Effects of the 2013-2015 warm anomaly in Prince William Sound, Alaska

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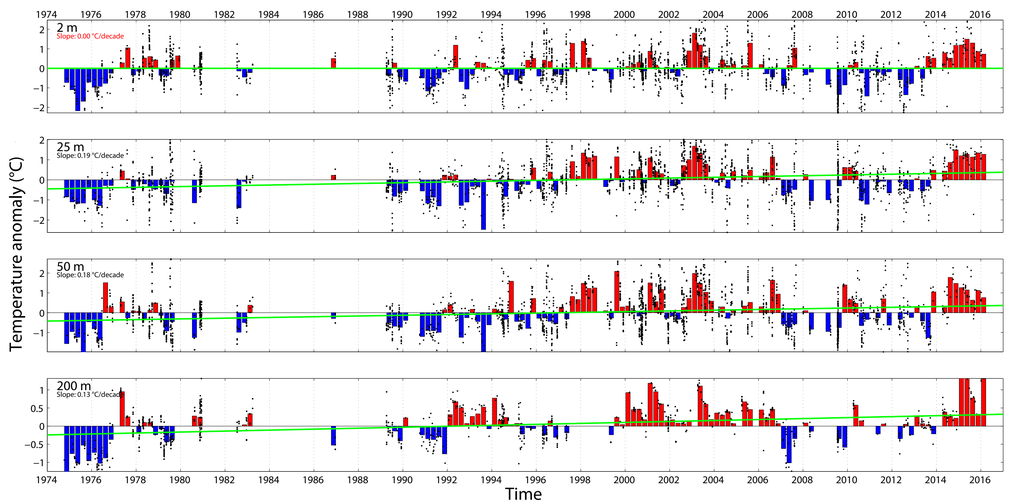
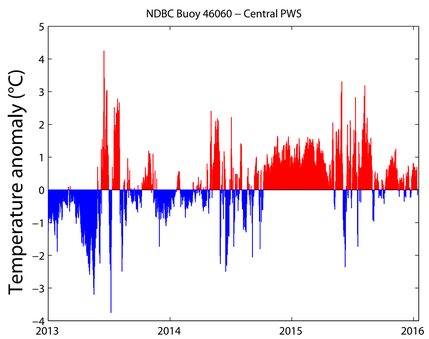


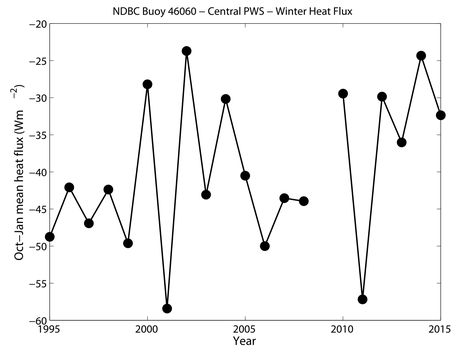
Temperature anomalies from CTD casts, central PWS (1974-2016)

Central PWS (CS, the blue region in the map, right) is exhibiting a long term warming trend at all depths, and anomalies shifted to generally positive in late 2013. The temperature trend is flat at the surface (and negative in NW PWS), presumably caused by cooling due to melting ice sheets along the periphery of PWS.



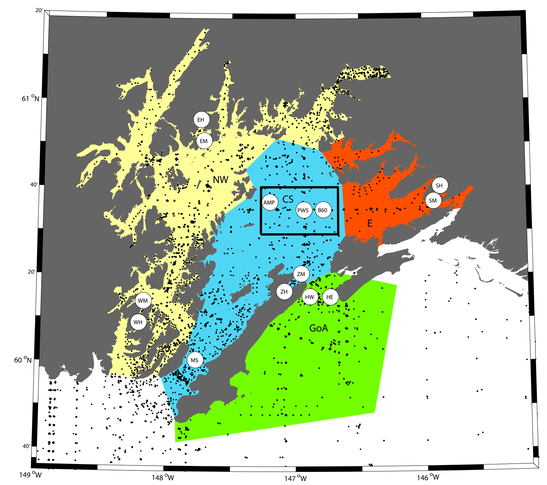
Surface Temperature

SST anomalies at buoy 46060 in central PWS began to switch towards positive anomalies in mid 2013, but oscillated into mid 2014 (unlike the GoA). By autumn 2014 surface temperature anomalies were strongly and consistantly positive well into 2015.



