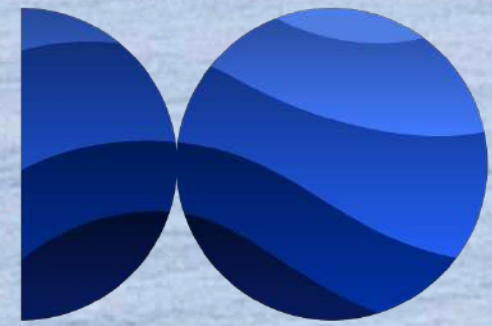


European Digital Twin Ocean



EDITO
Modellab



Comité de suivi individuel

Doctorat de Gabriel Mouttapa

commencé en février 2025

Mardi 23 septembre 2025

Encadrants : Julien Le Sommer et Emmanuel Cosme

Composition du CSI : Melika Baklouti et Arthur Vidard

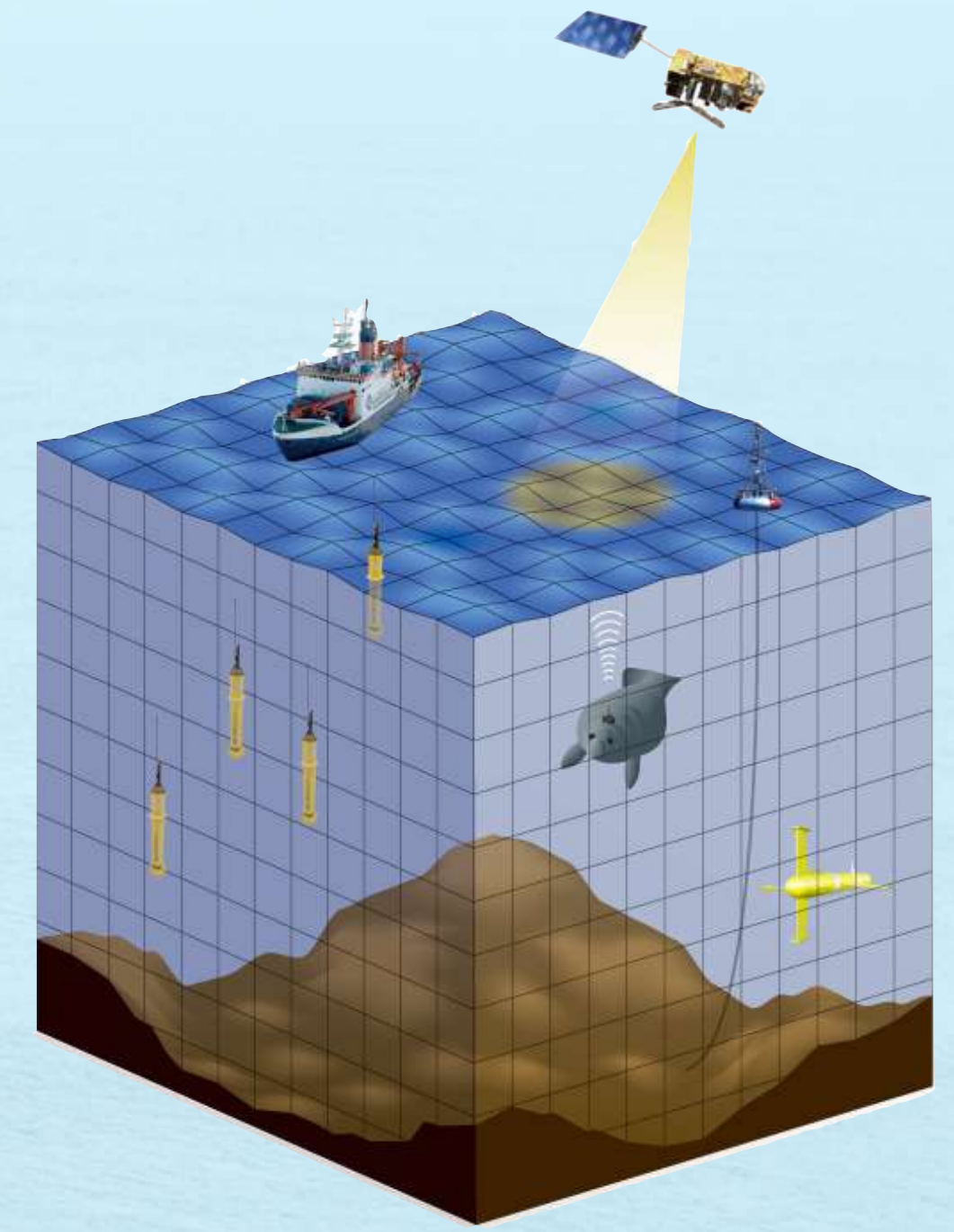
1. Contexte

Apport de la **programmation différentiable** à la
réduction des **incertitudes paramétriques et**
structurelles des modèles de **circulation océanique**

Circulation océanique

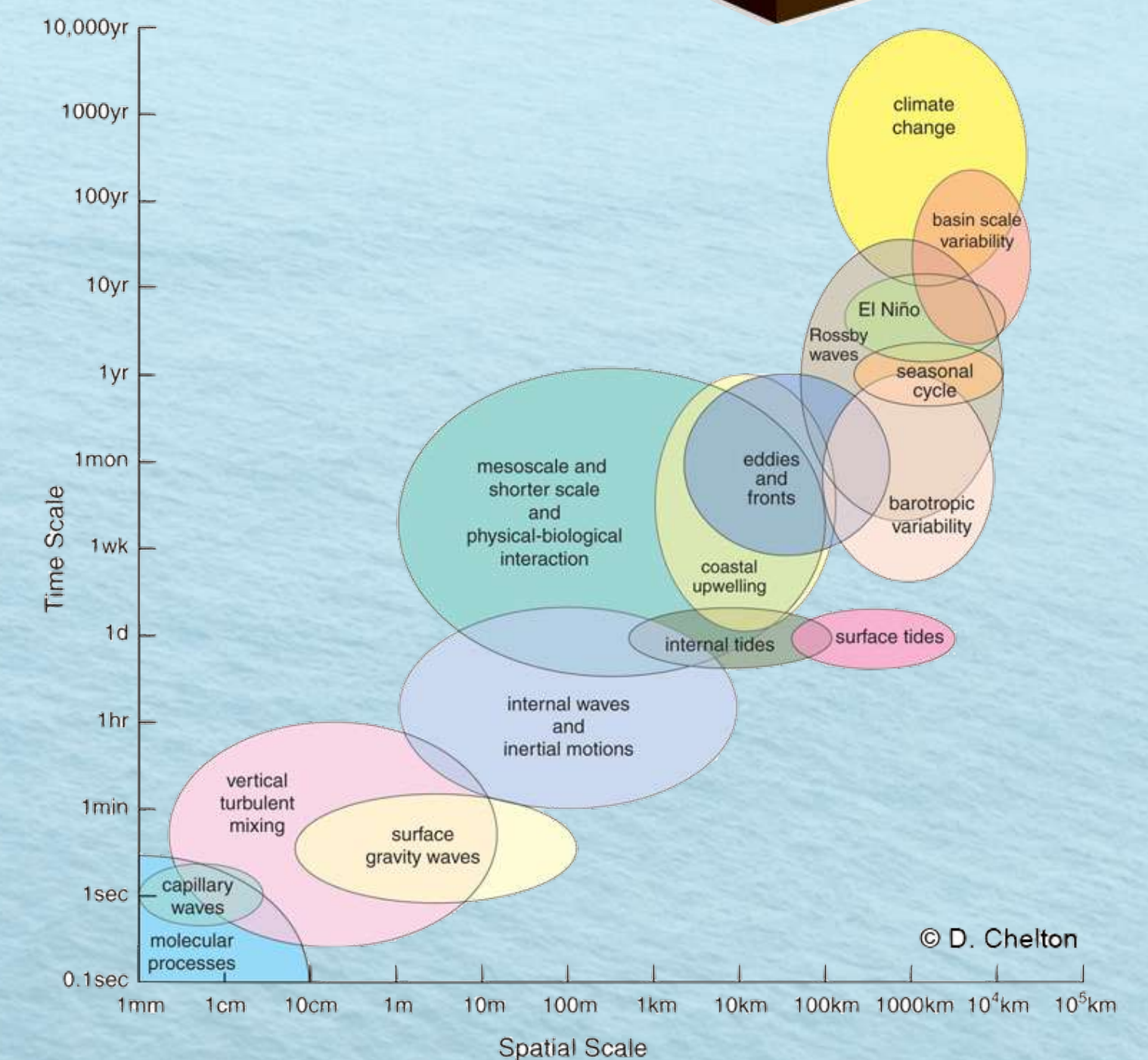
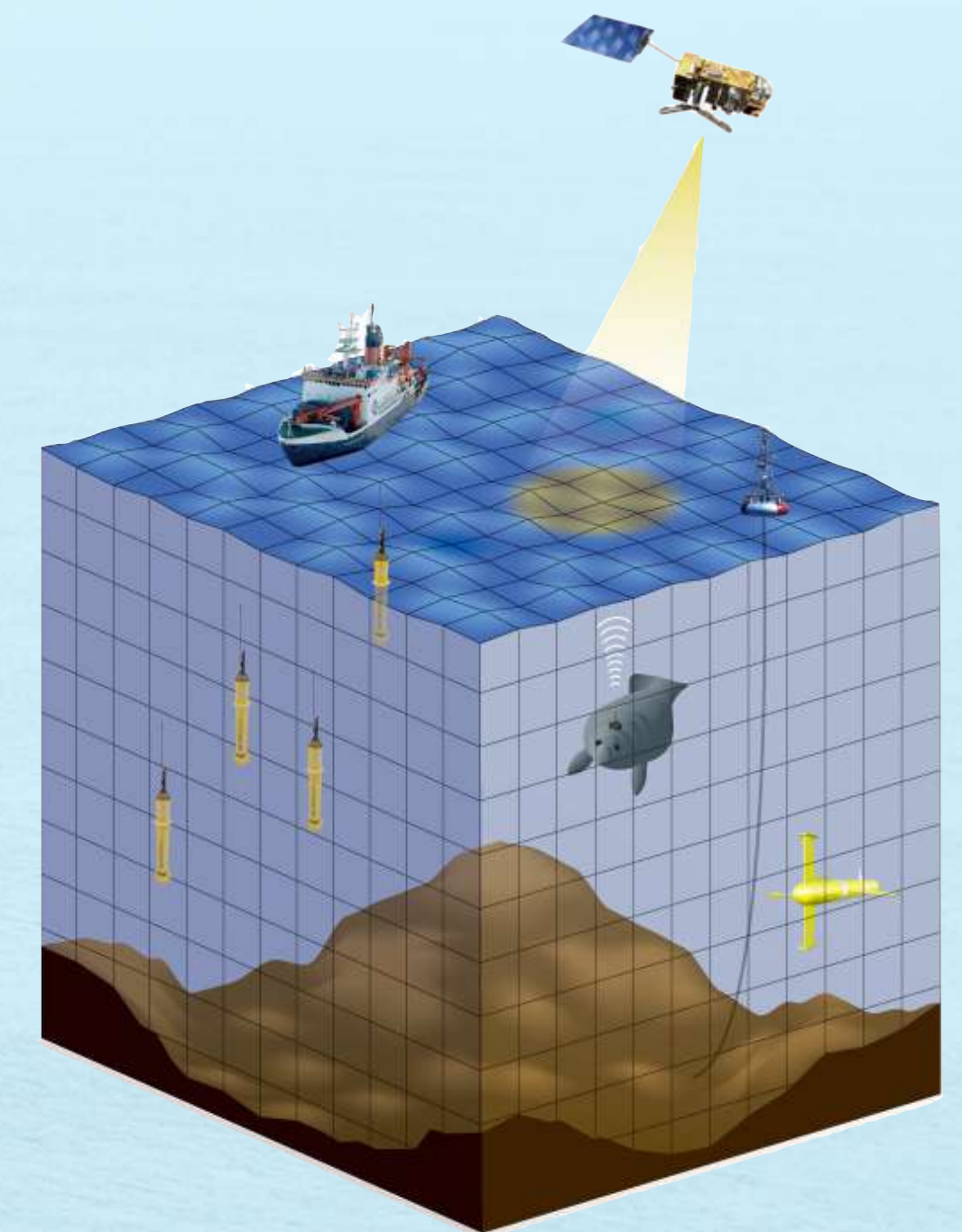
- **Utilisations des OGCM**

