Ecological Forecasting

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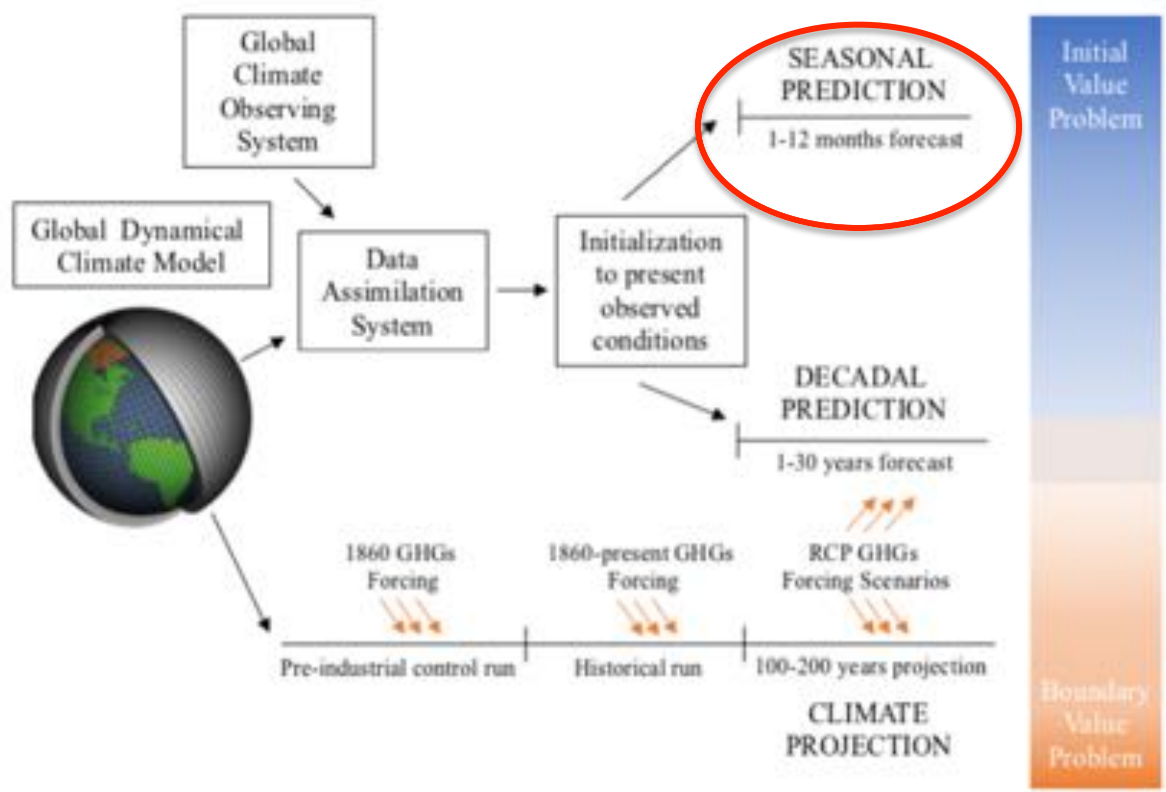
First examine seasonal forecasts on the physical system and SSTs in particular

Global Climate Models (GCMs)

- Developed to study c
- limate variability and change
- GCM Forecast system developed – mainly to predict ENSO
- Now being used to make seasonal to decadal forecasts of global SSTs and other climate variables

Here we evaluate SST forecast skill of GCMS from the North American Multi-Model Ensemble (NMME) for Large Marine Ecosystems (LMEs) – here: CC, GoA



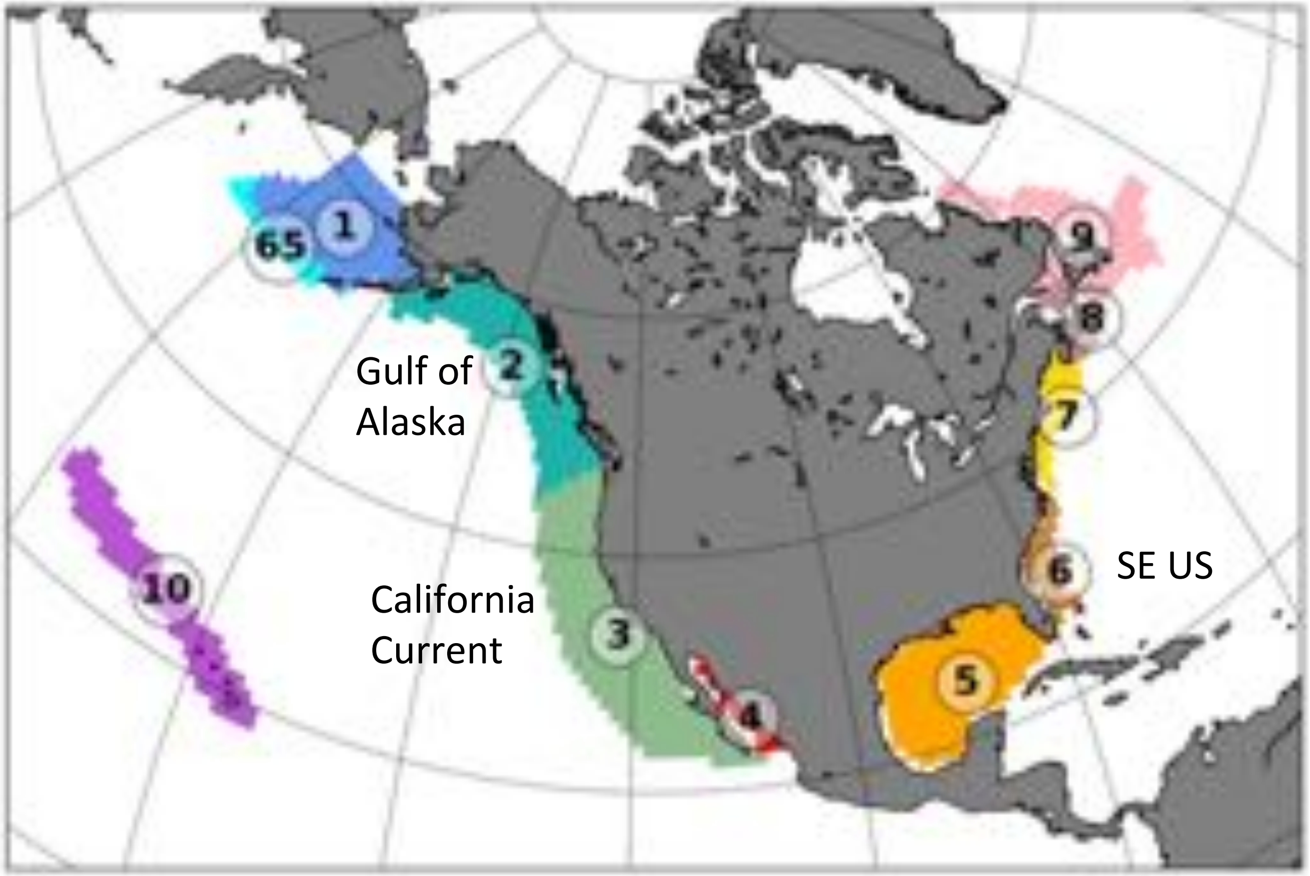
GCM – ocean, atmosphere, land, and sea ice

