Mesoscale air-sea variability captured by uncrewed surface vehicles in the tropical Pacific

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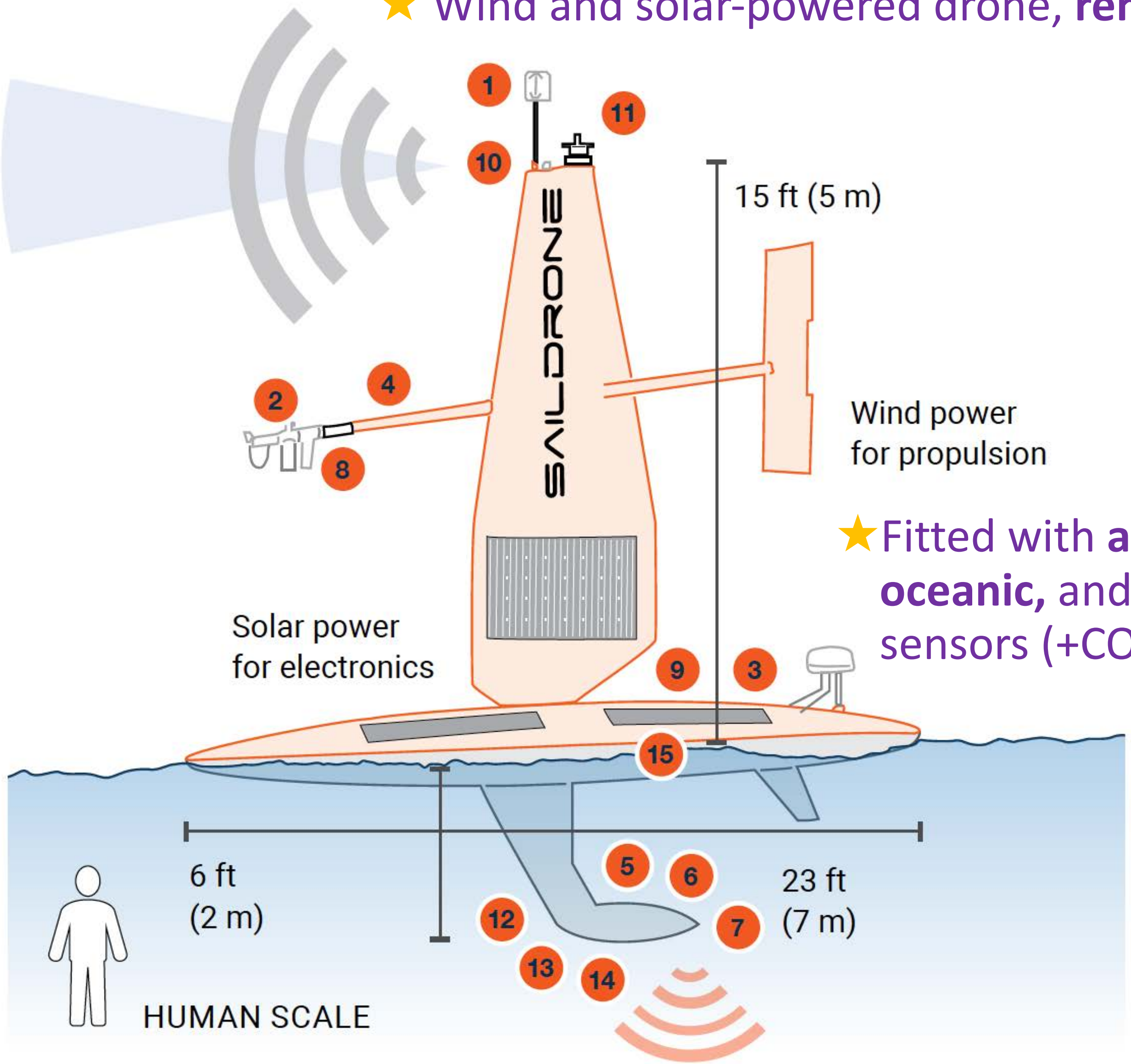
Captured by SD 1066's onboard camera in the Tropical Pacific Ocean

