COASTAL DYNAMICS

Jonathan GULA
gula@univ-brest.fr

- **Outline:**
  1. Introduction
  2. General equations
  3. Surface Waves
     - 3.1. Surface gravity waves
     - 3.2. Inertia-gravity Waves
     - 3.3. Coastal waves
  4. Tides
  5. Internal Waves
  6. **Geostrophy and thermal wind**
  7. Bottom and surface boundary layers
  8. Coastal circulation and responses to meteorological forcing Frontal dynamics
  9. Estuary plumes and regimes

Presentations and material will be available at :

jgula.fr/Coastal/

Geostrophic Balance

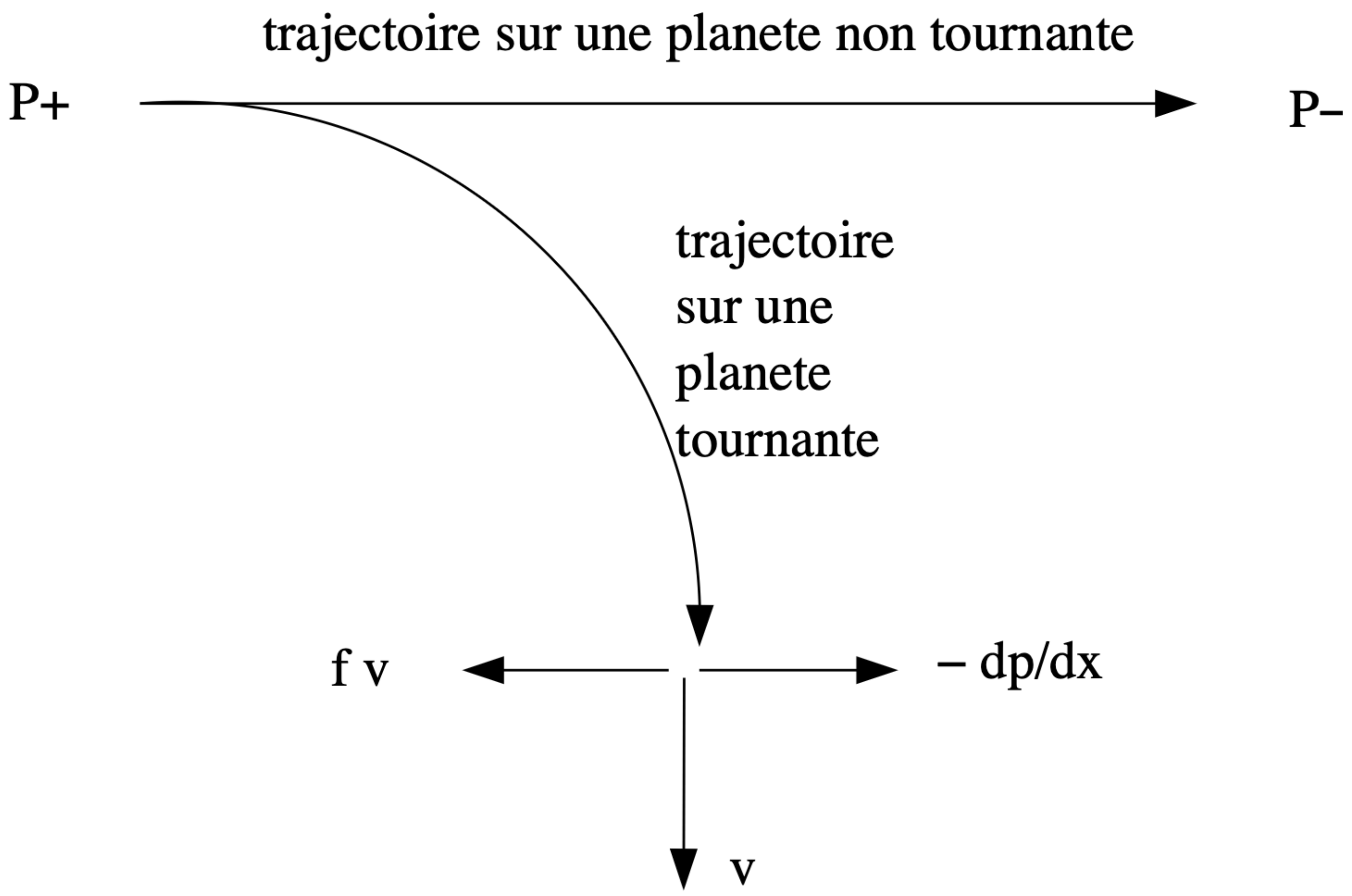
- When the relative acceleration is negligible compared to the Coriolis acceleration (and the forcing and dissipation effects are still negligible), equilibrium is achieved between the Coriolis acceleration and the horizontal pressure gradient.

- The horizontal pressure gradient is given by:

$$fv = \frac{1}{\rho_0}\,\partial_x p$$

$$fu = -\frac{1}{\rho_0}\,\partial_y p$$

Geostrophic Balance



Thermal wind

- Finally, an important relationship can be derived from geostrophic equilibrium with hydrostatic equilibrium. This is known as the **thermal wind** relationship.

- Let us derive geostrophic equilibrium according to z:

$$f\partial_z v = \frac{1}{\rho_0}\,\partial^2_{xz}p$$

$$f\partial_z u = -\frac{1}{\rho_0}\,\partial^2_{yz}p$$

Thermal wind

- and use hydrostatic equilibrium: $\partial_z p = -\rho g$

- Let us derive geostrophic equilibrium according to z:

$$\partial_z v = -\frac{g}{\rho_0 f}\,\partial_x \rho$$

$$\partial_z u = \frac{g}{\rho_0 f}\,\partial_y \rho$$

- These relationships are particularly useful for calculating the horizontal velocity field from hydrological measurements (temperature and salinity).

