Sea Surface Latent and Sensible Heat Fluxes in the Pacific Arctic from Saildrone Observations and Numerical Model Products

Chidong Zhang[1], Subhatra Sivam[2], Isabella Dressel[3], Dongxiao Zhang[4,1], Mark Yamane[4], Lisan Yu[5]

[1] NOAA Pacific Marine Environmental Laboratory, [2] University of Maryland, [3] University of Virginia, [4] University of Washington, [5] Woods Hole Oceanographic Institute

Introduction

- In situ observations of saildrones in the Arctic region provide rare opportunities to validate products of numerical models in this data-sparse area.
- In this study, comparisons are made for ocean surface fluxes of latent and sensible heat and surface state variables (temperature, humidity, wind) from saildrone observations, three global reanalysis products (MERRA2[1], ERA5[2], CFSR2[3]), for May - October and ECMWF ensemble forecasts for June – September of 2017, 2018, and 2019.
- This is an experimental study to explore applications of observations from uncrewed surface vehicles in model validation.

Summary

- The three reanalysis products compare well with saildrone observations in the mean, except the cold bias in surface temperature in CFSR2.
- All three reanalysis products suffer from sporadic large (>2σ) discrepancies from the observations.
- ECMWF forecasts are skillful for a lead time of 5 days. They are under-dispersed and fail to capture extreme values.
- Errors in surface temperature and humidity are primarily responsible for error in the surface fluxes.

Data

FIG 1 Saildrone

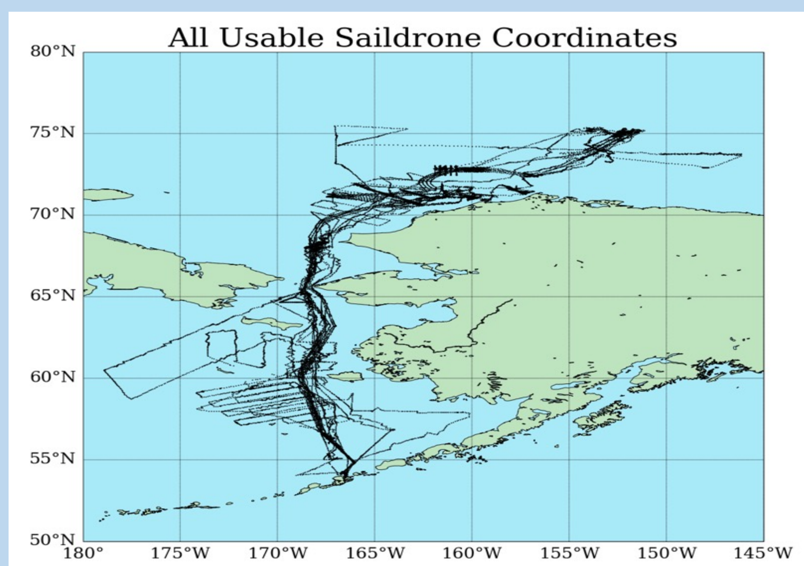

FIG 2 Saildrone tracks in 2017 - 2019

Saildrone (Fig. 1) Observations: air temperature and relative humidity at 2.3 m, wind speed and direction at 5.2 m, SST at -0.5 m, 1-min means for every 10 min.

Reanalysis Products: Hourly
0.625˚ x 0.25˚ (MERRA2), 0.25˚ x 0.25˚ (ERA5), 0.5 x 0.5˚ (CFSR2)

Ensemble Forecasts: 15 day lead time, initiation at 00Z, 50 members, 0.5 x 0.5˚

Gridded data were paired with hourly saildrone observations along saildrone tracks (Fig. 2)

Table 1 Number of paired saildrone observations and reanalysis data

	2017	2018	2019	Total
MERRA2	4592	8874	15598	29064
ERA5	4559	8807	15583	28949
CFSR2	4507	5989	15468	25964
Total	13658	23670	46649	83977

References

[1]Gelaro, R., McCarty, W., Suárez, M.J., Todling, R., Molod, A., Takacs, L., Randles, C.A., Darmenov, A., Bosilovich, M.G., Reichle, R. and Wargan, K., 2017. The modern-era retrospective analysis for research and applications, version 2 (MERRA-2). *Journal of climate*, *30*(14), pp.5419-5454.

