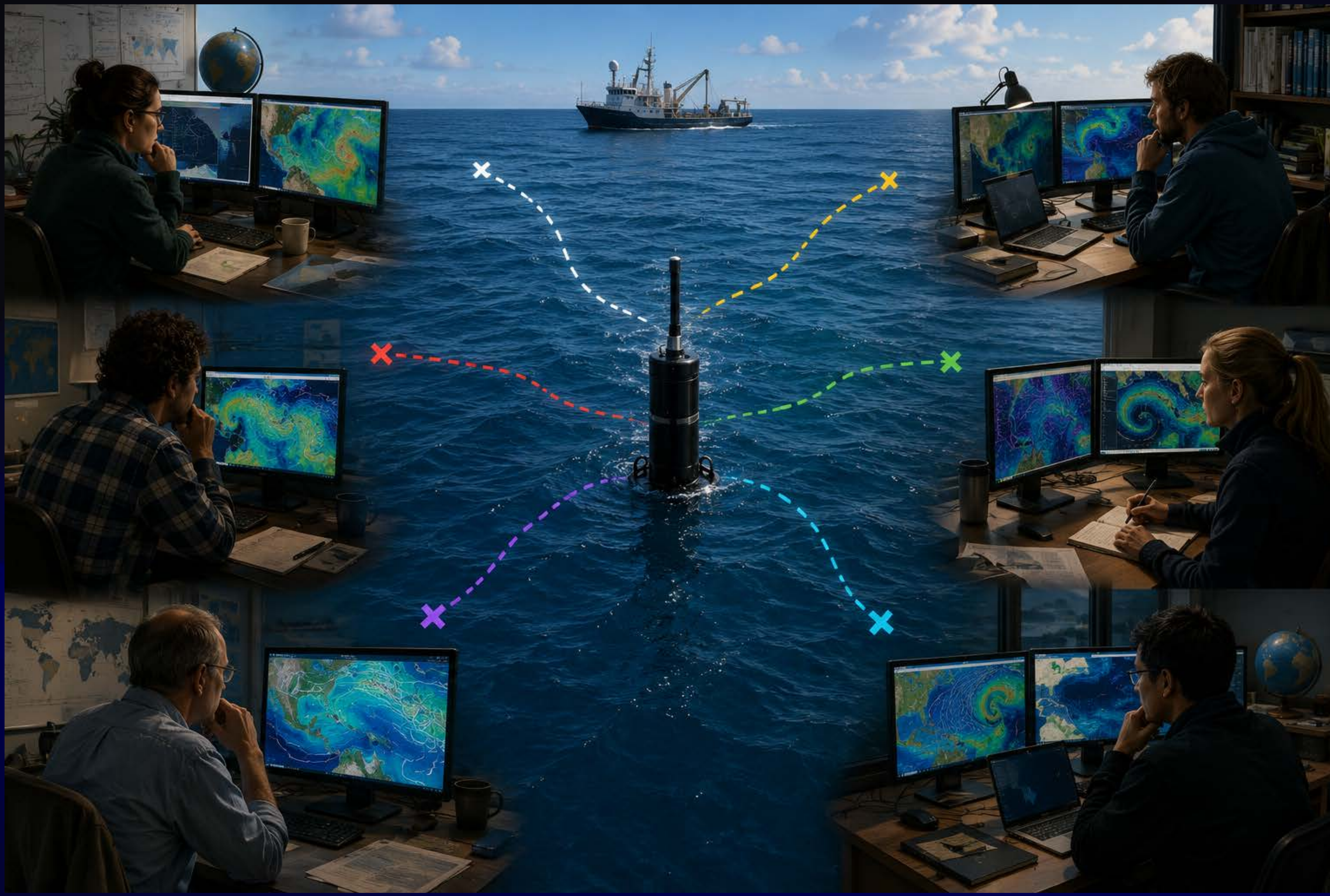
Where is the Monk? Contest Seminar

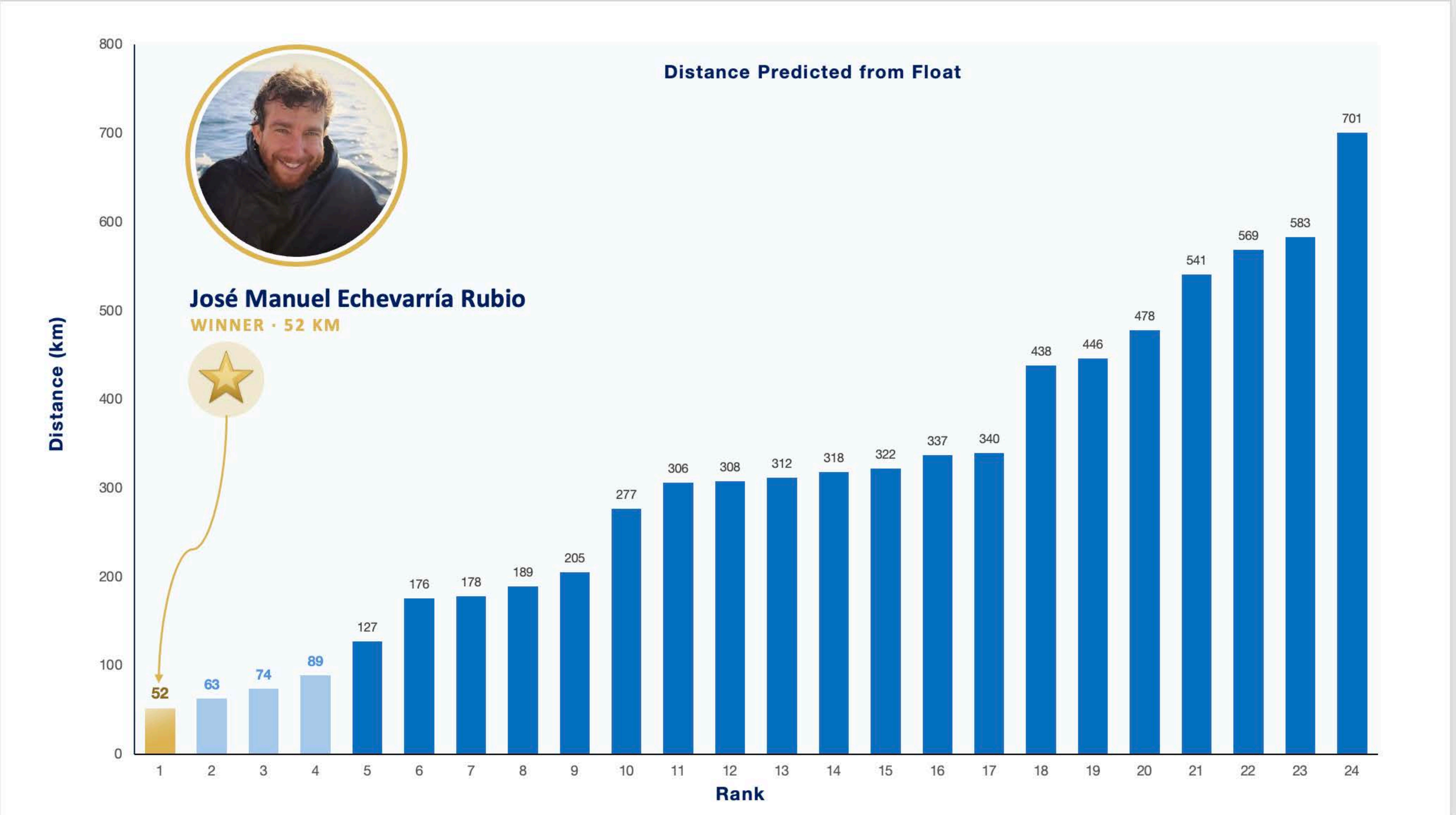
Agenda

- Introduction and Format
- Overview of common Lagrangian prediction framework and error sources
- Presentations from our winners:
  - José Rubio
  - Knut-Frode Dagestad
- Questions/Discussion

Introduction

- Thank you for your participation!
- Expect regular trajectory contests (with prizes)
- Seminars to highlight Lagrangian prediction development and the techniques of winners




