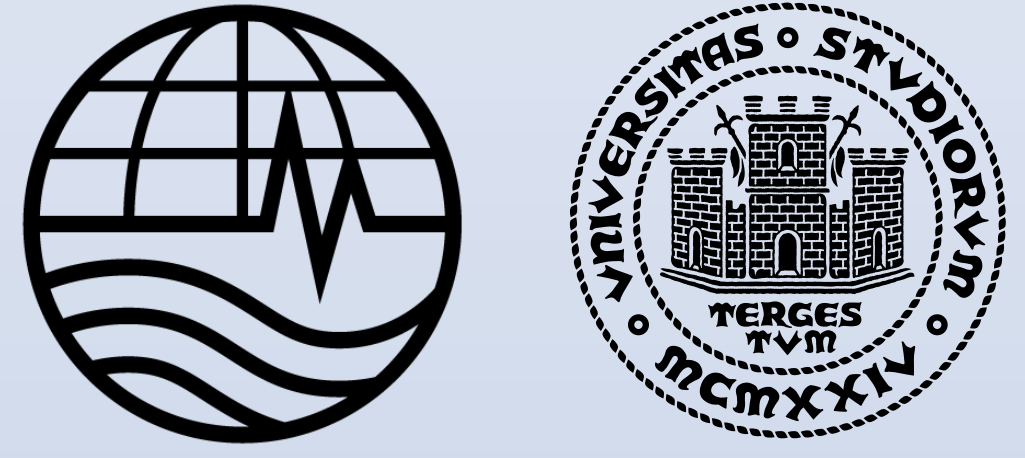


# Learning Subseasonal-to-Seasonal Global Ocean Forecasting on a Hierarchical Triangle Mesh



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## Abstract

The accuracy of medium-range weather predictions has steadily improved over the years. However, risk mitigation strategies for weather extremes require extended-range forecasts. **Subseasonal-to-Seasonal (S2S)** forecasts address this need, traditionally relying on ensembles of physics-based atmosphere-ocean coupled simulations. More recently, data-driven models emerged as a competitive alternative<sup>1</sup>. Still, these models lack a description of the ocean, whose coupling becomes critical at these timescales. To address this issue, we propose a **data-driven model for S2S global ocean forecasting** based on **Graph Neural Networks (GNNs)**. We present architectural improvements based on analogies with finite element methods required to deal with irregular domains.

## Dataset

The train/test dataset comprises the period from 1st of January 1993 to 31st December 2021. Daily means taken from the **GLORYS12 reanalysis**<sup>2</sup> have been regridded onto a 1° resolution grid using a conservative algorithm, and vertically down-sampled to 10 depth levels within the first 1.000 m.