[2]Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., Nicolas, J., Peubey, C., Radu, R., Schepers, D. and Simmons, A., 2020. The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society*, *146*(730), pp.1999-2049.

[3]Saha, S., Moorthi, S., Pan, H.L., Wu, X., Wang, J., Nadiga, S., Tripp, P., Kistler, R., Woollen, J., Behringer, D. and Liu, H., 2010. The NCEP climate forecast system reanalysis. *Bulletin of the American Meteorological Society*, *91*(8), pp.1015-1058.

MERRA2, ERA5, CFSR2

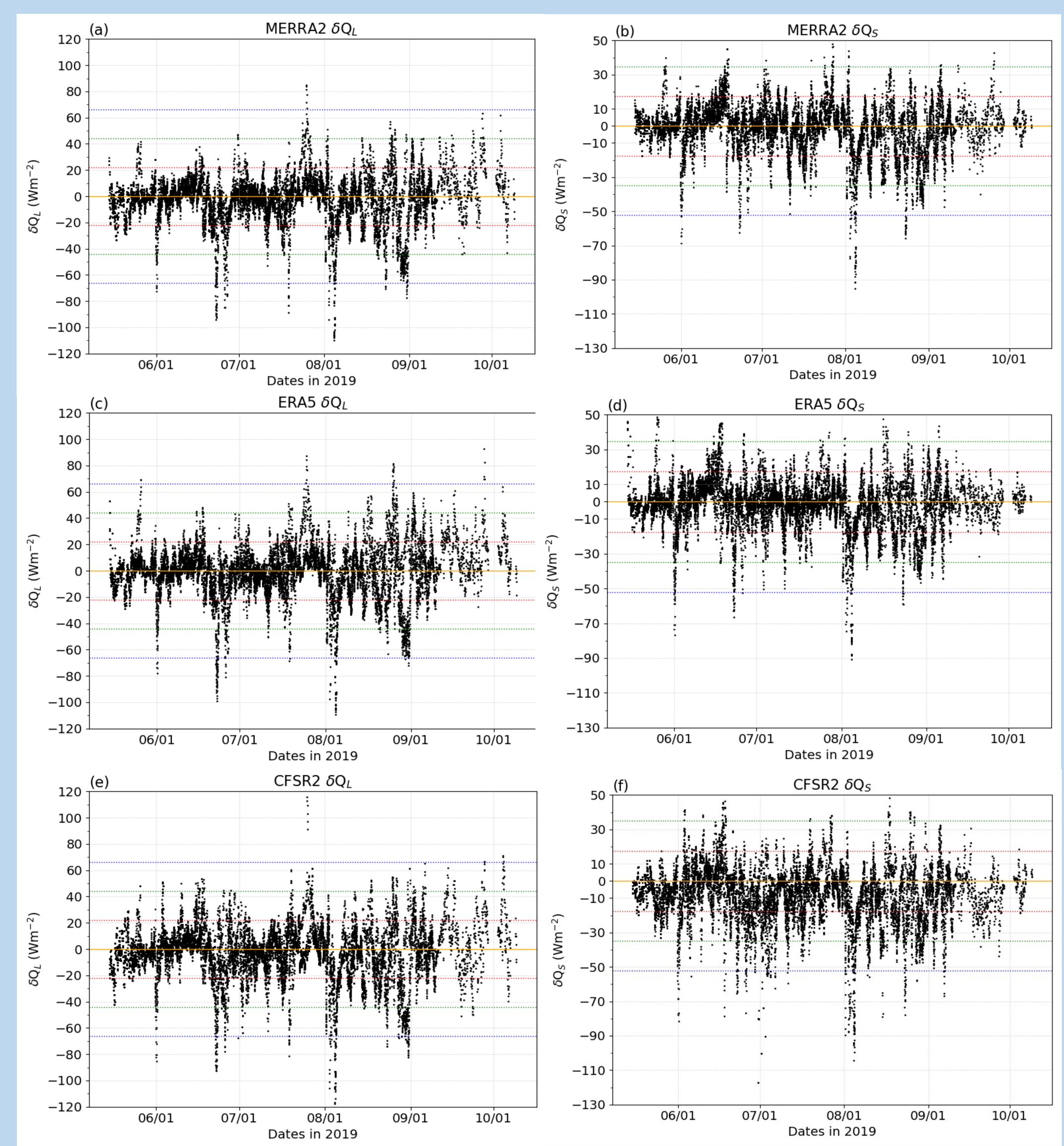

FIG 3 An example of time series of errors in latent (left) and sensible (right) heat fluxes in 2019

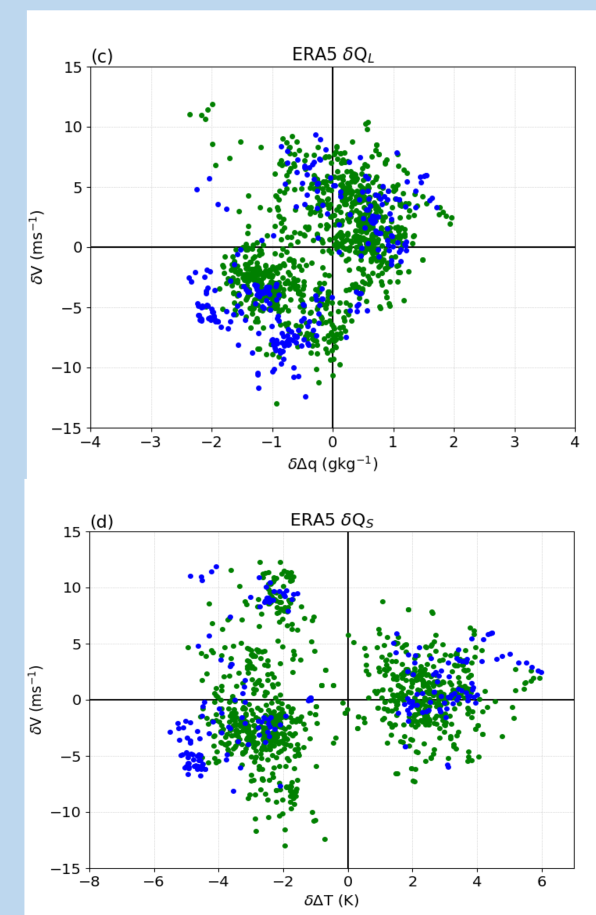

FIG 4 Errors of ERA5 in latent (upper) and sensible (lower) heat fluxes between 1 and 2 standard deviations (green) and greater than 3 standard deviations as functions of errors in wind speed and air-sea differences in humidity and temperature.

Table 2 Distributions of errors in latent and sensible heat fluxes

	<1σ	1σ - 2σ	2σ - 3σ	>3σ
MERRA2				
δQ_L	83.76%	12.89%	2.62%	0.73%
δQ_S	82.02%	14.63%	2.83%	0.52%
ERA5				
δQ_L	82.33%	13.30%	3.40%	0.97%
δQ_S	82.15%	13.88%	3.22%	0.75%
CFSR2				
δQ_L	80.80%	15.20%	3.24%	0.76%
δQ_S	74.21%	20.09%	4.66%	1.04%

Acknowledgements

The saildrone observations are available from https://data.pmel.noaa.gov/generic/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=saildrone.
The reanalysis data were downloaded from https://www.soest.hawaii.edu/soestwp/research/org/centers/asia-pacific-data-research-center-apdrc/, https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=overview

