Connecting seasonal climate predictions and marine resource decisions: progress and challenges

2017 US CLIVAR Summit
PPAI Panel

August 9, 2017

Charles Stock, NOAA/GFDL
(with special thanks to Desiree Tommasi and many others)

Progress in Oceanography 152 (2017) 15–49

Contents lists available at ScienceDirect

Progress in Oceanography

journal homepage: www.elsevier.com/locate/pocean

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Review

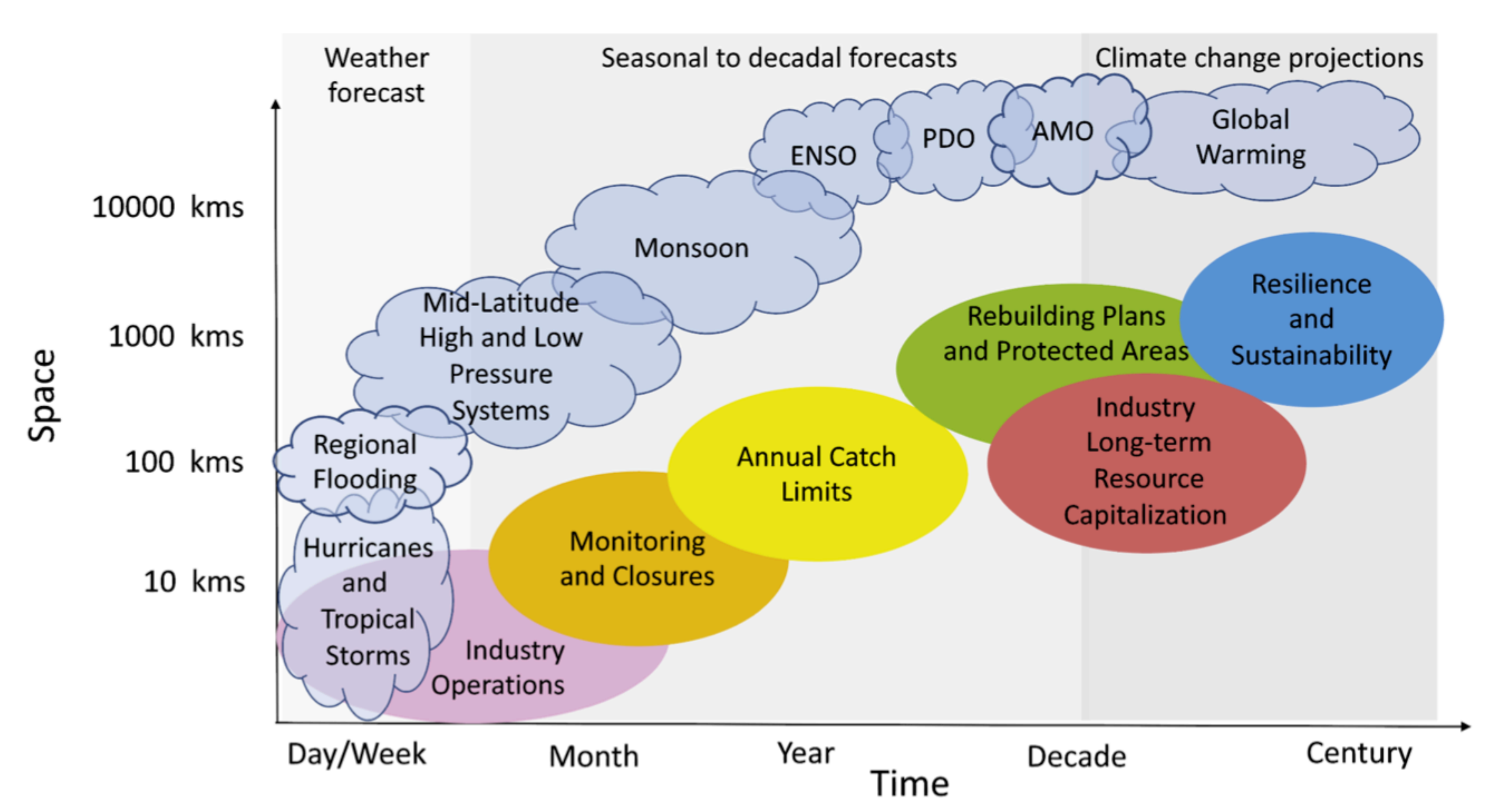
Managing living marine resources in a dynamic environment: The role of seasonal to decadal climate forecasts

CrossMark

Desiree Tommasi [a,*], Charles A. Stock [b], Alistair J. Hobday [c], Rick Methot [d], Isaac C. Kaplan [e], J. Paige Eveson [c], Kirstin Holsman [f], Timothy J. Miller [g], Sarah Gaichas [g], Marion Gehlen [h], Andrew Pershing [i], Gabriel A. Vecchi [b], Rym Msadek [j], Tom Delworth [b], C. Mark Eakin [k], Melissa A. Haltuch [d], Roland Séférian [l], Claire M. Spillman [m], Jason R. Hartog [c], Samantha Siedlecki [n], Jameal F. Samhouri [e], Barbara Muhling [a], Rebecca G. Asch [a], Malin L. Pinsky [o], Vincent S. Saba [p], Sarah B. Kapnick [b], Carlos F. Gaitan [b,1], Ryan R. Rykaczewski [q], Michael A. Alexander [r], Yan Xue [s], Kathleen V. Pegion [t], Patrick Lynch [u], Mark R. Payne [v], Trond Kristiansen [w], Patrick Lehodey [x], Francisco E. Werner [y]

NOAA/OAR/NMFS S&T SEED Project

Fisheries decisions across space and time scales



Tommasi et al., PinO, 2017

Should I go fishing?

Source: Discovery Channel

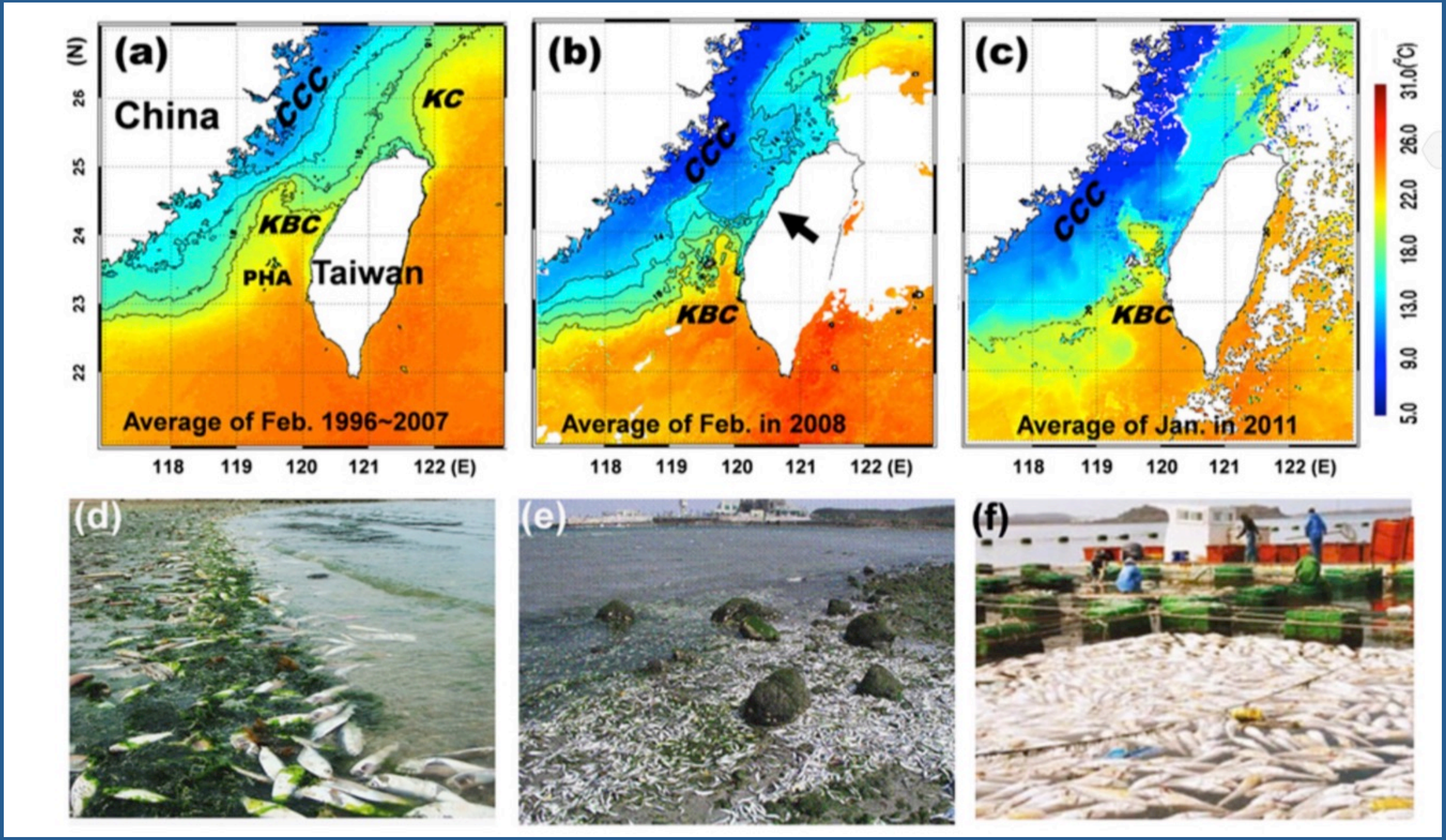
Where should I go fishing?

http://www.cmar.csiro.au/sbt-east-coast/
Hobday et al., 2011; CJFAS, 68

Source: Doug Helton/NOAA
Stanford News

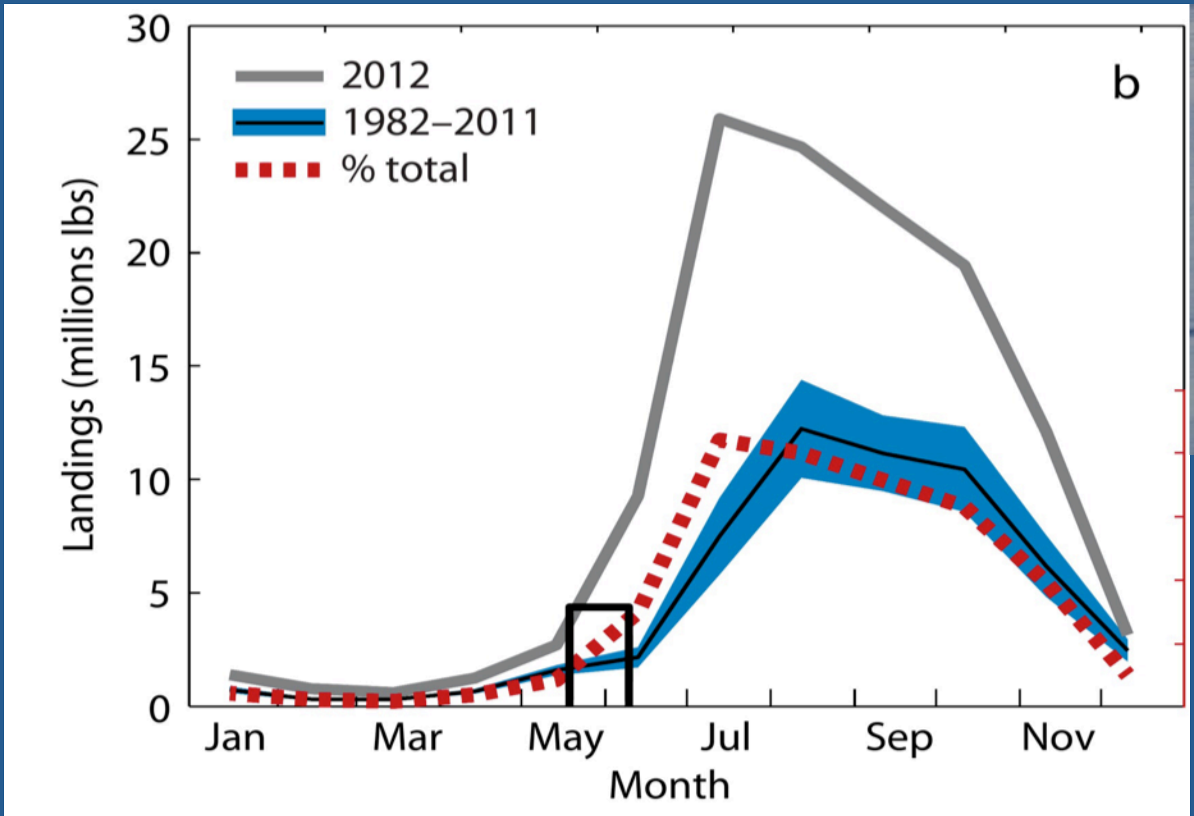
See also: https://www.pifsc.noaa.gov/eod/turtlewatch.php

When should I act to protect aquaculture against poor conditions?



Chang et al., 2013, Marine Policy

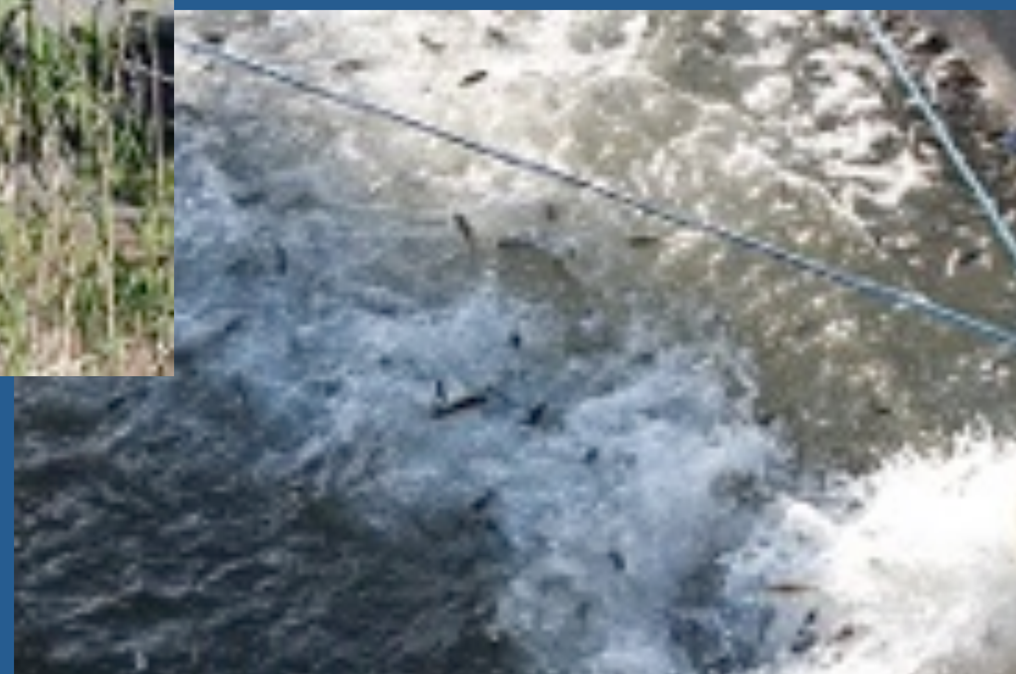
What should our processing and distribution capacity be ready for?



