# ship observations and autonomous ocean/air-sea observations during ATOMIC

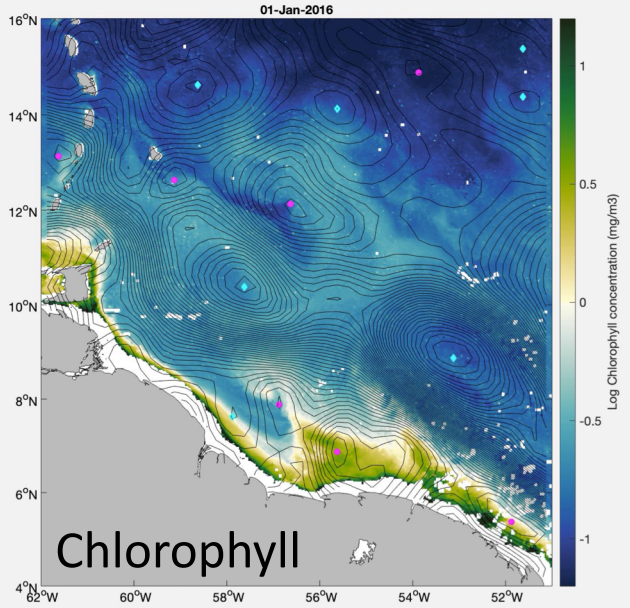
Elizabeth J. Thompson

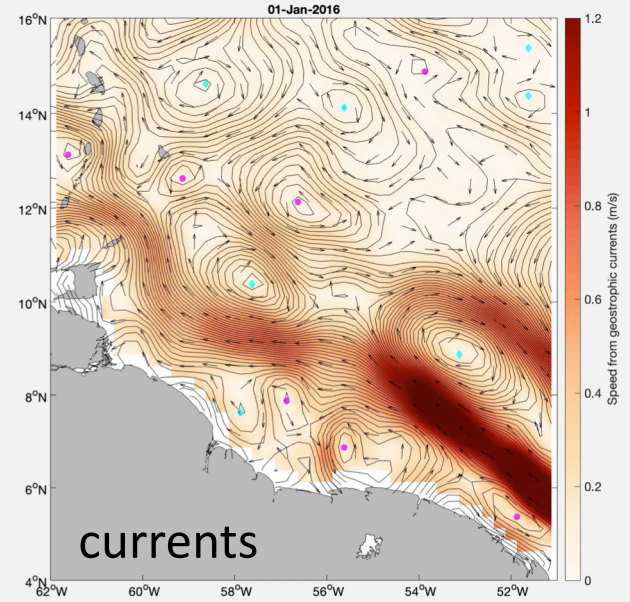
NOAA ESRL PSD

with contributions from all ATOMIC and EUREC$^4$A teams

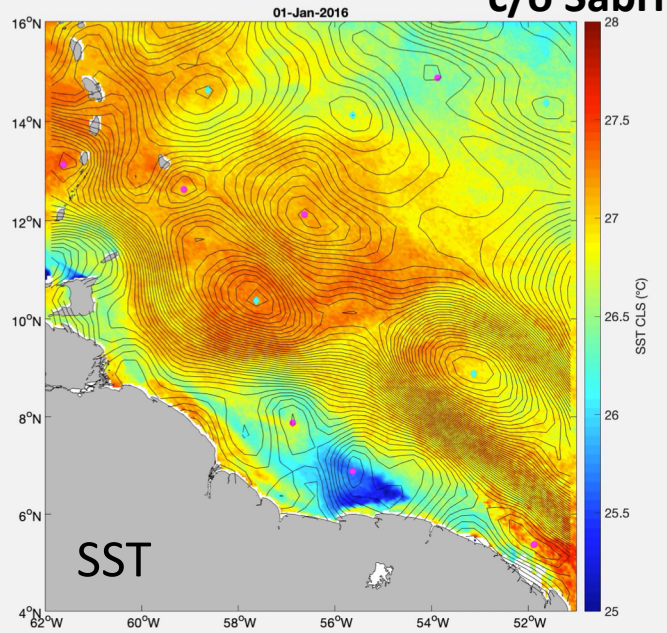
Beneath the patchy tropical clouds and persistent trade winds…

