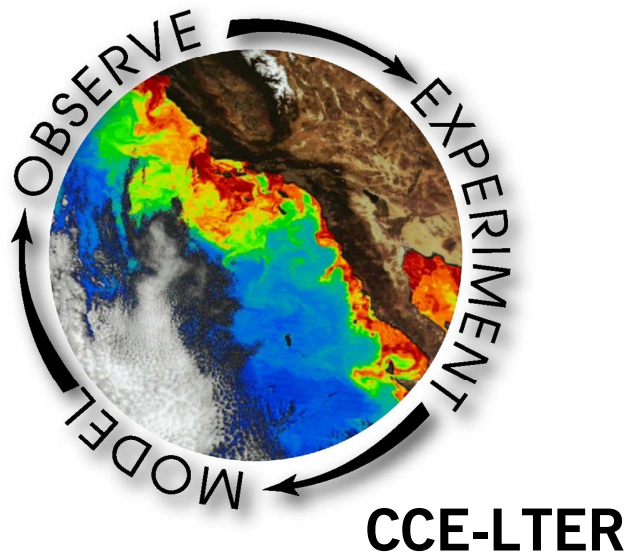


Decadal prediction of hypoxia along the US West Coast

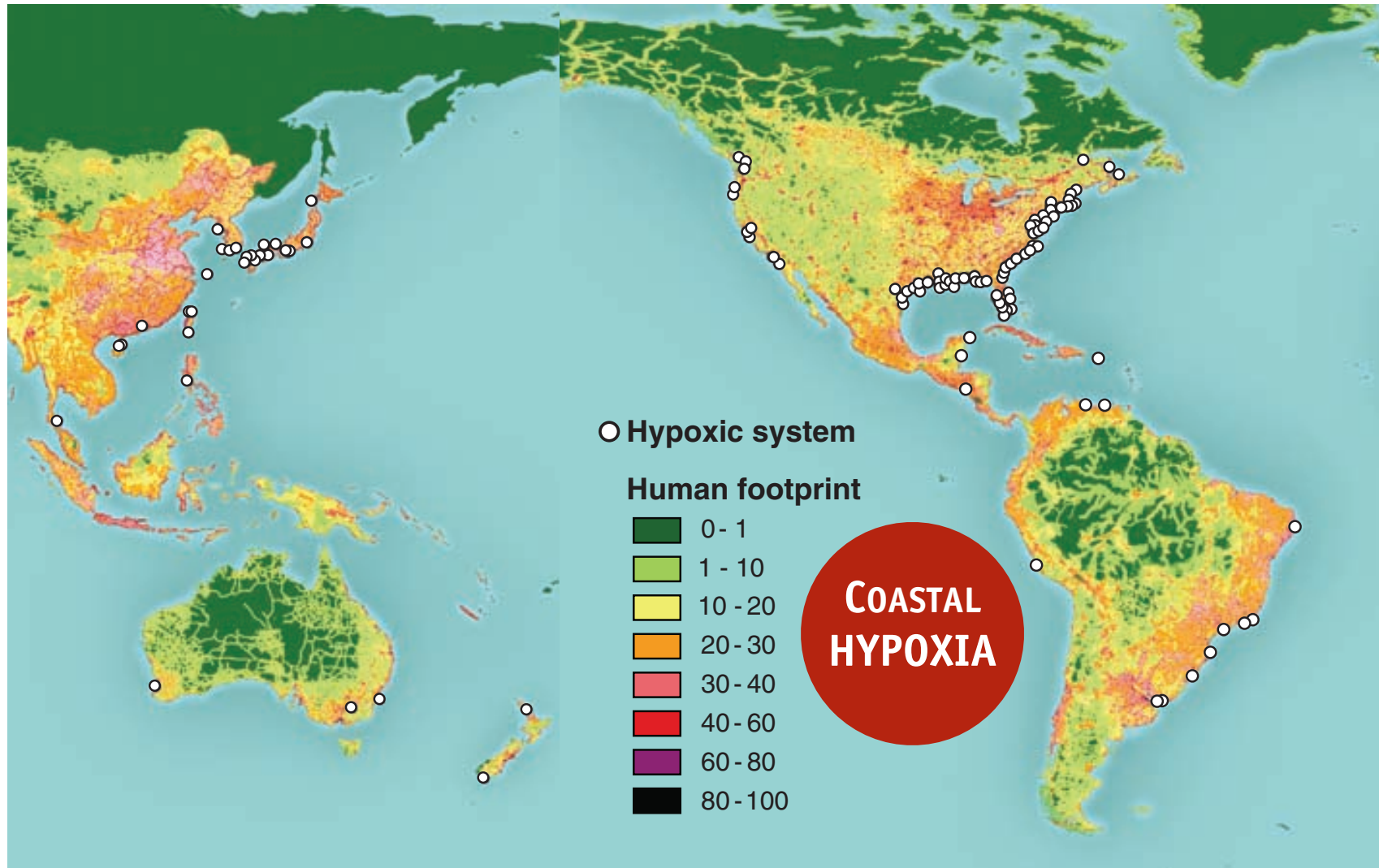
Mer Pozo-Buil, Emanuele Di Lorenzo, and Steve Bograd



**Georgia Institute
of Technology**

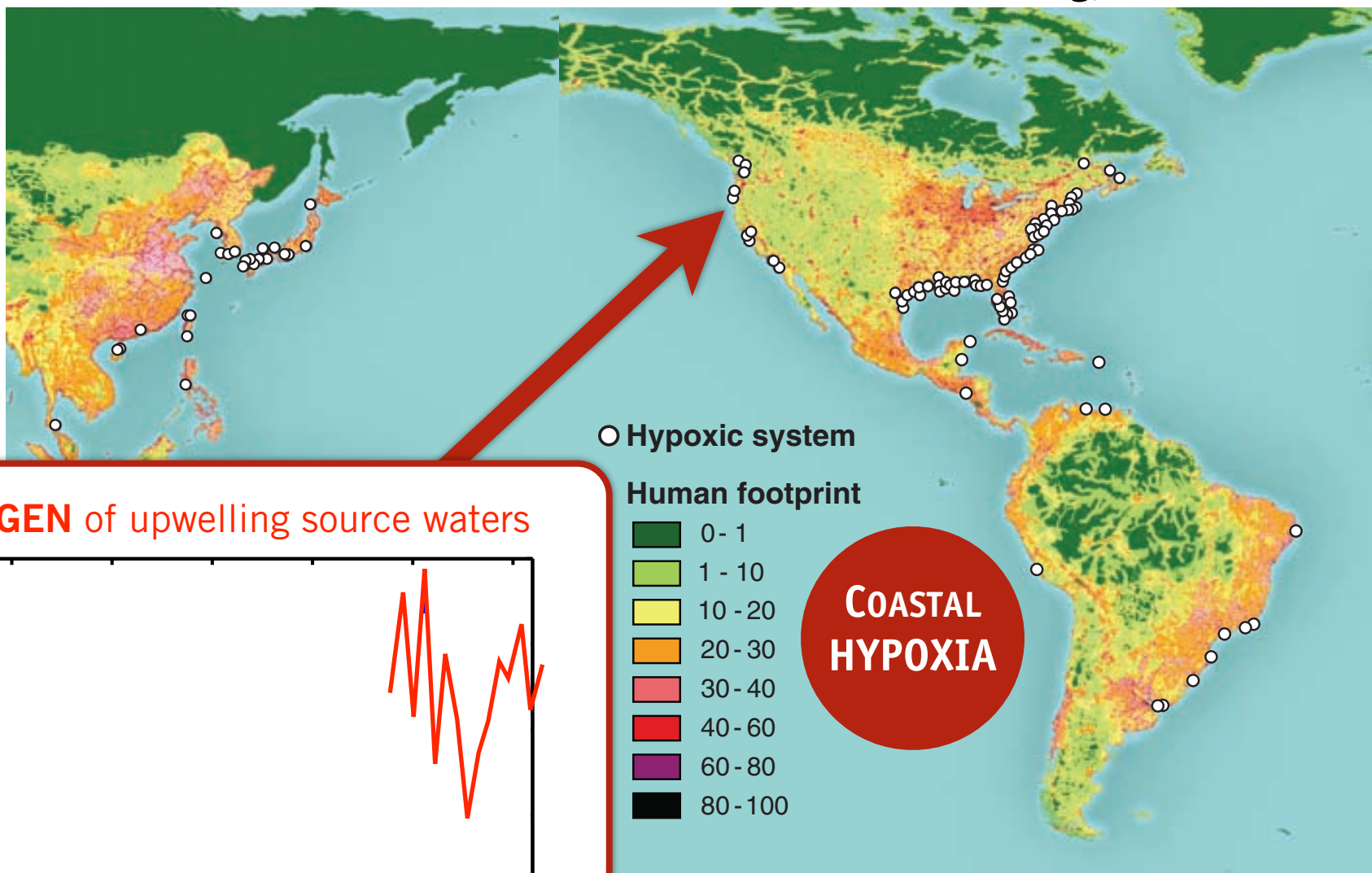
Human vs. physical controls of **COASTAL HYPOXIA**

Diaz and Rosenberg, Science 2008

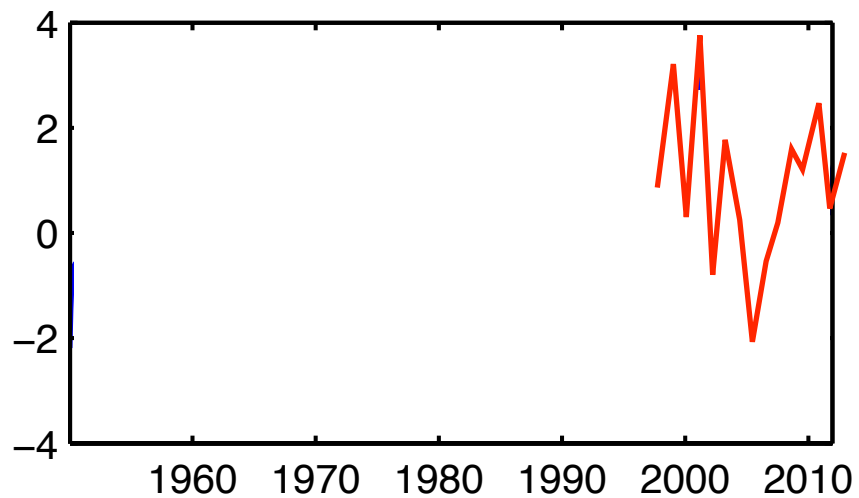


Human vs. physical controls of **COASTAL HYPOXIA**

Diaz and Rosenberg, Science 2008



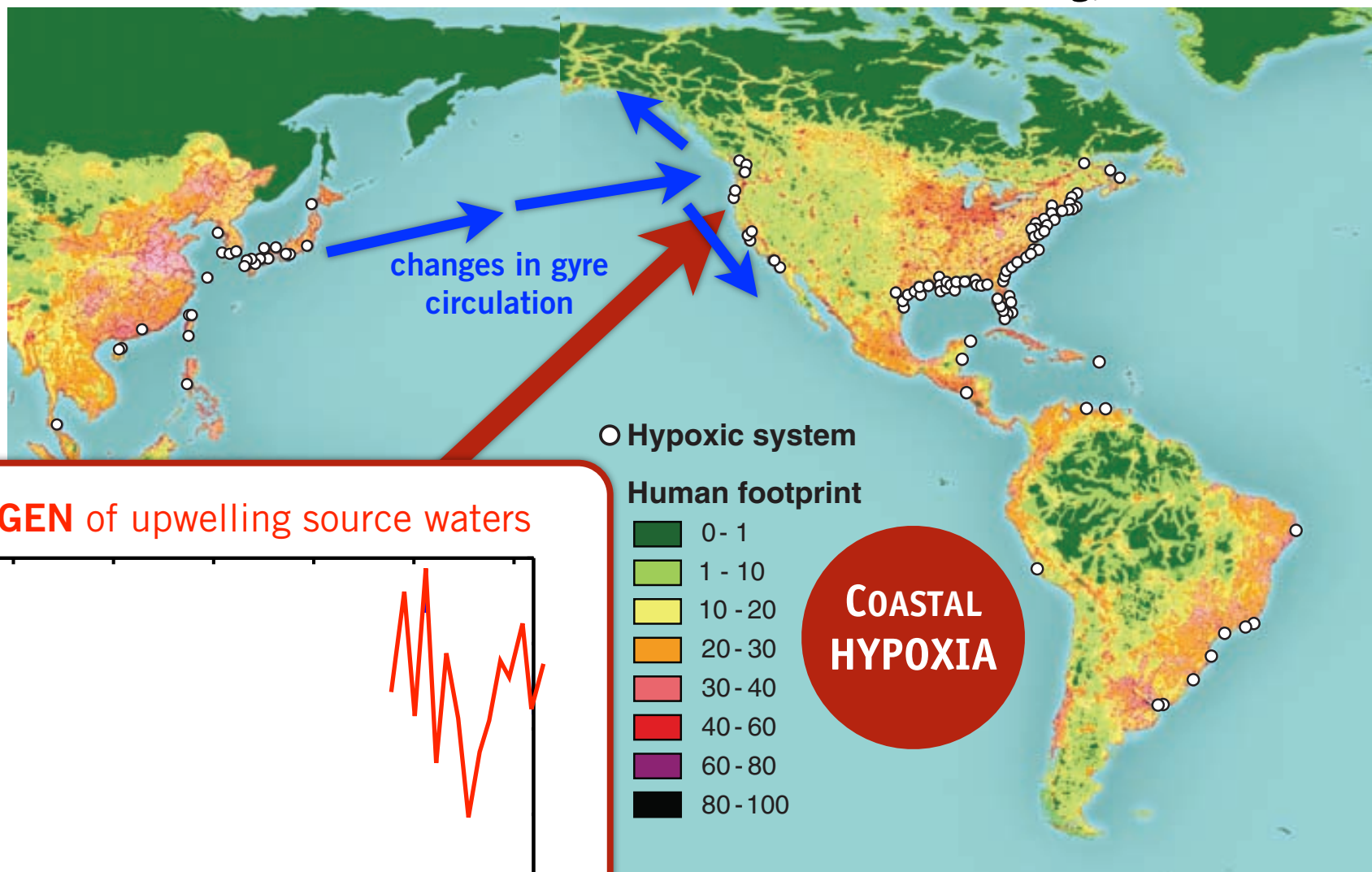
OXYGEN of upwelling source waters



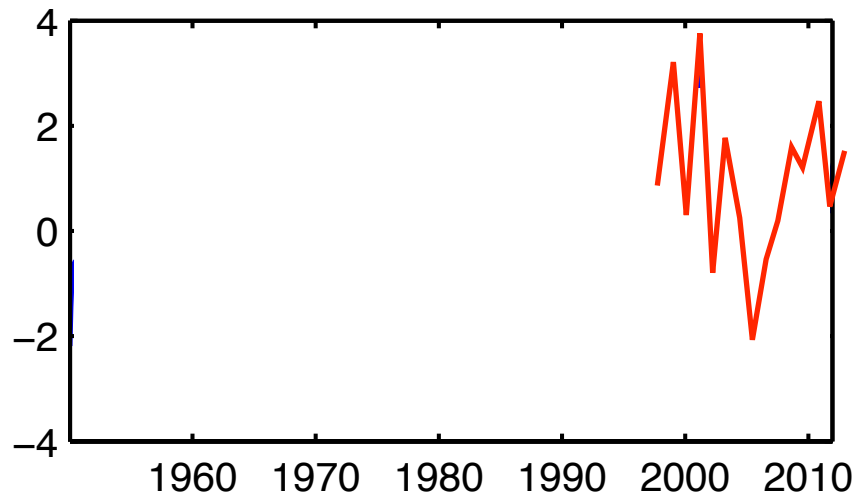
Oregon Shelf, observations by *Peterson et al. 2013*

Human vs. physical controls of **COASTAL HYPOXIA**

Diaz and Rosenberg, Science 2008



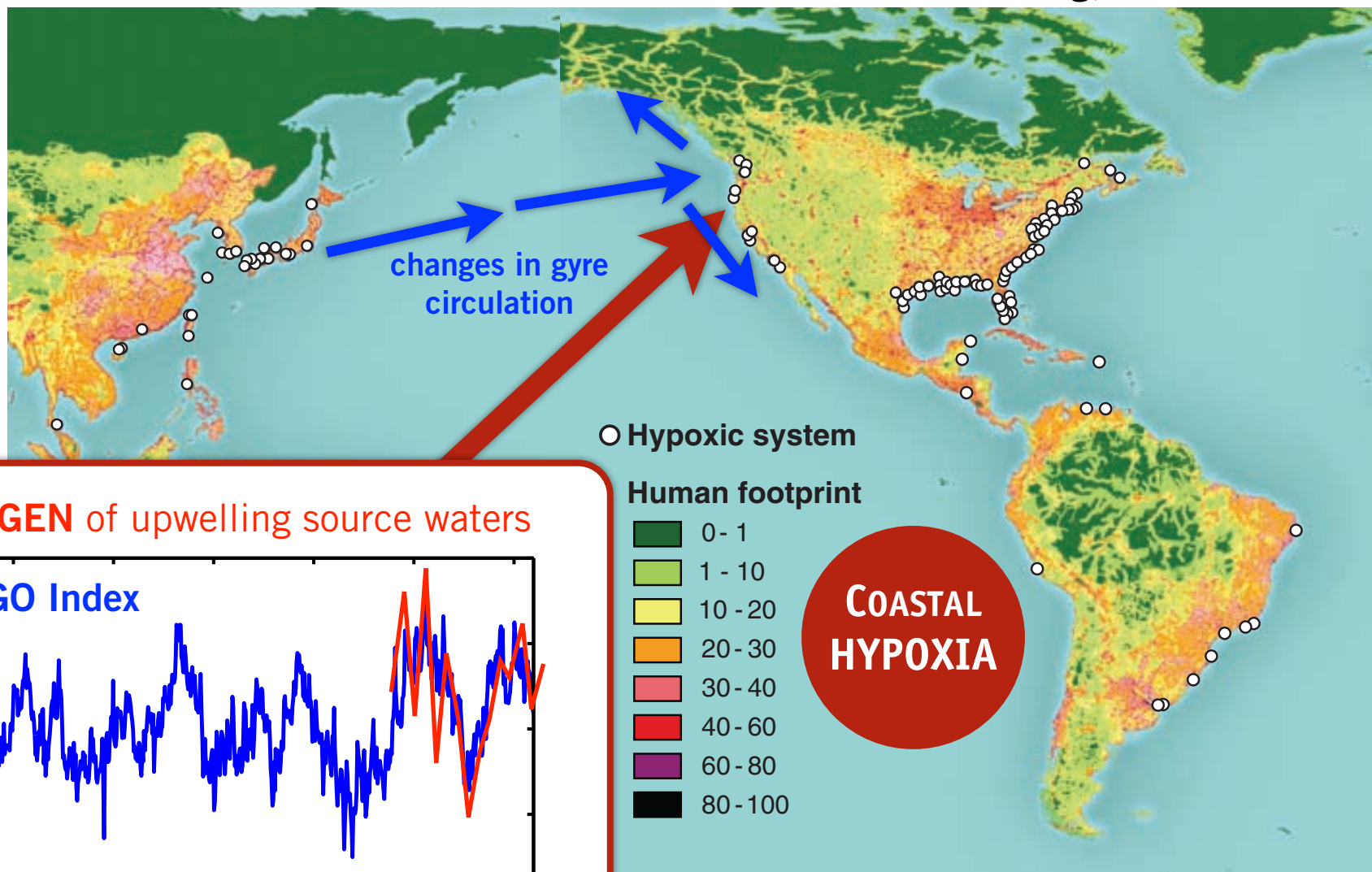
OXYGEN of upwelling source waters



Oregon Shelf, observations by *Peterson et al. 2013*

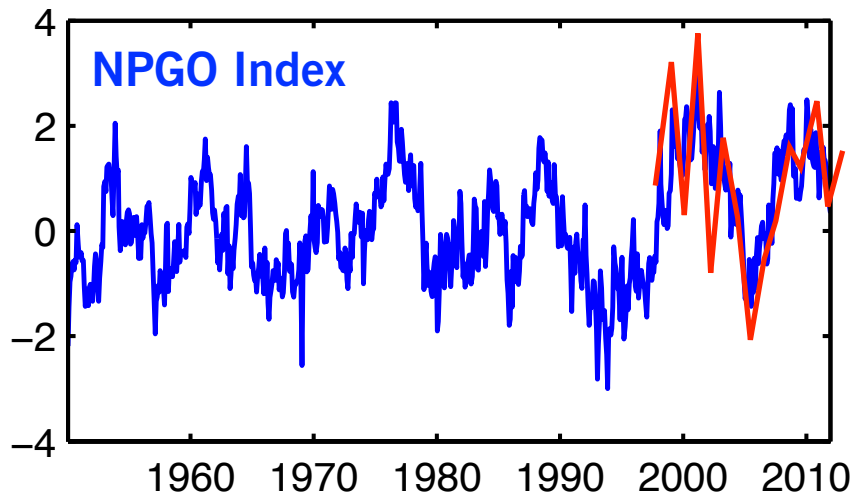
Human vs. physical controls of **COASTAL HYPOXIA**

Diaz and Rosenberg, Science 2008



OXYGEN of upwelling source waters

NPGO Index



Oregon Shelf, observations by *Peterson et al. 2013*

Human vs. physical controls of *COASTAL HYPOXIA*

QUESTION:

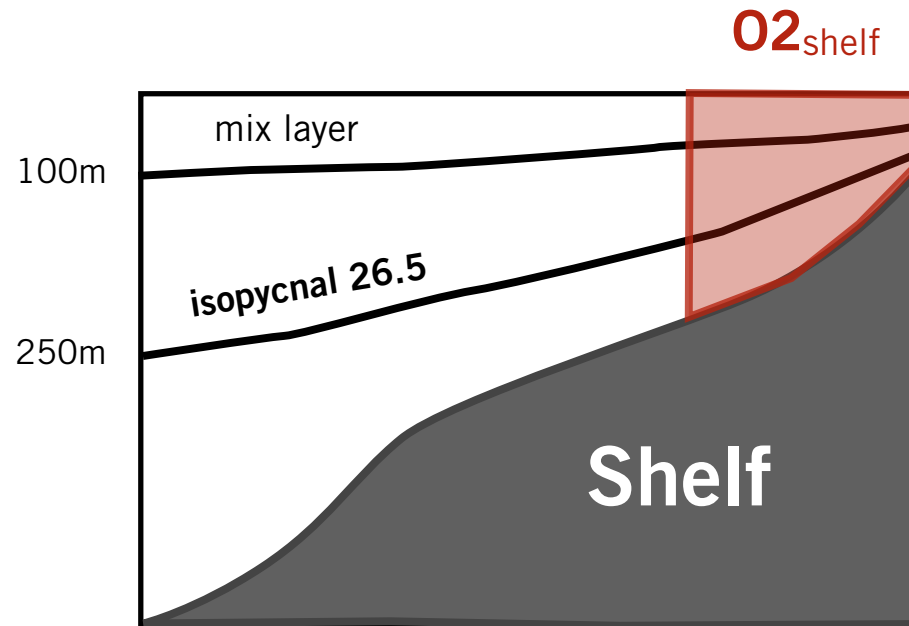
What are the large-scale ocean dynamics that impact *COASTAL HYPOXIA*?

Large-scale ocean dynamics impacting ***COASTAL HYPOXIA***

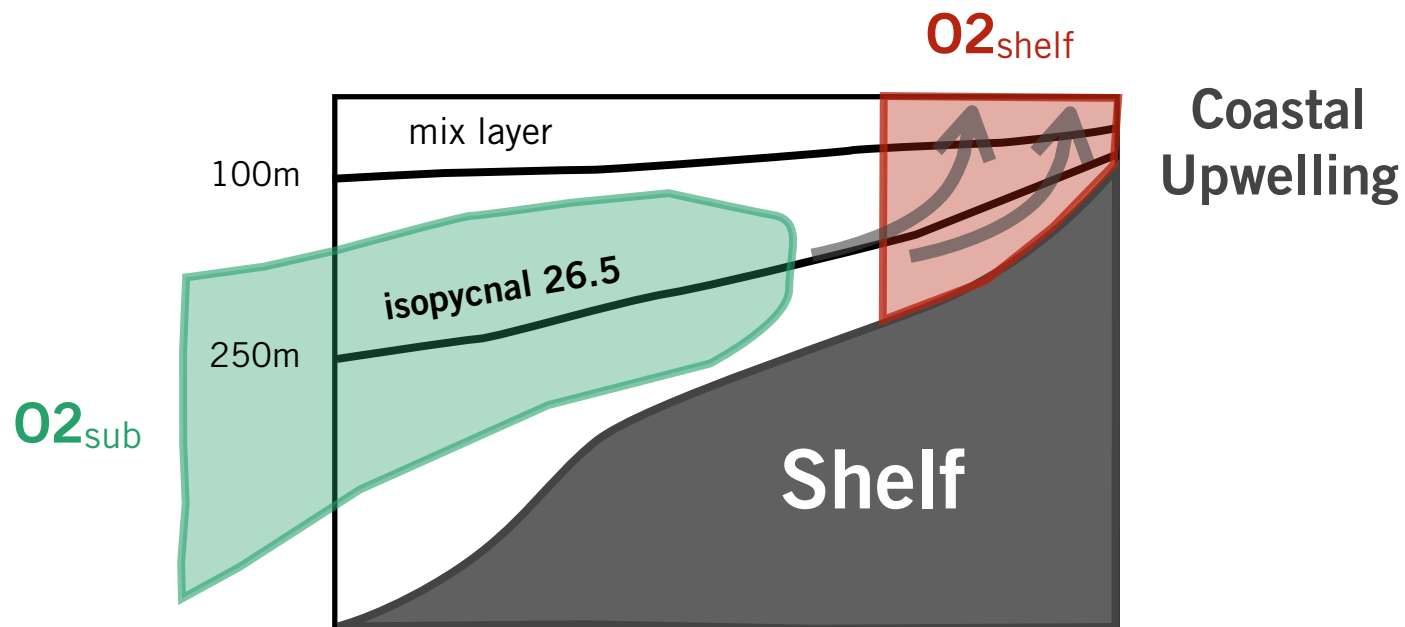
QUESTION:

What are the large-scale ocean dynamics that impact ***COASTAL HYPOXIA***?

