On the wave-current interactions

A.-C. Bennis[1,2,3], F. Dumas[1], F. Ardhuin[2], B. Blanke[3]

1- Laboratoire d'Océanographie spatiale, Ifremer, 29280 Plouzané, France
2- DYNECO/PHYSED, Ifremer, 29280 Plouzané, France
3- LPO, Université de Bretagne Occidentale

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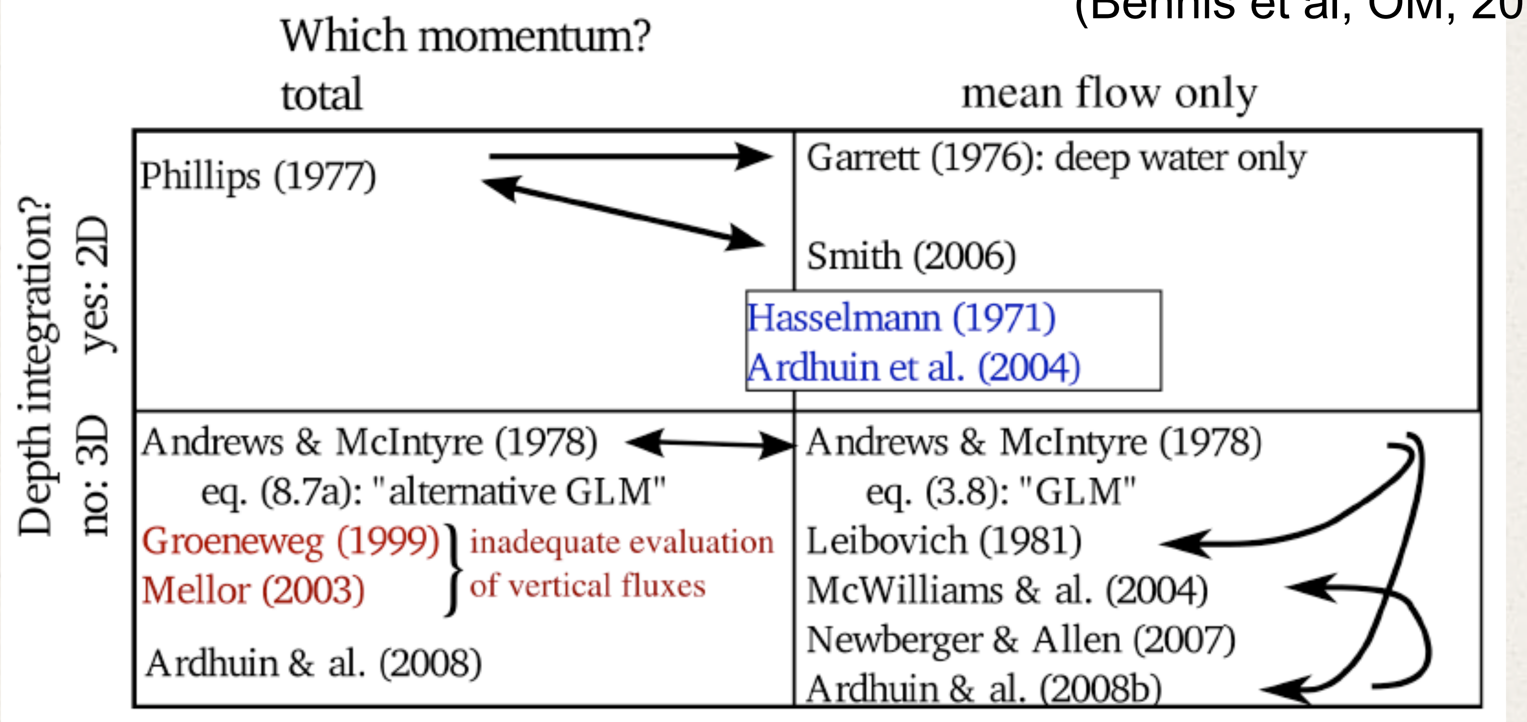
Some informations about the wave-current coupling...

1. Coupled wave-current modelling

a. The 3D challenge

Momentum equation formulated for:

- total momentum (includes Stokes drift): this is too complex
  (vertical flux of wave momentum is a strange beast)
- mean flow momentum only



(Bennis et al, OM, 2011)

1. Wave-current 3D coupling

b. Summary

<u>Where we are now:</u>

➢ *2-way coupling of WAVEWATCH III and MARS3D with PALM*

* Based on WWATCH version 3.14_Ifremer

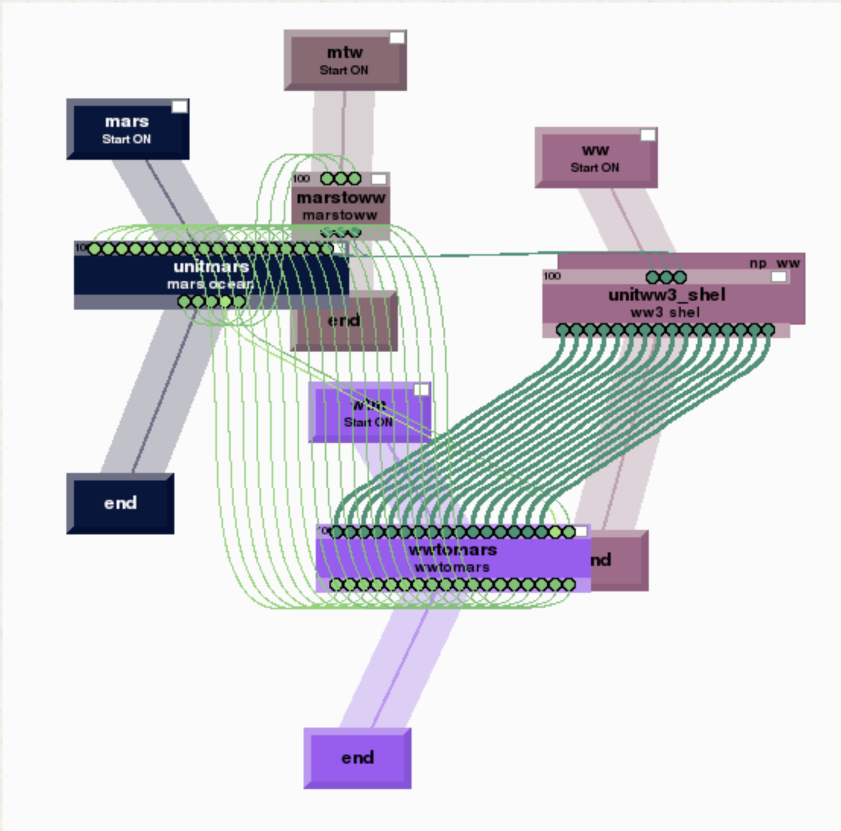
& SHOM and MARS3D version 8.0

* Wrong equations (Mellor 2003 and 2008)

well implemented

* Correct equations implemented

realistic validation OK (beach)



➢ *Now working on:*

- *Mixing/friction parameterizations*
- *Rip currents*

2

Impact of the mixing due to the wave breaking on the bottom friction … and the consequences

2. Bottom friction & mixing

a. Objectives

* To evaluate the impact of wave breaking on the bottom friction and the consequences on the longshore current and on the set-up.

