Forecast Applications at Different Timescales to Support Fisheries Management in a Changing Ocean

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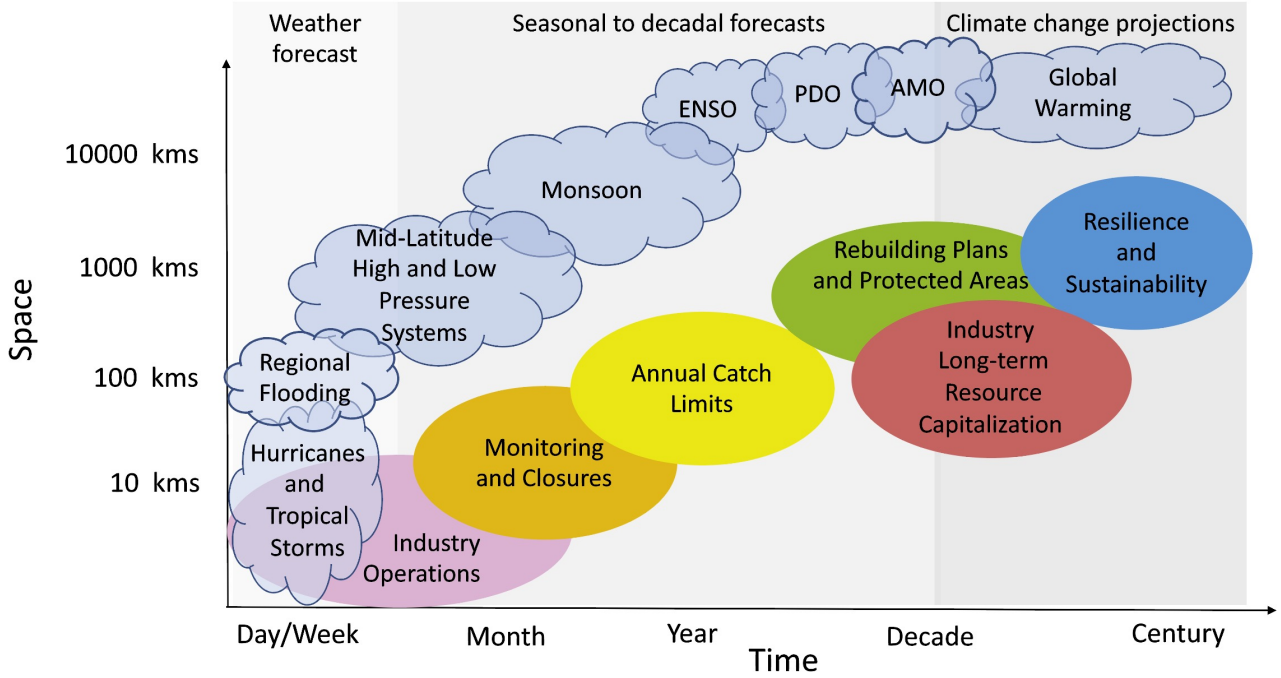
Daily to Decadal Ecological Forecasting along North American Coastlines Workshop
WHOI, April 14th, 2022

Fisheries decisions across time scales are impacted by climate effects



Aquaculture
- Extreme weather responses
- Stocking/harvest time

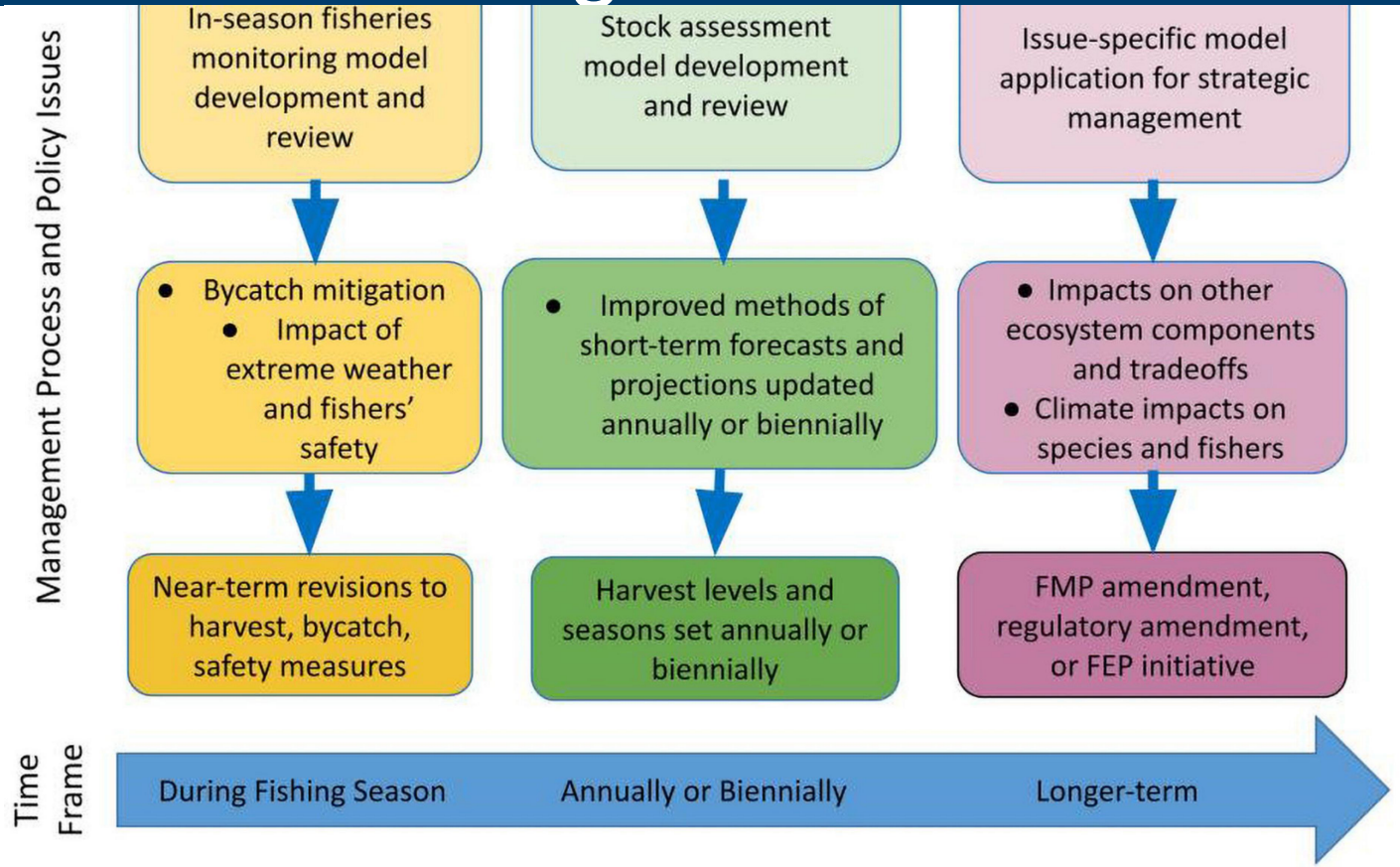
Fishing Industry
- Labor and gear needs
- Where/when/what to fish for

