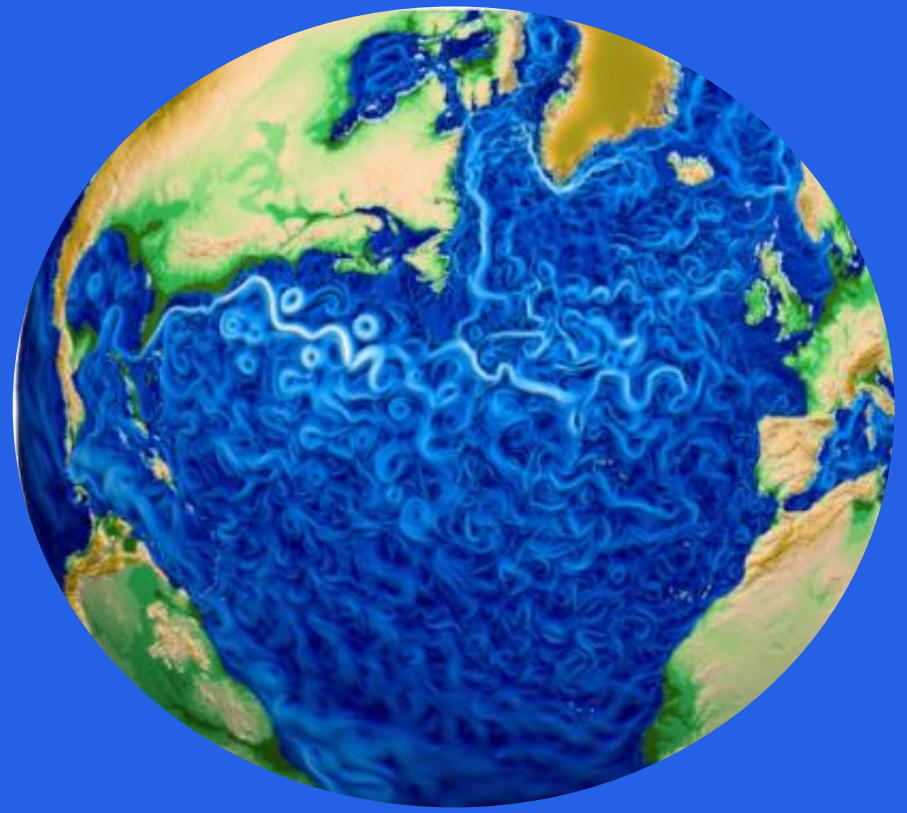
The Bureau of Meteorology

Verification and Intercomparison of Global Ocean Currents



Saima Aijaz[1], Gary B. Brassington[1], Prasanth Divakaran[1], Charly Régnier[2], Marie Drévillon[2] , K. Andrew Peterson[3], Jan Maksymczuk[4], and Lauriane Escalle[5]

[1]Bureau of Meteorology, Australia
[2]Mercator Océan International
[3]Environment and Climate Change Canada
[4]Met Office, UK
[5]Pacific Community

OceanPredict IV-TT Ocean Verification Online Seminar Series– 13 June 2024

Outline

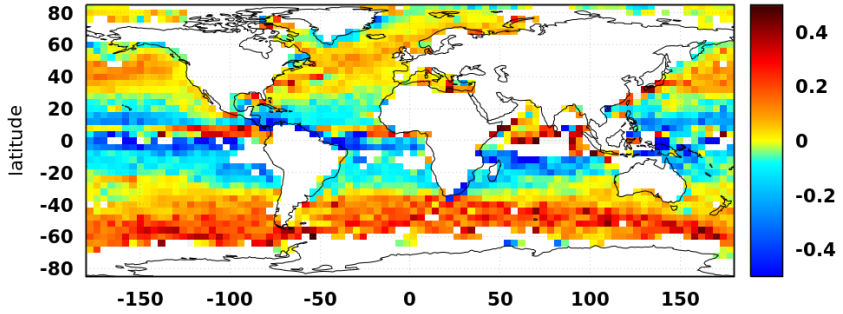
Eulerian currents verification & intercomparison

- Verification under the OceanPredict IV-TT CLASS4 data standard using observations from global drifting buoys
- Intercomparison of models from the Bureau of Meteorology, Mercator Océan, UK Met Office, and Environment & Climate Change Canada
- Use of drifting fish aggregating devices (FADs) as ocean observing system for verification

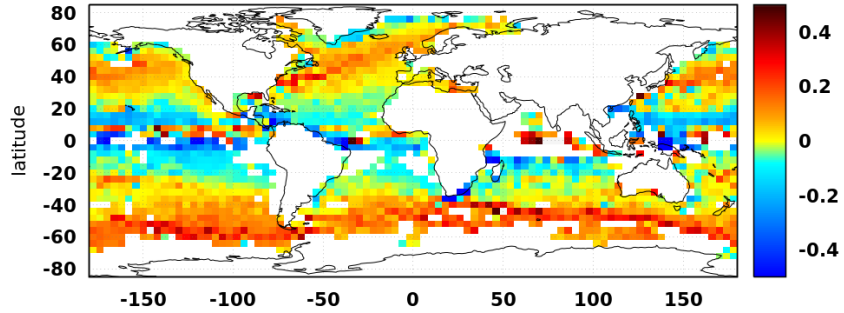
Lagrangian modelling

- Comparison of drifter trajectories with FADs trajectories
- OceanMAPS skill against FADs and against drifters

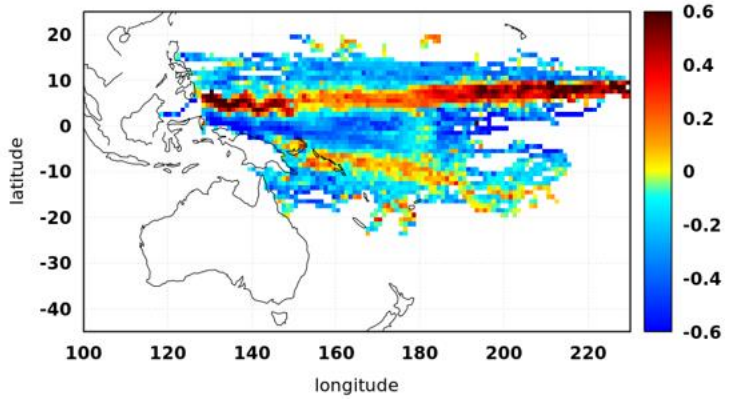
Currents OBS - drifters



Currents OMAPS 4.0i



Currents OBS - FADs



Zonal currents

Global forecast systems for intercomparison

	Ocean forecast system	Ocean model	Resolution	Atmospheric Input	Observations
Bureau of Meteorology	1. OMAPS3.4, ENS-OMAPS3.4, **4.0i**, 4.1i 2. OMAPS- NEMO-EnKF-C	MOM-5 NEMO 4.04	MOM-5: 1/10° ×1/10° (horizontal), 51 vertical levels NEMO: 1/4° at equator, 7 km at high latitudes, 75 vertical levels	ACCESS-G3	SLA, SST, salinity, temperature (no tides, no sea-ice)
Mercator Océan International	4. MOi GLOBAL_ANALYSISFORECAST_PHY_001_024	NEMO-3.1	1/12° at equator (2 km at Antarctic), 50 vertical levels	ECMWF global	SLA, SST, salinity, temperature, sea-ice (no tides)
UK Met Office	5. FOAM-025	NEMO-3.6	1/4° at equator, 7 km at high latitudes, 75 vertical levels	Met Office global NWP	SLA, SST, salinity, temperature, sea-ice (no tides)
	6. FOAM-12	NEMO-3.6	1/12° at equator, 7 km at high latitudes, 75 vertical levels	Met Office global NWP	SLA, SST, salinity, temperature, sea-ice (no tides)
	7. CPLDA	NEMO-3.6	1/4° at equator, 7 km at high latitudes, 75 vertical levels	Unified Model atmosphere	SLA, SST, salinity, temperature, sea-ice (no tides)
Environment & Climate Change Canada	8. GDPS-GIOPS	NEMO-3.6	1/4°, 50 vertical levels	CCMEP global NWP, GDPS	SLA, SST, salinity, temperature, sea-ice (no tides)
	9. GEPS	NEMO-3.6	1/4°, 50 vertical levels Ensembles	CCMEP global NWP, GEPS7.0	SLA, SST, salinity, temperature, sea-ice (no tides)

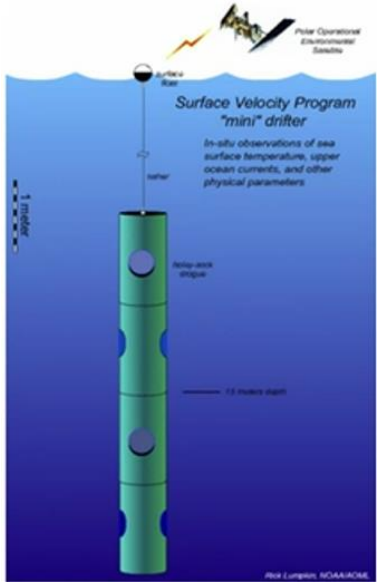
Aijaz, S., G. B. Brassington, P. Divakaran, C. Régnier, M. Drévillon, J. Maksymczuk, K. A. Peterson, 2023: Verification and Intercomparison of Global Ocean Eulerian Currents, Ocean Modelling, 186, 102241.

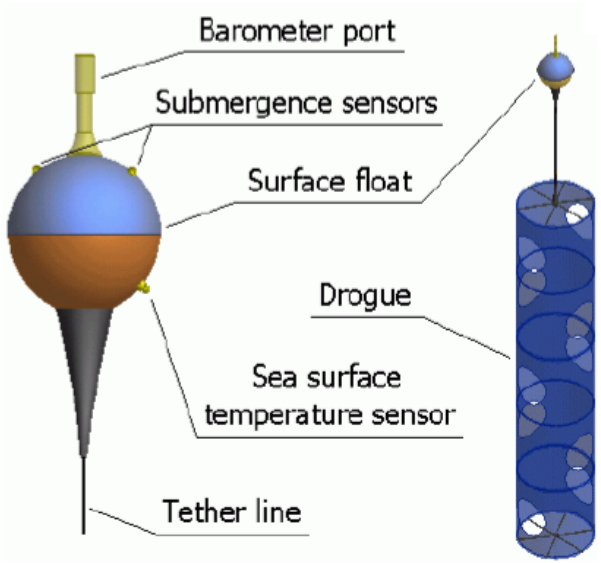
Global ocean observing systems

Global drifter program (GDP) & Fish aggregating devices (FADs)

- Global drifter buoys track currents at 15m depth. Their positions are tracked by satellites and accurate to within 1 km. The Coriolis data Centre (Ifremer and Météo-France) delivers the drifter observations.
- Drifting fish aggregating devices (FADs) consist of a floating raft, ropes or nets, and a satellite buoy for tracking. Not designed as ocean observing tool.