- recherche
- opérationnel
- système Terre



Circulation océanique

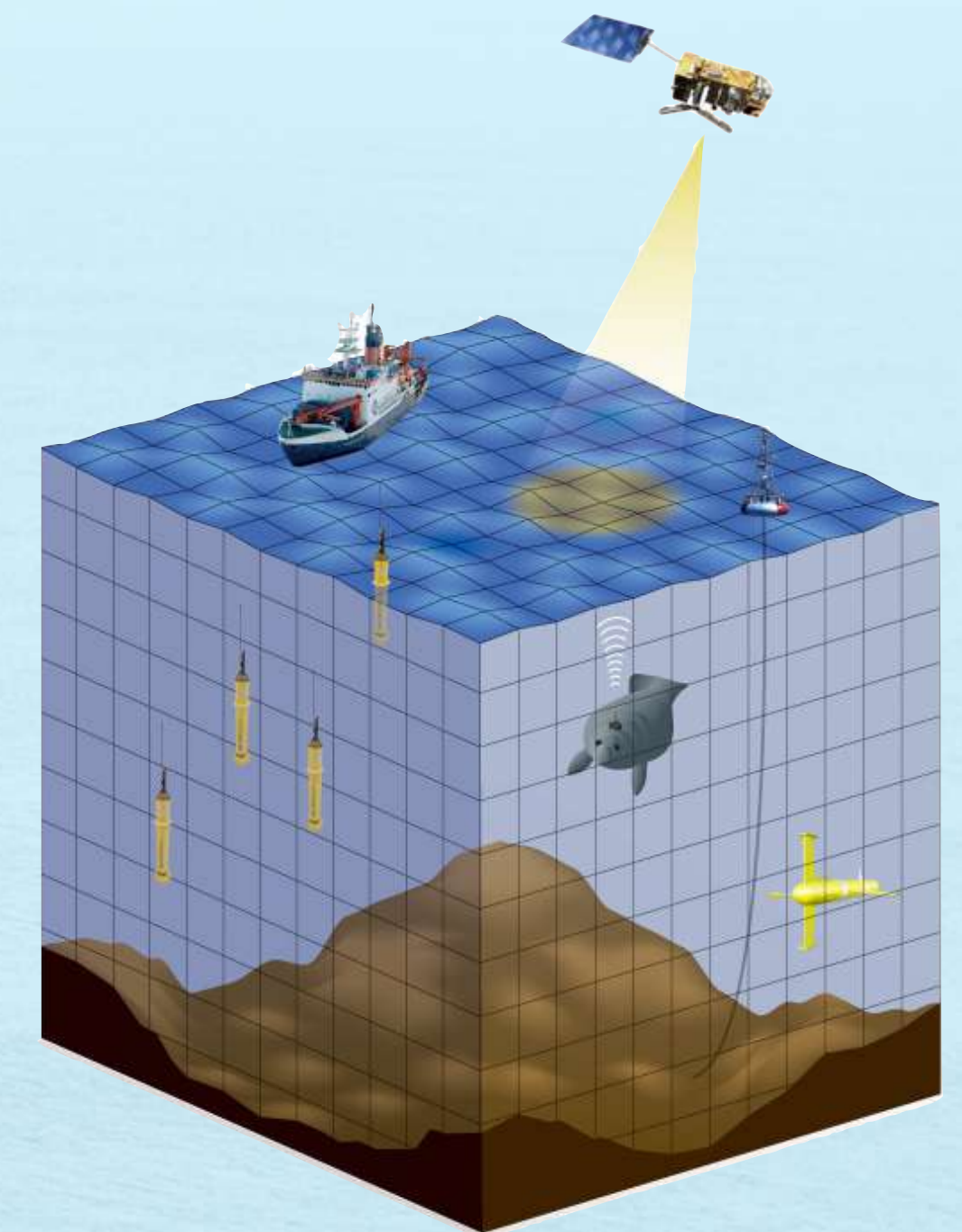
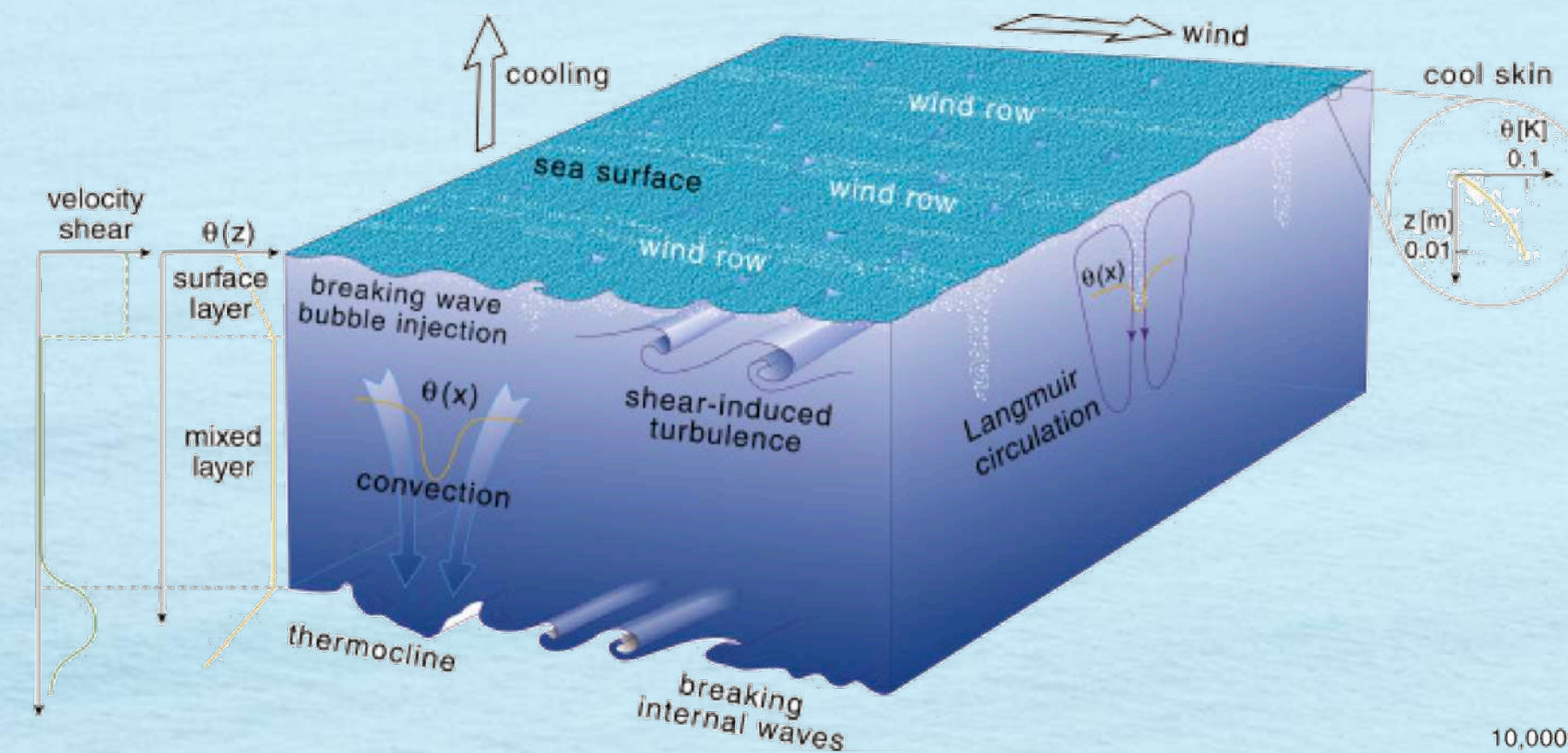
- **Utilisations des OGCM**
 - recherche
 - opérationnel
 - système Terre
- **Processus physiques**
 - grande diversité d'échelles en espace et temps



