VarDyn High Res. SSS

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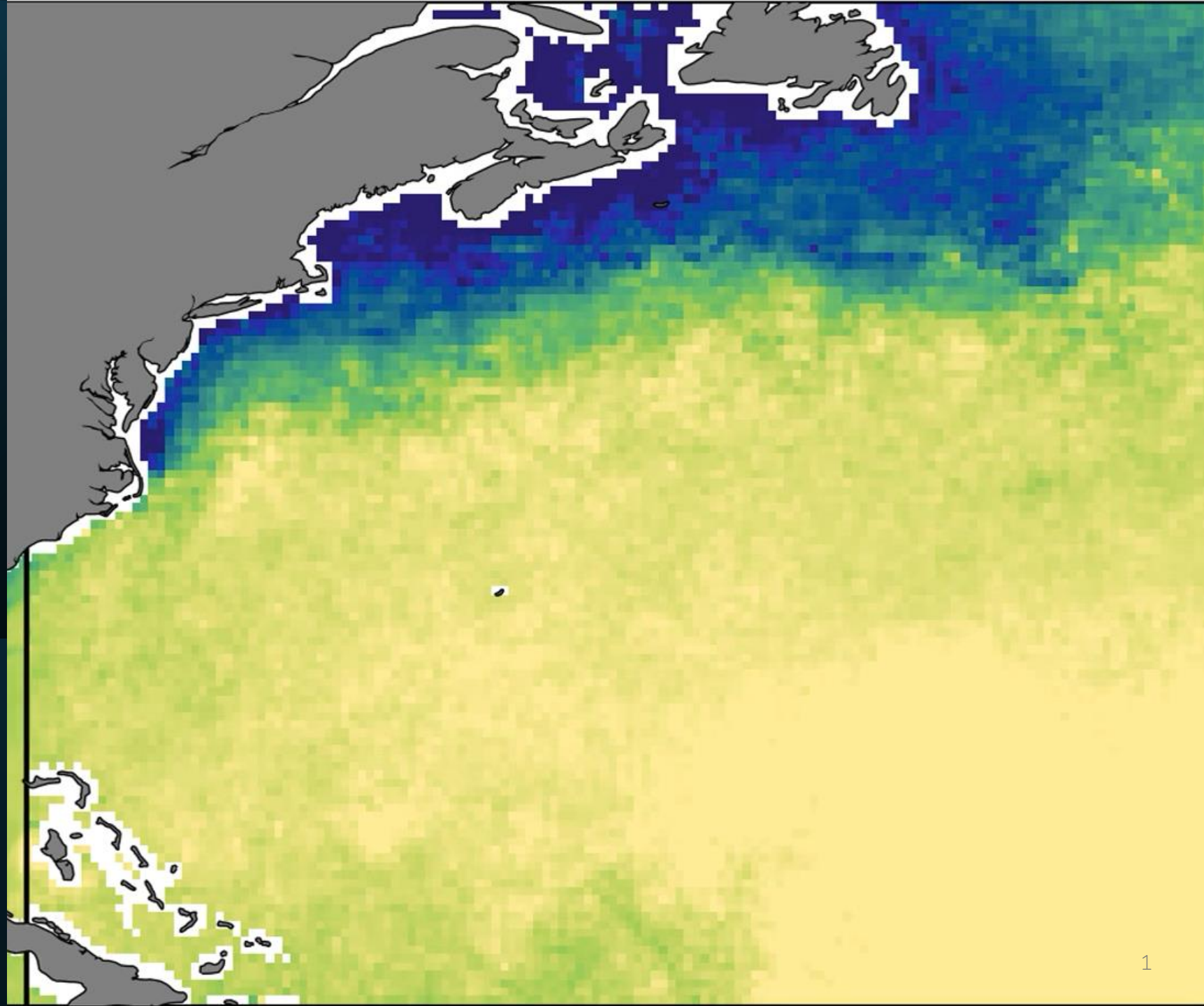
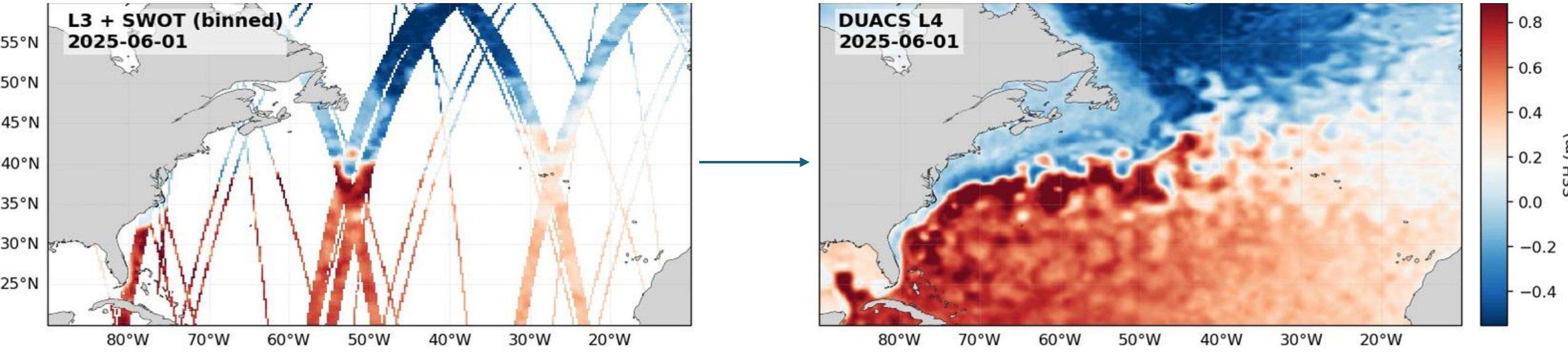


Context

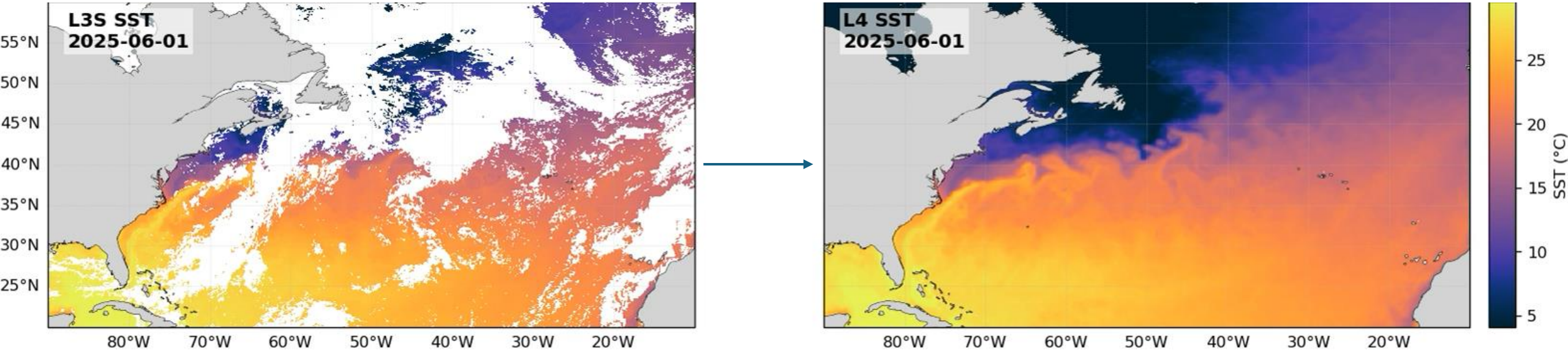
This talk is about reconstructing **gridded maps (Level-4)** from **sparse satellite observations (Level-2/3)**



Sea Surface Height (SSH) is measured traditionally by along-track altimeters and recently by SWOT.
The data are very accurate (~1-3cm), but the sampling is very weak, limiting the resolution of gridded maps.

Context

This talk is about reconstructing **gridded maps (Level-4)** from **sparse satellite observations (Level-2/3)**



Sea Surface Temperature (SST) is measured by Microwave radar (low resolution) and Infrared sensors (high resolution). The infrared data are affected by clouds, limiting the resolution of gridded maps.

Context

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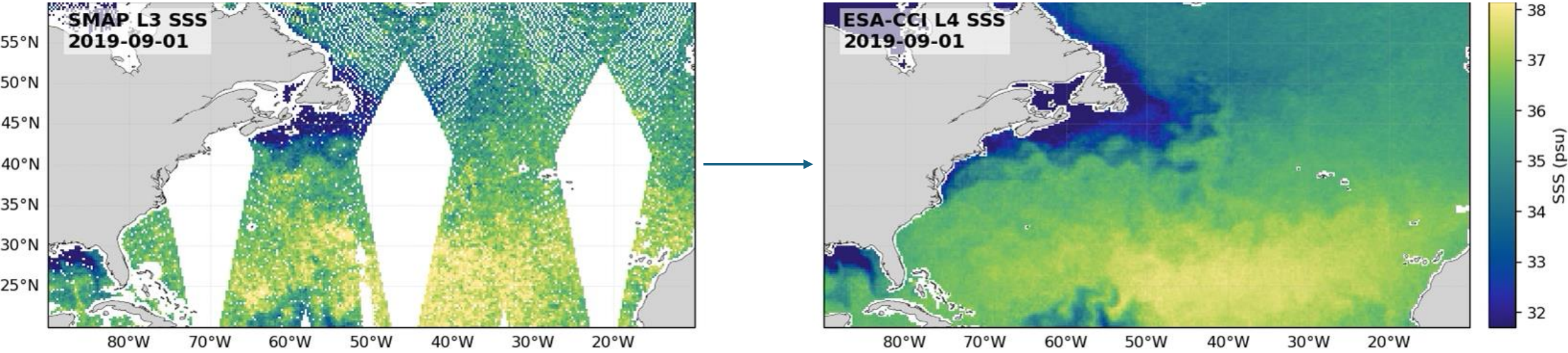


Sea Surface Salinity (SSS) is measured by Microwave radiometers (low resolution).
The low resolution + noise limits the resolution of gridded maps.