Distance Predicted from Float
José Manuel Echevarría Rubio
WINNER · 52 KM
Distance (km)
Rank
800
700
600
500
400
300
200
100
0
52
63
74
89
127
176
178
189
205
277
306
308
312
318
322
337
340
438
446
478
541
569
583
701
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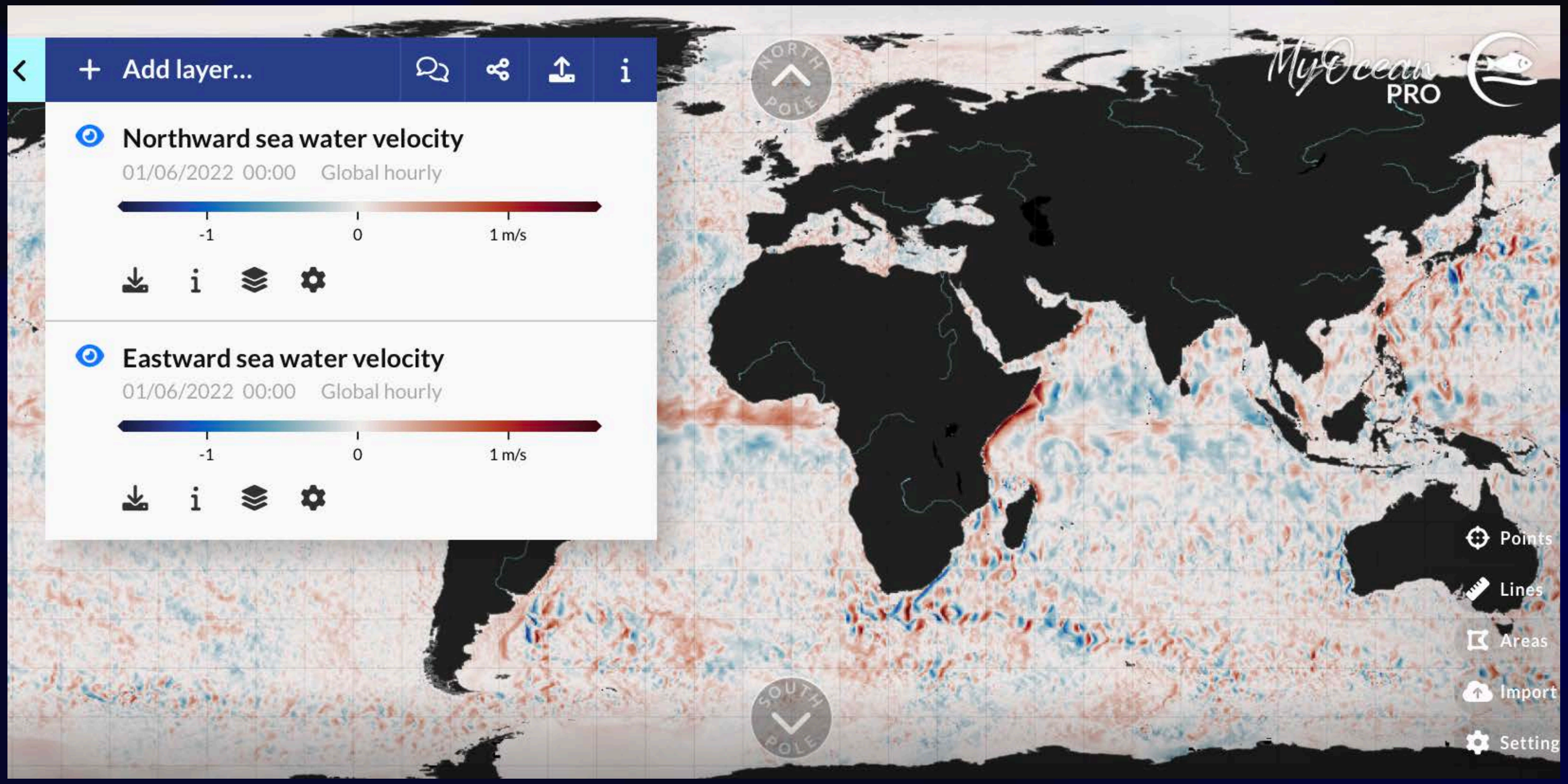
24

Lagrangian Prediction Framework

$$\hat{\boldsymbol{x}}(t+\Delta t) = \boldsymbol{x}(t) + \int_{t}^{t+\Delta t} \hat{\boldsymbol{u}}(\boldsymbol{x}(\tau), \tau)\, d\tau$$

Ocean Model

Ocean Model


Add layer...
Northward sea water velocity
01/06/2022 00:00 Global hourly
-1
0
1 m/s
Eastward sea water velocity
01/06/2022 00:00 Global hourly
-1
0
1 m/s
MyOcean
PRO
Points
Lines
Areas
Import
Setting

Lagrangian Prediction Framework

$$\boldsymbol{E} = \boldsymbol{x} - \hat{\boldsymbol{x}}$$

$$\frac{d\boldsymbol{E}}{dt} = \nabla_x \hat{\boldsymbol{u}}(\boldsymbol{x}(t), t)\boldsymbol{E}(t) + \hat{\boldsymbol{u}}(\boldsymbol{x}(t), t) - \boldsymbol{u}(\boldsymbol{x}(t), t)$$

