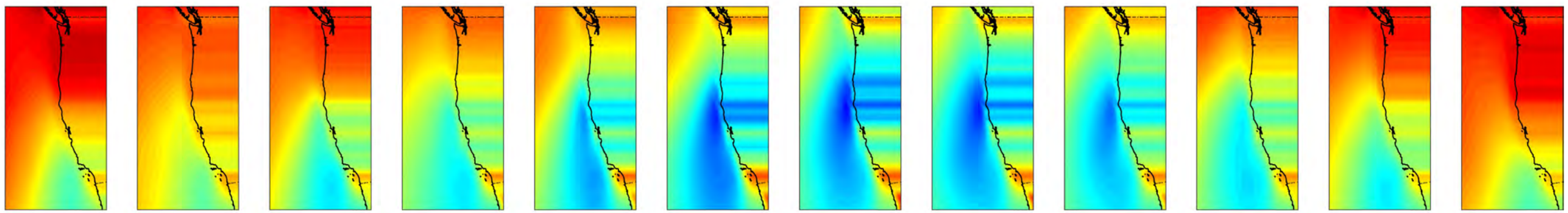
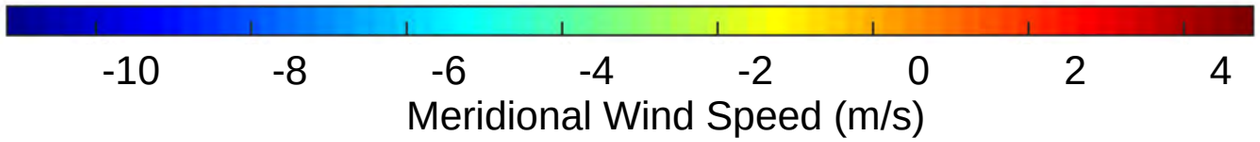
J
J
A
S
O
N
D

