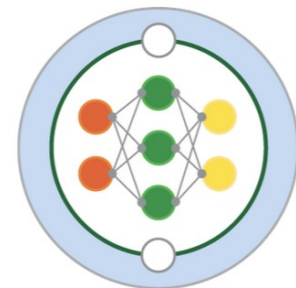# Online deployment of pre-trained machine learning components within geoscientific models through OASIS
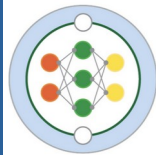
Alexis Barge[1] – Julien Le Sommer[1]

1: IGE, Université Grenoble-Alpes, France

M2LInES Annual Meeting 2024
4-7 June 2024

NB: *Underlined texts are links*

Motivation: interface for hybrid physics / AI modeling

Typical use cases of hybrid modeling

Parameterization from hi-fidelity models (LES, km-scale models)

Sane et al. 2023   *Frezat et al. 2022*

Correction of model error from reanalysis or DA increments

Gregory et al. 2024   *Chapman and Berner, 2023*

Acceleration of code components with neural emulators

Hogan and Bozzo, 2018   *Chantry et al. 2021*

Needs for Interfacing

Existing solutions

Implement or convert NN in Fortran

neural-fortran   *Fortran-Keras Bridge*   *FNN*   *inference-engine*

Call Python scripts from Fortran with Python bindings

call_py_fort   *Pyfort*

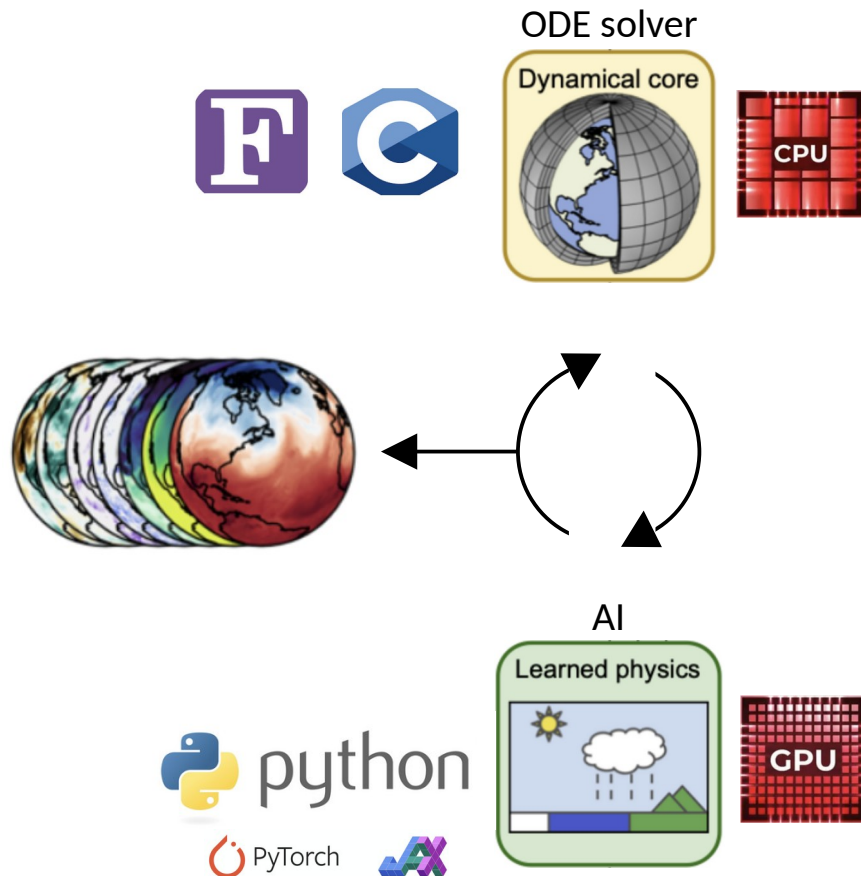Leverage the existing C/C++ bindings of specific ML libraries