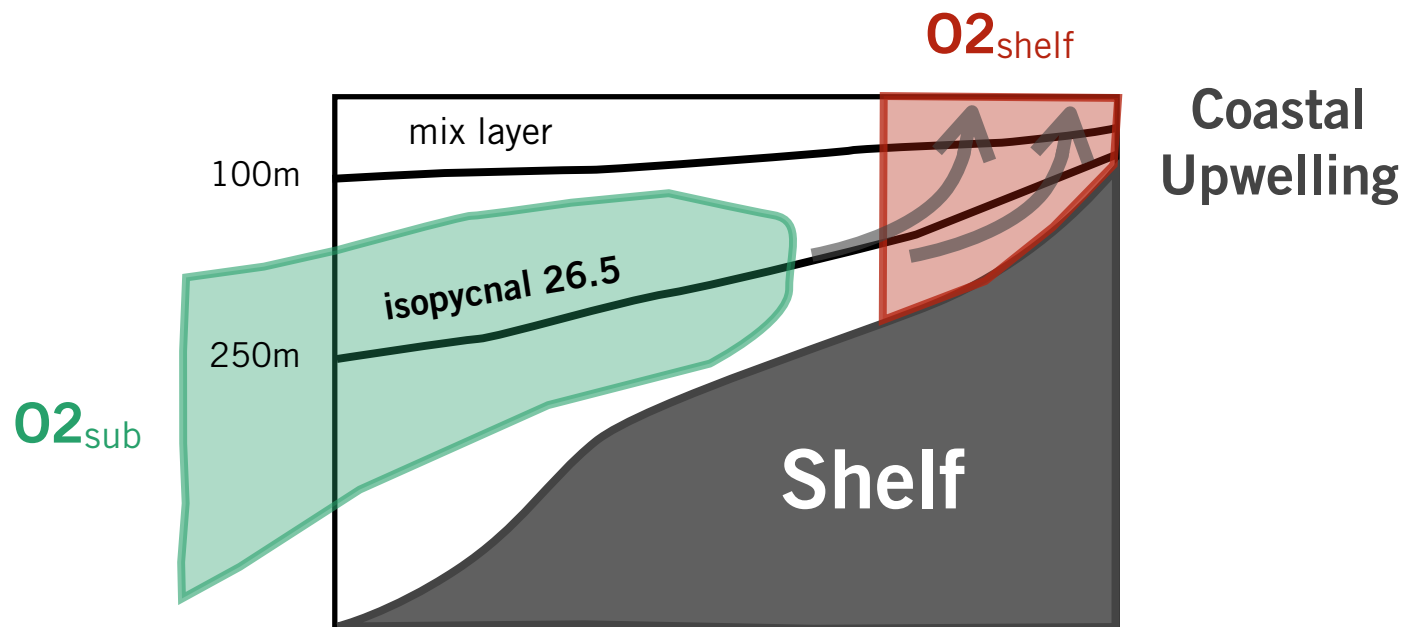
Large-scale ocean dynamics impacting *COASTAL HYPOXIA*



Large-scale ocean dynamics impacting *COASTAL HYPOXIA*



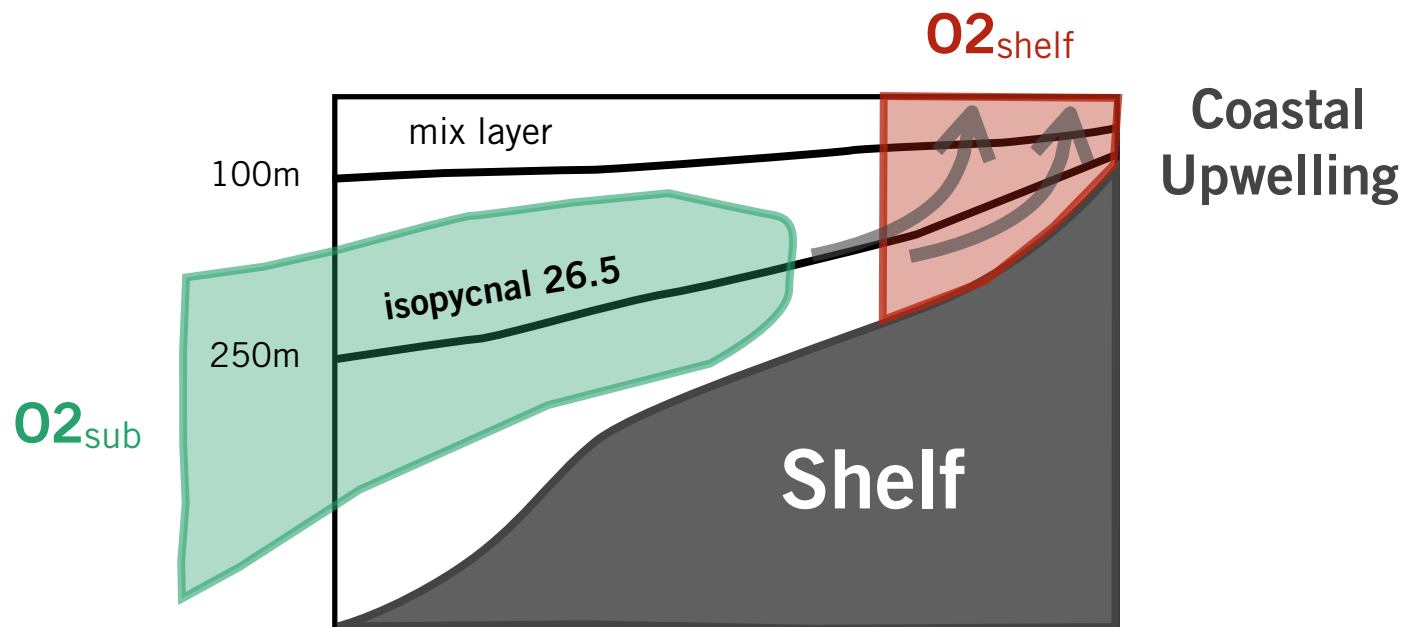
Large-scale ocean dynamics impacting **COASTAL HYPOXIA**



$$\frac{\partial O'_{shelf}}{\partial t} = -(1 + \lambda_{bio}) w' \cdot \bar{O}_{sub}$$

changes in upwelling
and productivity

Large-scale ocean dynamics impacting **COASTAL HYPOXIA**

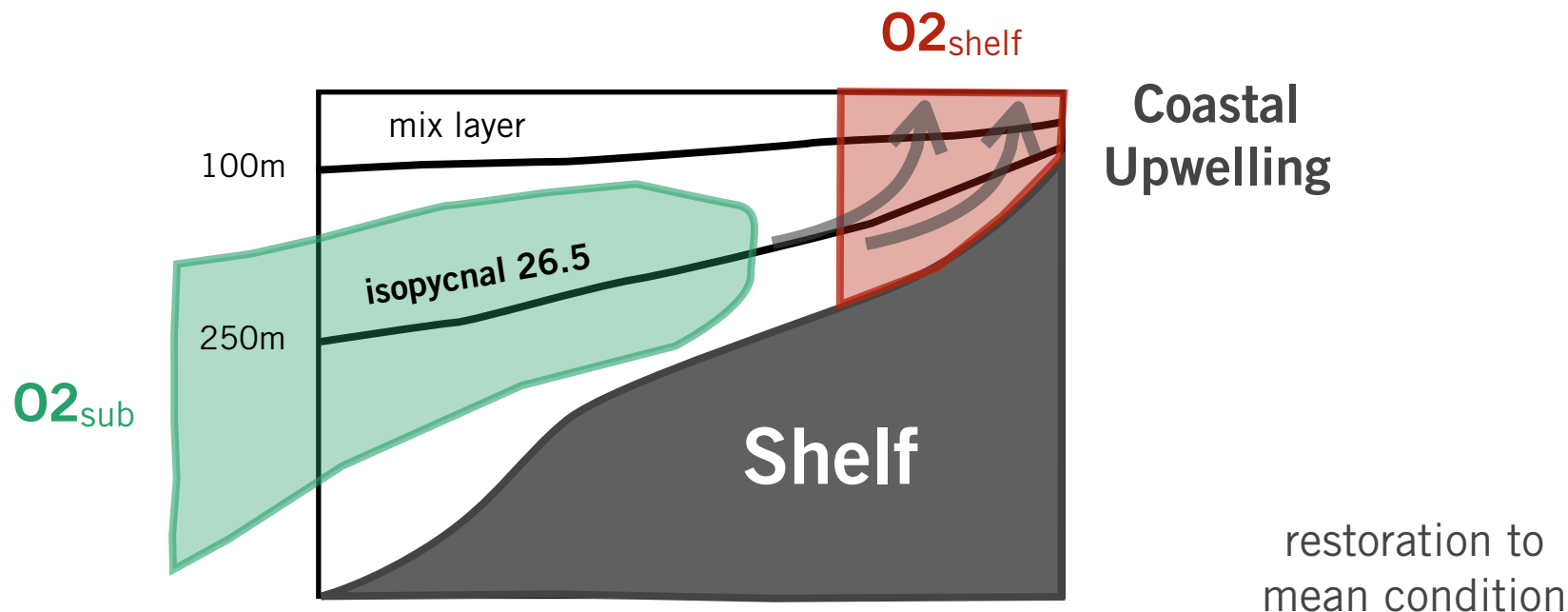


$$\frac{\partial O'_{shelf}}{\partial t} = -(1 + \lambda_{bio}) w' \cdot \bar{O}_{sub} + \bar{w} \cdot O'_{sub}$$

changes in upwelling
and productivity

anomalies in source waters
that feed mean upwelling

Large-scale ocean dynamics impacting **COASTAL HYPOXIA**

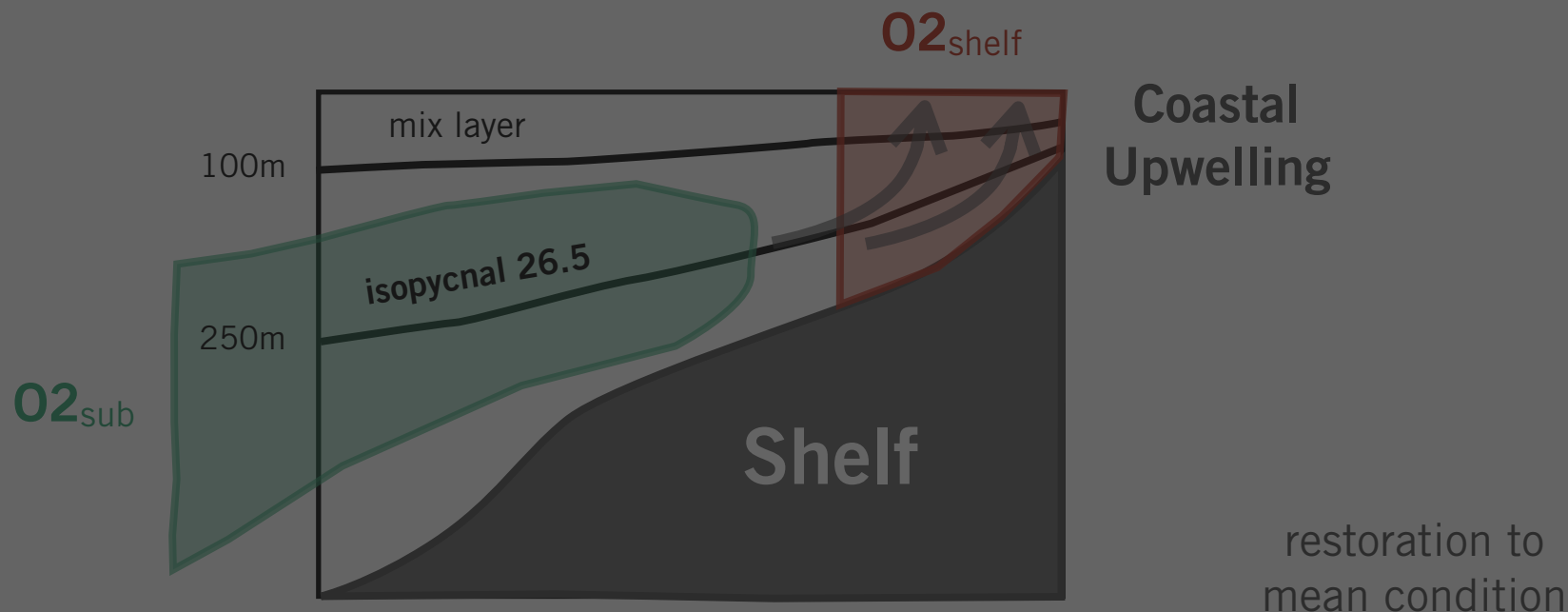


$$\frac{\partial O'_{shelf}}{\partial t} = -(1 + \lambda_{bio}) w' \cdot \bar{O}_{sub} + \bar{w} \cdot O'_{sub} - \epsilon O'_{shelf}$$

changes in upwelling
and productivity

anomalies in source waters
that feed mean upwelling

Large-scale ocean dynamics impacting **COASTAL HYPOXIA**



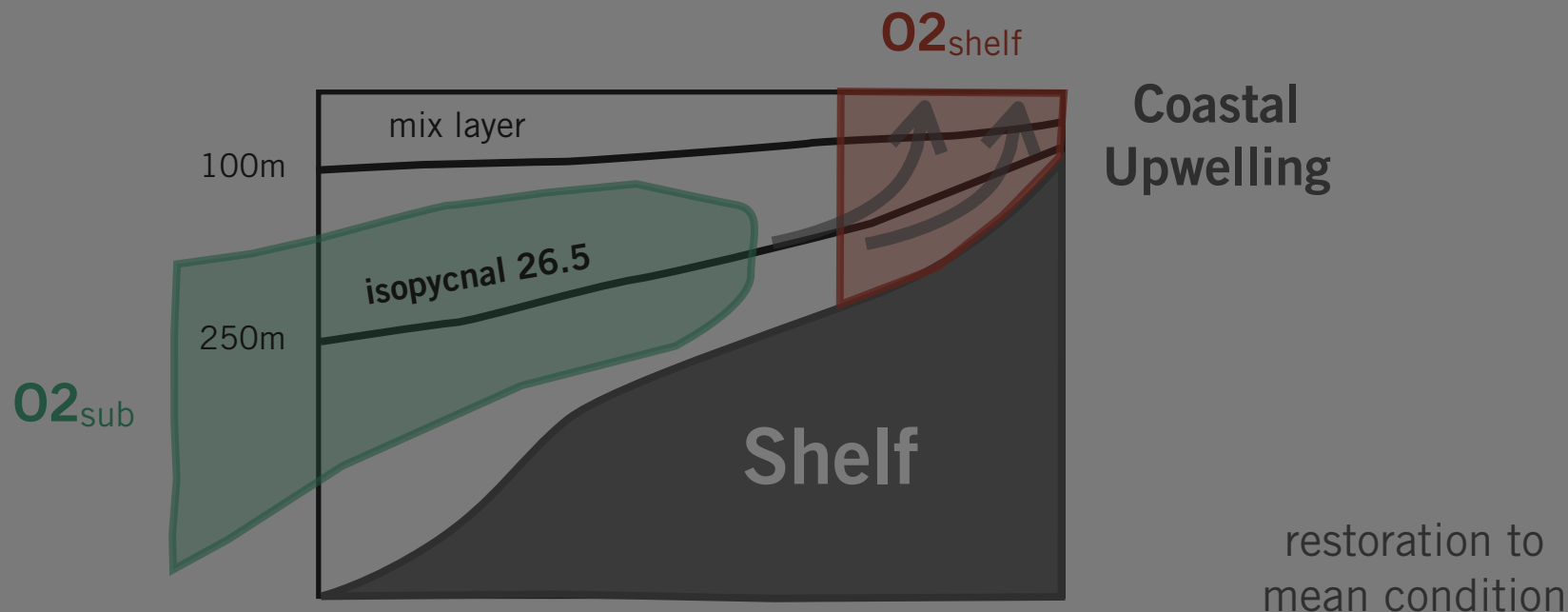
$$\frac{\partial O'_{shelf}}{\partial t} = -(1 + \lambda_{bio}) w' \cdot \bar{O}_{sub} - \bar{w} \cdot O'_{sub} - \epsilon O'_{shelf}$$

changes in upwelling and productivity

anomalies in source waters that feed mean upwelling

restoration to mean condition

Large-scale ocean dynamics impacting **COASTAL HYPOXIA**



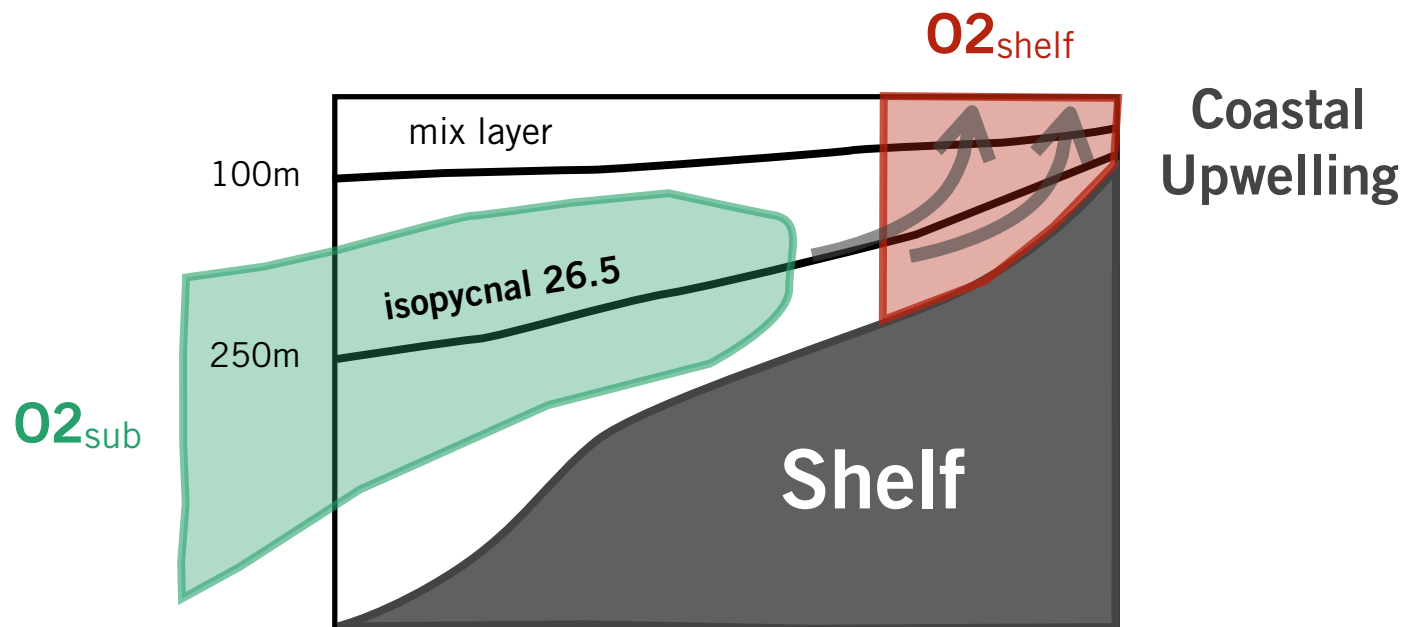
$$\frac{\partial O'_{shelf}}{\partial t} = -(1 + \lambda_{bio}) w' \cdot \bar{O}_{sub} + \bar{w} \cdot O'_{sub} - \epsilon O'_{shelf}$$

changes in upwelling and productivity

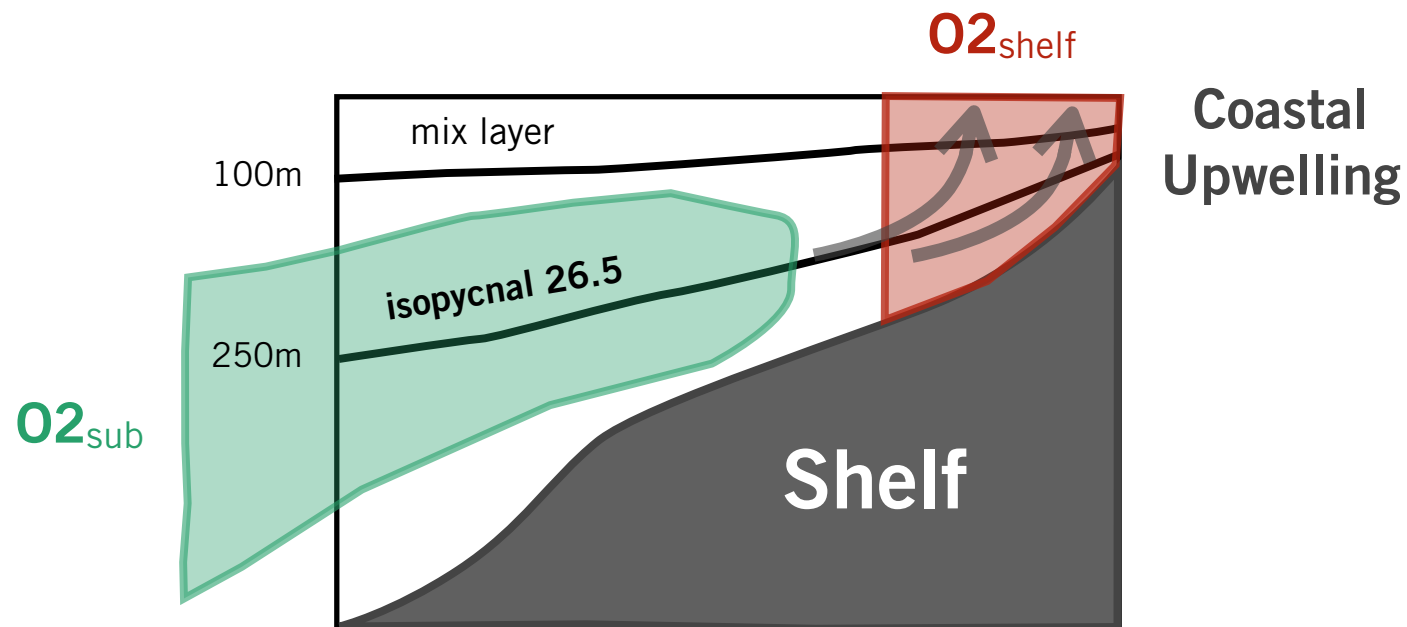
anomalies in source waters that feed mean upwelling

restoration to mean condition

Large-scale ocean dynamics impacting **COASTAL HYPOXIA**



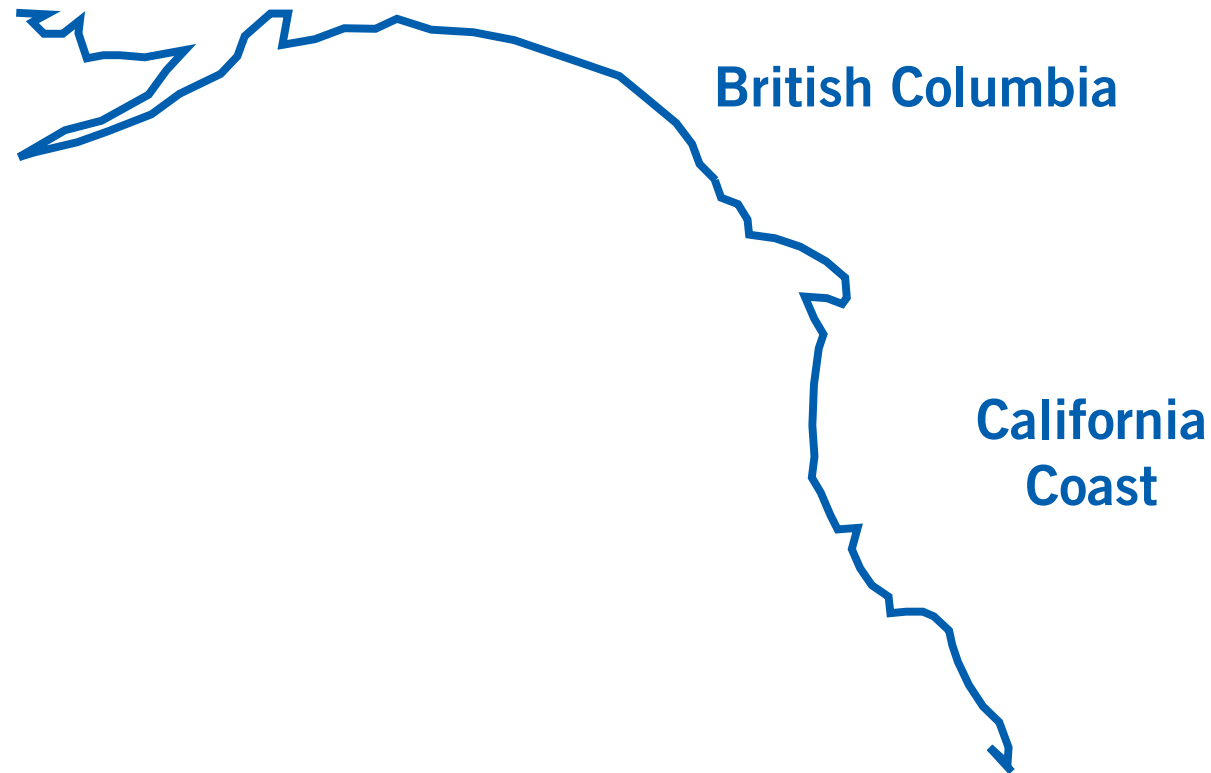
Large-scale ocean dynamics impacting *COASTAL HYPOXIA*



GOAL:

Develop a conceptual model of the large-scale dynamics controlling $O2_{sub}$

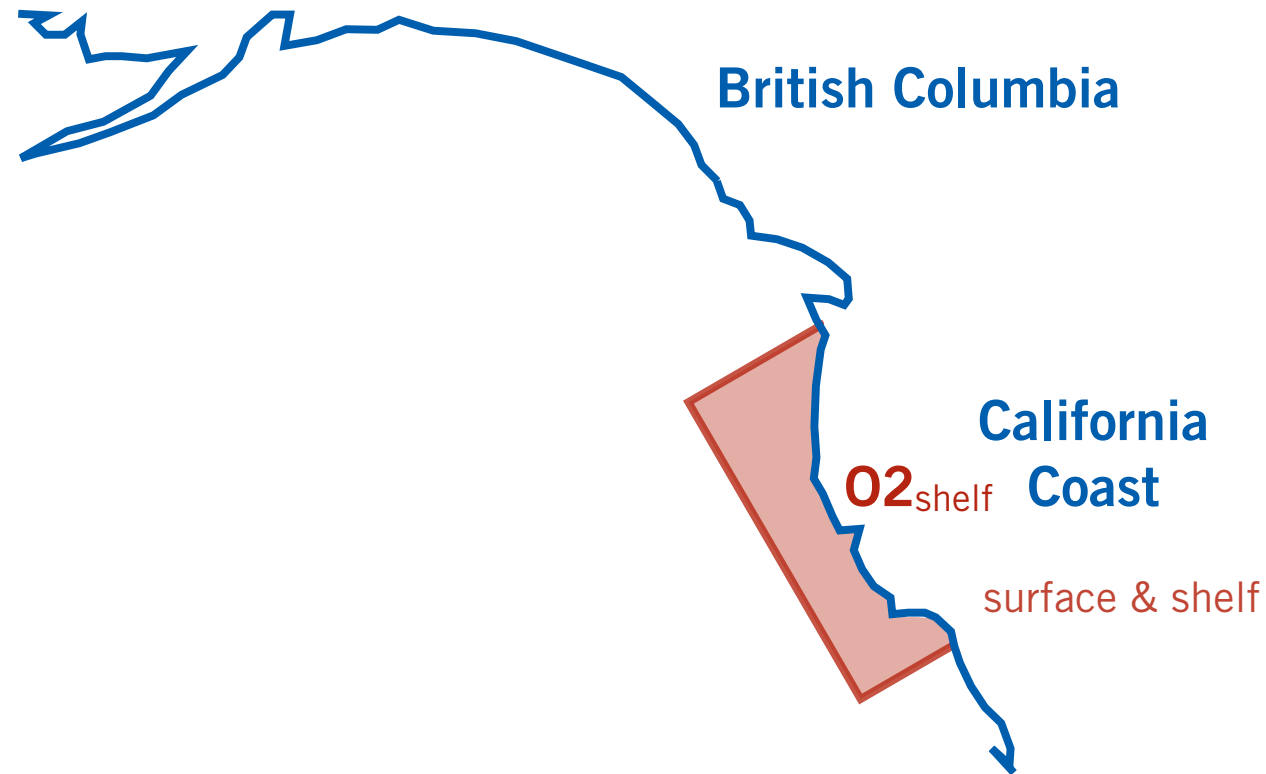
Large-scale ocean dynamics impacting Coastal Hypoxia



GOAL:

Develop a conceptual model of the large-scale dynamics controlling **O₂_{sub}**

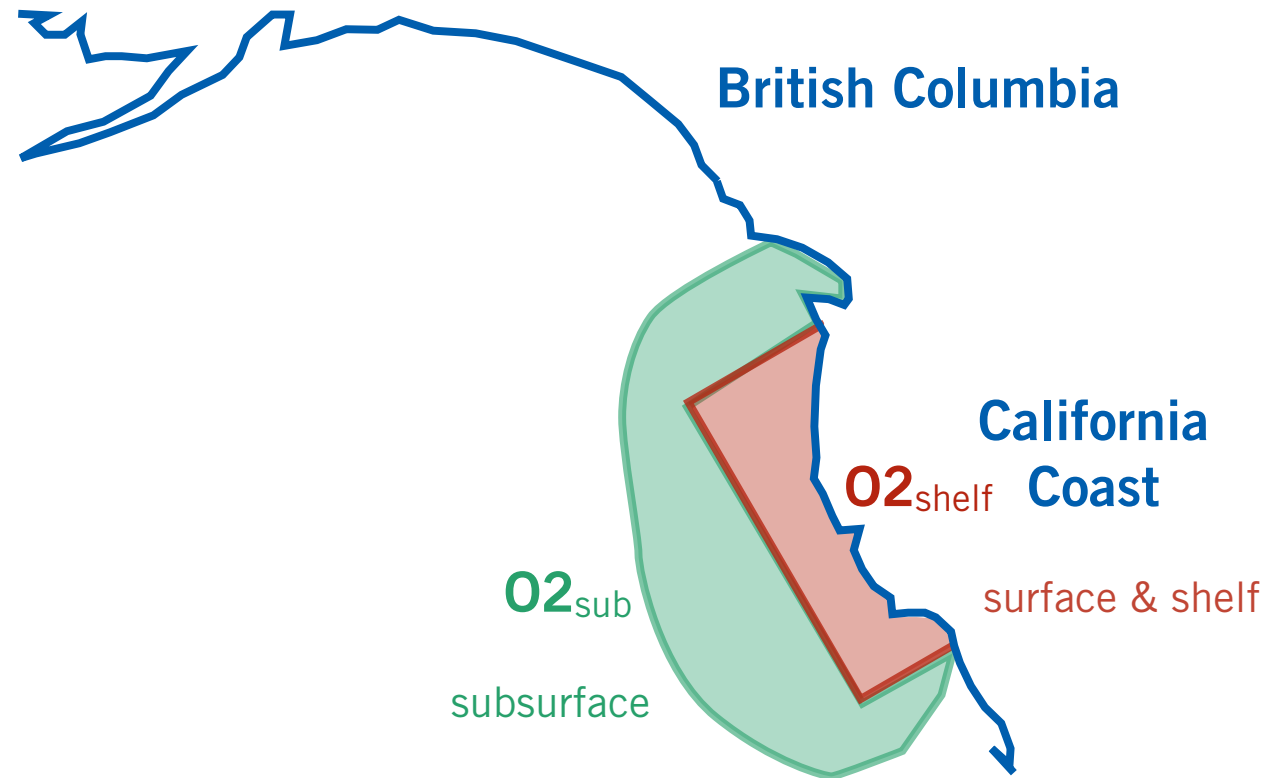
Large-scale ocean dynamics impacting Coastal Hypoxia



GOAL:

