Evariste Jupiter ZAHIBO

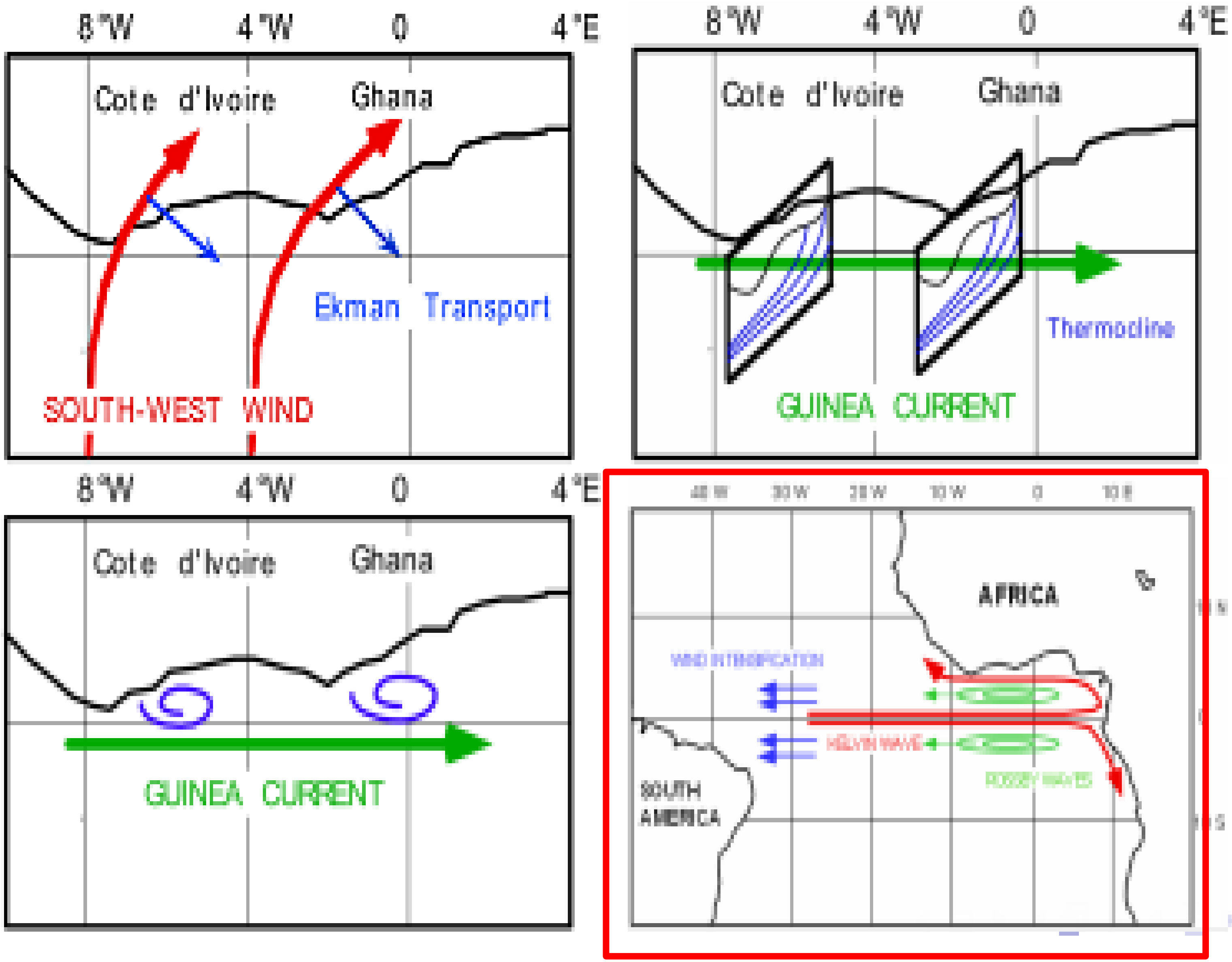
<u>Master thesis (April2018)</u>

- **Topic**: “the variability of aerosols tickness in urban and rural areas of Côte d'Ivoire over the period 2015 to 2016.”
- **Supervisors:** Prof. Véronique yoboué ; Dr Bebou (Aerosol and pollution team)

<u>PhD student (2020)</u>

- **Topic**: ***“Kelvin waves effects on the Gulf of guinea costal upwelling dynamics”***
- **Supervisors:** Prof. Aman Angora ; Dr Sandrine Djakouré

What's about costal upwelling of the Gulf of Guinea?