infero   *Ftorch*   *TF-lib*   *TorchClim*
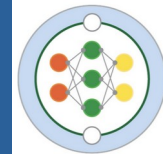
Leverage a more generic interface between Fortran and Python

smartsim   *PhyDLL*

ODE solver

AI

OASIS coupler for hybrid modeling

OASIS3-MCT https://oasis.cerfacs.fr/en/

Coupling library between different codes
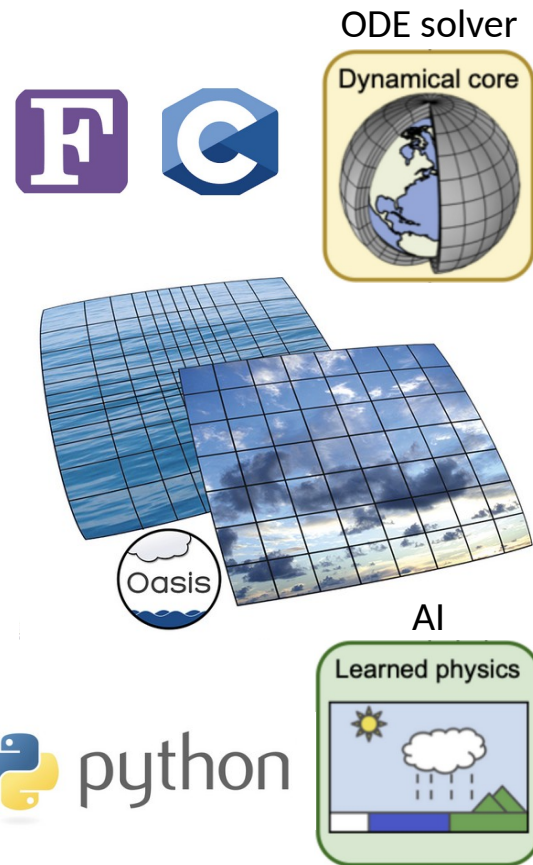
Interpolate and exchange 2D/3D fields

Widely deployed

Used by 67 climate modeling groups

Used in 5 of the 7 European ESMs used for CMIP6

New functionalities since OASIS3-MCT_5.0

Python and C/C++ API

Can we leverage OASIS for hybrid modeling ?