Global Model

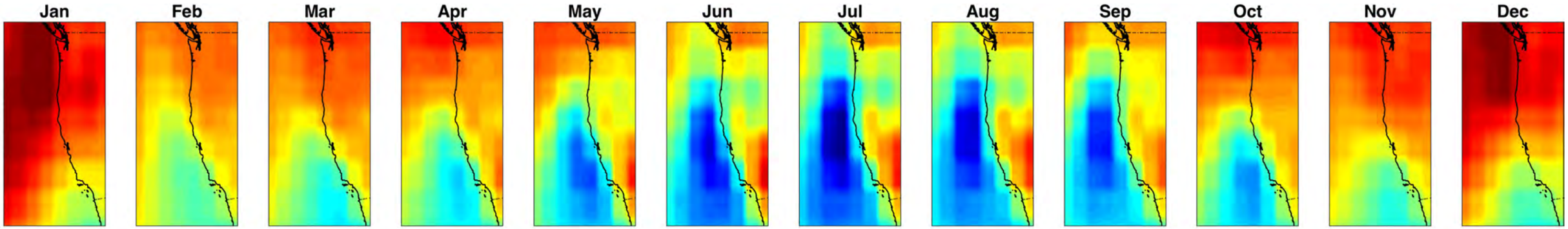


Observations

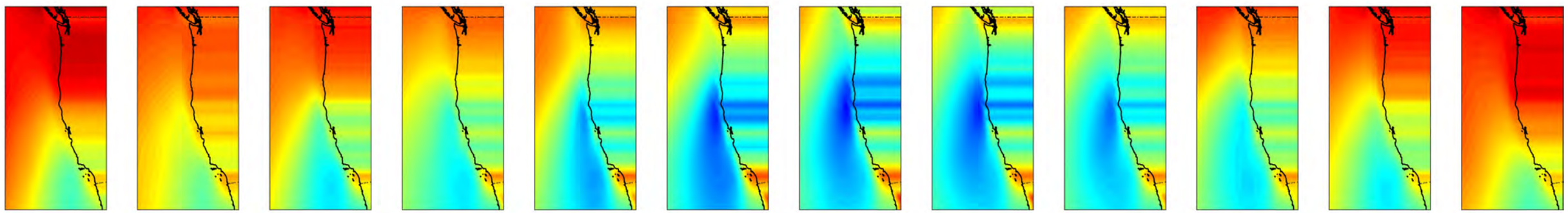




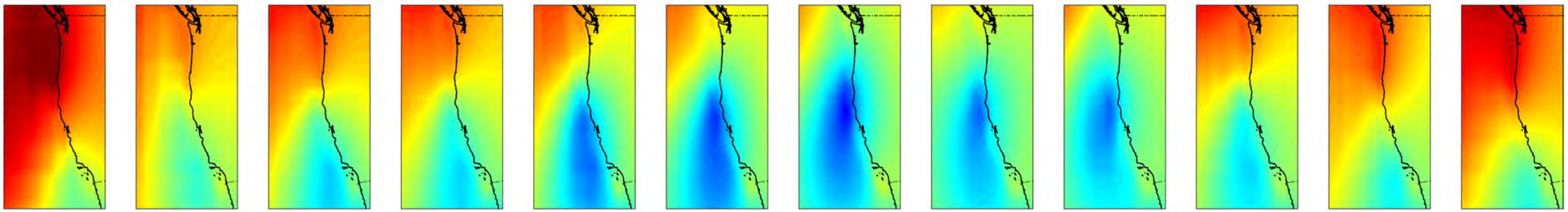
Global Model

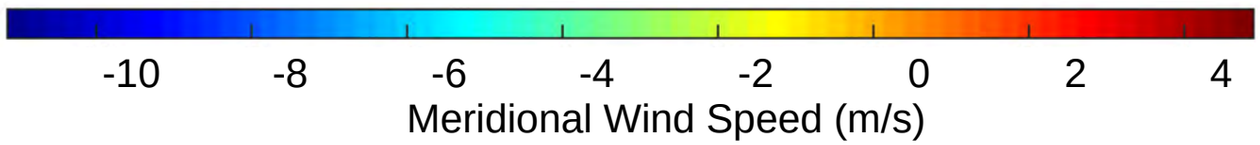


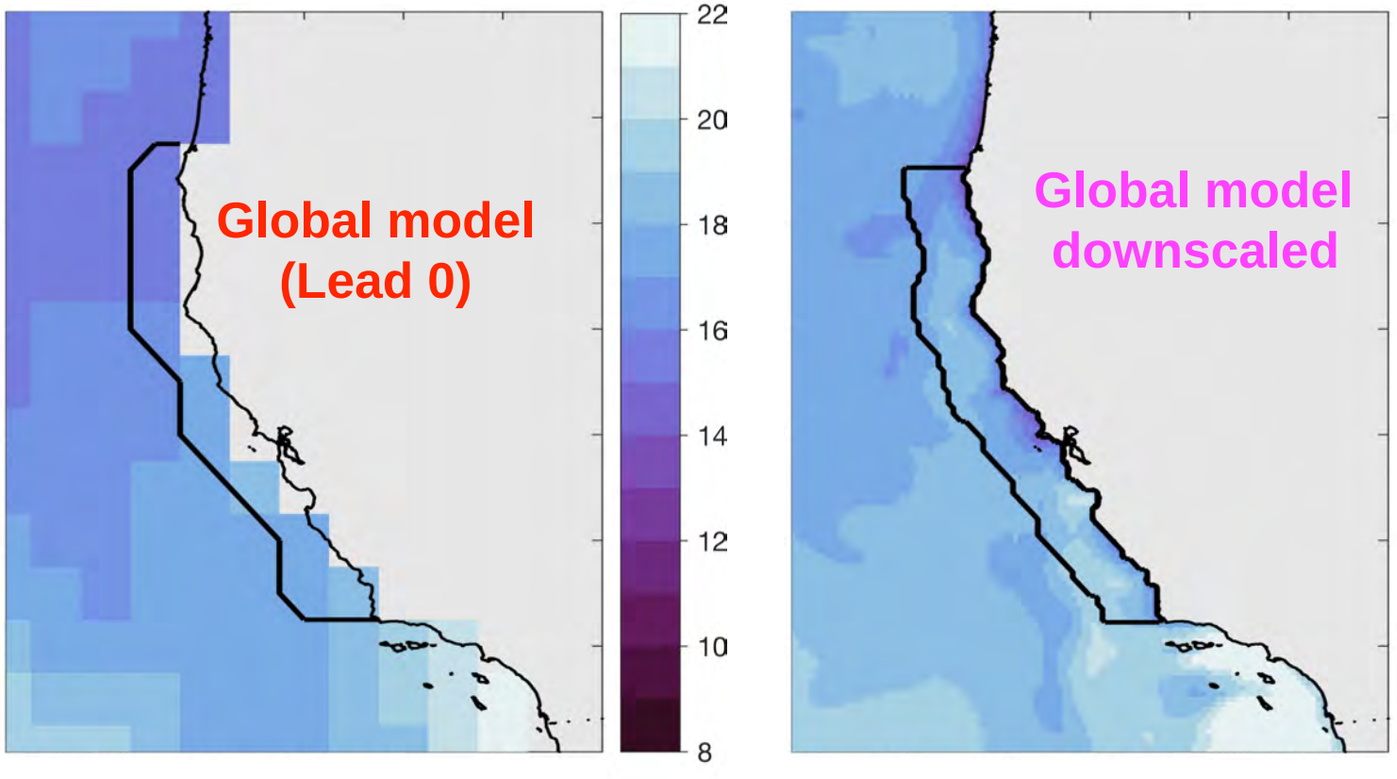
Observations

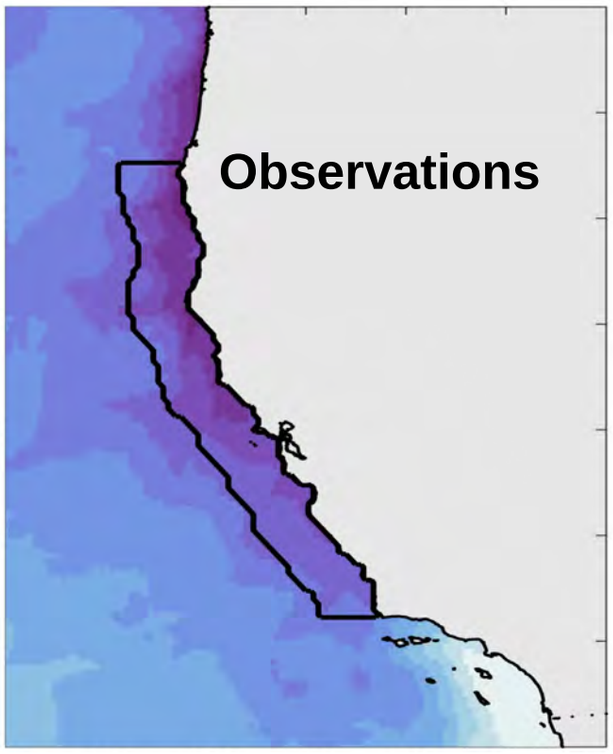


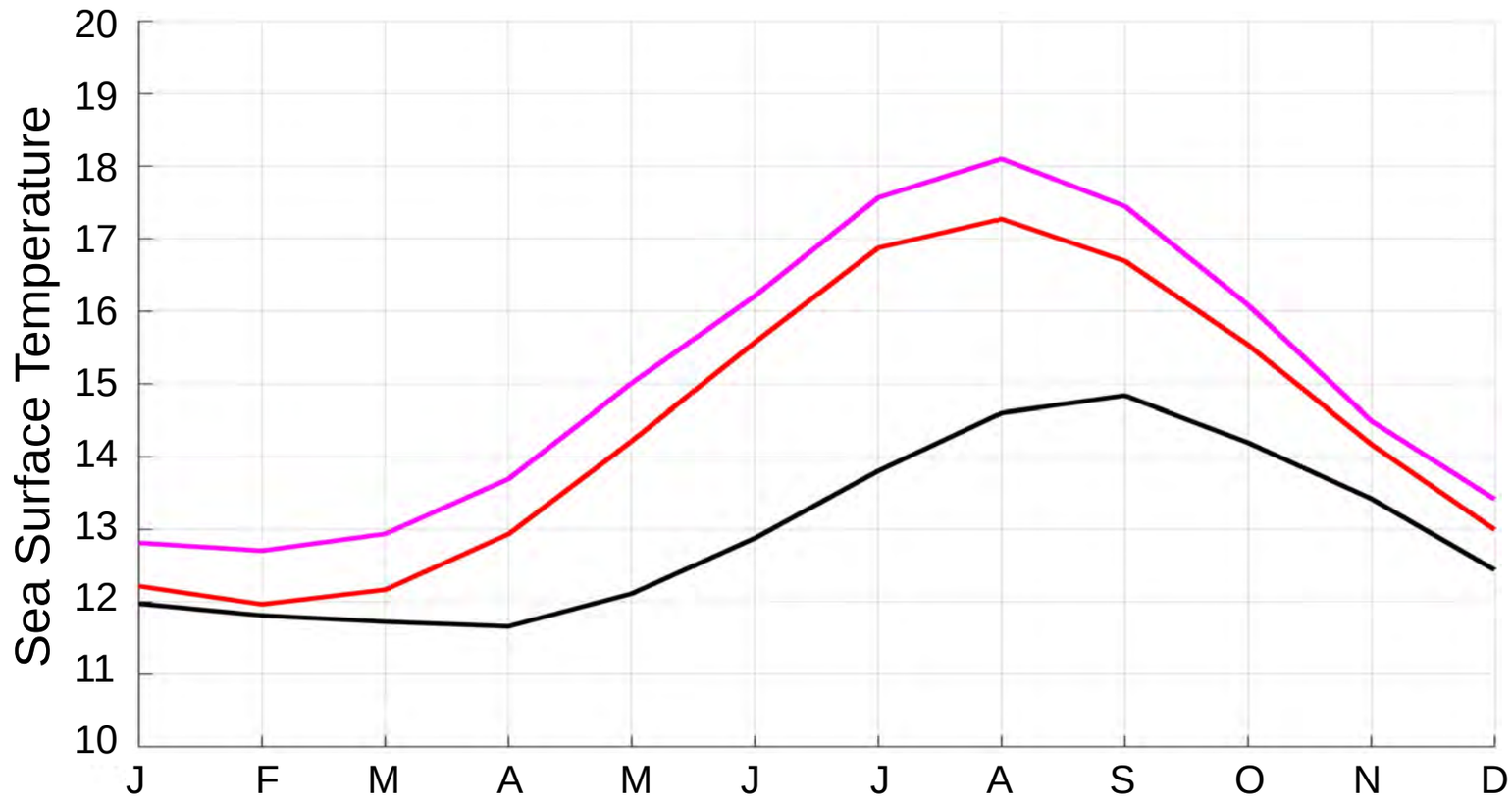
Bias Corrected Global Model






Global model
(Lead 0)
22
20
18
16
14
12
10
8
Global model
downscaled


Observations


Sea Surface Temperature
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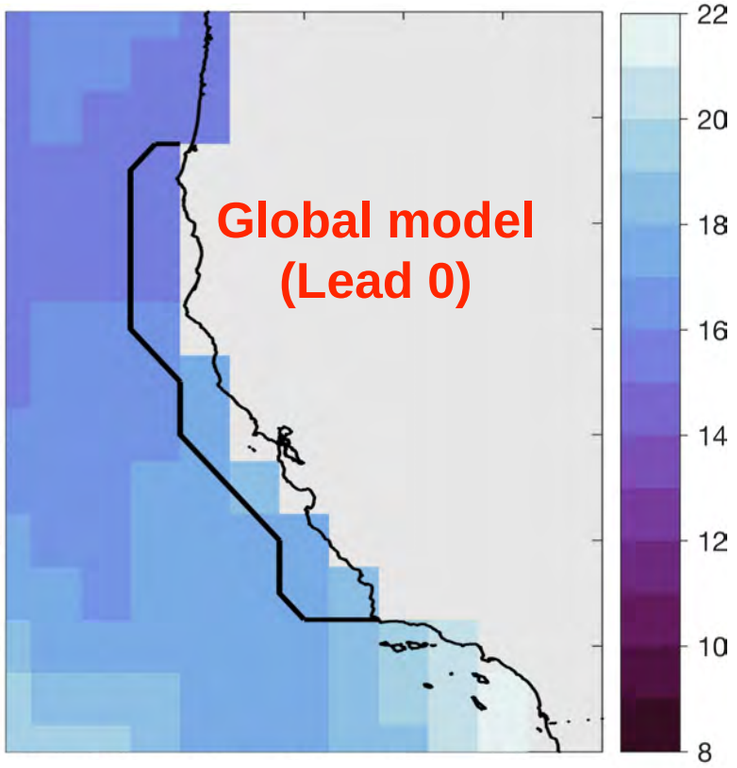
Global model
(Lead 0)