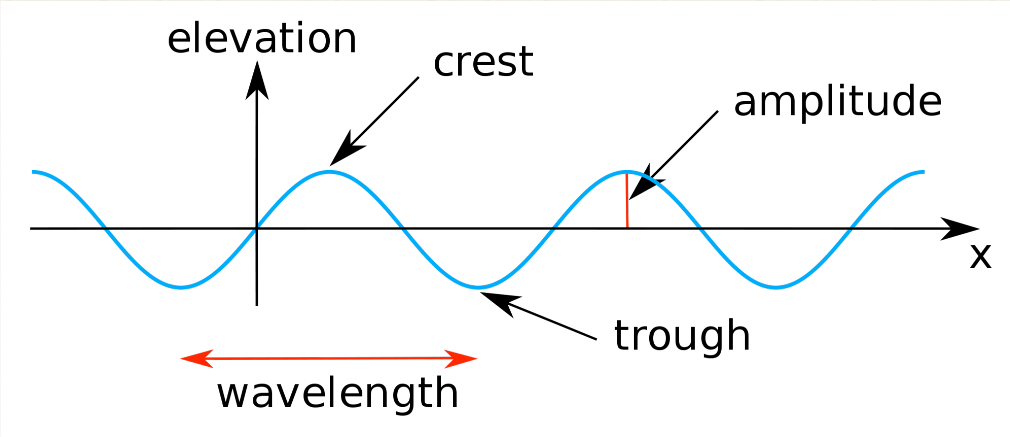
⇒ The parametrization of Mellor (2002) is used:
the bottom friction depends on the turbulent kinetic energy .

i) To redo the numerical experiments presented in Mellor (2002) paper
+ Addition of wave breaking at the surface.
=> comparison between the phase-averaged case and the phase-resolving case

ii) Application in nearshore zone:
- ML02 vs Walstra (2000)+Soulsby (1995).
- Impact on the longshore current
- Impact on the set-up

2. Bottom friction & mixing

a. Introduction



h(x,t)=a.cos(k.x-w.t)

- h: elevation
- a: amplitude
- k: wave number
- w: wave frequency
- Phi=(k.x-wt): wave phase

2. Bottom friction & mixing

b. Phase-averaged vs Phase-resolving

Equations for the phase-resolving case

$$\frac{\partial u}{\partial t} = \frac{\tau_{0x}}{h} + u_{bx}\omega cos(\omega t) + \frac{1}{D}\frac{\partial \tau_x}{\partial \varsigma},$$

$$\frac{\partial k}{\partial t} = \frac{1}{D^2}\cdot\frac{\partial}{\partial \varsigma}\left(\frac{\nu_V}{s_k}\cdot\frac{\partial k}{\partial \varsigma}\right) - \frac{\partial k}{\partial \varsigma}\cdot\frac{\partial \varsigma}{\partial t} + \mathrm{Prod} + \mathrm{Buoy} - \epsilon,$$

$$\frac{\partial \epsilon}{\partial t} = \frac{1}{D^2}\cdot\frac{\partial}{\partial \varsigma}\left(\frac{\nu_V}{s_\epsilon}\cdot\frac{\partial \epsilon}{\partial \varsigma}\right) - \frac{\partial \epsilon}{\partial \varsigma}\cdot\frac{\partial \varsigma}{\partial t} + \frac{\epsilon}{k}\left(c_1\mathrm{Prod} + c_3\mathrm{Buoy} - c_2\epsilon F_{wall}\right).$$

+ Soulsby (1995)

Equations for the phase-averaged case

$$\frac{\partial \overline{u}}{\partial t} = \frac{\overline{\tau}_{0x}}{h} + \frac{1}{D}\frac{\partial \overline{\tau}_x}{\partial \varsigma},$$

$$\frac{\partial \overline{k}}{\partial t} = \frac{1}{D^2}\cdot\frac{\partial}{\partial \varsigma}\left(\frac{\overline{\nu}_V}{s_k}\cdot\frac{\partial \overline{k}}{\partial \varsigma}\right) - \frac{\partial \overline{k}}{\partial \varsigma}\cdot\frac{\partial \varsigma}{\partial t} + \overline{\mathrm{Prod}} + \overline{\mathrm{Buoy}} - \overline{\epsilon} + \overline{P}_k,$$

$$\frac{\partial \overline{\epsilon}}{\partial t} = \frac{1}{D^2}\cdot\frac{\partial}{\partial \varsigma}\left(\frac{\overline{\nu}_V}{s_\epsilon}\cdot\frac{\partial \overline{\epsilon}}{\partial \varsigma}\right) - \frac{\partial \overline{\epsilon}}{\partial \varsigma}\cdot\frac{\partial \varsigma}{\partial t} + \frac{\overline{\epsilon}}{\overline{k}}\left(c_1\overline{\mathrm{Prod}} + c_3\overline{\mathrm{Buoy}} - c_2\overline{\epsilon}F_{wall}\right) + \overline{P}_{eps}.$$

$$\overline{P}_k = \omega u_b^2 (F_{1\Phi}F_{2z})^3,$$

$$\overline{P}_{eps} = C\frac{\overline{\epsilon}}{\overline{k}}P_k.$$

$$\overline{\tau}_x\big|_{z=0} = \frac{\overline{u}\kappa S_{M0}\sqrt{2\overline{k}_0}}{\ln\left(\frac{z}{z_0}\right)}.$$

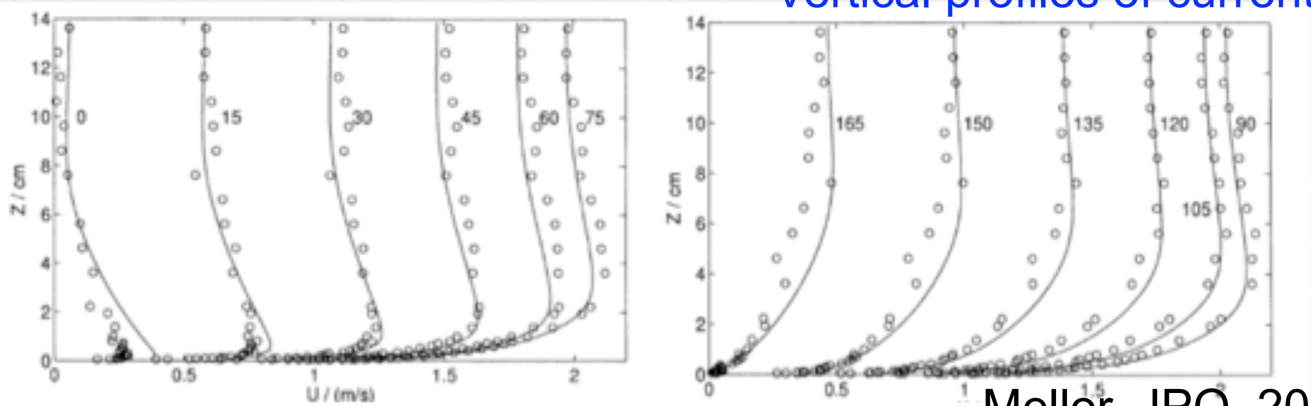
$$\overline{\tau}_x\big|_{z=0} = \frac{\overline{u}\kappa S_{M0}\sqrt{2\overline{k}_0}}{\ln\left(\frac{z}{z_0}+1\right)}.$$

