OCEAN PREDICTIONS ON SEASONAL TIME SCALES: EXAMPLES/LESSONS FROM THE NORTHEAST PACIFIC

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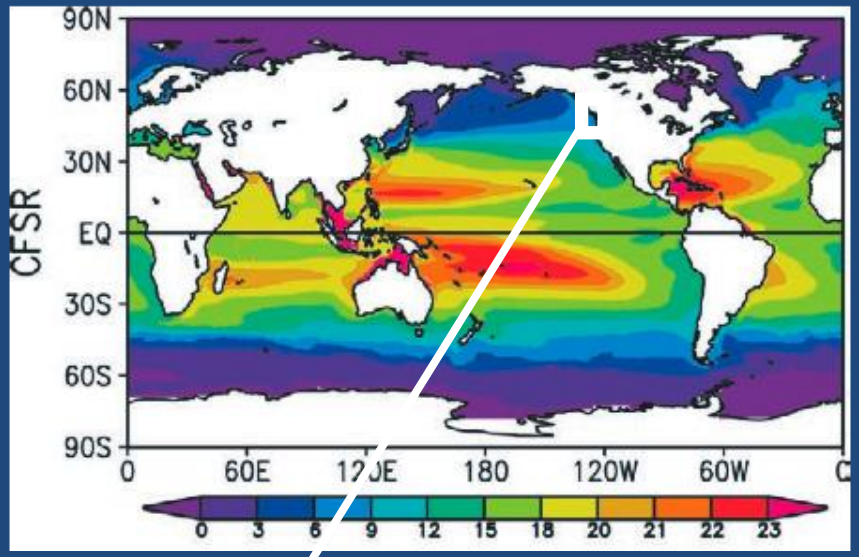
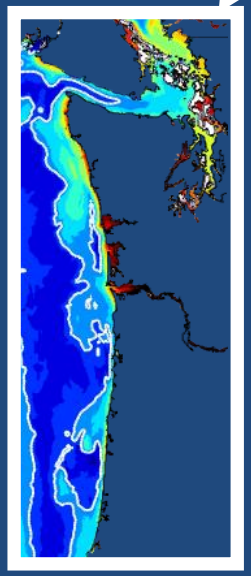
Methods of Prediction

- Methods:
  - Direct numerical modeling
  - Analogues (find a similar situation from the past)
  - Eulerian persistence (inertia)
  - Lagrangian persistence (advection or waveguide)
- Tools:
  - hydrodynamic/biological models
  - empirical relationships
  - EOFs/PCAs – correlations of patterns

Motivation: J-SCOPE project seeks to predict physics and biology of the coastal Pacific NW



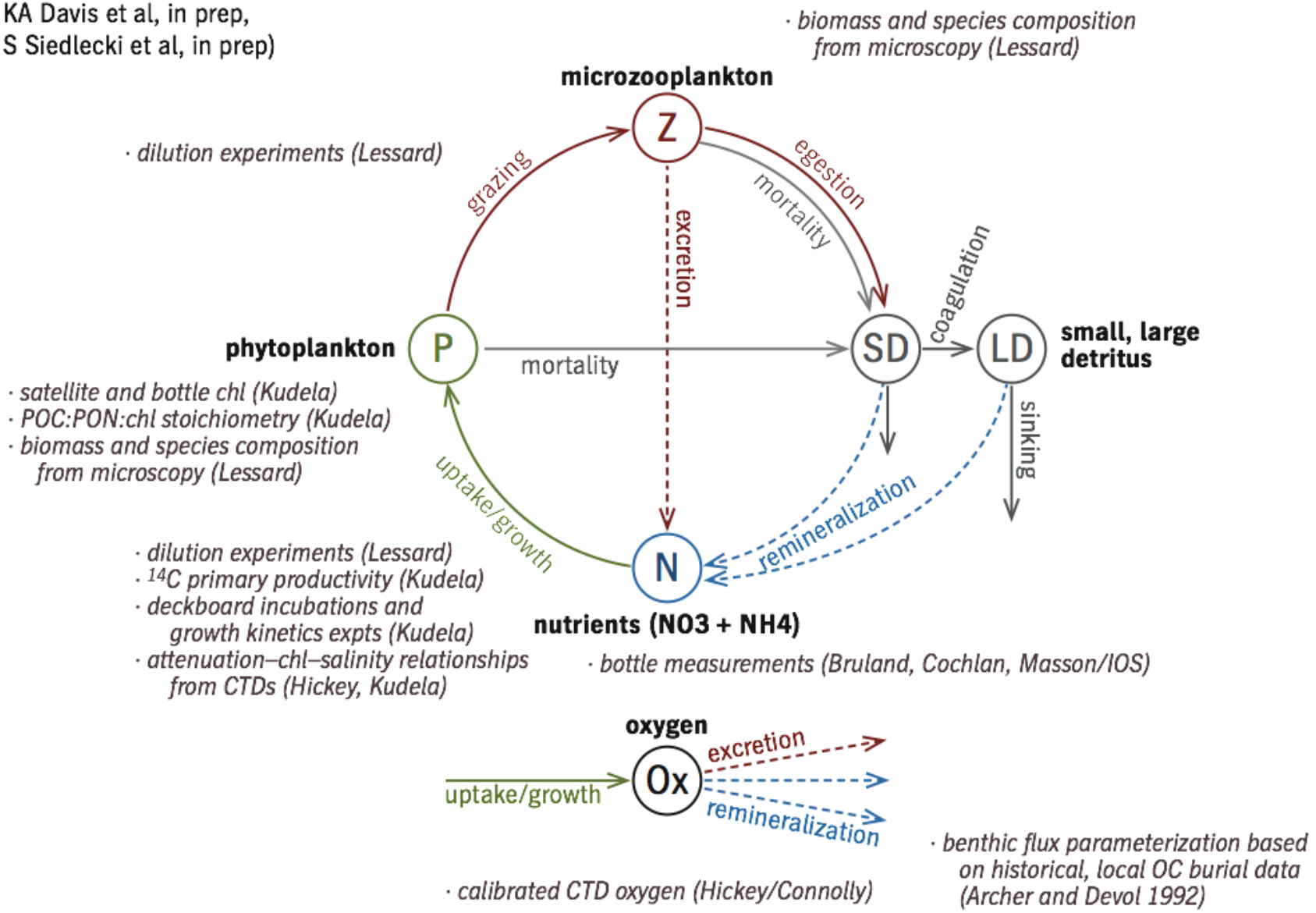


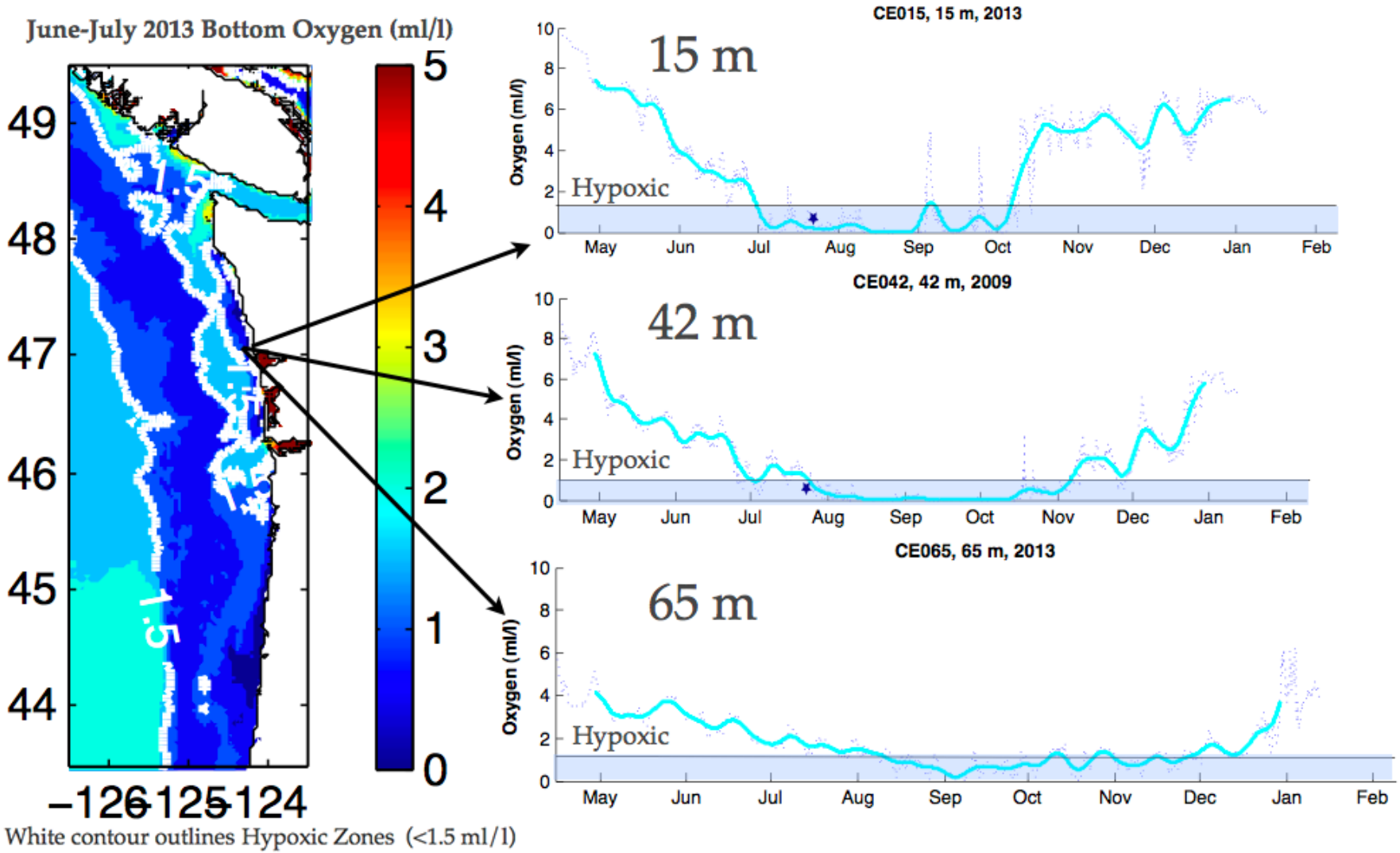
- The Climate Forecast System (CFS) – a global coupled air/sea/land model –is used for boundary conditions and atmospheric forcing of an established ROMS-based regional model with biogeochemistry (Cascadia domain, ~1.5 km resolution)
- Empirical relationships from observations are applied to the modeled fields to predict additional quantities (e.g. pH and fish)

