Modèle multicouche pour la description de films (presque) fins de tensioactifs.

Journées du GDR Transinter – 18 mars 2021

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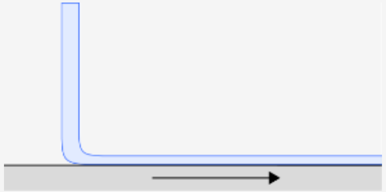
Process



Liquid film deposition

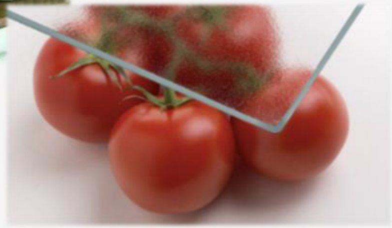
Drying

Advantages

→ Quick functionalization of large glass surfaces

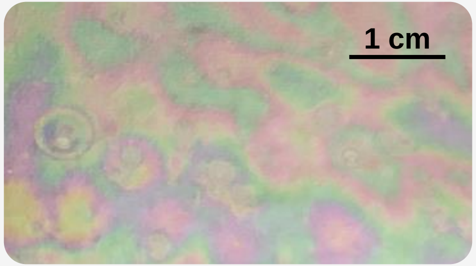
SG Planilaque

SG Albarino



Limitations during drying

→ Defects
→ Instabilities
→ Dewetting



Iridescence of a coating after drying
Antireflet AR3, RFL, Laurent Maillaud

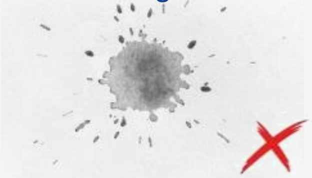
$$h_{humid} \sim 20\ \mu m$$
$$\lambda_{defects} \sim 1\ cm$$