Coastal Management
- Beach closures (e.g. HAB's, jellies)

Fisheries Management
- Fisheries closures to reduce unwanted and incidental capture
- Provision of catch advice

Tommasi et al., 2017

Need for climate-ready fisheries management



Tommasi et al. 2021

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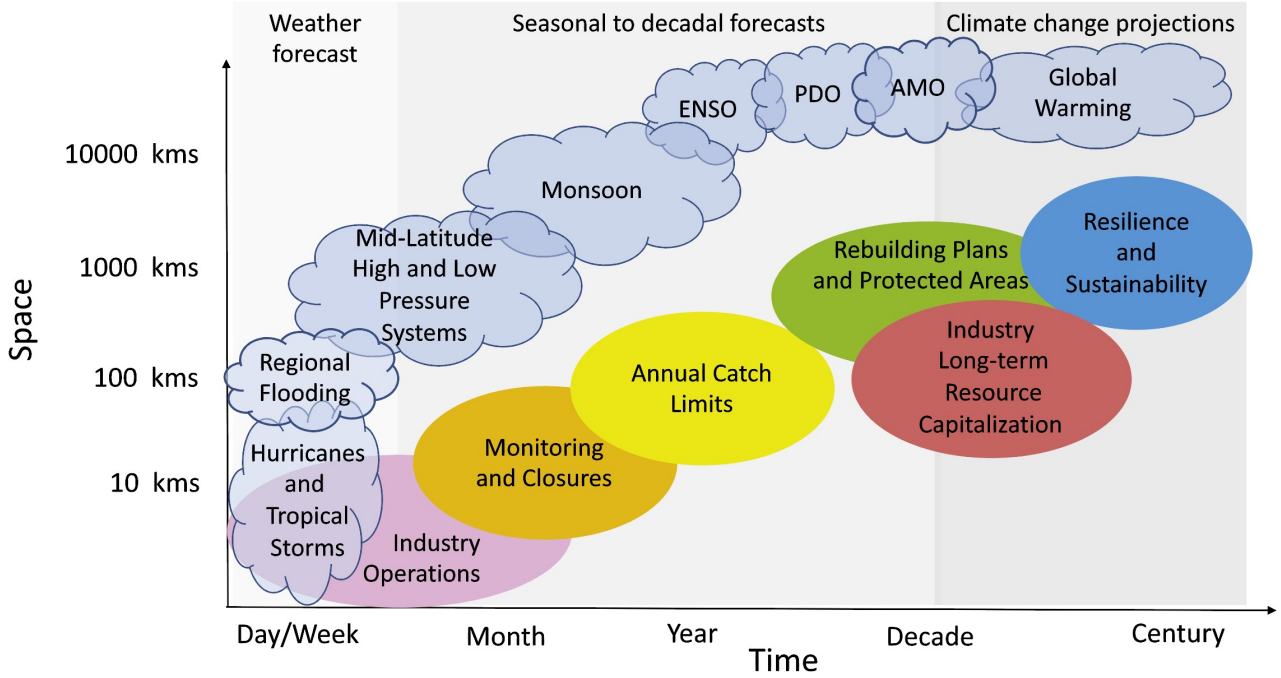

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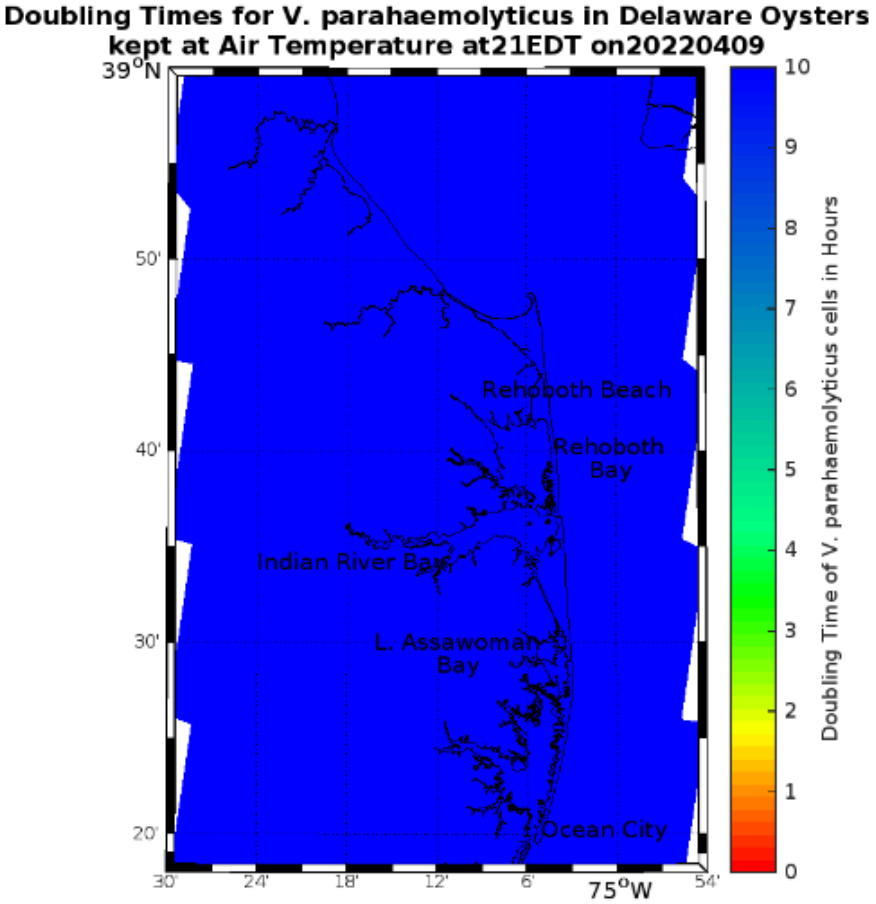
Tommasi et al., 2017