Figure courtesy of D. Tommasi

Multi-Model Forecasts

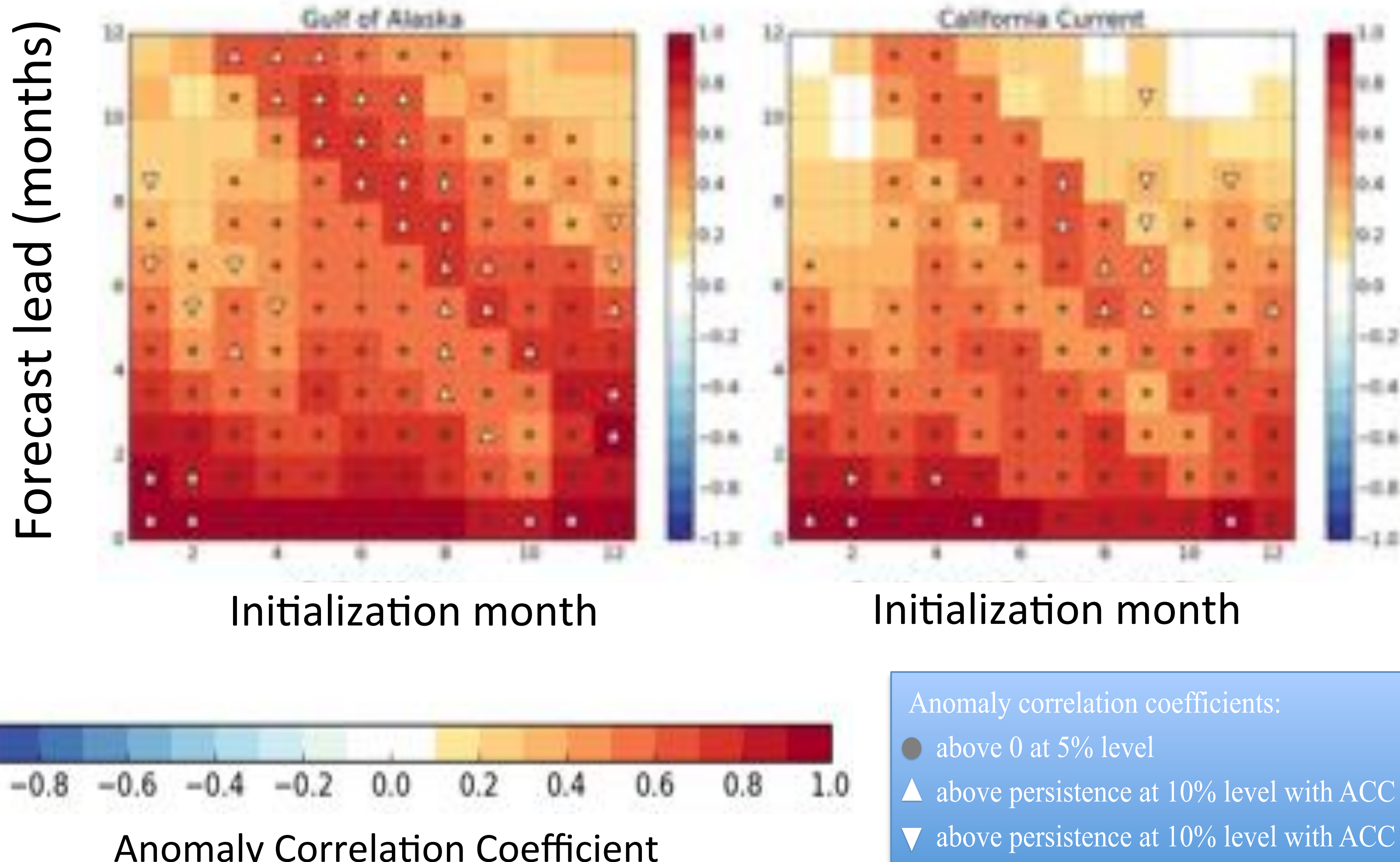
- Many studies have found that forecasts from multiple models are better than those from any single model
- Here we examine the skill of SST hindcasts from the North American Multi-Model Ensemble (NMME), phase 1
  - *Kirtman et al. 2014, BAMS*
- Monthly Hindcasts during 1982-2002 from 14 models
  - All output on a 1° lat x 1° lon grid
- Skill estimated by:
  - First average ensembles from individual models
  - Average models to create a multi-model mean hindcast
  - Bias correct hindcasts by removing drift (initialization month, lead)
  - Skill of SST hindcasts evaluated relative to ¼° Reynolds OI SST data set

Large Marine Ecosystems (LMEs)



LMEs 1: East Bering Sea (EBS), 2: Gulf of Alaska (GoA), 3: California Current (CC), 5: Gulf of Mexico (GoM), 6: Southeast U.S. Continental Shelf (SEUS), 7: Northeast U.S. Continental Shelf (NEUS), 8: Scotian Shelf (SS), 9: Newfoundland-Labrador Shelf (NL), 10: Insular Pacific Hawaiian (IPH), 65: Aleutian Islands

NMME Ensemble SST Forecast Skill
Gulf of Alaska and the California Current LMEs

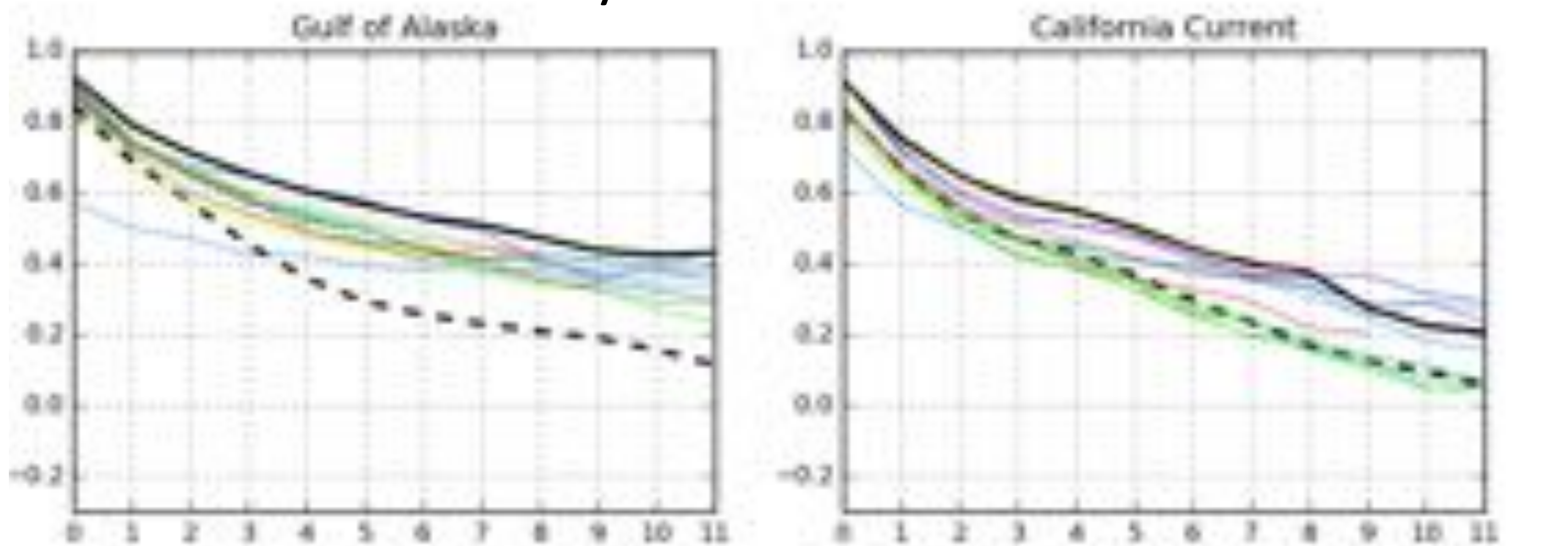


Anomaly correlation coefficients:

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

SST Forecast Skill for the Gulf of Alaska and the California Current LMEs

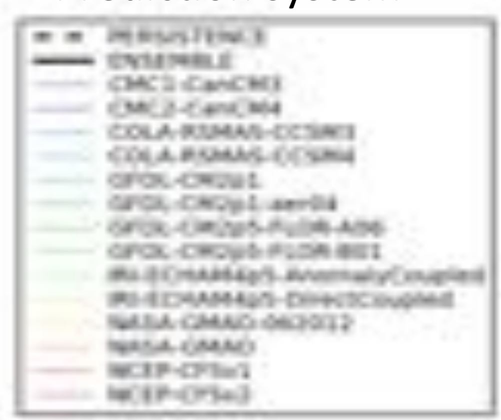
Anomaly Correlation Coefficient



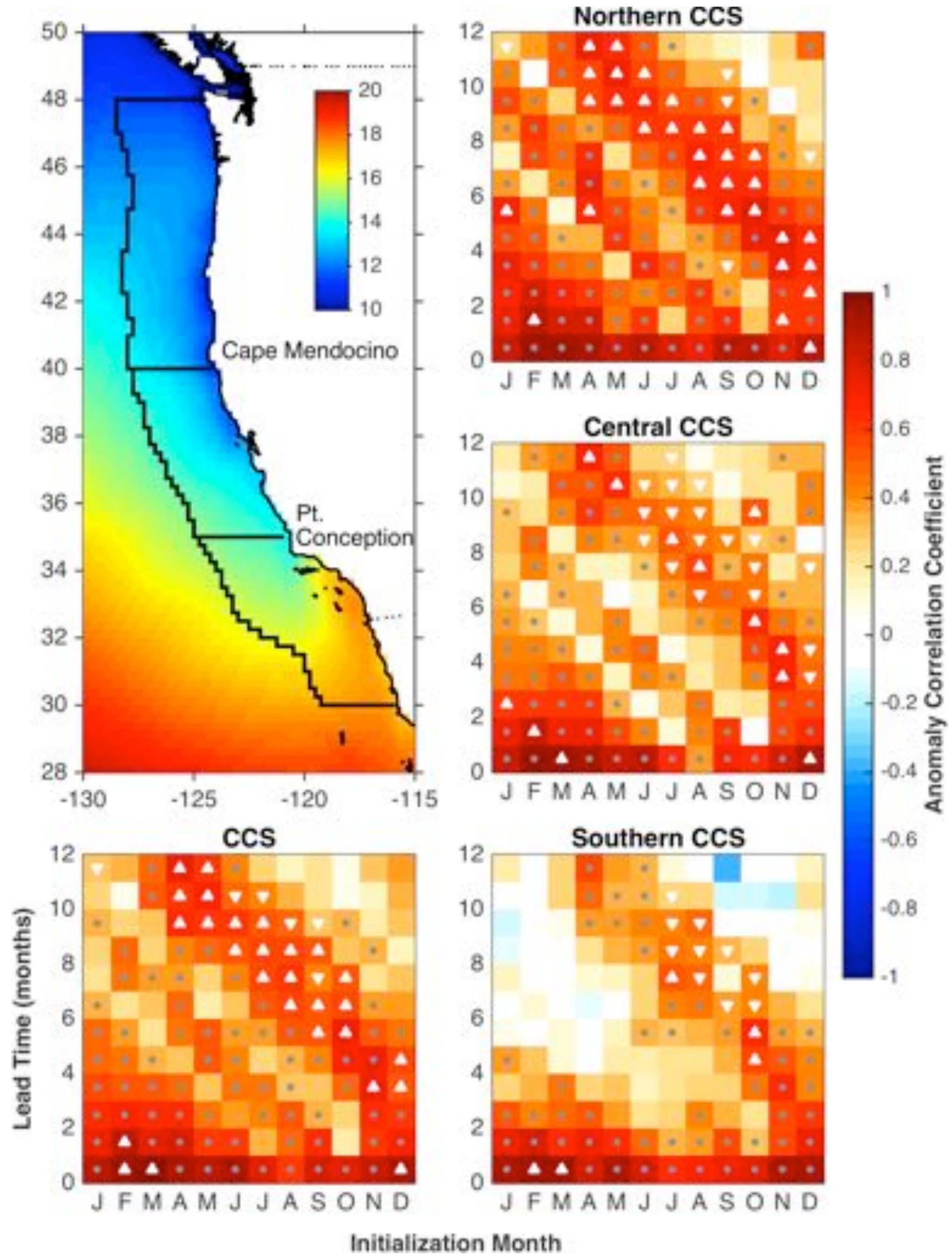
Forecast lead (months) Forecast lead (months)

Average of ACCs over all initialized months as a function of forecast lead time for each model, persistence and the multi-model mean.

Prediction system



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

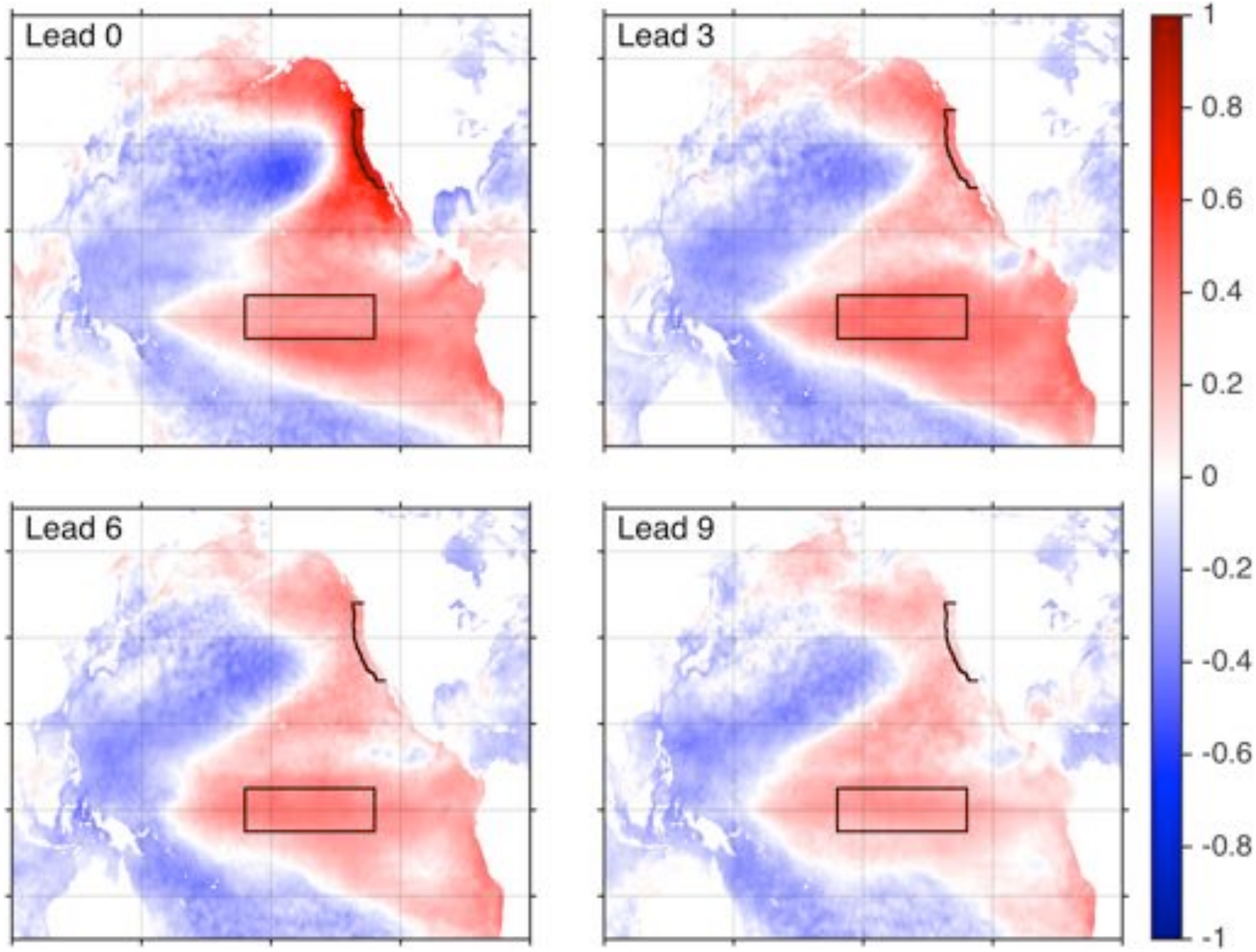


Anomaly correlation coefficients:

