Forecasting changes in cetacean density patterns

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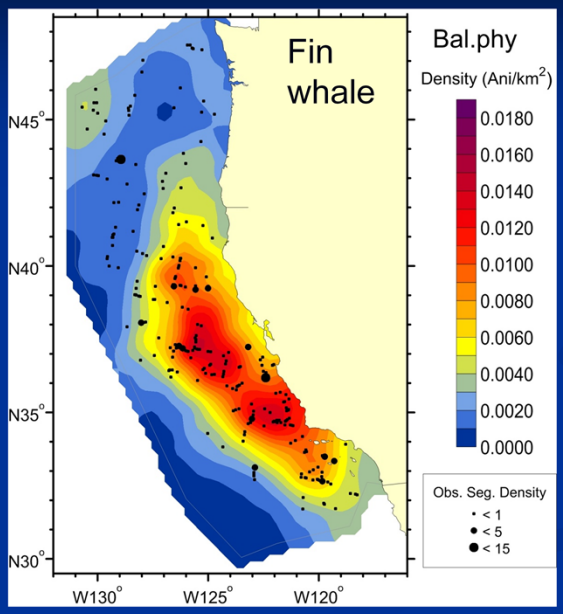
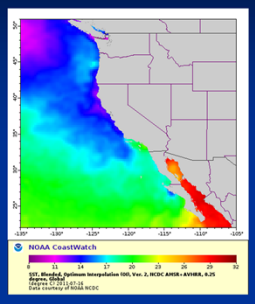
Average multi-year summer/fall density



Model averages represent our best prediction of spatial animal distribution.

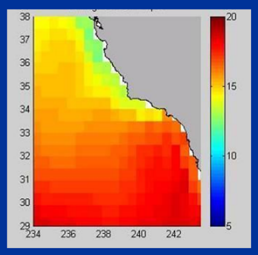
HOWEVER, they do not account for actual ocean conditions in any given year (e.g. strong El Niño)

Can we predict cetacean distributions weeks or months in advance?



NOWCASTS

- Use near real-time satellite products
- “Blended SST” = no coverage gaps
- Allows for daily to weekly predictions