Near-real-time to 5-day outlook

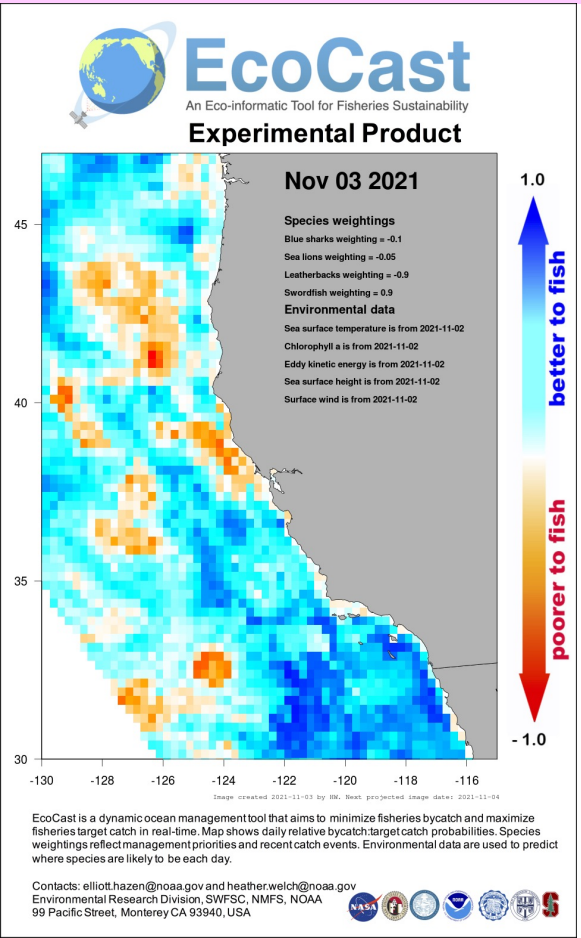


NOAA National Ocean Service

NOAA Ecological Forecasting

- Harmful Algal Blooms Forecasts
- Coastal Pathogen Forecasts
- Hypoxia Forecasts
- Coral Bleaching Forecasts

Near-real-time



Dynamic Ocean Management Tools to Reduce Bycatch

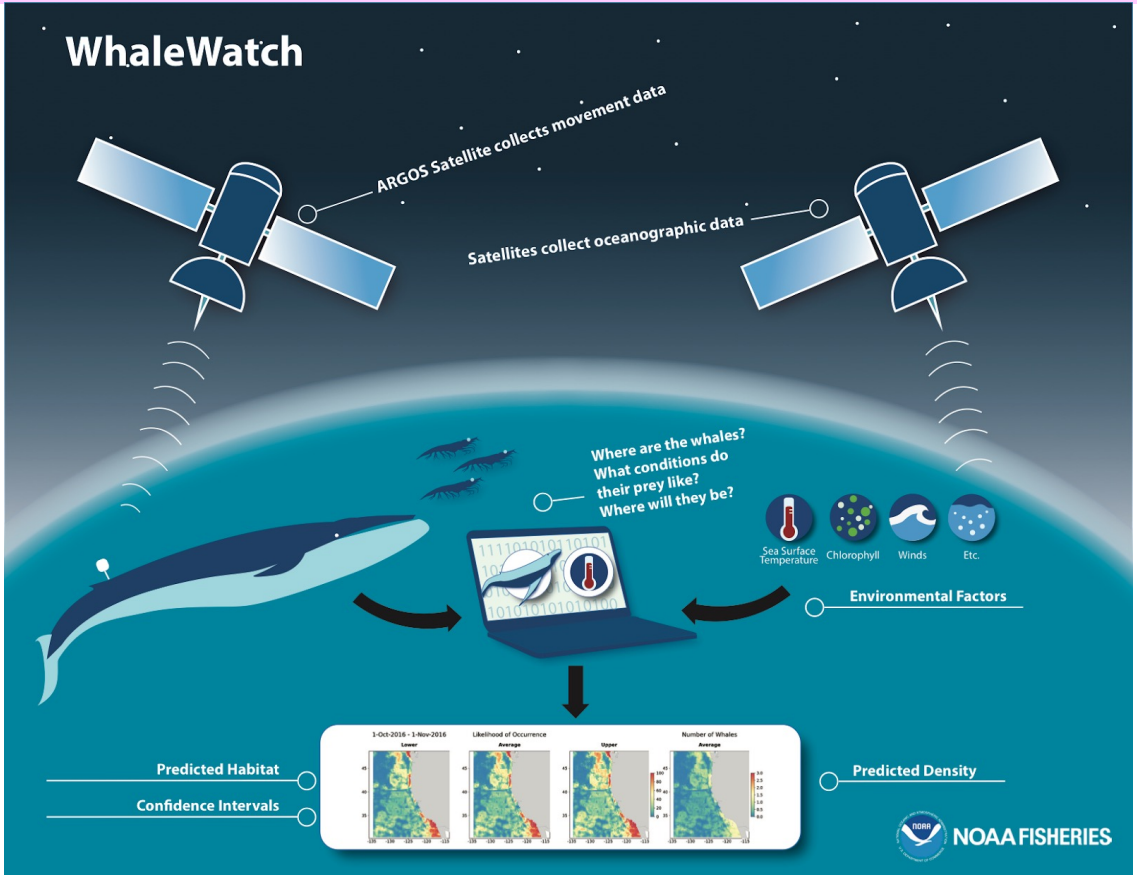
Nowcasts of ocean conditions linked to species distribution models to generate daily maps of bycatch risk

Hazen et al., 2018

https://coastwatch.pfeg.noaa.gov/ecocast/

Near-real time

- Monthly 25x25 km nowcasts of whale distributions for the current month
- Being updated to 10x10 km nowcasts of daily whale distributions