Develop a conceptual model of the large-scale dynamics controlling $O2_{sub}$

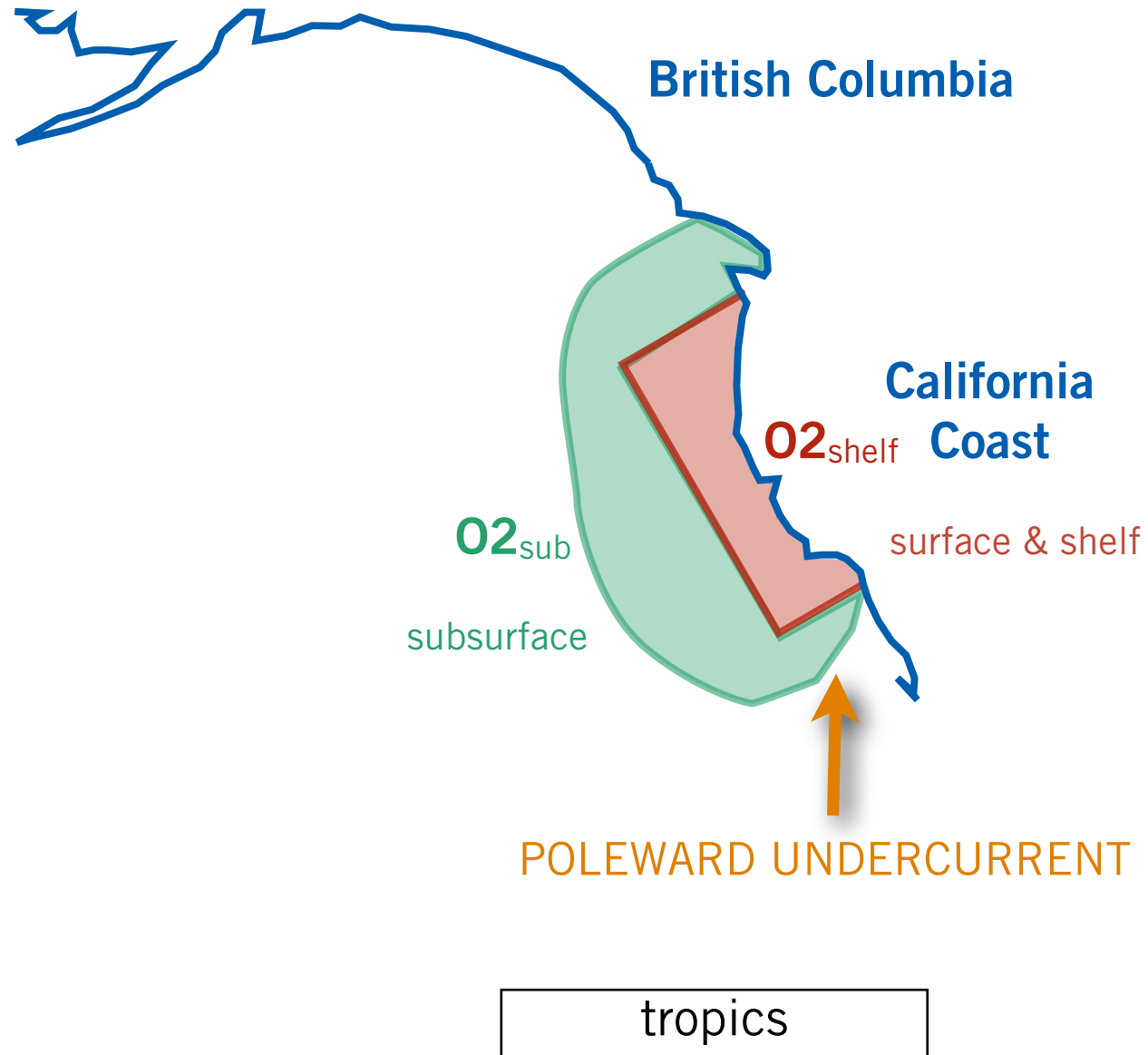
Large-scale ocean dynamics impacting Coastal Hypoxia



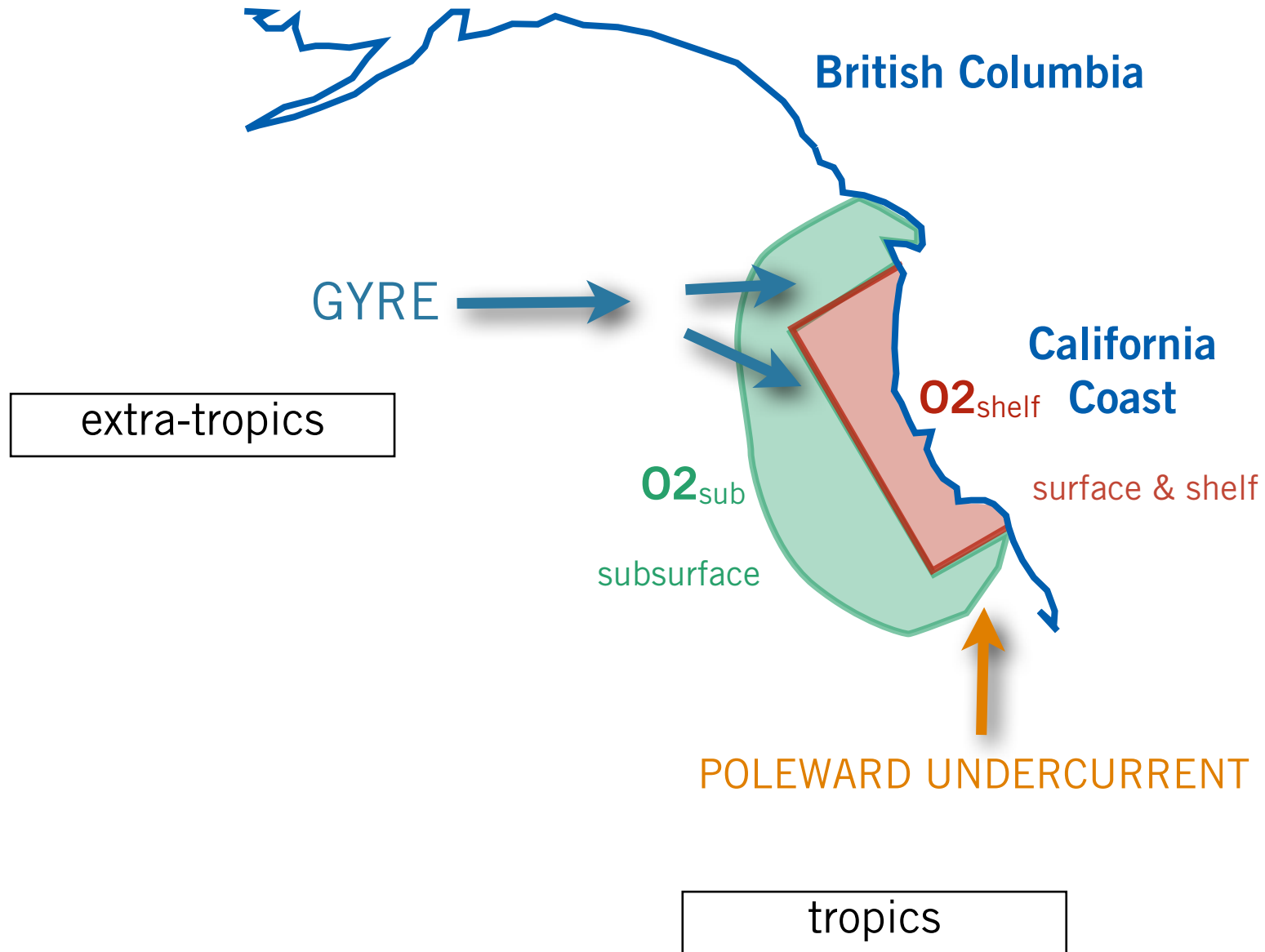
GOAL:

Develop a conceptual model of the large-scale dynamics controlling $O2_{sub}$

Large-scale ocean dynamics impacting Coastal Hypoxia

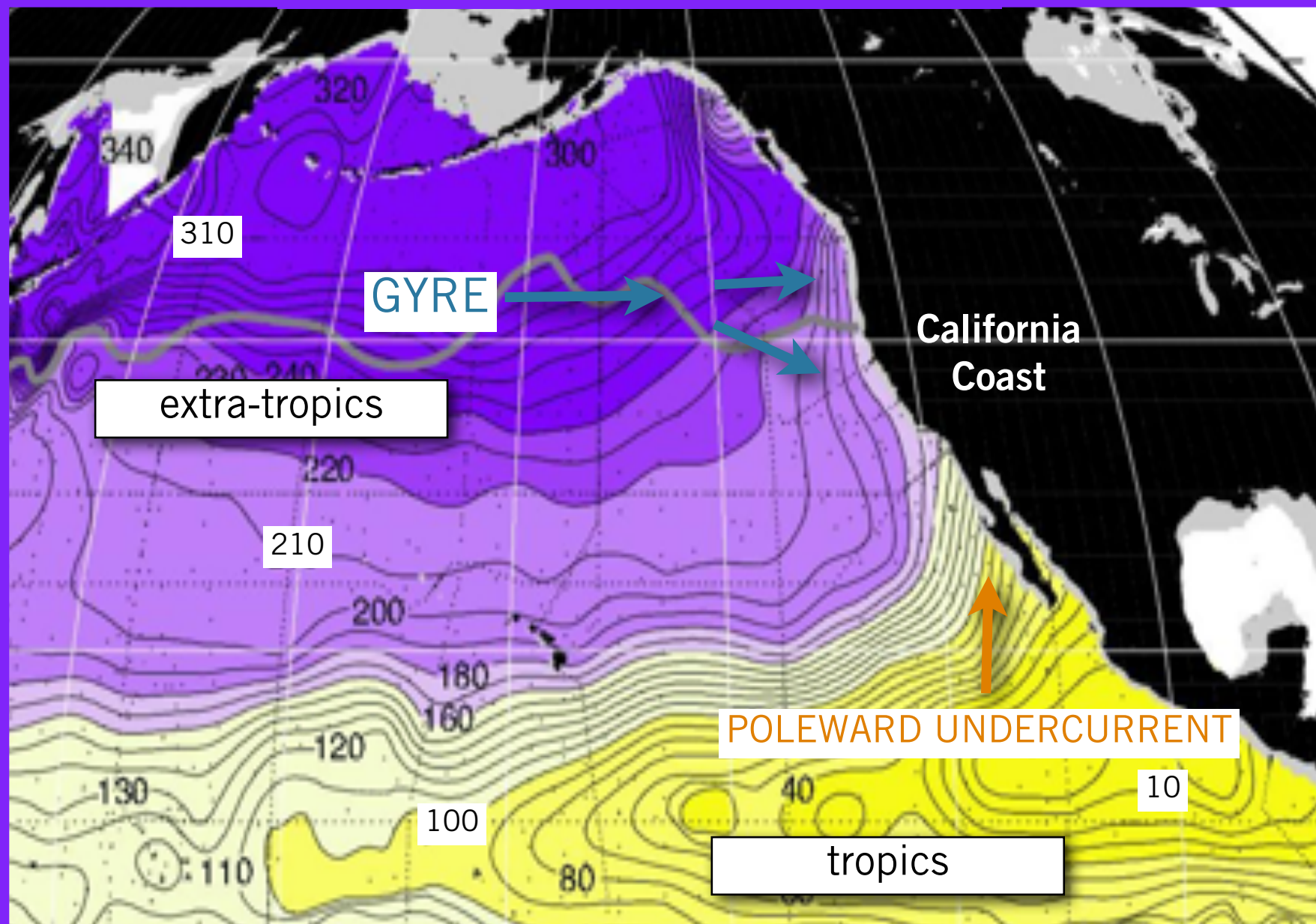


Large-scale ocean dynamics impacting Coastal Hypoxia



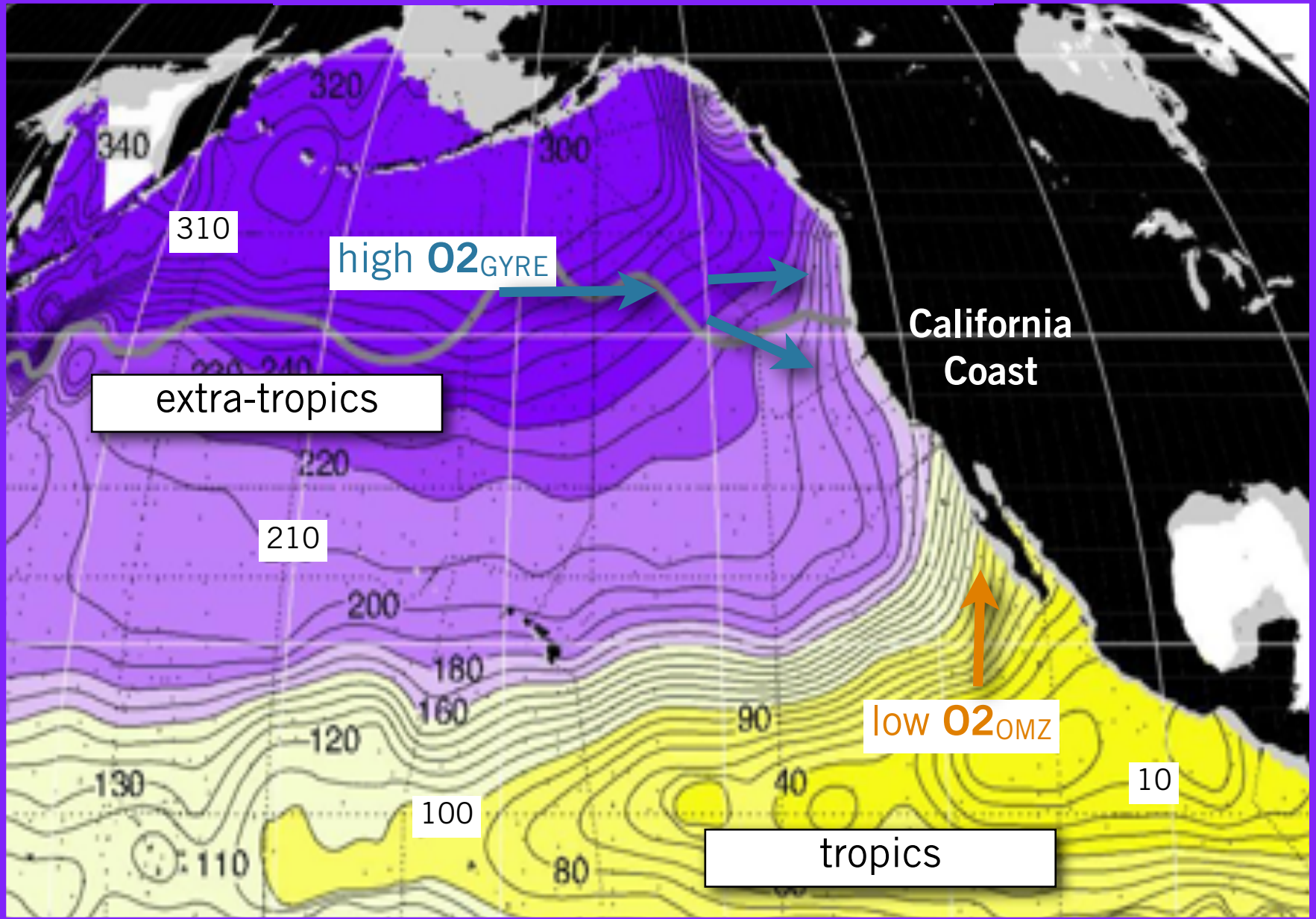
Large-scale ocean dynamics impacting Coastal Hypoxia

Oxygen Isopycnal 26.5



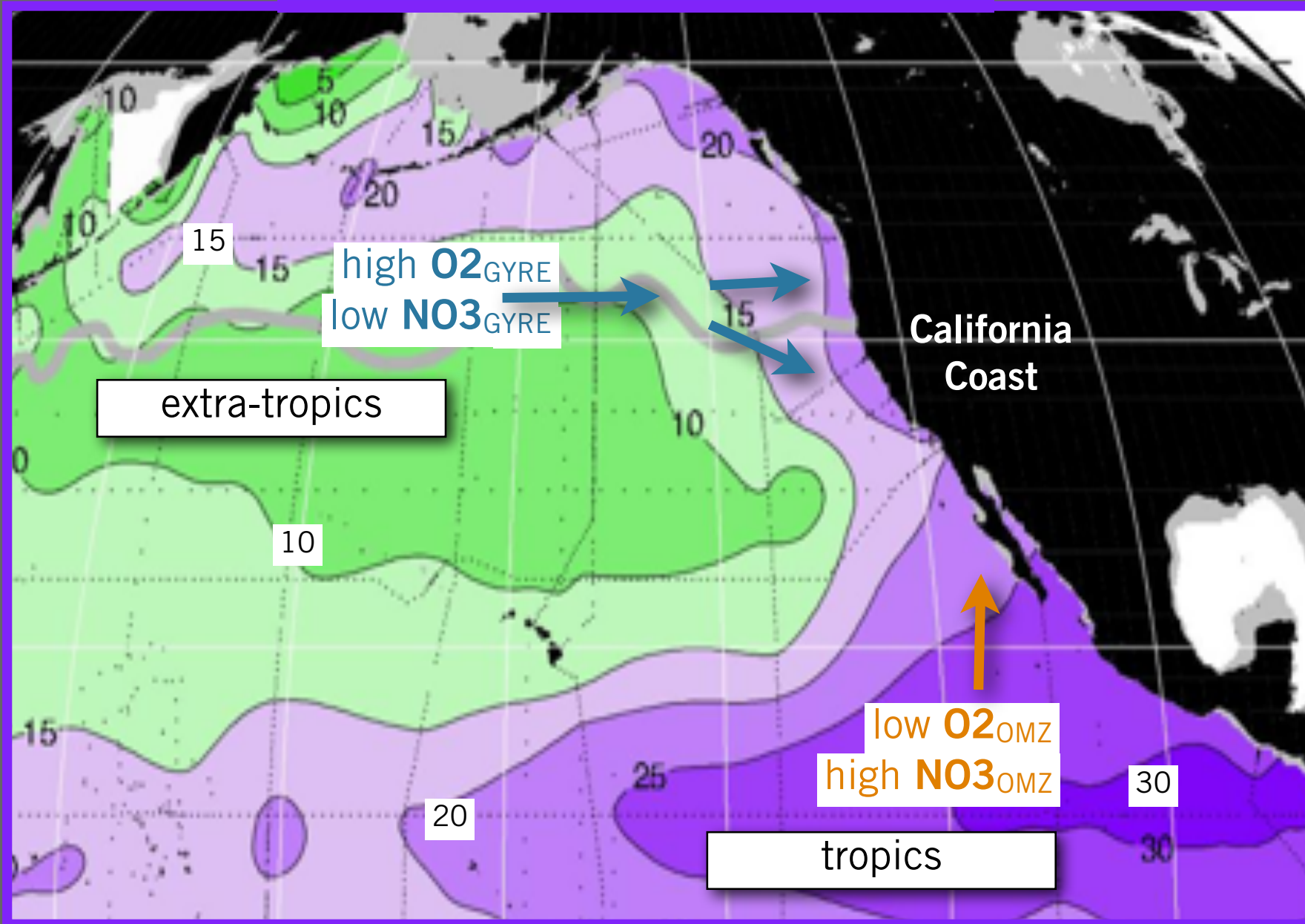
Large-scale ocean dynamics impacting Coastal Hypoxia

Oxygen Isopycnal 26.5

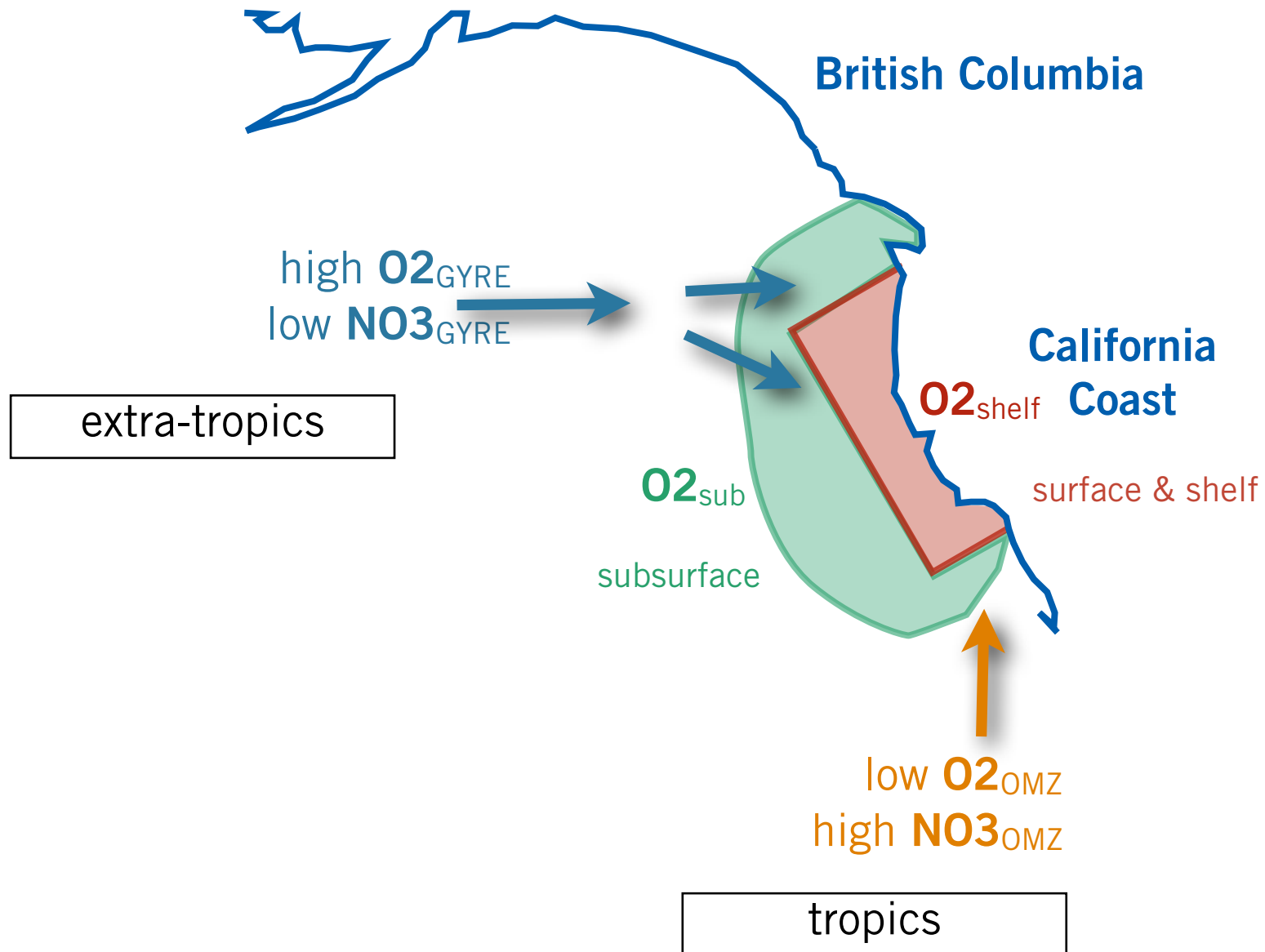


Large-scale ocean dynamics impacting Coastal Hypoxia

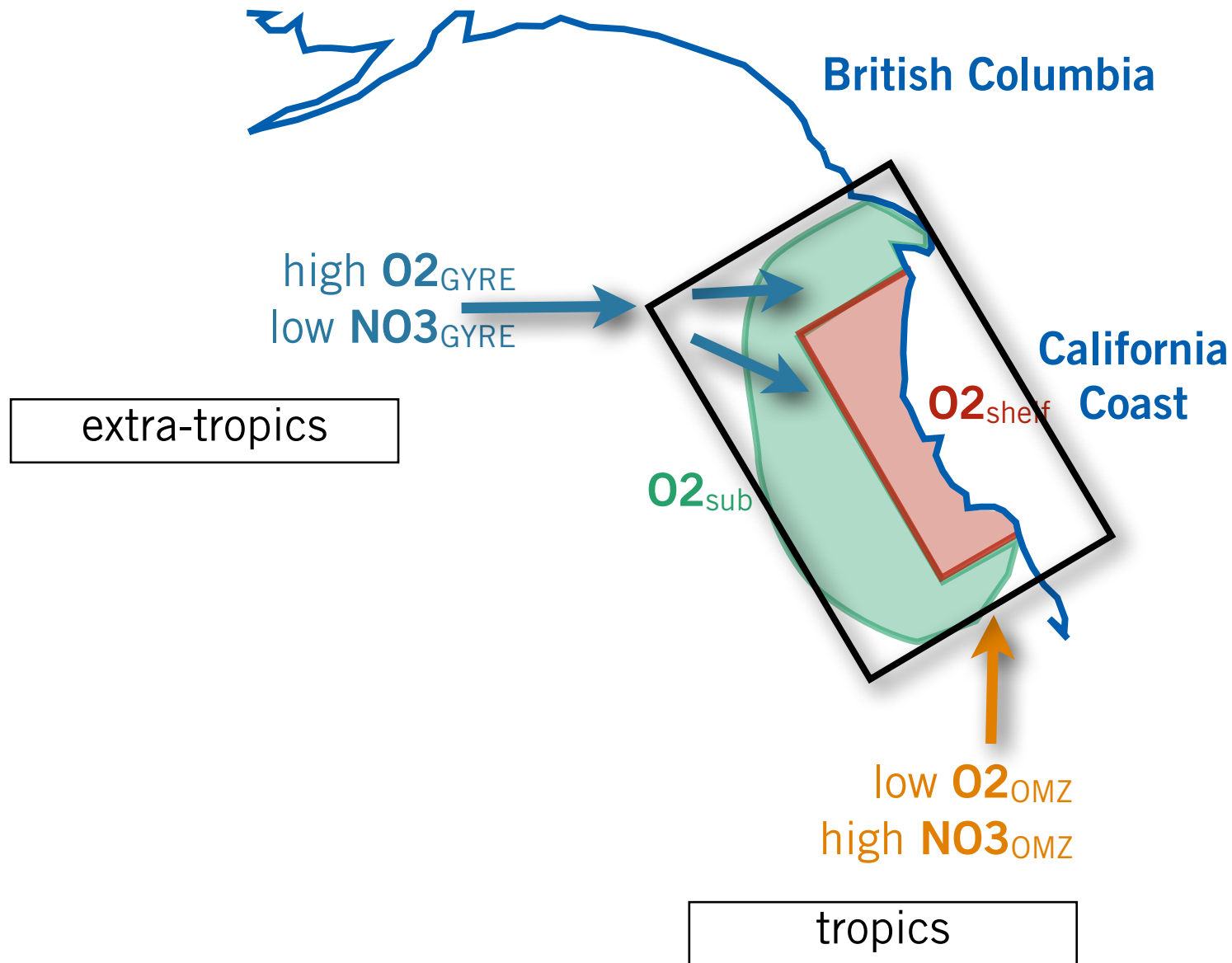
Nitrate Isopycnal 26.5



Large-scale ocean dynamics impacting Coastal Hypoxia

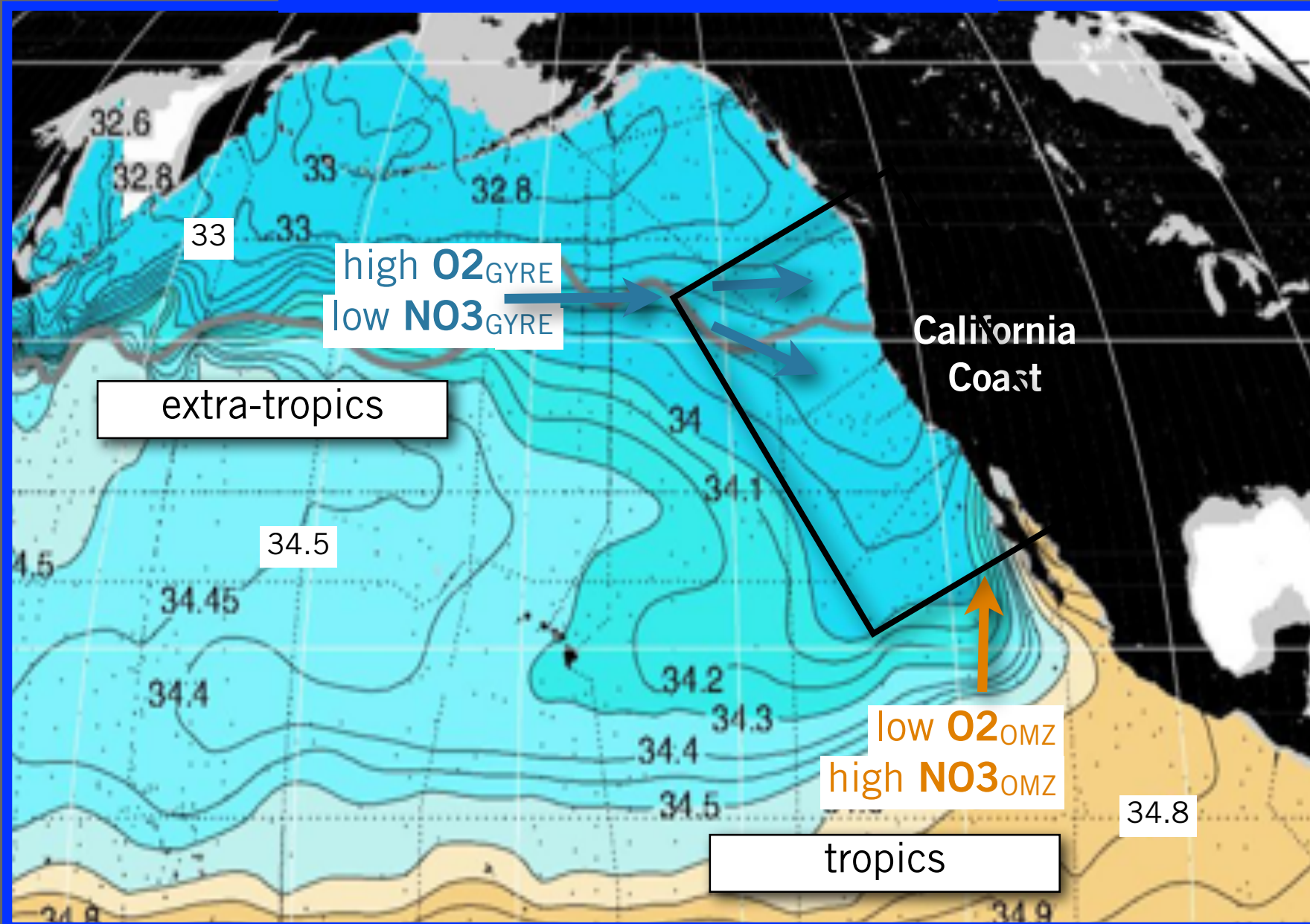


Large-scale ocean dynamics impacting Coastal Hypoxia



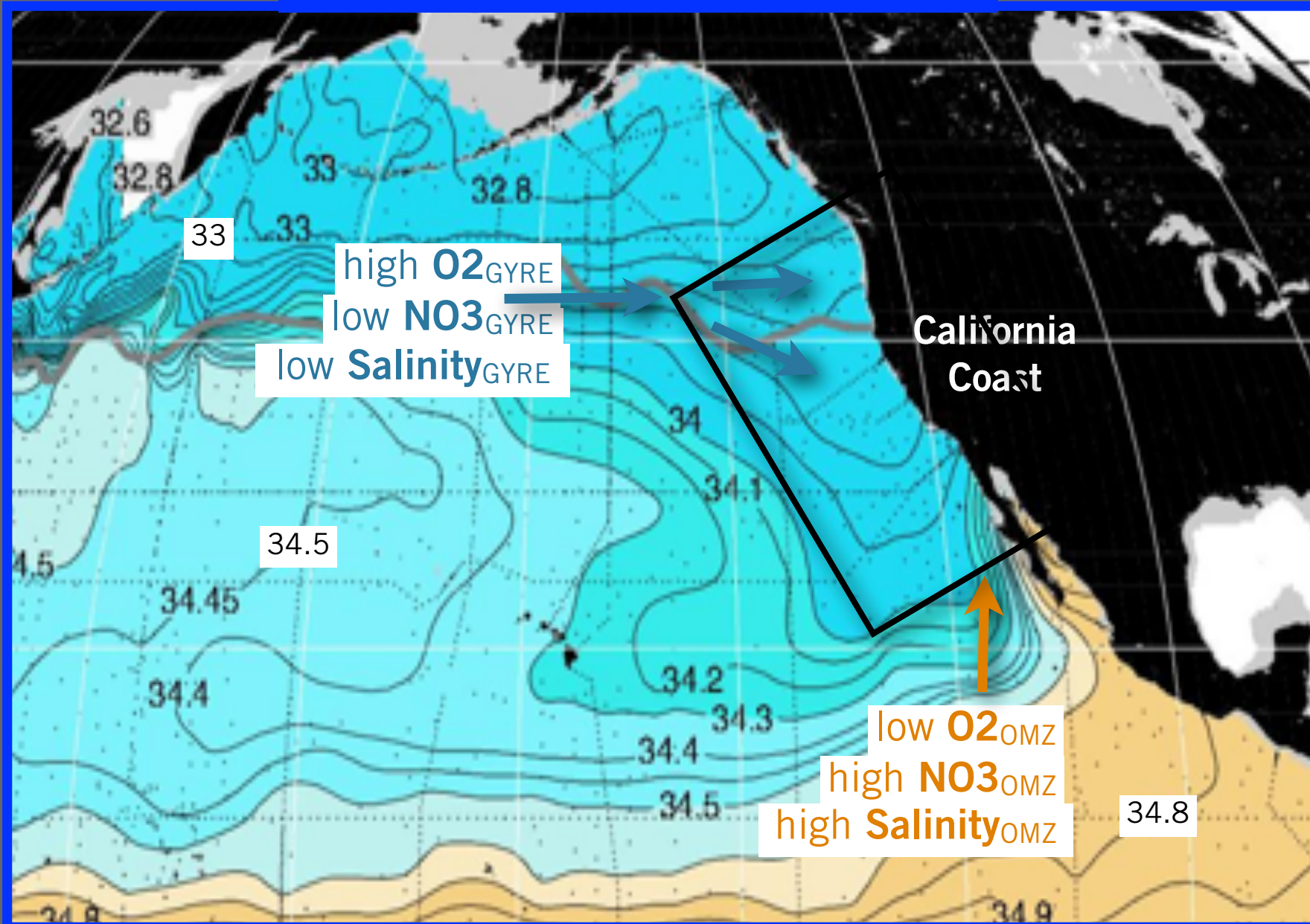
Large-scale ocean dynamics impacting Coastal Hypoxia