Circulation océanique

- **Utilisations des OGCM**

- recherche
- opérationnel
- système Terre

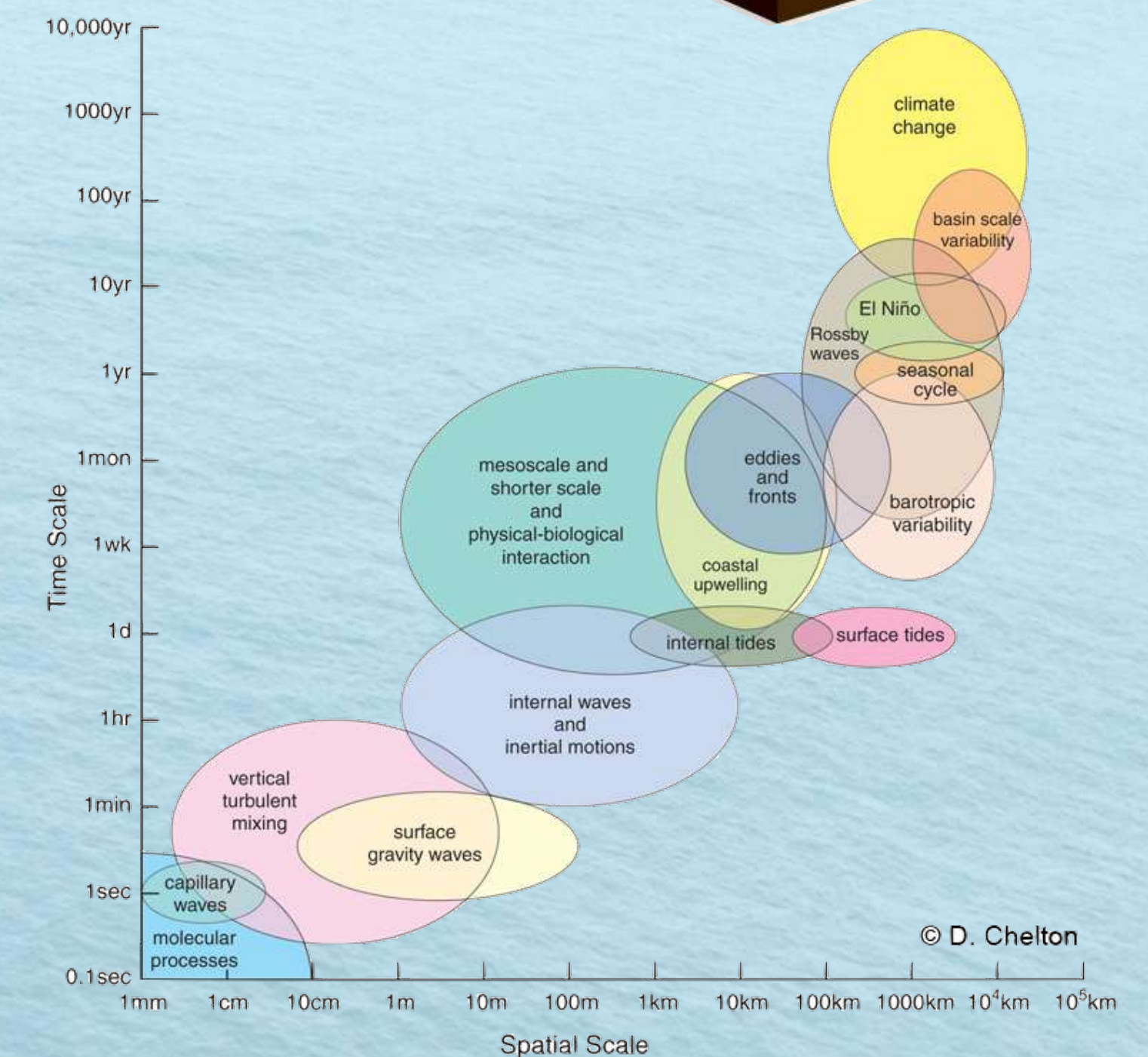


- **Processus physiques**

- grande diversité d'échelles en espace et temps

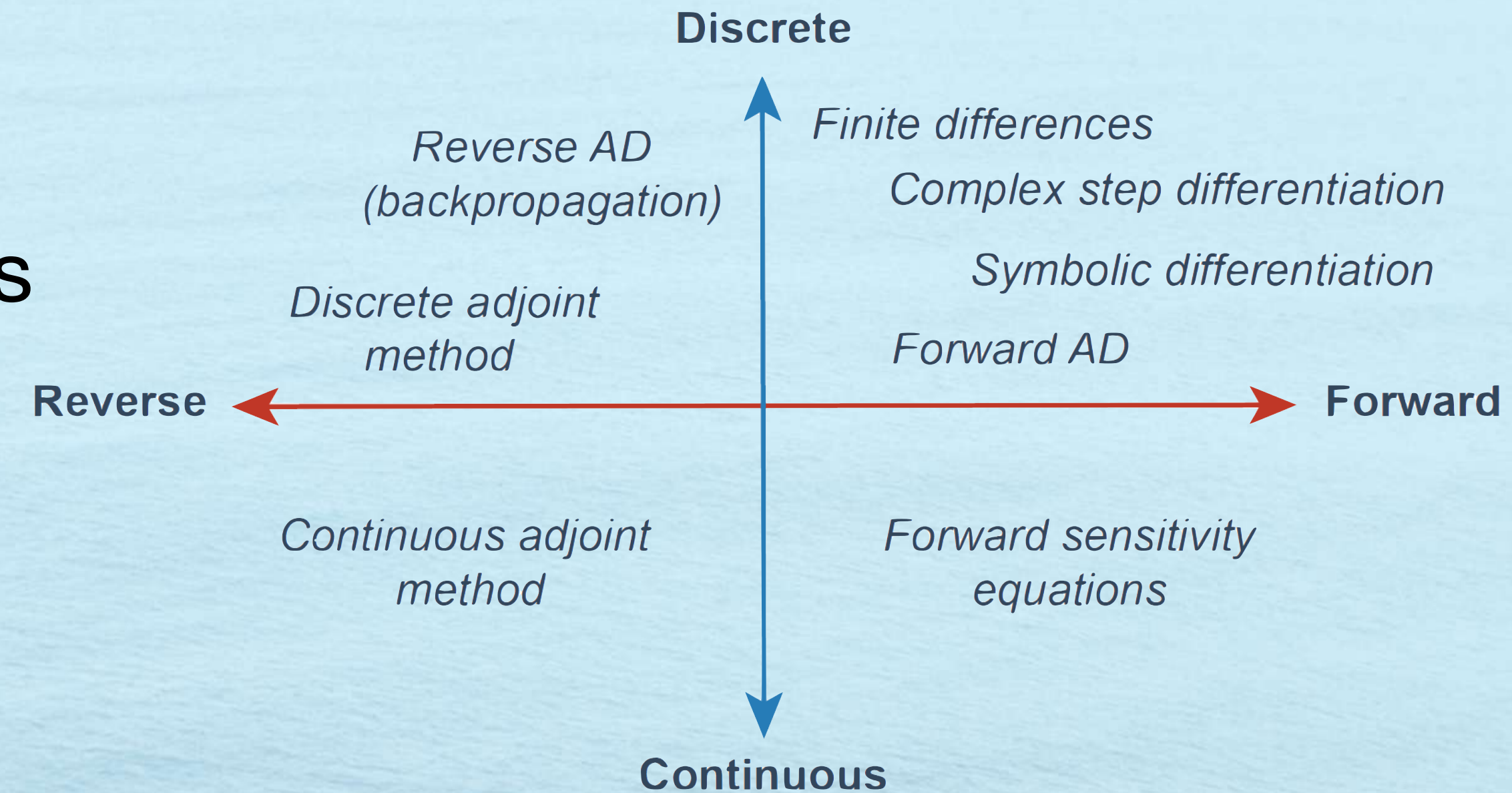
- **Paramétrisations**

- représentation des effets de la micro-échelle à grande échelle



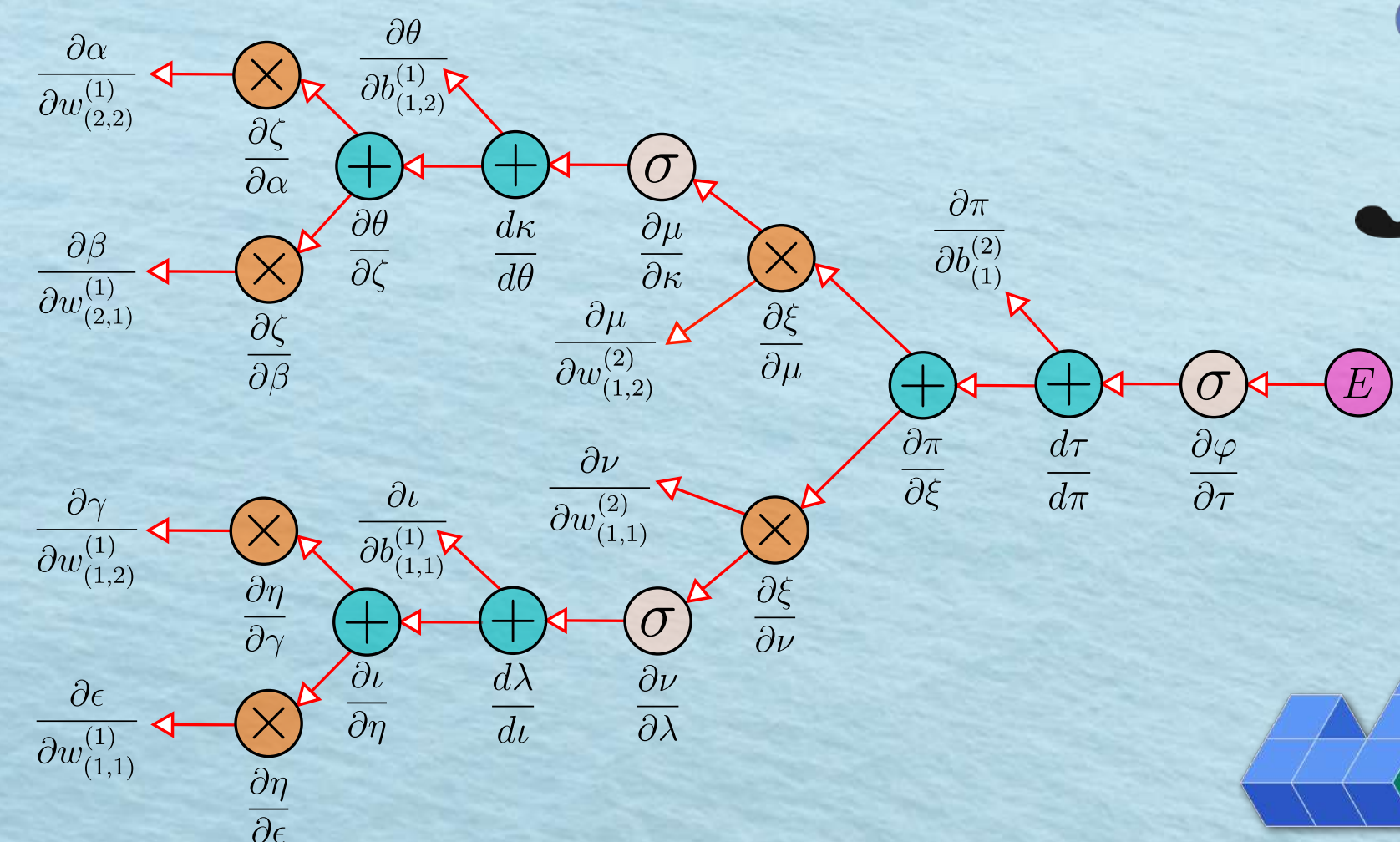
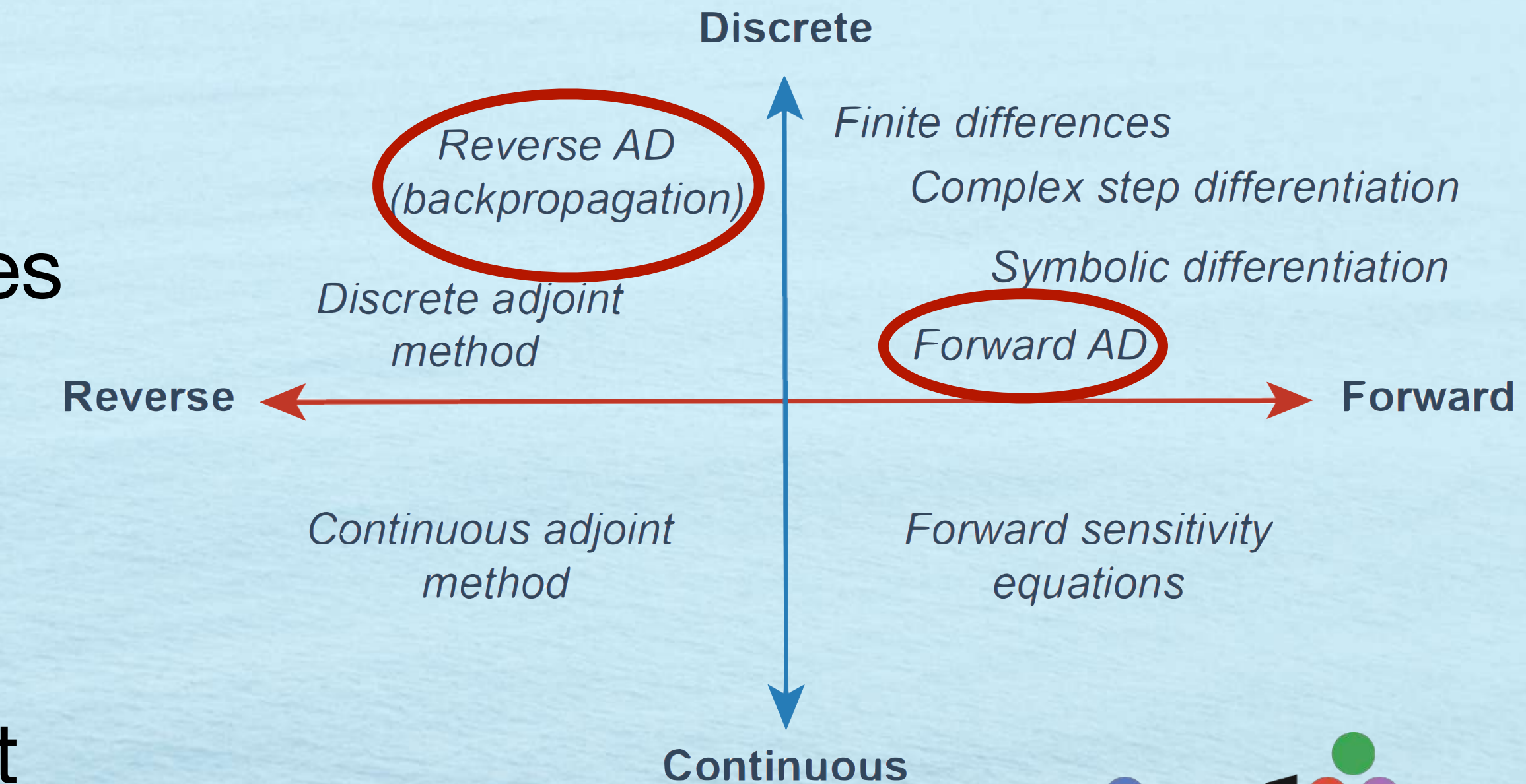
Programmation différentiable

- dérivation de solutions d'ED
- études de sensibilité, calibration, problèmes inverses et assimilation de données

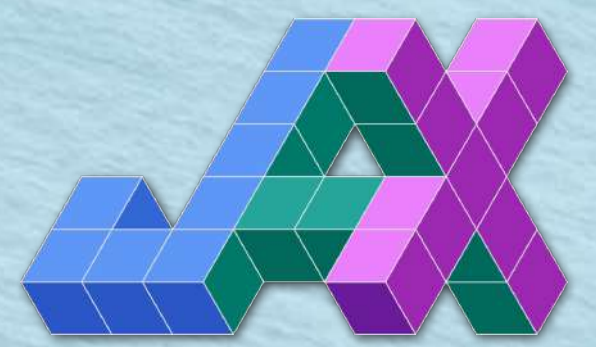


Programmation différentiable

- dérivation de solutions d'ED
 - études de sensibilité, calibration, problèmes inverses et assimilation de données
- auto-différentiation
 - différent des méthodes impliquant l'adjoint