GDP drifter





Schematic of drifter buoy

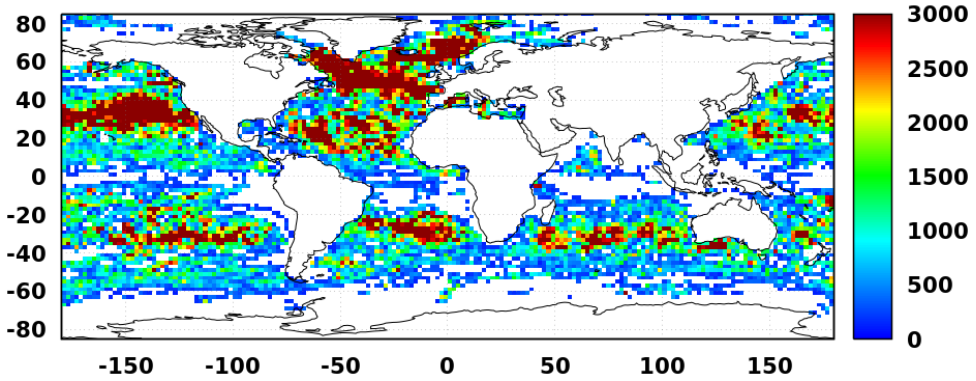
FADs

Fish aggregating device (FAD). Source: Pew Environment Group, international@pewtrusts.org

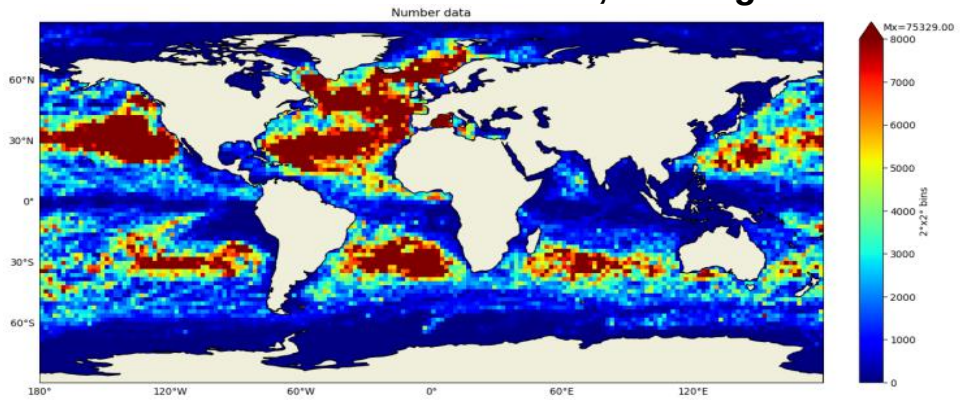
Number of GDP drifters & FADs

Drifters

MAY 2021 – MAY 2022 2x2 deg bins

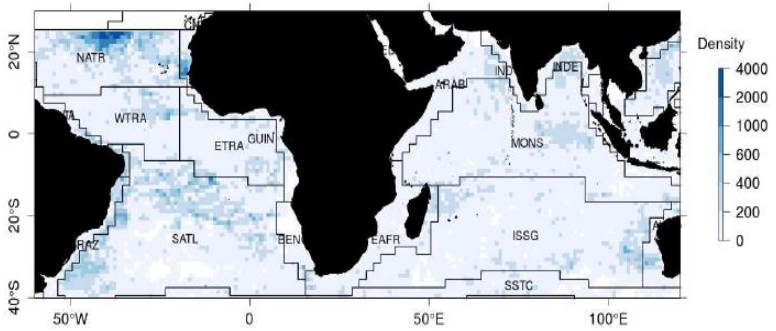


MARCH 2021 – JANUARY 2024, 2x2 deg bins

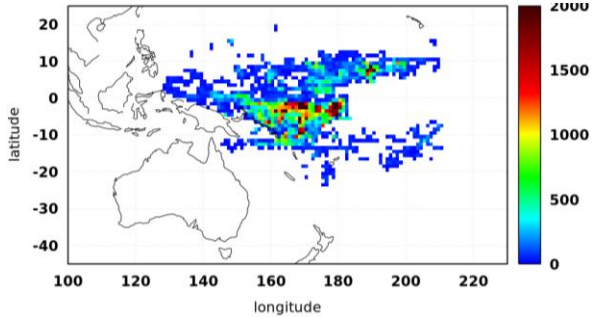


Source: https://catalogue.marine.copernicus.eu

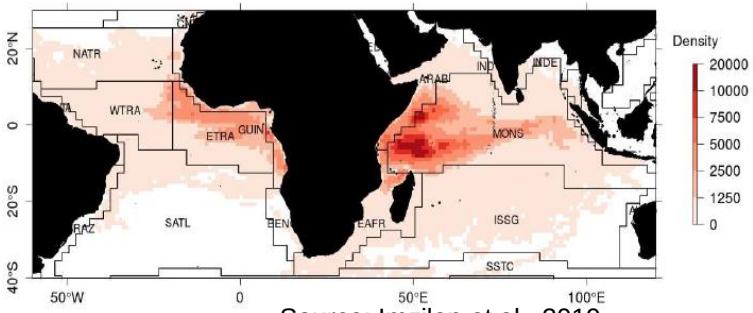
Drifters 2008-2014 1x1 deg bins



Drifters JAN-DEC 2020 1x1 deg bins

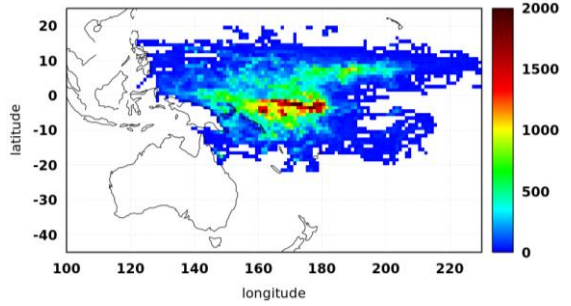


FADs 2008-2014 1x1 deg bins



Source: Imzilen et al., 2019

FADs JAN-DEC 2020 1x1 deg bins



Methodology – CLASS4 verification

- Global drifter observations are filtered over 24 hours using a Lanczos filter.
- Each agency prepares the CLASS4 currents drifter files, and sends it to the Bureau of Met., Australia
- Scaled Stokes drift from the MFWAM global wave model and tidal currents from FS2014 global tidal model are linearly added to the model best estimates and forecasts.
- Standard verification metrics are used: RMSE, STD, MAE, Bias, PDFs, CDFs, QQ-plots, complex correlations, Taylor diagrams, box plots.
- Statistical metrics are computed for daily, monthly, and annual time-periods.

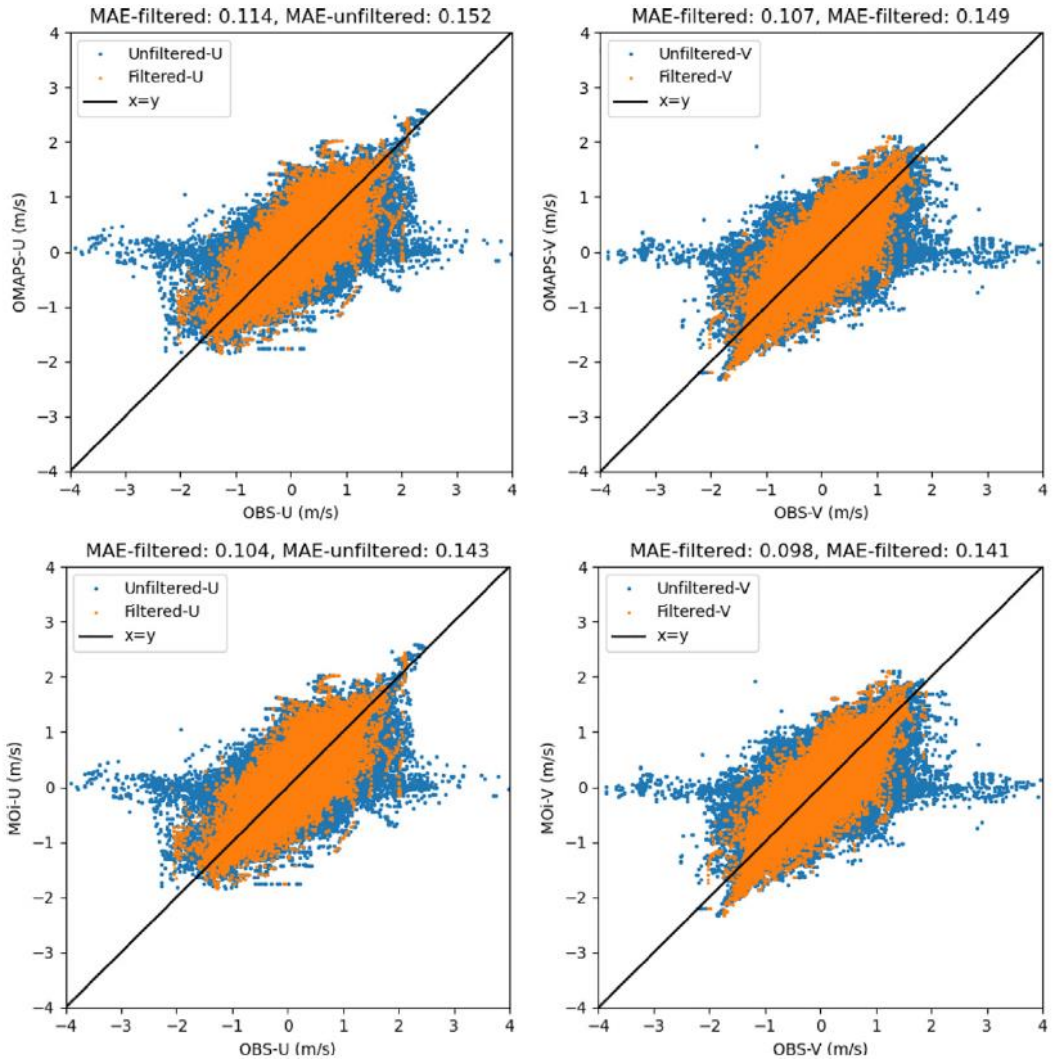
Verification timeframes

OMAPS versions	Timeframe	Representative year
OMAPS 3.2	1 July 2019 – 24 May 2020	2019-20
OMAPS 3.3	25 May 2020 – 19 May 2021	2020-21
OMAPS 3.4	20 May 2021 – 20 May 2022	2021-22
OMAPS 4.0i*	6 January 2022 – 20 May 2022	2021-22
OMAPS 4.1i		2023

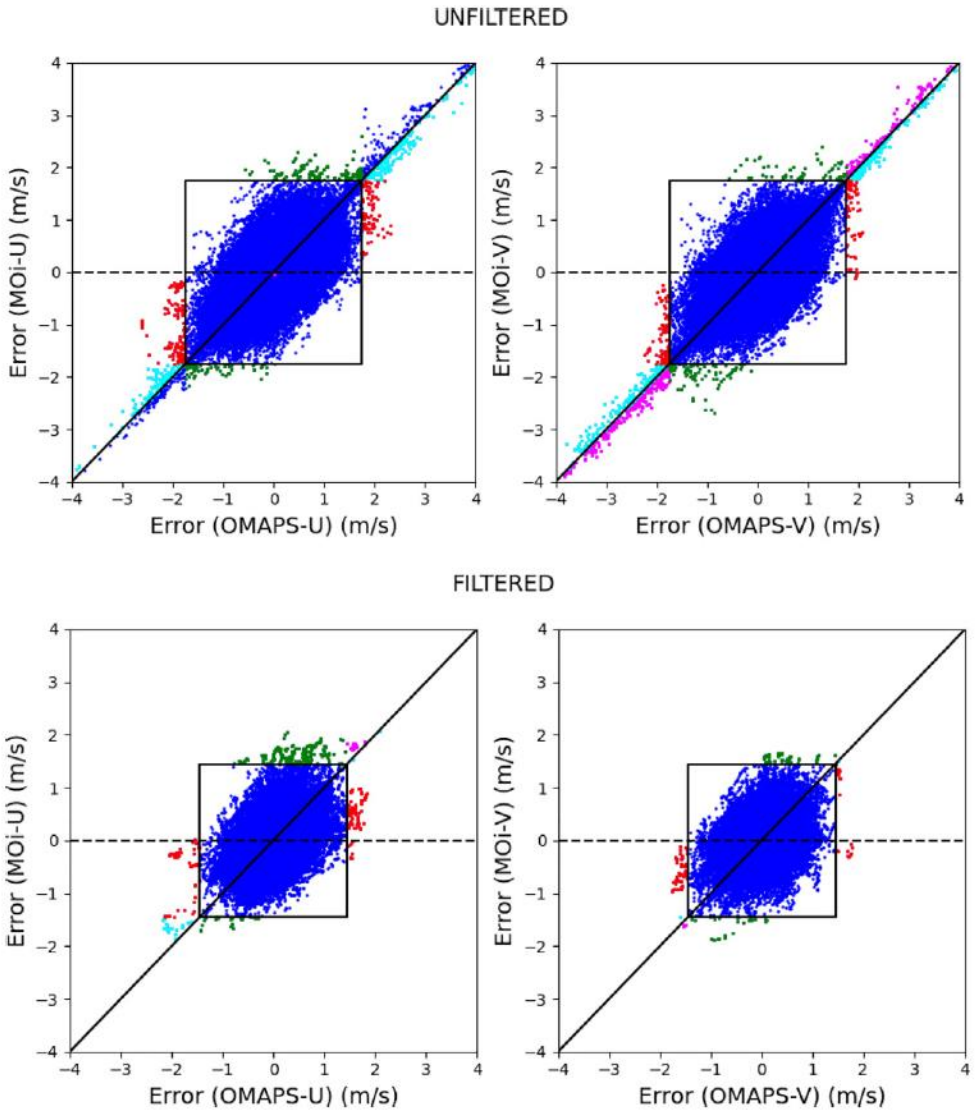
*operational in June 2022

Filtering and outliers

Filtered vs non-filtered



Outliers



- MOi error > OMAPS error
- OMAPS error > MOi error
- OMAPS errors > ±1.75 (unfiltered), > ±1.4 (filtered)
- MOi errors > ±1.75 (unfiltered), > ±1.4 (filtered)

