Using Saildrones to Validate Satellite-Derived Sea Surface Sea Surface Temperature along the California/Baja Coast

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ABSTRACT:

Traditional ways of validating satellite-derived sea surface temperature (SST) and sea surface salinity (SSS) products, using comparisons with buoy measurements, do not allow for evaluating the impact of mesoscale to submesoscale variability. Here we present the validation of remotely-sensed SST and SSS data against the unmanned surface vehicle (USV) – Saildrone – measurements from the Spring 2018 Baja deployment. More specifically, biases and root mean square differences (RMSD) were calculated between USV-derived SST and SSS values, and six satellite-derived SST (MUR, OSTIA, CMC, K10, REMSS, and DMI) and three SSS (JPLSMAP, RSS40, RSS70) products. Biases between the USV SST and OSTIA/CMC/DMI were approximately zero while MUR showed a bias of 0.2°C. OSTIA showed the smallest RMSD of 0.36°C while DMI had the largest RMSD of 0.5°C. An RMSD of 0.4°C between Saildrone SST and the satellite-derived products could be explained by the daily variability in USV SST which currently cannot be resolved by remote sensing measurements. For SSS, values from the JPLSMAP product showed saltier biases of 0.2 PSU, while RSS40 and RSS70 showed fresh biases of 0.3 PSU. An RMSD of 0.4 PSU could not be explained solely by the daily variability of the USV-derived SSS. Coherences were significant at the longer wavelengths, with a local maximum at 100 km that is most likely associated with the mesoscale turbulence in the California Current System.

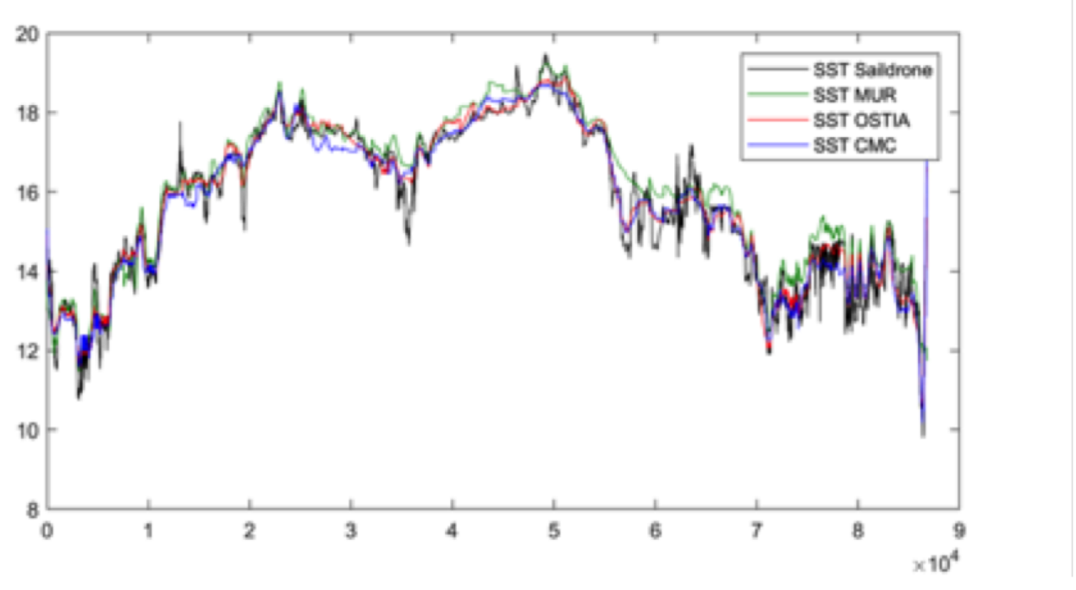


Figure: SST time series from Saildrone CTD, MUR, OSTIA, and CMC. MUR, OSTIA, and CMC are co-located to the Saildrone track.

