I. Abstract

- Understanding kinetic energy (KE) in the Arctic Ocean’s Beaufort Gyre sheds light on how this freshwater reservoir responds to wind-driven forcing and sea-ice and ocean changes.
- KE in the Beaufort Gyre is dominated by the mesoscale eddy field. The evolution, fate and equilibration scales of these eddies relate to energy pathways in the ocean (e.g., the exchange of energy between barotropic and baroclinic modes).
- Mooring measurements of horizontal velocities in the Beaufort Gyre allow us to partition KE into barotropic (BT) and baroclinic (BC) components.
- We find that a significant fraction of water-column KE can be represented by the BT plus the first two baroclinic modes (BC1 and BC2).
- To explain this KE distribution, we solve the quasi-geostrophic potential vorticity equation to quantify how energy may be redistributed between modes in the Beaufort Gyre. For the Beaufort Gyre stratification, we find mode-mode interactions that promote energy to remain in BC1 and BC2; this is consistent with the dominance of both BC1 and BC2 in the water column KE.
- Our results demonstrate the key role of halocline structure on dissipative processes in the gyre.

II. Mooring Measurements

- Data between 2003–2016 from 4 Beaufort Gyre Observing System (BGOS, see Proshutinsky et al., 2009) moorings (A, B, C and D) are analyzed.
- Each mooring includes a McLane Moored Profiler (MMP) profiling between 50 m and 2050 m collecting water column profiles of velocity, temperature, salinity and pressure.

III. Barotropic and Baroclinic Modes

- Water column horizontal velocity can be written as the sum of barotropic and baroclinic modes: 
  \[ u(z,t) = \sum_m n_m(t) P_m(z) \]
- The modes are calculated from the representative stratification \( N(z) \), via Sturm-Liouville equation:
  \[ \frac{d}{dz}(N(z)\frac{dP_m(z)}{dz}) + \frac{1}{1/R_m^2} P_m(z) = 0 \]
- \( f \): Coriolis parameter, \( R_m \): mth mode Rossby deformation radius.
- The mode structures in the Canada Basin show largest amplitudes within the upper 200 m. This relates to the Canada Basin being strongly stratified in the upper ocean, and weakly stratified at depth.

IV. Projecting KE onto Modes

- KE in the Canada Basin is dominated by the eddy field; eddies are where KE \( \gtrsim 10^2 \text{cm}^2 \text{s}^{-2} \).
- Eddy can be explained by the barotropic and the first two baroclinic modes.

V. Understanding the Vertical Structure of KE

- Mode-mode interactions can be quantified by solving the quasi-geostrophic potential vorticity (QGVP) equation.
- QGVP can also be represented by the sum of modes. The change of PV in the mth mode is given by:
  \[ \frac{\partial P_m}{\partial t} = \sum_i \frac{\partial \Psi_i}{\partial y} \frac{\partial v_i}{\partial z} + \frac{\partial \Psi_i}{\partial z} \frac{\partial v_i}{\partial y} \epsilon_{mij} \]
- The magnitude of \( \epsilon_{mij} \) indicates how \( j \)th mode advection of the \( i \)th mode can produce mth mode vorticity.
- For example, large magnitude of \( \epsilon_{212} \) indicates interaction between BC1 and BC2 flows.

Summary

- KE in the Canada Basin is dominated by the eddy field. We decompose velocities from the four mooring systems into barotropic and baroclinic modes and find that most of the water-column KE can be represented by the first two baroclinic modes.
- Our analysis points to the importance of the stratification in setting the energy partitioning, and therefore the structure and dynamics of eddy and gyre dissipative processes.