Morays-community: a framework to share reproducible hybrid ocean modeling experiments

Alexis Barge - Etienne Meunier - Marcela Contreras
David Kamm - Julien Le Sommer

1st May 2025

https://doi.org/10.5194/egusphere-egu25-18745

Need and issues with hybrid physics / AI models

Applications of hybrid modeling

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

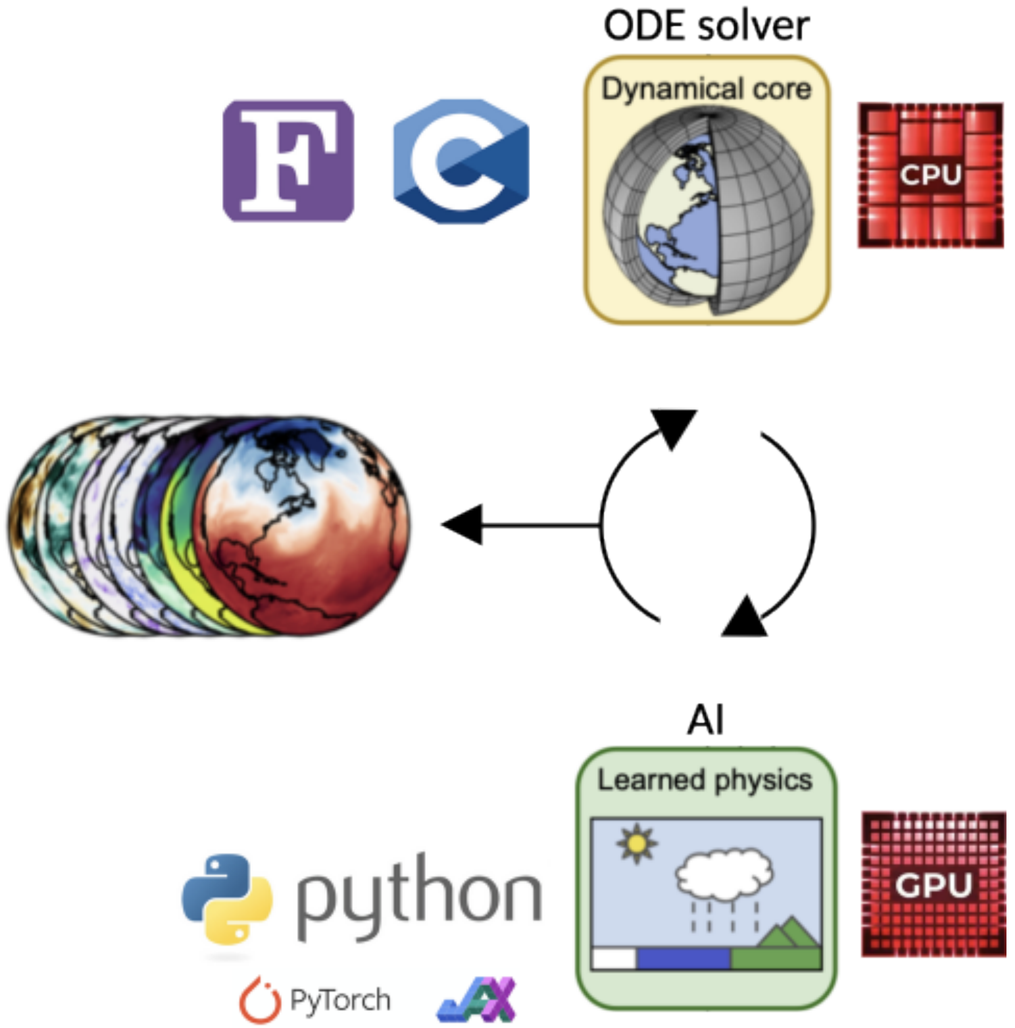
Sane et al. 2023 *Zhang et al. 2023* *Yuval et al. 2021*

Model error correction 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*



Practical questions raised

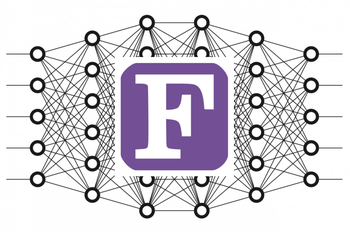
How to call ML from Fortran

- Computational efficiency
- Reproducibility: sharing weights and biases
- Reproducibility: production environment