Existing model error

New model error

$$\boldsymbol{\eta}(\boldsymbol{t}) = \hat{\boldsymbol{u}}(\boldsymbol{x}(t), t) - \boldsymbol{u}(\boldsymbol{x}(t), t)$$

$$\boldsymbol{\eta}(t) = \boldsymbol{b}(t) + \boldsymbol{\eta}'(t), \quad E[\boldsymbol{\eta}'] = 0$$

Model bias

High frequency, unresolved physics,
interpolation/integration/representation

Advection Scheme

OceanParcels

OpenDrift

Octopus

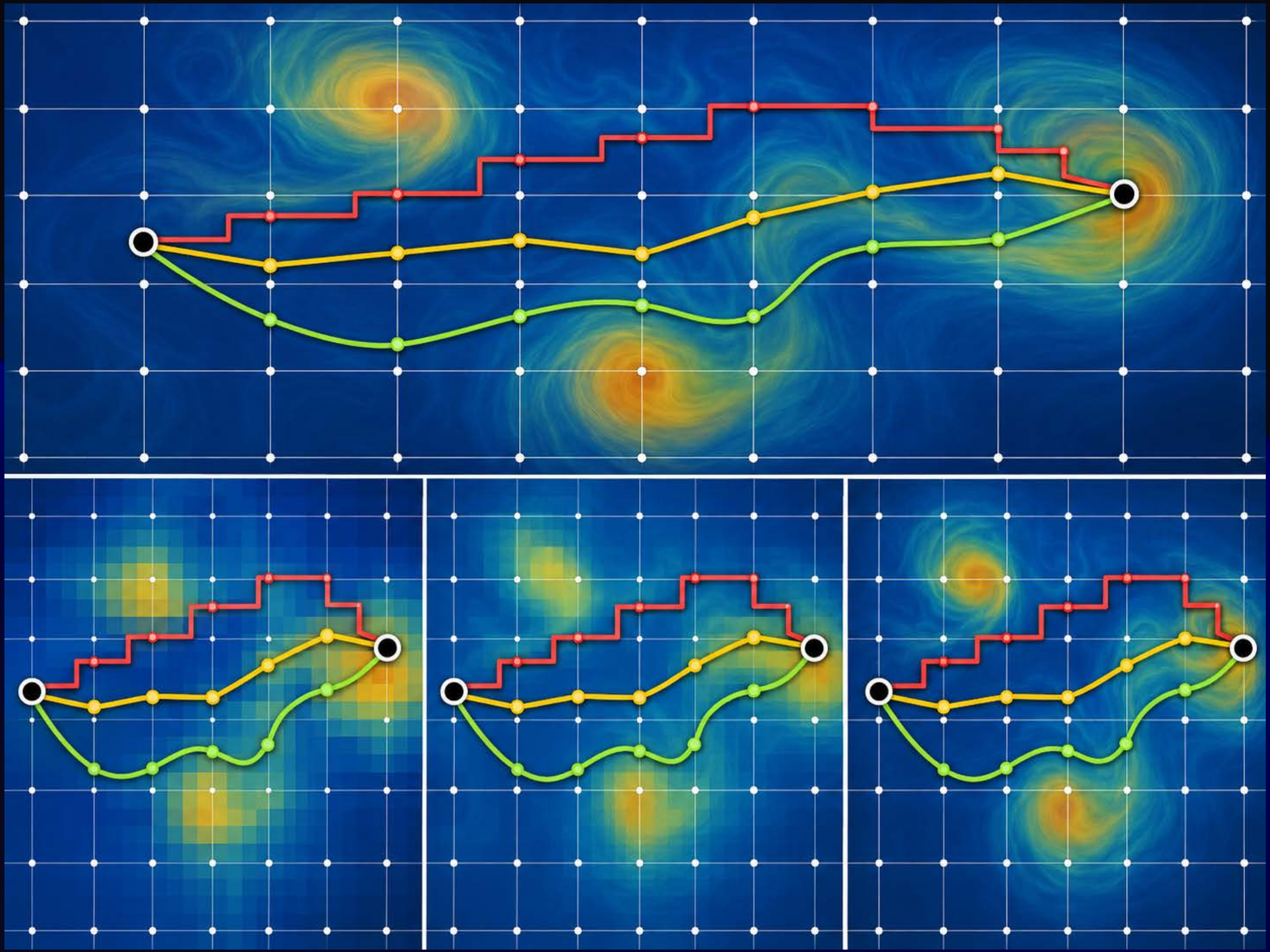
A tool for fast Lagrangian trajectory calculation

