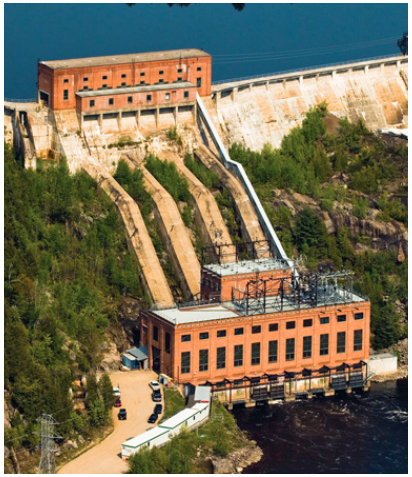
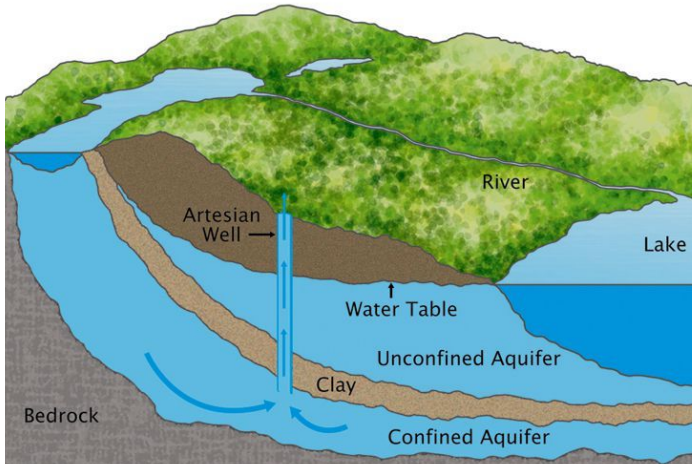
Applications:



pipe flows

underground rivers



confined aquifer

floating structures

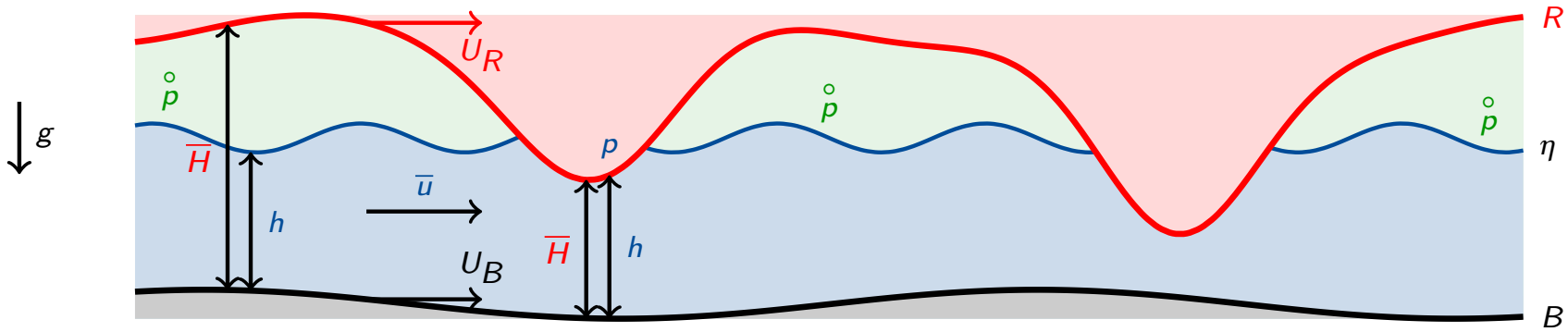
waves energy converters

oscillating water column

With real context simulations, farm of converters, optimization...

Fluid/structure interaction model:

- **Shallow water** type hydraulique model
  - **Efficient:** 2D mesh, robust
  - **Additional terms:** friction, wind, dispersion...
- **Rigid bodies** model
  - **Efficient:** no mesh, no time step restriction, robust
  - **Additional terms:** friction, wind, collisions, anchoring...
- **Isentropique** gaz model
  - **Efficient:** no mesh, no time step restriction, robust
  - **Additional terms:** merging and splitting of the air pokets...