2. Bottom friction & mixing

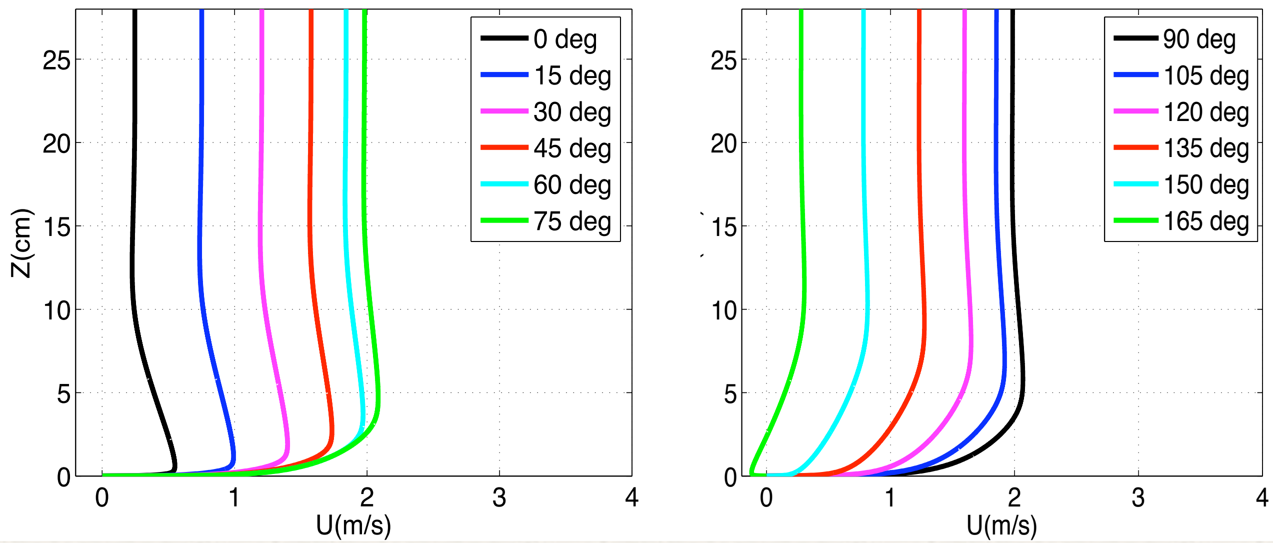
b. Phase-averaged vs Phase-resolving

- Oscillations of the wave bottom boundary layer with the wave phase for pure oscillatory flow.

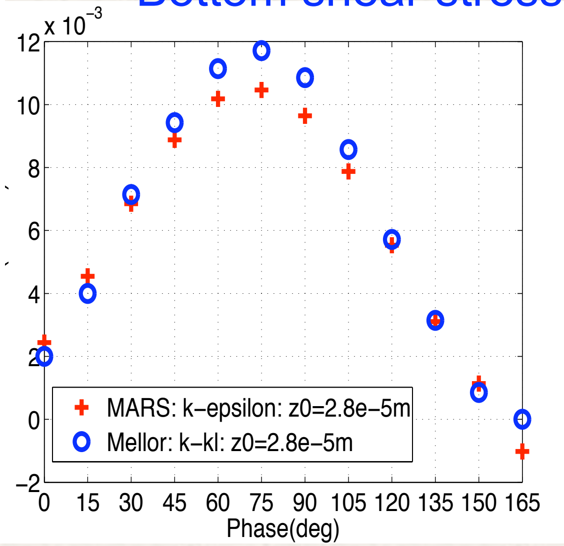
Vertical profiles of current



Mellor, JPO, 2002.



Bottom shear stress



Bennis et al, submitted, 2012.

2. Bottom friction & mixing

b. Phase-averaged vs Phase-resolving

Mean flow superimposed on an oscillatory flow:

* Five meshes are tested:

- refined meshes with 1200 grid points.

- depth of the first grid point:

** Mesh 1: $z_{bot} = 3.0.10^{-2}$ m.

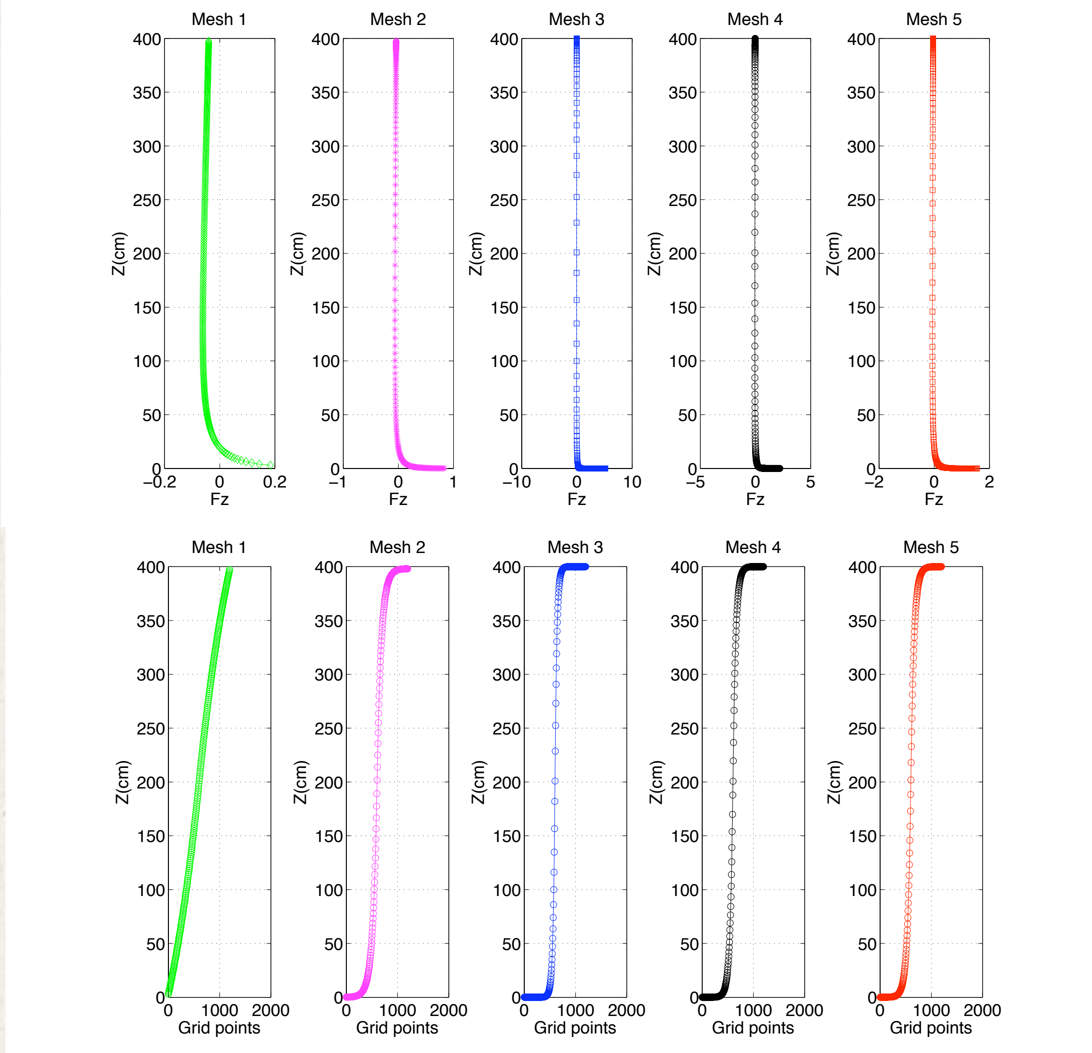
** Mesh 2: $z_{bot} = 9.2.10^{-4}$ m.