TRACMASS

TRACMASS is a Lagrangian trajectory code for ocean and atmospheric general circulation models. The code makes it possible to estimate water paths, Lagrangian stream functions (barotropic, overturning, etc.), exchange times,

Van Sebille et al. 2018

Advection Scheme



Advection Scheme

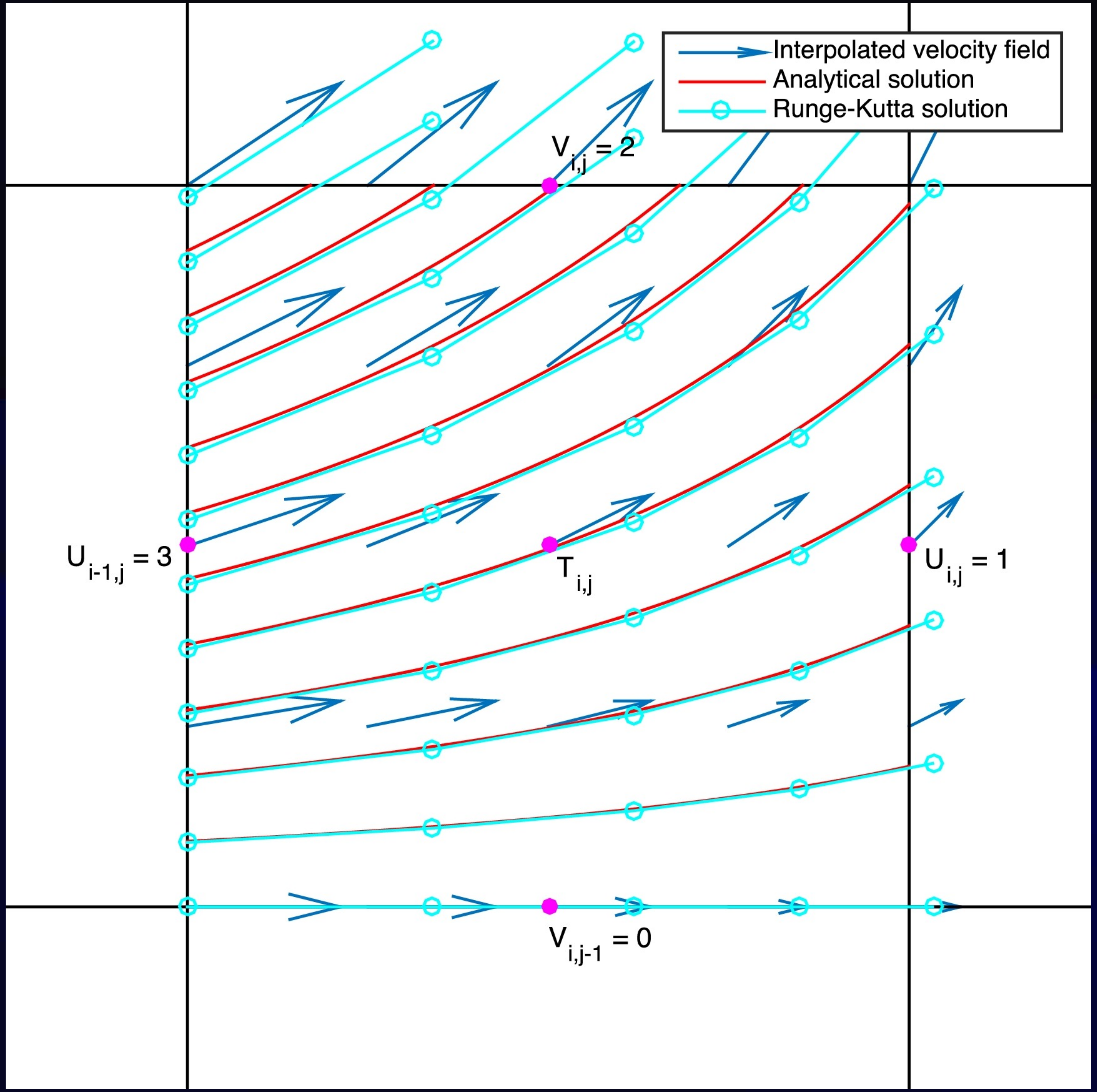
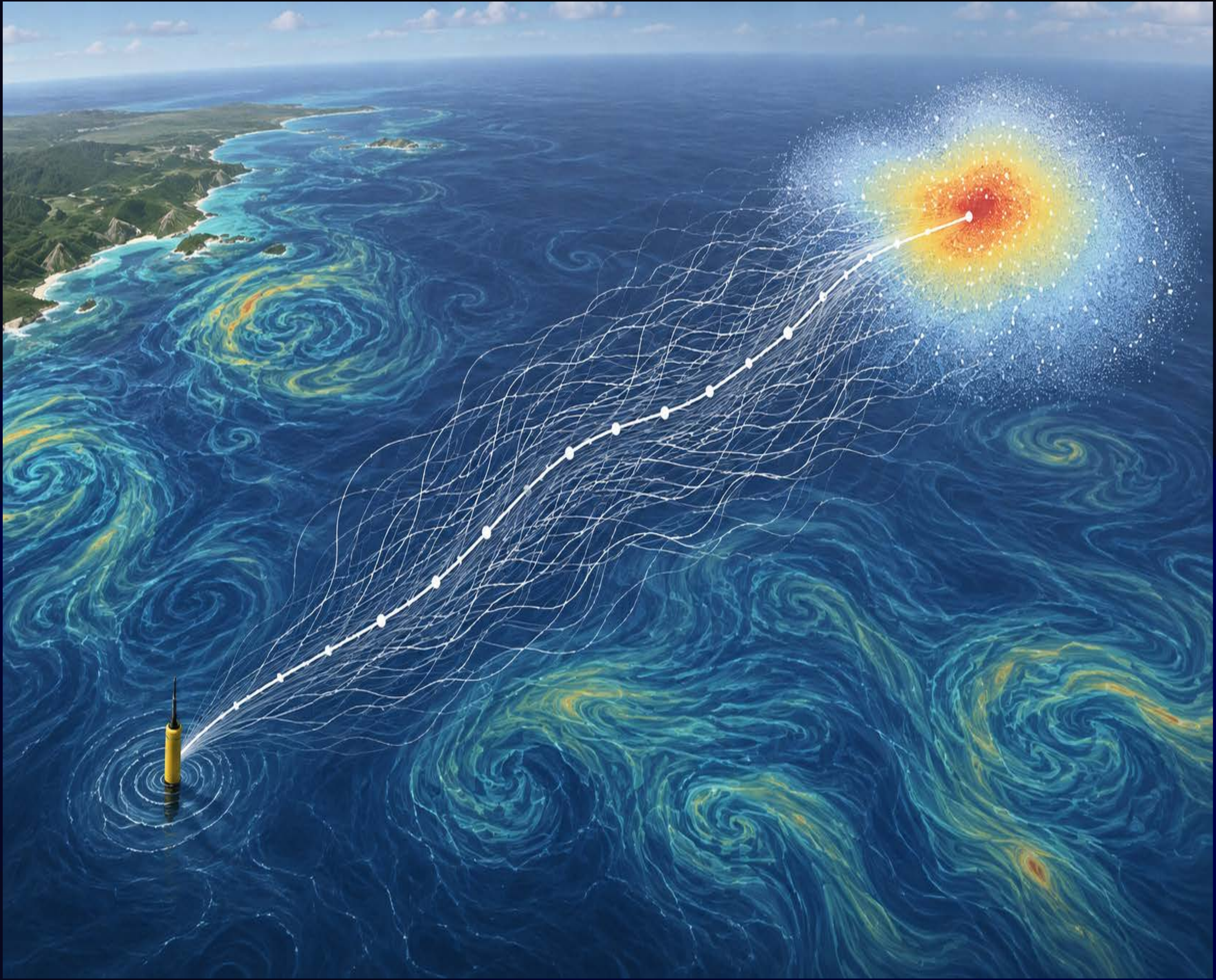


