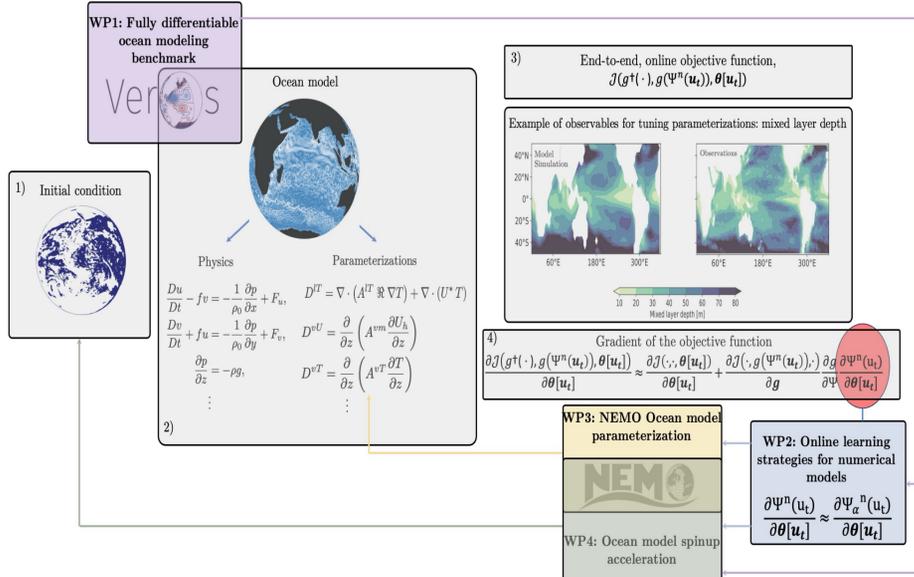


Leveraging differentiable programming And online learning for Hybrid Climate Simulators (LEAP-HCS)

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Context

In LEAP-HCS, We aim to solve estimation and parameter calibration challenges by treating them as optimal control problems. Current climate models often lack the differentiable programming capabilities required for efficient sensitivity analysis. In this context, we aim to develop gradient-based optimization methods that take into account the lack of AD platforms. Our methods will be demonstrated on the ocean component of climate models and will target improvements in spin-up acceleration and sub-grid scale model tuning.



[1] Meunier, E., Ouala, S., Frezat, H., Sommer, J. L., & Fablet, R. (2025). Towards fully differentiable neural ocean model with Veros. *arXiv preprint arXiv:2511.17427*.
 [2] Ouala, S., Chapron, B., Collard, F., Gaultier, L., & Fablet, R. (2024). Online calibration of deep learning sub-models for hybrid numerical modeling systems. *Communications Physics*, 7(1), 402.

Objectives

We aim to develop optimization methods for calibration of climate models.

- Objective 1: Validation of online learning based on numerical models that use DP for state and parameter calibration
- Objective 2: Development and validation of gradient based optimization methods that take into account the lack of DP
- Objective 3: Development of automated calibration methods for ocean model parameters and for spinup acceleration.

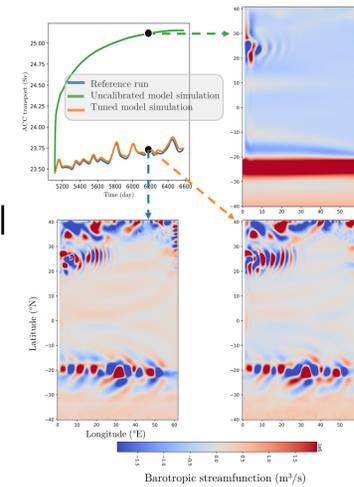
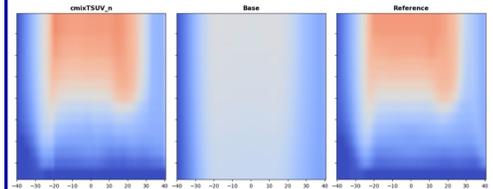
Organization

WP1: FULLY DIFFERENTIABLE OCEAN MODELING BENCHMARK WITH VEROS

Plan: In this work package, we focus on developing a fully differentiable ocean modeling benchmark. This benchmark will be used to assess optimization based on DP and to develop learning methods that account for the lack of DP

Current developments:

- Differentiable VEROS [1]
- Demonstration of AD in VEROS
- Development of a 1° global ocean configuration.



WP2: GRADIENT BASED OPTIMIZATION METHODS FOR NUMERICAL MODELS

In LEAP-HCS, we are interested in optimizing objective functions of the following form:

$$\hat{\theta}[\hat{x}_t] = \arg \min_{\theta[x_t]} \mathcal{J}(y_{t+nh}, g(\Psi^n(x_t)), \theta[x_t])$$

Gradient based optimization requires computing the sensitivity of the solution i.e.:

$$\frac{\partial \Psi^n(x_t)}{\partial \theta[x_t]} = \frac{\partial}{\partial \theta[x_t]} \Psi \circ \Psi \circ \dots \circ \Psi(x_t)$$

In this WP, we aim to develop gradient approximation methods. We have shown in previous works [2], that carefully designed gradient approximation can be suitable for such problems.

WP3/4: APPLICATION TO PARAMETER CALIBRATION AND SPINUP ACCELERATION OF THE NEMO OCEAN MODEL

- **Coupling of ML/optimization libraries in python with NEMO, in collaboration with TRACCS PC5**



COMPACT
New computing paradigms

- **Automatic tuning of NEMO-ORCA1 parameterizations**
- **Spinup acceleration**