Observing Coupled Ocean-Atmosphere for Advancing Earth System Science

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- Multiscale ocean-atmosphere interactions play a critical role in global weather-climate continuum, from extreme weather events (e.g., hurricanes), subseasonal-to-seasonal (e.g., MJO, marine heat waves) to climate variability (e.g., ENSO) and climate change
- Air-sea exchanges of energy, mass, and momentum are influenced by not only the air-sea interface, but also the upper ocean and atmospheric boundary layer known as the Air-Sea Transition Zone.

What is the Air-Sea Transition Zone?

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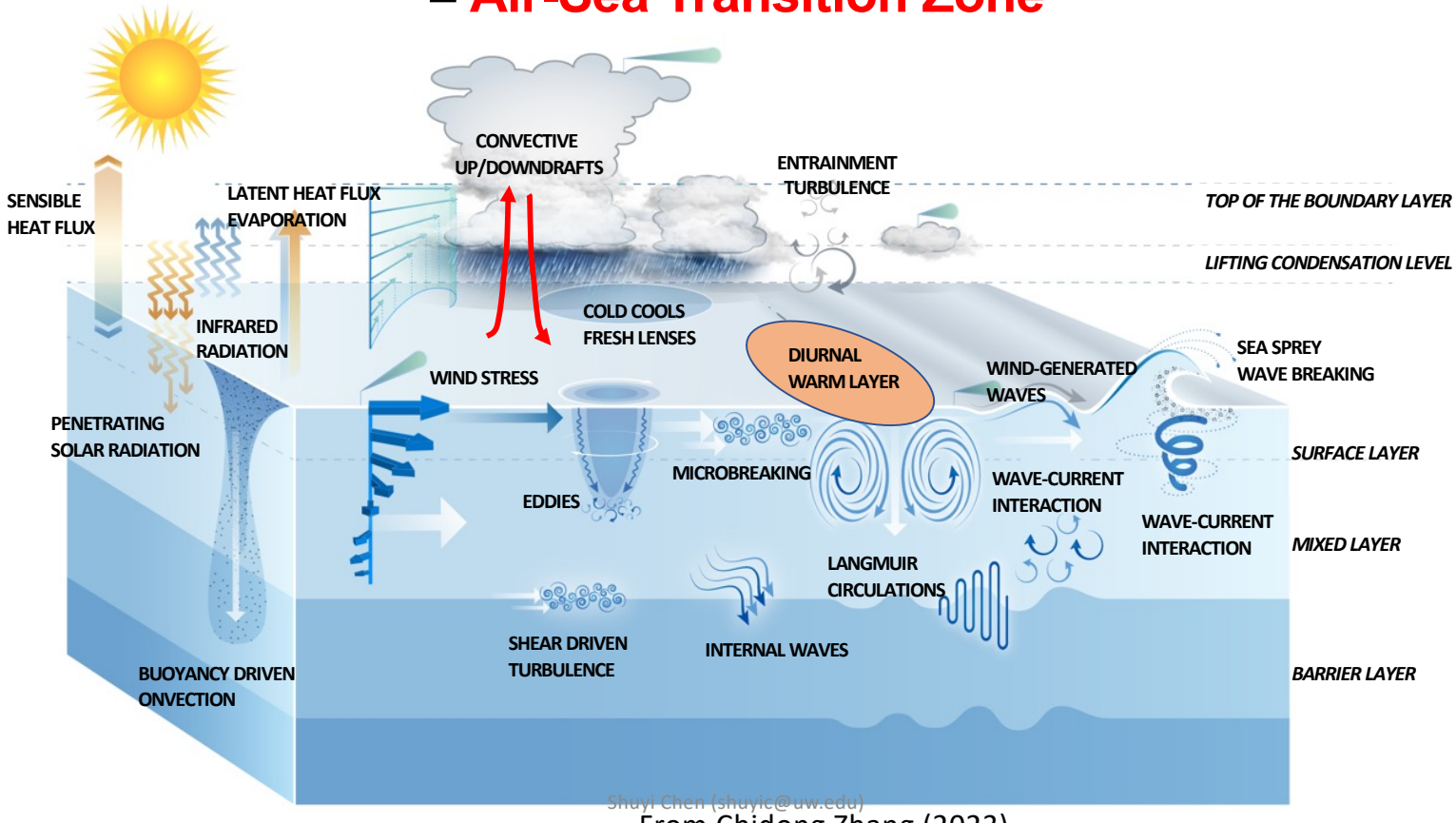
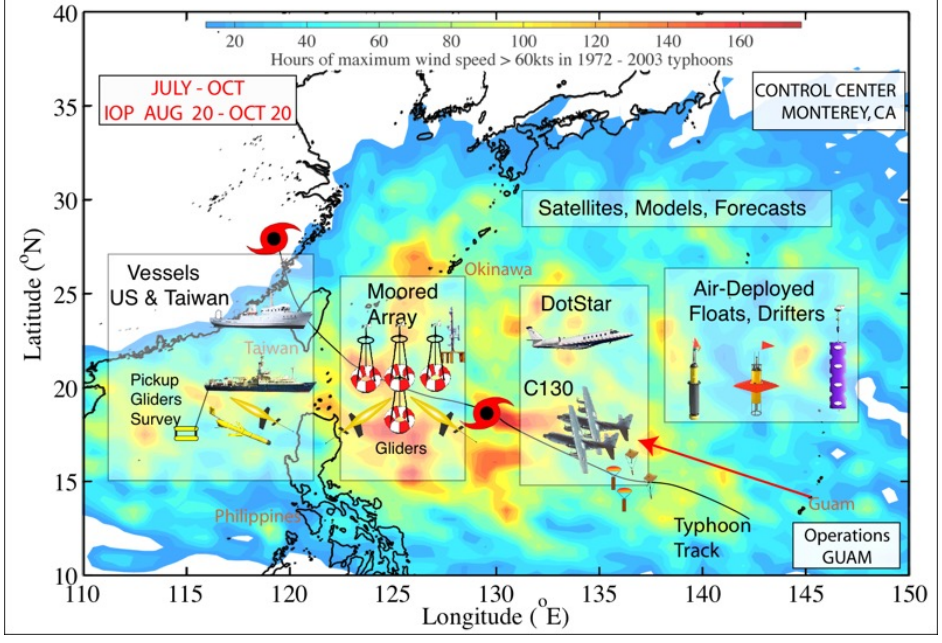
Upper Ocean + Air-Sea Interface + Atmospheric Boundary layer
= Air-Sea Transition Zone