Need to explore options and practices for reproducible hybrid modeling

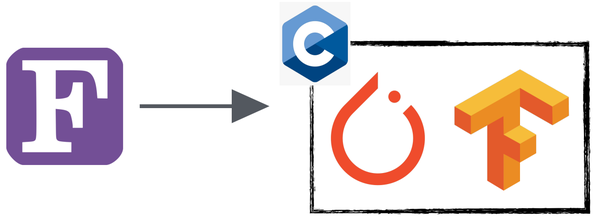
Landscape of existing solutions

Neural Network in Fortran

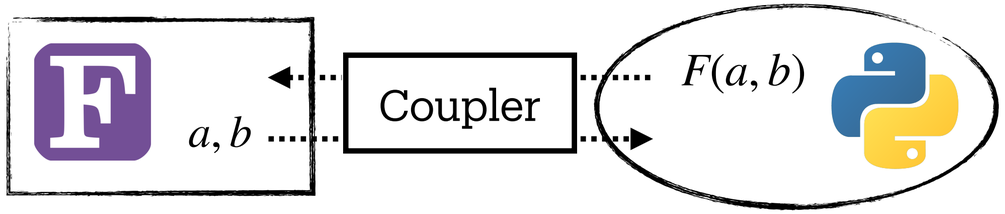


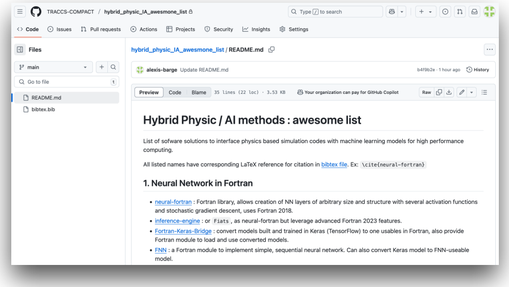
Call Python scripts from Fortran with Python bindings

Leverage C/C++ bindings of ML libraries



Leverage high-level couplers Fortran and Python APIs





NB: Physics / AI methods awesome list

https://github.com/TRACCS-COMPACT/hybrid_physics_AI_awesome_list

Open to contribution

Large variety of solutions

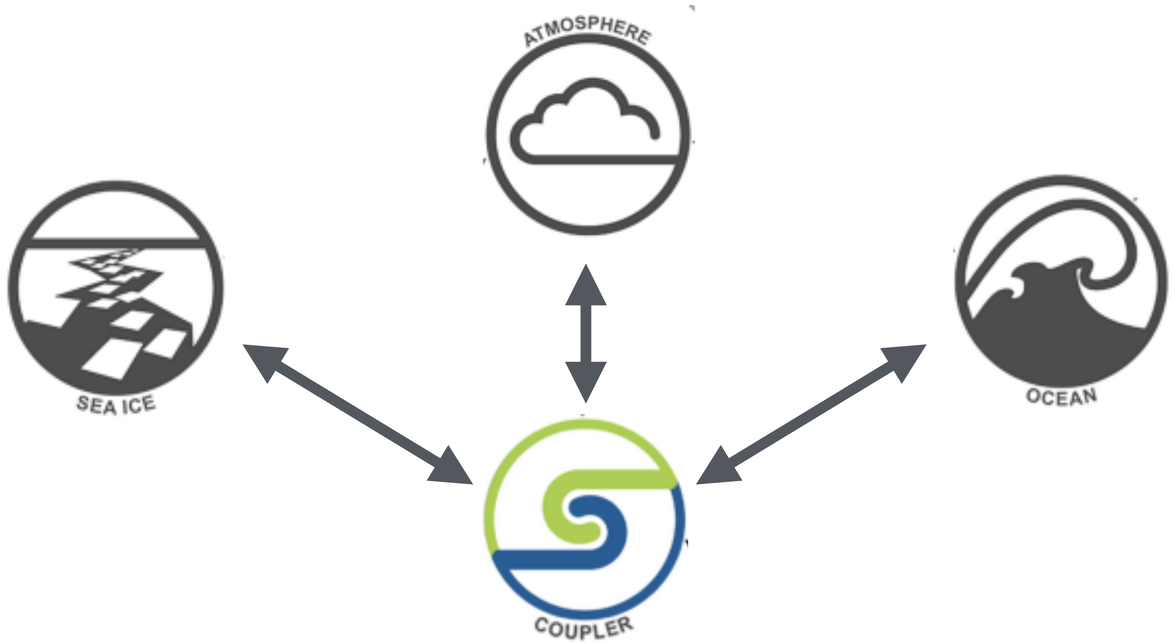
No standard procedures for sharing codes and experiments