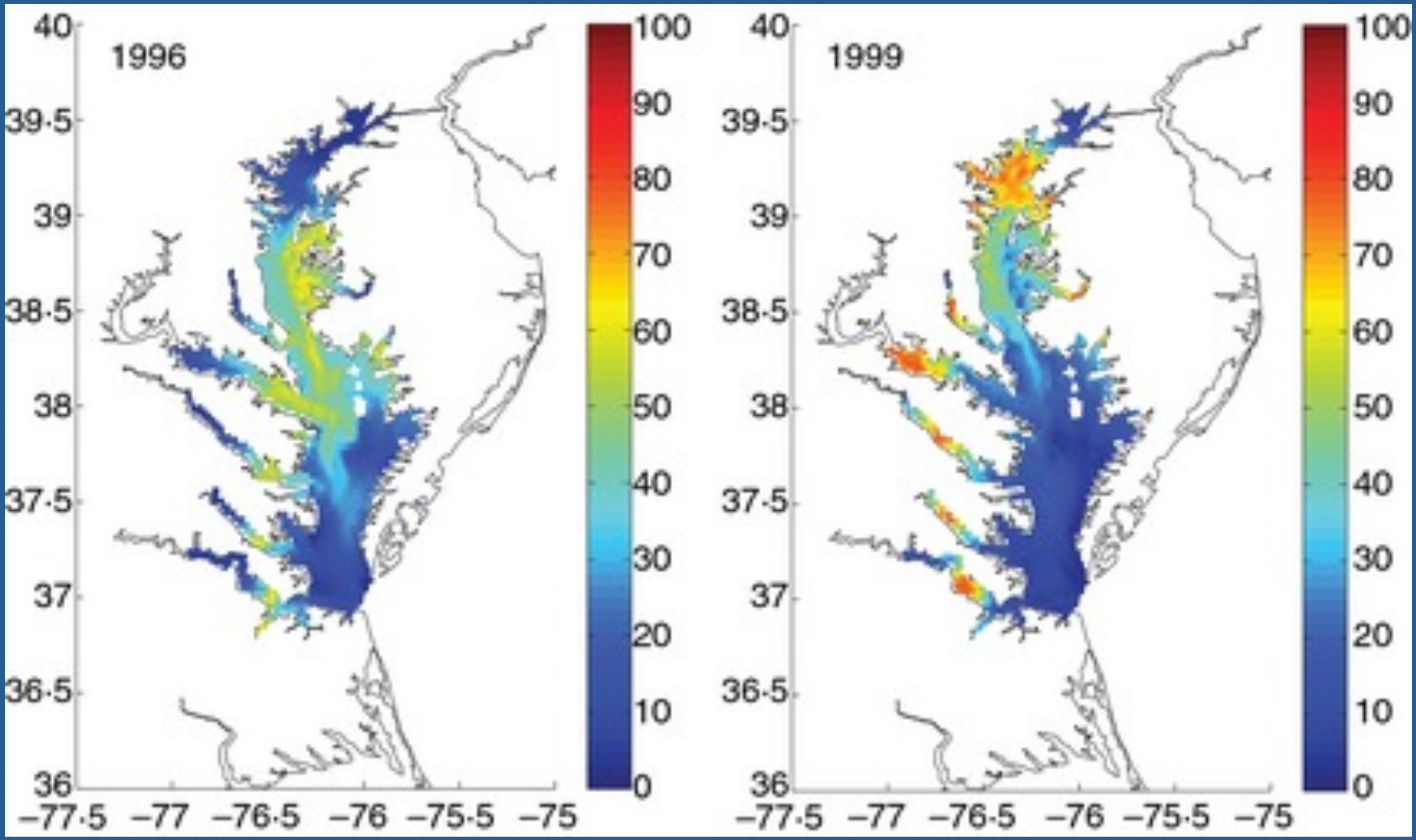
Mills et al., 2013, Oceanography;
http://www.gmri.org/our-work/research/projects/gulf-maine-lobster-forecasting

When should I release salmon fry from my hatchery?

www.fws.gov; trucking salmon in the Sacramento River

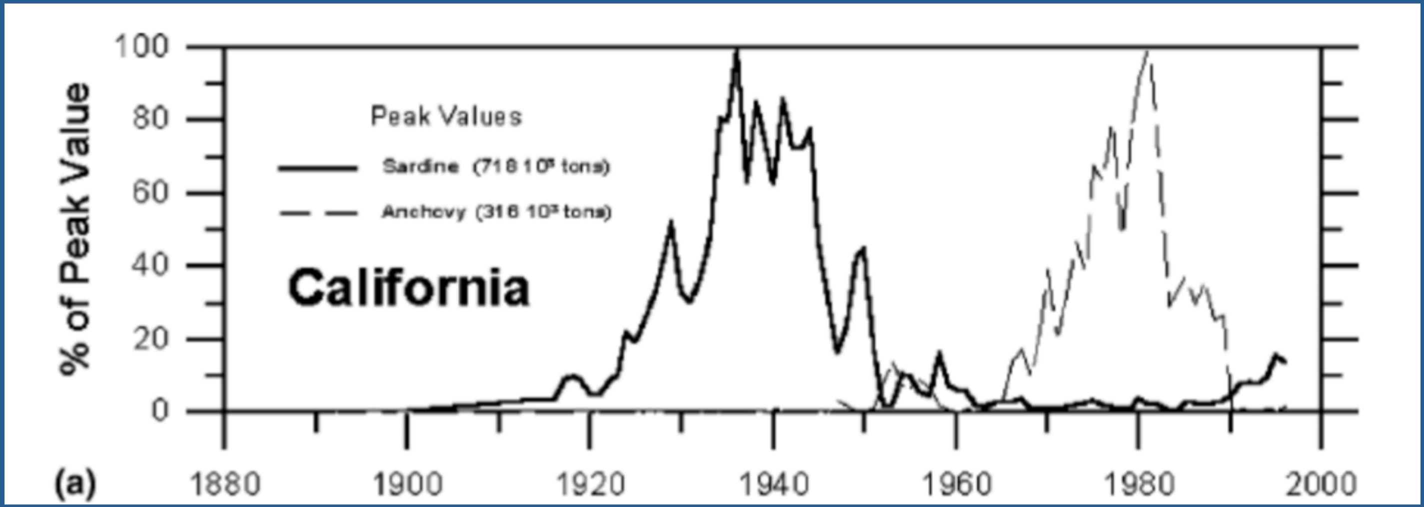


How should I best deploy monitoring/ modify closures to protect human health?



Jacobs et al., Journal of Applied Microbiology 2014

How much catch should be allowed next year?



Women cannery workers on the line - 1949

Unloading sardines - 1920s

End of an Era - Cannery Row.1950

Photos courtesy of the city of Monterey, time series de Young et al., PinO, 2004

Seasonal climate predictions and marine resource decisions

- All living marine resources, and the industries built around them, are shaped by climate
- Failing to account for climate variation and change in decision-making can lead to painful economic and health outcomes
- An opportunity for seasonal climate prediction?

Challenges in applying seasonal climate predictions to marine resource decision

- Complex relationship between climate and marine resources
- Decisions at local to regional scales
- High “burden of proof”/regulatory inertia for decisions with economic and public health consequences

Challenges in applying seasonal climate predictions to marine resource decision

- Complex relationship between climate and marine resources (but many first-order relationships with basic climate variables)

- Decisions at local to regional scales (could be hard, but it doesn't hurt to look…)

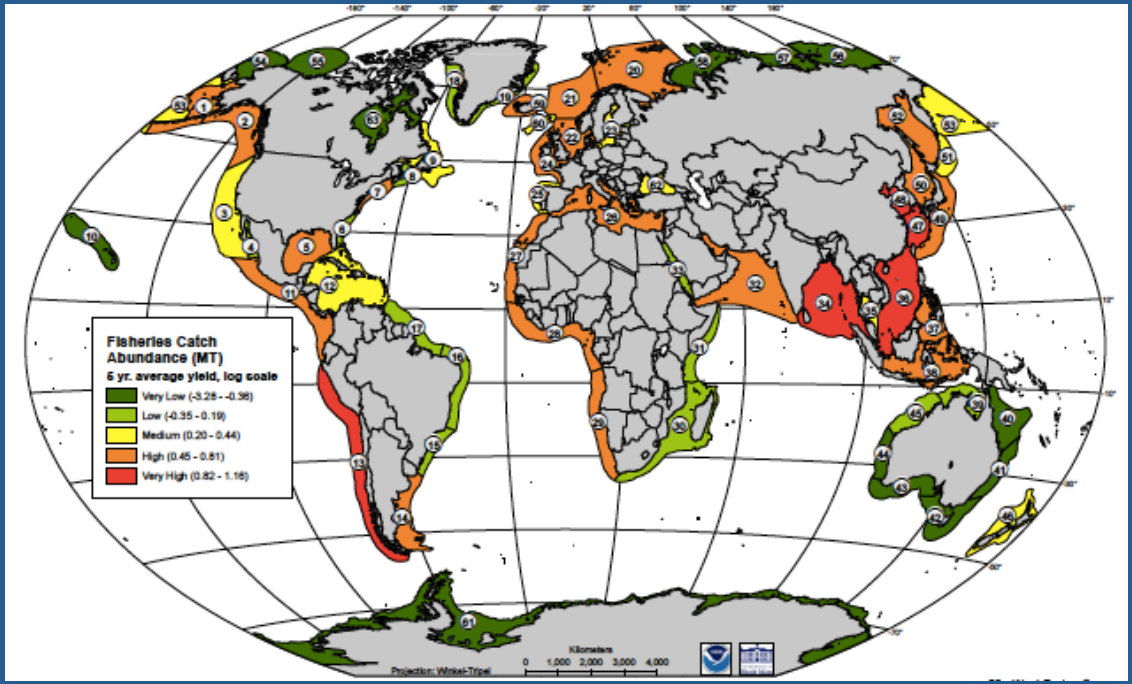
- High "burden of proof"/regulatory inertia for decisions with economic and public health consequences (but this challenge was met for weather prediction and we have 30+ years of hindcasts to assess confidence)

Seasonal Sea Surface Temperature anomaly predictions for coastal ecosystems

- SST anomalies are both leading indicators and important drivers of ecosystem fluctuations
- Assessment of SST predictions has been strongly skewed toward basin-scale variations (e.g., ENSO) and SSTs often viewed as precursors to predicting regional air temp/precip anomalies
- For marine resources, SST anomalies are of direct interest, and predictions along continental margins are essential

Stock et al., 2015, Progress in Oceanography, 137, 219-236

Synthesize predictability across Large Marine Ecosystems (LMEs)



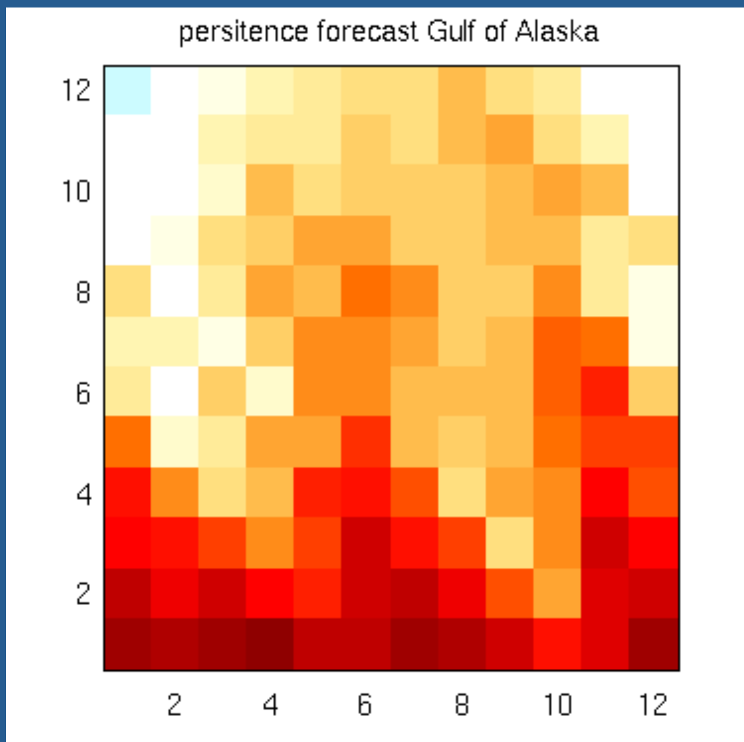
Large Marine Ecosystems: Ocean areas, generally along continental margins whose ecological systems are characterized by similarities in bathymetry, hydrography and biological productivity, and whose plant an animal populations are inextricably linked to one and other in the food chain (Sherman and Alexander, 1986)

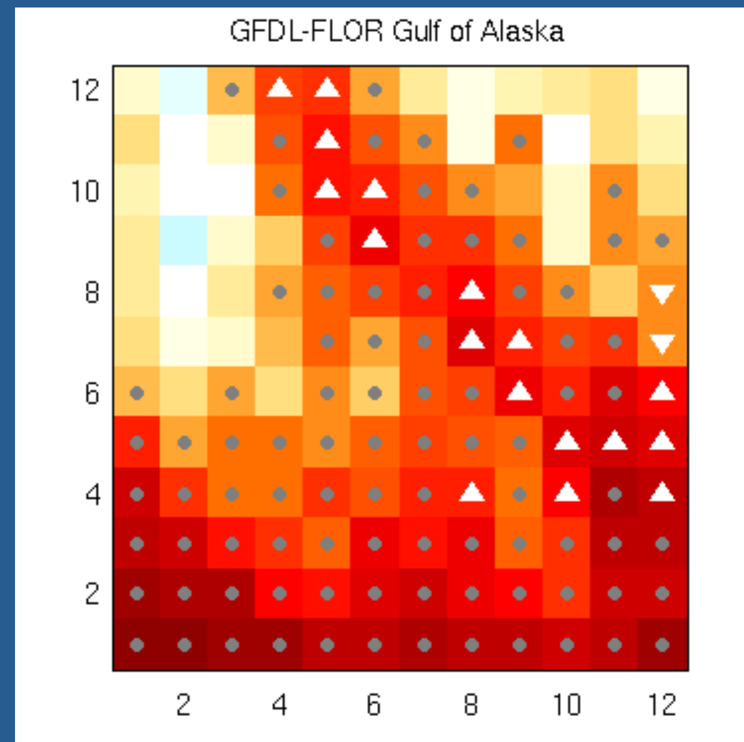
Gulf of Alaska SST anomaly predictions

Persistence ACC

GFDL-FLOR ACC

Forecast lead (months)