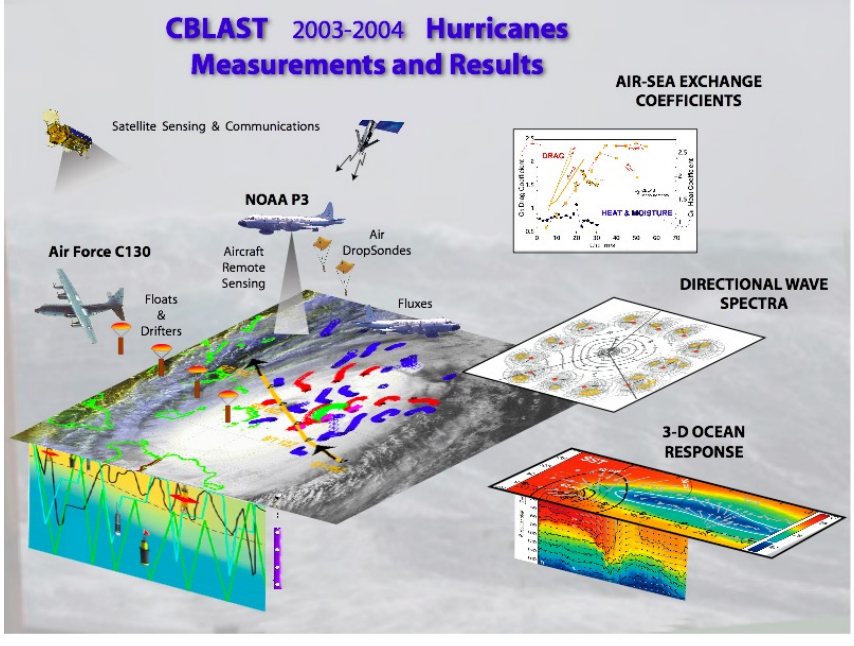
From Chidong Zhang (2023)

Impact of Typhoons on Ocean in Pacific (ITOP)-2010
D'Asaro et al. (2014)



How TC-induced cold wake affect TC structure and intensity?

Coupled Boundary Layers Air-Sea Transfer (CBLAST)
Black et al. (2007), Chen et al. (2007)



How surface waves affect air-sea fluxes in TCs?

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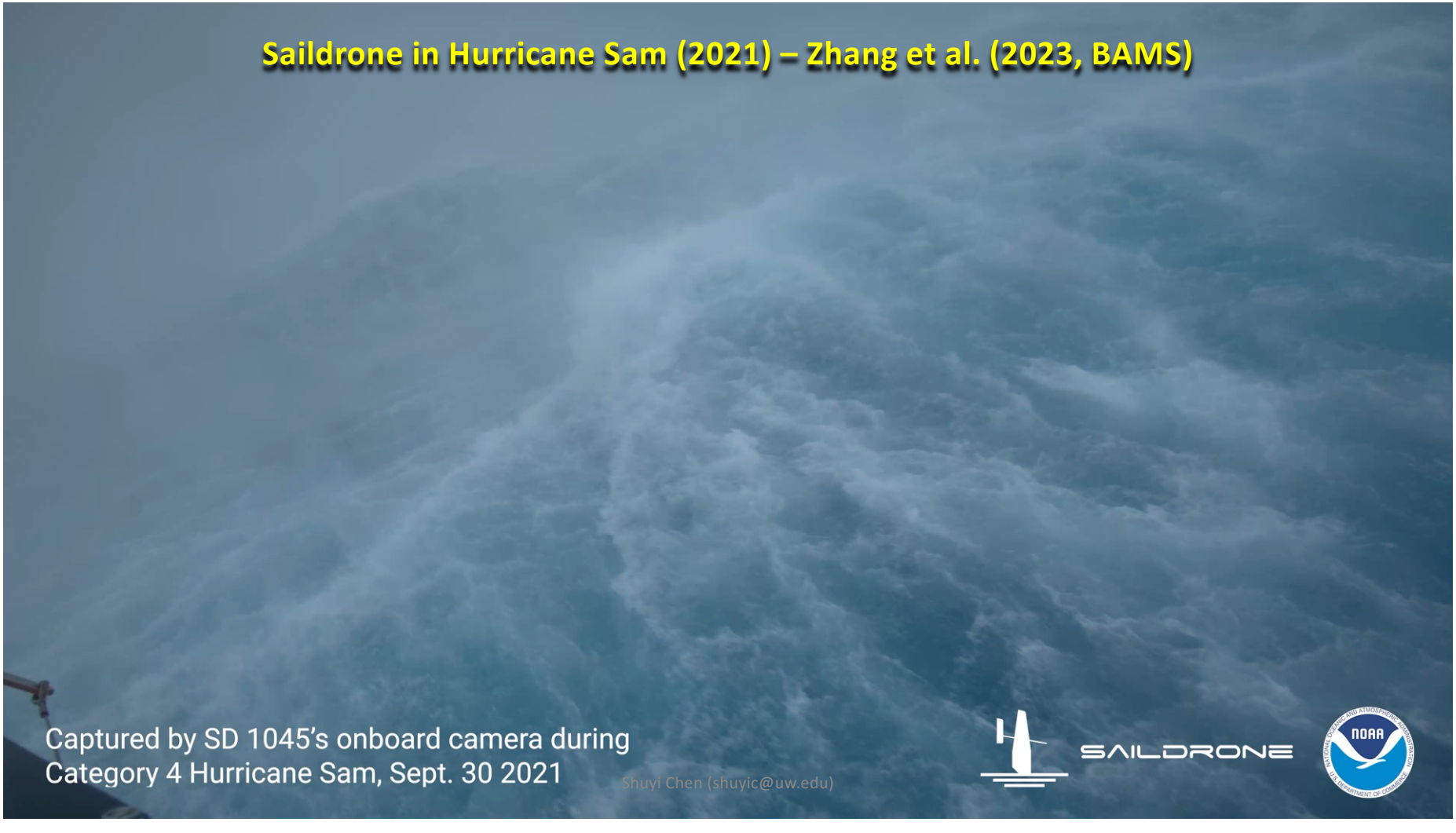
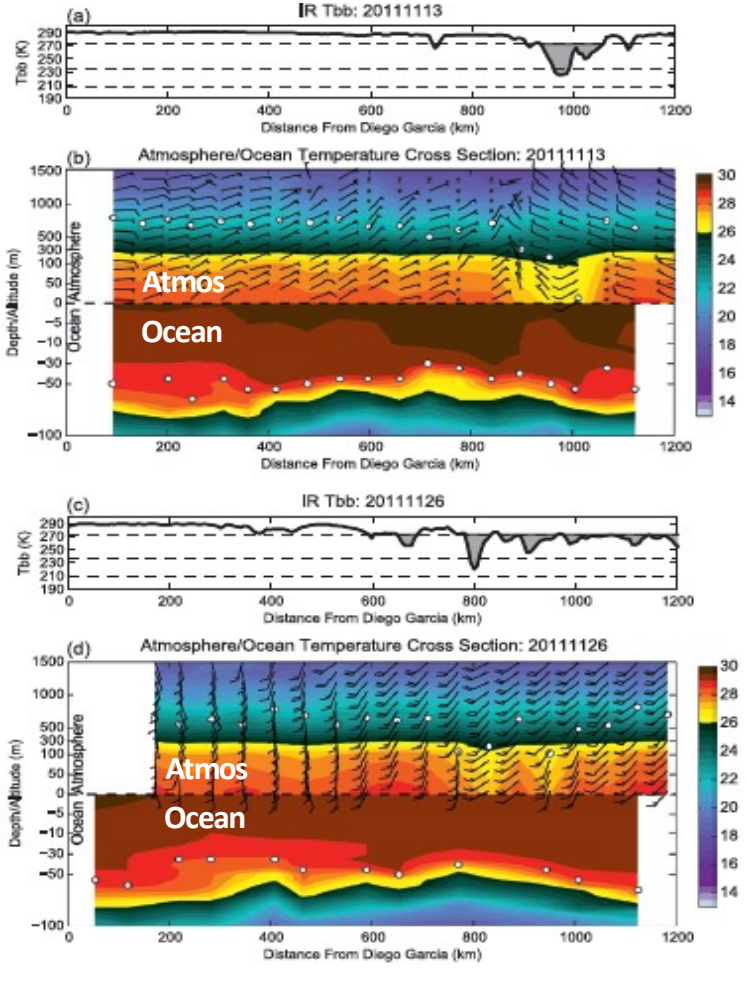
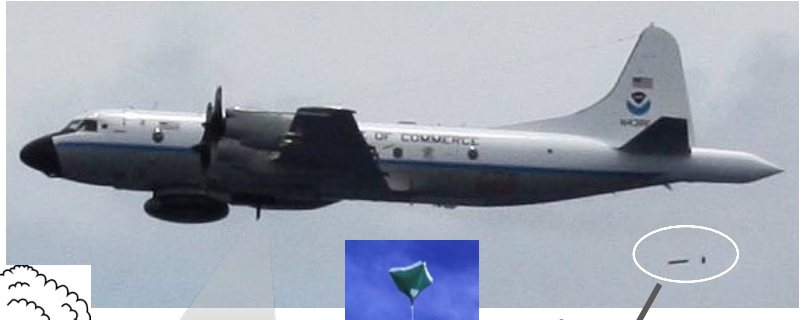
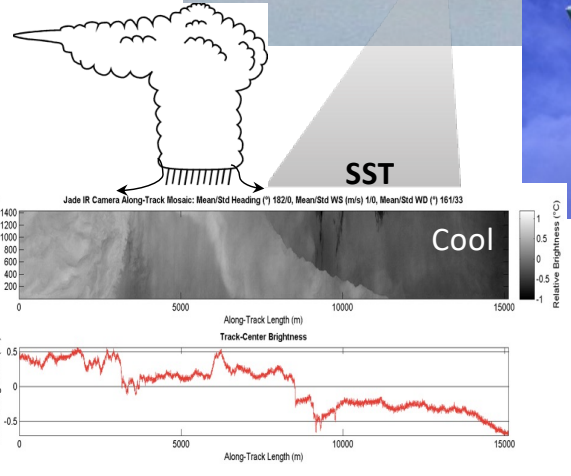
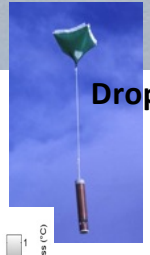