SAILDRONE EXPLORER

★ Telemetered **1-min mean and std. dev.** Data

★ Wind and solar-powered drone, **remotely piloted**

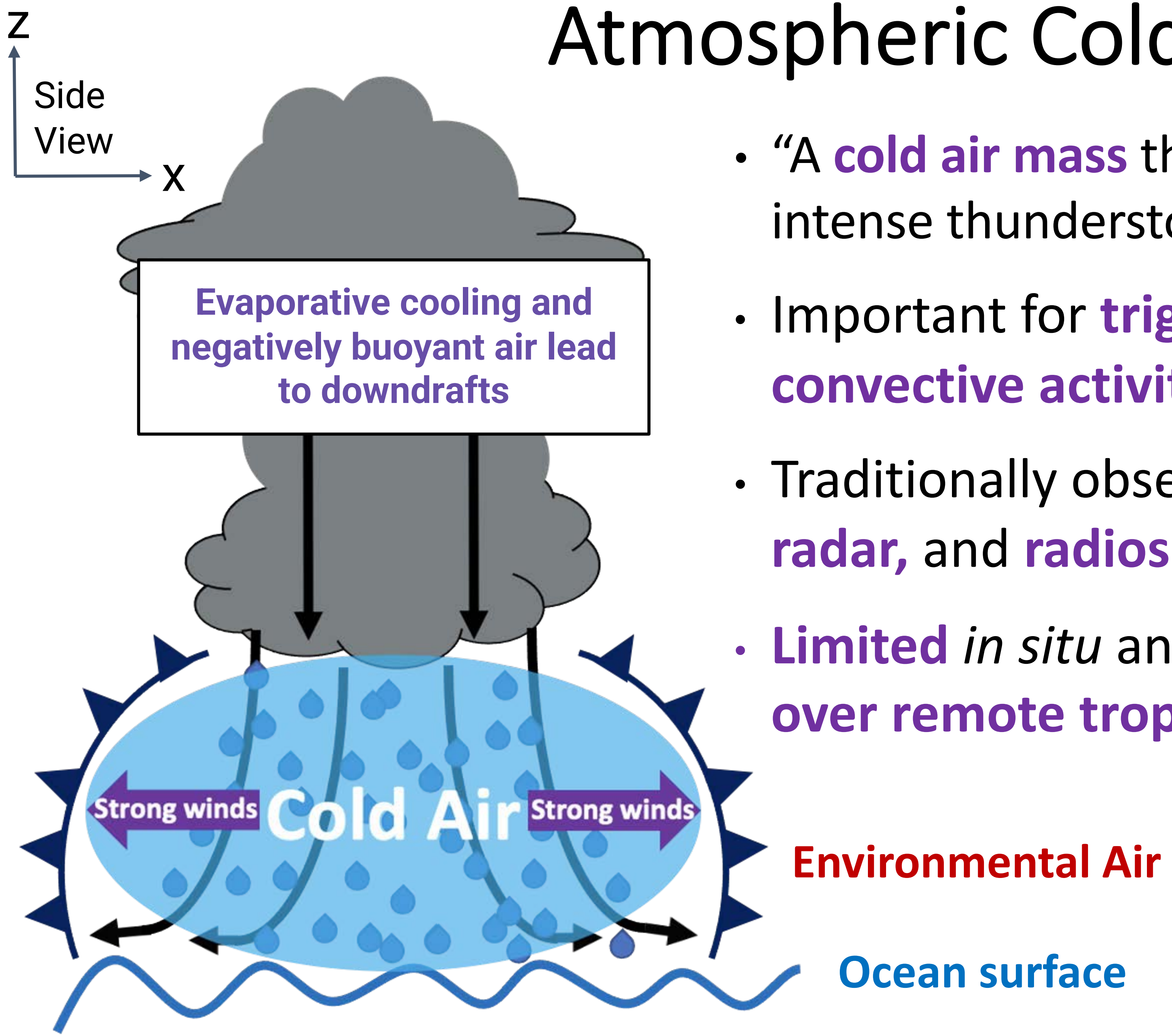


★ Fitted with **atmospheric, oceanic,** and **biogeochemical** sensors (+CO_2 sensor)

PAYLOAD OPTIONS

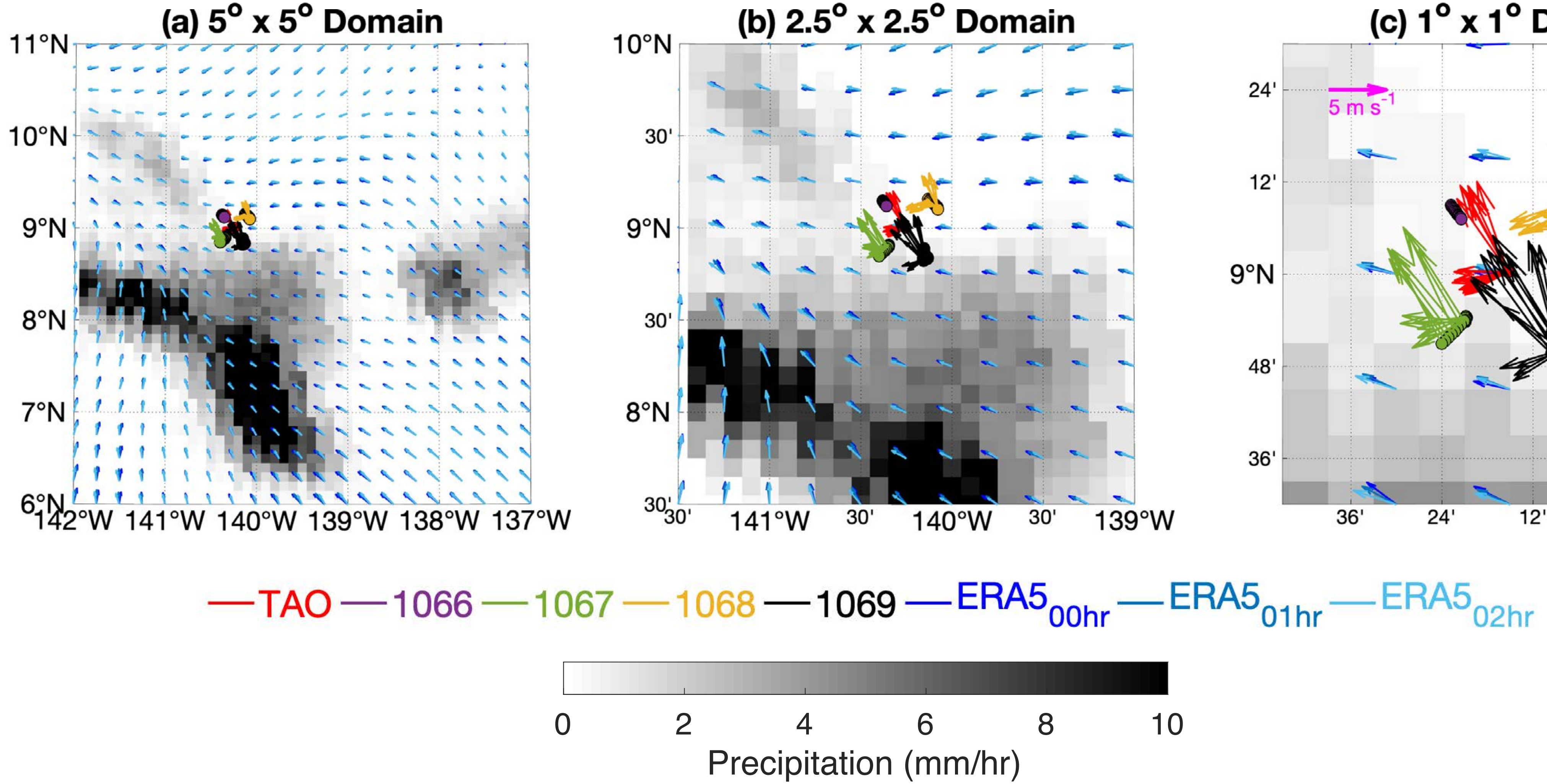
No.	Variable	Sensor	
1	Wind speed & direction	Gill Windmaster 3D Ultrasonic 20Hz @ + 5.2 m	ATMOSPHERIC
2	Air temp & humidity	Rotronic HC2 - S3 with rad shield @ + 2.3 m	ATMOSPHERIC
3	Barometric pressure	Vaisala Barocap PTB210 @ +0.2 m	ATMOSPHERIC
4	Photosynthetically active radiation	LI-COR LI-192SA @ +2.6 m	ATMOSPHERIC
5	Salinity & temperature	Seabird SBE 37 @ -1.5 m	OCEAN
6	Dissolved oxygen	Seabird SBE 37 ODO @ -1.5 m	OCEAN
7	Chlorophyll-a	Wetlabs ECO-FL-S G4 @ -0.5 m	OCEAN
8	Skin temperature	Heitronics CT 15.10 @ +2.3	OCEAN
9	Wave height & period	Dual GPS aided IMU	OCEAN
15	Carbon	NOAA PMEL ASVCO2 (pCO2) Atmospheric & dissolved pCO2	OCEAN
10	AIS transceiver		MDA
11	Smart camera array	360° High-resolution optical cameras with ML target detection	MDA
12	Ocean currents	Teledyne RDI Workhorse ADCP 300 kHz @ -1.9 m	ACOUSTIC
13	Fish biomass	Simrad WBT Mini (EK80) @ -1.9 m	ACOUSTIC
14	Bathymetry	Shallow-water single-beam: Airmar DT800	ACOUSTIC
		Deep-water single-beam: Teledyne Echotrac E20	
		Deep-water single-beam: Simrad WBT Mini	

Atmospheric Cold Pool



- “A **cold air mass** that flows outward beneath intense thunderstorms” (e.g., Charba 1974)
- Important for **triggering and organizing convective activity** over ocean
- Traditionally observed by **weather stations, radar,** and **radiosondes** over land
- **Limited** *in situ* and surface-based observations **over remote tropical Pacific**