 - découpage en fonctions élémentaires
 - reverse vs. forward



julia



2. Travail effectué

Position du problème

- Paramétrisation du mélange vertical
 - du à la stratification et anisotropie de l'océan
 - “fermetures physiques” à ajuster
 - $k - \varepsilon$, TKE, KPP, CATKE, $k\varepsilon\tau$
- Développement des paramétrisations face à des données
 - calibration des paramètres
 - paramétrisations hybrides
 - paramétrisations Deep Learning

diffusion turbulente

$$\overline{T'w'} = -K_t \frac{\partial \bar{T}}{\partial z}$$

$$\overline{u'w'} = -\nu_t \frac{\partial \bar{u}}{\partial z}$$

viscosité turbulente

$$(\nu_t, K_t) = f_\theta(X)$$

paramètres de la fermeture

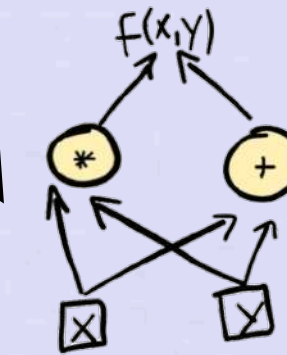
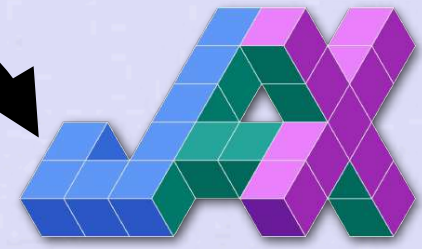
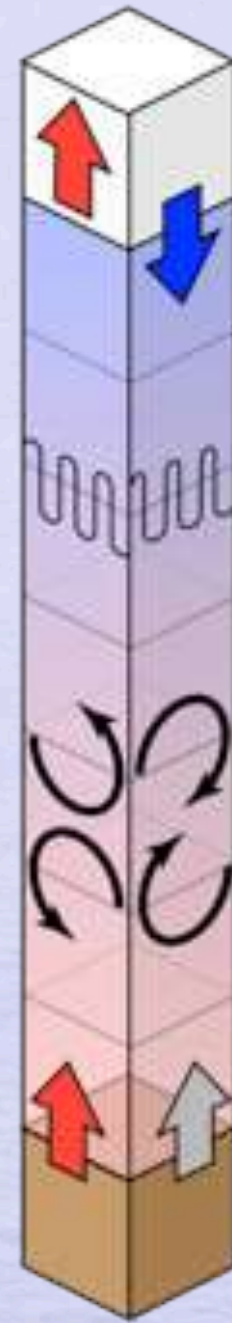
Développement de Tunax