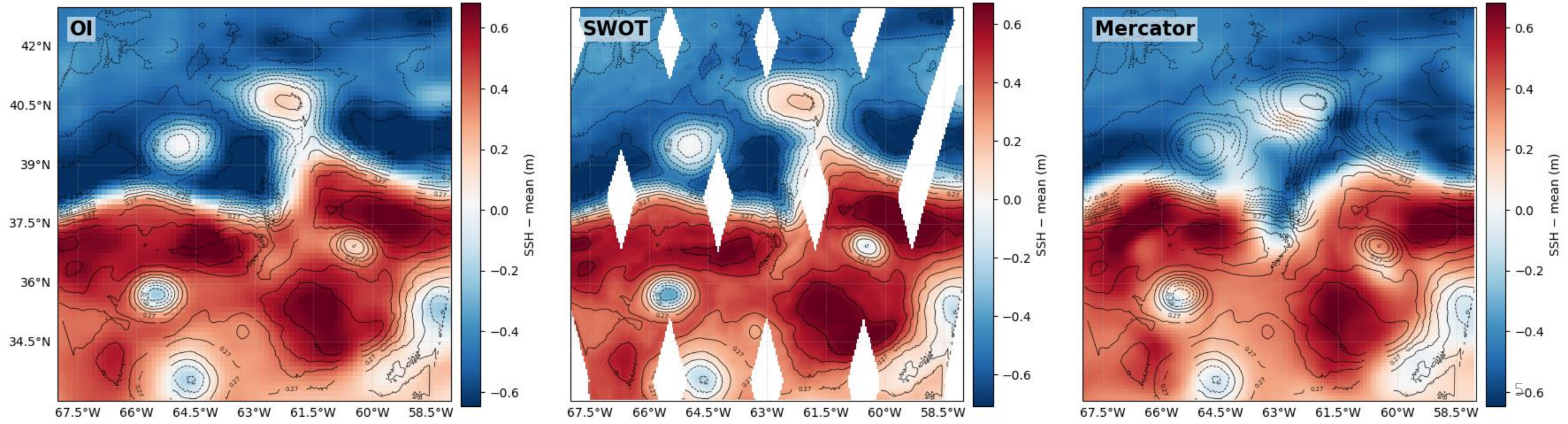
Context

More robust / data oriented

Optimal interpolation (OI)

Reanalysis using Primitive Equations models with data assimilation

More physics assumed



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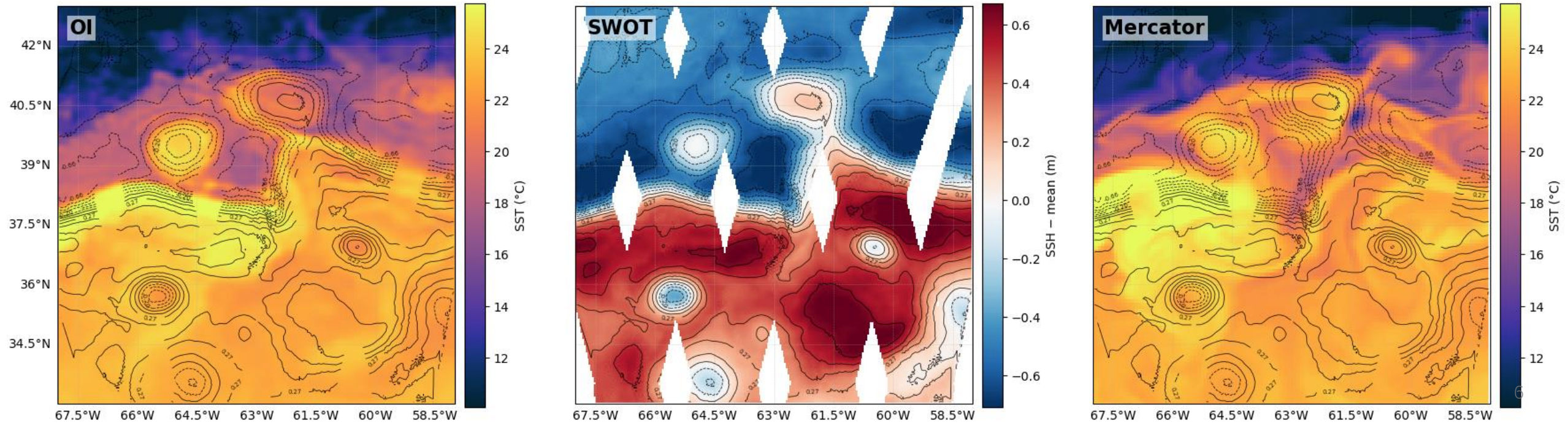

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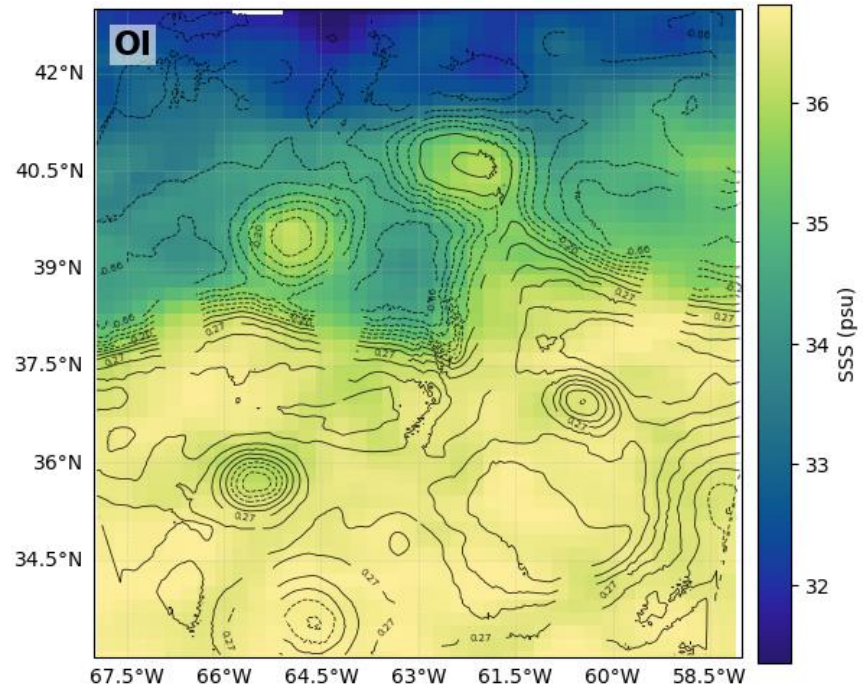
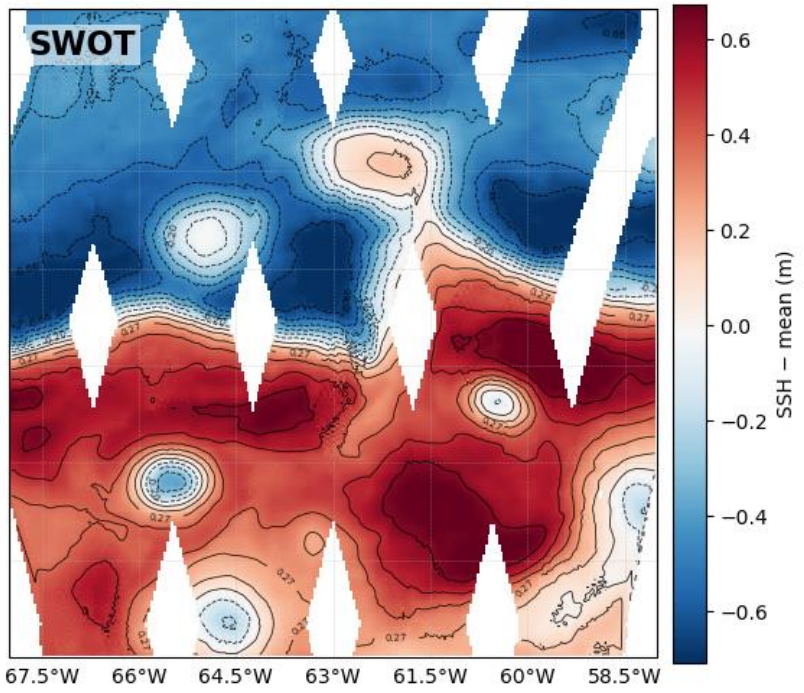
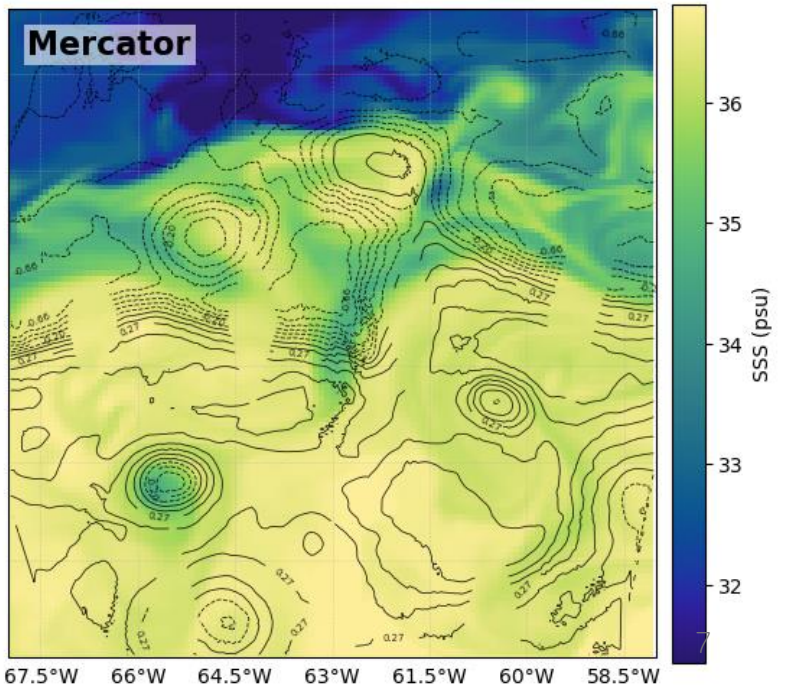
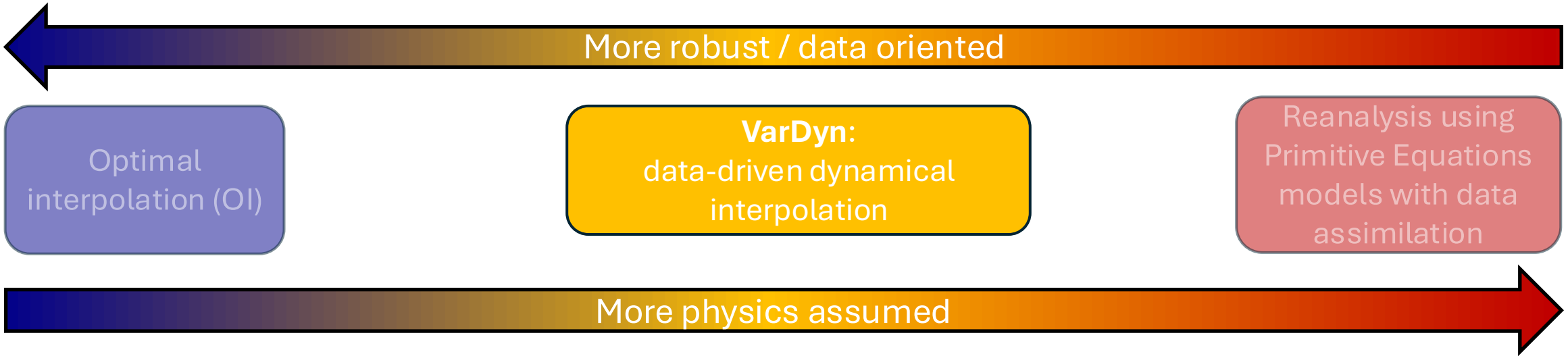