CMG
UW Coastal Modeling Group

A biogeochemical model for the US Pacific Northwest coast

(NS Banas et al, JGR, 2009,
KA Davis et al, in prep,
S Siedlecki et al, in prep)





Forecast: Hypoxia begins in July, 2013 for Cape Elizabeth region of WA coast

Oxygen model - Siedlecki et al, in prep


Photo credit:
Ellen Starr

What is the CFS ocean forecast skill?

- The oceanic component of the CFS is the Geophysical Fluid Dynamics Laboratory Modular Ocean Model, version 3 (MOM3) (Pacanowski and Griffies 1998).
  - Horizontal resolution: 0.3-1.0 degree
  - Vertical resolution: 40 layers (27 layers in upper 400 m)
- The CFS group at NOAA generated a long series or “reforecasts” of 1979-2009, which excluded all data beyond the initial forecast date

Density and quality of assimilated data varies through time and space.

The CFS assimilates a broad range of data types; the quantity and quality of this data has increased over time (e.g. ARGO)

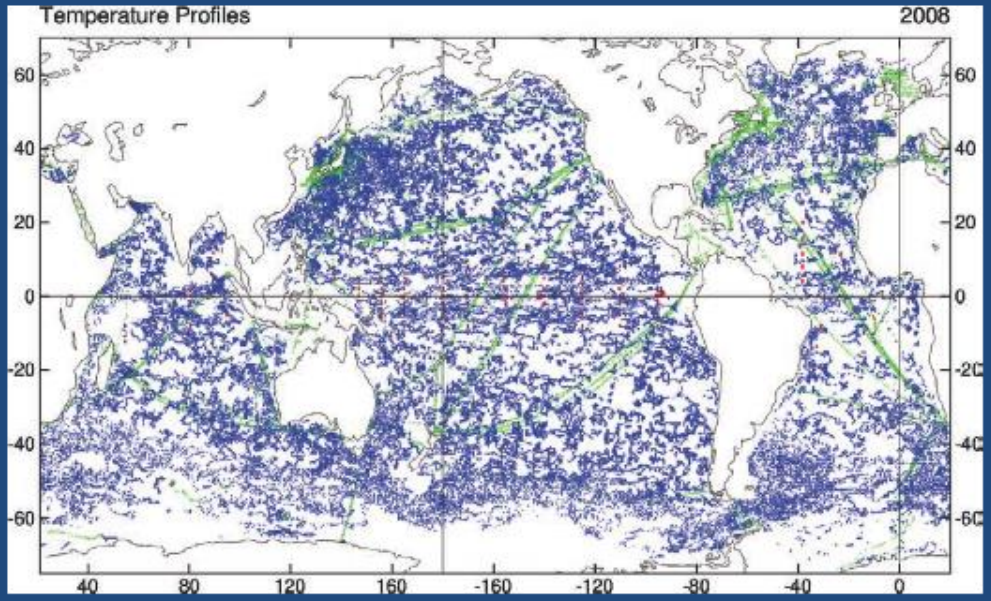


FIG. 13. As in Fig. 12, but for the year 2008. The Argo array (blue) provides a nearly uniform global distribution of temperature profiles.

Wen et al. 2012

Even with such rich data sources, the hindcast is not “reality”; in some places we may be comparing two random time series.

CFS prediction of ENSO and PDO

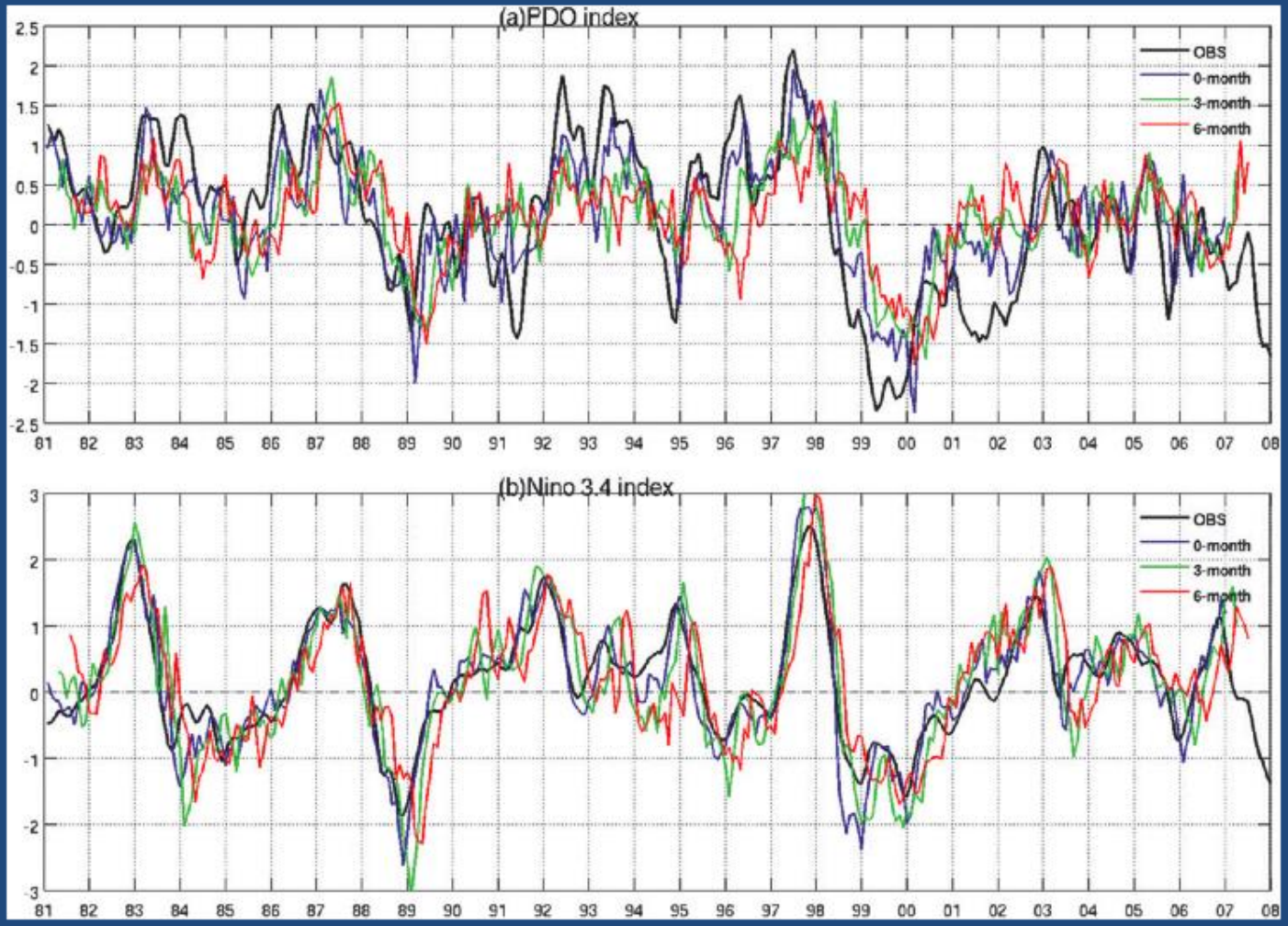
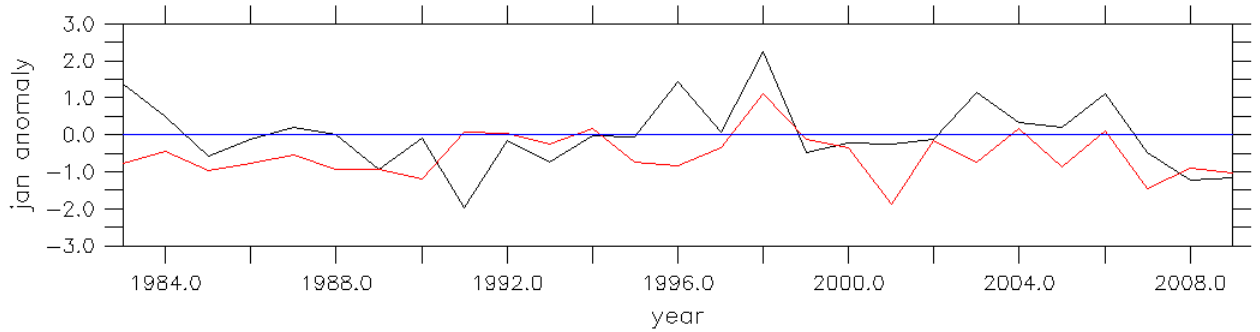