- modèle SCM complètement différentiable utilisé pour
 - la comparaison de paramétrisations
 - la calibration de paramètres vis-à-vis d'une base de donnée
 - la sensibilité vis-à-vis d'une base de donnée



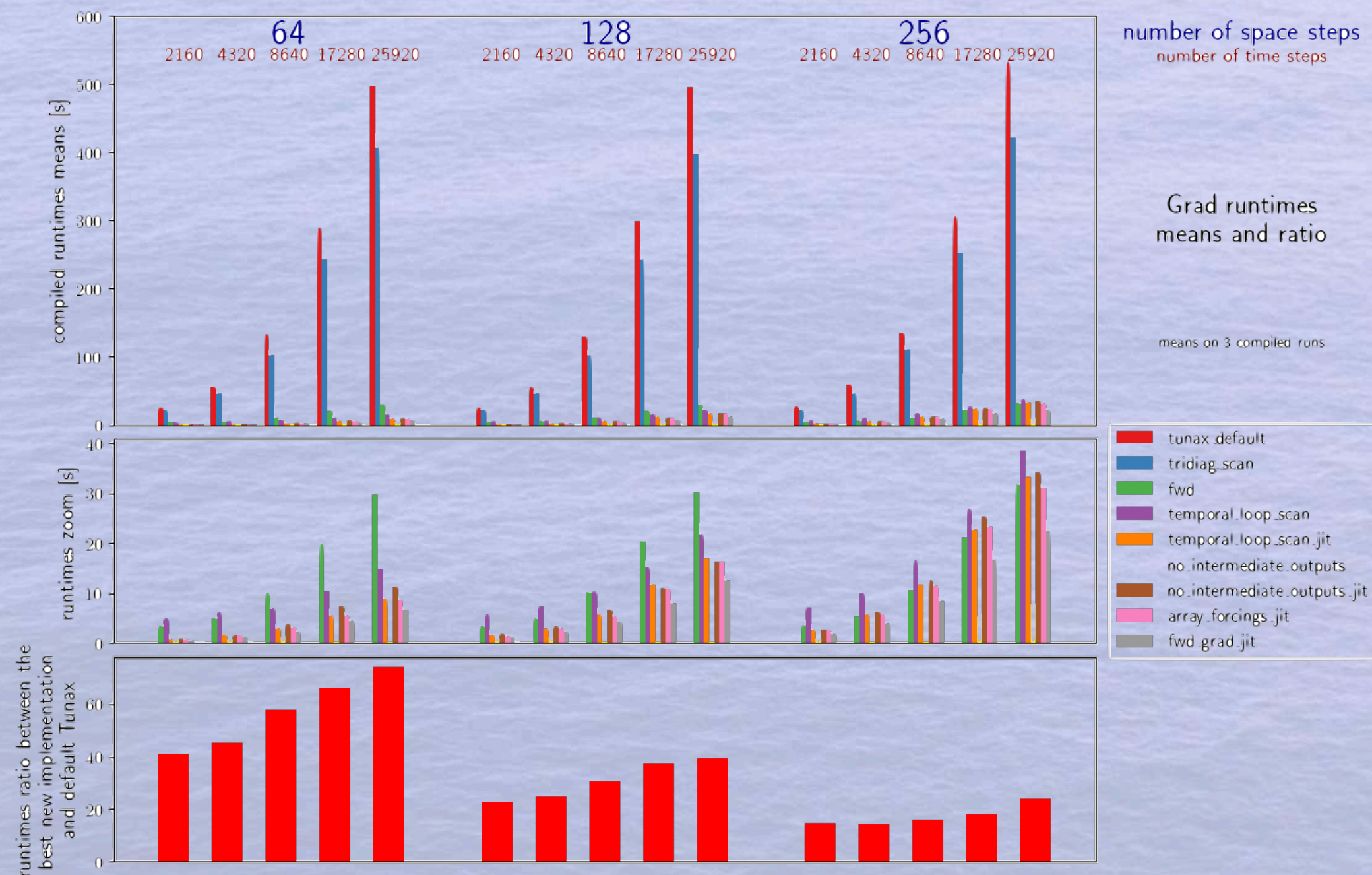
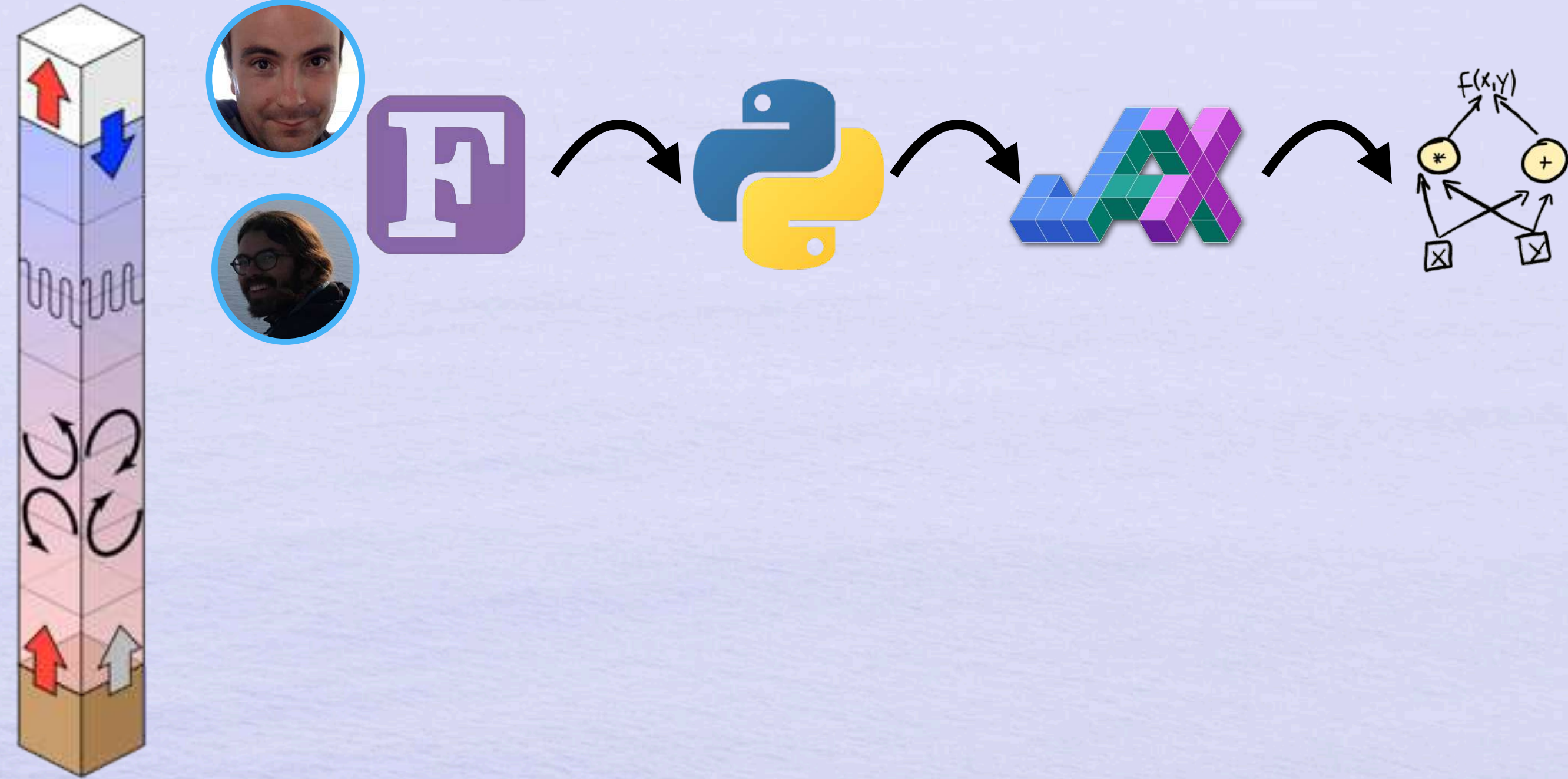
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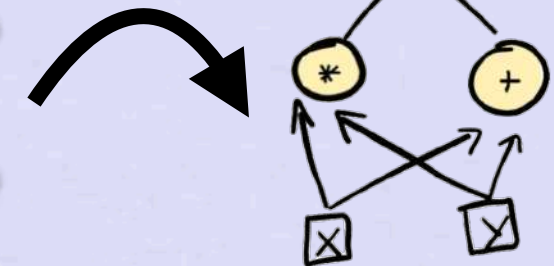
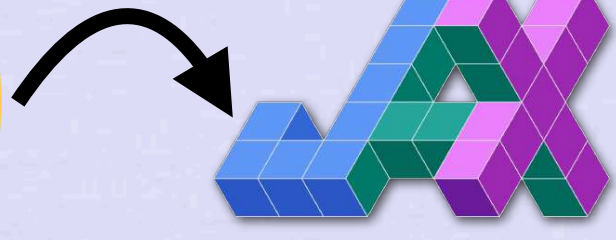
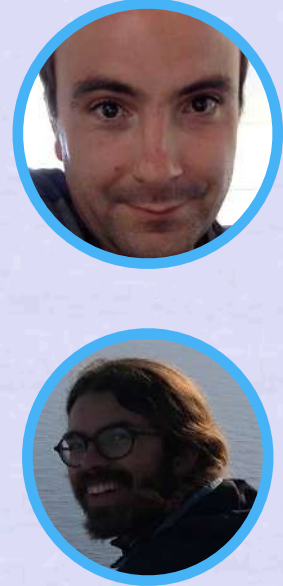
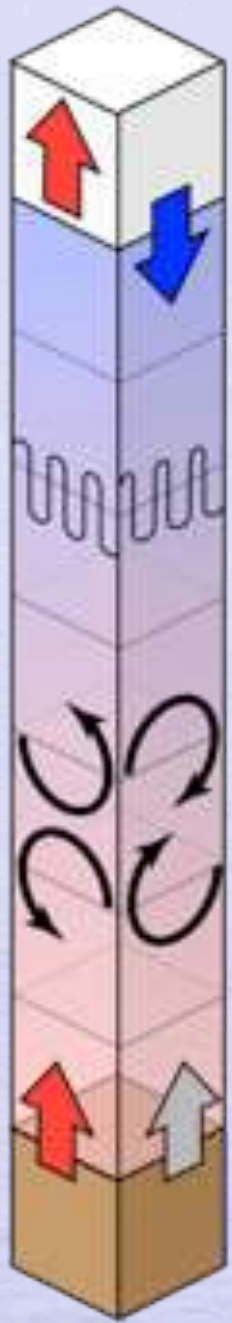
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 - amélioration des performances