Context

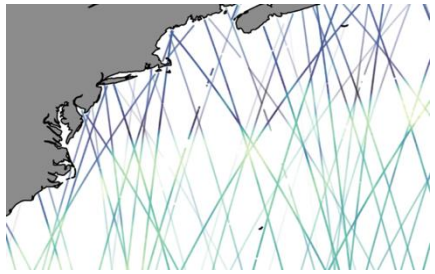


VarDyn strategy:

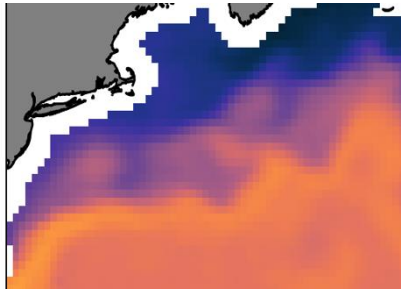
- Use reduced surface-focused models matched to observation density, enabling a controllable and fully data-driven reconstruction.
- SSH, SST, and SSS are dynamically coupled (through advection along geostrophic currents)
- SST/SSS were first included to improve the mapping of SSH.
- VarDyn SST/SSS are side products (for now)

VarDyn: Method

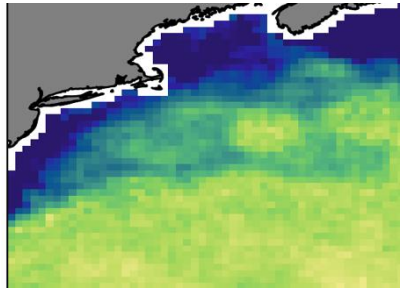
Altimetry L3 SSH



MicroWave L3 SST



SMOS & SMAP L3 SSS



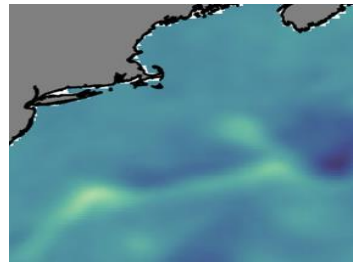
QG model

u, v geostrophic velocities for advection

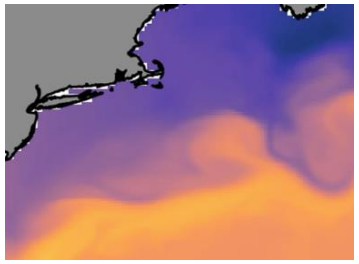
Advective/Diffusion models

4Dvar data assimilation

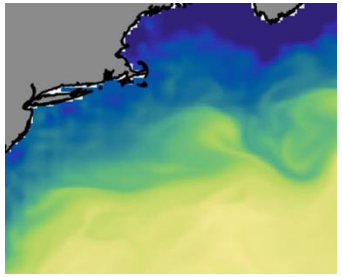
L4 SSH



L4 SST

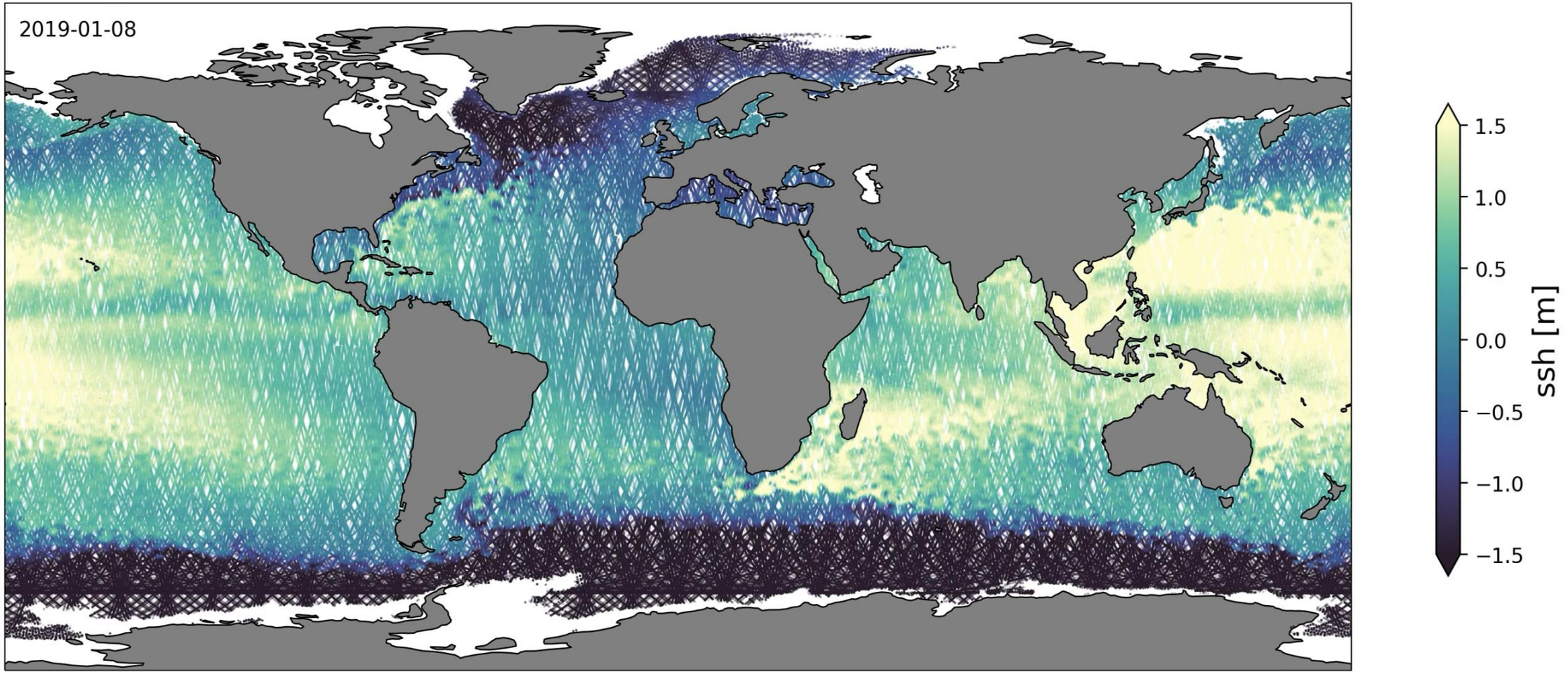


L4 SSS



SSH performances

Input dataset:
Cryosat-2, HaiYang-2AG, HaiYang-2B, Jason-3, Sentinel-3A, Sentinel-3B