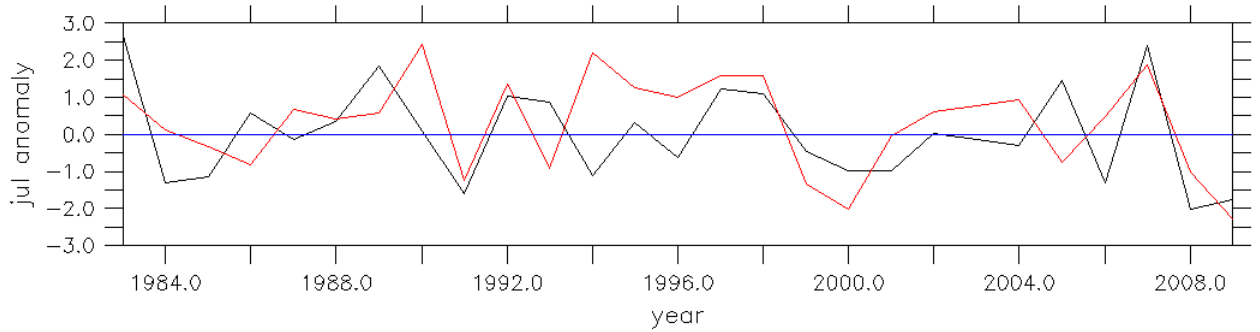
FIG. 5. Time series of (a) the PDO index and (b) the Niño-3.4 SST anomaly during 1981–2006. Black line denotes observation, and blue, green, and red lines denote CFS predictions at 0-, 3-, and 6-month lead, respectively.

Wen et al, 2012

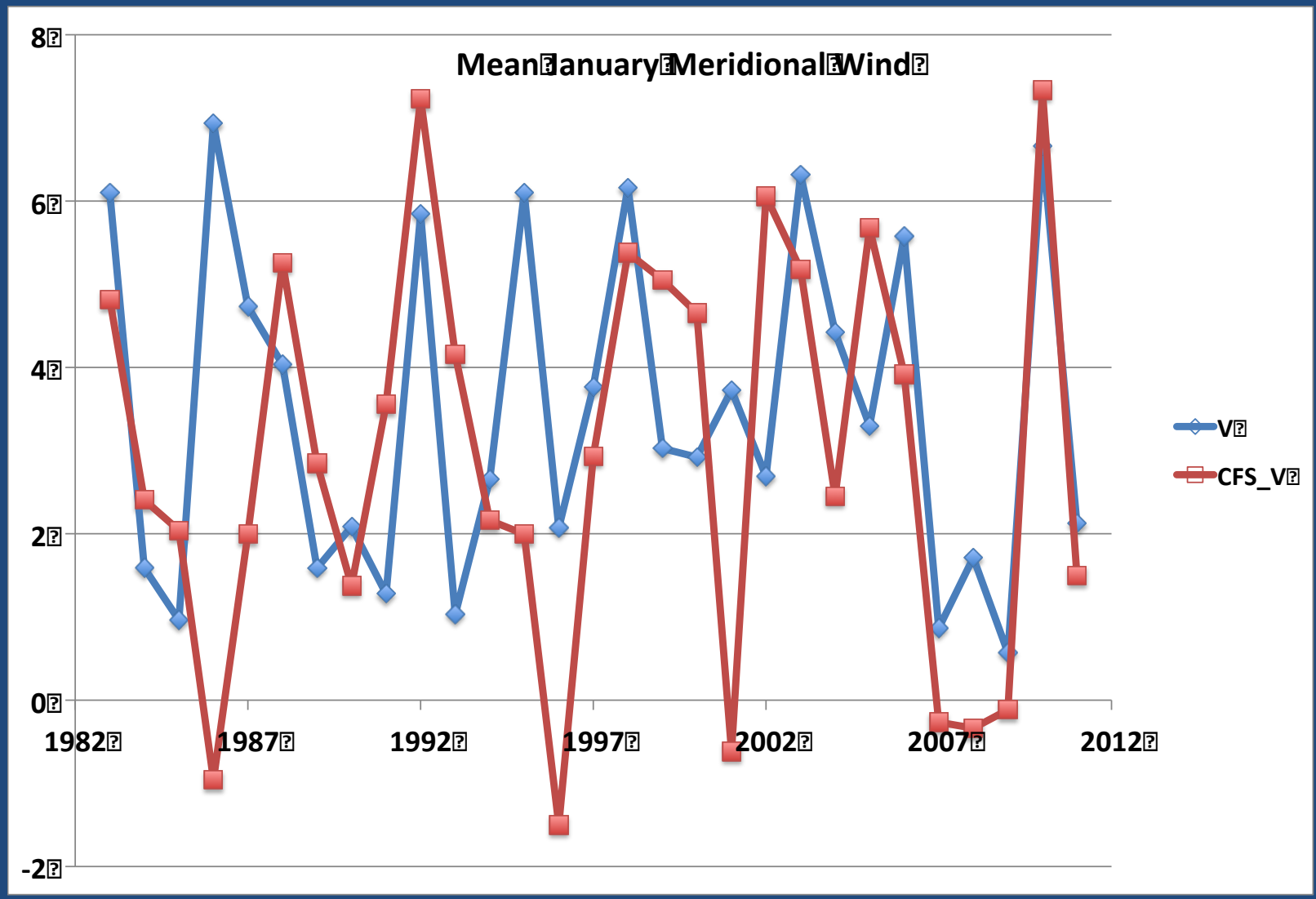
Sample time series at Newport OR



temperature−15z jan anomaly (black = hindcast, red = forecast)



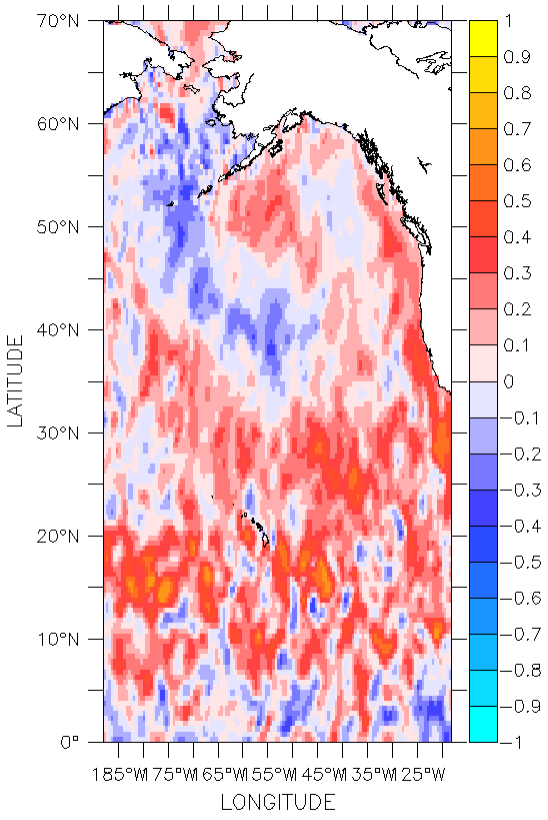
temperature−15z jul anomaly (black = hindcast, red = forecast)


Mean January Meridional Wind
8
6
4
2
0
-2
1982
1987
1992
1997
2002
2007
2012
V
CFS_V

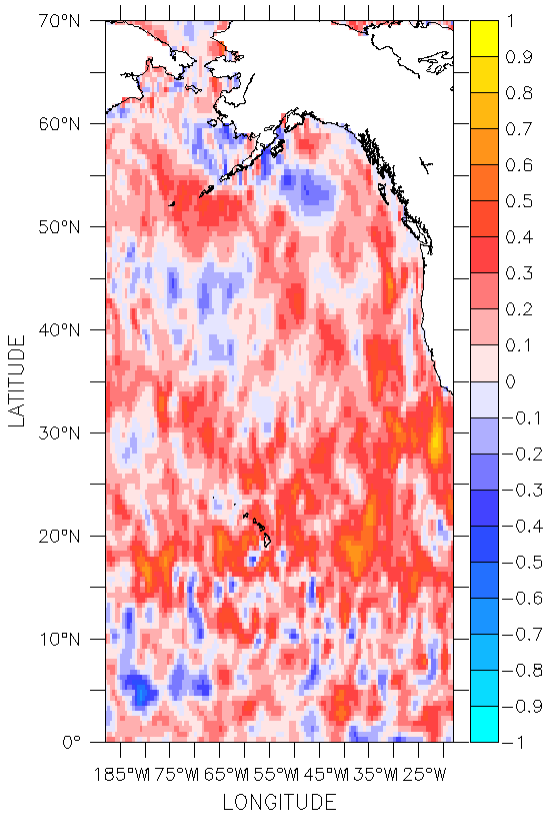
Anomaly correlation maps

- 6-month CFS reforecasts of monthly averages for the NE Pacific (relative to their climatology) have been compared with the corresponding CFS reanalysis anomalies.
  - Four 6-month forecasts ending in January and July of each year (29 years total; hence 116 realizations each of January and July forecasts)
- Where does the prediction correlate with reanalysis?