ECMWF Ensemble Forecasts

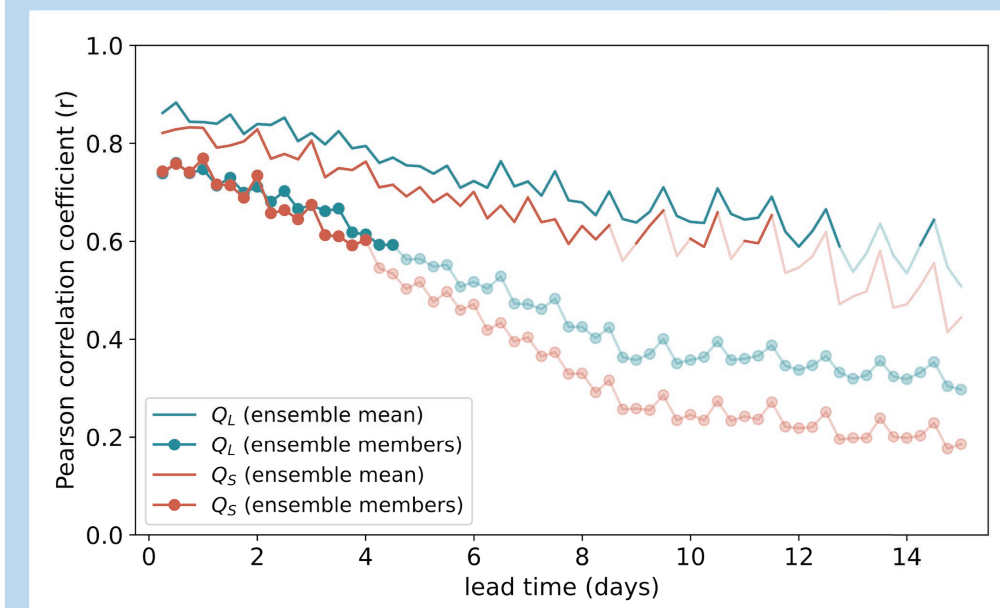

FIG 5 Correlation coefficients between ensemble mean/members and observations. Heavy lines mark significance at the 95% confidence level based on the effective sample sizes (latent: 11, sensible: 15) determined by autocorrelation of saildrone observations.

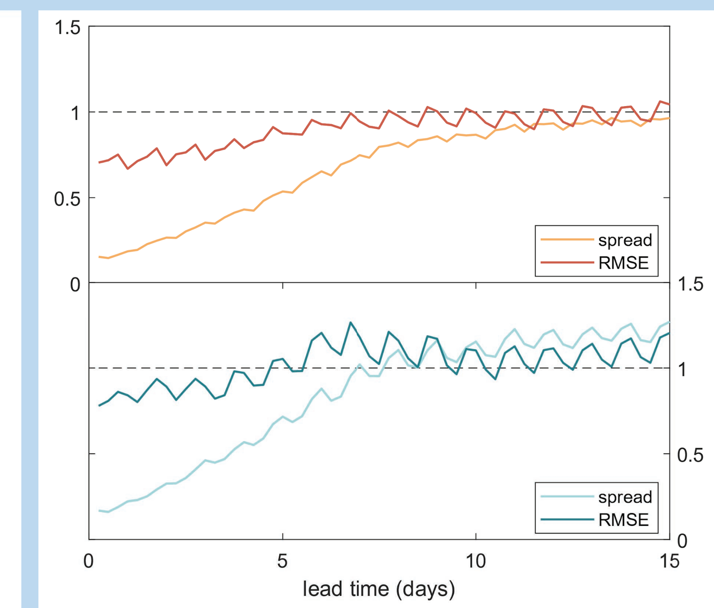

FIG 6 Ensemble spread and forecast RMSE (normalized by the observation standard deviation) for sensible (upper) and latent (lower) heat fluxes.

