Drivers and Ecological Consequences of Ocean Acidification and Hypoxia (OAH) in the California Current

SCCWRP Climate Change Research Portfolio

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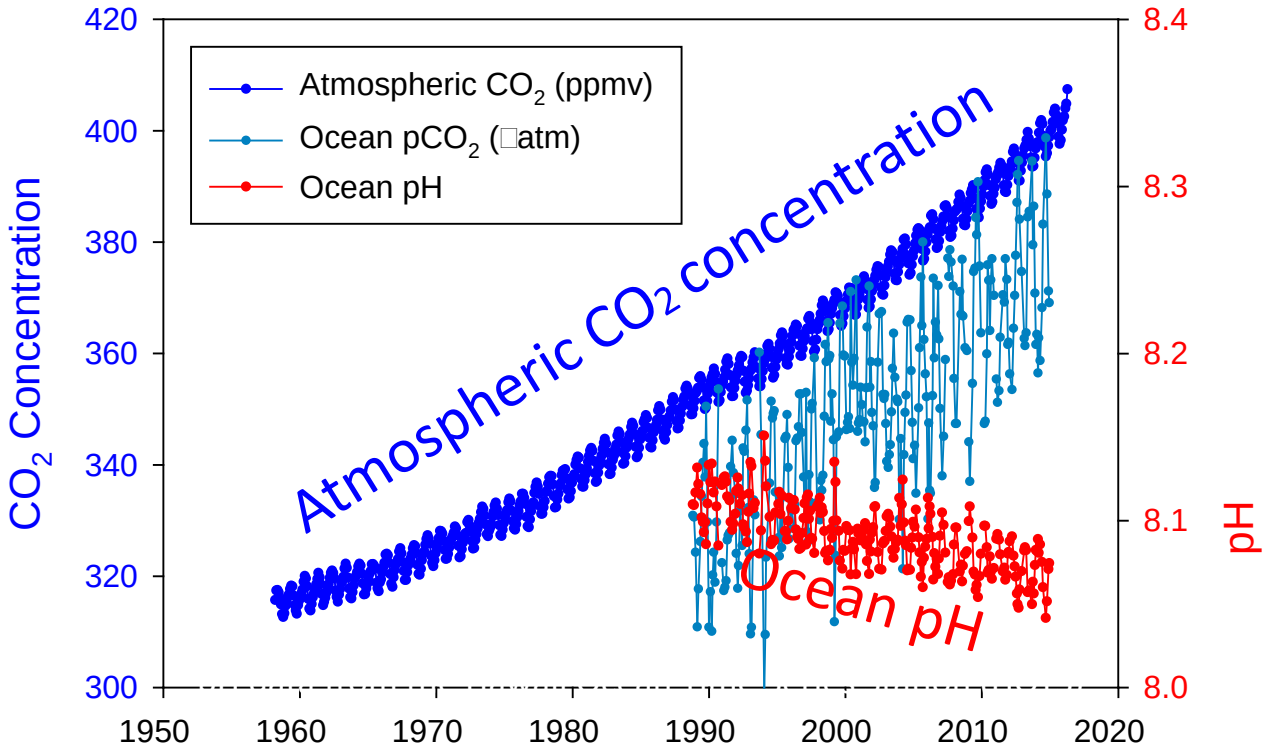
Ocean Acidification: The Other CO_2 Problem

30% of atmospheric CO_2 is absorbed into the ocean

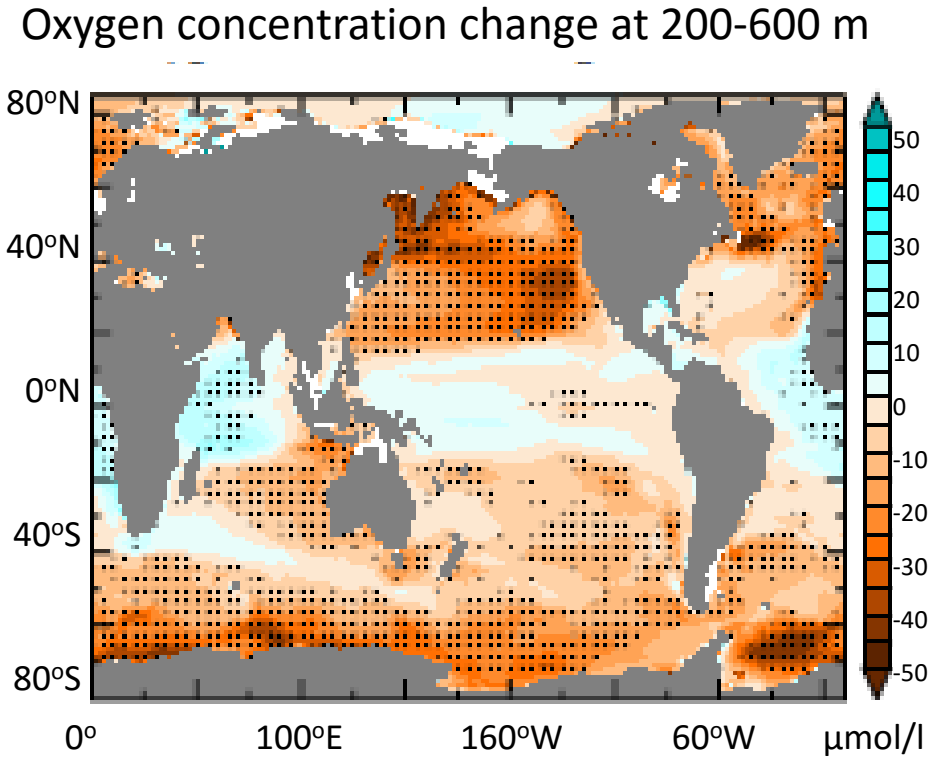
- As a result, CO_2 levels in seawater are rising
- Ocean pH decreases when CO_2 dissolves in seawater



pH data from the Hawaii Ocean Time Series Station (HOTS)

