Selecting **appropriate methods for modeling** the distribution of fish life stages may provide more insight into **species responses to environmental variability**

The influence of size and ontogeny on the distribution of juvenile forage fishes

Rebecca A. Howard[1], Lorenzo Ciannelli[1], John C. Field[2], Brian K. Wells[2,3], Lewis A.K. Barnett[4], Rebecca G. Asch[5]

[1]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University; [2]NOAA Fisheries, Southwest Fisheries Science Center; [3]NOAA Fisheries, Northwest Fisheries Science Center; [4]NOAA Fisheries, Alaska Fisheries Science Center; [5]Department of Biology, East Carolina University

Objectives

We aimed to (1) determine if variability in life history impacts how we can best model the distributions of different fish species and (2) evaluate the benefit of using size-structured species distribution models compared to size-aggregate models.

Data

Rockfish Recruitment and Ecosystem Assessment Survey and Pre-Recruit Survey (1987 - 2018)

- Data collected off U.S. West Coast from April to June in the California Current System
- Includes CTD data (temperature and salinity)
- Used catch and size data for northern anchovy (*Engraulis mordax*), shortbelly rockfish (*Sebastes jordani*), widow rockfish (*S. entomelas*), Pacific hake (*Merluccius productus*), and Pacific sanddab (*Citharichthys sordidus*)

Methods

Variable coefficient generalized additive models (GAMs)

- *Size-aggregated models* included all catches for all sizes
- *Size-structured models* incorporated two models, one for small sized fish and one for large sizes
- Variable coefficient terms (lon, lat, by = climate index) allow location of catch to vary with a given climate index (PDO, NPGO, or ONI), for which an average value was calculated for each year during the pre-survey months. Best model was selected using AIC.

$$\ln(count+1) = year + s(lon, lat) + s(day\ of\ year) + s(SST) + s(SSS) + s(depth) + s(lon, lat, \text{by} = climate\ index) + \varepsilon$$

Leave-one-group-out cross validation

- Iteratively left out one year of data, then predicted on left out year's data
- Calculated yearly root mean square error (RMSE) and overall RMSE for size-aggregate and size-structured models (**Figure 1, Table 1**)

Predictive error increases for anomalously warm years

Figure 1 shows that the RMSE noticeably increases during the years the California Current System experienced a marine heat wave (2014-2016). These figures show the RMSE for the combined size-structured models for each species but this pattern of increasing RMSE was seen for all species and for both model types. As seen in other studies (Muhling et al., 2020), these results show that it is difficult to forecast species distributions under anomalous environmental conditions as model accuracy is decreased.

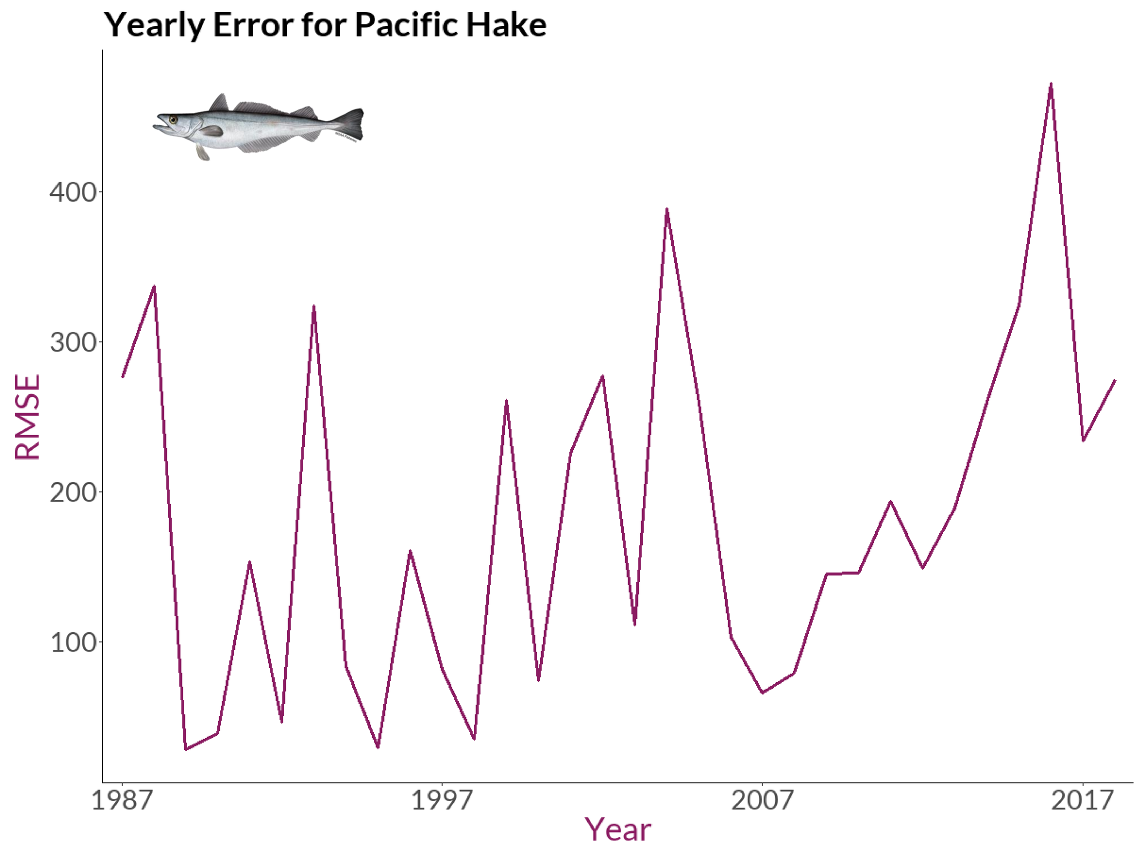
Size-structured models improve predictions for some species

