Global Daily Altimeter Sea Surface Height (DASH1.0) 1993-2025

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- Goals
  - Open-source altimeter sea level mapping software (DASH)
- Methods
  - automatic outlier detection
  - two-scale 3DVAR based on JEDI packages
  - Trained emulator
- Results
  - 32-year daily global ¼° dynamic topography mapping
    - > 1,000,000 1HZ L2 nadir altimeter tracks
  - Data degradation Observing System Experiments

source: Labrador.com

DASH1

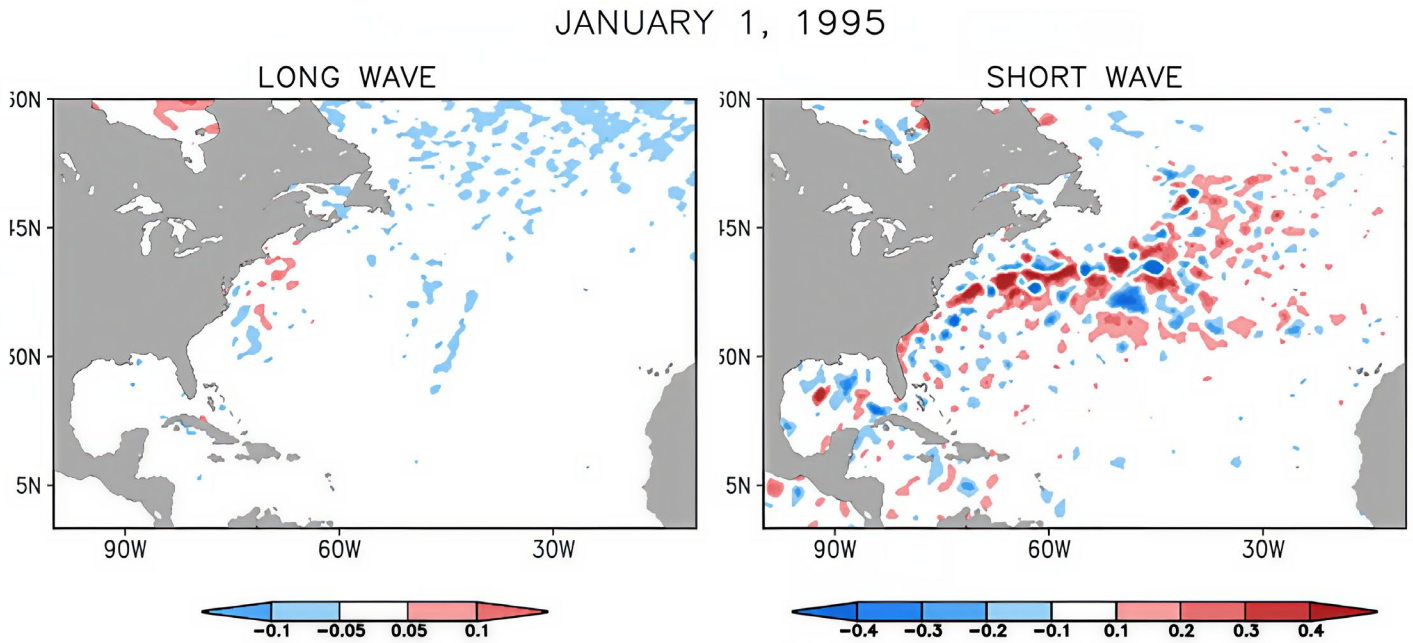
Two-scale decomposition & mapping

1) Along-track decomposition :

$$\eta_{track} = \overline{x}_{track} + x'_{track}$$

2) Map on 1/4°grid using 3DVar with different **B**

$$J(\mathbf{x}) = (\mathbf{x} - \mathbf{x}_b)^T \mathbf{B}^{-1} (\mathbf{x} - \mathbf{x}_b) + (\mathbf{y}_o - \mathbf{H}\mathbf{x})^T \mathbf{R}^{-1} (\mathbf{y}_o - \mathbf{H}\mathbf{x})$$



Advective background model

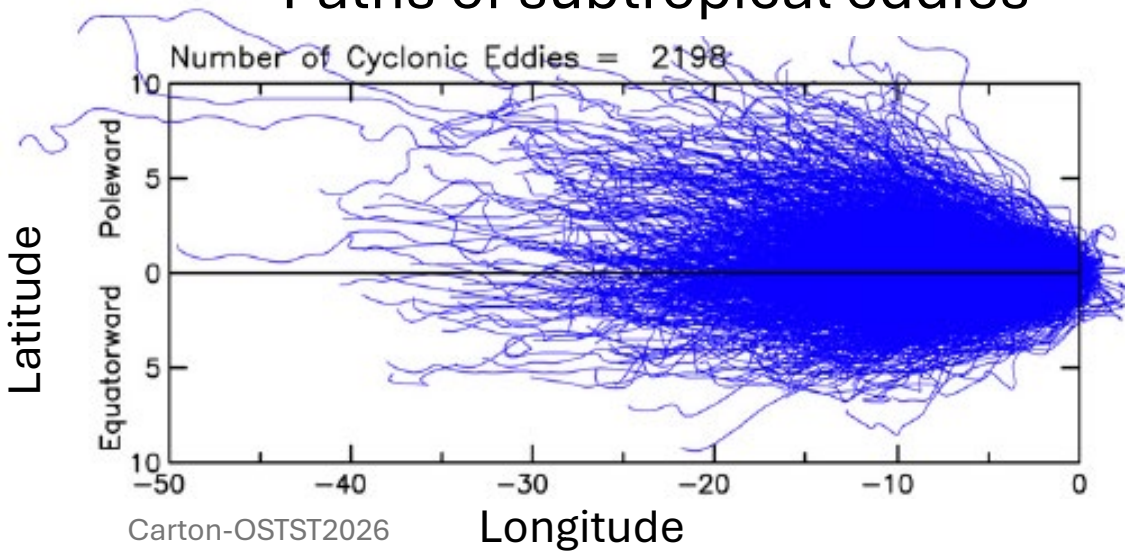
$$\mathbf{x}_b = \mathbf{x}_a(t-1) - \int_{t-1}^{t} [c^x(y)\frac{\partial \mathbf{x}_a(\tau)}{\partial x} + \upsilon\nabla^2\mathbf{x}_a(\tau) + (\kappa + \kappa_{smag})\nabla^4\mathbf{x}_a]d\tau$$