22
20
18
16
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12
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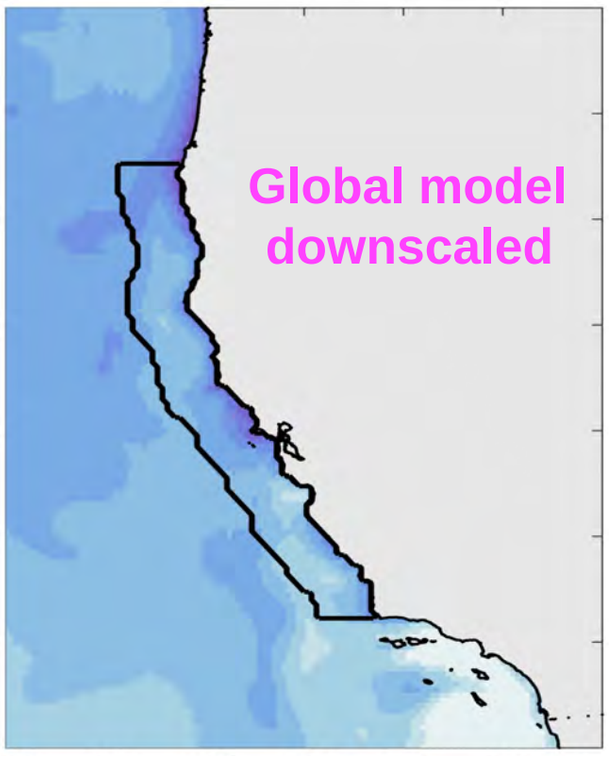
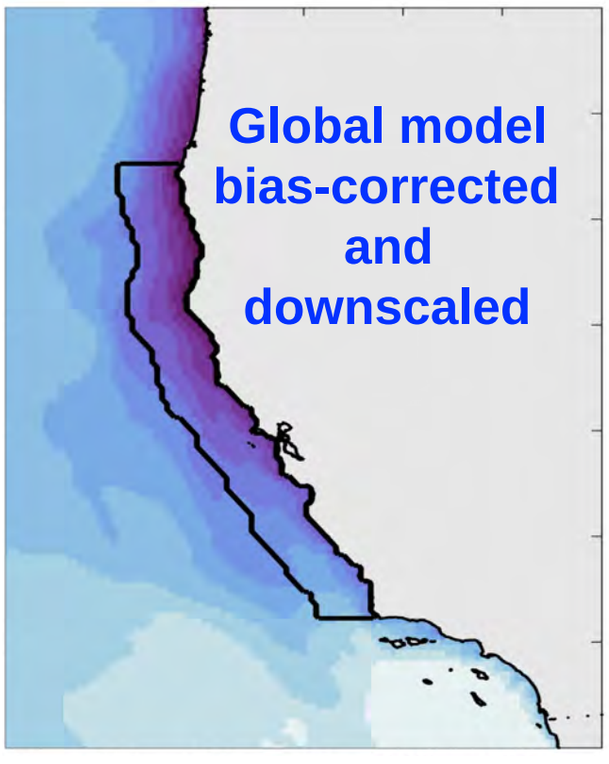
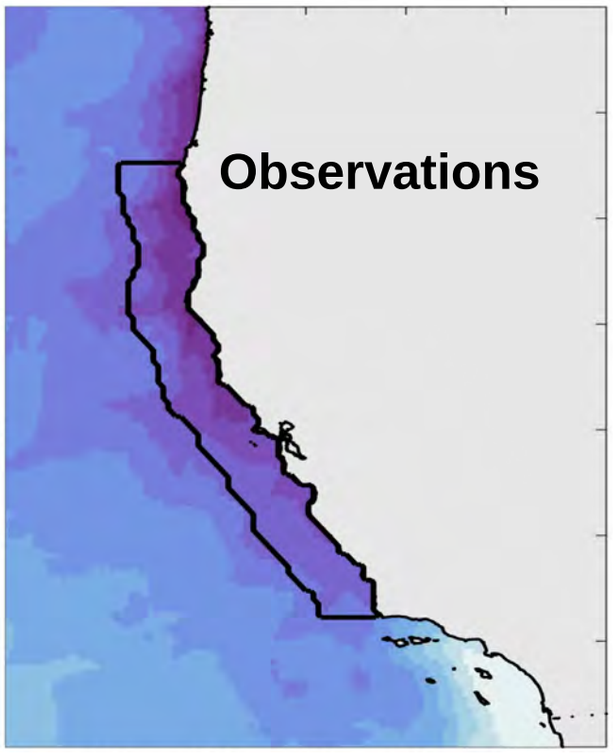
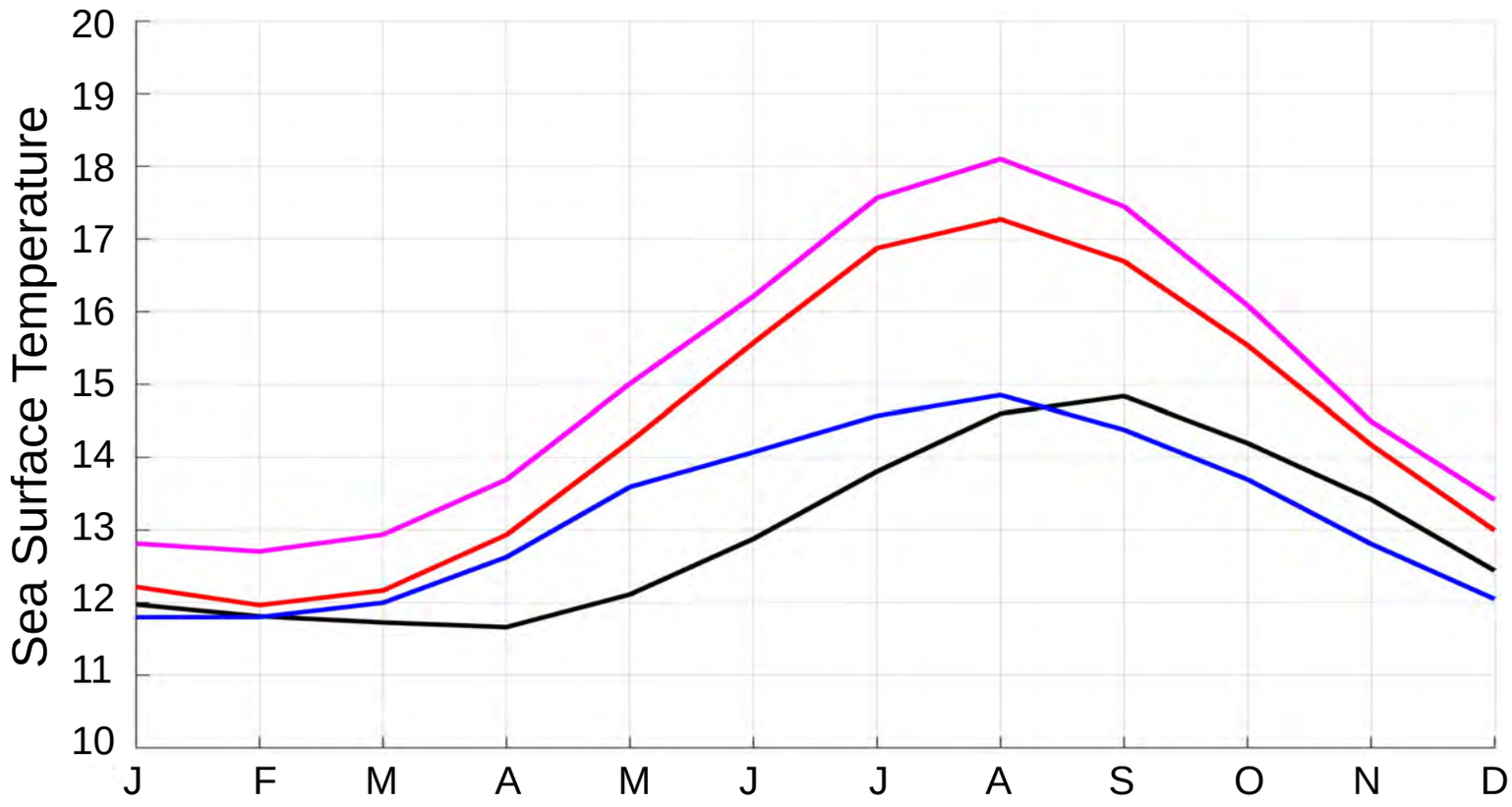
8