Capturing subgrid/subpixel variability

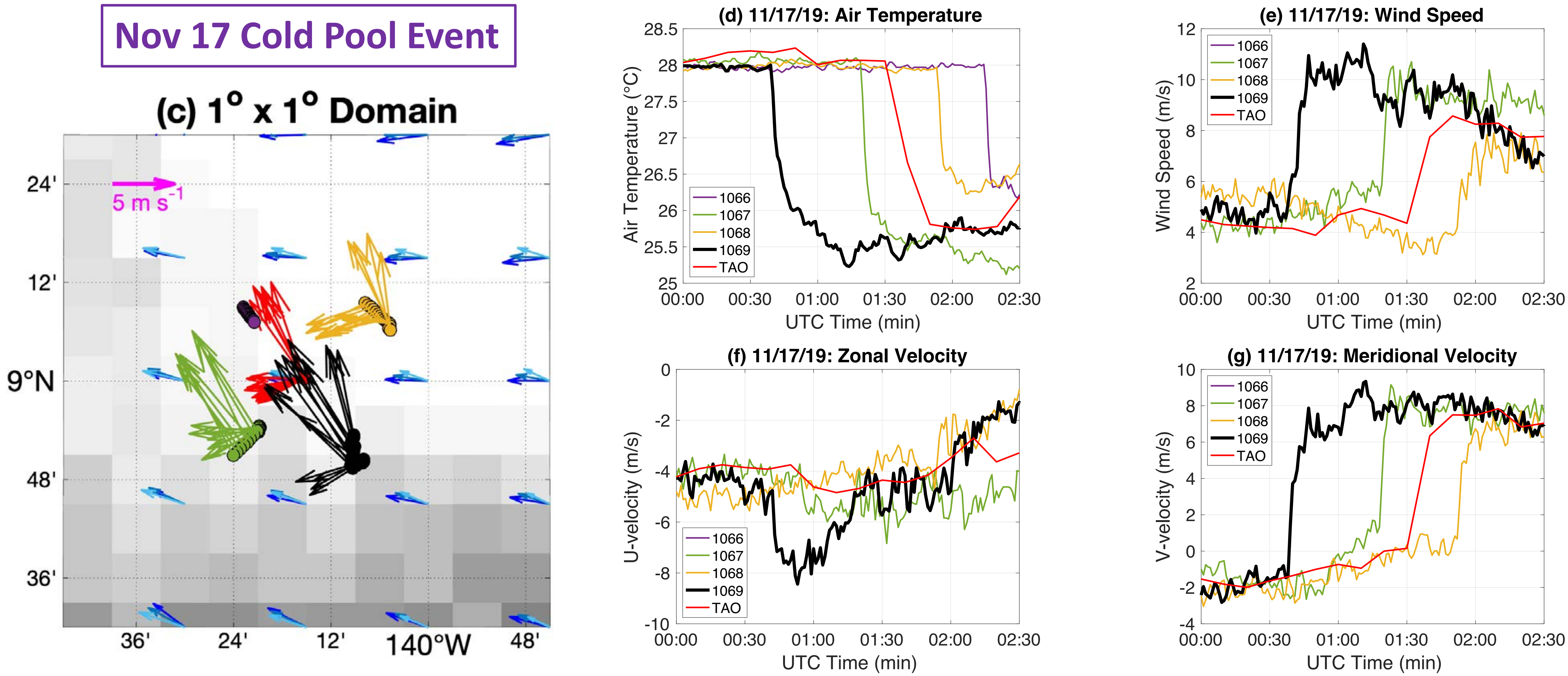


IMERG Precipitation Product (shading): 30-min, 0.1° x 0.1° resolution

ERA5 Wind Speed and Direction (blue vectors): hourly, 0.25° x 0.25° resolution

Wills et al. 2022 (in review)

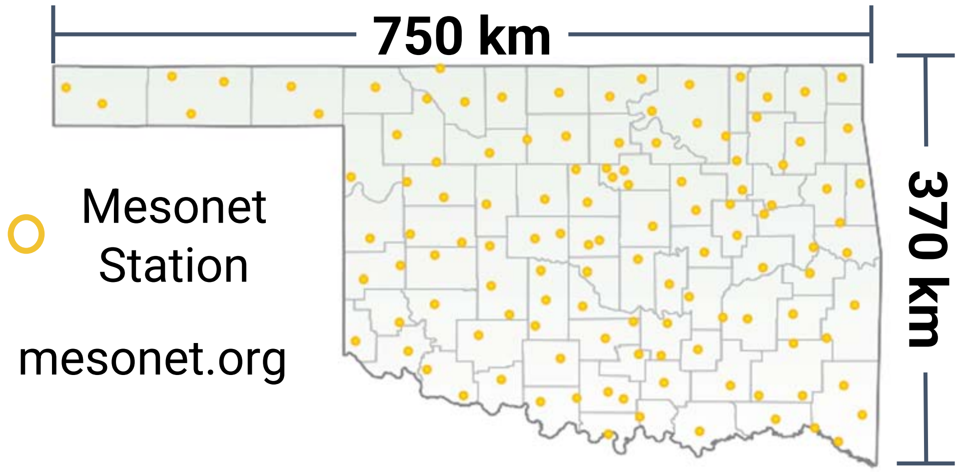
Capturing subgrid/subpixel variability



Temporal Resolution: TAO Buoy (10-min) v. Saildrone USV (1-min)

Wills et al. 2022 (in review)