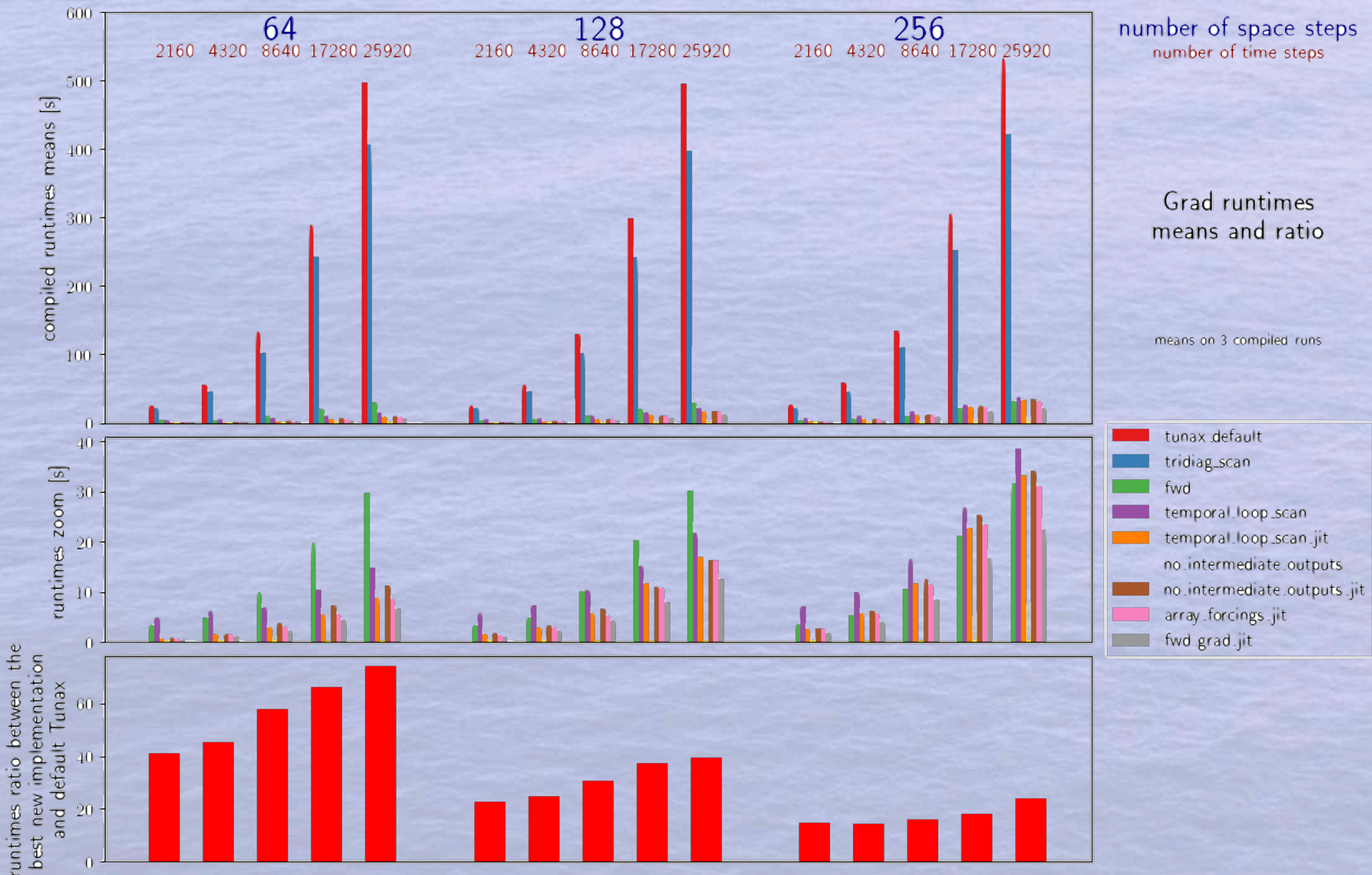


Développement de Tunax

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 - la sensibilité vis-à-vis d'une base de donnée
 - amélioration des performances



- science ouverte et collaborative (JOSS)



tunax Public

main 1 Branch 3 Tags

Go to file Add file Code

Gabriel Mouttapa Bump version to 0.2.0 3972f68 · last month 219 Commits

.github/workflows	Update run_tests.yaml	10 months ago
docs	fix doc bug	last month
tests	tests	10 months ago
tunax	Bump version to 0.2.4	last month
.gitattributes	git	10 months ago
.gitignore	Merge branch 'main' into enhanced_state	5 months ago
LICENSE	license	11 months ago
README.md	fixing read the docs	last month
poetry.lock	forcings	5 months ago
pyproject.toml	Bump version to 0.2.0	last month

README License

Python 3.10,3.11,3.12,3.13 PyPI 0.2.5 docs passing Run tests passing License CC-BY-NC

Description

This package provides a framework for calibrating the parameters of vertical physics schemes of ocean circulation models using variational optimization. The parameters are calibrated through the minimization of an 'objective function' which compares model predictions with 'Large Eddy Simulations' (LES). *Tunax* is written in JAX in order to use automatic differentiation for computing the gradient of the objective function with respect to model parameters.

About

Automatic calibration of vertical ocean physics in JAX

tunax.readthedocs.io/en/latest/

ocean closure calibration turbulence differential

Readme View license Activity Custom properties 7 stars 3 watching 0 forks Report repository

Releases 3

v0.2.5 Latest on Aug 12

+ 2 releases

Packages

No packages published [Publish your first package](#)