EOPHIS: a library for deploying ML models through OASIS

Couplers are already in codes

Low development to adapt existing interfaces

OASIS3-MCT : 5 of the 7 European ESMs in CMIP6
YAC : ICON
CMEPS : NCAR CESM — NOAA UFS
FMS : NOAA GFDL
CPL7/MCT : E3SM
C-COUPLER2 : Chinese institutions models



OASIS3-MCT5 https://oasis.cerfacs.fr/en

Coupling library between different codes
Interpolate and exchange 2D/3D fields
Python, C/C++ and Fortran API

Widely deployed in European models

Eophis

Deploy OASIS API in Python scripts
Manage connexions between exchanges and ML models
Configure coupling environment
~ 1.5k lines

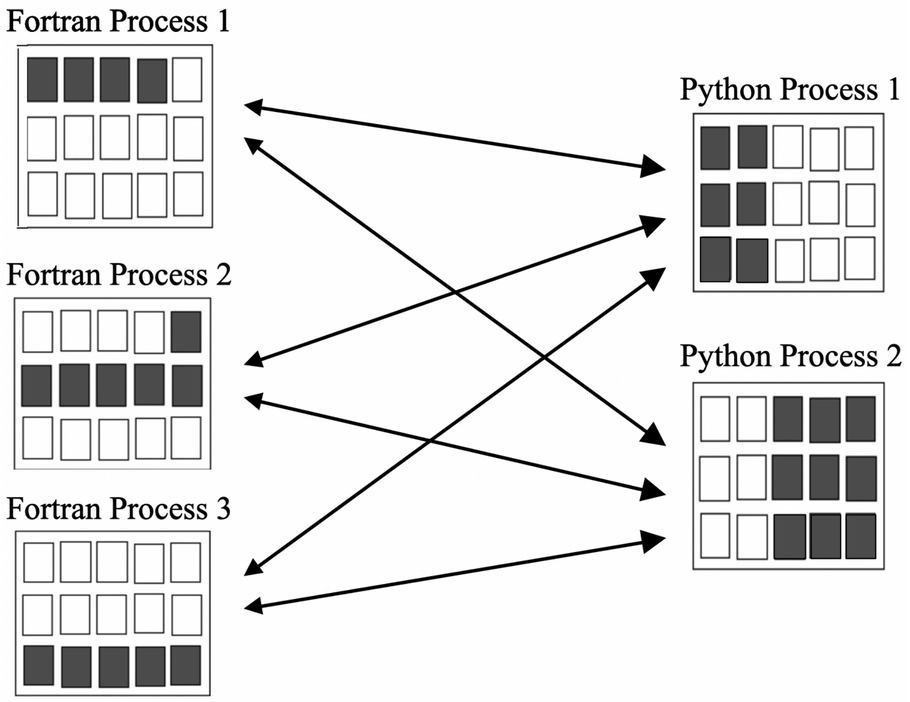
https://github.com/meom-group/eophis

MIT Licensed , Open Source

Benefits for using couplers