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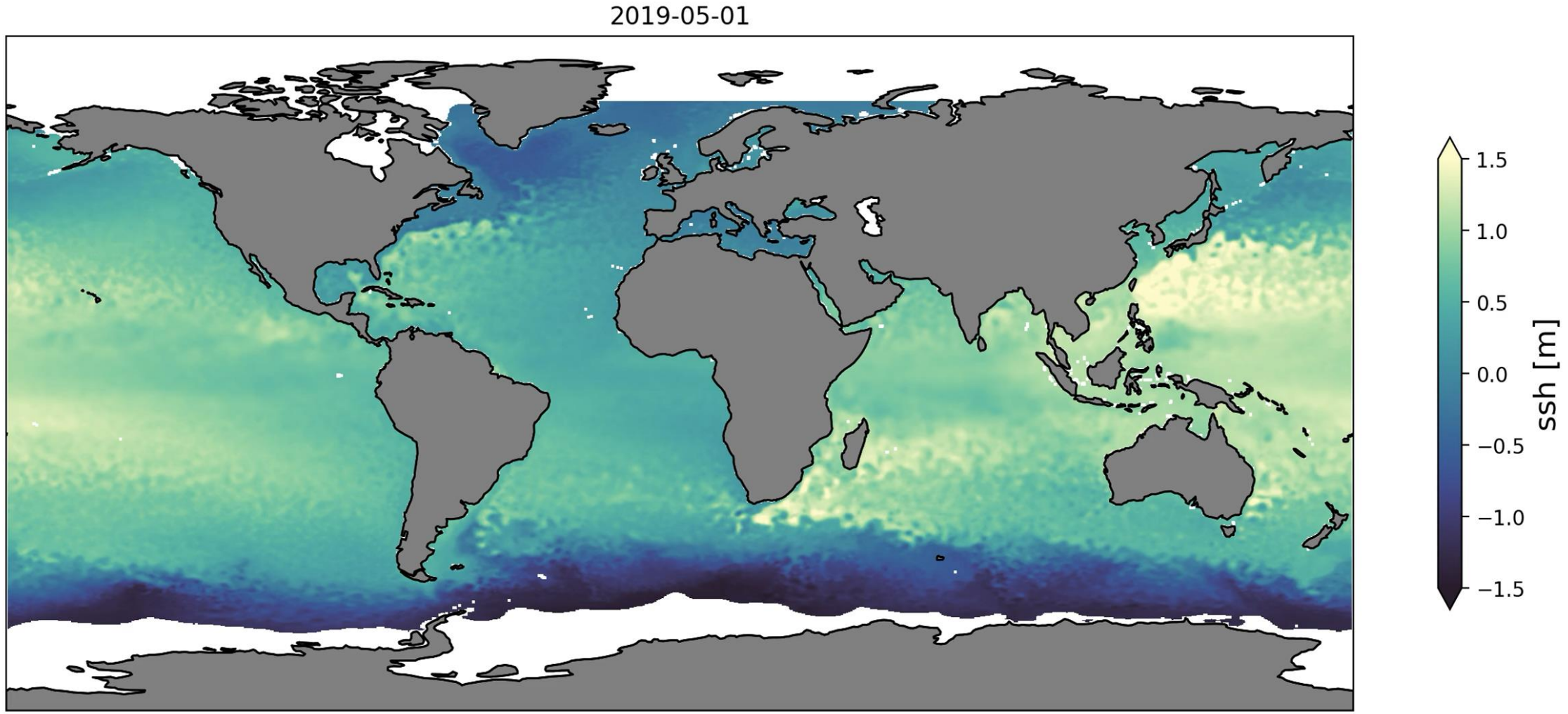

SSH performances

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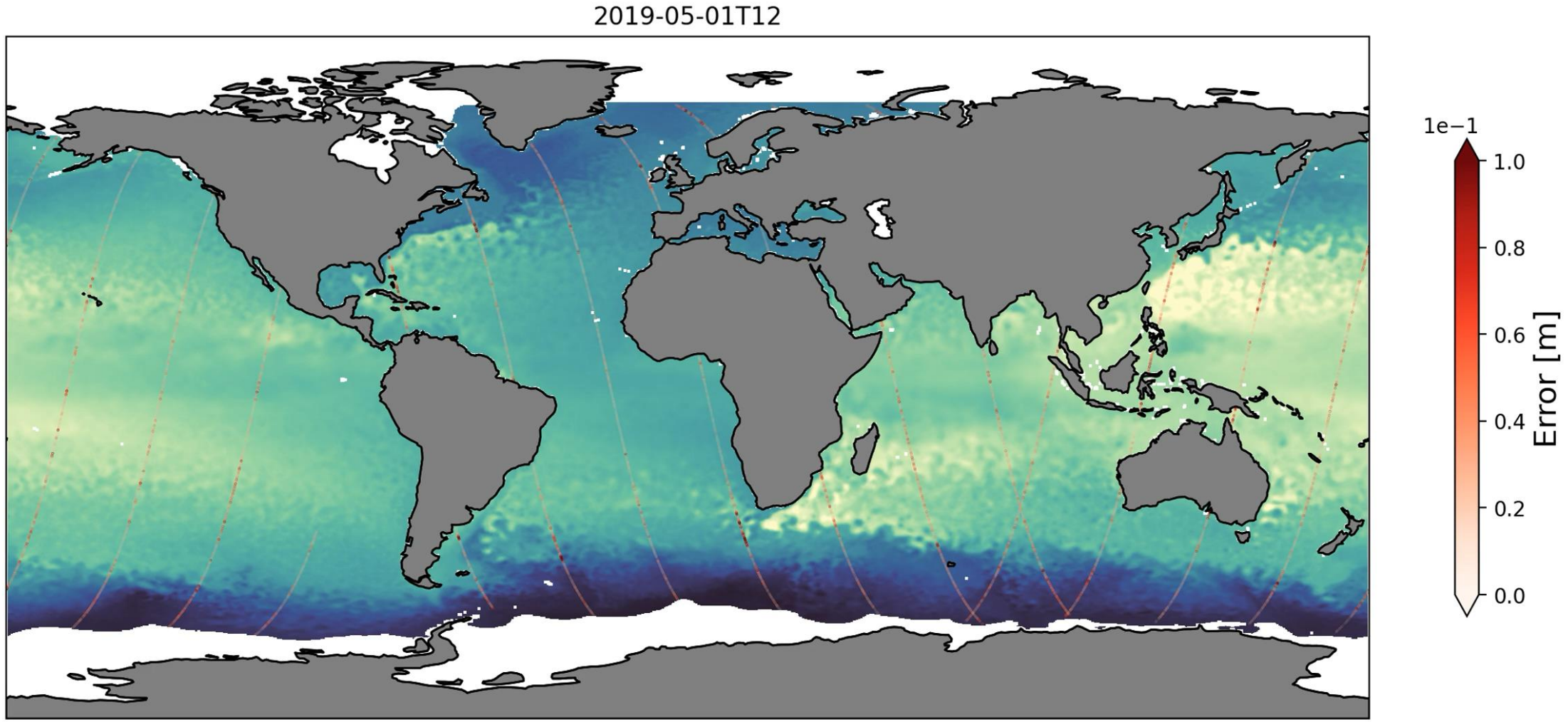
Absolute error with SARAL/AltiKa altimeter
(which does not belong to the input dataset)



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Absolute error with SARAL/AltiKa altimeter
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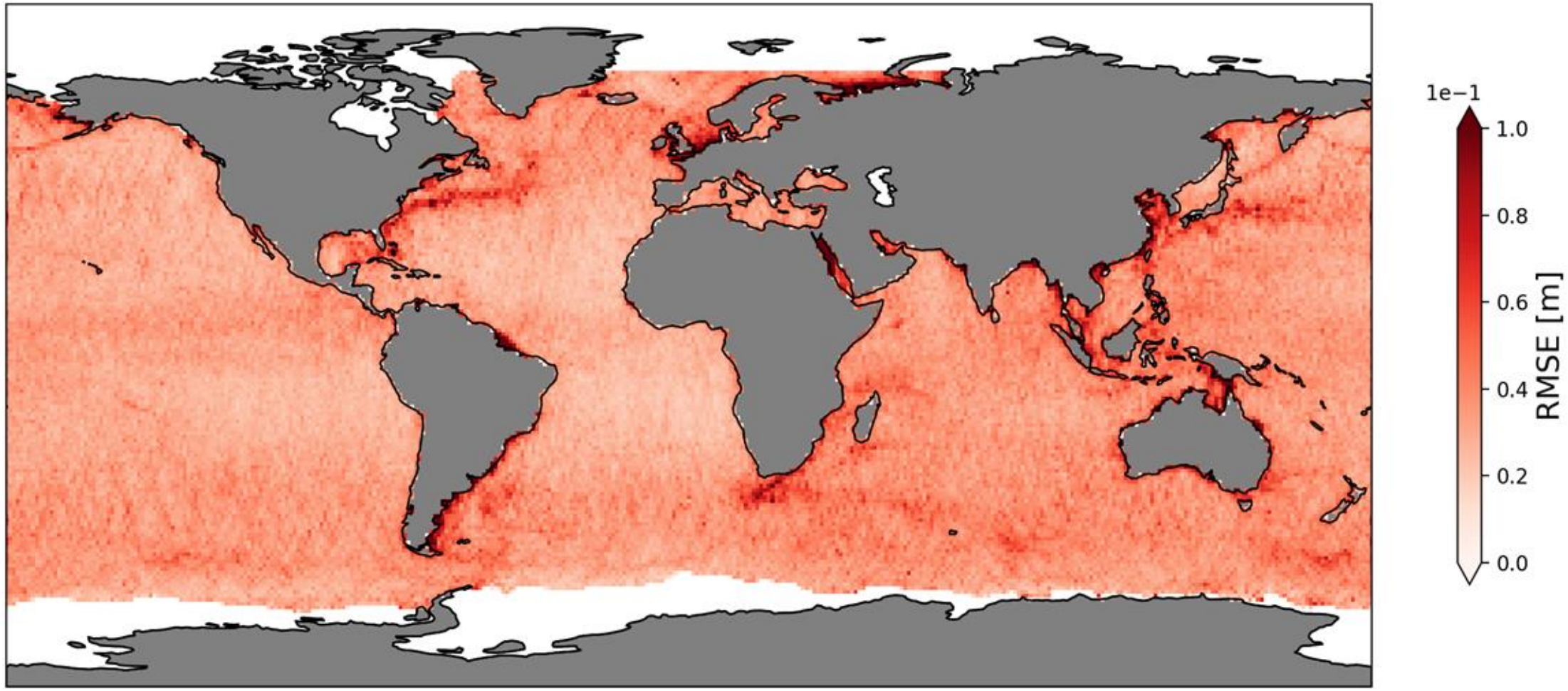
Time averaged Root Mean Square Error (RMSE) in 1°x1° bins