Salinity Isopycnal 26.5

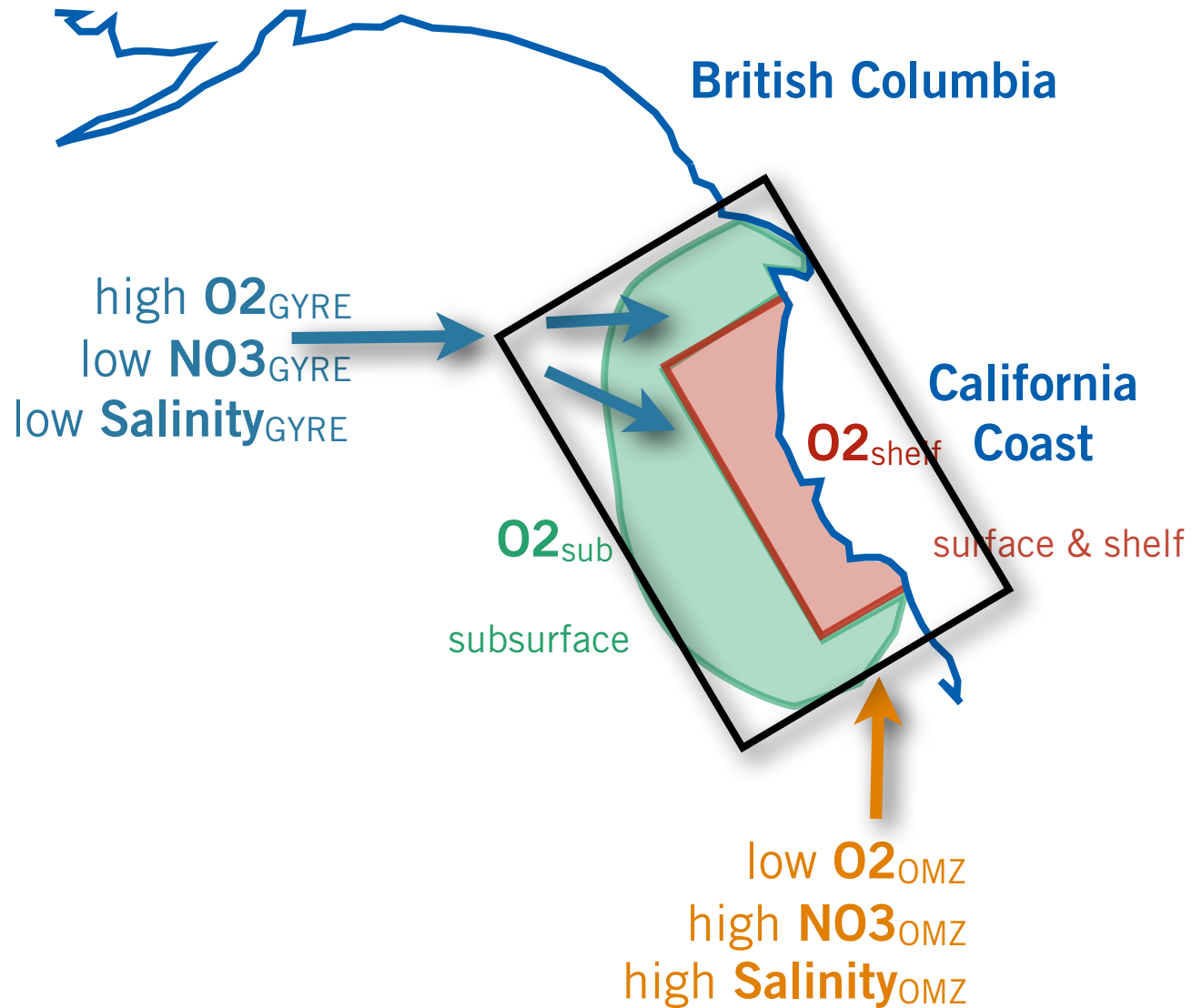


Large-scale ocean dynamics impacting Coastal Hypoxia

Salinity Isopycnal 26.5

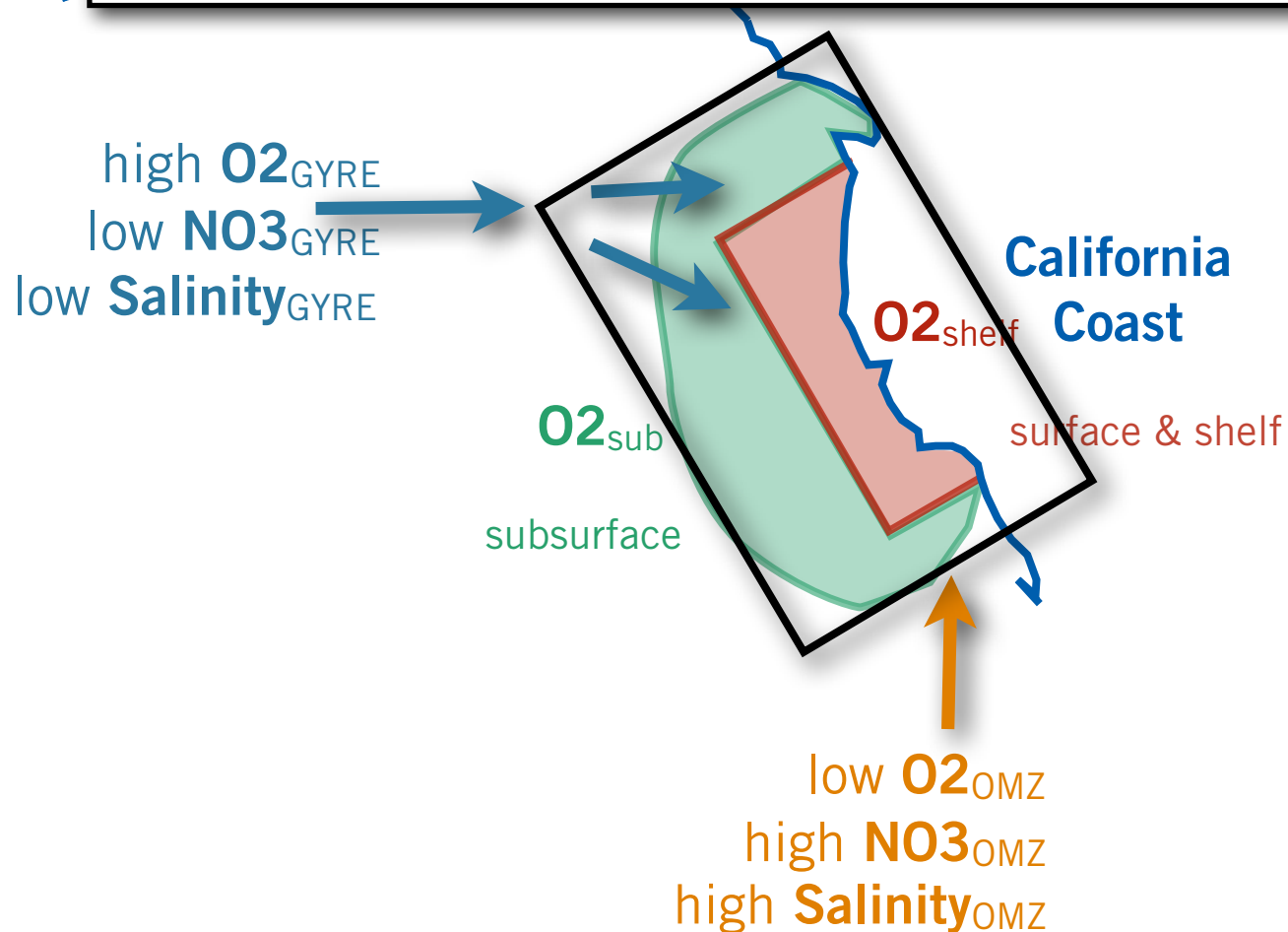


Large-scale ocean dynamics impacting Coastal Hypoxia



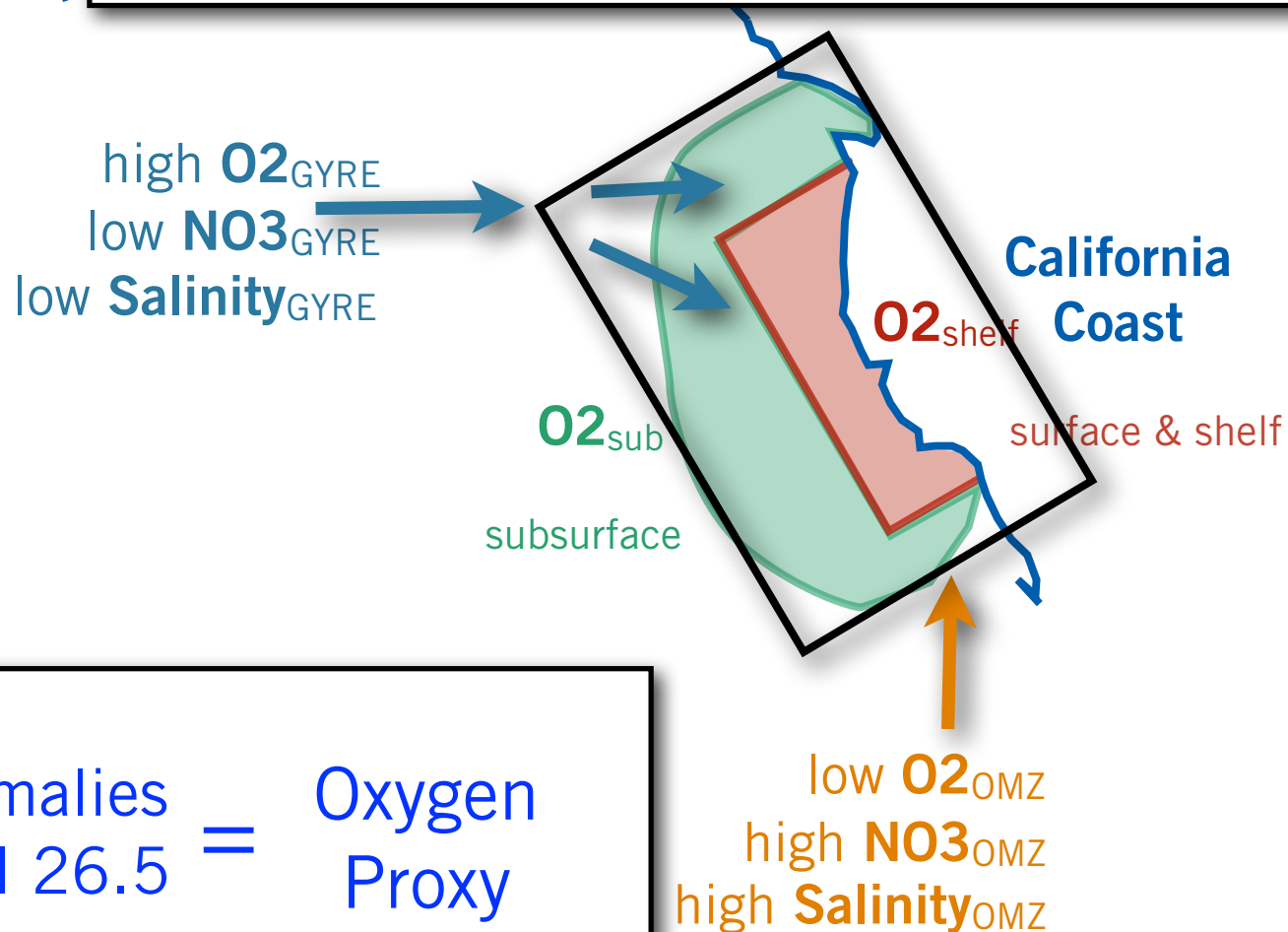
Large-scale ocean dynamics impacting Coastal Hypoxia

CalCOFI Oxygen (Bograd et al. 2008; Koslow et al., 2011)
Newport Oxygen (Pierce et al., 2012; Peterson et al., 2013)
California Oxygen (Deutsch et al., 2011)



Large-scale ocean dynamics impacting Coastal Hypoxia

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salinity anomalies on isopycnal 26.5 = Oxygen Proxy

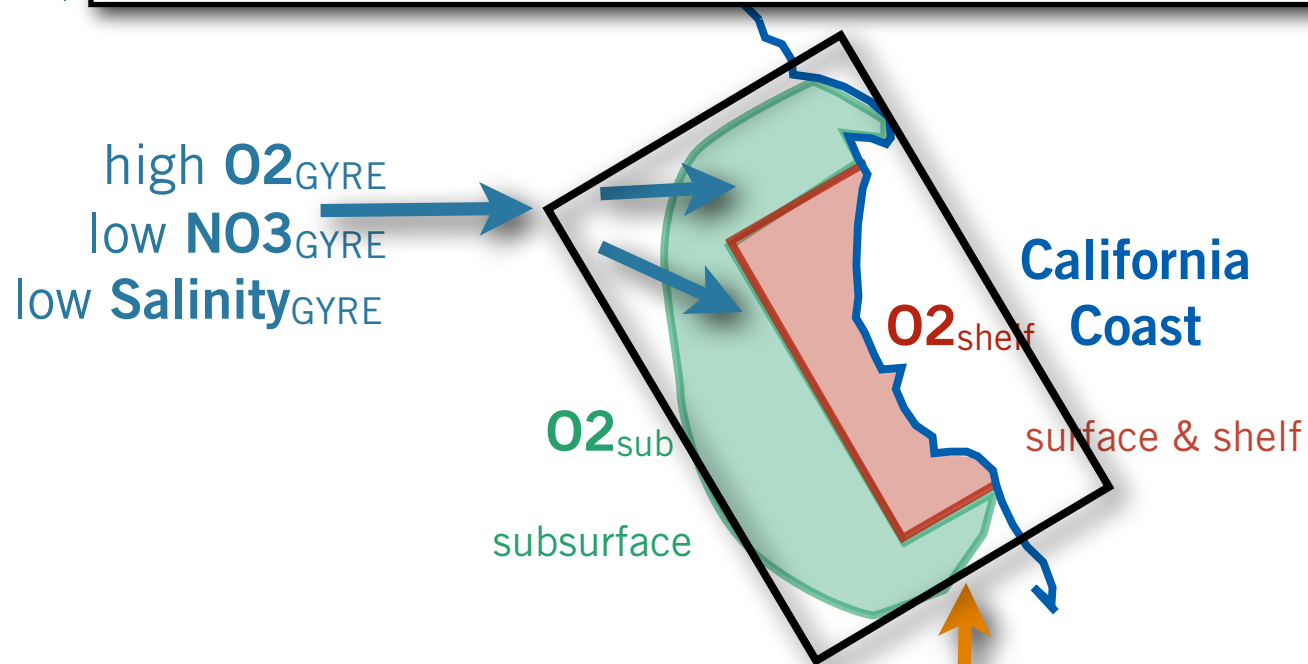
Large-scale ocean dynamics impacting Coastal Hypoxia

ECMWF ORA3 Oxygen Proxy

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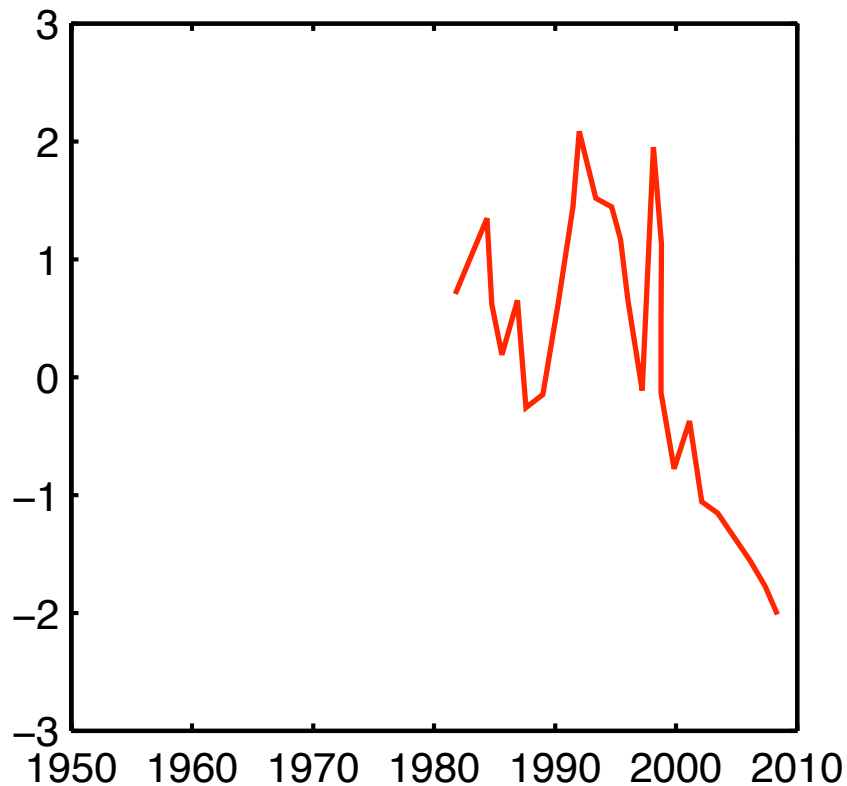
low $O2_{OMZ}$
high $NO3_{OMZ}$
high $Salinity_{OMZ}$

ECMWF ORA3 Oxygen Proxy

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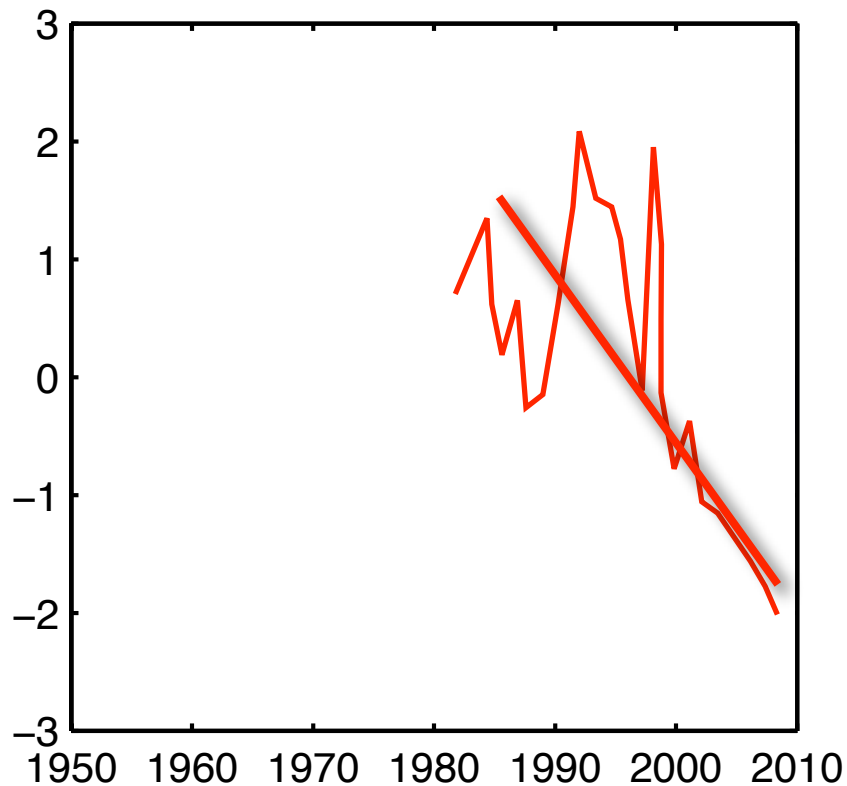
Observations ***SUBSURFACE OXYGEN***
in the California Current System

ECMWF ORA3 Oxygen Proxy

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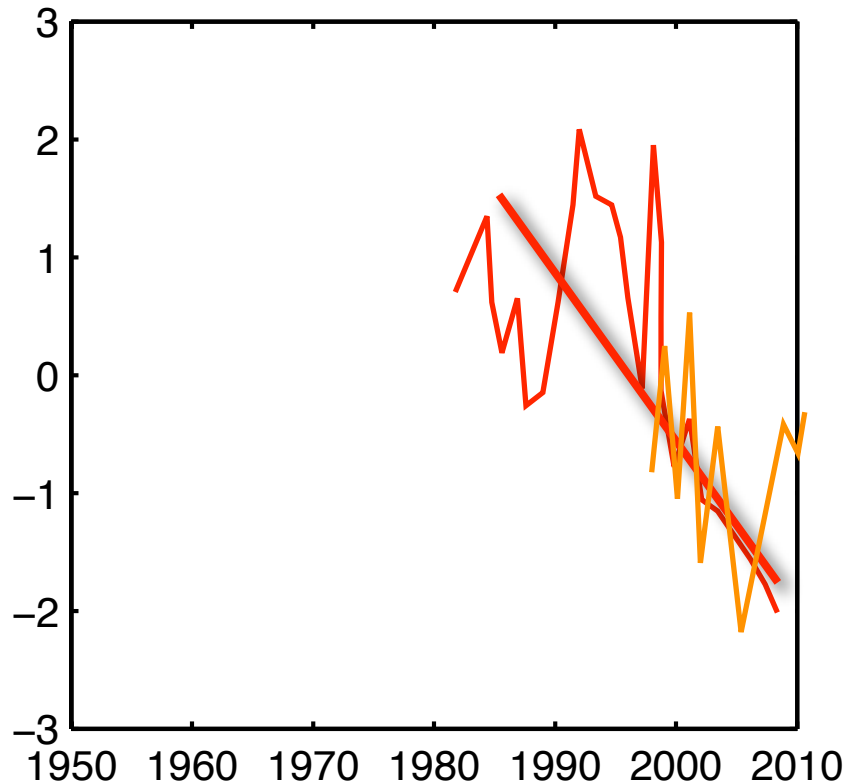
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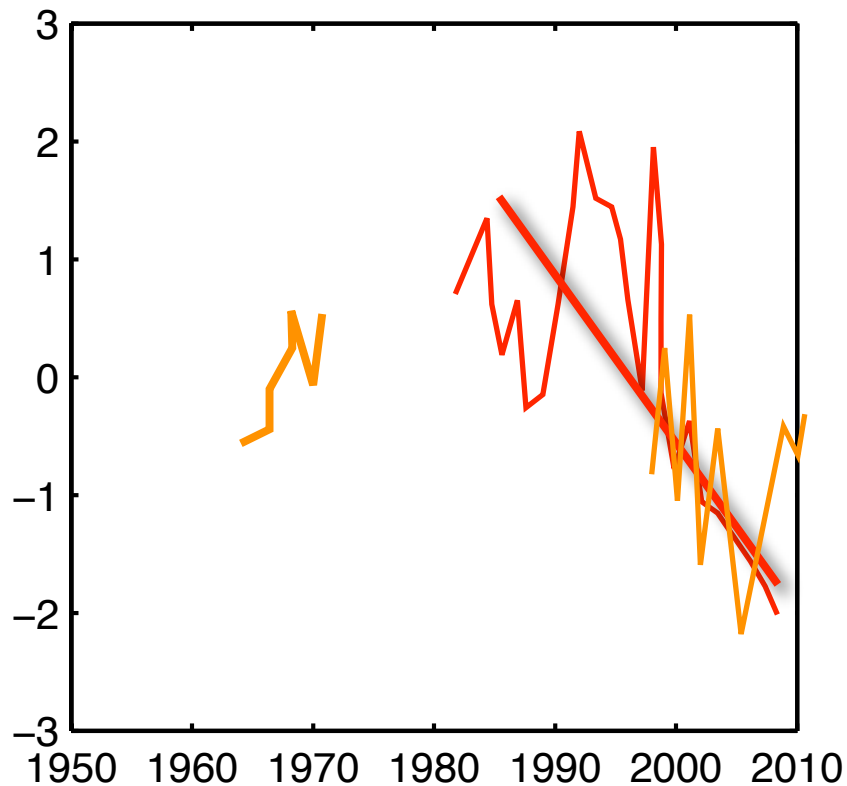
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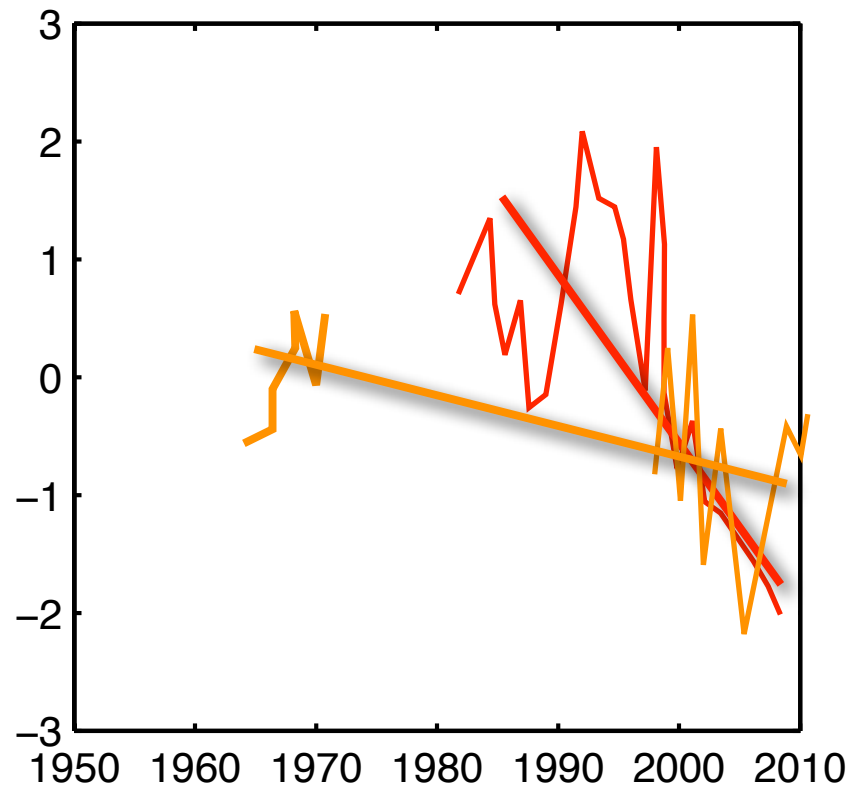
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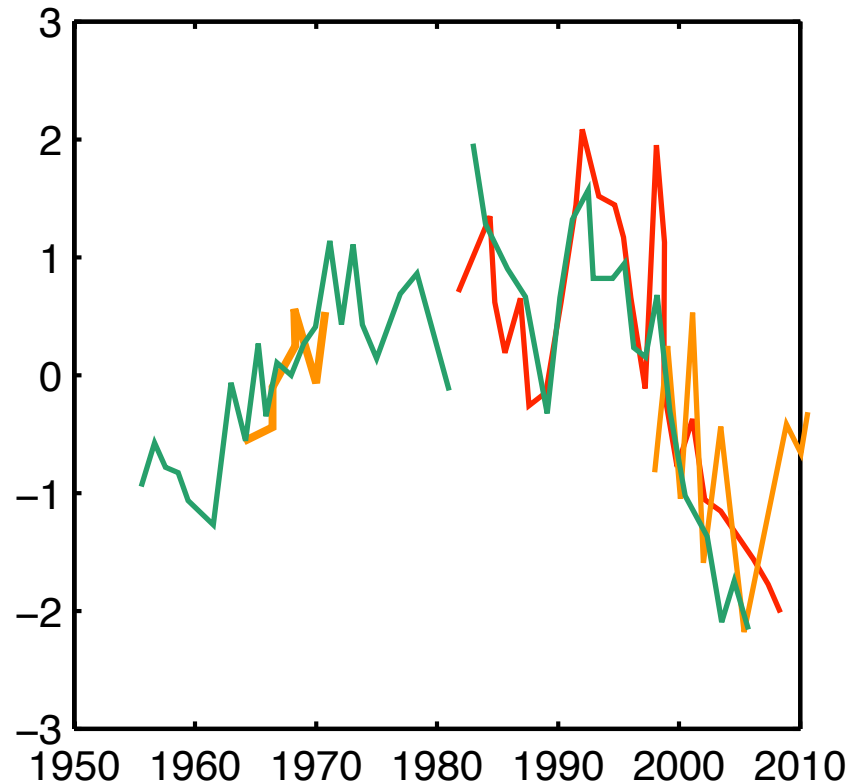
Observations ***SUBSURFACE OXYGEN***
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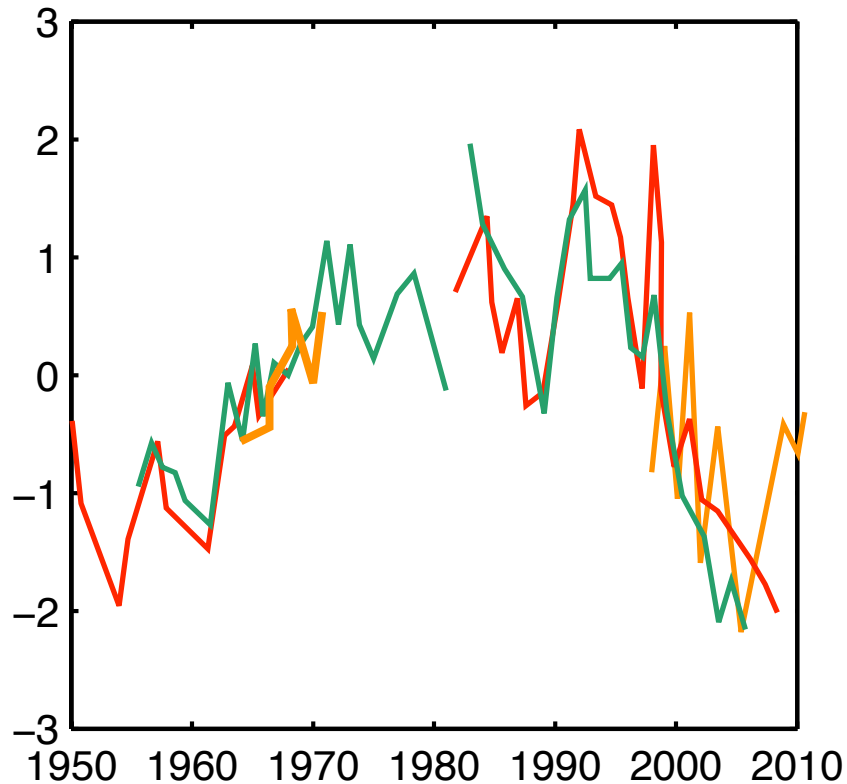
Observations ***SUBSURFACE OXYGEN***
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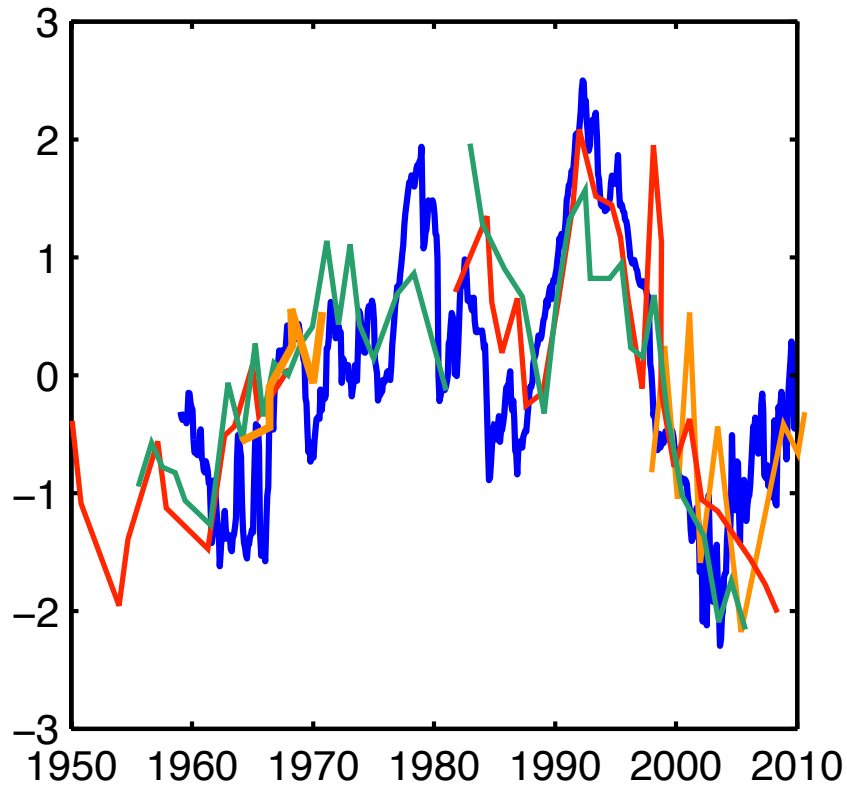
Observations ***SUBSURFACE OXYGEN***
in the California Current System