Global model
downscaled


Global model
bias-corrected
and
downscaled


Observations


Sea Surface Temperature
20
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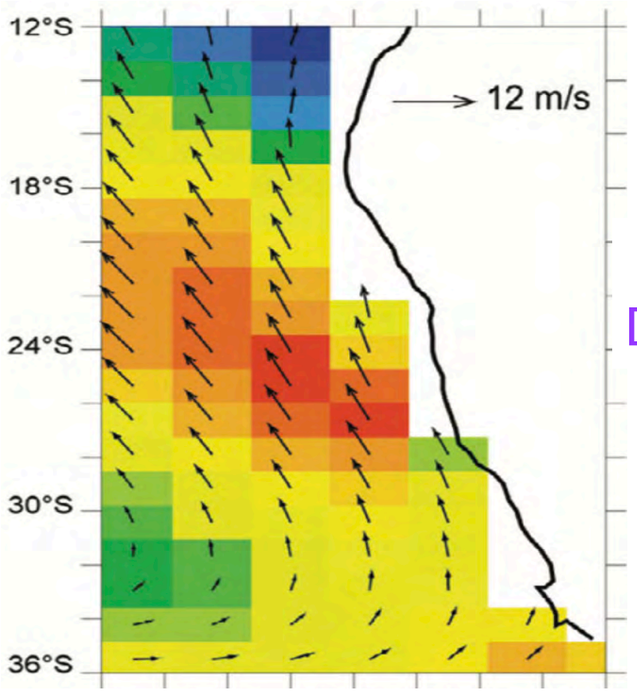
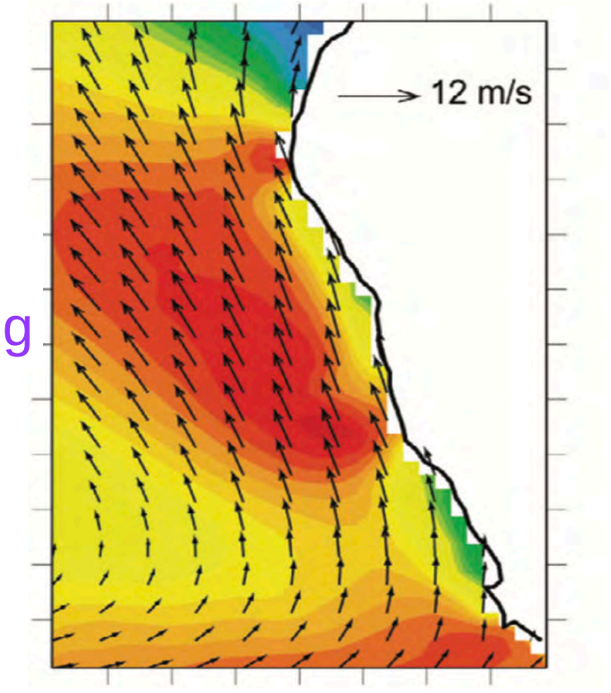
Global Model

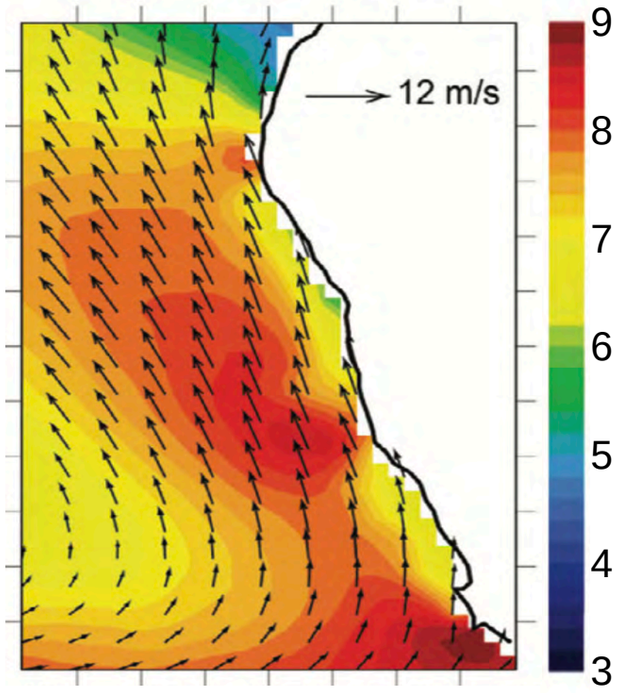


Statistical Downscaling

Global Model Downscaled



Observations

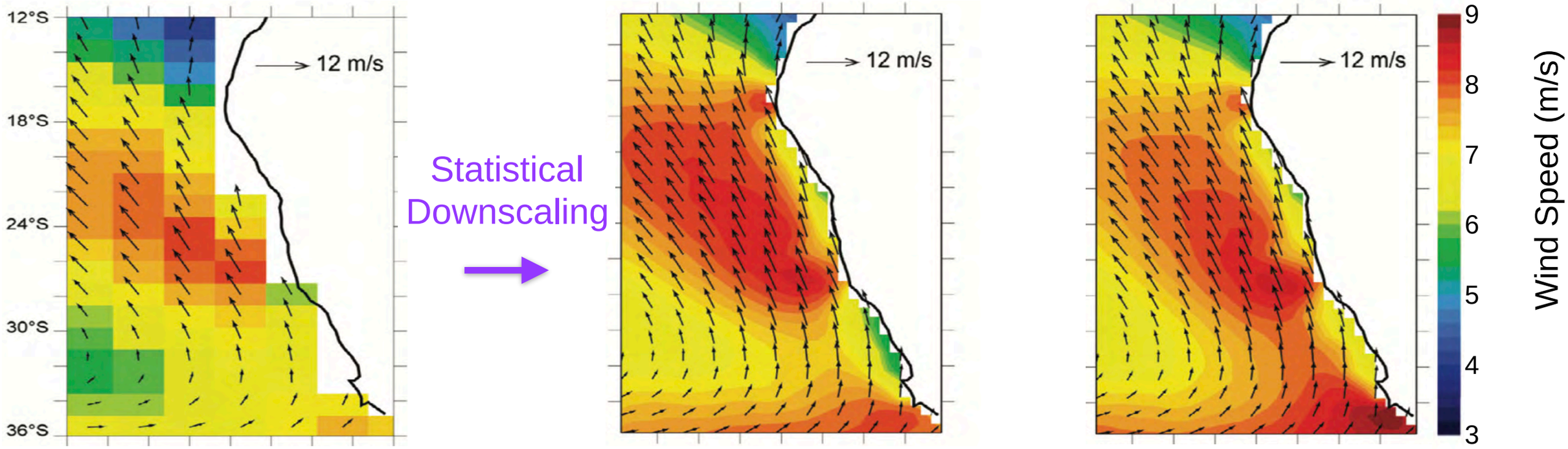


Machu et al. (2015)

Global Model

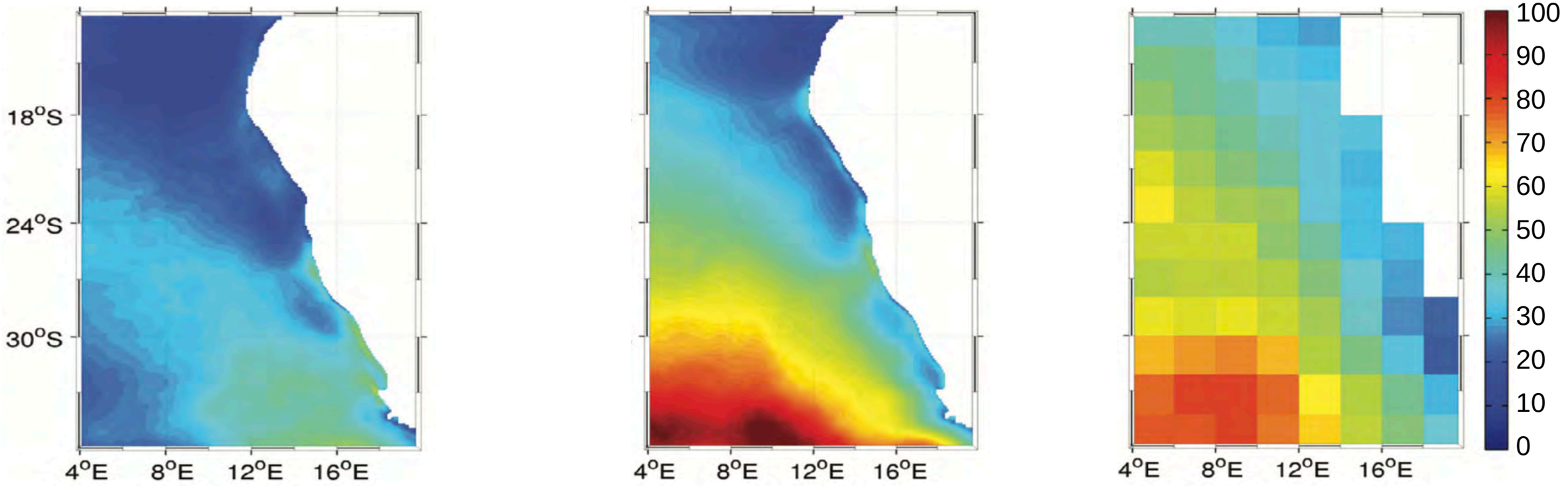
Global Model Downscaled

Observations

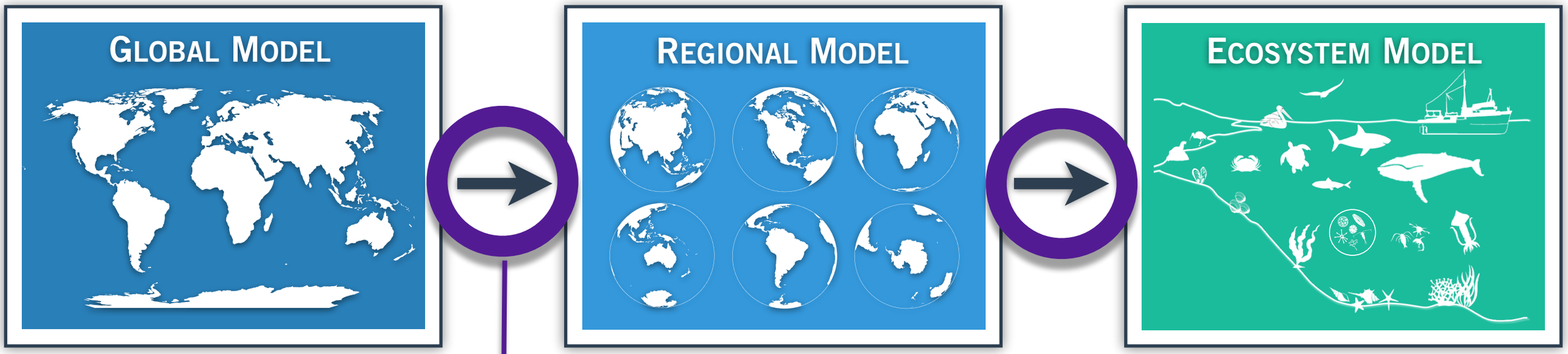


Statistical Downscaling

Dynamical Downscaling



Machu et al. (2015)



Which model(s)?

scenario uncertainty

vs.