Forecast initialization month

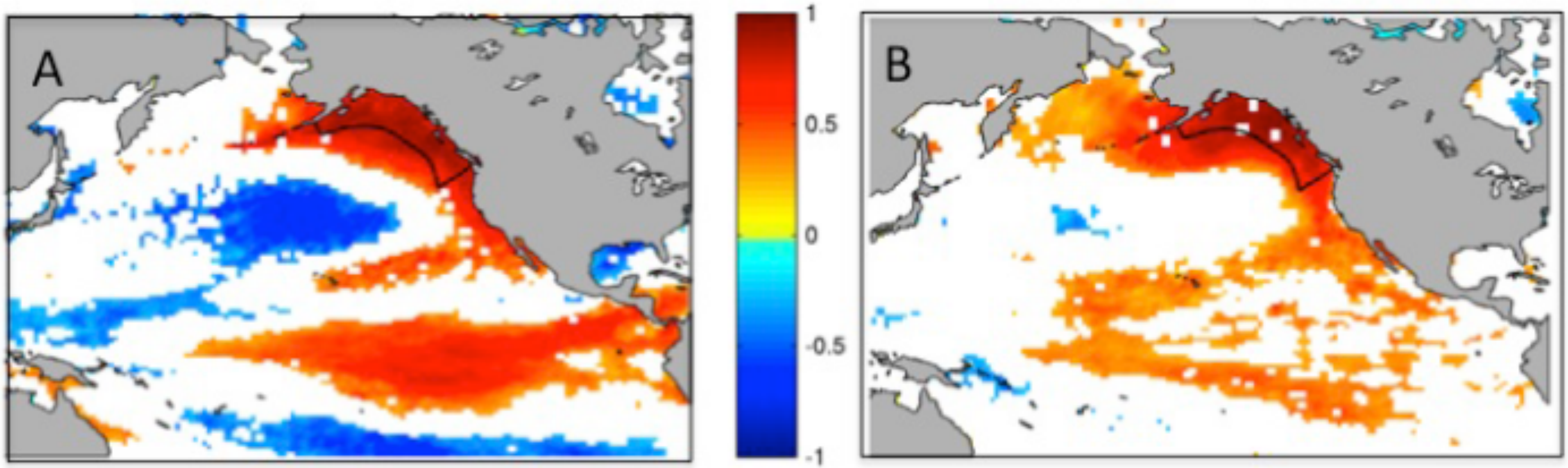
Forecast initialization month

-1

1

Stock et al., 2015, Progress in Oceanography, 137, 219-236

Forecast captures seasonal transition between less predictable localized SST anomaly and more predictable basin-scale patterns

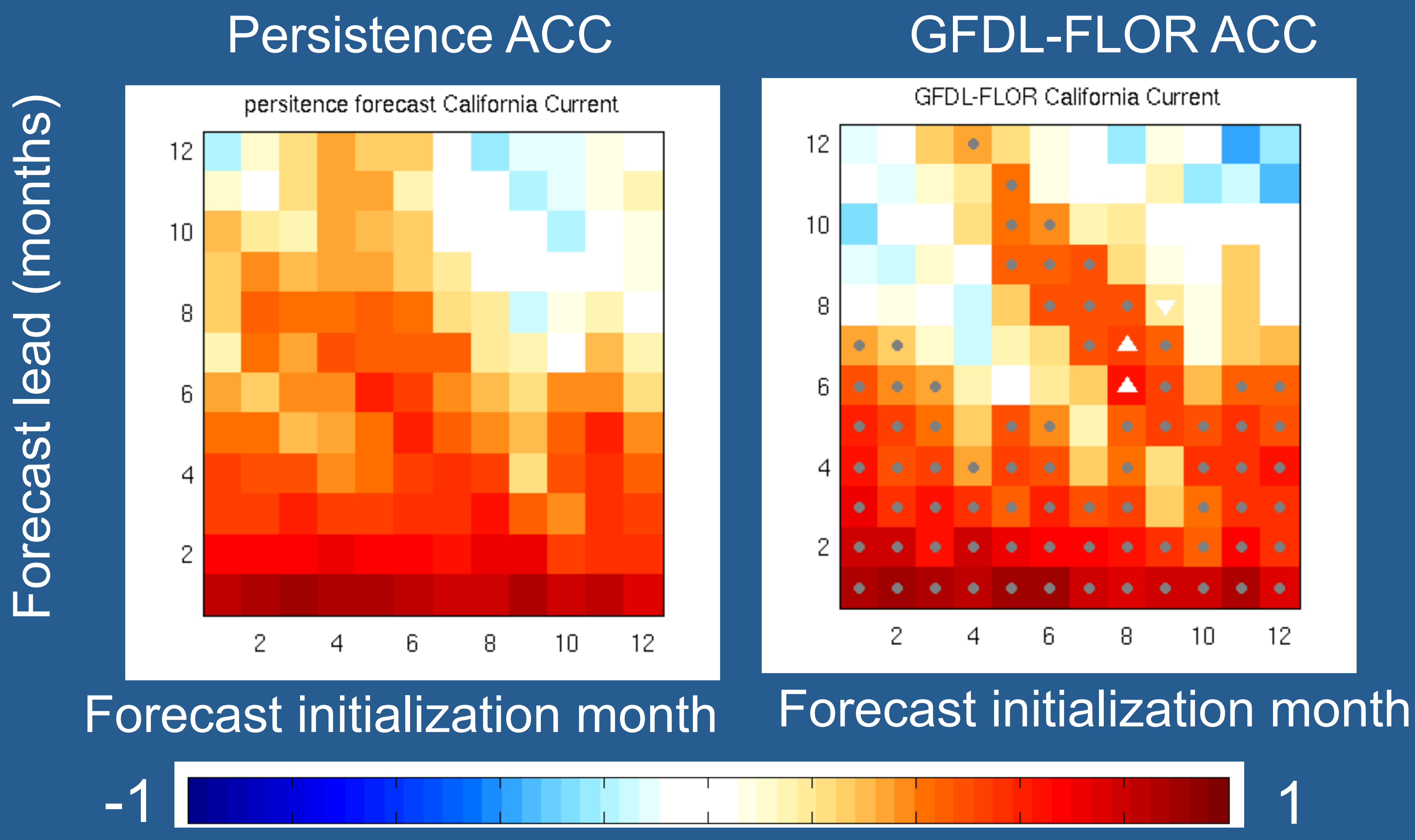


Correlation between March GoA SST anomaly and SST anomalies over the North Pacific Basin

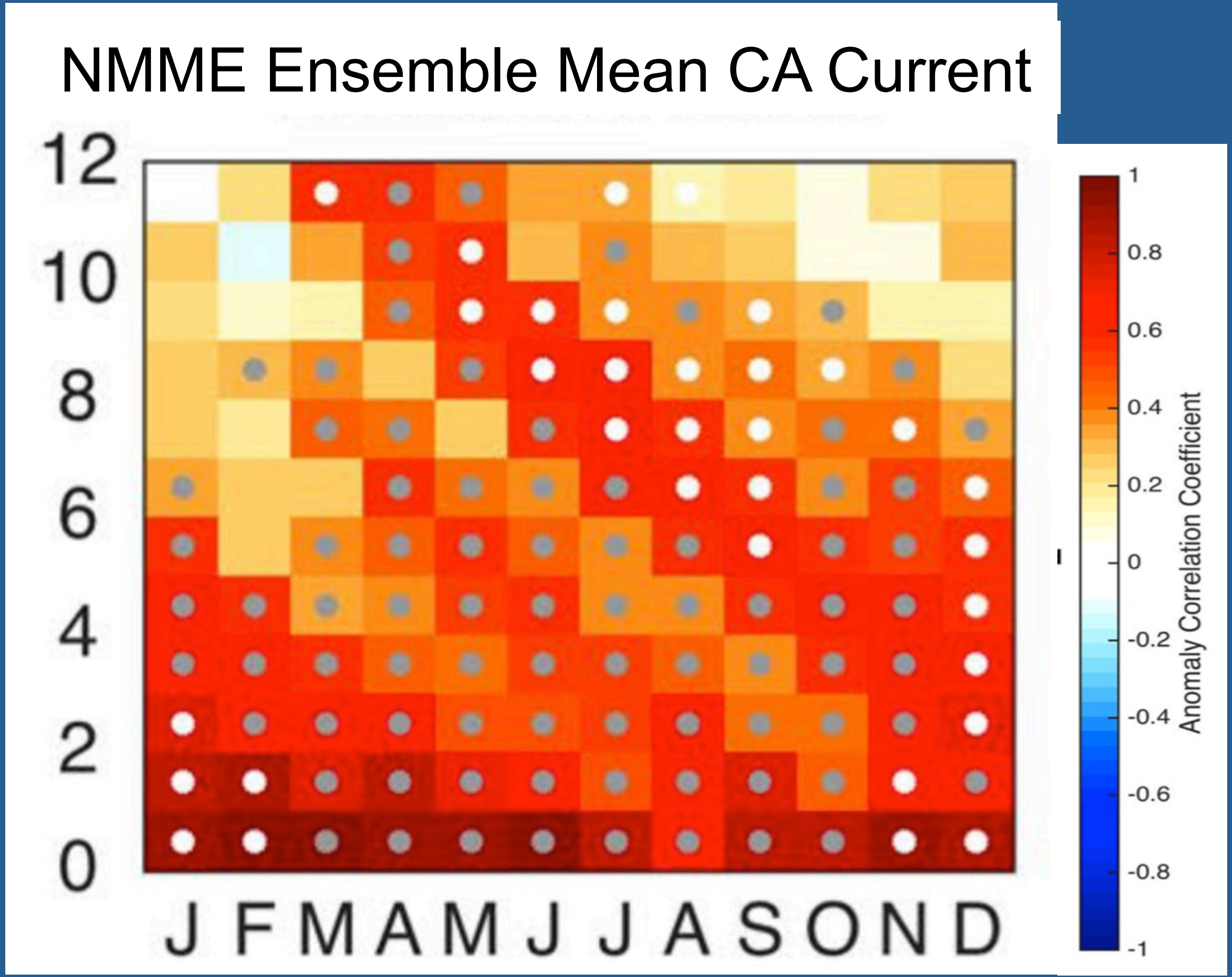
Correlation between August GoA SST anomaly and SST anomalies over the North Pacific Basin

Stock et al., 2015, Progress in Oceanography, 137, 219-236

California Current patterns similar to GoA but not as separable from persistence



NMME often improved anomaly correlation relative to individual models

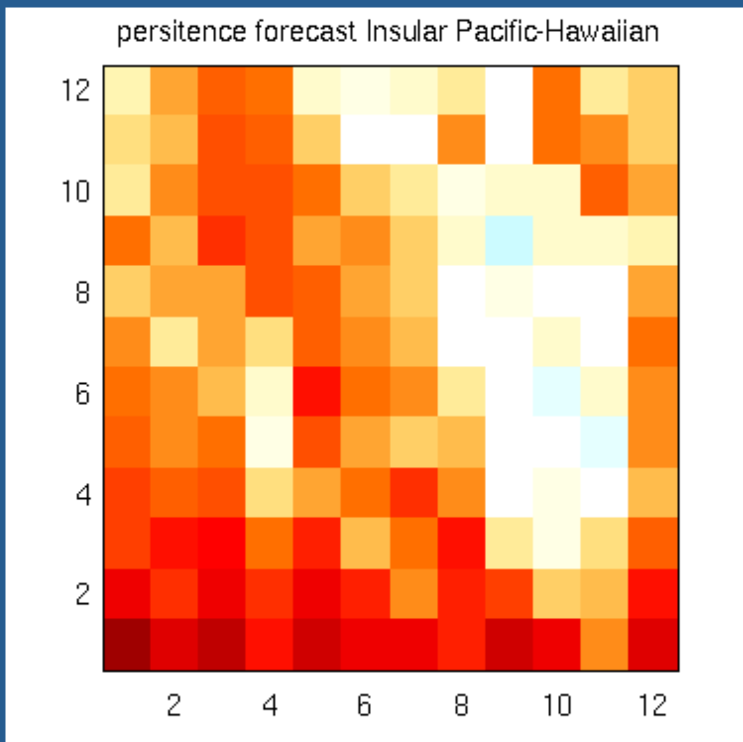


CPO SEED-extension:Jacox et al., Climate Dynamics, 2017
(see also Hervieux et al., Climate Dynamic, 2017)

Insular Pacific/Hawaiian (IP/H) SST anomaly predictions

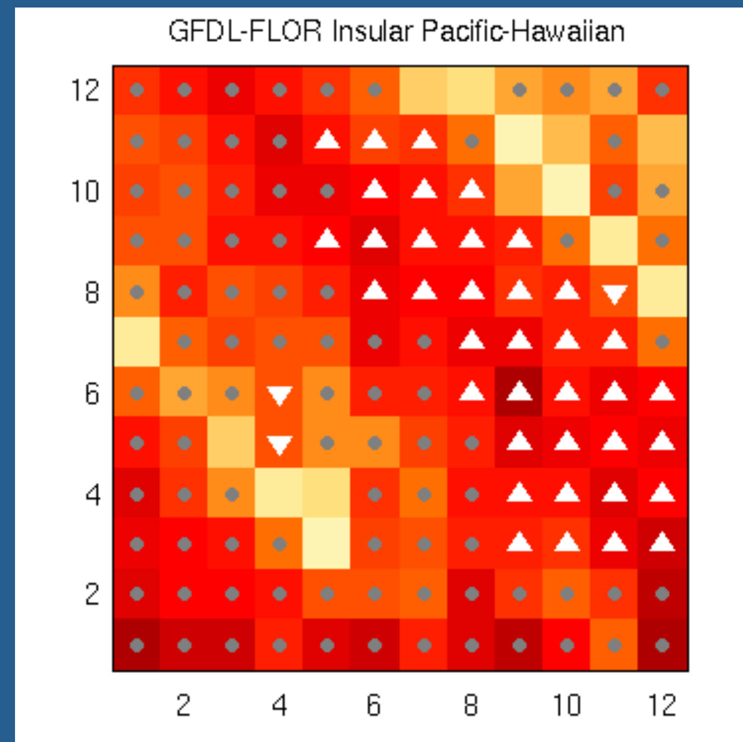
Forecast lead (months)

Persistence ACC



Forecast initialization month

GFDL-FLOR ACC



Forecast initialization month

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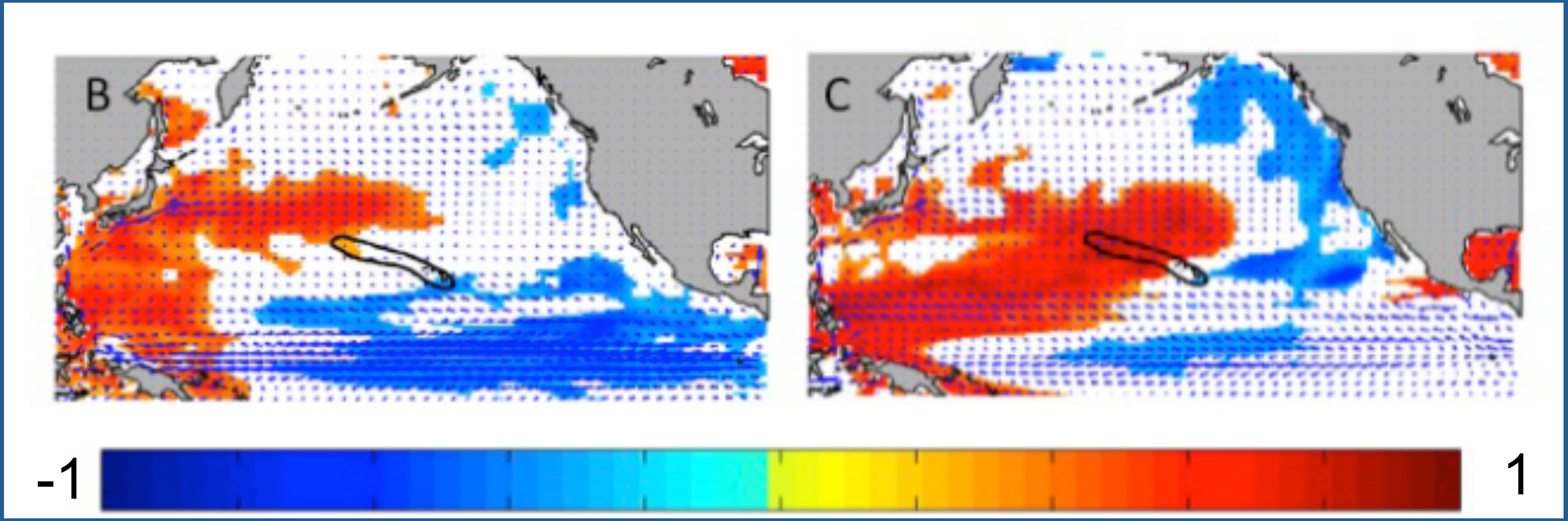
Stock et al., 2015, Progress in Oceanography, 137, 219-236