SSH performances

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Cryosat-2, HaiYang-2AG, HaiYang-2B, Jason-3, Sentinel-3A, Sentinel-3B

Absolute error with SARAL/AltiKa altimeter
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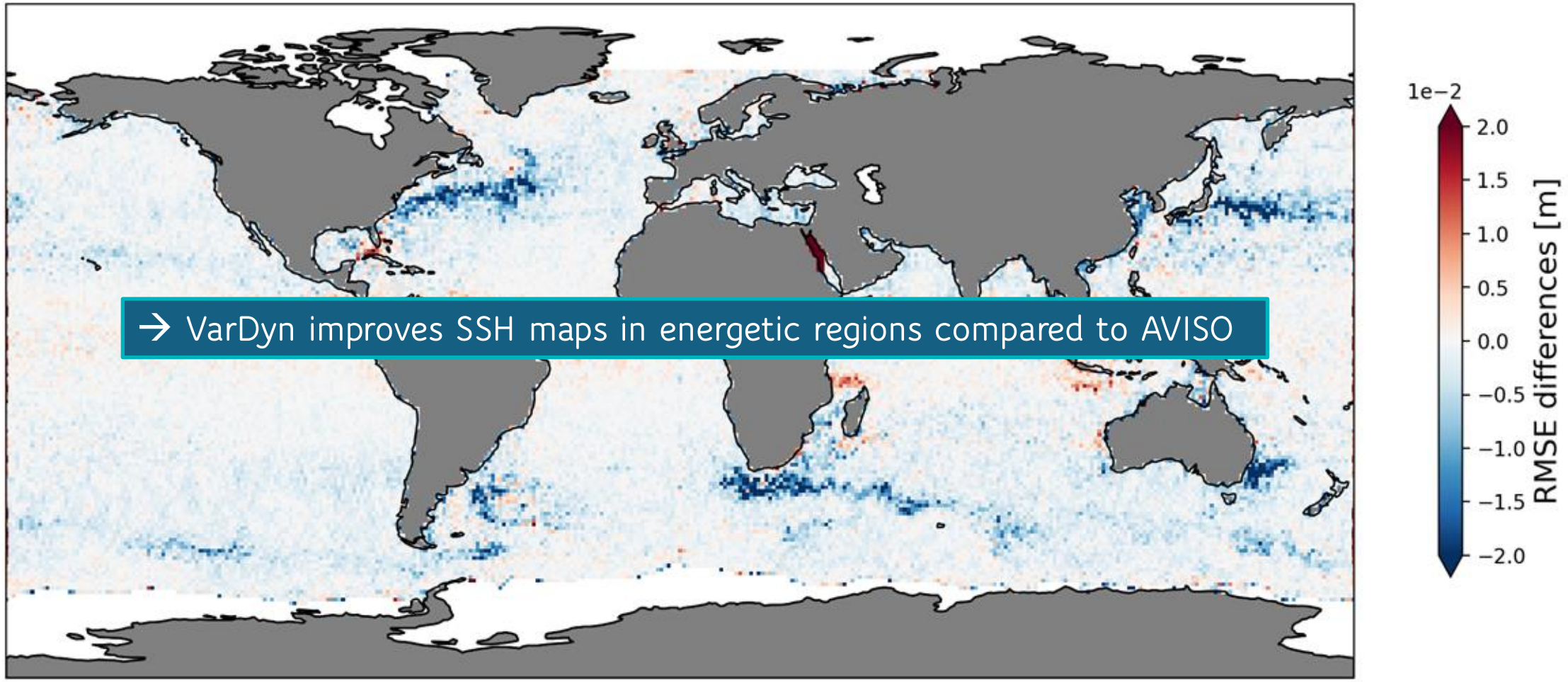
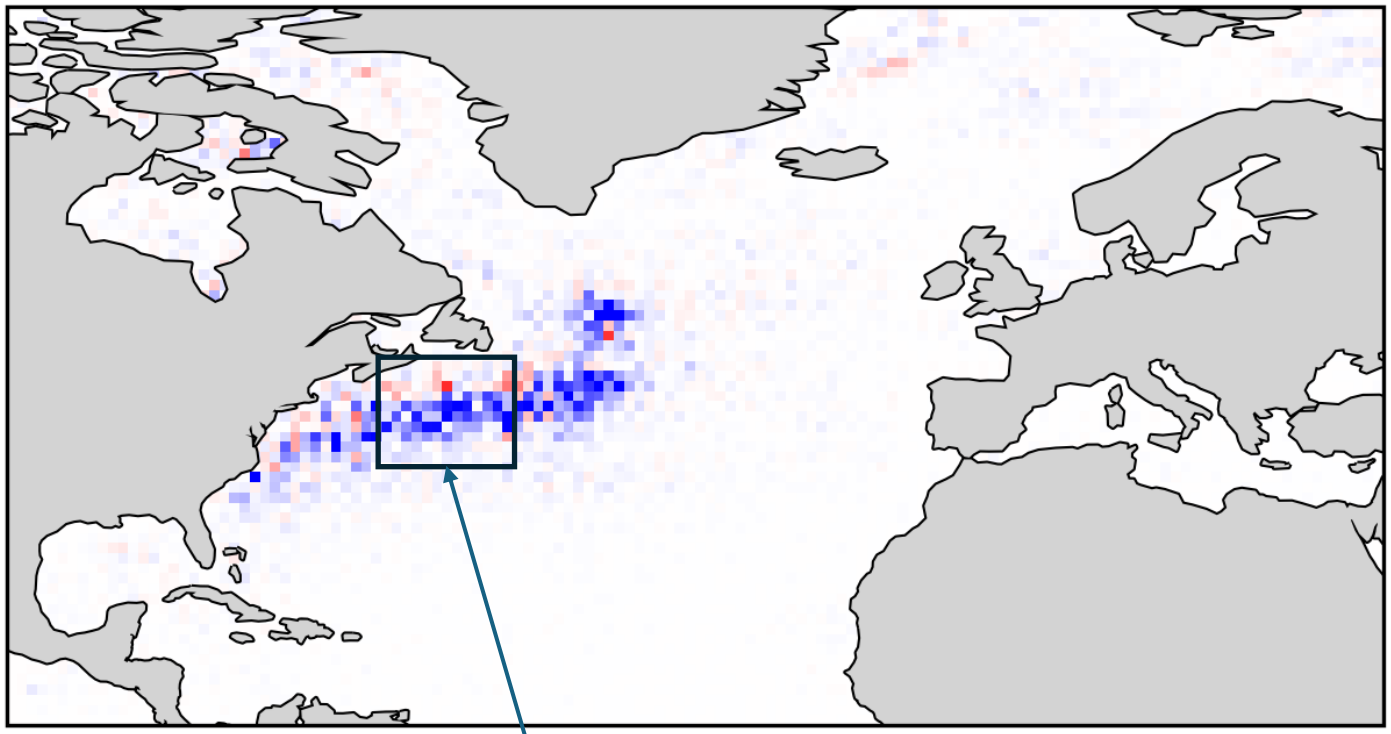
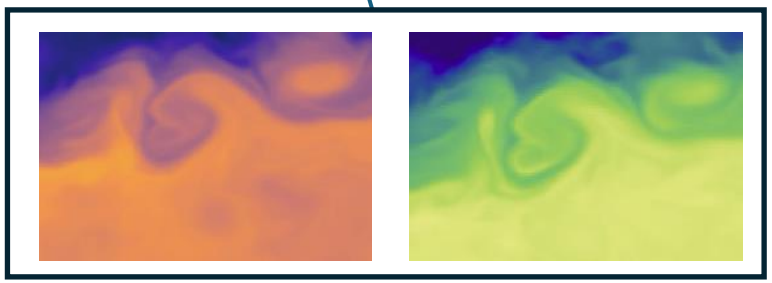
RMSE Gain/Loss of VarDyn compared to AVISO