Surface N/S velocity anomaly correlation

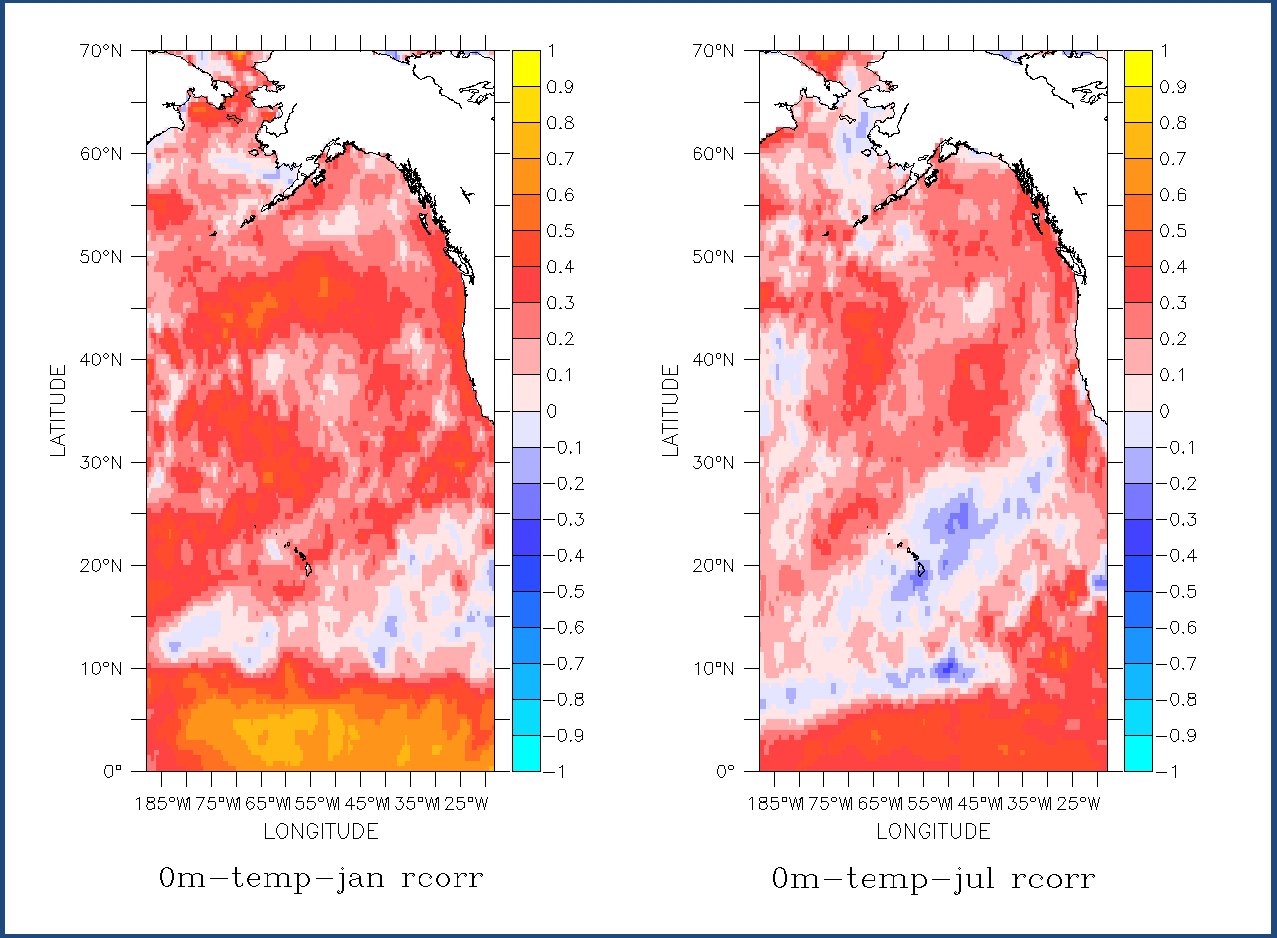


0m−v−jan rcorr

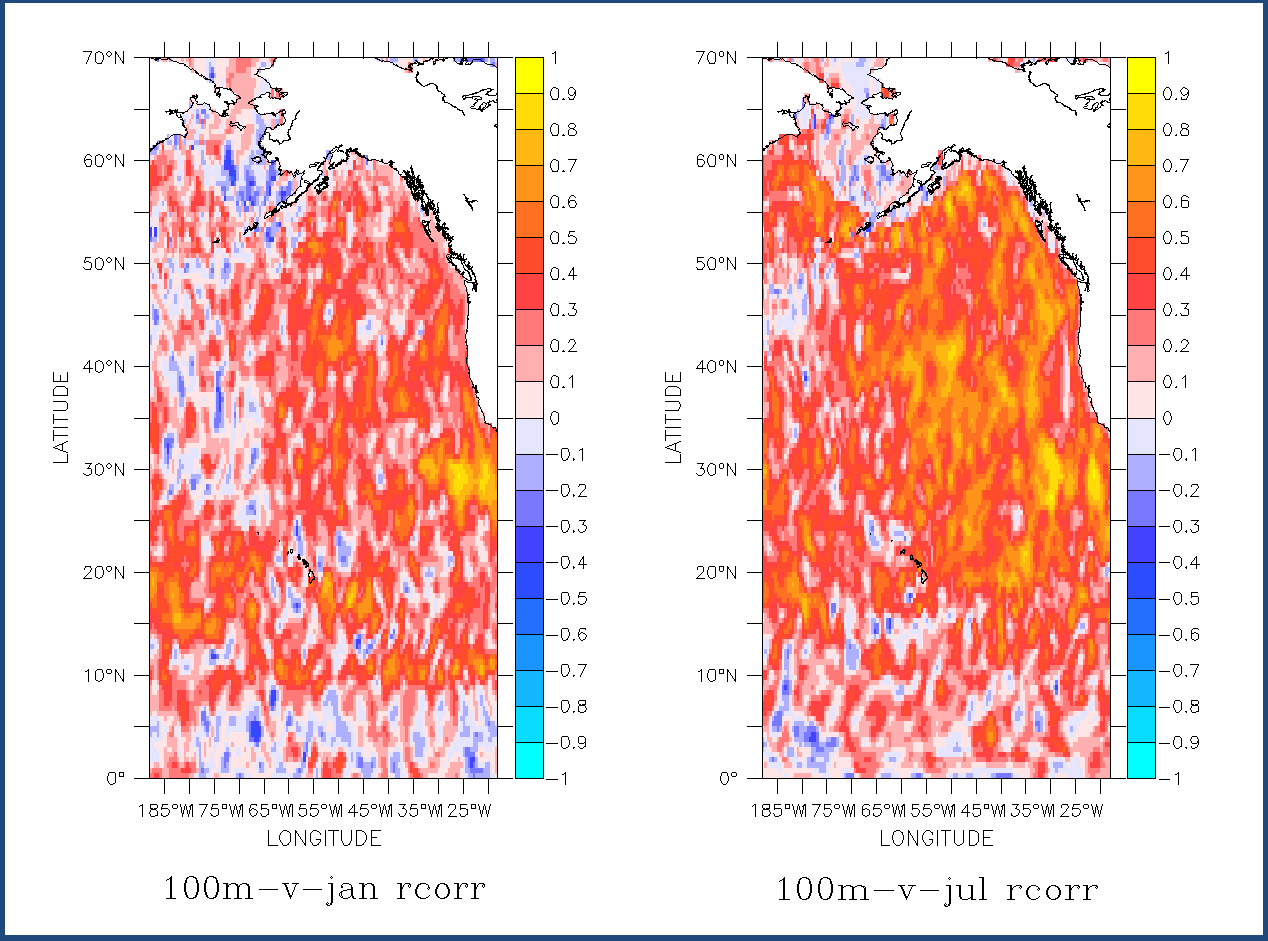


0m−v−jul rcorr

SST anomaly correlation: CFS does better forecasting Jul->Jan than forecasting Jan-> Jul (consistent with “spring predictability barrier”)



