Lecture 24: Coastal Ocean Process-Oceanic Frontal System

- Coastal boundary
- $O(\Delta h) \sim O(h)$
- $L_x \ll L_y$
- Motion is constrained within the shelf;
- Significant time- and spatial variations.
Local wind

\( \bar{\tau}_S \sim \bar{\tau}_b \)

Coriolis force \sim Vertical Diffusion

Vorticity wind

Interpretation of the diagram:
- \( \bar{\tau}_S \sim \bar{\tau}_b \) indicates a balance between the stresses at the surface and the bottom.
- Coriolis force and vertical diffusion are significant in the flow dynamics.
- Vorticity wind suggests a rotational component in the flow.

Axes:
- \( x \)
- \( y \)

Regions:
- Near-shore zone
- \( f \)-plane
- \( \beta \)-plane
- Interior Ocean

Ekman transport

Over the continental shelf,

\[ L_x \ll L_y \]

Looking at the horizontal continuous equation,

\[ \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} = 0 \]

\[ O\left(\frac{U}{L_x}\right) \sim O\left(\frac{V}{L_y}\right) \quad \rightarrow \quad U \sim V\left(\frac{L_x}{L_y}\right) \ll V \]

The cross-shelf velocity is one order of magnitude smaller than the along-shelf velocity.

Unlike the open ocean, the cross-shelf velocity over the continental shelf generally does not satisfy the geostrophic balance. The structure and distribution of the cross-shelf velocity is closely related to vertical mixing.
In the open ocean:

The motion is quasi-geostrophic with a slowly time variation scale

In the coastal ocean:

The motion is featured by strong nonlinear multiple-scale processes

Examples:

Small-scale high frequency surface waves $\rightarrow$ Large-scale vertical resuspension of the sediments

Small-scale turbulent mixing $\rightarrow$ Formation of tidal mixing fronts

Point freshwater discharge $\rightarrow$ Large-scale buoyancy-driven flow

Most interesting physical process:

1) Oceanic fronts, 2) Near-surface and bottom turbulent boundary layers; 3) Coastal trapped waves; 4) Steady and time-dependent wind- and density-driven flows; 5) Wind-mixing, tidal-mixing, tidal residual currents,
Coastal Oceanic Fronts

1) Low-salinity front; 2) Tidal mixing front; 3) Shelf break front; 4) Upwelling front

1) Low-salinity front

\[ fu = -\frac{1}{\rho} \frac{\partial P}{\partial y} \]

\[ P = P_0 + \rho g (\zeta - z) \]

\[ fu = -g \frac{\partial \zeta}{\partial y} \]

Low-salinity plume or estuarine plume
Decoupled from the bottom boundary layer

**a: Near-surface front**

Frontal zone

Low-salinity water

high salinity water

Mixing is caused by shear instability at the interface between low and high salinity waters

Coupled with the bottom boundary layer

**b: Surface-bottom front**

Frontal zone

low-salinity water

high salinity water

Mixing is controlled by the dynamics of the bottom boundary layer.
From Dr. Justic at LSU
The South Atlantic Bight
Image number: 1
(Time interval: 2 hours)

Wind

Pee Dee
Santee
Cooper
Savannah
Ogeechee
Altamaha
Satilla
St. Marys
St. Johns

Cape Fear
Changjiang River, The East China Sea
The East China Sea

Changjiang River
MODIS SST
LATEX shelf

Atchafalaya River

Mississippi River
The South Atlantic Bight
### Nutrients due to the Changjiang River Discharge

<table>
<thead>
<tr>
<th>Year</th>
<th>DIN (µmol N/L)</th>
<th>DIP (µmol P/L)</th>
<th>DIN/DIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>9</td>
<td>0.58</td>
<td>16</td>
</tr>
<tr>
<td>1992</td>
<td>56</td>
<td>0.68</td>
<td>82</td>
</tr>
<tr>
<td>1997</td>
<td>106</td>
<td>&gt;0.91</td>
<td>117 (450)</td>
</tr>
</tbody>
</table>

DIN: Dissolved inorganic nitrogen  
DIP: Dissolved inorganic phosphorus
Saltwater Intrusion into the Changjiang River

Days: 60