Adaptive Mesoscale Network



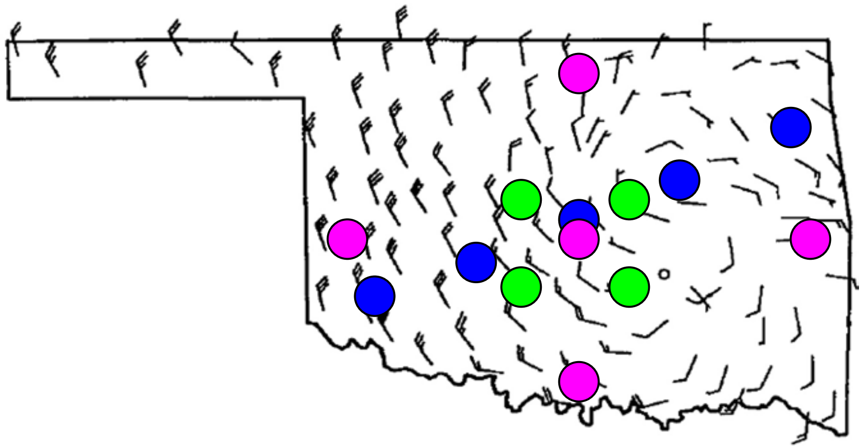
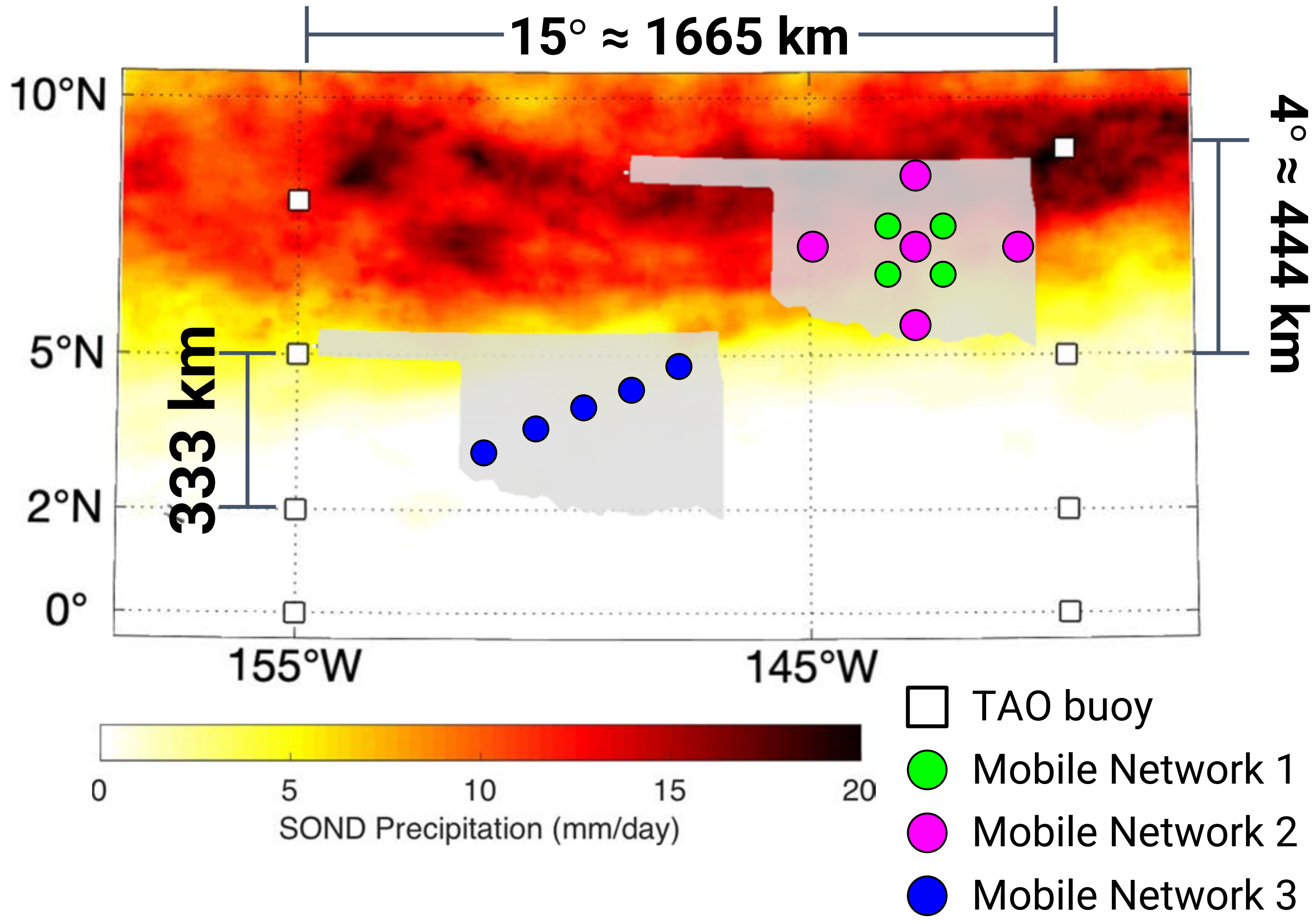
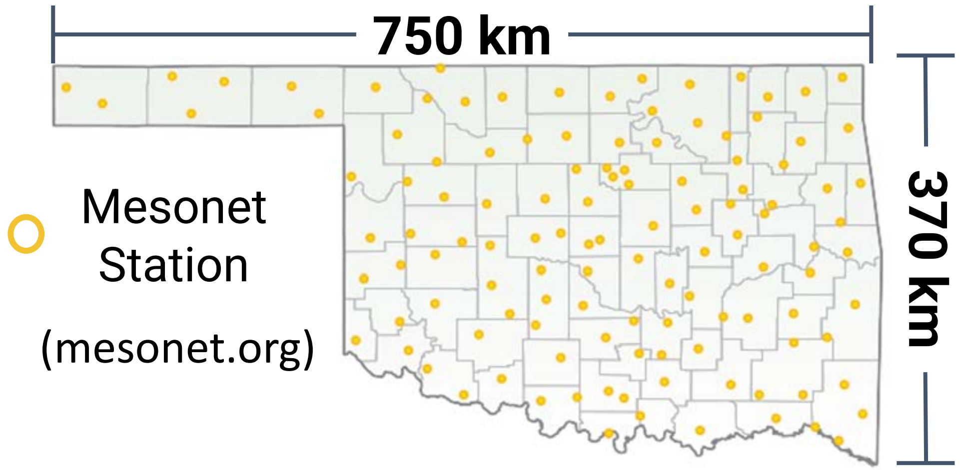


FIG. 13. Mesonet data for 0800 UTC 13 December 1993 showing a strong wind circulation centered in Oklahoma.

Brock et al. (1995):
The Oklahoma mesonet: A technical overview.



