ASSESSING THE ABILITY OF SATELLITES TO RESOLVE SPATIAL SST VARIABILITY THE NORTHWEST TROPICAL ATLANTIC ATOMIC REGION

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INTRODUCTION/MOTIVATION

The Atlantic Tradewind Ocean-Atmosphere Mesoscale Interaction Campaign (ATOMIC) occurred in January-February 2020 in the tropical Northwest Atlantic region east of Barbados in association with the European EUREC^{4}A (Elucidating the role of clouds-circulation coupling in climate) field campaign. Major foci included investigating cloud and air-sea interaction processes in tropical trade wind regions to help improve the understanding and prediction of weather and climate. The large number of high-quality in situ SST observations provided a unique opportunity to:

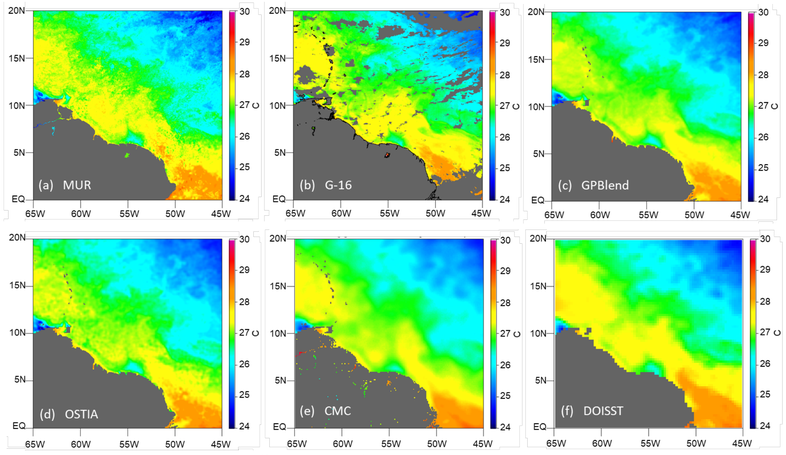
- Evaluate the accuracy of satellite-derived SST products in the northwest tropical Atlantic ATOMIC region
- Examine SST variability on sub-satellite spatial scales
- Assess the ability of satellites to accurately resolve spatial SST variability
  - At the product scale
  - At coarser scales

SST PRODUCTS

Satellite

Blended L4 SST Analyses
- NASA MUR – 0.01° resolution
- UK Met Office OSTIA – 0.05° resolution
- NOAA GOES-POES Blended – 0.05° res.
- CMC – 0.1° resolution
- DOISST (Reynolds) – 0.25° resolution

Gridded Individual Sensor Retrievals
- GOES-16 ABI – 0.02
  - NOAA NESDIS L3 version 2.7
- NOAA-20 VIIRS – 0.02
  - NOAA NESDIS L3 version 2.8



Satellite SST products on February 2, 2020

In situ

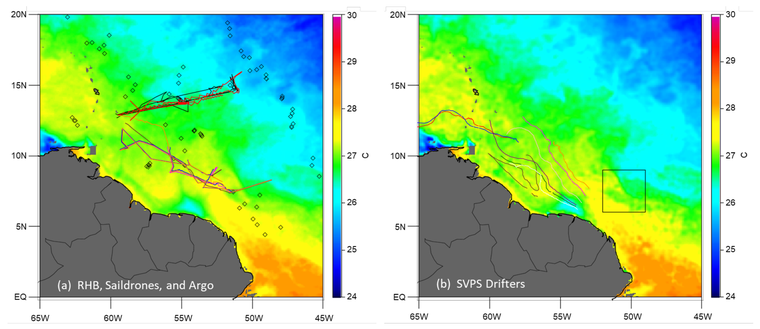
NOAA Research Vessel Ronald H. Brown
- Sea Snake at ~0.05-m depth
- Thermosalinograph at ~5-m depth

Saildrones
- 3 Deployed by NASA and 2 by NOAA
- Sea-Bird SBE 37 MicroCAT at ~0.5-m depth

Surface Velocity Program Drifters
- 9 deployed by NOAA
- Sensor 1 at ~ 0.3-m depth