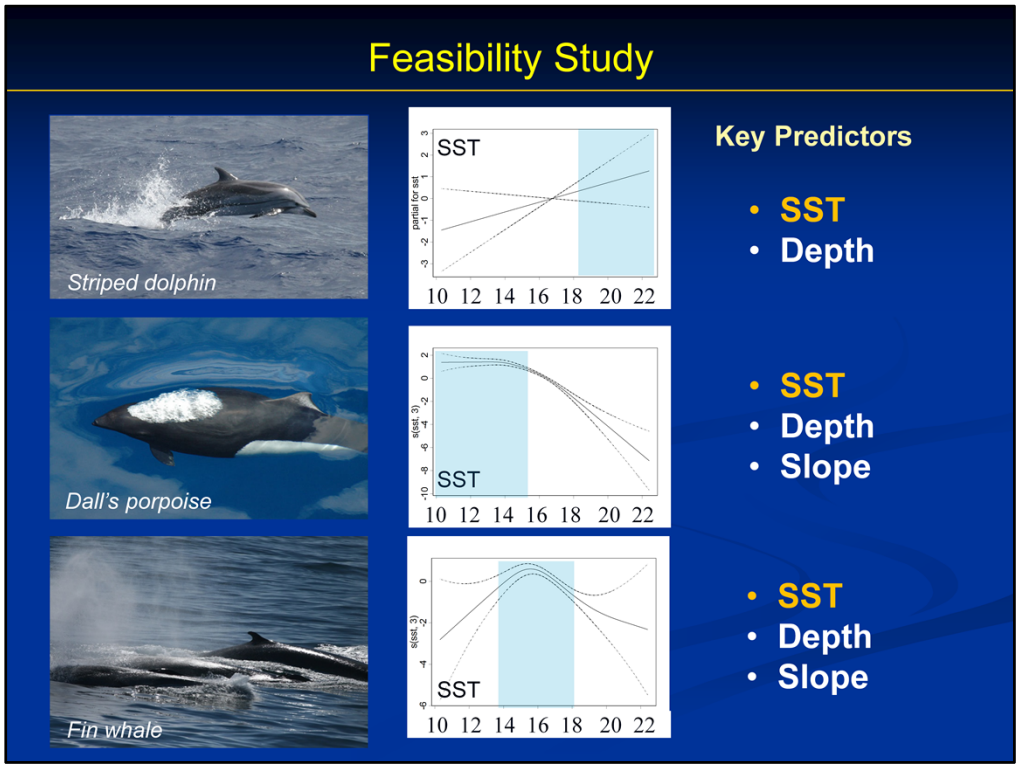


FORECASTS

- Use ocean circulation models, e.g. *Regional Ocean Modeling System (ROMS*)
- Predict months in advance

Becker et al. 2012, Endangered Species Research

Advances in high performance computing and high-resolution physical models now make forecasts of oceanic properties possible.

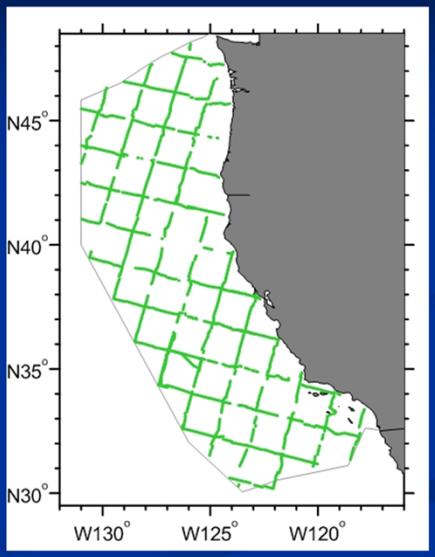


We conducted a feasibility study using three different species that have consistently been associated with certain sea surface temperatures.
These plots show the functional relationship of the encounter rate GAMs with SST. For the feasibility study we limited potential predictors to SST, depth, and slope.

Validation

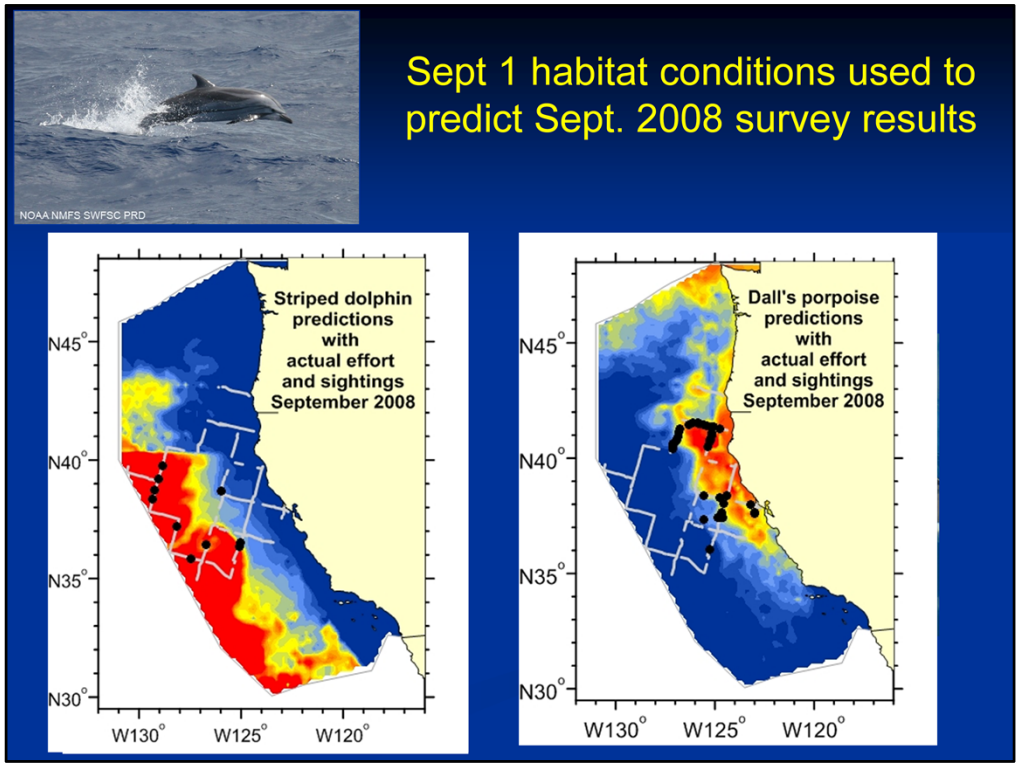
- Use 1991-2005 models to predict density on environmental conditions for 2008.
- Use 2008 survey data to assess predictive performance.

