East Meets West: Dynamic Biogeography of the Subarctic North Pacific

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- Funded by NASA's InterDisciplinary Science (IDS) program “Life in a Moving Ocean”
- Goal: to better understand the connection between ocean dynamics and the structuring of Meso-Marine Ecosystems (MME) in the Subarctic North Pacific
- Use satellite fields (OSCAR surface currents, SST, winds, salinity) together with Continuous Plankton Recorder (CPR) data
- i.e. The moveable nature of biotic communities.

Introduction: Meso-Marine Ecosystems in the Subarctic North Pacific

- Large Marine Ecosystems (LME) (often > 200,000 km^2) are structured by similar atmospheric and oceanographic conditions and often contain similar biotic communities

- LME lack information on mesoscale variability that can drive productivity across trophic levels.

- Batten *et al*. (2006) introduced the concept of **Meso-Marine Ecosystems (MME) in the East Subarctic North Pacific (SNP)**, defined by analyses of phytoplankton and zooplankton community composition obtained from the **North Pacific Continuous Plankton Recorde**r program (CPR). They found ten distinct MME using only three years of data

- ***Objective: test the hypothesis that MME community structure is variable between years and is influenced by currents, gyre flow, eddies, and SST.***

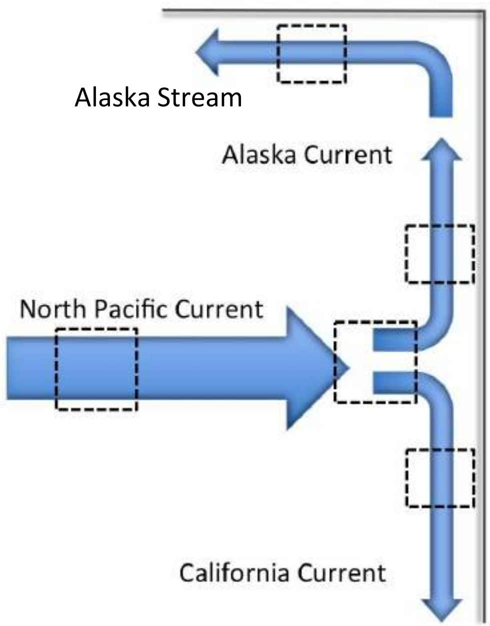
LME in the North Pacific, which correspond to oceanographic and geopolitical boundaries.

CPR data: sheets of plankton samples at about 10m depth from commercial ships that cross the SNP since 2000. CPR data tracks shown in black overlaid on a representative SST field.

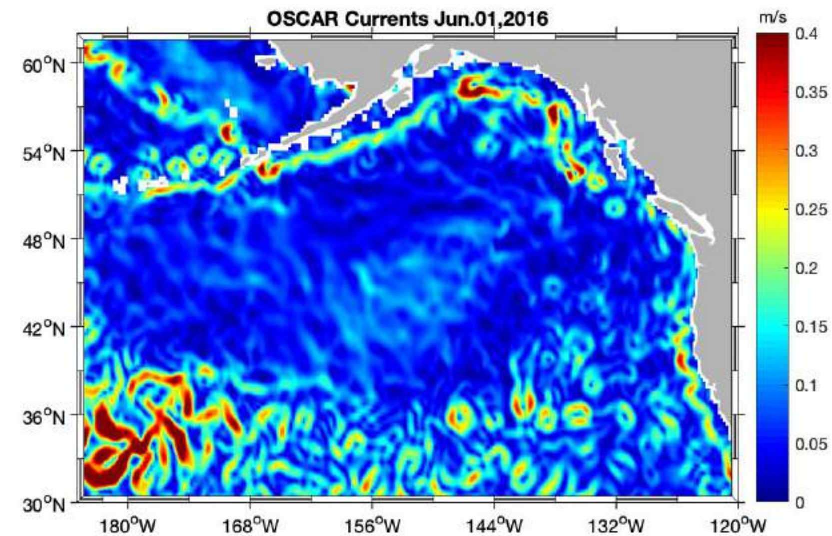
Batten SD, Hyrenbach KD, Sydeman WJ, Morgan KH, Henry MF, *et al*. (2006) Characterizing Meso-Marine Ecosystems of the North Pacific. Deep-sea Research Part II 53:270-290.