ODE solver

Dynamical core

Oasis

AI

python

Learned physics

OASIS coupler for hybrid modeling: drawing

OASIS3-MCT *https://oasis.cerfacs.fr/en/*

Coupling library between different codes

Interpolate and exchange 2D/3D fields

Widely deployed

Used by 67 climate modeling groups
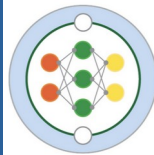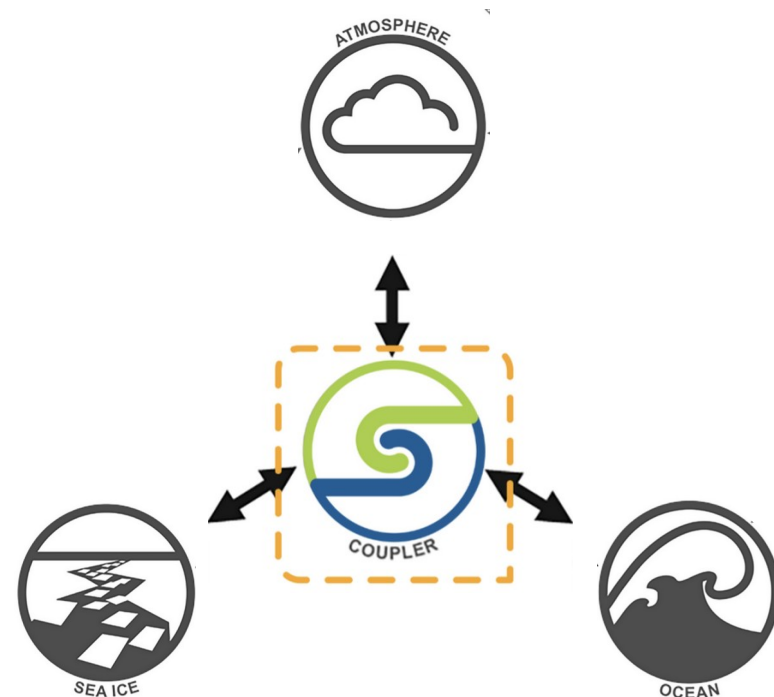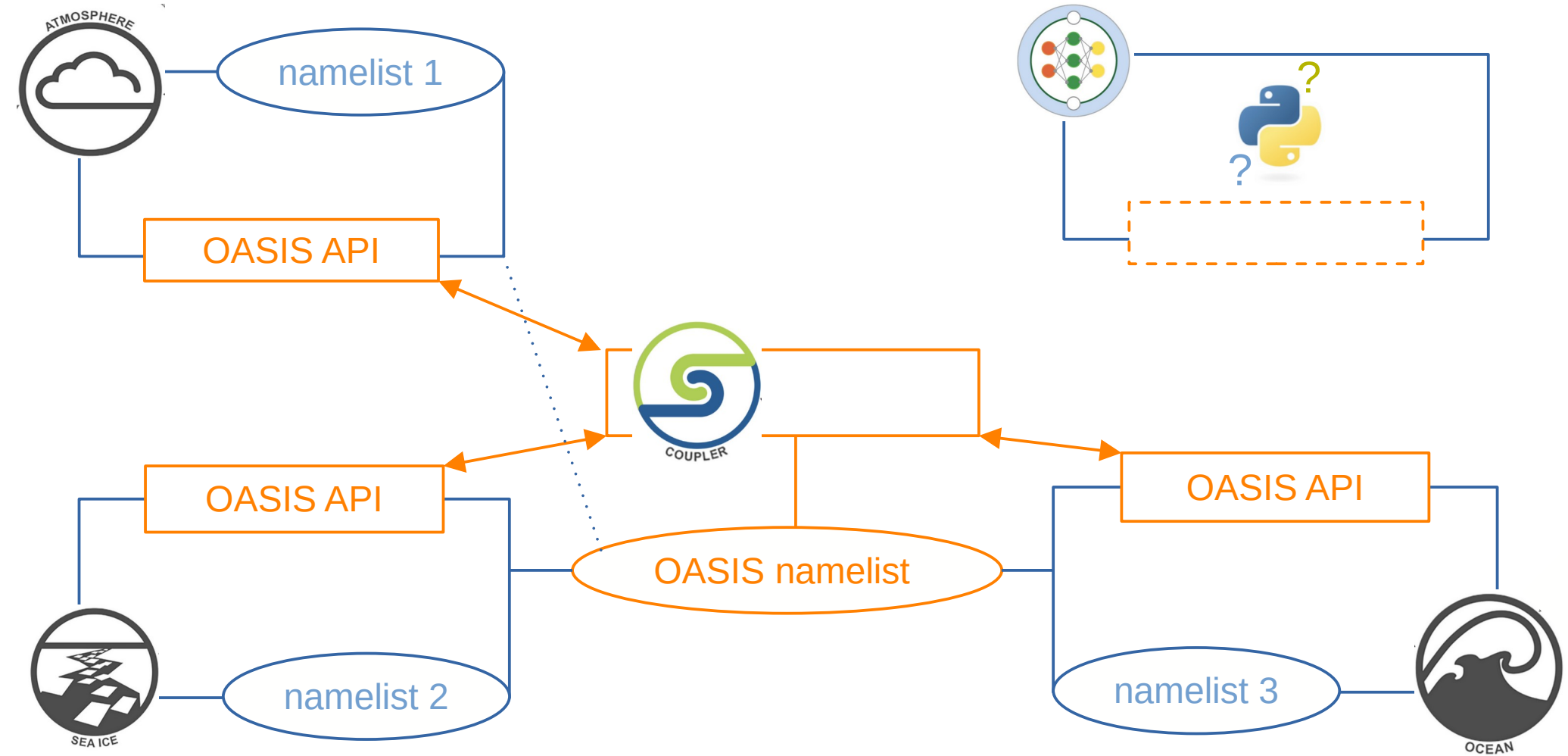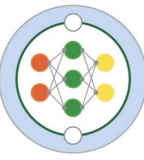
Used in 5 of the 7 European ESMs used for CMIP6