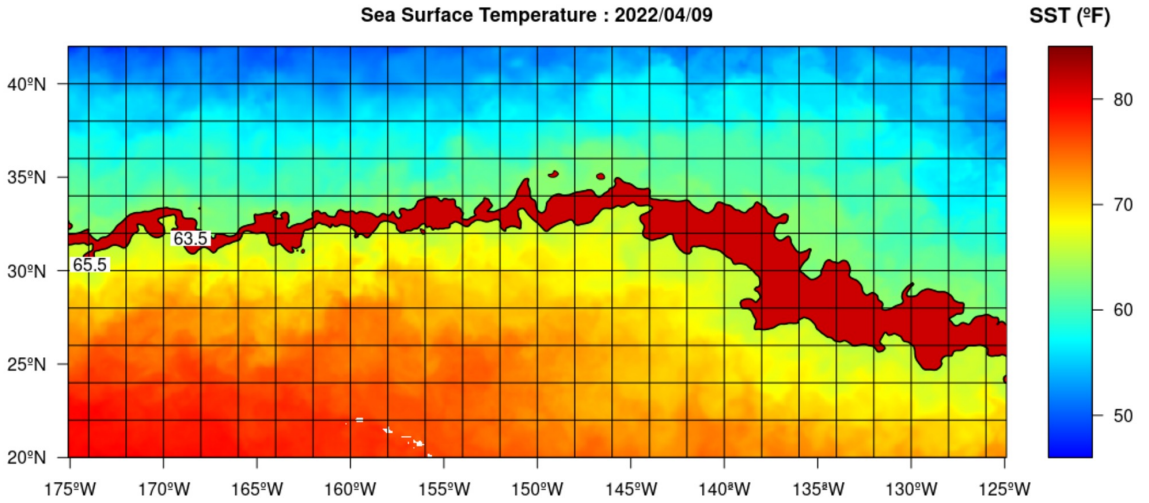
Hazen et al. 2016
Abrahms et al., 2019

https://www.fisheries.noaa.gov/west-coast/marine-mammal-protection/whalewatch

Near-real time

EXPERIMENTAL PRODUCT

Avoid fishing between solid black 63.5°F and 65.5°F lines to help reduce loggerhead sea turtle interactions

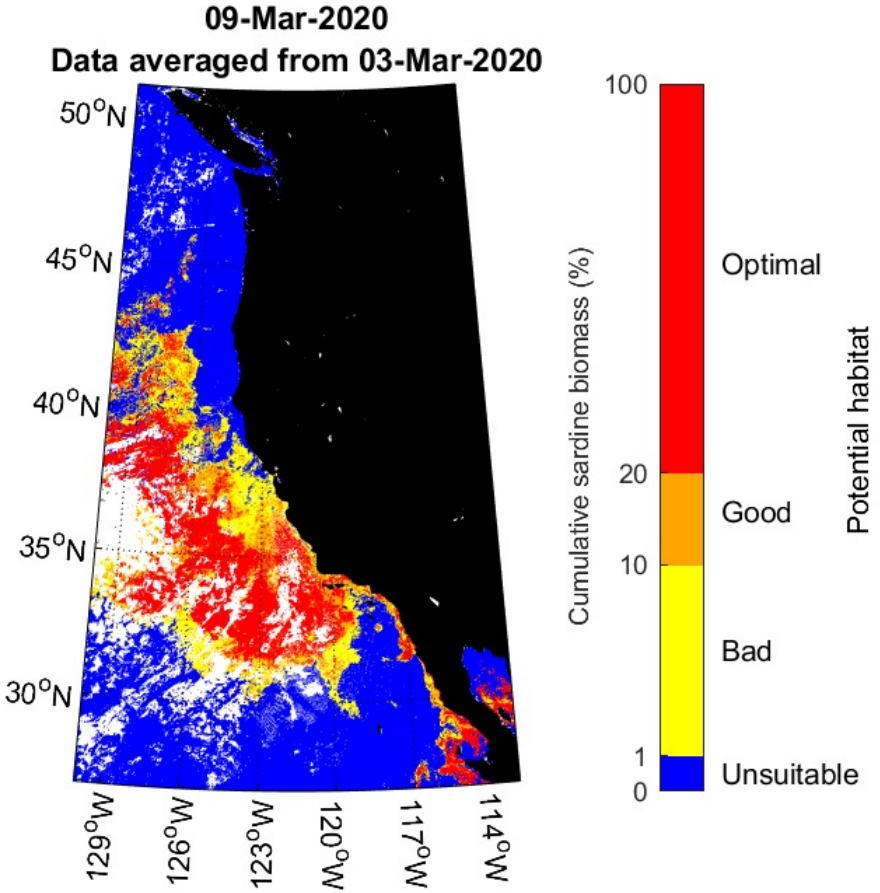


PACIFIC ISLANDS FISHERIES SCIENCE CENTER
ECOSYSTEM SCIENCES DIVISION
1845 Wasp Blvd, Honolulu, HI 96818
http://www.pifsc.noaa.gov/eod/turtlewatch.php
contact: melanie.abecassis@noaa.gov

Data provided by the OceanWatch - Central Pacific node

TurtleWatch

Near-real time



Sardine Potential Habitat to Optimize Survey Coverage

Nowcasts of ocean conditions linked to sardine species distribution model

Zwolinski et al. 2011
Demer et al. 2012
Demer et al. 2014

https://swfscdata.nmfs.noaa.gov/AST/sardineHabitat/habitat.aspx

Environmental Inputs

- Sea surface temperature (SST)
- SST standard deviation
- Sea surface height (SSH)
- SSH standard deviation
- Eddy kinetic energy
- Wind stress curl
- Chlorophyll a
- Isothermal layer depth (ILD, 0.5˚C deviation from SST)
- Bulk Brunt Väisälä frequency (A measure of stratification over upper 200 m)

Seasonal Dynamic Ocean Management Tools

Seasonal Prediction System

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Habitat Model

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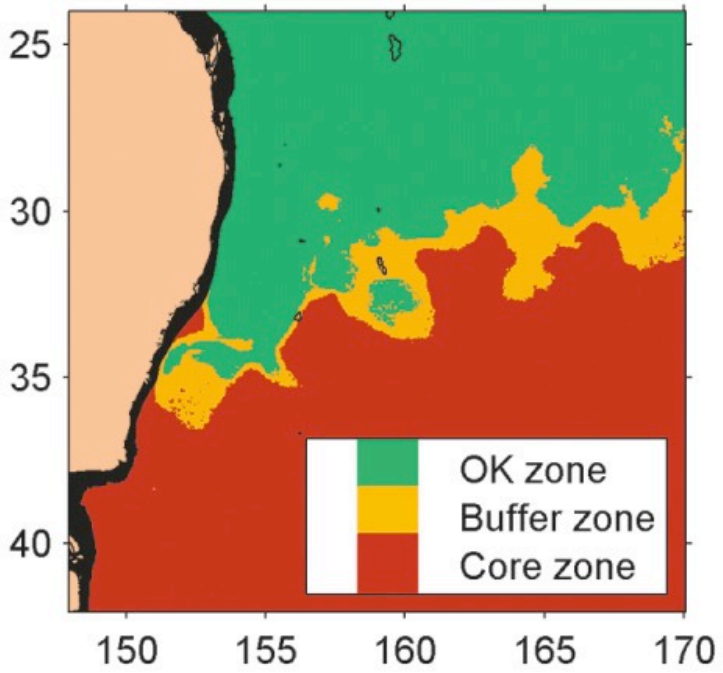
Southern Bluefin Tuna Habitat Boundary Forecast – up to 4 month lead time