** Mesh 3: $z_{bot} = 3.2.10^{-8}$ m.

** Mesh 4: $z_{bot} = 1.3.10^{-5}$ m.

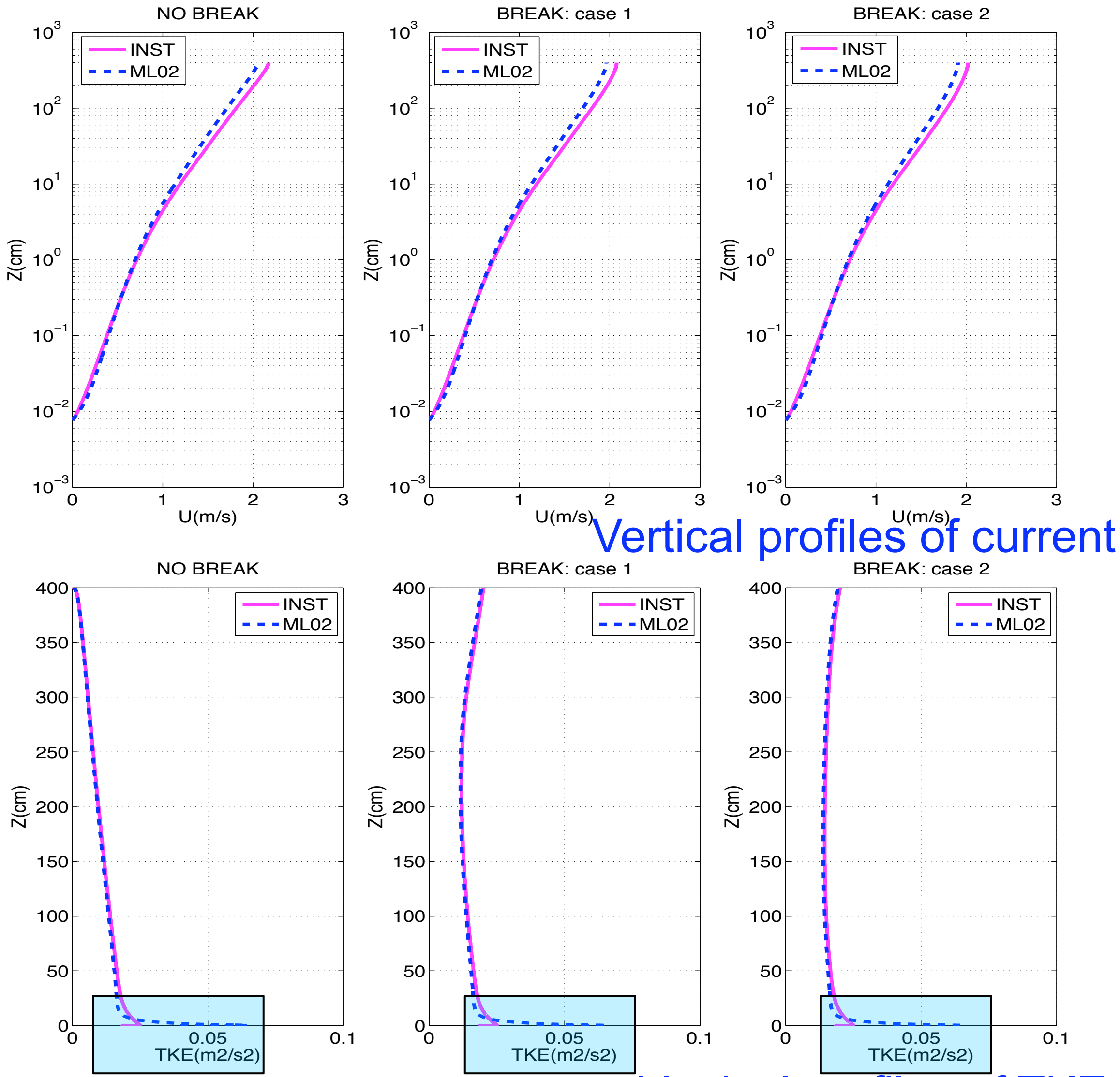
** Mesh 5: $z_{bot} = 7.6.10^{-5}$ m.

=> $0.2 < Fz(bottom) < 5$.



2. Bottom friction & mixing

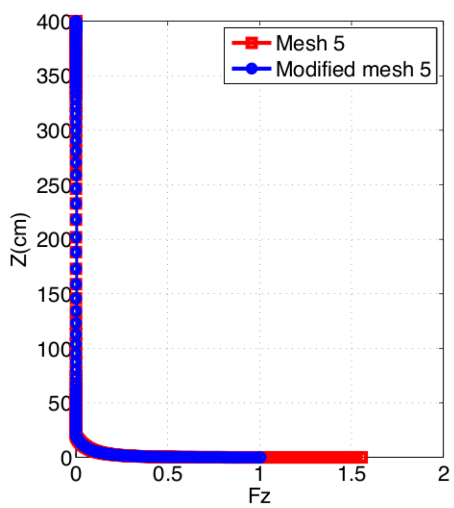
b. Phase-averaged vs Phase-resolving



Vertical profiles of current

Vertical profiles of TKE

- The original Fz function must be changed.
- Currents are very close.
- TKE near the bottom is greatly enhanced.



Bennis et al, submitted, 2012.