How to obtain **homogeneous thin waterborne coatings ?**

→ Non-wetting liquid

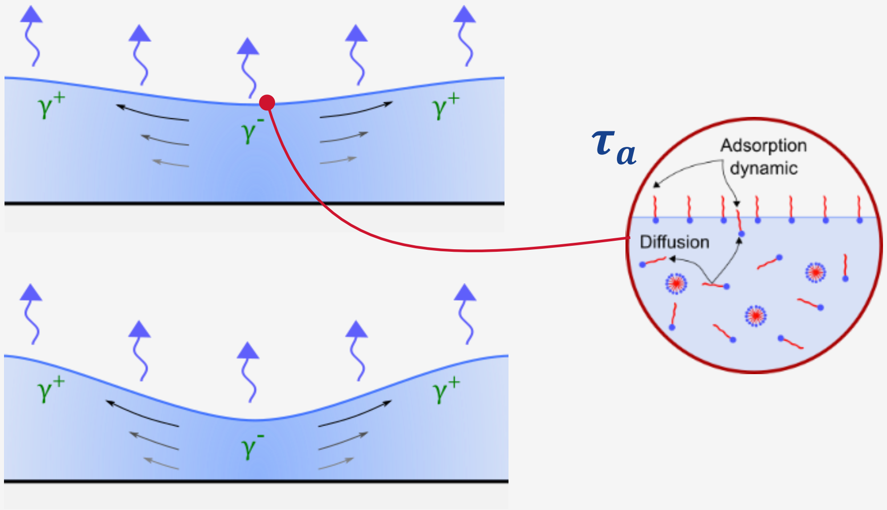
→ Orange peel

→ Coffee ring



→ Aqueous films on glass
→ No particles

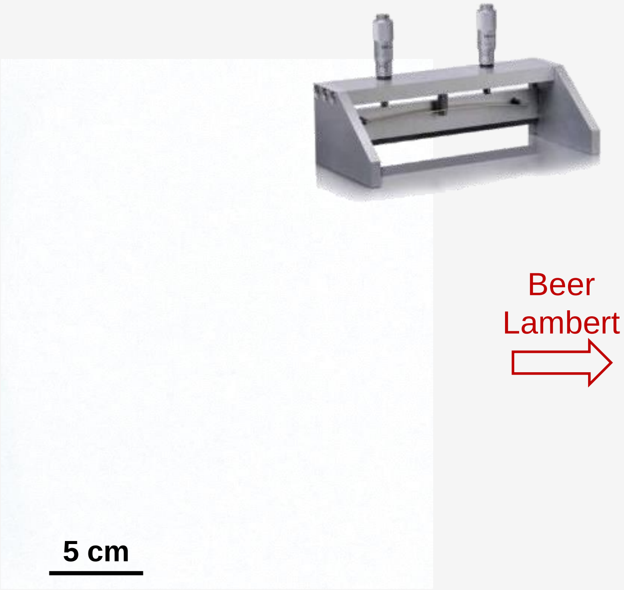
Evaporation-induced Marangoni flows



What is the influence of **surfactants**

on **aqueous film stability** during **drying** ?

