Shelf Breaks and Shelf Currents

What are the important processes at the shelf break?

*Shelf break fronts:* The shelf break is often the boundary between shelf and slope or ocean waters of differing T/S properties. The shelf waters being shallower heat and cool faster than the adjacent, deeper slope waters. Also they receive freshwater runoff reducing their salinity and density. Note that the heating that occurs in the spring is often coincident with higher runoff causing the shelf to be much less dense than slope/ocean waters. Schematic of the processes on board.

*Eddies and meanders* in boundary currents flowing just offshore of the shelf break

*Frontal:* small cold core cyclonic features that form in the shear between the western boundary currents (Gulf Stream is prototypical) and the shallow slow moving shelf waters. They propagate downstream at about 1/3 the speed of the current itself. The cross shelf currents created by the passage of the frontal eddy cause net onshore flow of heat, salt, momentum and nutrients. Example: South Atlantic Bight frontal eddies.

*Meanders:* Meanders in the boundary currents cause the boundary current to move towards or away from the shelf break. Onshore movement increases the surface currents at the shelf break and increases temperatures (all isotherms descend). Offshore movement of the meander decreases surface currents and may cause a reverse flow. Temperatures decrease as isopleths ascent. Example: South Atlantic Bight (although frontal eddies often dominate the scene), downstream from Cape Hatteras where meanders form constantly (work by Rossby and colleagues show flow towards the slope water as meanders form).

*Warm Rings:* Warm rings that form in the western Boundary current migrate into the slope water and then can interact with the shelf waters. They cause significant cross isobath flow at the shelf break when then impinge on the shelf break. Example: Middle Atlantic Bight.

*Intrusions*

Shallow shelf break systems (South Atlantic Bight): the intrusion becomes wind driven on the shelf and doesn’t reside long there (< 1 month)
Deep shelf break systems (Middle Atlantic Bight): the intrusion (or the cold, resident winter shelf water) resides on the shelf throughout the summer since it is below the Ekman layer and often not connected via isopyncals to the slope water.

*Ekman Dynamics:* Does the Ekman layer reach the bottom? What does the Ekman layer look like? How would one identify it in a current meter record?

*Shelf break depth:* Ekman layer depth, isopycnal connections. Contrasting Examples: northeast Florida shelf vs. Off middle U.S.

*Upwelling:* usually only considered in eastern boundary areas where shelves are usually narrow (< 10 km) and the shelf break deep (< 100 m). Examples: California, Peru, NW Africa, Namibia, Galicia.

*Canyons:* Submarine canyons cause perturbations in the along isobath flow of shelf and slope water. The divergence and convergence of the isobaths result in upwelling and downwelling (not wind relate) in the vicinity of the canyon. Examples: Norfolk canyon and others north of Cape Hatteras, canyons off Oregon and Washington. See papers by Klinck and Hickey.

**What are the important processes on the shelf?**

The shallow shelf waters respond to the winds, baroclinic and barotropic pressure gradients. They also often respond to forcing from the adjacent ocean via eddies, meanders, etc.

**Bottom Layers/cold pools**

MAB cold pool and SAB transient pool - Houghton, Atkinson

**Large Scale Coherent Flows**

Large scale ( > 1000 km) coherent flows are now recognized at many locations in the world ocean. The principle force driving the large coastal currents is the cross shelf pressure gradient created by the influx of river runoff.

*Alaska Coastal Current -*

**Figure of Region**

The Alaska Coastal Current originates off northern British Columbia. It is an onshore portion of the Alaska Current that is farther offshore being part of the North Pacific Gyre. The Alaska Coastal Current is driven primarily by buoyancy forcing from river runoff and rain thus is restricted to the inner few 10's of kilometers of the shelf. The Alaska Coastal Current's path is northward along northward British Columbia and southeast Alaska then westward past Yakutat, Prince William Sound, through Shelikof Strait and eventually into the Bering Sea. Predominate forcing is by strong winter winds and high summer and fall runoff and precipitation. Royer [1979] noted that the large amount of runoff entering the coastal
waters of SE and Central Alaska sufficiently dilute the coastal waters to raise sea level thus increasing the volume of the Alaska Coastal Current.

The ACC is over 1000 km long and the flow is in the 1 Sv range.

Figure 1, 6, and 8 from Johnson, Royer and Luick. JGR 93:12423-12437.

*Middle Atlantic Bight* - A coastal current flows from the Greenland/Labrador area to the Mid-Atlantic Bight region. Note papers by Chapman.

*Australia* - Coastal currents occur off both Australia coast. See Tomczak book.

*Southeast United States Shelf* - A coastal current flows along the coast from Cape Fear to Cape Canaveral. It is driven by the cross shelf pressure gradient created by the near line source of river input. The current is stalled by northward winds but predominately flows southward over the inner 10-20 kilometers of shelf. Lee, Atkinson, Blanton papers

*West Coast U.S.* - The California to Washington area has the California Current flowing offshore with coastal upwelling causing high variability in the coastal waters. Hickey papers

*Norwegian Coastal Current* - The Norwegian Coastal Current flows around southern Norway then northward along the coast. It is forced by runoff and winds. see Mork papers

**River Plumes**

River plumes form discrete features when the rivers are well separated from one another. The plumes flow onto the shelf turning in response to Coriolis and often form a geostrophically balanced coastal current. This balance is disrupted by winds that may move the plume away from the coast with upwelling water between the coast and the plume.

Examples include:

- Major Rivers: Mississippi, Chesapeake system, Delaware system, Hudson, Connecticut, Amazon, Yellow, etc.
- Linear systems: southeast U.S.

**Expected and Observed Climate Changes**

The previous examples of shelf processes illustrate the critical balance between buoyancy forces, mixing forces, pressure gradients and remote forcing. Now, with our increasing appreciation for climate change, whether natural or anthropogenic, it seems possible that we will observe significant changes in shelf processes. In this final section some of the observed changes are described.

*Increase of upwelling winds* - Increasing: Bakun

*Runoff changes* - Increasing
Winter Storms - Increasing

Comment

Our knowledge of continental shelf processes is based on very few long term measurements. Rather efforts have focussed on studies over two or three years at the most. The only long term records we have of the shelf waters are tide data and data gathered from commercial ships. It seems clear that our understanding of shelf waters and our ability to predict changes in coastal waters and the effect on fisheries, recreation and commerce is very inadequate. Long term studies in keeping with the time and space scales of the processes involved are necessary.

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