Saildrone in Hurricane Sam (2021) – Zhang et al. (2023, BAMS)
Captured by SD 1045's onboard camera during
Category 4 Hurricane Sam, Sept. 30 2021
Shuyi Chen (shuyic@uw.edu)
SAILDRONE
NOAA

Chen et al. (2016, BAMS): Aircraft Observations of Air-Sea Interaction in MJO during DYNAMO

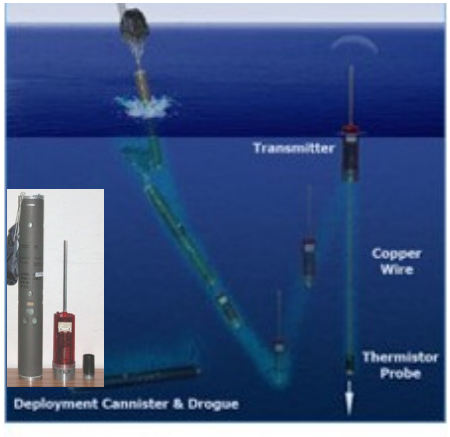








AXBT (Airborne eXpendable BathyThermograph)



Clouds, wind, and atmosphere-ocean temperature profiles by dropsondes and AXBT during MJO suppressed (top left) and active (bottom left) phases.

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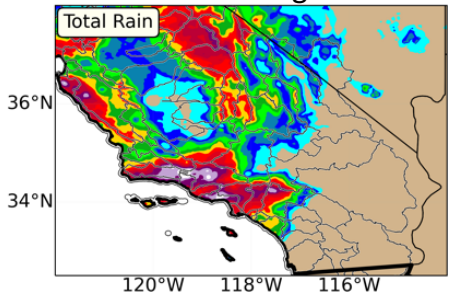
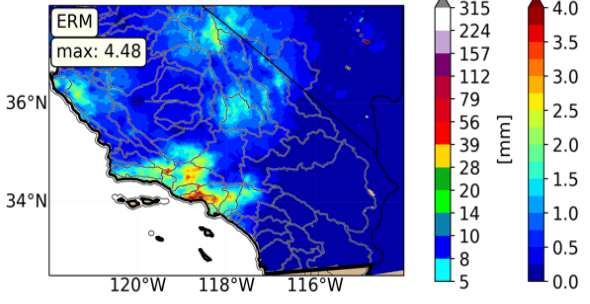
1,000 Year Flood LA County, CA (Feb 5, 2024)

