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Marine and Freshwater Research

Supplementary Material

Finding lobsters: investigating a period of unusually low settlement of *Panulirus cygnus* by using larval dispersal modelling

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Table S1. The proportion of particles considered “not alive” due to leaving the domain, beaching, outside of temperature conditions, and not leaving the shelf for Passive and OVM simulations within Run H.

	2000	**2001**	**2007**	**2008**	**2011**	**2012**
Passive						
Out of domain	0.21	0.22	0.20	0.20	0.22	0.22
Beached	0.24	0.25	0.44	0.33	0.26	0.29
Too hot	0.00	0.00	0.00	0.00	0.00	0.00
Too cold	0.09	0.05	0.07	0.07	0.06	0.07
>15 days to leave the shelf	0.32	0.33	0.23	0.32	0.31	0.27
OVM						
Out of domain	0.19	0.19	0.20	0.20	0.19	0.20
Beached	0.19	0.21	0.38	0.35	0.21	0.24
Too hot	0.00	0.00	0.00	0.00	0.00	0.00
Too cold	0.09	0.05	0.07	0.07	0.06	0.06
>15 days to leave the shelf	0.37	0.35	0.27	0.32	0.35	0.28

Table S2. The proportion of particles considered “not alive” due to leaving the domain, beaching and outside of temperature conditions within Run O.

	2000	**2001**	**2007**	**2008**	**2011**	**2012**
Out of domain	0.48	0.39	0.35	0.32	0.34	0.31
Beached	0.06	0.03	0.01	0.05	0.03	0.05
Too hot	0.03	0.02	0.01	0.03	0.04	0.03
Too cold	0.02	0.02	0.02	0.01	0.01	0.01

Table S3. The proportion of particles considered “not alive” due to leaving the domain, beaching, outside of temperature conditions, and not reaching the nearshore within 21 days for passive, 0.05, 0.1 and 0.15 m s^{-1} within Run S.

	2000	**2001**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Passive								
Out of domain	0.61	0.76	0.69	0.76	0.78	0.69	0.63	0.71
Too hot	0.05	0.05	0.1	0.09	0.01	0.06	0.04	0.01
Too cold	0.24	0.15	0.11	0.07	0.12	0.16	0.18	0.2
<21 days to reach the nearshore	0.06	0.01	0.04	0.03	0.02	0.04	0.09	0.03
0.05 m s^{-1}								
Out of domain	0.51	0.62	0.57	0.64	0.63	0.48	0.53	0.64
Too hot	0.05	0.02	0.1	0.06	0.02	0.06	0.09	0.04
Too cold	0.17	0.07	0.11	0.07	0.12	0.15	0.07	0.08
<21 days to reach the nearshore	0.06	0.07	0.04	0.07	0.02	0.09	0.08	0.04
0.1 m s^{-1}								
Out of domain	0.47	0.58	0.52	0.57	0.62	0.48	0.51	0.62
Too hot	0.05	0.01	0.1	0.1	0.02	0.08	0.05	0.04
Too cold	0.16	0.06	0.11	0.07	0.09	0.14	0.08	0.06
<21 days to reach the nearshore	0.06	0.07	0.04	0.03	0.01	0.04	0.1	0.04
0.15 m s^{-1}								
Out of domain	0.47	0.58	0.52	0.57	0.61	0.48	0.51	0.62
Too hot	0.05	0.02	0.1	0.09	0.02	0.08	0.06	0.05
Too cold	0.16	0.07	0.11	0.07	0.09	0.14	0.09	0.06
<21 days to reach the nearshore	0.07	0.08	0.04	0.03	0.04	0.05	0.1	0.04

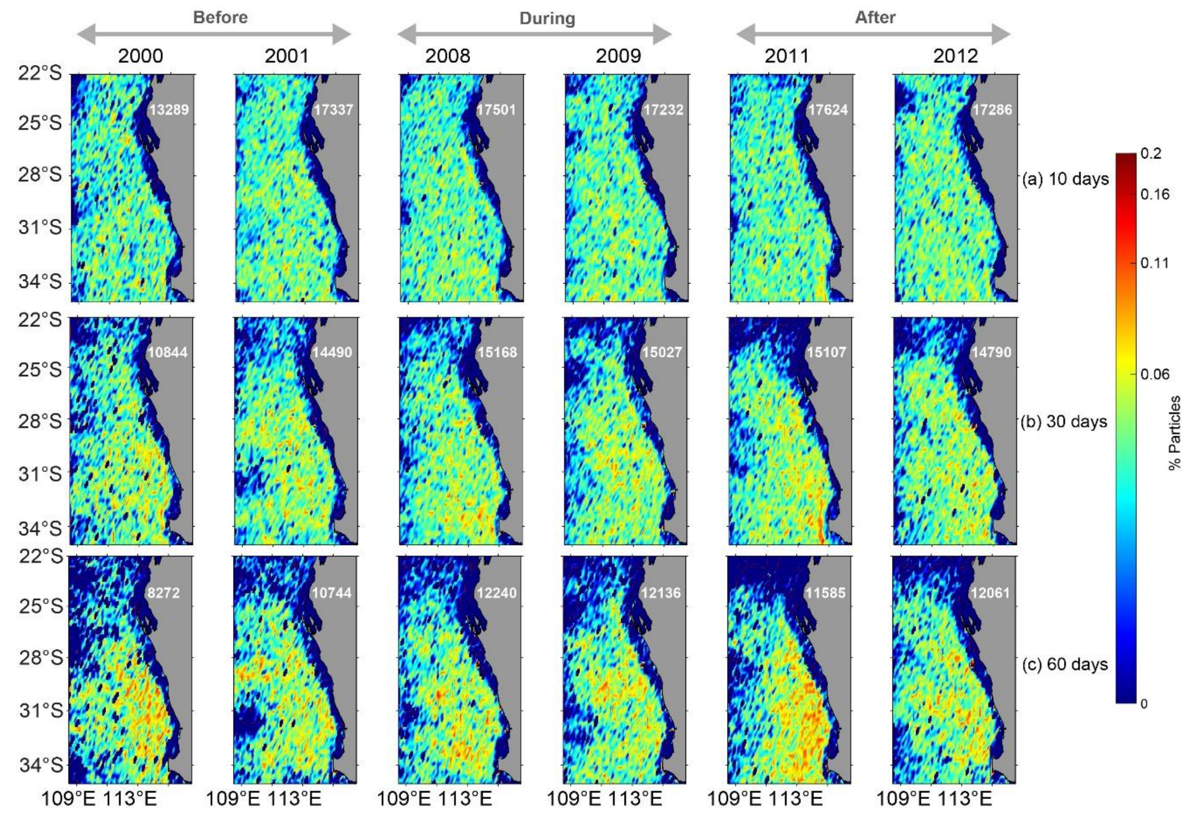


Figure S1. Distribution of particles (assumed mid-stage phyllosoma) after (a) 10 (b) 30 and (c) 60 days of particle tracking with passive transport (Run O). White values indicate the number of active particles used for the associated figure.