Zonal propagation

dissipation

Chelton et al (2011a,b)

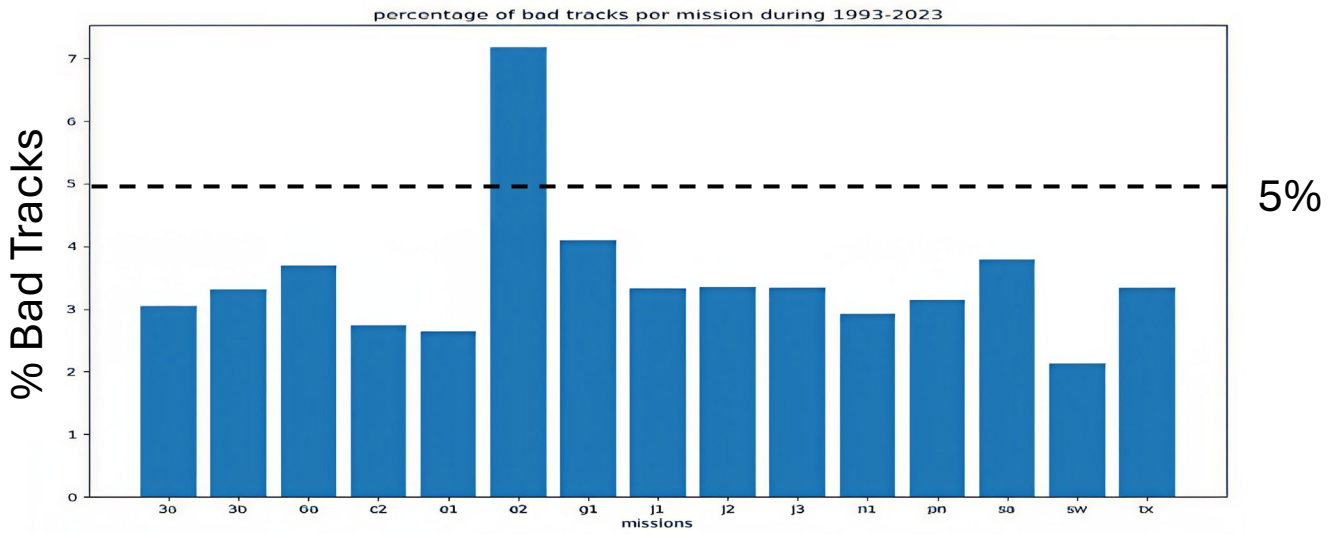
Paths of subtropical eddies



Outlier detection

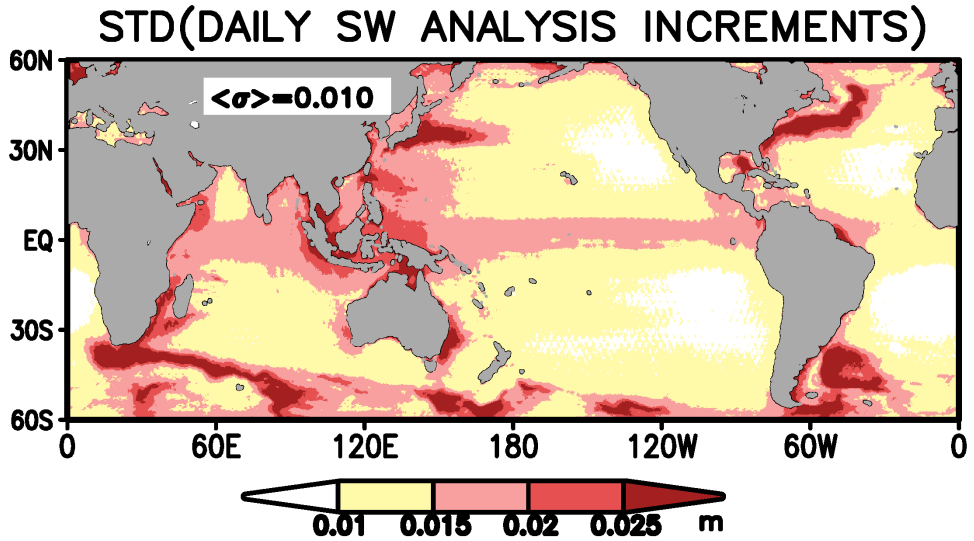
Two criteria

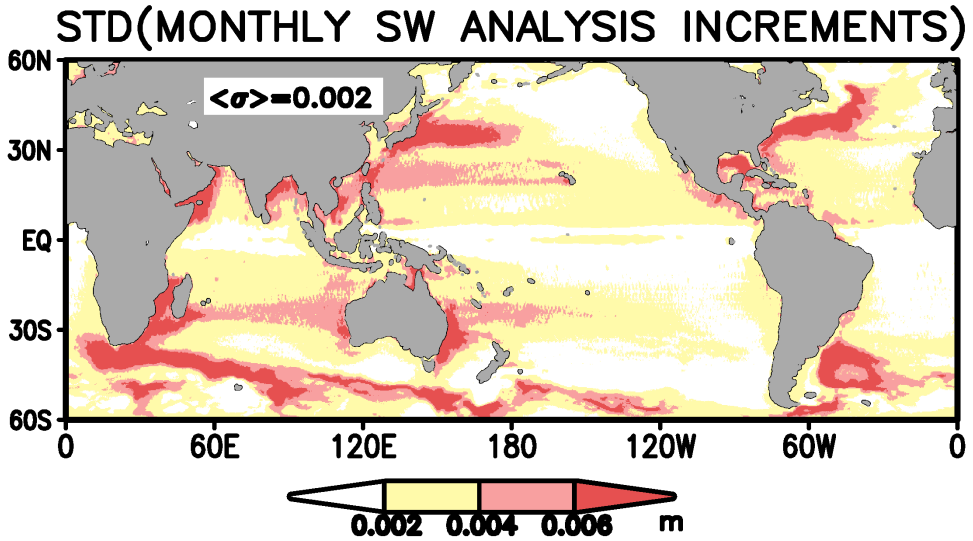
1) spatial smoothness based on along-track average of cross-track correlation (follows Pujol et al, 2016; Pujol et al., 2023).
2) track misfit based on the along-track RMS difference from preliminary gridded sea level