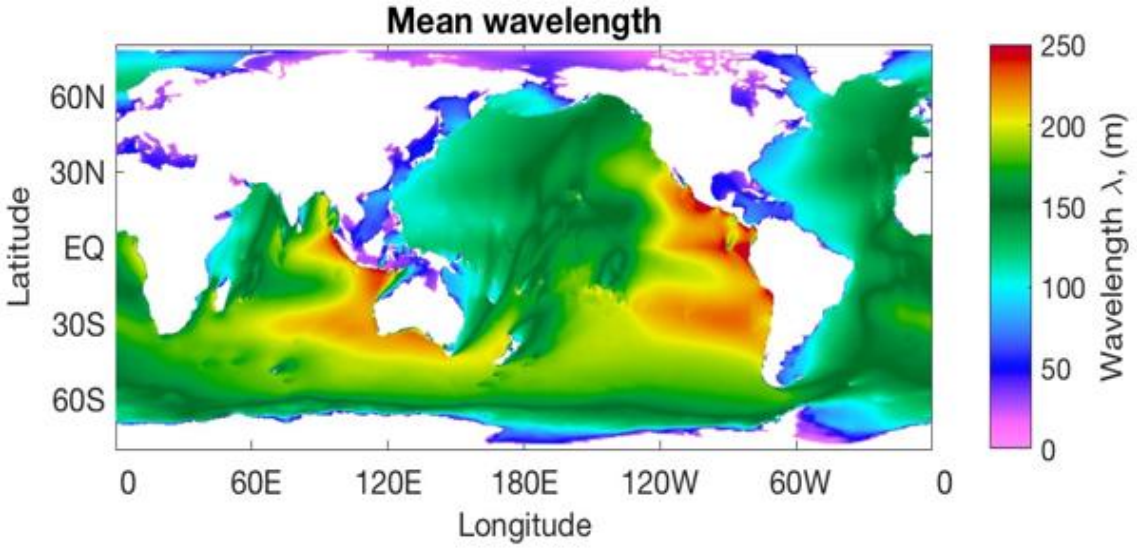
Stokes Drift scaling

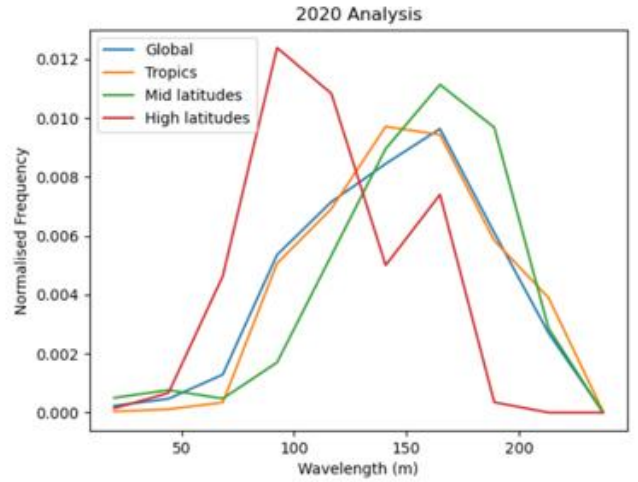
Deep water stokes drift (Phillips, 1977)

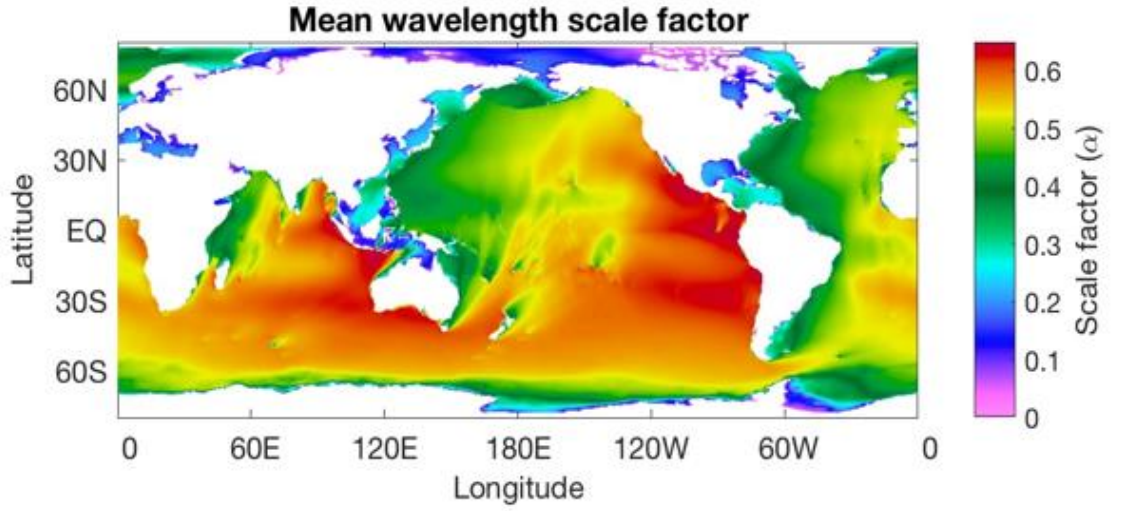
$$u_s = \frac{4\pi^2 a^2}{\lambda T} e^{4\pi z/\lambda}$$

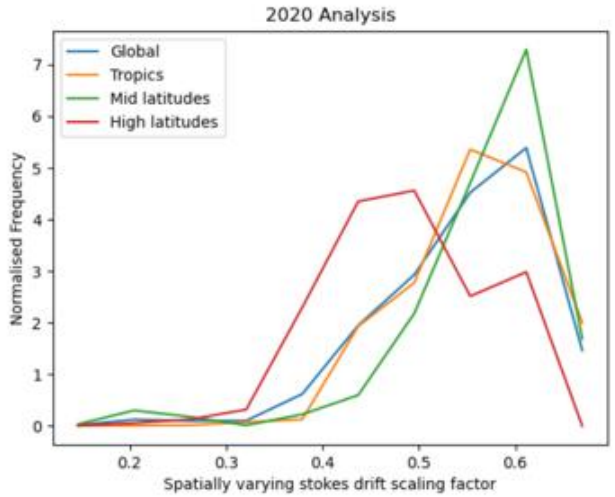
$$u_{s0} = \frac{4\pi^2 a^2}{\lambda T}$$