↓

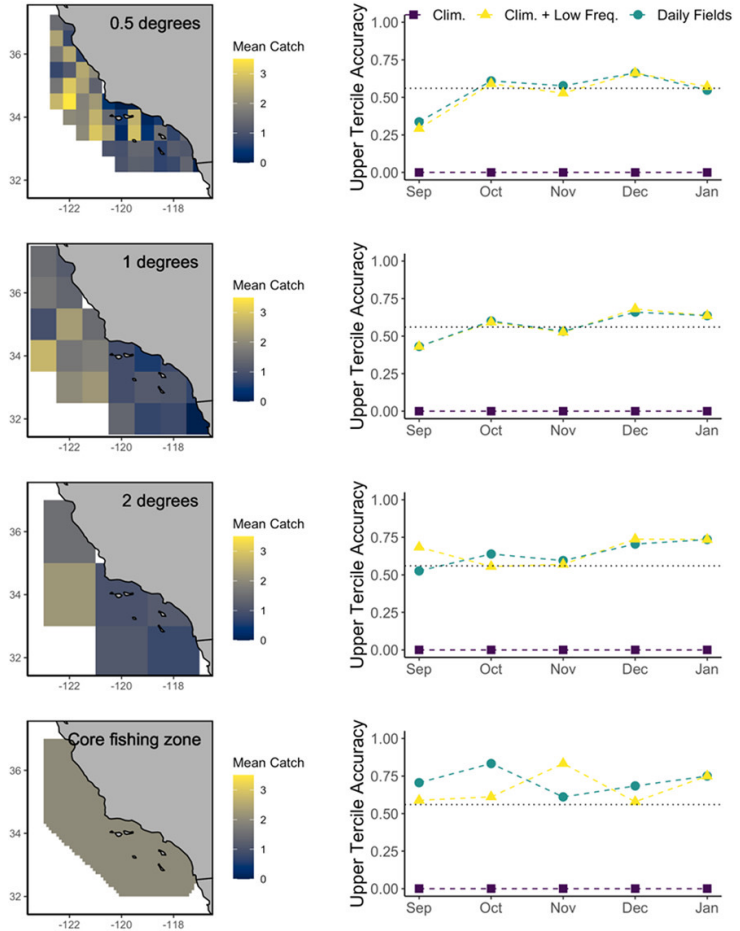
Improved Operational Decision



Forecast Input: monthly SST anomalies

Hobday et al. 2011

Potential for Skillful Seasonal Forecasts of Species Distributions



Predictive Performance for Swordfish Catch Anomalies

- Low frequency component dominant source of predictive skill
- Impact of spatial resolution

Environmental Input:
SST, Chlorophyll a, ILD

Brodie et al. 2021

Seasonal Hake Forecast

J-SCOPE Seasonal Prediction System

↓

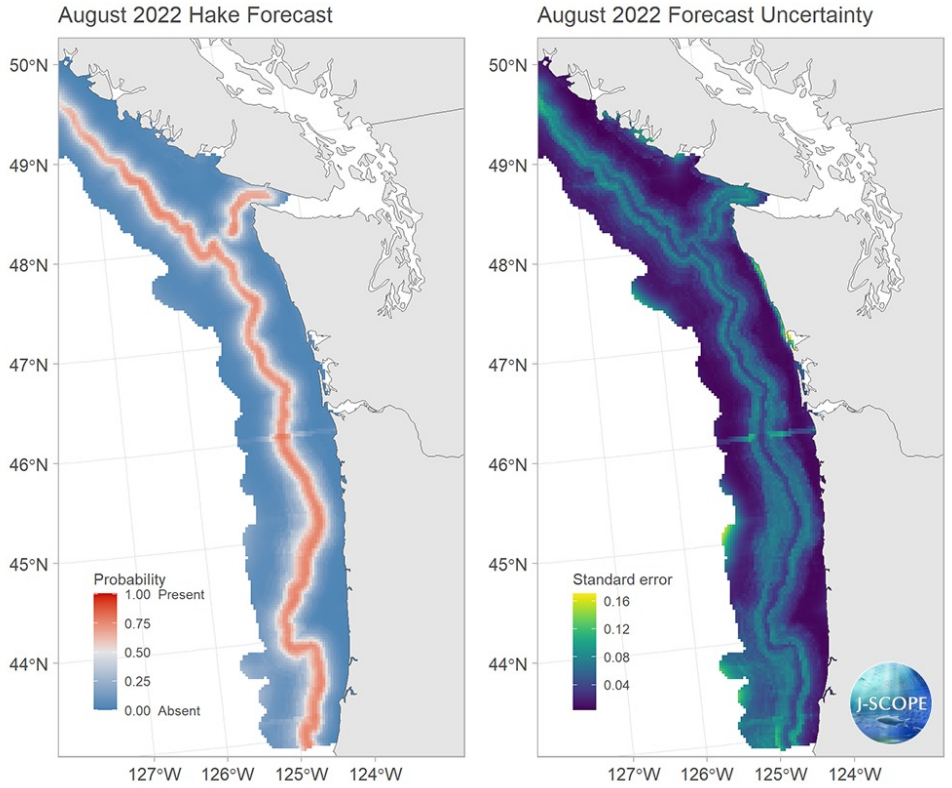
Habitat Model

↓

8 month lead time hake forecast

↓

Improved survey planning and early warning of ecological shifts



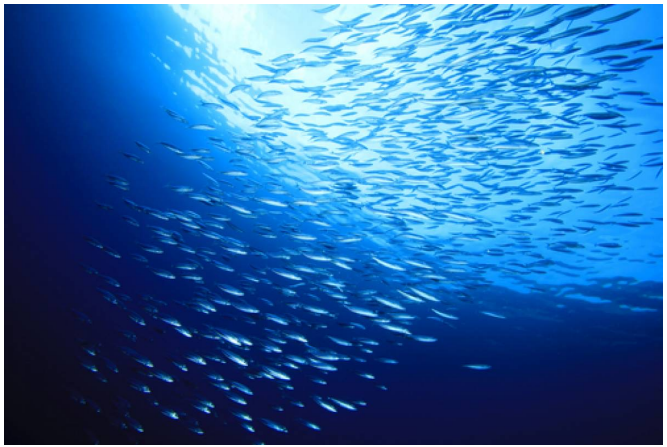
http://www.nanoos.org/products/j-scope/forecasts.php?forecast=2022-01&var=hake