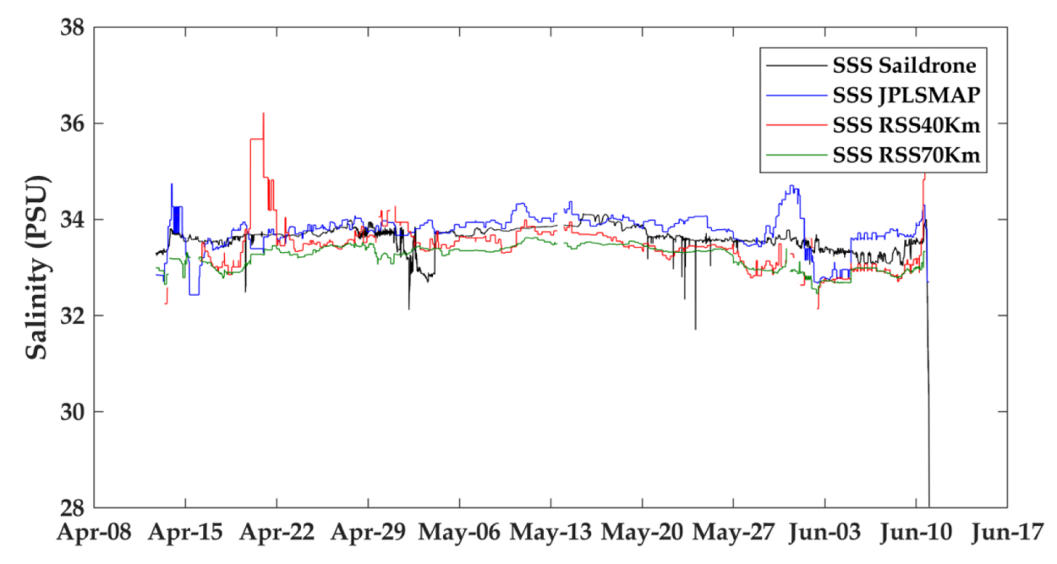


Figure: SSS time series from Saildrone CTD, JPLSMAP, RSS40, and RSS70.

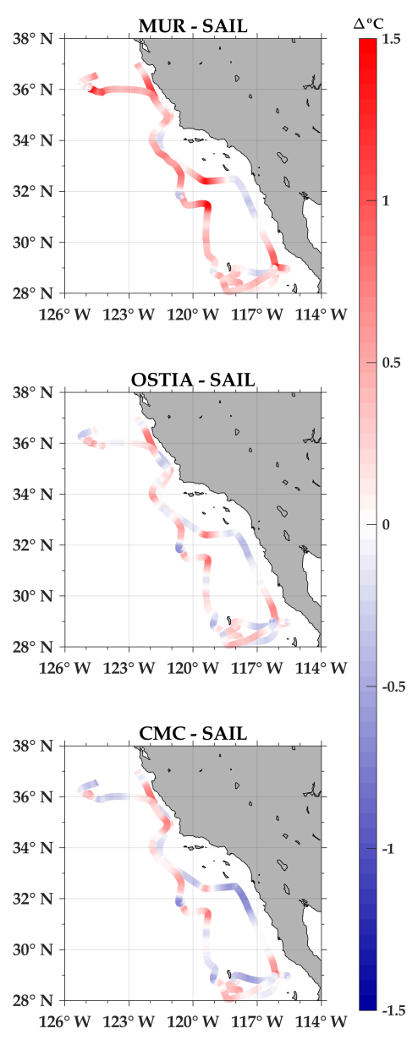


Figure: Difference plots for each of the remotely sensed SST products and the Saildrone-derived SST.

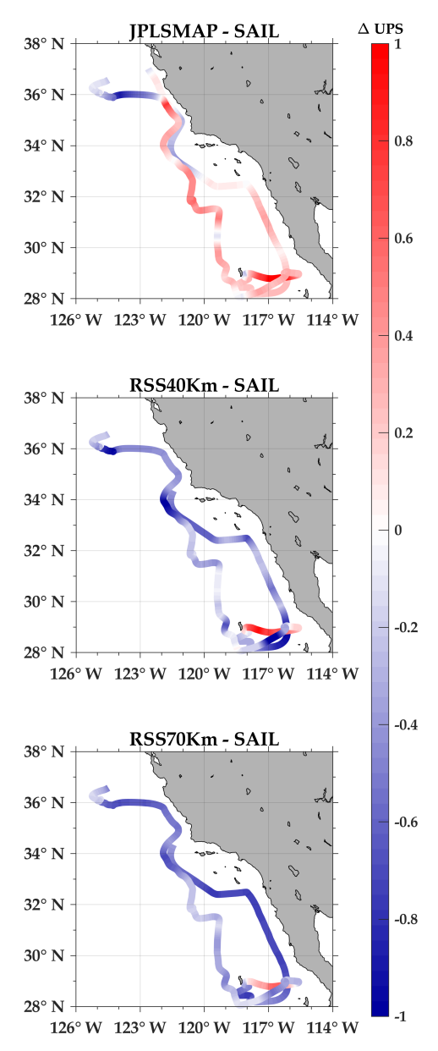


Figure: Difference plots for each of the remotely sensed SSS products and the Saildrone-derived SSS.

Tables Summarizing Statistics

Sea Surface Temperature

Parameter	Bias (°C)	Standard Deviation (°C)	Correlation	Signal-to-Noise Ratio
CMC	-0.03	0.44	0.97	4.5
OSTIA	0.04	0.39	0.98	6.2
MUR	0.32	0.46	0.97	5.1
REMSS	0.11	0.43	0.97	4.4
K10	0.16	0.49	0.96	4.0
DMI	0.04	0.5	0.96	4.2