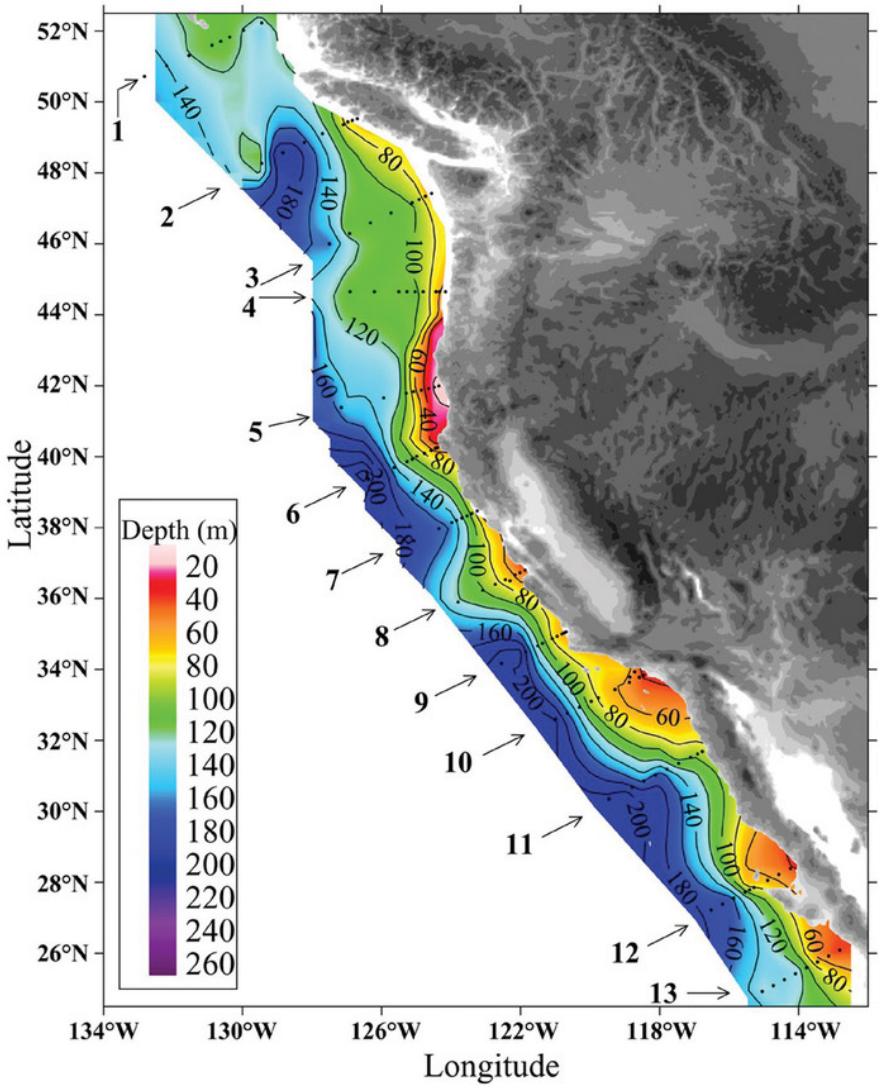
Declines in pH Are coupled with Increasing Temperatures, and Hypoxia, particularly in Eastern Pacific Ocean

Business As Usual Scenario, Year 2090-2099

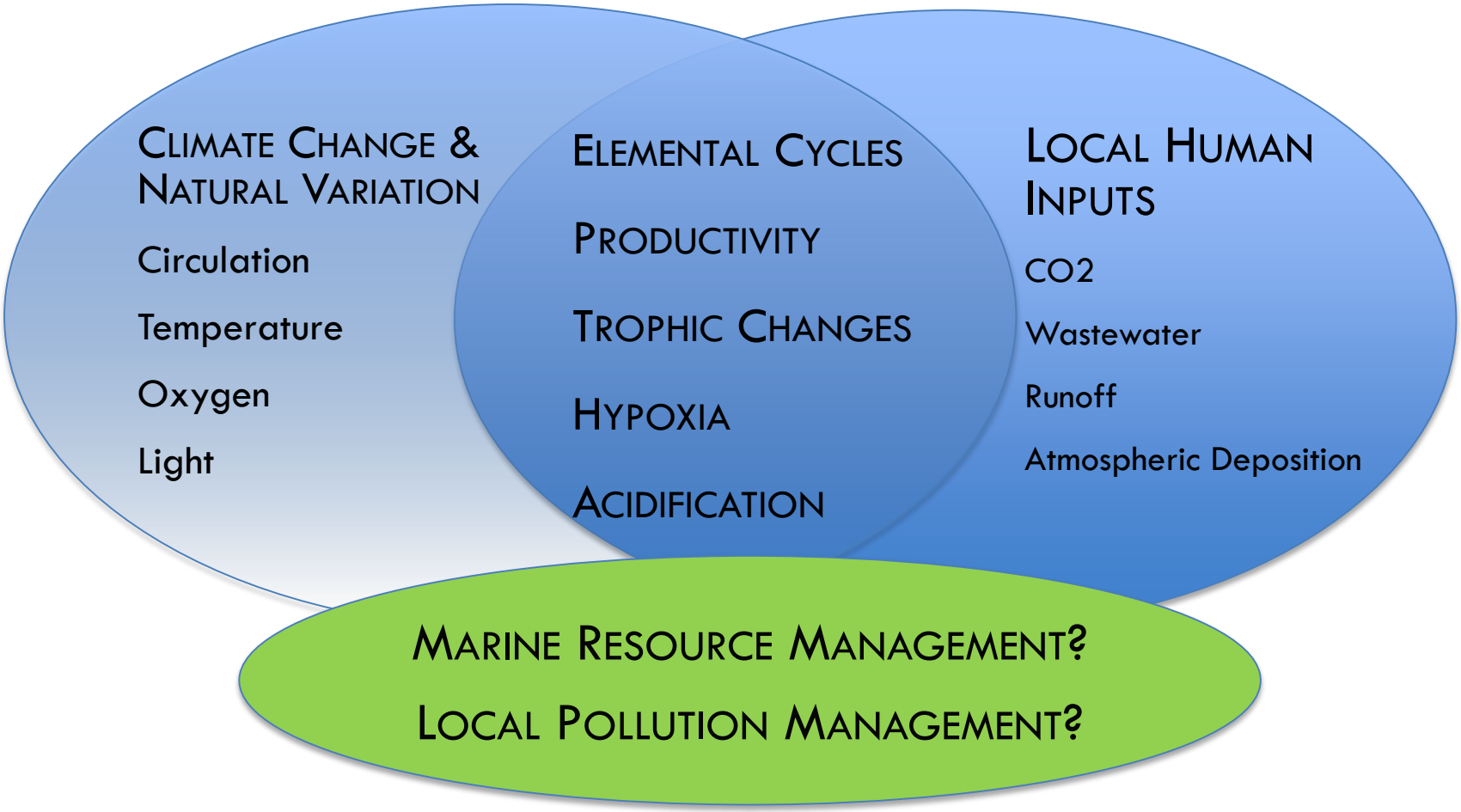


The West Coast Is Particularly Vulnerable

- We have a narrow continental shelf
  - Upwelling of low pH and low O2 waters occurs close to shore
  - CCS ecosystem will be sensitive to even small changes on OAH
- Corrosive water already being seen in shallow water close to shore
  - Along California coast, SCB and San Francisco Coast are OA “hot spots”
- Significant decline in O2 and shoaling of O2 minimum zone over past 2 decades
- Significant temperature anomaly in 2014-2016
  - “The Blob”!



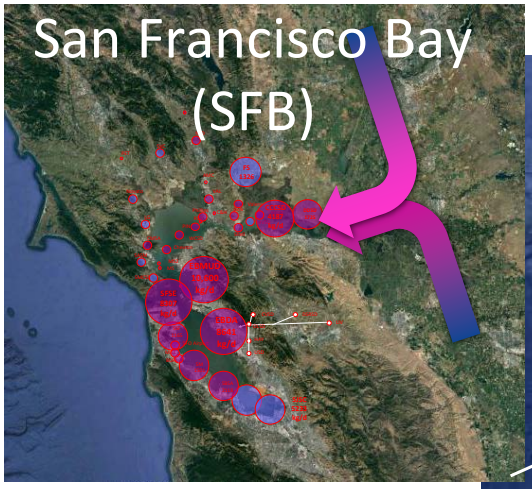
Global Change? Local Pollution Stress?