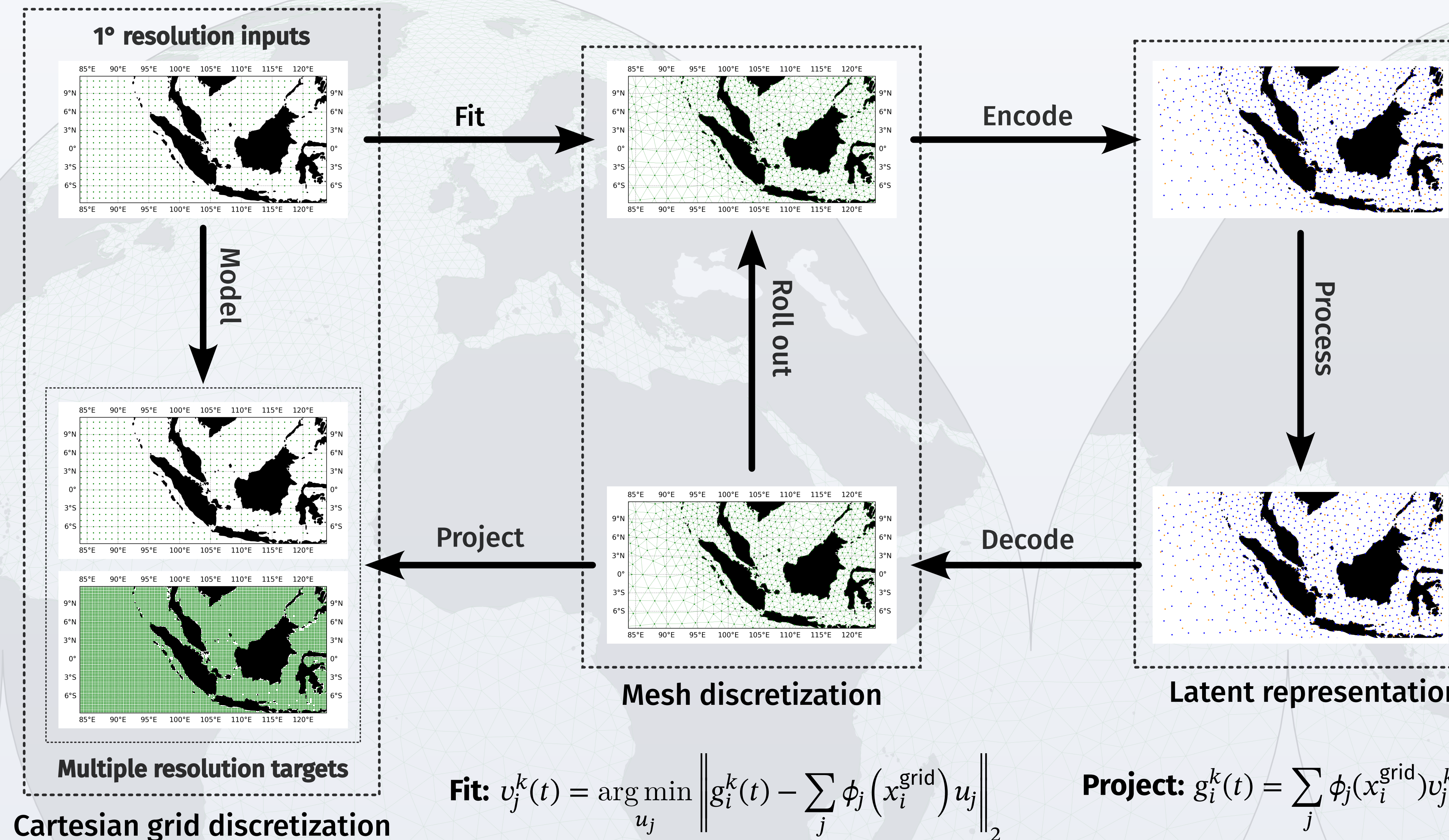
## Problem Statement

Given a time series of ocean states and forcings, the goal is to learn a forecasting model, parametrized by a GNN, for the next system state given the past ones, and current values of forcing variables, so that system trajectories can then be rolled-out iteratively.