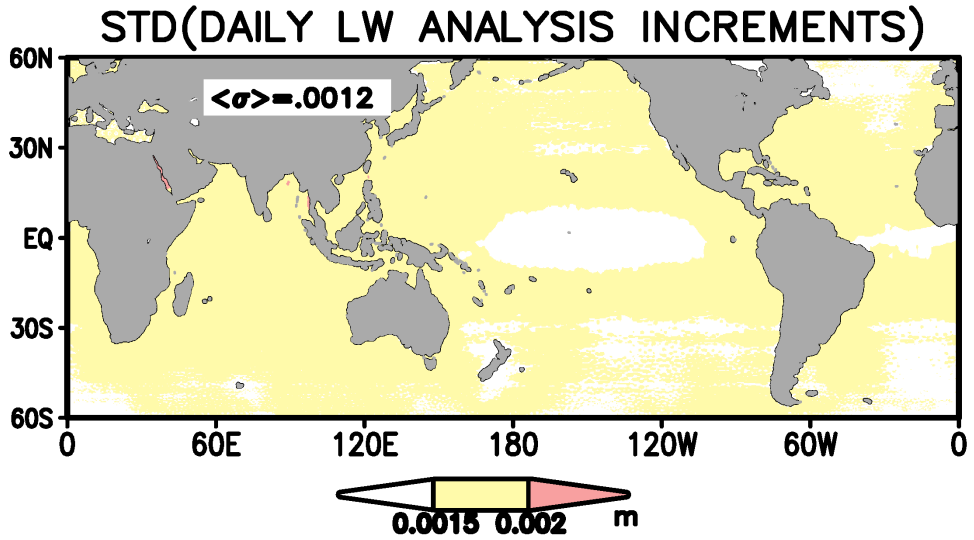


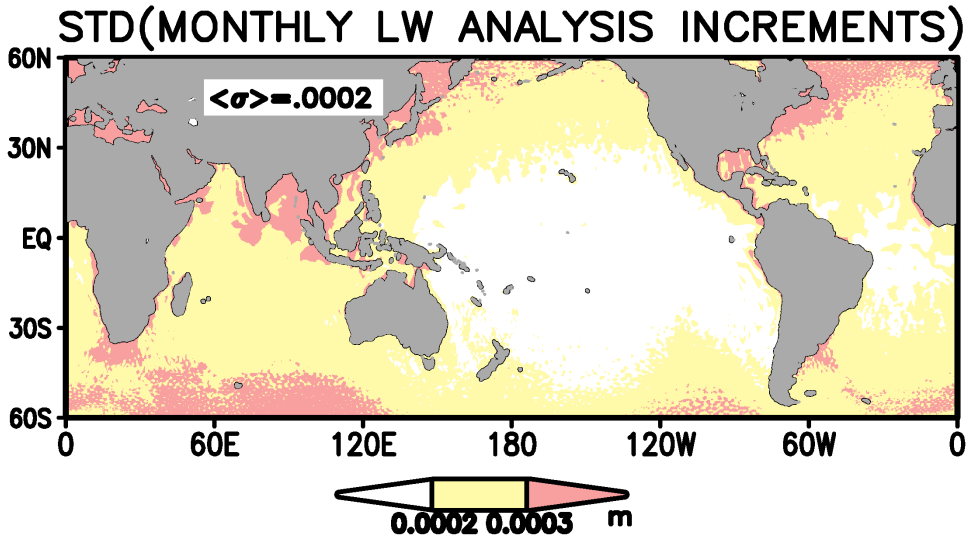
ERS2

Analysis Increments

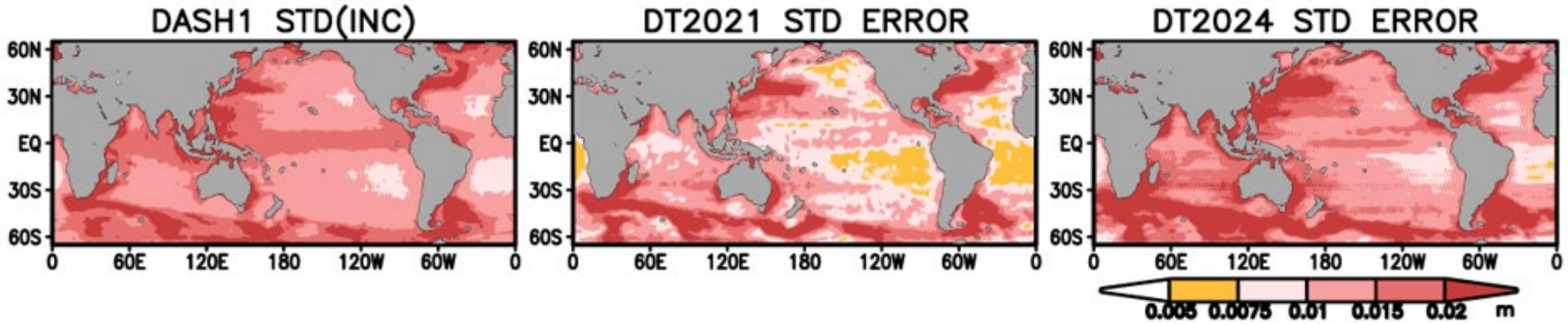