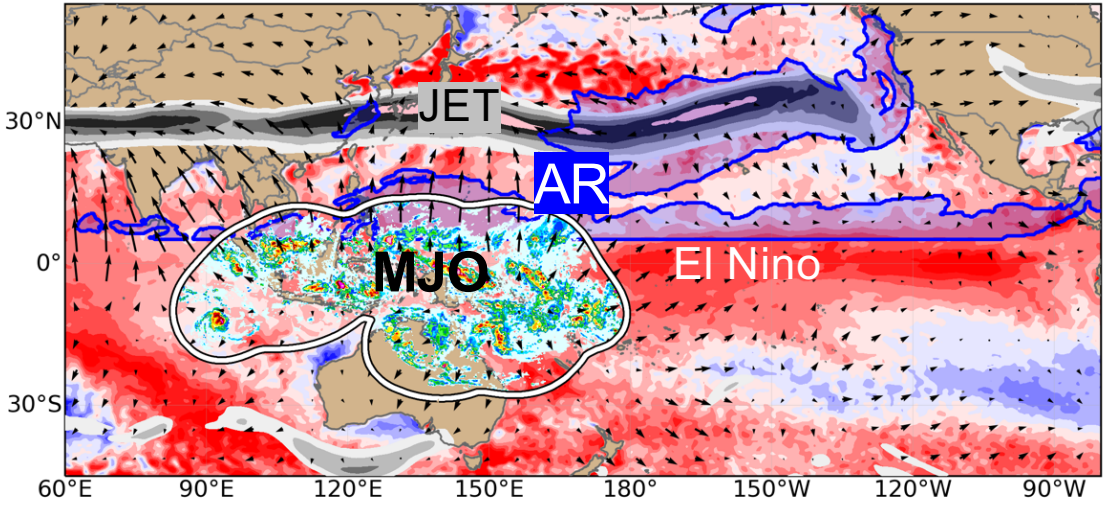
Rainfall Stage IV



ERM



Key Players: El Nino, MJO, Jet, and Atmospheric River 1/20/24



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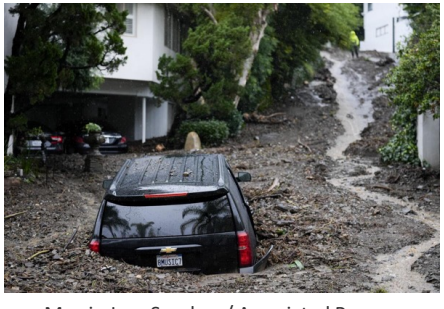
Flooding

Kyle Grillot / The Washington Post



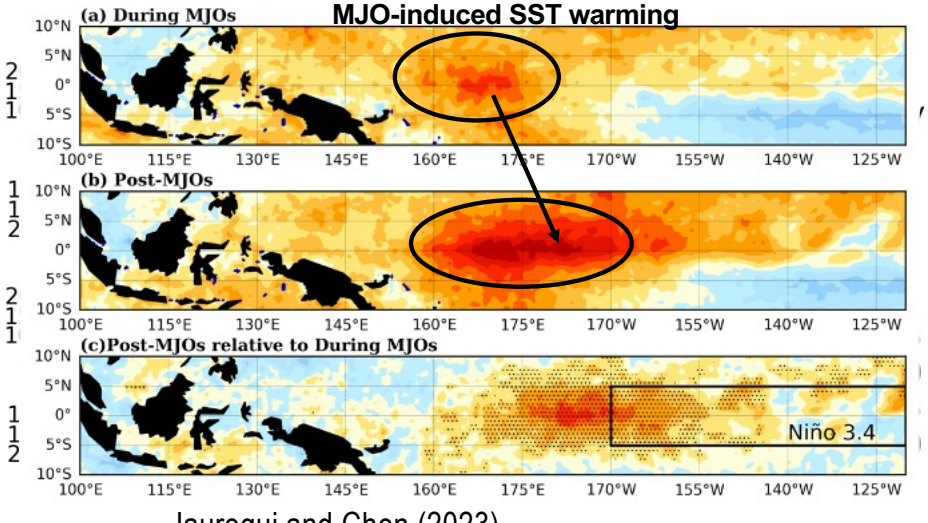
Marcio Jose Sanchez / Associated Press

Mazza, Chen, Kerns (2024)

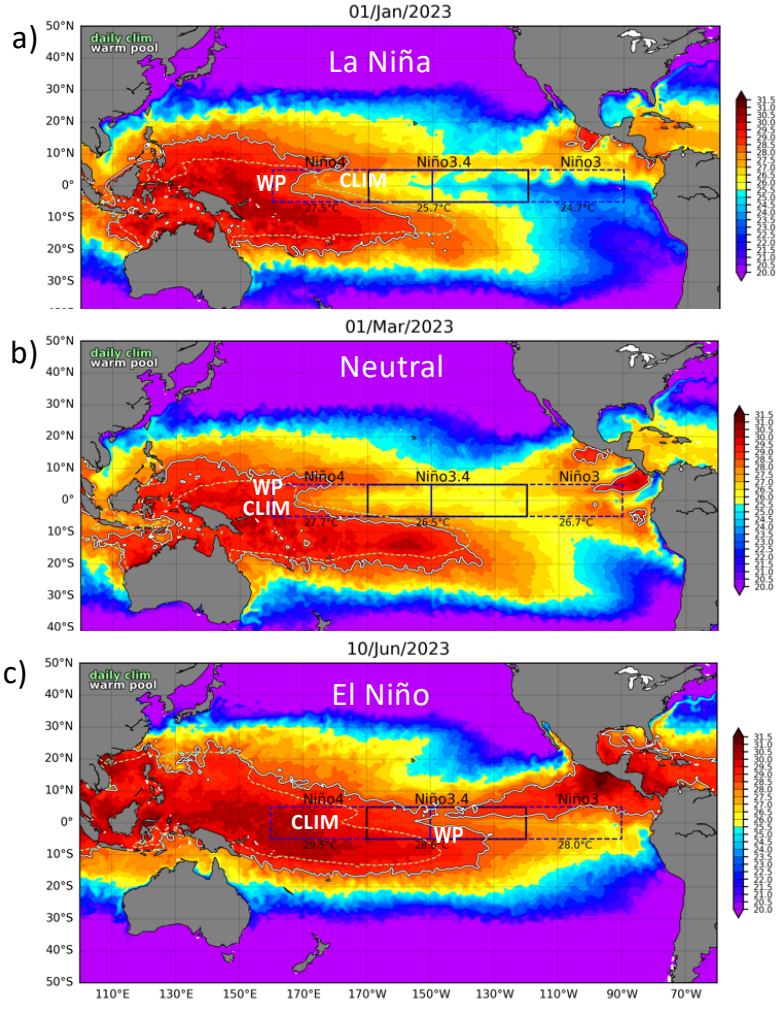
Onset of the 2023 El Niño

Chen et al. (2024)

a) 1 January 2023 – La Niña
b) 1 March 2023 – Neutral
c) 10 June 2023 – El Niño
d) Eastward extension of warm pool is associated with 3 MJO events that contributed during the onset of El Niño (Jan – Jun 2023) Niño3,4 region (a-c).