Forecast captures seasonal transition between different basin-scale influences

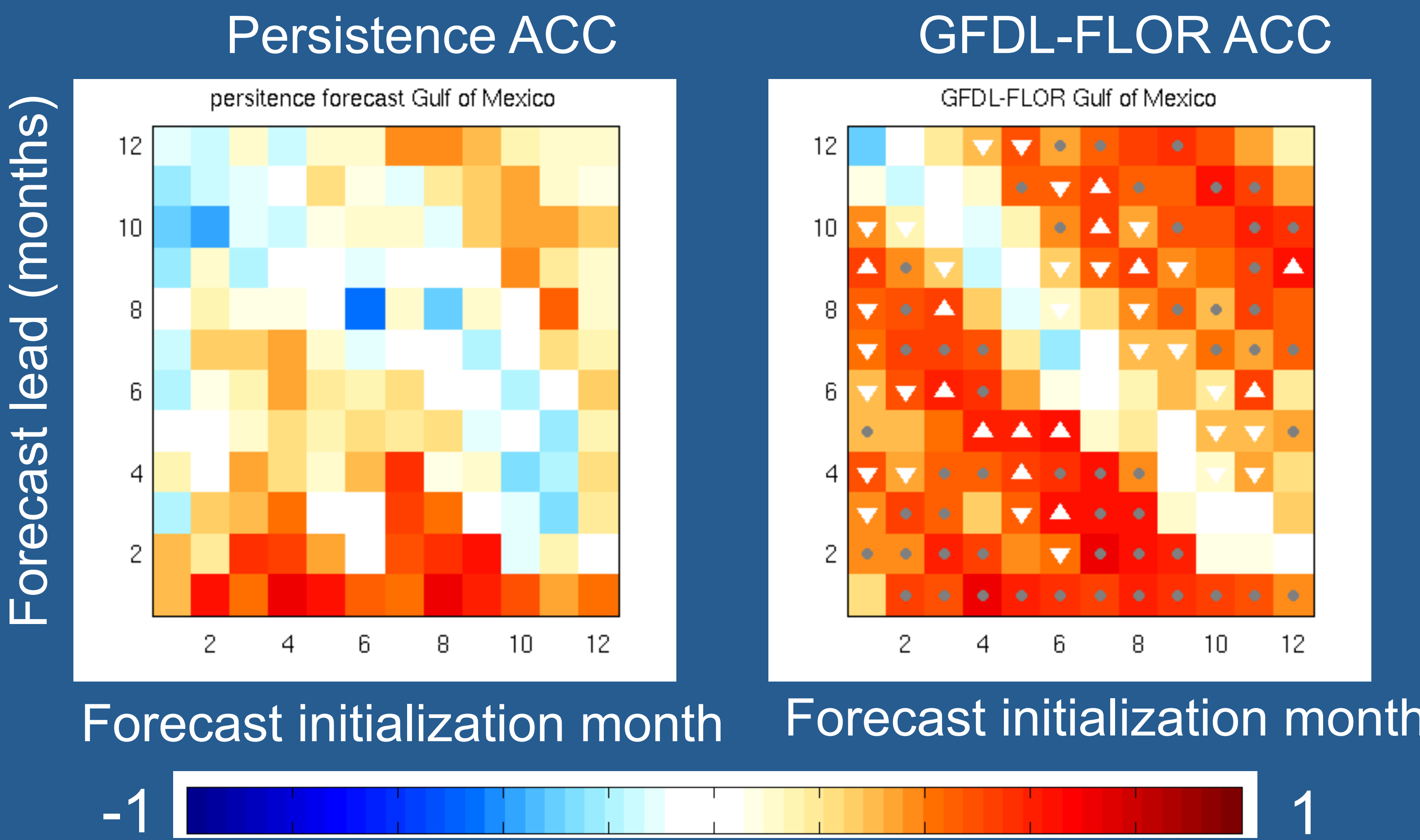


Correlation between Sep initialized SST anomaly and predicted Jan-Mar SST anomalies in the IP/H

Correlation between Feb forecast from Sep initialization and Jan-Mar IP/H anomalies

Stock et al., 2015, Progress in Oceanography, 137, 219-236

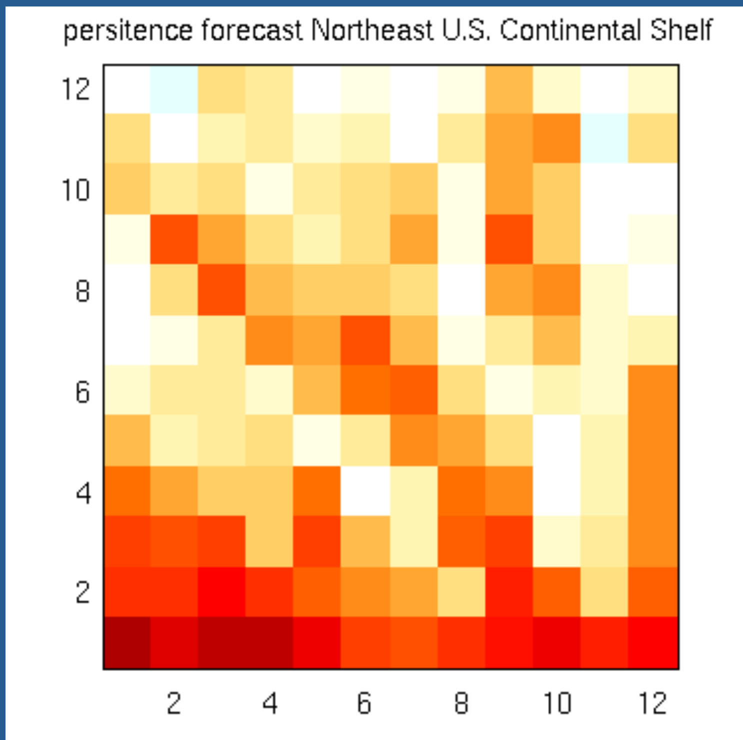
Multiple cases of skill above persistence in the Gulf of Mexico



Smaller scale is challenges forecast systems in the Northeast U.S

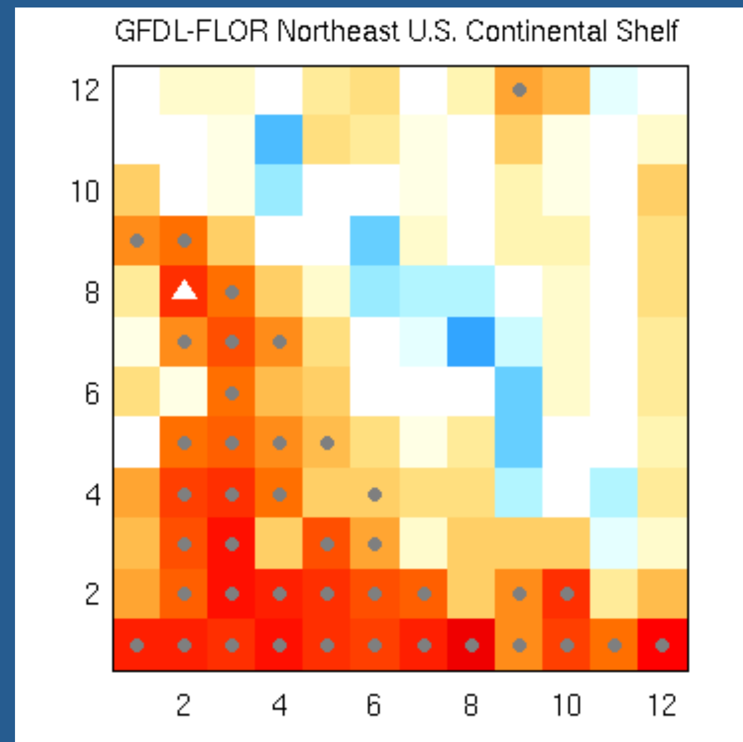
Persistence ACC

Forecast lead (months)

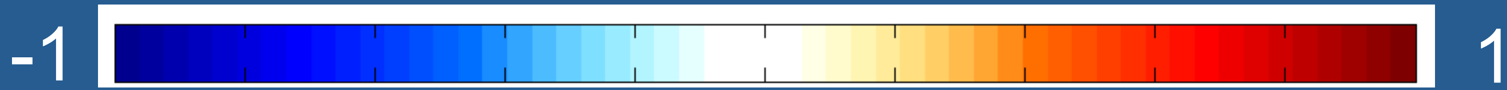


Forecast initialization month

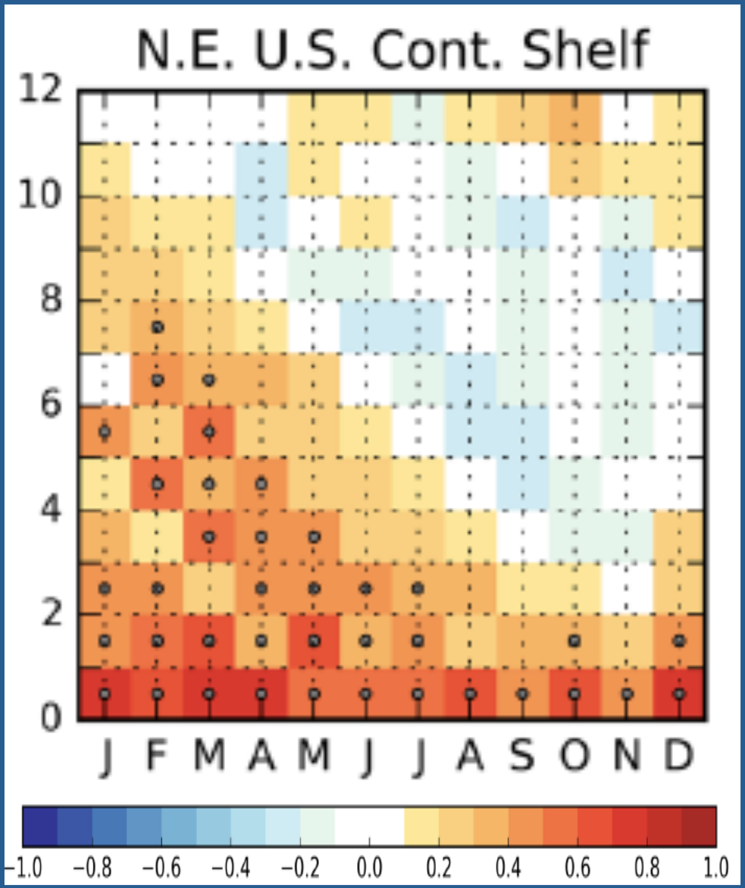
GFDL-FLOR ACC



Forecast initialization month

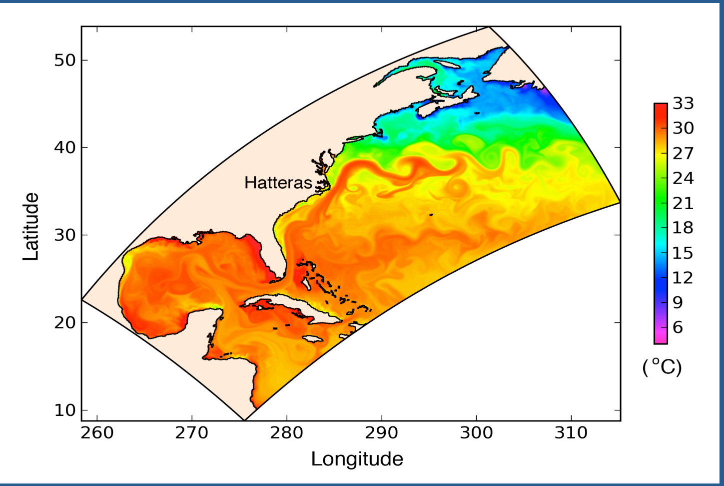


Even the NMME doesn't help for some systems



Hervieux et al., Climate Dynamic, 2017

- Are these systems unpredictable, or do they just lie beyond our present model's capacity?



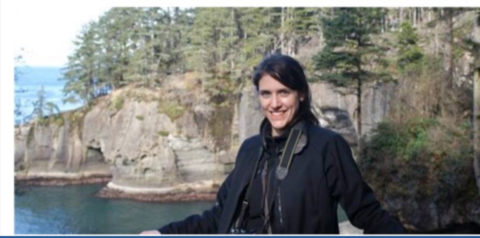
NOAA/COCA; Curchitser et al.

Regional ocean prediction from global climate prediction systems

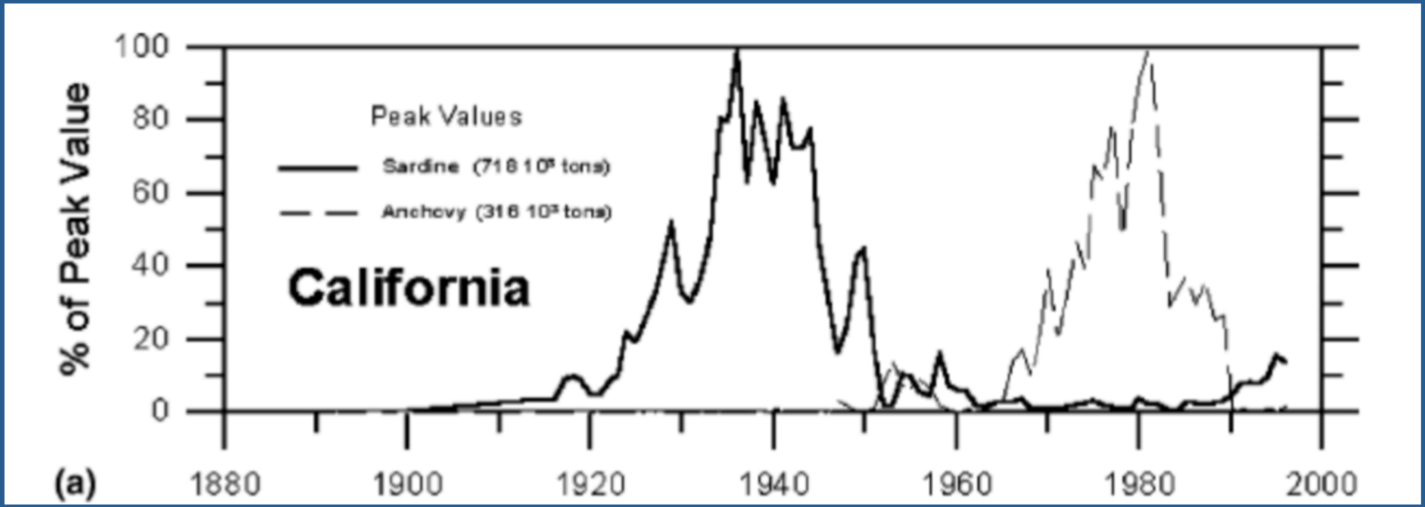
- SST Forecast skill varies widely by LME, initialization month, lead time and, to a degree, forecast system.
- There are many cases with high skill that also exceeds persistence. Analysis across 64 LMEs confirms this.
- Diverse mechanisms responsible for skill, but successfully capturing the interplay between local and basin-scale variation is a common thread.
- Less luck with salinity, promising results with sea ice (Bushuk et al., 2017; GRL + others)

Room for improvement, but what can we do with what we have?