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

Processes that influence predictability

ENSO



Correlation of Pacific basin wide SST with CCS regionally averaged SST 0, 3, 6, and 9 months prior in CanCM4 model

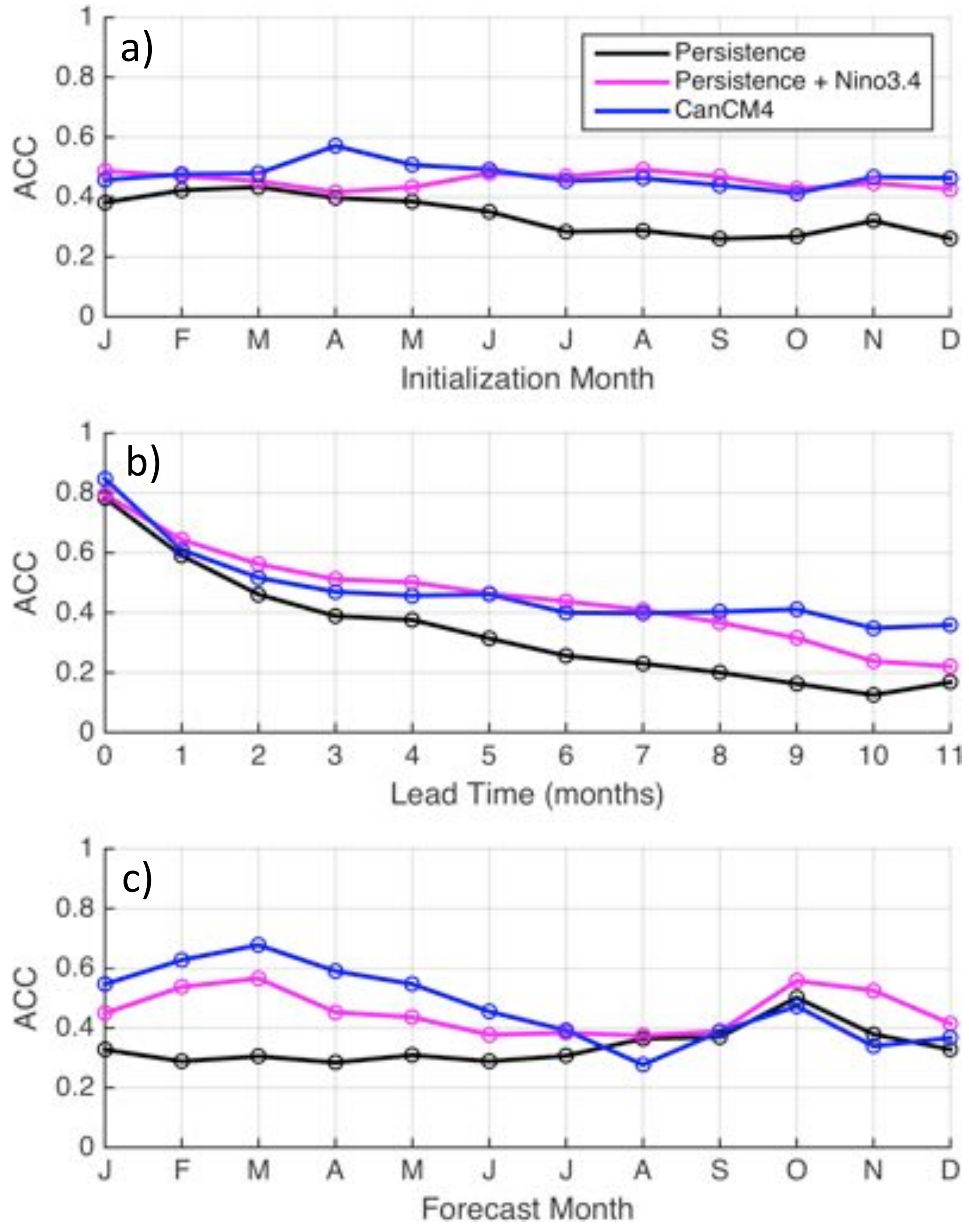
Forecast Skill in the CC LME for:

a) initialization,

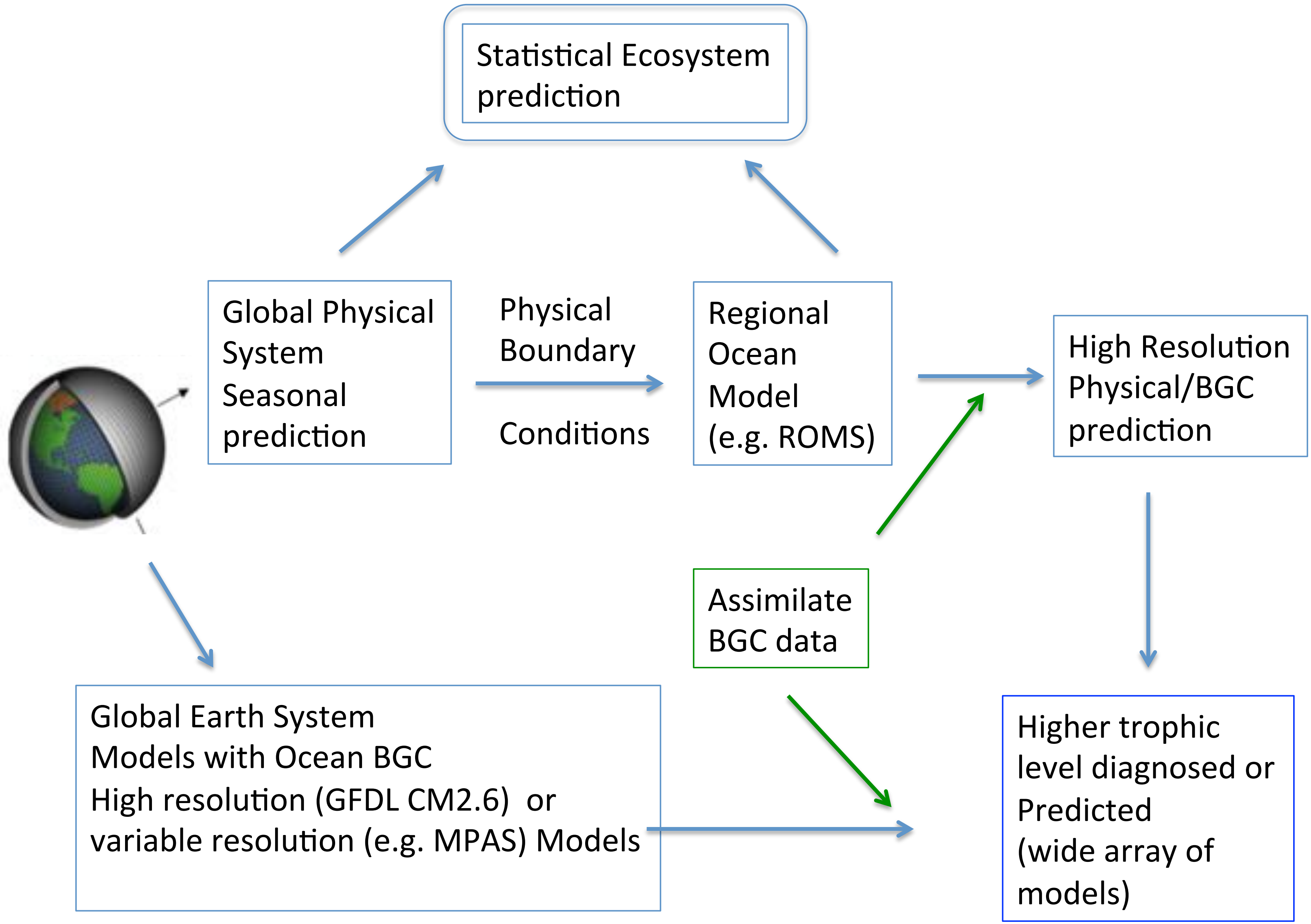
b) lead time

c) forecast month

Persistence + Nino3.4 forecast from a simple multiple linear regression model



Ecosystem Prediction



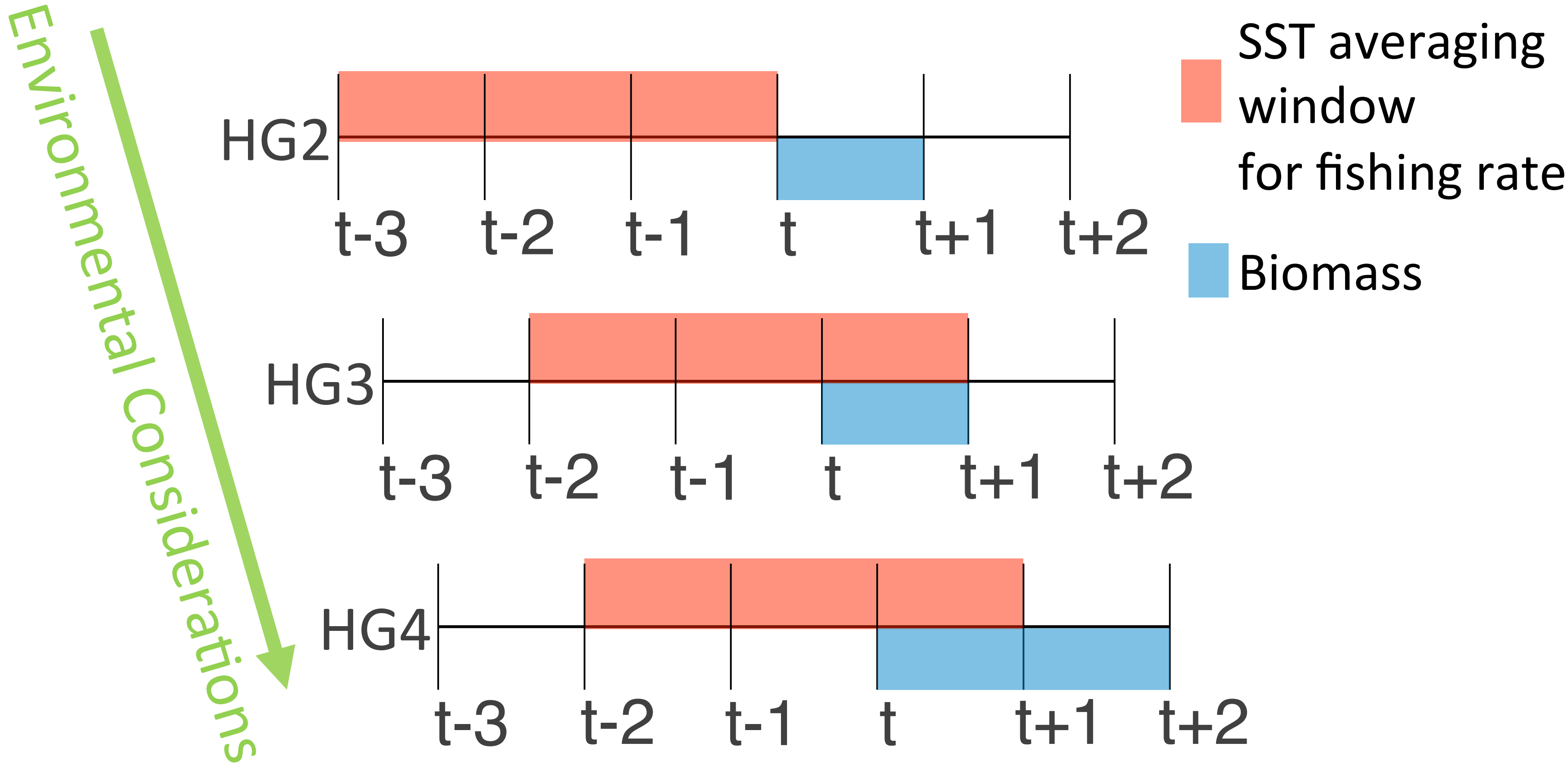
Application of SST forecasts to Pacific Sardines

- Sardine population simulated using an age-structured model
  - Recruitment dependent on (parents) biomass and SST
- Current harvest guideline (HG) dependent on previous year's SST and biomass in southern CC LME (HG2)
- Use late winter/early spring SST forecast from an NMME model
  - Use in HG (controls fishing rate) to get predicted biomass (HG3)
- Use the predicted biomass to inform the following years biomass (HG4)

Tomassi et al. submitted to Ecological Applications

To test forecast utility, compared effectiveness of four different sardine HGs

HG1 – constant fishing rate of 0.18



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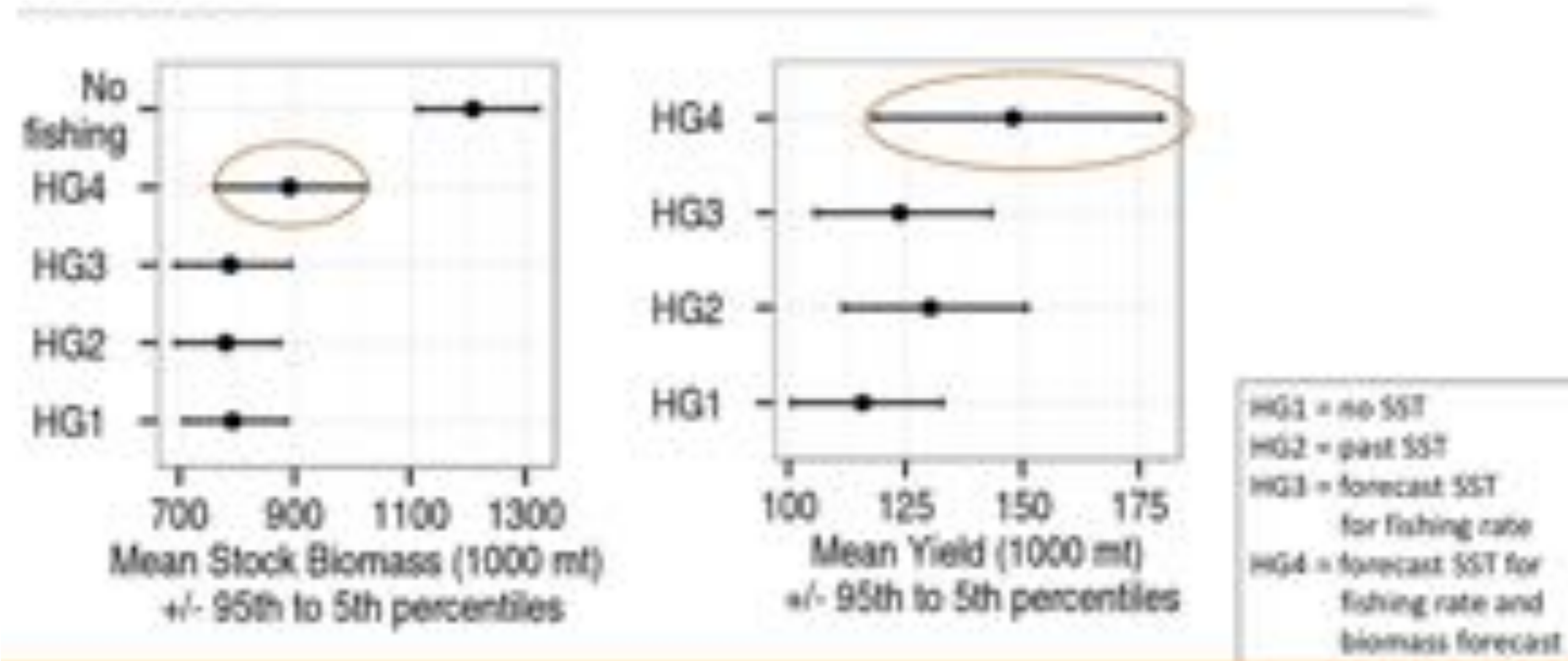
Application of SST forecasts to Pacific Sardines