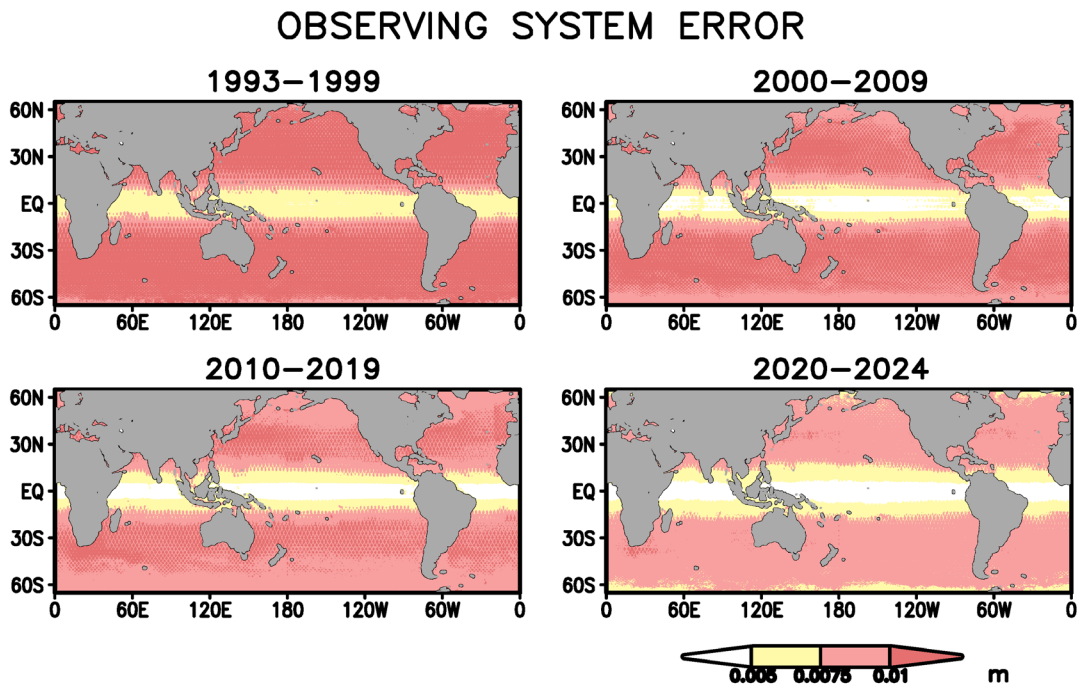




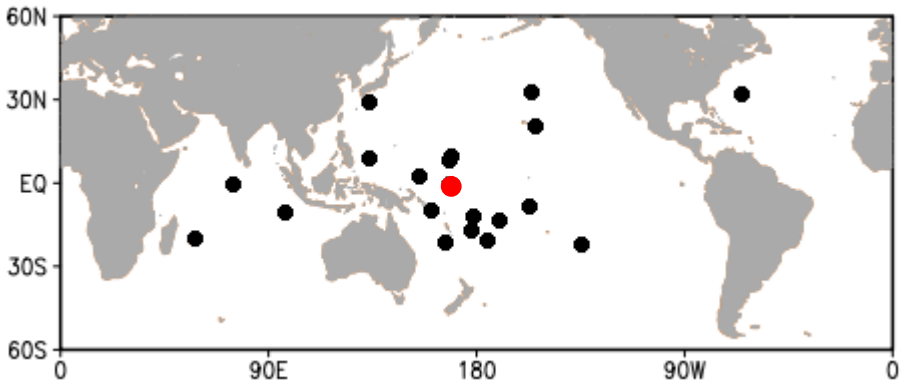
Error



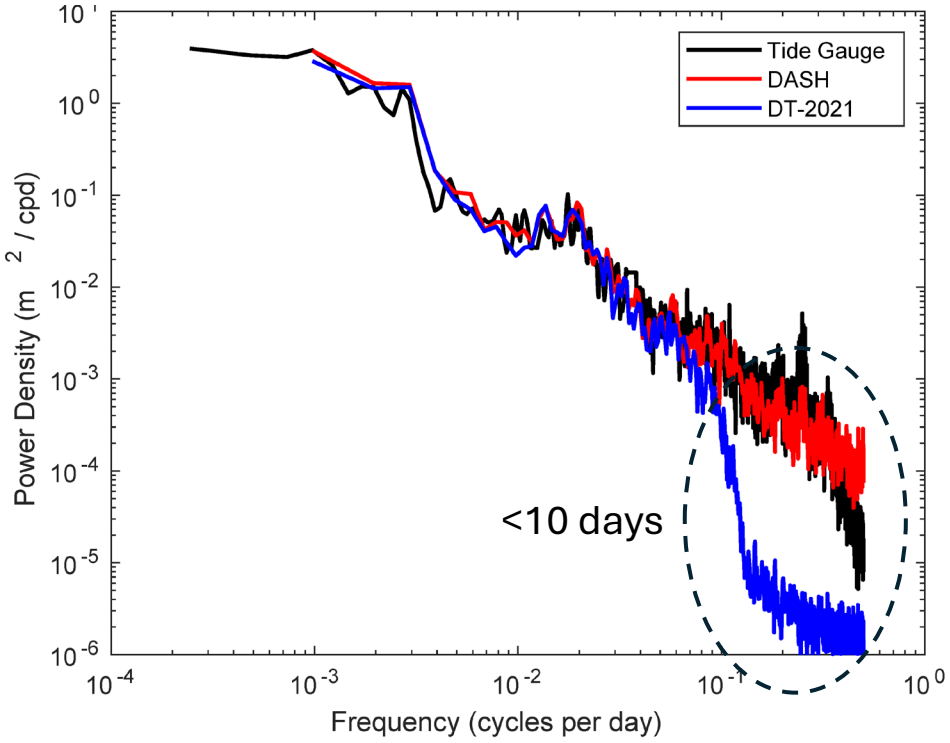
OSEs contaminate observations with 2cm noise