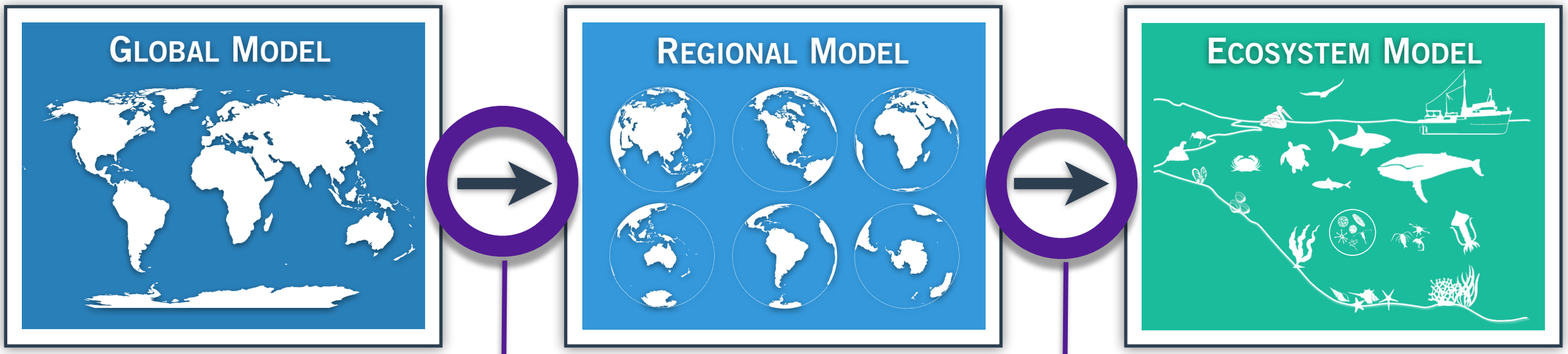
model uncertainty

vs.

internal variability

Ensemble size

Model Bias



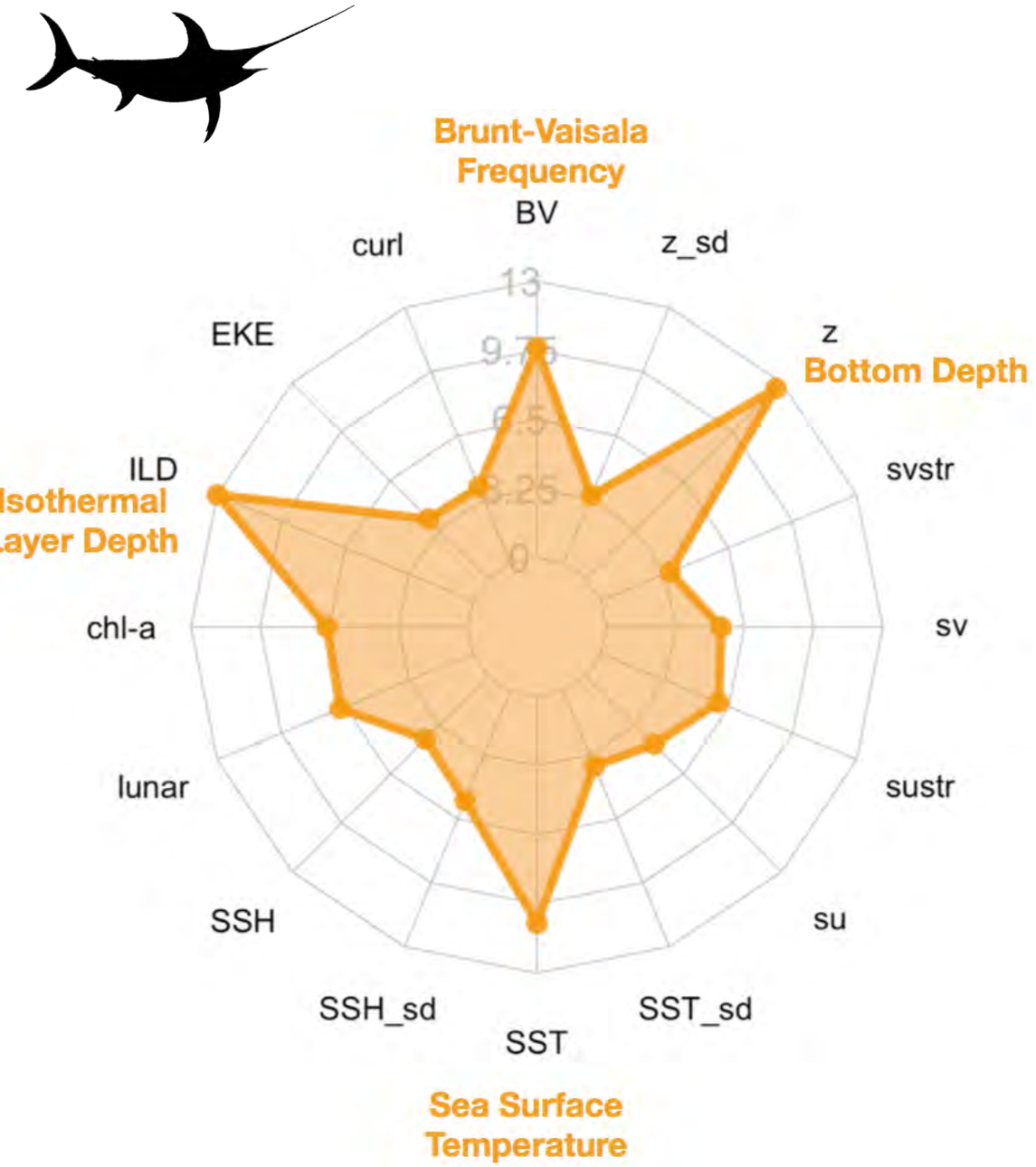
Which model(s)?