Argo Floats
- NOAA/NESDIS/STAR, V2.50
- 0.02° resolution, hourly

Study period: January 1 – February 24, 2020

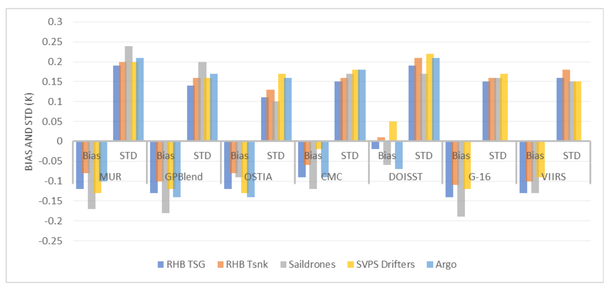


In situ SST products overlaid on (left) GOES-POES Blend and (right) OSTIA on February 2, 2020. The black box at right corresponds to the region shown in the later panel.

SST PRODUCT ACCURACY

Collocation and Statistics

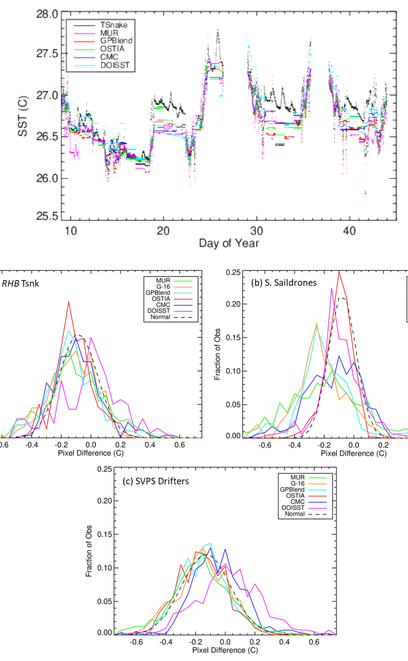
- Nighttime observations collocated and averaged within grid cells
- Results largely consistent and overall satellite product accuracy very good
- Standard deviation values ~0.15 K
  - Better for OSTIA, worse for MUR and DOISST
- Regional cool bias of ~0.1 K in most products
  - DOISST smaller bias consistent with stronger impact of in situ observations



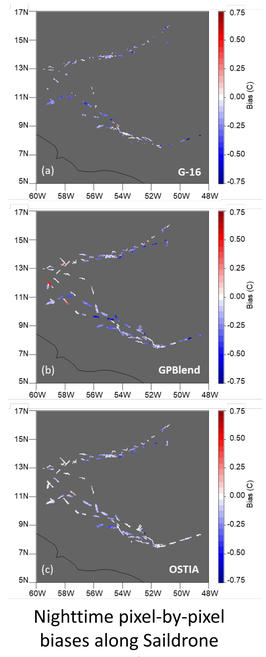
Bias and standard deviation as a function of product and in situ platform

Bias Exploration

- Bias shows significant pixel-to-pixel variations
- RHB sea snake comparison shows good agreement for some pixels but larger cool biases for others
- Distributions of differences very non-Gaussian
  - Hint of secondary peaks at zero bias
- Colder bias of some southern G-16 retrievals likely related to aerosol contamination
  - Retrievals also impact GPBlend with stronger dependence on G-16
- Biases show little other regional coherence



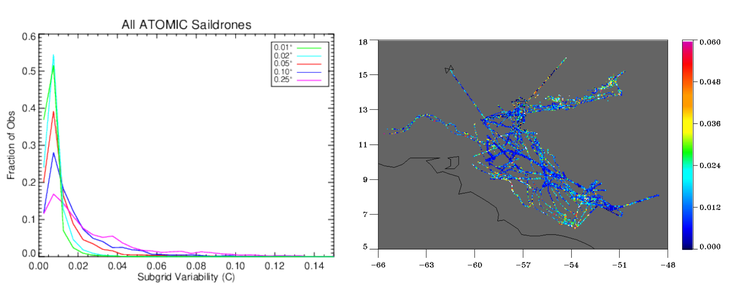
Distributions of satellite-Saildrone SST differences