Table 1 shows the average RMSE for the size-aggregate and size-structured models for each species. For northern anchovy and Pacific sanddab, the size-structured models clearly have a lower RMSE. For the two rockfish species and Pacific hake, the RMSE is about the same for each model. This shows that for the rockfishes and Pacific hake, the size-aggregate model may be sufficient for modeling species distributions, while for the other species it may be better to use a size-structured approach.

Climate effects on species abundance differ by size grouping

Figure 2 depicts both the species' distributions and the effect of the variable coefficient term on abundance for different size groupings. Blue circles represent a decrease in abundance with an increase in the climate index value, while the red circles represent an increase in abundance with an increase in the climate index value. Size indicates magnitude of increase or decrease. This "effect" of climate is different depending on the size grouping, as is the predicted distribution of the species. These maps also illustrate how despite the low reduction in error with the size-structured models for these species, there are still differences in distribution for different size groupings.

Figure 1: Yearly predictive error calculated through leave-one-group-out cross validation



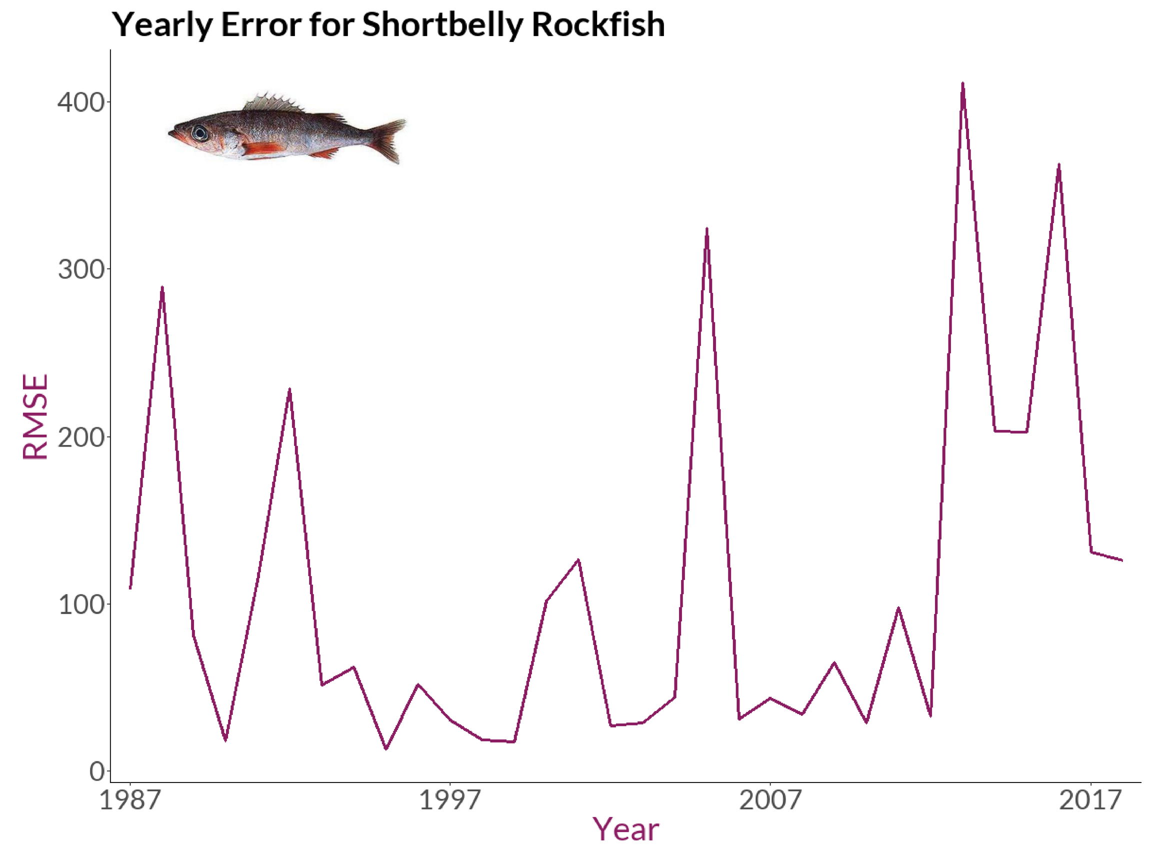
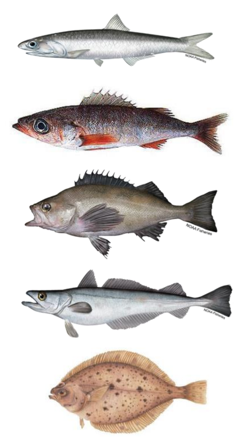
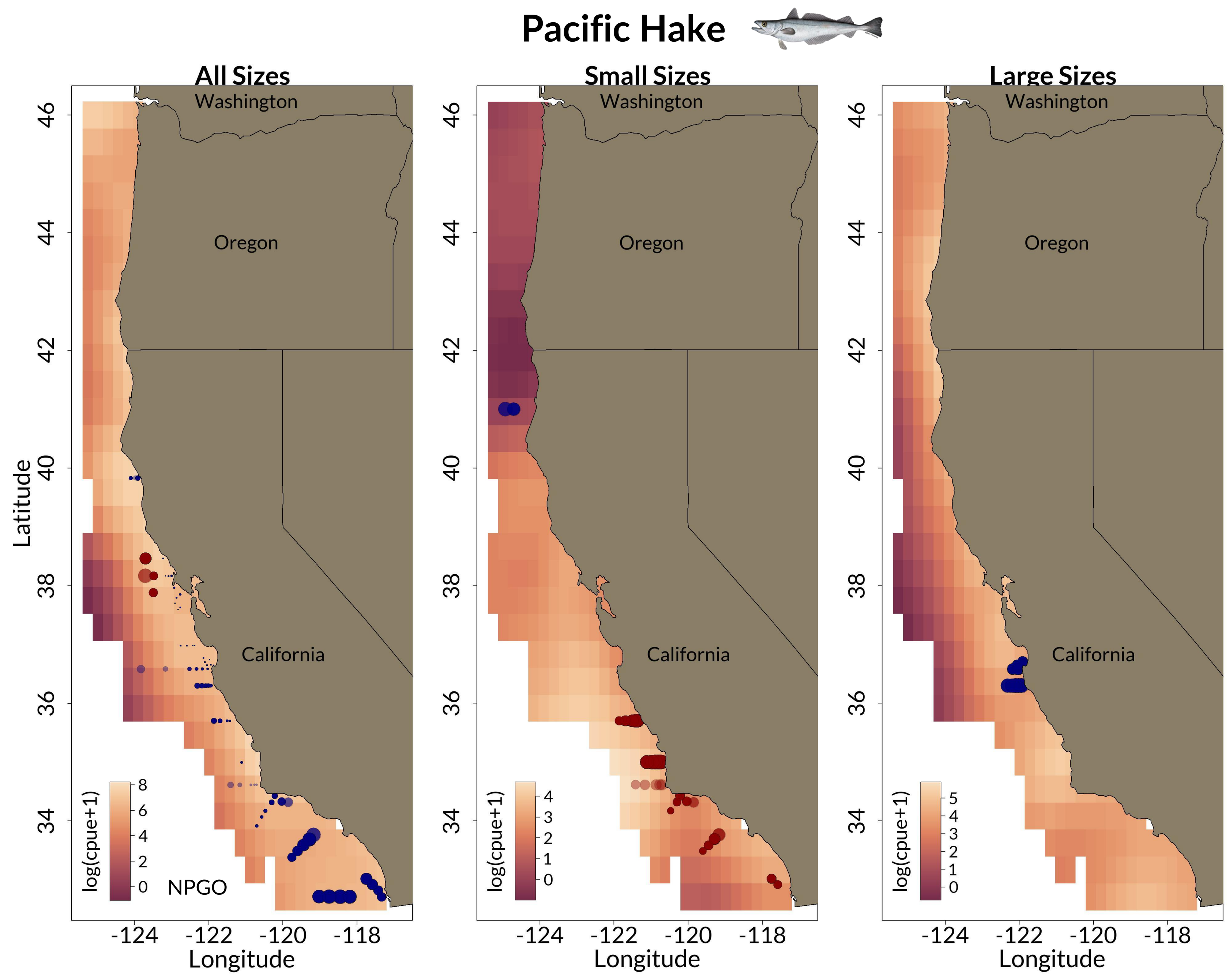