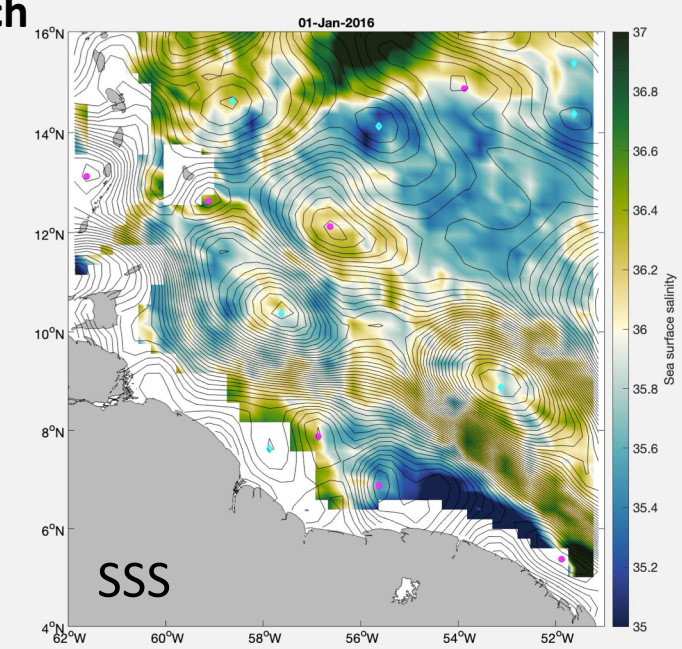
… earth's largest ocean eddies shed from the Amazon & Orinoco Rivers into the Caribbean & Atlantic. The result is a richly textured surface field of eddies, fronts, and filaments.
~ 6 eddies / yr
translating @ 15 cm/s