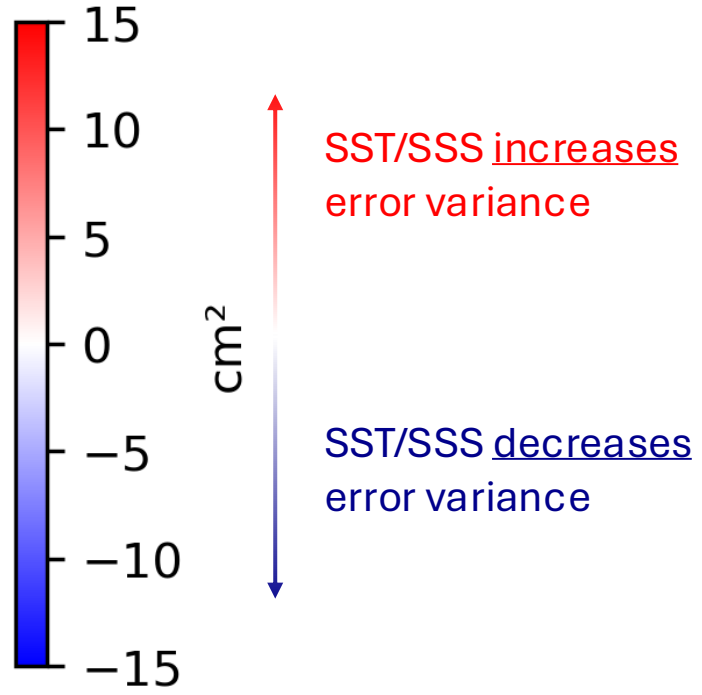


SSH/SST/SSS synergies

Change in SSH mapping variance error when assimilating SST/SSS in VarDyn



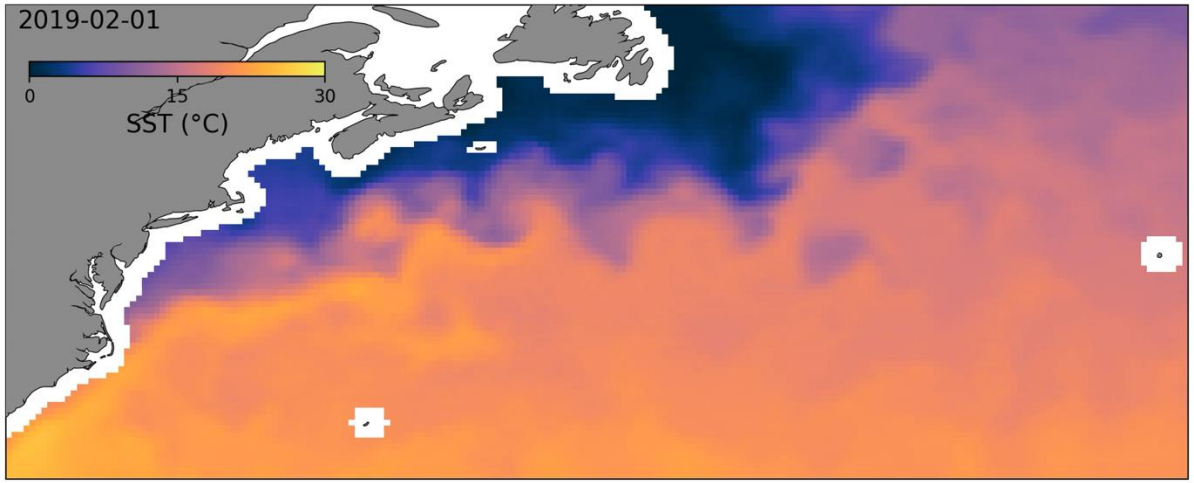




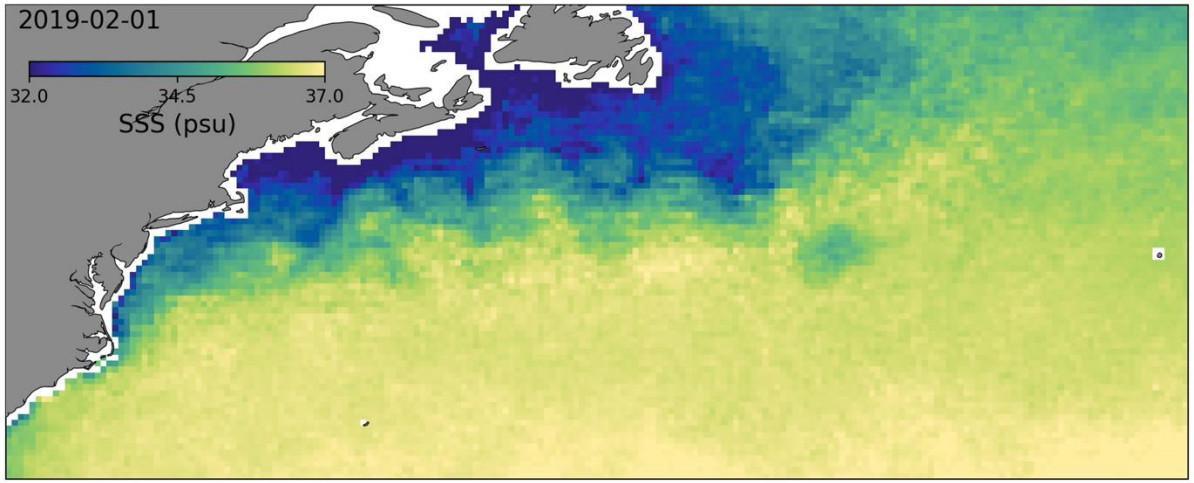
→ SST/SSS strong gradients improves SSH maps accuracy