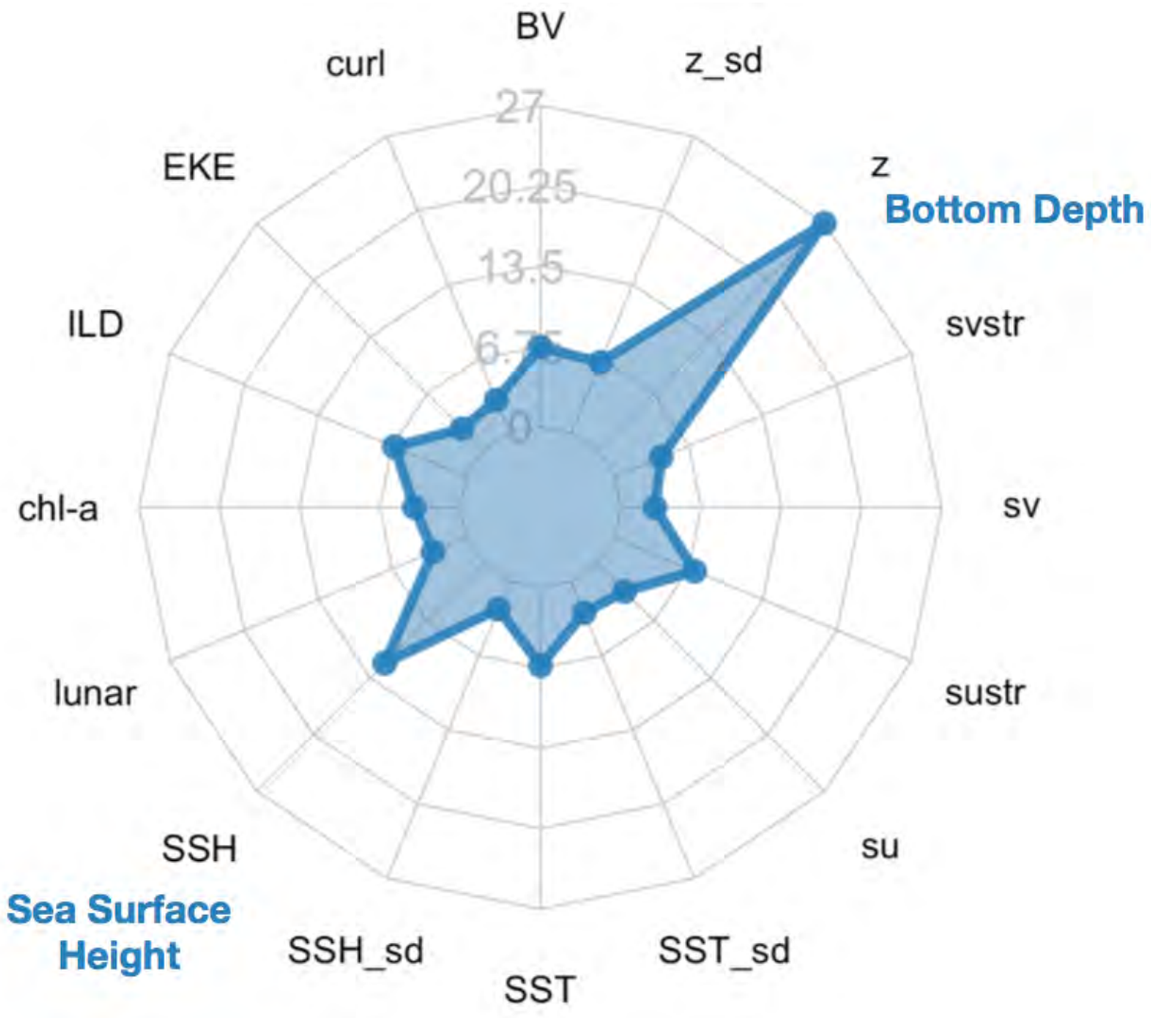
scenario uncertainty
vs.
model uncertainty
vs.
internal variability

Ensemble size

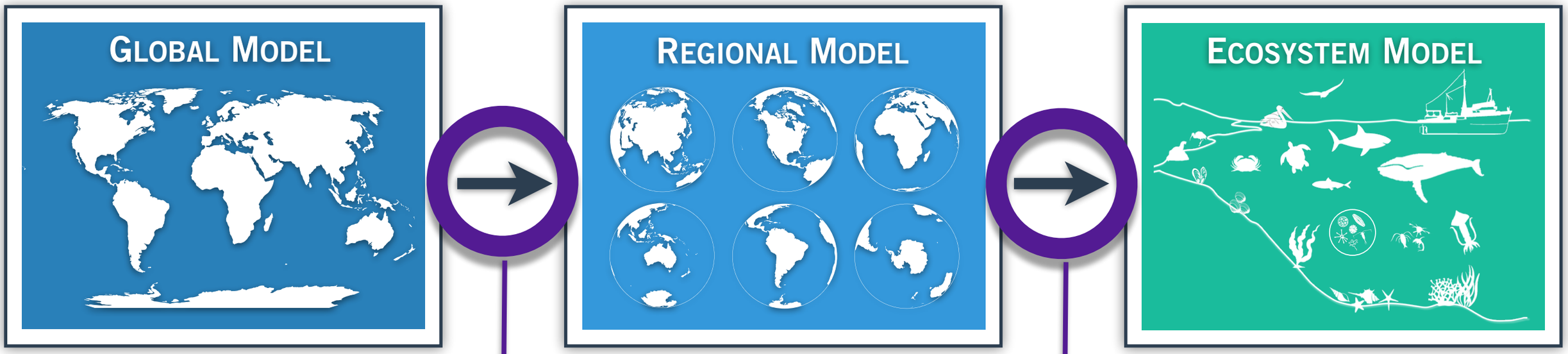
Model Bias

Which variables?





Brodie et al. (2018)



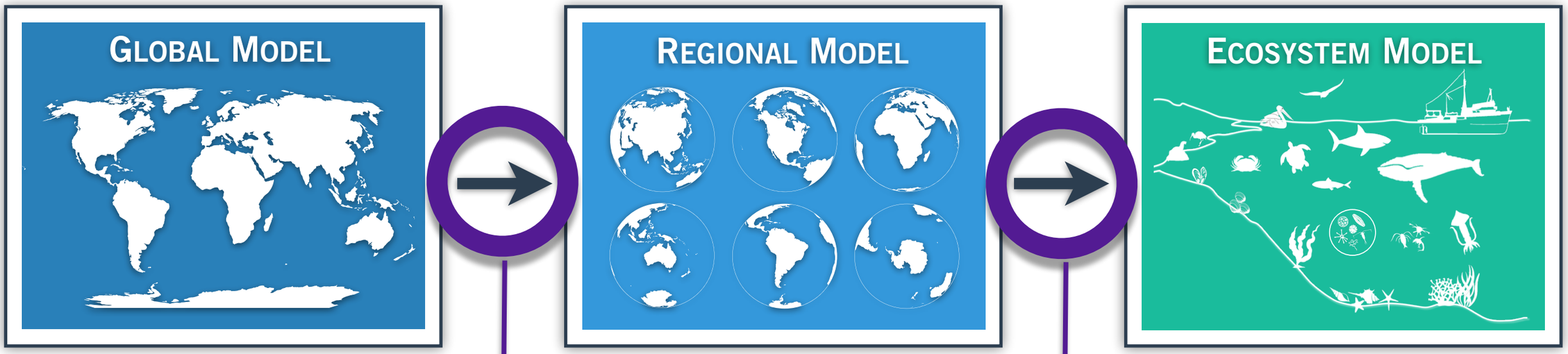
Which model(s)?

scenario uncertainty
vs.
model uncertainty
vs.
internal variability

Ensemble size

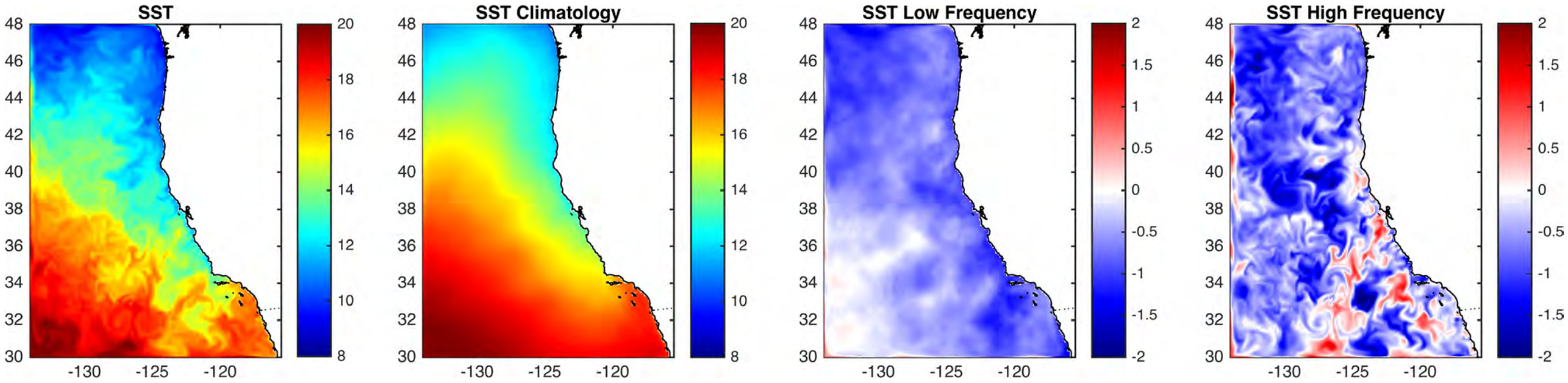
Model Bias

Which variables?