**Daily interpolated model / satellite data**
**c/o Sabrina Speich**

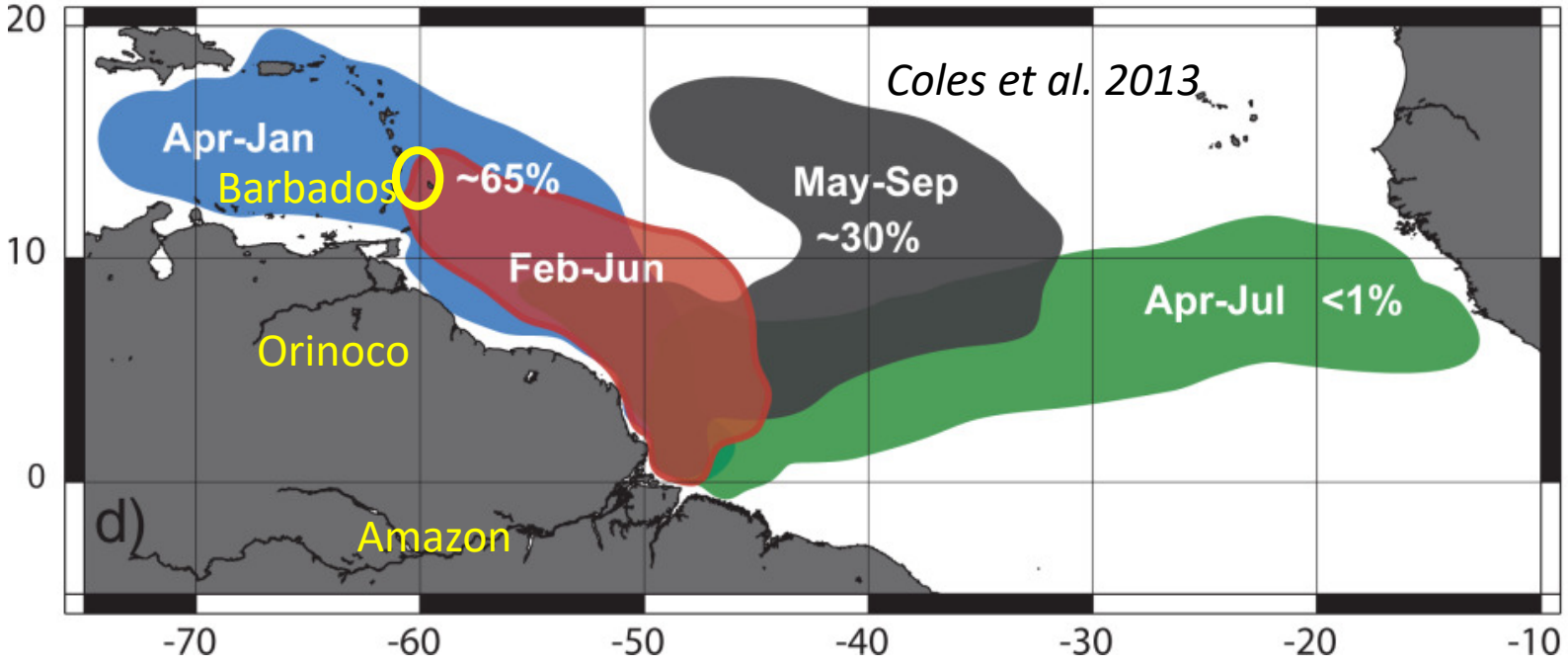


Beneath the patchy tropical clouds and persistent trade winds…

… earth's largest ocean eddies shed from the Amazon & Orinoco Rivers into the Caribbean & Atlantic. The result is a richly textured surface field of eddies, fronts, and filaments.

**Seasonal extent of Amazon outflow determined by modeled drifters**



## Current ATOMIC projects:

- **First goal**: measure properties of atmosphere, ocean, and air-sea interface across ocean eddies as the evolve in this unique region

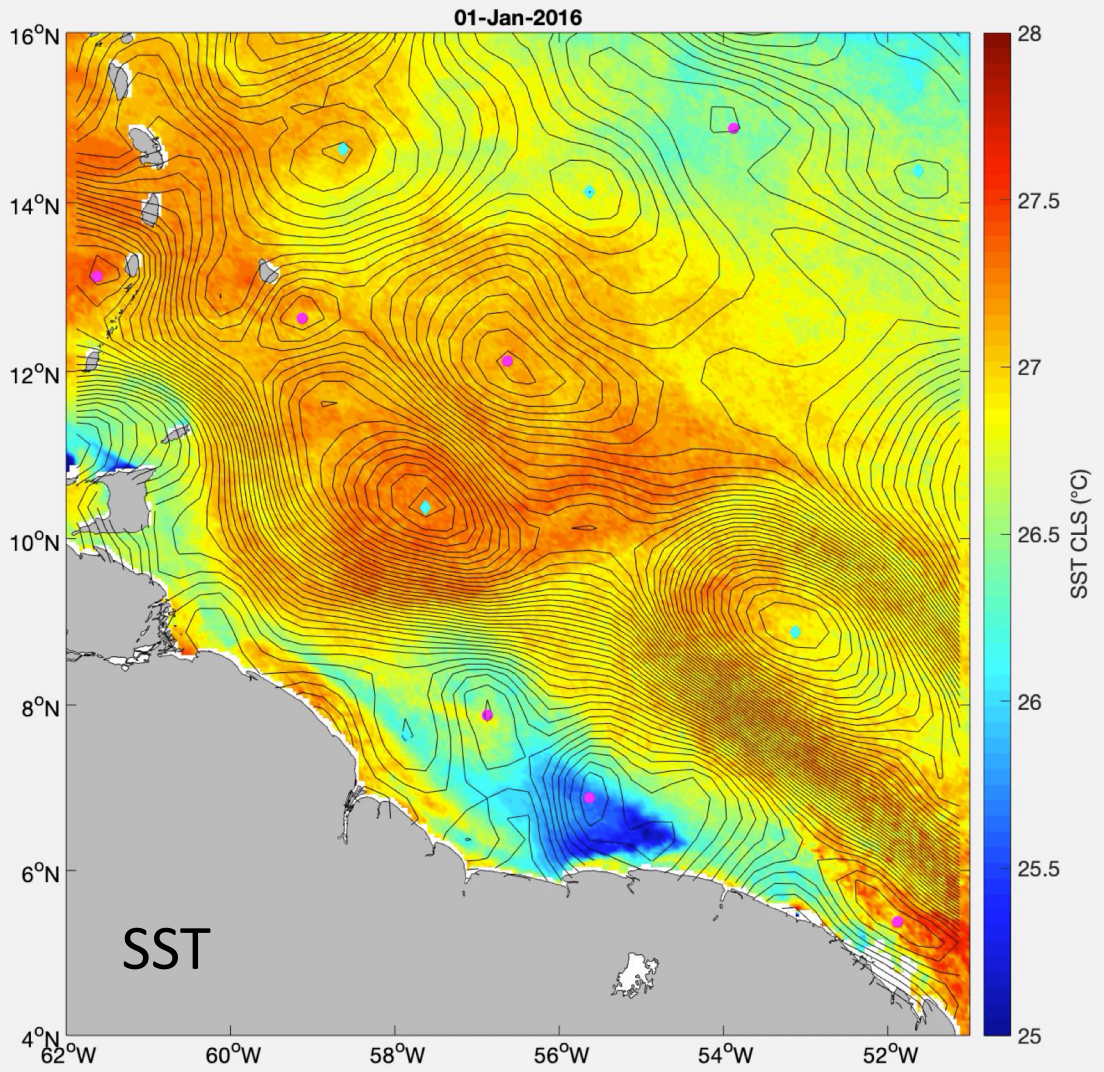
- **Follow-up goals**: understand physical mechanisms responsible for feedbacks between:
  - surface waves -> fluxes,
  - wind + ocean current + ocean stability -> waves
  - clouds -> ocean stratification,
  - salinity stratification <- -> SST (diurnal + long term) <--> wind + current