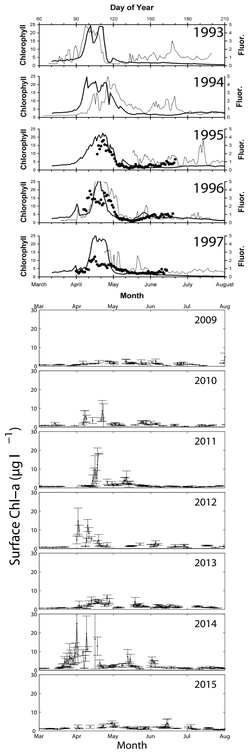
Heat Flux

Mean sensible winter heat flux (average between Oct 1 and Jan 31 of each year) out of the surface ocean has been decreasing over time, and have generally been low in recent years. This pattern is consistent among buoy observations on the NGoA shelf (not shown).



Map of locations mentioned in the poster. Black dots = CTD cast locations (all years), circles = station locations (B60 = NDBC buoy 46060). Black box = bounding box for MODIS surface chl-a averages.

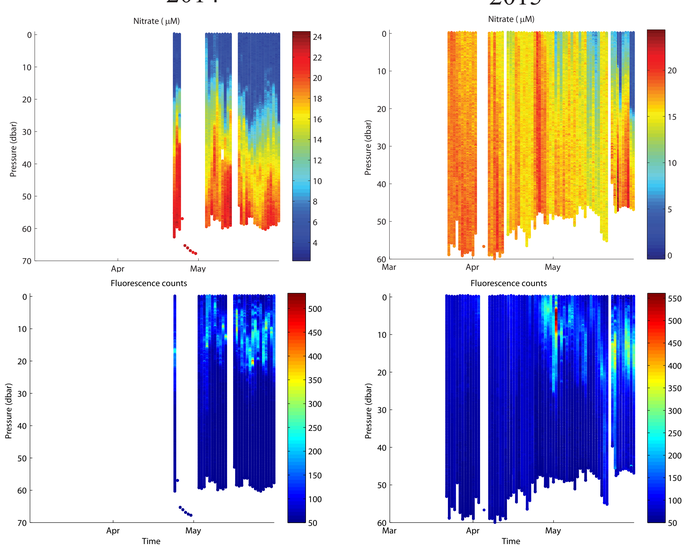
Spring bloom



Surface Chl-a timeseries

Top panel: 1993-1997 from a buoy in central PWS ("AMP" site on map). Thin line = in situ fluorescence, black dots = filtered chl fluorescence, thick line = NPZ model prediction. After Eslinger et al. (2001; Fish Oceanogr. 10(suppl. 1):81)

Bottom panel: 2009-2015 from MODIS observations (mean ± sd) in central PWS.

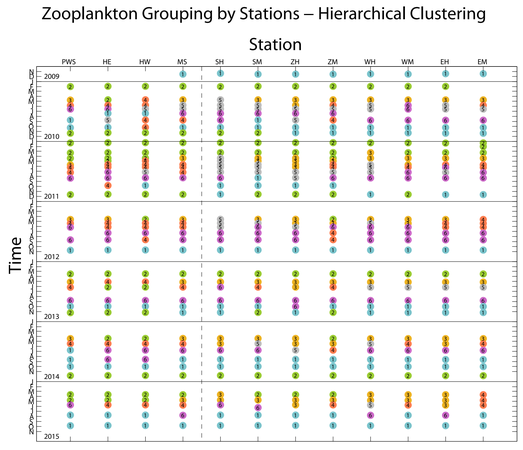


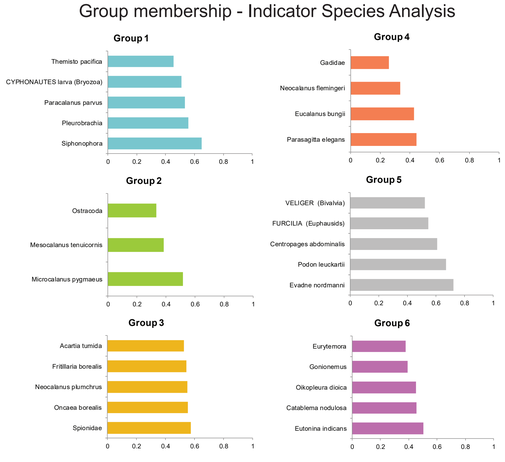
PWS Profiling mooring (located at "AMP" station on map)