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1. Identifying priorities in ecological indicators to forecast

- As a first step, predict key physical variables:
  - e.g. SST, bottom temperature, depth of the 1026 kg m^3 isopycnal
  - surface winds/timing and intensity of upwelling.
  - Some ecological forecasts can be based on these indicators.
  - Improved downscaling of surface atmospheric fields from large-scale climate models to regional ocean models?
- Biogeochemistry:
  - phytoplankton
  - oxygen, aragonite saturation (pH)
  - Initialization of BGC now often based on relations with with temperature and salinity. Can this be improved on?
- Tailored forecasts for key higher trophic level (salmon)
  - Wide range of complexity for now
  - Move towards full ecosystem models?

2. Data Streams

- Climate model output exists NMME forecasts (although may require access to archive for some surface variables and fields as a function of depth for surface and side boundary conditions for regional models)
- Phytoplankton estimate from space exists – algorithms enhanced?
- Other BGC fields?
  - Enough observations to test forecasts
  - More observations to initialize models

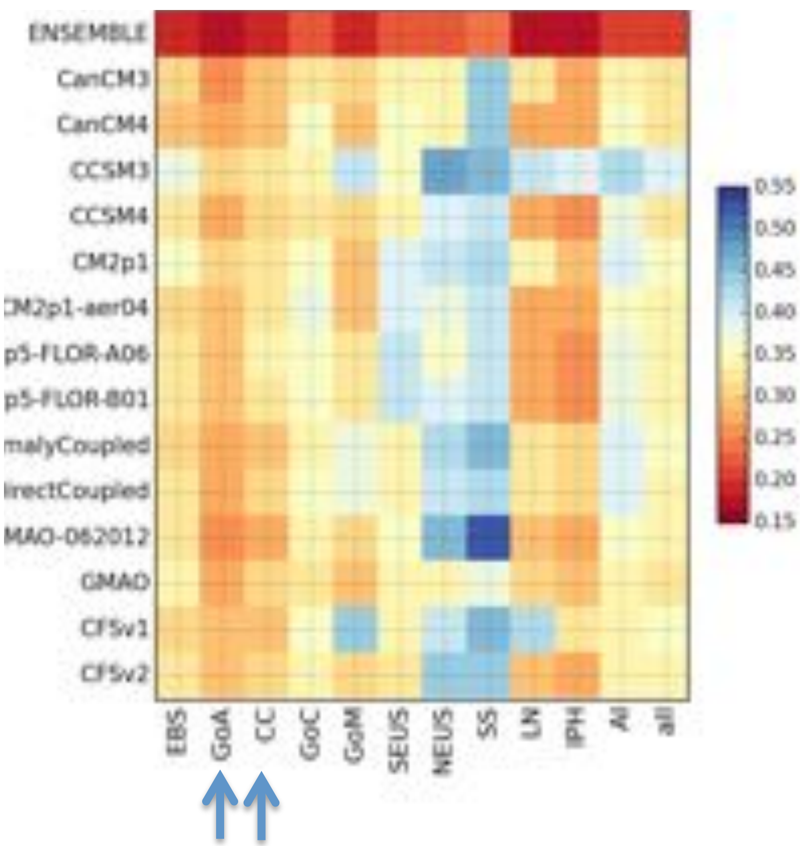
3. Providing uncertainty estimates on the forecasts

- Can draw on expertise from the weather forecast community on skill estimates for probability forecasts. Many methods to estimate probability skill
- Using large ensembles from multiple models
- Some data assimilation systems (e.g. ensemble Kalman filters)
- Some statistical prediction methods, e.g. Linear Inverse models (LIMs), provide error estimates and state based estimates of skill.

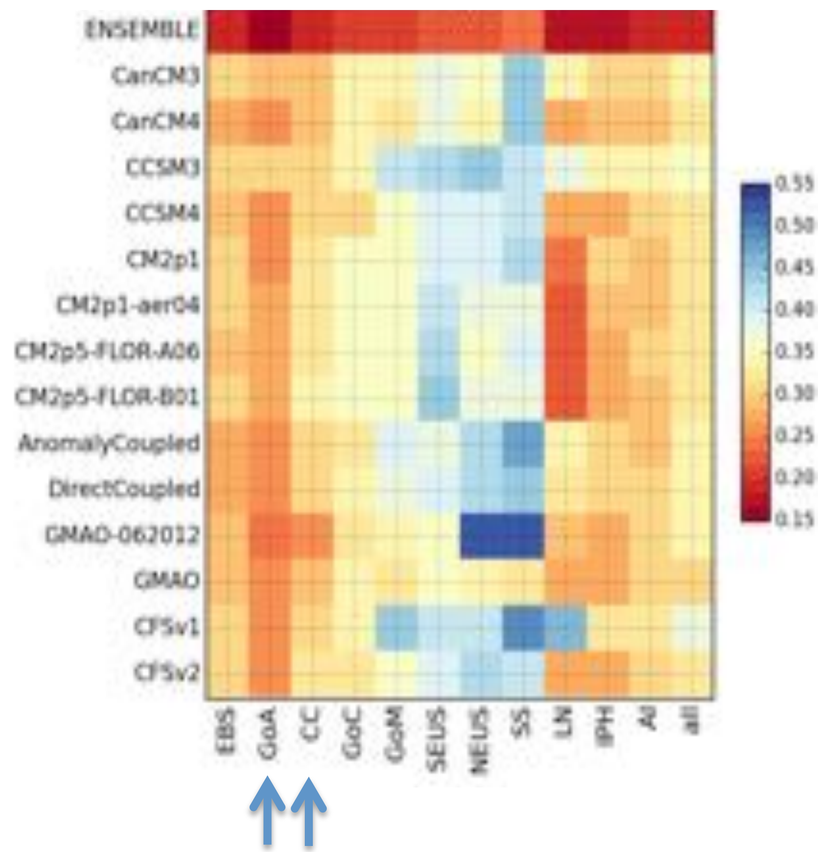
Probability forecast assessment

Briar score how well do models forecast the probablity of an SST anomaly being in the cold (lower), neutral or warm tercile