Back to Cannery Row….



Tommasi et al., 2017; Ecological Applications



Women cannery workers on the line - 1949

Unloading sardines - 1920s

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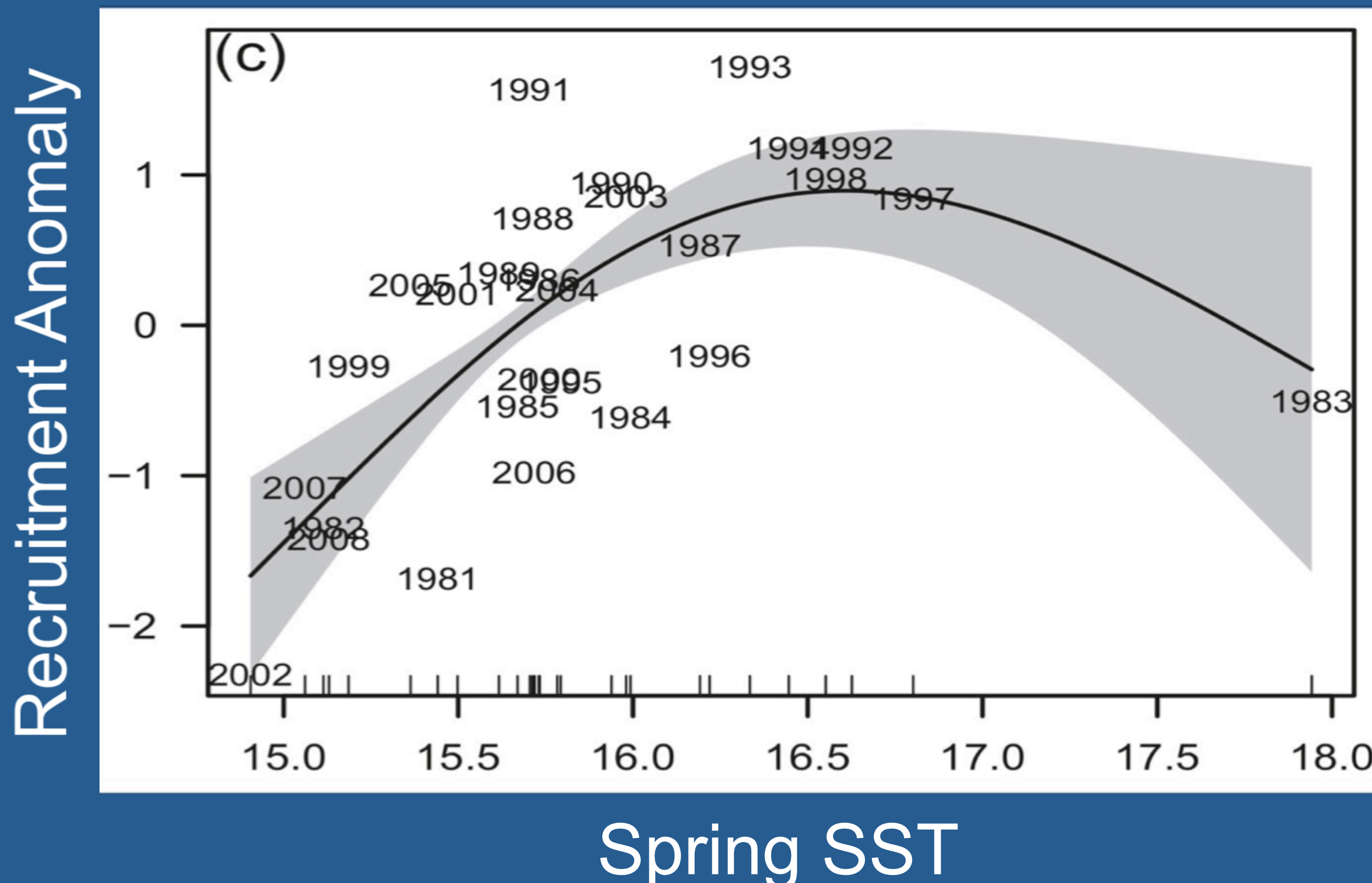
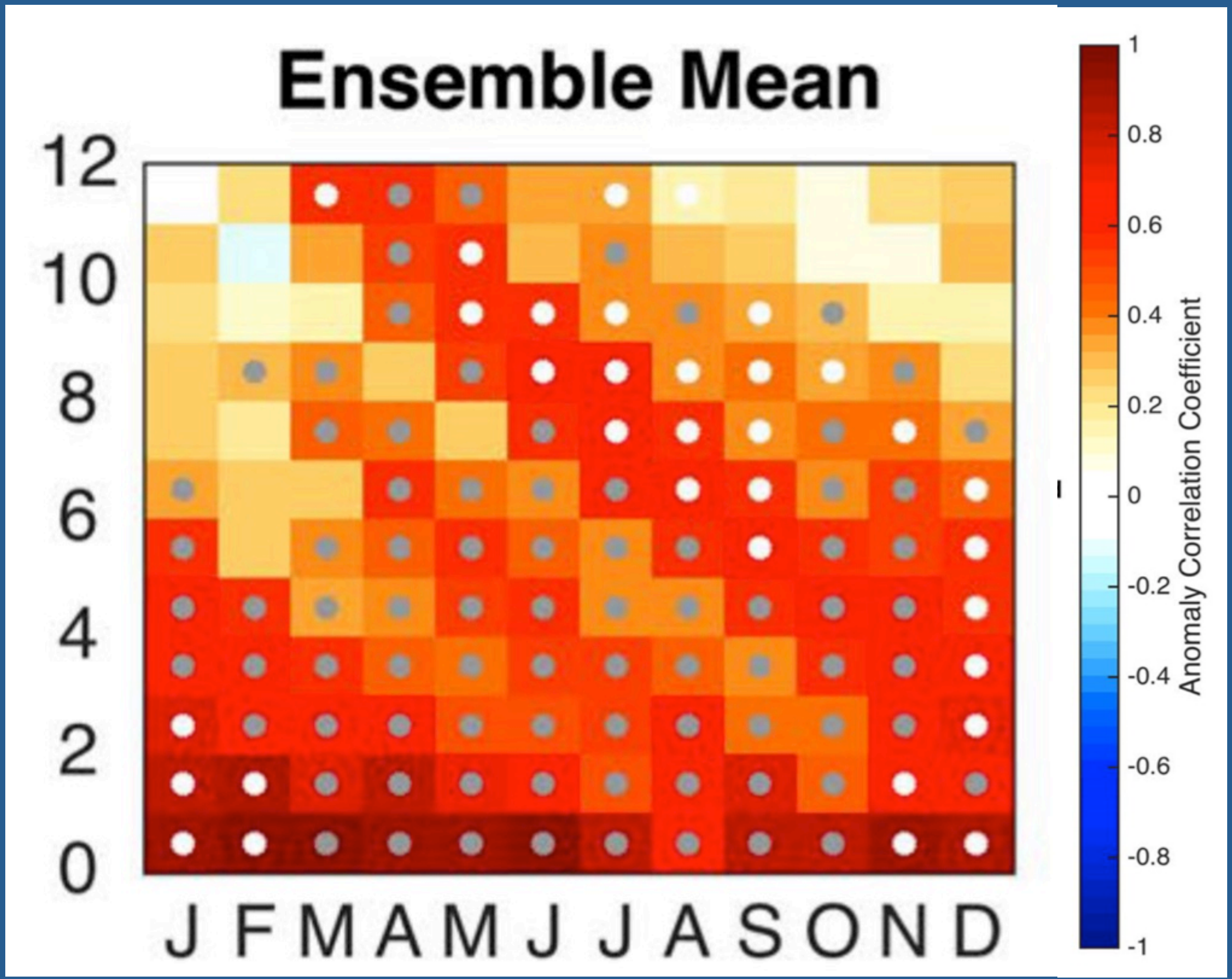
Photos courtesy of the city of Monterey, time series de Young et al., PinO, 2004

California sardine recruitment linked to SST anomalies



Lindegren and Checkley, 2012

Current models exhibit significant seasonal SST anomaly prediction skill California Current



Jacox et al., Climate Dynamics, 2017
(see also Stock et al., PinO, 2015; Hervieux et al., Climate Dynamic, 2017)

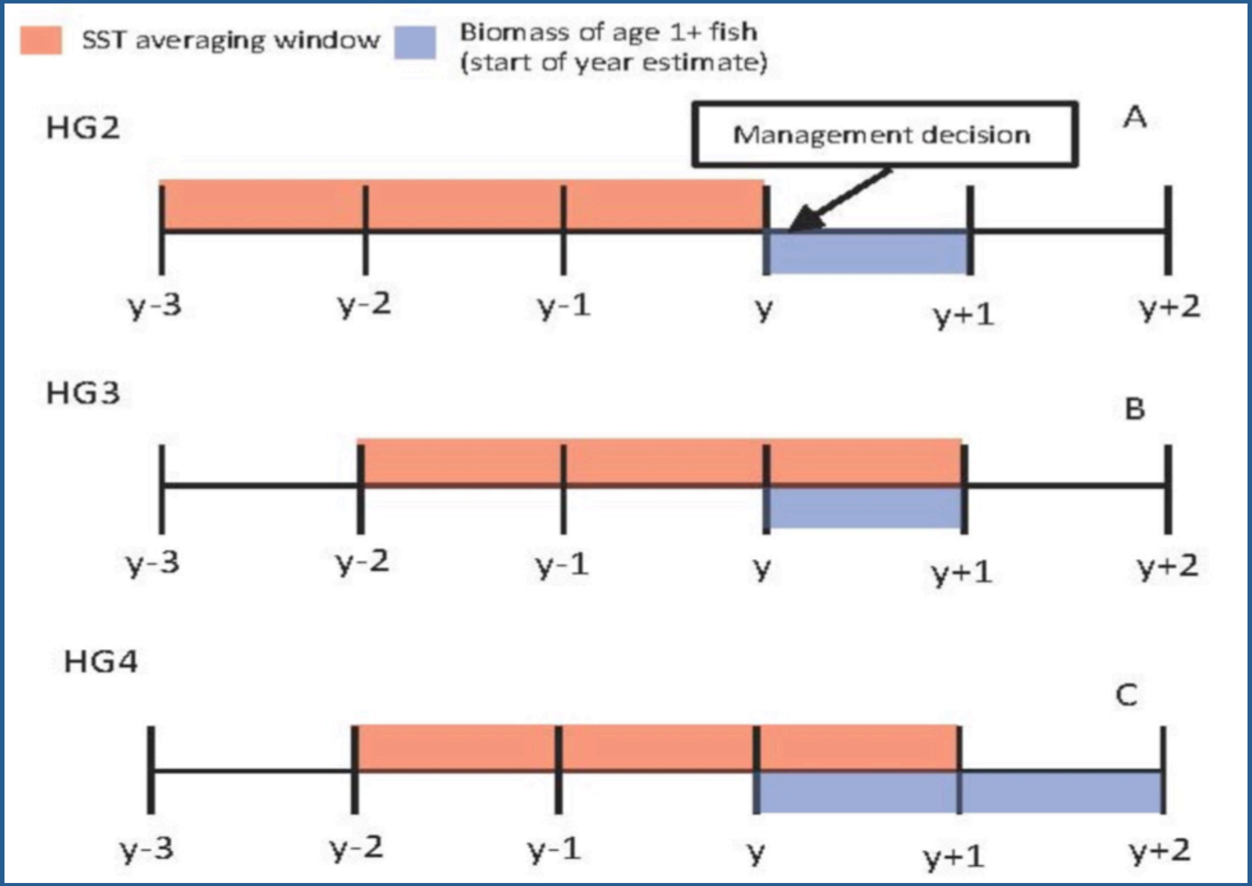
Setting harvest guidelines*

$$HG_t = (B_t - 150000)E_{msy}$$

- HG = harvest guideline for stock (catch limit in tons yr-1)
- B = an estimate of the stock biomass (tons)
- E_{msy} = the exploitation rate (fraction of stock removed per year) producing the maximum sustainable yield
- 150,000 ton "harvest-cutoff" below which the stock is closed (HG = 0)

*Each term relies on objective, data-driven statistical analysis, refined across decades of scientific work, scrutinized by management, industry and independent scientists.