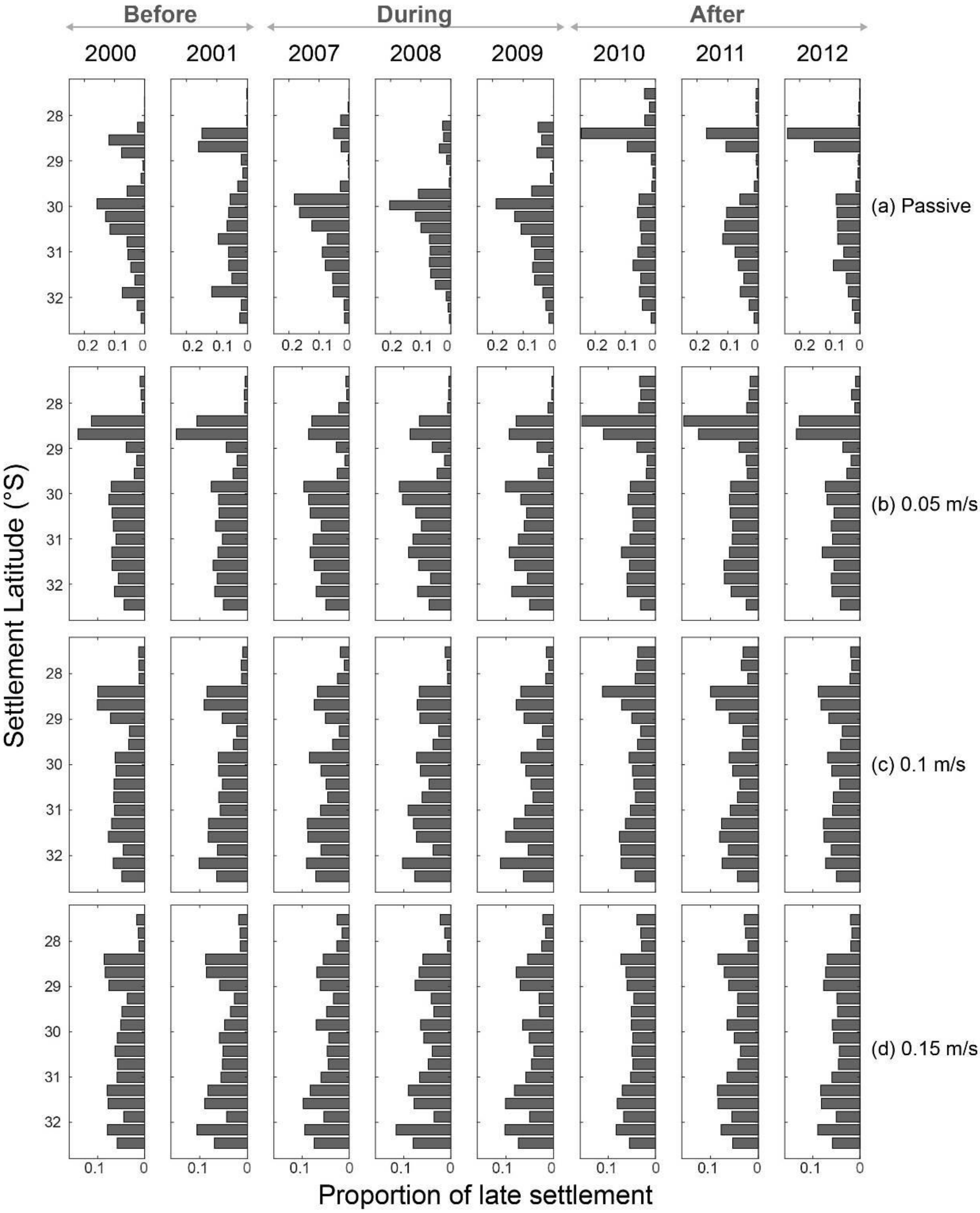


Figure S2. Settlement latitudes for successfully settled particles in the late portion of the season (Run S). Late settlement is the successful settlement between November and March. (a) Passively transported particles; and swimming particles at (b) 0.05 m s^{-1}; (c) 0.1 m s^{-1}; (d) 0.15 m s^{-1}.

Table S4. Pairwise test results for the latitudinal shift data for all pairs within Location and Timing.

Pairwise tests		*t*	*P*
North	Early *v.* Late	0.47	0.68
	Before *v.* During	5.88	**0.009** (MC)
	Before *v.* After	3.99	**0.026** (MC)
	During *v.* After	2.38	0.074 (MC)
South	Early *v.* Late	4.51	**0.005**
	Before *v.* During	8.15	**0.003** (MC)
	Before *v.* After	7.02	**0.006** (MC)
	During *v.* After	0.23	0.819 (MC)
Early	North *v.* South	6.63	**0.003**
Late	North *v.* South	6.54	**0.003**
Before	North *v.* South	5.13	0.122 (MC)
During	North *v.* South	7.51	**0.017** (MC)
After	North *v.* South	4.04	**0.048** (MC)

P(MC) are *P* values based on Monte Carlo bootstrapping and were used where the number of unique permutations was <100.

Extended Validation

Here we further expanded ozROMS validation. The observations obtained in the study region are compared with ozROMS results. This extended validation aims to ensure the accuracy of the predicted high-resolution velocity fields used in particle tracking simulation.

Comparison of Two Rocks radar and ozROMS surface currents.

Three years (2015–2017) of quality control radar measurements collected at the Two Rocks are compared with the results of ozROMS. In order to quantify the skills of surface velocity components between radar measurements and model data, RMSE and skill levels (Wilmot 2012) were used. The model data is interpolated in the radar grid points. An example of time series extracted at the radar grid point from the model is shown in Figure S3. It is shown that the model reproduces well the seasonal cycle of currents. The statistics of surface current component comparisons from 3 years data set are shown in Figure S4. The spatial distribution of the RMSE computed between the radar data and ozROMS across the radar coverage indicated small RMSE values (<0.05 m s^{-1}) in the region. The Skill level results show the same pattern as the RMSE. The skill levels (Wilmot 2012) are higher than 0.6 in the radar coverage.

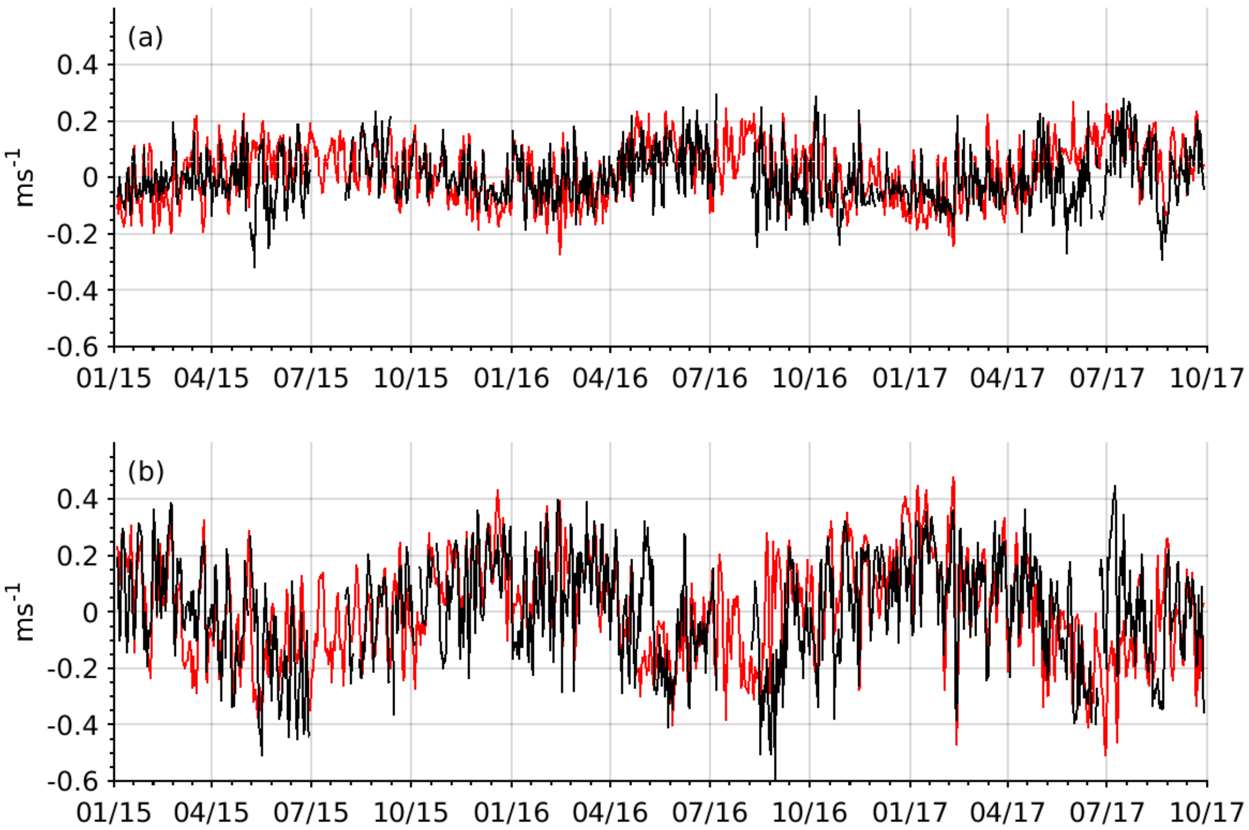


Figure S3: Comparison of the radar measured (black) and ozROMS (red) predicted surface currents at 115.0369°E and 30.8772°S.