- The Northern of the Gulf of guinea between Côte d'ivoire and Nigeria are a region where there is a very particular phenomenon of upwelling

- Contrary to most of the other upwellings that occur along the meridian coasts(south-north), this occurs along a zonal coast (west- east)

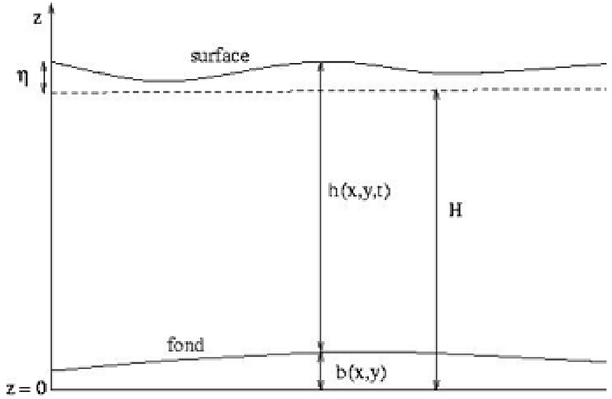
What factors generate the costal upwelling of GG?

Upwelling generally result from the response of:

- Ekman Transport
- Guinea current
- The effects of caps
- Costal Waves

What theories generate Kelvin waves?

A kelvin waves are progressives waves guided by a coast , where it is assumed that the velocities remain everywhere parallel to the banks;
a Wave in the ocean that balances the earth's coriolis force against a topographic boundary such as a coastline,



$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} - fv = -g\frac{\partial h}{\partial x}$$ *x-momentum*

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + fu = -g\frac{\partial h}{\partial y}$$ *y-momentum*

$$\frac{\partial h}{\partial t} + u\frac{\partial h}{\partial x} + v\frac{\partial h}{\partial y} = -h\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)$$ *continuity*

$$\frac{\partial u}{\partial t} - fv = -g\frac{\partial \eta}{\partial x}$$

$$\frac{\partial v}{\partial t} + fu = -g\frac{\partial \eta}{\partial y}$$

$$\frac{\partial \eta}{\partial t} + H\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) = 0$$

$$\frac{\partial v}{\partial t} = -g\frac{\partial \eta}{\partial y}$$

$$\frac{\partial \eta}{\partial t} + H\frac{\partial v}{\partial y} = 0$$

$$\frac{\partial^2 v}{\partial t^2} = c^2\frac{\partial^2 v}{\partial y^2} \quad \text{où} \quad c = \sqrt{g\,H}$$

We obtain the equation of propagation of a plane wave at the speed c, whose solution is the form:

$$v = V_1(x, y+ct) + V_1(x, y-ct)$$

Now we Consider a semi-infinite ocean, bounded vertically by a flat bottom and a free surface, and laterally by a vertical wall representing the coast. Normal speed a long this wall (x = 0) is zero (u = 0).

Kelvin waves and Costal upwelling Dynamics?

Since the wave is non-dispersive, all signals must travel at speed c. The solution for v at y=0 and time t consists of two waves traveling in opposite directions:

$$v = V_1(x, y+ct) + V_2(x, y-ct)$$

The corresponding solution for η is $\eta = \sqrt{H/g}\,(-V_1 + V_2)$

(check this by substitution:

$$\rightarrow \frac{\partial}{\partial t}(V_1+V_2) = -\sqrt{gH}\frac{\partial}{\partial y}(-V_1+V_2) \qquad \rightarrow \frac{\partial V_1}{\partial t} = c\frac{\partial V_1}{\partial y}$$

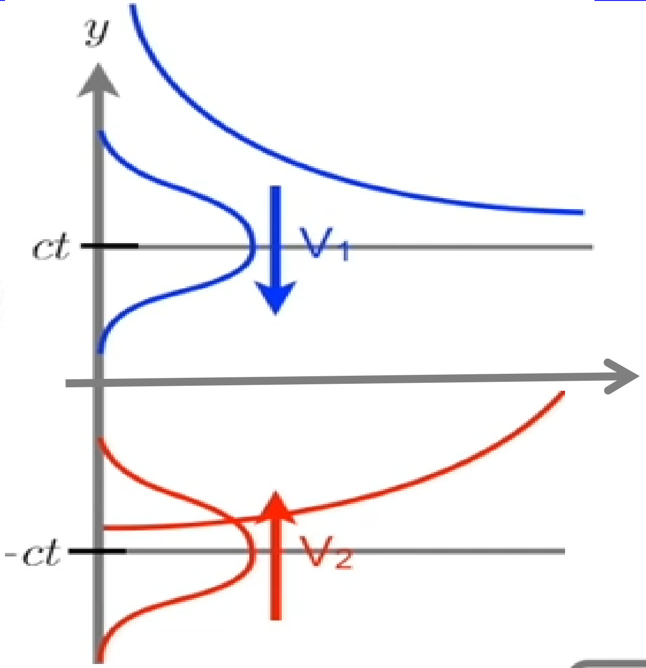
$$\frac{\partial}{\partial t}(-V_1+V_2) = -\sqrt{gH}\frac{\partial}{\partial y}(V_1+V_2) \qquad \frac{\partial V_2}{\partial t} = -c\frac{\partial V_2}{\partial y} \quad)$$

