Offre de Stage IPSL 2025

(Soutenu par le programme EUR IPSL-*Climate Graduate School*)

Titre du sujet de stage / *Title of the internship* :

Deep Ocean Modeling Using Conditional Diffusion Models

Description du sujet / *Description of the internship work (1 page maximum)* :

Context

Ocean models are essential tools for a wide range of applications, a global scale. These models face several technical challenges, such as: including forecasting weather patterns, understanding climate change, and supporting oceanographic research. The Nucleus for European Modelling of the Ocean (NEMO) is a key framework used for simulating ocean dynamics on

- Integrating complex mathematical equations across a gridded representation of the Earth's surface.
- Parametrizing physical phenomena to accurately mimic real-world ocean behaviors.
- Ensuring the stability of long-running simulations.

The goal of this internship is to develop a faster approach by using neural networks to generate the stable post spin-up state directly. The model would learn from the initial conditions and specific parameters of the simulation to emulate the stable state, significantly reducing the computational cost of the spin-up phase. The goal is to develop diffusion models [1] to generate stable initial states for ocean models.

Diffusion models are a state-of-the-art deep learning approach for generative learning, known for their flexibility and ability to be constrained by a wide variety of criteria. They are widely used in a variety of domains (e.g. video and image generation, inverse problems, time series forecasting [2]).

Internship Tasks

As an intern, your work will be centered around the following objectives:

1. Study deep learning work on geophysical field generation, focusing on diffusion-based approaches.
2. Extend the existing diffusion model to improve the generation of high resolution simulations of DINO fields.
3. Implement a set of physical metrics to assess the physical integrity of the generated states, with support from ocean modeling specialists.
4. Investigate the conditioning of the diffusion model on physical parameters to improve the flexibility of the generation process.
5. (Optional) Apply developed generative strategy on global climate model simulations

Profile

- Educational Background: Ongoing studies (Master's or engineer's) in computational science, applied mathematics, machine learning, or related fields.
- Technical Skills:
- Experience with scientific computing and deep learning techniques.
- Knowledge of Python and PyTorch.
- Familiarity with neural networks, specifically diffusion models, would be a strong advantage.
- Analytical Skills: Ability to handle complex datasets and understand the physical processes governing ocean models. Strong understanding of the mathematical foundations behind diffusion models, including concepts such as Markov chains and inverse problems.
- Teamwork and Communication: The intern will collaborate with an interdisciplinary team of researchers and engineers, and clear communication skills are essential.

Opportunities

- Hands-on experience in applying cutting-edge machine learning techniques to address environmental data challenges.
- Mentorship from experienced researchers in both machine learning and environmental science domains.
- Gain knowledge in Diffusion Model, one of the core-concept of current deep learning research
- Potential for co-authorship on publications resulting from the internship project.
- **Potential thesis extension based on the result of the internship.**

[1] J. Ho et al Denoising Diffusion Probabilistic Models https://arxiv.org/abs/2006.11239
[2] I. Price et al GenCast: Diffusion-based ensemble forecasting for medium-range weather https://arxiv.org/abs/2312.15796
[3] L. Huang et al DiffDA: a Diffusion Model for Weather-scale Data Assimilation https://arxiv.org/abs/2401.05932
[4] Kohl, G. et al Benchmarking autoregressive conditional diffusion models for turbulent flow simulation. https://arxiv.org/abs/2309.01745
[5] M. Lienen et al From Zero to Turbulence: Generative Modeling for 3D Flow Simulation https://arxiv.org/abs/2306.01776

Responsable du stage (Nom/prénom/statut) / *Supervisor (Name, first name and status)* :

Luther Ollier (thesitif LOCEAN) (luther.ollier@locean.ipsl.fr)

Laboratoire d'accueil / *host laboratory* : LOCEAN

Adresse à laquelle a lieu le stage / *address* : Laboratoire LOCEAN, Sorbonne-Université, Paris

Équipe de recherche concernée (si pertinent) ou autre participant à l'encadrement du stage / *Research team concerned (if relevant) or other participant in the supervision of the placement* :

Etienne Meunier (Postdoc LOCEAN) (etienne.meunier @locean.ipsl.fr),
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Niveau du stage (Licence, M1, M2, *internship*) / *Level of the intern* : M2

Licence ou Master(s) où sera proposé le sujet / *Bachelor's or Master's degree(s) where the subject will be proposed* :

M2 et écoles d'ingénieur

Thème scientifique de l'IPSL concerné / *IPSL theme concerned* : SAMA

Durée du stage / *Internship duration* : 6 months

Période / *Period of the year* : March – October (Flexible)

Est-il prévu une thèse dans le prolongement du stage ? / *Is a PhD thesis planned after the internship ?* No

To apply: Please send your CV, cover letter, and any relevant academic transcripts to luther.ollier@locean.ipsl.fr.