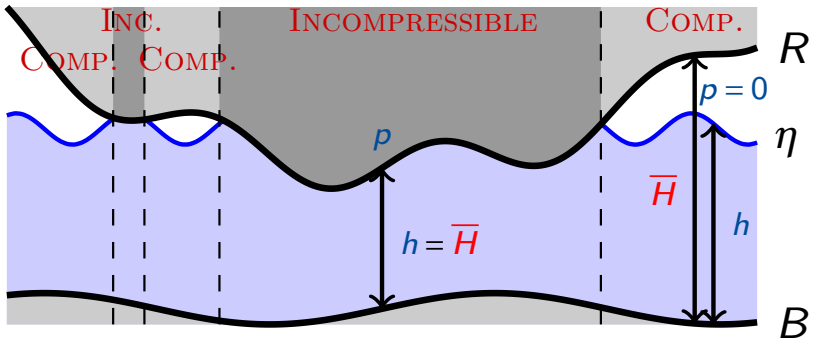


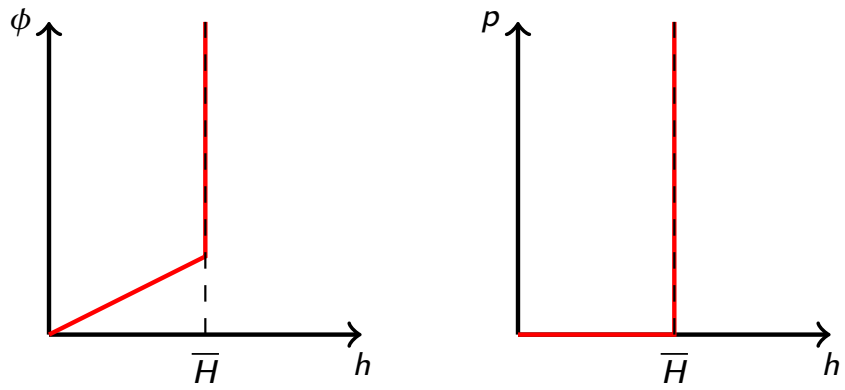
Given parameters:	Fluid unknowns:	Solid unknowns:	Air unknown:
$B(t,x)$: bottom	$\overline{u}(t,x)$: horizontal velocity	$(\Lambda,\Theta)_i(t)$: body position	$\mathring{p}(t,x)$: air pressure
$U_B(t,x)$: bottom velocity	$h(t,x)$: water depth	$\left(\dot{\Lambda},\dot{\Theta}\right)_i(t)$: body velocity	
$R_i^0(\Theta)$: body lower surface	$p(t,x)$: roof reaction	$R(t,x)$: roof elevation	
		$U_R(t,x)$: roof velocity	

Shallow water model with roof:

$$
\begin{aligned}
\partial_t h + \nabla\cdot(h\overline{u}) &= 0 \\
\partial_t(h\overline{u}) + \nabla\cdot(h\overline{u}\otimes\overline{u}) &= -h\nabla\phi(h,p) \\
\min\left(p, \overline{H}-h\right) &= 0
\end{aligned}
$$

$$\phi(h,p) = g(h+B+p)$$



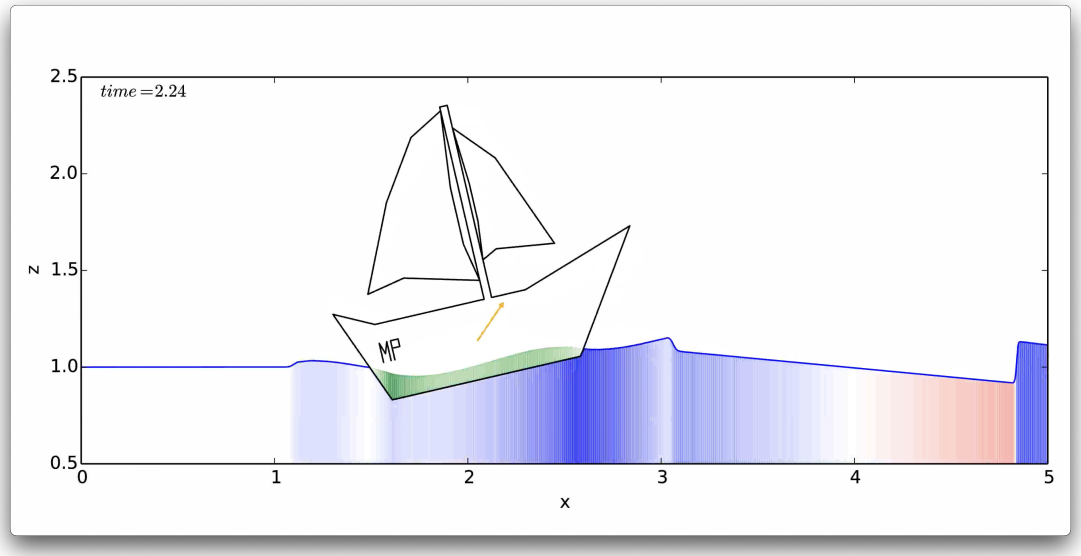


Schemes:

- **Low-Froude** scheme
  to avoid restrictive CFL condition.
- **Newmark** scheme
  to ensure the energy stability.
- **Good discretization** of the
  pressure field to the body