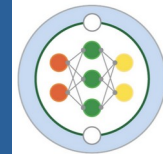*New functionalities since OASIS3-MCT_5.0*

Python and C/C++ API
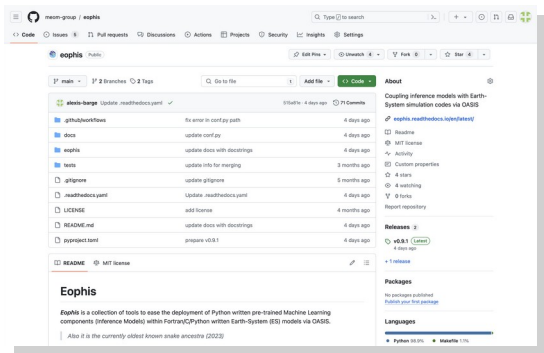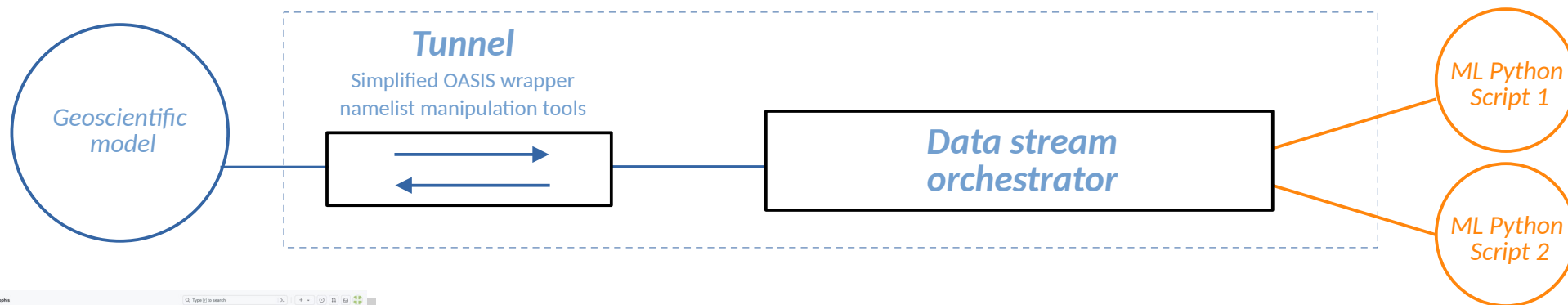
Can we leverage OASIS for hybrid modeling ?

OASIS coupler for hybrid modeling: reality

EOPHIS: a library for deploying ML models through OASIS

OASIS usage	Coupling setup Interpolation / restart definition Namelist
Aimed usage	No interpolation / restart Back and forth exchange only Use by non-experts