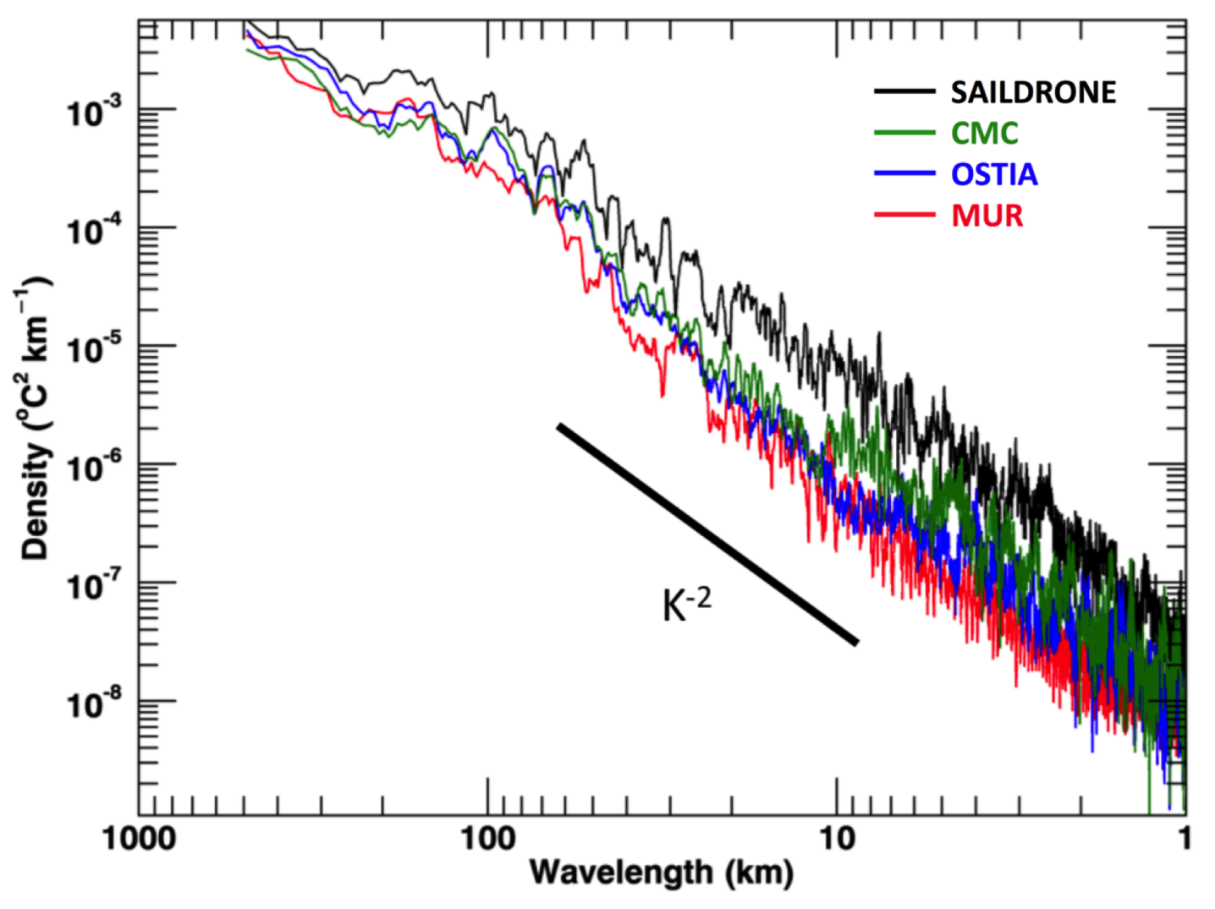


Figure: Power spectra for the three satellite-derived SST products and Saildrone SST. For the purpose of reference, the k^{-2} slope is overlaid.