Side products: High-Res. SST/SSS

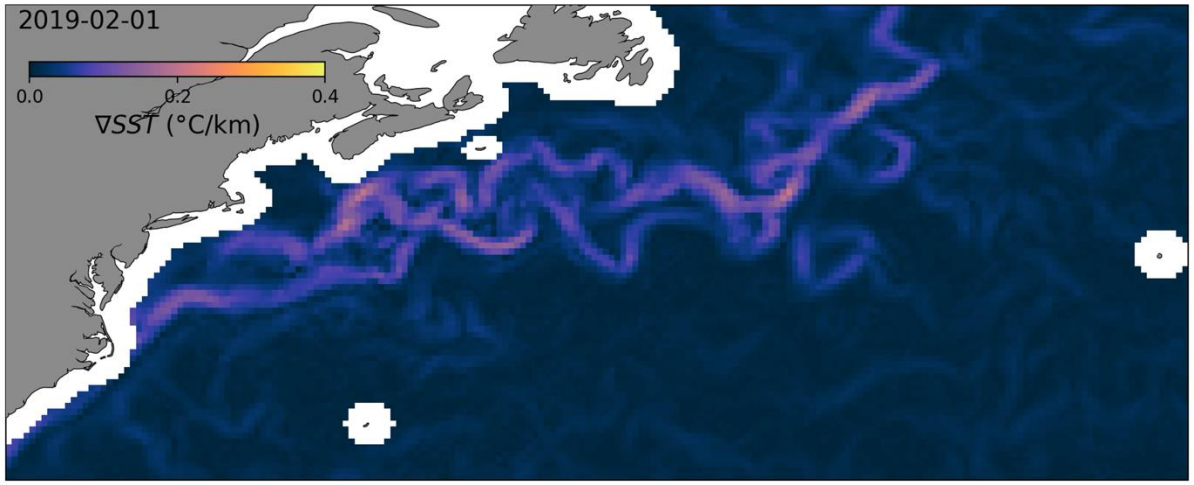
REMSS / VarDyn - SST



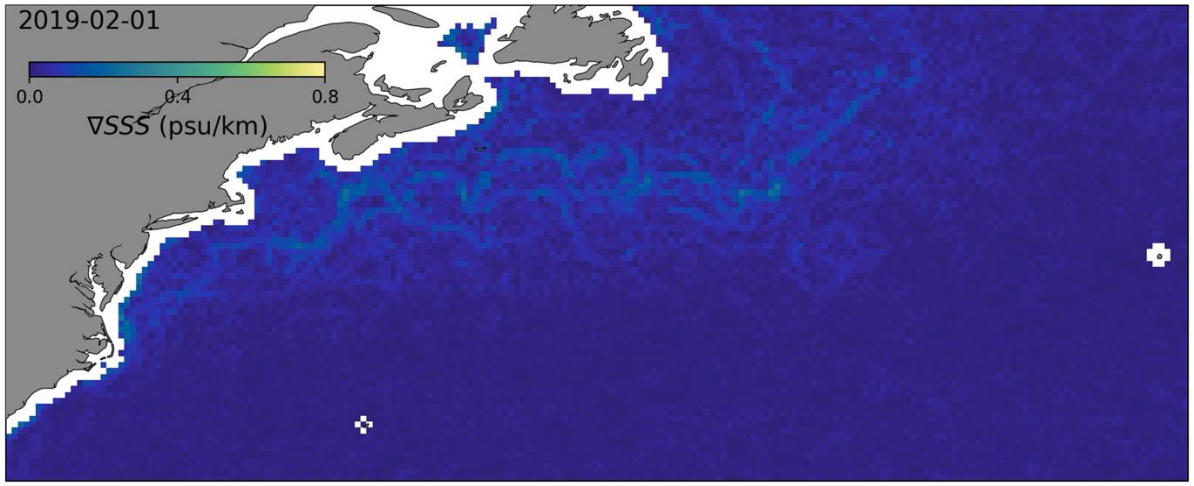
ESACCI / VarDyn - SSS



REMSS / VarDyn - ∇*SST*



ESACCI / VarDyn - ∇*SSS*



Side products: High-Res. SST/SSS

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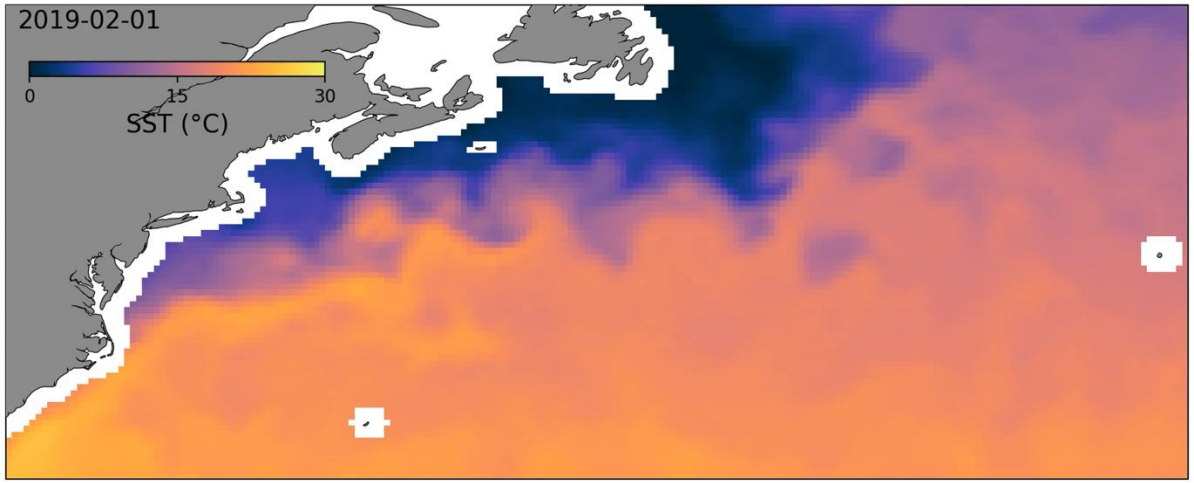

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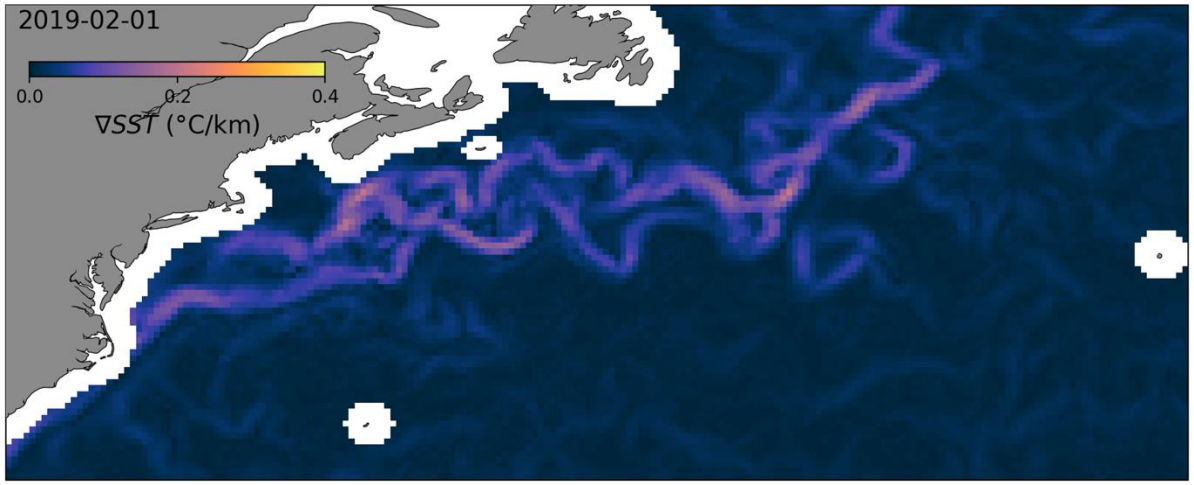
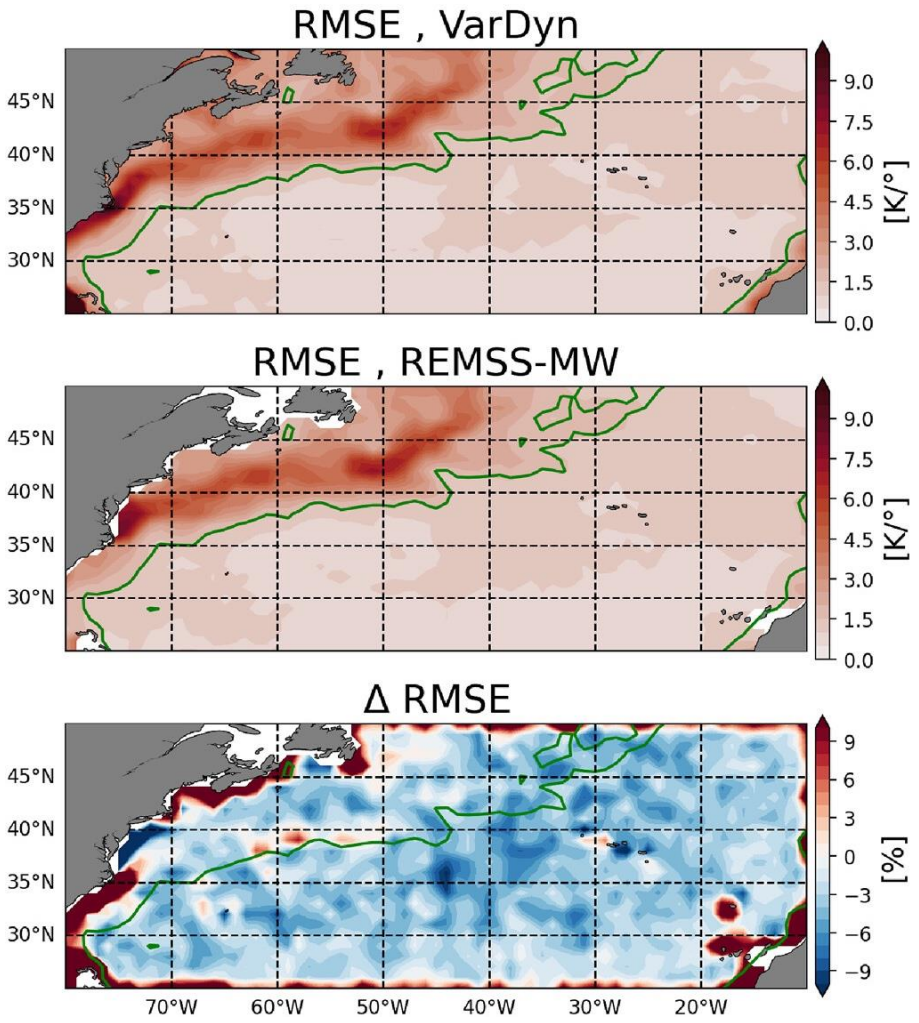