Fin whale
Balaenoptera physalus



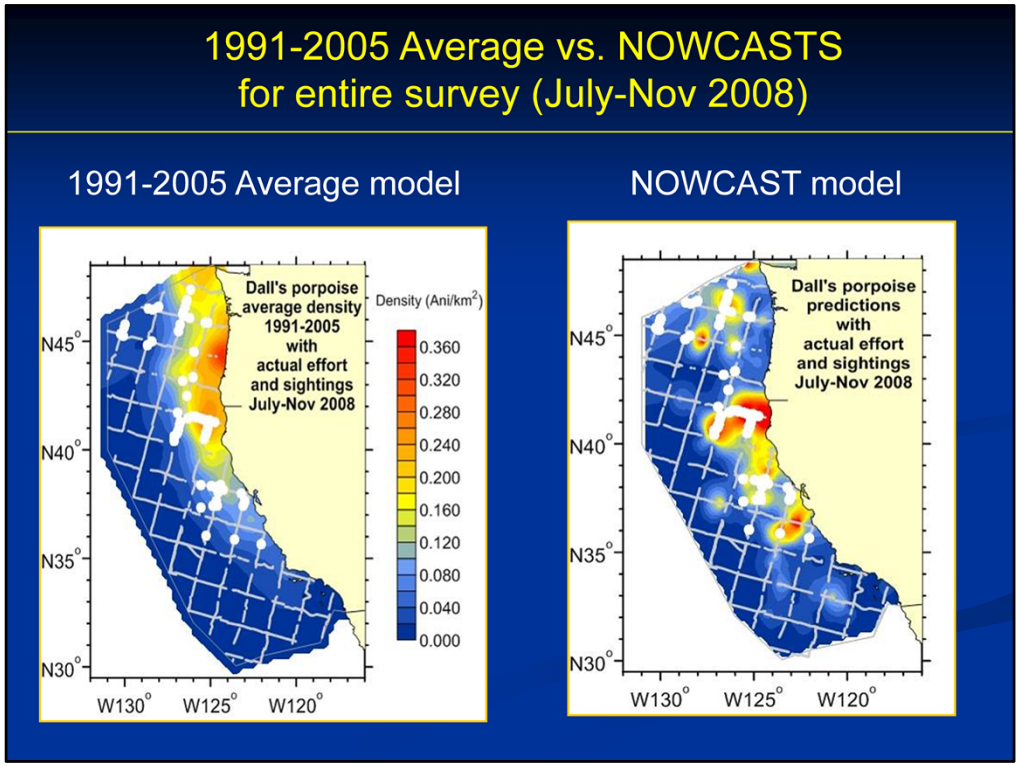
Completed transect lines 2008

We set up a mock forecast ('validation') where we built models with the 1991-2005 survey data and predicted on environmental conditions during 2008. We then used actual effort and sightings from our 2008 survey to evaluate model performance.