Thermal wind

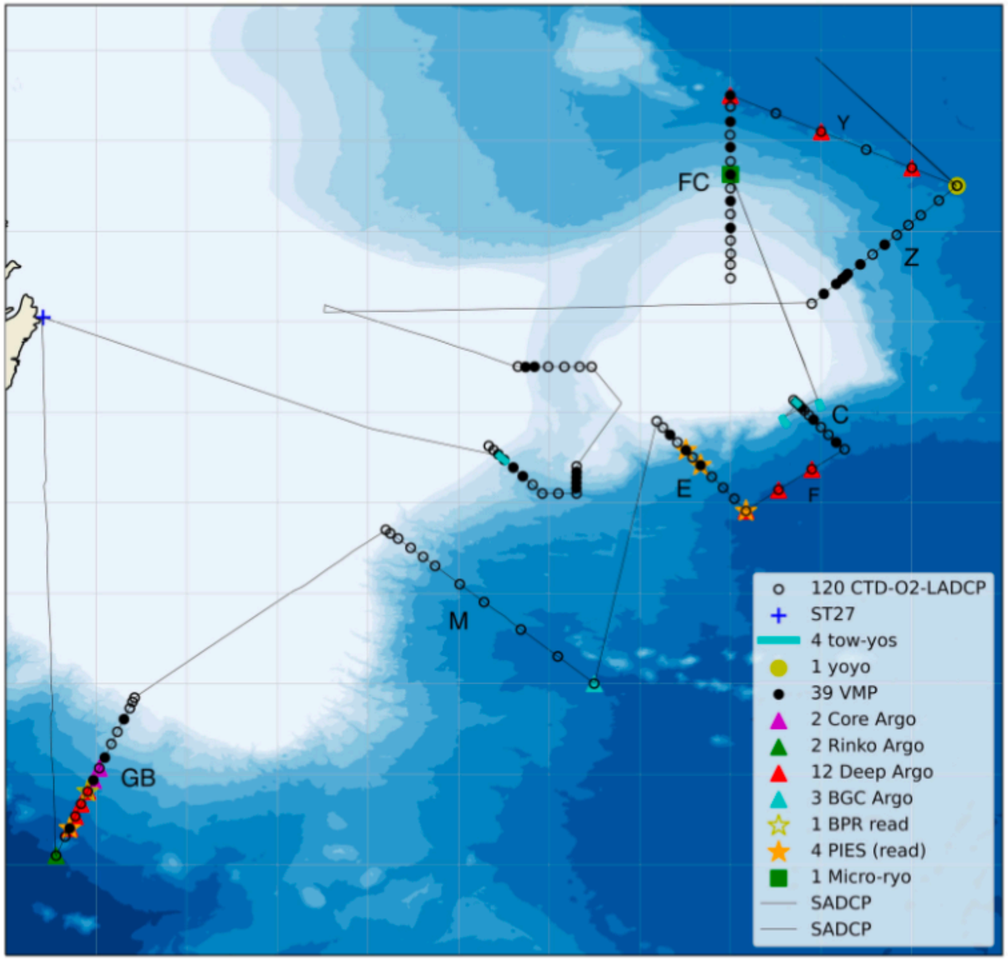


Figure 3: Map of Transition Zone with hydrographic sections of CROSSROAD cruise 2024.

Thermal wind

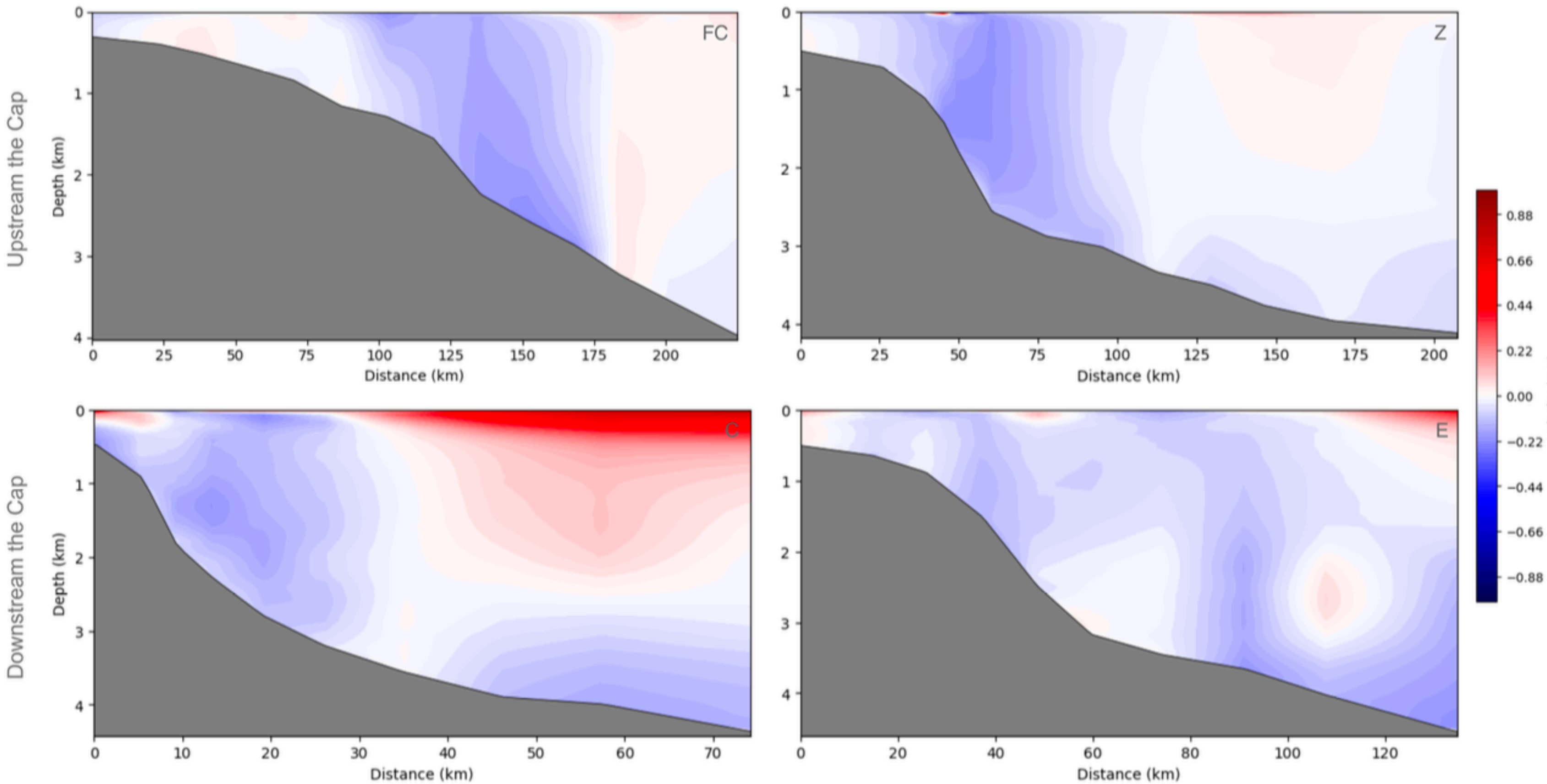
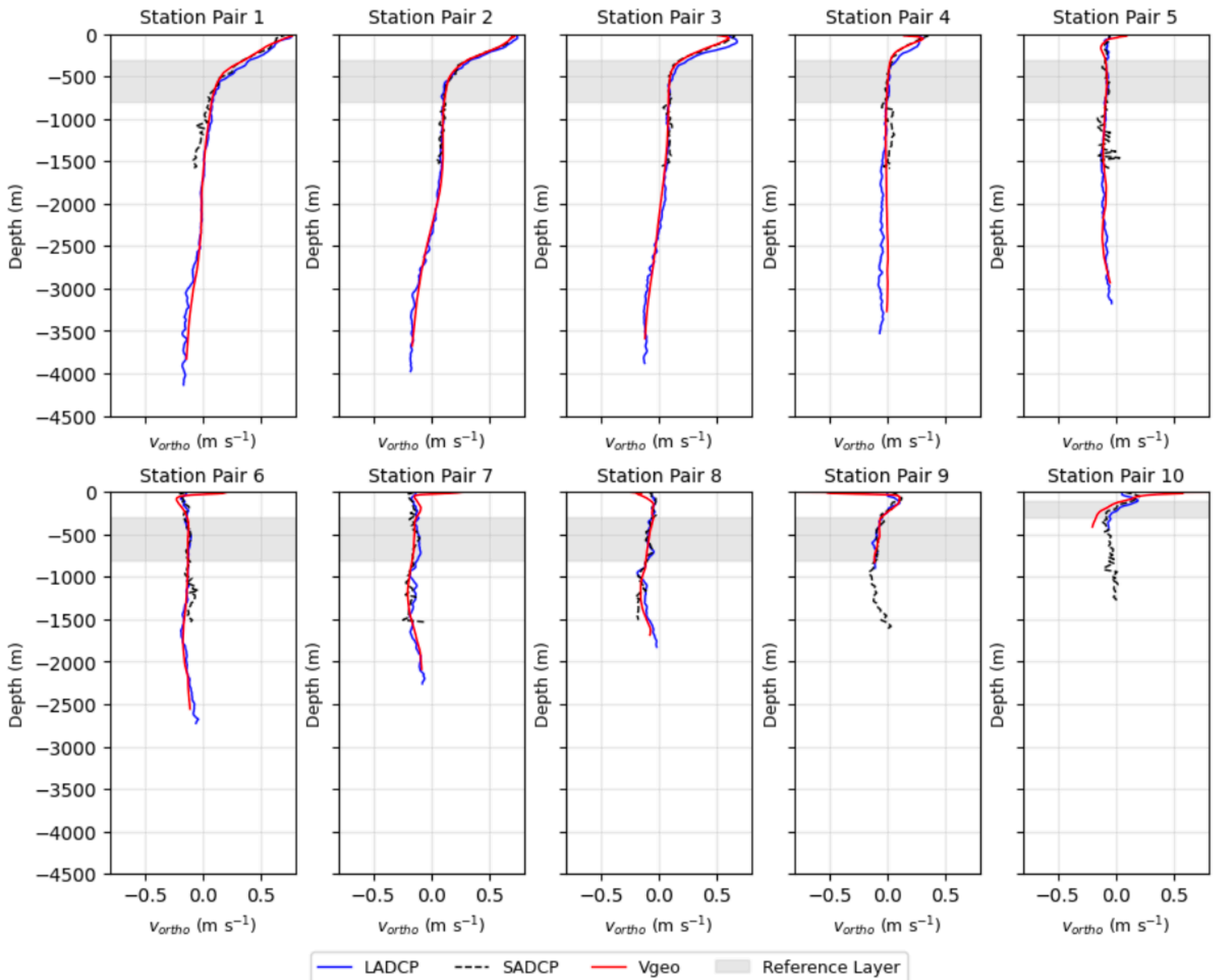