Circulation in the Subarctic North Pacific

- General circulation in the SNP
  - North Pacific Current: broad, slow flow from Kuroshio extension across basin
  - Bifurcation into Alaskan Current flowing north and California Current flowing south

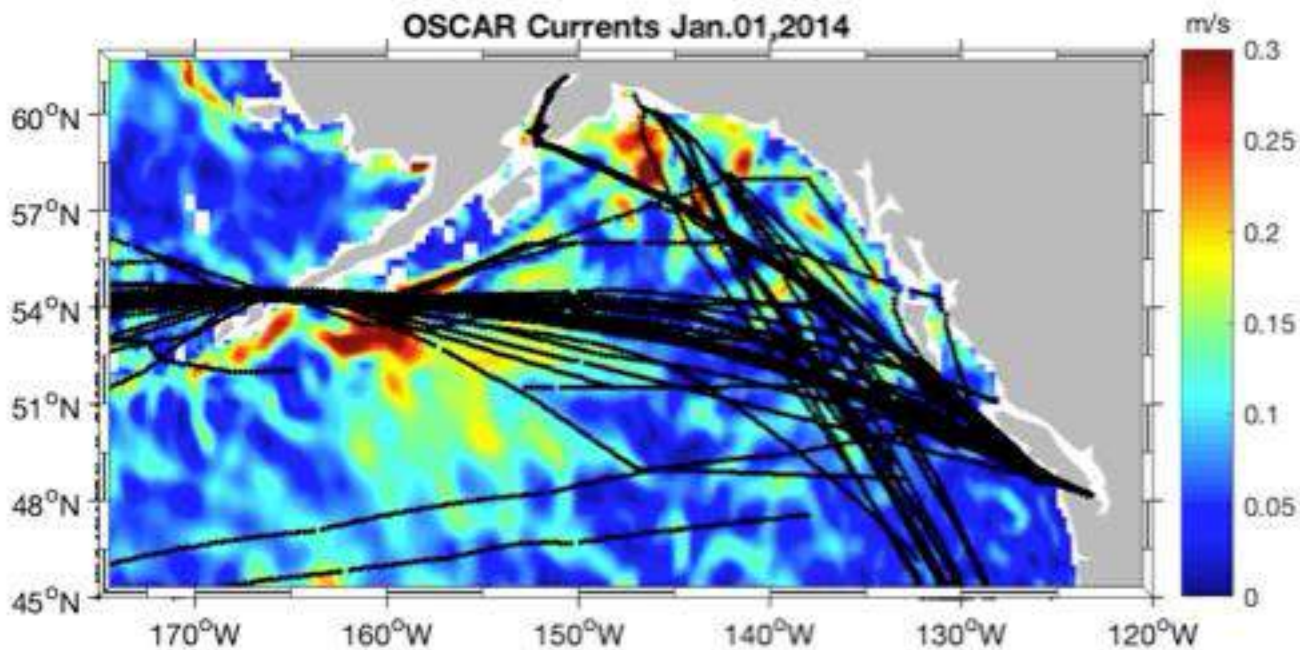


OSCAR satellite based currents



