Marine Resource Management

Presenter: Antonietta Capotondi

Subject Matter Experts: Michael Alexander, Christopher Cox, Michael Jacox, Sang-Ik Shin

NOAA Physical Sciences Laboratory Review
November 16-20, 2020

Physical Science for Marine Resources Management

What do we mean by Marine Resources?

Living Marine Resources

Tourism, Recreation, Shipping along U.S. Coasts

Arctic ecology, transportation, gas/oil resources

Offshore wind energy

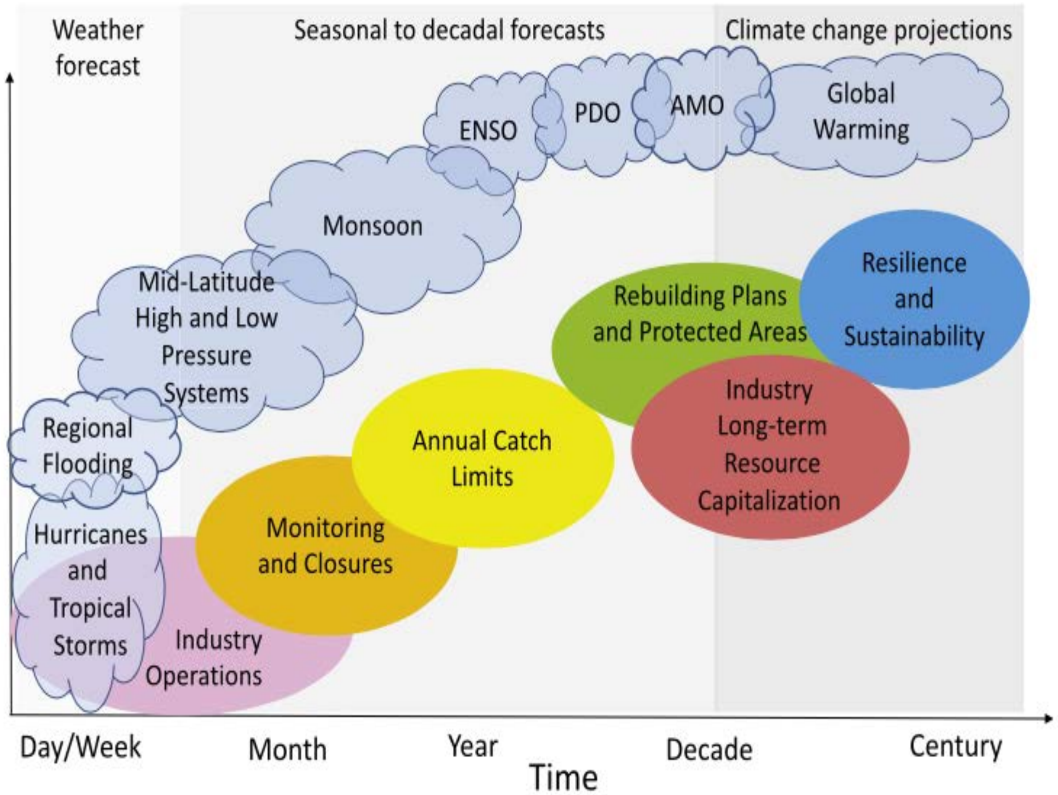
<u>Management of those resources requires</u>:

- Climate information
- Observations and modeling capabilities
- Understanding of physical processes (e.g. air-sea fluxes)

Understand and Predict Physical Drivers of Living Marine Resources

NOAA National Marine Fishery Service (NMFS) needs information for management and planning

Climate provides an important source of predictability for physical ecosystem drivers in NMFS key areas (**Capotondi**, **Jacox**, et al. 2019; **Jacox**, **Alexander**,..**Capotondi**, et al., 2020)



Tommasi, Stock,..Kaplan,..Delworth,..**Alexander**,..Saba..Werner (2017)

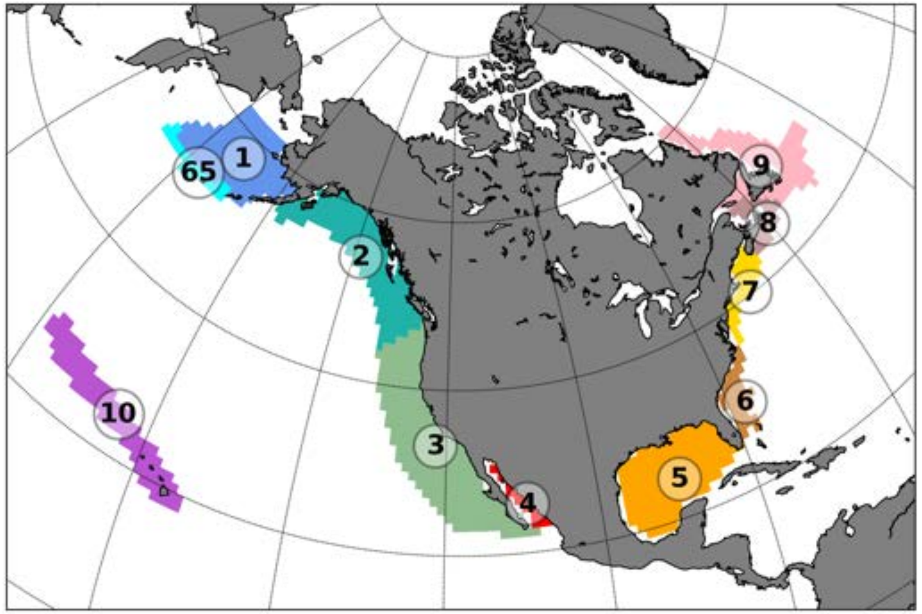
Climate research in PSL supports prediction and projection of physical ecosystem drivers especially in the Pacific sector:

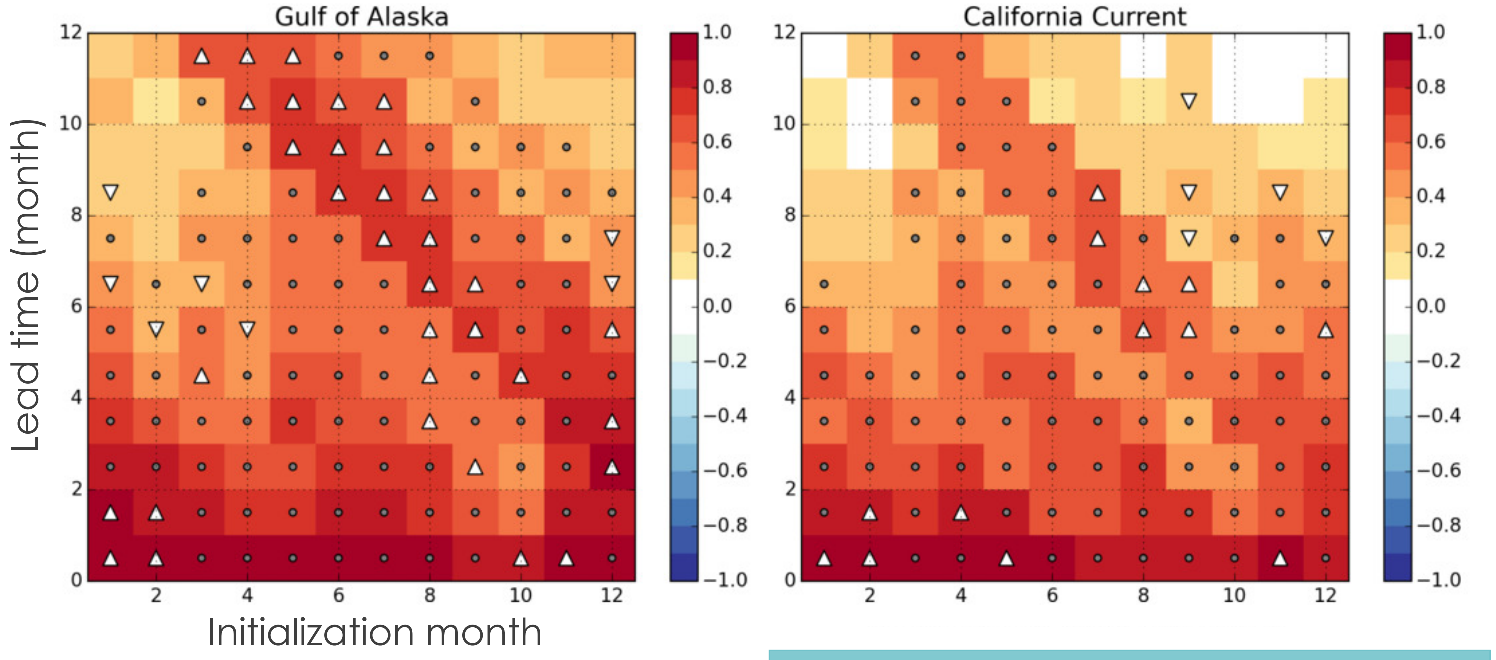
- ENSO pattern diversity can result in different impacts on areas relevant for marine resources (**Capotondi**, **Sardeshmukh**, et al., 2019; **Capotondi**, Wittenberg,..,McPhaden, 2020)
- The PDO results from the superposition of different processes and should not be viewed as a "mode" of variability (**Newman**, **Alexander**…Mantua et al. 2016).

NMME SST Forecast Skill for US LMEs (Ensemble of NMME models)

SSTs are important for biology as well as physics

Large Marine Ecosystem Regions





Anomaly Correlation Coefficient

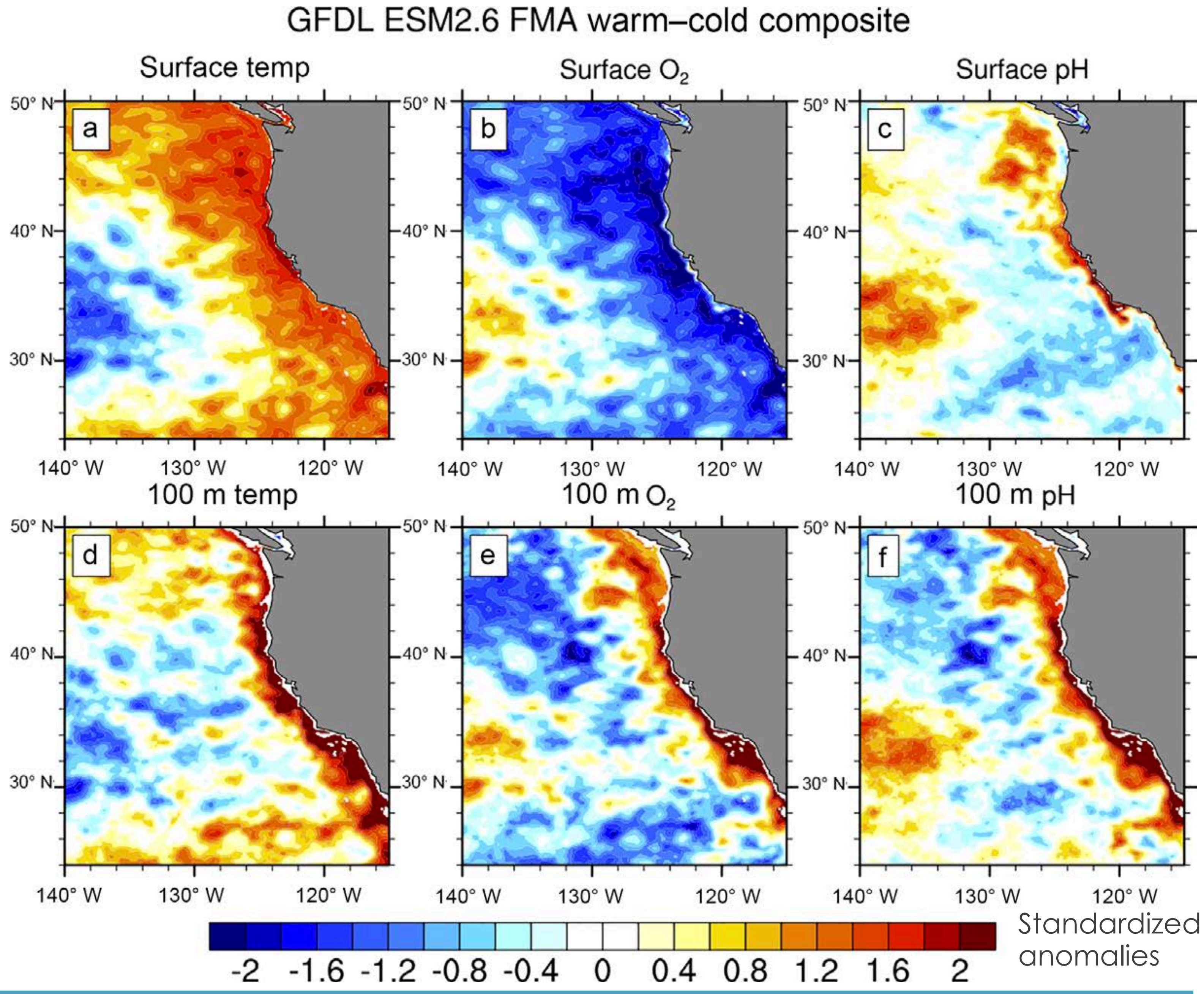
Anomaly correlation coefficients:

- ● above 0 at 5% level
- ▲ above persistence at 10% level with ACC > 0.5
- ▼ above persistence at 10% level with ACC < 0.5.