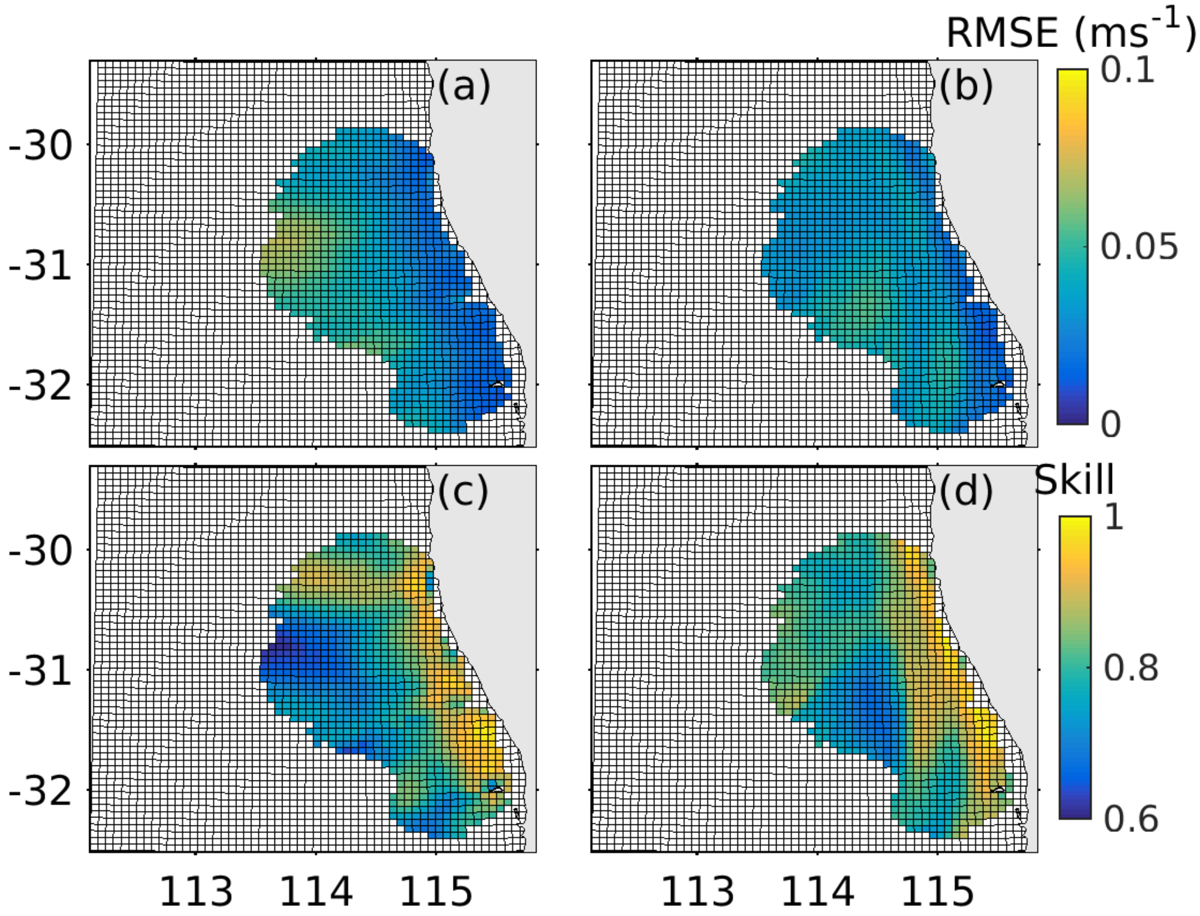


Figure S4. (a, b) Route mean square error (RMSE) between radar and ozROMS velocity components in east-west and north–south respectively. (c, d) Skill between radar and ozROMS velocity components in east–west and north–south respectively.

Comparison of Two Rocks ADCP mooring data and ozROMS current profiles

Current measurements from ADCP deployments off Two Rocks during 2010–2015 were used to evaluate the ozROMS results. Example of comparison between measured and ozROMS currents at different depths in 2011 and 2012 are shown in Figures S5 and S6 respectively. Regression plot including RMSE and Skill levels estimated at different depth using all moorings are shown in Figure S5. The root mean square error (RMSE) between the ozROMS and ADCP were <0.1 m s^{-1} for all depth levels. Skill levels are greater than 0.8 at all depths. Skill levels are slightly low in east–west current component compared to north–south component.

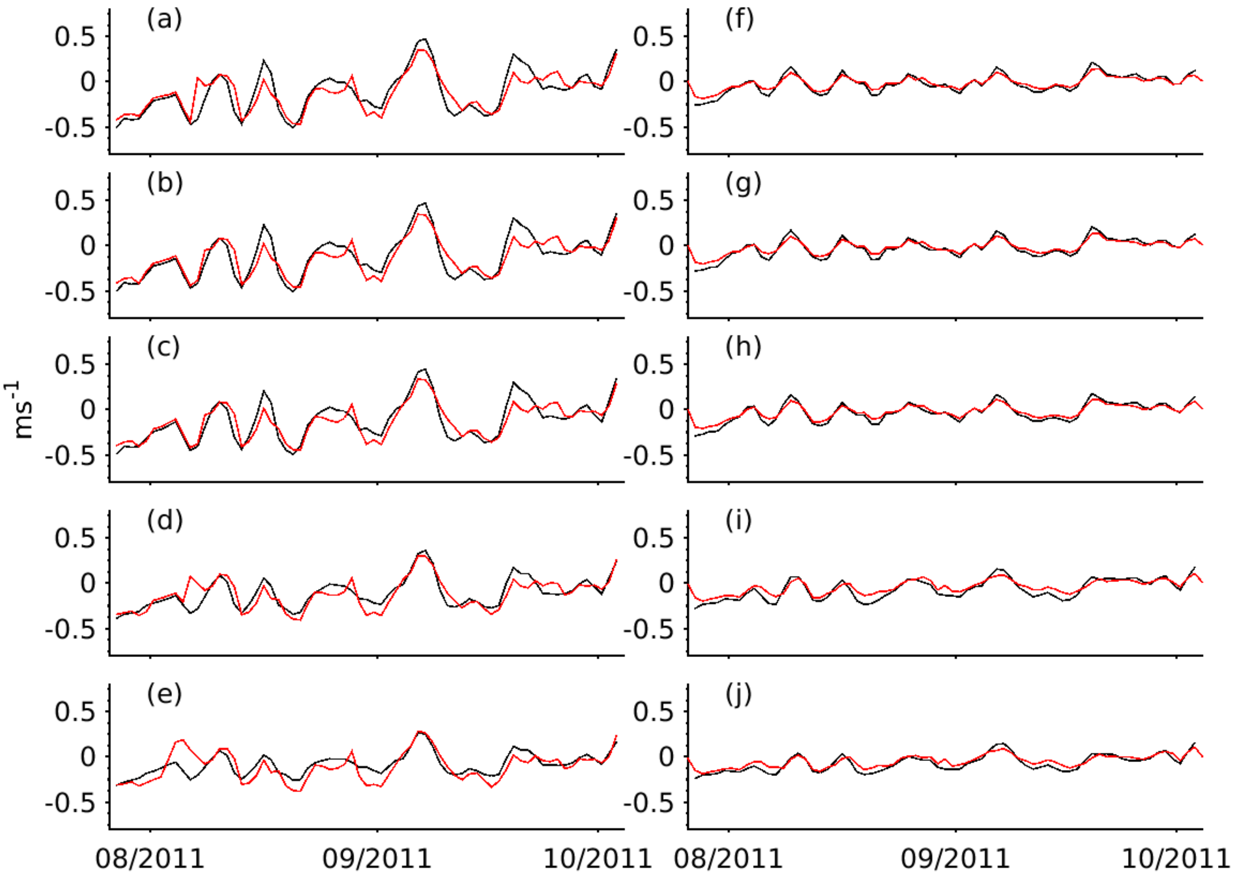


Figure S5: Comparison of the current mooring (black) and ozROMS (red) predicted north–south (a–e) and east–west (f–j) velocity components at different depths (mooring location 115.416°E, 32.000°S) for depth at (a, f) 8 m; (b, g) 11 m; (c, h) 16 m; (d, i) 32 m; and (e, j) 40 m.