Jauregui and Chen (2023)



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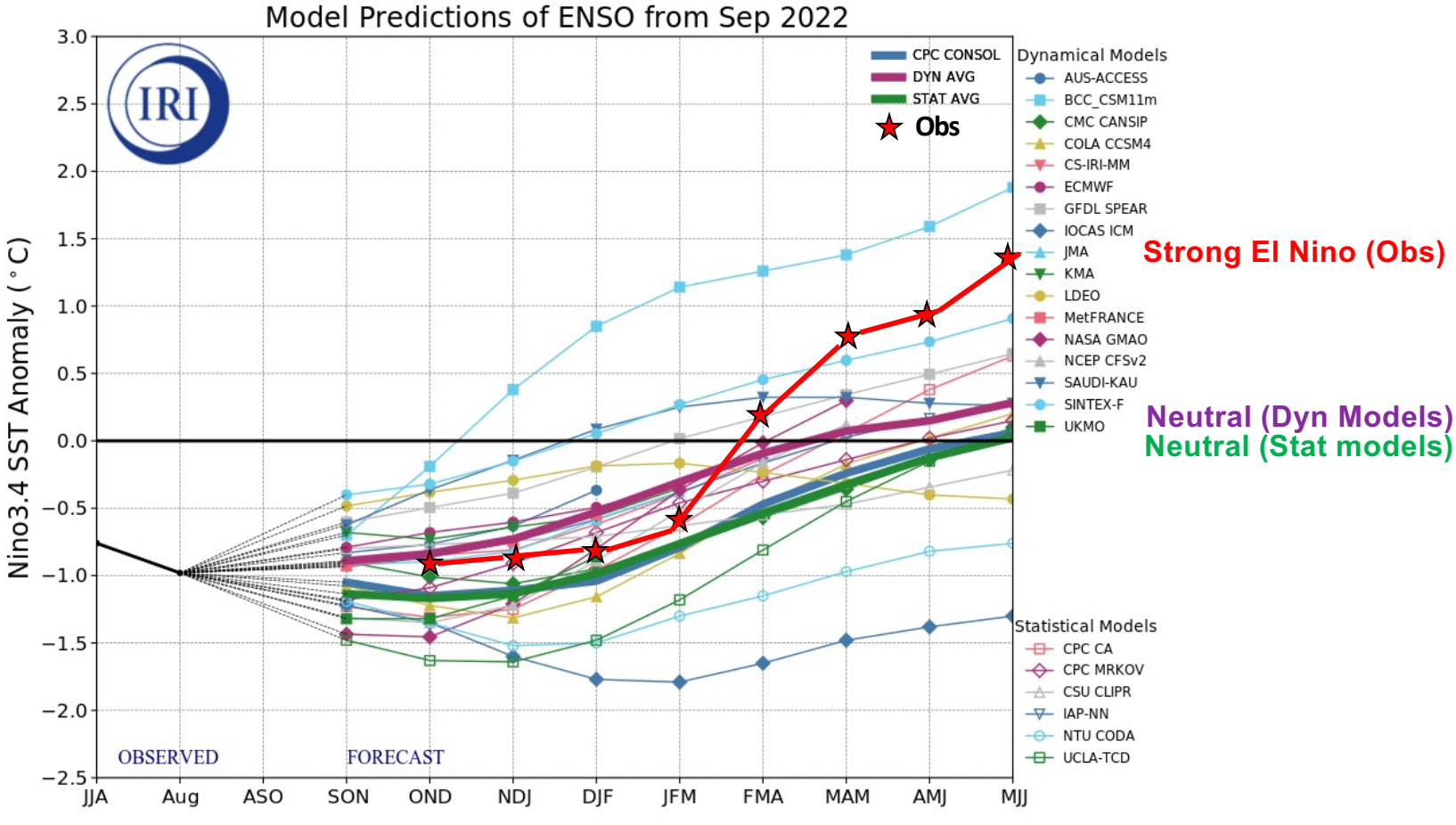