Instability quantification

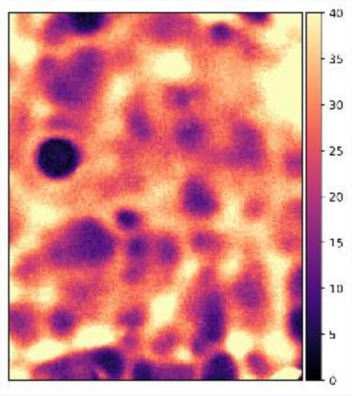


SDS at **10 CMC**

blade height: **40 µm**

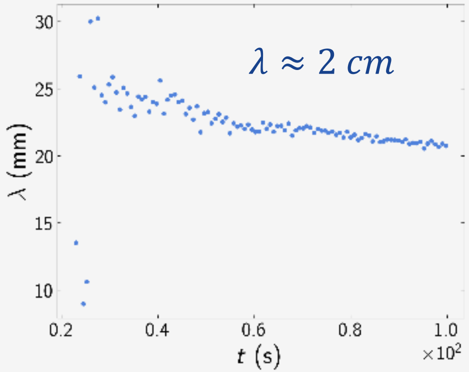
speed **x10**

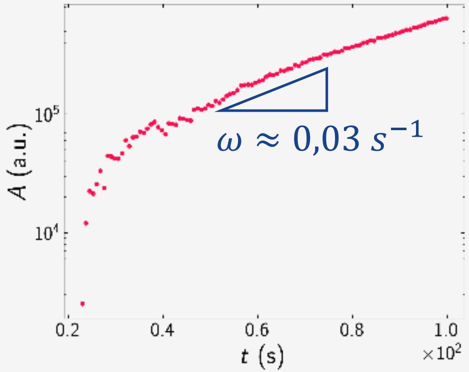
Beer Lambert ⇨



Thickness map

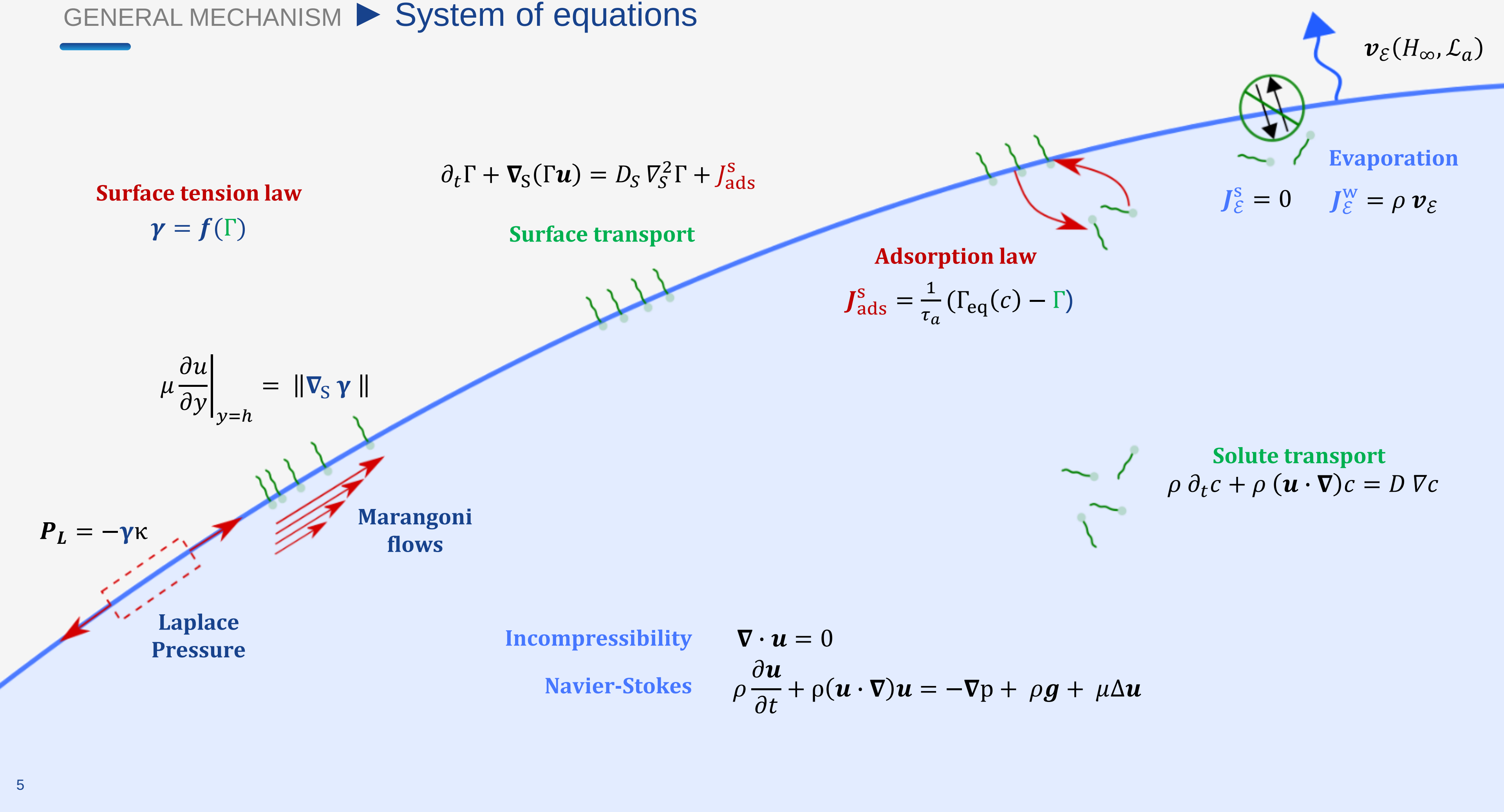
FFT ⇨





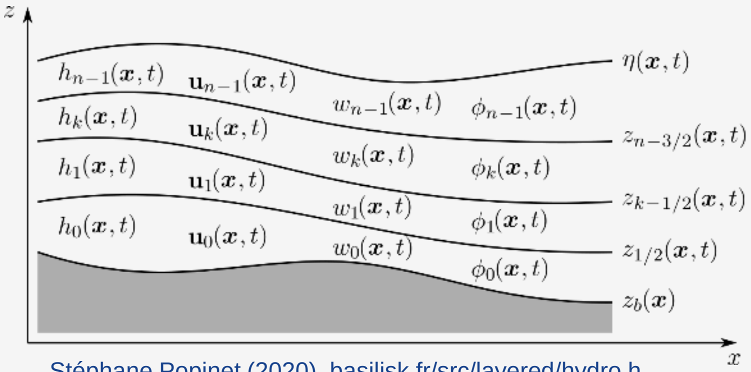
→ Exponential growth of the amplitude

→ Evaporation-induced instability


$\boldsymbol{v}_{\mathcal{E}}(H_\infty, \mathcal{L}_a)$
Surface tension law
$\boldsymbol{\gamma} = \boldsymbol{f}(\Gamma)$
$\partial_t \Gamma + \boldsymbol{\nabla}_S(\Gamma \boldsymbol{u}) = D_S\, \nabla_S^2 \Gamma + J_{\text{ads}}^{\text{s}}$
Surface transport
Evaporation
$J_{\mathcal{E}}^{\text{s}} = 0 \quad J_{\mathcal{E}}^{\text{w}} = \rho\, \boldsymbol{v}_{\mathcal{E}}$
Adsorption law
$J_{\text{ads}}^{\text{s}} = \frac{1}{\tau_a}(\Gamma_{\text{eq}}(c) - \Gamma)$
$\mu \left.\frac{\partial u}{\partial y}\right|_{y=h} = \|\boldsymbol{\nabla}_S\, \boldsymbol{\gamma}\|$
Solute transport
$\rho\, \partial_t c + \rho\, (\boldsymbol{u} \cdot \boldsymbol{\nabla}) c = D\, \nabla c$
Marangoni flows
$\boldsymbol{P_L} = -\boldsymbol{\gamma}\kappa$