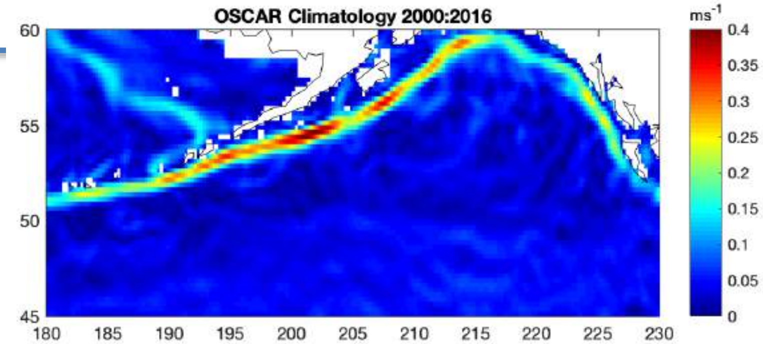
www.esr.org/research/oscar

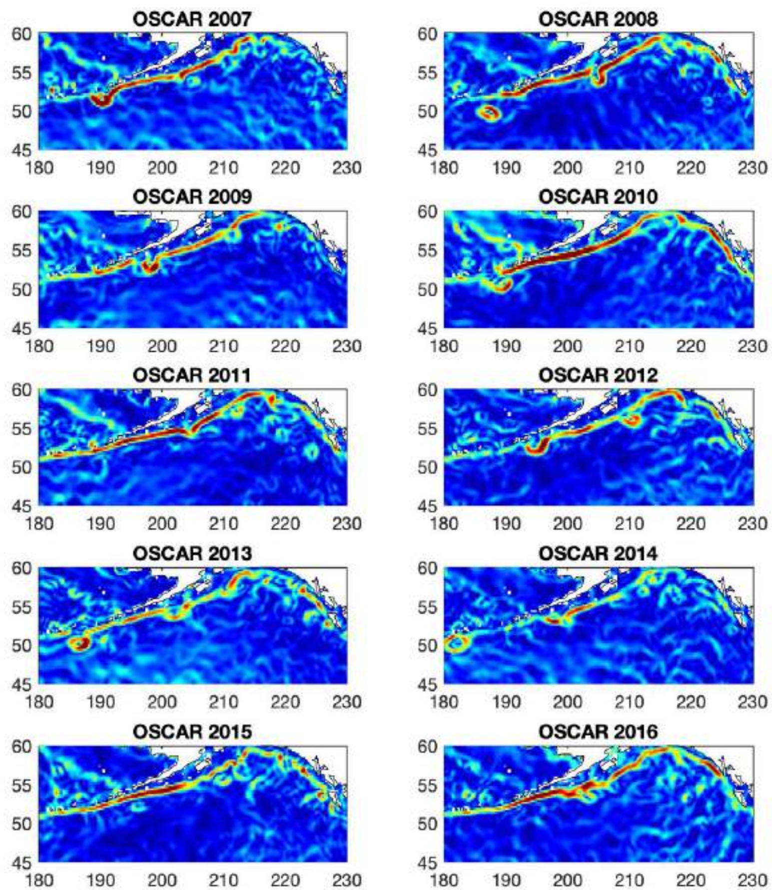
Circulation in the Subarctic North Pacific (movie)

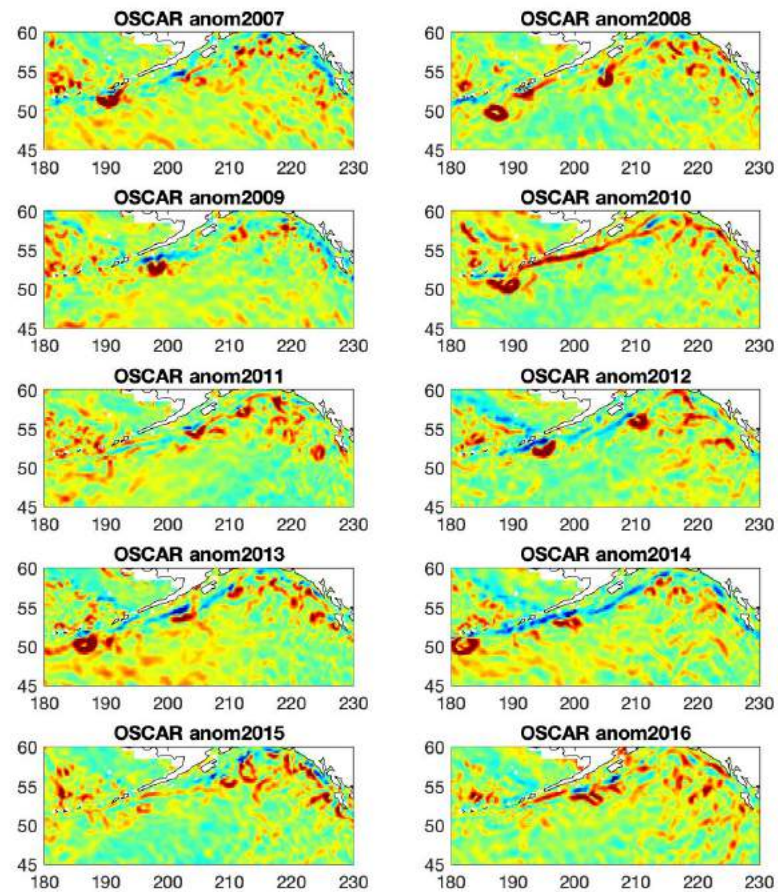


Alaska Current and Stream

- OSCAR averages for 2007:2016 (left), anomalies from 2000:2016 climatology (right)