100m N/S velocity anomaly correlation: predictability improves with depth

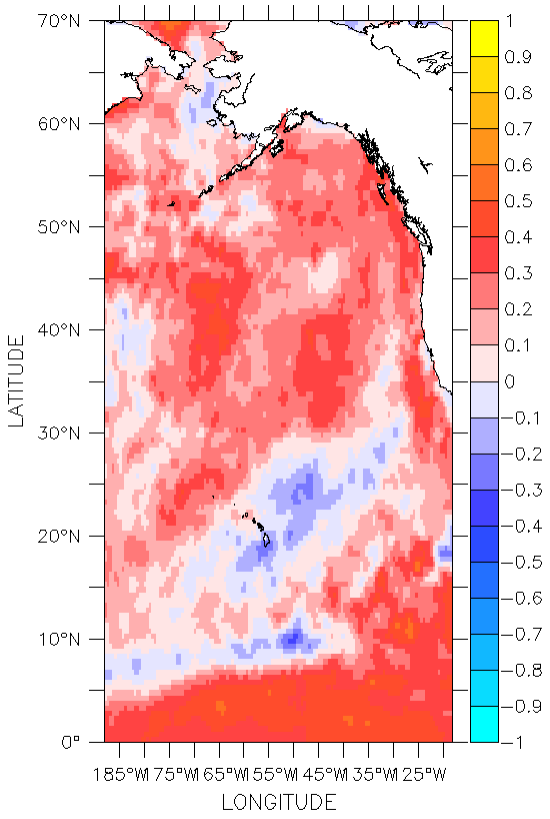


Compare CFS model forecasts with simple persistence

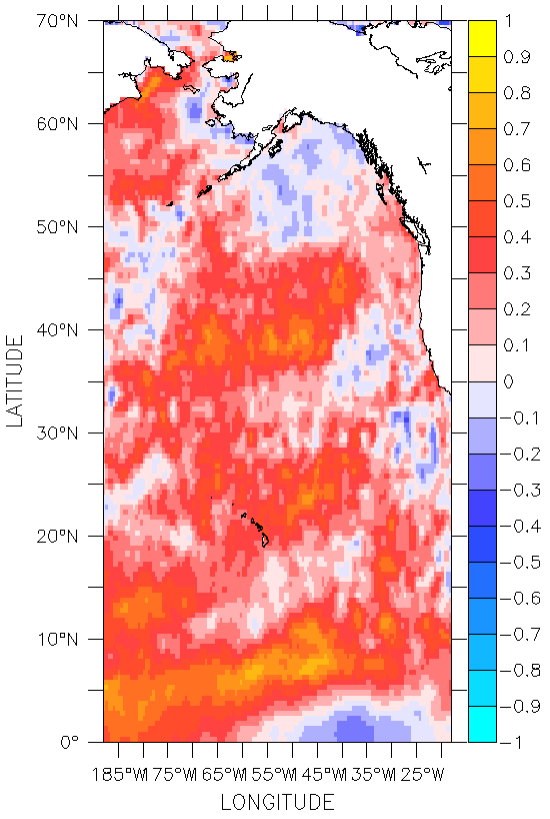
- Anomaly correlation maps using model forecast vs. reanalysis
- Anomaly correlation maps using *persistence* forecast vs. reanalysis
- Take the difference of the two -> what has improved? (Wen et al. (2012) have explored this for global SST)

SST anomaly correlation: model does better along coast and equator

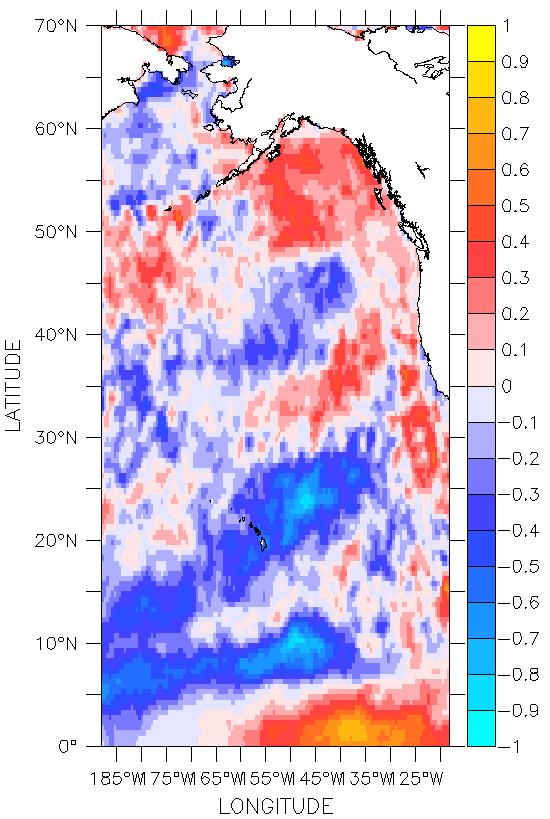
Model forecast



Persistence forecast



Model – Persistence



Wen et al. (2012) analysis

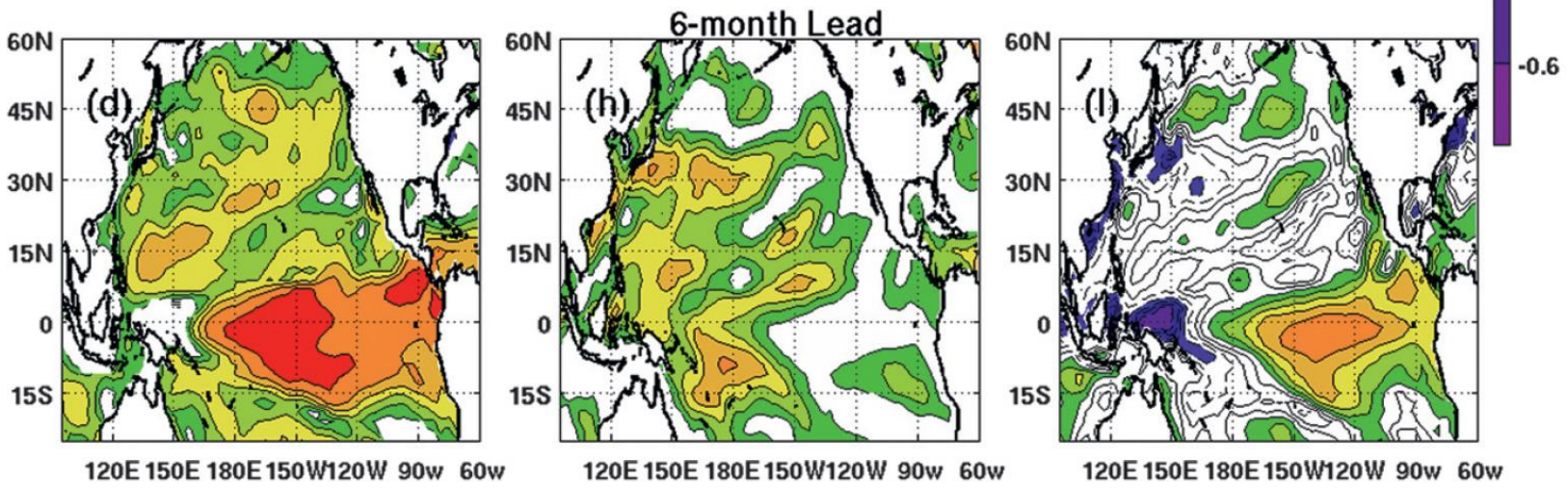
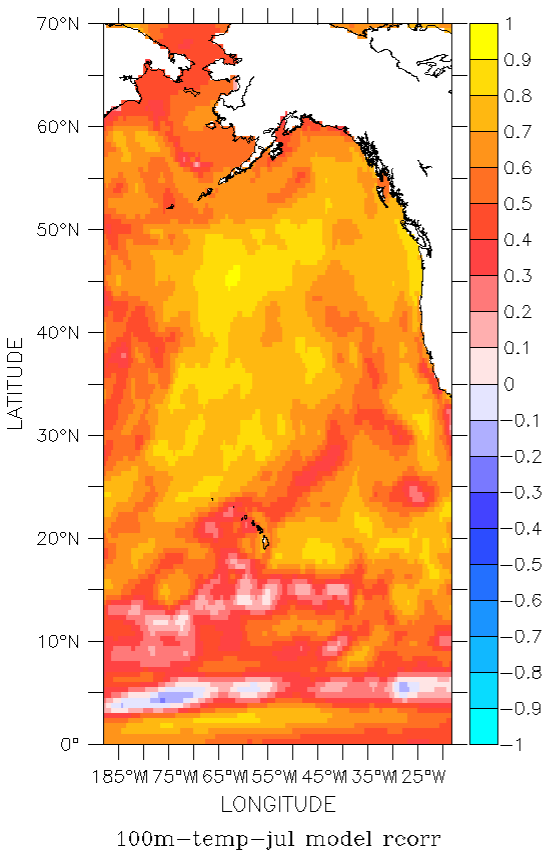


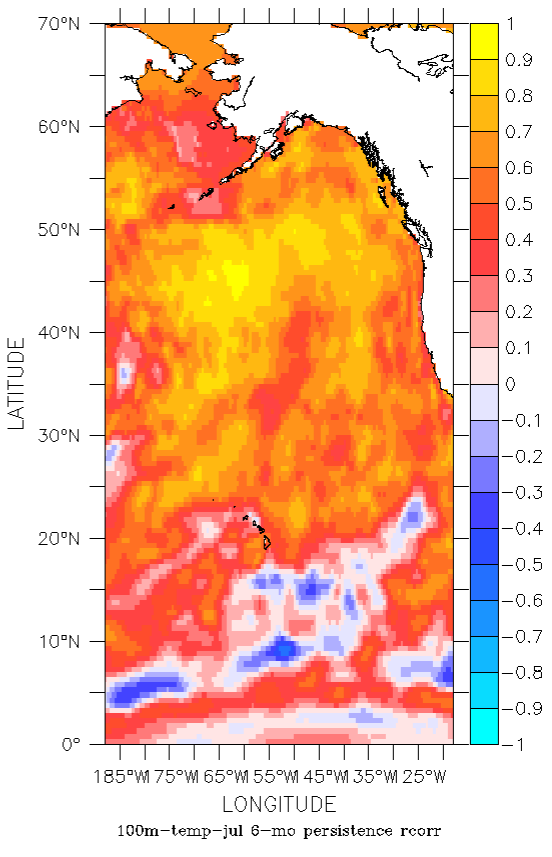
FIG. 3. Correlation skill of (a)–(d) CFS SST predictions, (e)–(h) SST persistence, and (i)–(l) difference in correlation skill between CFS predictions and persistence at 0-, 2-, 4-, and 6-month lead. For CFS minus persistence positive values (solid lines) mean CFS skill is better than persistence. The contour interval is 0.1. Correlation skill higher than 0.1 is significant at the 95% confidence level.