ECMWF ORA3 Oxygen Proxy

CalCOFI Oxygen (Bograd et al. 2008; Koslow et al., 2011)

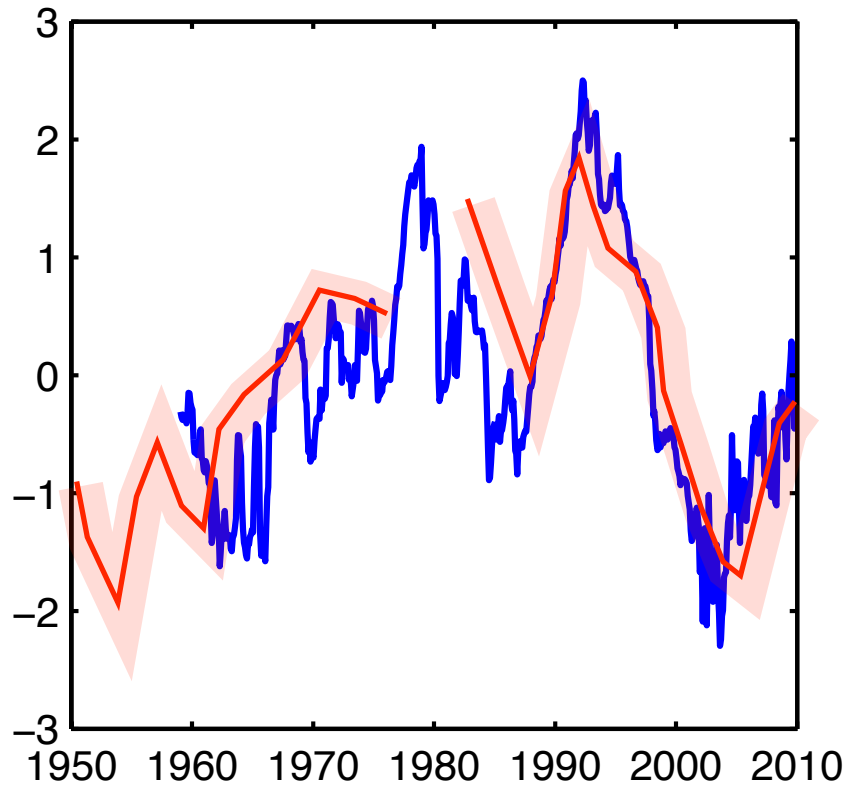
Newport Oxygen (Pierce et al., 2012; Peterson et al., 2013)

California Oxygen (Deutsch et al., 2011)

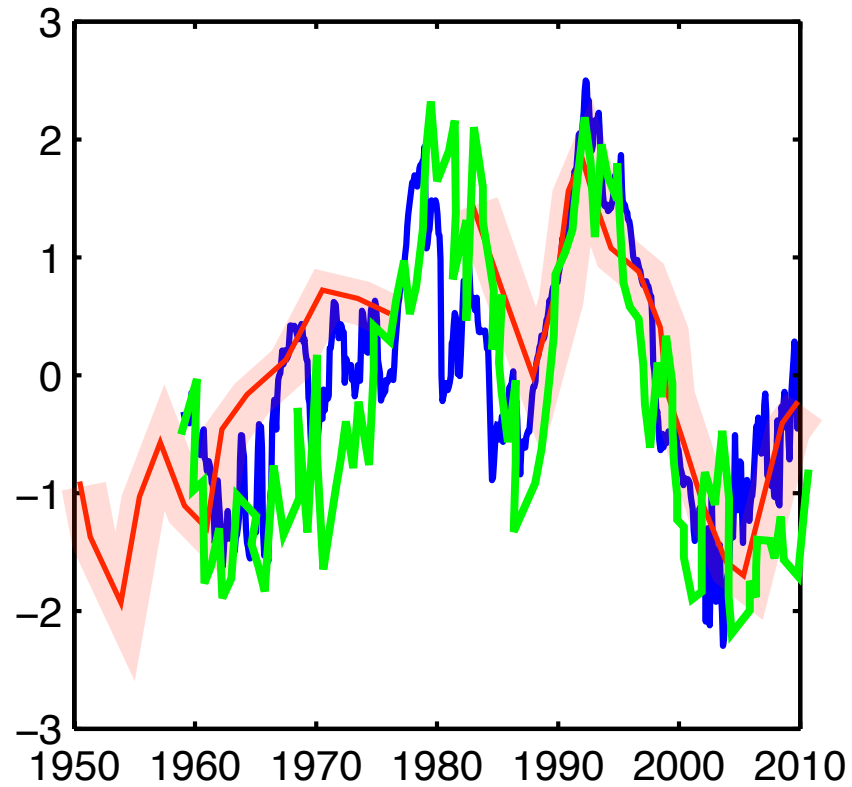


Observations ***SUBSURFACE OXYGEN***
in the California Current System

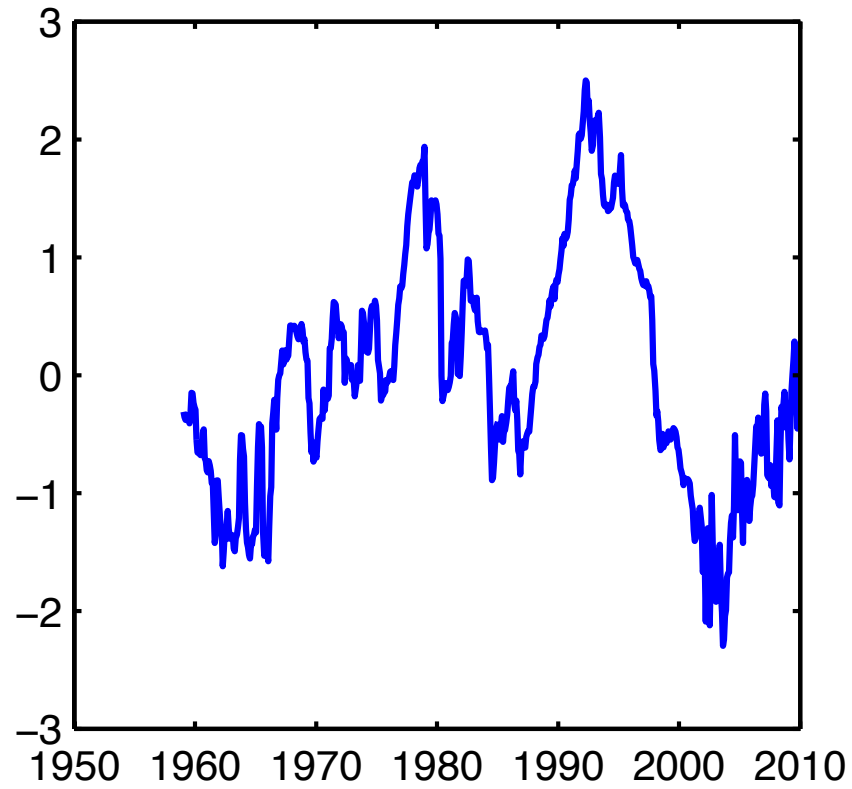
ECMWF ORA3 Oxygen Proxy
Observations Oxygen



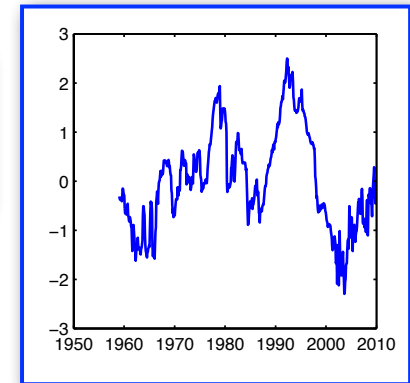
ECMWF ORA3 Oxygen Proxy
Observations Oxygen
SODA Reanalysis Oxygen Proxy



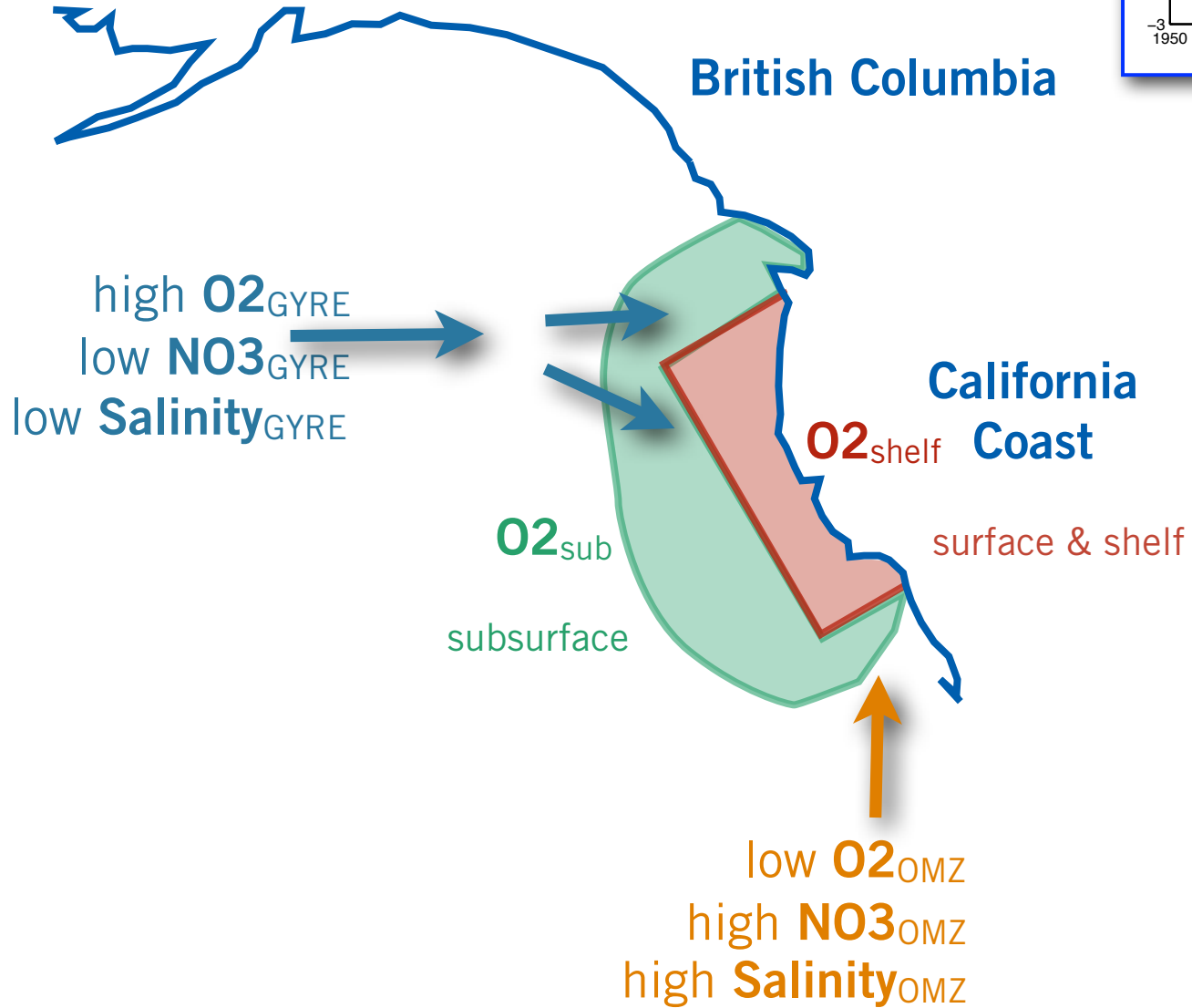
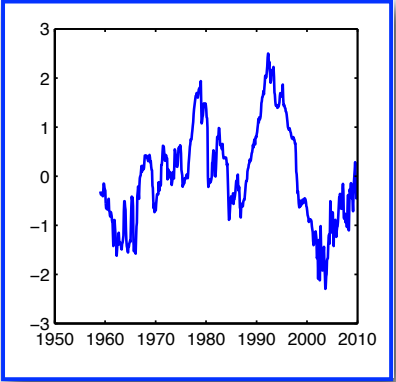
ECMWF ORA3 Oxygen Proxy Index



ECMWF ORA3 Oxygen Proxy Index

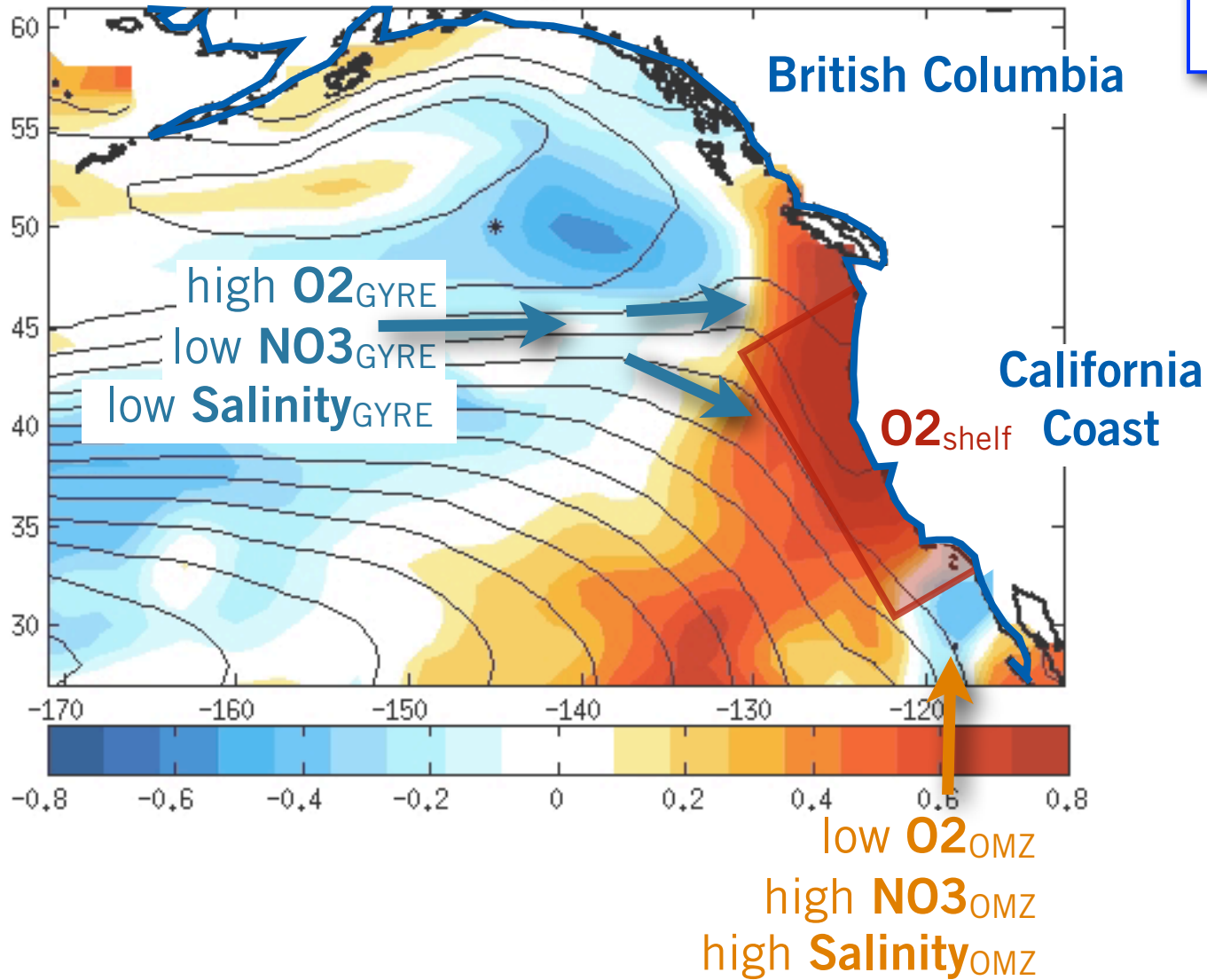
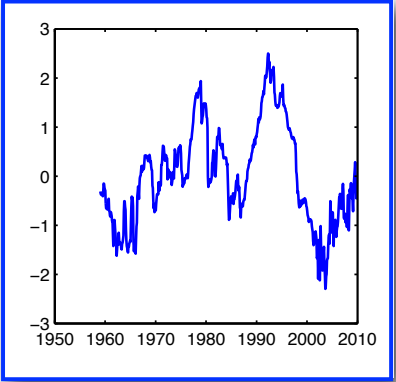


ECMWF ORA3 Oxygen Proxy Index



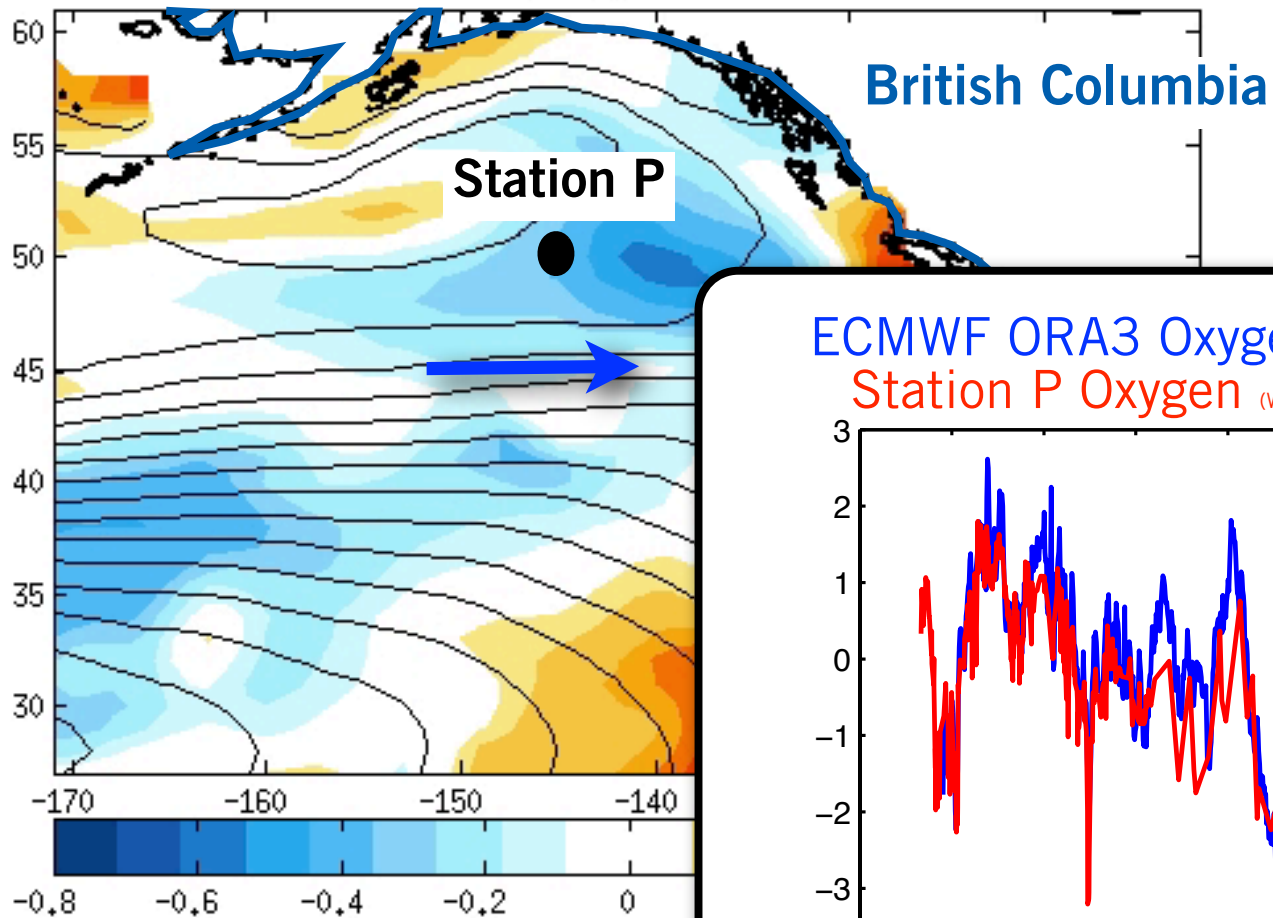
ECMWF ORA3 Oxygen Proxy Index

Correlation with Salinity ISO=26.5

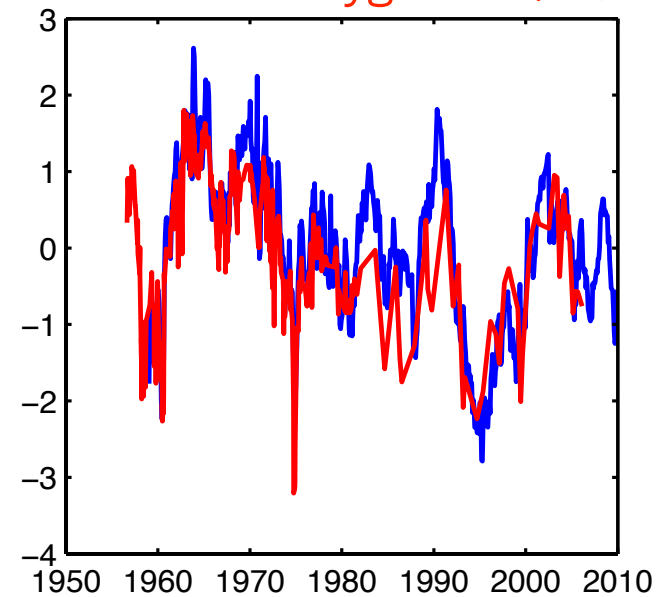


ECMWF ORA3 Oxygen Proxy Index

Correlation with Salinity ISO=26.5

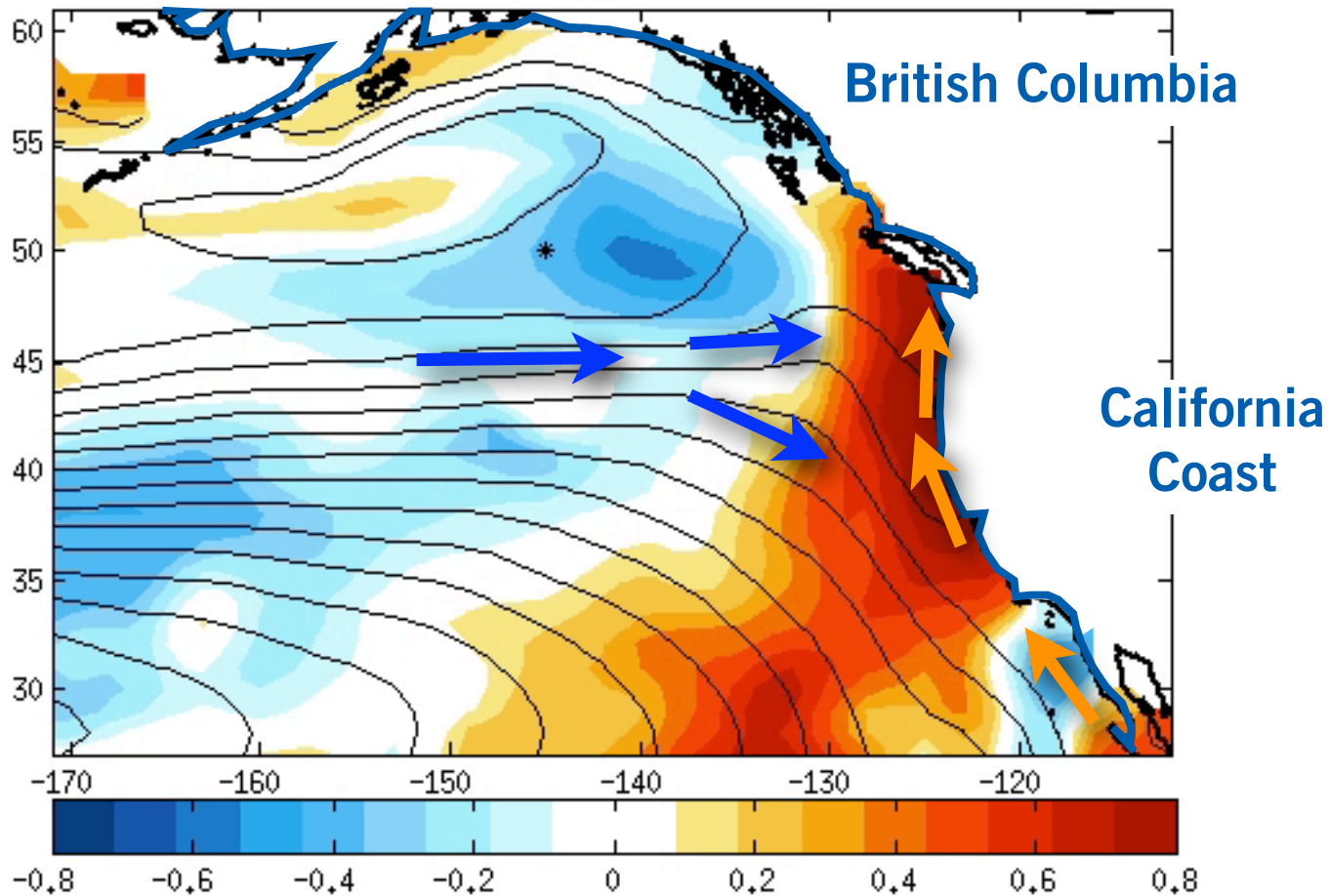


ECMWF ORA3 Oxygen Proxy (Station P)
Station P Oxygen (Whitney et al., 2011)