Forecast Input: monthly temperature at 250 m

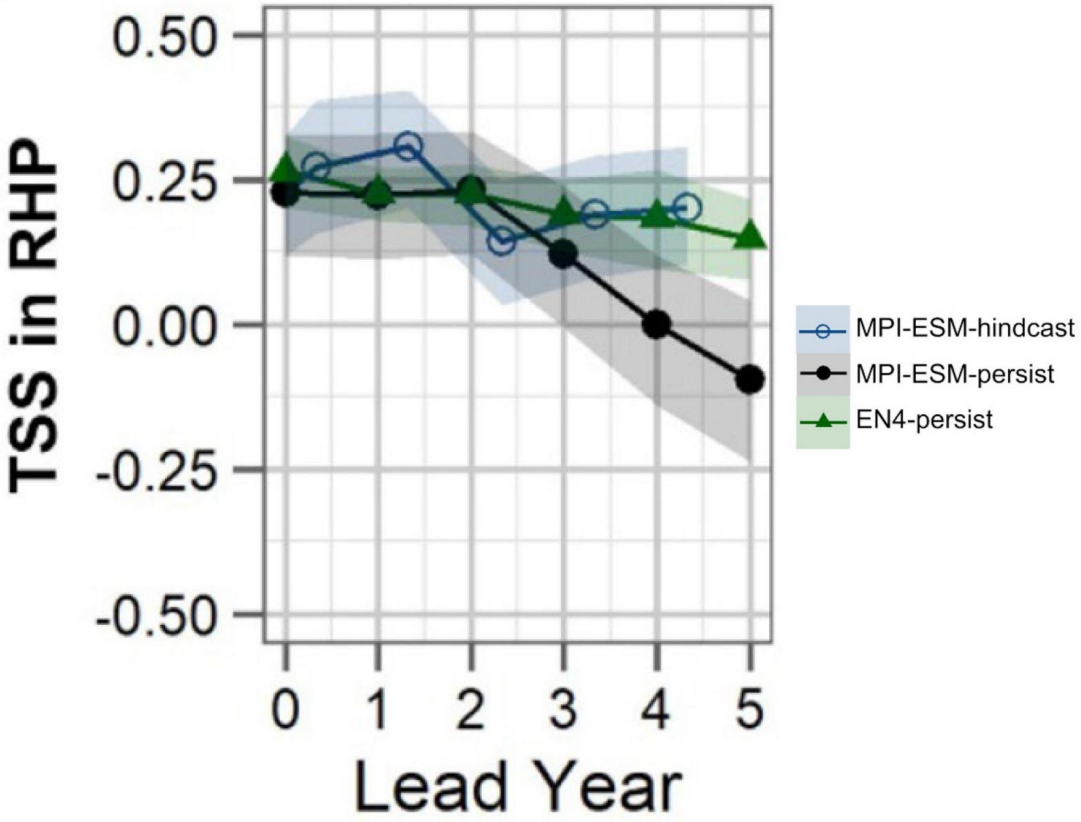
Malik et al. 2021

Multi-annual Forecasts of Species Distributions

- Survey Planning
- Avoid International Conflicts over Fishing Rights
- Plan for Changing Fishing Opportunities
- Plan for Changing Interactions



Multi-annual Forecasts of Species Distributions



Multi-annual Forecasts of suitable blue-whiting spawning habitat

- 0-5 lead time forecasts of March-April spawning habitat
- Low frequency dynamics of North Atlantic Subpolar Gyre dominant source of predictive skill

Forecast Input: monthly salinity at depth of spwaning

Miesner et al. 2022

Forecasts of Stock Abundance/Biomass

- Often catch limits based on 1 to 3 year forecasts of stock biomass
- For some species (e.g. North Pacific tunas), 10 year projections used to inform catch advice

Initial Conditions
Age structure
Biomass at age

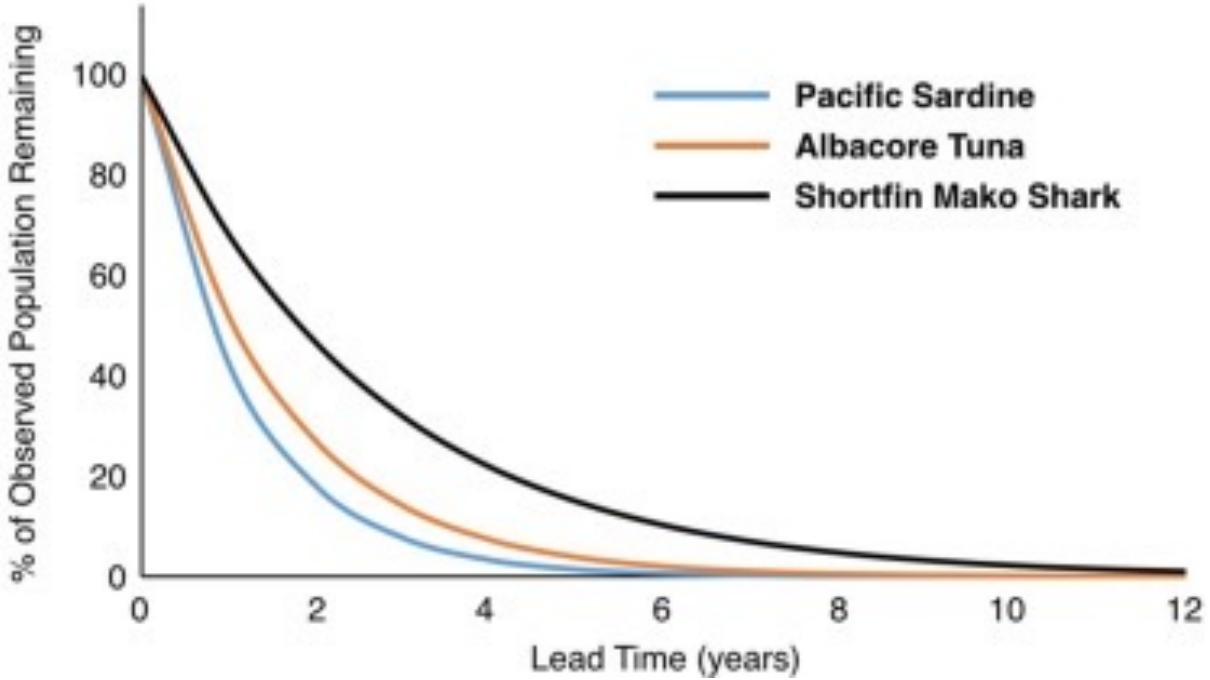
Productivity
Recruitment
Mortality
Growth