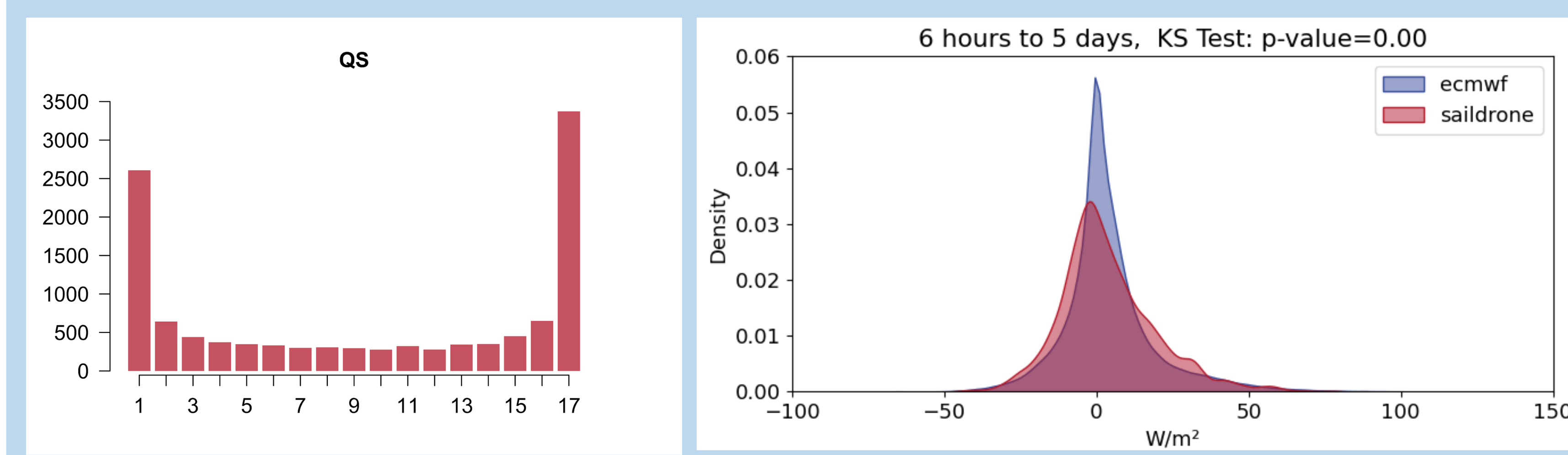

FIG 7 Rank histograms (left) and probability density functions (right) for sensible heat flux at lead times of 6 hours–5 days.

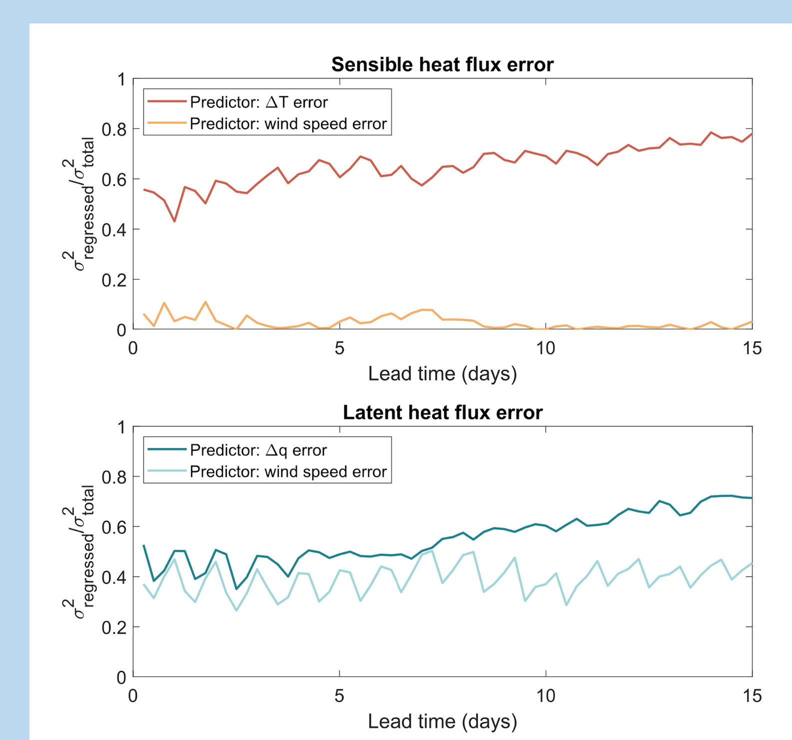

FIG 8 Fractions of variance in forecast errors explained by errors in wind speed and air-sea differences in temperature for sensible heat fluxes (top) and wind and air-sea differences in humidity for latent (bottom) heat fluxes.