These are example NOWCAST results: density predictions for striped dolphin (left panel) and Dall's porpoise (right panel) using blended daily SST values for September 1, 2008. High predicted densities are depicted with red and orange, low densities with blues.

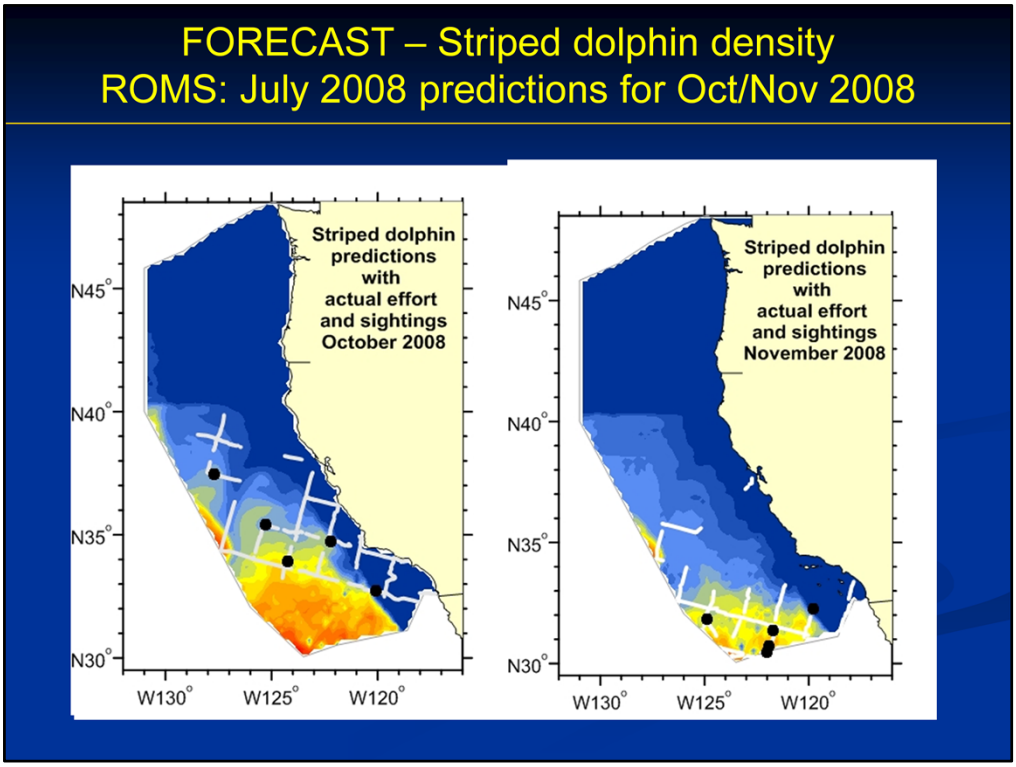
Actual survey effort (white lines) and species sightings (black dots) are shown for the entire month of September 2008. Our initial nowcast prediction is showing some forecast ability on a scale of 2-4 weeks.



Next we used daily blended SST for each survey day to make 'nowcast' predictions for the entire 2008 survey. Gray lines are 2008 survey transects, white dots are 2008 sightings.

The left panel shows our Dall's porpoise average density prediction based on the 1991-2005 survey data. The right panel shows the new 'nowcast' density predictions (using daily SST values).

The nowcast more accurately captured Dall's porpoise distribution patterns than the average"model, i.e. picking up the high-density area off northern CA and the lower density area off the OR/WA coast.



Forecast models were created for October and November 2008, respectively, from ROMS predictions made during July (3-4 months before). Sample forecast densities for striped dolphin are shown in these two figures, along with survey effort (white lines) and sightings (black dots) during those months. There was good concordance, with sightings in areas of moderate to high density predictions, and few or no sightings along transects predicted to have low density.