Figure 8: Cross-section of along-transect Geostrophic velocity ($m\,s^{-1}$) upstream (FC, Z)) and downstream (C, E) of the Flemish Cap. Positive velocities in red and negative velocities (DWBC) in blue.

Thermal wind



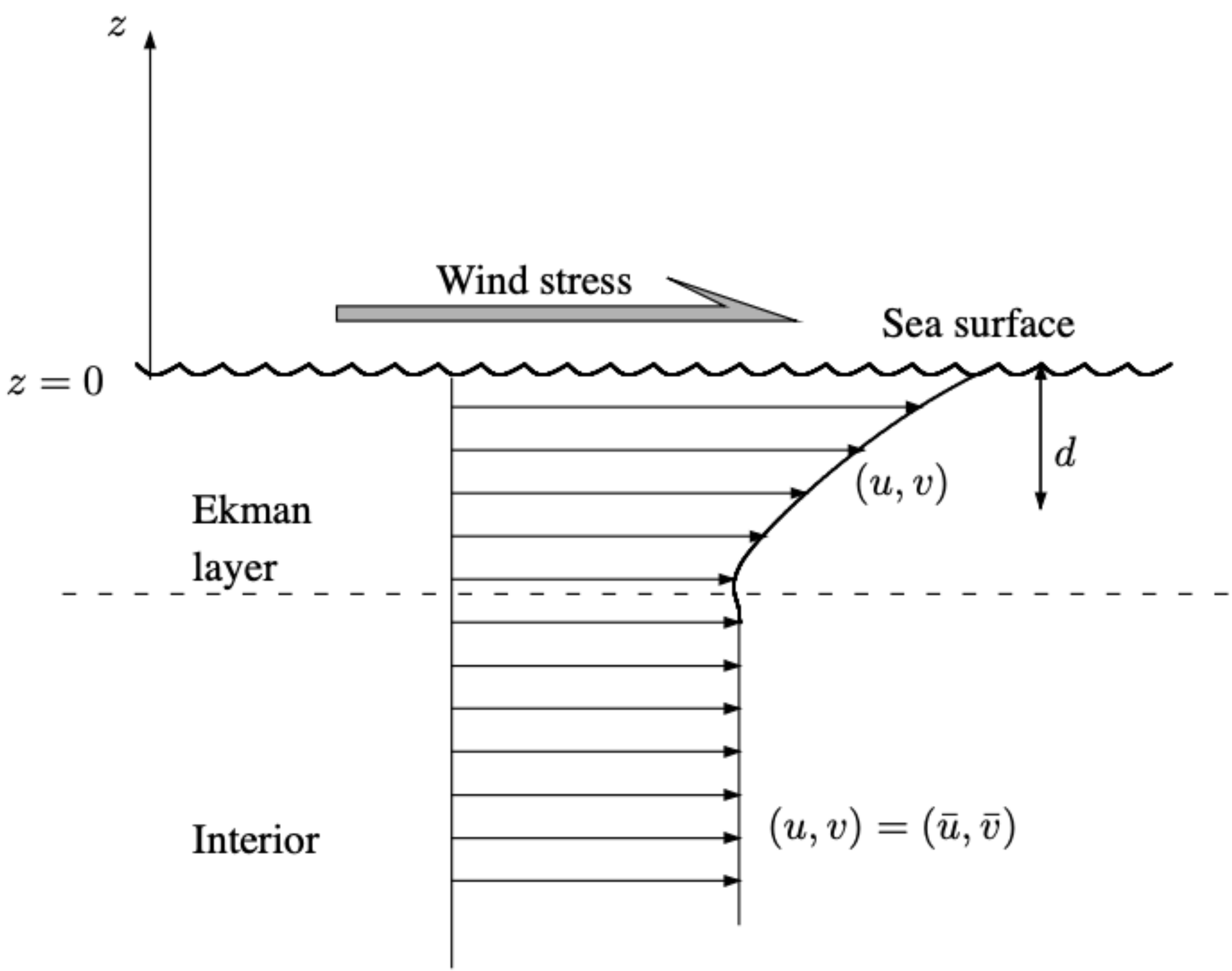
- **Outline:**

    1. Introduction
    2. General equations
    3. Waves
        3.1. Surface gravity waves
        3.2. Coastal waves
        3.3. Internal waves
    4. Tides
    5. Geostrophy and thermal wind
    6. **Bottom and surface boundary layers**
    7. Coastal circulation and responses to meteorological forcing
    8. Frontal dynamics
    9. Estuary plumes and regimes