Hervieux, G., M. A. Alexander, C.A. Stock, **M. G. Jacox**, *et al., 2017, Climate Dynamics*

Jacox, M., M. A. Alexander, C.A. Stock, **G. Hervieux**, *2017, Climate Dynamics*

ENSO influence in the California Current System from a high-resolution Earth System Model

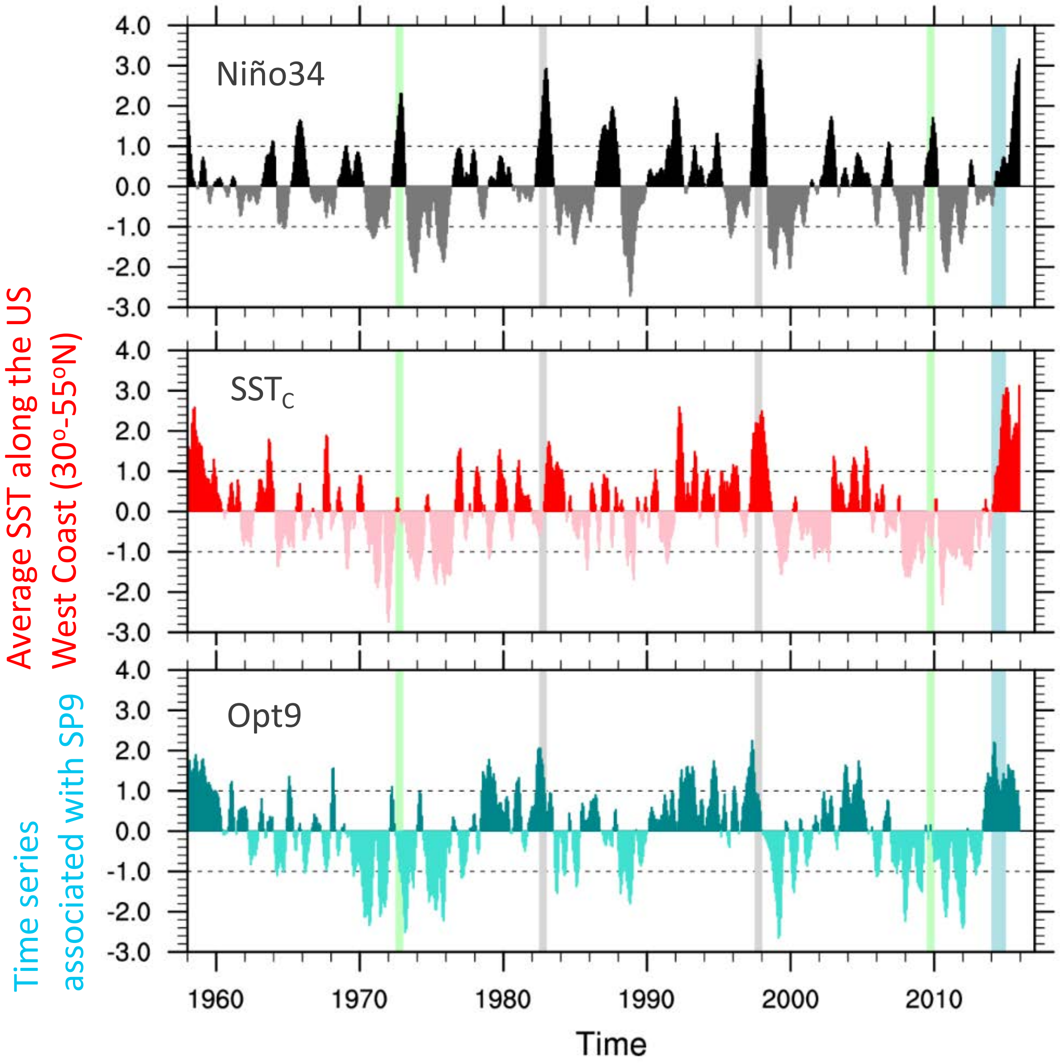


Turi, G., M. Alexander, N. Lovenduski, **A. Capotondi, J. Scott**, …, **J. M. Jacox**,, (2018, *Ocean Sci.)*

Also see:

Brady, R. X., N. S. Lovendusky **M. A. Alexander**, **M. Jacox**, and N. Gruber, (2019: Biogeosciences)

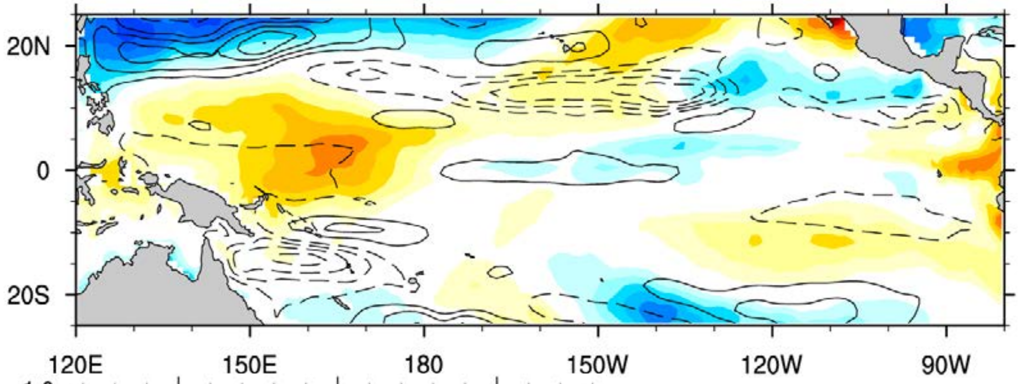
Which El Niño Flavors are Most Important for US West Coast Marine Warming?

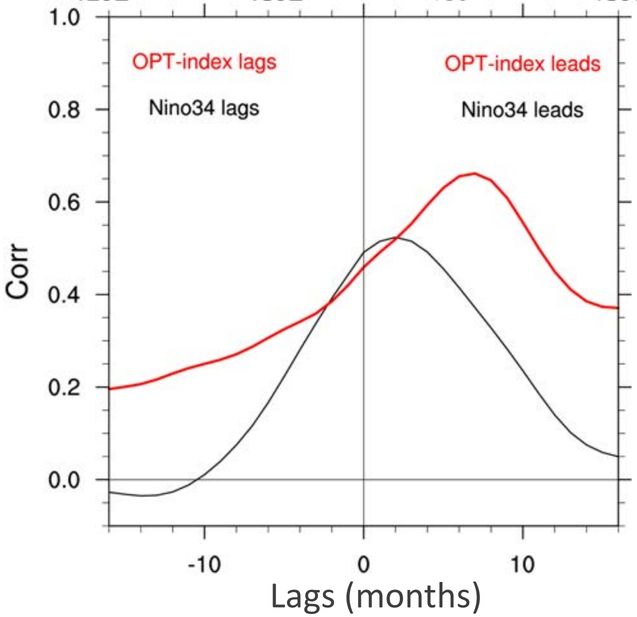


Capotondi, Sardeshmukh, et al., Sci. Rep., 2019

$SST_C(t) = \boldsymbol{H}\,\boldsymbol{X}_{opt}(0)$

SST (shading) and SSH (contours) anomalies most conducive to US West Coast warming at 9 months lead time (**SP9**)



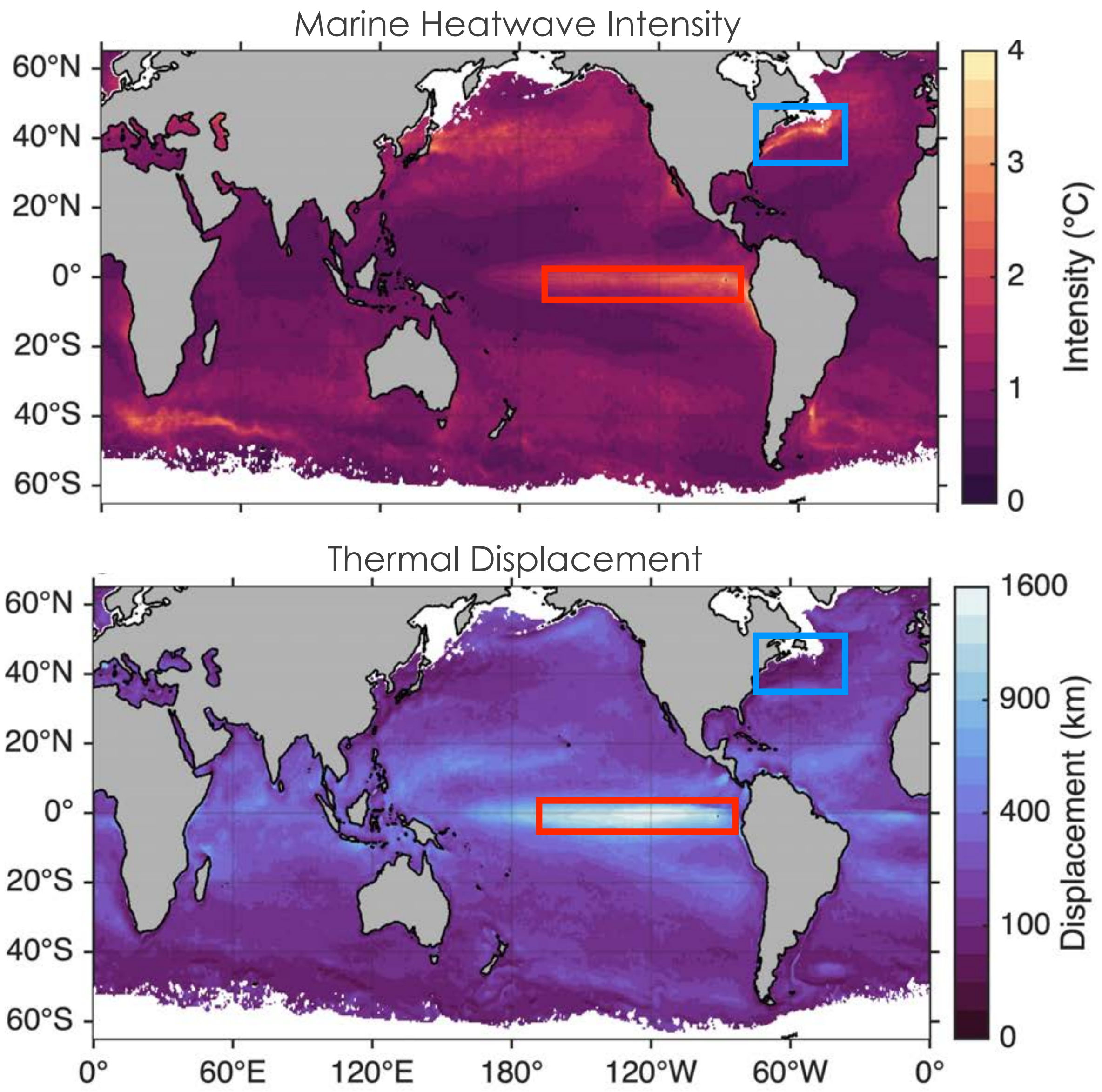


Lag-Correlations between Niño3.4 and SST_C (black) and Opt9 and SST_C (red)

Largest corr. with Niño34 is about 0.5 with Niño34 leading by 2-3 months

Largest corr. with Opt9 is about 0.65 with Opt9 leading by 7 months

Thermal Displacement as a Fisheries-Relevant Metric for Characterizing Marine Heatwaves



Thermal displacement is the distance that must be travelled to maintain constant SST, a simple proxy for habitat displacement.

Thermal displacements vary from 10s to 1000s of kilometers.

On a global scale, thermal displacement is not significantly correlated with heatwave intensity.

Depending on the regional SST patterns, a given location can be characterized by, for example:

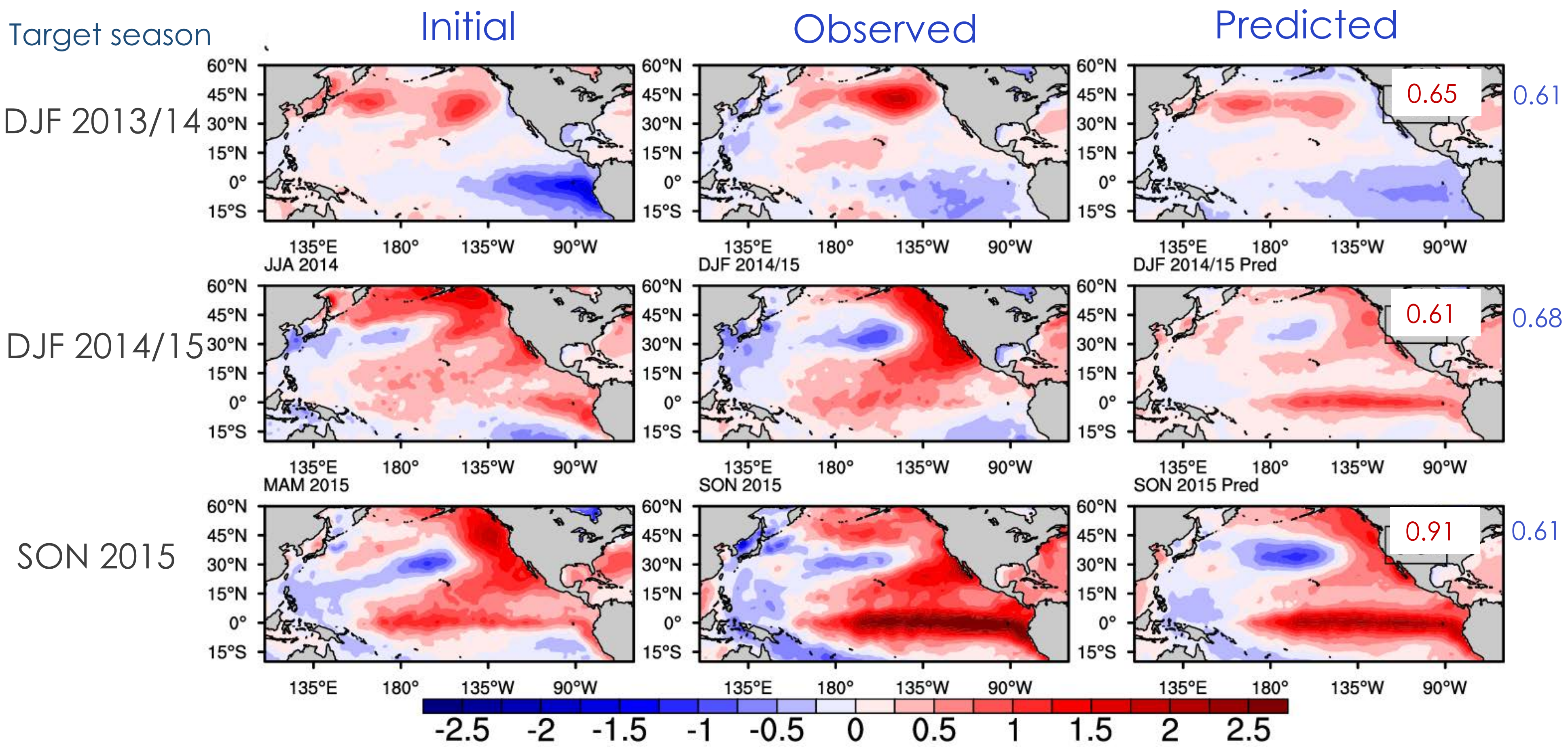
Intense heatwaves and large displacements