Ratios of observed/predicted (FORECAST)

	Density Ratio (survey/model predicted)			
	October 2008		November 2008	
	Average	Forecast	Average	Forecast
Striped dolphin	0.27	0.47	0.44	0.53
Dall's porpoise	0.18	0.23	-	-
Fin whale	2.77	1.78	1.33	0.99

FORECAST model ratios were closer to 1 than (static) 'average' models for both Oct and Nov 2008 for all three species

For model evaluation we also compared the model-based abundance values to standard line-transect estimates for October and November 2008.
(Ratios are line-transect derived (="survey") : model predicted densities; ratios close to 1 are best)

For all 3 species and both months, the forecast predictions were more similar than our average predictions to those estimated using standard line-transect analyses, particularly for fin whale, for which the November prediction ratio was almost one.

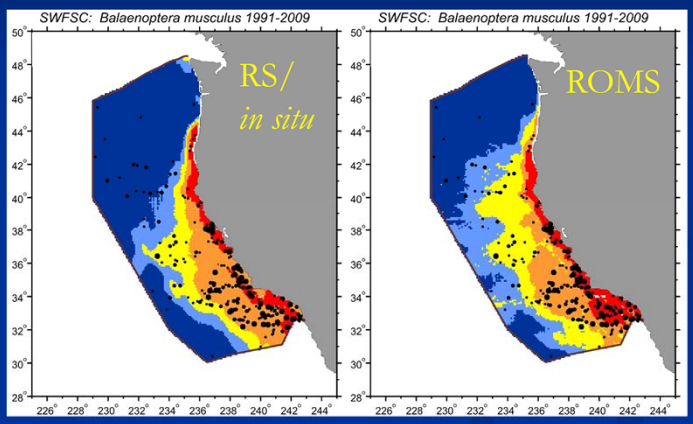
Building on ROMS case study using 8-day, 0.1 degree UCSC ROMS reanalysis

Additional predictors:
salinity, mixed layer depth, sea surface height, potential energy anomaly (stratification)