Geoscientific model

Tunnel
Simplified OASIS wrapper
namelist manipulation tools

Data stream orchestrator

ML Python Script 1

ML Python Script 2

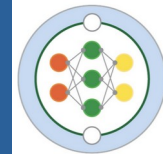*https://github.com/meom-group/eophis*

MIT Licensed
Open source

Key features

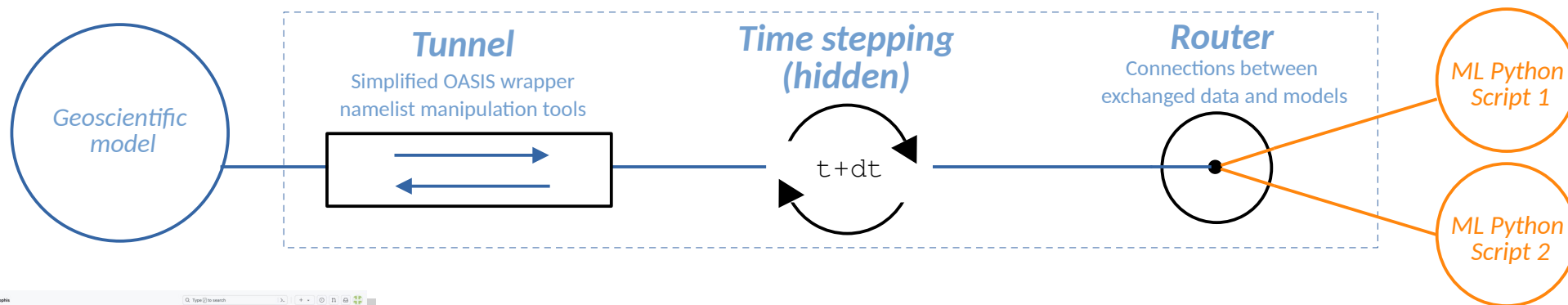ML-framework agnostic solution (TF, PyTorch, Jax ...)

ML-models as pluggable scripts with minimal bindings

Easy sharing of ML-models across geoscientific codes

EOPHIS: a library for deploying ML models through OASIS

OASIS usage	Coupling setup Interpolation / restart definition Namelist	Time advancement for exchange synchronicity
Aimed usage	No interpolation / restart Back and forth exchange only Use by non-experts	Time not required

Geoscientific model

Tunnel
Simplified OASIS wrapper namelist manipulation tools

Time stepping (hidden)
t+dt

Router
Connections between exchanged data and models

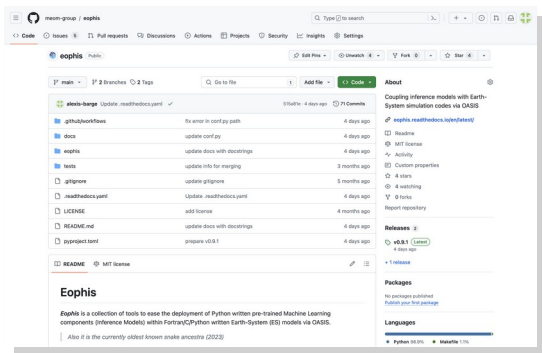**ML Python Script 1**

ML Python Script 2

Key features

ML-framework agnostic solution (TF, PyTorch, Jax …)

ML-models as pluggable scripts with minimal bindings
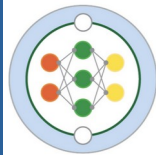
Easy sharing of ML-models across geoscientific codes
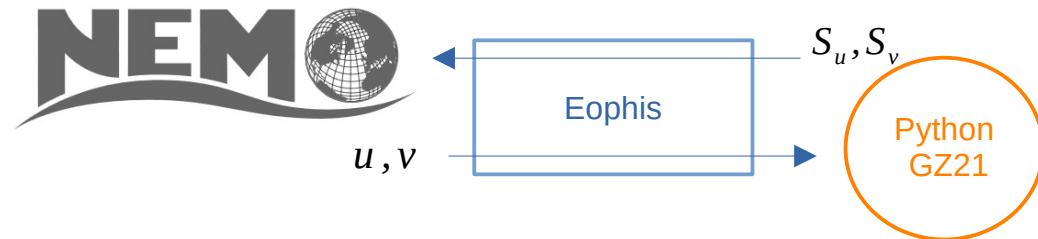
Deployment of ML models in idealized NEMO