Intense heatwaves and small displacements

Jacox, **Alexander**, Bograd, and **Scott** Nature (2020)

Exploring marine heatwaves predictability using LIM

6-month SST LIM predictions
LIM's state vector includes SST and SSH (a measure of upper ocean heat content)



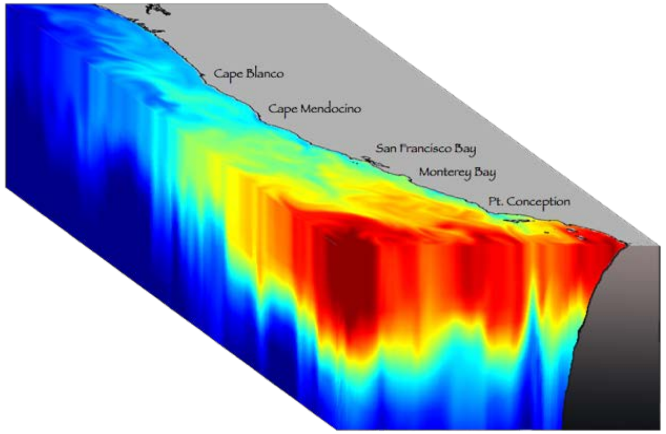
LIM predictions show skill in reproducing both pattern and amplitude relative to damped persistence, especially during the development of the 2015/16 El Nino event

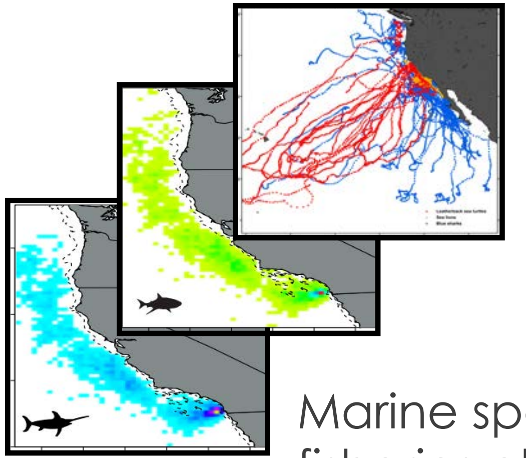
Pattern correlations between predicted and observed: LIM, damped persistence

Capotondi, **Newman**, et al. JGR Oceans, in prep.

Ocean Reanalyses and Forecasts to Inform U.S. West Coast Fisheries Management

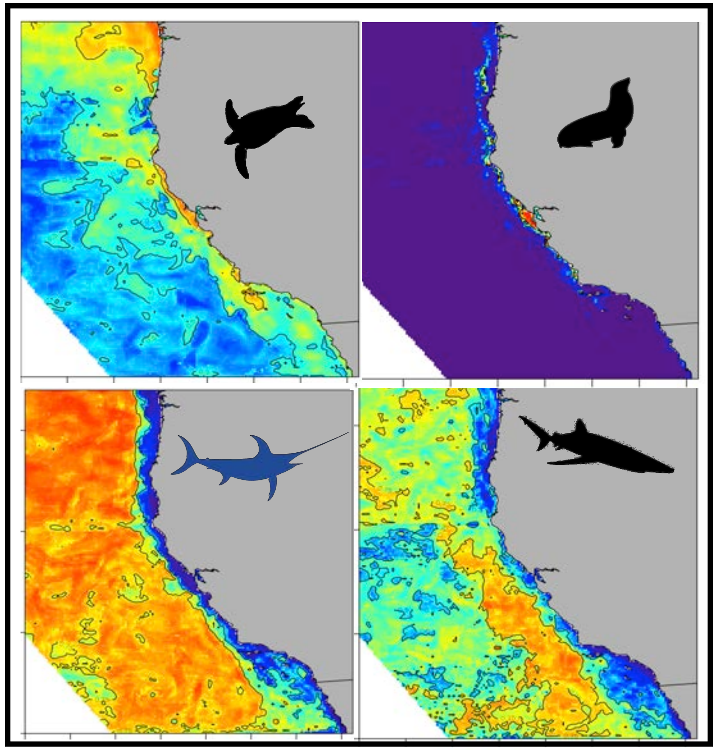
Ocean model output
(near real time or forecast)



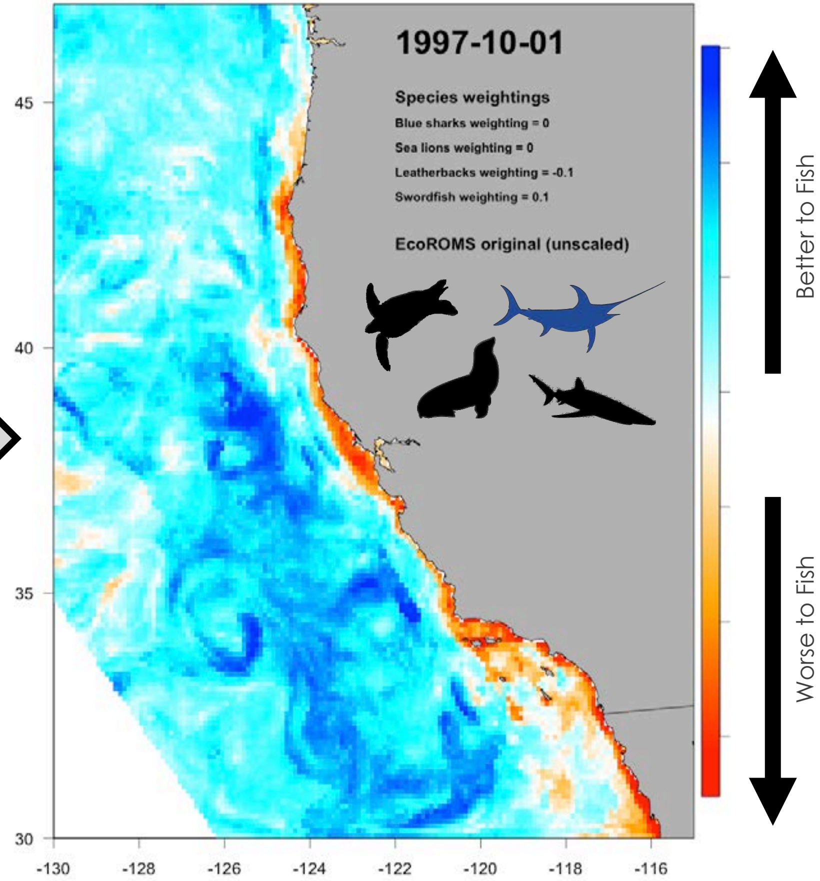


Marine species data (tag tracking,
fisheries observers)

Predicted habitat suitability



Integrated fishing suitability

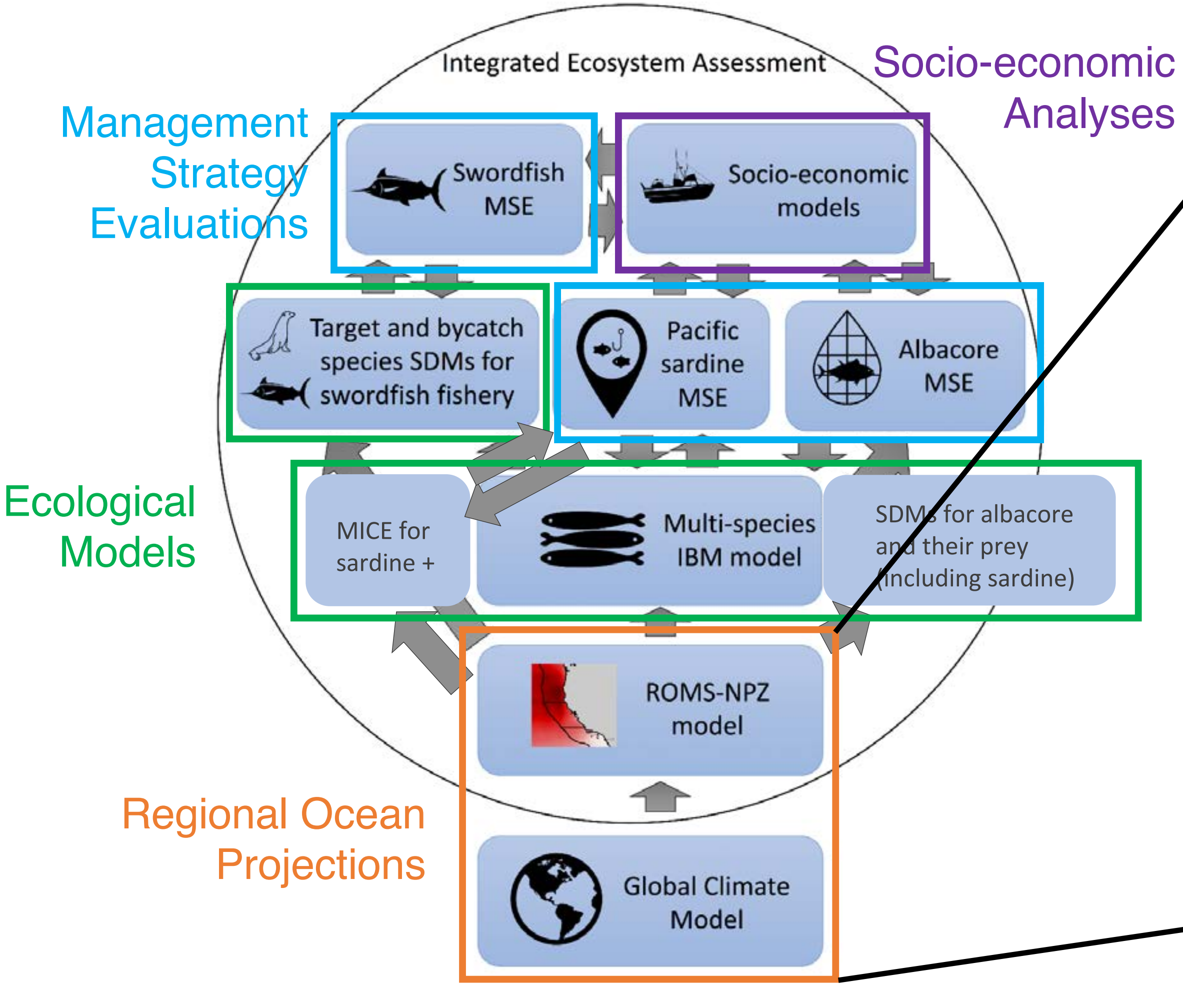


[Welch, …, **Jacox**, et al. (2019)]
[Brodie, **Jacox**, et al. (2018)]

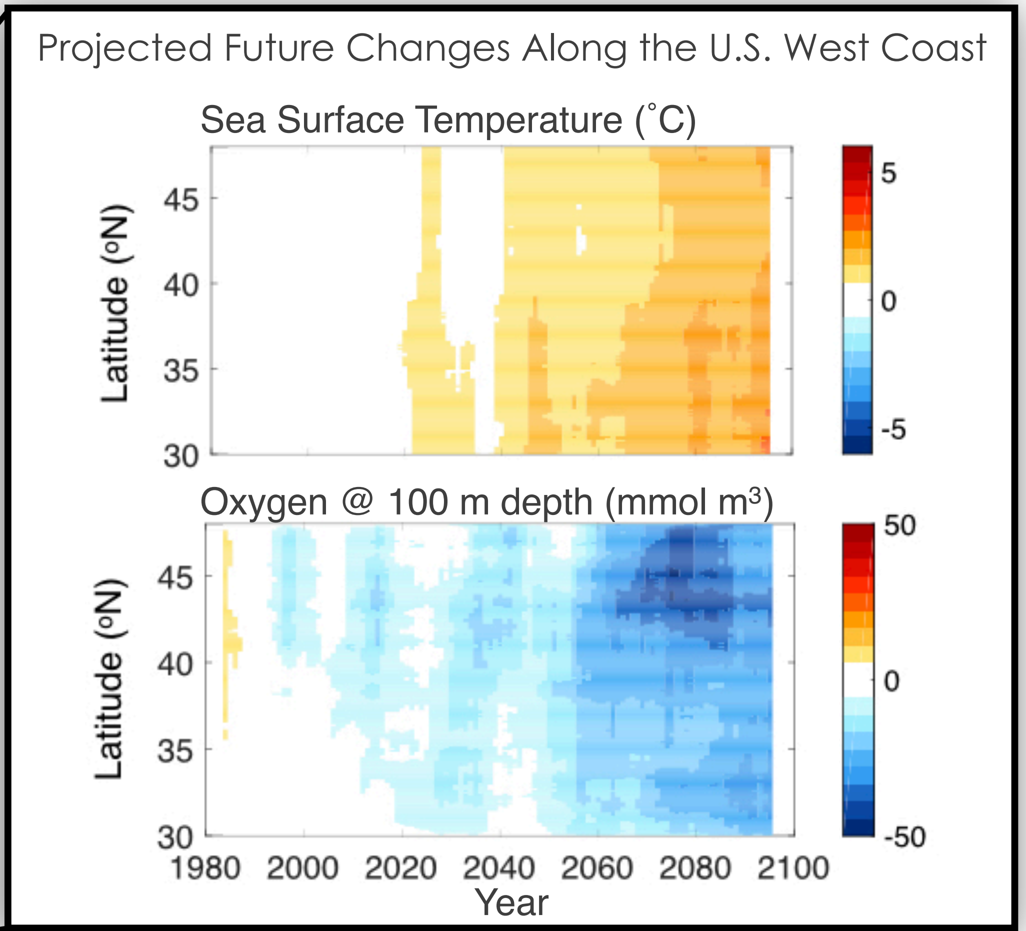
Climate and Regional Ocean Modeling to Evaluate Climate Change Impacts on Fisheries

Pis: Jacox (PSL/SWFSC), Alexander (PSL), Curchitser (Rudgers), Muhling (UCSC), Rykaczewski (PIFSC), Himes-Cornell (FAO)