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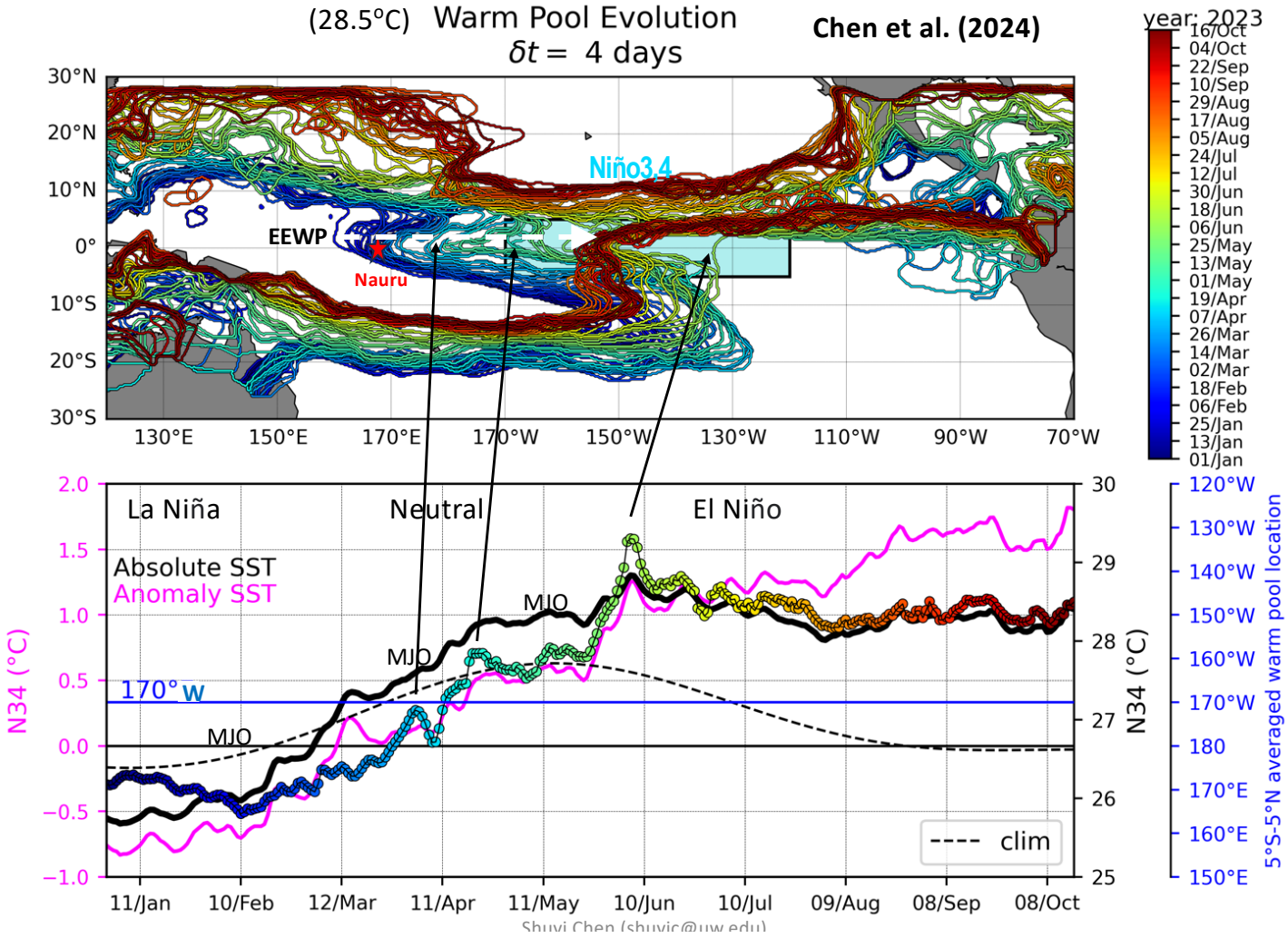
(28.5°C) Warm Pool Evolution
δt = 4 days
Chen et al. (2024)
year: 2023
16/Oct
04/Oct
22/Sep
10/Sep
29/Aug
17/Aug
05/Aug
24/Jul
12/Jul
30/Jun
18/Jun
06/Jun
25/May
13/May
01/May
19/Apr
07/Apr
26/Mar
14/Mar
02/Mar
18/Feb
06/Feb
25/Jan
13/Jan
01/Jan
Niño3.4
EEWP
Nauru
30°N
20°N
10°N
0°
10°S
20°S
30°S
130°E
150°E
170°E
170°W
150°W
130°W
110°W
90°W
70°W
La Niña
Neutral
El Niño
Absolute SST
Anomaly SST
MJO
MJO
MJO
170° W
clim
N34 (°C)
N34 (°C)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
30
29
28
27
26
25
120°W
130°W
140°W
150°W
160°W
170°W
180
170°E
160°E
150°E
5°S-5°N averaged warm pool location
11/Jan
10/Feb
12/Mar
11/Apr
11/May
10/Jun
10/Jul
09/Aug
08/Sep
08/Oct
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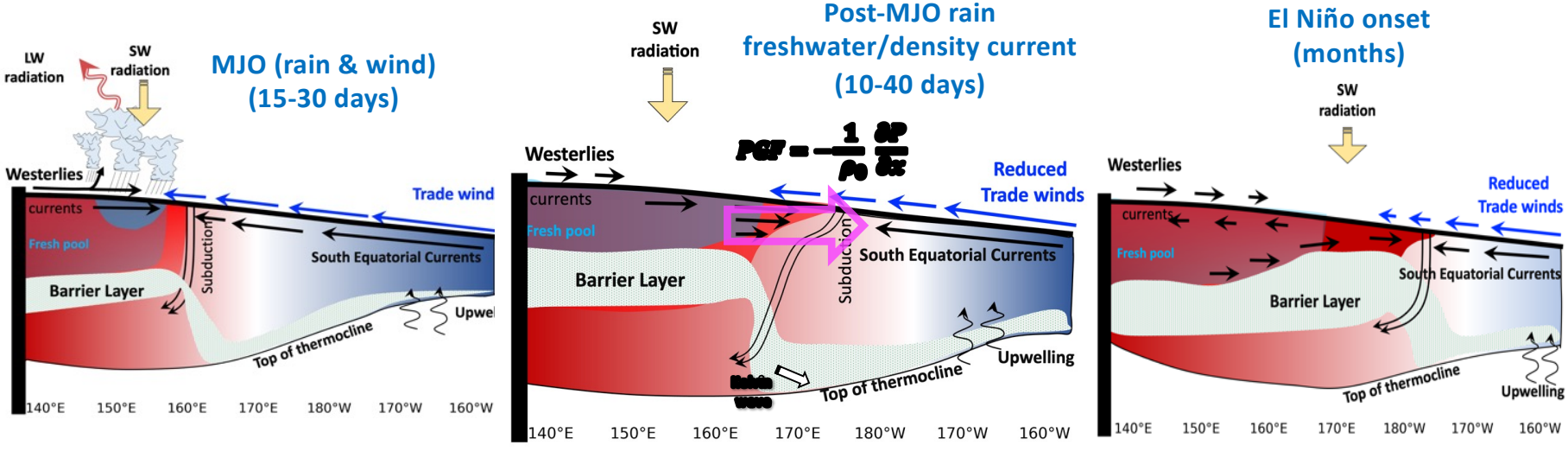
The MJO-El Niño Multiscale Air-sea Interaction Processes

Kerns and Chen (2021), Jauregui and Chen (2023, 2024)



Based on Kerns and Chen (2021) and Jauregui and Chen (2023, 2024)
https://orca.atmos.washington.edu/publications.php

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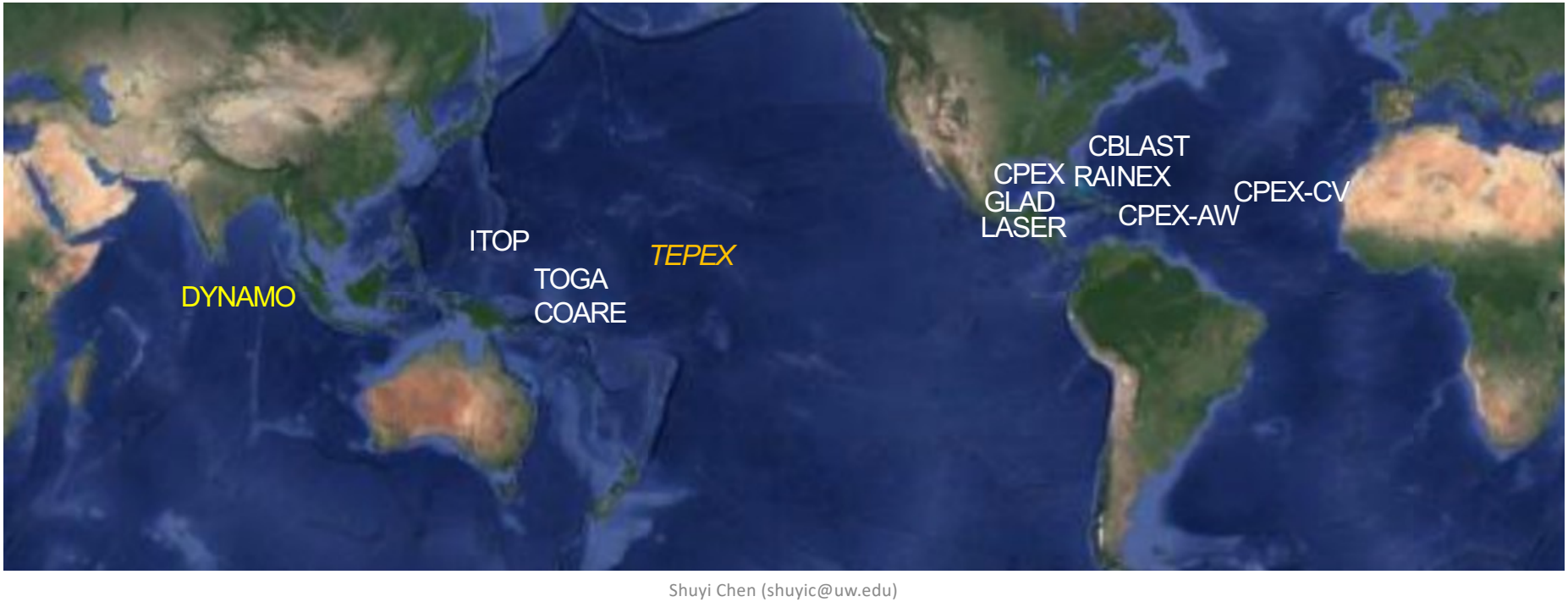
Tropical Field Campaigns – Air-Sea Interface and Transition Zone