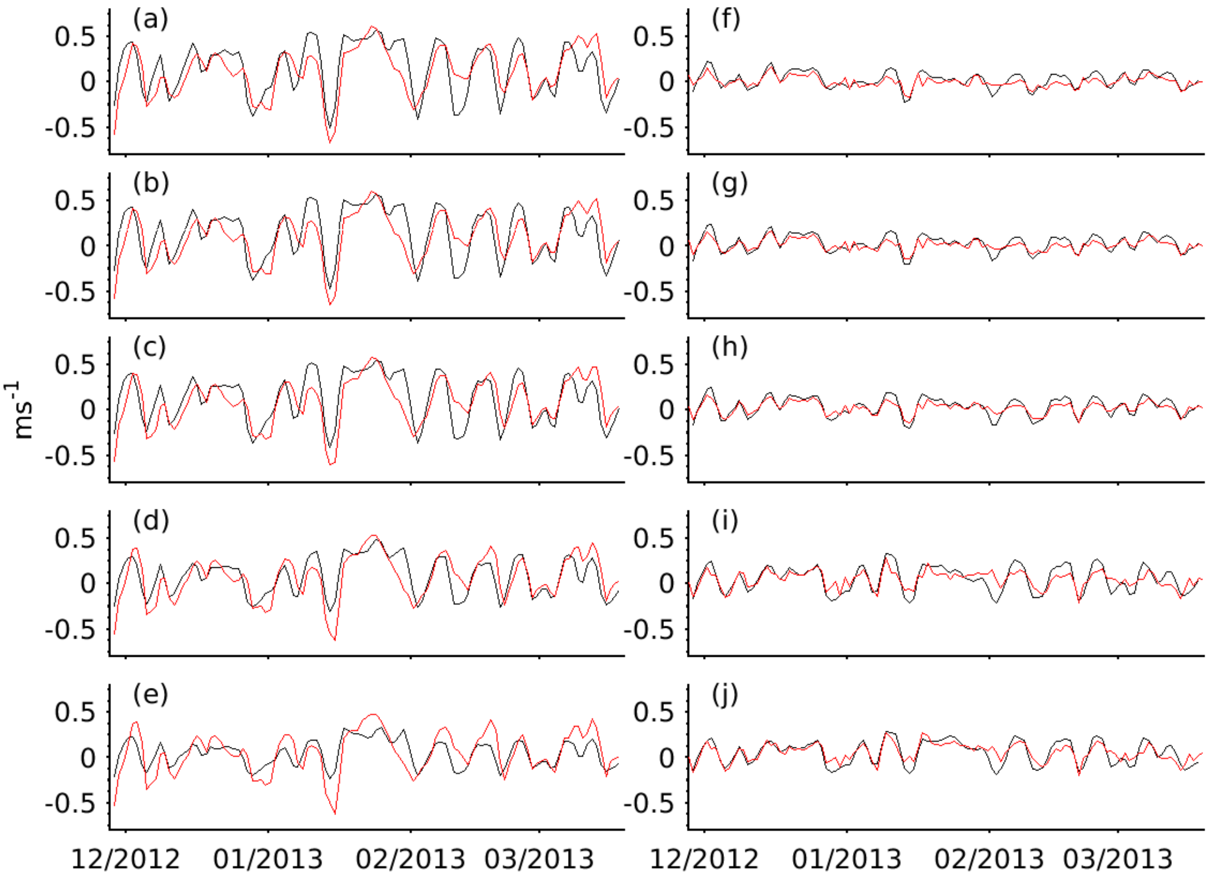
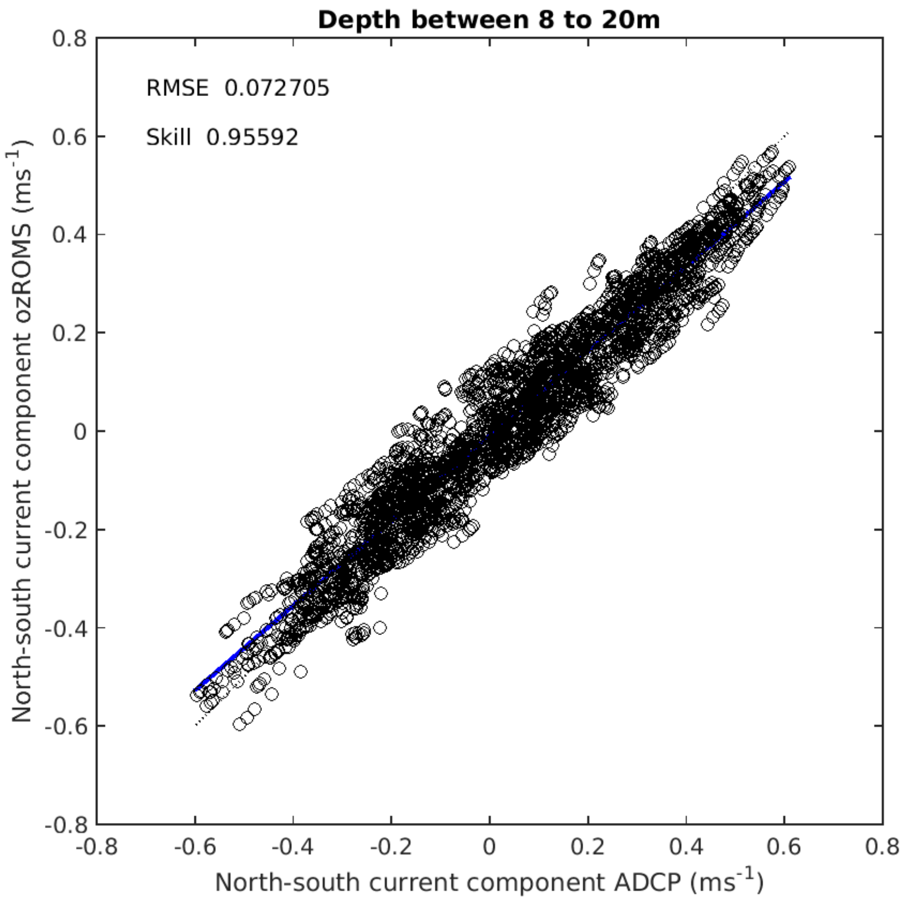
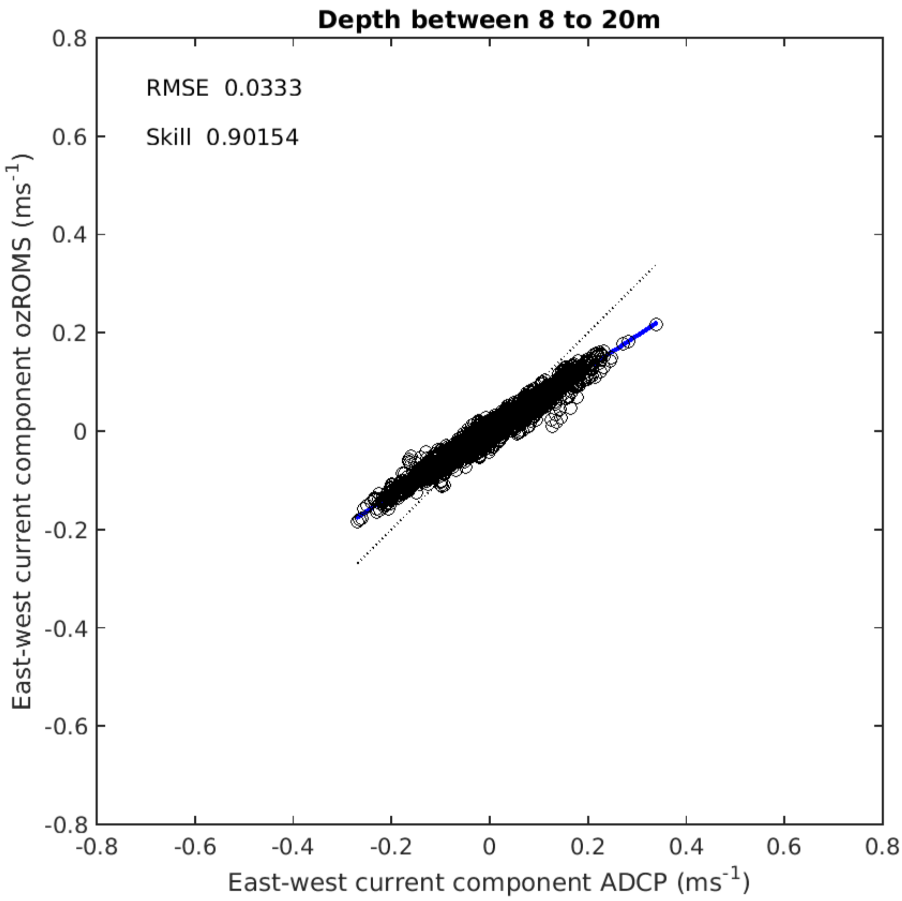
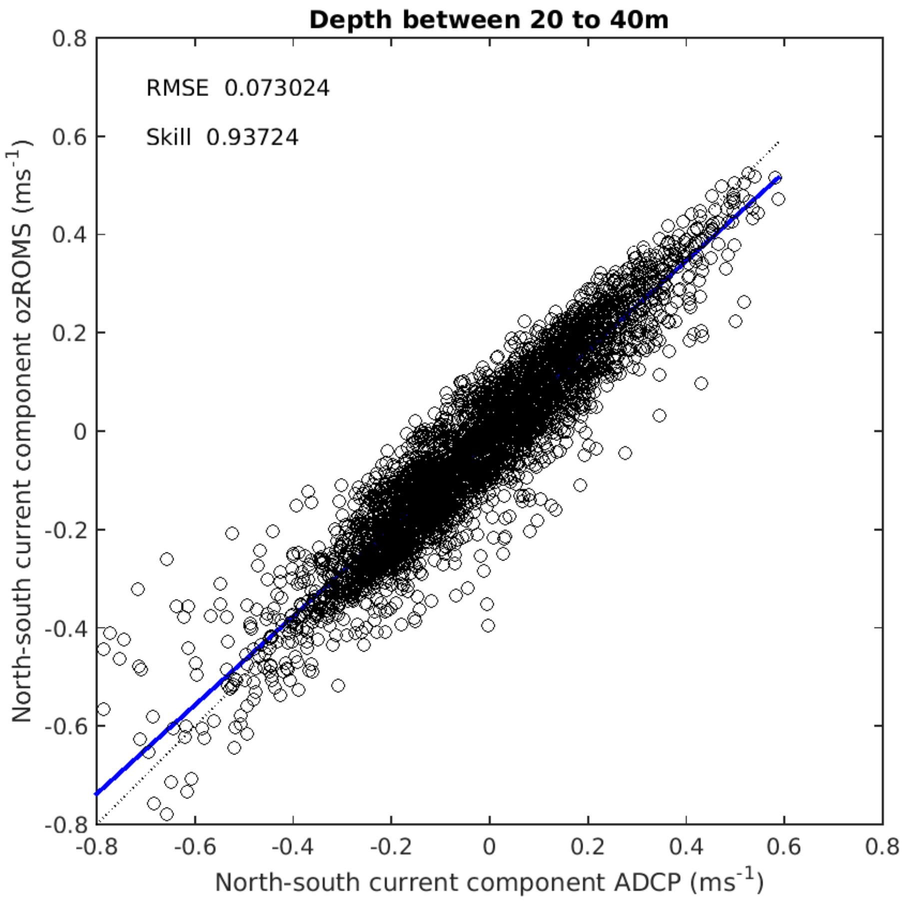
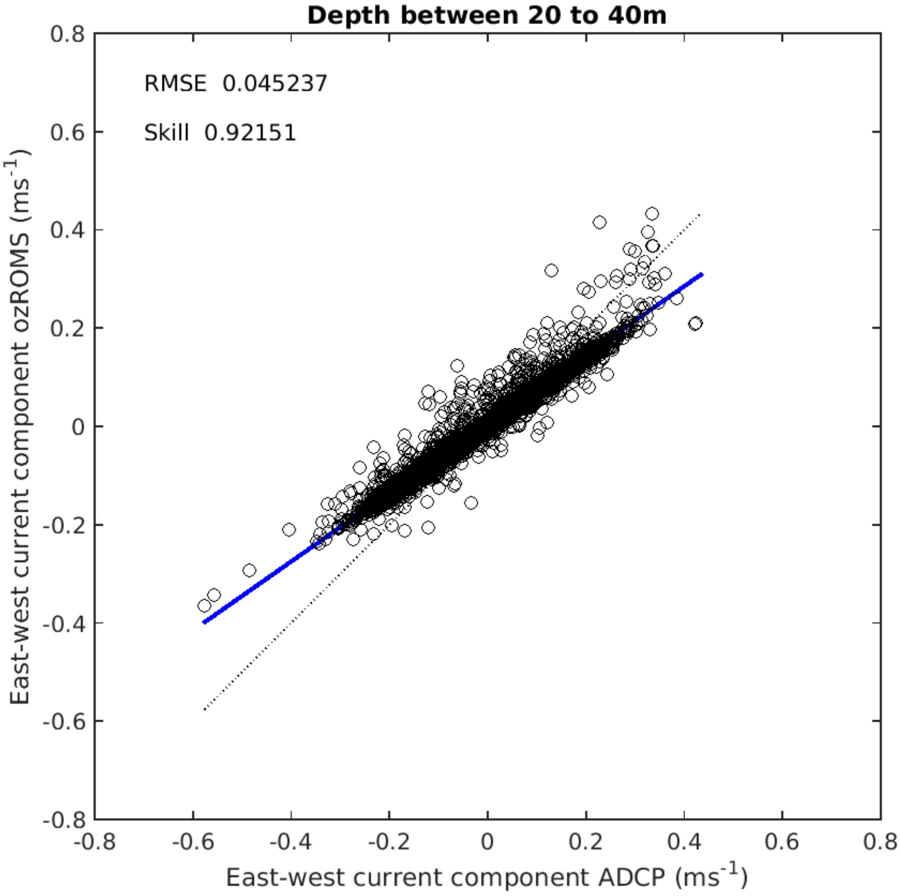