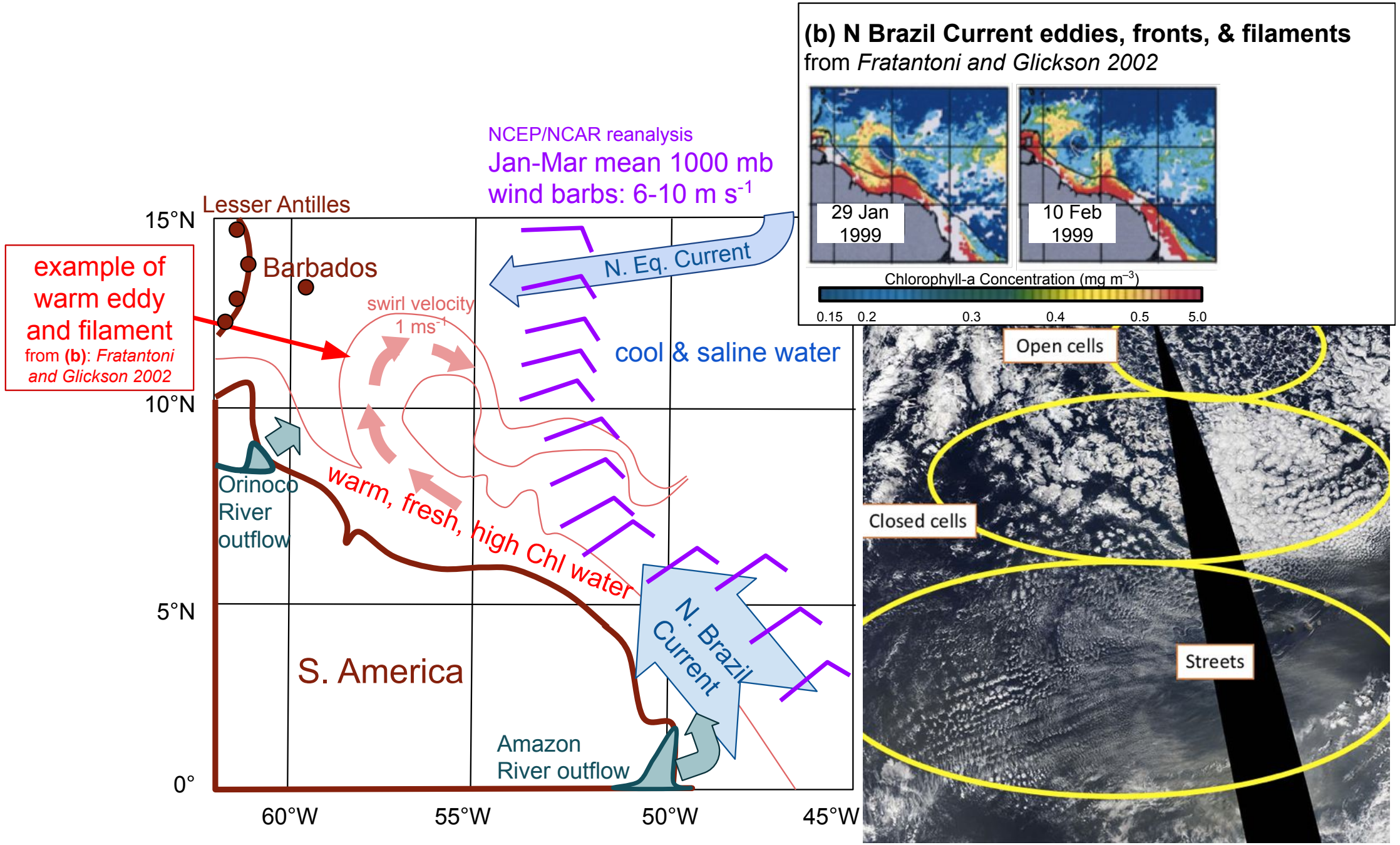
  … on scales ranging from turbulence to regional and sub-seasonal