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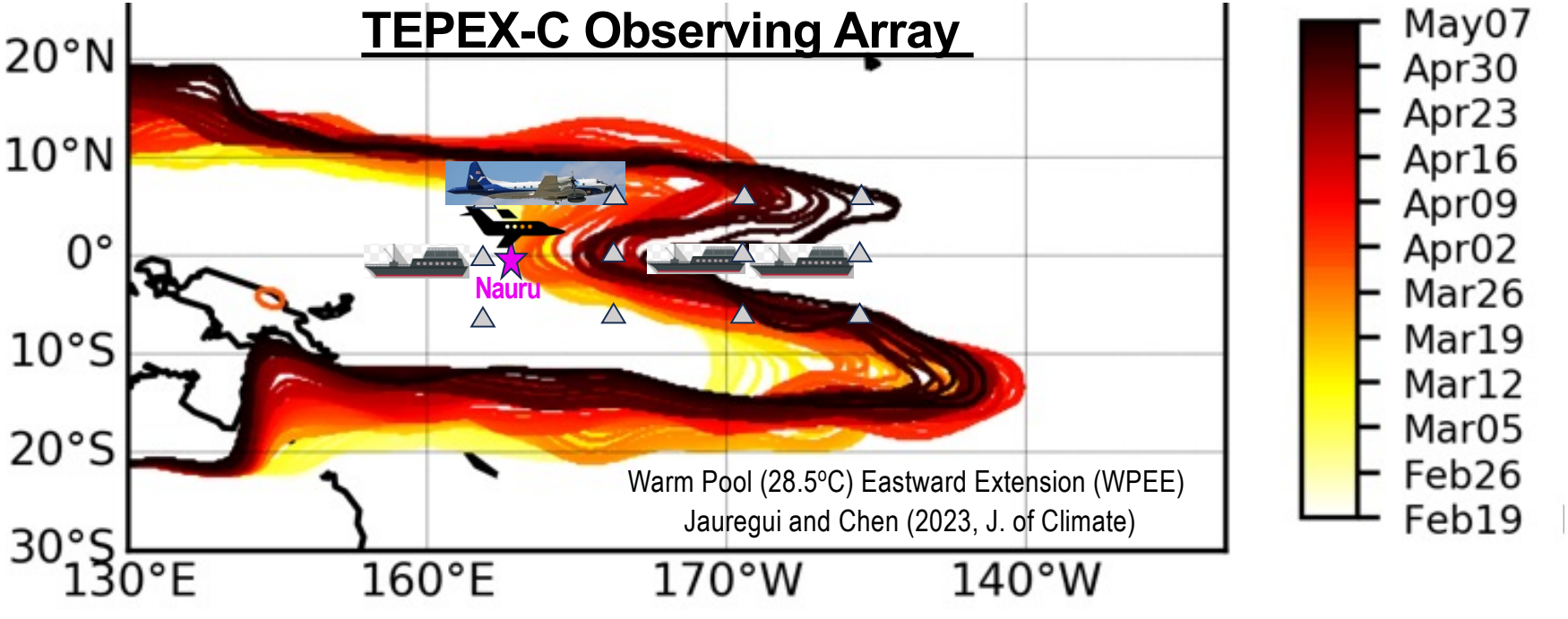
Proposed Tropical Equatorial Pacific Experiment (TEPEX) Field Campaign 2026



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SailBuoy

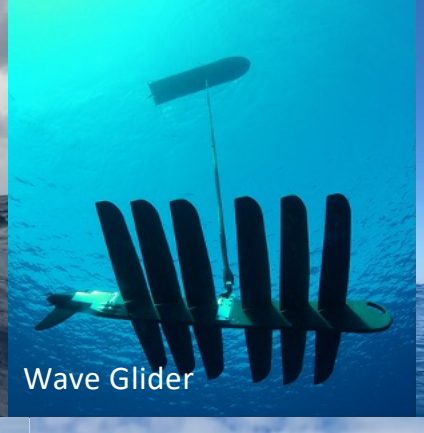

C-Enduro

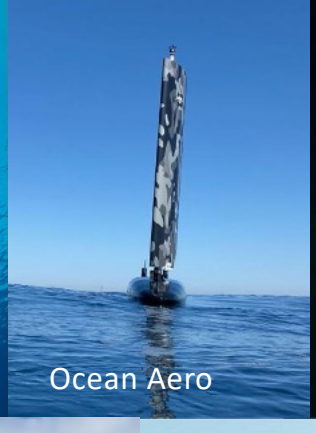

Data Xplorer


Saildrone (Hurricane Wing)