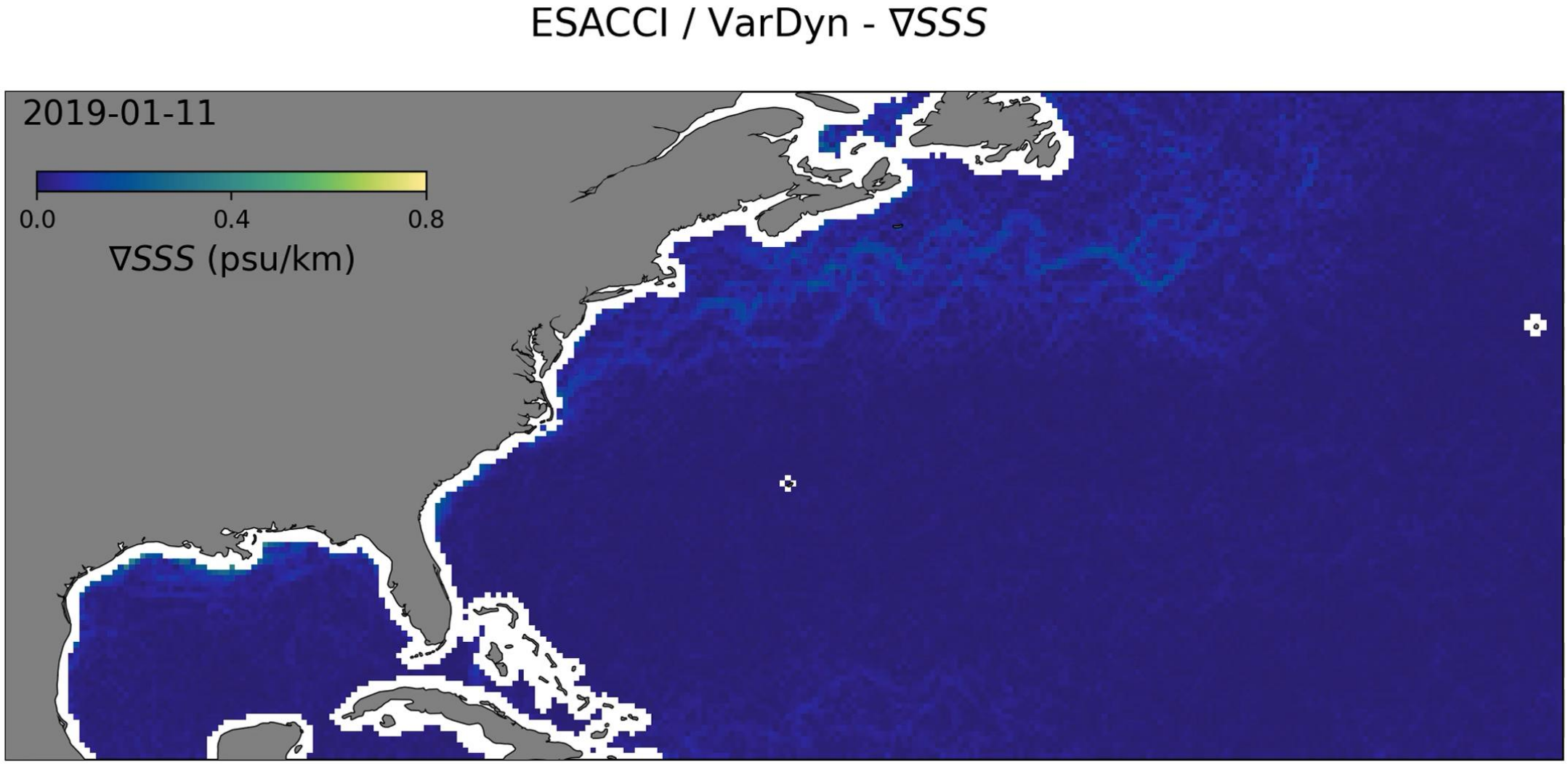
Comparison with Infrared measurements



Conclusions

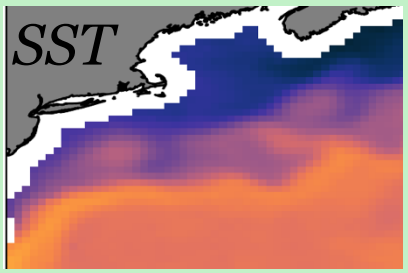
- VarDyn is a physics-informed inversion tool for estimating gridded SSH, SST, and SSS fields from sparse satellite observations.
- The fields are physically consistent and close to the observations.
- SSH performances are demonstrated globally.
- SST performances are demonstrated regionally.
- SSS performances still need to be validated (in situ?)
  → Open to collaborations.

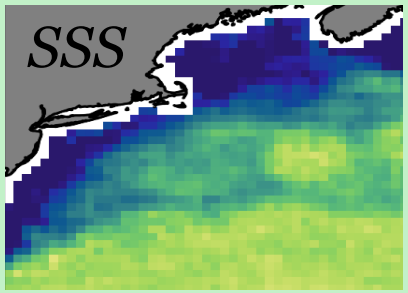
High Res SSS



Multi-Sensor Inversion

Satellite L3 products





SSH Dynamics

$$u = -\frac{g}{f}\frac{\partial SSH}{\partial y}\ ;\ v = \frac{g}{f}\frac{\partial SSH}{\partial x}$$

$$q = \frac{g}{f}\nabla^2 SSH - \frac{g}{f}\frac{1}{{L_R}^2}SSH$$

$$\frac{\partial q}{\partial t} + u\frac{\partial q}{\partial x} + v\frac{\partial q}{\partial y} = F_{SSH}$$

Coupled Model

$$\mathrm{X} = \boldsymbol{M}(\mathrm{X}_0, F)$$

With:

$$\mathrm{X} = \begin{pmatrix} SSH \\ SST \\ SSS \end{pmatrix}_t \qquad \mathrm{F} = \begin{pmatrix} F_{SSH} \\ F_{SST} \\ F_{SSS} \end{pmatrix}_t$$

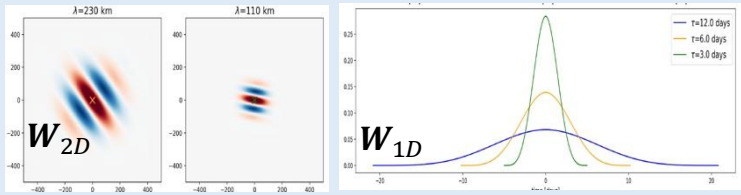
Tracer Dynamics

$$\frac{\partial SST}{\partial t} + u\frac{\partial SST}{\partial x} + v\frac{\partial SST}{\partial y} = F_{SST}$$

$$\frac{\partial SSS}{\partial t} + u\frac{\partial SSS}{\partial x} + v\frac{\partial SSS}{\partial y} = F_{SSS}$$

Order reduction

$$\begin{pmatrix} \mathrm{X}_0 \\ \mathrm{F} \end{pmatrix} = \boldsymbol{W} \cdot \Psi = \begin{pmatrix} \boldsymbol{W}_{2D}\Psi_{\mathrm{X}_0} \\ \boldsymbol{W}_{3D}\Psi_{\mathrm{F}} \end{pmatrix}$$

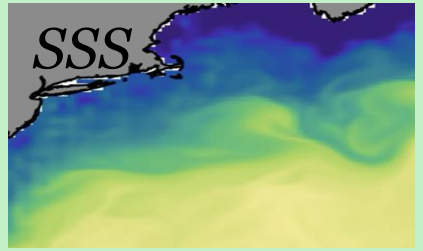


Variational cost function

$$\mathcal{J}(\Psi) = \left\| \mathrm{Y}^{\mathrm{obs}} - \boldsymbol{M}(\boldsymbol{W} \cdot \Psi) \right\|_{\mathbf{R}}^2 + \left\| \Psi^{\mathrm{b}} - \Psi \right\|_{\mathbf{B}}^2$$

$$(SSH, SST, SSS)^{opt} = \boldsymbol{M}(\boldsymbol{W} \cdot \Psi^{\mathrm{opt}})$$

VarDyn L4 products



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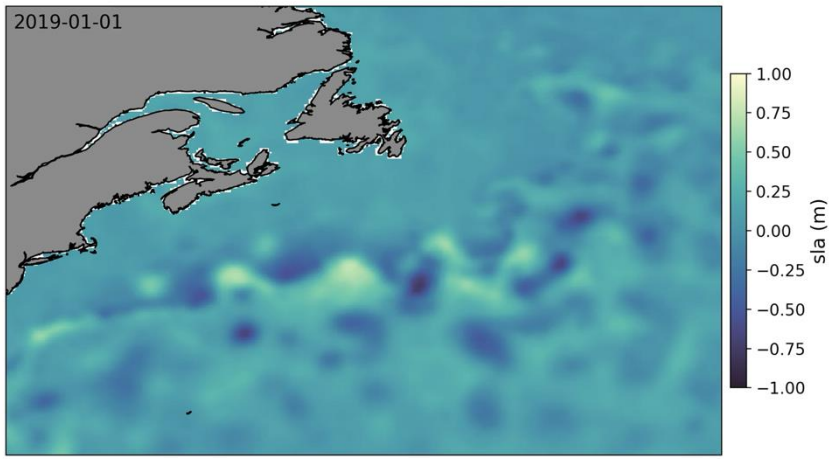
VarDyn: SSH/SST/SSS simultaneous reconstructions

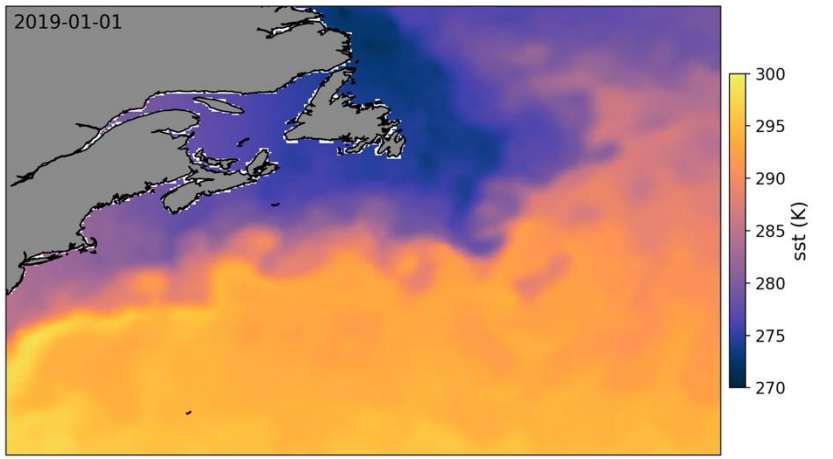
In addition to SSH & SST fields, VarDyn provides the corrective fluxes

SLA



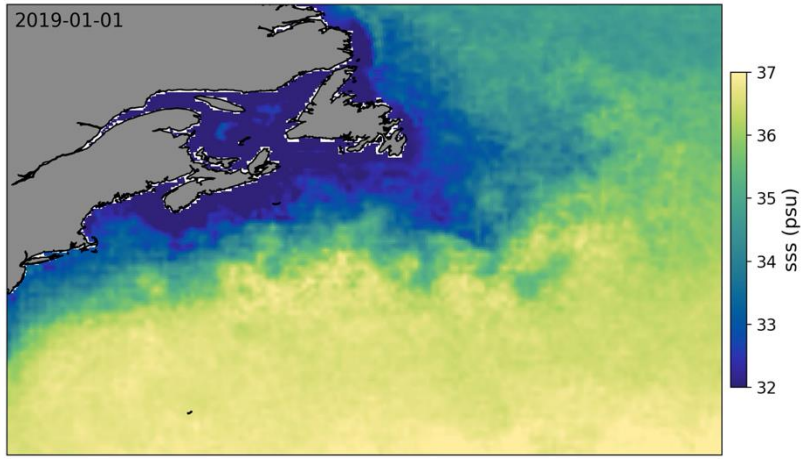
$$\frac{\partial q}{\partial t} + u\frac{\partial q}{\partial x} + v\frac{\partial q}{\partial y} = F$$

SST



$$\frac{\partial SST}{\partial t} + u\frac{\partial SST}{\partial x} + v\frac{\partial SST}{\partial y} = F$$

SSS



$$\frac{\partial SSS}{\partial t} + u\frac{\partial SSS}{\partial x} + v\frac{\partial SSS}{\partial y} = F$$

High Res SSS