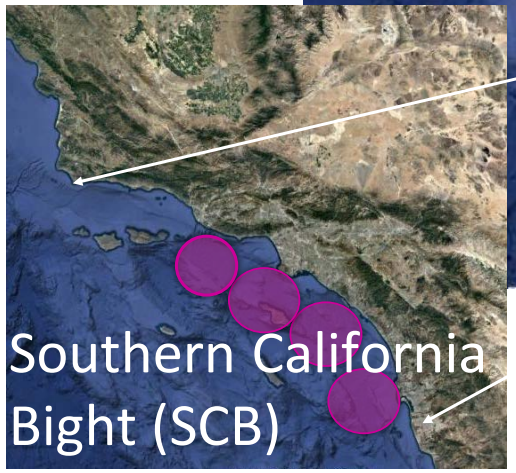


California Has Significant Coastal Nitrogen Export

ANNUAL COASTAL N EXPORT (Gg YR-1)

Pathway	SFB*	SCB	Other	Total
POTW Outfall	17	45	20	82
River Export	17	4	19	39
Total	34	49	39	121





- 8 largest POTW ocean outfalls represent 50% of coastal export
- In SCB, anthropogenic coastal N export has doubled available nitrogen in nearshore

OAH Research Elements

Earth Systems Model Development and Applications

- Primary Tools to Disentangle Effects of Climate Change, Natural Variability and Anthropogenic Inputs

Ocean Observations

- Model validation
- Quantify OA-Hypoxia-Temperature status and trends

Biological Impacts of OA-Hypoxia-Temperature

- Implications of observed/predicted trends for ecosystem services and beneficial uses

WRF-ROMS-BEC Model

Atmospheric forcing

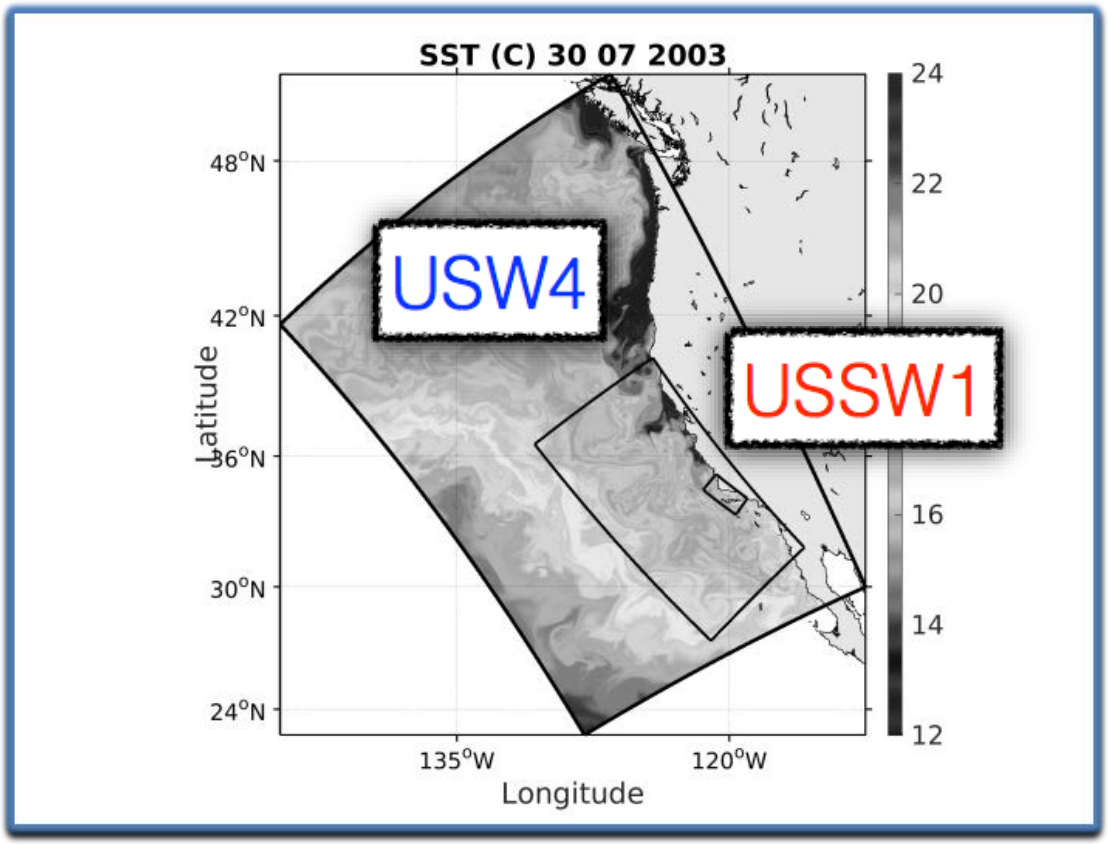
WRF (Weather and Research Forecast Model)

Physical model

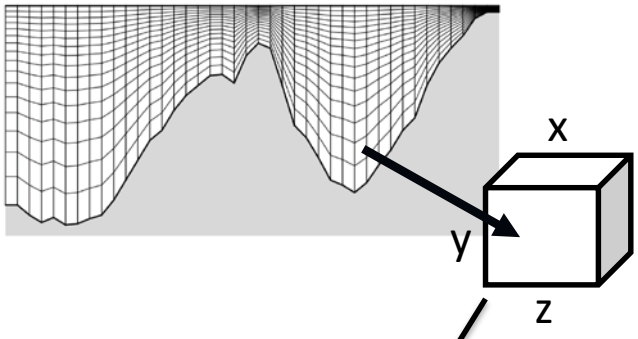
ROMS (Regional Oceanic Model System)

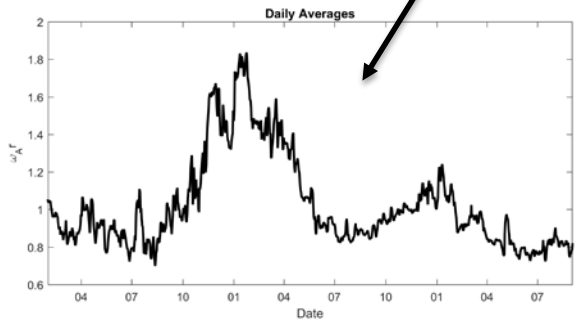
Biogeochemistry

BEC (Biogeochemical Elemental Cycling)