Example: The Future Seas project



https://future-seas.com



Pozo-Buil, **Jacox**,..**Alexander**, Bograd,..Rykaczewski, Stock, 2020

High-Resolution Modeling of the U.S. East Coast

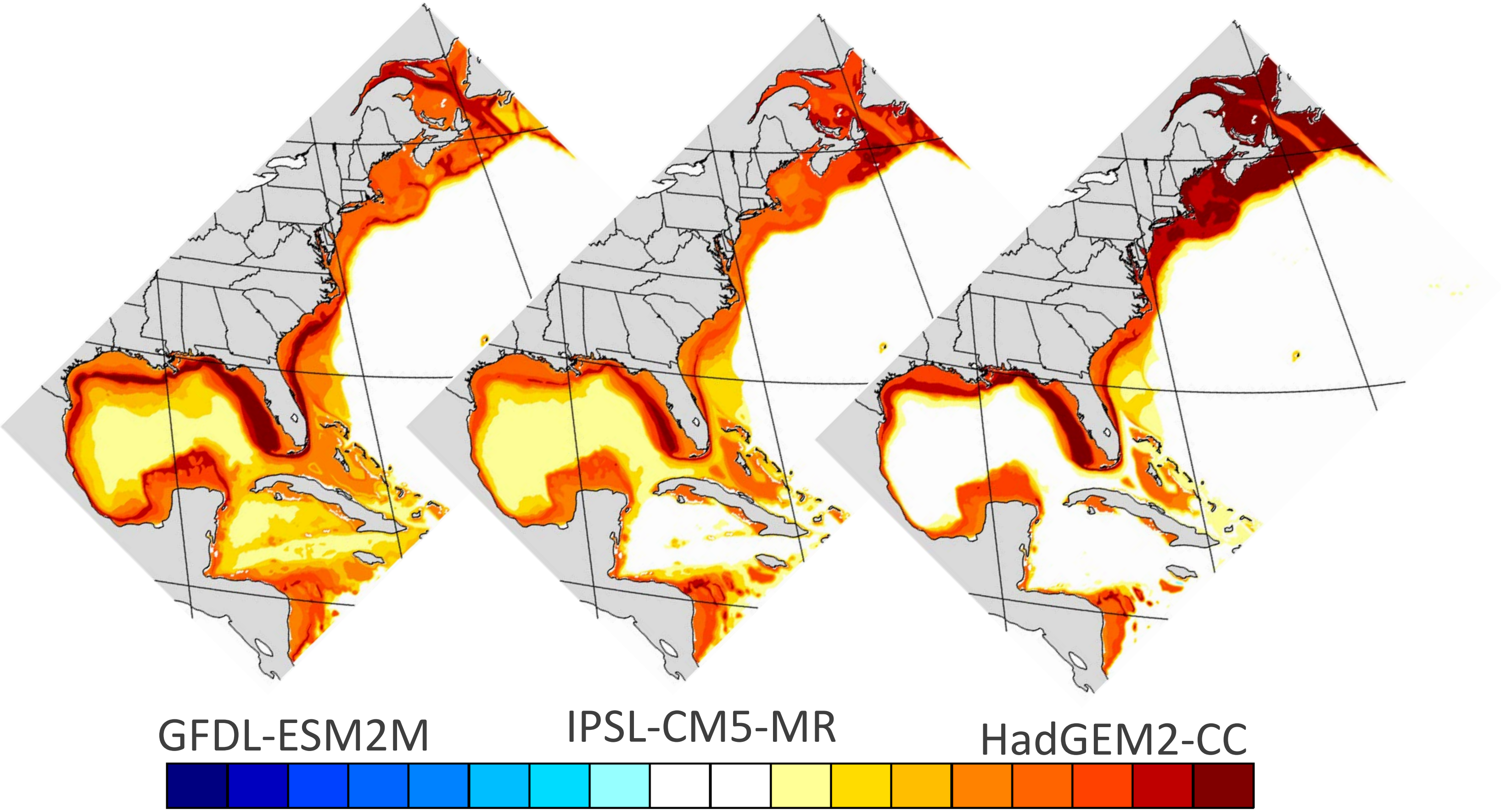
Regional Model Simulations:

- ROMS: 7 km grid NW Atlantic
- Control hindcast simulation
- future simulations driven by 3 CMIP5 GCMS: GFDL, IPSL, HadGEM2

  RCP8.5 forcing: 2070-2099

- Used in studies of potential biogeochemical and ecological changes in the Gulf of Maine. (Seidelecki S., … **Alexander** et al. & Pershing, A. **Alexander** et al., submitted to *Elementa, Sci.of the Anthropocene)*

Bottom Temperature difference (°C)
RCP8.5 – Control : 2070-2099 minus 1976-2005



Alexander, M. A., S. **Shin**, J. D. **Scott**, et al. (2020, *J. Climate*)

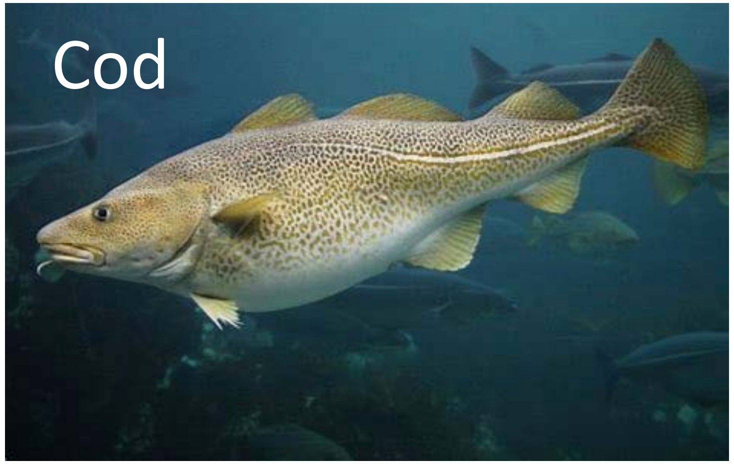
Shin, S., and M. A. Alexander (2020, *J. Climate*)

Studies on the Effects of Climate Change on Marine Species

- Pershing, A, **M. A. Alexander** et al. (2015, *Science*) Slow Adaptation in the Face of Rapid Warming Leads to the Collapse of *Atlantic Cod* in the Gulf of Maine
- Le Bris, A., …, **M. A. Alexander**, et al. , (2018, *PNAS*): Climate vulnerability and resilience in the most valuable North American fishery. *Lobster*.

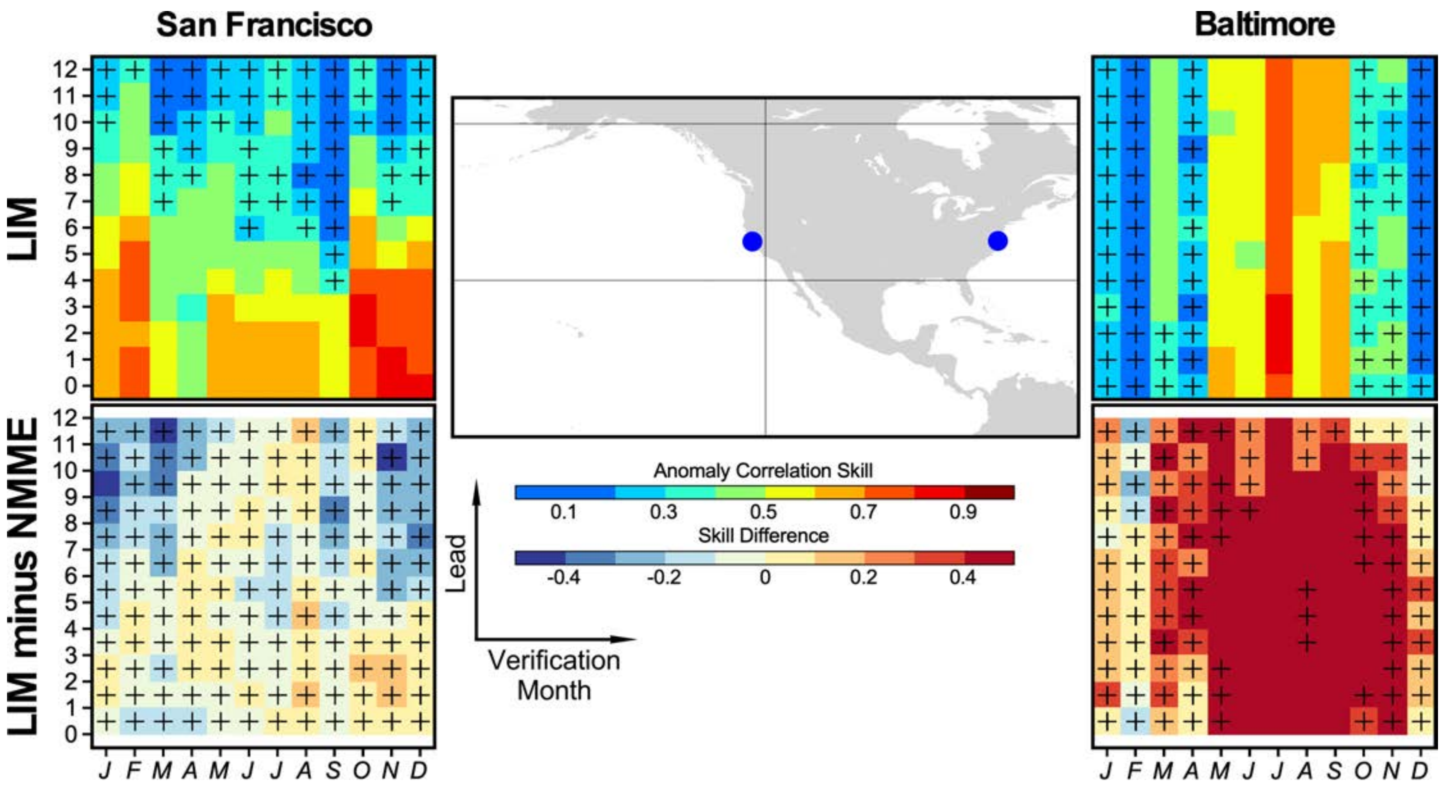
Scenario planning workshops and reports:

- Borggaard, D. L., …, **M. Alexander**, et al. 2019. *Atlantic Salmon* Scenario Planning Pilot Report. NOAA Fisheries Greater Atlantic Regional Fisheries Office, 89 p.
- Borggaard, D. L., …, **M. Alexander**, et al. 2020. *North Atlantic Right Whale* Scenario Planning Pilot Report. NOAA Fisheries Greater Atlantic Regional Fisheries Office



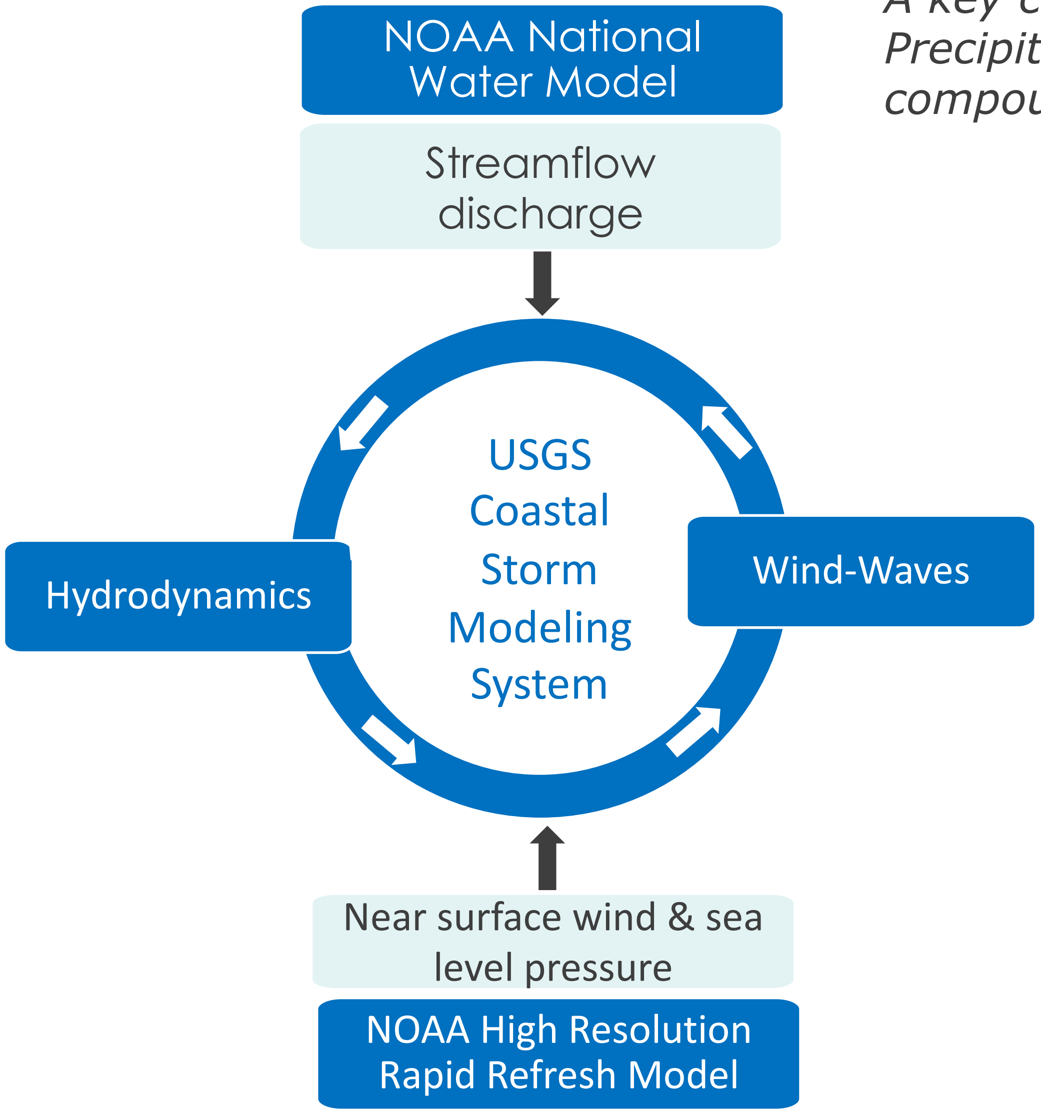
Predicting changes in sea level and coastal inundation

- U.S. Coasts are vulnerable to coastal inundation due to the combined effect of sea level rise and natural sea level variations.
- NMME and LIM show potentially useful skill in sea level predictions.
- PSL part of new NOAA/NASA "RISE" collaboration: to evaluate incorporating seasonal SL predictions (pilot project: San Diego and Charleston) in NOAA products such as Seasonal High Tide Bulletin and Annual High Tide Flood Outlook