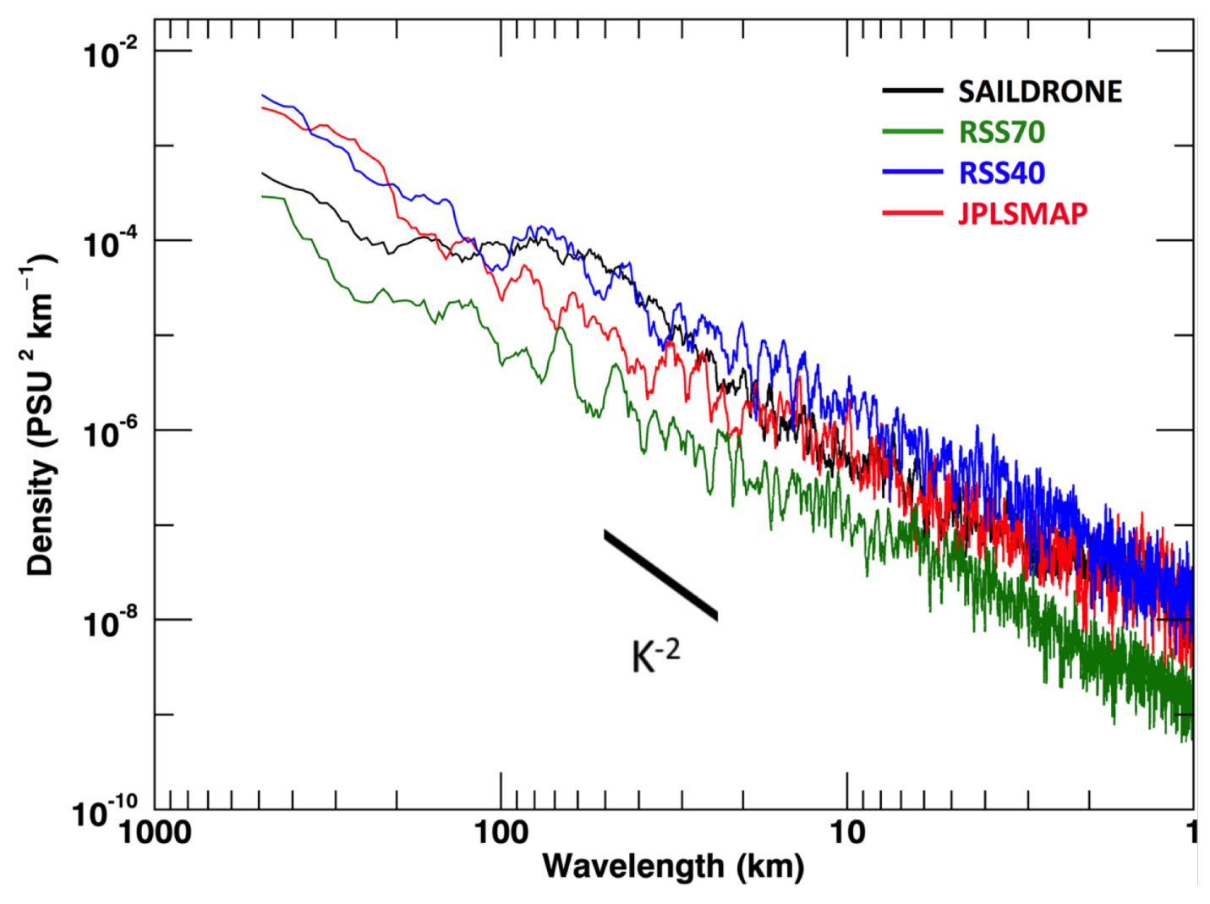


Figure: Power spectra for the three satellite-derived SSS products and Saildrone SSS. For the purpose of reference, the k^{-2} slope is overlaid.

Sea Surface Salinity

Parameter	Bias (PSU)	RMSD (PSU)	Correlation	Signal-to-Noise
JPLSMAP	0.15	0.37	0.57	1.3
RSS40	-0.17	0.45	0.49	1.1
RSS70	-0.37	0.23	0.57	1.1

