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 km²) 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 Recorder 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.

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.

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
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
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

- 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 (e.g. 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
• 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