Spatial and temporal visualizations of satellite-derived sea surface temperatures for Alaska fishery management areas

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Abstract

A common pursuit in fisheries research is to understand the relationship between fisheries data and the surrounding environment. However, environmental data are often unavailable at similar scales as fishery data. To mitigate this disconnect, more than 6,000 daily satellite datasets (containing ~ 24 billion individual temperature records) from 2003—2019 were rectified with spatial fisheries management areas. This union facilitates a smoother linkage between satellite-derived sea surface temperatures and the spatial management units often used by state and federal scientists in Alaska. Visualizations of these data help users to explore the spatial (e.g., state and federal management grids) and temporal (e.g., daily, weekly, monthly) scales of the data and allow users to filter, download, and visualize trends. For users in regions outside of Alaska, R code can easily be modified for different spatial regions to integrate NASA or other environmental satellite data with spatially-explicit fishery information.

Introduction

This project sought to join several datasets to better facilitate exploration of the role that sea surface temperatures (sst) may have on commercial fisheries in Alaska waters. While the scope of this effort is limited to Alaska, the approach could be easily modified (by simply changing geographic coordinates and spatial strata) to make use of the same global temperature dataset.

The dataset visualized here includes daily average sst for each of 1,756 management areas (polygons) in Alaska state and federal waters from January 01, 2003–March 02, 2019. Most of the state management areas are regular polygons (rectangles). The accompanying visualizations provide users with an opportunity to readily filter and extract desired subsets of data, as well as exploring trends in temperatures and temperature anomalies. The latter

may be particularly useful for users that are less familiar with programming environments but that are still interested in comparing trends in temperatures across areas. By including the ability for users to download subsets of data at different spatial or temporal scales, the visualizations more readily enable users to extract only the data of interest, reducing file sizes and processing times for subsequent analyses. For users with access to fishery-dependent data (not shown), the sst dataset can be linked by location and date to further explore trends in catch and fisher behaviors.

Methods

Spatial data

Alaska's commercial fisheries are prosecuted in federal and state waters, with many catch locations recorded by spatial strata. Two primary units for these spatial strata are the Alaska Department of Fish and Game (ADF&G) groundfish statistical areas and the National Marine Fisheries Service (NMFS) reporting areas. A shapefile of the state areas was downloaded from the ADF&G with polygons representing the state groundfish statistical areas (also called "stat6" areas). In addition to having downloads enabled, this link also allows an interaction exploration of the map with associated data attributes for each statistical area. The majority of the polygons span 1° longitude x 0.5° latitude though many of the nearshore areas follow coastline contours and form less regular features. Attributes for these state polygons include additional information about the polygons related to several different fisheries and management programs including whether a polygon: occurred in state or federal waters (STATEFED); occurred in the Bering Sea Aleutian Islands (BSAI) or Gulf of Alaska (GOA) fishery management plan area (FMP_AREA_C); and in which NMFS reporting area (NMFSAREA) the polygon occurred.

Alaska has a clearly defined management area grid but for other areas globally with less defined structure, users could create their own spatial grid system (Bivand *et al.* 2013) for stratification of their fishery environment.

Temperature data

Sea surface temperature (sst) data originated from the NASA Group for High Resolution Sea Surface Temperature Level 4 analysis (JPL MUR MEaSUREs Project. 2015). These data were extracted from the NOAA CoastWatch West Coast Node ERDDAP server where they were searchable as "Multi-scale ultra-high resolution (MUR) SST Analysis fv04.1, Global, 0.01°, 2002 - present, daily." Data from the CoastWatch site can be manually extracted using a graphical user interface that allows users to specify geographic coordinates and dates, but for querying multiple days of data, an automated data scraping script was more feasible. The data scraping script is described in conjunction with matching to the spatial management areas below. Processing and download of the full script (2003 - 2019) required several hundred hours of processing time.

Data processing

U.S. federal waters extend beyond the 180° meridian, resulting in both positive (west of the meridian) and negative (east of the meridian) longitudes. To simplify coding (performed via R 3.5.0 [R Core Team 2018]), the temperature extraction and matching with state management areas was performed separately for the positive and negative regions (no single state statistical areas straddles the 180° meridian). Daily netcdf temperature files were downloaded and extracted (R packages **ncdf4** [Pierce 2017] and **RCurl** [Duncan Temple Lang and the CRAN team 2018]) for the North Pacific, bounded from 167°W to -130.01°W longitude and 47°N to 68°N latitude, and from 167°E to 179.9°E longitude and 47°N to 60°N. For each day, a point-in-polygon operation (R package **sp** [Pebesma and Bivand 2005; Bivand, et al., 2013]) matched all temperature data with a state statistical area. The typical 1° x 0.5° grid cell contained about 5,000 temperate records. All temperature records for each statistical area (> 4.3 million records per day) were averaged to yield a single mean and standard deviation for each statistical area and day. Before averaging across management areas, the full dataset included ~24 billion records but the final dataset was aggregated to ~10 million records. Matching was only performed on state statistical areas; NMFS reporting areas are larger than state statistical areas so any reporting at the NMFS reporting area level resulted from averaging the single mean values for each state statistical area contained in that NMFS area.