$$\alpha = \frac{\frac{\lambda}{4\pi}(1-e^{4\pi z/\lambda})}{\Delta z}$$





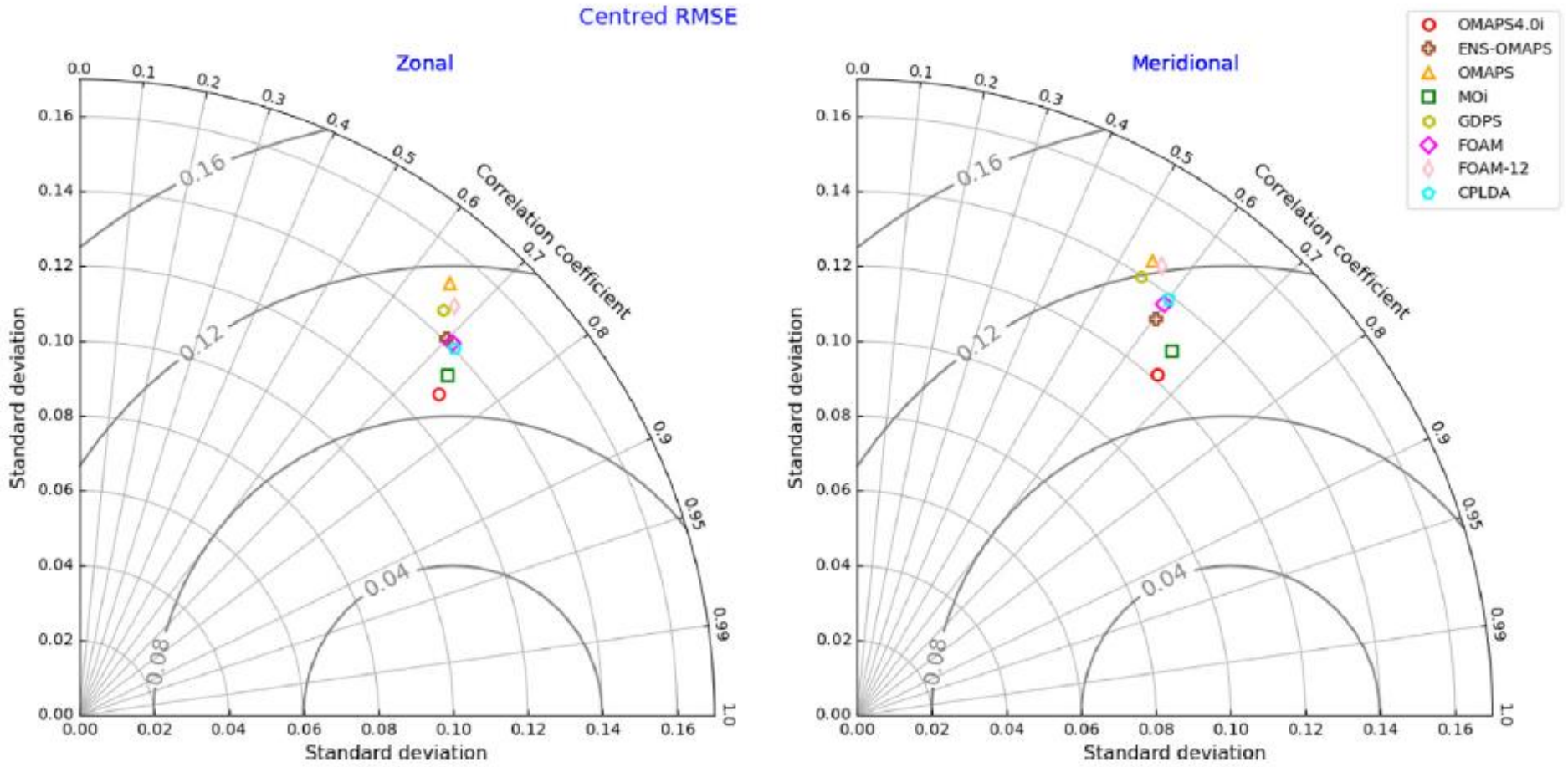




Global Analysis

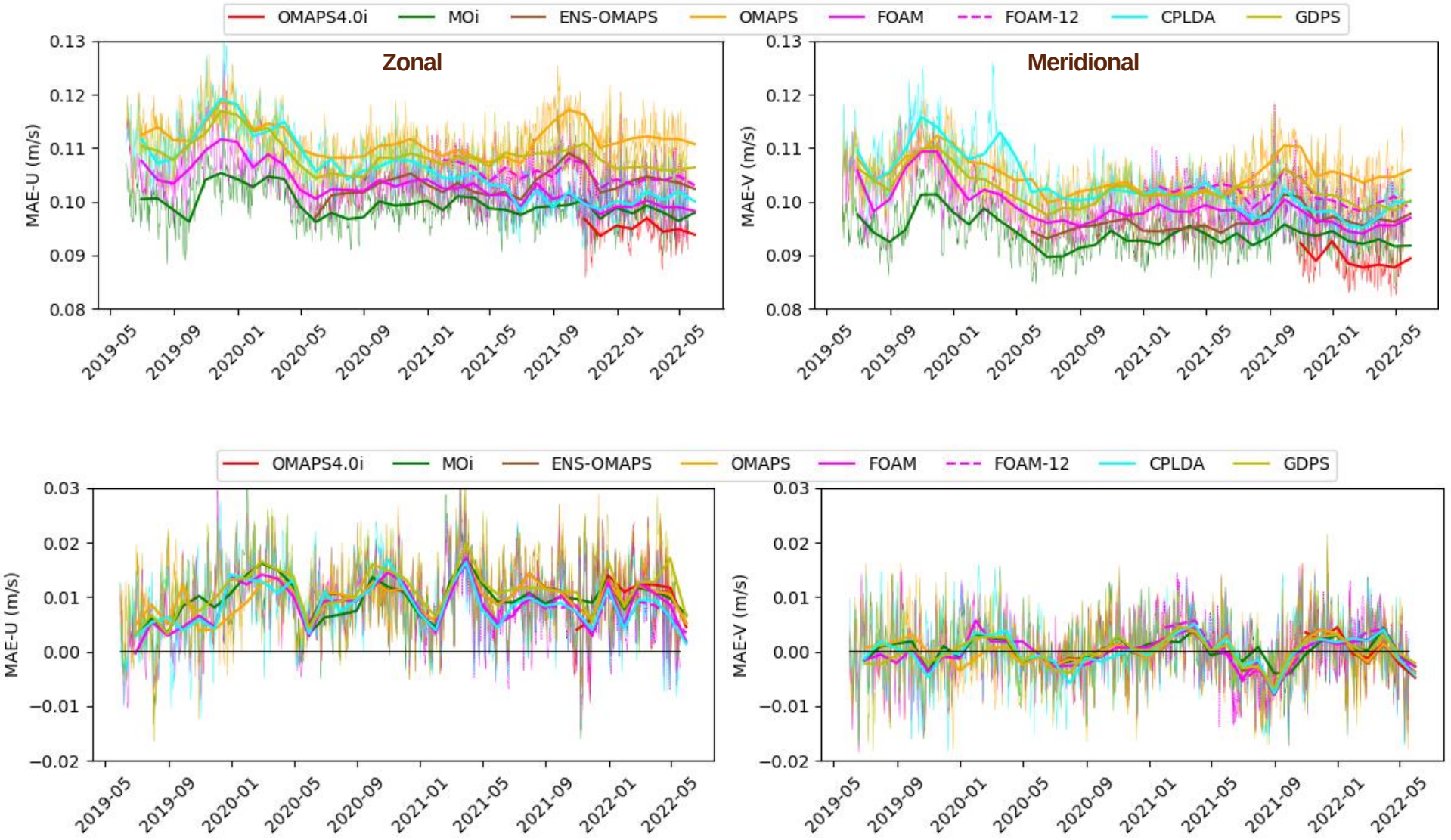
Analysis (model best estimates + Stokes drift)

Time period: 20 May 2021 – 19 May 2022



Aijaz et al. (2023)

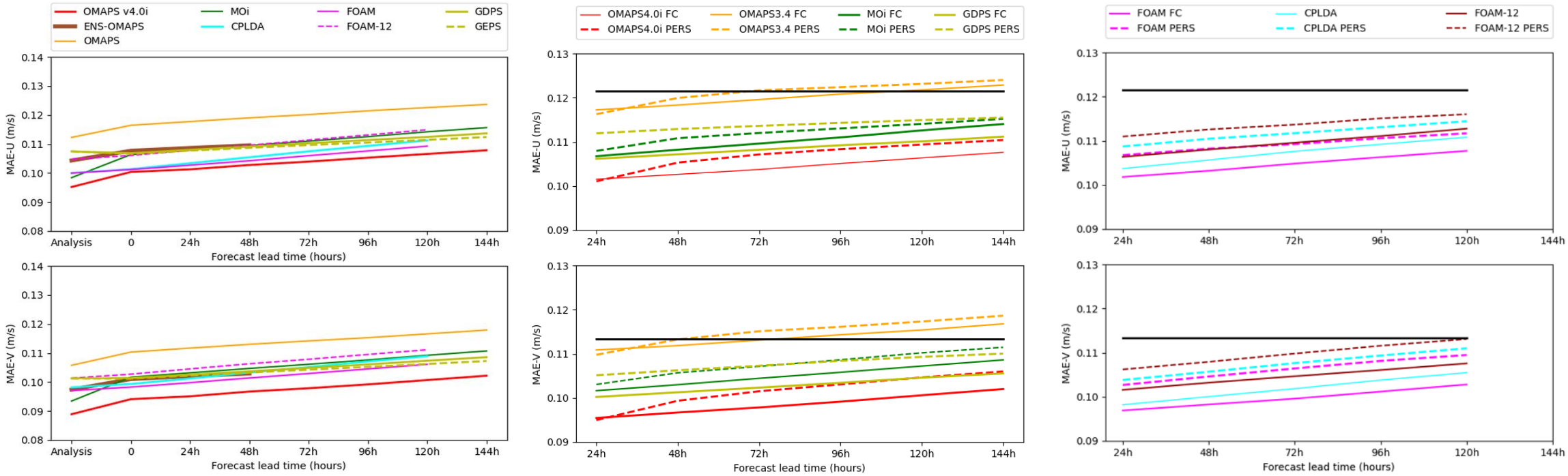
Global Analysis - Daily and monthly means



Mean absolute error (MAE) - Global

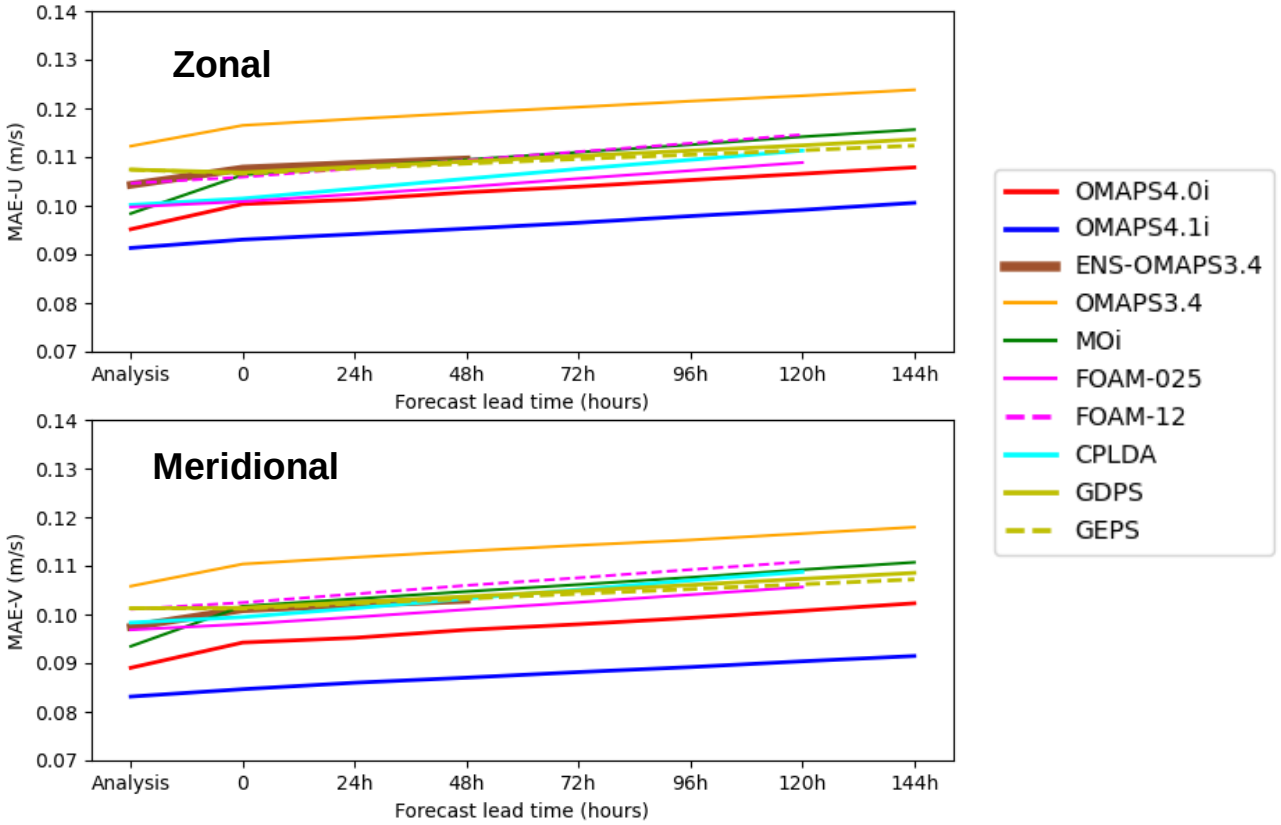
Model forecast/persistence/climatology (2021-22)