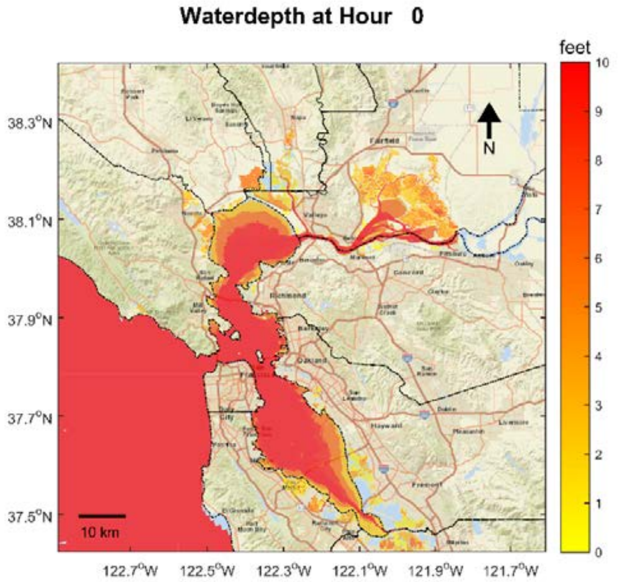


Shin and **Newman**, GRL, 2020

Hydro-CoSMoS: An Integrated Coastal Flood Forecast System



A key component of NOAA's Advanced Quantitative Precipitation Information (AQPI) system to address compound flooding in the San Francisco Bay area



Products include:

- Time of first flood
- Flood duration
- Time of peak flood
- Flood potential from wave runup
- Potential products include wave height and levee overtopping potential

Navigating the Arctic: **Coupled Arctic Forecast Systems (CAFS)**

High-resolution (9-10 km, 40 vertical levels) 0-10 day forecasts over the Arctic Ocean
sea ice thickness/concentration/drift; upper ocean temperature/salinity/currents; meteorology/surface energy budget

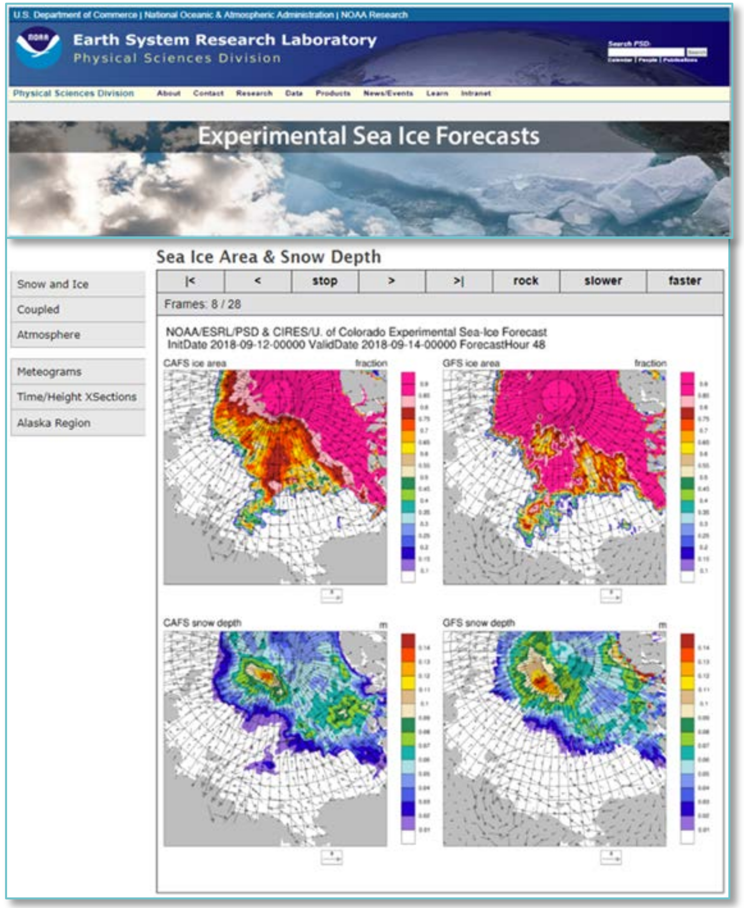
CAFS provides model guidance for NWS ice forecasts

Users of NWS ice forecasts include

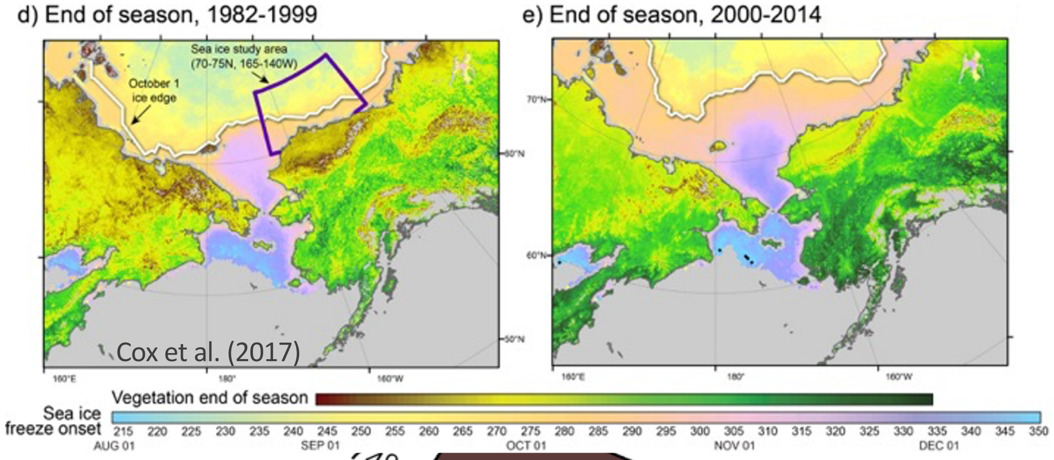
U. S. Coast Guard, fishermen (crab, cod, etc), tug/barge operators, oil/natural gas tankers, subsistence hunters, research vessels

2015-2020 Milestones

- *2015-2018: CAFS development and validation*
- *2015-2020: Forecasts available daily from PSL*
- *2017-2018: NWS-AR SIP product format compatibility (e.g., GIS)*
- *2018: autumn-only -> year-round forecasting*
- *2018-2020: Guidance for NCEP for UFS development*
- *2015-2020: Support: SeaState, ICEX, SODA MOSAiC; YOPP, SIDFEx*

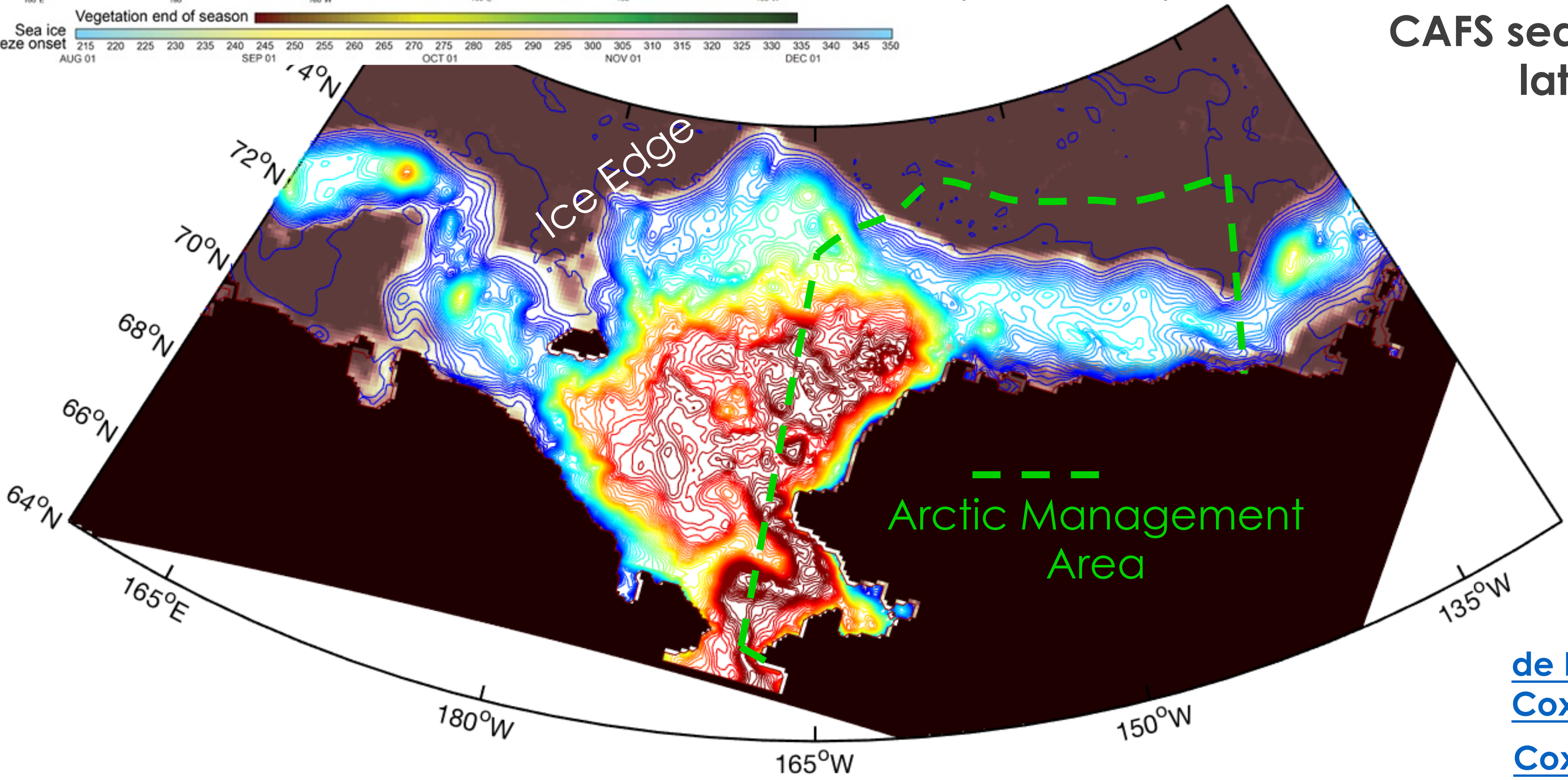


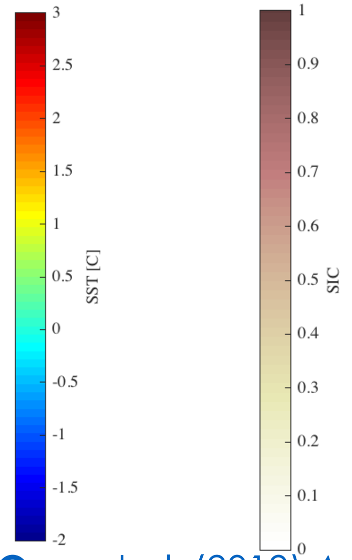
Intrieri, Solomon, Persson, Cox, de Boer, Hughes, Capotondi, *Mon Weath Rev. (2020),* submitted.



- CAFS forecasts can support fishery management in the Arctic region.
- CAFS can help understand impacts on non-fish and endangered species, e.g., polar bears, and shorebirds negatively impacted by more distant food source at ice edge (Arctic cod)

CAFS sea ice concentration and SST late freeze-up, 11/2017





[**de Boer, Cox**, et al. (2019) *Arctic*](#)
[**Cox** … **Gallagher**… (2019) *GRL*](#)
[**Cox** et al., (2017) BAMS](#)

Parameterization of turbulent fluxes

$$Sensible\ Heat: H_s = \rho_a c_{pa} \overline{w'T'}$$

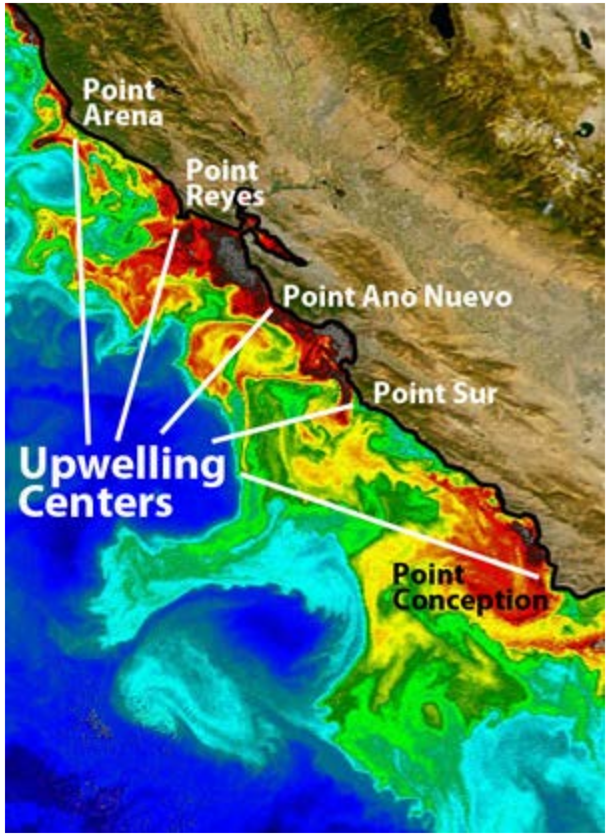
$$Latent\ Heat: H_l = \rho_a L_e \overline{w'q'}$$

$$Stress: \vec{\tau} = \rho_a \overline{w'u_x'}\hat{i} + \rho_a \overline{w'u_y'}\hat{j}$$

$$Gas\ Exchange: F_x = \overline{w'r_x'}$$

$$Particle\ Exchange: F_n = \overline{w'n(r)'} - w_g \overline{n(r)} + \overline{w_s'n(r)'}$$

- Sensible, Latent heat and wind stress influence upper-ocean stratification and currents
- Gas and particle exchange in gaseous or liquid/solid forms controls uptake of, e.g., CO_2, methane, O_2 by ocean or generation of sea-salt aerosols by whitecaps
- Parameterizations are widely used in modeling studies of both physical and biological systems
- Wind stress parameterizations are used to determine wind stress and wind stress curl in the California Current region, where they control coastal upwelling.