Nighttime pixel-by-pixel biases along Saildrone tracks

Sub-grid Variability

- Variability expressed here as standard deviation of observations within grid cell
- Sub-grid variability increases with coarser resolution but very small in ATOMIC
- Notably less than other studies and regions
- Small component of uncertainty budget
- Small contribution from diurnal variations

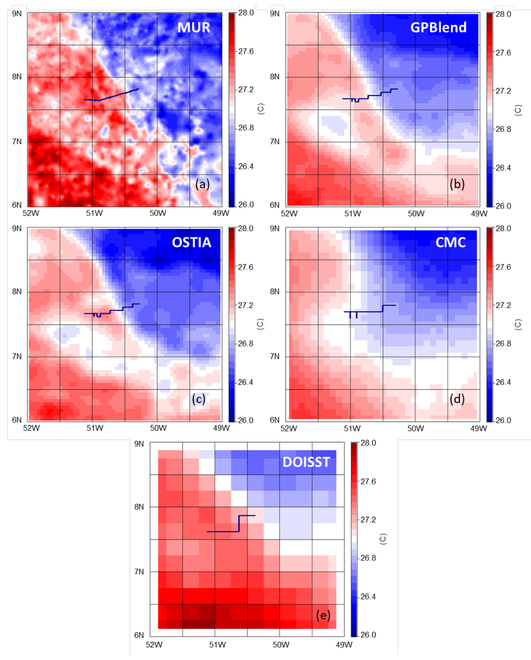


REPRESENTATION OF SST VARIABILITY

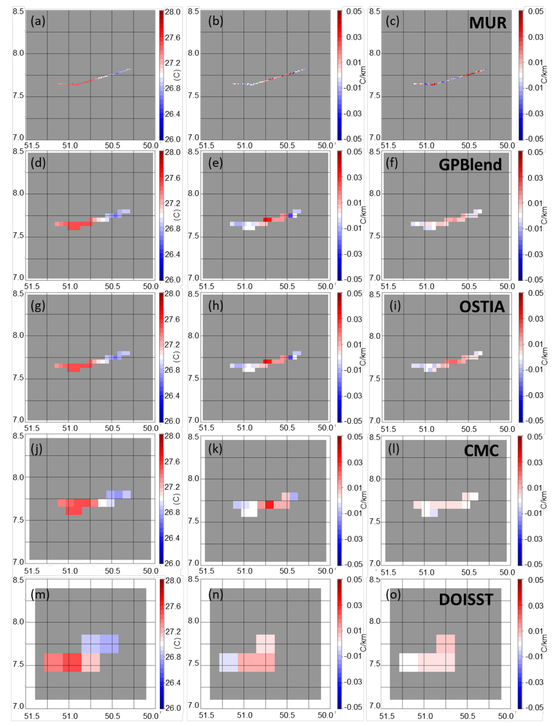
Gradient Comparison

- Computed gradients along Saildrone tracks averaging all observations within the corresponding grid cells
- Correlated satellite- and Saildrone-derived gradients
- Poor correlation at grid scale even for individual satellite sensor products

Analysis	RHB		Saildrones					
	Tsnk	TSG	1026	1060	1061	1063	1064	All
MUR	0.06	0.09	0.09	0.05	0.05	0.07	0.18	0.07
GPBlend	0.29	0.41	0.21	0.17	0.17	0.19	0.38	0.24
OSTIA	0.30	0.41	0.35	0.33	0.36	0.30	0.32	0.32
CMC	0.17	0.20	0.12	0.09	0.08	0.06	0.22	0.12
DOISST	0.20	0.20	0.19	0.13	0.27	0.14	0.21	0.19
G-16	0.21	0.32	0.12	0.09	0.14	0.12	0.24	0.16
VIIRS	0.28	0.32	0.15	0.10	0.18	0.11	0.19	0.15