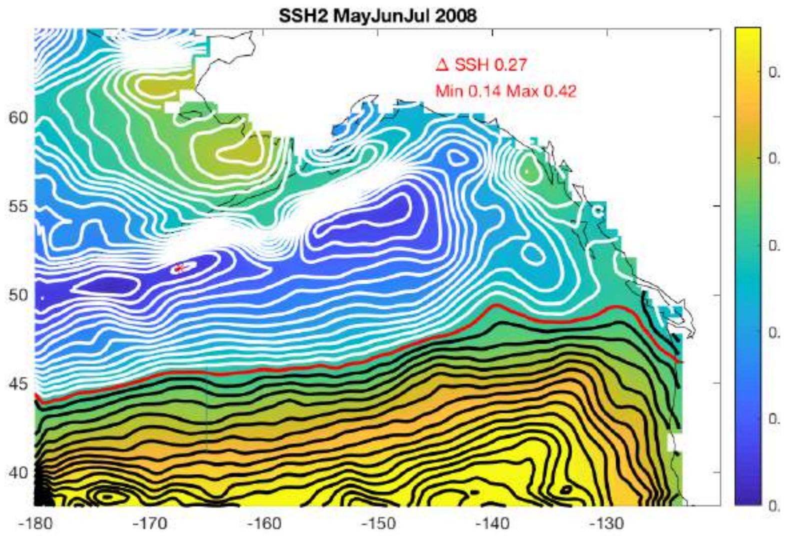


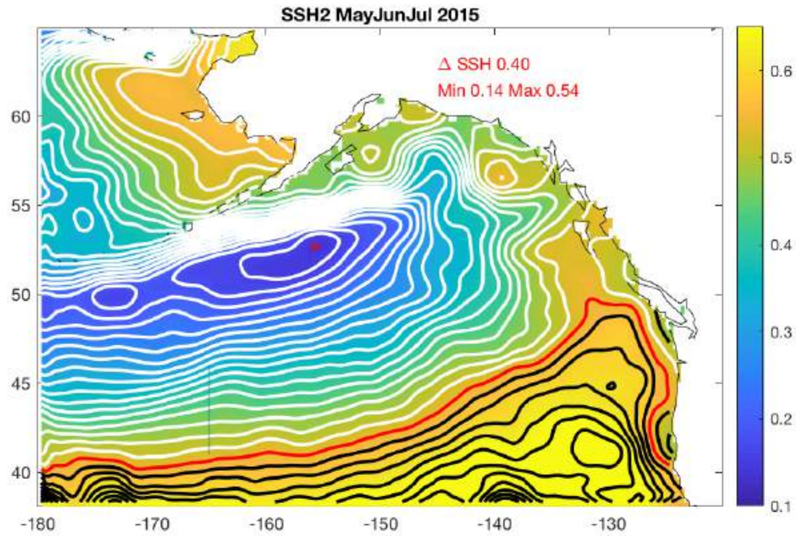




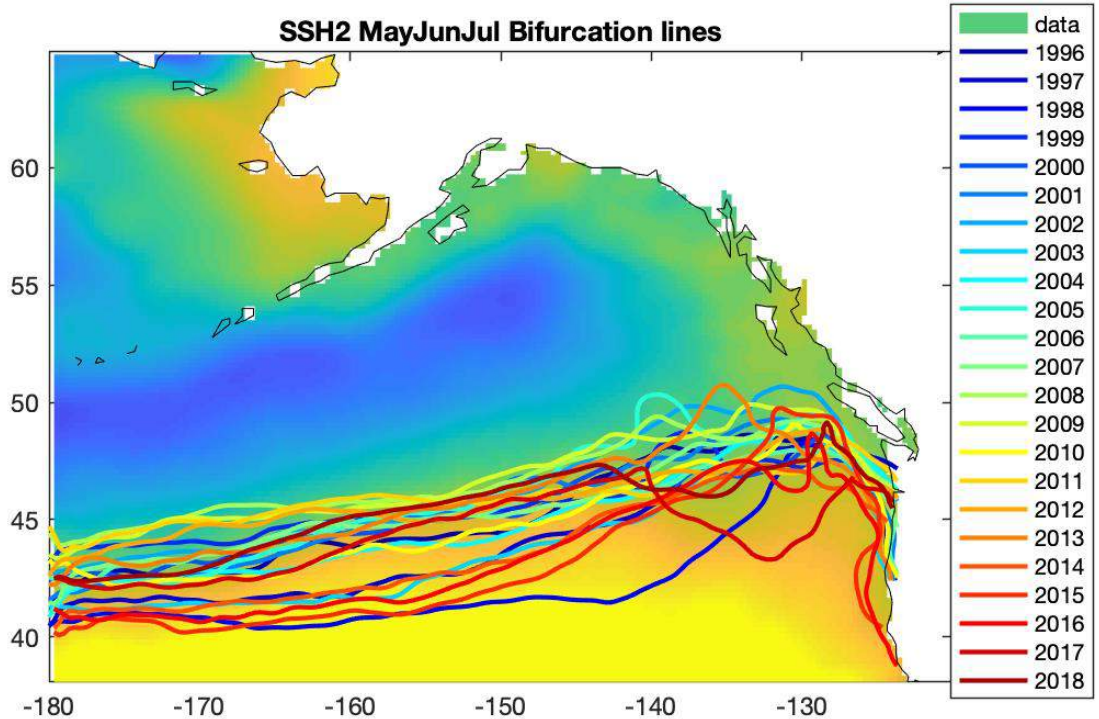
North Pacific Current and Gyre

- The position of the NPC and gyre is not fixed
  - 2 extreme example cases.
- SSH contours for the summer months are plotted. The geostrophic flow is along contours.
- Bifurcation line in red: division between the 2 gyres.