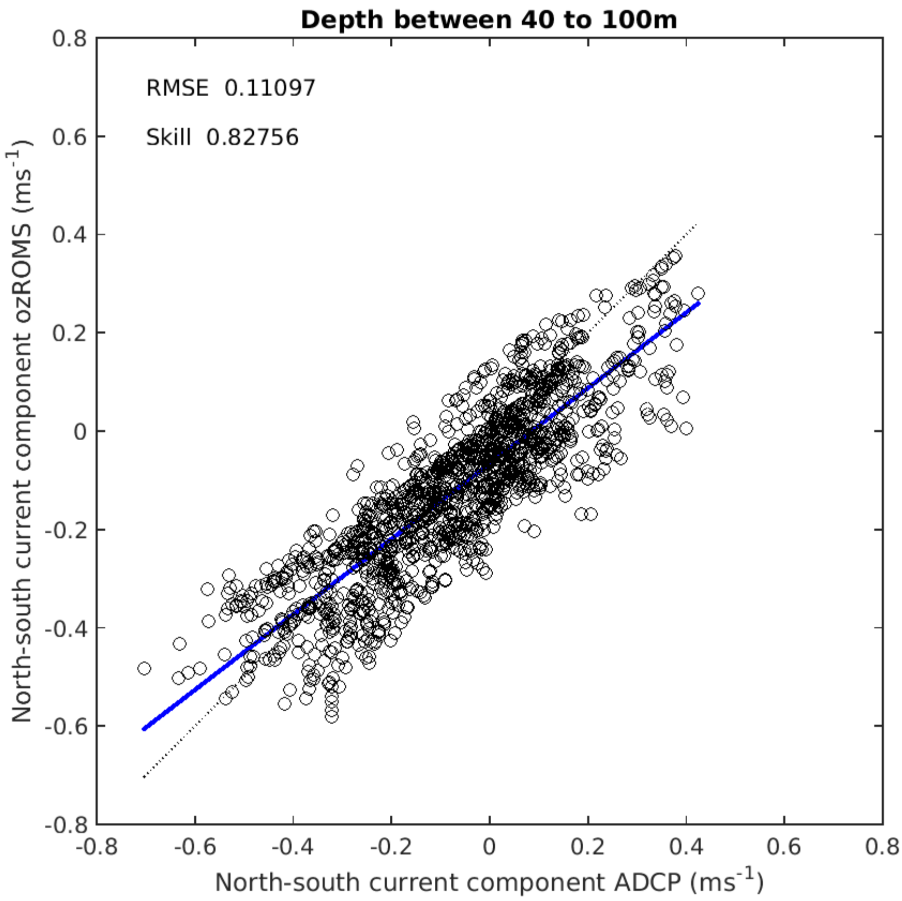
Figure S6: Comparison of the current mooring (black) and ozROMS (red) predicted north–south (a–e) and east–west (f–j) velocity components at different depths (mooring location 115.402°E, 32.000°S). for depth at (a, f) 8 m; (b, g) 11 m; (c, h) 16 m; (d, i) 32 m; and (e, j) 40 m.


Depth between 8 to 20m
RMSE 0.072705
Skill 0.95592
North-south current component ozROMS (ms-1)
North-south current component ADCP (ms-1)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

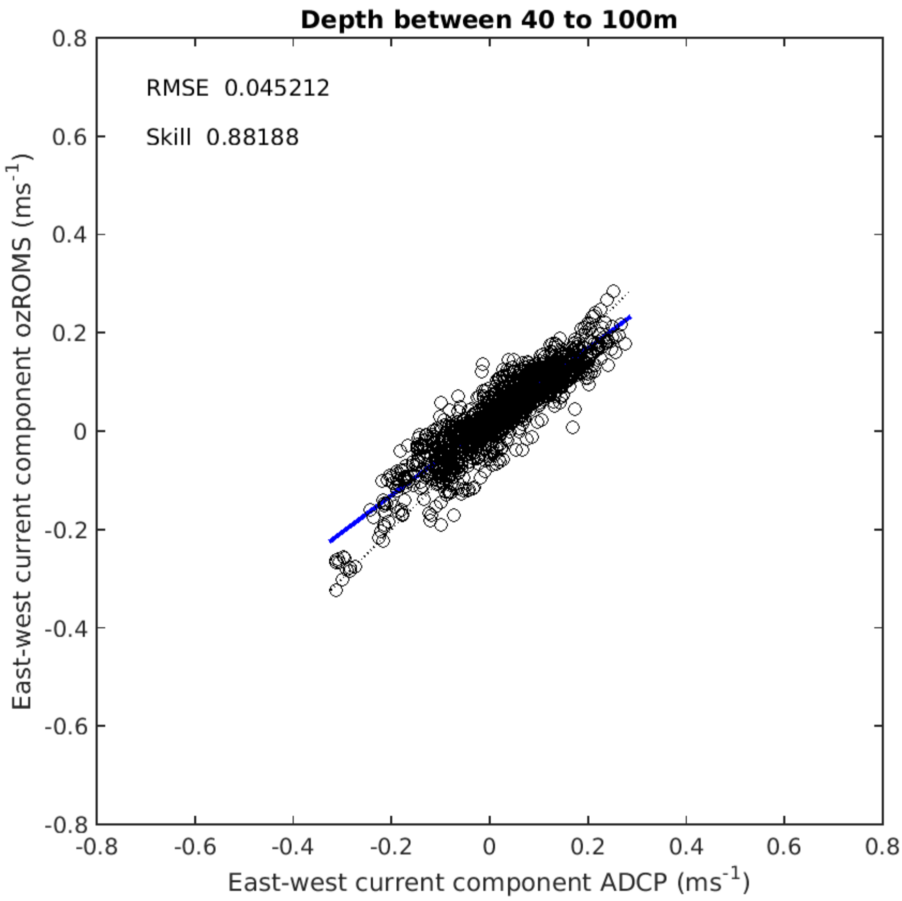

Depth between 8 to 20m
RMSE 0.0333
Skill 0.90154
East-west current component ozROMS (ms-1)
East-west current component ADCP (ms-1)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8

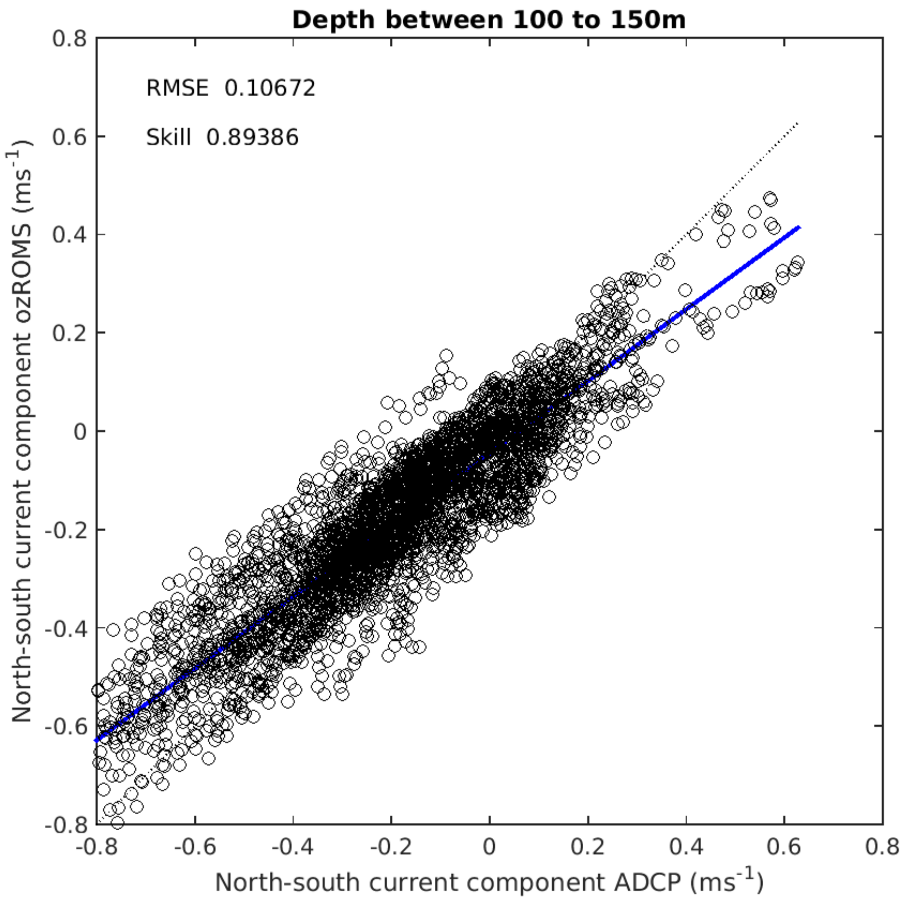

Depth between 20 to 40m
RMSE 0.073024
Skill 0.93724
North-south current component ozROMS (ms^{-1})
North-south current component ADCP (ms^{-1})
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8