Island Gauge Comparisons



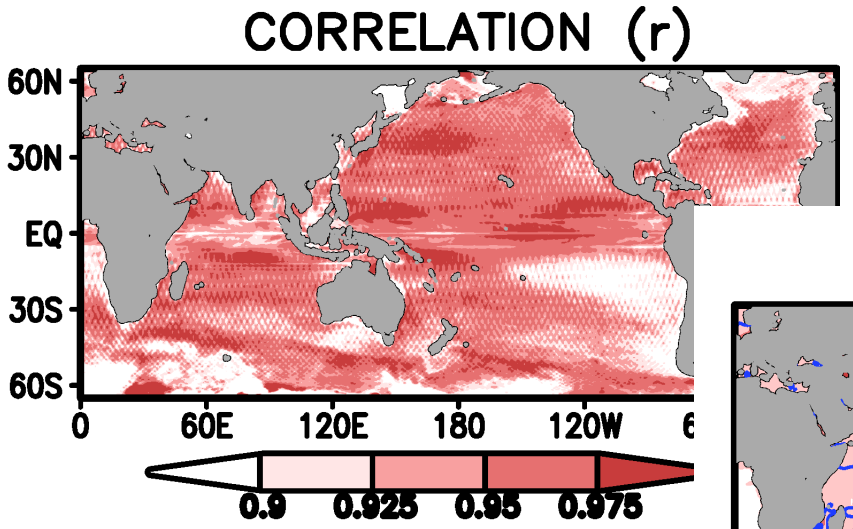
Kiribati

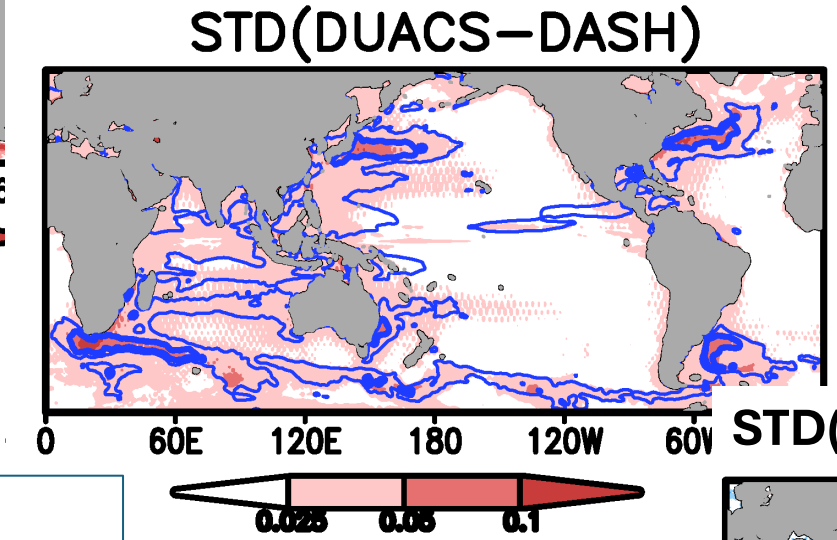


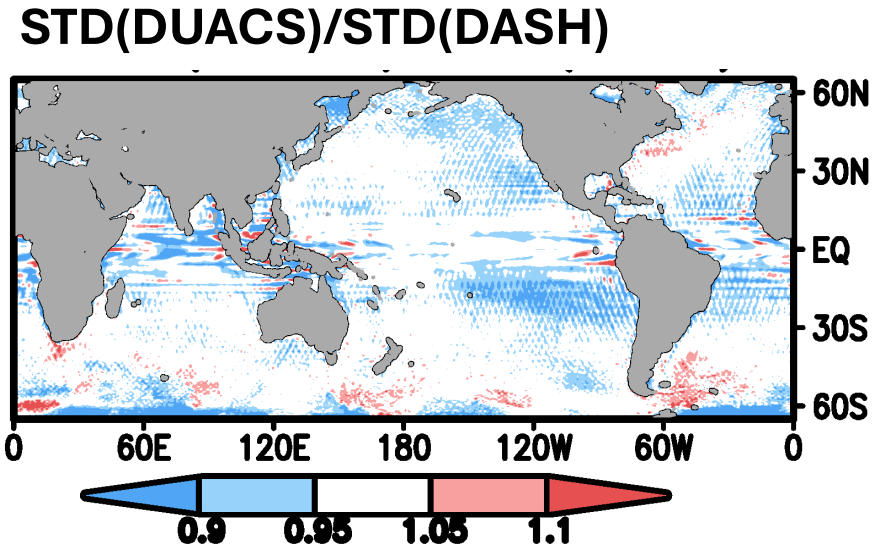
STD DIFFERENCE (m)

Station	JEDI/RADS	DUACS
Bermuda	0.061	0.058
Kiribati (Christmas ii)	0.034	0.033
Cocos (keeling Island)	0.058	0.042
Funafuti A&B	0.026	0.026
Gan ii (addu atoll)	0.035	0.035
Hilo	0.045	0.042
Honiara-B	0.032	0.032
Kapingamarangi	0.050	0.048
Kwajalein*	0.028	0.028
Majuro-C	0.030	0.027