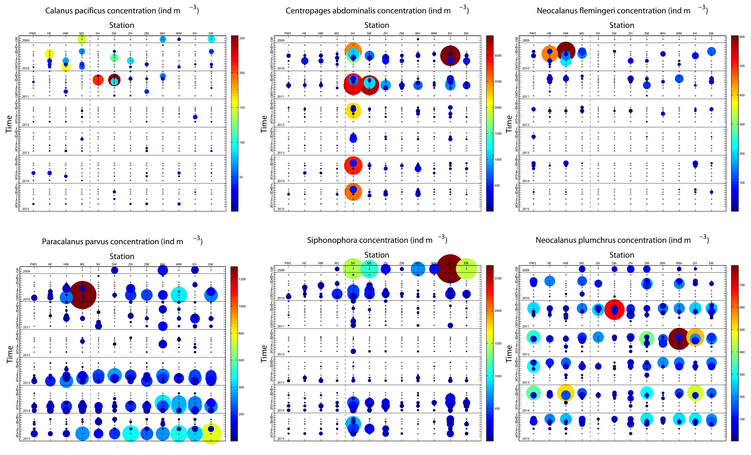
Daily profiles of Nitrate concentration (top panels) and cholorophyll-a fluorescence (bottom panels) in 2014 (left panels) and 2015 (right panels). Nitrate concentrations were measured with a Satlantic SUNA. Chlorophyll-a fluorescence is expressed as digital counts, which are linearly related to chlorophyll concentration.

- Spring bloom usually initiates in May.
- 2014 bloom was ~ 2 weeks earlier than usual
  - All nitrate depleted in surface 20 m by late Apr.
- 2015 bloom: small "bloomlet" early May
  - surface nitrate high well into May (and into June)
  - MODIS suggests a small bloom as well.

Zooplankton







- Clustering/ISA shows no major shifts in taxa groups
- Some species have shown year-to-year shifts
  - *N. flemingeri* (large, spring calanoid) has been comparatively rare in recent years.
  - Some "warm water" spp. have become more common, others (e.g. *C. pacificus*) have not.

The Fine Print:

Profiles of temperature and salinity were collected from several sources. The database described by Musgrave et al. (2013, Cont. Shelf Res. 53:20-29) was merged with casts from the NOAA NODC World Ocean Database. Casts in the database were verified with automated methods to eliminate duplicate casts, and for physically unlikely values (-2°C < T > 25°C, 0 < S > 35), and questionable casts were visually examined prior to being discarded. Casts done as part of recent oceanographic monitoring programs conducted by the author (2009-present) were also included. Temperature was seasonally detrended by fitting all years' data to a second order cosine curve to produce a composite model annual cycle, and anomalies calculated as the difference between observations and the model.

Data from buoy 46060 was downloaded from the NOAA ERDDAP server (data product: cwwcNDBCMet). Hourly observations were converted into daily averages and anomalies calculated with the same method as described for CTD casts. Heat flux was calculated with the TOGA COARE algorithm (Fairall et al., 1996, J. Geophys. Res. 101:3747-3762) without cool-skin correction. Because Buoy 46060 does not measure relative humidity or dewpoint, relative humidity was estimated as the daily average from several other buoys in the region.

Surface chl-a estimates were calculated from MODIS L3SMI daily composites (NOAA ERDDAP product: erdMH1chla1day), in a box centered in central PWS (see map). All non-masked pixels within the box were averaged and standard deviation calculated for each day that there were observations.

Zooplankton were collected with a 202µm mesh, 60 cm diameter bongo net towed from 50 m (or bottom) to surface. Plankton were identified to species or lowest practicable taxonomic level under a microscope. Station/taxa groups were determined by heirarchical cluster analysis on the log(n+1) transformed taxa x station matrix using Ward's agglomerative method. Indicator species analysis (Defrene & Legendre, 1997, Ecol. Monogr. 67:345-366) was done to identify the species most representative of each group. Rare taxa (occurring in <5% of all samples) were excluded, and the significance of the ISA value assessed by Monte Carlo simulation; taxa found to be not significantly different from random (p<0.05) were not considered.

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