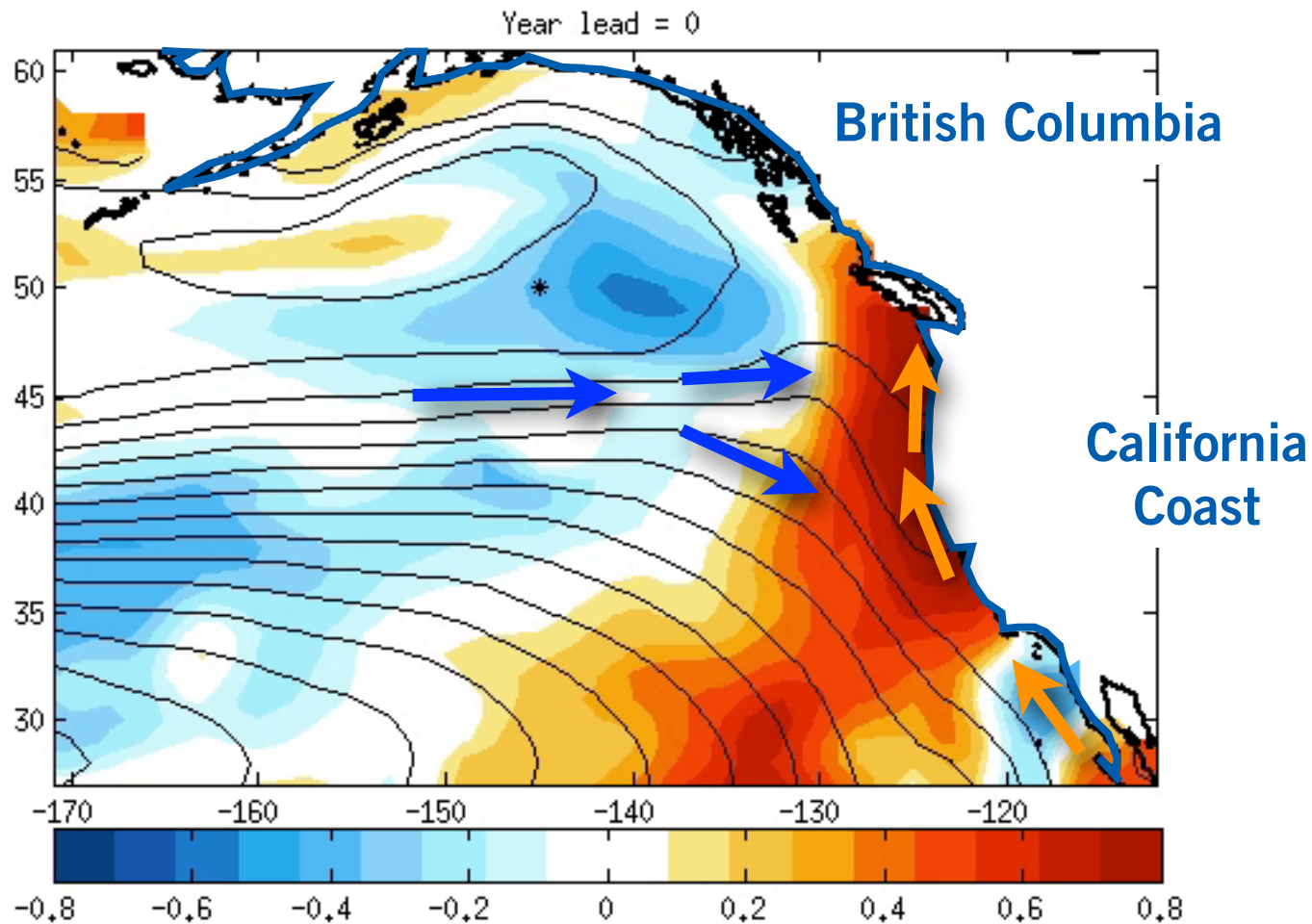


ECMWF ORA3 Oxygen Proxy Index

Correlation with Salinity ISO=26.5



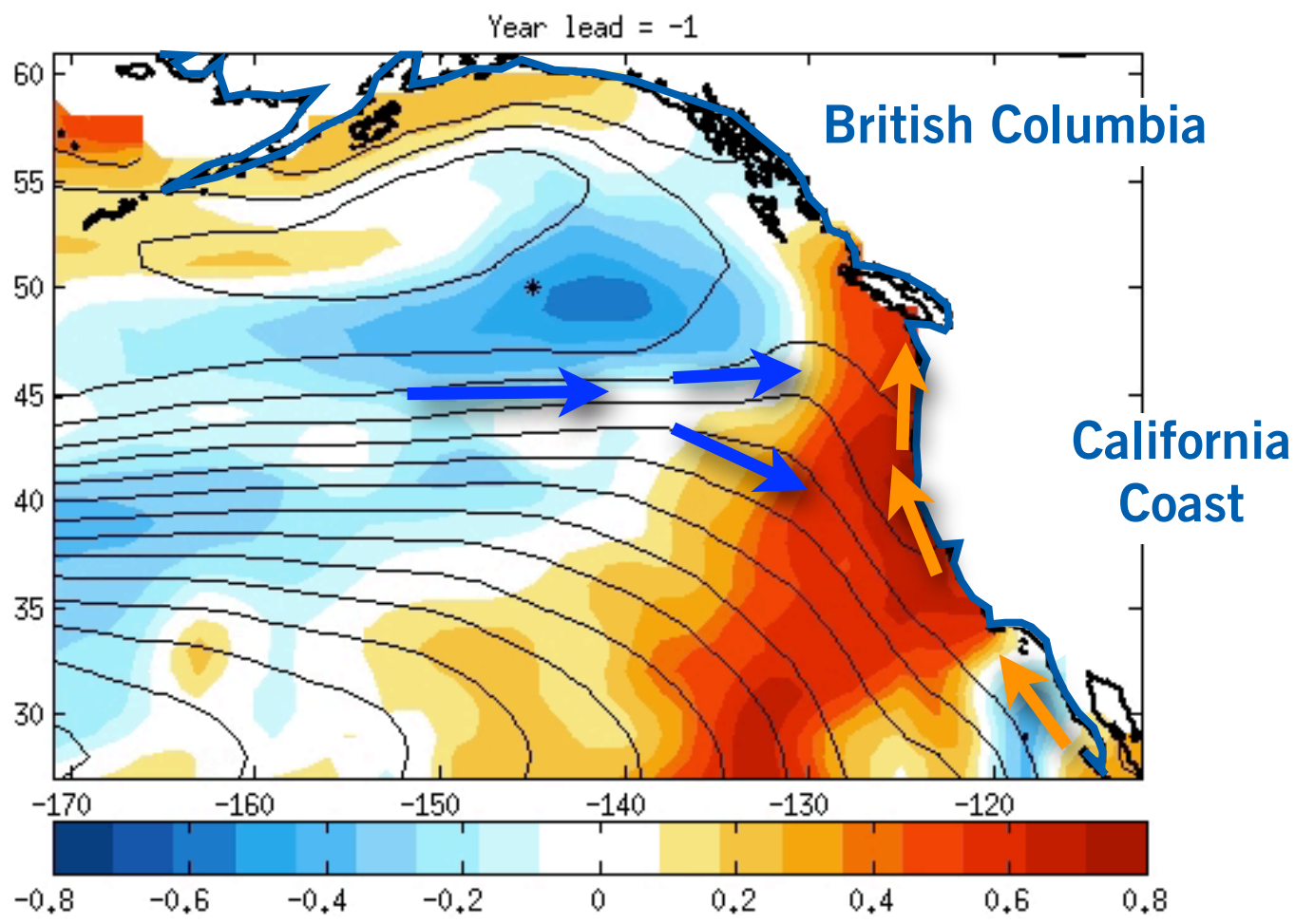
ECMWF ORA3 Oxygen Proxy Index



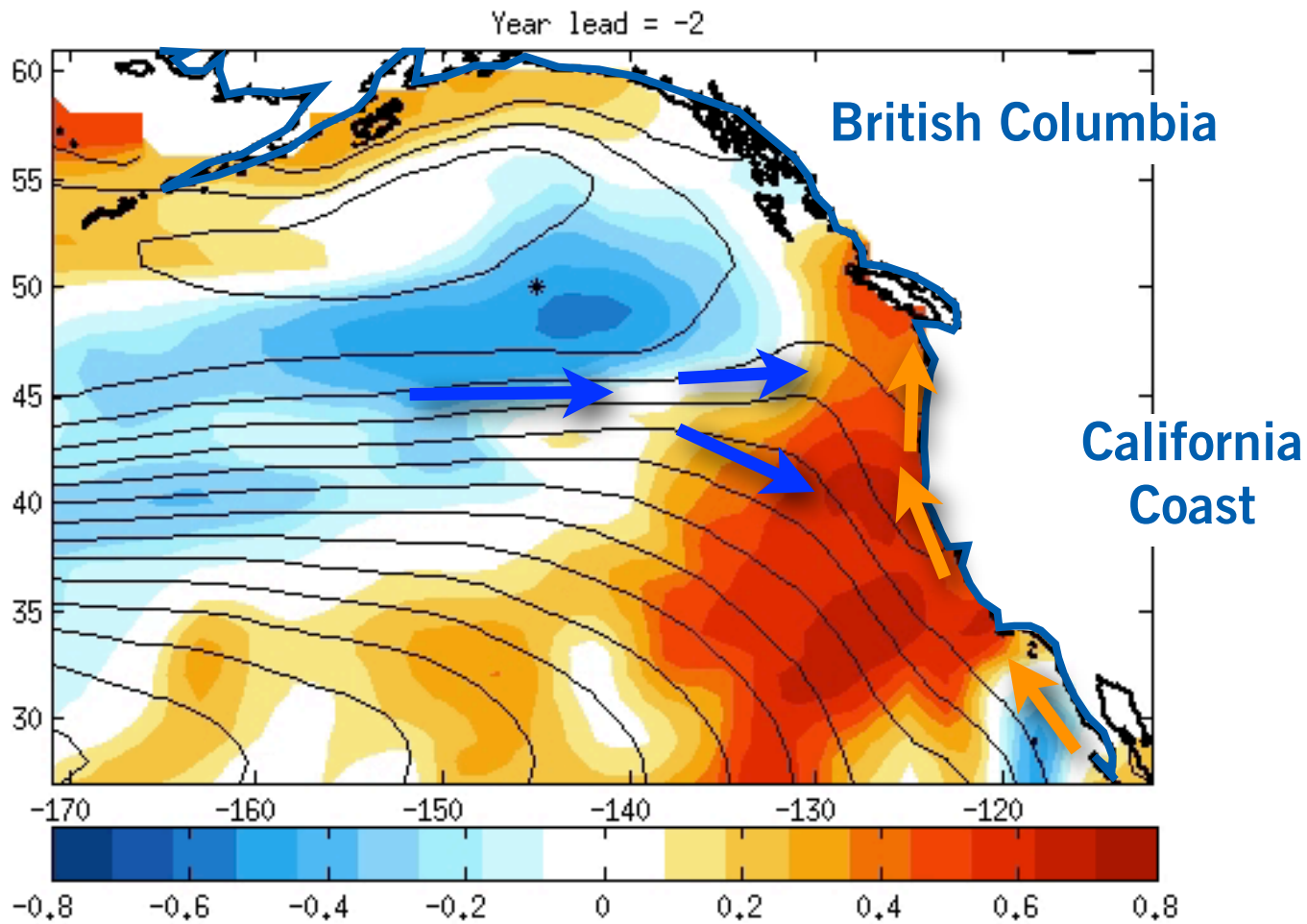
QUESTION:

Where did these anomalies come from?