Additional species:
14 cetacean species/guilds

Additional surveys:
2009 & 2014

Model comparison

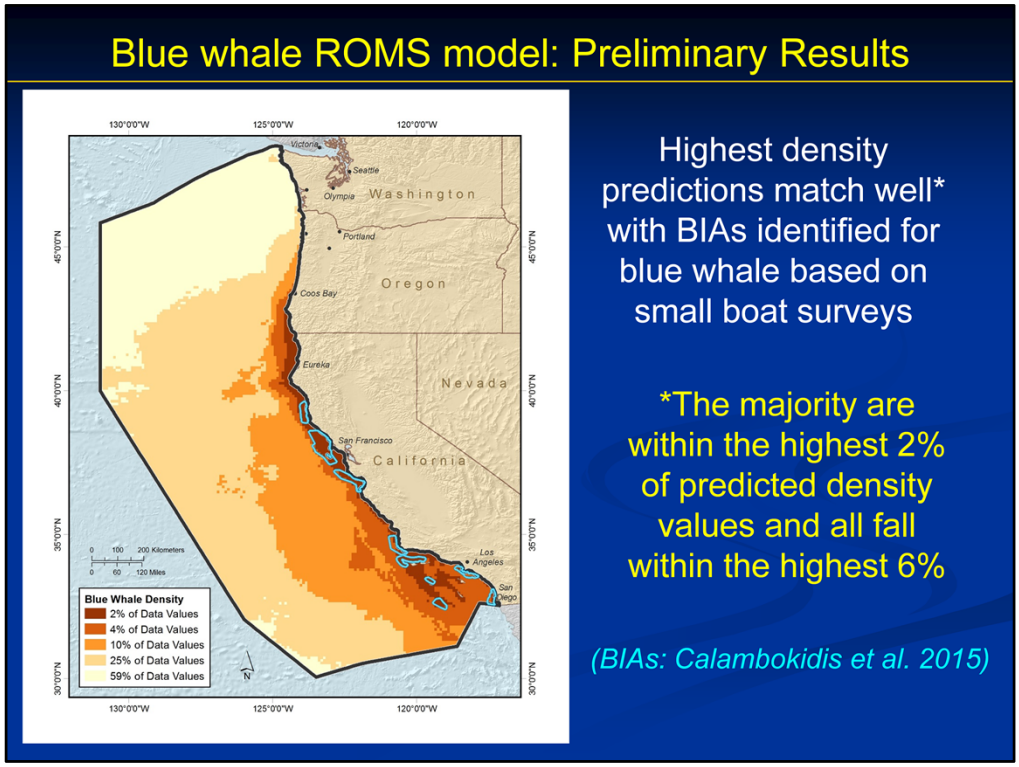


Models built with ROMS data can support dynamic species management (nowcasts, forecasts, climate change)

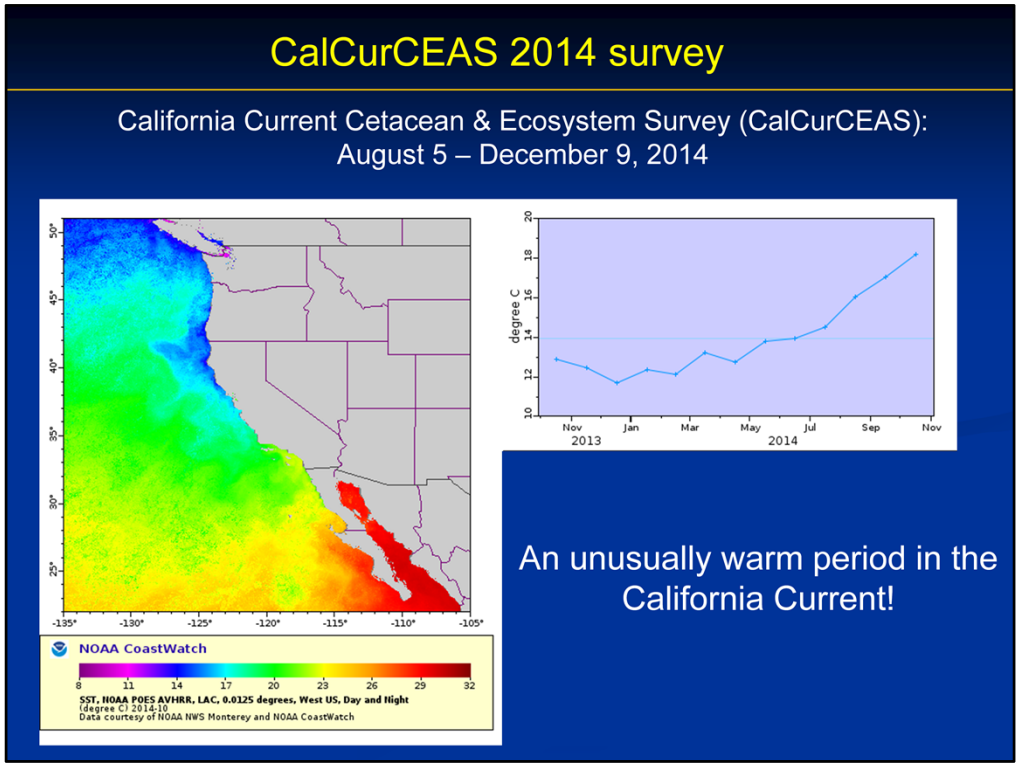
Becker et al., in prep.

We are now moving forward with developing additional models for 14 species, using additional ROMS habitat variables and incorporating new survey data.