  - Flow is split between the Alaska Current to the north, California Current to the south
  - Traditionally understood to trade off in strength between the 2, which we do not observe

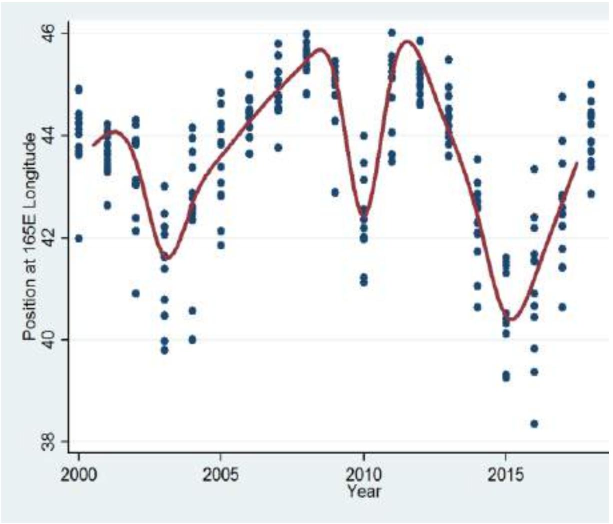




North Pacific Current and Gyre Position Variability



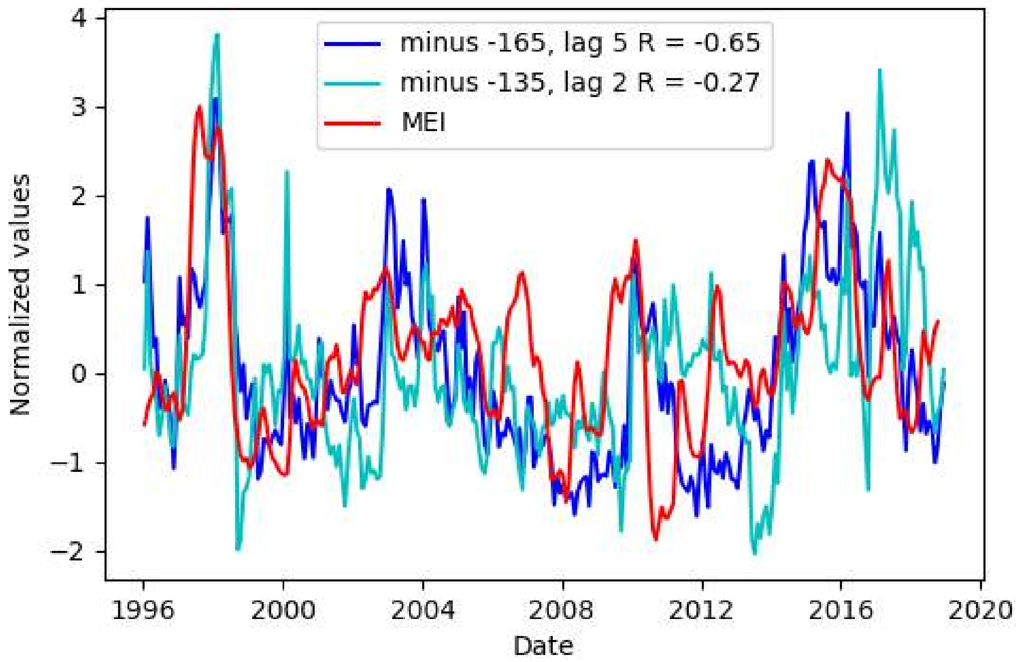
The bifurcation lines for years 1996: 2018