FC – Forecast **PERS – Persistence** **Climatology (solid black line)**

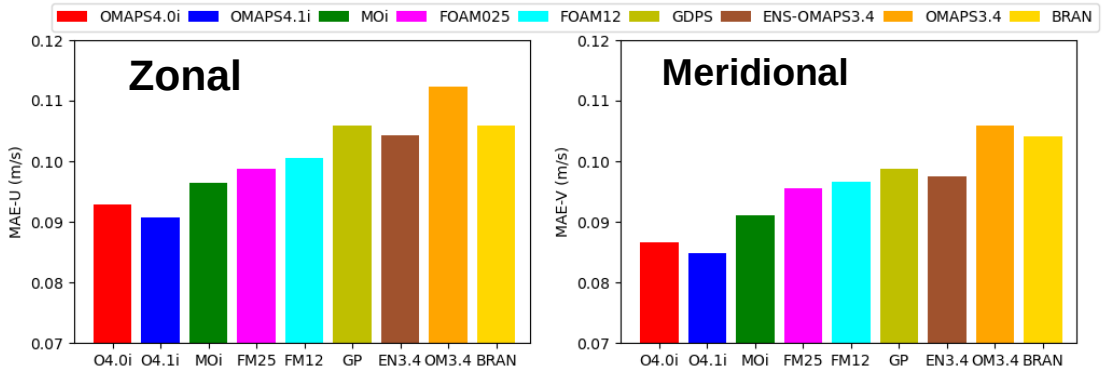


Eulerian verification – Global drifters (GDP)
Mean Absolute Error (MAE) - Global

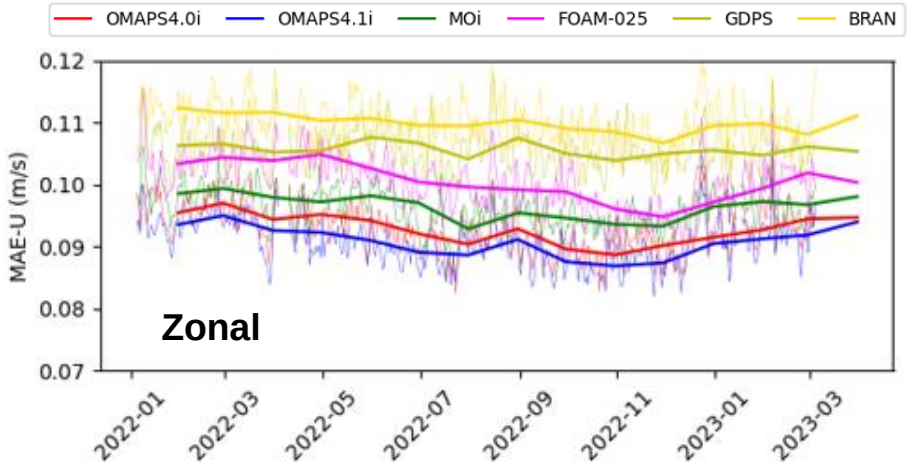
Forecast error growth



Analysis - Global



Daily & monthly means



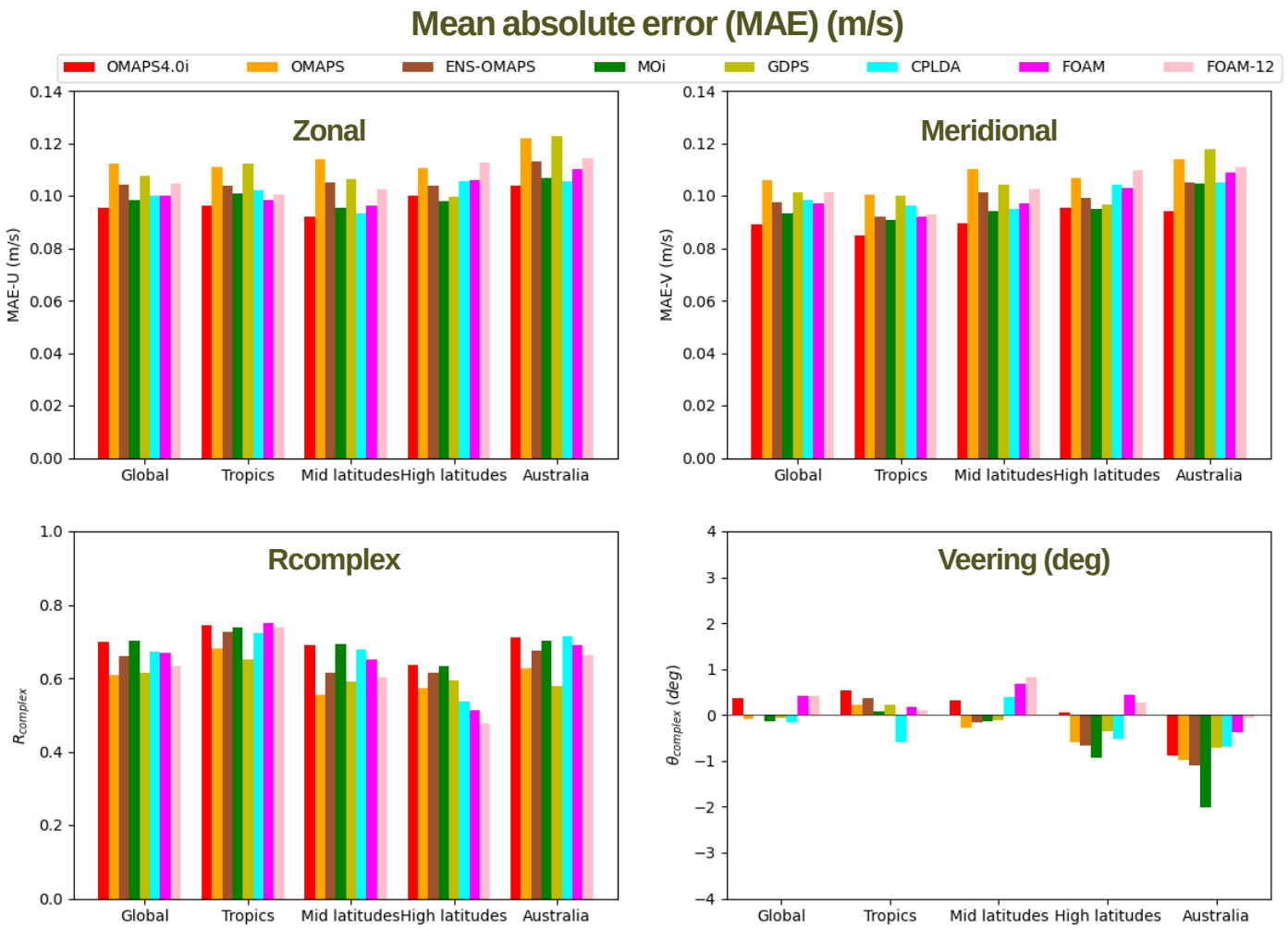
Time period: 20MAY2021 – 19MAY2022 (364 days) except
OMAPS 4.1i: 1JAN2023 – 26FEB2023 (57 days)

Time period: 1JAN2022 – 10MAR2023 (432 days) except
OMAPS 3.4, EN-OMAPS: 20MAY2021 – 20MAY2022

Regional Statistics

Analysis (model best estimates + Stokes drift)

Time period: 20 May 2021 – 19 May 2022

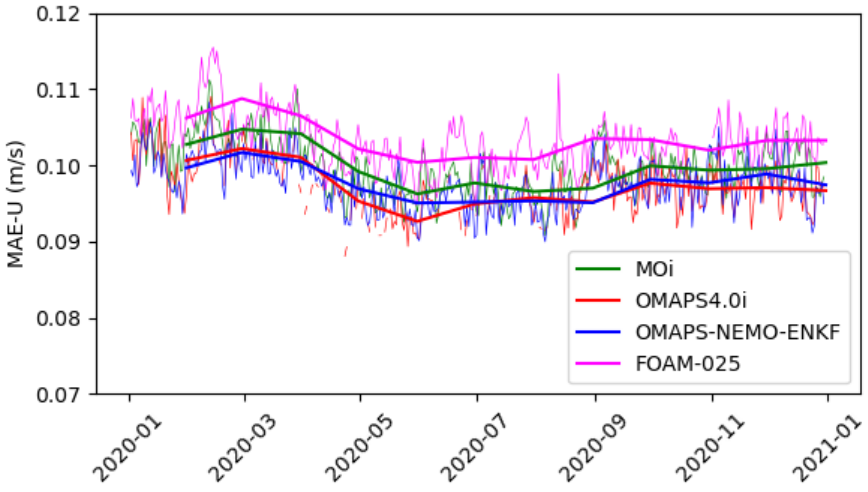


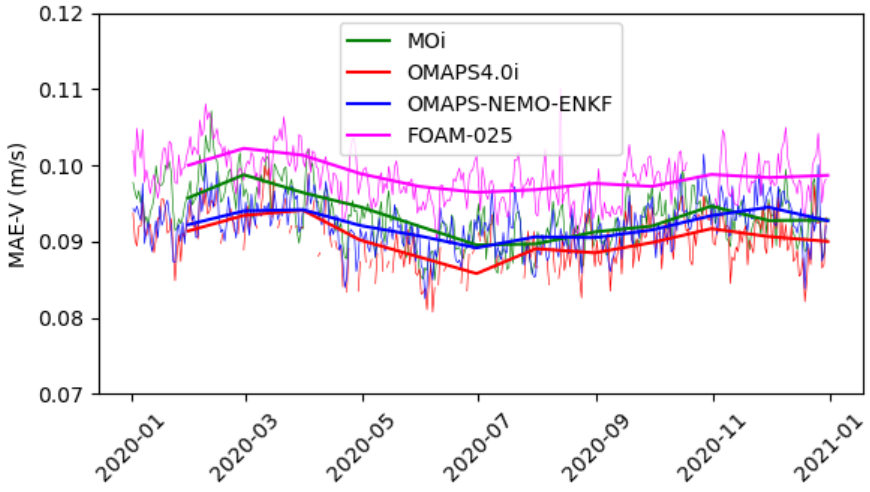
Tropics (30°S-30°N)
Mid-latitudes (50°S-30°S, 30°N-50°N)
High-latitudes (75°S-50°S, 50°N-75°N)
Australia (0°S-50°S, 90°E-180°E)

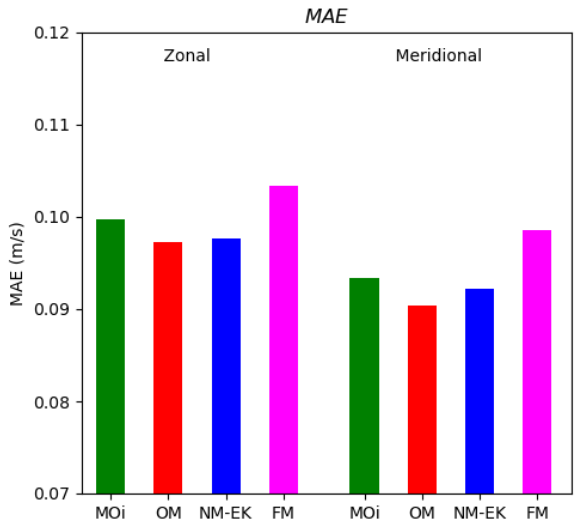
Number of samples, N: 9.3 M (Global), 3.5 M (Tropics), 3.9 M (mid-lats), 1.9 M (high-lats), 730k (Australia)

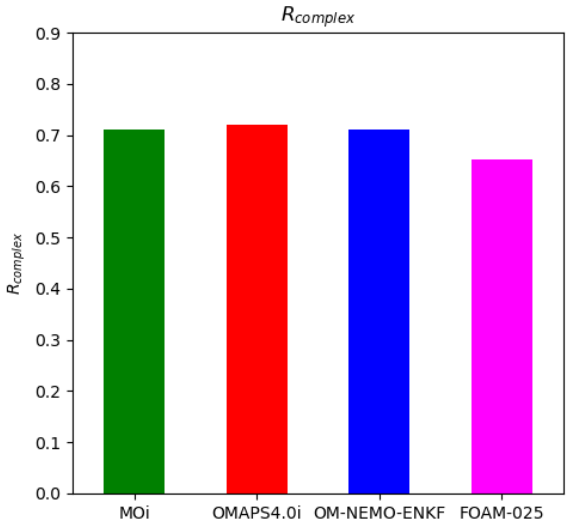
OMAPS-NEMO-EnKF-C
Global Analysis

2JAN2020 – 30DEC2020 (OMAPS-NEMO-ENKF: ***3-day average,*** all other models: ***daily average***), N = 10,907,611









- MOi NEMO Tripolar – 1/12 deg

- OMAPS 4.0i
- MOM5 Rectilinear – 1/10 deg

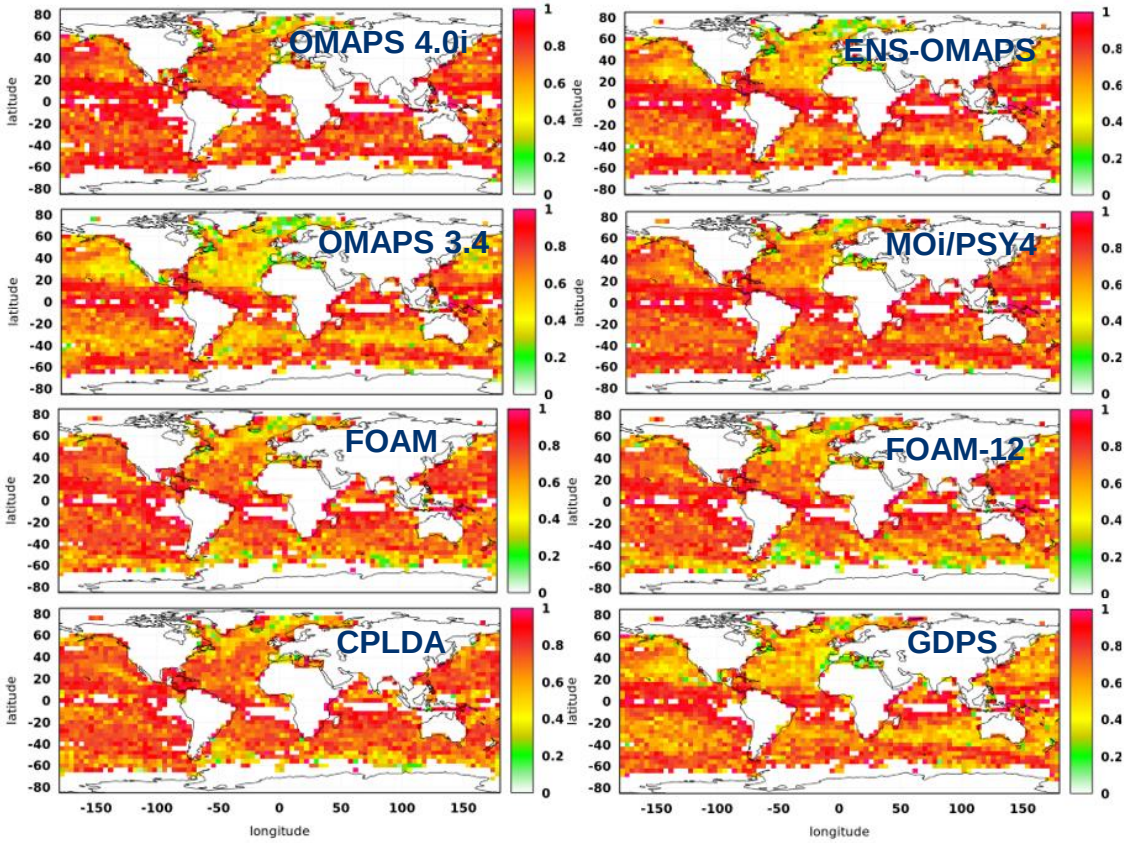
- OMAPS-NEMO-ENKF & FOAM-025
- NEMO Tripolar ORCA025 – 1/4 deg