Contributors 2

GabrielMouttapa Gabriel Mouttapa

lesommer Julien Le Sommer

Calibration partielle de $k - \varepsilon$

Base de données

105 LES moyennées

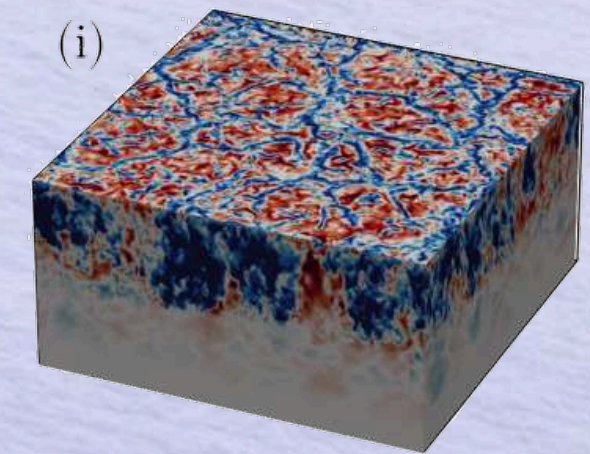
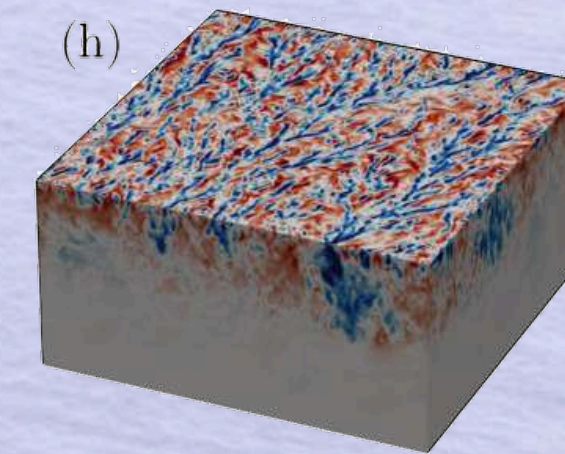
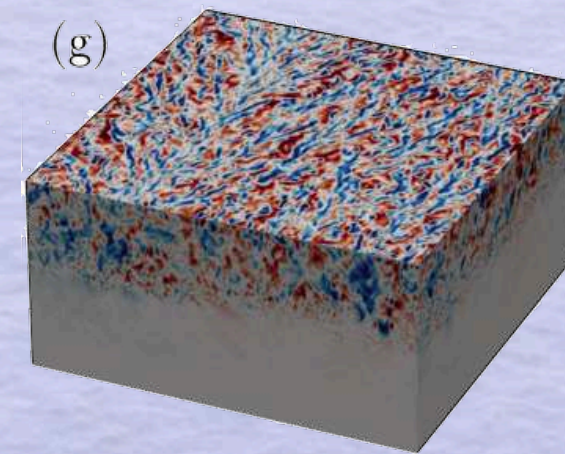
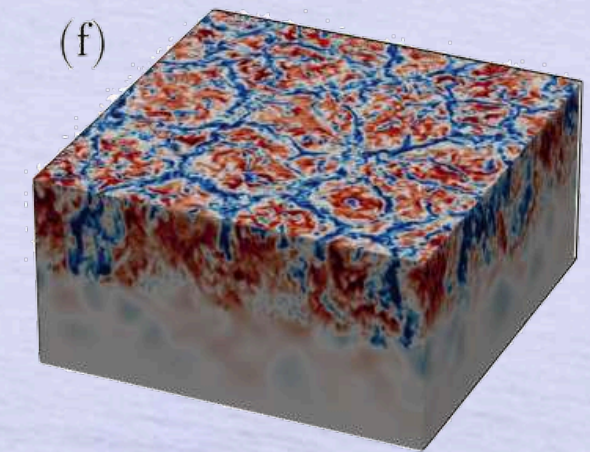
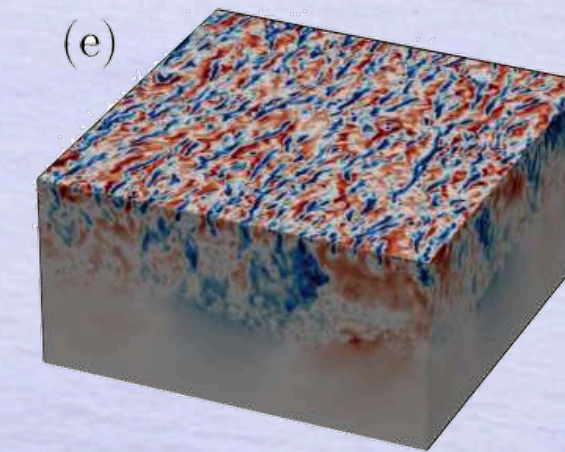
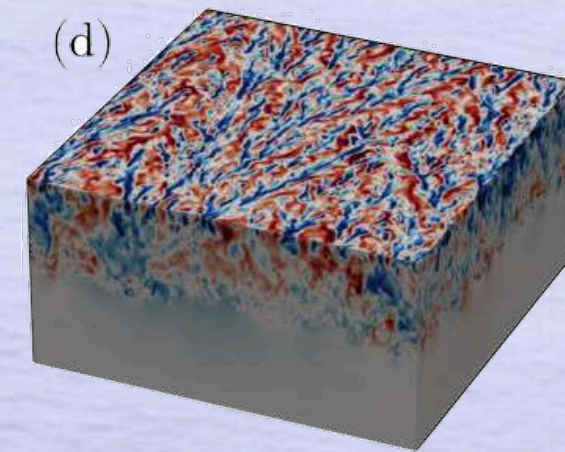
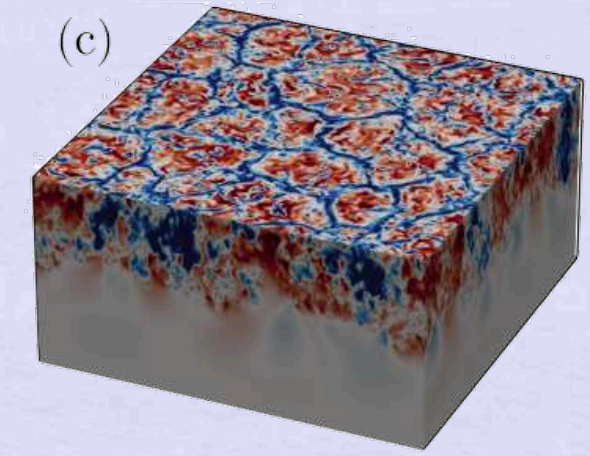
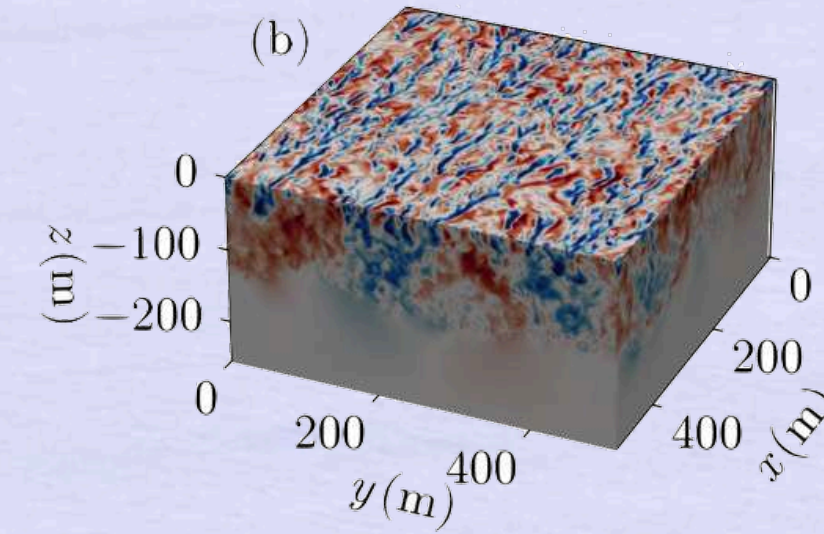
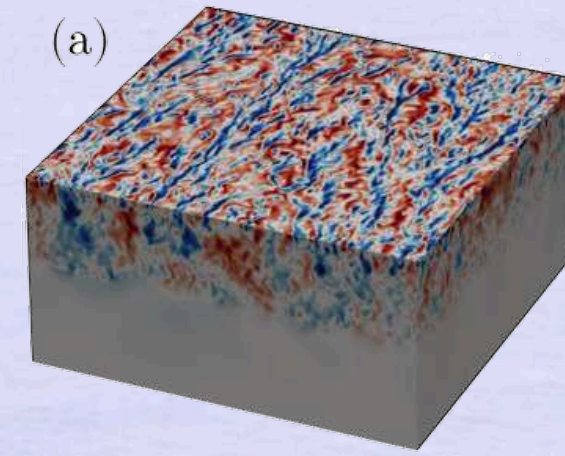
5 durées N^m (6h-3j)

×

3 pas d'espace

×

7 cas physique idéalisés m
(Wagner)



Calibration partielle de $k - \varepsilon$

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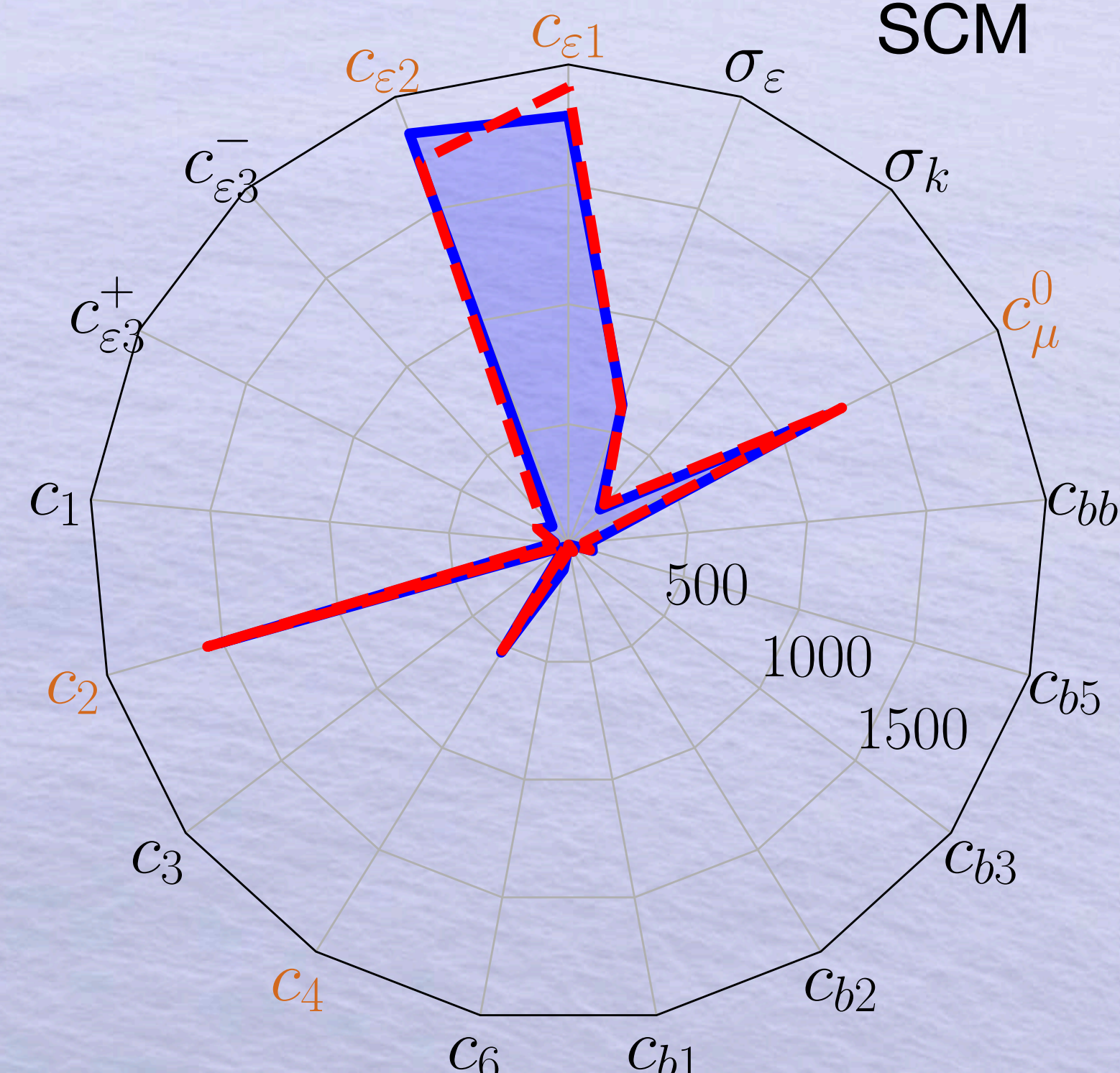
Fonction de coût