Fig. 2. Illustration of time stepping solutions on an Arakawa C-grid with edges of non-dimensional length=1. Velocities (u, v) across the four edges are given in numbers at the magenta dots. The blue arrows are the linearly interpolated velocities within the grid. Assume particles are released on the $i-1$ (left) edge. The red lines are pathlines of the analytical solution for these particles. The cyan piecewise linear lines are the solutions to RK4 timestepping with $dt = 0.1$. The two types of integration lead to similar solutions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

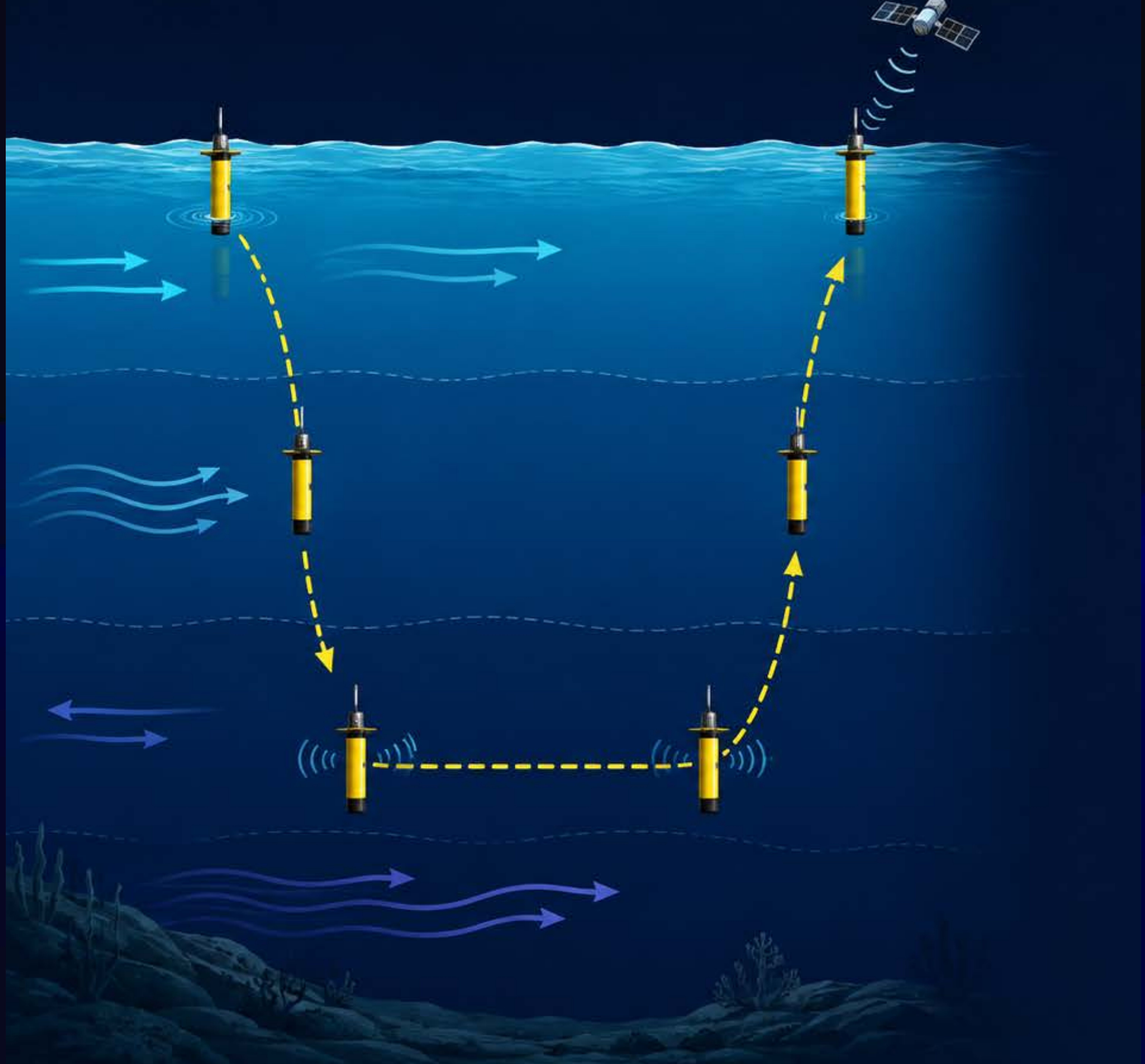
Van Sebille et al. 2018



Lagrangian trajectories are non-linear and path dependent.

The exact state of the meso-scale eddy field defines path, not just energy spectra