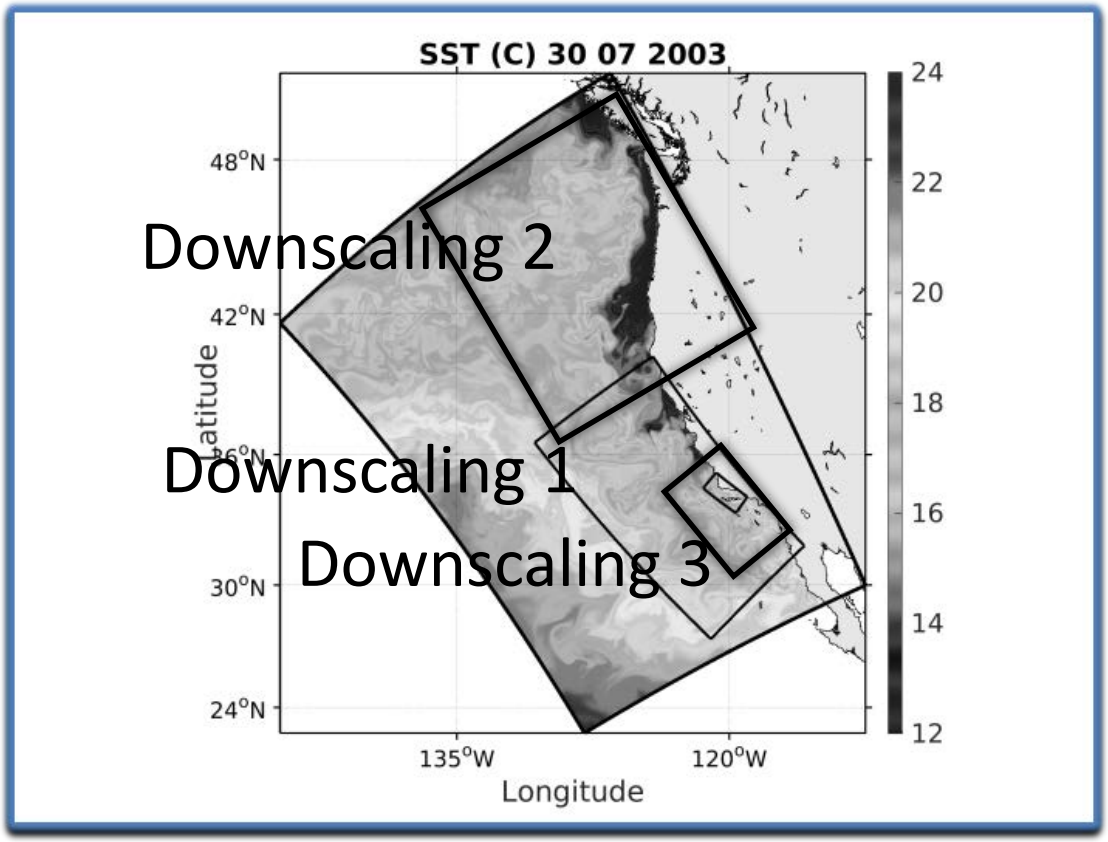
Grid: 60 variable depth levels





aragonite time-series from the model

Model contains huge amount of information (>35 state-variables and > 66 million grid cells per output (daily) for multiple years)
And multiple time and space configurations



STATE VARIABLES

Ocean physics

Nutrients
Nitrate, nitrite, ammonia
phosphate
silicate, Iron

Plankton
[2 phytoplankton groups an zooplankton biomass]

Organic matter

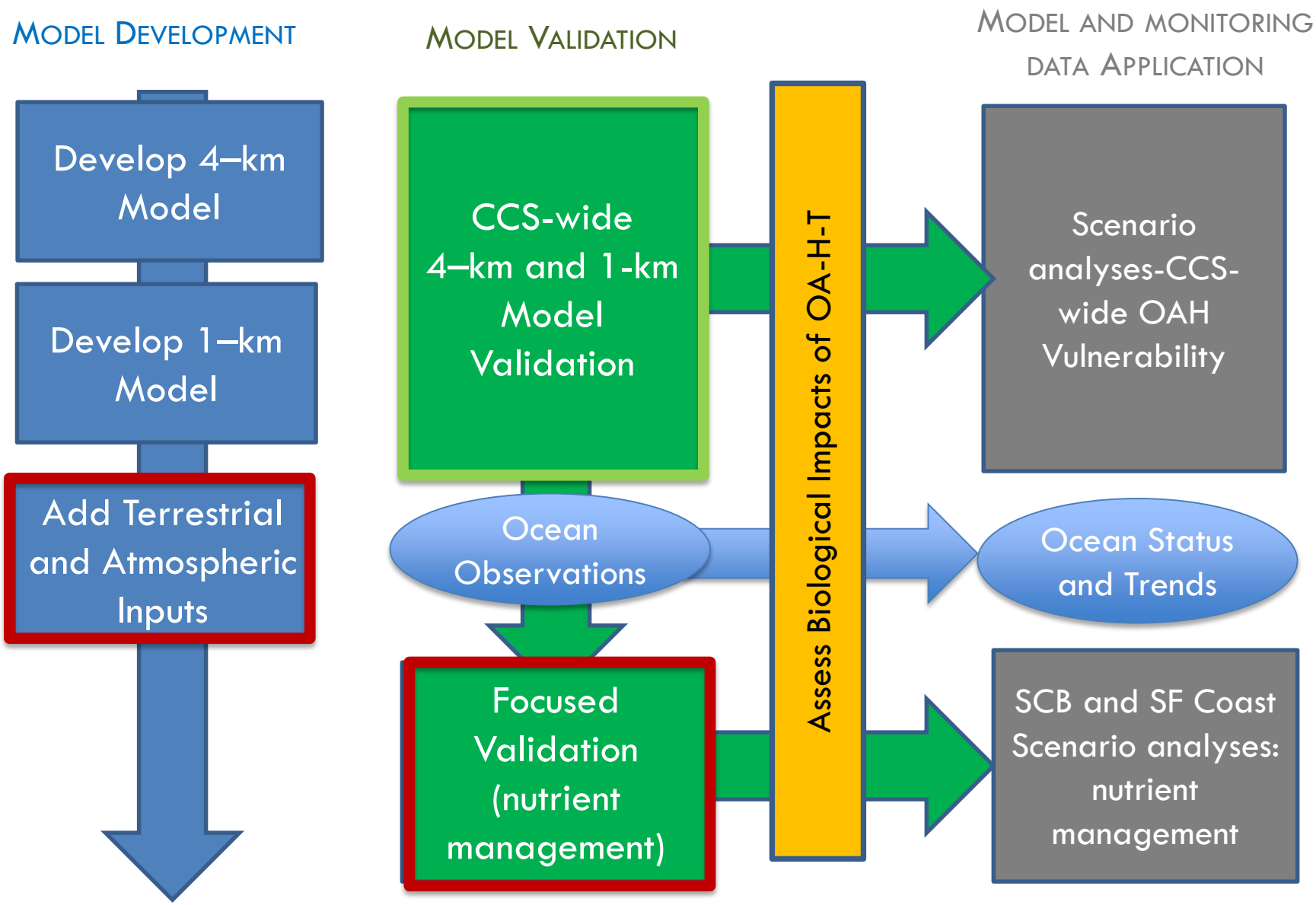
Oxygen

Carbonate system

From a Manager's Perspective: Three Questions

- Are modeled predictions of OA and hypoxia sufficiently accurate and precise to inform management action?
  - Nutrient management
  - Marine resource management
- What are the biological implications of observed or modeled OAH status and trends?
  - How do we deal with impacts from co-occurring stressors?
- What are cost-effective management strategies?