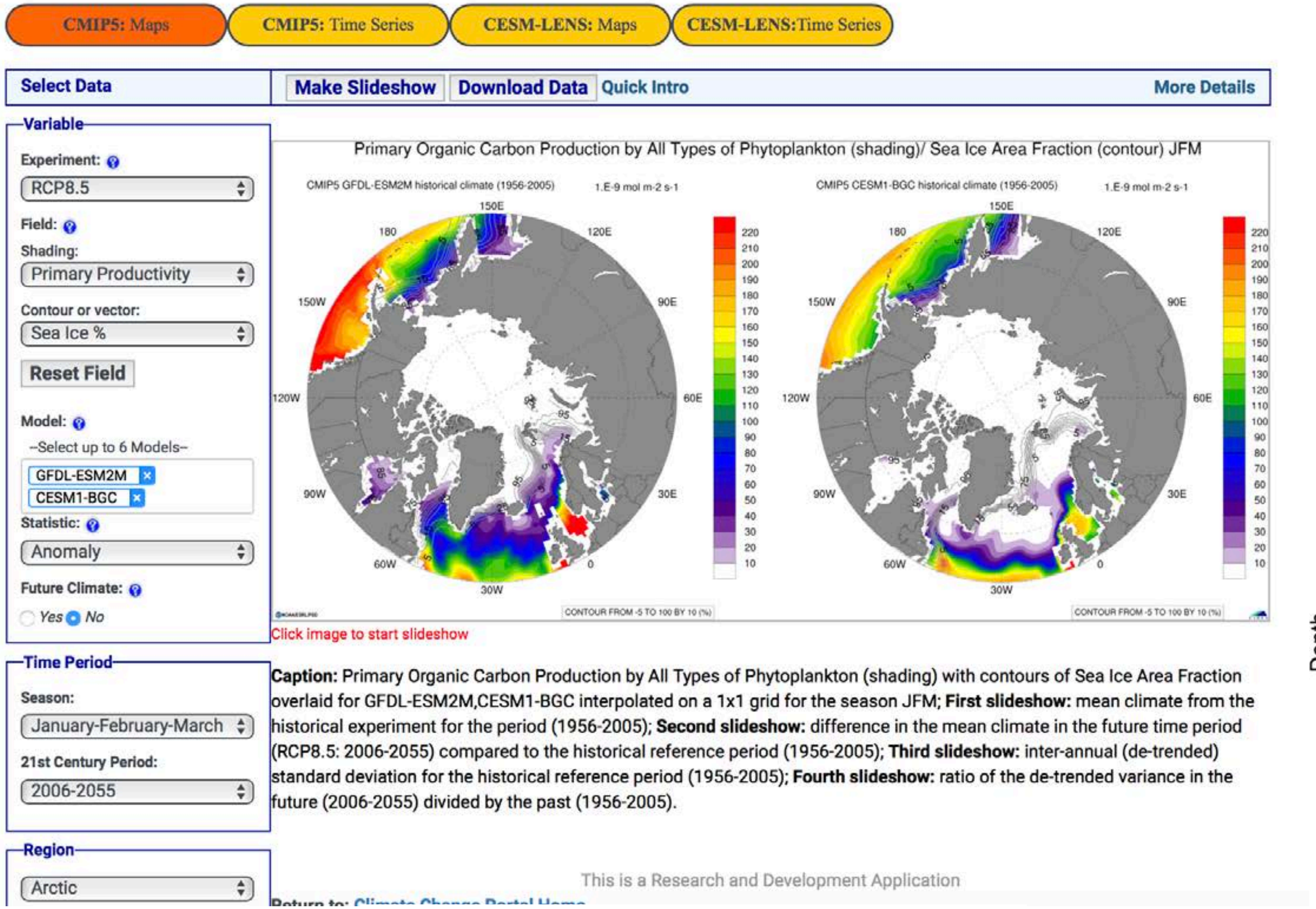


Blomquist, B., C. **Fairall**, …L. **Bariteau**, JGR, 2017

Brumer, Zappa, **Blomquist**, **Fairall**, et al., GRL, 2017

Fairall, C., L. **Bariteau**,….B. **Blomquist**, ..S. **Pezoa**, ..E. **Thompson**, Front. Mar. Sci, 2020, in prep.

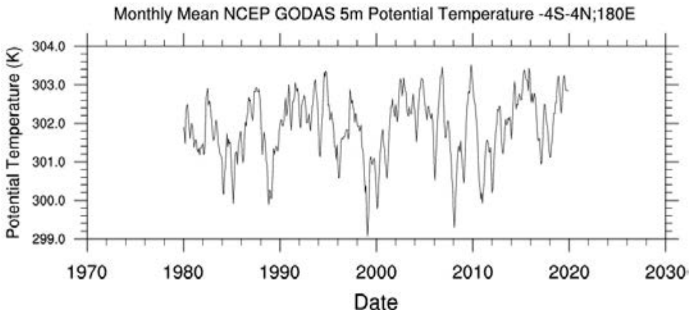
NOAA Climate Change Web Portal



https://psl.noaa.gov/ipcc/

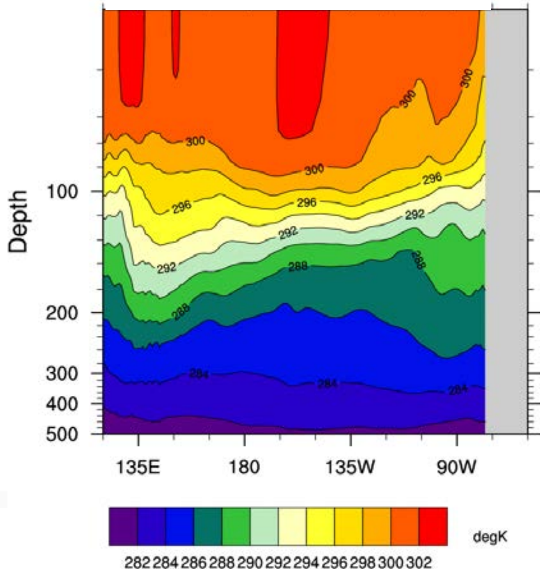
Scott, **Alexander**, **Murray**, **Swales**, and **Eischeid**, BAMS, 2016

Web-based Ocean Reanalysis Intercomparison Tool

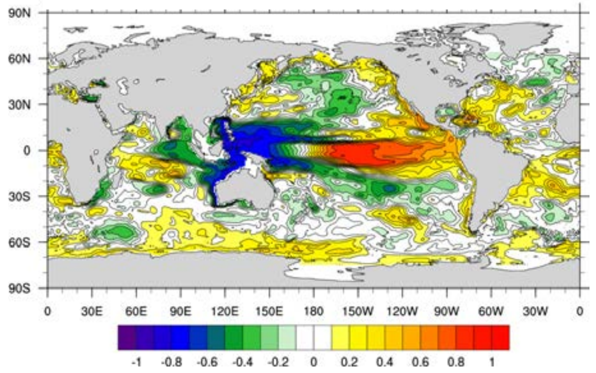


Time series

Vertical sections



Global correlation maps



https://psl.noaa.gov/data/writ/

Service

NOAA:
Climate-Fishery initiative, Integrated Ecosystem Assessment,
Expert groups on specific fish species (**Alexander**, **Jacox**); NOAA Marine Task Forces (**Capotondi**, **Jacox**, **Dias**); NOAA RISE Pilot Project (**Newman**)

International:
North Pacific Marine Science Organization (PICES): Joint PICES/CLIVAR working group on "Climate and ecosystem predictability" (**Jacox**, **Capotondi**)
UN Decade of the Ocean for sustainable Development (**Cox**)
Arctic Icebreaker Coordinating Committee (**Persson**)

Next five years activities

"Understanding and Predicting the Nation's Path through a Varying and Changing Climate"

- **Collaborate with NOAA Fisheries:** newly developed Climate-Fishery initiative
- **Extreme ocean events:** extend understanding to subsurface properties and climate change influence
- **Coastal sea level prediction**
- **Arctic sea ice:** Improve understanding of biological and societal impacts of decreasing sea ice coverage
- **Turbulent flux parameterizations**: Incorporate the effect of surface ocean waves
- **Offshore wind energy:**
  - **Third Wind Forecasting Improvement Project (WFIP3):** Collaborate with DOE partners to improve forecasts for offshore wind energy,
  - **Climate influence on offshore wind resources**
- **Interaction among Marine Resources:** e.g., influence of offshore wind turbines on marine life and fisheries

Conclusions

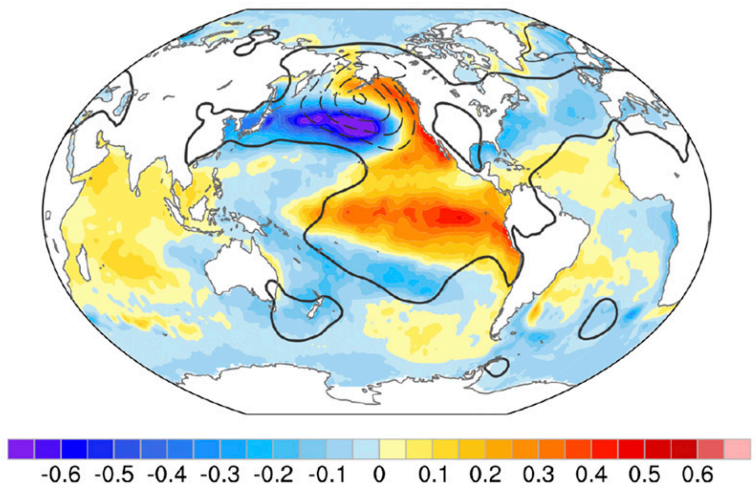
PSL is involved in many activities that are relevant for a broad range of Marine Resources including:

- Understand the processes that affect the ocean physical system
- Collaborate with fisheries experts on determining the impact of the physical ocean system on living marine resources, as well as on coastal sea-level, arctic sea ice, and offshore wind energy
- Use this understanding to provide guidance on how these systems will evolve in future climates

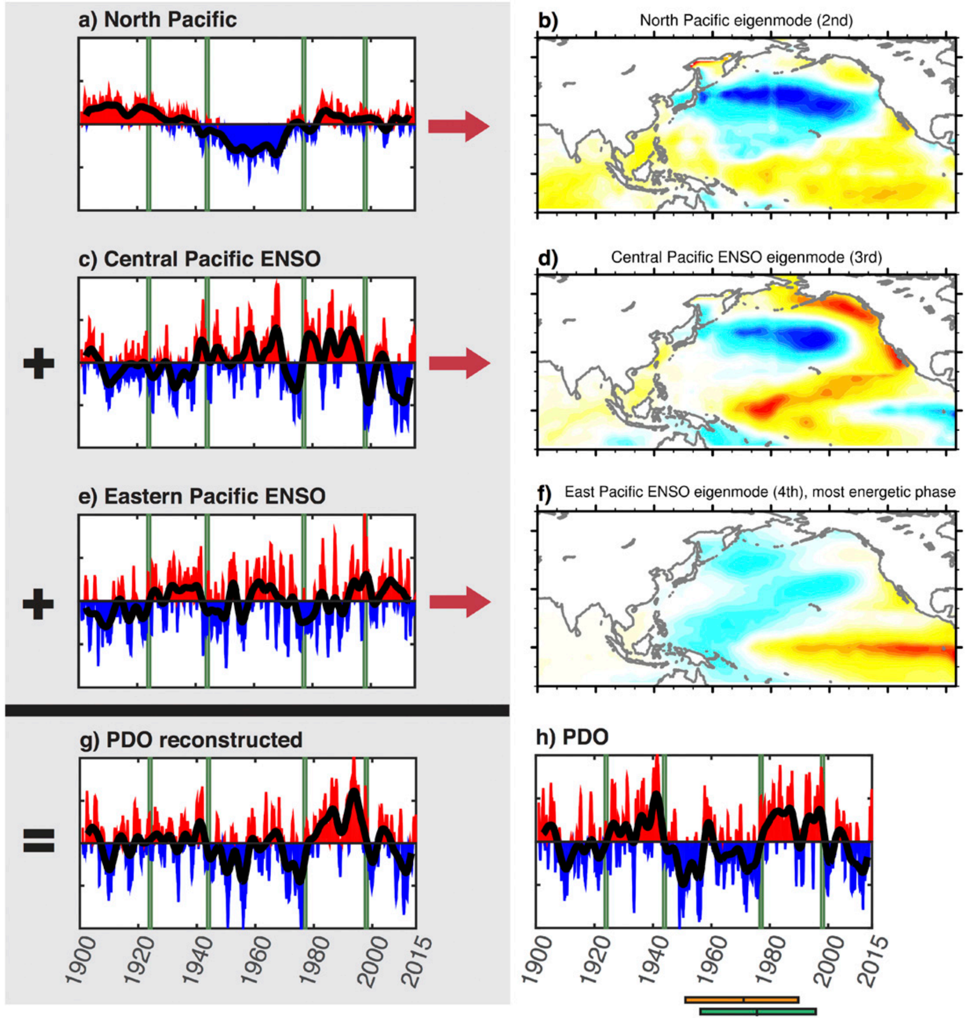
PSL uses its knowledge of the physical system to effectively act as a bridge between physical science and Marine Resources applications.