2. Bottom friction & mixing

c. Application in surf zone

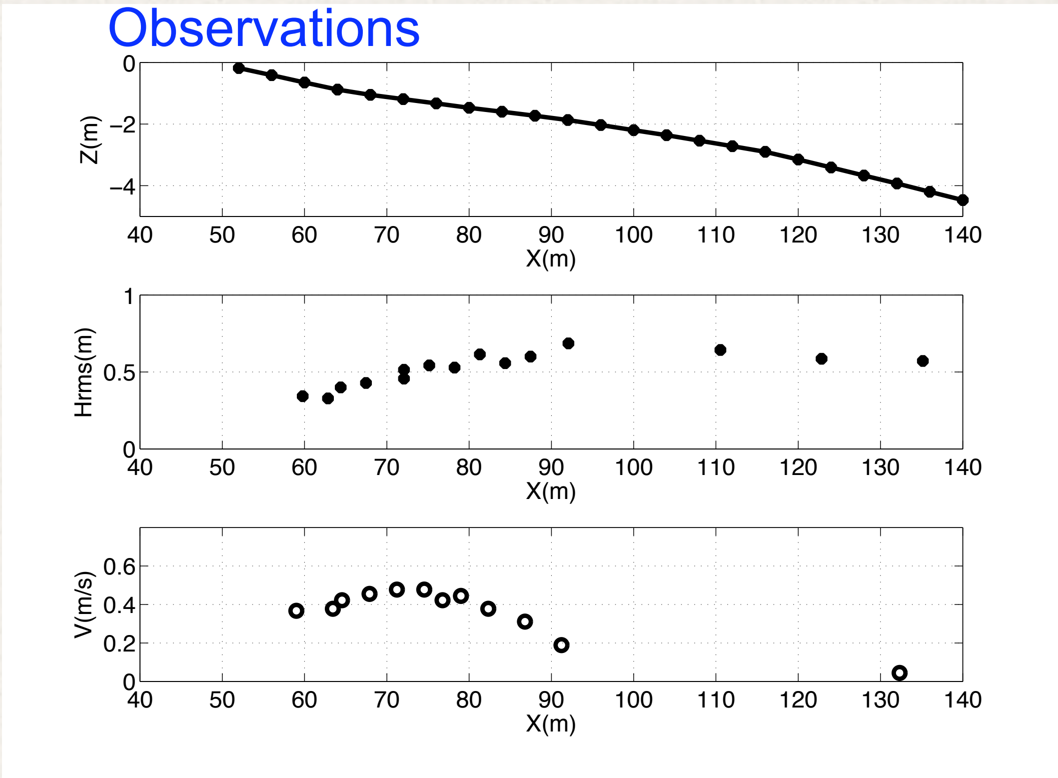
* NSTS configuration: Leadbetter beach

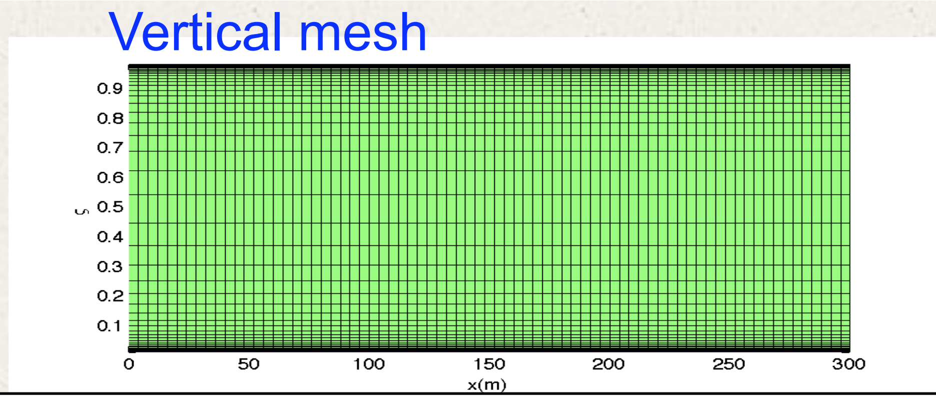
* Simulations of 3D circulation in surfzone: MARS-WWATCHIII
- dx=4m, dy=20m
- dt=1s
- 100 sigma levels (refined mesh)

* Hs<1.1m, T=12s, θ=109 deg

* Impact of the modelization of the bottom shear stress on the longshore current and set-up

- Mellor (2002) vs Walstra (2000)+Soulsby(1995)

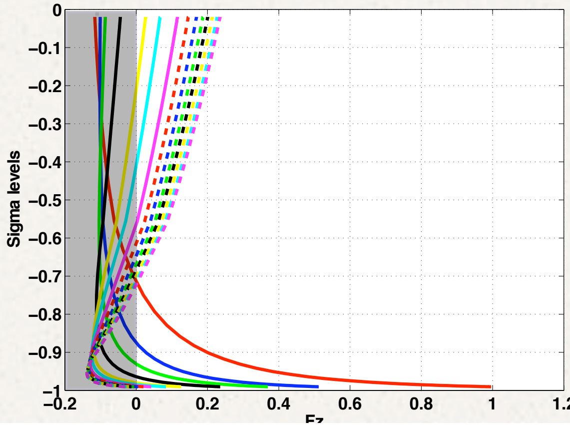


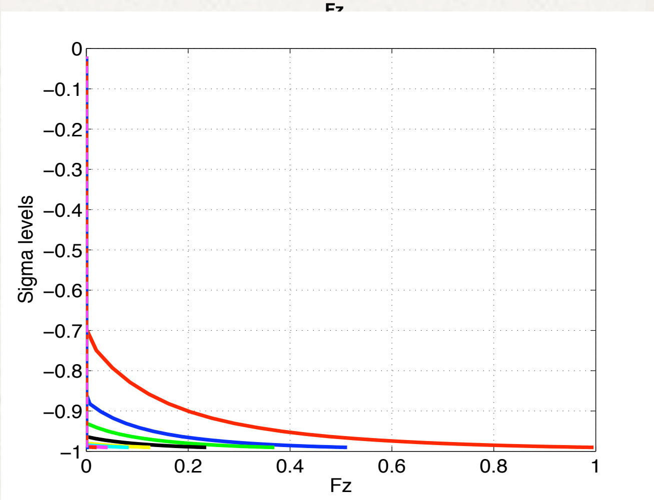


2. Bottom friction & mixing

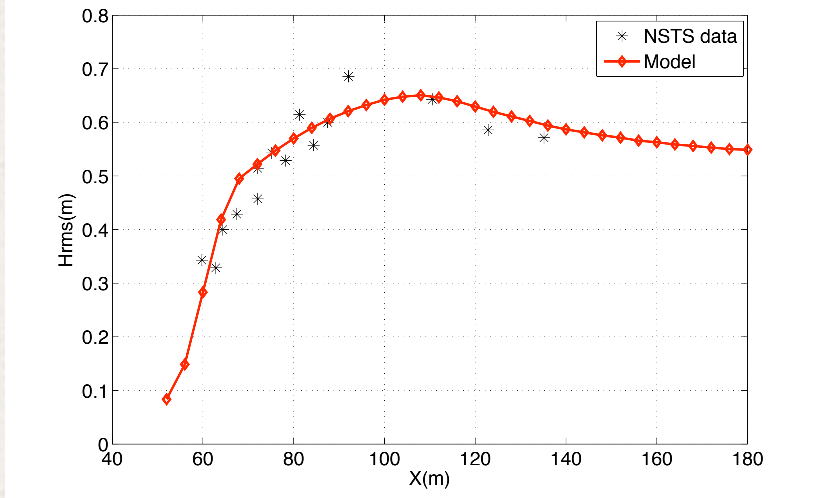
c. Application in surf zone

The Fz function must be changed:
=> Inappropriated positive values near the surface