Laplace Pressure
Incompressibility
$\boldsymbol{\nabla} \cdot \boldsymbol{u} = 0$
Navier-Stokes
$\rho \frac{\partial \boldsymbol{u}}{\partial t} + \rho(\boldsymbol{u} \cdot \boldsymbol{\nabla})\boldsymbol{u} = -\boldsymbol{\nabla}\text{p} + \rho \boldsymbol{g} + \mu \Delta \boldsymbol{u}$

Semi-discrete, non-hydrostatic, multilayer description

Stéphane Popinet
basilisk.fr



Stéphane Popinet (2020). basilisk.fr/src/layered/hydro.h

New approach for extended films :

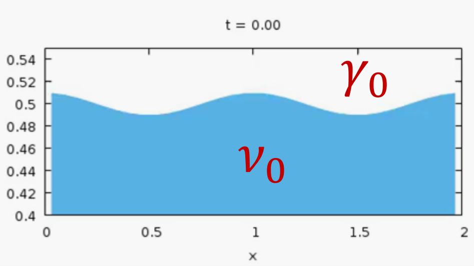
- ✓ Include non-hydrostatic effects
- ✓ Conservative
- ✓ Numerically efficient
- ✓ Interface description

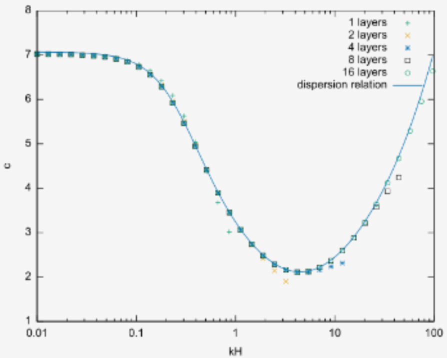
- ✓ For metre-scale to kilometre-scale waves

Surface tension implementation for micrometre-scale to metre-scale waves

- Laplace pressure : Top boundary conditions on pressure $\phi_S = -\kappa \cdot \gamma / \rho$
- Marangoni flows : Top boundary conditions on vertical viscosity $\left.\frac{\partial u}{\partial y}\right|_{\eta} = \frac{\mathbf{1}}{\boldsymbol{\nu}} \|\boldsymbol{\nabla}_S\, \boldsymbol{\gamma}\,\|$
- Surfactants : Experimental isotherms, surface advection