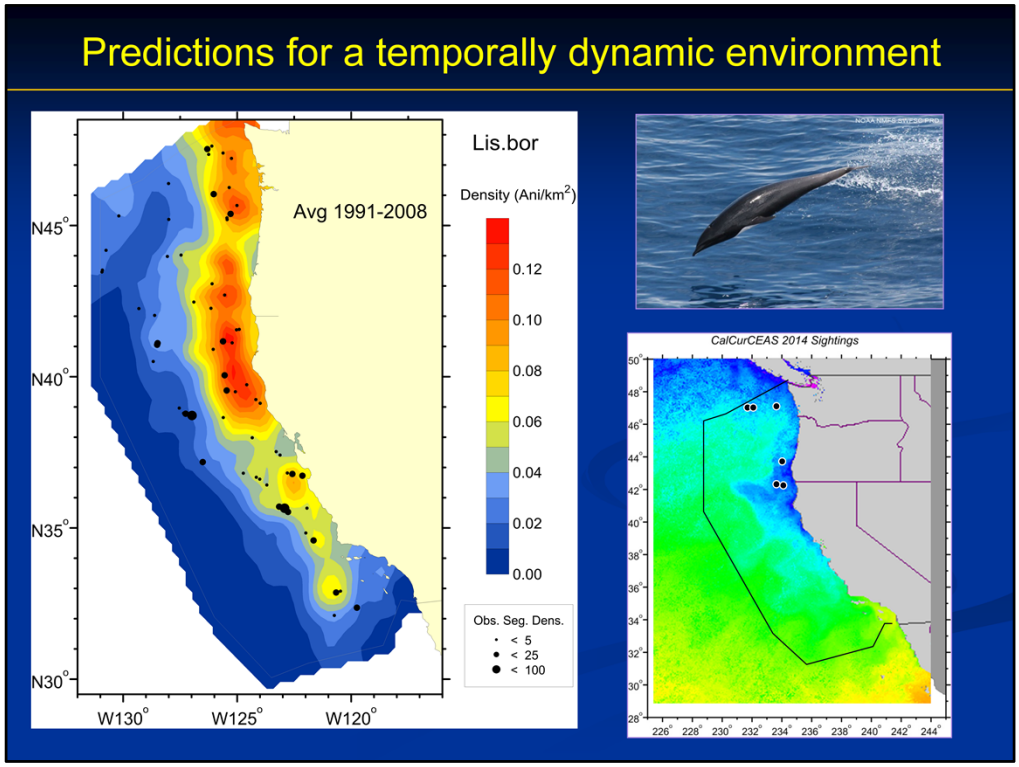
Such ROMS-based models could be used to support dynamic management, so we are comparing the modeled densities to those built with our traditional measured data sources (remotely sensed and in situ). The two panels show, for example, that blue whale density predictions for models using ROMS vs traditional habitat variables are very similar.



The blue whale model built with ROMS data had better performance metrics than the model built with measured data, and it also fit external (independent) data very well. The areas shown with the blue boundaries are “biologically important areas” (BIAs) identified by Calambokidis et al. 2015 using a completely different dataset (mainly small boat surveys).



Our 2014 CalCurCEAS survey coincided with an unusually warm event in the California Current. The plot on the left shows SST for October of 2014. The right panel is a monthly plot of SST showing an almost linear increase in temperature in late summer into fall, during the survey.



During such unusual warm-water events, species ranges may shift dramatically; in such cases, our average density predictions may not be a good representation of true distributions.

For example, this is our average density prediction for northern right whale dolphins (a cool-temperate species) based on the 1991 - 2008 survey data. During the warm conditions in 2014, northern right whale dolphin were only seen in the far northern portion of our study area in the coolest water. This more limited distribution is not captured well by our average prediction, but we expect that nowcast models would be more accurate (work in progress). For this reason, it is important to move towards dynamic species-distribution modeling, on a real-time and forecast basis – particularly as climate changes and species distributions may change.

Summary and conclusions

- Results are promising for dynamic species management:
  - NOWCASTS possible on time scales of days to weeks
  - FORECASTS possible on time scales of 3-4 months
- Advances in remote sensing and ocean model products allow cetacean predictions at a variety of temporal scales (nowcasts, forecasts, seasonal, climate change)
- This capability is increasingly important for assessment of current and future risks to marine mammals in a changing environment.

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