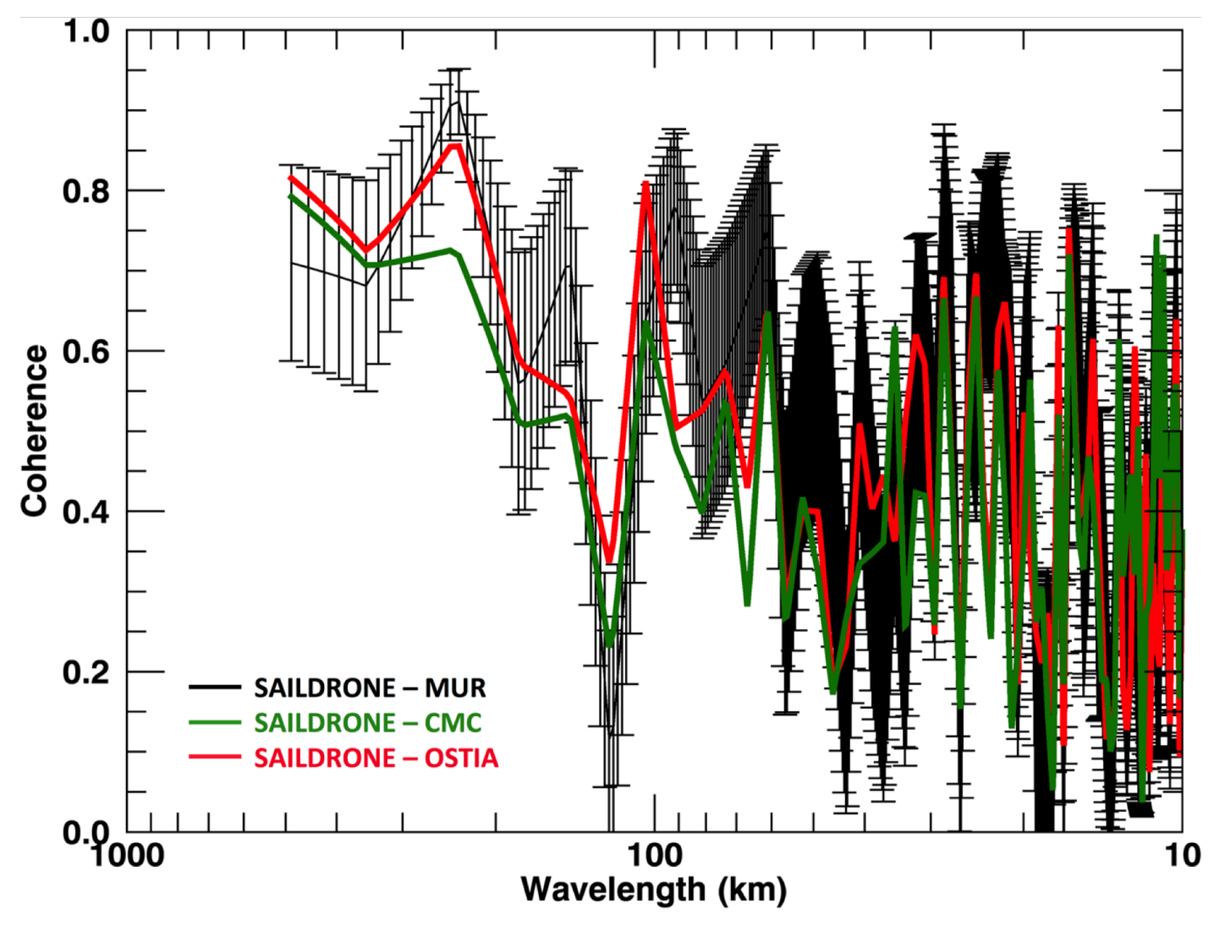


Figure: Coherences between the Saildrone SST and the SST from the MUR, OSTIA, CMC products.

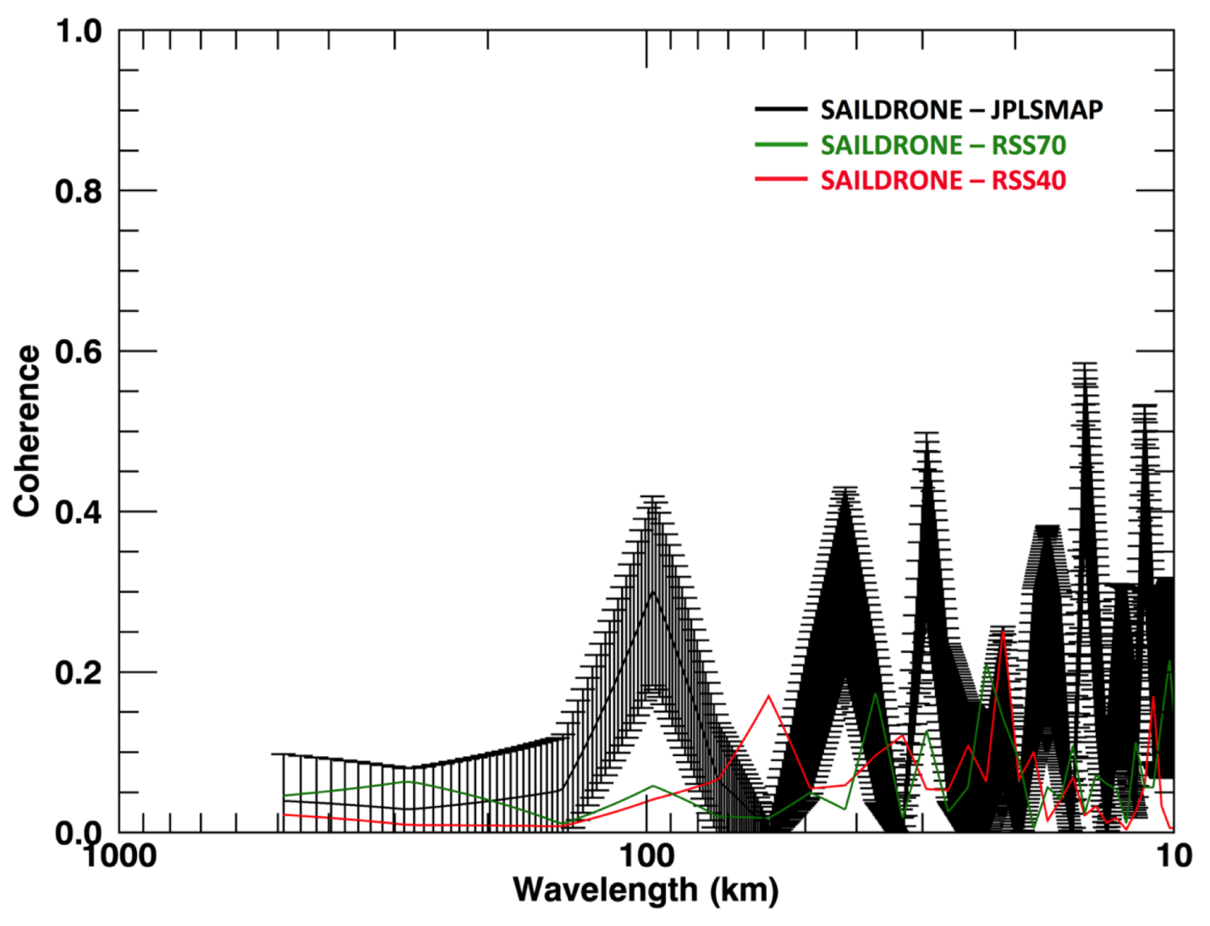


Figure: Coherences between the Saildrone SSS and SSS from JPLSMAP, RSS40, and RSS70 products.