Presentations and material will be available at :

jgula.fr/Coastal/

Ekman currents



Ekman currents

- **See notes:**
  - *Solve the Ekman problem*

Ekman currents

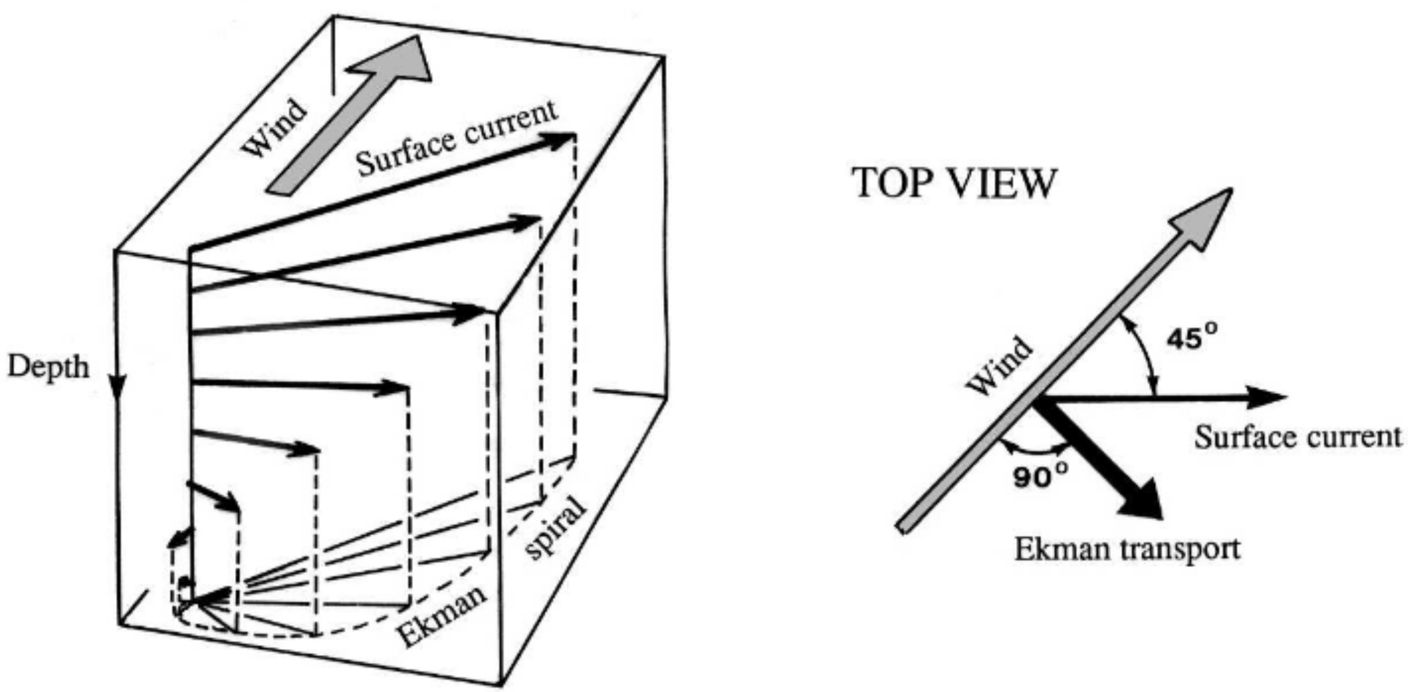


Figure 8-7 Structure of the surface Ekman layer. The figure is drawn for the Northern Hemisphere ($f > 0$), and the deflection is to the right of the surface stress. The reverse holds for the Southern Hemisphere.

Ekman currents

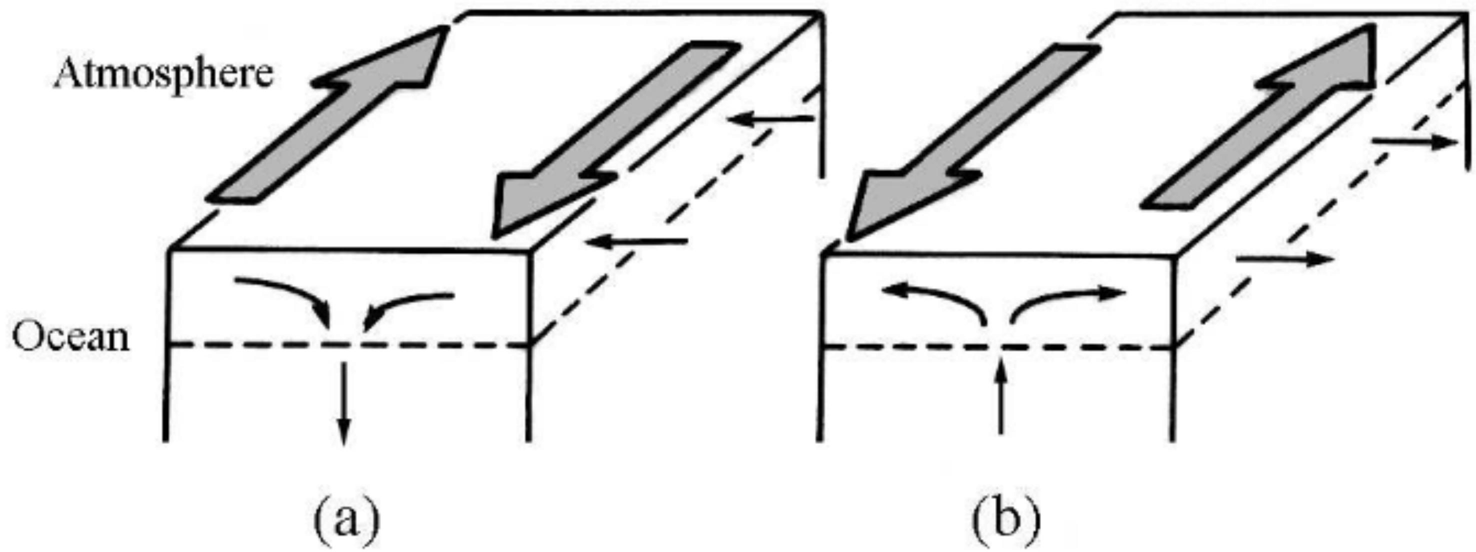


Figure 8-8 Ekman pumping in an ocean subject to sheared winds (case of Northern Hemisphere).