Fishing
Selectivity
Fishing mortality

Forecast
Often called projection as it depends on a fishing mortality scenarios

Forecasts of Stock Abundance/Biomass

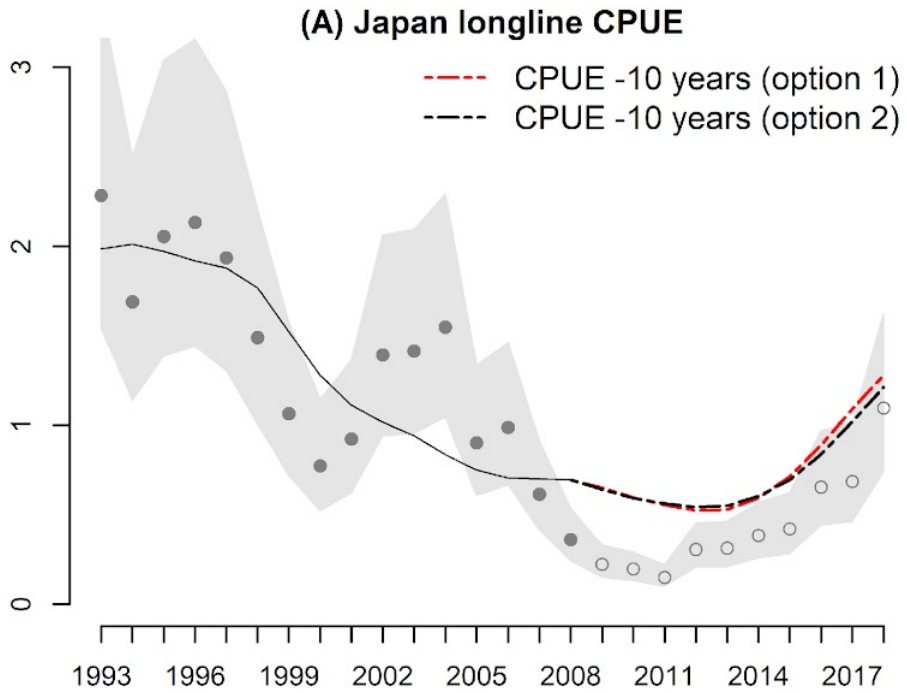
Contribution of Biological Persistence to Prediction Skill



Jacox et al. 2020

Forecasts of Stock Abundance/Biomass

Contribution of Fishing Mortality to Prediction Skill



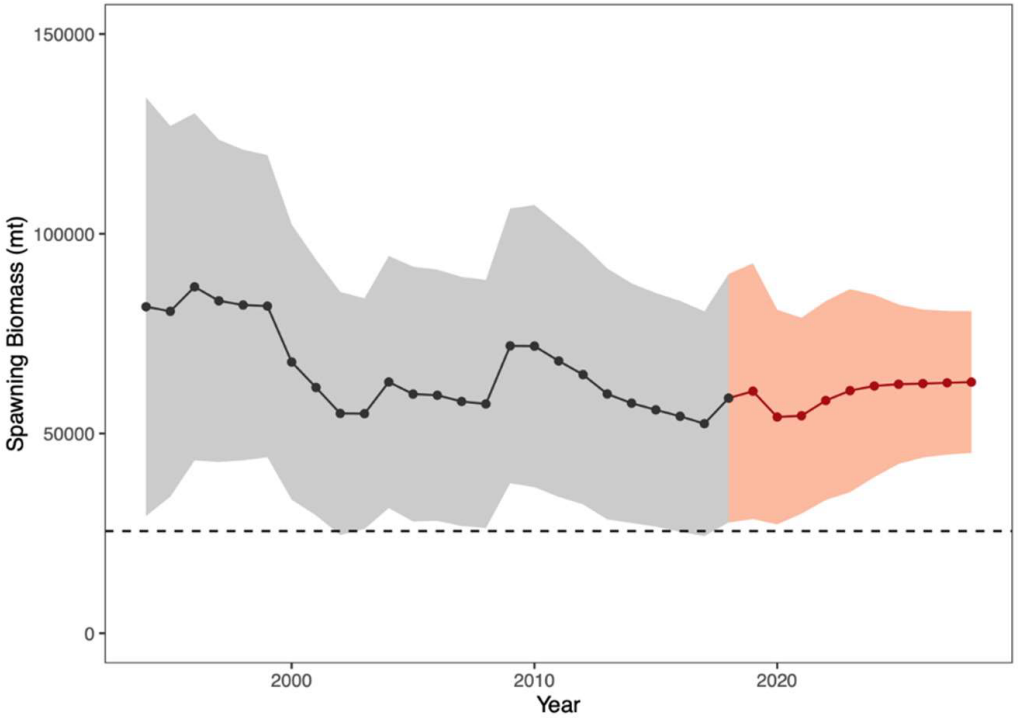
10-year lead time retrospective forecast of bluefin tuna CPUE

- All stock dynamics kept at long-term mean conditions except catch
- CPUE derived from retrospective forecast of biomass