These errors compound over time

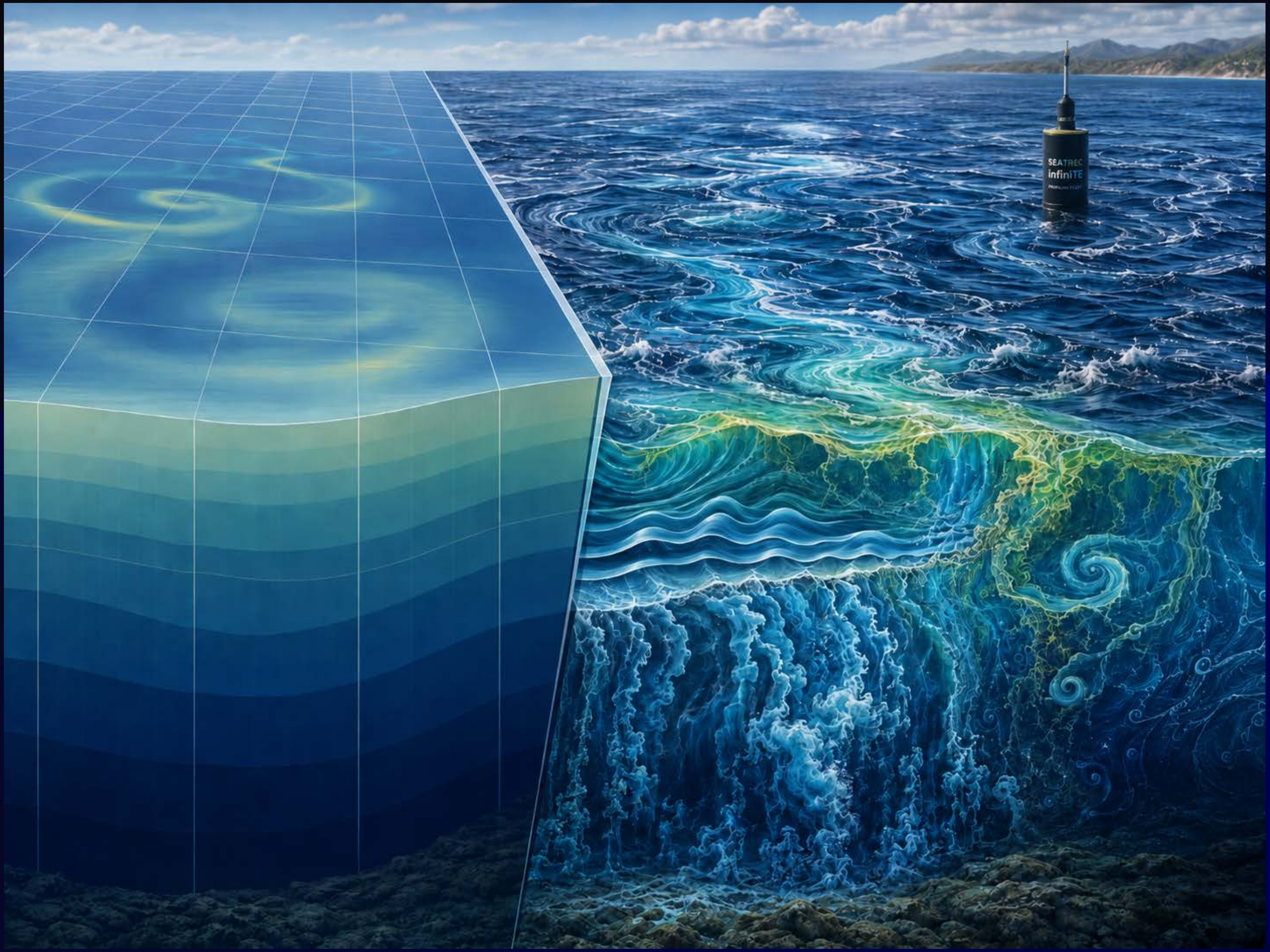


Profiling floats experience ocean shear as they ascend and descend to park depth

Depending on mission, a substantial amount of float displacement can happen under the surface, so accurately representing 3D currents is important

Unresolved Processes

In the ocean, floats experience finescale motions - waves, currents, tides - which are not resolved in many global models.



$$\boldsymbol{\eta}(t) = \boldsymbol{b}(t) + \boldsymbol{\eta}'(t), \quad E[\boldsymbol{\eta}'] = 0$$

$$\boldsymbol{e}_M(t) = \int_0^t \boldsymbol{\eta}(\tau)d\tau$$

$$\boldsymbol{C}_\eta(s,r) = E[\boldsymbol{\eta}'(s)\boldsymbol{\eta}'(r)^T]$$

$$\boldsymbol{P}_M(t) = \int_0^t (t-\tau)\boldsymbol{C}_\eta(\tau)d\tau$$

Short Timescale

$$\sqrt{\boldsymbol{P}_M(t)} \propto t$$

Long Timescale

$$\sqrt{\boldsymbol{P}_M(t)} \propto \sqrt{t}$$

Taylor 1922

Lacasce 2008

Lagrangian Prediction Framework

Scaling order	Scaling regime
t	Ballistic
$\sqrt{t}$	Diffusive
t	Bias dominated

Potential Improvements / Points for Discussion

- Bespoke regional models for prediction
- Better interpolation/advection schemes
- Better representation of finescale motion
- Ensemble forecasts (multiple models, AI driven, persistence)
- Previous prediction calibration

Presentations From our Winners

- José Rubio
- Knut-Frode Dagestad

Questions?