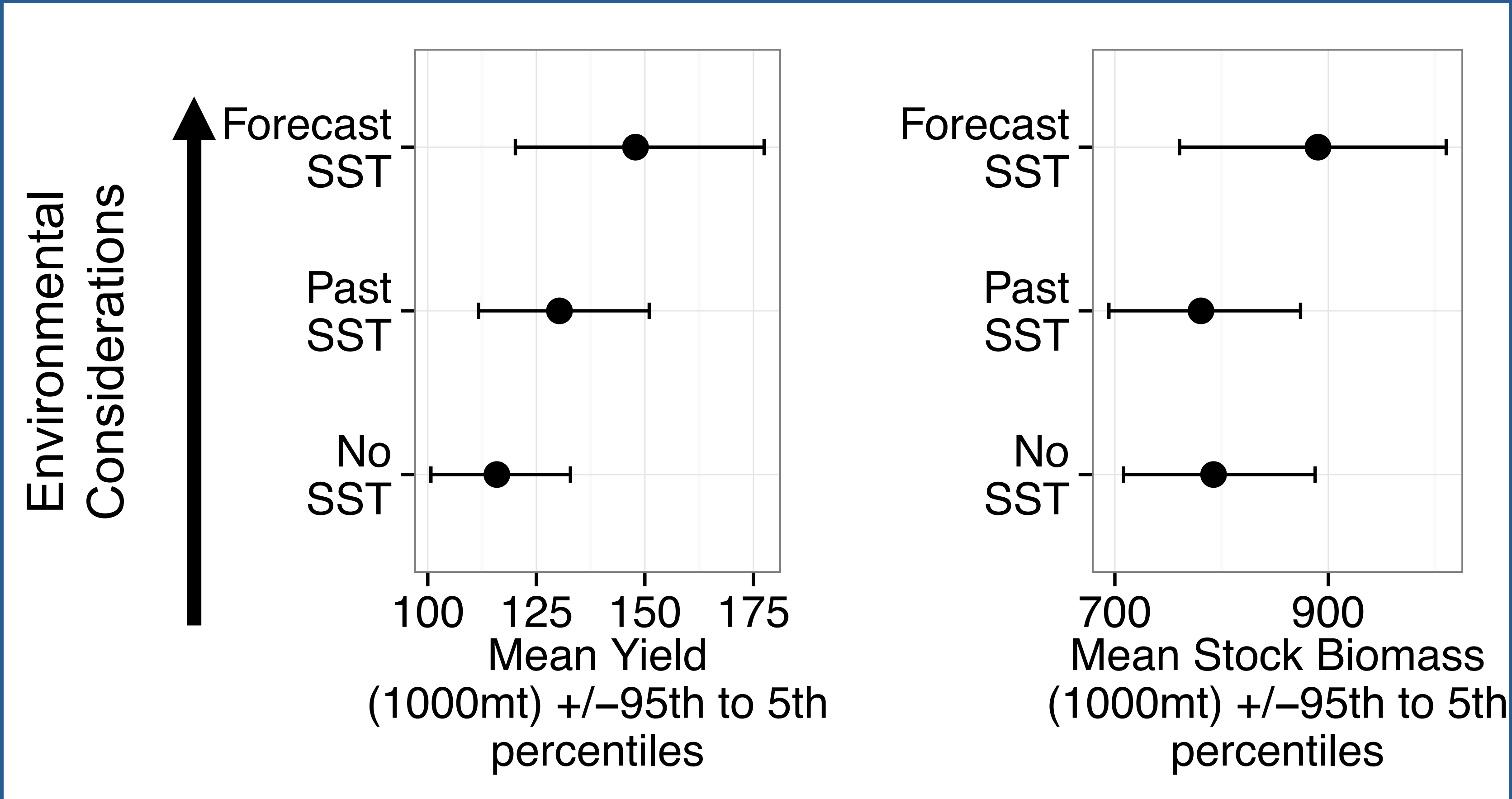
Consider harvest guidelines with increasing use of environmental data to anticipate change



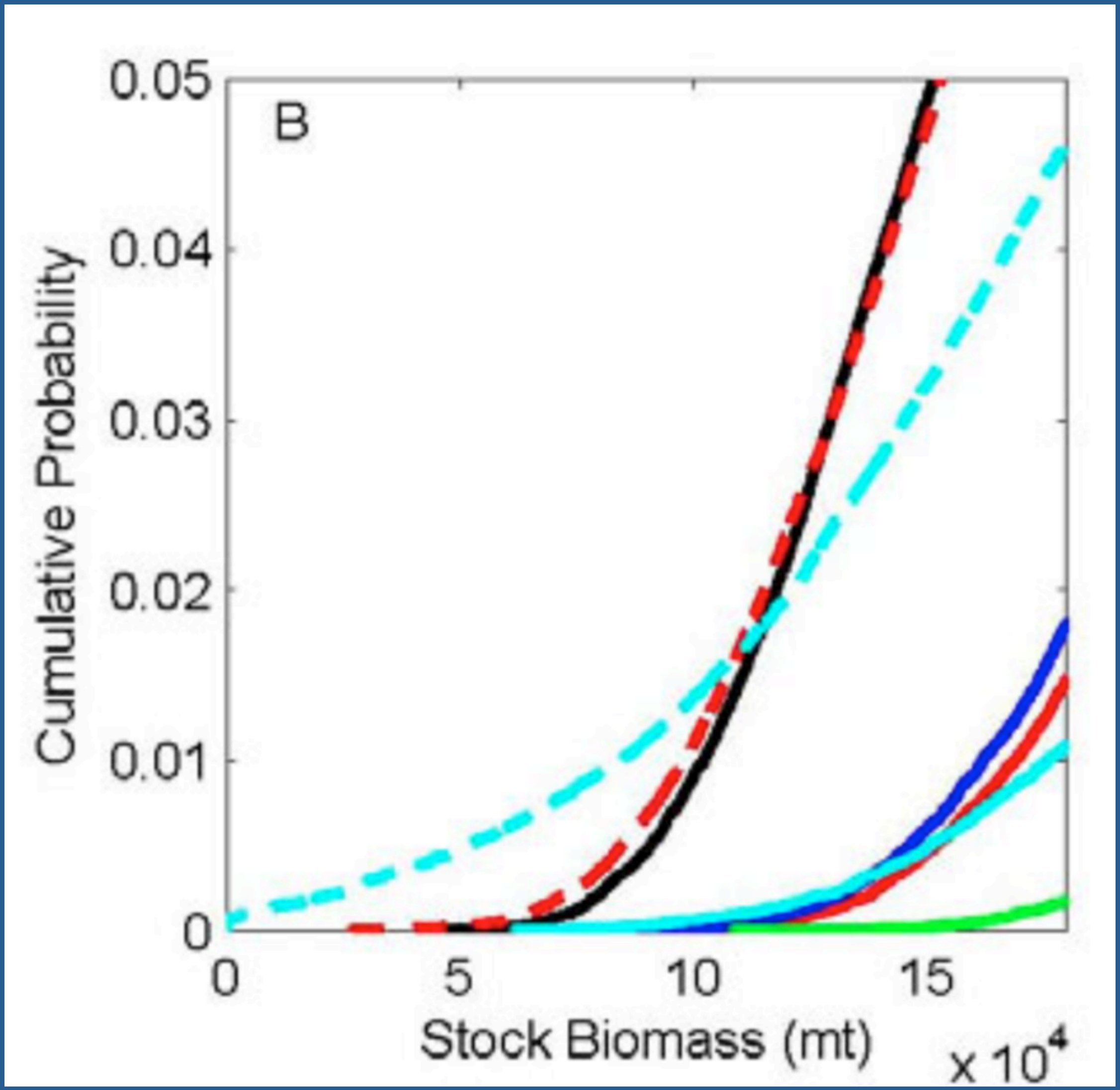
28 years * 1000 iterations * 4 MSEs = 112,000 simultions

Tommasi et al., 2017, Ecological Applications

Increased expected yield and stock biomass through anticipatory management



Tommasi et al., 2017; Ecological Applications



Important to balance anticipatory management with harvest cutoff

Red = past SST

Light Blue = forecast SST

Dashed = no low biomass cutoff

Tommasi et al., 2017; Ecological Applications

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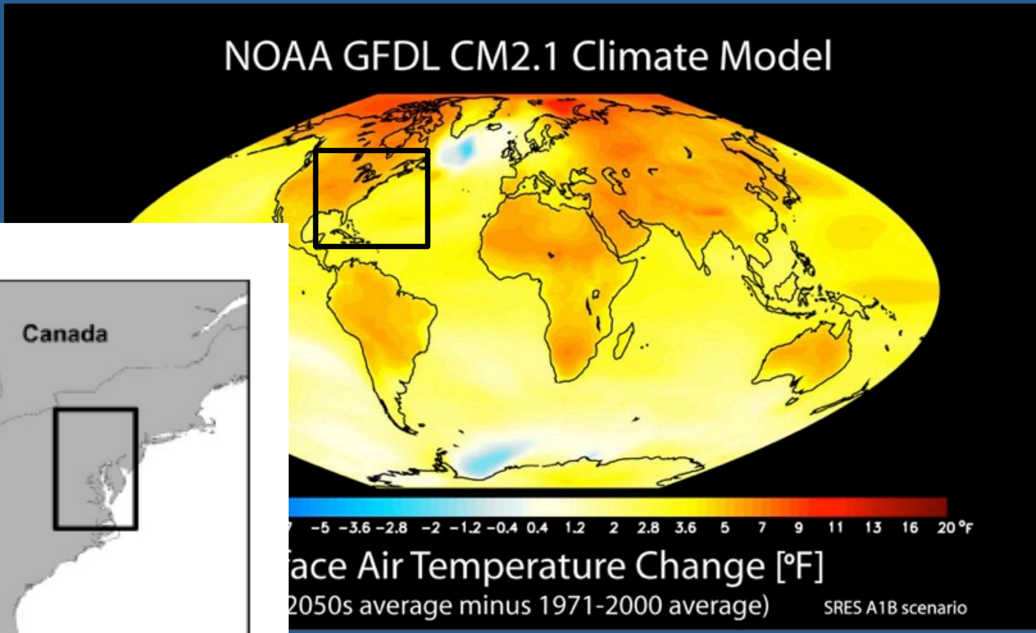
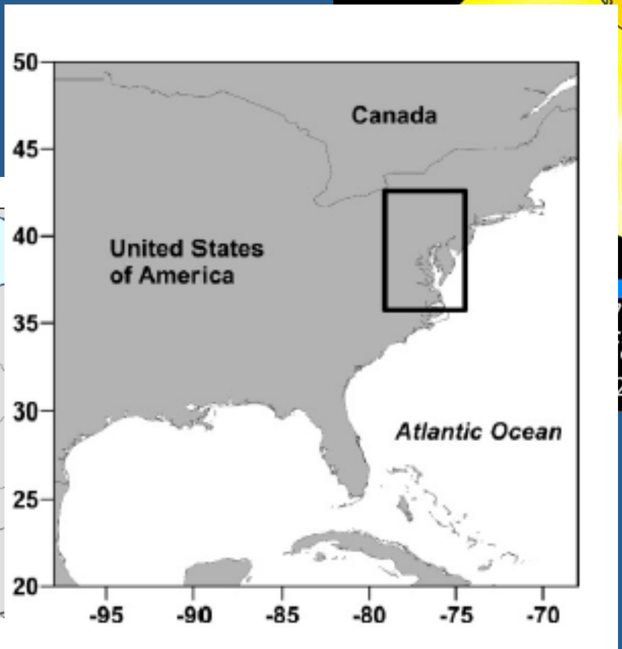
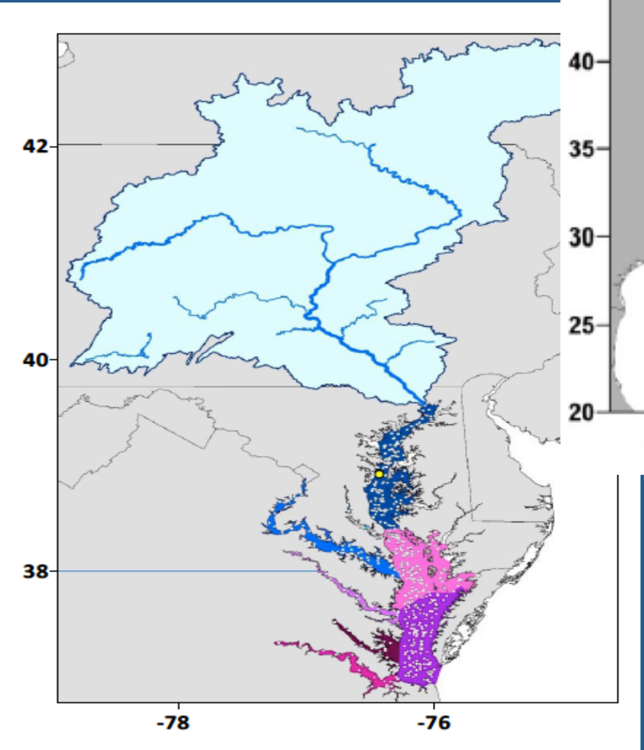
- High "burden of proof"/regulatory inertia due to economic and public health consequences (but this challenge was met for weather prediction and we have 30+ years of hindcasts)

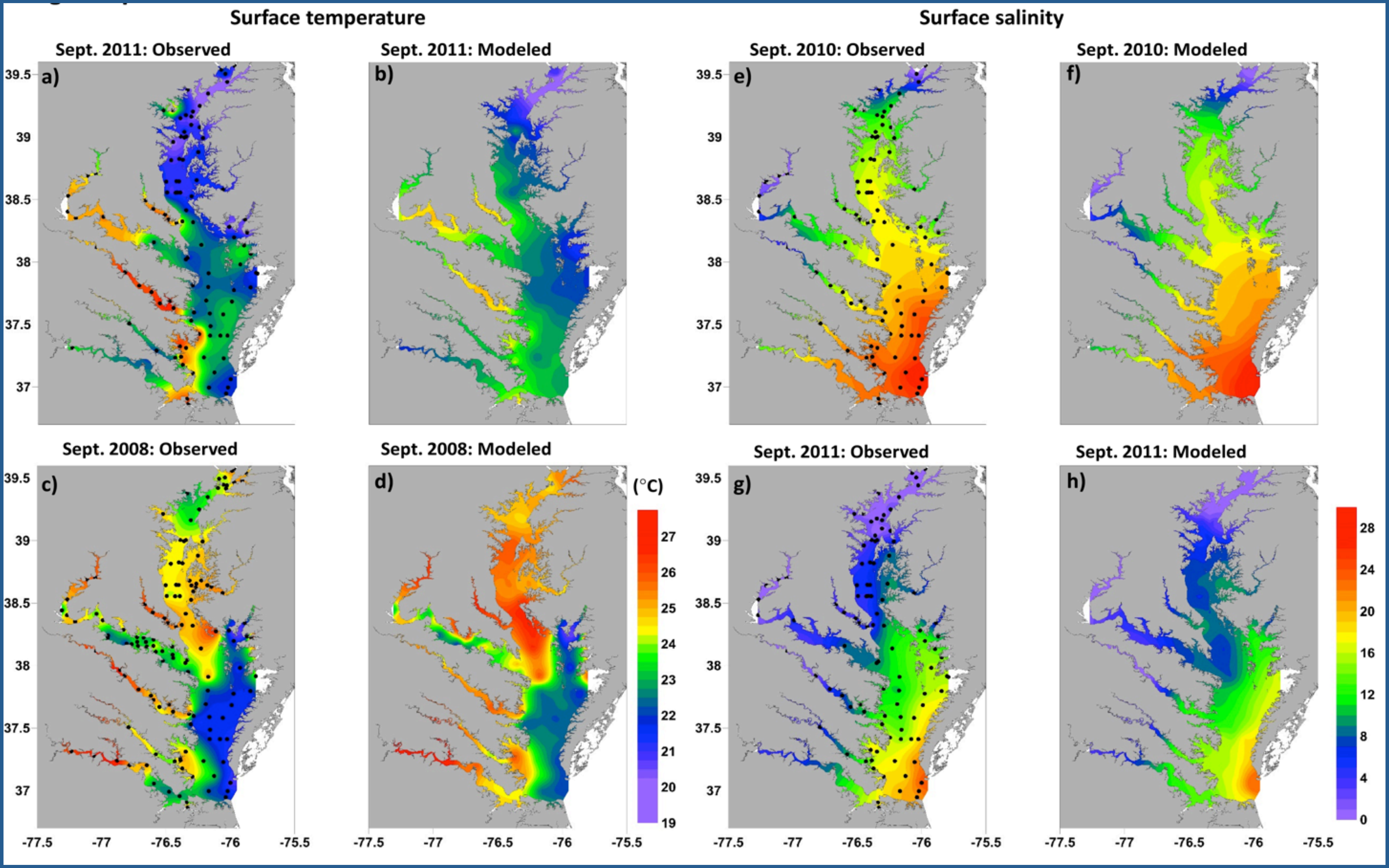
Bridging scales between large-scale climate and coastal resources