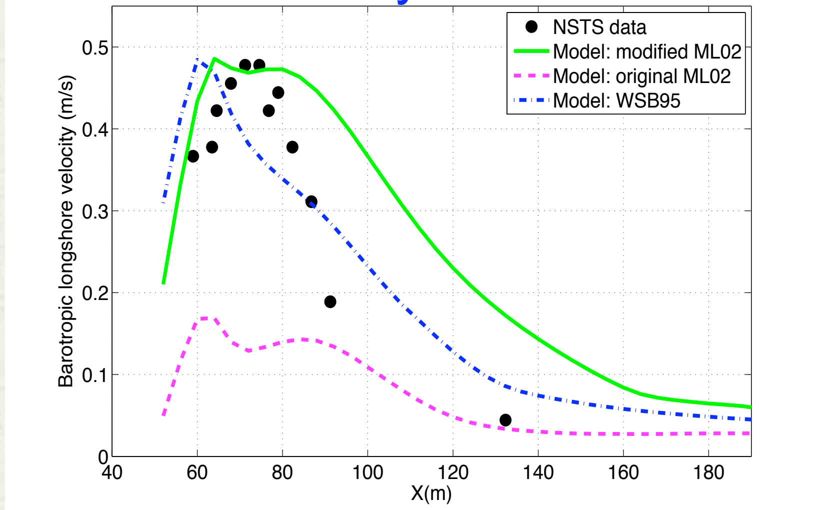




Hs is correctly simulated



The ML02 parametrization must be modified to correctly simulate the current



2. Bottom friction & mixing

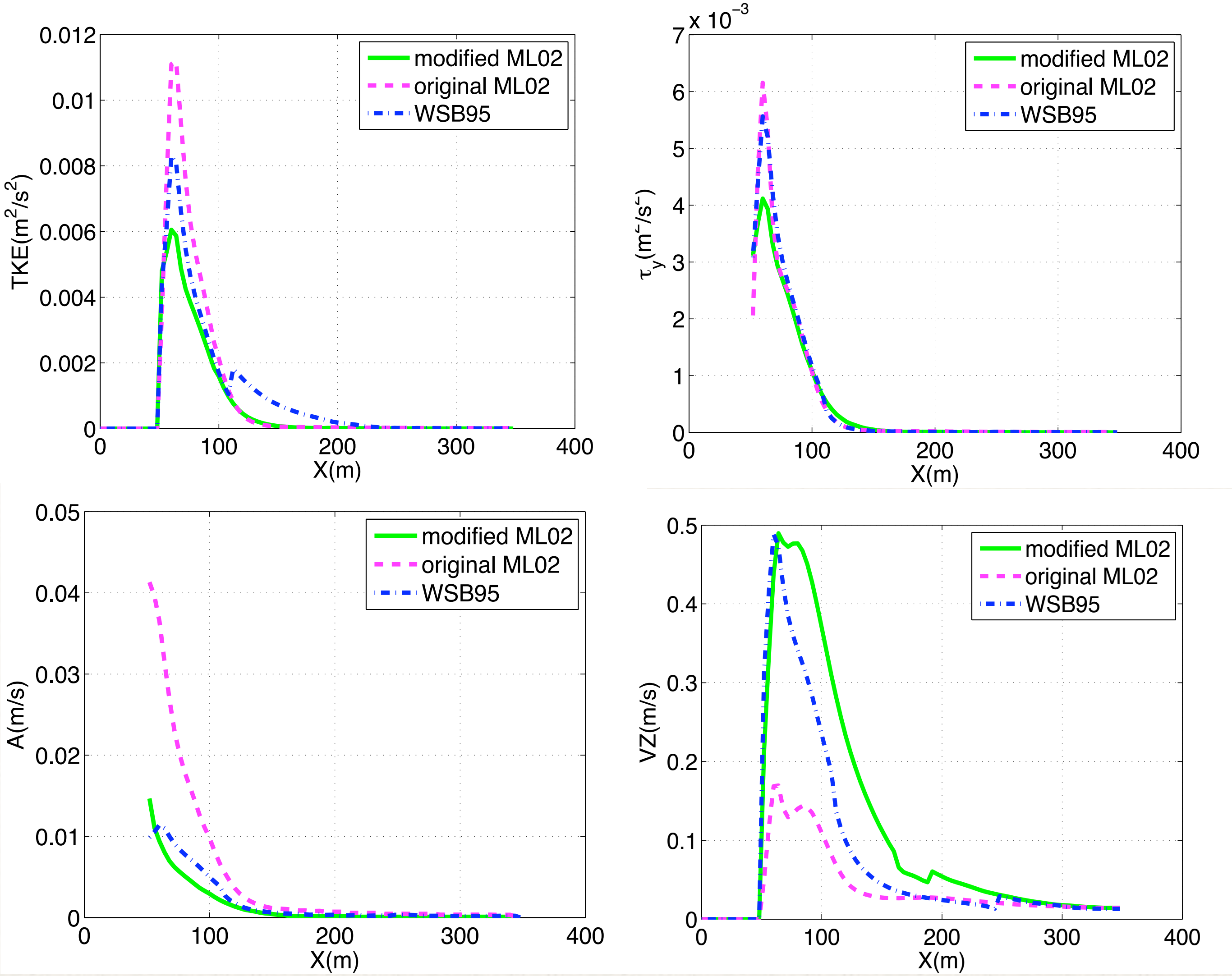
c. Application in surf zone

$$\tau_y|_{z=0} = A \cdot \widehat{v},$$

$$A = \frac{\kappa S_{M0}\sqrt{2k_0}}{\ln\left(\frac{z}{z_0}\right)}.$$

* TKE overestimated:
=> weakest longshore current

* Modified bottom stress gives similar A term than in the WSB95 case:
⇒ longshore current is ok



3

Rip currents...

3. Rip currents

a. Configuration & Objectives

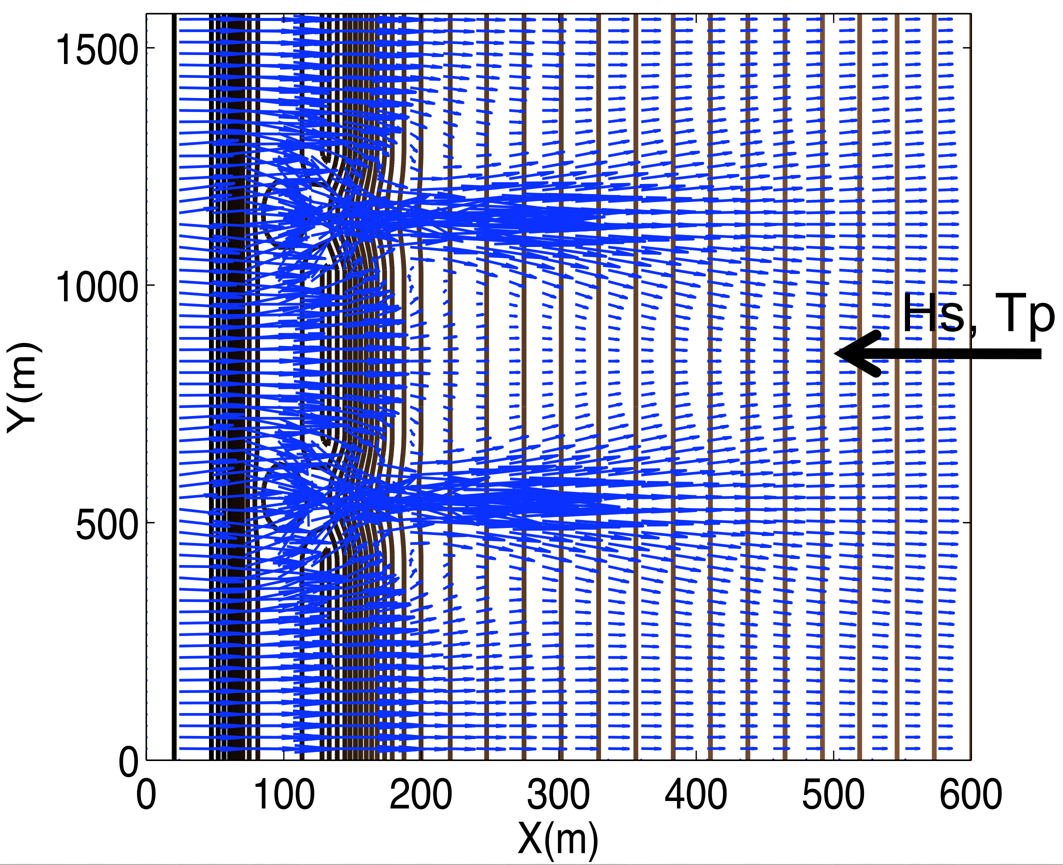
* The bathymetry is an approximation of the beach profile measured at Duck on October 11, 1990