GZ21 Model

Stochastic subgrid forcing

Infer stochastic elements from 2D velocities

Guillaumin and Zanna, 2021

DINO.GZ21

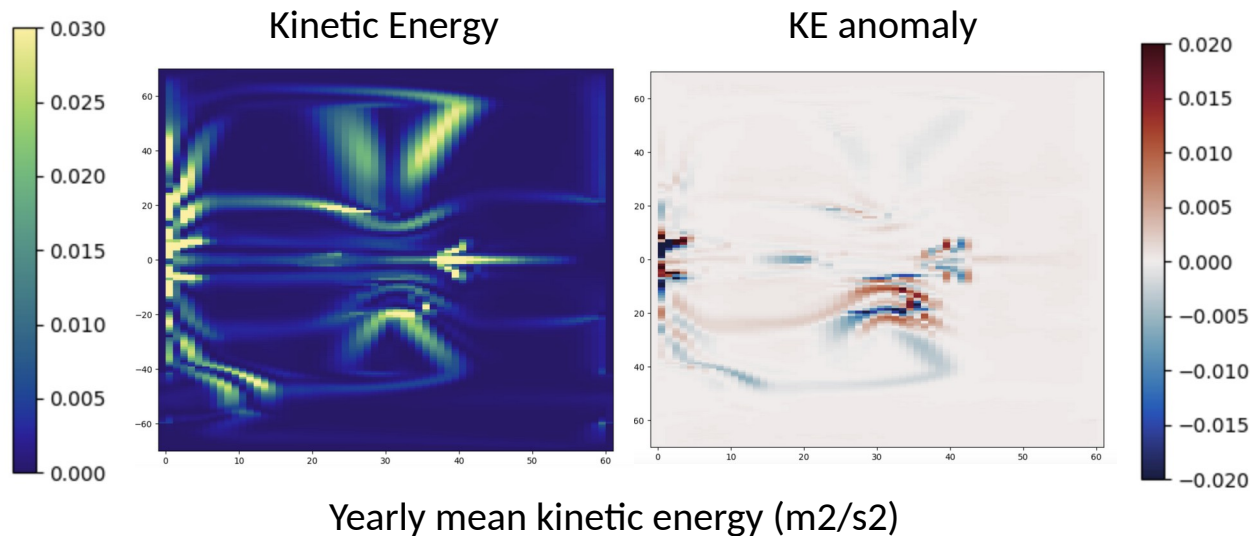5 years low-res *DIabatic NeverwOrld2*

Implementation of retroactive GZ21

Collaboration with E.Meunier and D.Kamm
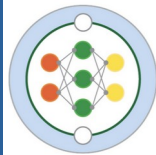
Perspectives

High-resolution simulation

Scientific evaluation

Performance optimization

Yearly mean kinetic energy (m2/s2)
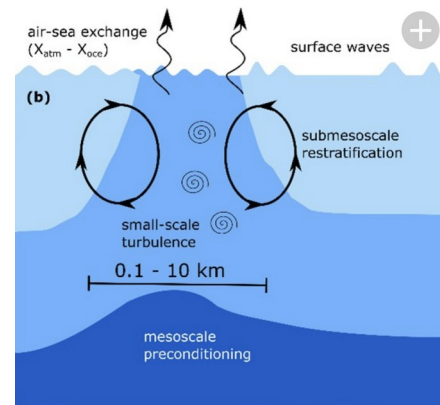
Restratification due to submesoscale eddies

Unresolved vertical transports in ocean near-surface mixed layer

Modeled by Mixed Layer Eddies (MLE) parameterizations

Use of ML parameterizations currently an active research field

Bodner et al., submitted to JAMES (2024)
Zhou et al., submitted to JAMES (2024)