Ekman currents

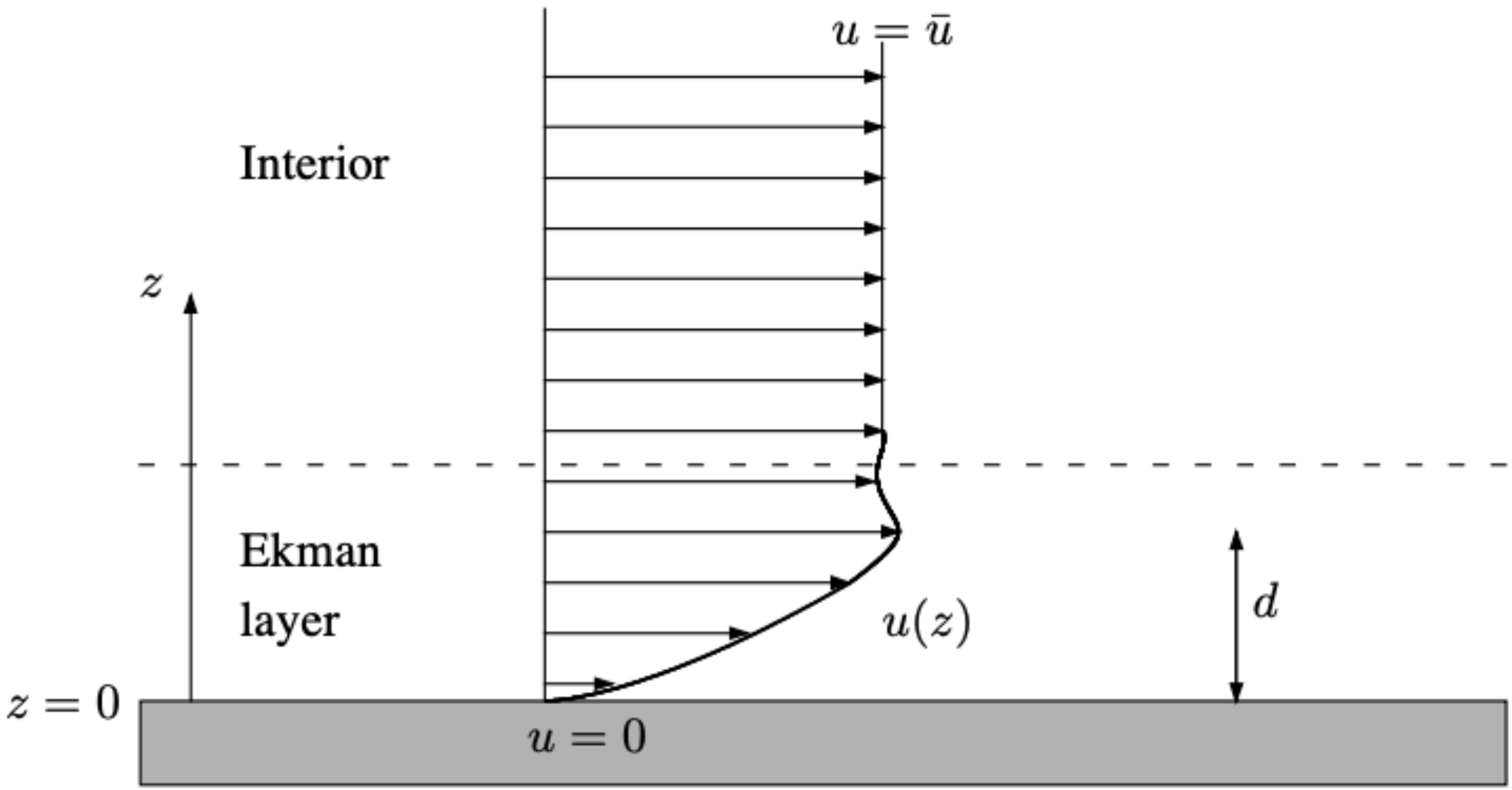


Figure 8-3 Frictional influence of a flat bottom on a uniform flow in a rotating framework.

Ekman currents

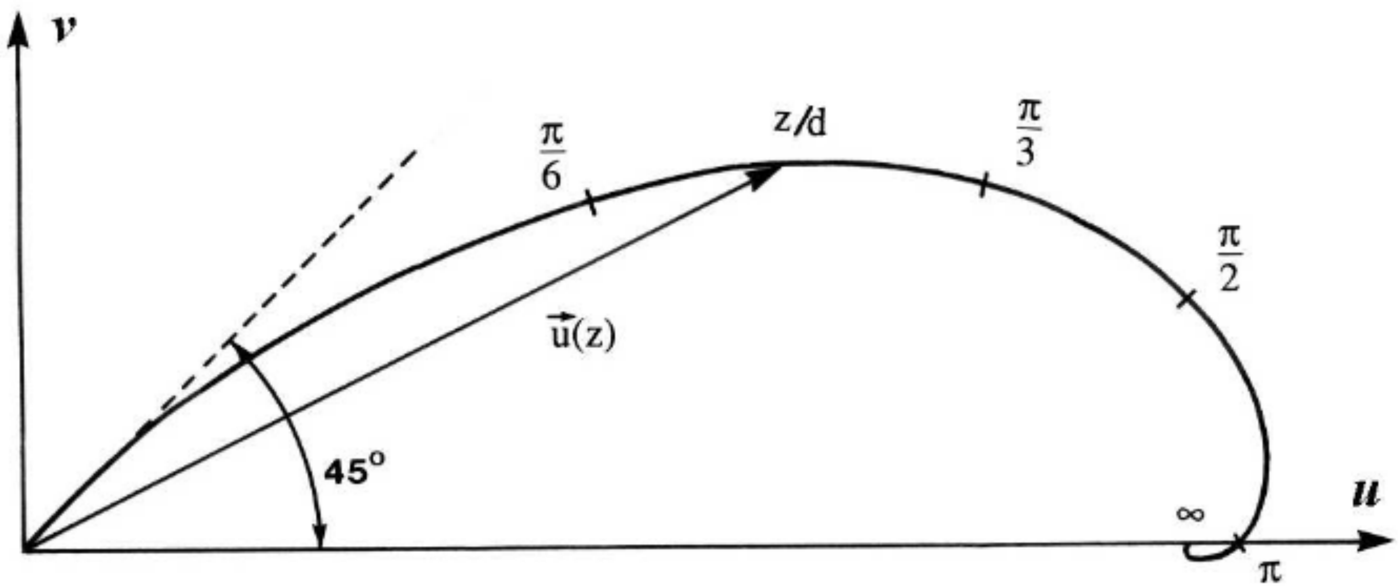


Figure 8-4 The velocity spiral in the bottom Ekman layer. The figure is drawn for the Northern Hemisphere ($f > 0$), and the deflection is to the left of the current above the layer. The reverse holds for the Southern Hemisphere.

- **Outline:**

1. Introduction
2. General equations
3. Waves
   3.1. Surface gravity waves
   3.2. Coastal waves
   3.3. Internal waves
4. Tides
5. Geostrophy and thermal wind
6. Bottom and surface boundary layers
7. **Coastal circulation and responses to meteorological forcing**
8. Frontal dynamics
9. Estuary plumes and regimes

Presentations and material will be available at :