Monthly position of bifurcation line at 165E for each year, with spline fit

Comparison with ENSO Index

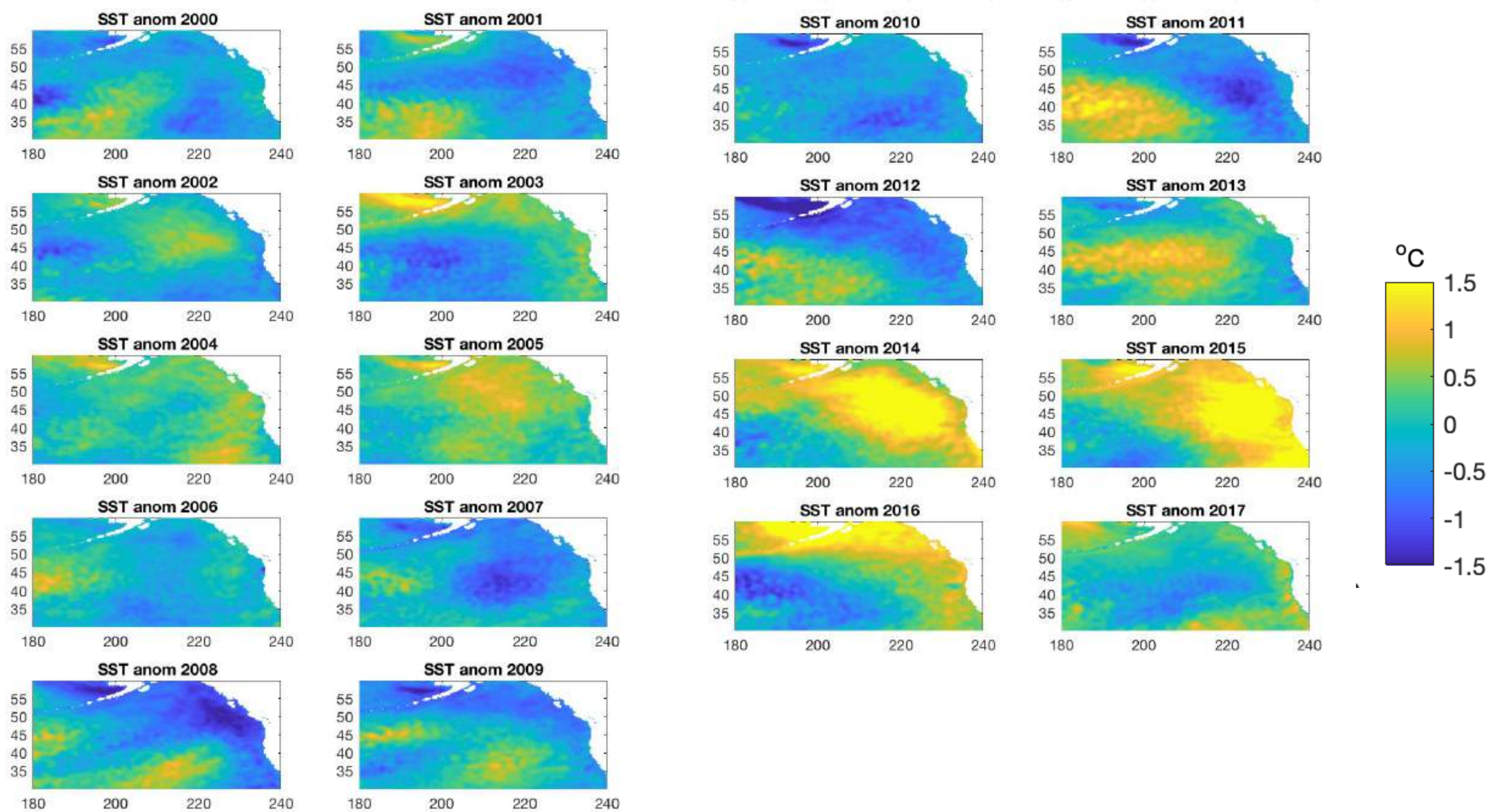
- Gyre structure is tied with the winds (not shown), which in turn is tied to large oscillations like ENSO