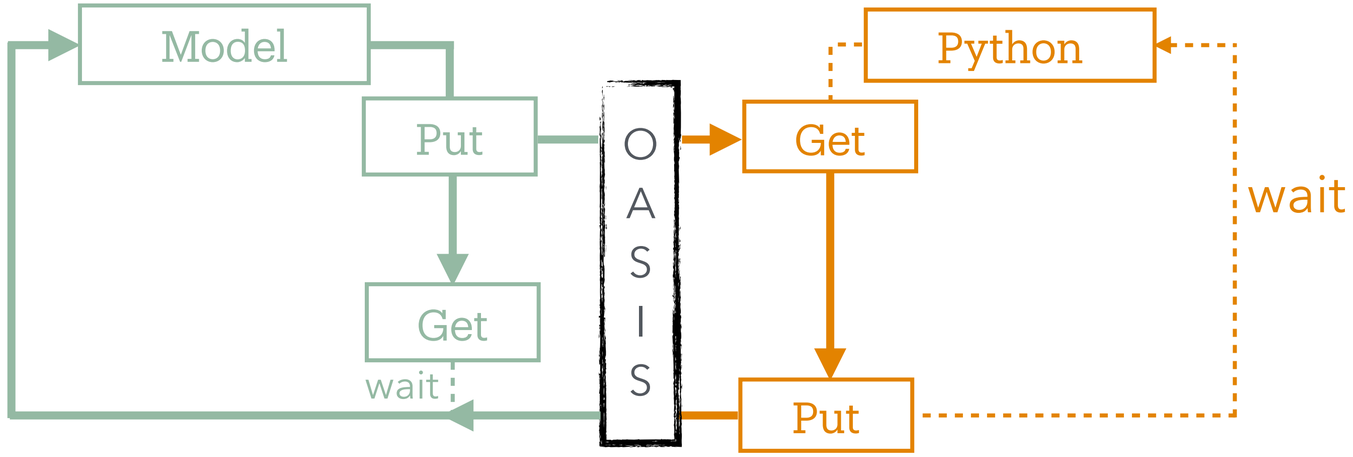
Adjustment of resources

Optimal process number for model and inference
Isolate GPU access to Python processes
Flexibility (fast, smooth, cheap…)

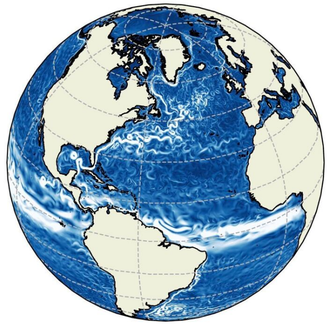


Asynchronicity

Send inputs as soon as possible
Continue computation as far as possible
Wait for Python returns
Time overlap reduces resources overhead



Existing use cases with NEMO and EOPHIS

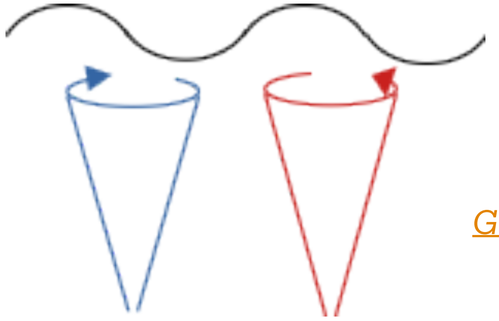


Realistic

Eddy closures

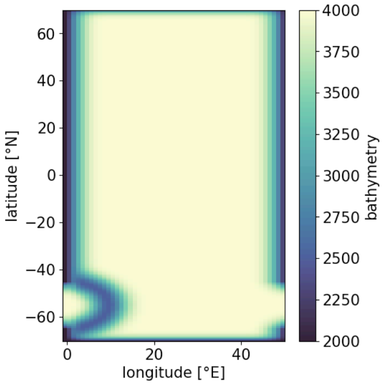
— tracer fluxes

— Momentum fluxes



Stanley et al., 2022

Guillaumin and Zanna, 2021

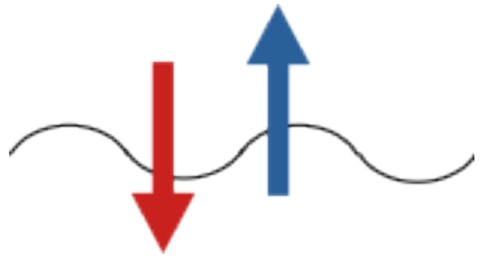


Idealized

Air sea fluxes

— Correction

— Bulk formae



Storto et al., 2024

Biri et al., 2021

Wu et al., 2025 (under review)