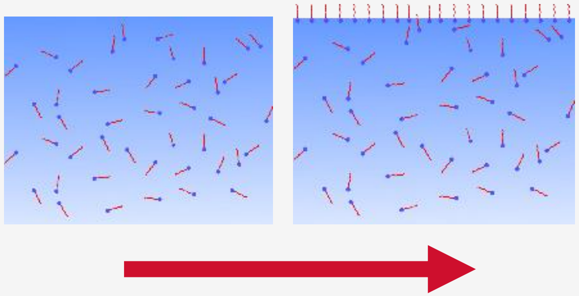
Laplace pressure

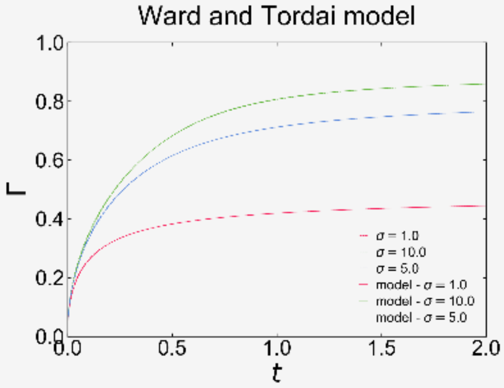




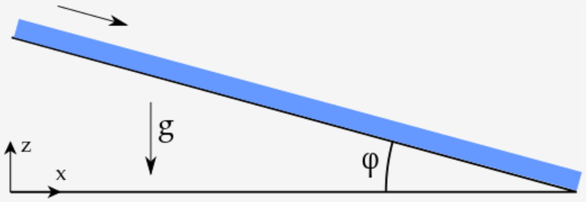
Gravitocapillary waves
Dispersion relation