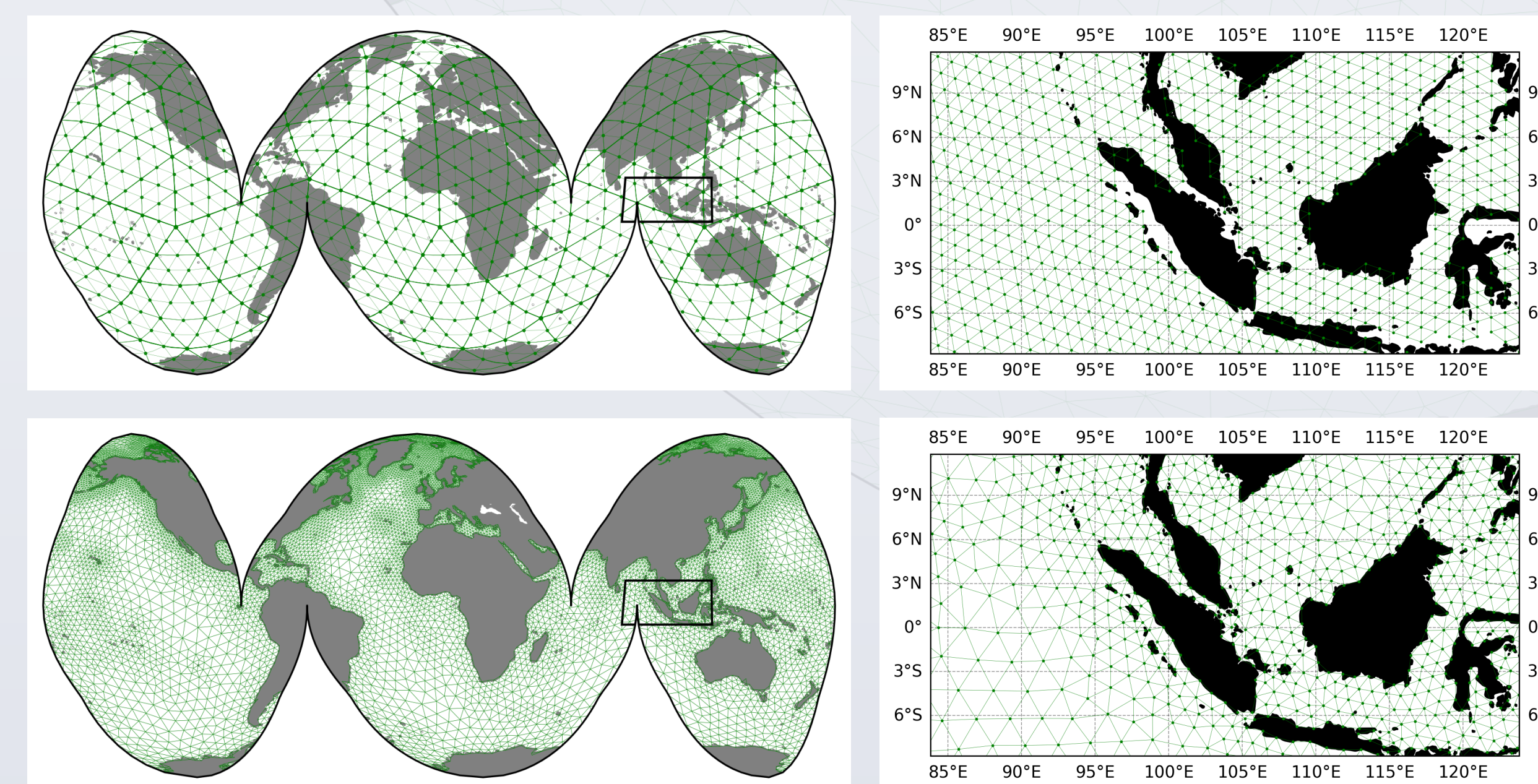
- $g_i^k(t^n)$  Ocean state variables defined on grid
- $u_j^k(t^n)$  Ocean state variables defined on mesh-graph vertices
- $\phi_j(x)$  Basis functions
- $x_i^{\text{grid}}$  Grid cell center locations

$$\text{Model: } g_i^k(t^n) = f_{\Theta}(g_i^k(t^{n-1}), g_i^k(t^{n-2}), \dots)$$

## Model architecture



## Comparison with a Masked Icosahedral Multi-Mesh



### Masked Icosahedral Multi-Mesh

The global map shows only 3 refinements, while the zoom-in shows a multi-mesh using 6 (30,205 vertices and 235,706 edges).

### Global Ocean Triangle Mesh-Graph

The global map shows a coarse mesh with 9,310 vertices and 2,602 edges, the zoom-in shows a detail with 25,542 vertices and 5,044 edges (the coarse mesh is omitted) for the same area.

## Processor



<sup>1</sup> Remi Lam, et al. Learning skillful medium-range global weather forecasting. *Science*, 382(6677):1416–1421, December 2023. doi:10.1126/science.adi2336. URL <https://tinyurl.com/3vzt656k>

<sup>2</sup> European Union-Copernicus Marine Service. Global Ocean Physics Reanalysis, 2018. URL <https://tinyurl.com/58kna52>