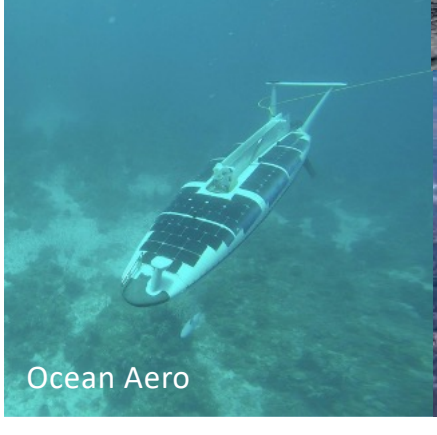
AutoNaut


Underwater Glider


Wave Glider

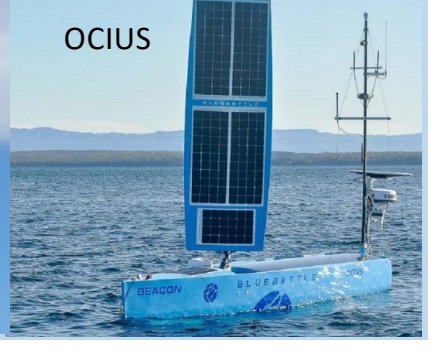

Ocean Aero


MAS

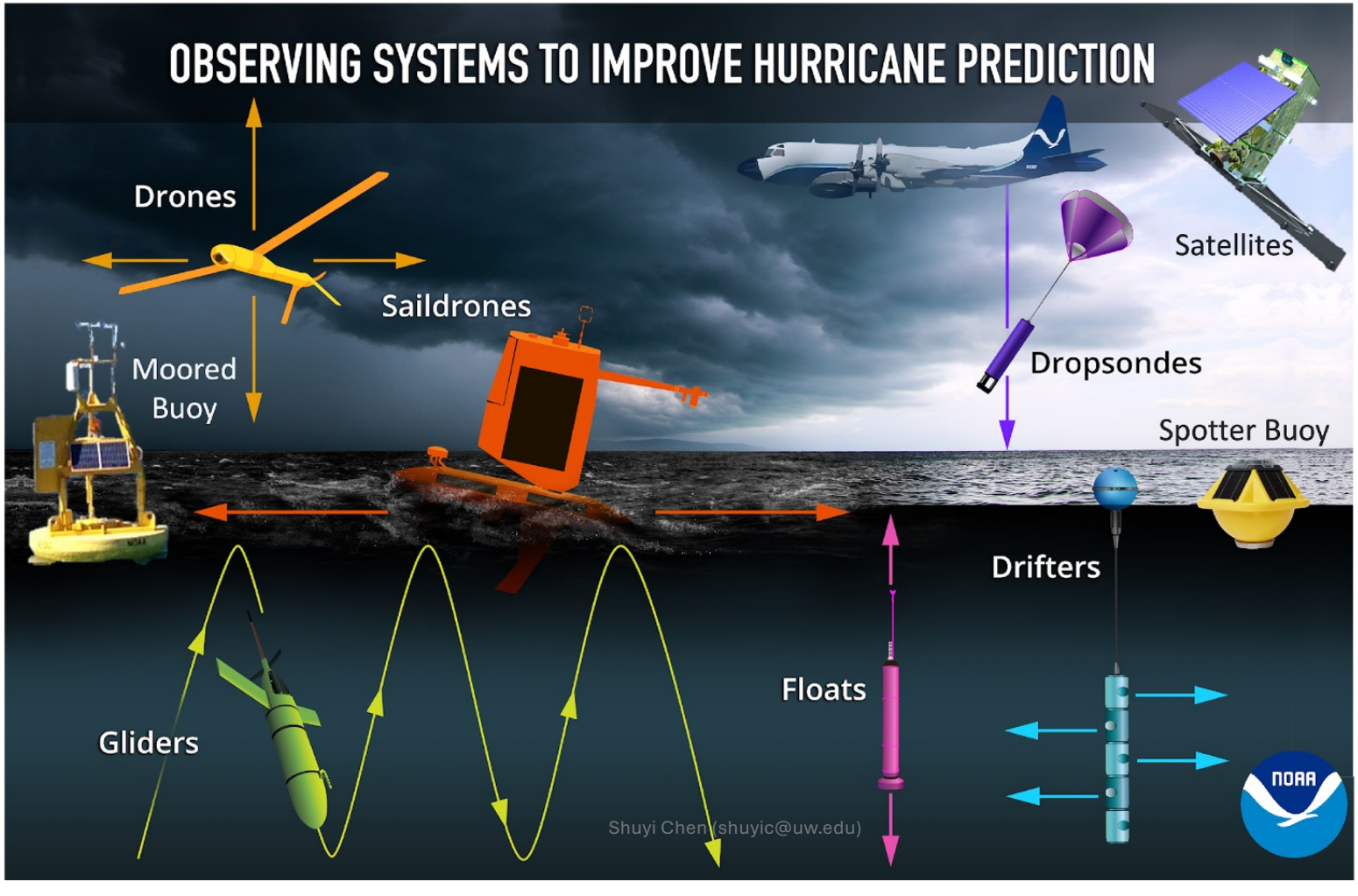

Ocean Aero


Harris FVR-90


Shuyi Chen (shuyic@uw.edu) Meteodrone



OCIUS


OBSERVING SYSTEMS TO IMPROVE HURRICANE PREDICTION
Drones
Saildrones
Moored Buoy
Satellites
Dropsondes
Spotter Buoy
Drifters
Floats
Gliders
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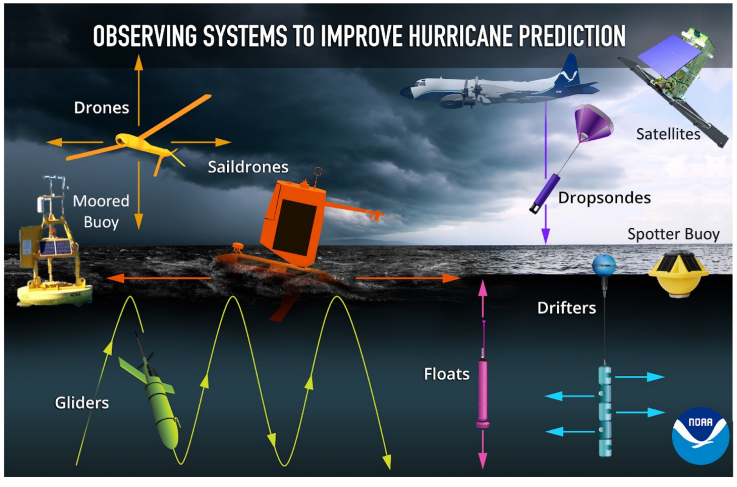
NOAA

Ways Forward to Observe ASTZ to Meet Challenges and Fill Gaps

- Multiscale ocean-atmosphere interactions play a critical role in global weather-climate continuum, from extreme weather events (e.g., hurricanes and winter storms), subseasonal-to-seasonal (e.g., MJO, marine heat waves) to climate variability (e.g., ENSO) and climate change
- Air-sea exchanges of energy, mass, and momentum are influenced by not only the air-sea interface, but also the upper ocean and atmospheric boundary layer known as the Air-Sea Transition Zone (ASTZ)



- Lack of integrated observations of ASTZ hinders the accuracy Earth system modeling and prediction
- Emerging technologies in uncrewed observing platforms and AI/ML present unprecedented opportunities for transformative Earth system observing, modeling, and prediction
- NSF can make transformative changes by embracing interdisciplinary research and removing barriers of its current siloed disciplinary funding structure
- NSF can lead and collaborate with NOAA, NASA, DOD, and DOE on major national and international field campaigns like Tropical Equatorial Pacific Exp (TEPEX) planned over the Pacific in 2026-27 and others

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