Technical Elements of Climate Change Research

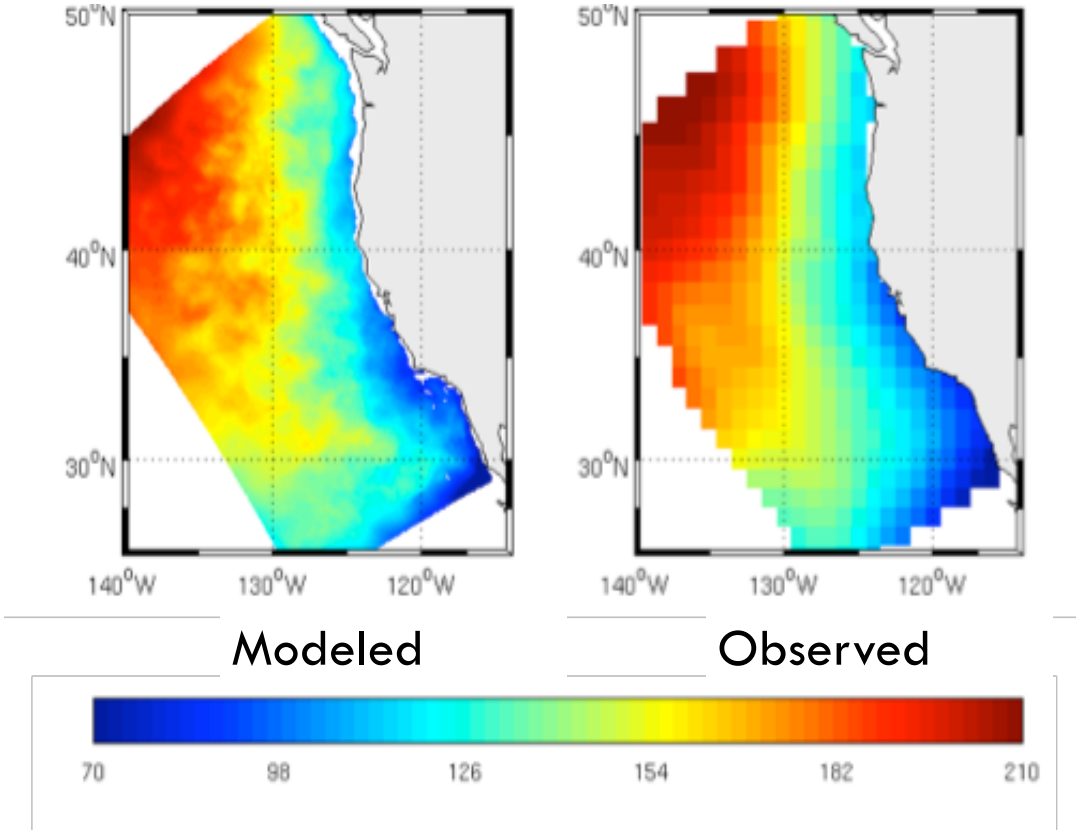


4-km and 1-km Validation Provide Assurance that We've Appropriately Modeled Ocean Forcing

Good consistency of coast-wide 4-km and 1-km solutions for atmospheric and oceanic physical & biogeochemical outputs against available coast-wide data sets

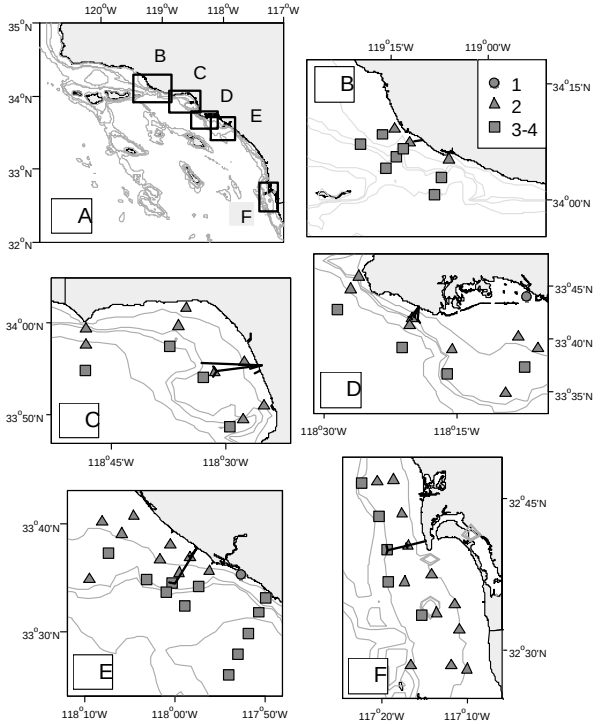
- spatial patterns, seasonal cycles, and range of natural variability

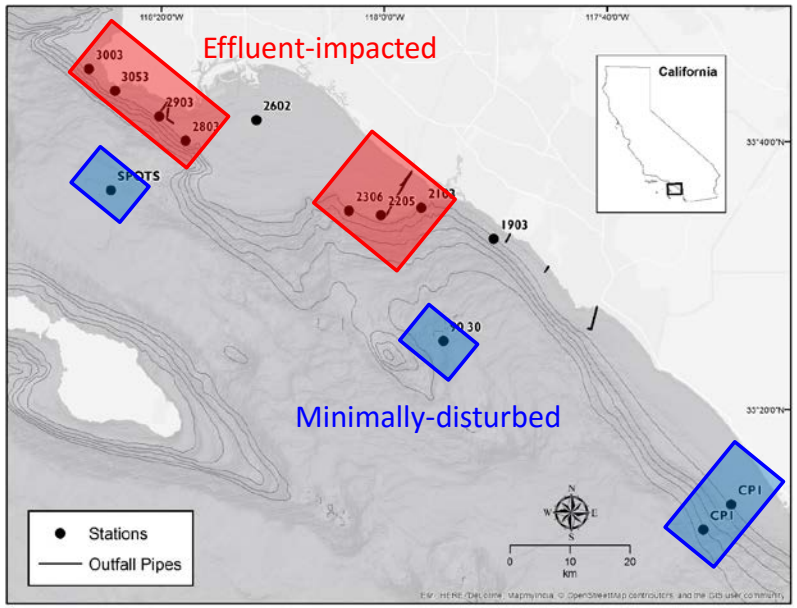
Oxygen distribution at sigma=26.5 [~100-250m]



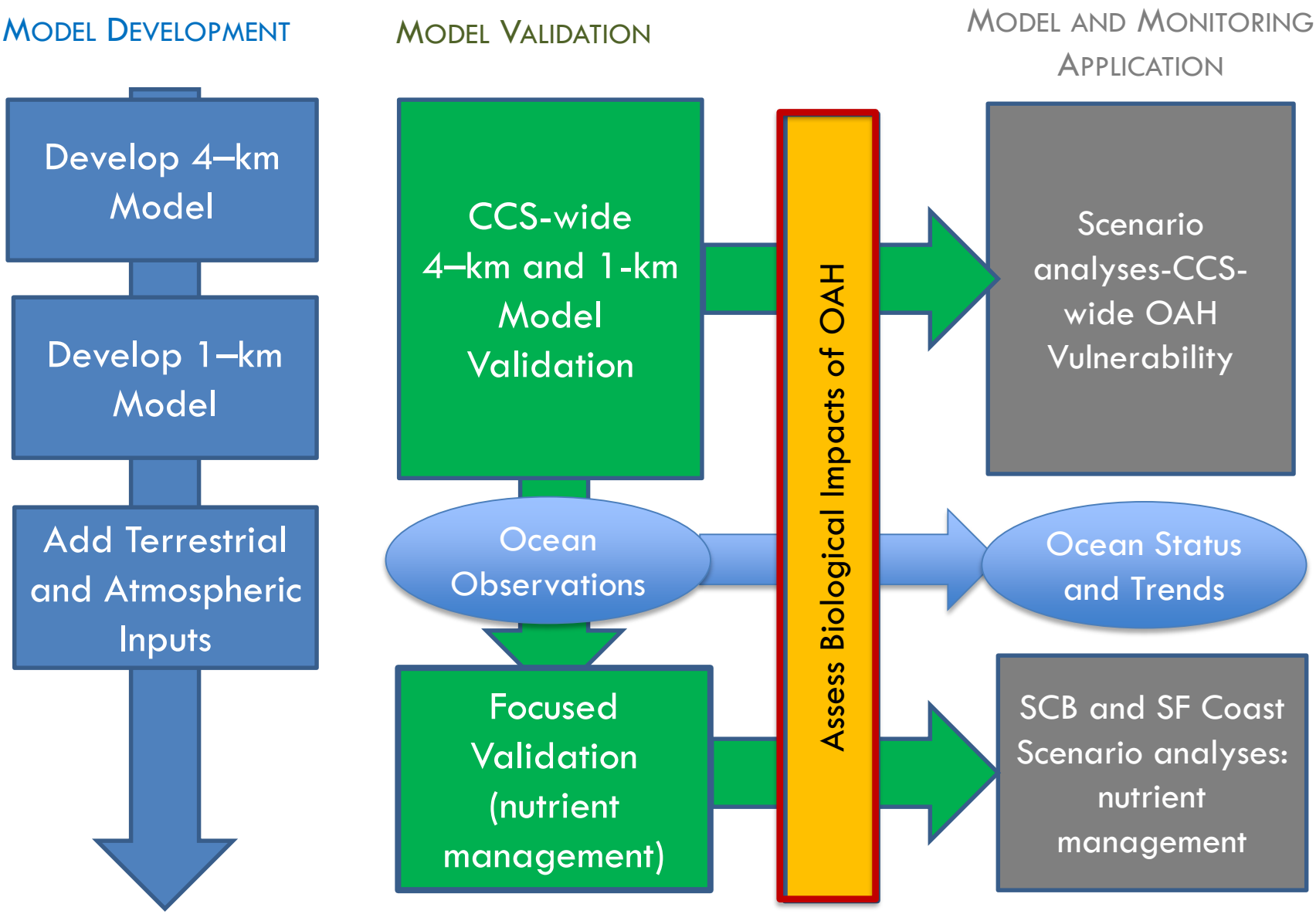
Focused Validation: Investments to Improve Monitoring of OAH Chemistry and Process Rates