  … throughout time and across space

- **Final products:** benchmark datasets for…
  - future satellite validation satellite development
  - future development of satellite monitoring capability
  - current + future coupled modeling studies

**Daily interpolated model / satellite data c/o Sabrina Speich**



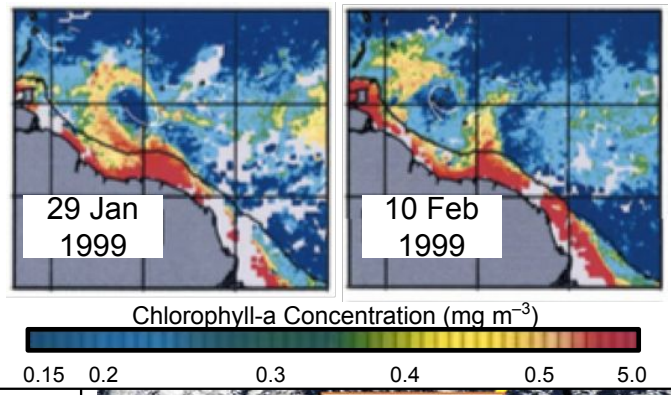

(b) N Brazil Current eddies, fronts, & filaments
from Fratantoni and Glickson 2002
29 Jan 1999
10 Feb 1999
Chlorophyll-a Concentration (mg m$^{-3}$)
0.15 0.2 0.3 0.4 0.5 5.0
NCEP/NCAR reanalysis
Jan-Mar mean 1000 mb
wind barbs: 6-10 m s$^{-1}$
Lesser Antilles
15°N
10°N
5°N
0°
60°W
55°W
50°W
45°W
example of warm eddy and filament
from (b): Fratantoni and Glickson 2002
Barbados
N. Eq. Current
swirl velocity
1 ms$^{-1}$
cool & saline water
Orinoco River outflow
warm, fresh, high Chl water
N. Brazil Current
S. America
Amazon River outflow
Open cells
Closed cells
Streets

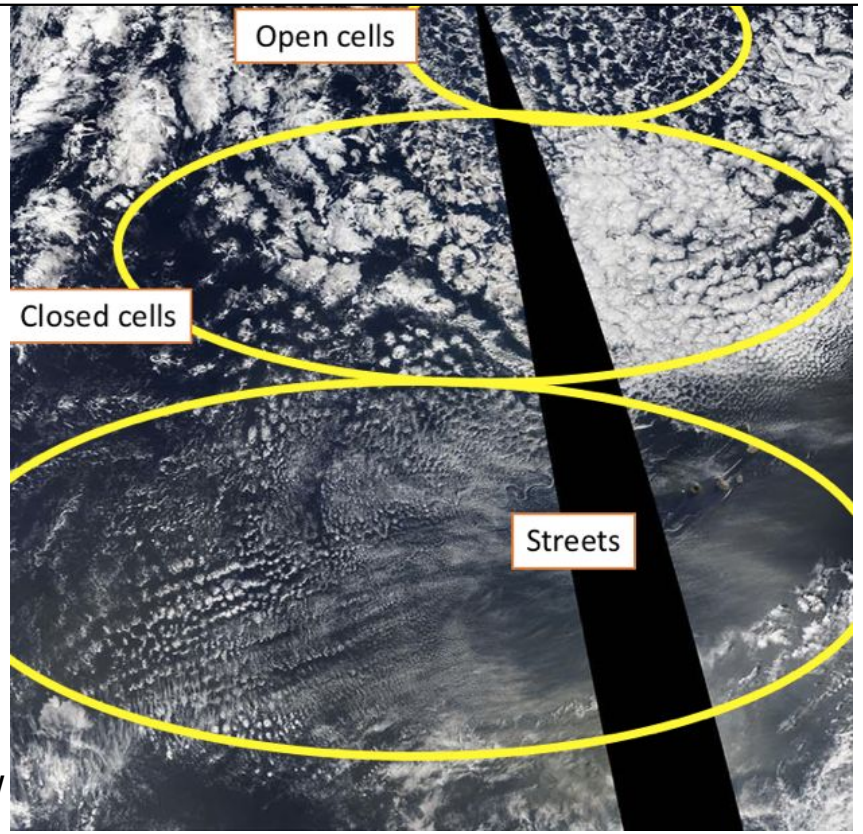
1 ship,
2 wave gliders &
6 Saildrones roaming
same scene