paramètres à calibrer

$$J(\theta) = \sum_{m=1}^M \sum_{i=1}^{N^m} \left\| M \left(X_{i,\theta}^m - X_i^{m,LES} \right) \right\|^2$$

poids des variables

état de la colonne d'eau du
SCM



Calibration partielle de $k - \varepsilon$

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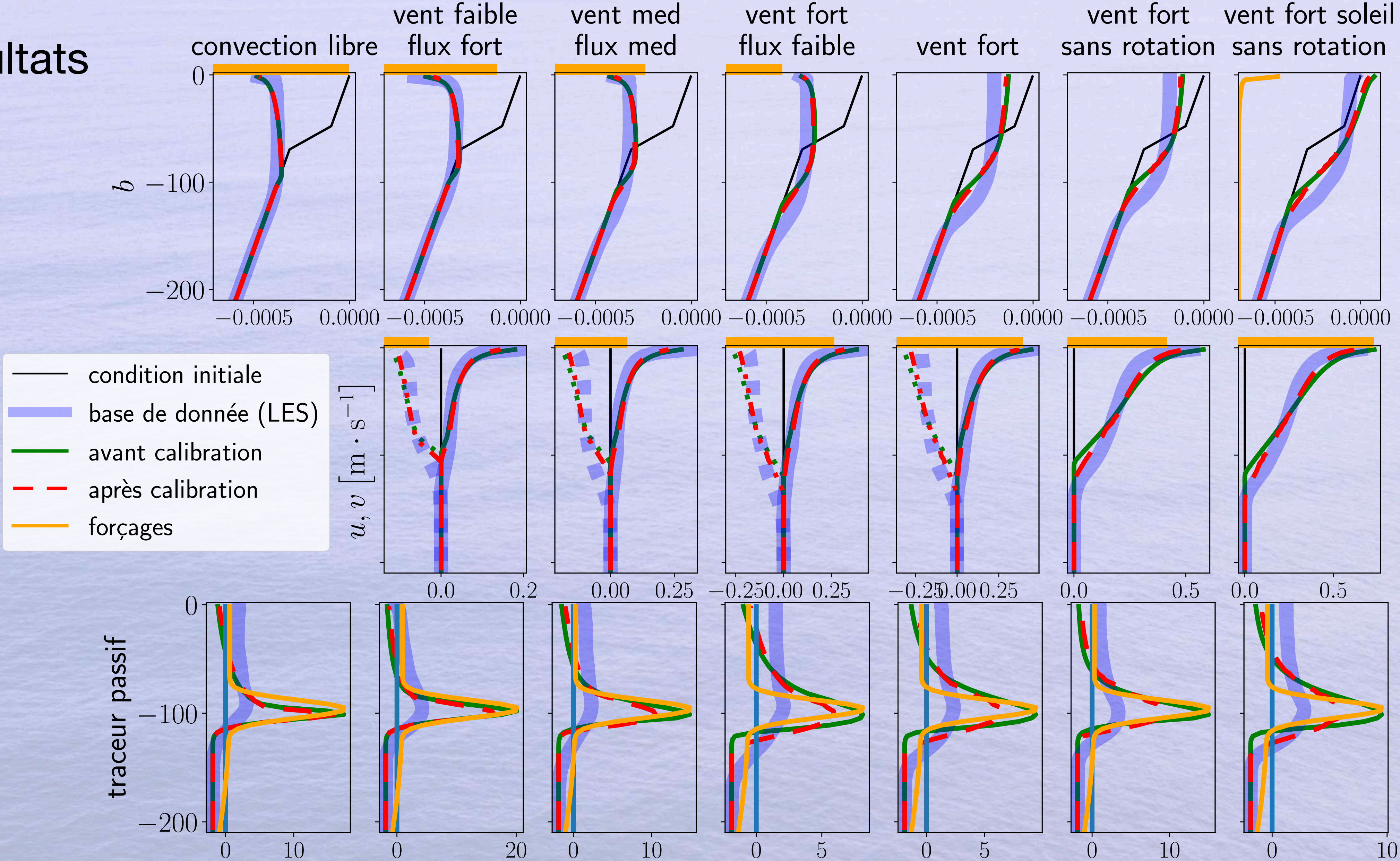
Problème de minimisation

recherche de $\operatorname{argmin}_{\theta \in \mathbb{R}^p} J(\theta)$ en

utilisant $\nabla_{\theta} J$ calculé avec l'autodiff

Calibration partielle de $k - \varepsilon$

Résultats





Marta Mrozowska



Bruno Deremble



Gregory Wagner

Collaboration en cours

Fast and efficient: Bayesian optimization with GPU acceleration for ocean models

Marta Agnieszka Mrozowska¹, James Emil Avery¹, Aster Stoustrup¹, Roman Nuterman², Carl-Johannes Johnsen¹, and Markus Jochum³

¹Kobenhavns Universitet
²Niels Bohr Institute, University of Copenhagen
³University of Copenhagen

November 11, 2024







Abstract

Ocean general circulation models (OGCMs) contain numerous parameterizations of sub-grid scale processes. The parameter tuning procedure is rarely reported and often done by hand. We present an automated alternative: Bayesian optimization, a method which has recently emerged as a frontier in expensive black box optimization. VerOpt, a Python package for the ocean model Veros, adapts Bayesian optimization to climate model tuning. We use VerOpt to identify a set of parameter values of the Turbulent Kinetic Energy (TKE) closure scheme that minimize mixed layer depth (MLD) bias in Veros. We present the results of two optimization procedures: TWIN and OBS. The goal is to minimize modeled MLD error relative to a target map. In TWIN, the target is MLD simulated using Veros with a known parameterization. The ratio of two TKE parameters $c_{kc} - 1$, proportional to the critical Richardson number Ric , is the dominant factor in setting the global MLD. After 180 model simulations, the lowest error in the TWIN experiment is 1.18%. In OBS, the target is MLD climatology. The MLD bias is smallest when $Ric < 1$, and the default TKE parameterization falls within this range. We find, however, that altering the TKE parameterization is not sufficient to reduce the significant MLD bias of 42.62%. The OBS experiment results indicate that the TKE scheme parameters are not the dominant source of MLD bias in Veros. We discuss other possible sources of MLD bias, as well as the potential of extending of the optimization procedure to other parameterizations.

Bayesian Optimisation

projet de papier comparant ces méthodes avec la calibration différentiable

Formulation and Calibration of CATKE, a One-Equation Parameterization for Microscale Ocean Mixing

Gregory LeClaire Wagner¹ , Adeline Hillier¹ , Navid C. Constantinou^{2,3} , Simone Silvestri¹, Andre Souza¹ , Keaton J. Burns¹, Chris Hill¹ , Jean-Michel Campin¹, John Marshall¹ , and Raffaele Ferrari¹

¹Massachusetts Institute of Technology, Cambridge, MA, USA, ²University of Melbourne, Parkville, VIC, Australia, ³ARC Center of Excellence for the Weather of the 21st Century, Parkville, VIC, Australia

Abstract We describe CATKE, a parameterization for fluxes associated with small-scale or “microscale” ocean turbulent mixing on scales between 1 and 100 m. CATKE uses a downgradient formulation that depends on a prognostic turbulent kinetic energy (TKE) variable and a diagnostic mixing length scale that includes a dynamic convective adjustment (CA) component. With its dynamic convective mixing length, CATKE predicts not just the depth spanned by convective plumes but also the characteristic convective mixing timescale, an important aspect of turbulent convection not captured by simpler static CA schemes. As a result, CATKE can describe the competition between convection and other processes such as shear-driven mixing and baroclinic restratification. To calibrate CATKE, we use Ensemble Kalman Inversion to minimize the error between 21 large eddy simulations (LESs) and predictions of the LES data by CATKE-parameterized single column simulations at three different vertical resolutions. We find that CATKE makes accurate predictions of both idealized and realistic LES compared to microscale turbulence parameterizations commonly used in climate models.

Ensemble Kalman Inversion