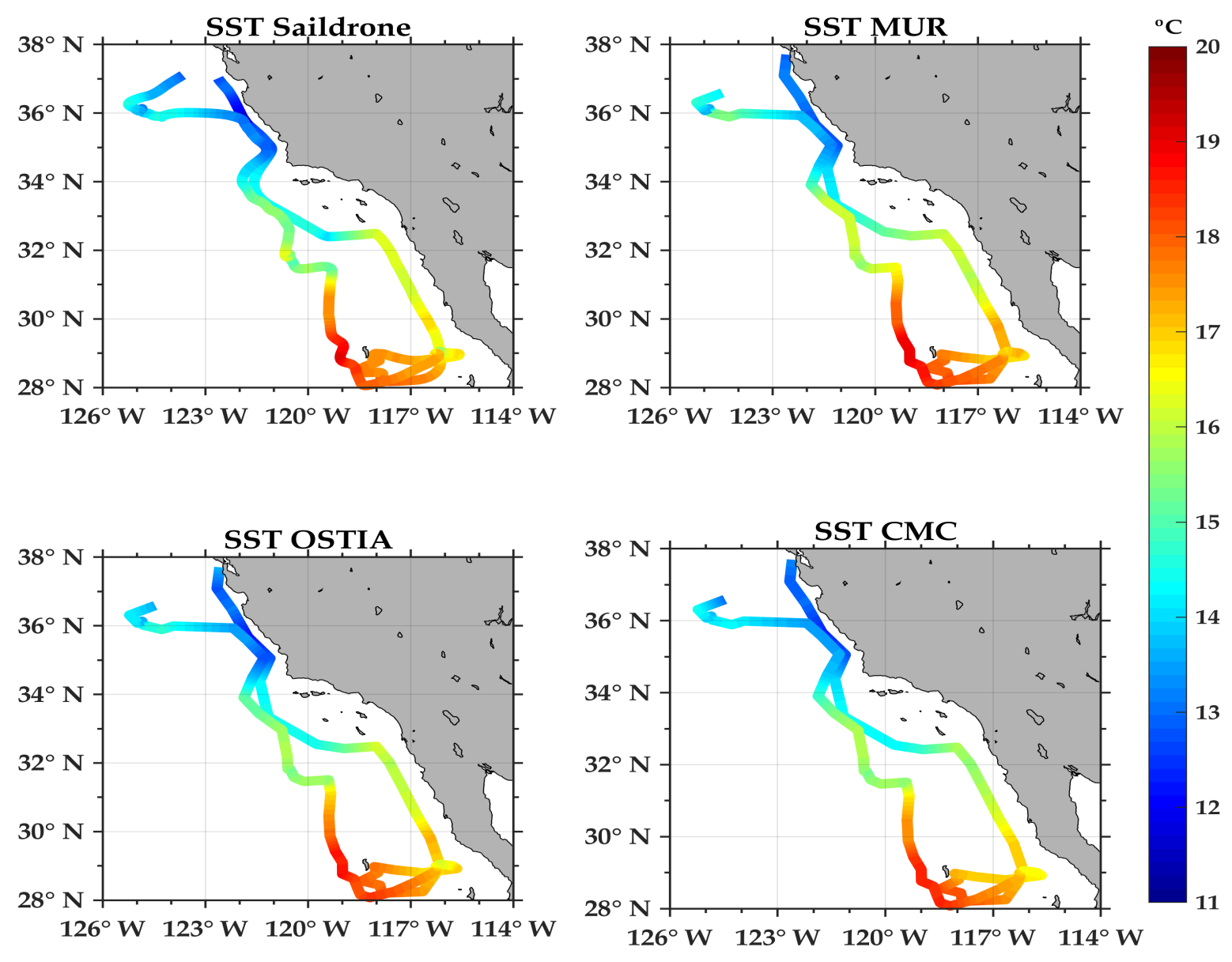
Introduction:

As a motivating factor in the study, the application of remote sensing techniques for understanding coastal and open-ocean surface water properties is an area of active research, helping to better understand oceanic structures like eddies and fronts. These features are associated with upwelling and downwelling and have been recognized to play an important role in shaping physical and biogeochemical processes in the ocean [1], and influence the spatiotemporal variability in primary productivity levels [2,3]. Typically, these mesoscale and submesoscale features reveal a clear signature in sea surface temperature (SST) [4] and sea surface salinity (SSS) [5]. Hence, continued efforts are needed to characterize and observe these structures and improve the validation quality of remotely sensed SST and SSS observations.