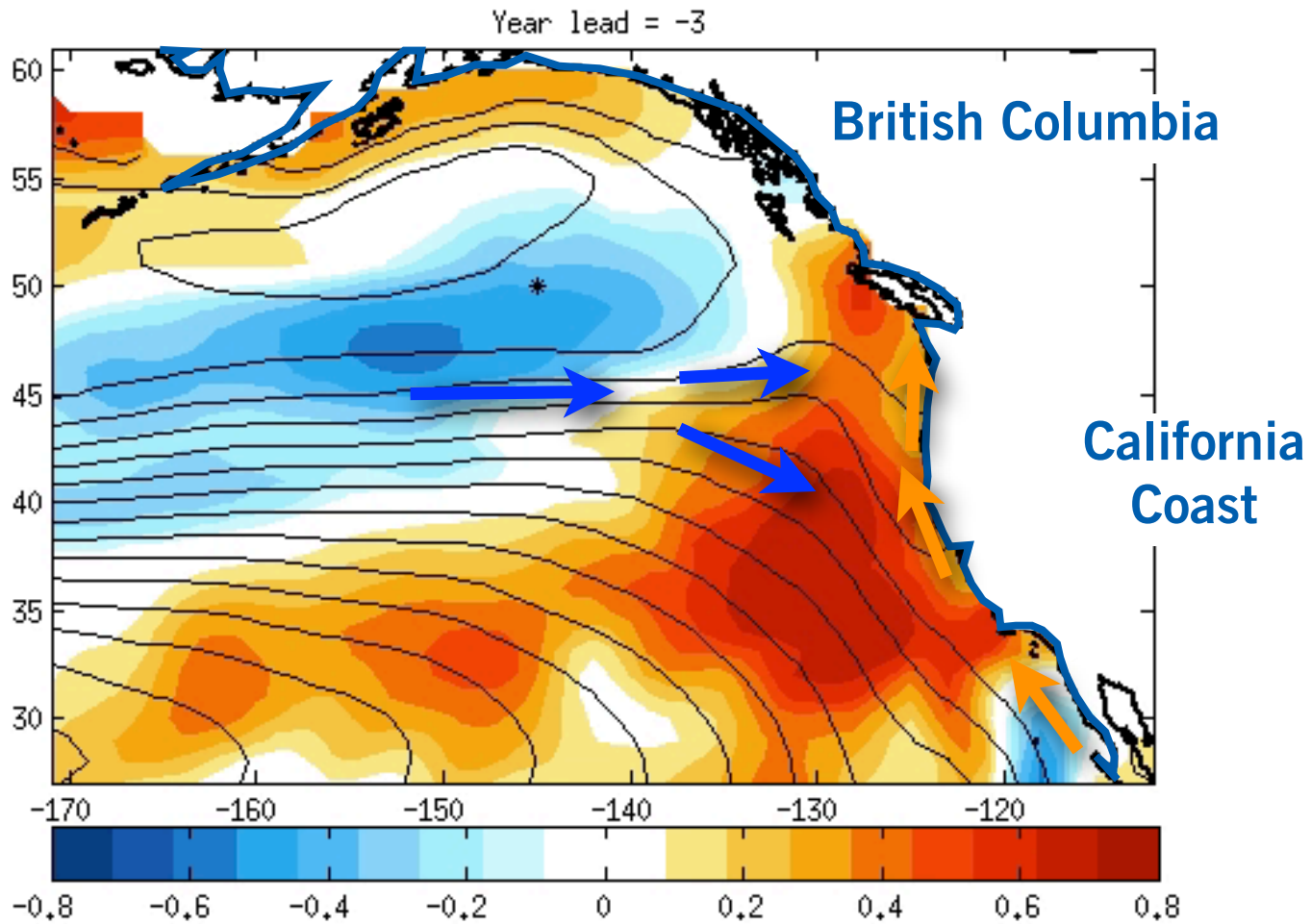
ECMWF ORA3 Oxygen Proxy Index



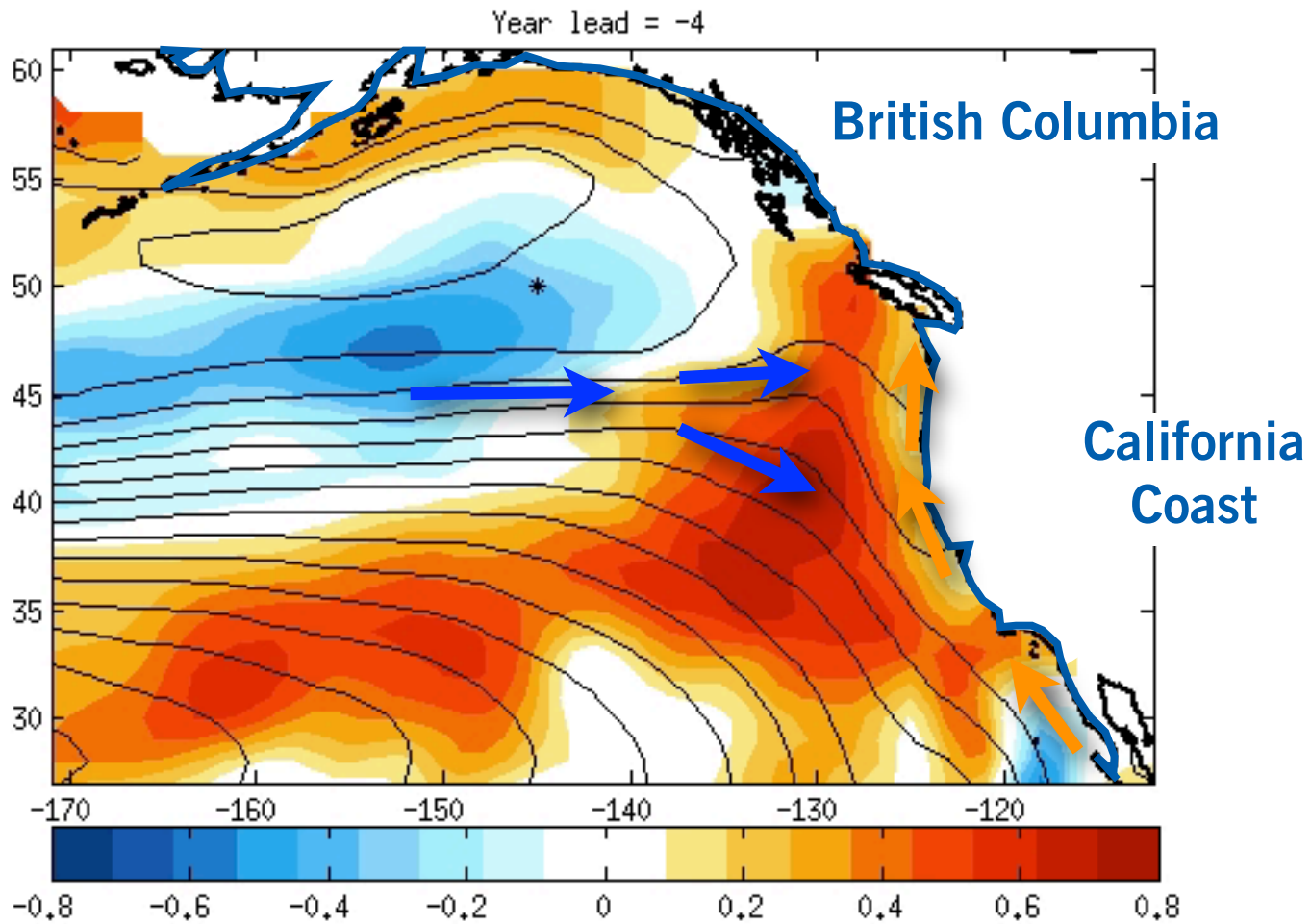
ECMWF ORA3 Oxygen Proxy Index



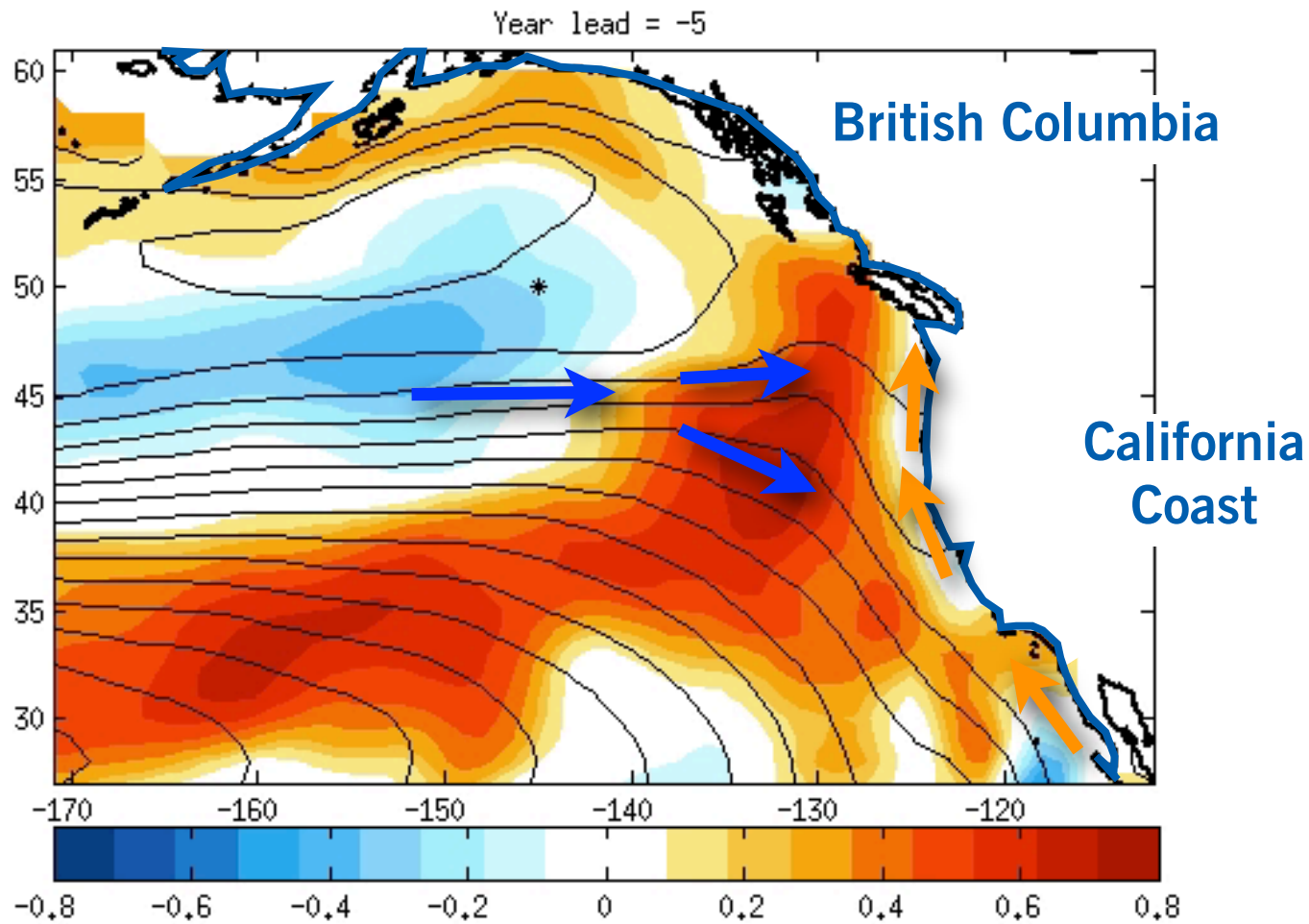
ECMWF ORA3 Oxygen Proxy Index



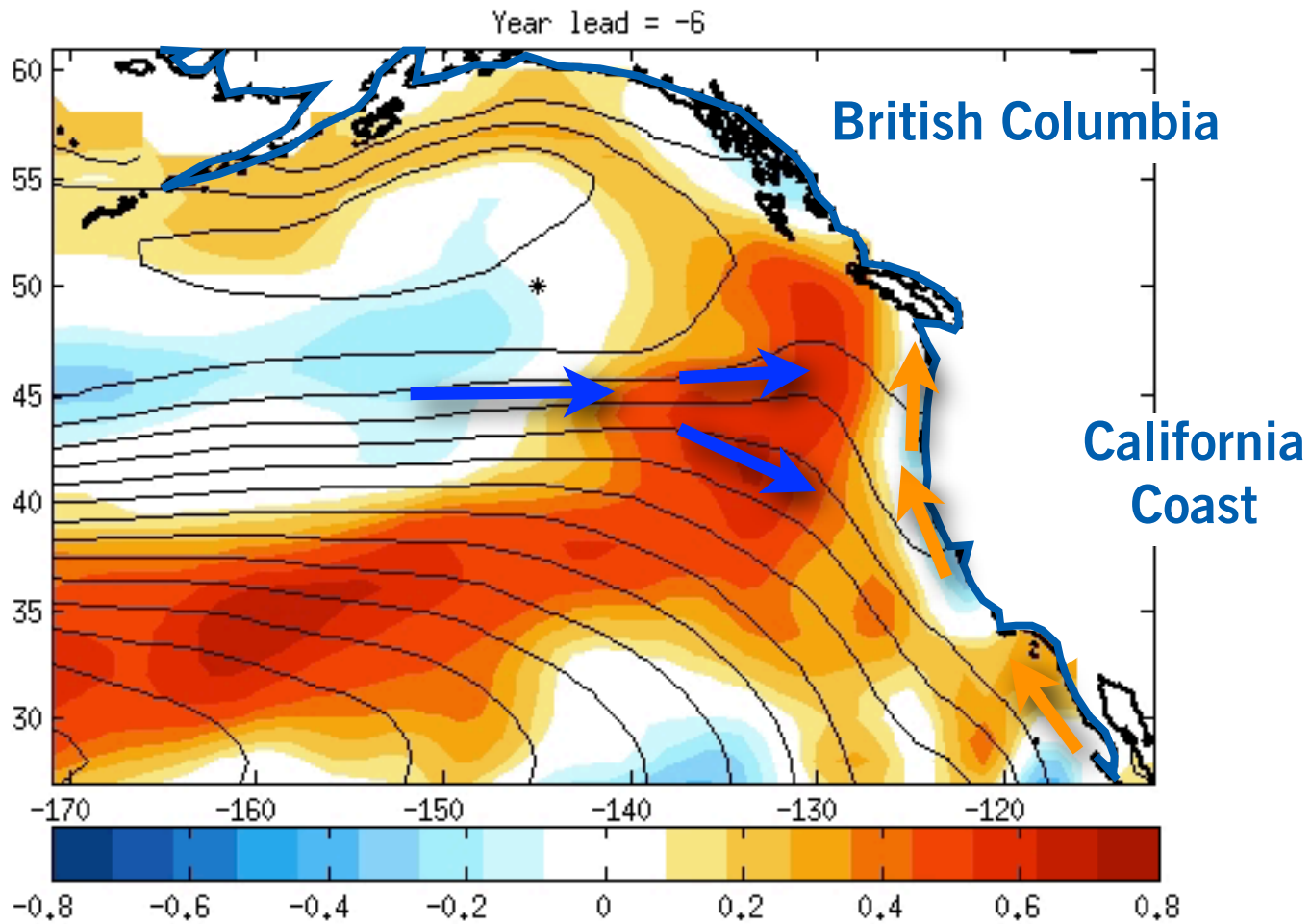
ECMWF ORA3 Oxygen Proxy Index



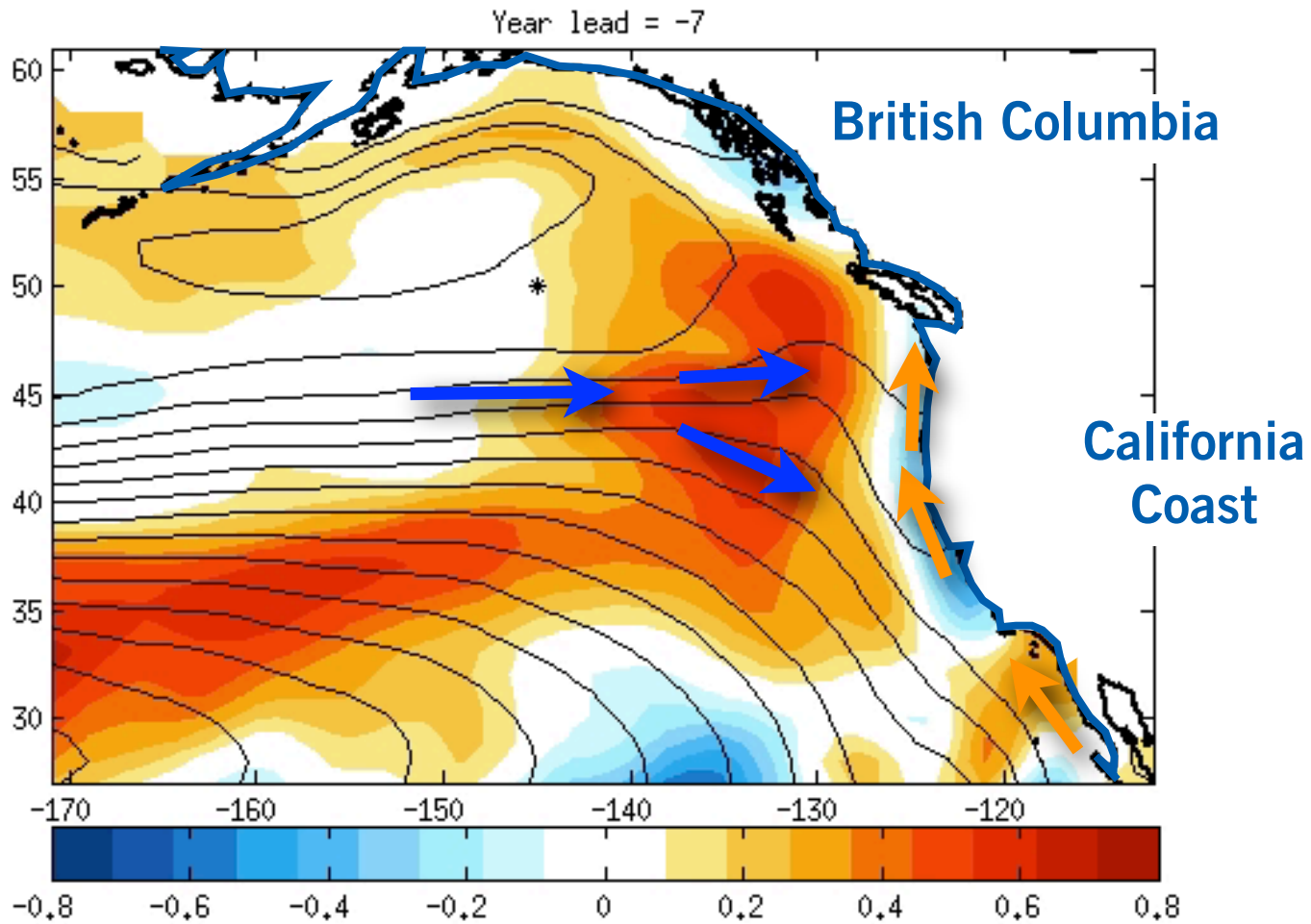
ECMWF ORA3 Oxygen Proxy Index



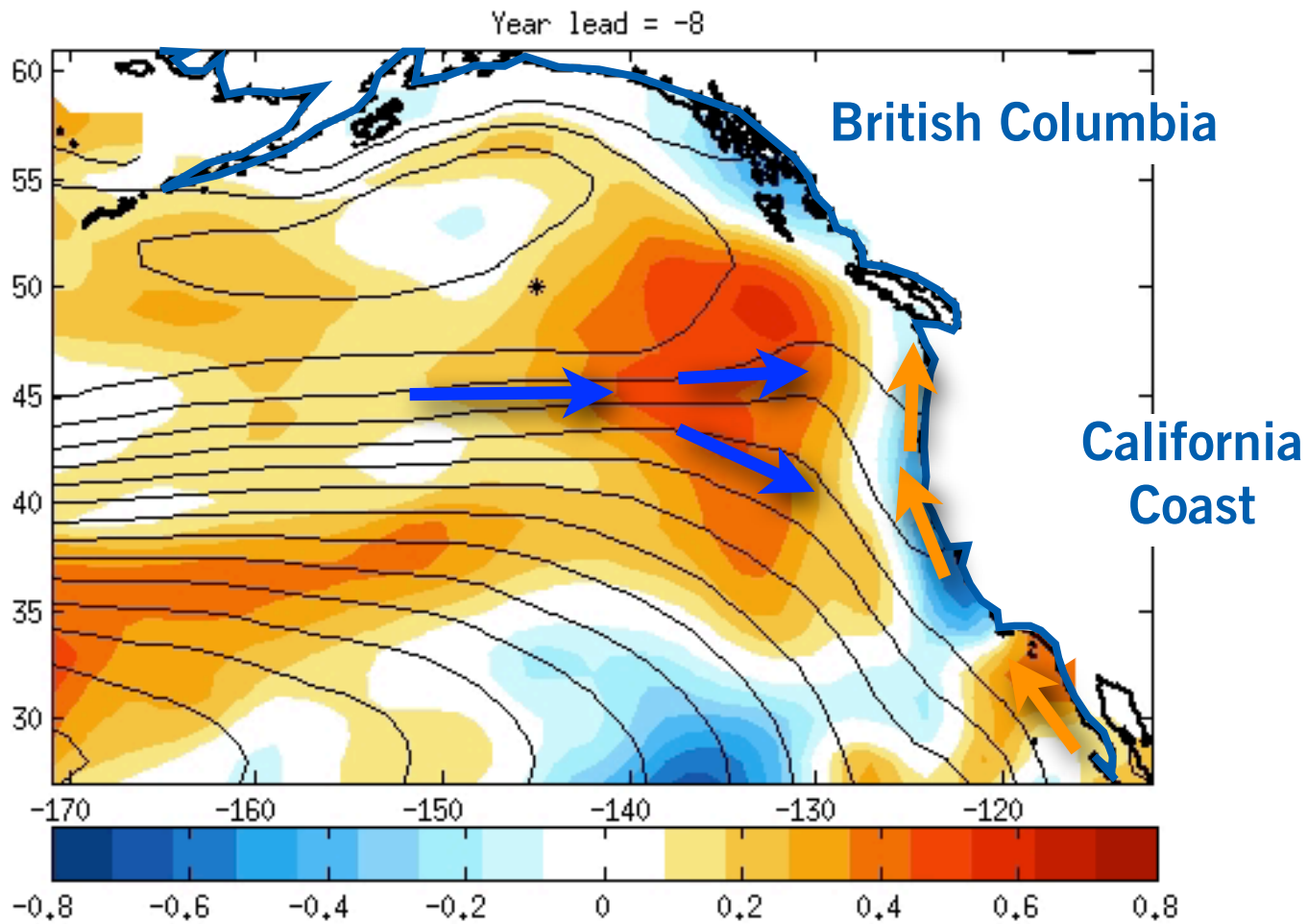
ECMWF ORA3 Oxygen Proxy Index



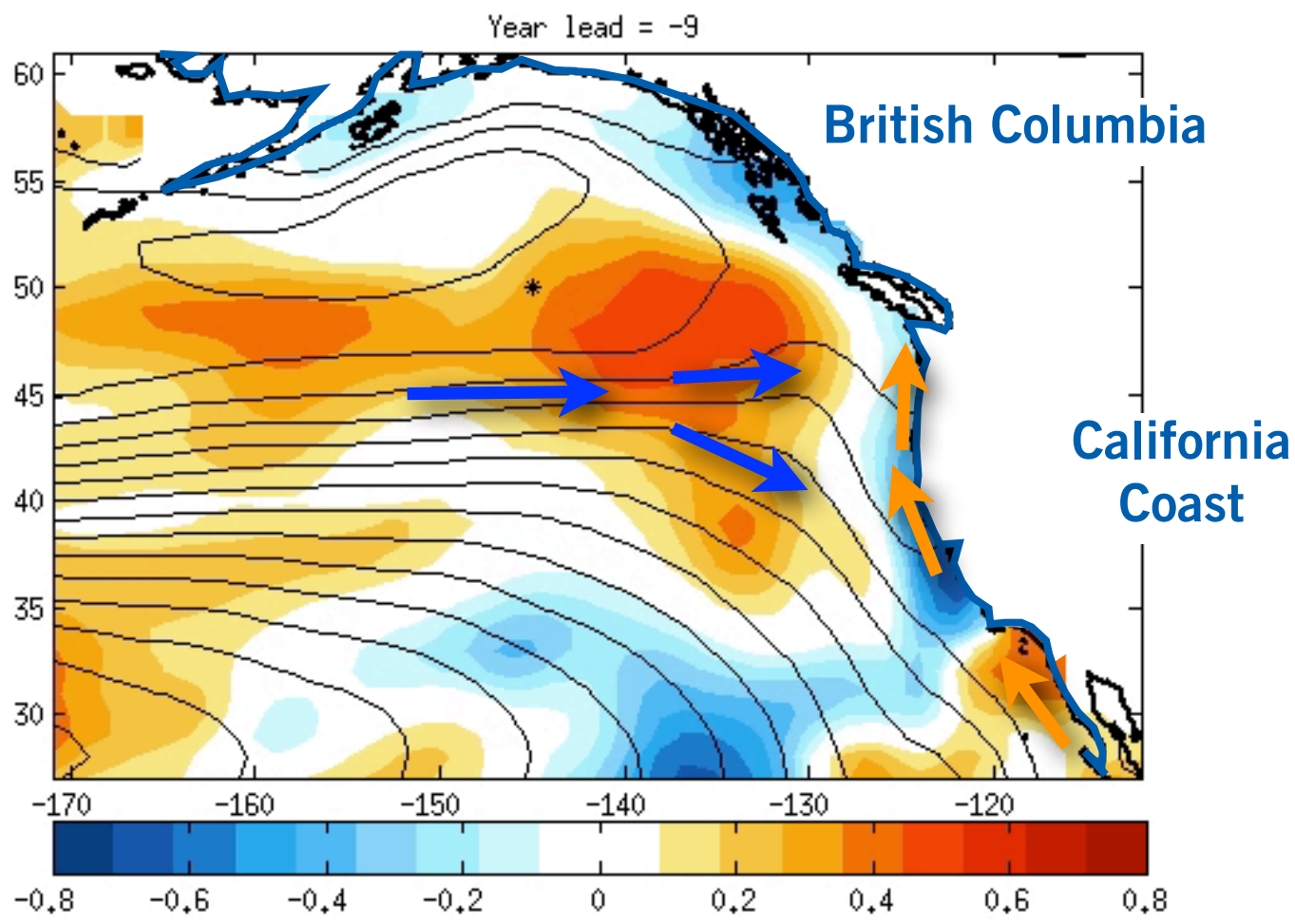
ECMWF ORA3 Oxygen Proxy Index



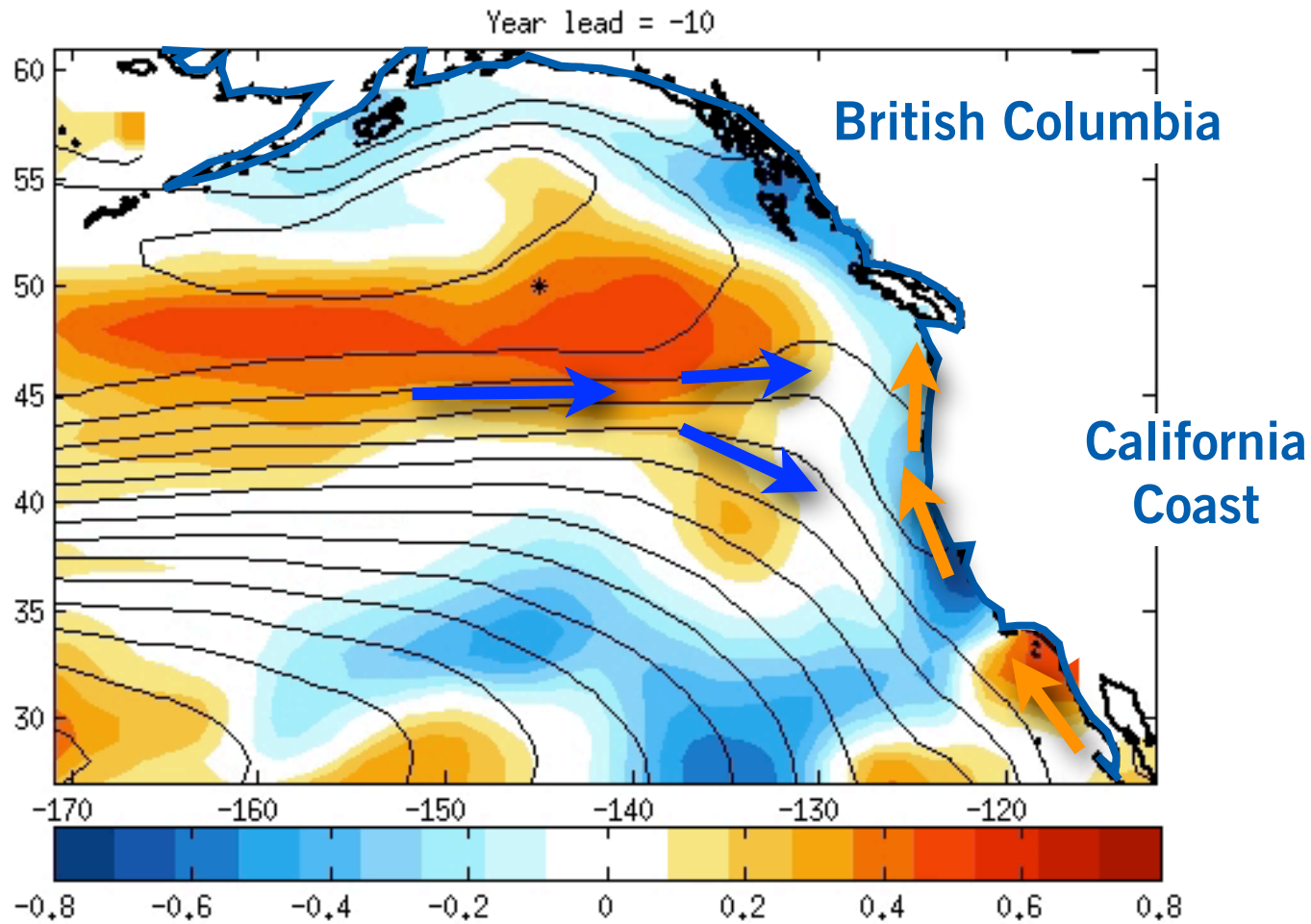
ECMWF ORA3 Oxygen Proxy Index



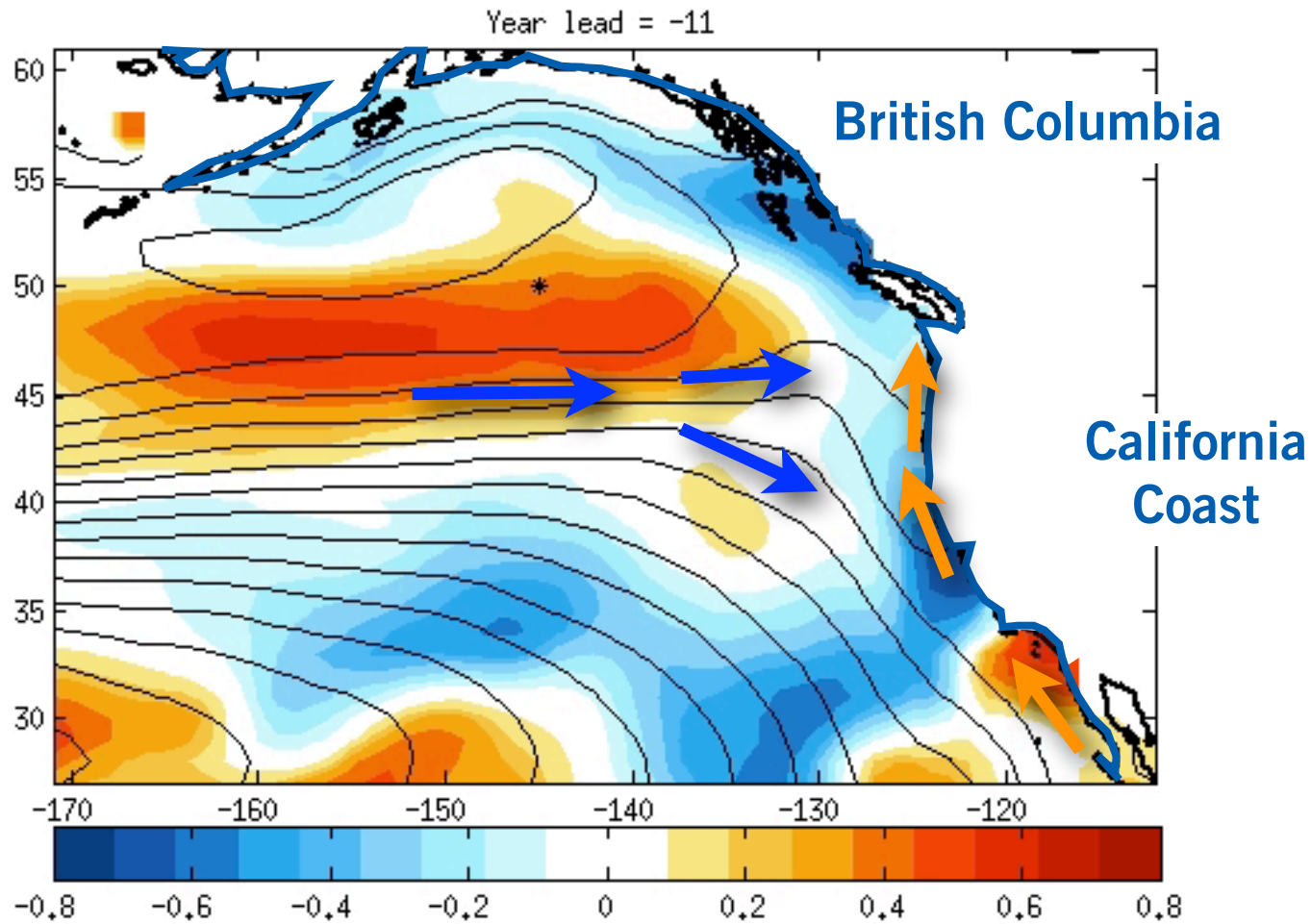
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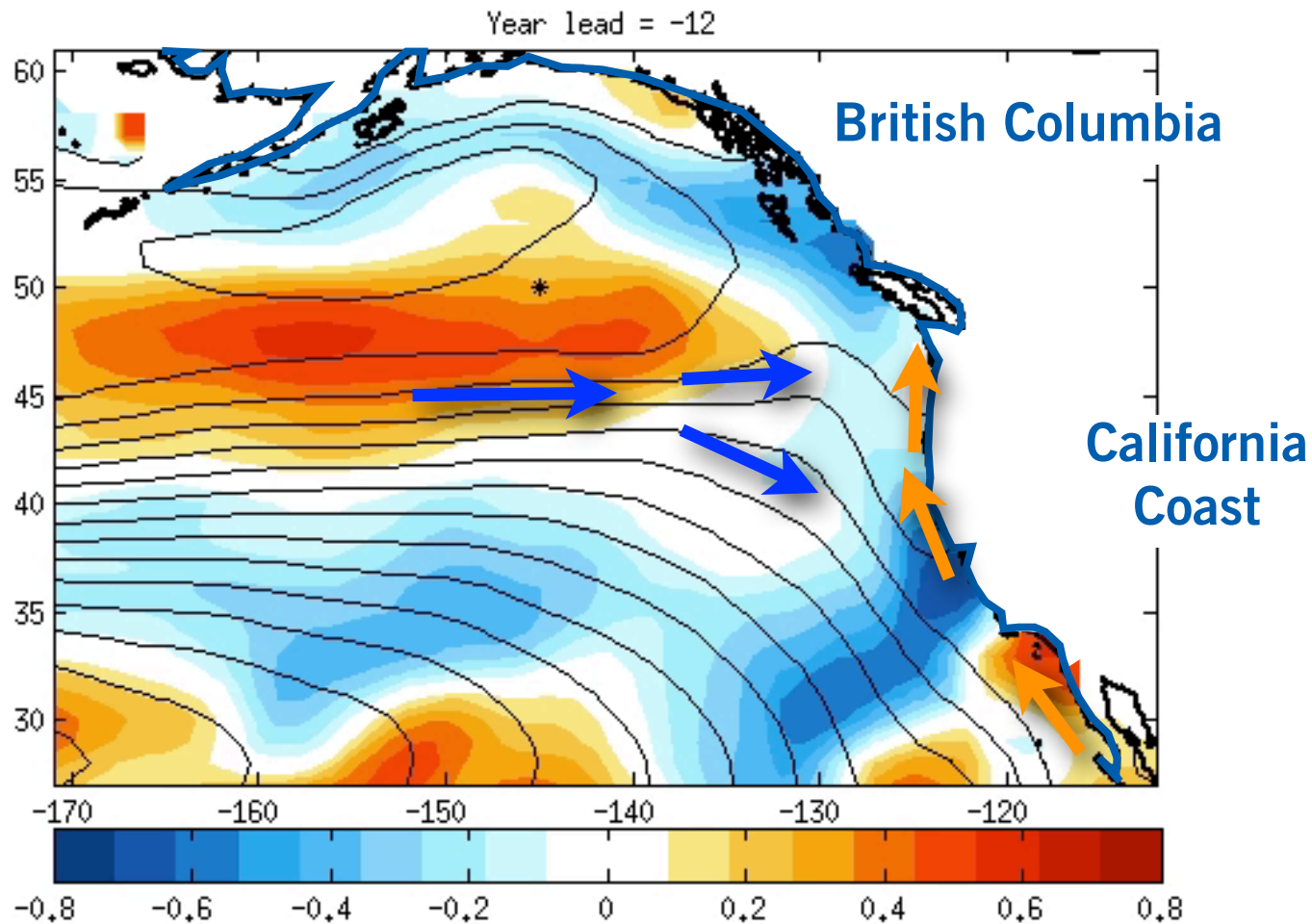
ECMWF ORA3 Oxygen Proxy Index



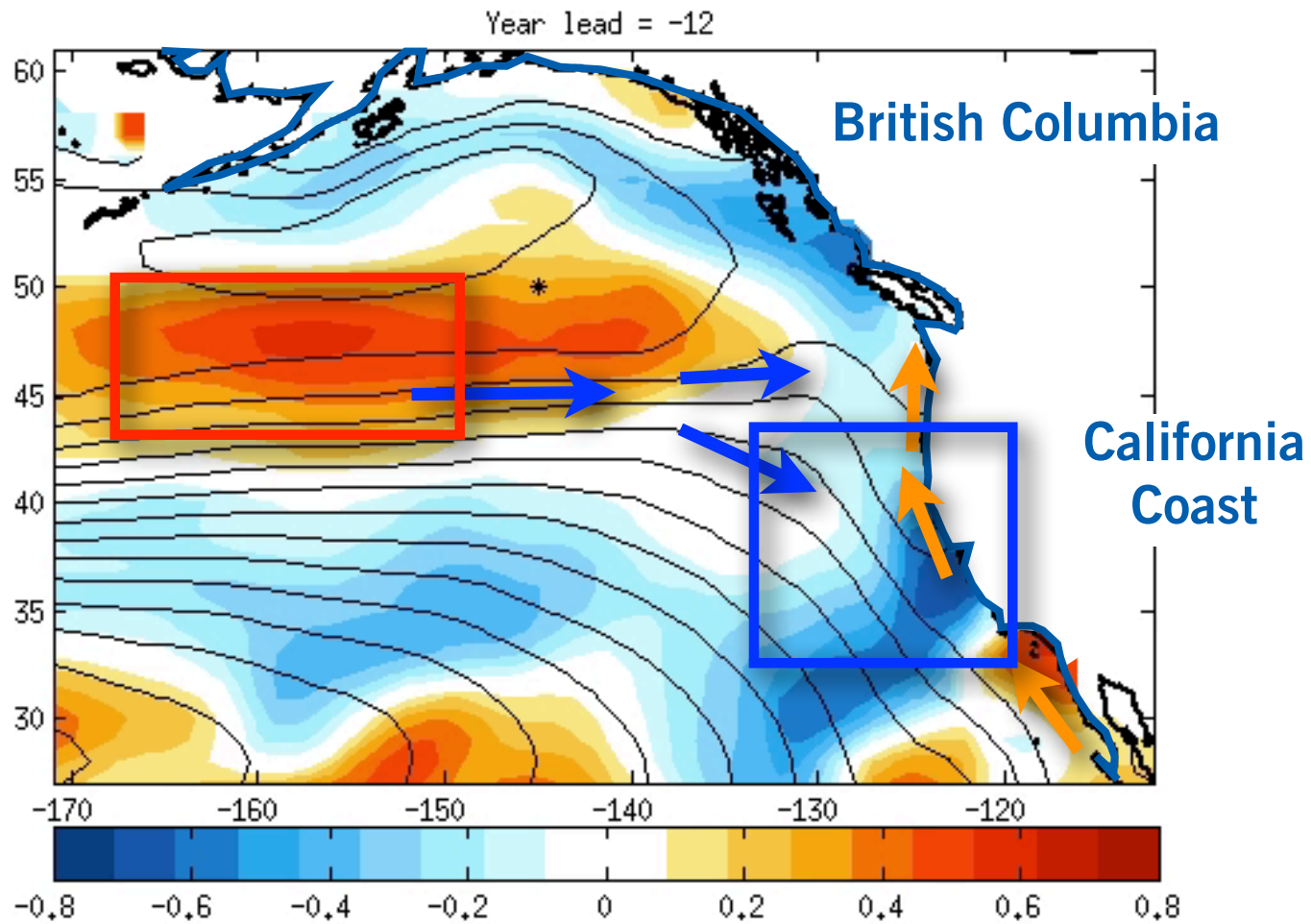
ECMWF ORA3 Oxygen Proxy Index



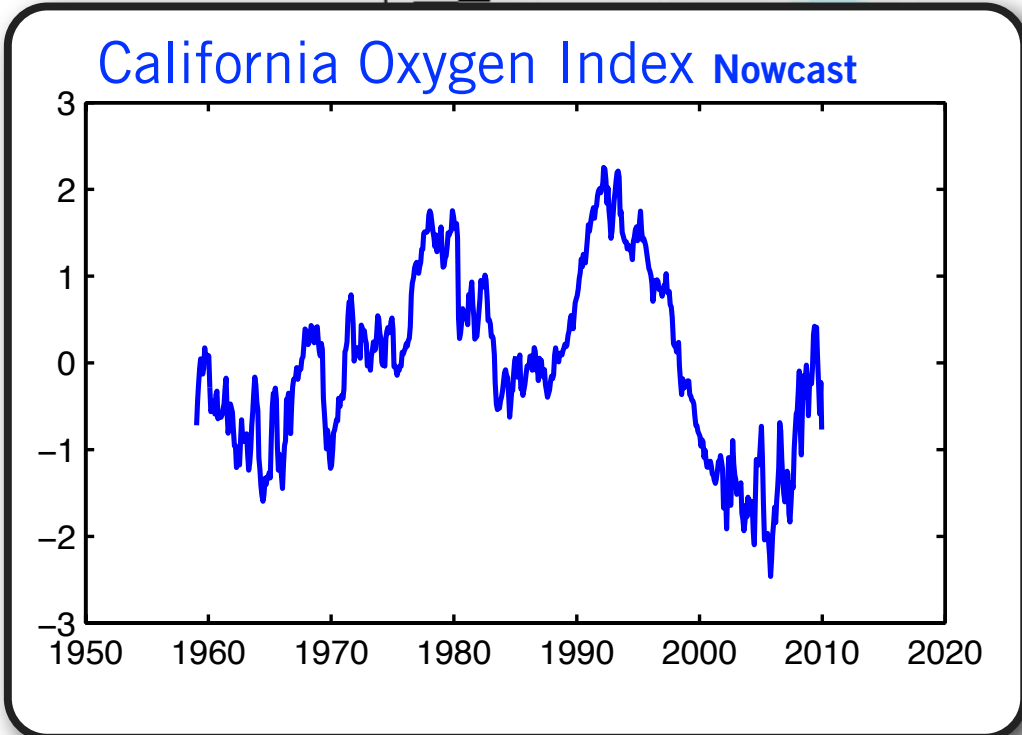
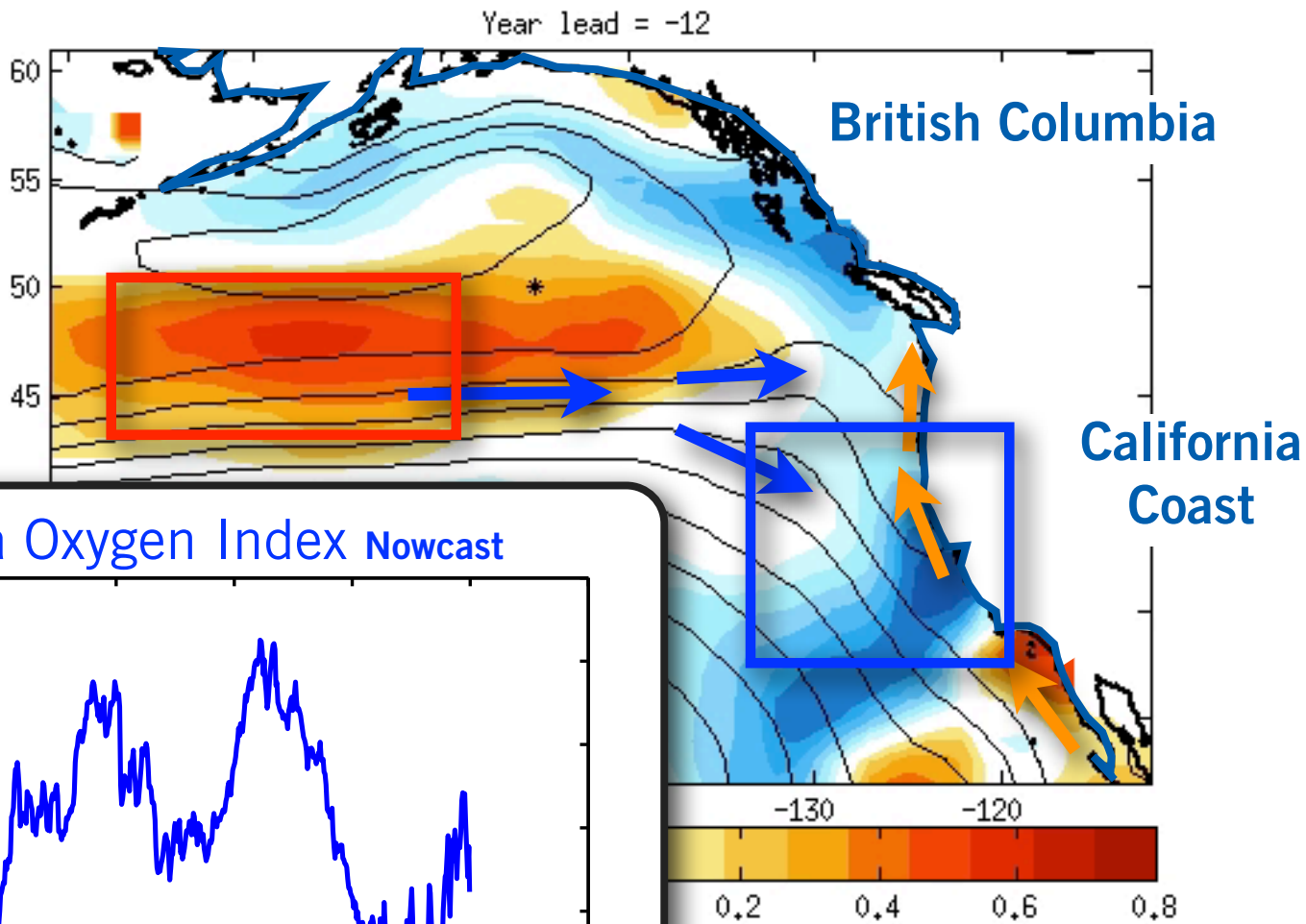
ECMWF ORA3 Oxygen Proxy Index