BrS Cold Tercile

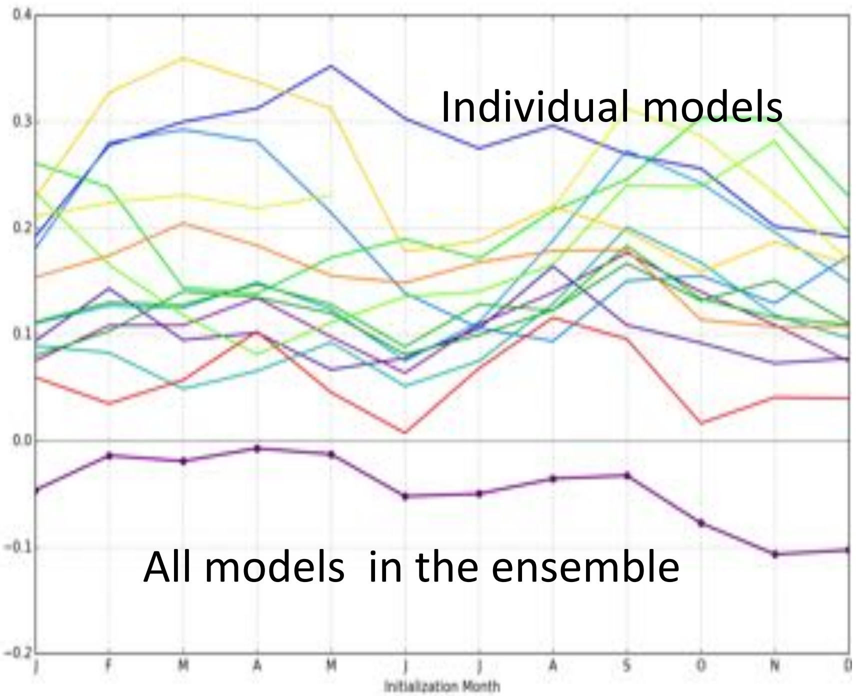


BrS Warm Tercile

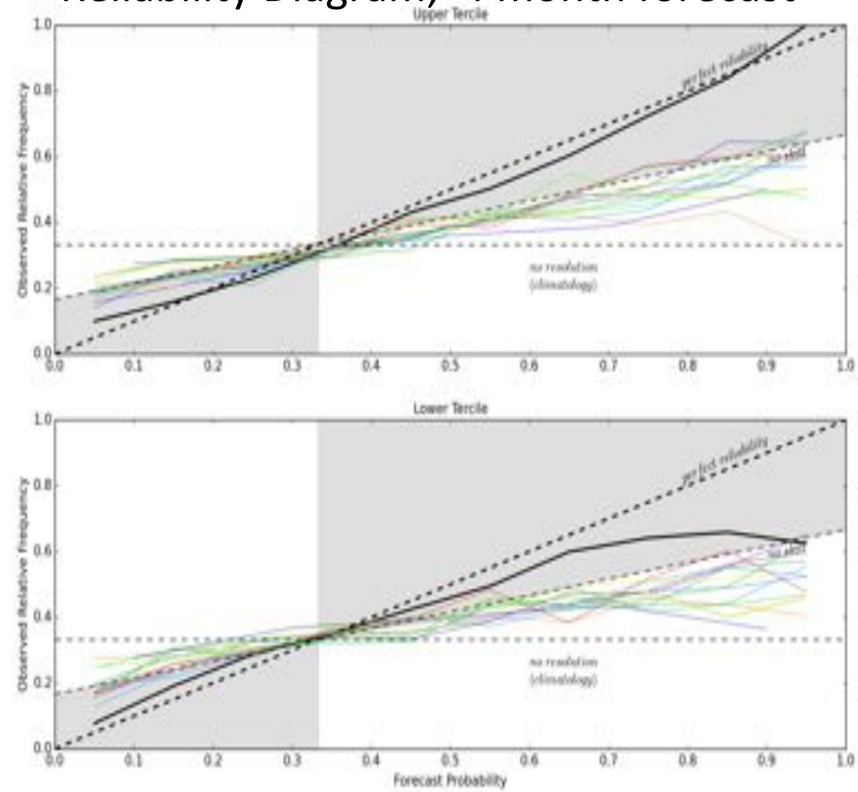


Model Spread vs skill

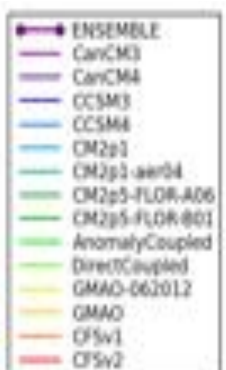
4 MONTH FORECAST
RMSE – SPREAD (IDEALY =0)

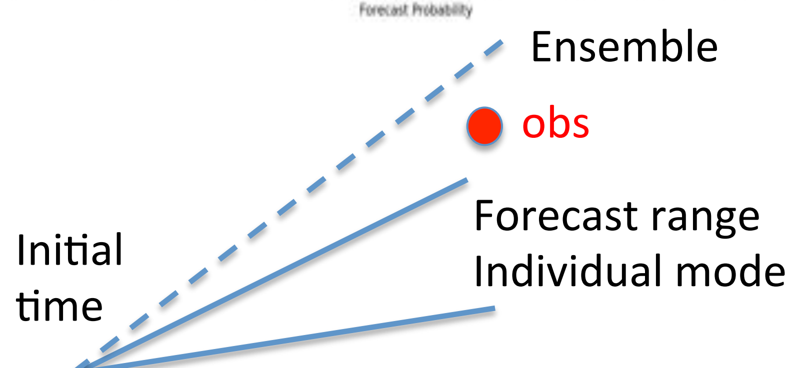


Reliability Diagram; 4 month forecast



Individual Models
Spread< RMSE;
"underdispersive"
"Overconfident"





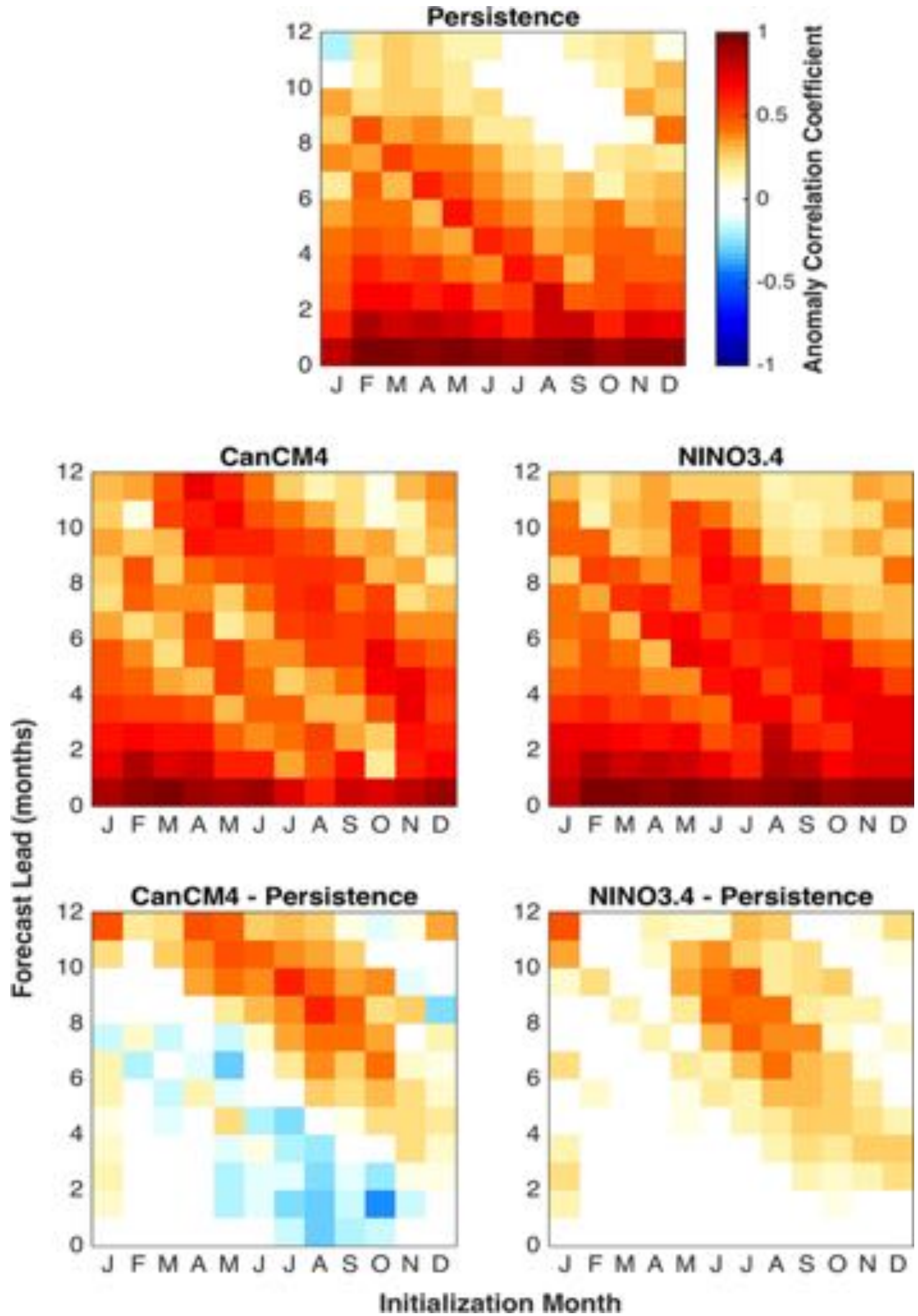
4. Developing communication strategies to stakeholders and the general public.