100m T anomaly correlation: model does better along coast and equator

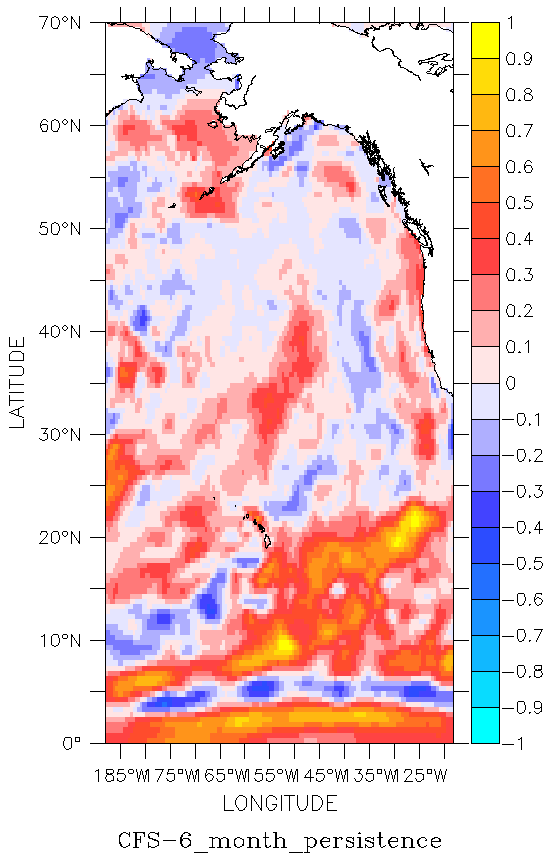
Model forecast



Persistence forecast

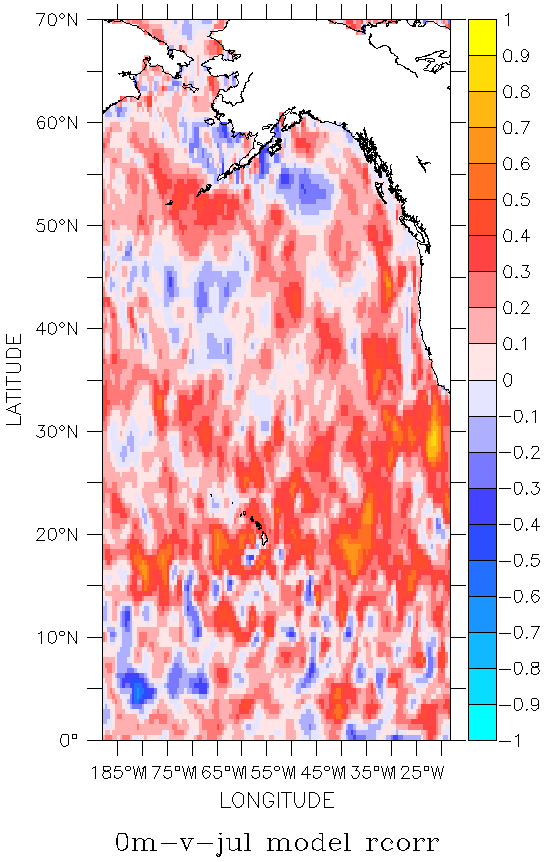


Model – Persistence

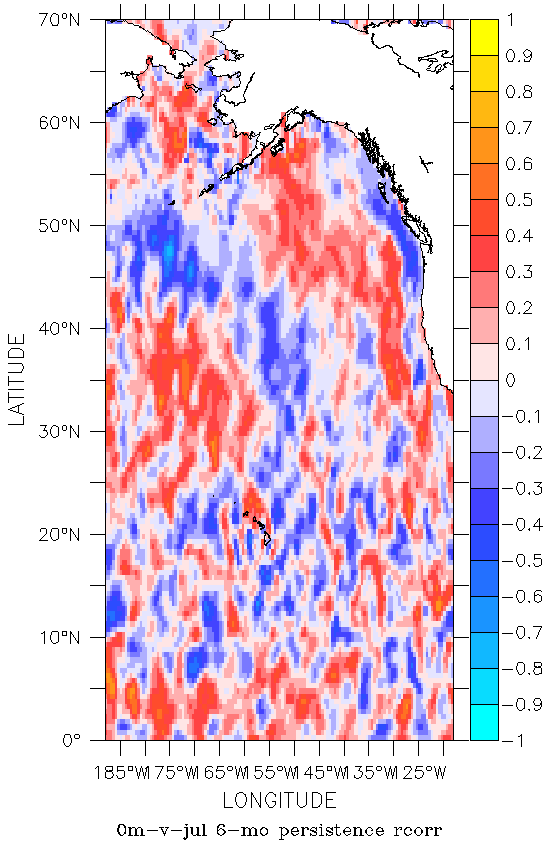


0m N/S velocity anomaly correlation: model does better along coast

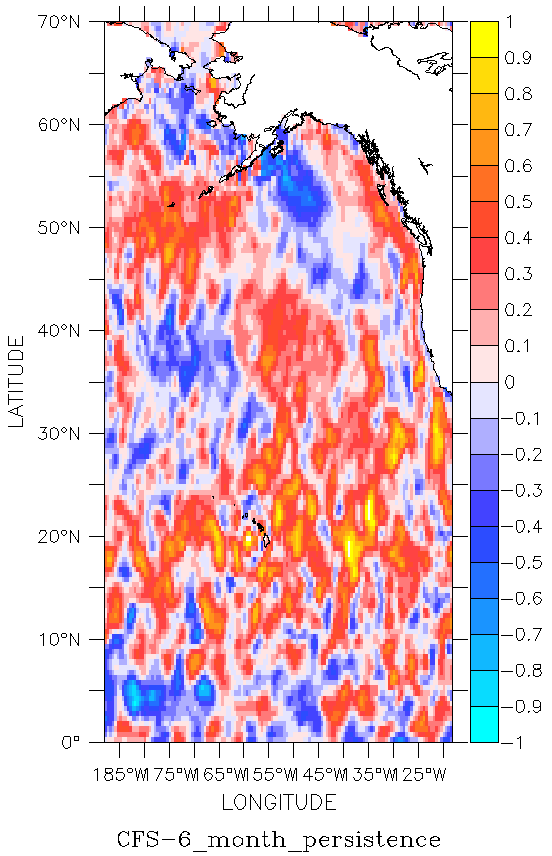
Model forecast