Adaptive drone network to address range of tropical phenomena

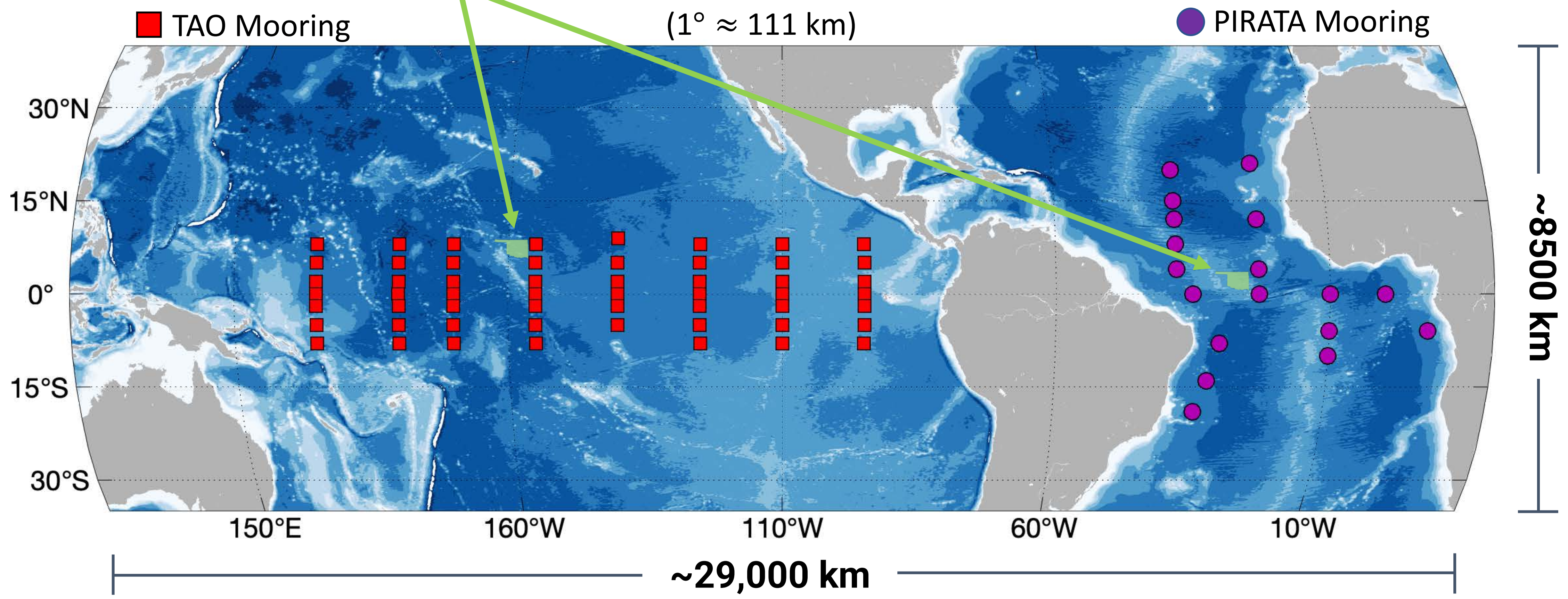


Tropical Atmosphere-Ocean (TAO) Array

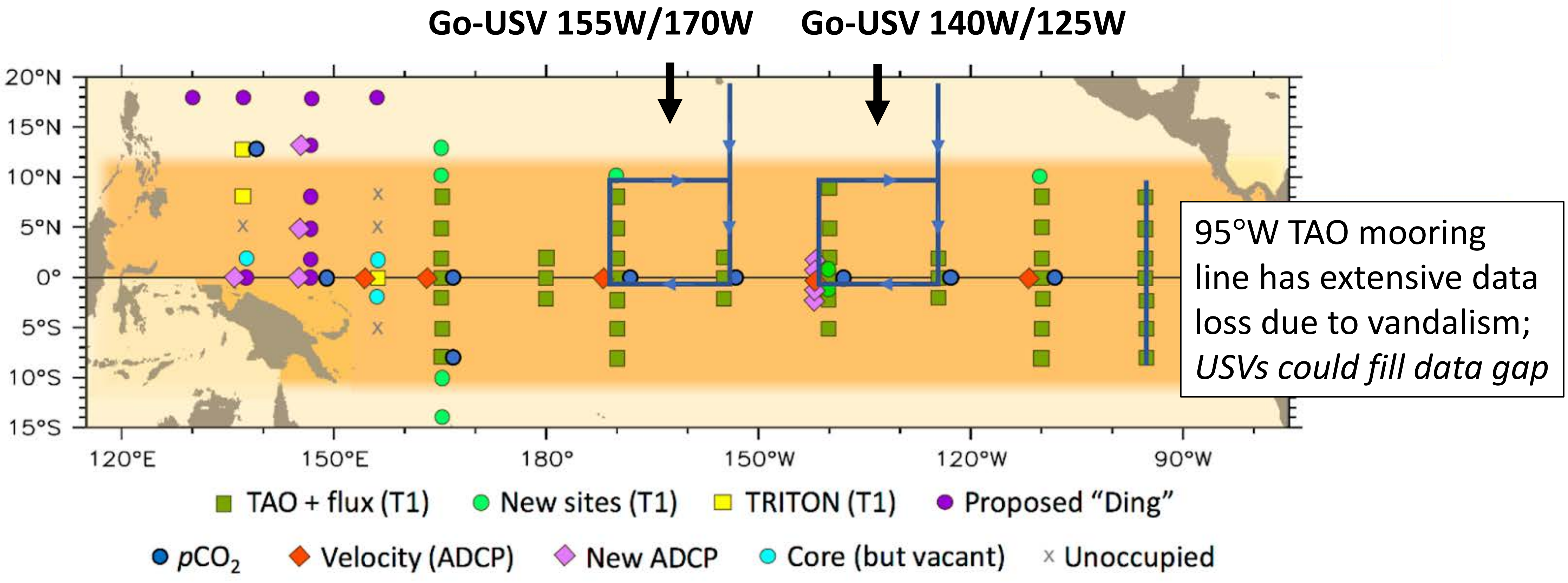
- Network of moored buoys 8°S - 9°N, 165°E - 95°W
- Spaced 10° - 15° longitudinally, and 2°- 4° latitudinally

Prediction and Research Moored (PIRATA) Array

- Network of moored buoys 19°S - 21°N, 38°W - 8°E
- Spaced 10° - 18° longitudinally, and 3°- 9° latitudinally



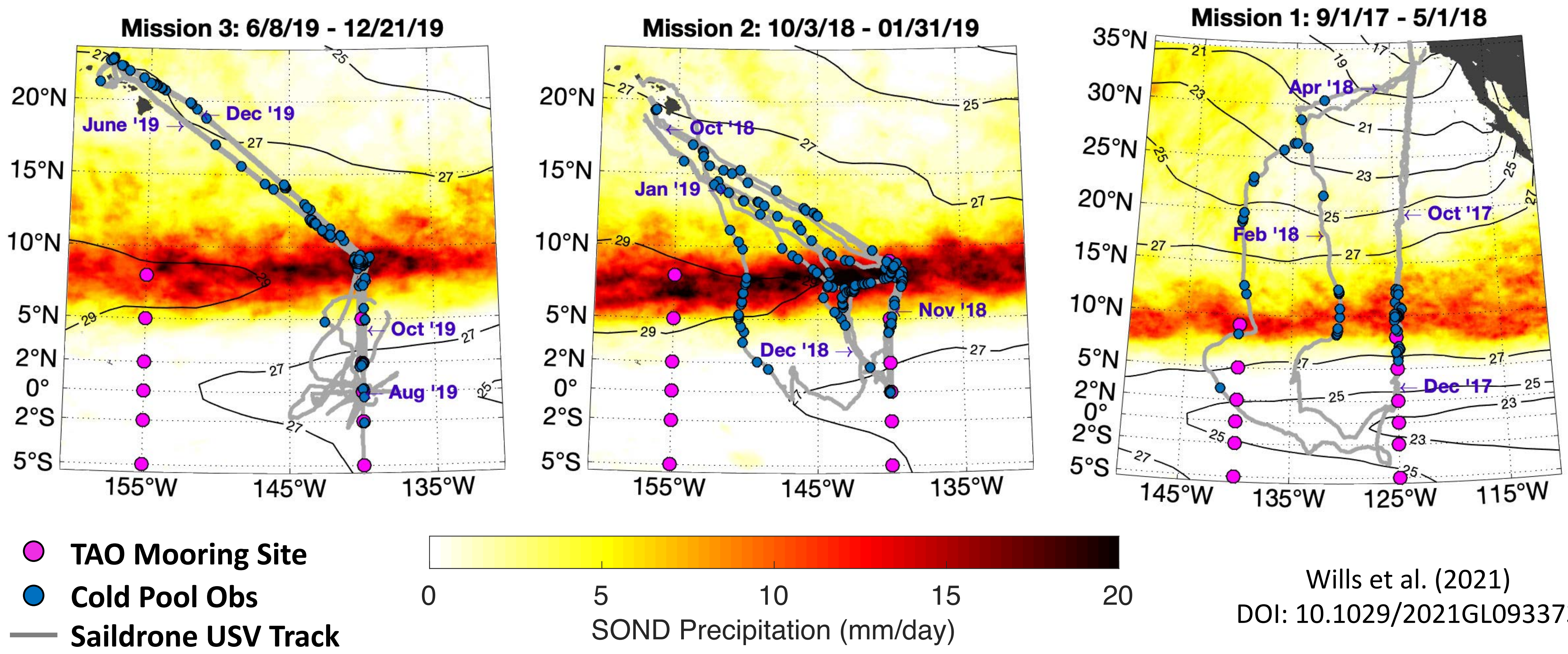
Tropical Pacific Observing System (TPOS)