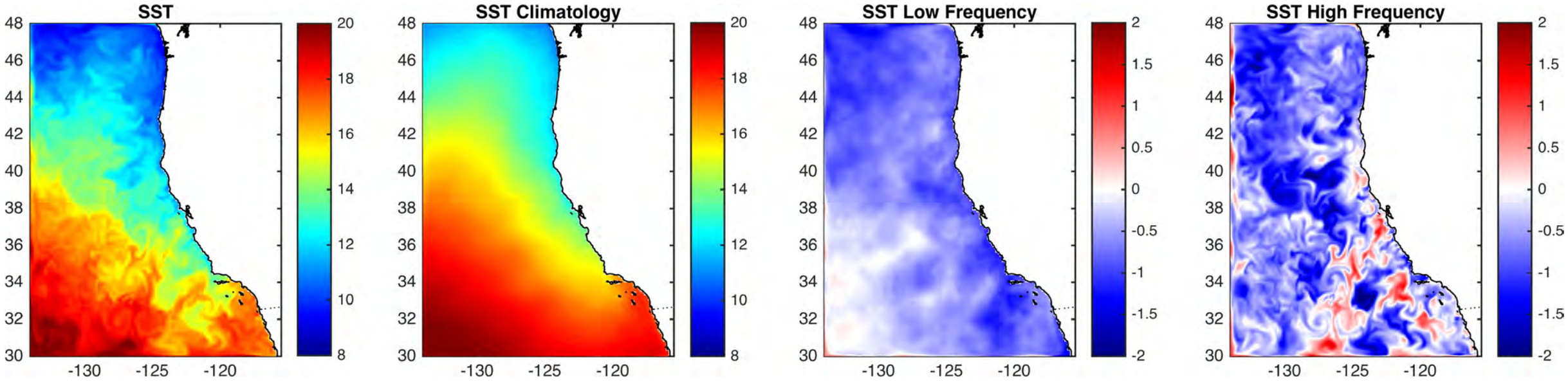


- Which model(s)?
  - scenario uncertainty
    vs.
    model uncertainty
    vs.
    internal variability
  - Ensemble size
  - Model Bias
- Which variables?
- Which spatiotemporal scales?

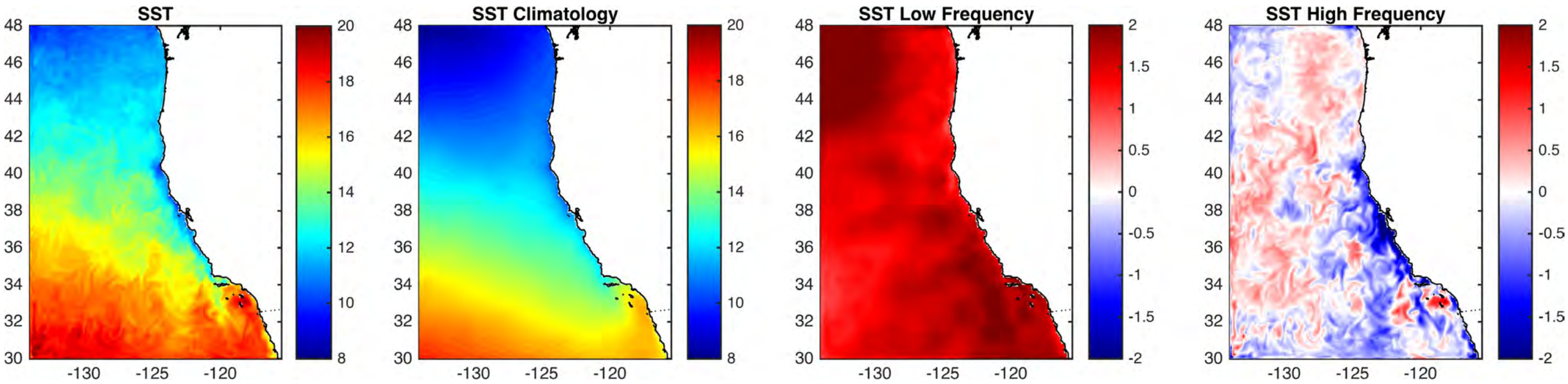
November 23, 2007 (La Niña)