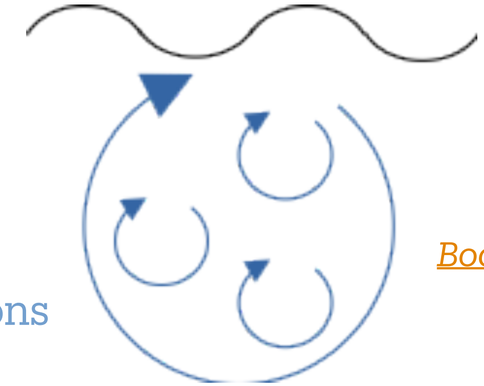
1D-Column

Parameterizations

— vertical mixing

— Mixed layer eddies

— Subgrid density fluctuations

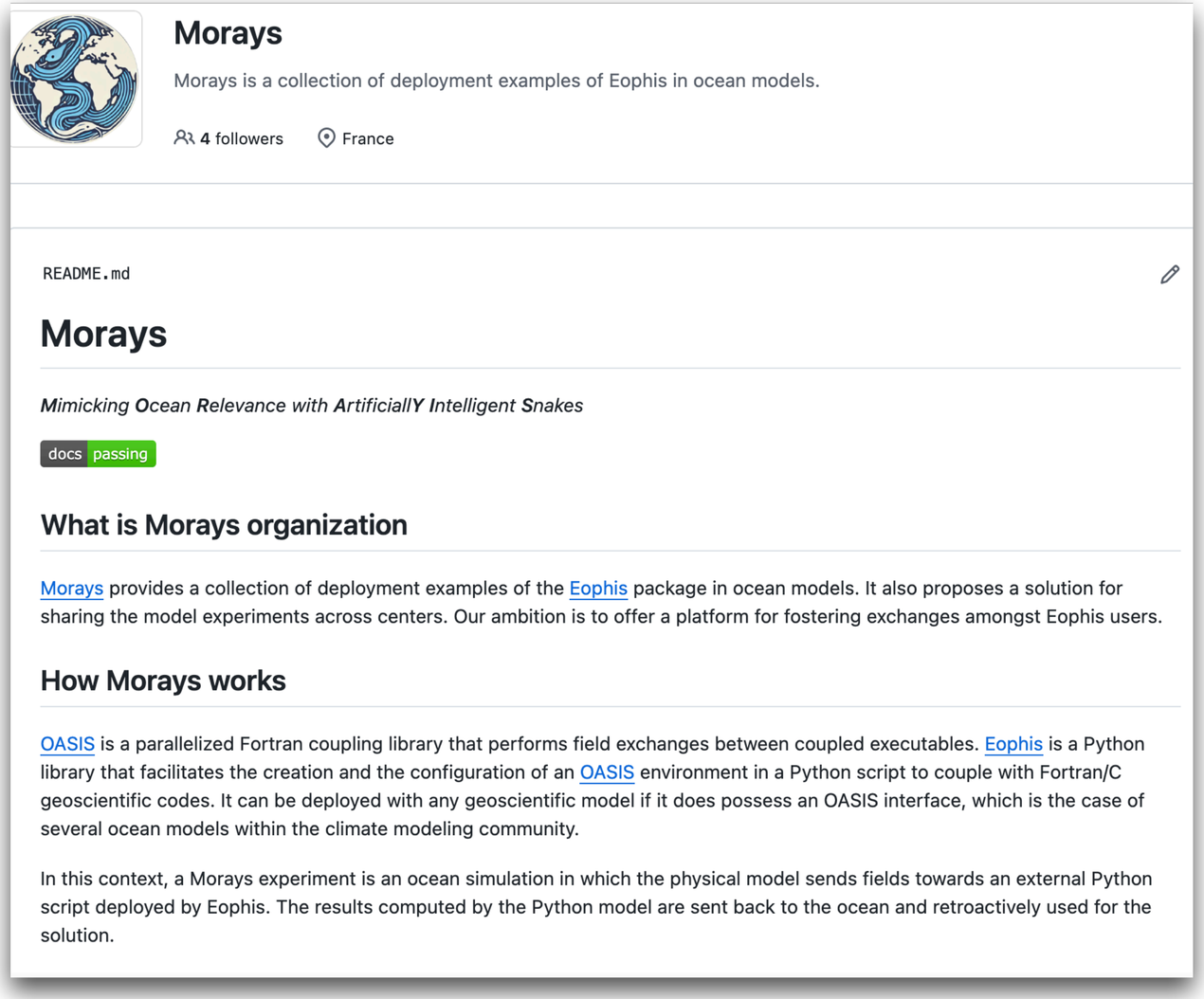


Liang et al., 2021

Bodner, Balwada and Zanna 2024

Stanley et al., 2022

Morays-Community: Reproducible hybrid ocean modeling



Morays

Morays is a collection of deployment examples of Eophis in ocean models.