- Multivariate ENSO index (red) plotted with bifurcation position (flipped upside down)
- Note: Middle basin section (-165) is less affected by “blob” events than -135.

SST Changes Basin Scale

- SST anomaly yearly averages from 2000: 2017
- Dramatic "Blob" events
- We expect that MMEs will respond to changing climate conditions



General Summary of Physical Properties in SNP

- Alaska Current consists of traveling eddies for most months
- Alaska Stream has stable years and meandering years
- Hot spot of eddies shed at the end of the Alaska Stream
- The basin circulation shifts latitudinally by over 5 degrees between years
  - Connected with wind anomalies and ENSO
- Not a simple trade off between Alaska Current and California Current (in the surface currents)

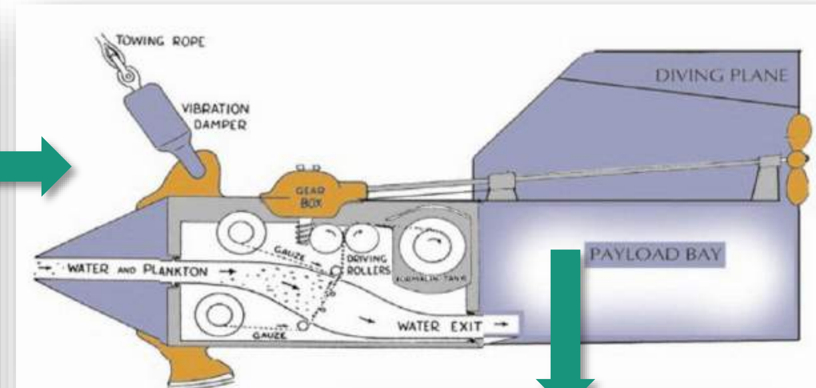
- Extremes in SST between years, particularly the Blob years

- (Not Shown) key areas chosen to described more detailed states, such as freshening of currents, correlations between variables and regions, etc.

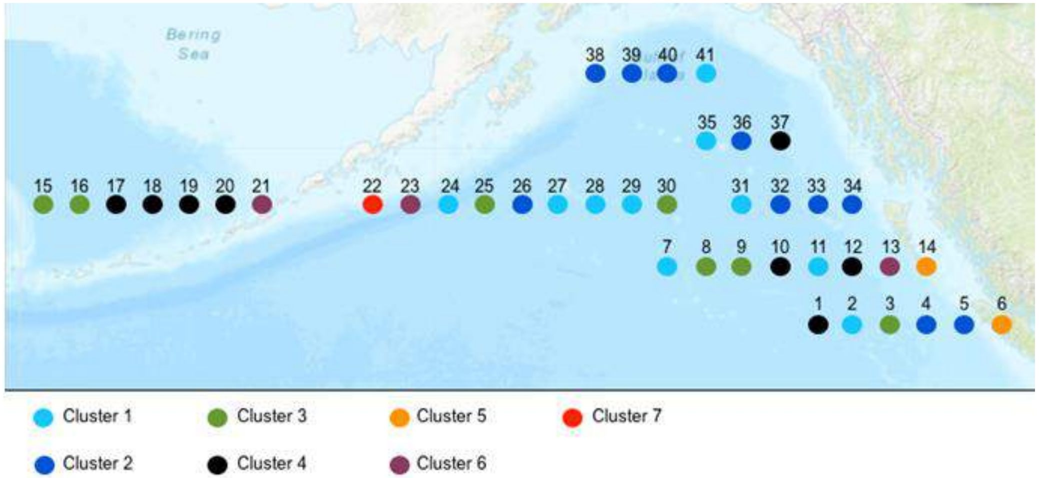
- Why are we doing this?
  - We want to have a strong knowledge of the conditions and variability in the SNP in order to put the CPR observations into context for analysis