Properties:

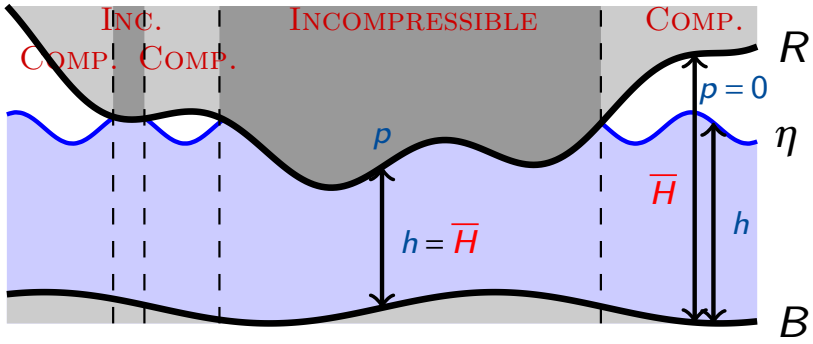
- **Decreasing** of the
  discrete **mechanic energy**.
- Stability of the
  steady state at rest.
- Convergence to
  return to equilibrium.

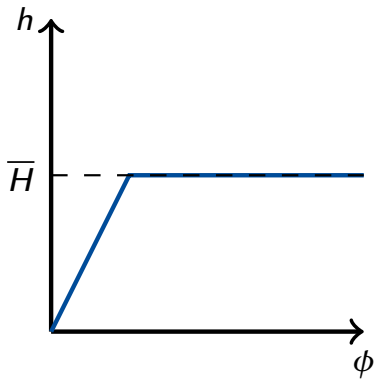


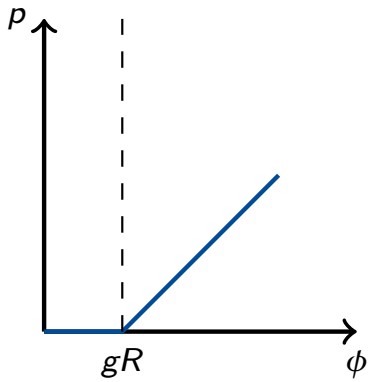
Shallow water model with roof:

$$\begin{aligned} \partial_t h(\phi) + \nabla\cdot(h(\phi)\overline{u}) &= 0 \\ \partial_t(h(\phi)\overline{u}) + \nabla\cdot(h(\phi)\overline{u}\otimes\overline{u}) &= -h(\phi)\nabla\phi \\ \min\left(p, \overline{H}-h\right) &= 0 \end{aligned}$$

$$\begin{aligned} h(\phi) &= \min\left(\frac{\phi}{g}-B, \overline{H}\right) \\ p(\phi) &= \max(0, \phi - gR) \end{aligned}$$







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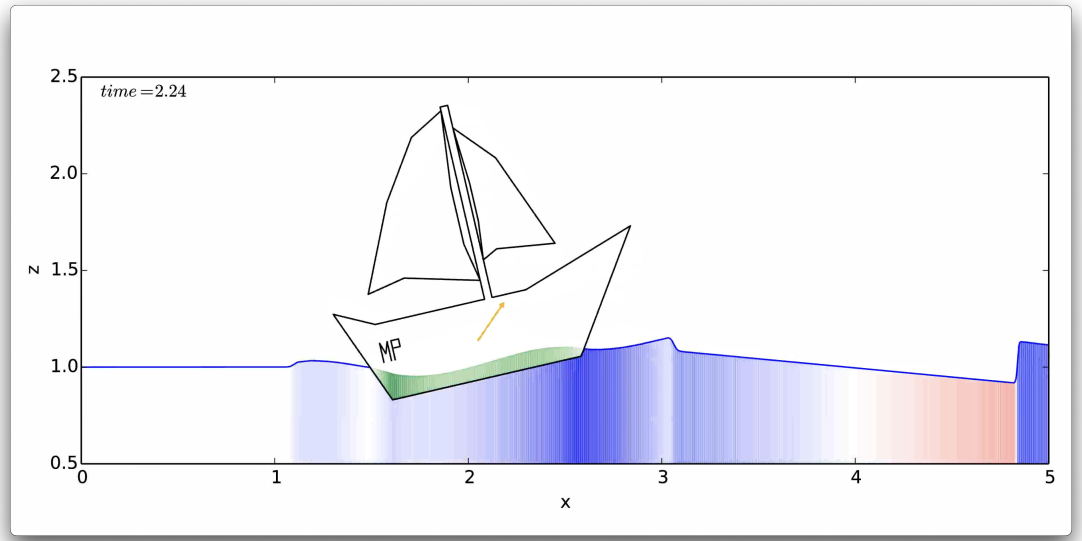
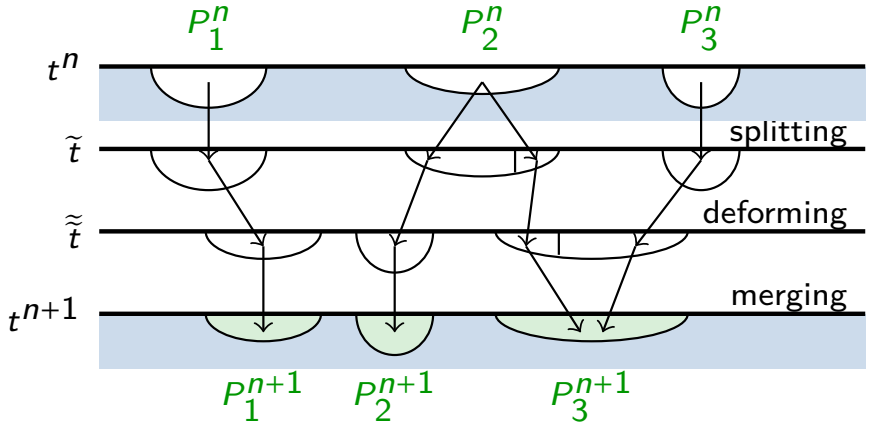