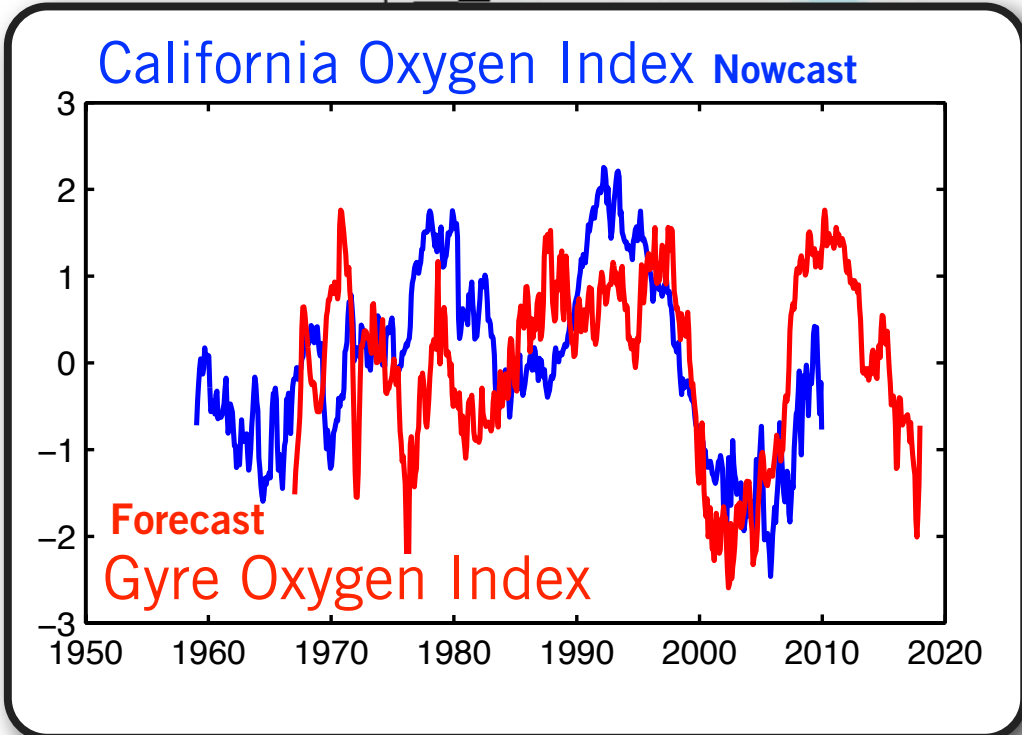
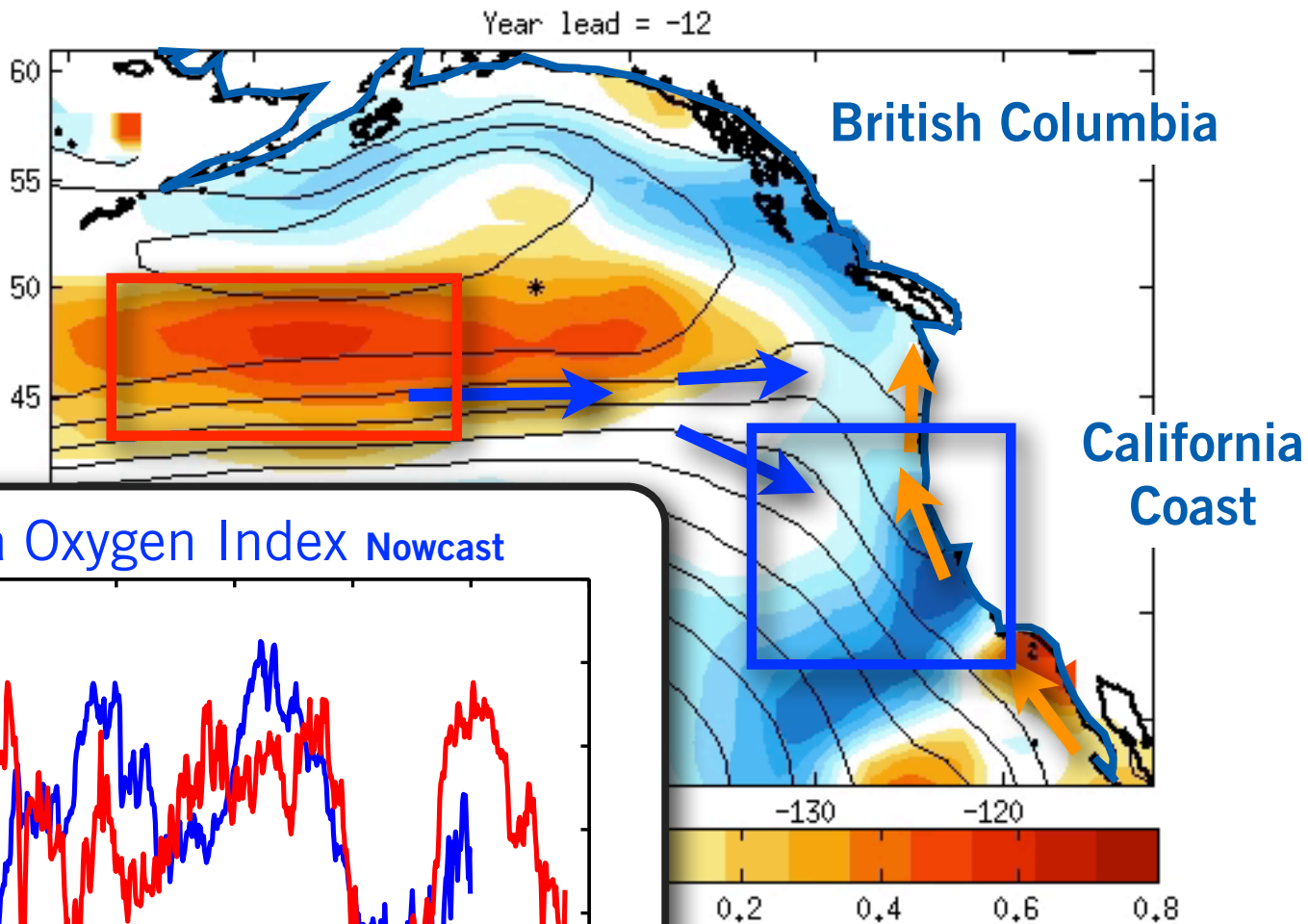
ECMWF ORA3 Oxygen Proxy Index



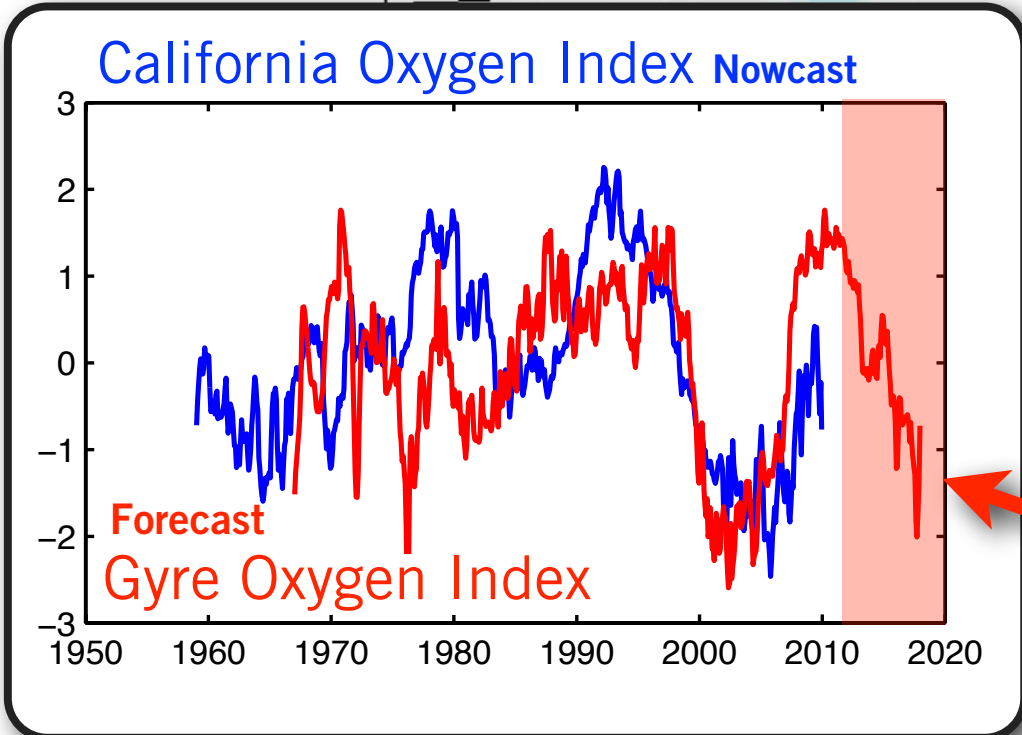
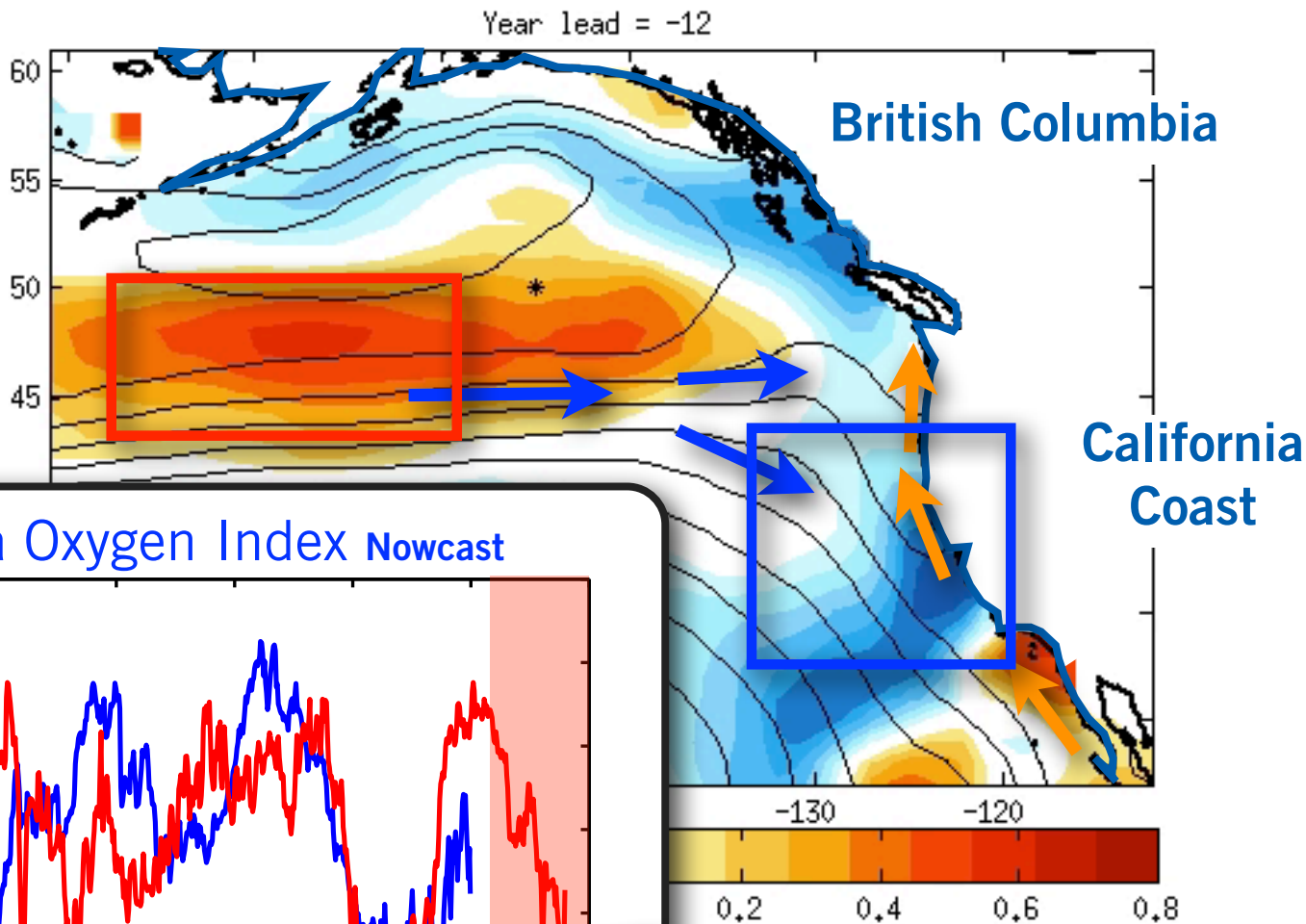
ECMWF ORA3 Oxygen Proxy Index



ECMWF ORA3 Oxygen Proxy Index



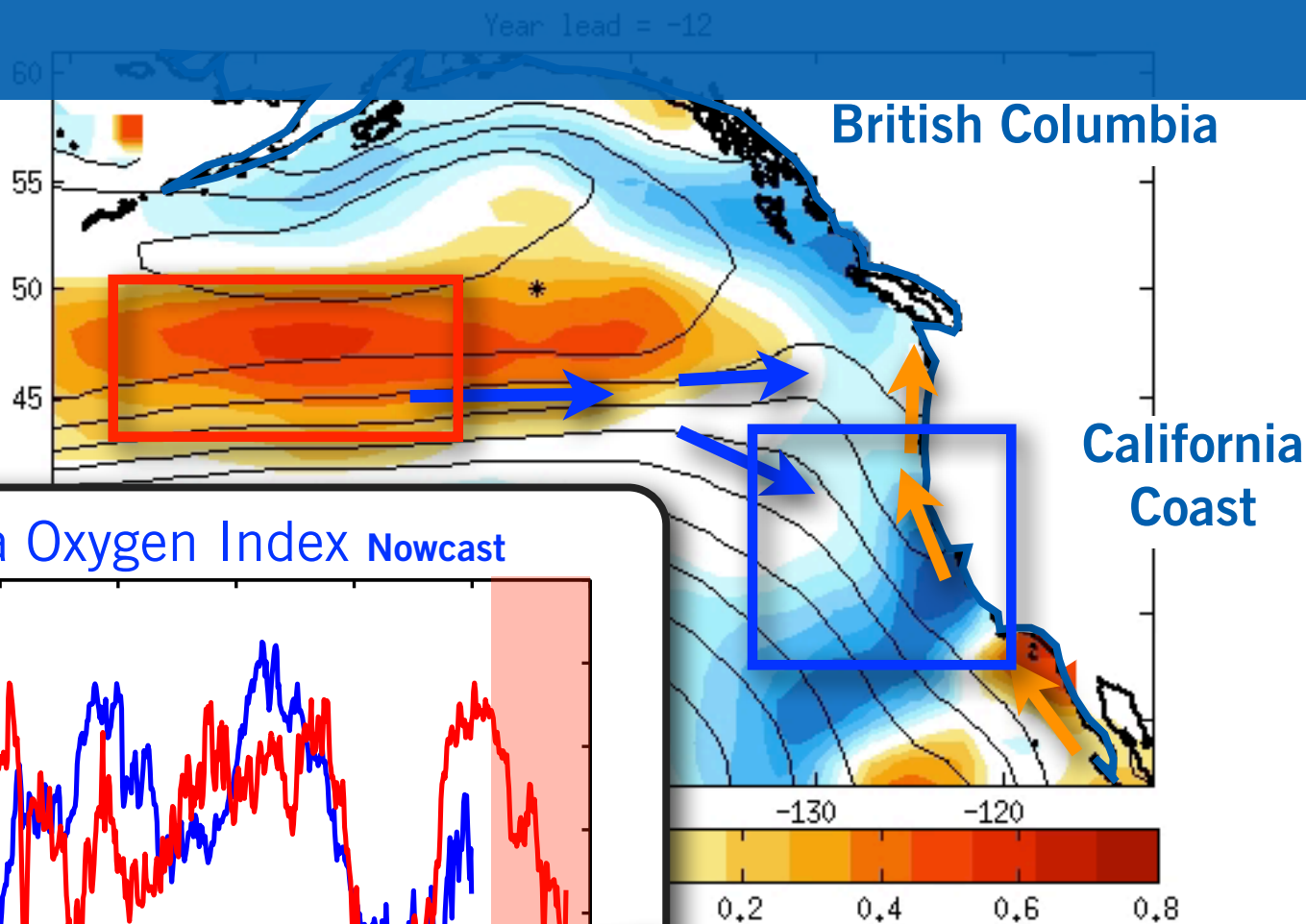
ECMWF ORA3 Oxygen Proxy Index



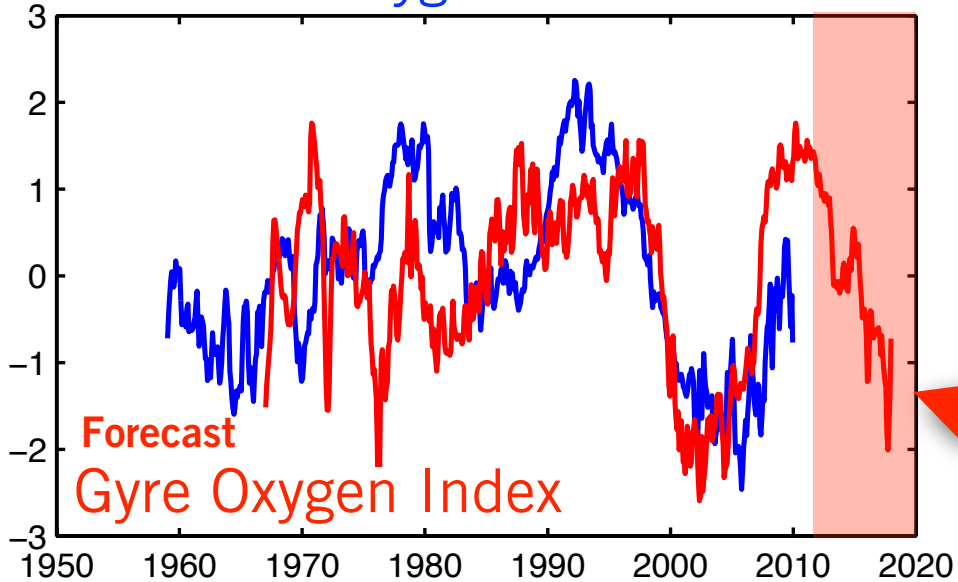
towards another period of strong hypoxia?

COMMENTS & CHALLENGES

ECMWF ORA3 Oxygen Proxy Index



California Oxygen Index Nowcast

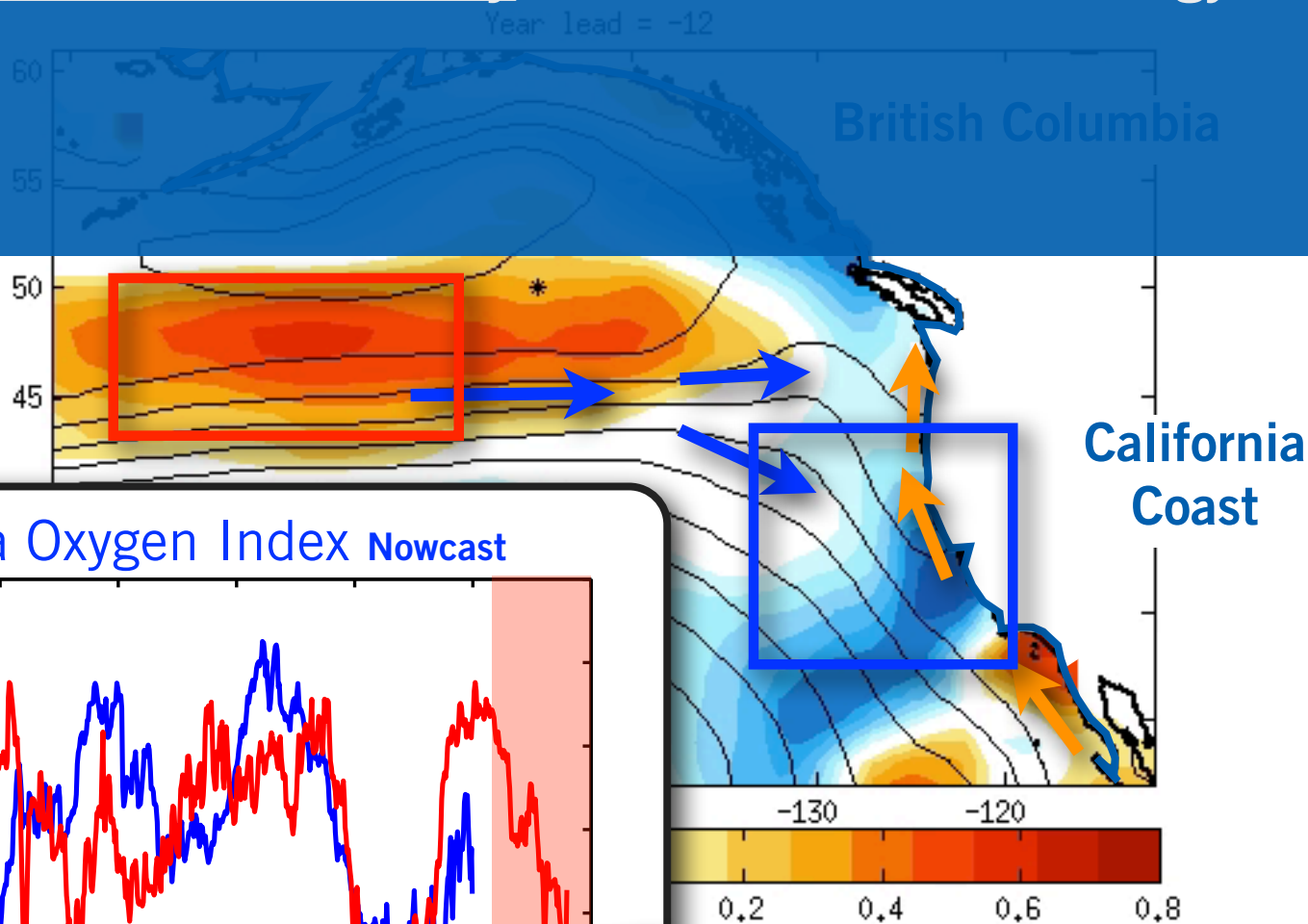


towards another period of strong hypoxia?

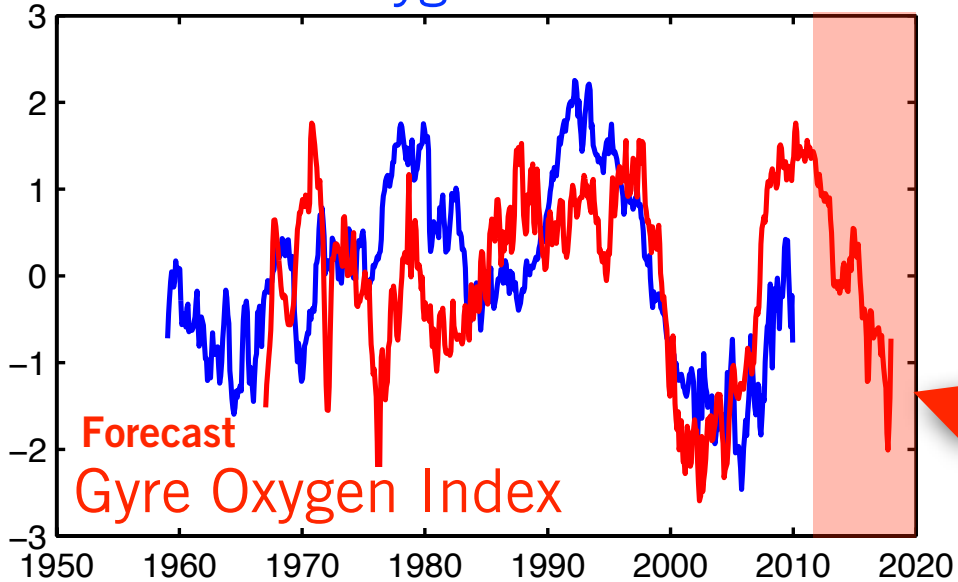
COMMENTS & CHALLENGES

ECMWF ORA3 Oxygen Proxy Index

1. strong decadal variability in subsurface O₂ from gyre dynamics



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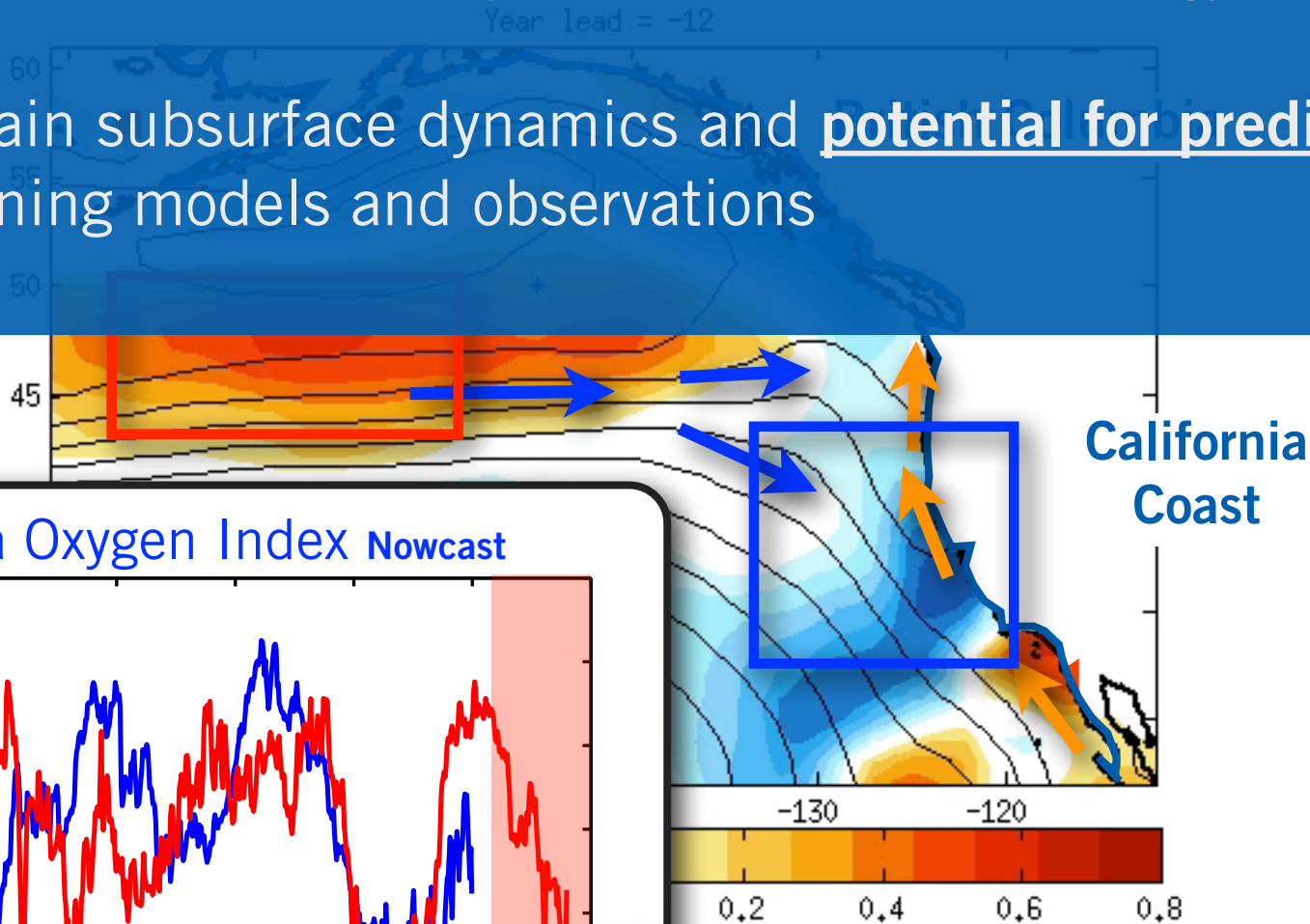
towards another period of strong hypoxia?

COMMENTS & CHALLENGES

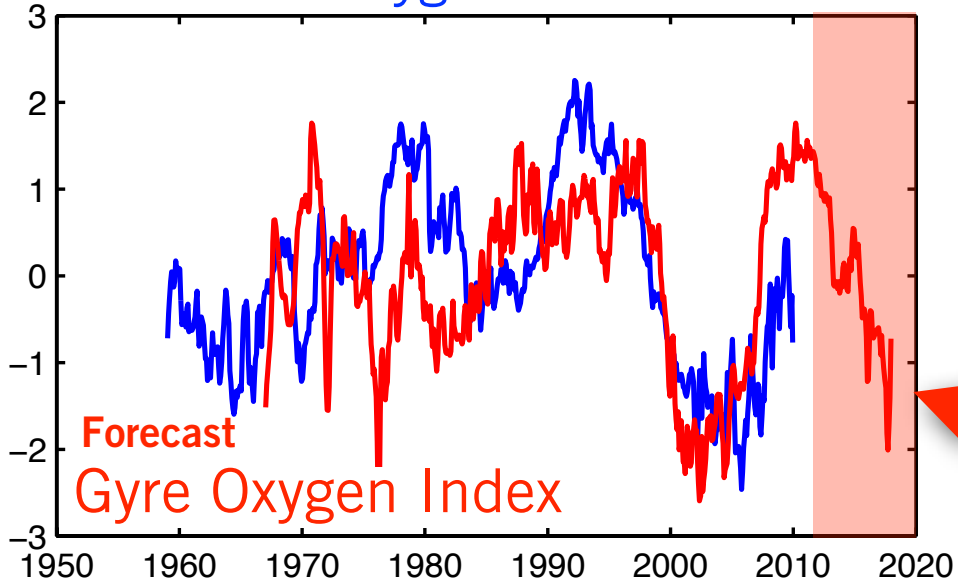
ECMWF ORA3 Oxygen Proxy Index

1. strong decadal variability in subsurface O₂ from gyre dynamics

2. constrain subsurface dynamics and potential for predictability by combining models and observations



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towards another period of strong hypoxia?