Depth between 20 to 40m
RMSE 0.045237
Skill 0.92151
East-west current component ozROMS (ms-1)
East-west current component ADCP (ms-1)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

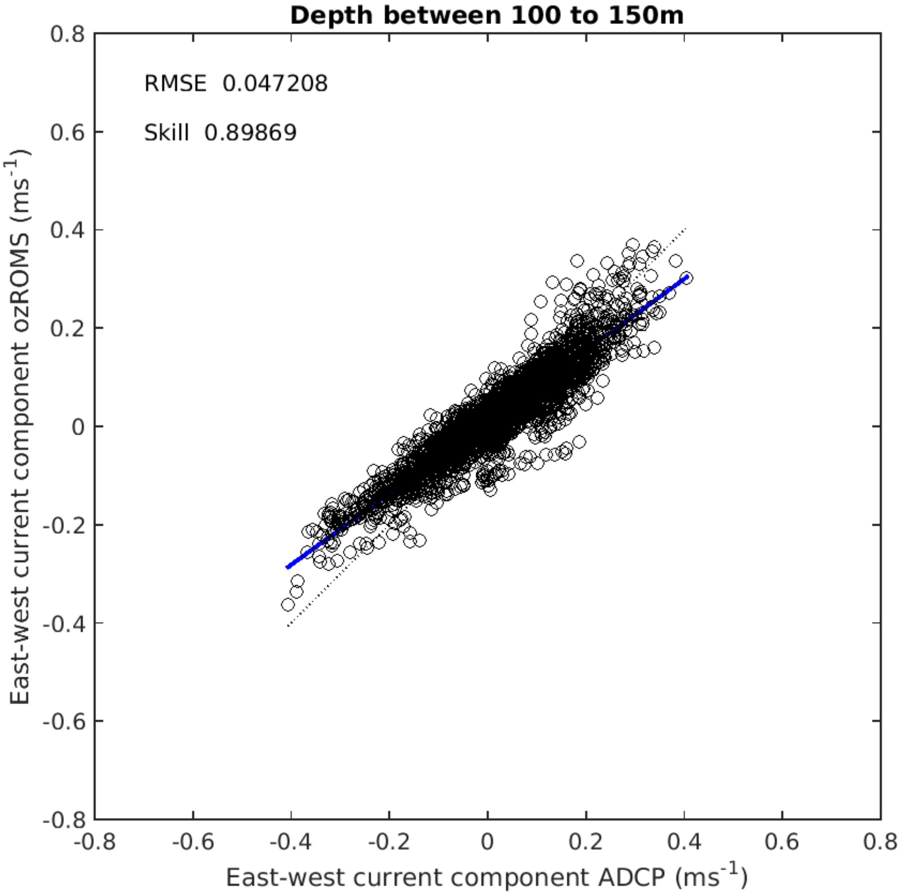


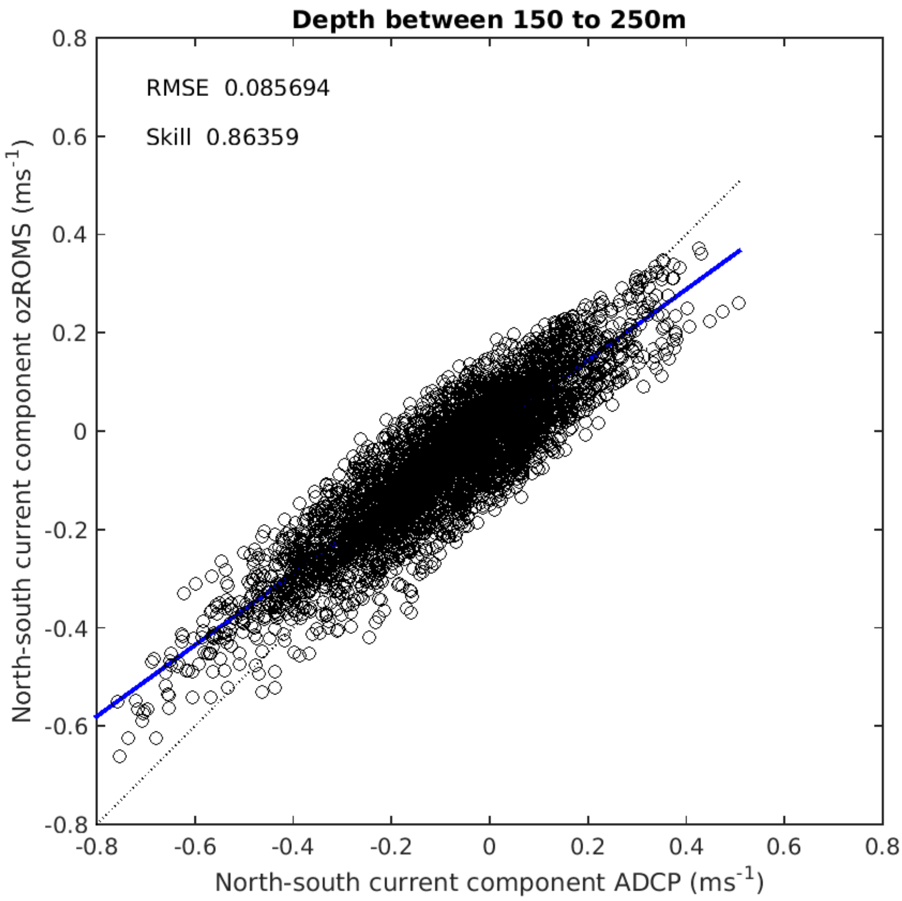
Depth between 40 to 100m
RMSE 0.11097
Skill 0.82756
North-south current component ozROMS (ms-1)
North-south current component ADCP (ms-1)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8


Depth between 40 to 100m
RMSE 0.045212
Skill 0.88188
East-west current component ozROMS (ms^{-1})
East-west current component ADCP (ms^{-1})
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8



Depth between 100 to 150m
RMSE 0.10672
Skill 0.89386
North-south current component ozROMS (ms^{-1})
North-south current component ADCP (ms^{-1})
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8


Depth between 100 to 150m
RMSE 0.047208
Skill 0.89869
East-west current component ozROMS (ms^{-1})
East-west current component ADCP (ms^{-1})
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8



Depth between 150 to 250m
RMSE 0.085694
Skill 0.86359
North-south current component ozROMS (ms-1)
North-south current component ADCP (ms-1)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8