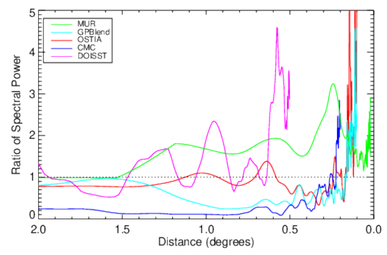
Satellite SST and Saildrone tracks on February 2, 2020



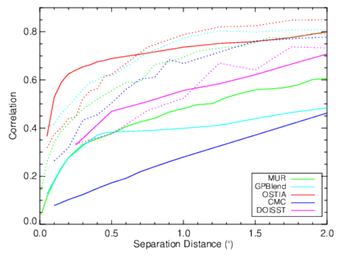
Saildrone SST | Saildrone Gradient | Satellite Gradient

Variability on Longer Spatial Scales

- Satellite products known to accurately reflect variability on larger scales but how large?
- Compared spectra of satellite and gridded Saildrone SSTs and evaluated correlation of SST values as a function of separation distance
- Representation of variability better on scales of 50-100 km and greater



Ratio of satellite to Saildrone 1063 spectra



Solid: Southern Saildrones, Dotted: North

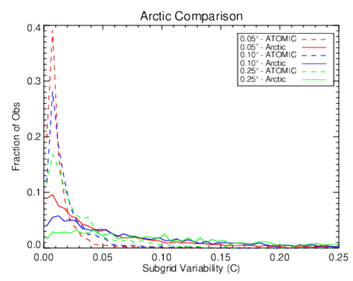
Simulation of Required SST Product Accuracy

- Simulated accuracy required to reproduce Saildrone cell-to-cell variations on different scales assuming various noise levels
- Accuracies of 0.05 K or better required on scales of product resolution
- Requirements very challenging for current SST products

Analysis and Resolution	N	Analysis r	Correlation with assumed noise (SD) levels				
			0.025 K	0.05 K	0.10 K	0.15 K	0.2 K
MUR (0.01°)	34442	0.08	0.40	0.21	0.11	0.07	0.05
GPBlend (0.05°)	6200	0.17	0.72	0.47	0.26	0.18	0.12
OSTIA (0.05°)	6420	0.26	0.73	0.48	0.27	0.18	0.14
CMC (0.10°)	3303	0.09	0.84	0.62	0.37	0.26	0.21
DOISST (0.25°)	1592	0.23	0.93	0.78	0.53	0.38	0.28

COMPARISON WITH ALASKA/ARCTIC REGION

- Similar computations performed for 2019 MISST deployment of 2 Saildrones to the Bering, Chukchi, and Beaufort Seas
- Sub-grid variability ~6 times larger in the Arctic
- Precision required to resolve spatial variability at satellite product grid scale relaxed to ~0.4 K
- Product accuracy also degraded so products still struggle to resolve spatial variability at their grid resolution



Analysis and Resolution	N	Analysis r	Correlation with assumed noise (SD) levels					
			0.1 K	0.15 K	0.2 K	0.4 K	0.5 K	0.75 K
GPBlend (0.05°)	7769	0.37	0.94	0.88	0.82	0.59	0.50	0.36
OSTIA (0.05°)	7733	0.47	0.94	0.88	0.82	0.58	0.50	0.35
CMC (0.10°)	3968	0.39	0.96	0.92	0.87	0.67	0.58	0.43
DOISST (0.25°)	1705	0.51	0.98	0.95	0.93	0.78	0.70	0.54

CONCLUSIONS

- **Satellite SST absolute accuracy good during ATOMIC**
  - **Most products exhibit small cool bias of ~0.1 K**
  - **Random errors less than 0.2 K**
- **In situ SST measurements exhibit high degree of consistency across platforms**
- **Sub-grid SST variability small during ATOMIC relative to both other regions and satellite product uncertainty**
- **Satellite SST products unable to provide reliable representation of spatial variability on the scale of their grid resolution**
  - **Product precision of 0.05 K or less required to reproduce variability in ATOMIC**
- **Better representation of spatial variability on scales of 1° or more**
- **Variability larger and required product accuracy lower in the Arctic, but product accuracy also degraded**