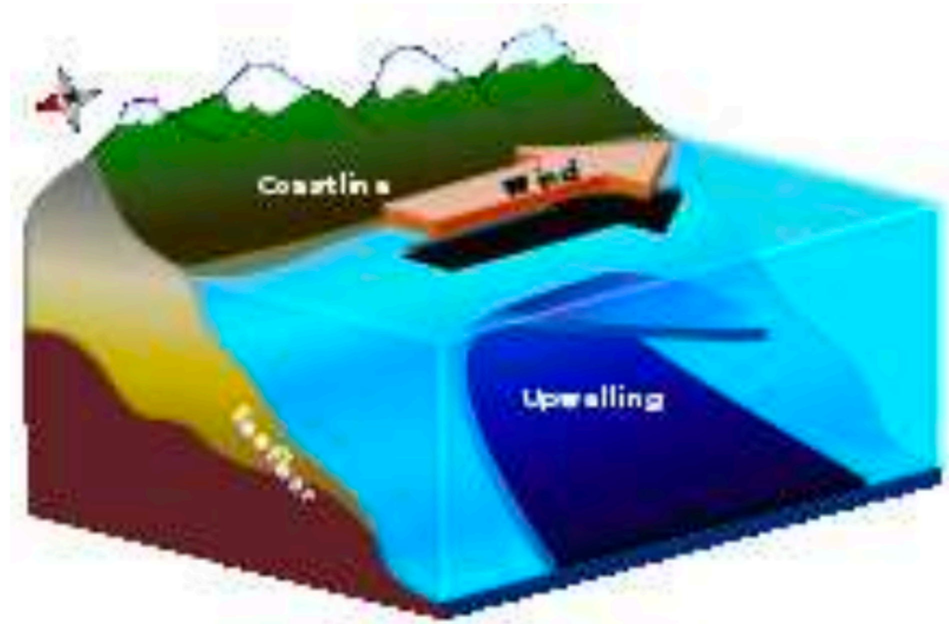
jgula.fr/Coastal/

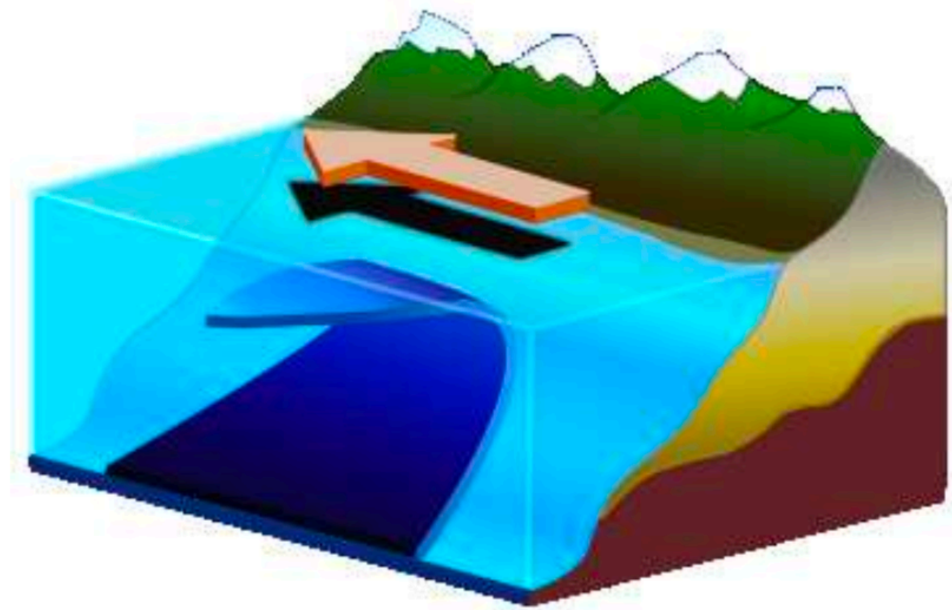
Coastal circulation

- An **upwelling** is a rise of deep water (often cold and rich in nutrients) to the surface, due to the divergence of the surface mass flow, itself resulting from Ekman transport from the coast to the open sea.

- This occurs when a wind blows toward the equator parallel to a meridian coast.