Surfactant adsorption



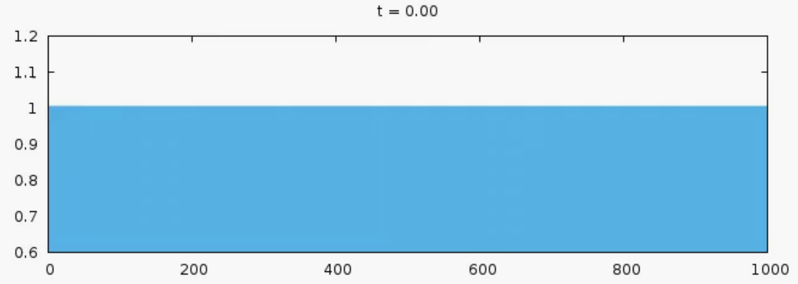


Kapitza instability

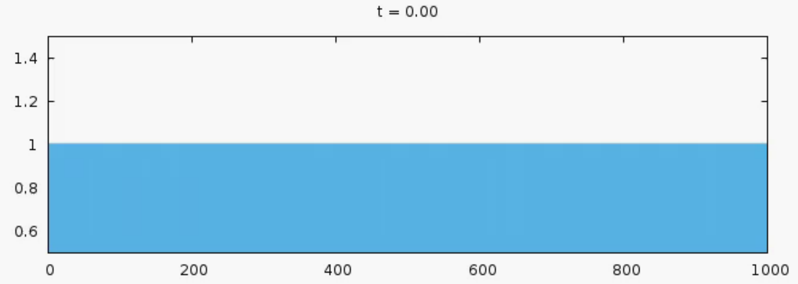


$$\phi = 6{,}4°$$
$$Re = 19{,}33$$
$$We = 5{,}43$$

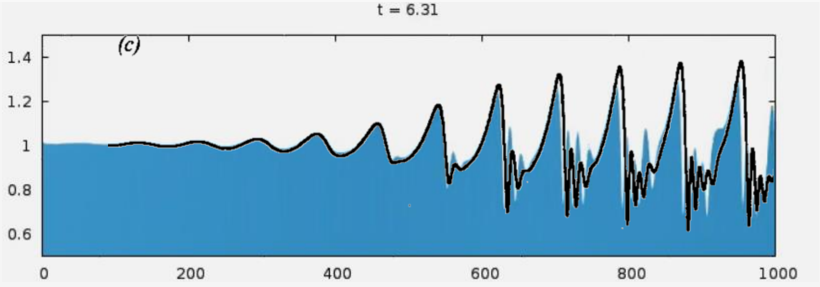
7 Hz



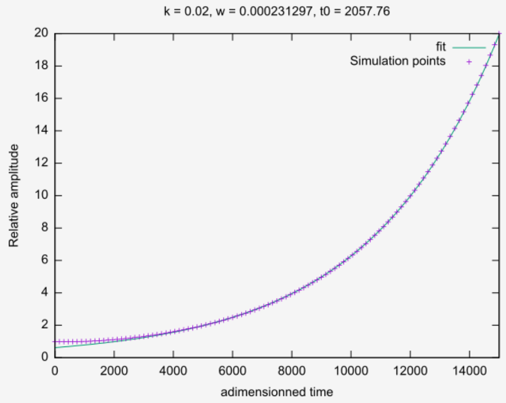
4,5 Hz

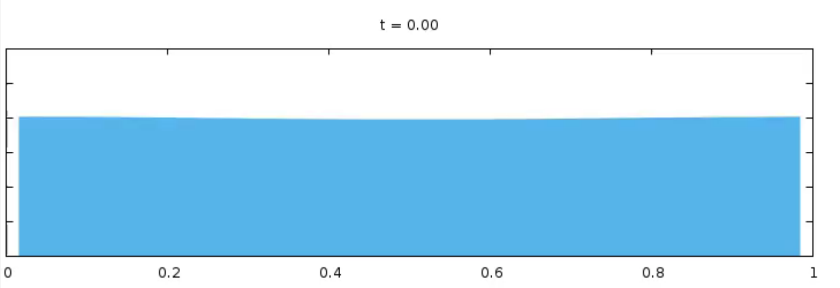


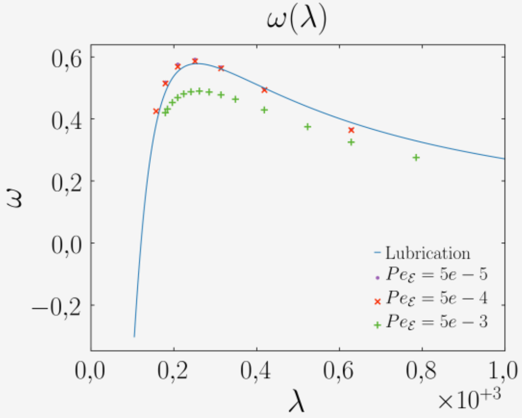
3 Hz

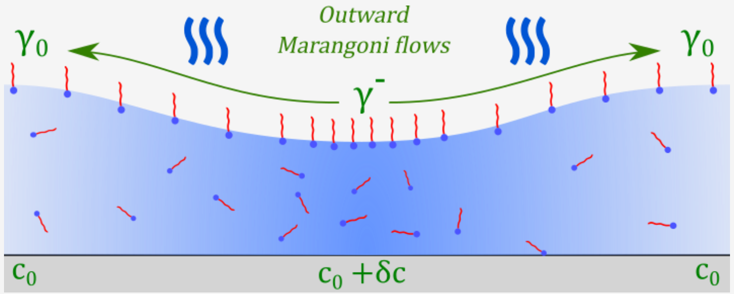


Comparison with Malamataris (2002)









$$Fr^2 = 3{,}8$$
$$We = 8{,}3 \cdot 10^{-4}$$
$$Re = 1$$

- ✓ Evaporation-induced Marangoni instability with surfactants
  - → Adsorption kinetics, evaporation rate…

- ✓ A conservative and numerically efficient description for extended films
- ✓ Implementation for thin (and not so thin) films with micrometer-scale to meter-scale waves

→ On the Basilisk sandbox and paper in writing

- ✓ Promising to go beyond lubrication, especially for problems with surfactants