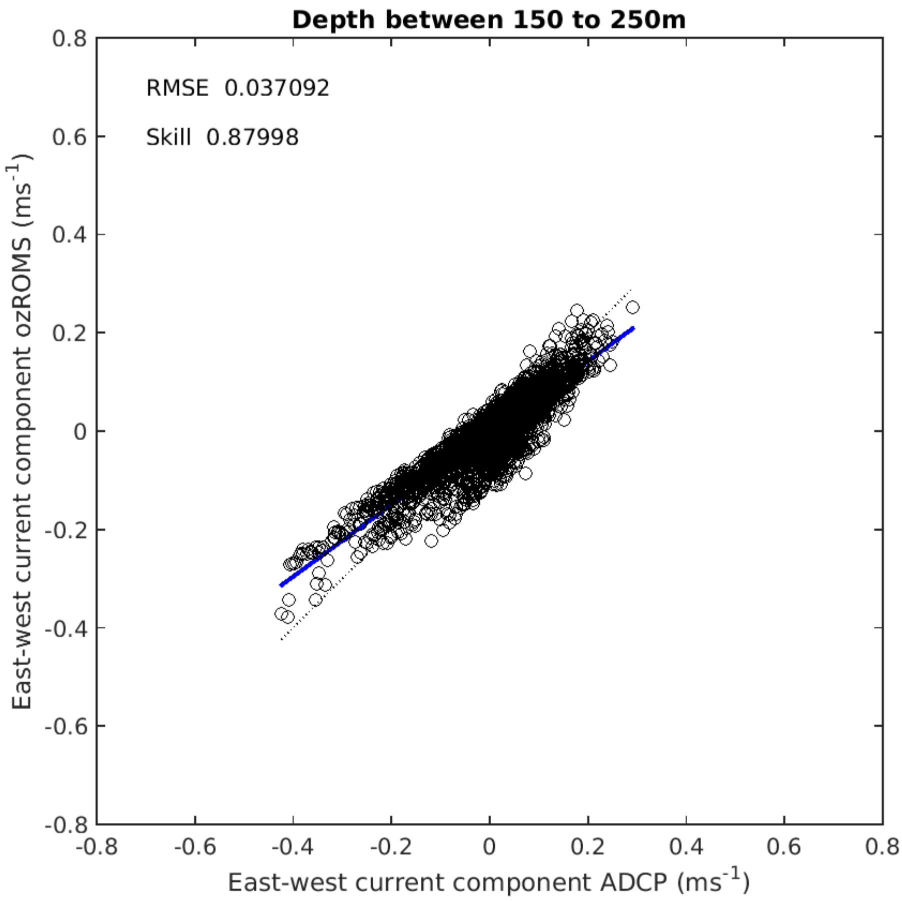
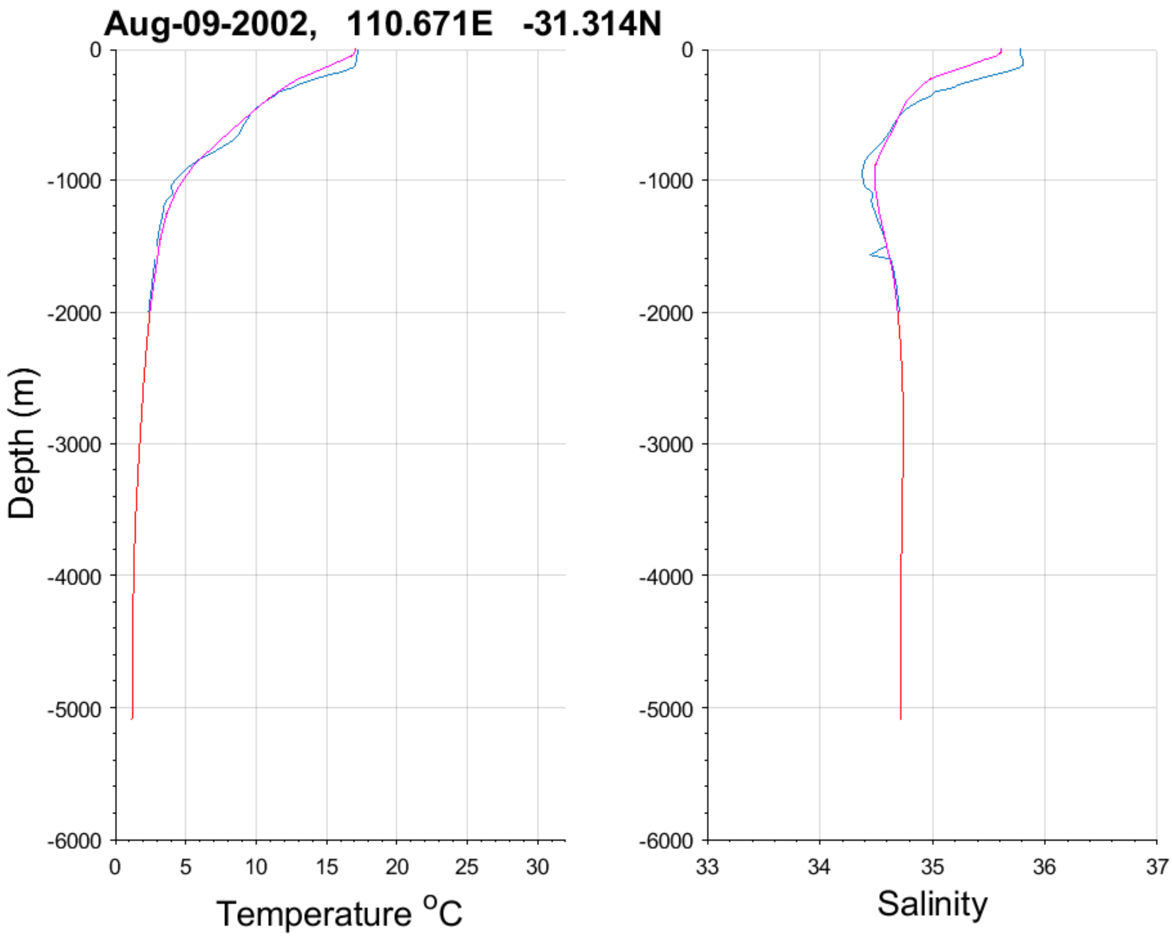


Figure S7: Statistical representation of mooring data and ozROMS north–south and east–west (f–j) velocity components at different depths.

Comparison of ARGO and ozROMS predicted salinity and temperature profiles.

Temperature and salinity profiles extracted from all individual ARGO from 2000 to 2017 compared with ozROMS profiles. The ozROMS profiles were interpolated into ARGO profiles depths, example of profiles are shown on Figure S8. The spatial distribution of RMSE, skill levels and bias are shown in Figures S9 and S11 respectively. The simulated profiles indicated a good correspondence with the Argo profiles (RMSE for temperature and salinity <1.5°C and <0.45). Skill levels for both temperature and salinity are greater than 0.95 for majority of profile coverage. The estimated bias varies from –0.9 to 0.6 for temperature and –0.25 to 0.25 for salinity.


Aug-09-2002, 110.671E -31.314N
Depth (m)
0
-1000
-2000
-3000
-4000
-5000
-6000
0 5 10 15 20 25 30
Temperature °C
33 34 35 36 37
Salinity

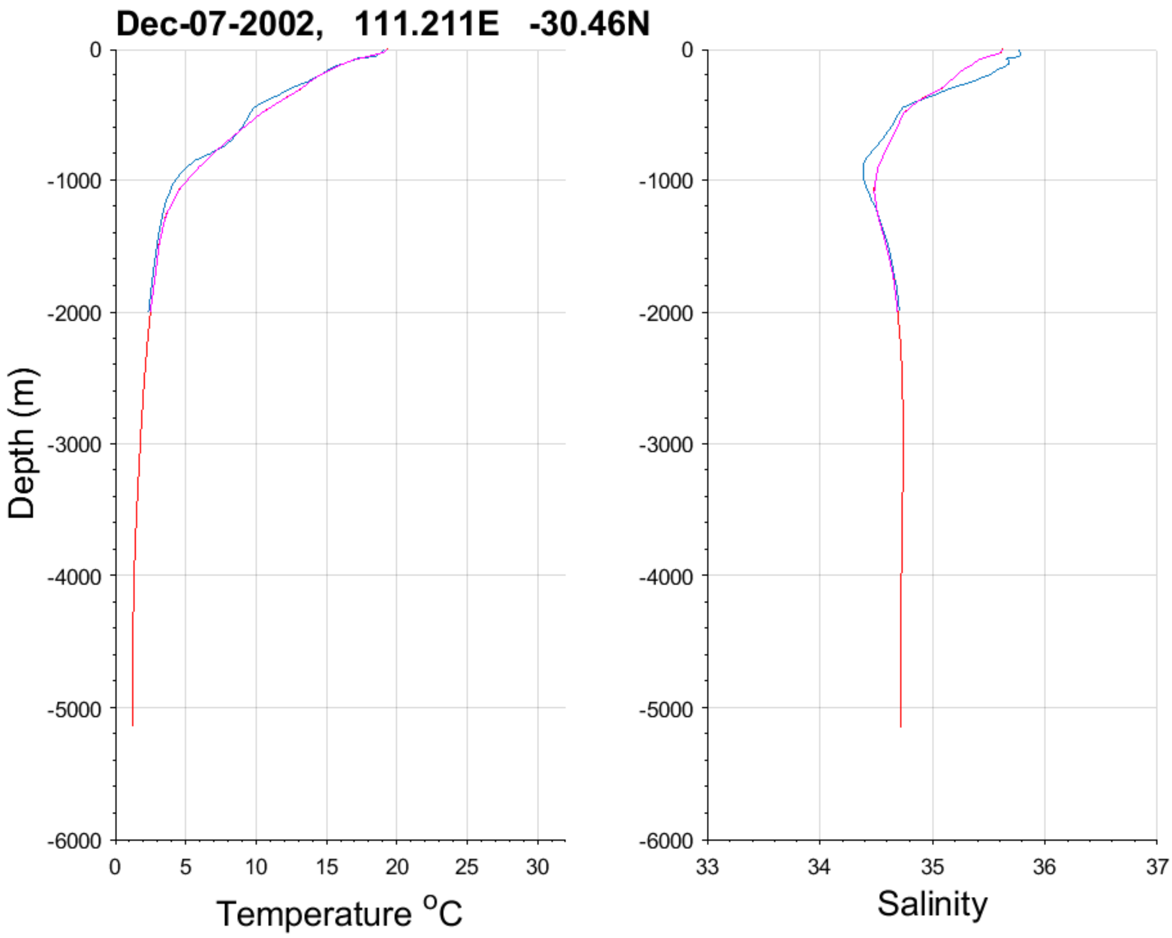


Figure S8: Temperature and salinity profiles. ARGO profile data in blue and ozROMS profile in red. OzROMS interpolated into ARGO depths are in purple.