Spatial statistics, 4x4 degree bins

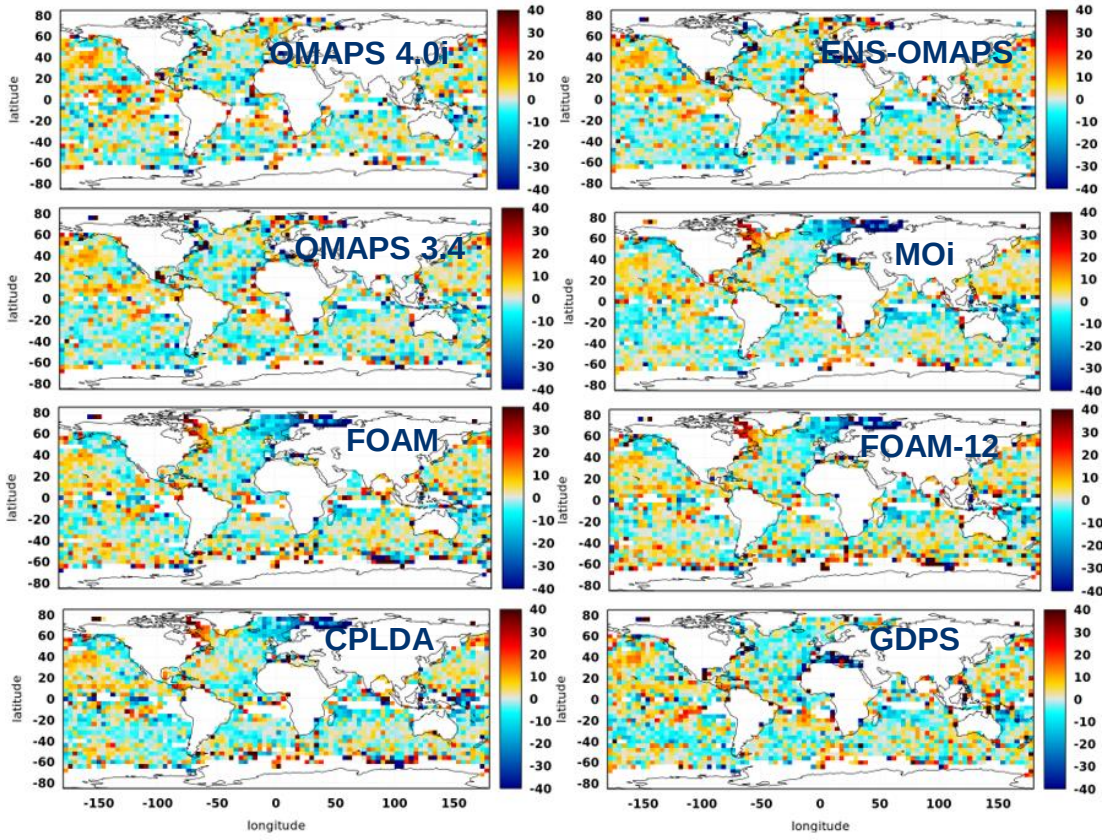
Analysis (model best estimates + Stokes drift)

Time period: 20 May 2021 – 20 May 2022 (365 days)

Rcomplex



Veering (degrees)

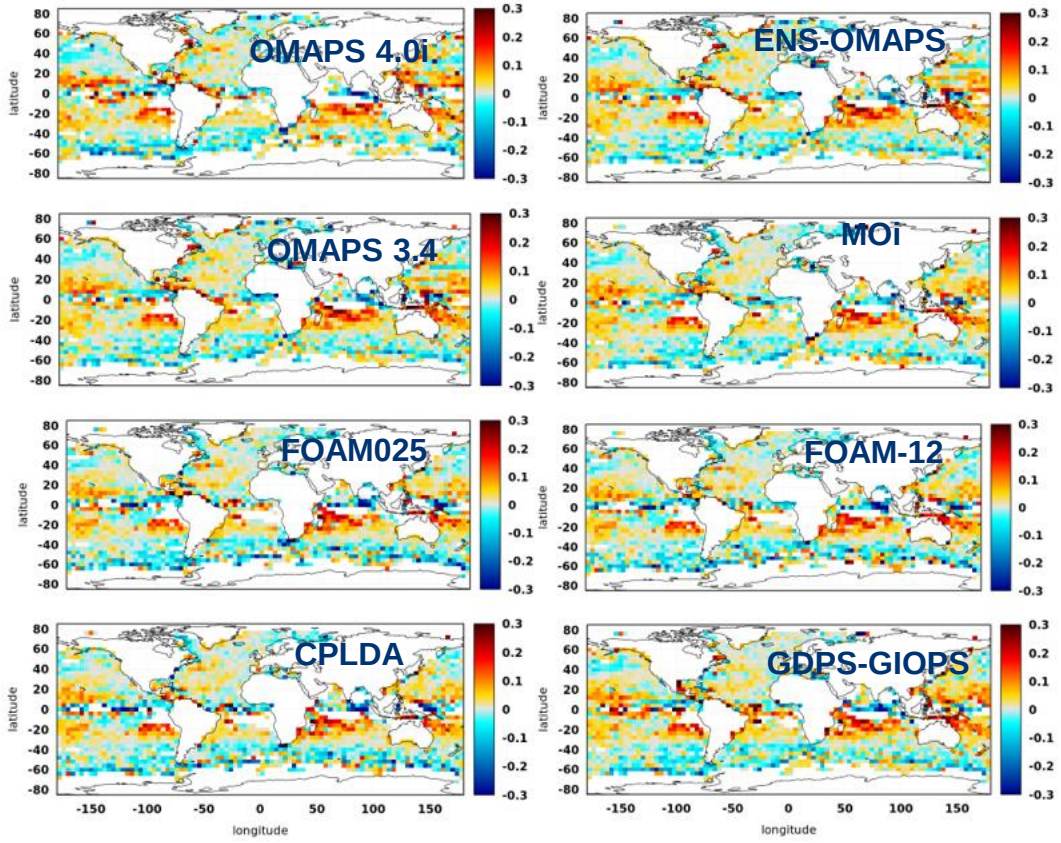


Spatial statistics, Mean error 4x4 degree bins

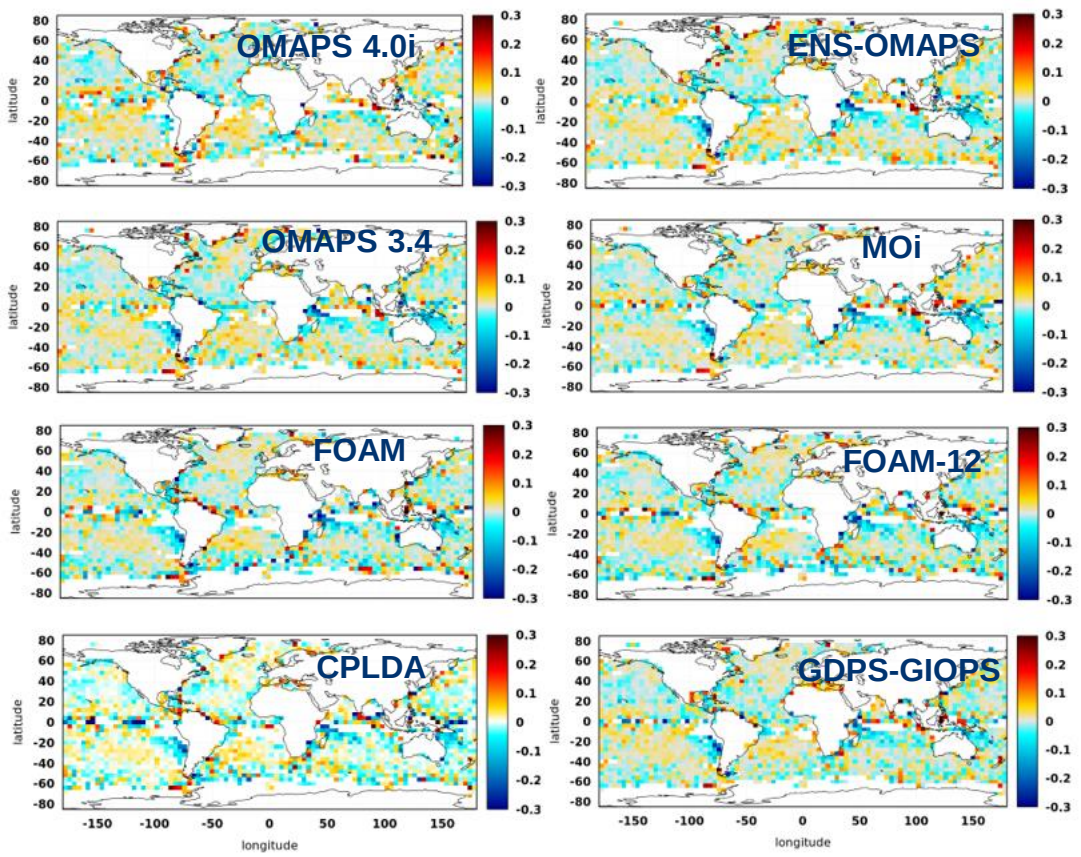
Analysis (model best estimates + Stokes drift)

Time period: 20 May 2021 – 19 May 2022 (364 days)