Proposed Hydrographic Surveys

- Like Go-SHIP, "Go-USV" missions will monitor multidisciplinary variables in pairs along repeat sections.
- Go-USV air-sea interaction observations will coordinate with underway TPOS ship measurements (as available) and leverage TAO buoys to increase sampling density in otherwise data sparse ocean regions.

Central and Eastern Tropical Pacific Pilot Studies

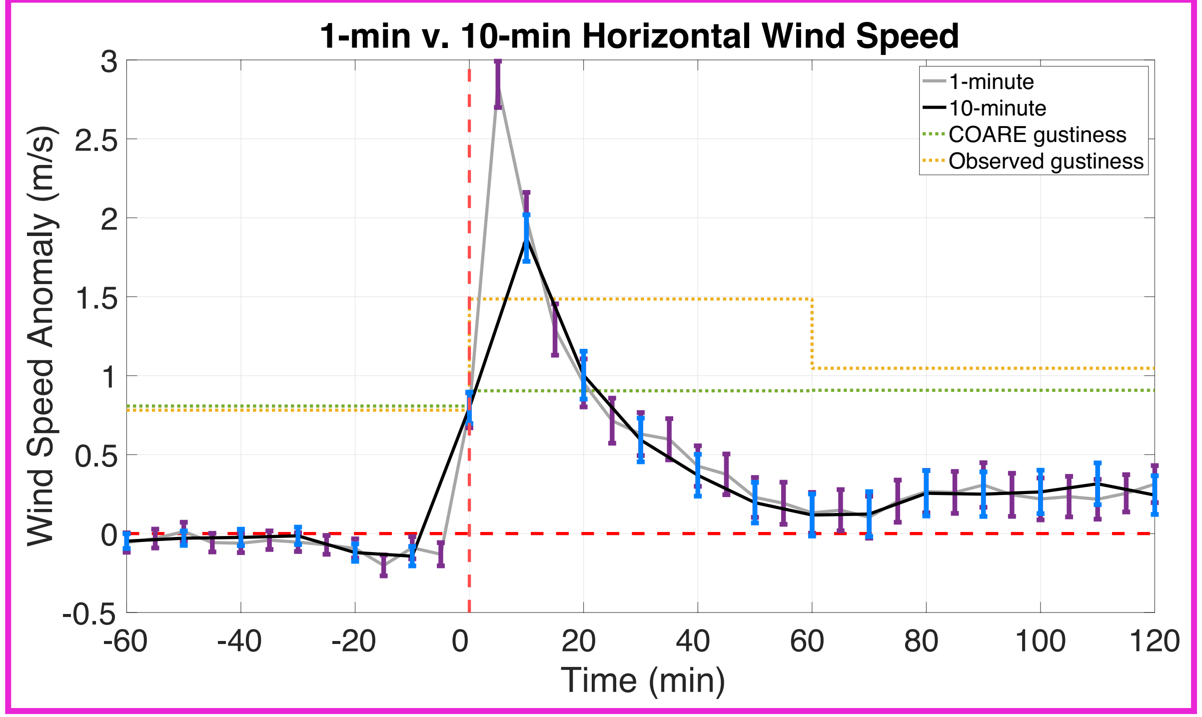


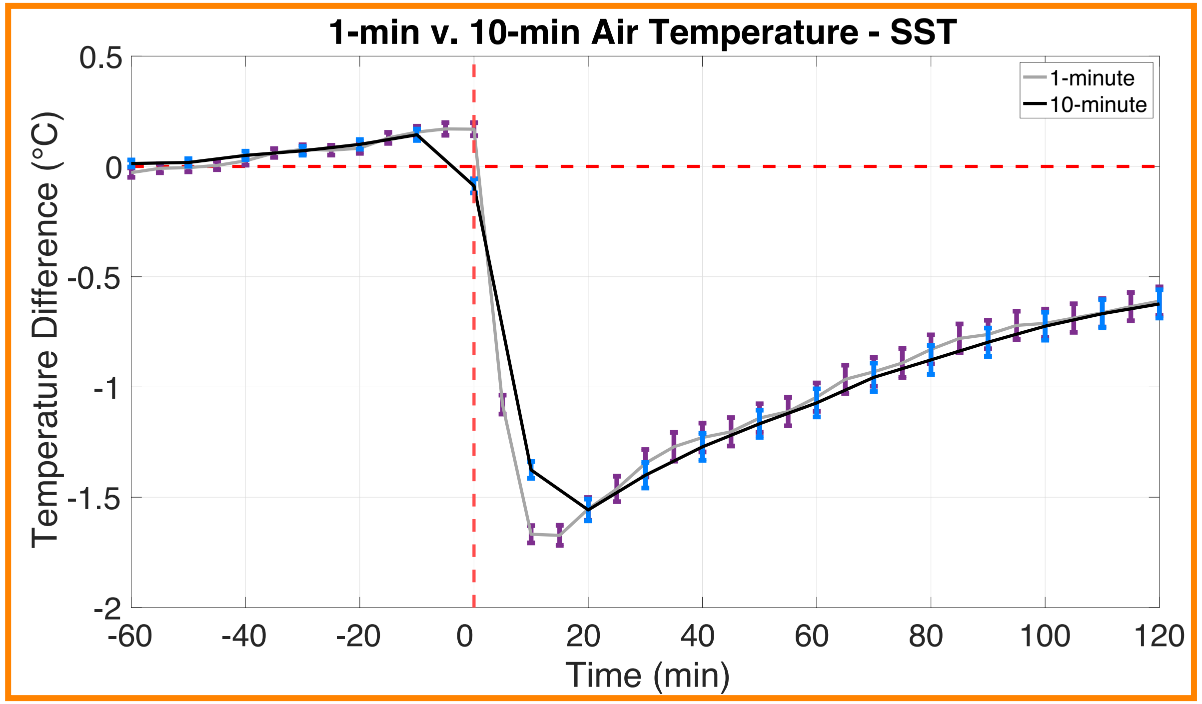
Wills et al. (2021)
DOI: 10.1029/2021GL093373