Substituting this solution into the geostrophic balance equation we can derive the x-dependence

$$\frac{\partial V_1}{\partial x} = -\frac{f}{\sqrt{gH}}V_1 \qquad \frac{\partial V_2}{\partial x} = \frac{f}{\sqrt{gH}}V_2$$

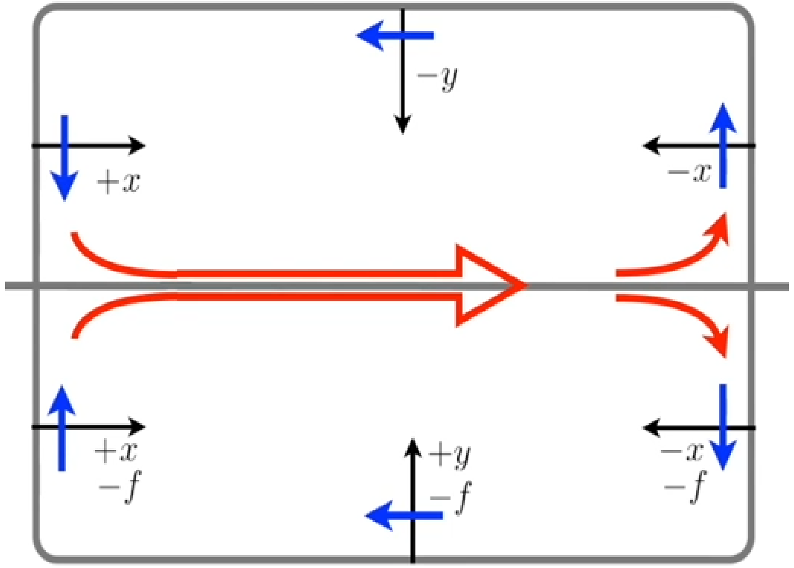
$$V_1 = V_{01}(y+ct)\,e^{-\frac{x}{R}} \quad ; \quad V_2 = V_{02}(y-ct)\,e^{+\frac{x}{R}}$$

These relations have exponential solutions in x with a scale distance of the Rossby radius of deformation $L_R = c/f$.
V_2 is a growing solution so we reject it as unphysical.
V_1 decays away from the coast with boundary layer width L_R



Since the only solution is V1, we conclude that for a system bounded on the west (X>0) the wave propagates in the négative y direction; i.e to the South. If x<0 this reserves so on the eastern side of the basin the Kelvin wave goes northwards . So in the northern hemisphere a Kelvin wave will keep the coast to its right as it is purched against it by the Coriolis force

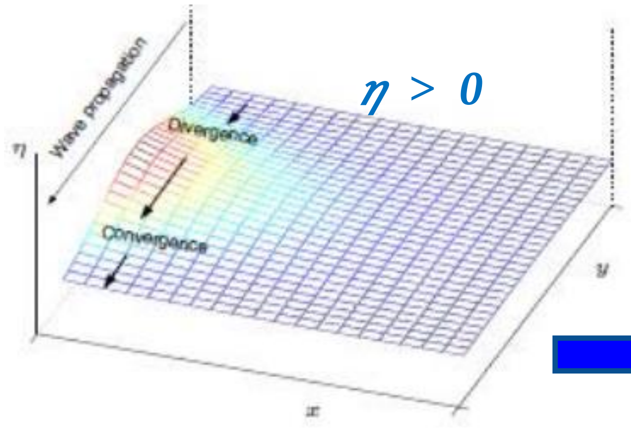
$$\begin{cases} u = 0 \\ v = F(y+ct)\,e^{-\frac{x}{R}} \\ \eta = -\sqrt{\dfrac{H}{g}}\,F(y+ct)\,e^{-\frac{x}{R}} \end{cases}$$