Occasional timeout errors occurred during the data download process for a given day; the R script includes several quality control steps to ensure that any missing data were re-queried and rectified with the full dataset. Additional steps included extraction of Julian day, week (starting on Sunday), month, and year for each record. The **sp** package was used to extract the bounding box coordinates for each statistical area to allow the user to more easily filter areas based on the coordinates (e.g., filter out all statistical areas whose minimum latitude is less than some value).

Average depth for each statistical area was also calculated so that users could more easily subset areas that were primarily on or off the continental shelf. To maintain consistency with the temperature data, geographic coordinates for each state statistical area matched those from the temperature queries. Bathymetry data were obtained and rasterized for the same spatial ranges as for the temperature data (R package **marmap** (Pante and Simon-Bouhet 2013) and depths were extracted (R package **raster** [Hijmans 2017]) for each of the individual coordinates. Mean and standard deviations of depths were calculated for each statistical area. Areas with large standard deviations may be useful for identifying statistical areas that include the continental slope.

R scripts for data processing can be found at https://github.com/jordanwatson/ERDDAP.

Visualizations

The first loading of each visualization may take as much as a minute to load, depending on server traffic and speed, as the file being loaded contains 19 columns of information with nearly 10 million rows.

The first visualization allows users to select statistical areas from an interactive map and to compare temperature time series from those areas. For example, a researcher exploring recruitment trends of walleye pollock (*Gadus chalcogrammus*) in the GOA, may want to quickly determine whether spawning populations near Shelikof Strait experienced different temperatures than those fish recruiting near the Shumagin Islands. Adding state statistical areas 605431 (Shumagin Islands) and 555701 (Shelikof Strait), for example, to the second visualization would facilitate a rapid comparison between the western Shelikof and the Shumagin Islands. By default, data are displayed at the daily time scale, but using a drop-down menu, users can choose to smooth the data by using weekly or monthly averaged data instead. A year filter allows users to zoom into finer slices of temporal data.

The second visualization facilitates the rapid assessment of sst anomalies. This common metric is often used to explore how patterns of warmer or cooler than average years may be associated with fishery recruitment successes or failures. The visualization allows comparison of anomalies for each of the NMFS reporting areas by season, where summer is defined as April through September and winter is defined as October through the following March. Additionally, a slider allows the user to filter areas based on the average depth of each ADF&G statistical area within a given NMFS reporting area (the continental shelf is often described as about 200m and shallower). A second tab also allows users to explore anomalies for an individual month. Finally, a map is provided in a third tab to provide spatial reference for each of the NMFS reporting areas (or see Spatial Data section above for downloadable maps of these areas).

Finally, the third application is simply a queryable table of the data . Different tabs allows users to view the data by ADF&G statistical area or by NMFS reporting area, and within each tab, the data can be viewed at the daily scale or averaged with spatial areas by week or month. Data can be downloaded as either csv or rds file types. For R users, rds files are recommended as they are much smaller.

Citations

Bivand, R.S., Pebesma, E., Gomez-Rubio, V. 2013. Applied spatial data analysis with R, Second edition. Springer, NY. http://www.asdar-book.org/

Hijmans, R.J. 2017. raster: Geographic Data Analysis and Modeling. R package version 2.6-7. https://CRAN.R-project.org/package=raster

JPL MUR MEaSUREs Project. 2015. GHRSST Level 4 MUR Global Foundation Sea Surface Temperature Analysis (v4.1). Ver. 4.1. PO.DAAC, CA, USA. Dataset accessed [2018-05] at http://dx.doi.org/10.5067/GHGMR-4FJ04.

Pante, E. and Simon-Bouhet, Benoit. 2013. marmap: A Package for Importing, Plotting and Analyzing Bathymetric and Topographic Data in R. PLoS ONE 8(9): e73051. doi:10.1371/journal.pone.0073051

Pebesma, E.J., R.S. Bivand, 2005. Classes and methods for spatial data in R. R News 5 (2) https://cran.r-project.org/doc/Rnews/.

Pierce, D. 2017. ncdf4: Interface to Unidata netCDF (Version 4 or Earlier) Format Data Files. R package version 1.16. https://CRAN.R-project.org/package=ncdf4

R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Temple Lang, D. and the CRAN team (2018). RCurl: General Network (HTTP/FTP/...) Client Interface for R. R package version 1.95-4.10. https://CRAN.R-project.org/package=RCurl