Malakal-B	0.032	0.034
Midway	0.067	0.065
Nauru	0.057	0.051
Noumea	0.058	0.058
Nuku'alofa-B	0.045	0.046
Pago-Pago	0.074	0.071
Penrhym	0.039	0.038
Port-louis	0.046	0.050
Rikitea	0.040	0.038
Suva-b	0.053	0.052

DASH1 compared to DUACS DT2021



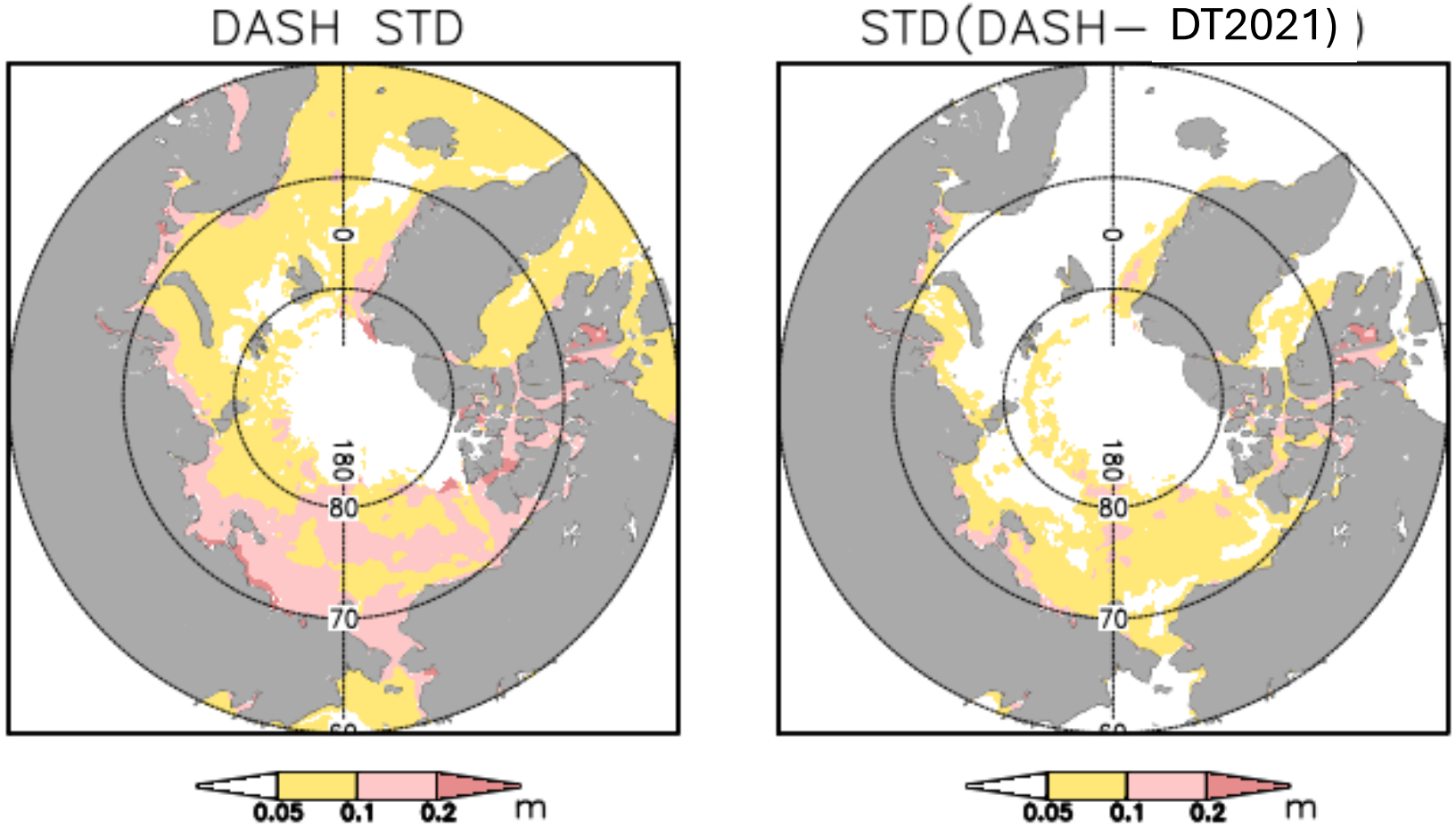




Different near continents and in the Indian Ocean

DUACS has ~5% lower variability

Arctic


DASH STD
0
180
80
70
0.05
0.1
0.2
m
STD(DASH– DT2021)
0
180
80
70
0.05
0.1
0.2
m

DASH(2)