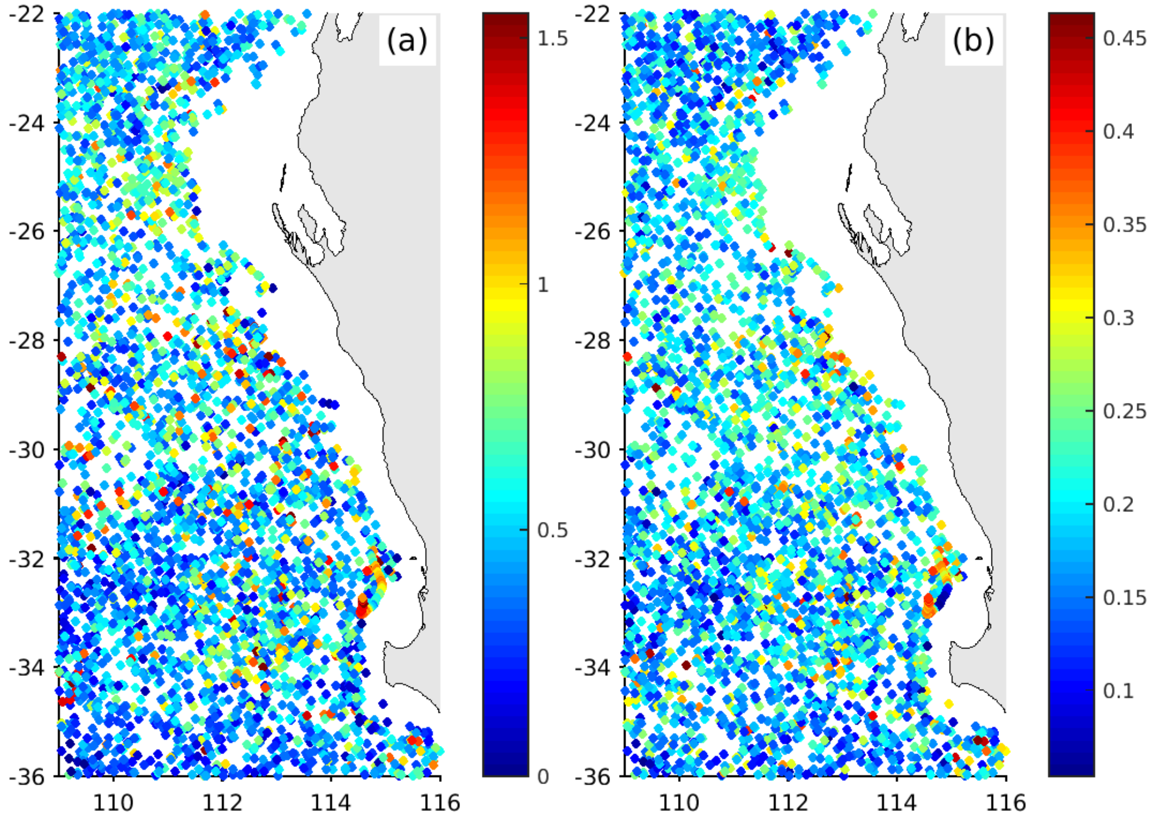


Figure S9: Spatial distribution RMSE of temperature (a) and salinity (b) estimated using ozROMS and ARGO depth profiles.

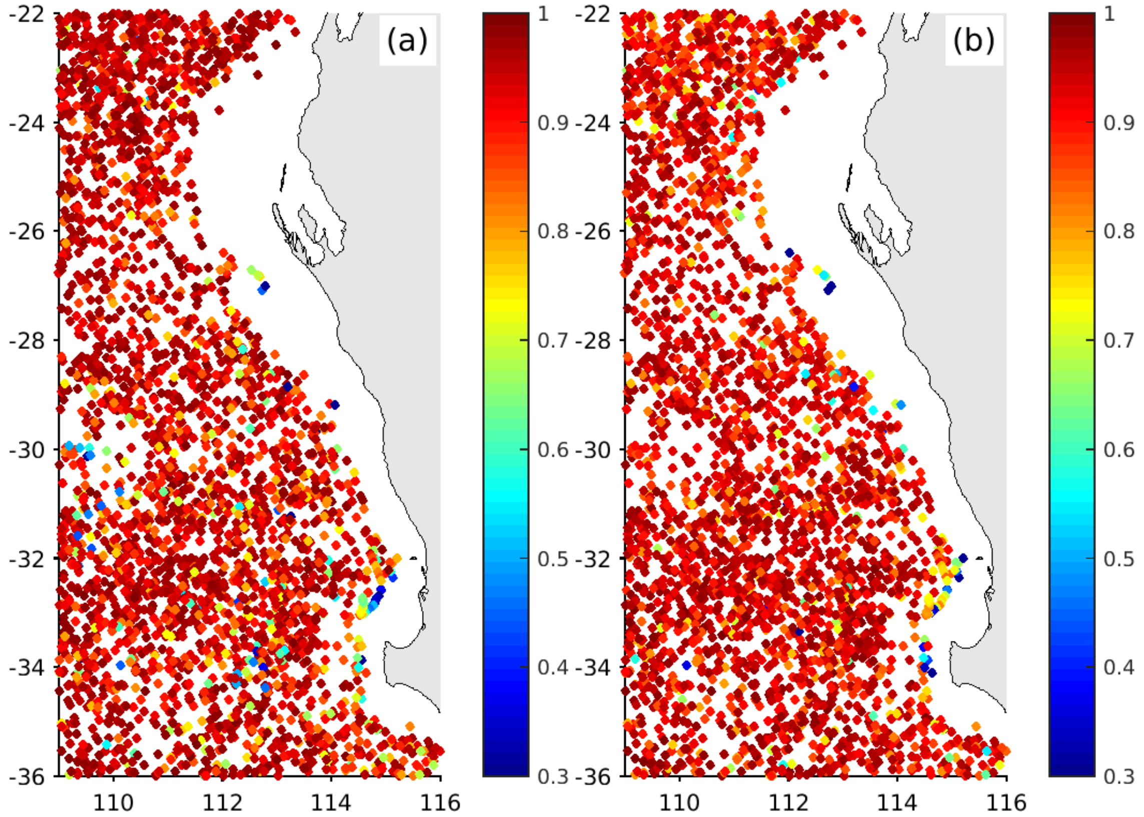


Figure S10: Spatial distribution skill levels of temperature (a) and salinity (b) estimated using ozROMS and ARGO depth profiles.

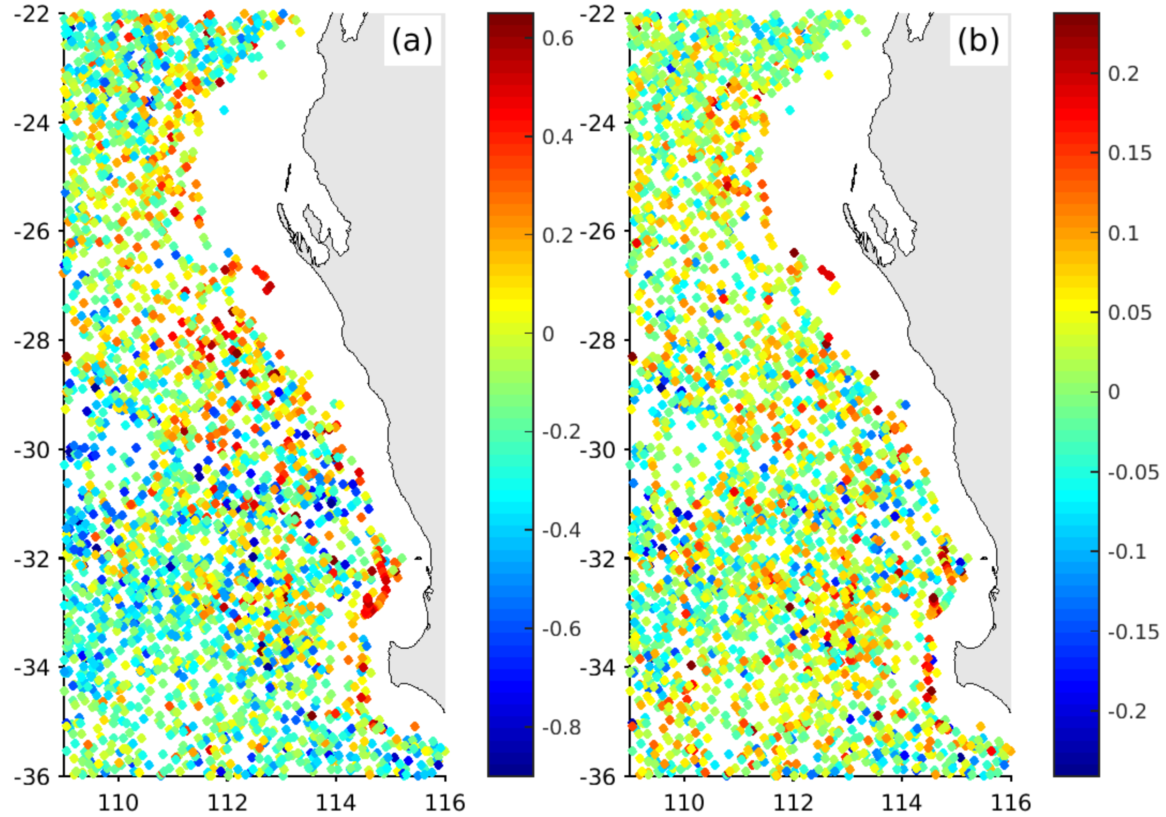


Figure S11: Spatial distribution bias for temperature (a) and salinity (b) estimated using ozROMS and ARGO depth profiles.

Reference

Willmott CJ, Robeson SM, Matsuura K (2012) A refined index of model performance. *International Journal of Climatology* **32**, 2088–2094. doi:10.1002/joc.2419