* Simulations of 3D circulation in surfzone: MARS-WWATCHIII
- dx=12m, dy=12m, dt=1s
- 15 sigma levels

* Hs=1m, T=10s, θ=90 deg

* Comparison of results between the one-way mode and the two-mode
- barotropic currents
- vorticity
- forcing terms

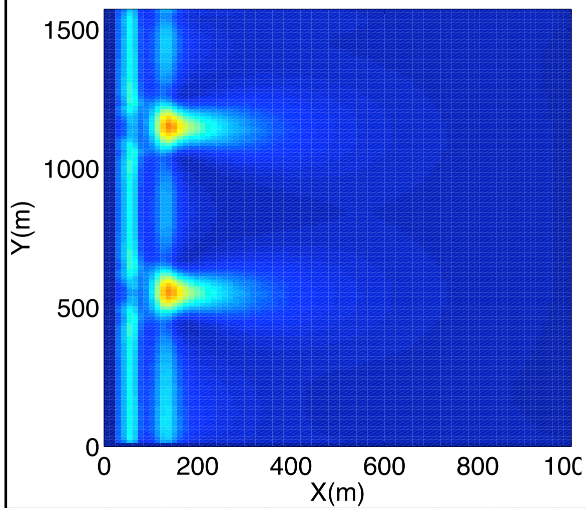
<u>One-way mode</u>:
vector current over bathymetry