Supplementary Slides

Pacific Decadal Oscillation (PDO)

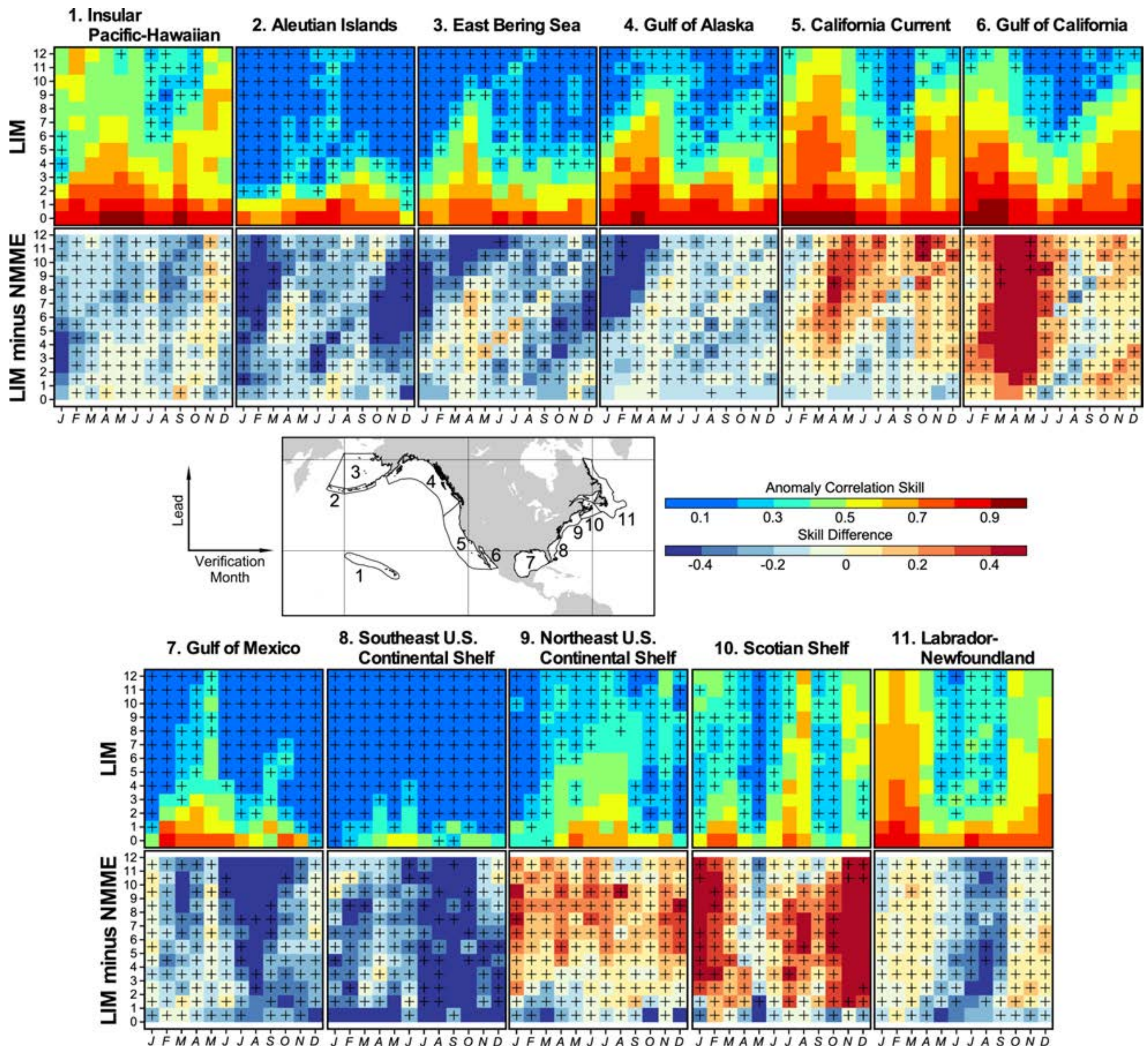


The PDO, defined as the leading empirical orthogonal function of North Pacific SST, has traditionally been regarded as a "mode" of variability. Instead, it should be seen as resulting from the superposition of different processes.



Newman, Alexander, ……Smith, 2016

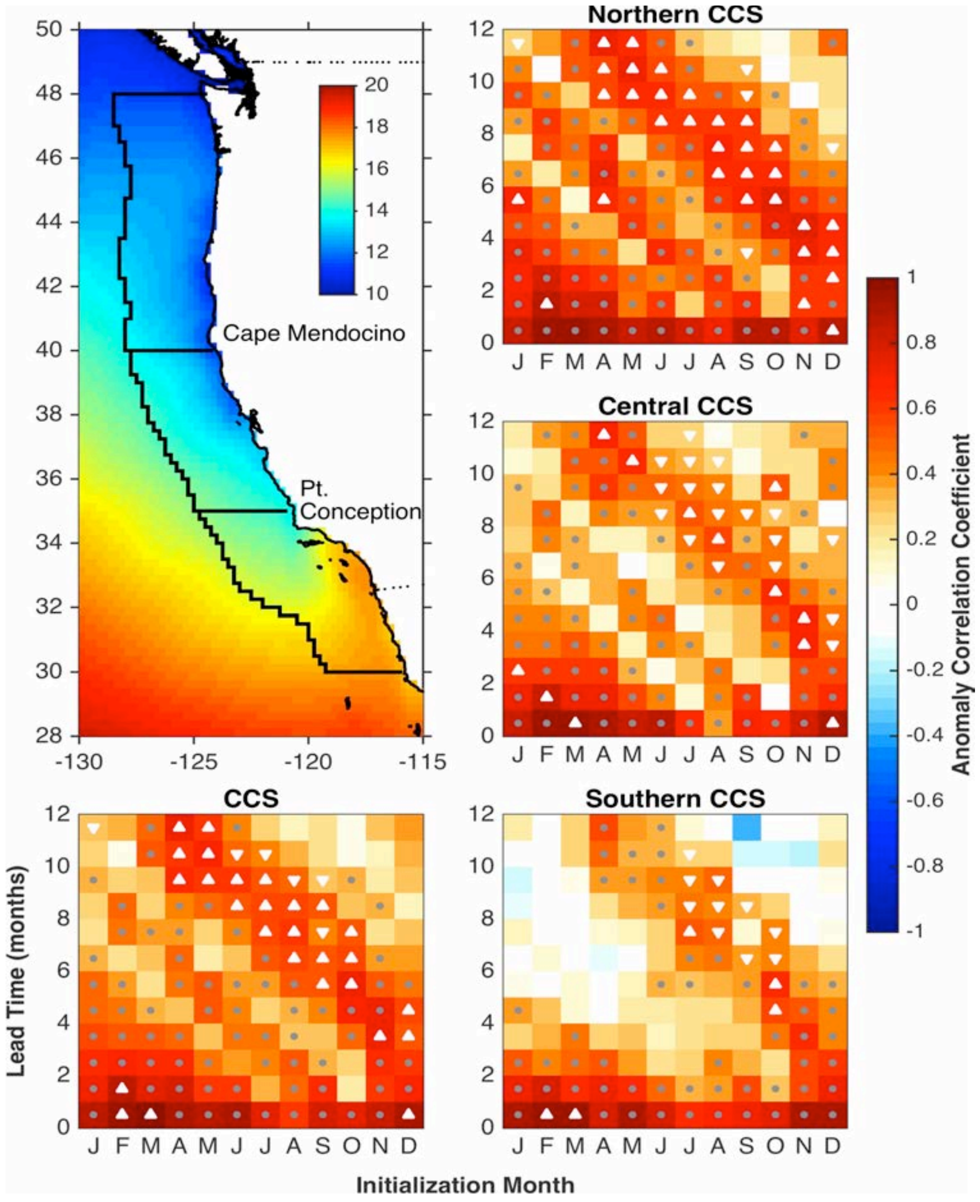
Comparison of LIM and NMME SST forecast skill in the LME regions



Hindcast skill (ACC) for 3-sub regions in the California Current LME from CanCM4

Anomaly correlation coefficients:

- ● above 0 at 5% level
- ▲ above persistence at 10% level with ACC > 0.5
- ▼ above persistence at 10% level with ACC < 0.5.

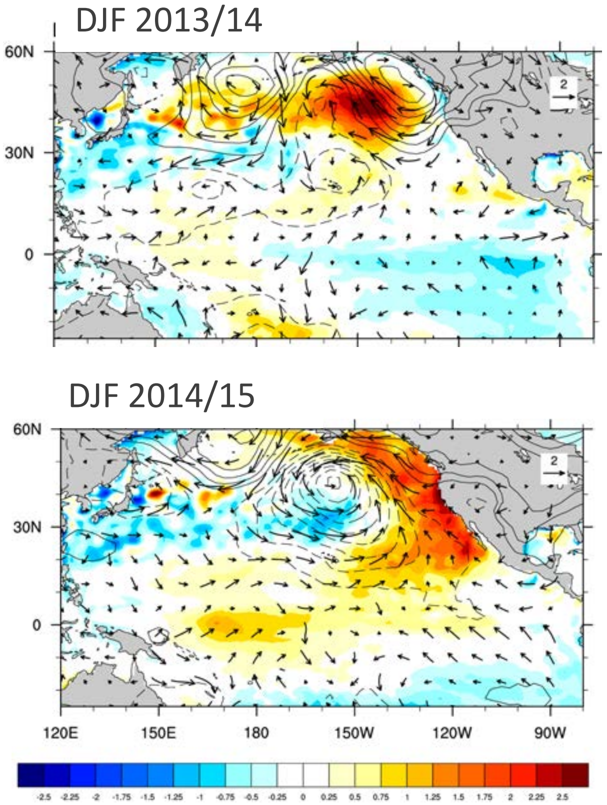


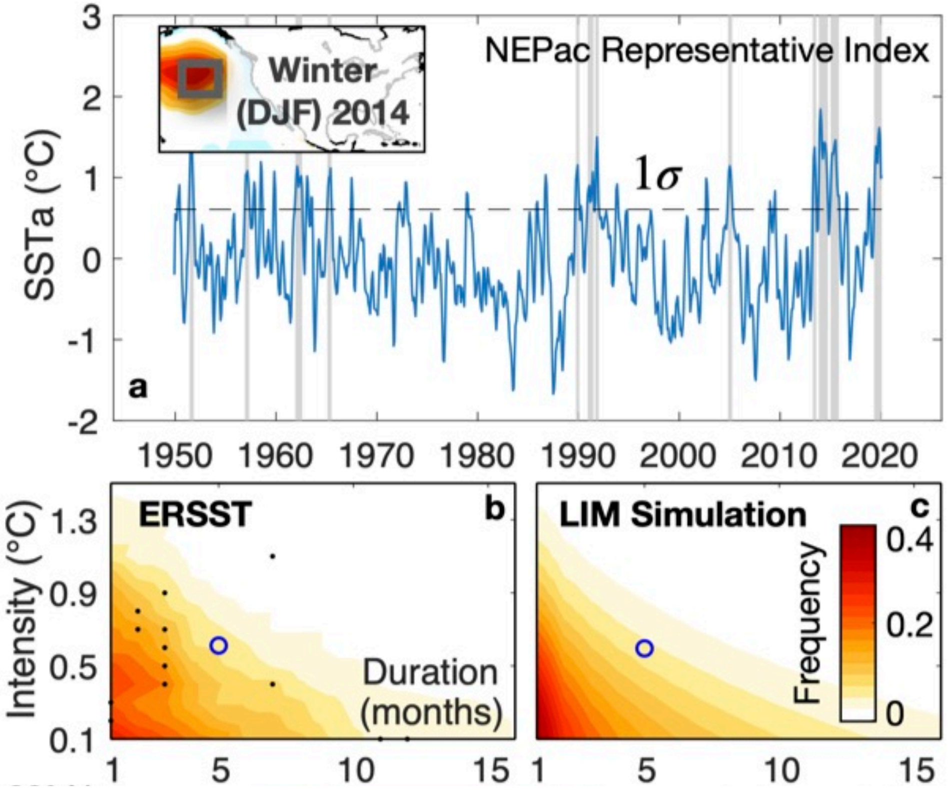
[**Jacox, M. G., M. A. Alexander**, C.A. Stock, and. **G. Hervieux**, *2017, Climate Dynamics*]

Understanding Northeast Pacific Marine Heatwave using LIM

$$d\boldsymbol{x} = \mathbf{L}\,\boldsymbol{x}\,dt + \mathbf{S}\,\mathbf{r}\,(dt)^{1/2}$$

x = state vector
L = matrix encapsulating the predictable system dynamics
S = stochastic forcing amplitude covariance matrix
r = random noise vector from N(0,1)



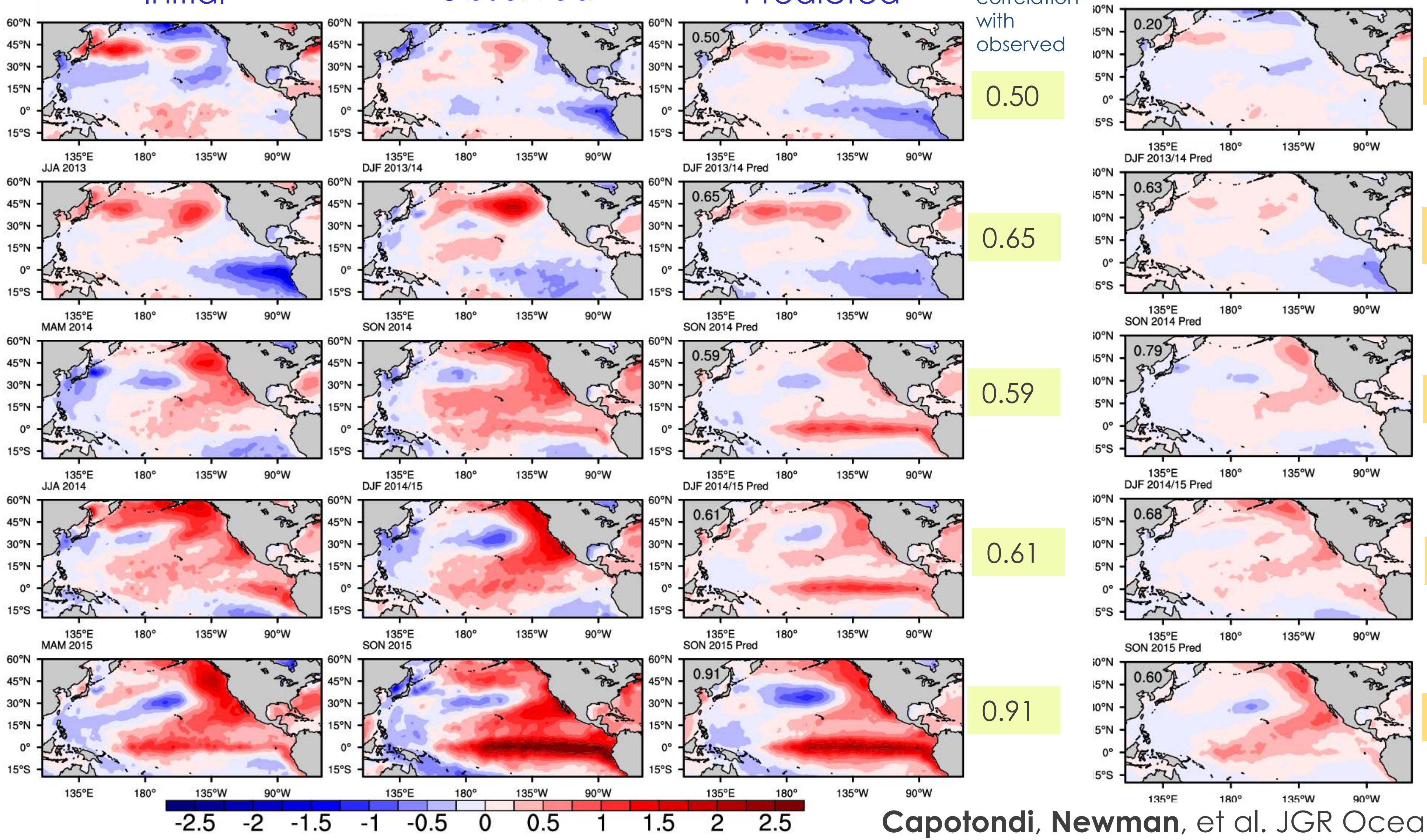


A 35,000-year LIM simulation captures the statistics of the observed warm events. It is used to understand the relationship between warming in the Northeast Pacific and tropical Pacific conditions.