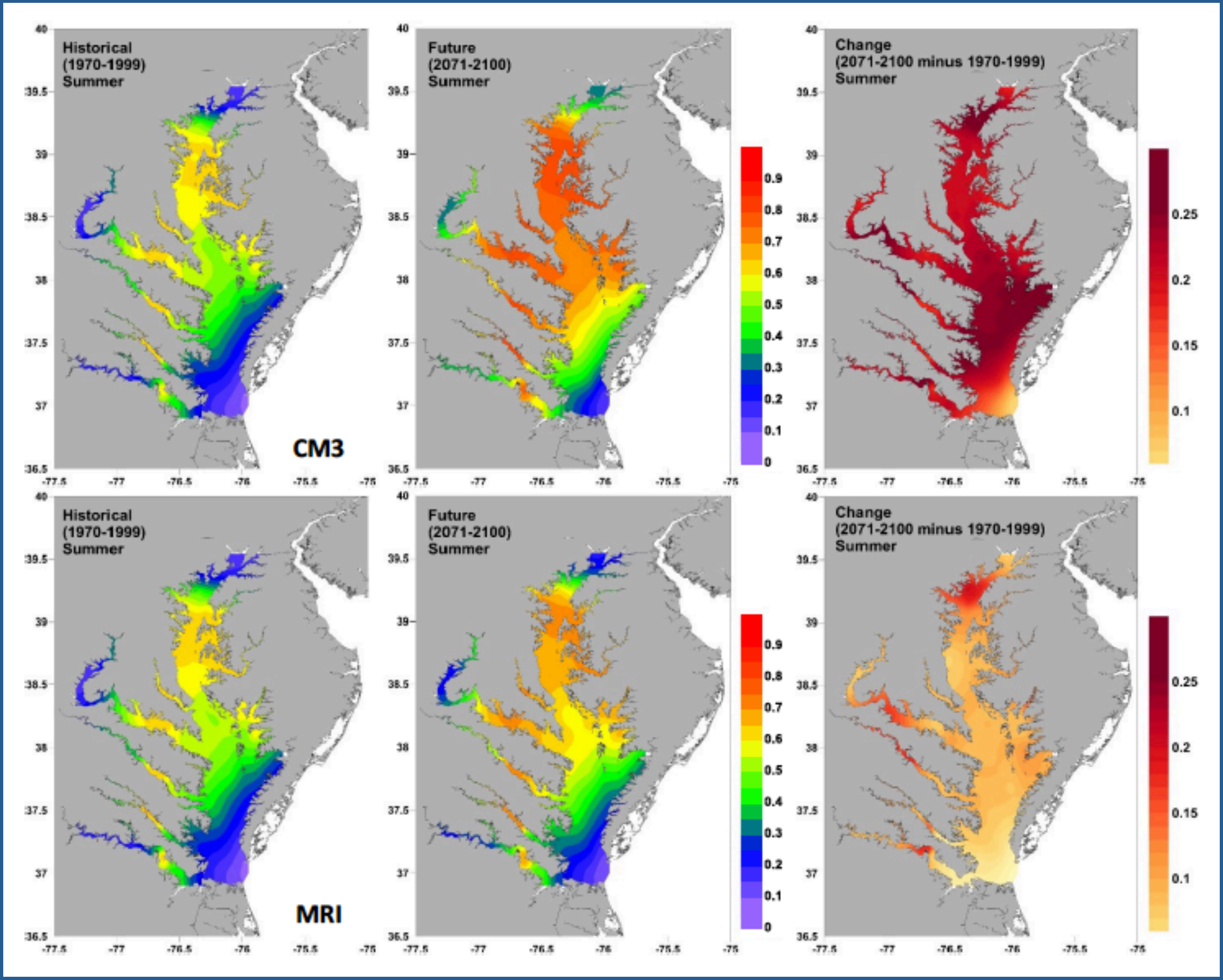


Skillful out-of-sample habitat anomaly prediction for Chesapeake Bay sub-regions



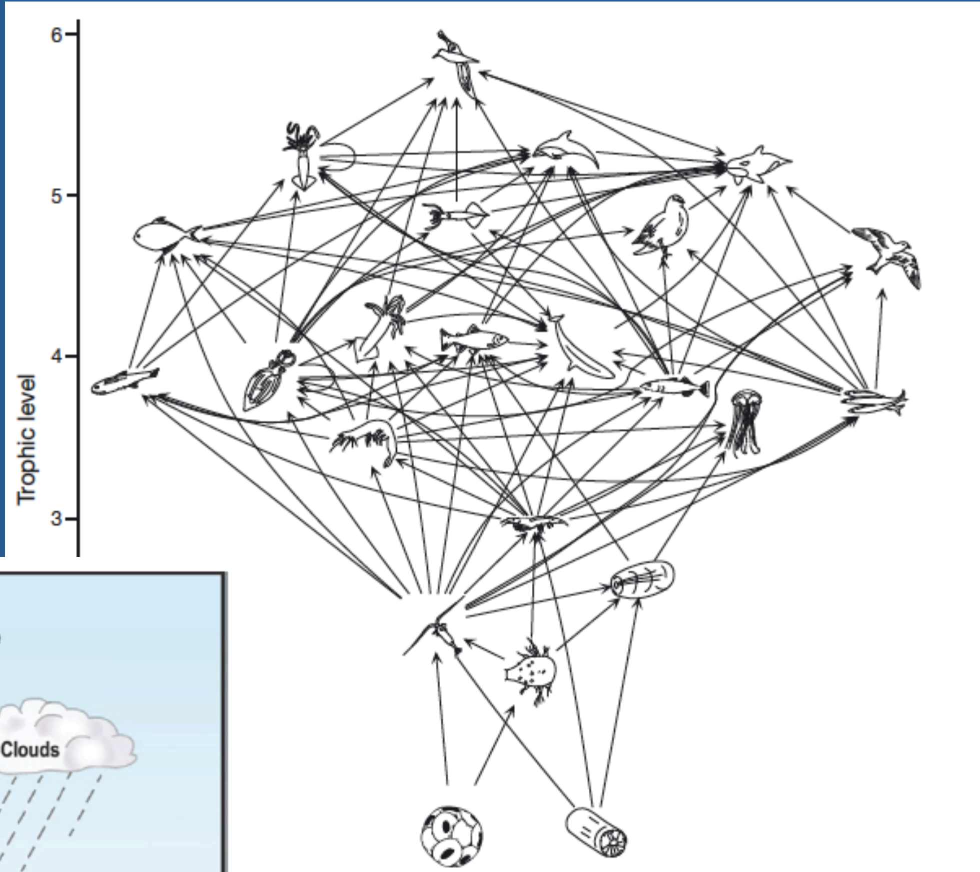
Muhling et al., Estuarine, Coastal and Shelf Science, 2017