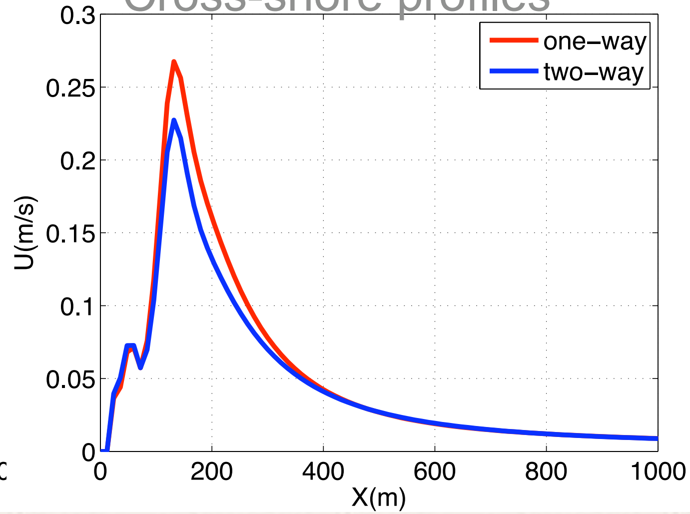
3. Rip currents

b. One-way mode vs Two-way mode: barotropic currents

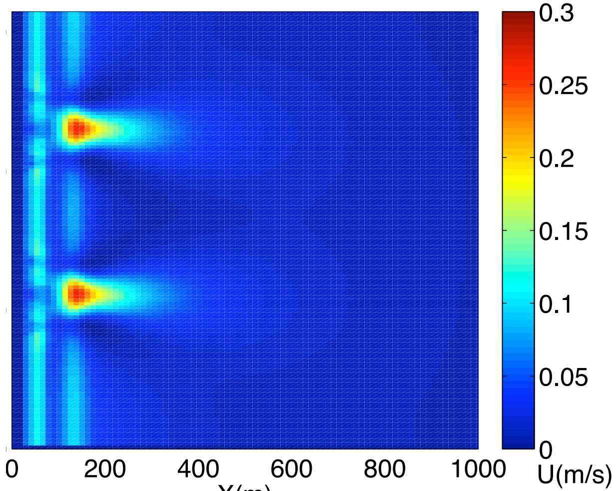
Two-way mode



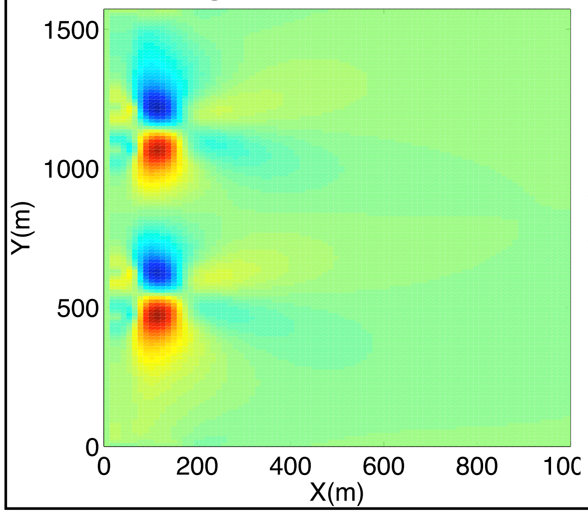
Cross-shore profiles



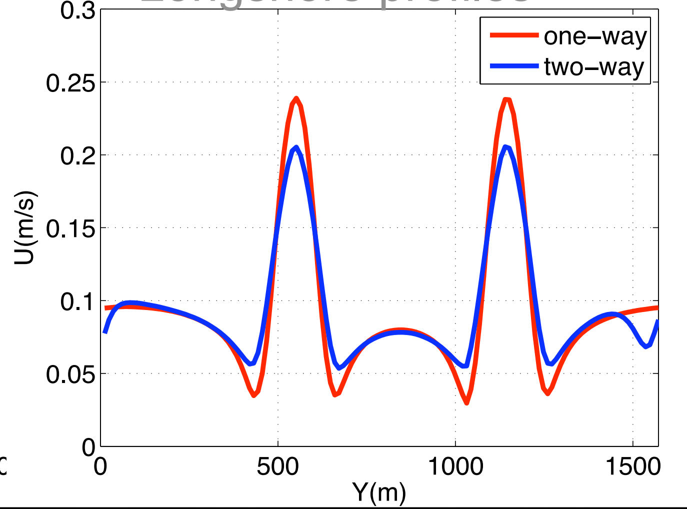
One-way mode



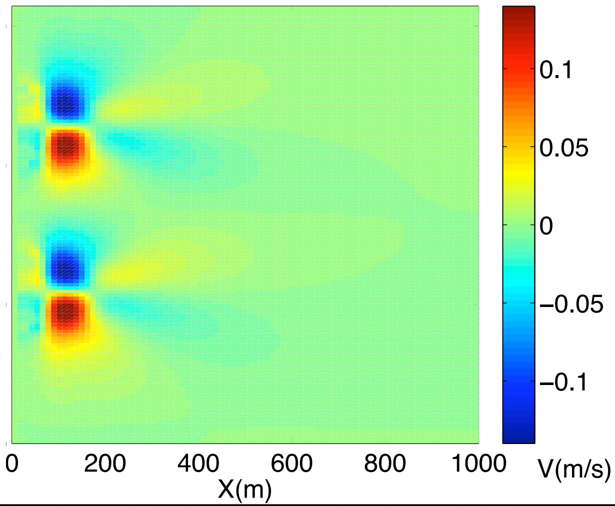
Two-way mode

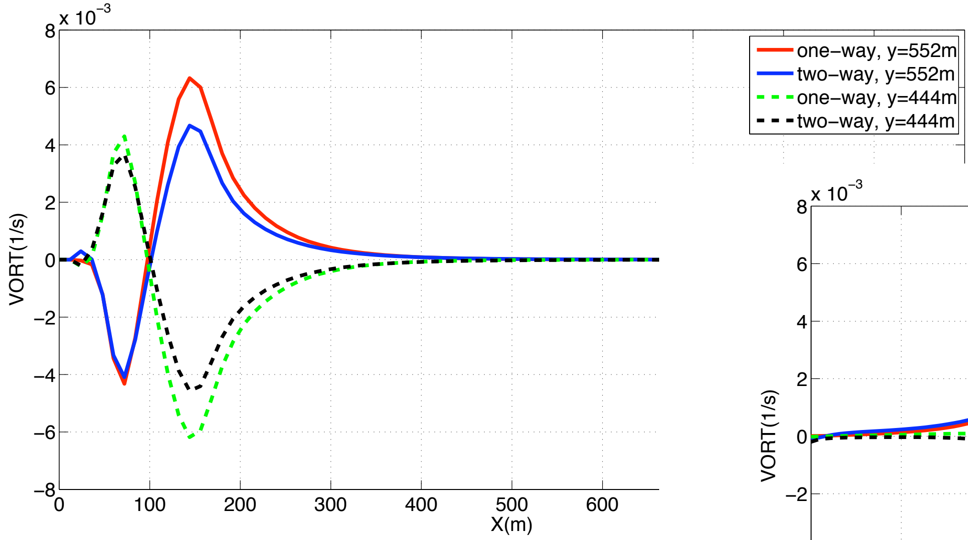


Longshore profiles



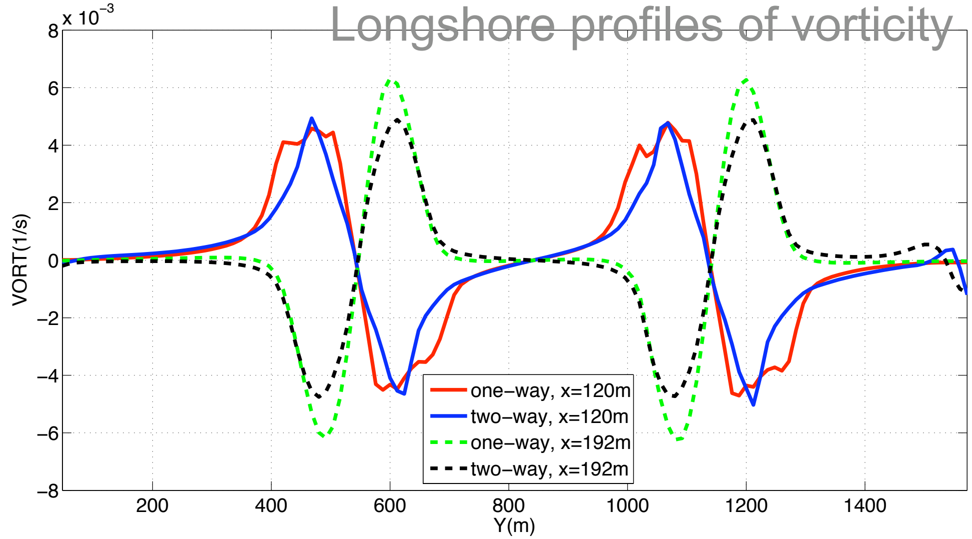
One-way mode



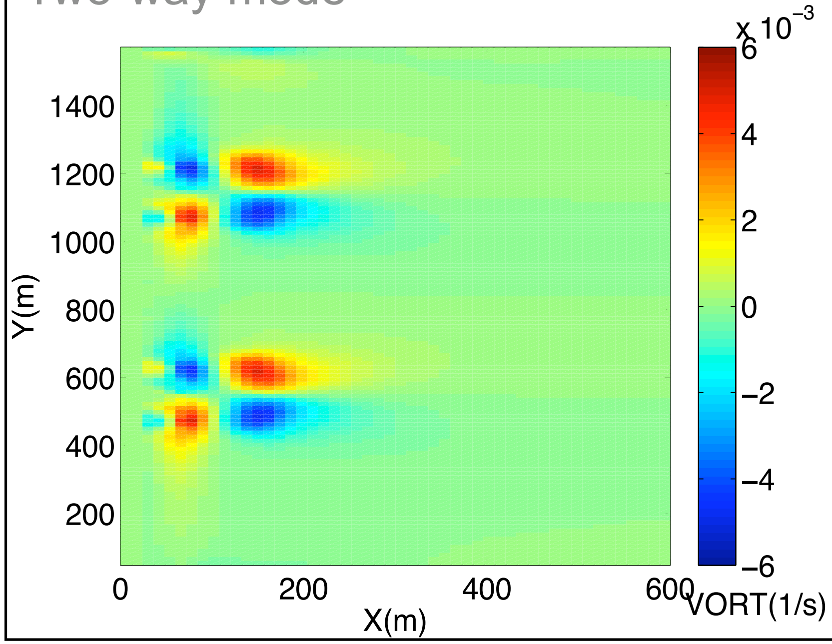


Cross-shore profiles of vorticity

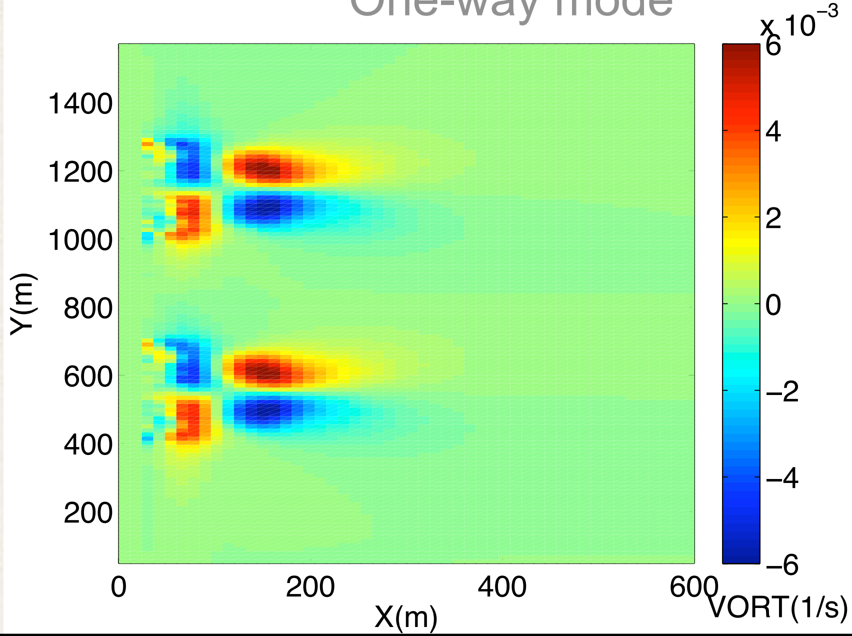
Longshore profiles of vorticity



Two-way mode



One-way mode



TO CONCLUDE:

* Rip currents are correctly simulated by the 3D wave-current model

* One way-mode vs Two-way mode
    - The current intensity is reduced when the feedback is activated
    - The vorticity is reduced when the feedback is activated and its offshore extension is lesser
    - The forcing terms from breaking are less important for the two-way mode than for the one-way mode

=> Here the impact of the feedback is weak

IN THE FUTURE:

* High resolution numerical simulations

* To extend this study for other rip systems