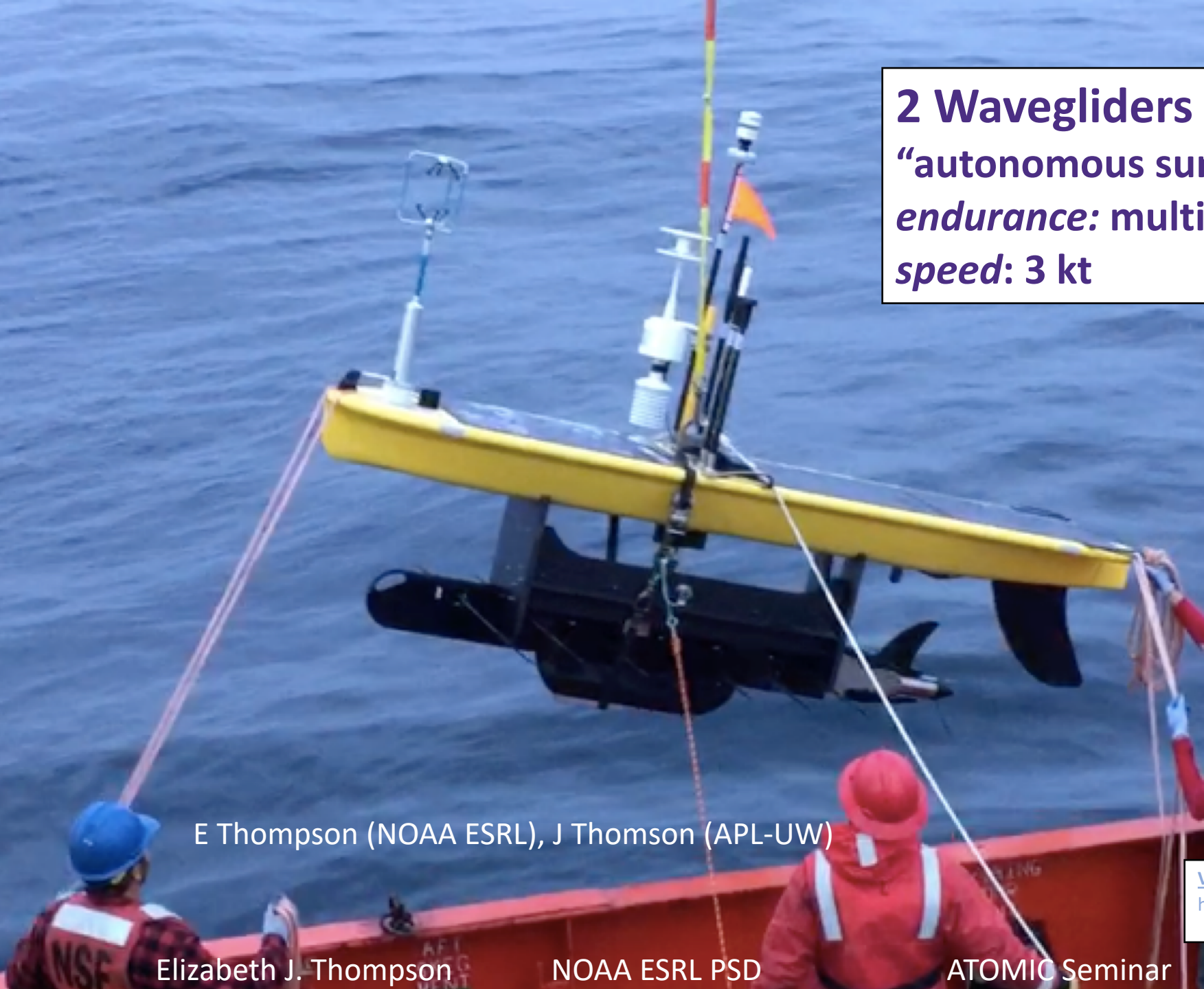
NCEP/NCAR reanalysis
Jan-Mar mean 1000 mb
wind barbs: 6-10 m $s^{-1}$