Xu, **Newman**, **Capotondi** and Di Lorenzo, 2020, GRL, revised

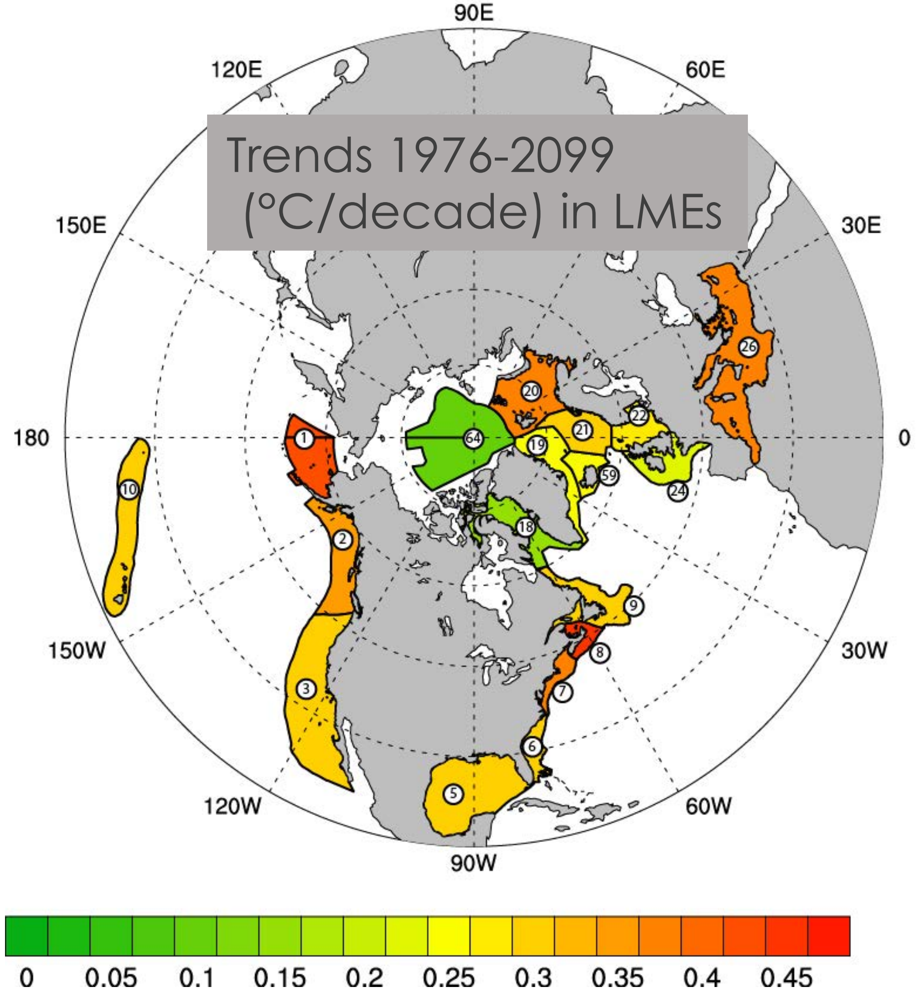
6-Month Lead SST Predictions – LIM vs. Damped Persistence

Target season	Pattern correlation with observed (Predicted)	Pattern correlation with observed (Damped persistence)
MAM2013	0.50	0.20
DJF2013/14	0.65	0.63
SON2014	0.59	0.79
DJF2014/15	0.61	0.68
SON2015	0.91	0.60

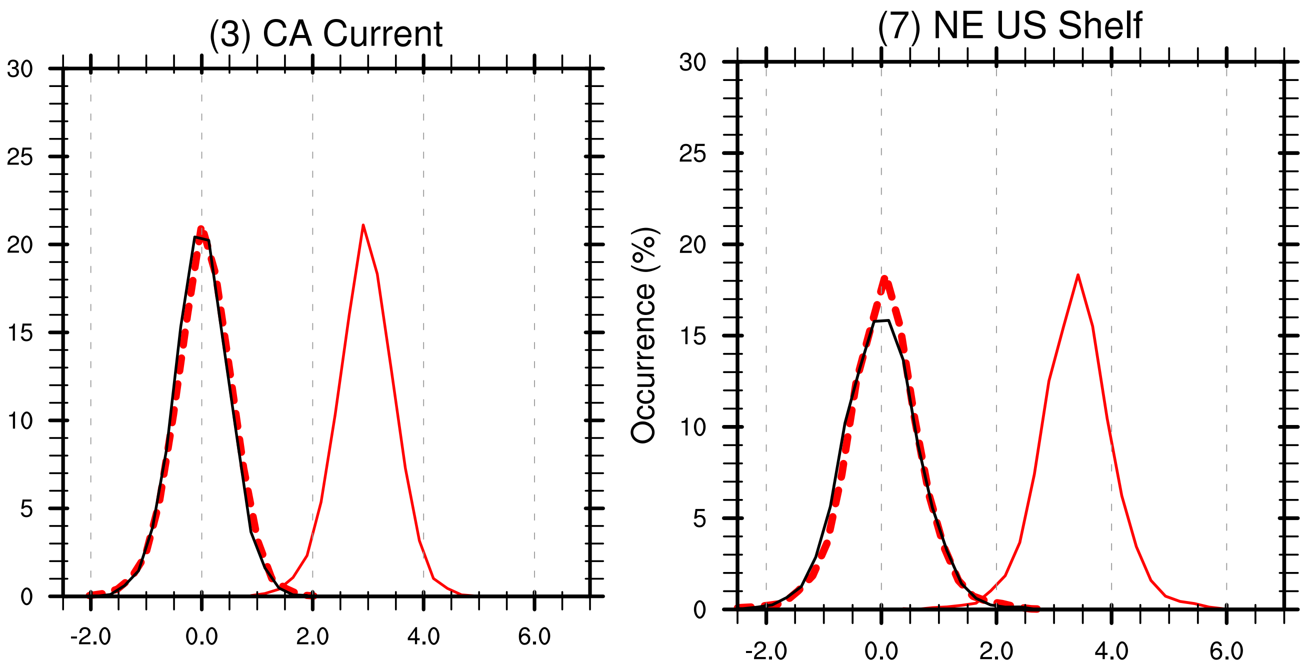


Capotondi, **Newman**, et al. JGR Oceans, in prep.

SSTs Changes RCP8.5 CMIP5



Monthly SSTA Histograms



Black:1976-2005

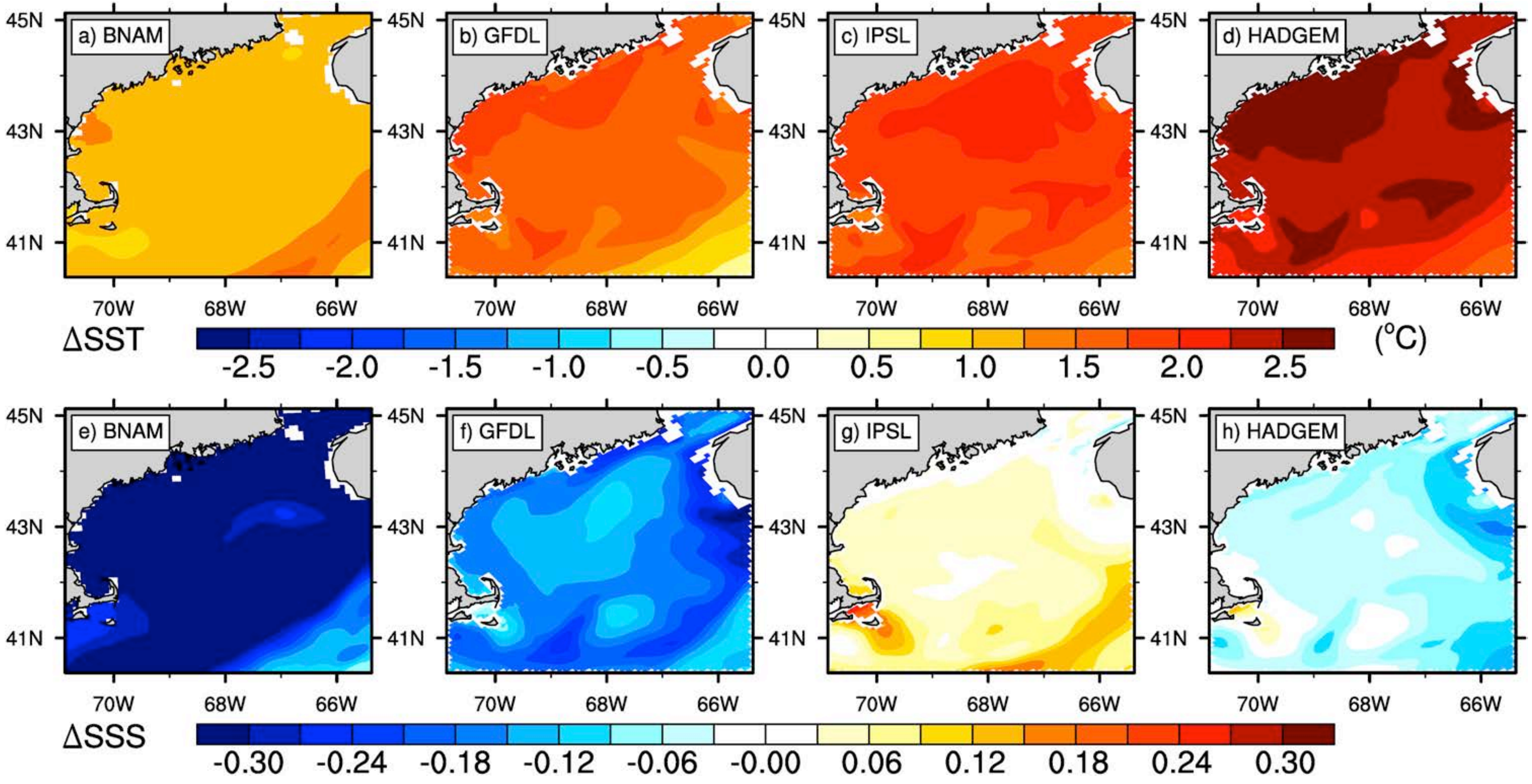
Red Solid 2070-2099 including mean change

Red dashed 2070-2099 mean change removed

SSTs detrended in each 30-year period

Alexander, Scott, et al. 2018, *Elementa Sci Anthro.*

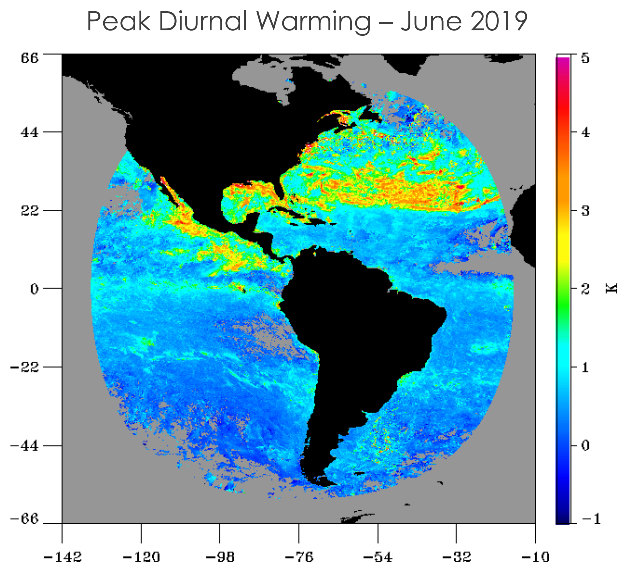
Projected Change in Bottom Temperature and Salinity Gulf of Maine in 2050 from 1976-2005

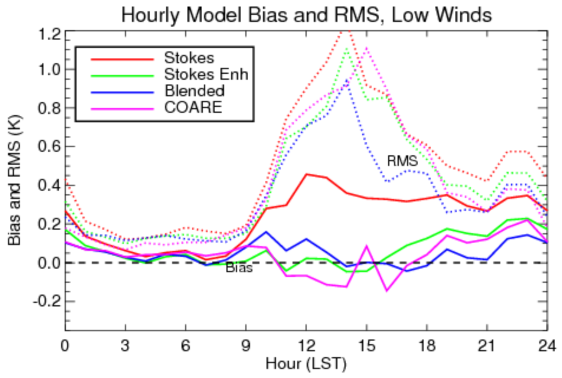


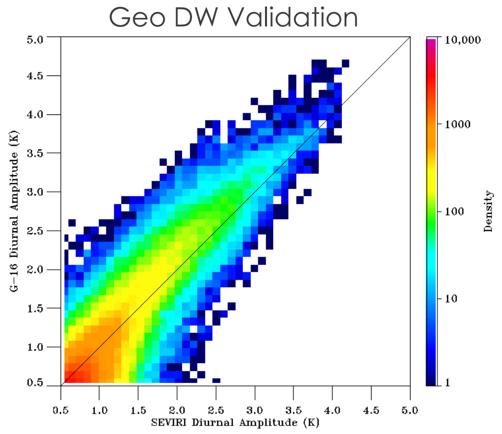
Brickman D., **M. A. Alexander**, A. Pershing, **J. D. Scott**, *Elementa Science of the Anthropocene*, 2020, Submitted.

Improvement of Satellite-Derived Sea Surface Temperature

- Development and validation of diurnal warming models
  - Implemented improved physical model in partnership with NESDIS
  - Transitioned into operational blended SST product and under evaluation at EUMETSAT
- Assessment of product accuracy and uncertainty
  - Validation of diurnal warming amplitudes from geostationary sensors
  - Comparison of scales of spatial variability in ATOMIC







Wick and Castro, *Remote Sensing*, 2020, submitted