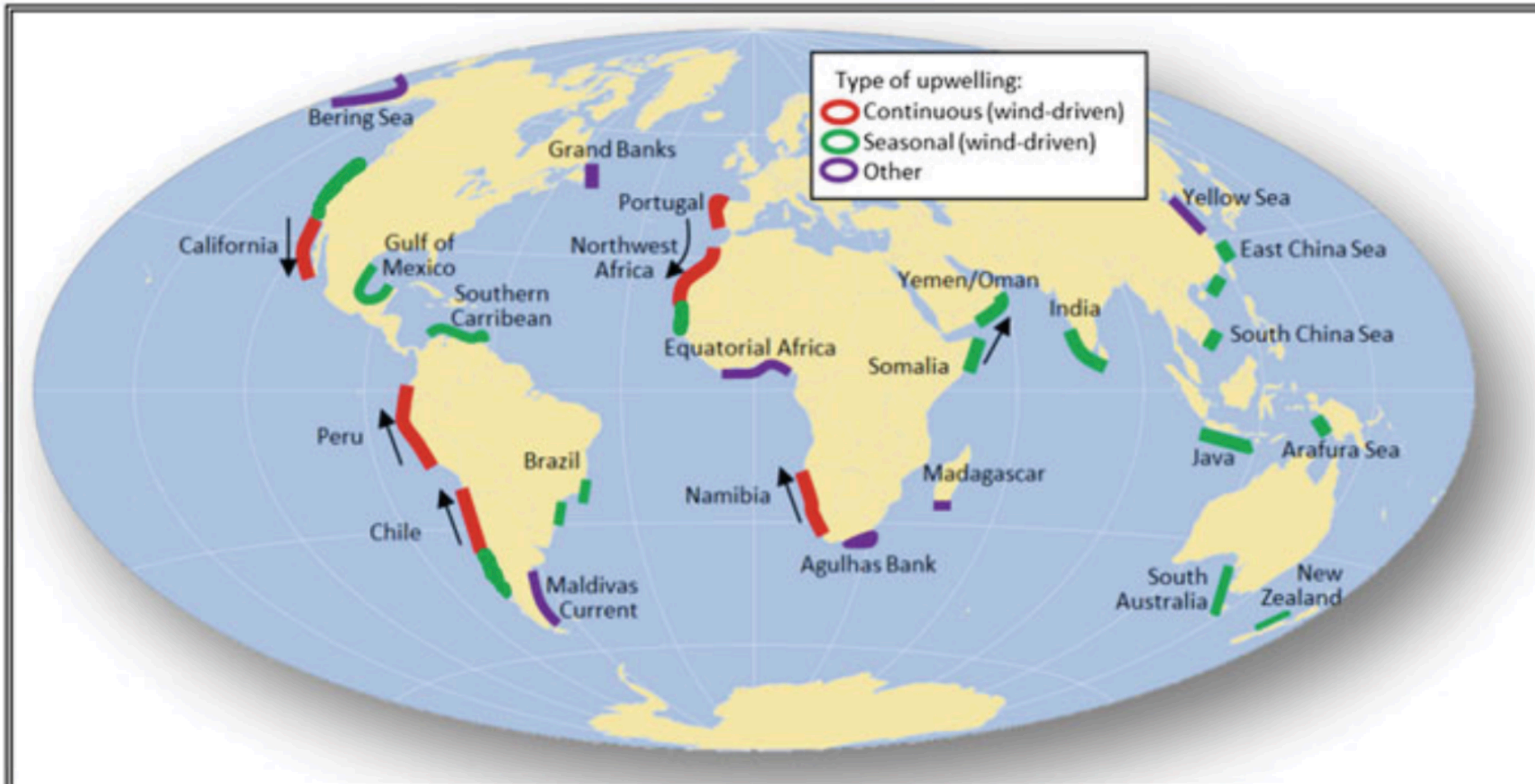
-





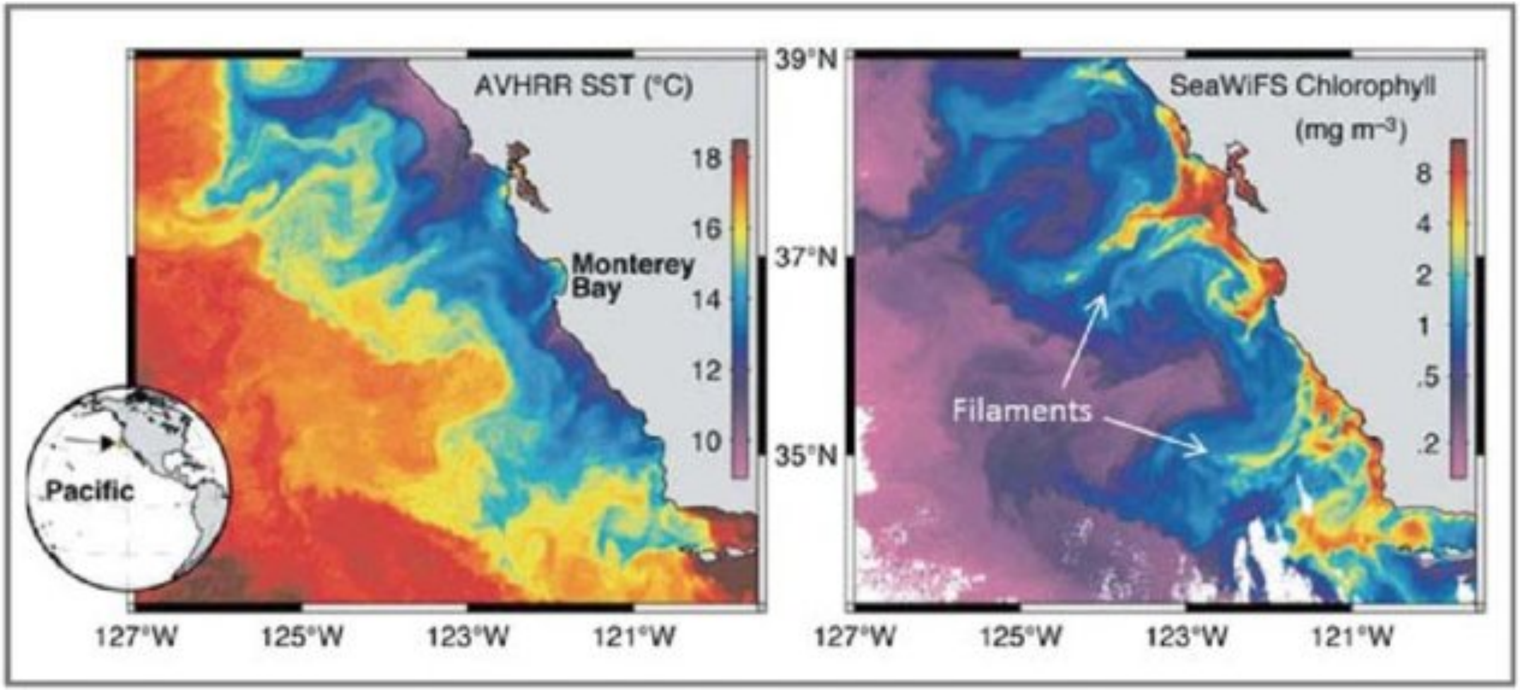
Coastal circulation

- This is the case for eastern coasts subject to anticyclonic winds and the major eastern edge upwellings of Portugal-Morocco-Canary Islands, Benguela, California, Peru/Chile, etc.



Coastal circulation

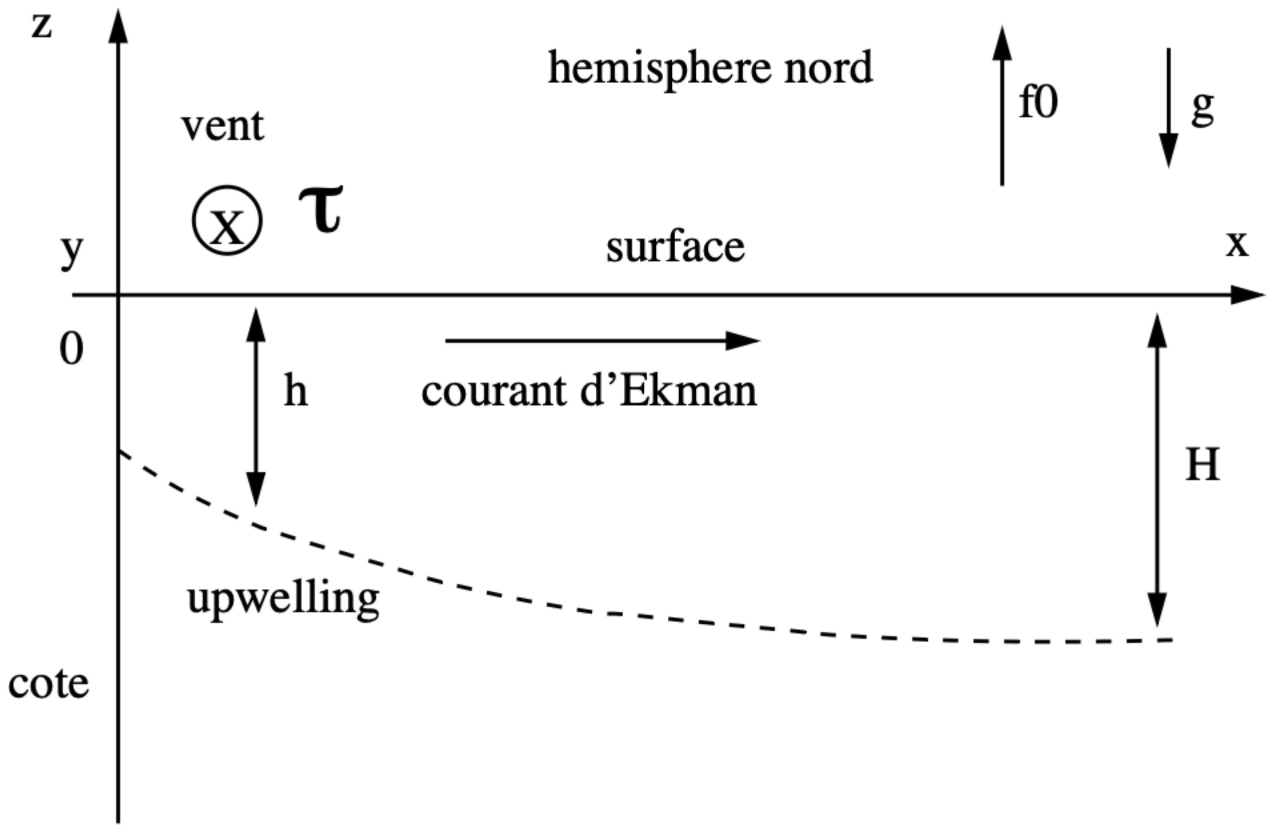
- The Ekman current thus creates shallow upwellings near the coast (200 m deep over 10 km) and then deeper upwellings on the continental slope. The boundary currents associated with these upwellings at the surface are quite wide (about 100 km), directed towards the Equator, fairly slow (about 40 to 80 cm/s) and highly seasonal.



