Sustained observations of mesoscale and submesoscale surface circulation off the U.S. West Coast

Sung Yong Kim¹,*, Eric Terrill¹, Bruce Cornuelle¹, Burt Jones², Libe Washburn³, Mark Moline⁴, Jeffrey Paduan⁵, Toby Garfield⁶, John L. Largier⁷ Greg Crawford⁸ and P. Michael Kosro⁹

¹Scripps Institution of Oceanography
²University of Southern California
³University of California, Santa Barbara
⁴California Polytechnic State University
⁵Naval Postgraduate School
⁶San Francisco State University
⁷University of California, Davis
⁸Vancouver Island University, Canada
⁹Oregon State University

*syongkim@mpl.ucsd.edu

** The order of co-authors is geographically assigned.
Outline

• Introduction
  • What’s oceanic sub-meososcale and mesoscale?
  • Surface current measurement using high-frequency radar (as a part of coastal ocean observing system)

• Details of observed surface circulation
  • Driving forces of surface circulation
  • Low frequency signals trapped near the coast
  • Statistics of sub-meososcale eddies
  • Applications of surface transport model (e.g., river/outfall discharges and oil spill)

• Summary
Oceanic processes in time and spatial scales

Oceanic processes in time and spatial scales

(Chelton 2001, Dickey et al, RG 2006)
Coastal Ocean Observing System (COOS)

- HF radar, ADCP, Wave Buoys
- AUV, Glider, Floats
- Tide gauges
- Meteorological stations
- Newly developed instruments

Radio signals used in high-frequency radar

3-30 MHz (between AM radio and TV)
Wavelength ($\lambda_r$) : 10 ~ 100 (m)

Bragg backscattering
When the radar signals are backscattered in phase,

$$\lambda_w = \frac{\lambda_r}{2}$$
HFR surface current maps off the USWC (Cascade maps)
Subinertial alongshore surface currents

- 61 HFRs, 14 NDBC wind buoys hourly observations (2007 to 2008)
- Effective spatial coverage (blue; 6 km) and coastline axis (red; 25 km apart from shoreline)
Subinertial alongshore surface currents

- Rotated currents following the shoreline
- Daily averaged alongshore surface currents.
- Seasonal California Currents.
- Phase speeds of 10 and 100 – 300 km/day
- Slower mode feature is found in southern CA and (intermittently) north.

(Kim et al, JGR 2011)
• Hourly alongshore surface currents.
• High-frequency structure coherent with diurnal wind and tides.
• Poleward progression of convergence front.

(Kim et al, JGR 2011)
Sampling domain in computation of energy spectra

- HFR surface currents (1, 6, and 20 km resolution; hourly) off southern California and on coastline axis (USWC)
- Gridded ALT products [CCAR (daily) and AVISO (weekly)] and along-track altimeter (ALT; Envisat/Jason-1; weekly) on NE Pacific
- CalCOFI shipboard ADCP (Line 90; quarterly)
- SoCAL was chosen because it contains relatively minimum ageostrophic components.
Energy spectra in the wavenumber domain (1D)

\[ S_{u_{\perp}}(k_{\parallel}) = \left( \frac{g}{f_c} \right)^2 \left( 2\pi k_{\parallel} \right)^2 S_{\eta_{\parallel}}(k_{\parallel}), \]

Power spectrum of cross-track geostrophic currents from along-track SSHAs

K^{-2} power law related to sub-mesoscale.

Robust estimate on k-2 spectra with data in other regions.

Two kinds of ALT data: Envisat and Jason-1
HFR data with three resolutions:
1 km and 6 km data are sampled from SoCAL, because minimum ageostropic components are expected.
20 km data are from the coastline axis.
San Diego shoreline water quality sampling

Water quality

Rainfall

River flux
Lagrangian particle track model

- Objectively mapped surface currents
- Forward time integration
- Particle concentrations vs. water quality samplings
- ROC (Receiver Operating Characteristics) analysis

AOC = 0.72
Exposure map (2D PDF)

Exposure map normalized by # of particles at the source location.
(when each source is active)
Hyperion Discharge & oil spill experiment
Summary

• The operational USWC HFR network as a backbone of regional coastal ocean observing system (ROOS) provides the detailed aspects of coastal surface circulation and ocean dynamics at a resolution (km in space and hourly in time) of never before resolved.

• Observed surface currents contain responses to the low frequency, tides, wind forcing, and Earth rotation.

• HFR observations can be a useful resource to study surface circulation, eddies and interaction of energy at submesoscale, and ocean state estimates and can provide various environmental applications.