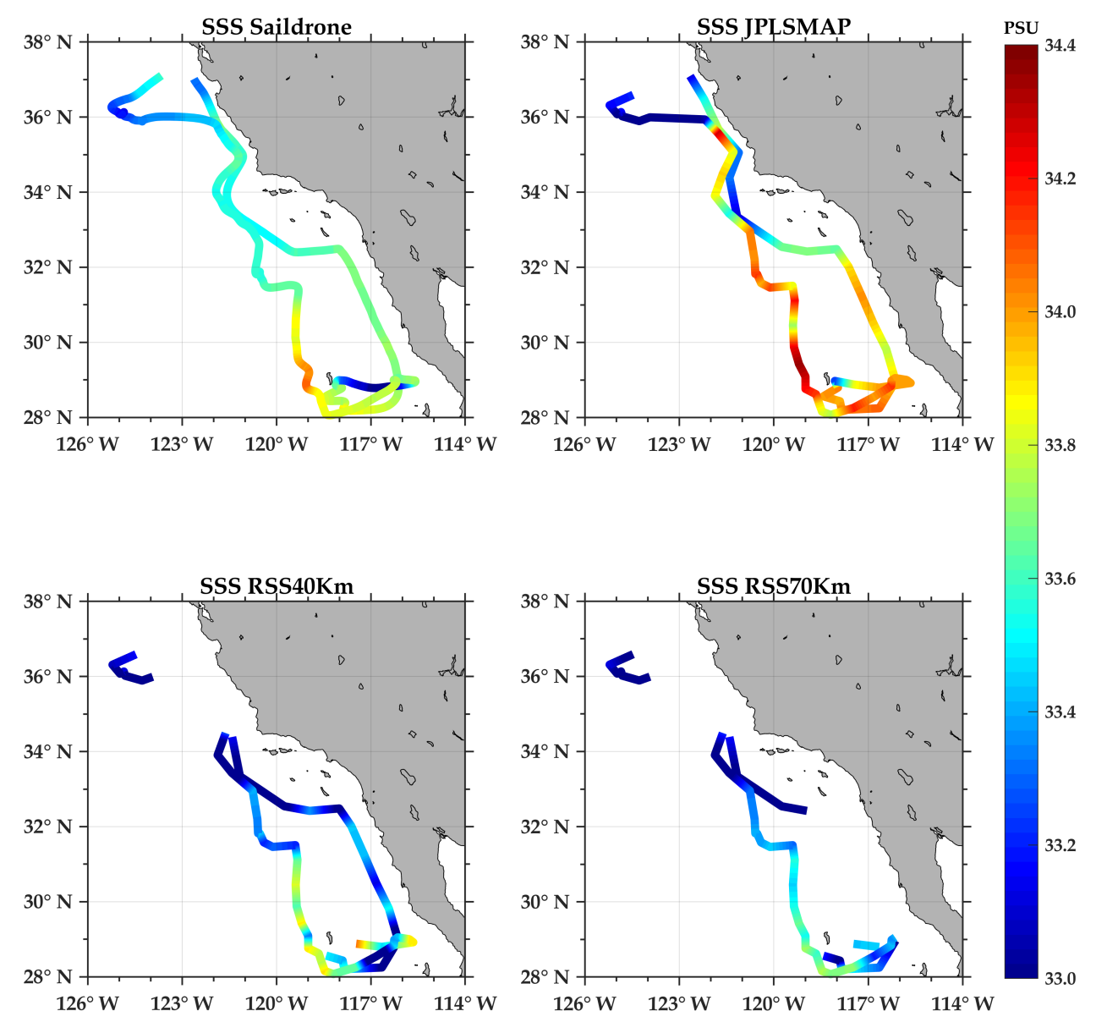
Methodology:

Six different satellite derived GHRSST Level 4 products were compared directly with sea surface temperature (sST) measured from the Saildrone Conductivity, Temperature, and Depth (CTD) instrument. Statistics were also derived comparing three different sea surface salinity products (SSS) with the salinity measured by the Saildrone CTD. The SST products included the MUR, OSTIA, CMC, NAVO K10, REMSS, and DMU Level 4 products The SSS products included the JPL Soil Moisture Active Passive (SMAP) Version 2.0, the Remote Sensing Systems (RSS) version 40km product, and the RSS 70km product. Biases, Root Mean Square Differences (RMSD), correlations, and Signal to Noise ratios were calculated for all the products.