Example of a fully developed eddy field and upwelling filaments seen in satellite images of sea surface temperature and chlorophyll-a concentrations in the Californian upwelling system (from Ryan et al. 2005)

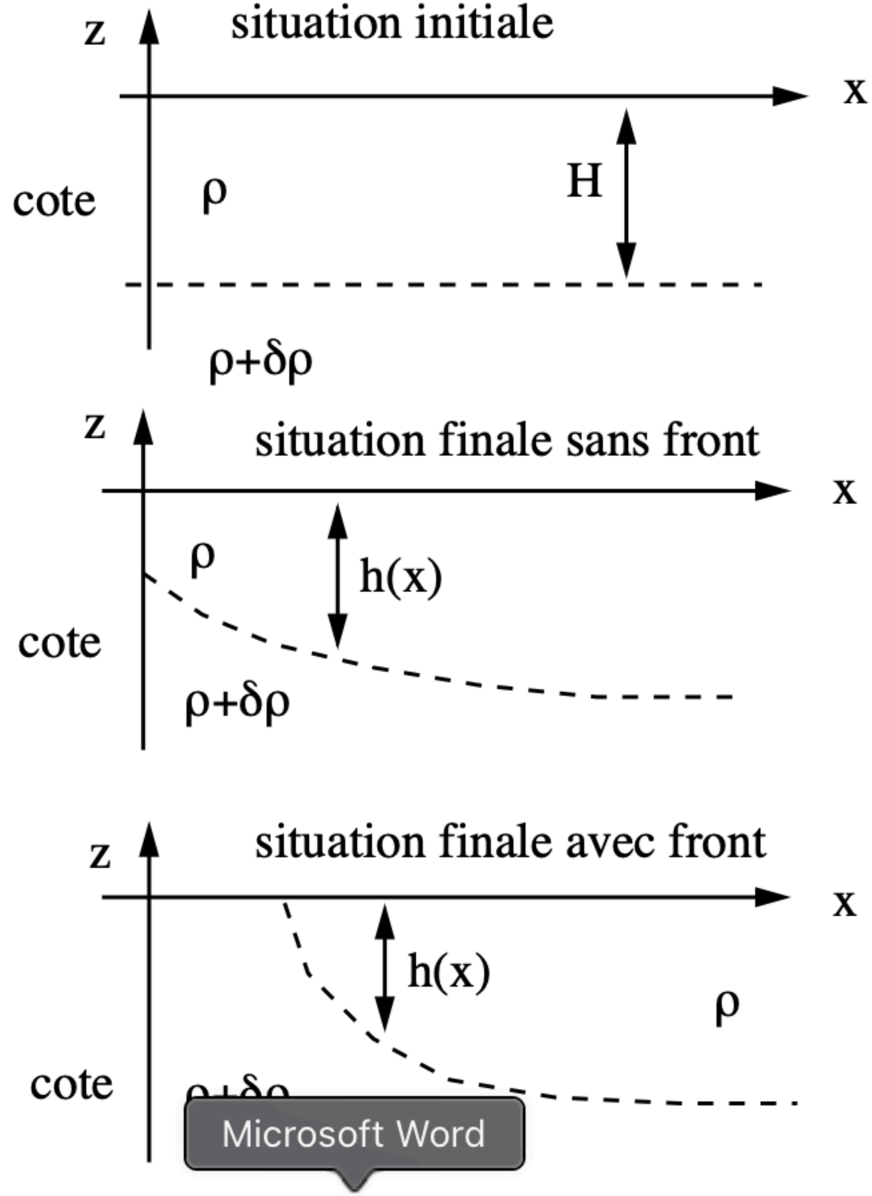
Coastal circulation

- Theory:



Coastal circulation

- Theory:

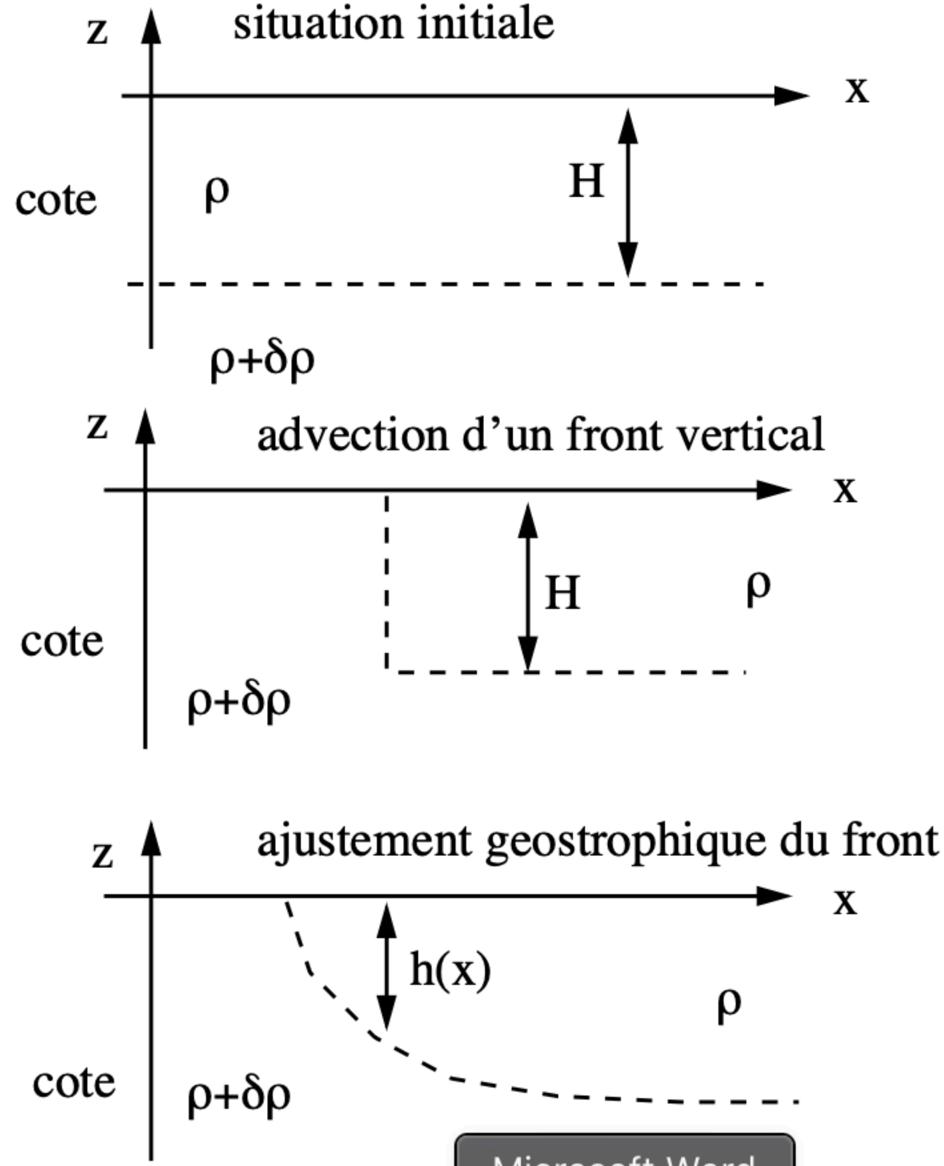


Coastal circulation

- **See notes:**
  - *Simple upwelling model*

Coastal circulation

- Theory:



Microsoft Word