Lesser Antilles
Barbados
N. Eq. Current
swirl velocity
1 $ms^{-1}$
cool & saline water
6 SWIFT
drifters
Orinoco
River
outflow
warm, fresh, high Chl water
10 AOML
surface drifters
S. America
N. Brazil
Current
Amazon
River outflow
15°N
10°N
5°N
0°
60°W
55°W
50°W
45°W

**(b) N Brazil Current eddies, fronts, & filaments**
from *Fratantoni and Glickson 2002*





## 2 Wavegliders

**"autonomous surfboard"**

***endurance:* multiple seasons**

***speed*: 3 kt**

Key capabilities:

- wave spectra
- currents: surface to 20 m
- ocean T, S, Chlorophyll, Fluorescence: 0.25 m, 8 m
- air-sea fluxes and surface met:
  - IR/solar radiometers
  - bulk RH (*latent heat flux*)
  - turbulent T, wind (*sensible, momentum flux*)
  - pressure
- sky camera

E Thompson (NOAA ESRL), J Thomson (APL-UW)

**Video by Liquid Robotics:** stop at 1:15… start again at 1:30-1:39
https://www.youtube.com/watch?v=m7gmf4Mfba4

sky camera on R/V *Sally Ride*
PISTON 2019 experiment
c/o Igor Razenkov, Bob Holtz,
and Ed Eloranta (U Wisconsin)
and Jeff Ried (NRL)


# 7 Saildrones

**"autonomous sailboats"**

***endurance:*** **multiple seasons**

***speed*: 3 kt**

## Key capabilities:

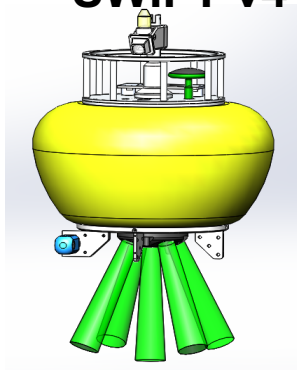
- bulk wave statistics
- currents: surface to 100 m
- Ocean T, S pCo2, Fl, Chl, $O^2$
- bulk air-sea fluxes and surface met:
  - IR/solar radiometers
  - T, RH, wind, P
- sky camera

D. Zhang (JISAO/UW), C. Zhang (NOAA PMEL)
C. Gentemann (ESR), J. Karstensen (GEOMAR),
S. Speich (ENS)

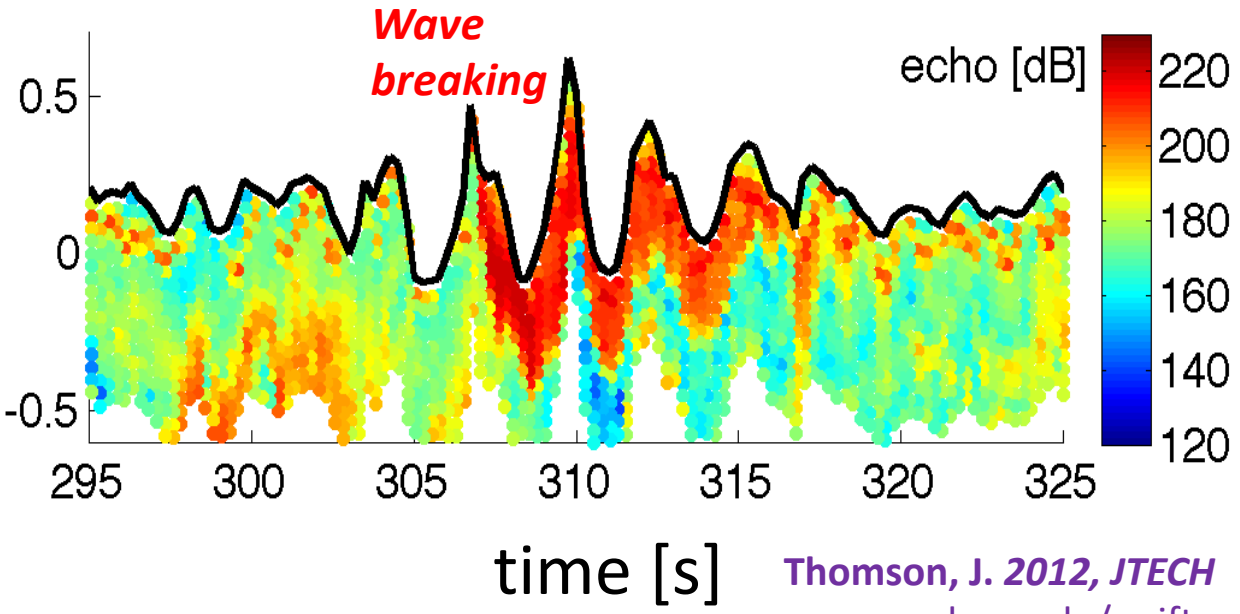
**Video by NOAA Fisheries**
https://www.youtube.com/watch?v=ugDnC0iidL4