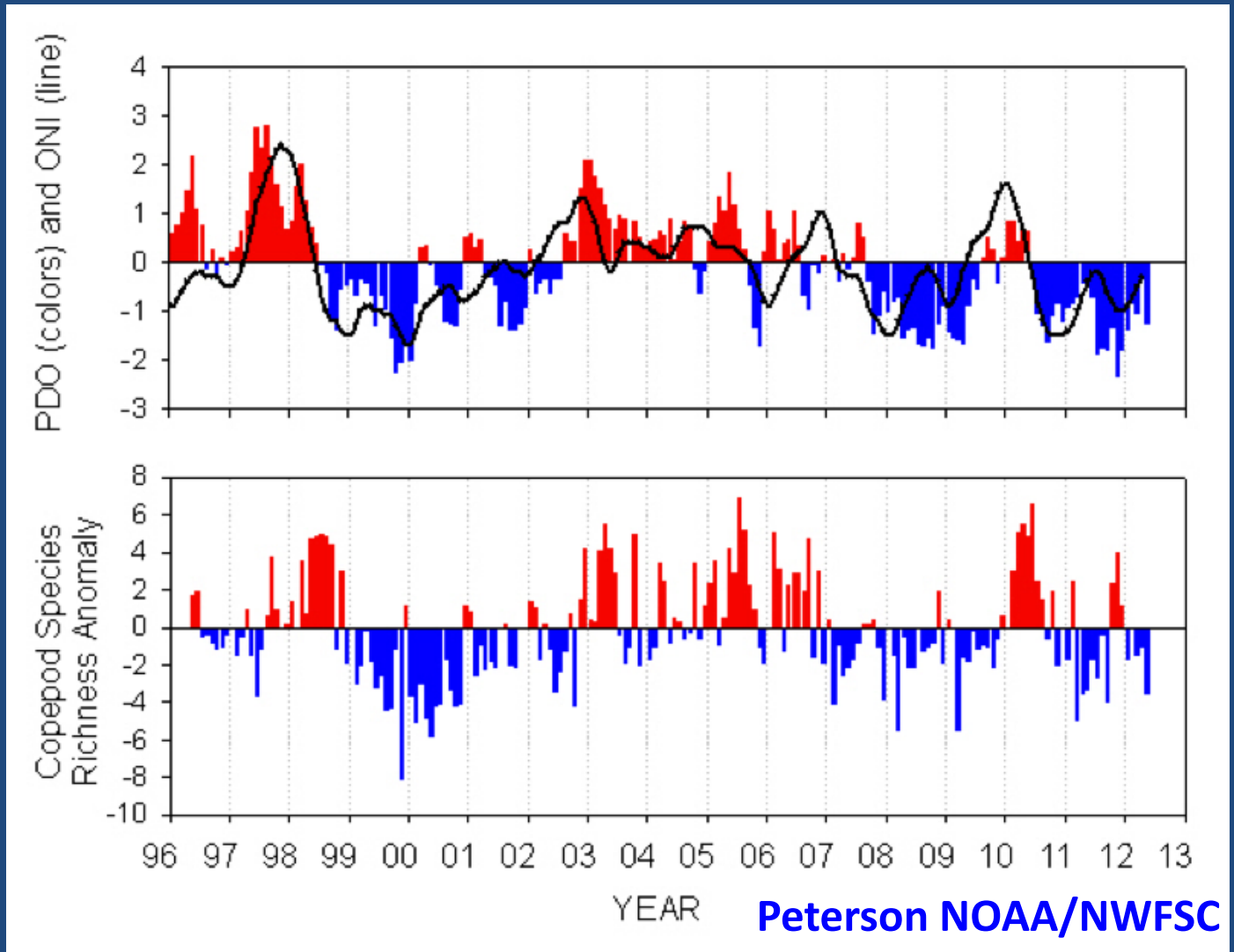
Persistence forecast



Model – Persistence

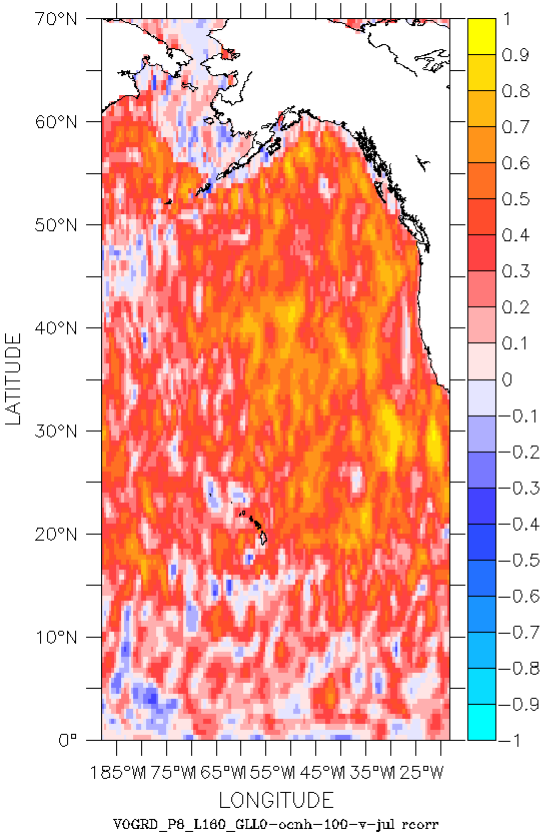


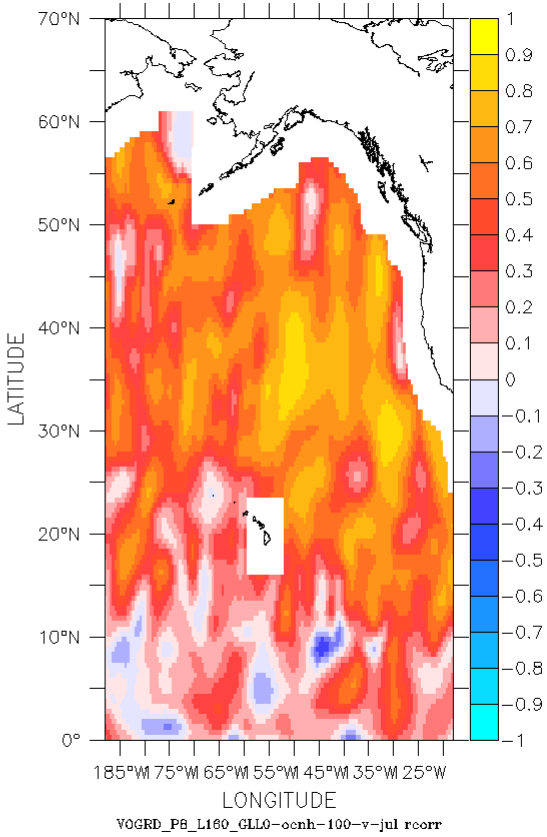
This is good news for predicting boreal/subtropical zooplankton!



Peterson NOAA/NWFSC

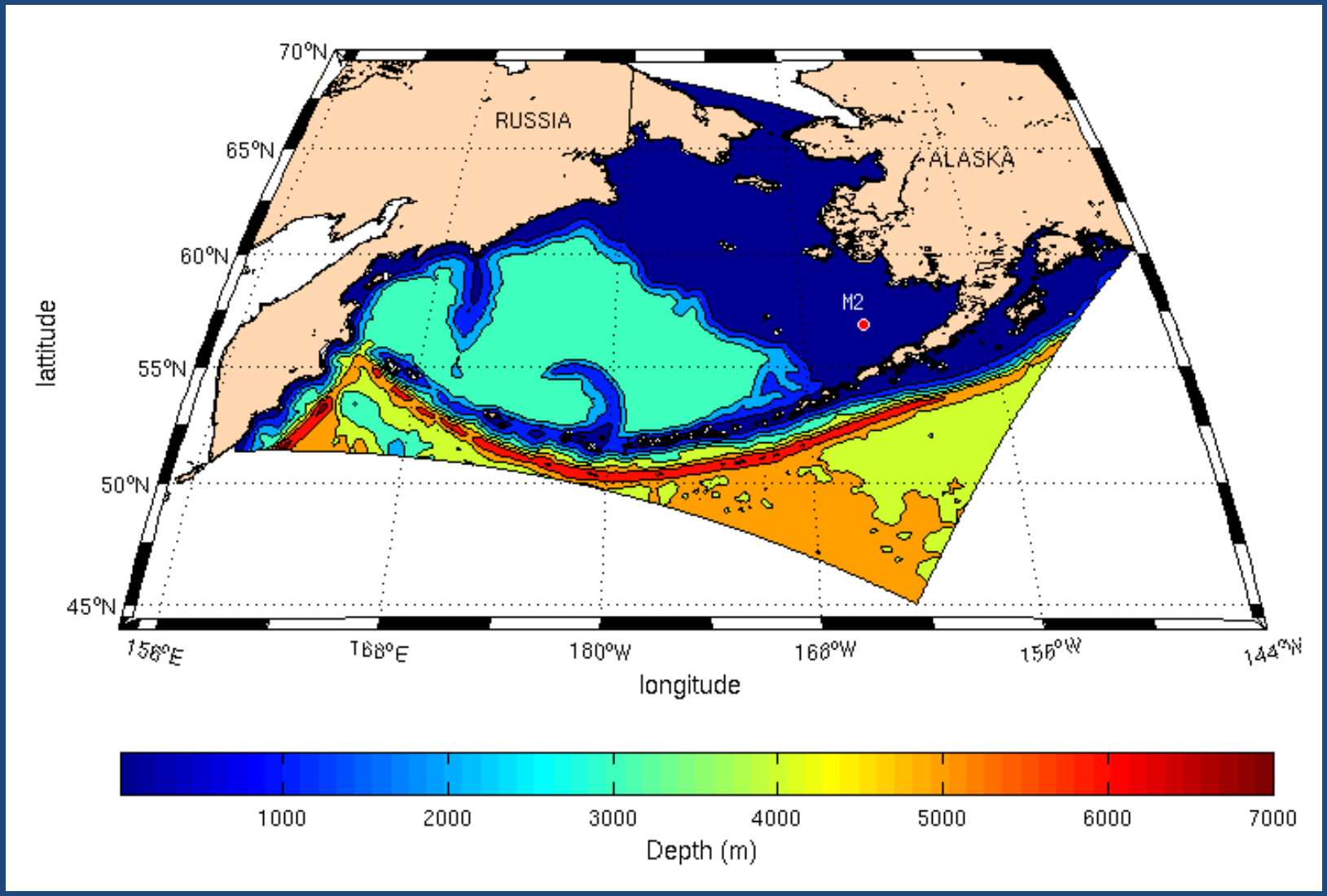
100m N/S velocity anomaly correlation: compare results after spatial averaging -> forecast skill improves