(work by Luyu Sun)

Inputs

- Along-track DT, DASH1 Gridded (0.25° x 0.25° x1dy)

Output

- Gridded DT analysis, +6 h to +48 h

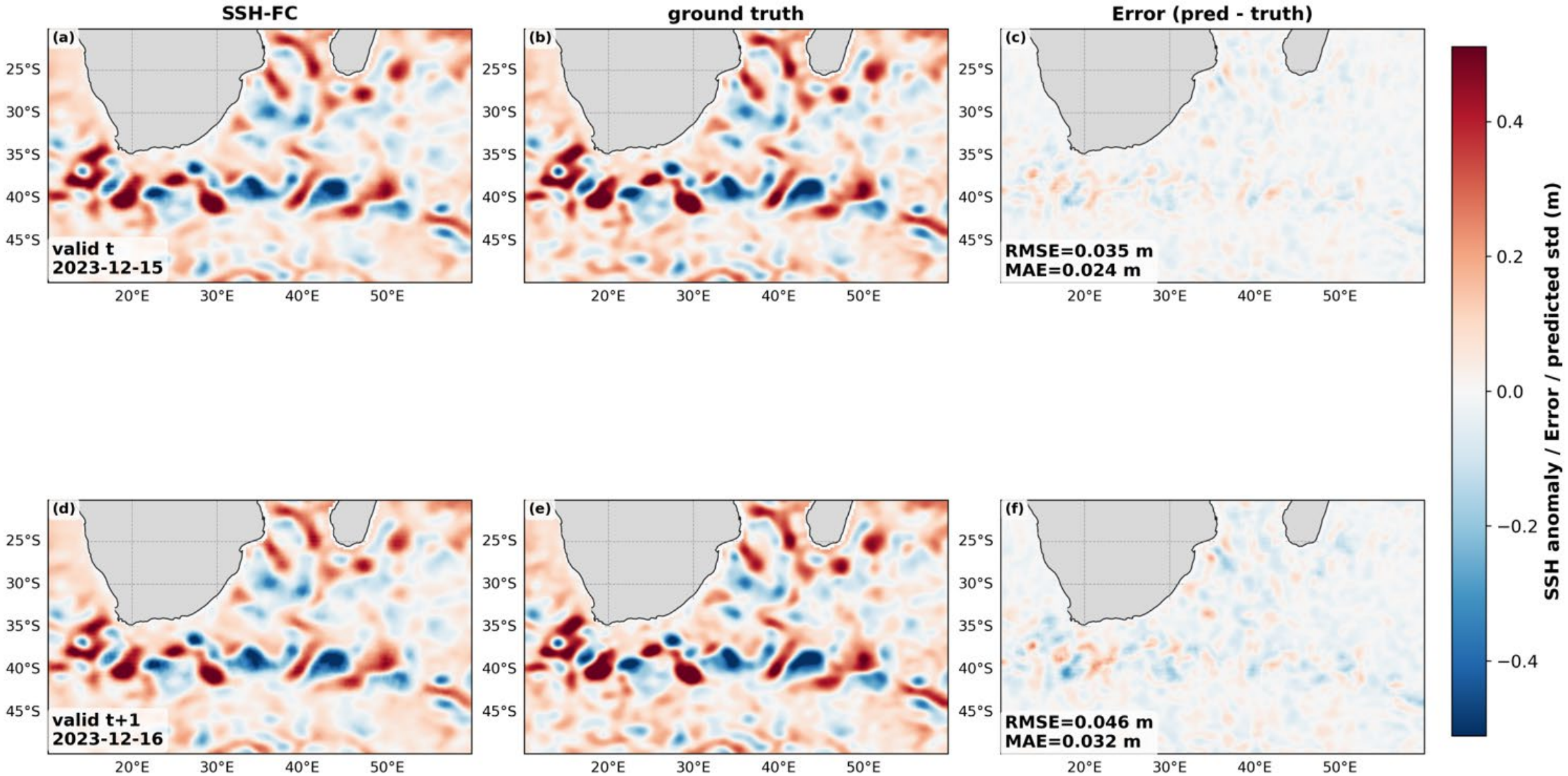
Training

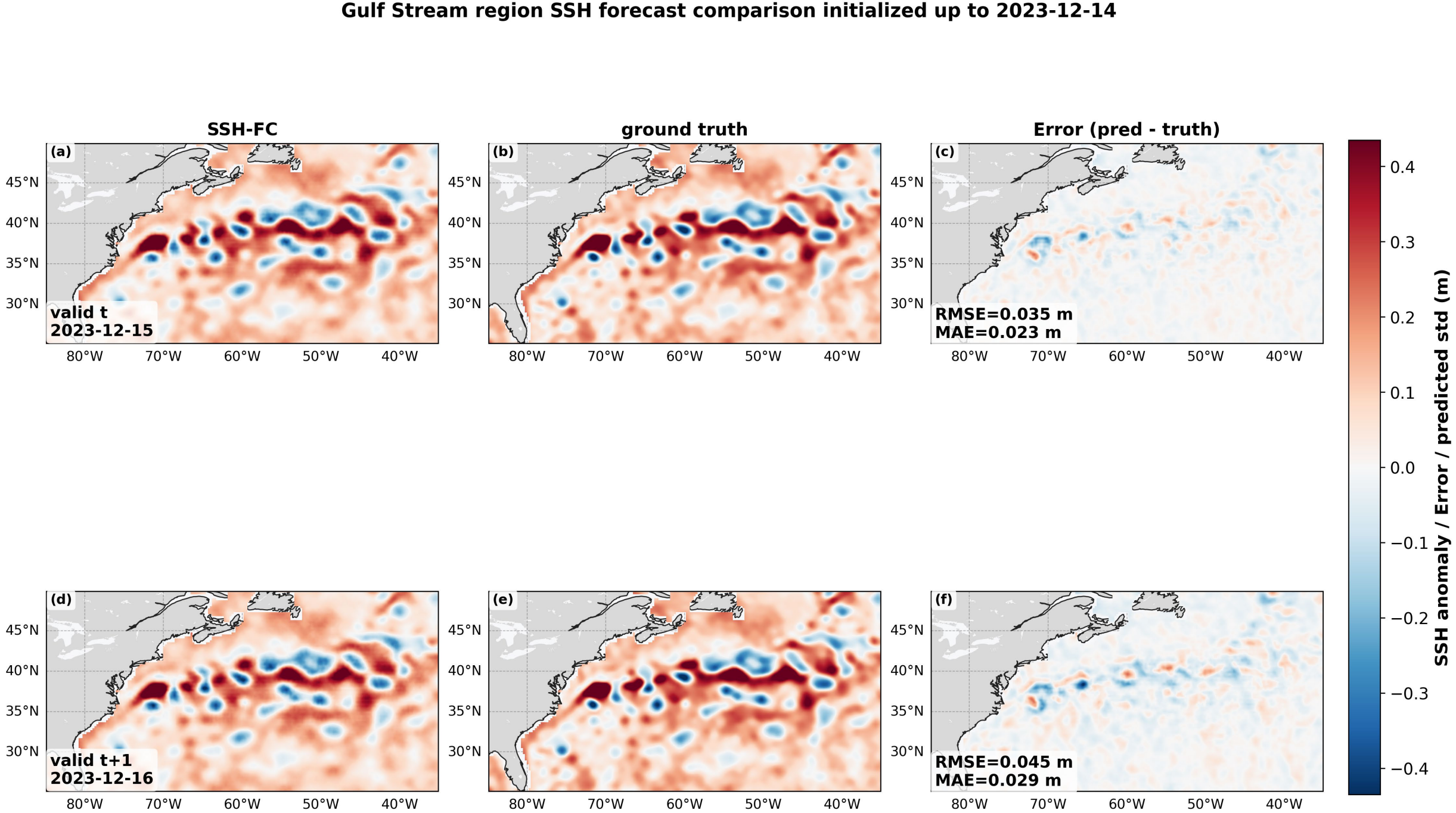
- 2023 JEDI-OISSH analyses (9 months for training; 2 months validation; 1 month testing)
- Multi-lead supervised learning (gridded DASH; high-pass and low-pass along-track altimetry; smoothness regularization)
- UNet Architecture

Loss Function

$$L = \lambda_{grid} \underbrace{\left\|\eta - \eta_{ij}^{DASH}\right\|}_{\text{Grid forecast loss}} + \lambda_{hp} \underbrace{\left\|\eta - \eta_{hp}^{obs}\right\|}_{\text{High-pass along-track loss}} + \lambda_{lp} \underbrace{\left\|\eta - \eta_{lp}^{obs}\right\|}_{\text{Low-pass along-track loss}} + \lambda_{sm} \underbrace{\left\|\nabla^2\eta\right\|}_{\text{Smoothness regularization}}$$

$$(\lambda_{grid} = 1;\ \lambda_{hp} = 1;\ \lambda_{lp} = 1;\ \lambda_{sm} = 0.001)$$


Agulhas region SSH forecast comparison initialized up to 2023-12-14