Air pockets model:

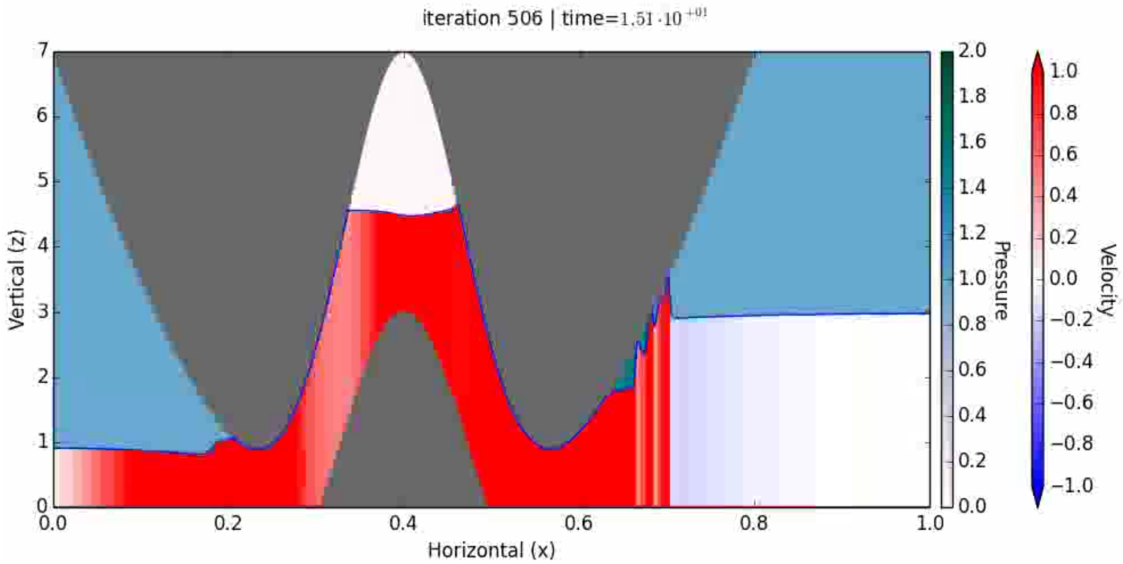
Question: How model air pressure $\mathring{p}$?

- **Large sound velocity** asymptotic regime
  uniform pressure per air pocket
- **Polytropic deformation** ($PV^m = c_{st}$)
  usually isothermal ($m = 1$)
- **Isochoric polytropic merging**
  usually adiabatic ($m = \gamma \approx 1.4$)
- **Isochoric polytropic splitting**
  usually isobar ($m = 0$)



Property:

- for **small** enough time steps,
  the model is **well-posed**.



	Numerical analysis +Numerical evidences	Operational tool 2D implementation
▸ Roof modeling	✔	✔
▸ Layerwise 3D	✔	✔
▸ Dispersion	✔	Uhaina
▸ Body dynamics	✔	☺ Chrono
▸ Air pockets modeling	✔	
▸ High order	with M. Ricchiuto	
▸ Immersed structure	with D. Lannes	
▸ Ice modeling	with H. Beaugendre ☺	
▸ Non-hydro DF	with M. Kazolea ☺	
▸ Infiltration	with M. Coquerelle ☺	
▸ Morphodynamique	☺	

Doc/Post-Doc: ☺