- 5 Agencies undertook 2 year effort to improve pH measurements
  - First-ever synoptic survey of pH and saturation state on the SCB shelf
- Commitment to install moored sensors by each of the POTWs
- Quantified "rates" of nutrient & carbon transformations that drive OAH outcomes
  - Effluent impacted versus minimally disturbed
- Examined seasonal rates (upwelling vs. stratification) for 2 years





Technical Elements of Modeling Program



Biological Effects of OAH: Our Challenge

Managers are investing millions in OA research and monitoring

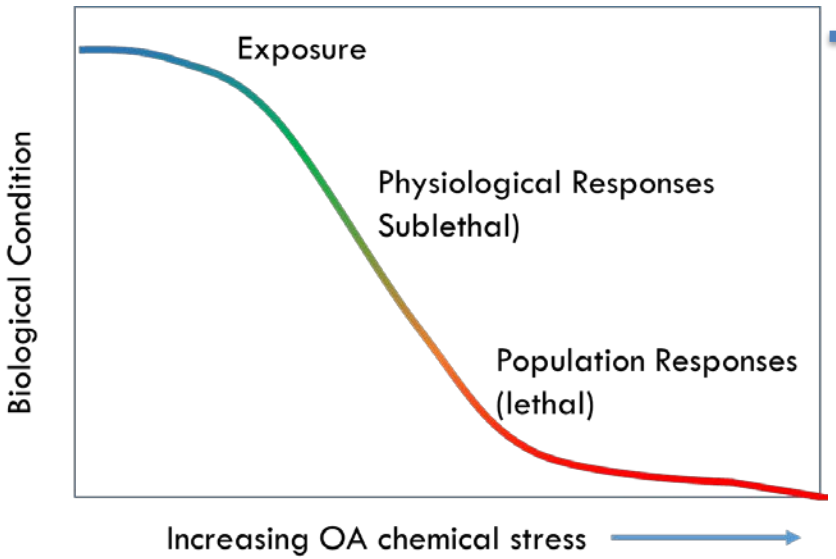
- Observations: Creating a coordinated west coast monitoring network of biological and chemical measurements
- Coupled physical-biogeochemical models to guide nutrient and marine resource management
- Mitigation Research - Investigating the effects of seagrass restoration as OA mitigation strategy

Our Challenge

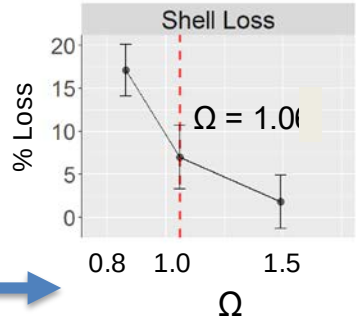
- We don't know how to interpret all that data
- Not clear at what thresholds biota are responding
- Even less clear how OA stress interacts with that from co-occurring stresses, such as hypoxia or temperature

Indicator Development and Threshold Science: Field Observations & Laboratory experiments

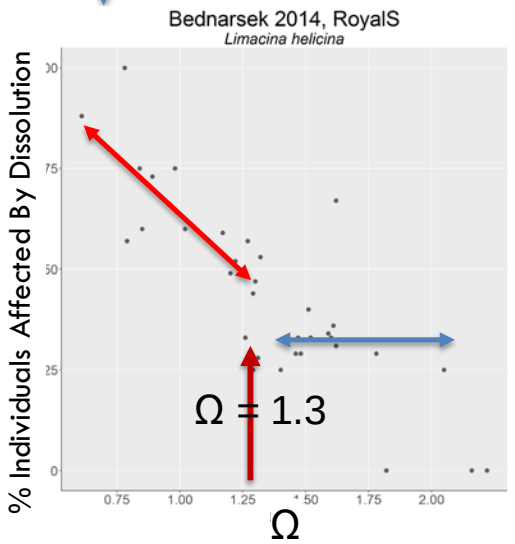
Early Focus on calcifiers!



Laboratory Experiments



Field Obs. of
Stress-Response



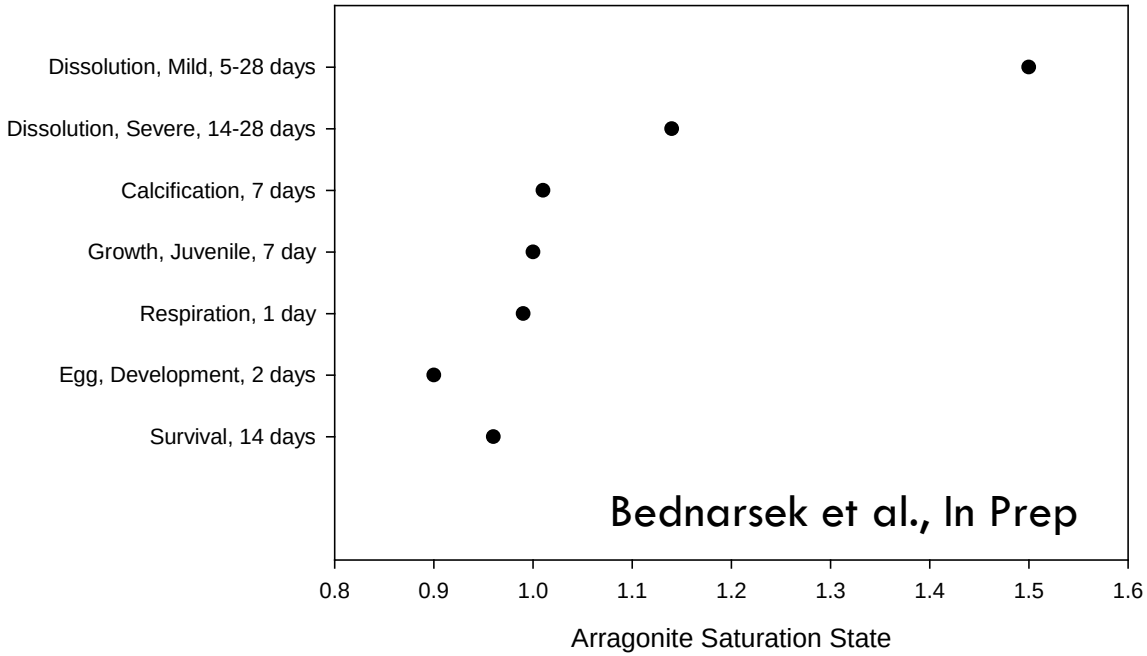
Expert workshops to get Consensus on Key Thresholds