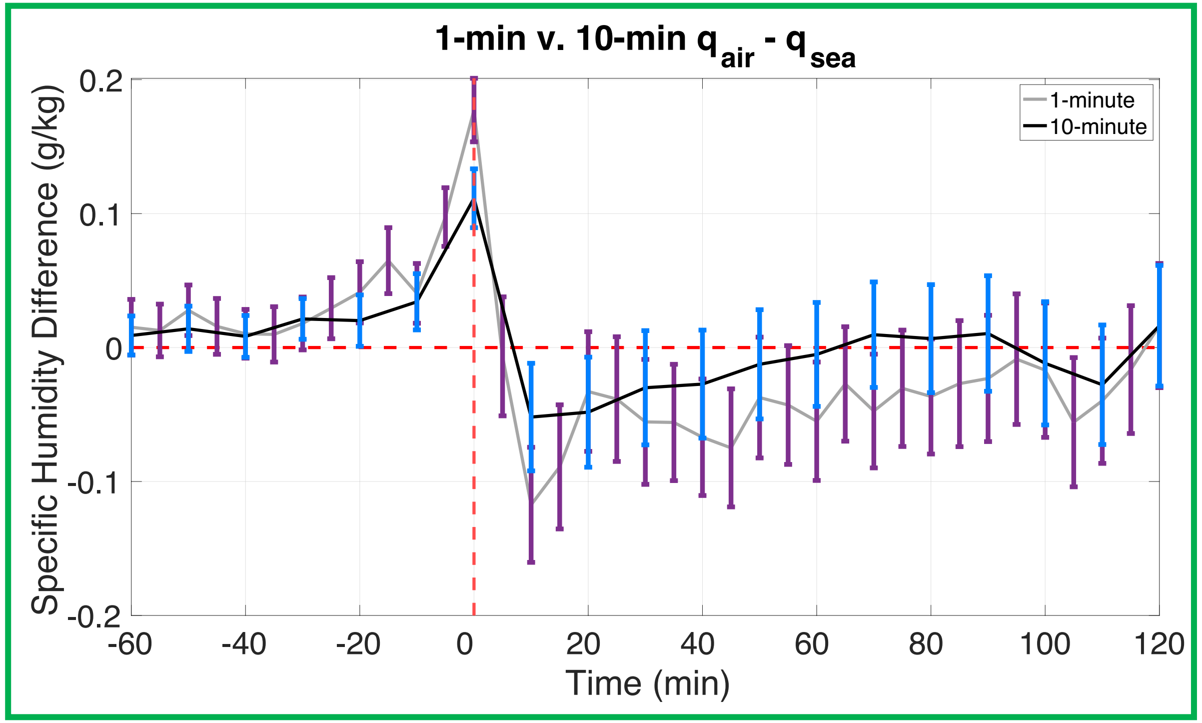
Cold pool events identified as **surface air temperature drops** of **1.5°C over a 10-minute period**

How do atmospheric cold pools influence air-sea heat fluxes?

Results based on 276 qualifying cold pool events







Bulk latent heat flux: $Q_L = \rho L_e C_E \boxed{U_r} \boxed{\triangle\, q}$

Bulk sensible heat flux: $Q_S = \rho c_p C_H \boxed{U_r} \boxed{\triangle\, \theta}$

Wills et al. 2022 (in review)

COARE Algorithm Gustiness Parameter

- COARE 3.5 algorithm applies a "gustiness" parameter, u_g, that **relates the scalar- and vector-averaged winds**:

Gustiness Parameter

$$u_g^2 = \underbrace{U^2}_{\text{scalar wind}} - \underbrace{|\vec{u}|^2}_{\text{vector wind}}$$

- u_g^2 reflects the **missing wind variance** over a select time period
- Tuned to hourly average values that accounts for the underestimation of air-sea fluxes **associated with boundary layer large eddies within low-wind regimes during fair weather conditions** (e.g., Edson et al. 2013; Fairall et al. 1996, 2003)

★ Able to calculate missing wind variance associated with convective cold pools from high-resolution Saildrone measurements

COARE Algorithm Gustiness Parameter

- COARE 3.5 algorithm applies a "gustiness" parameter, u_g, that **relates the scalar- and vector-averaged winds**:

Gustiness Parameter

$$u_g^2 = U^2 - |\vec{u}|^2$$

scalar wind vector wind

★ Calculating **hourly-average** and **10-min average** missing wind speed variance (u_g^2)

$$U = \frac{1}{n}\sum_{t=1}^{n} u_t = \frac{1}{n}\left(\sqrt{u_1{}^2 + v_1{}^2} + \sqrt{u_2{}^2 + v_2{}^2} + \ldots\sqrt{u_n{}^2 + v_n{}^2}\right)$$