Existing closure framework

Fox-Kemper et al., 2008b   *Calvert et al. 2020*

Submesoscale vertical buoyancy fluxes

$$\overline{w'b'}_\Psi = \underline{\Psi} \times \nabla_H \overline{b}^z \quad \rightarrow \text{streamfunction-induced transport}$$
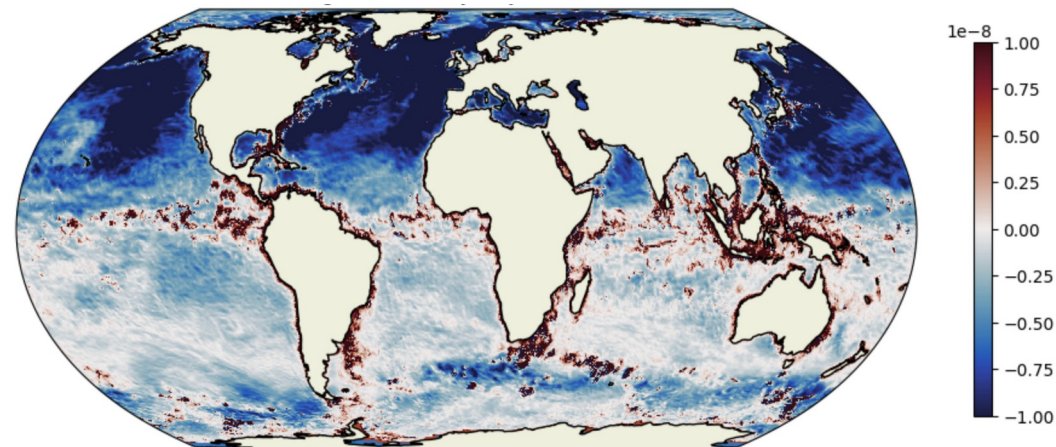
$$\underline{\Psi} = f(|\overline{\nabla b^z}|, \overline{f}, \overline{H}, \overline{Q^*}, \text{div}(u), rot(u), |\tau|, \overline{\sigma^z})$$

eORCA025-MLE.BDZ24

10 years forced global 1/4deg simulation

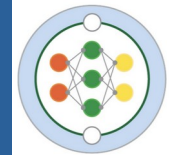Infer 2D vertical buoyancy fluxes with Bodner et al. model
Collaboration with A.Bodner and D.Balwada

Snapshot of outsourced vertical buoyancy flux (W/m2)
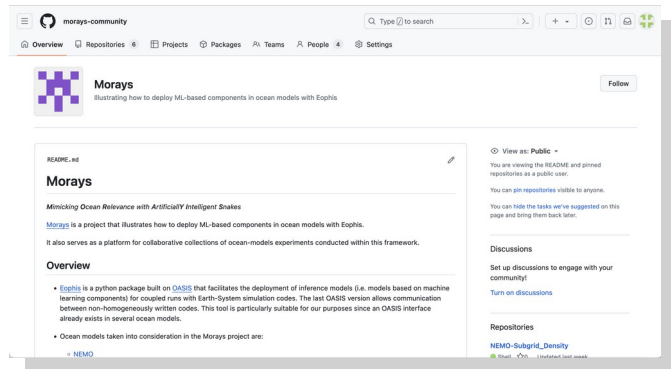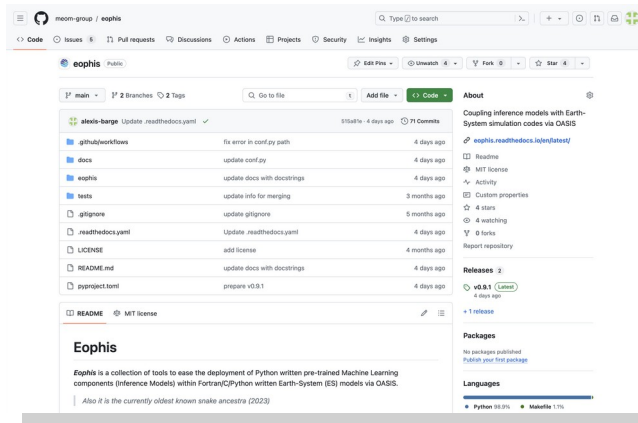Successful external ML model call

Wrap-up

Eophis : a framework agnostic interface for ML models

Future developments :

- parallel execution with data exchanges across multiple processors
- performances analysis on GPUs vs CPUs (for inference)

https://github.com/meom-group/eophis

MIT Licensed , Open source

A Github org for sharing ML-based ocean closures (w/ Eophis)

MORAYS-community : examples deployment and use cases

Ocean model agnostic (NEMO, CROCO) with commonly agreed templates

Toward reproducible hybrid ocean modeling

https://github.com/morays-community

Getting Started

https://morays-doc.readthedocs.io/en/latest/getting_started.html