Mean annual error, zonal

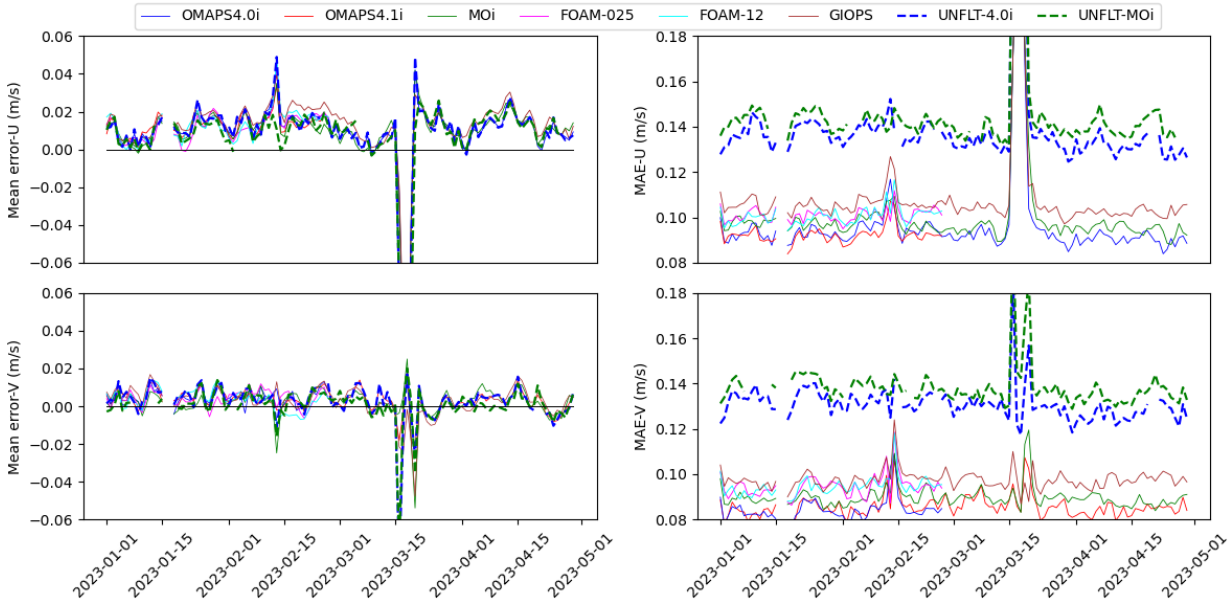


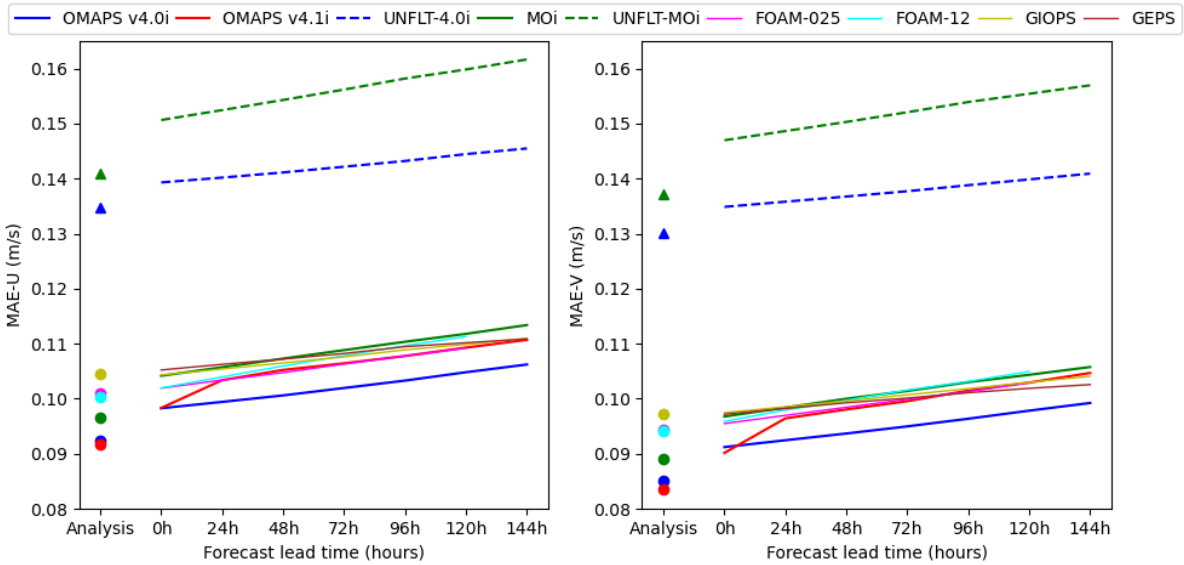
Mean annual error, meridional



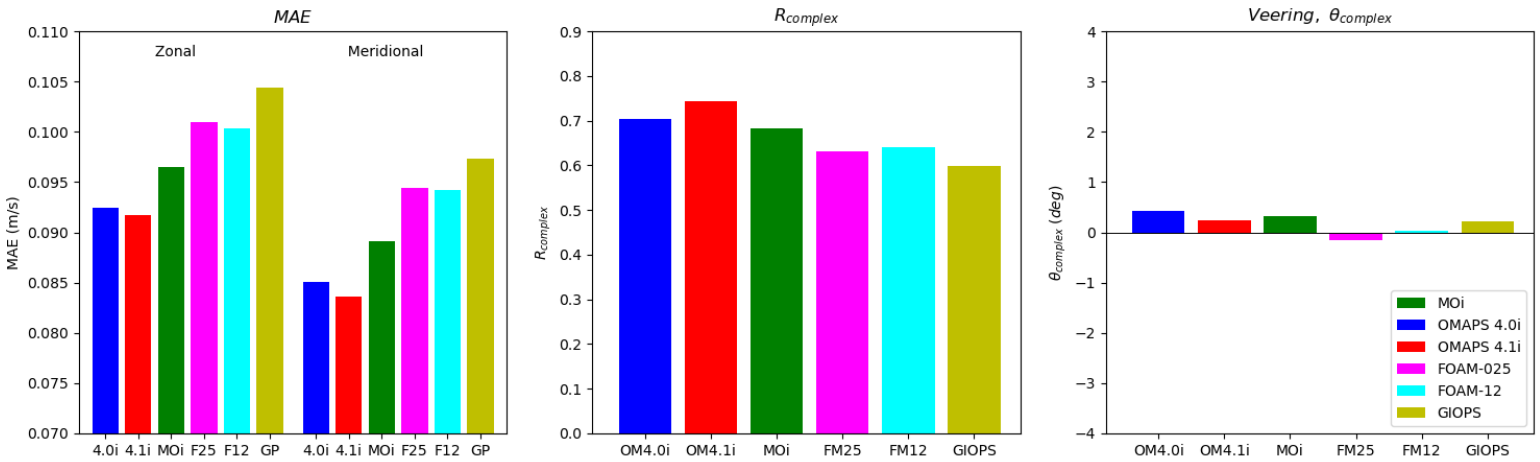
Global statistics- 1 JAN 2023 – 30 APR 2023

MOi-NEMO (GLO12v4), OMAPS 4.0i (unfiltered obs)





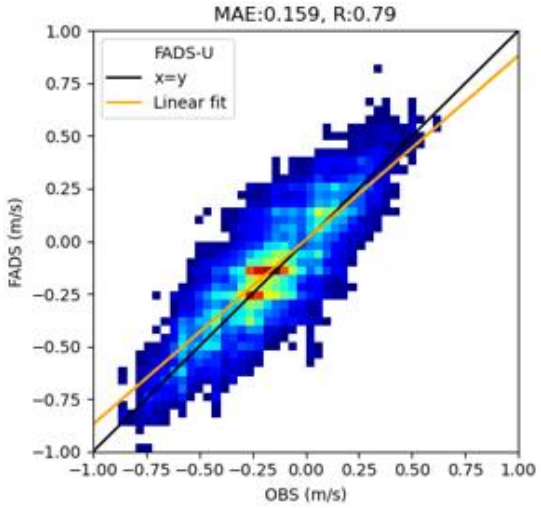
Global, N= 2,304,106

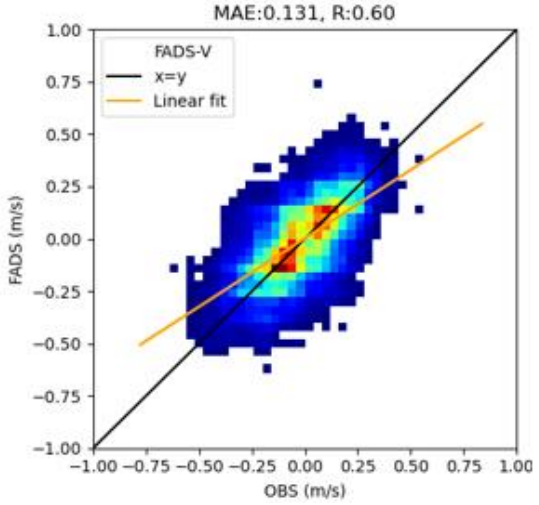


Data period: 1 Jan 2023 –30 April 2023, N=2,304,106

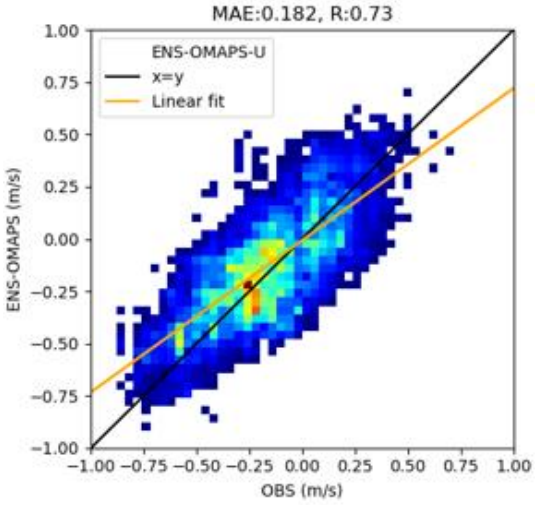
Eulerian verification – FADs in WCPO
1JAN2020-31DEC2020

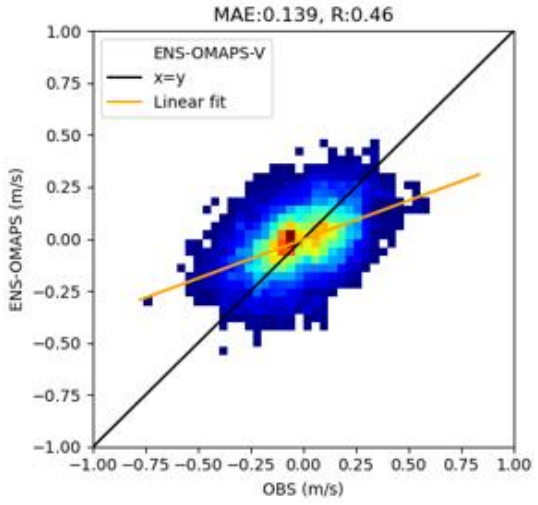
FADs vs GDP



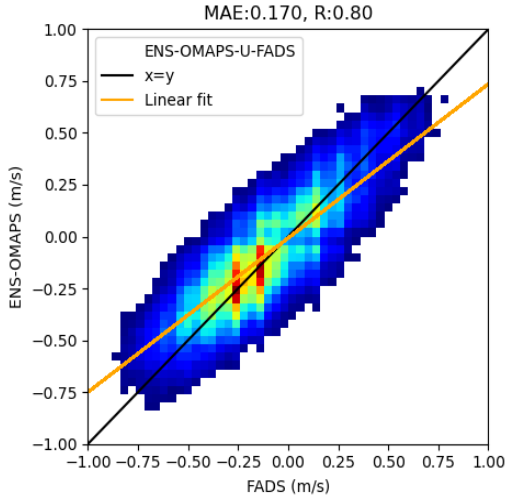


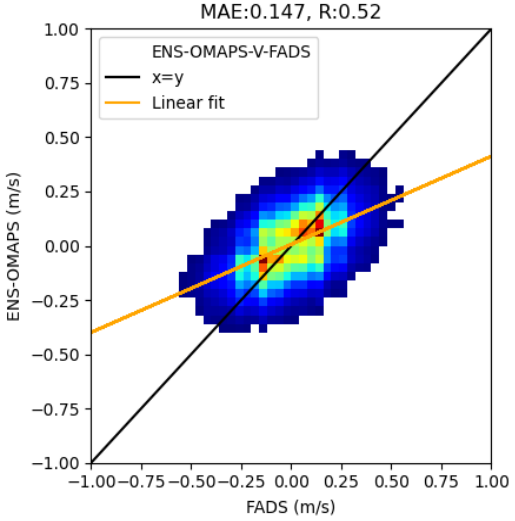
OceanMAPS vs GDP



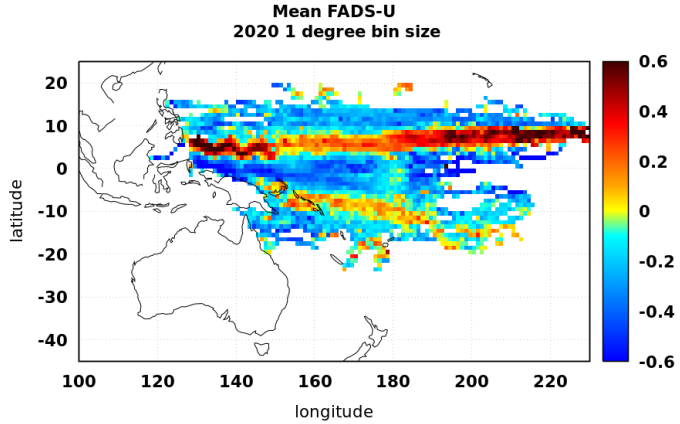


OceanMAPS vs FADs

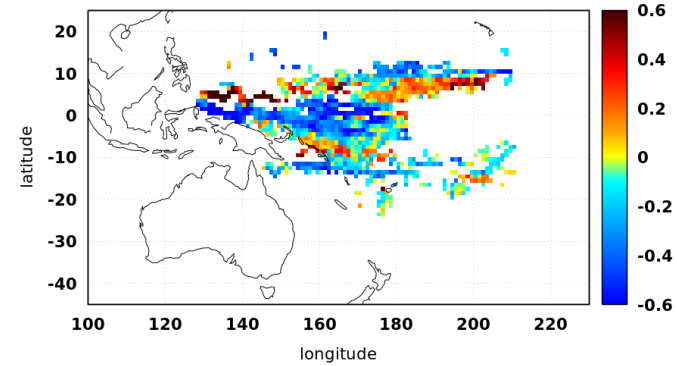




FADs currents



GDP currents



Lagrangian diagnostics

OceanParcels (**P**robably **A** **R**eally **C**omputationally **E**fficient **L**agrangian **S**imulator)