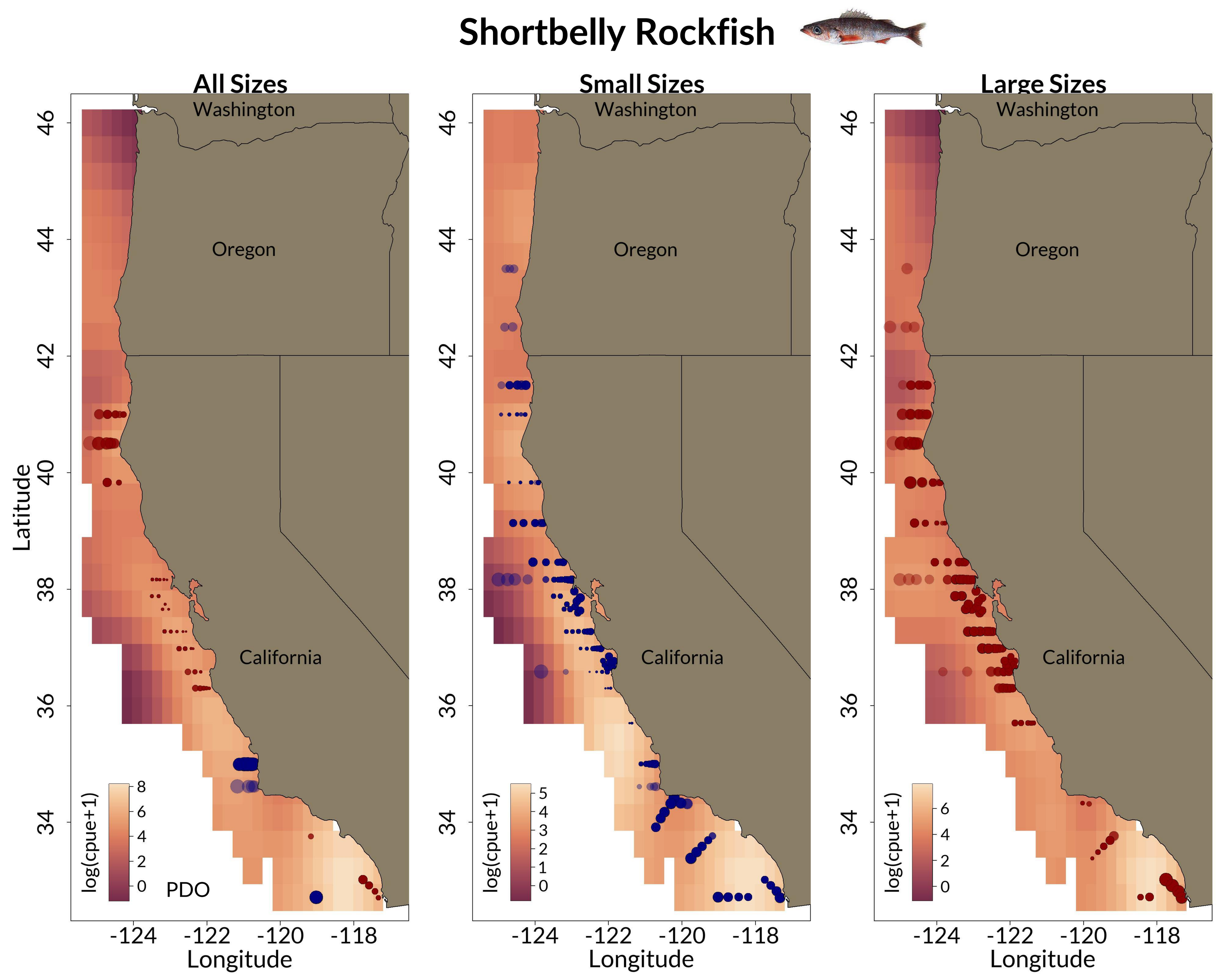
Table 1: Average predictive error per model



Species	Aggregate Model	Structured Model	Percent Decrease
northern anchovy	371	321	13.5%
shortbelly rockfish	111	110	0.9%
widow rockfish	12	12	0%
Pacific hake	186	182	2.2%
Pacific sanddab	65	54	16.9%

Figure 2: Species distributions and effect of variable coefficient term





Take a picture to get in touch

Contact: Rebecca Howard: howardre@oregonstate.edu

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Oregon State University College of Earth, Ocean, and Atmospheric Sciences