- Partnering with existing NOAA entities/programs:
  - Fishery councils
  - Integrated Ecosystem Assessment (IEA)
  - Regional Integrated Sciences and Assessments (RISAs)?
- Appropriate NGOs (some have working relations with fishery community)
- Work closely with fishery community and other stake holders in devleloping products (succesful examples from Australia)
- Web based distribution with
  - videos explaining the results
  - emphasis on probability forecasts

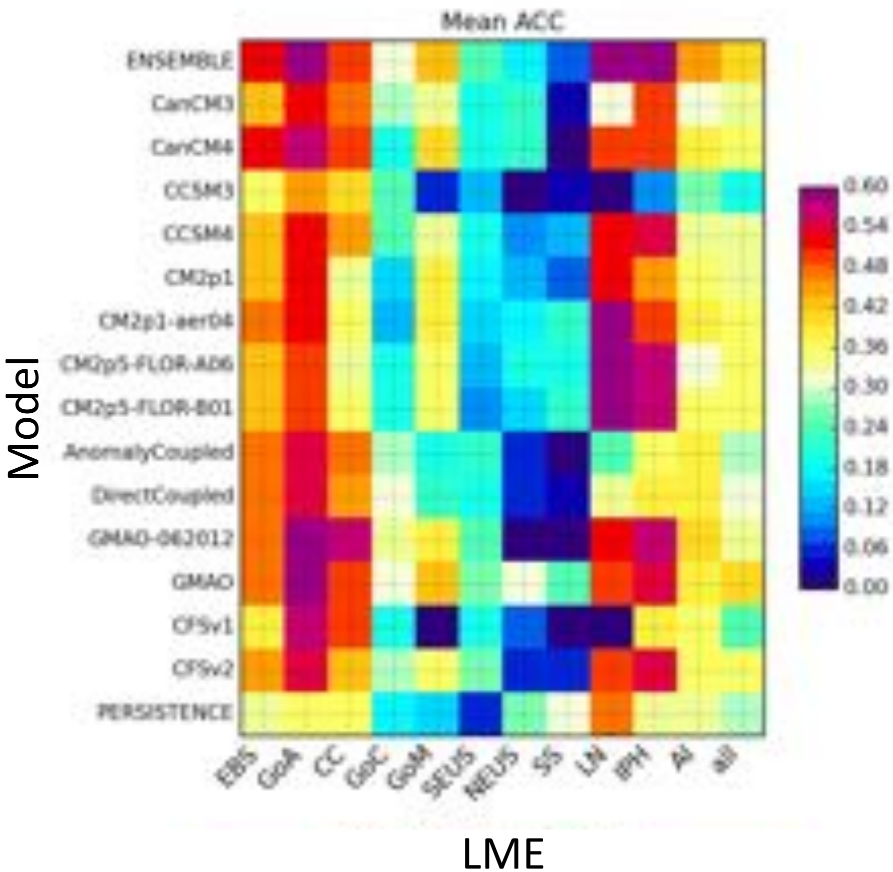
Summary Alexander

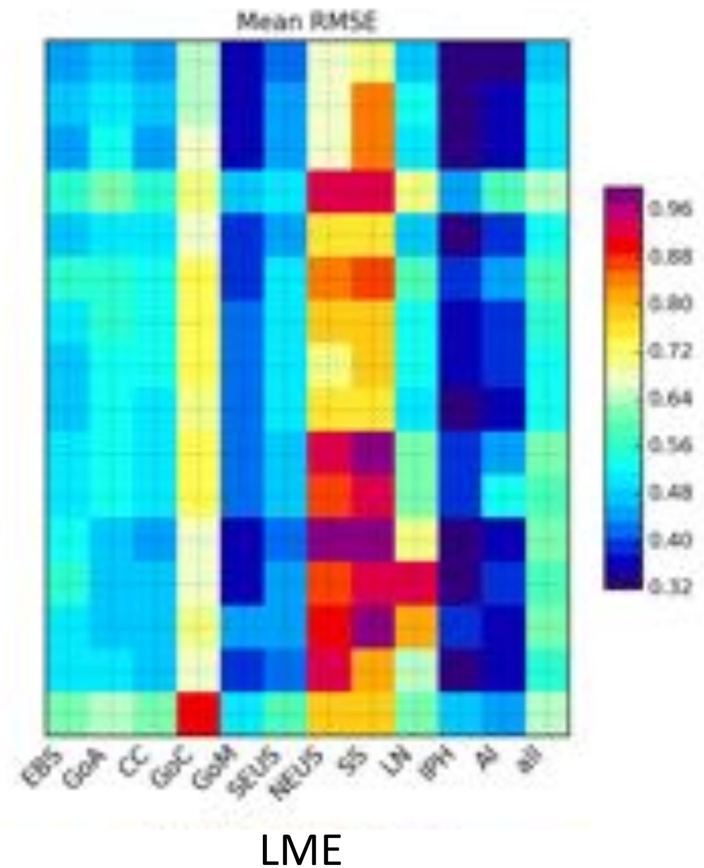
- As a first step explored seasonal SST forecast skill from climate models
- GCMs have skill in predicting SSTs but varies widely by region,
  - Gulf of Alaska & California Current reasonably good
- Skill in LME CC sub-regions
  - Decreases from north to south in the 3 California Current subregions
  - CC Skill mainly from persistence and ENSO
- Multi-model mean generally the best forecast though not necessarily for all regions at all time
  - Increase in skill of ensemble large for probability forecasts
- Steps that are needed to go from large-scale physical model forecasts to fine-scale ecosystem forecasts are discussed

CanCM4 model skill (ACC) relative to the influence to persistence and ENSO on SSTAs in the CCS.



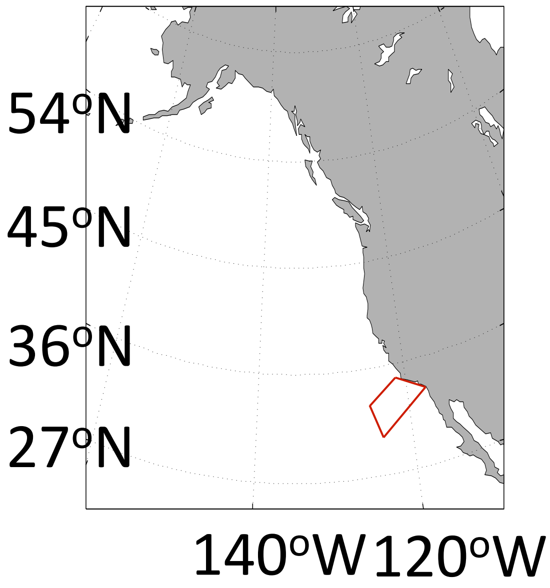
Overall Skill Estimates of SST hindcasts





Application of SST forecasts to Pacific Sardines

- Robust recruitment – spring SST relationship
- Climate variability drives fluctuations in abundance
- Current harvest guideline (HG) dependent on previous year's SST in southern California Current LME



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