CPR survey operation

- CPRs towed at about 10m depth from commercial ships that cross the SNP
- Filters plankton onto mesh that is preserved then processed in the lab



Clustering Analysis of the Overall CPR data

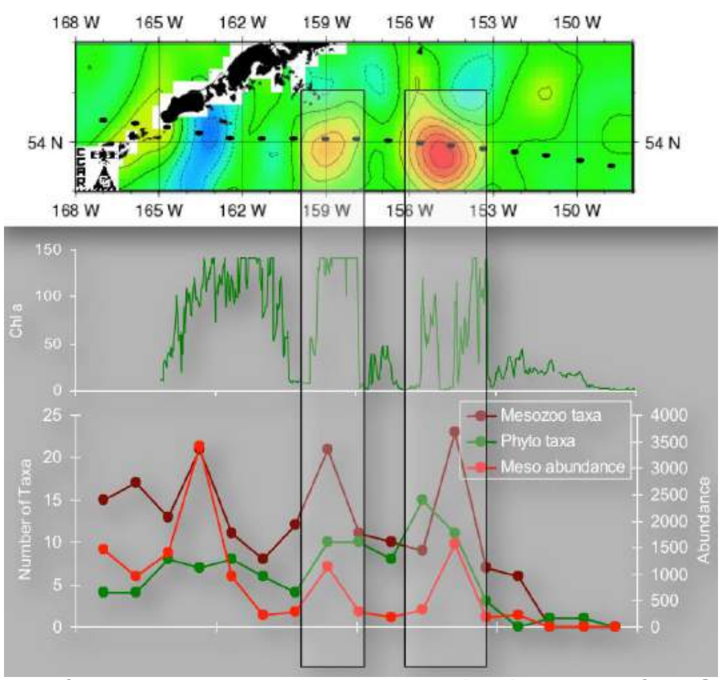


Cluster1	+clione, -plumchrus, -longiremis, -euphausiacea, -pseudocalanus
Cluster 2	-clione , -chaetognatha -oithona, -plumchrus
Cluster 3	+clione, +chaetognata, +oithona, +c.pacificus
Cluster 4	+n. plumchrus (not really from PCs (?))
Cluster 5	+abdominalis, +longiremis, +marshallae
Cluster 6	+pseudocalanus, +euphausiacea, +salpidae
Cluster 7	+bungii, +helicina

- Summer data from all years, with top 18 groups chosen out of the raw data, grouped into 2 degree bins
- Shows the overall pattern in plankton communities
- Features: Some communities are clearly more shelf-oriented (eg cluster 5) or hotspots (e.g 7) and some are widespread and likely related to oceanography (e.g. 3 and 4).
- Now that we have the "climatology" of the biology we are looking into how this changes inter-annually with ocean conditions and which conditions are the major drivers of basin-scale community structure.

Next Step: Eddy CPR analysis

- There is potentially considerable variability in the plankton within and across an eddy, which can be missed with coarse sampling
- Only every fourth CPR sample is routinely analyzed but all samples are archived. We are reanalyzing the archived CPR samples within and around select eddies
  - 560 sample chosen for the first year of re-sampling
  - 255 in the “best” eddies: persistent, large, sampled several times, away from coasts
  - 305 outside the eddies for in/out comparison



Top: June 2005 SSH anomaly and CPR path. CPR transited through two eddies, dots show analyzed samples (every 4th). Middle: Chl-a fluorescence from CTD attached to the CPR showing elevated chl-a within eddies. Bottom: Broad biological properties from analyzed CPR samples, suggesting elevated productivity/diversity, but better resolution is needed.

Ongoing Work

- Finalize the physical oceanography paper characterizing the North Pacific Gyre and associated currents
  - Interconnections
    - Correlations between timeseries in the boxes, winds, bifurcation position, respective flow rates into Alaska and California Currents
  - Broad Goal: inform studies with limited sampling the influential local and large-scale regions
- Continue clustering analyses, definition of MMEs based on groupings informed by physical regimes
  - Interannual and decadal variation
- Eddy analyses now that the first year of CPR subsampled reanalyses are complete

Extras

Time series within the 5 boxes

- Monthly anomalies in red, smoothed in black from 2000:2017

- Strong freshening in Cal Current
- SST anomaly in Alaska 1 & 2 very high again

- Ongoing work to define the interconnections