Based on 1-min **wind speed** measurements

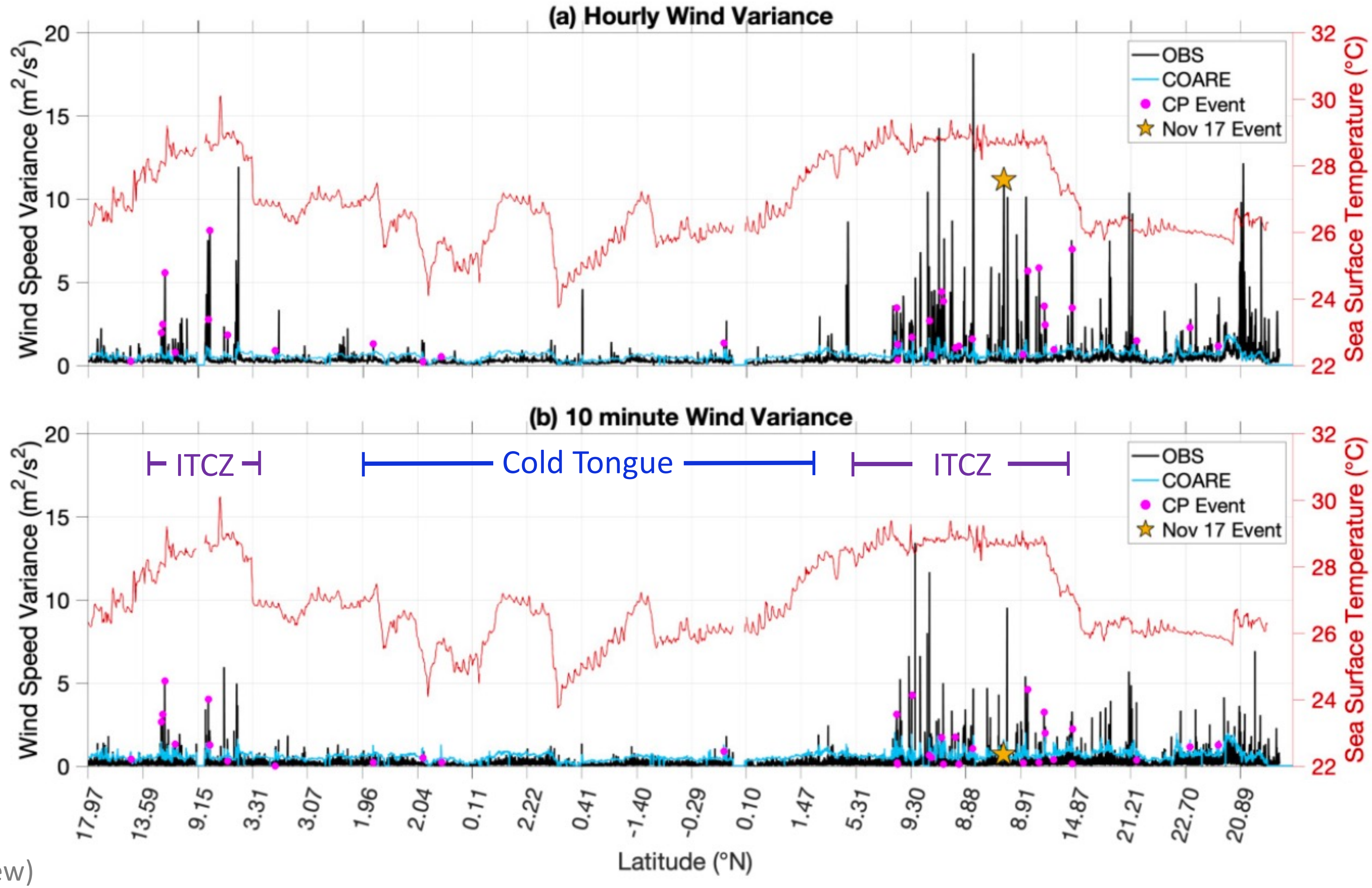
$$|\vec{u}| = \sqrt{\bar{u}^2 + \bar{v}^2}$$

Based on 1-min **zonal** and **meridional** velocity measurements

COARE output v. obs: Missing Wind Variance

Comparing **hourly** scalar and vector winds

Comparing **10-min** scalar and vector winds

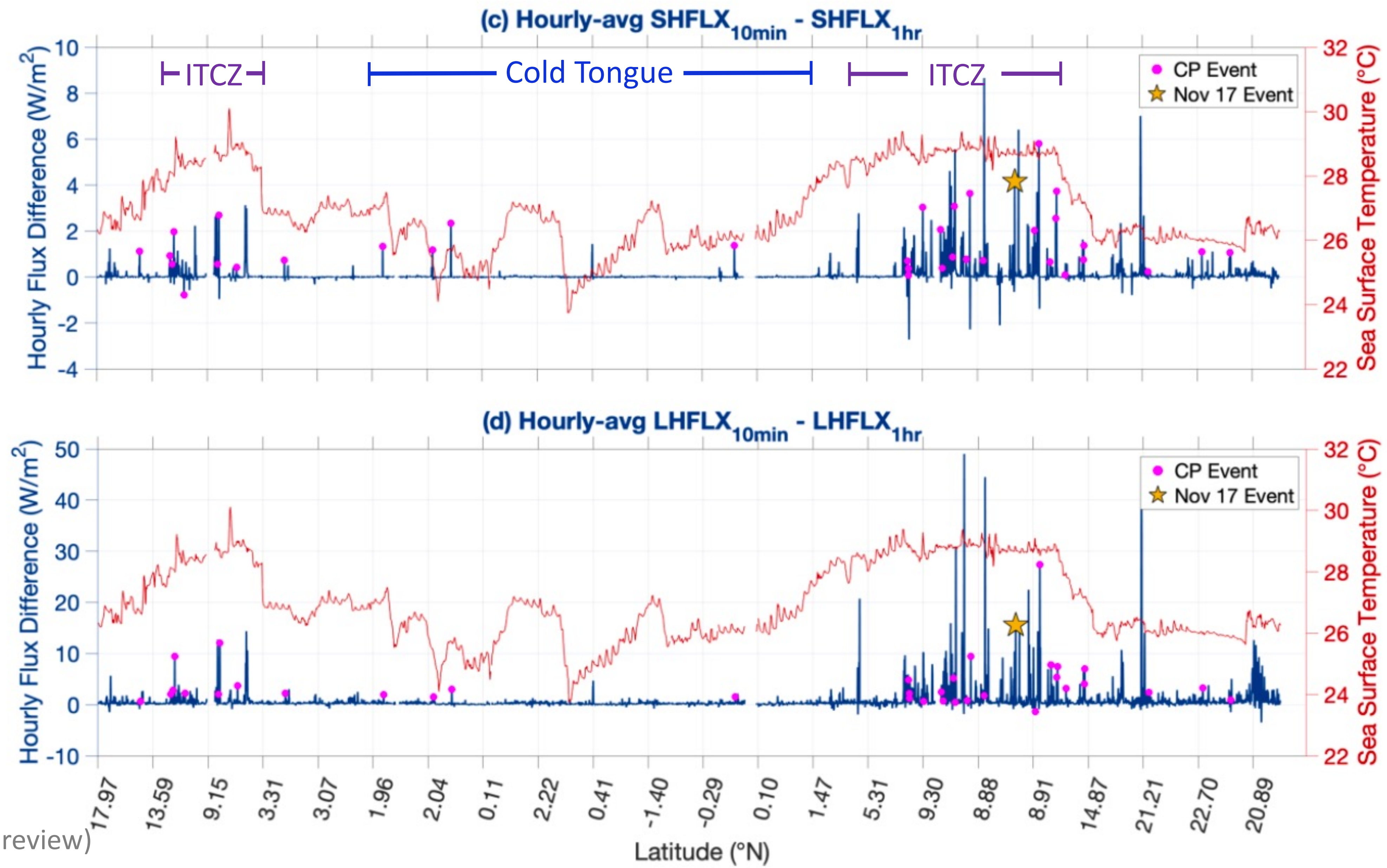


Wills et al. 2022 (in review)

Bulk Heat Flux Estimates: 10-min v. 1-hr Input

Sensible heat flux

Latent heat flux



Wills et al. 2022 (in review)

Challenges/Opportunities

- Limited availability of high-resolution in situ observations over remote ocean regions to
  - **Measure** the marine boundary layer **beyond the near-surface**
  - **Validate findings** from previous modeling experiments and satellite measurements
  - **Compare** bulk flux **estimates to direct observations** in varying conditions
  - **Ingest into data assimilation** systems for operational forecast models

- International Programs and Collaborations
  - UN Decade of Ocean Science for Sustainable Development Program – **OASIS "Observing Air-Sea Interactions Strategy"** (airseaobs.org)
  - Potential 2026 **TPOS field campaign** to target PUMP and EEWP process studies through NOAA CVP program

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SAILDRONE