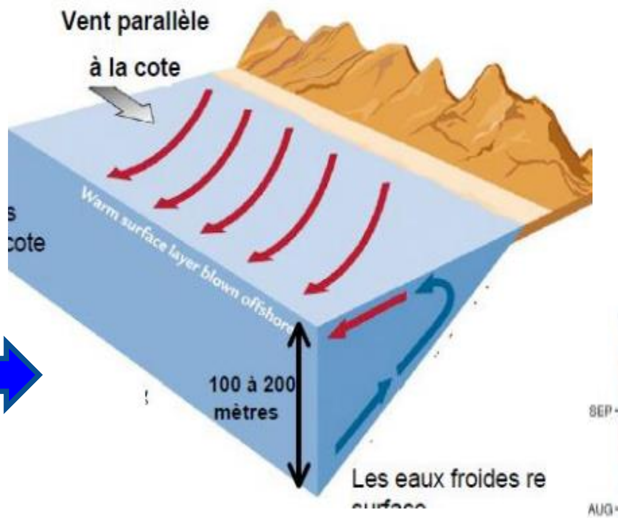


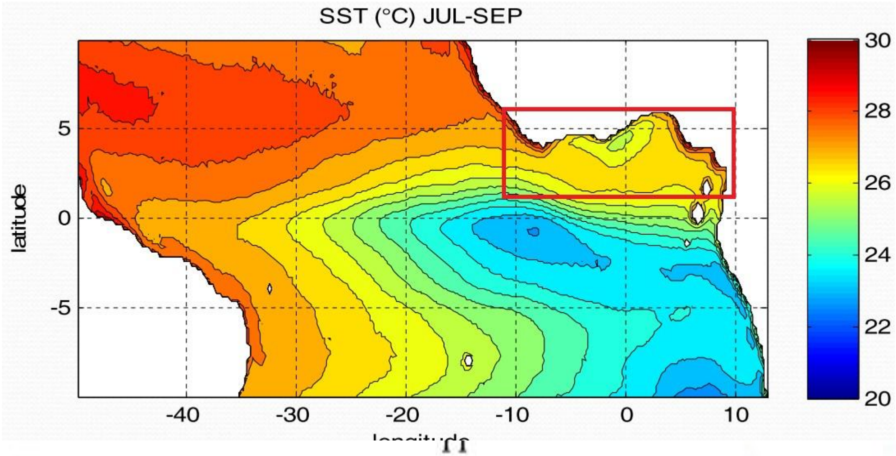
Kelvin waves and Costal upwelling Dynamics?

A wave creating an upwelling (surface elevation $\eta > 0$) is associated to a current in the direction of the wave direction.

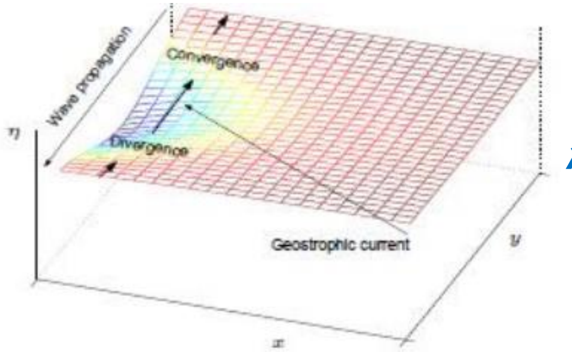
$\eta > 0$



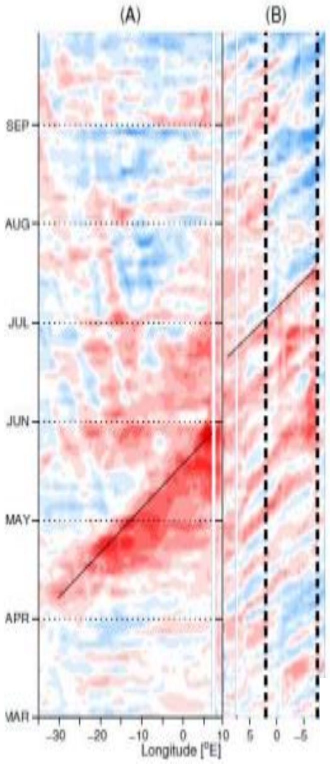




A wave creating a downwelling (hollow in the surface $\eta < 0$) is associated to a current in the opposite direction of the wave direction.



$\eta < 0$



Hövmuller diagrams of depth of thermocline and SST anomalies along the equator and the Northern GG in 2005 (Djakouré, 2015).

Left: Kelvin waves

Right: Instability waves