SST Products Along Saildrone Track



SSS Products Along Saildrone Track

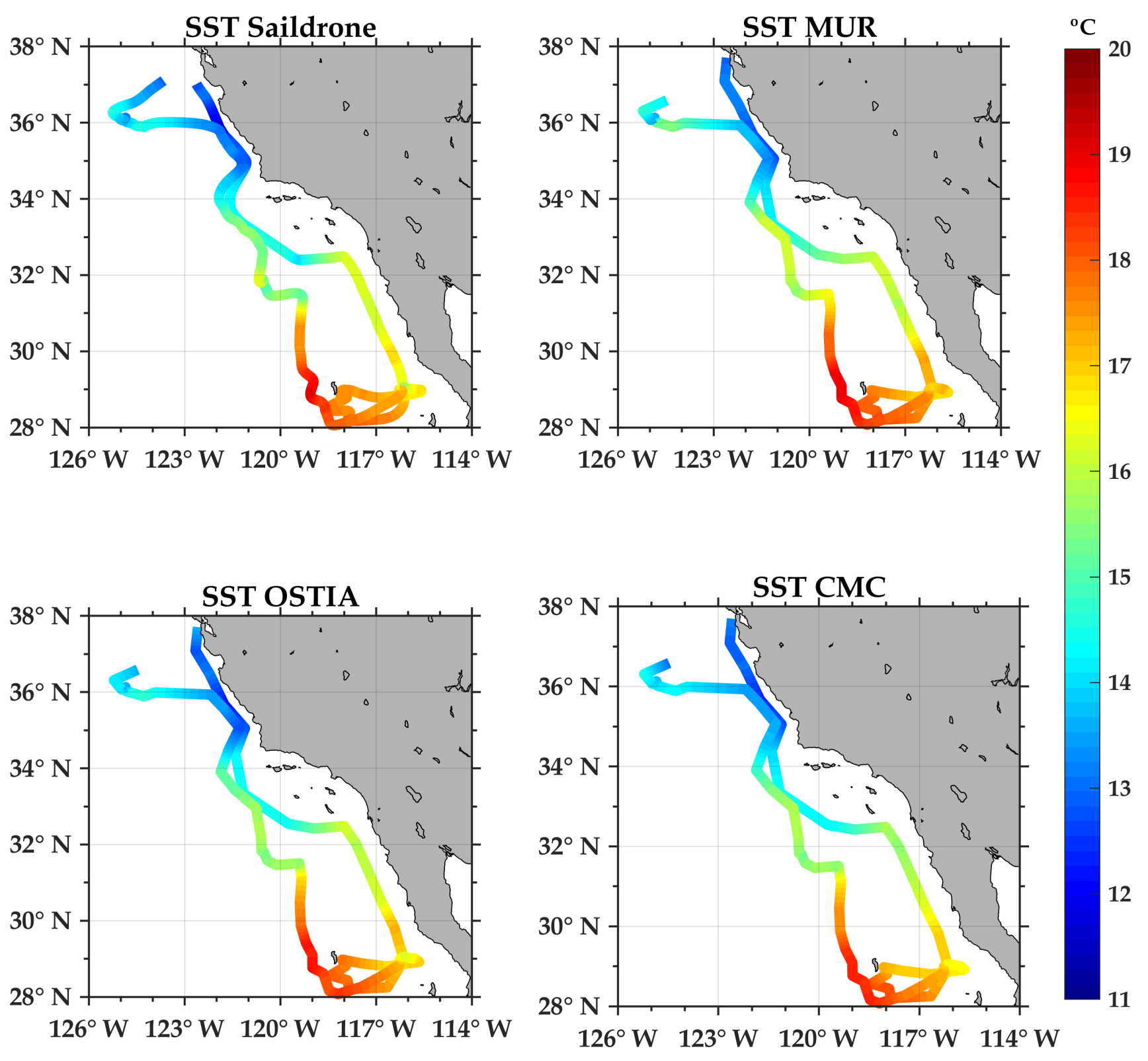


CONCLUSIONS:

Results from in this study present the first known validation of satellite-derived SSS and SST measurements off the California and Baja coasts, using a USV. Overall correlations of Saildrone SST with SST values from MUR, OSTIA, CMC, REMSS, K10, and DMO products exceed 0.97. OSTIA and CMC show biases that are close to zero, with MUR showing positive biases of 0.3°C, RMSD differences are consistent with other validation studies on regional to global scales. The consistency of RMSD off the California/Baja coasts with global comparisons is promising for applications of high-resolution SST retrievals in coastal regimes. Coherences between MUR, OSTIA, CMC and the Saildrone SST are close to one at the longer wavelengths with a minimum at approximately 200 km before increasing again at 100 km.

Results for SSS and the comparisons of Saildrone SSS with the JPLSMAP, RSS40, and RSS70 satellite-derived products are encouraging, but not as statistically significant as for SST. Most likely this is due to two issues: (1) the lower spatial resolution of the SSS satellite-derived data; (2) land contamination. Land contamination results as part of the satellite footprint are over land. For both SMAP and SMOS this occurs at distances less than 100 km from land. Overall the highest correlation (approximately 0.6) was found between Saildrone SSS and the JPLSMAP product, while the lowest correlation (0.4) was found for the RSS40 product. Results are consistent with the RSS40 product having the least spatial smoothing, thus more noise, but the highest spatial resolution. This is consistent with the lower S/N ratio. The RSS70 product shows the lowest RMSD around 0.3 PSU, while the RSS40 product shows the highest RMSD at approximately 0.4 PSU. Additionally, when RMSD values of satellite minus Saildrone are compared with the daily variability of SSS and SST observations from Saildrone, the RMSD for SST can be explained by the unresolved daily variability. However, for SSS, RMSD values are significantly larger, indicating the increased noise and/or possible land contamination of the satellite-derived SSS products. Results are encouraging though that the RMSD of 0.3 PSU is only slightly higher than RMSD values of global comparisons of 0.2 PSU [3]. Coherences show a peak at 100 km (same as SST), but become statistically insignificant at wavelengths <100 km.

With this work, we intend to illustrate the potential of using USVs for validating remotely sensed ocean data in coastal regions. Future work will focus on applications of remote sensing data in challenging regimes while incorporating Saildrone to validate the satellite products and the relationship to mesoscale submesoscale features.


SST Saildrone
SST MUR
SST OSTIA
SST CMC
38° N
36° N
34° N
32° N
30° N
28° N
126° W
123° W
120° W
117° W
114° W
°C
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