Evidence of vertical coupling in the Kuroshio Extension

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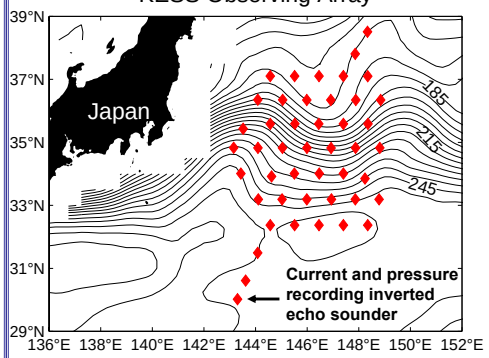
KESS Observing Array

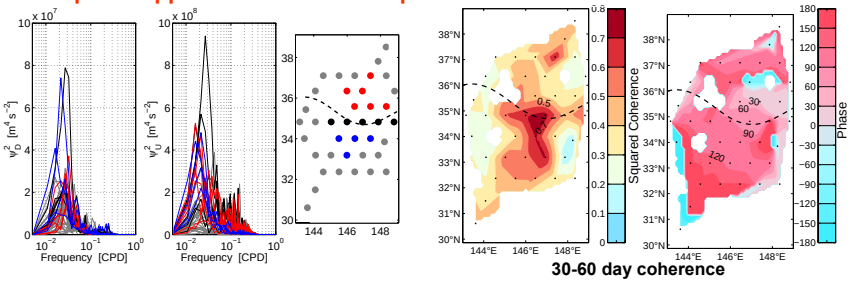


♦ Estimates upper and deep ocean streamfunction, ψ_U and ψ_D

Major Points

1. 30-60 day upper and deep circulation exhibited strong energy and coherence near Kuroshio jet axis.
2. Deep eddies propagated SSW across the array and interacted with upper-ocean meanders.
3. Deep-pressure anomalies were consistent with 30-60 day topographic Rossby wave (TRW) dispersion.
4. Ocean general circulation model for the Earth Simulator (OFES) also showed coupling between SSW propagating deep eddies and upper-ocean meanders in the 30-60 day band in KESS region.

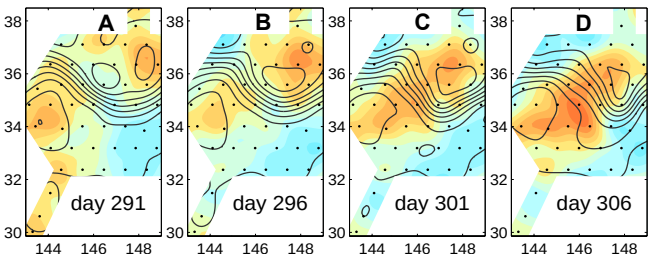
1. Deep and upper streamfunction: spectra and coherence



- Between 50% and 25% of the total variance was in the 30-60 day band for deep and upper streamfunctions, respectively.
- Squared coherence and energy is largest near the Kuroshio trough region.
- In regions of high coherence deep streamfunction leads upper streamfunction, on average 90° ≈ 10 days.

* Dashed line: mean Kuroshio path

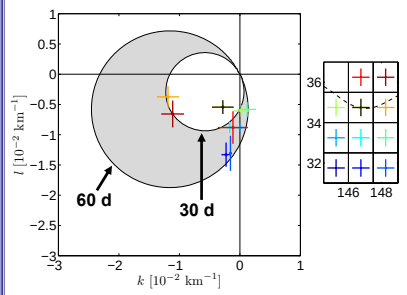
2. Case study: upper and deep ocean interaction



A-B) A deep anticyclone propagated through the KESS array from the northeast.

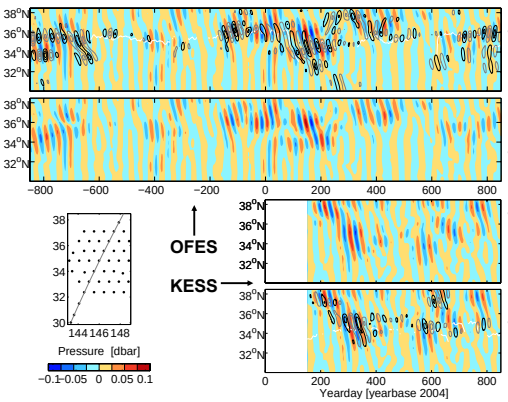
C-D) Kuroshio meander steepened and eddy intensified during interaction.

3. 30-60 day TRW dispersion



- Wavenumbers (*k,l*) estimated from CEOF of bottom pressure.
- Most (*k,l*) pairs consistent with TRW dispersion (shaded-grey region).
- Black (*k,l*) pair does not agree with TRW dispersion.
  - Deep-pressure anomalies do not propagate as free waves when the upper and deep fields are strongly coupled.

4. Hovmöller diagrams: 30-60 day bottom pressure and ψ_U, OFES and KESS



- ~ 50 cases of strong SSW propagation of 30-60 day pressure anomalies in OFES (5 yr.) .
  - ~16 similar cases in KESS (2 yr.).
- Similar phase speeds and directions in KESS and OFES.
- Like KESS, strong upper anomalies develop jointly with deep anomalies, as wave-packets cross the baroclinic zone.
- The agreement shows that OFES models this recurrent energetic process well in the Kuroshio Extension.

Impacts of the major findings

- Strong statistical coupling and phase offset between upper and deep streamfunction is characteristic of baroclinic instability.
  - Our case is different from classic baroclinic instability. Short barotropic TRWs entered from the northeast and coupled to the baroclinic Kuroshio Extension.
- Vertical coupling and joint growth of upper and deep anomalies lasts for a limited time, ~ 14 d, because deep anomalies propagate SSW across the jet rather than along it.
- Since TRWs propagate SSW across the KESS array, they can only couple to meanders in a segment of mean path flowing NW to SE, allowing a favorable phase-match.
  - Since growth due to this process is localized to this region by bathymetry it may explain the semi-permanent nature of the Kuroshio Extension crest/trough feature downstream of Japan.

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