Projected changes in *V. vulnificus* distributions

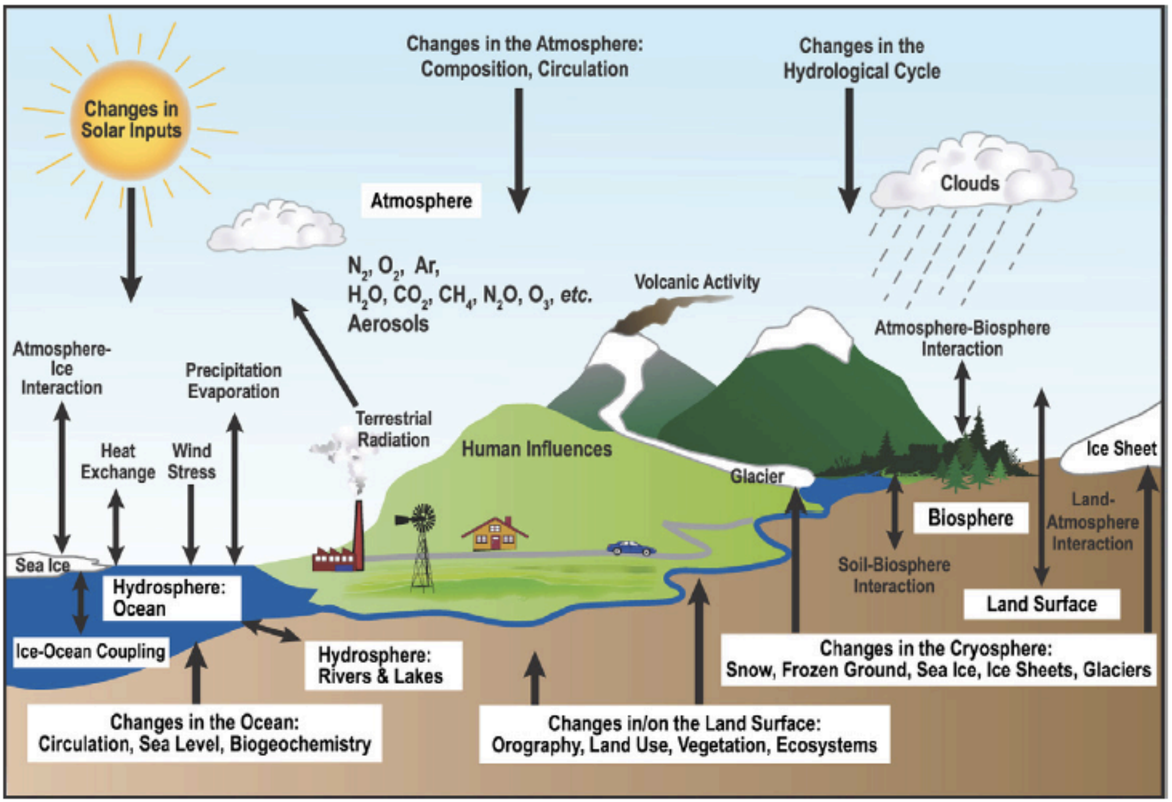


Muhling et al., Geohealth, 2017

Complex ecosystem responses to climate forcing

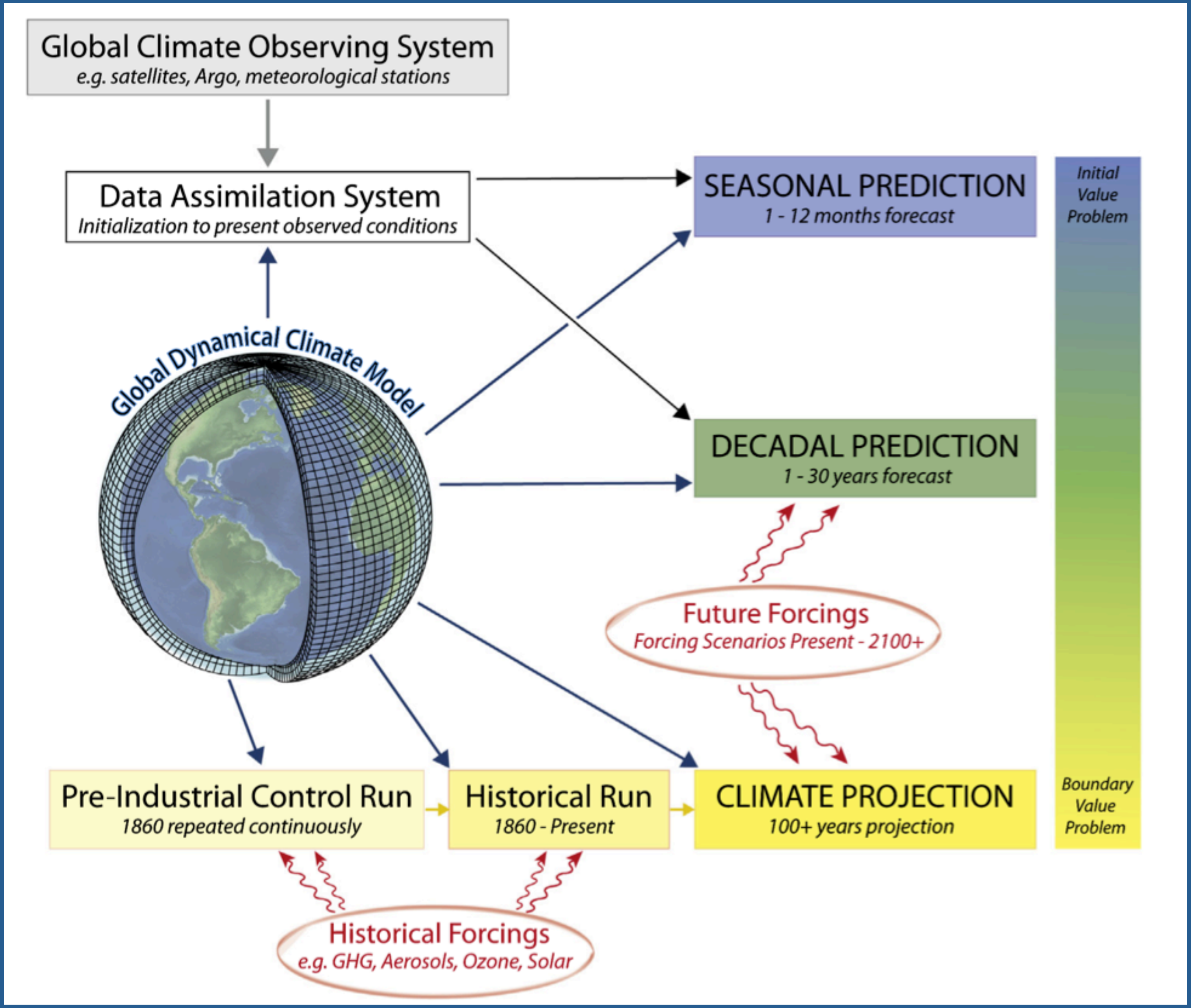


Kearney et al., 2012; 2013



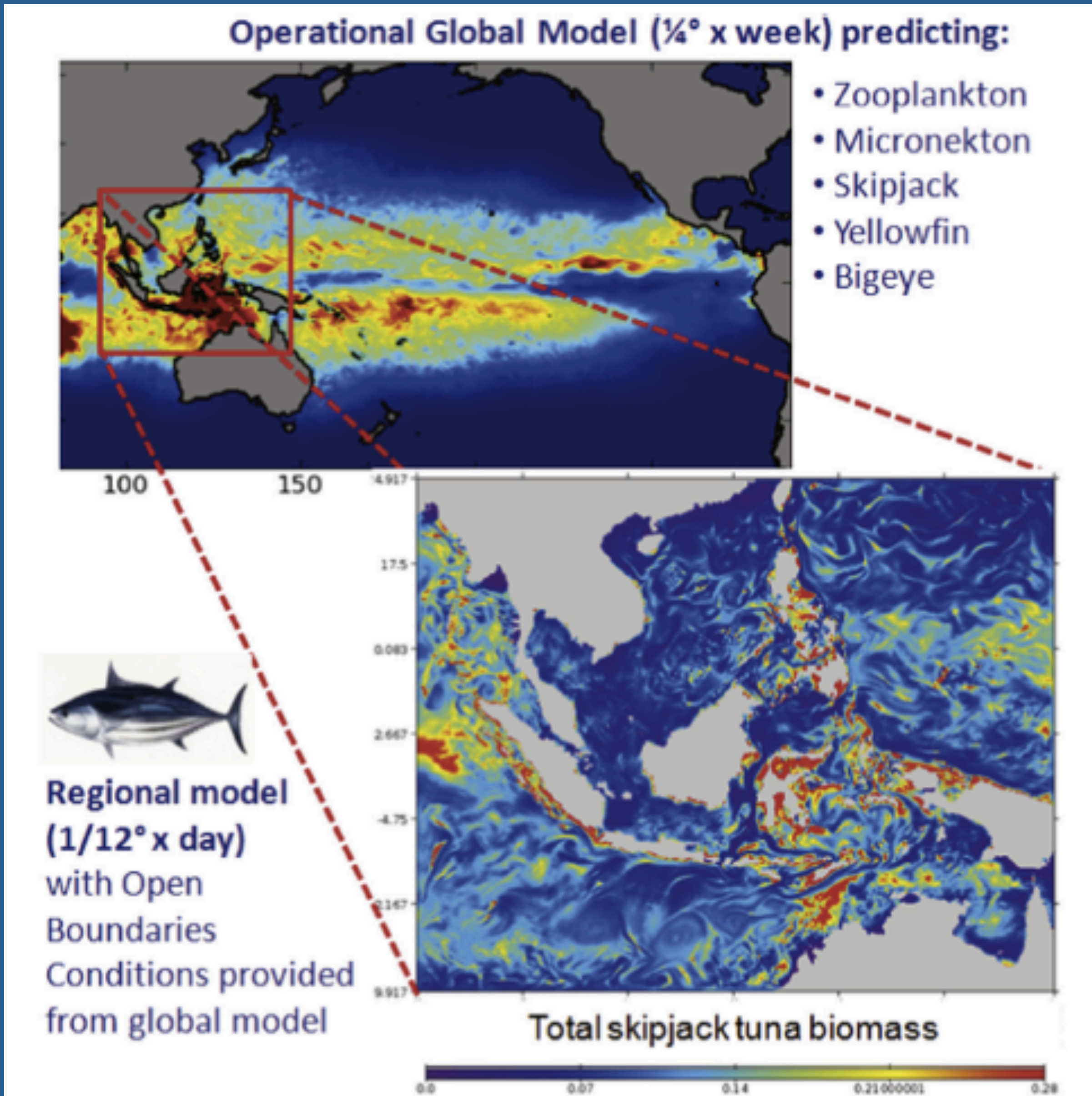
IPCC AR4, WG1 Report

Seamless climate predictions and projections across time scales



Tommasi et al., PinO, 2017

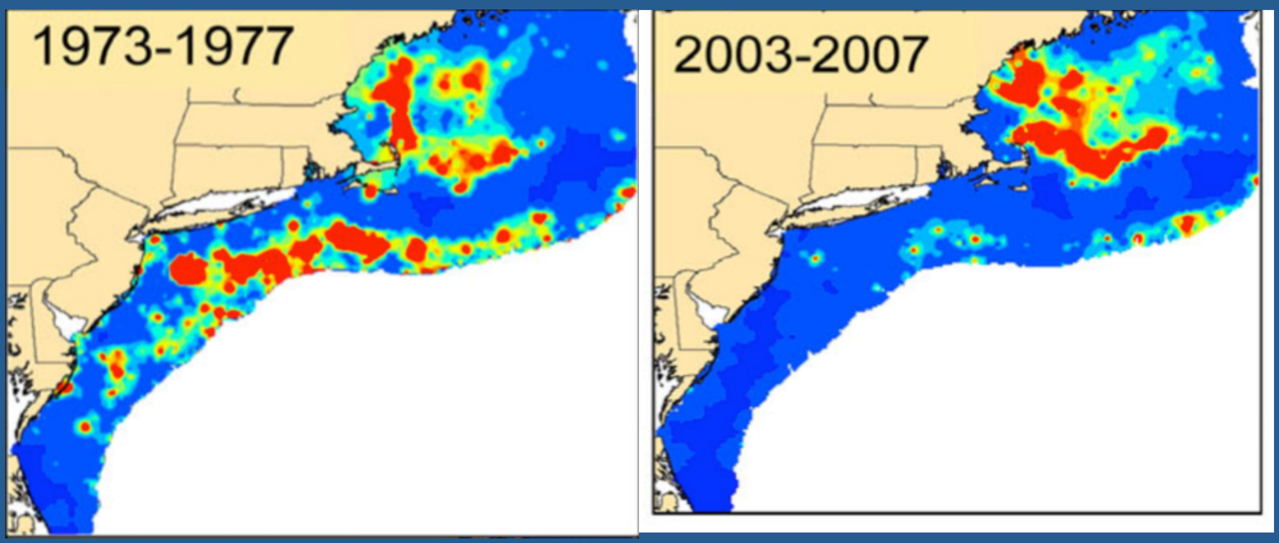
Holistic regional marine resource prediction



Gehlen et al., 2015; Journal of Operational Oceanography

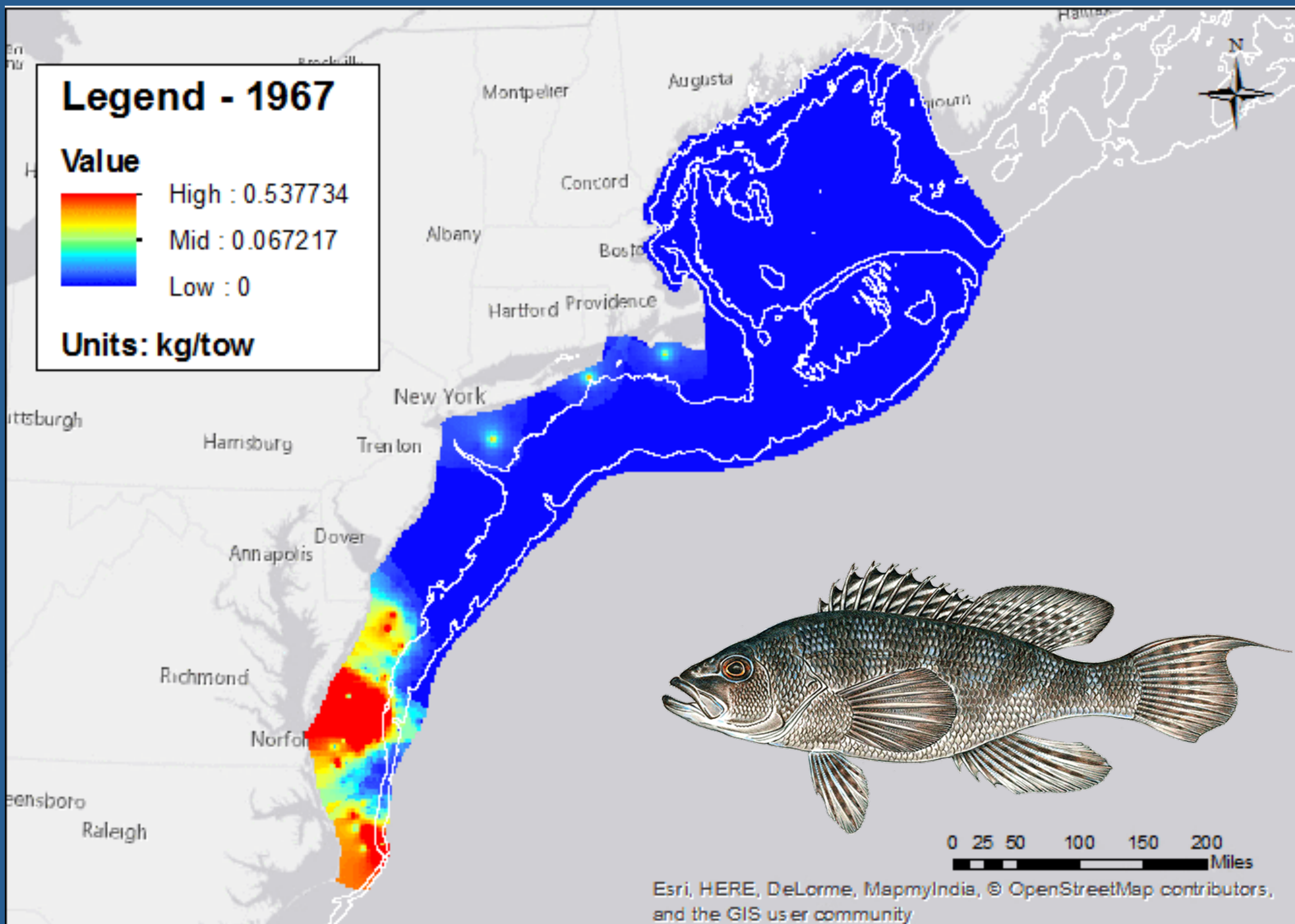
Changing baselines under climate change: managing fish on the move

Does a recovery plan make sense if warming is extirpating a fishery from my region?



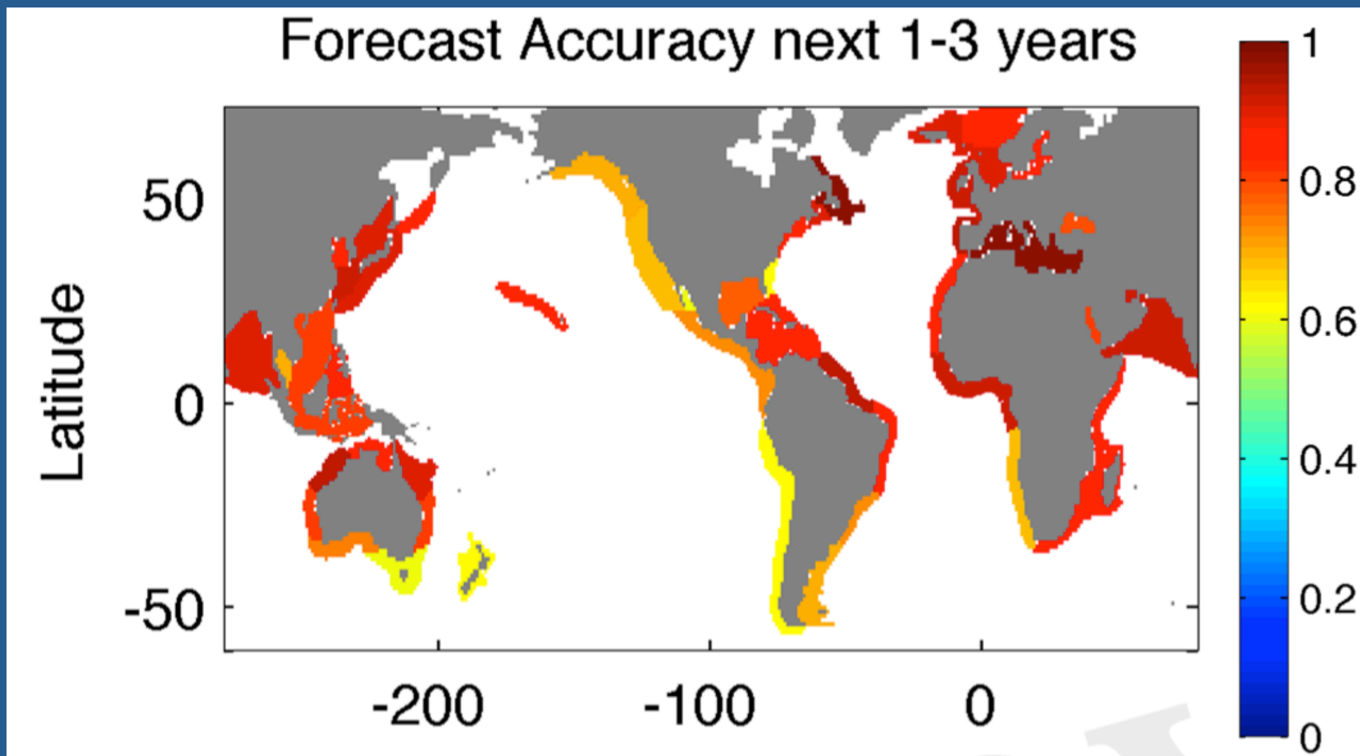
Nye et al., MEPS, 2009

When should new fisheries be opened?



Movie: oceanadapt.rutgers.edu (Pinsky, Selden); Picture: Mass DFG

Useful multi-annual climate prediction for fisheries



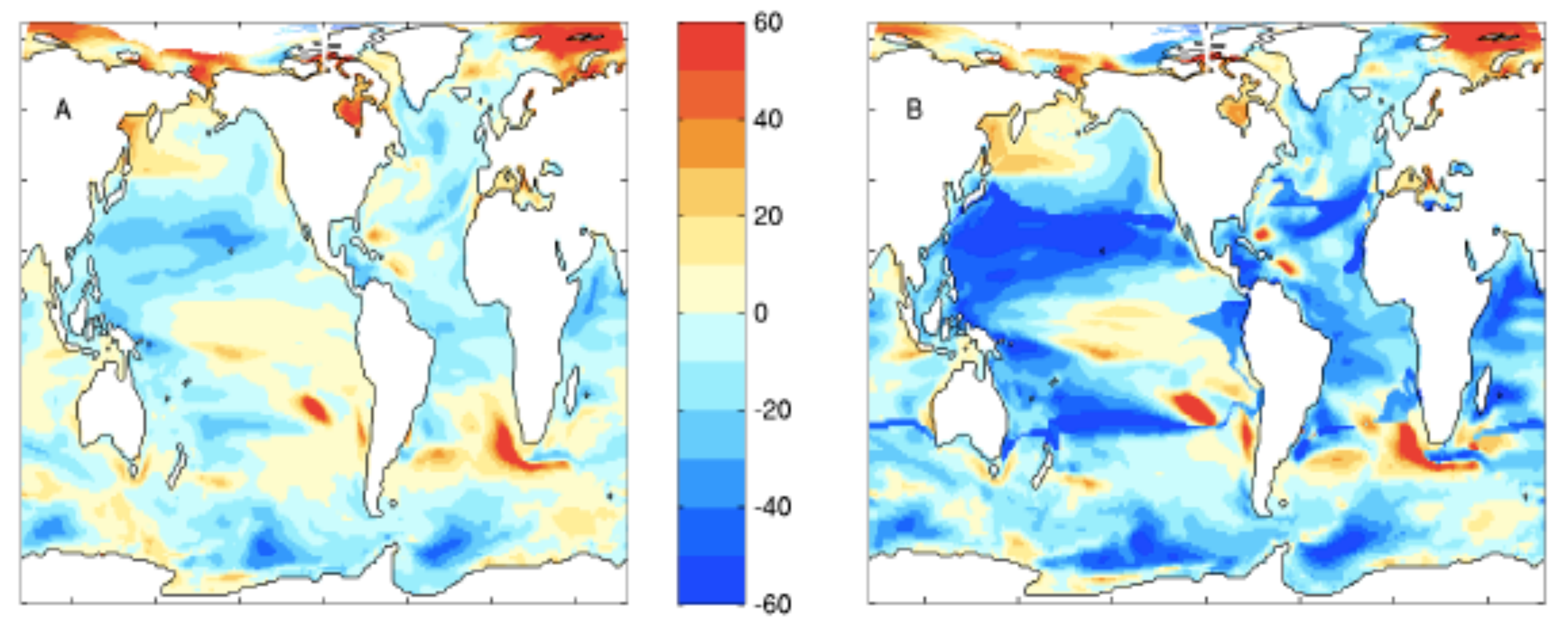
Skill in most LMEs is due to the predictable signature of radiative forcing over 50 year time-scales rather than evolving modes of climate variability

Tommasi et al., (2017), Frontiers

Overall fisheries productivity baselines may also be changing rapidly

% NPP change

% Catch change



Potential for regional changes in fish catch in excess of 50%

Stock et al., PNAS, 2017

Can dynamic management with short-term forecasts provide long-term resilience?