4 followers France

README.md

Morays

***M**imicking **O**cean **R**elevance with **A**rtificiall**Y** **I**ntelligent **S**nakes*

docs passing

What is Morays organization

Morays provides a collection of deployment examples of the Eophis package in ocean models. It also proposes a solution for sharing the model experiments across centers. Our ambition is to offer a platform for fostering exchanges amongst Eophis users.

How Morays works

OASIS is a parallelized Fortran coupling library that performs field exchanges between coupled executables. Eophis is a Python library that facilitates the creation and the configuration of an OASIS environment in a Python script to couple with Fortran/C geoscientific codes. It can be deployed with any geoscientific model if it does possess an OASIS interface, which is the case of several ocean models within the climate modeling community.

In this context, a Morays experiment is an ocean simulation in which the physical model sends fields towards an external Python script deployed by Eophis. The results computed by the Python model are sent back to the ocean and retroactively used for the solution.

GitHub Morays-Community

Use cases of ML closures in ocean models with Eophis

Examples deployment and tutorials

https://github.com/morays-community

Templates for sharing hybrid experiments

Reproducible environments and codes

Documentation and tutorials

Open to contribution

Morays-Community: Reproducible hybrid ocean modeling

ORCA1 Air-Sea Heat

DOI 10.5281/zenodo.15052861

Context and Motivation

Purpose of this experiment is to correct the air-sea heat fluxes as a function of oceanic and atmospheric state predictors on a global ORCA1 config. More details about scientific context can be found in Storto et al. 2024. Corrected heat fluxes are written in an output file with the NEMO ouput system (XIOS).

Variations

- **S24** : Air-Sea heat fluxes correction computed with Artificial Neural Network proposed by Storto et al. 2024.

Requirements

Compilation

- NEMO version : v4.0.7 patched with morays, local `CONFIG/my_src` sources and `ANNIF` module.
- **ANNIF** compilation:

```
cd ORCA1_AirSea_Heat.S24/CONFIG/ANNIF
./Compile_gcc.ksh  # edit if necessary, should build annif.o
```

- Code Compilation manager : none, use standard `makenemo` script

```
Don't forget to include annif.o module in NEMO arch file
```

Python

- Eophis version : v1.0.1
- **S24** dependencies :

```
pip install -f ORCA1_AirSea_Heat.S24/INFERENCES/requirements.txt
```

Run

- NEMO Production Manager : none, use submission script `job.ksh` in `RUN`

Post-Process

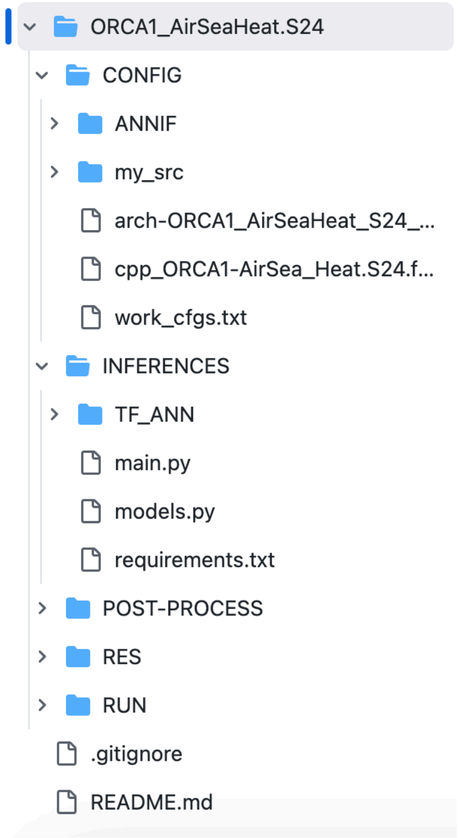
- No Post-Process libraries

Detailed context in README

NEMO and Eophis version, additional patches
Clear instructions to install Python model
Additional libraries and tools (post-process for example)

Structure

CONFIG: Model sources, compilation
INFERENCES: Python scripts, weights
RUN: Namelist and input files
POSTPROCESS: Template scripts
RES: Figures



Deployment tutorial

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