Expert Interpretation

Literature Review

Meta-Analyses

Pteropod Thresholds



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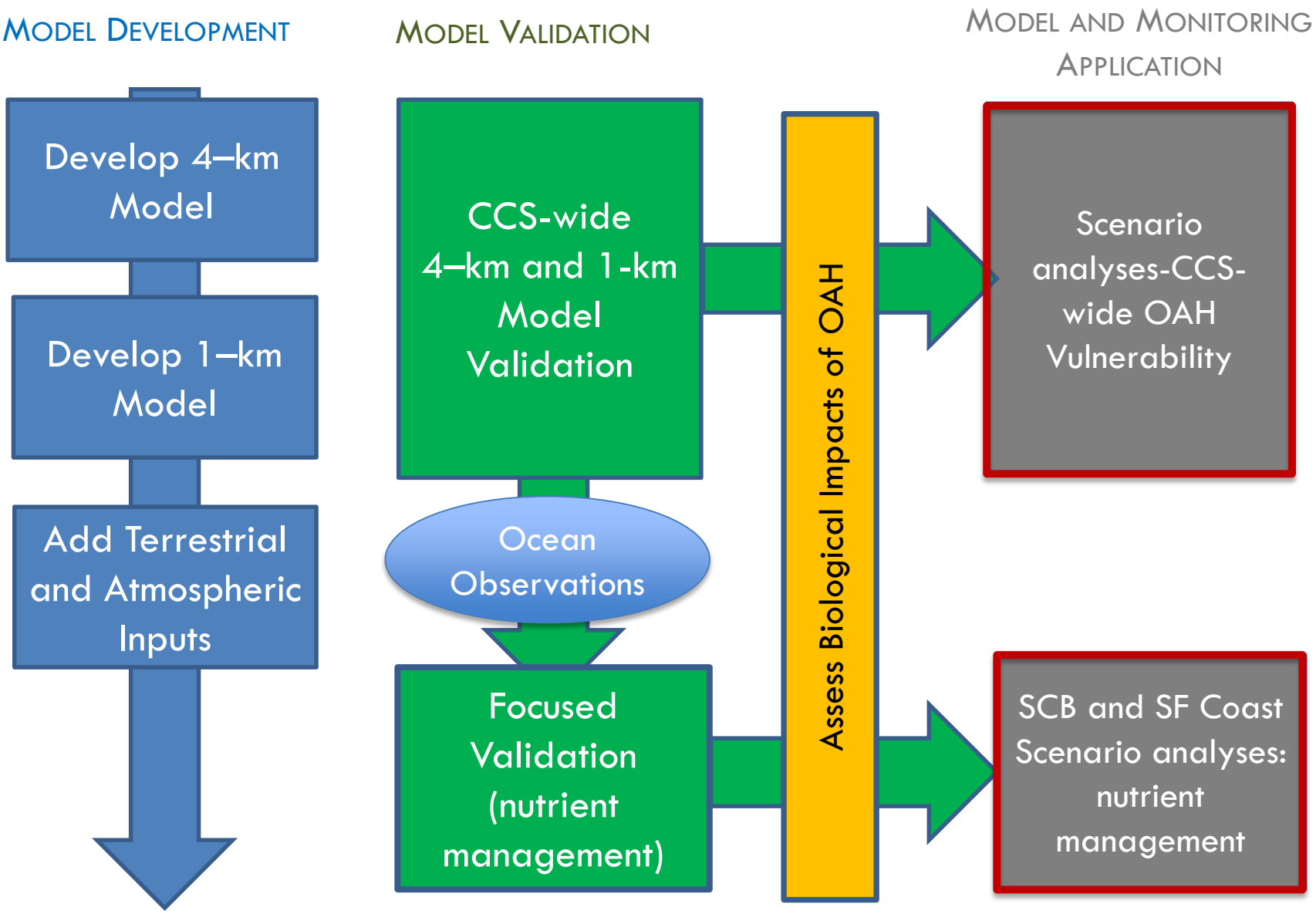
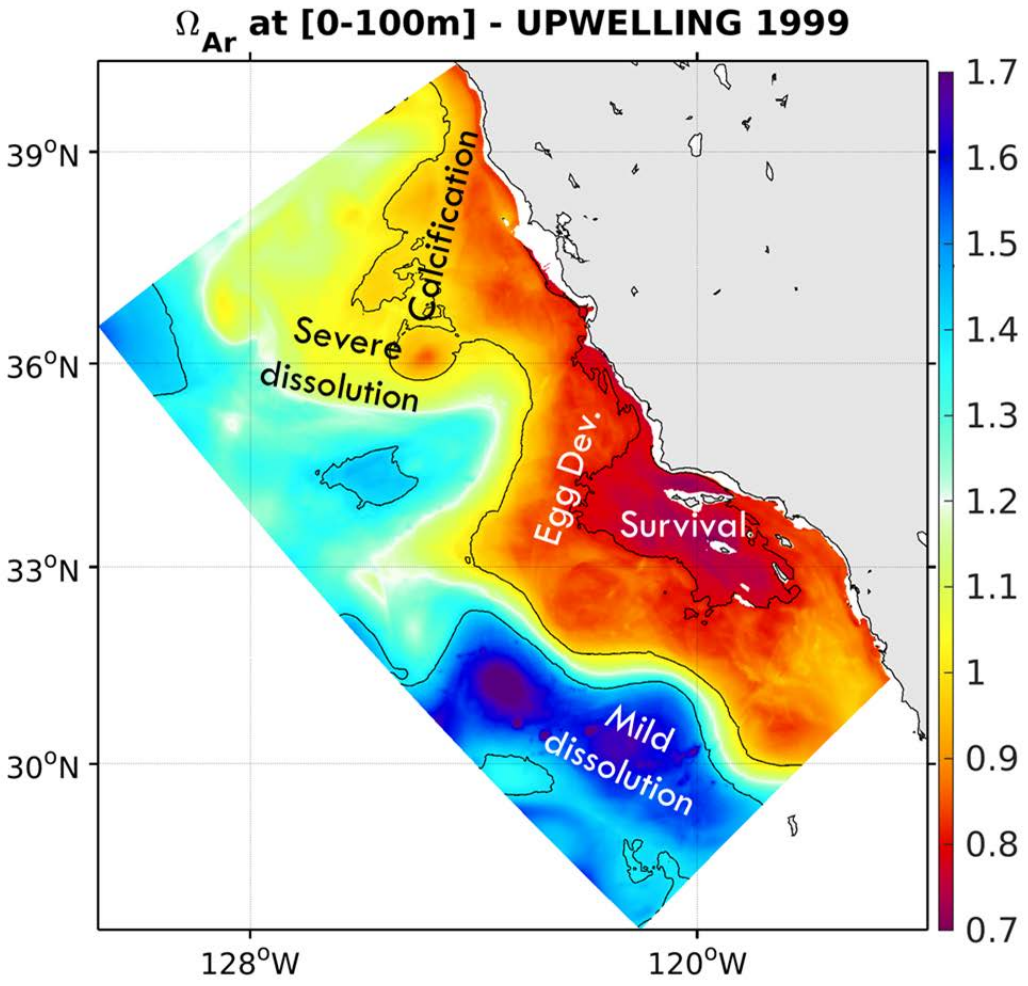