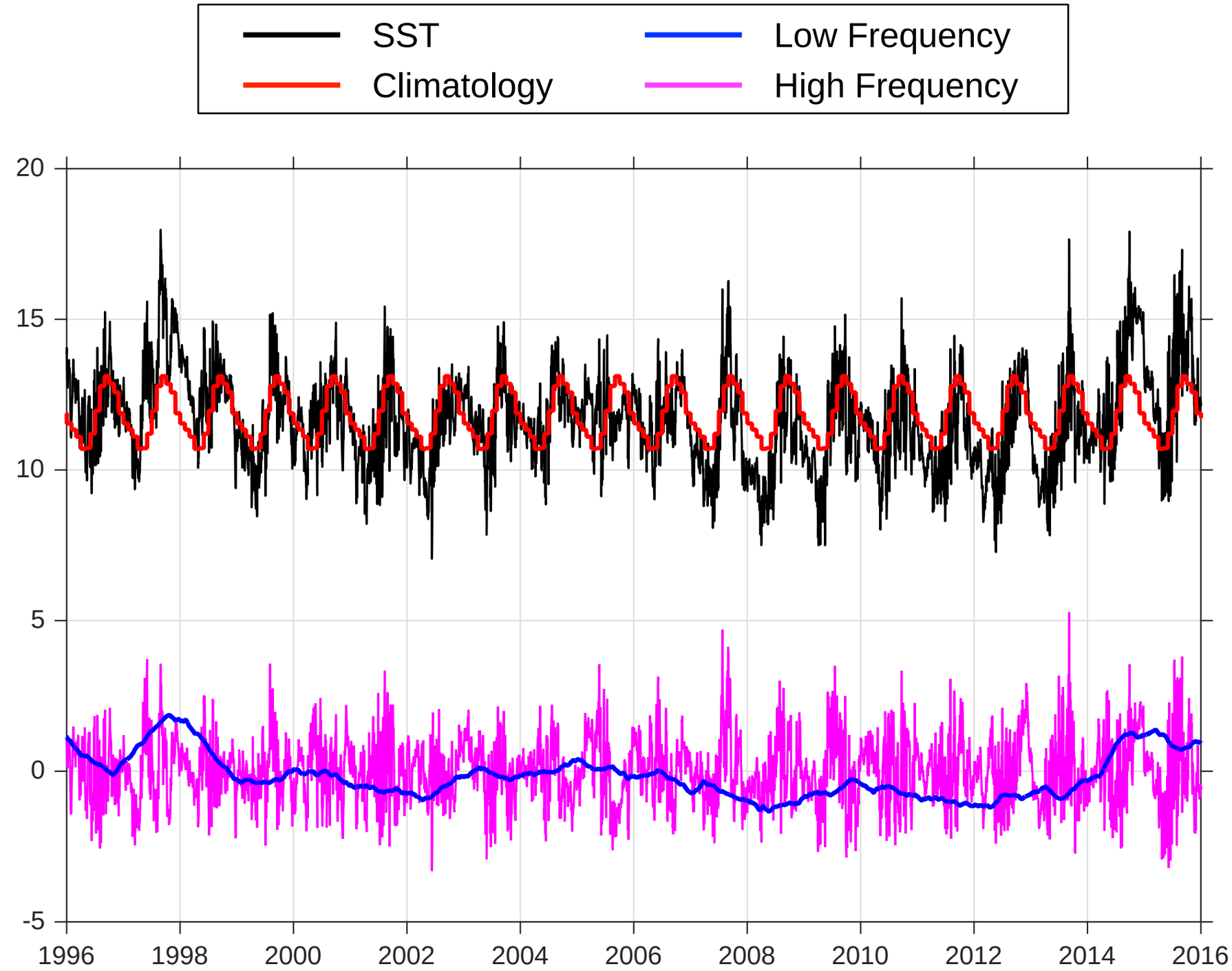


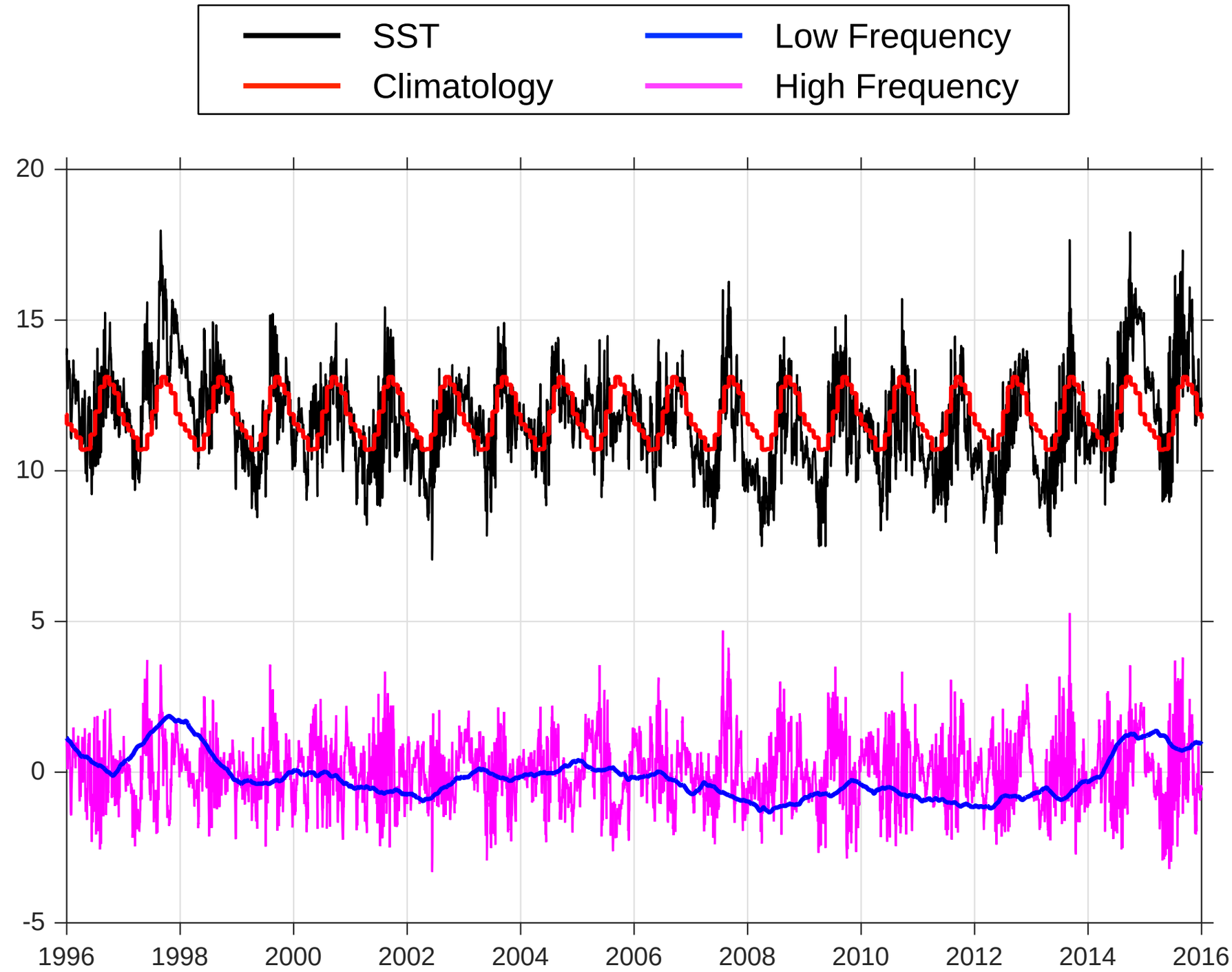
November 23, 2007 (La Niña)

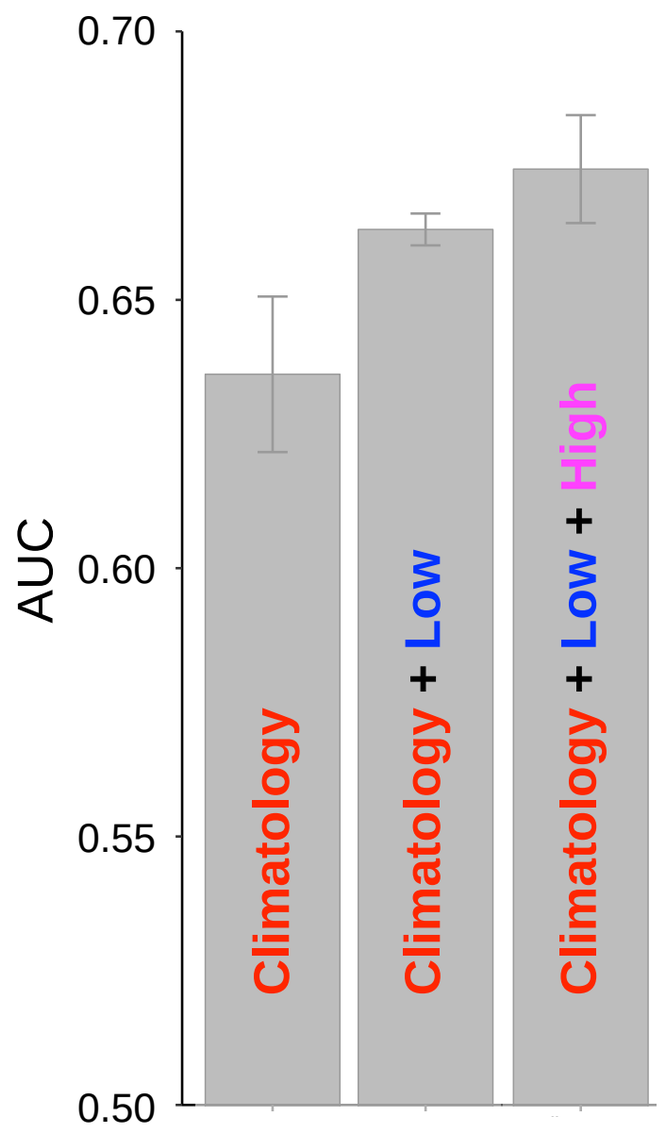


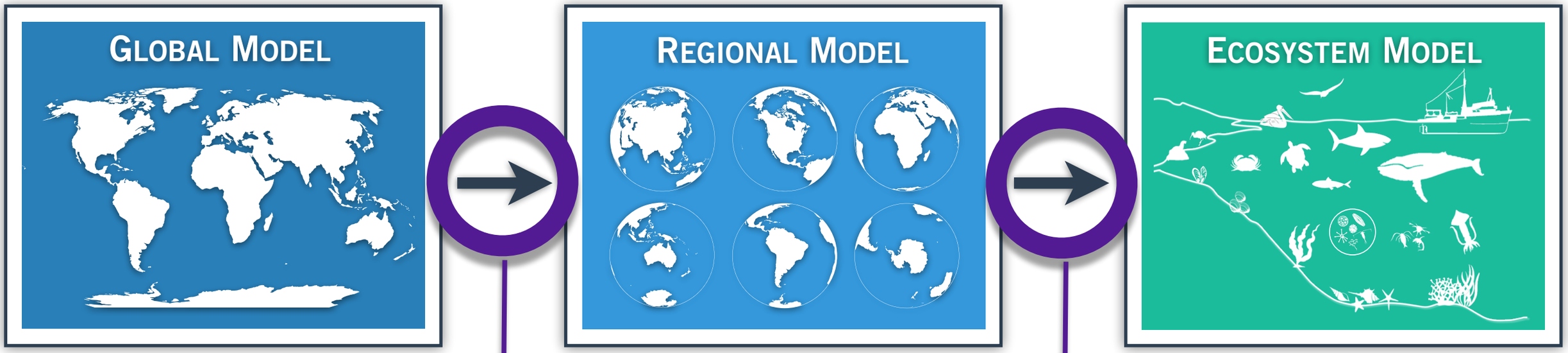
April 15, 2015 (NE Pacific Warm Anomaly)




SST
Climatology
Low Frequency
High Frequency
20
15
10
5
0
-5
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016


SST
Climatology
Low Frequency
High Frequency
20
15
10
5
0
-5
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016


AUC
0.70
0.65
0.60
0.55
0.50
Climatology
Climatology + Low
Climatology + Low + High



Which model(s)?

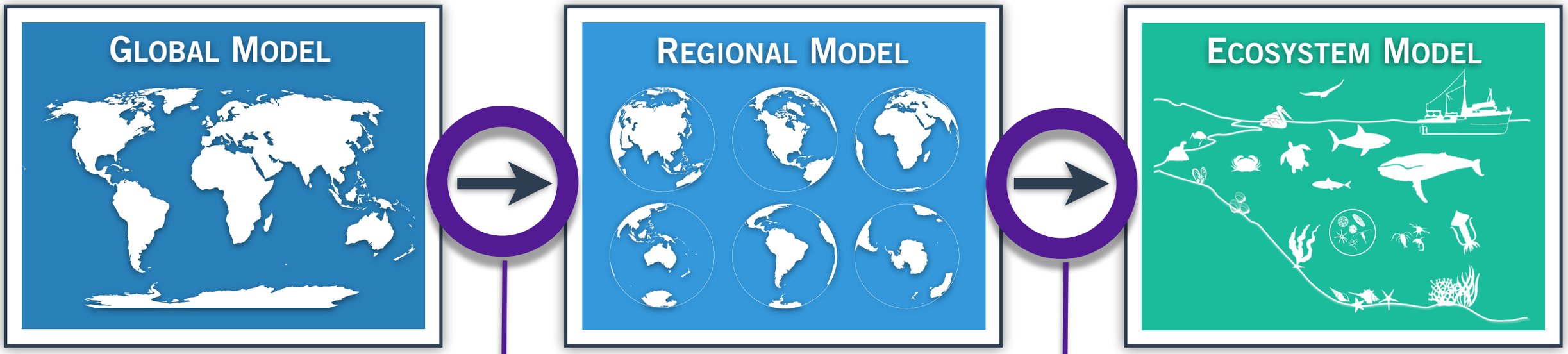
scenario uncertainty
vs.
model uncertainty
vs.
internal variability

Ensemble size

Model Bias

Which variables?

Which spatiotemporal scales?



Which model(s)?

scenario uncertainty
vs.
model uncertainty
vs.
internal variability

Ensemble size

Model Bias

Which variables?

Which spatiotemporal scales?

Consistent with predictability?