SSH-FC
ground truth
Error (pred - truth)
(a)
(b)
(c)
(d)
(e)
(f)
valid t
2023-12-15
valid t+1
2023-12-16
RMSE=0.035 m
MAE=0.024 m
RMSE=0.046 m
MAE=0.032 m
25°S
30°S
35°S
40°S
45°S
20°E
30°E
40°E
50°E
SSH anomaly / Error / predicted std (m)
0.4
0.2
0.0
−0.2
−0.4


Gulf Stream region SSH forecast comparison initialized up to 2023-12-14
SSH-FC
ground truth
Error (pred - truth)
(a)
(b)
(c)
(d)
(e)
(f)
valid t
2023-12-15
valid t+1
2023-12-16
RMSE=0.035 m
MAE=0.023 m
RMSE=0.045 m
MAE=0.029 m
45°N
40°N
35°N
30°N
80°W
70°W
60°W
50°W
40°W
SSH anomaly / Error / predicted std (m)
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4

Summary

DASH1

- Open-source two-scale 3DVar
- Automatic outlier detection (OSTST2026 ERR2026_006)
- Retains variability in the 1-20dy band
- Global daily 1/4°x1/4° DH data set available shortly

DASH2

- Supervised learning using DASH1
- UNet Architecture
- Can add more training data (e.g. winds, SST)
- So far seems promising