Lee et al. 2021

Forecasts of Stock Abundance/Biomass

Albacore Tuna Projections for Catch Advice

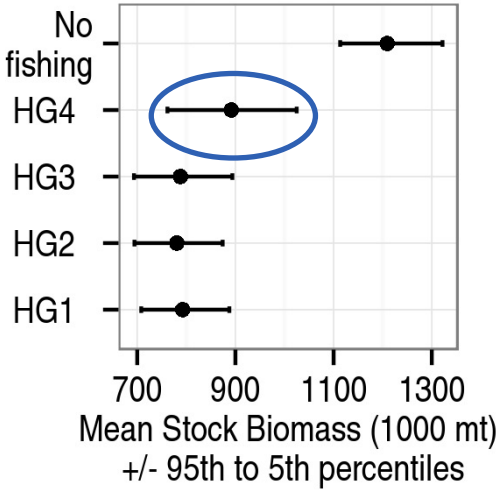


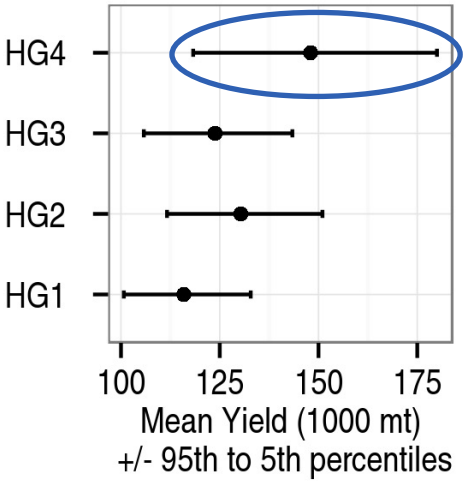
- Recruitment sampled from historical distribution
- Mortality, growth, selectivity kept constant to historical mean
- Fishing mortality constant to average of last three years

ISC 2020

Forecasts of Stock Abundance/Biomass

Performance of sardine harvest guideline





HG1 = no SST
HG2 = past SST
HG3 = forecast SST for fishing rate
HG4 = forecast SST for fishing rate and biomass forecast

- Catch advice based on a biomass forecast dependent on a recruitment forecast informed by a seasonal SST forecast better than status quo
- Results are lead-time dependent. Forecast accuracy too low to be useful at leads of 5 months or greater

Tommasi et al. 2017

Future Needs for Expanded Use of Climate Predictions in Fisheries Decisions

- Need for strong mechanistic understanding of environment-fisheries link and empirical environment-fisheries relationship need to be regularly tested with new data (**iterative forecast cycle**, Dietz et al. 2018)

- Focus not on what is feasible but **what is useful** (Payne et al. 2017)

- **Co-development** with end users – dedicated personnel
  - *Appropriate spatial scale, variables of interest*

Future Needs for Expanded Use of Climate Predictions in Fisheries Decisions

- Improved **accessibility** and **delivery** of forecast output
- **Skill assessment** of variables other than SST
- **Long retrospective forecasts** to test reliability of ecological forecasts
- **Long reanalyses** (with biogeochemistry) for ecological model training

Thank you for your attention!

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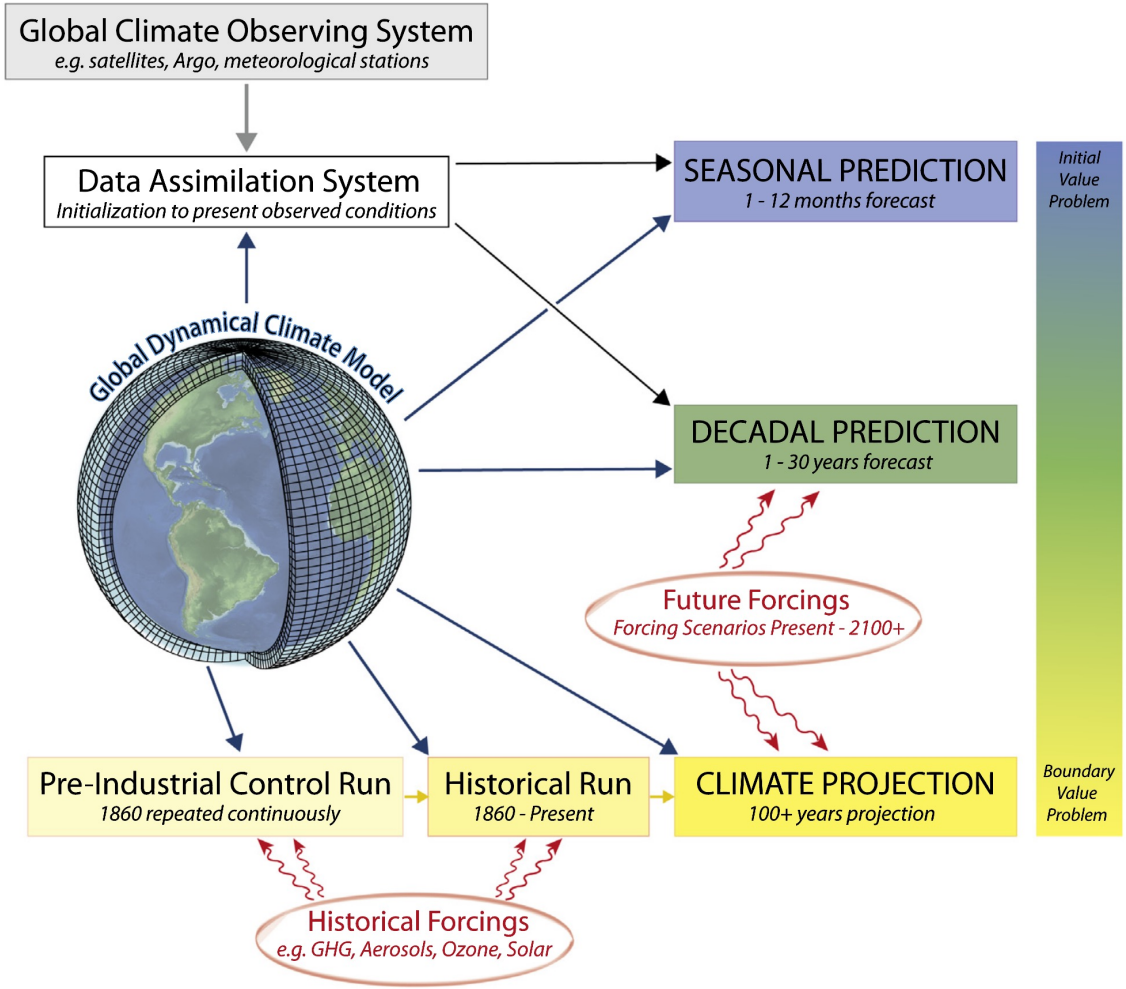
Climate predictions differ from climate projections

- Prediction models are initialized with observations
- Initial value problem
- Predict statistics of climate over monthly to 30 year time scales (seasonal to decadal forecast) or evolution of single weather feature at hourly to weekly timescales (weather forecast)



Tommasi et al., 2017