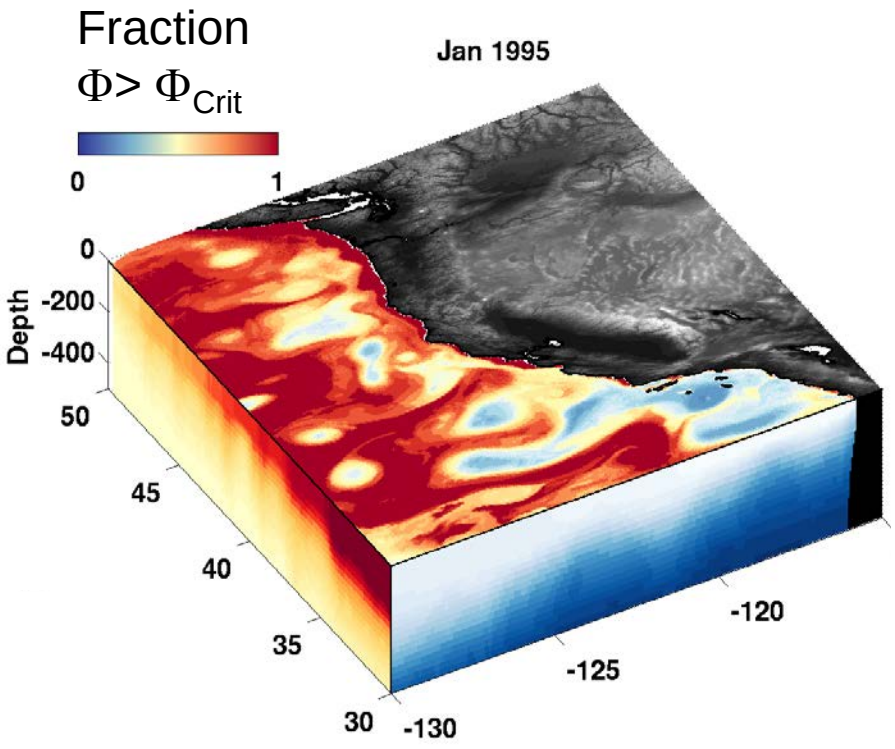
Use Thresholds to Translate Model Output and Monitoring Data



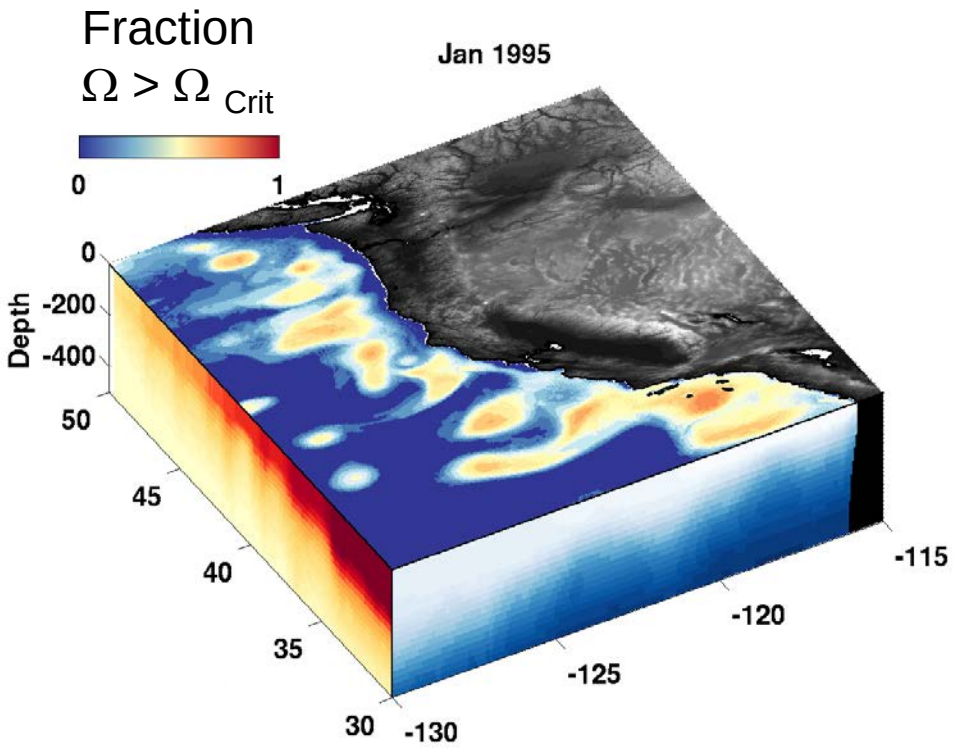
Multi-Stressor View of Habitat Compression

(Evan Howard, In Prep)

Metabolic Index-Volume fraction of upper 300 m that is suitable for temperature-dependent metabolism



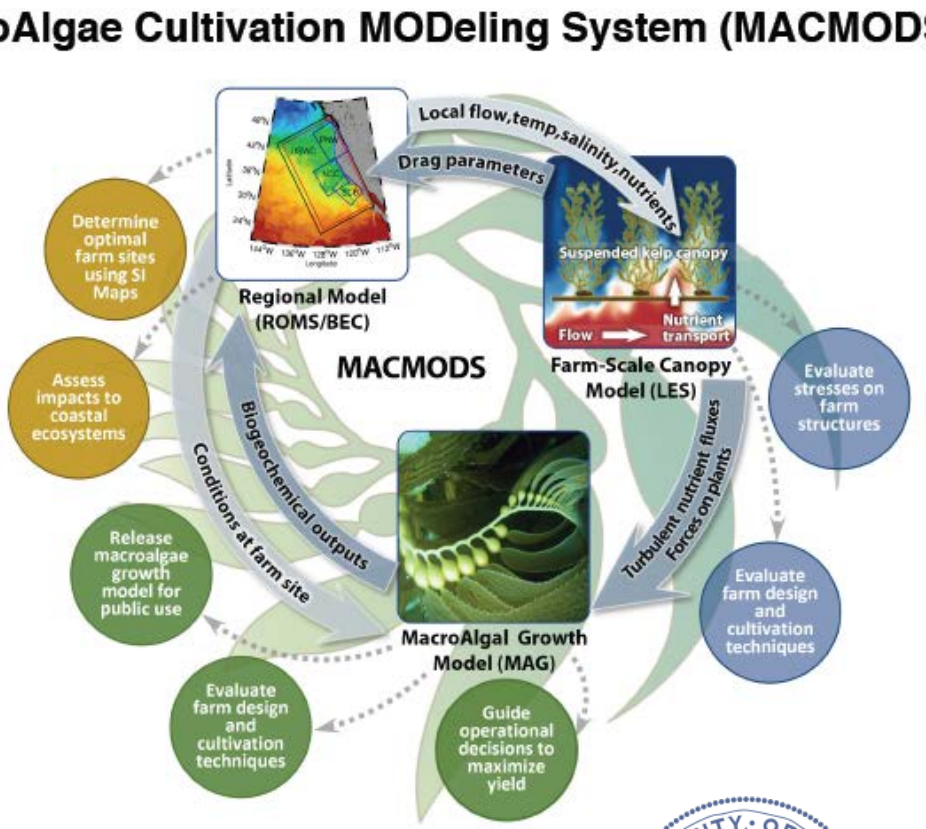
oxygen metabolism ($\Phi > \Phi_{Crit}=3$)



calcifying ($\Omega > \Omega_{Crit}=1$)

Investments in Observations and Modeling Can Yield Ready Application to Other Climate Change Mitigation Strategies

Optimize kelp culture



Quantify mitigation potential for OAH

Evaluate POTW nutrients as subsidy?

CATALINA SEA RANCH

Thank You!

Questions? Comments