Introduction: A process study in supercritical regions

- Regions with supercritical tidal flow and supercritical topography
- Energetic internal tide generation site with intensive mixing
- A diversified mixing distribution (q) related to the multiplicity of processes controlling turbulent mixing in this area

Objective: describing and identifying the different regimes of internal wave in these regions

1. Numerical approach: SNH modeling

SNH model resolves the nonhydrostatic & non-Boussinesq equations:

Features of SNH model:
- nonhydrostatic\(^1\)
- non-Boussinesq\(^2\)
- high resolution
- free surface
- Moving bottom\(^3\)

Time splitting

- Continuity
- Momentum
-Heat
-Salinity
-State

Non-Boussinesq mode

- External mode
- Internal mode

2. Numerical configuration at laboratory scale

Laboratory scale (DNS)

- 2D vertical
- Topography
- Bottom Boundary Conditions
- Initial conditions
- Loading of the bottom boundary
- Forcing terms

Fig. Vertical section of the density at t=0 s. Vertical physical and geometrical parameters in our numerical configurations.

3. Topographic control on vertical mode generation

Above subcritical topography

- Mode 1 hydraulic control
- Mode 2 hydraulic control

Above supercritical topography

- Mode 1 ISW train & plunging wave breaking
- Mode 2 ISW train

Focus on non-linear internal waves propagating along the pycnocline and emitted primarily in supercritical regions:

- Hydraulic control (supercritical tidal flow)
- Strong interaction between the pycnocline and the topography (efficient primary generation)
- Supercritical slope
- Strong non linearity leading to internal solitary wave (ISW) formation

Key parameters

- Muzzle Froude number \( F_r = U_{muzzle} / c \)
- Topographic forcing degree \( B = h / h_t \geq 0.6 \)
- Supercritical slope \( \theta / y < 1 \)

Another key parameter:

- \( \lambda_1 / \lambda_2 \geq 1 \)

- Topographic control on vertical mode generation: a resonance phenomenon: \( \lambda_1 \) maximal for \( \lambda_1 / \lambda_2 = 1 \)

4. Topographic control on soliton formation

Mode 1 hydraulic control

- without ISW formation

Mode 2 hydraulic control

- Mode 1 ISW train

Hydraulic & topographic control on:

- ISW formation (splaying to all modes)
- Breaking event (kinematic instability)
- Vertical mode propagation

Non-Linear regime

5. Instabilities: vortexes and jet formation

Lee-side vortexes & jet separation

DOWNSWEEP jet

Ocean scale (LES)

6. Gibraltar strait configuration

- Lock exchange vs initialization
- Phase of tide forcing and model bottom in SIMG8R.
- Color line represents horizontal velocity output highlighting gravity currents and fronts induced by the lock exchange initialization.

7. Internal tide dynamics at Gibraltar strait: a supercritical region

Mode 1 soliton train \( \lambda_1 \) above TN

Two modes 2 \( \lambda_2 \) & \( \lambda_2' \) above TN

Mode 2 \( \lambda_2' \) generated above ES

Two simplified configurations

- Generation of \( \lambda' \) related to ES (\( \lambda_2' \))
- A propagation or generation impacted by the frontal area

Two generation areas

Conclusions

- Identification and adaptation of key parameters for supercritical region dynamics
- Regions characterised by a complex multimodal structure
- Interactions between internal tides - topography and tidal current above supercritical regions: hydraulic and topographic controls on vertical mode generation, propagation, ISW formation and instabilities.

References