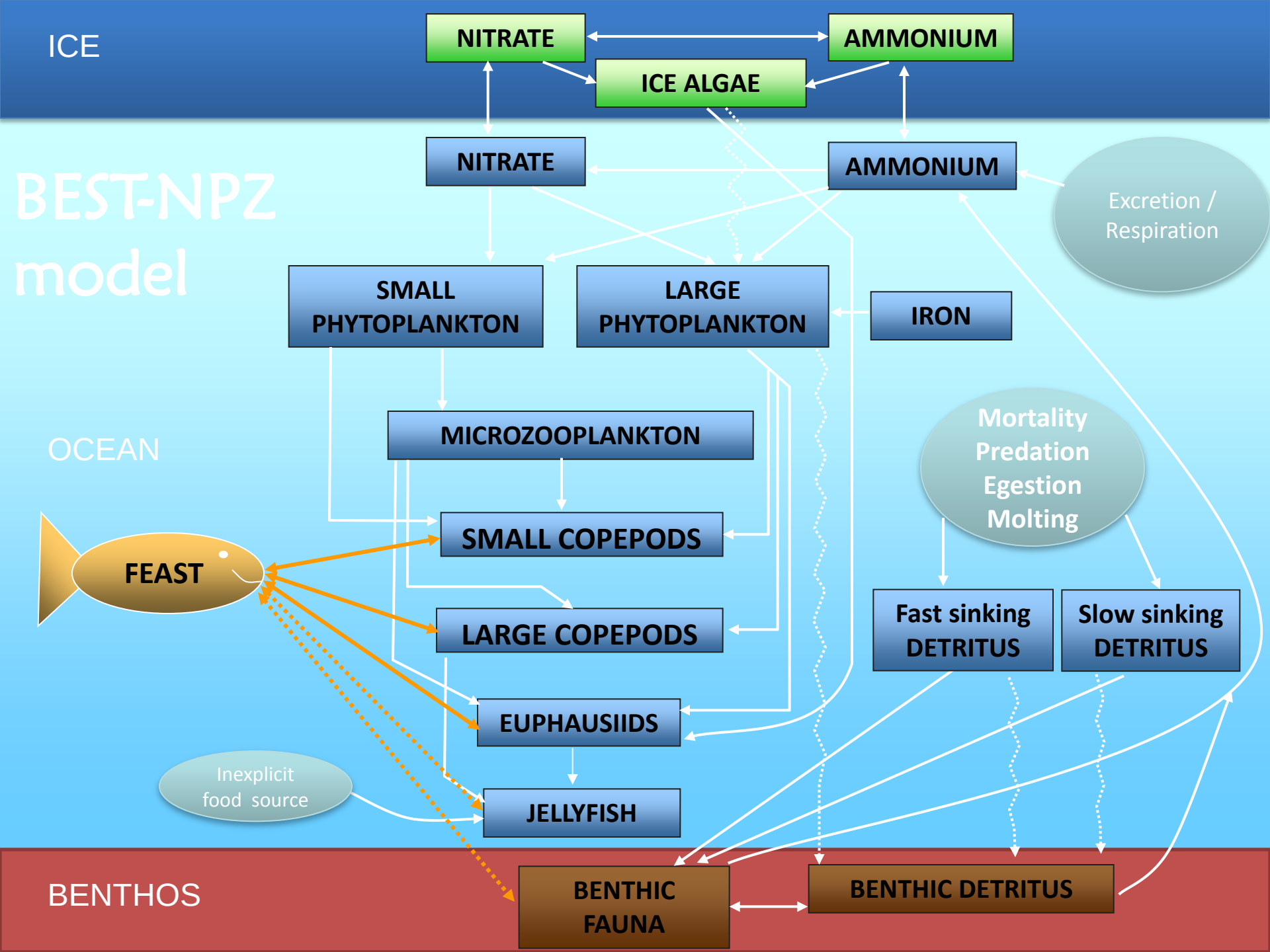




Bering Sea Model

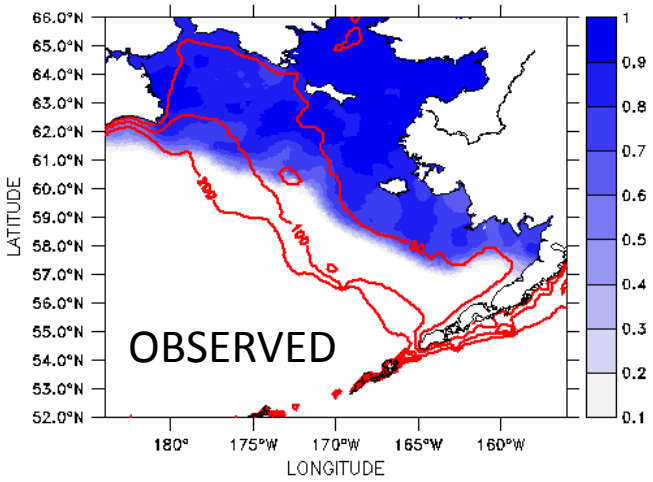
10 layers, 10-km grid
Includes ice and tides
CCSM heat flux algorithms

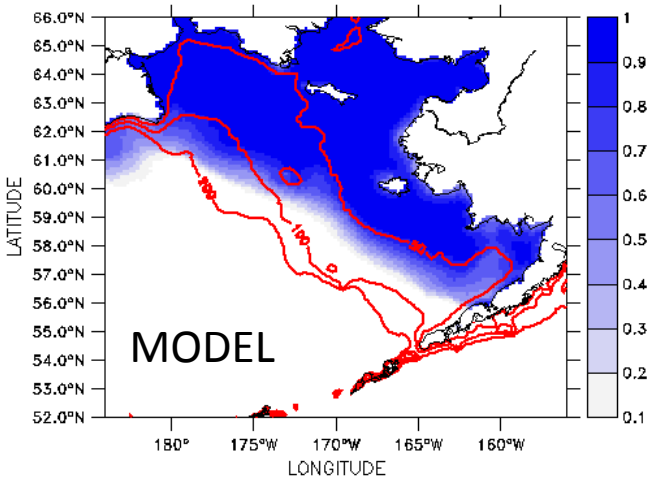



ICE
NITRATE
AMMONIUM
ICE ALGAE
NITRATE
AMMONIUM
Excretion / Respiration
BEST-NPZ model
SMALL PHYTOPLANKTON
LARGE PHYTOPLANKTON
IRON
OCEAN
MICROZOOPLANKTON
Mortality
Predation
Egestion
Molting
SMALL COPEPODS
FEAST
LARGE COPEPODS
Fast sinking DETRITUS
Slow sinking DETRITUS
EUPHAUSIIDS
Inexplicit food source
JELLYFISH
BENTHOS
BENTHIC FAUNA
BENTHIC DETRITUS

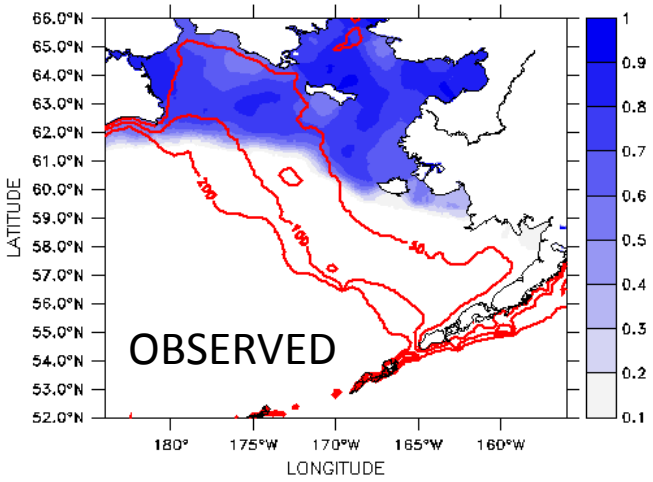
PREDICTION OF JANUARY FRACTIONAL ICE COVER

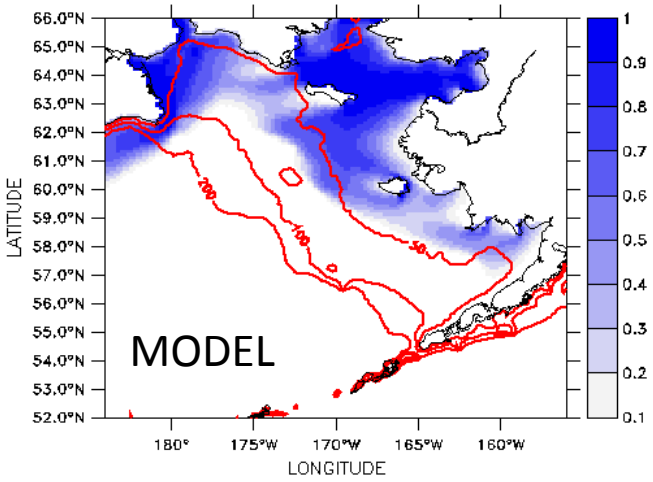
compare 2012 hindcast with data (GODAE/GHRSST)





compare 3-month 2014 forecast with data (forecast date: Oct 2013)





Conclusions

- CFS has significant skill for temperature and velocity, partly through persistence at depth
- Enhanced skill in coastal zone may allow predictions of boreal versus subtropical zooplankton, with implications for salmon
- Biological persistence at large space/time scales can be exploited for prediction
- Biological predictability studies are needed
- Looking ahead, bio forecasts with uncertainty, available online!