- A set of Python classes and methods to create particle tracking simulations using output from ocean circulation models.
- Velocity fields from OceanMAPS
- Skill (Liu and Weisberg, 2011) of OceanMAPS against GDP vs skill against FADs

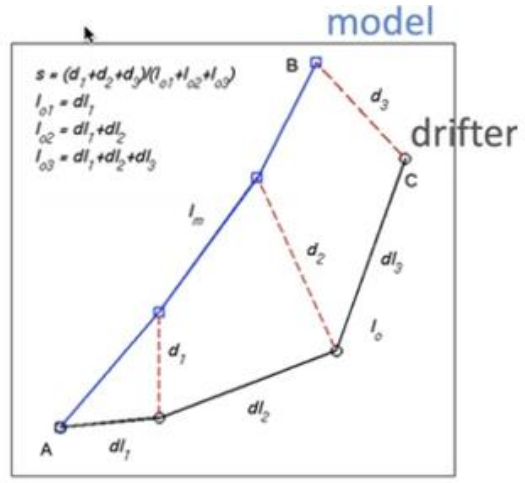
OceanParcels

Liu Index

$$\text{Liu} = \frac{\sum_{i=1}^{N} d_i}{\sum_{i=1}^{N} lo_i}$$

Skill score

$$\text{S} = \begin{cases} 1 - Liu & (Liu \leq 1) \\ 0 & (Liu > 1) \end{cases}$$



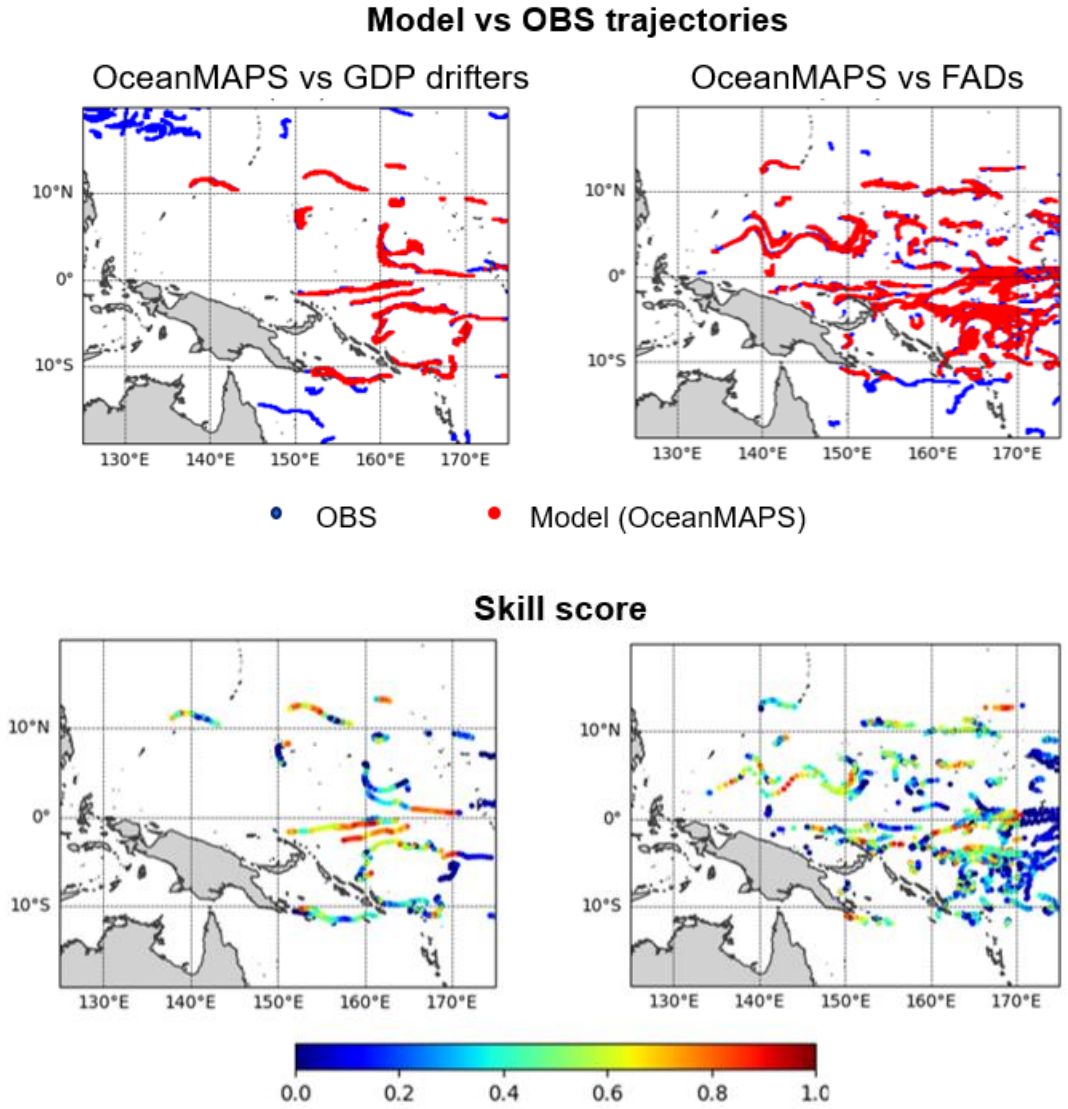
Separation distance

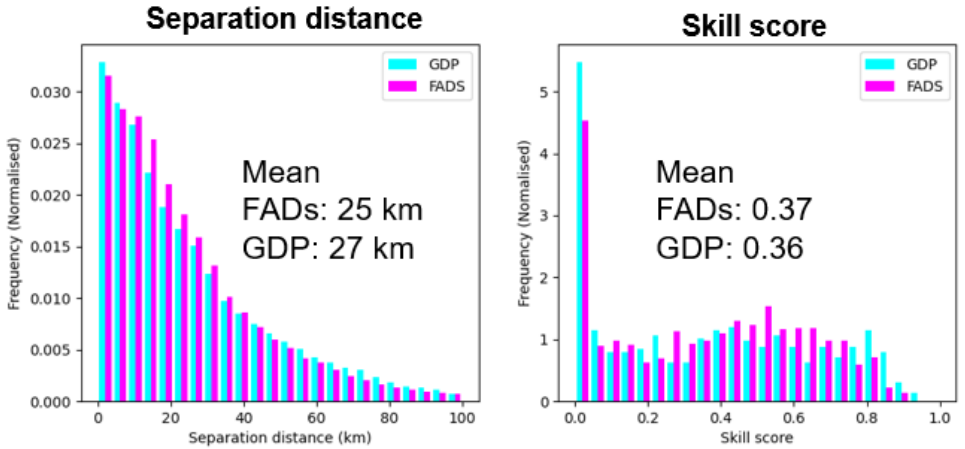
$SD = d_n$ n=nb days drift

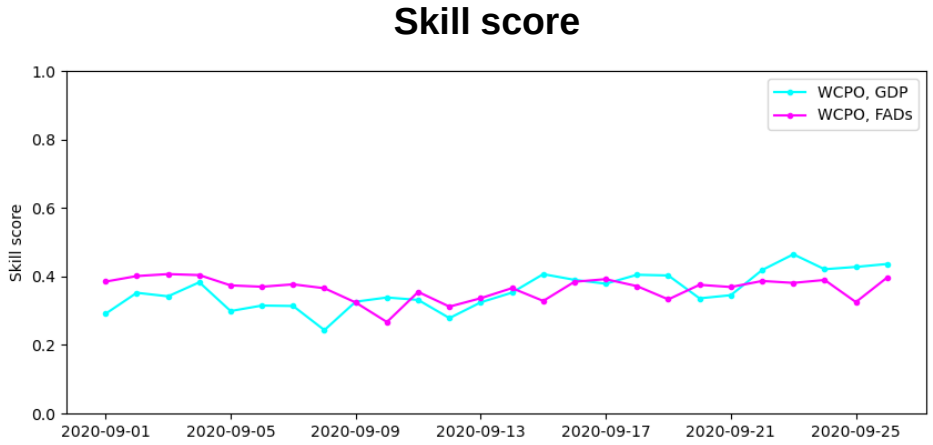
d_i is the separation distance
lo_i is the length of the observed trajectory
N is the number of drifting hours/days

Liu and Weisberg (2011). Evaluation of trajectory modeling in different dynamic regions using normalized cumulative Lagrangian separation, J. Geophys. Res.-Oceans, 116, C09013.

Skill score, OceanMAPS vs GDP/FADs

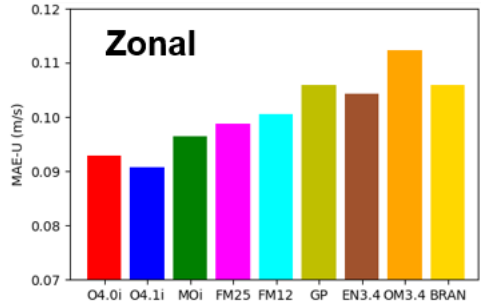


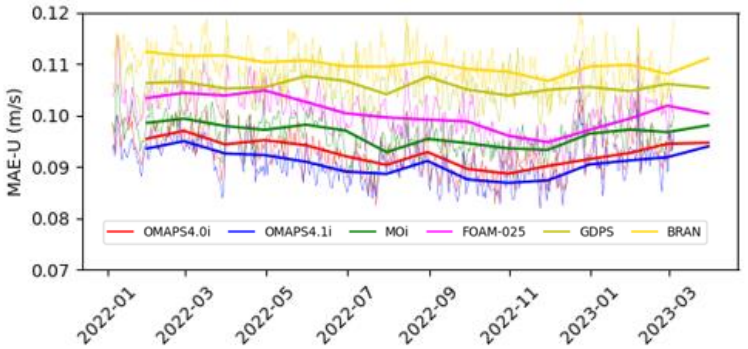


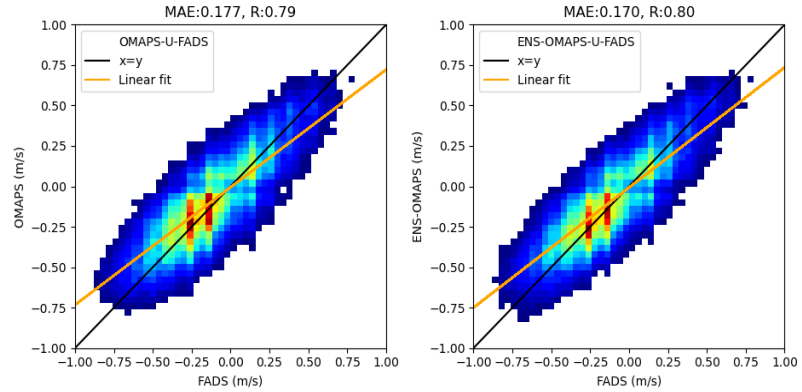


Summary

- OMAPS 4.0i/4.1i currents outperform the high-performing models such as the Mercator Océan MOi, and the Met Office FOAM.
- Remarkable statistical equivalence in all models despite differences in model configurations, DA, interpolations etc.
- Current verification is independent as currents are not assimilated during initialisation or DA process.
- Trends in mean errors and the correlations of FADs currents against the the drifters are consistent with those from OceanMAPS
- Mean separation distances and skill scores of OceanMAPS vs FADs and OceanMAPS vs drifters are remarkably similar.
- Lagrangian diagnostics reveals with coherent physical features.
- FADs provide valuable comparisons and offer potential assimilation applications for ocean and coupled ocean models.
- **Future work**: Assess the impact on ocean current performance from SWOT







The Bureau of Meteorology

Thank you

Saima Aijaz

Saima.Aijaz@bom.gov.au