SWIFT v3

SWIFT v4



# 6 SWIFT buoys: measure **waves** and **air-sea interactions** in the wave-following reference frame:




**Thomson, J. *2012, JTECH***

www.apl.uw.edu/swift

Key capabilities:

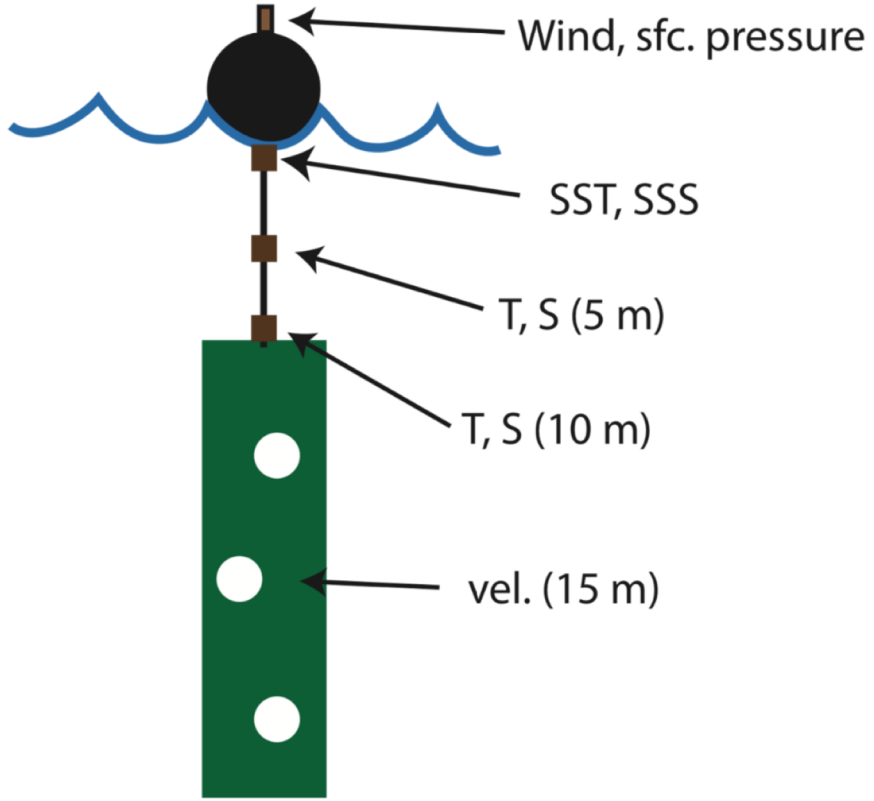
- wave spectra
- turbulent dissipation rate in upper 0.5 – 4 m
- currents: surface to 20 m
- ocean T, S, Chlorophyll, Fluorescence: 0.25 m, 8 m
- air-sea fluxes and surface met:
  - IR/solar radiometers
  - bulk RH (*latent heat flux*)
  - turbulent T, wind (*sensible, momentum flux*)
  - pressure
- sky camera


E Thompson (NOAA ESRL), J Thomson (APL-UW)

# 10 AOML Surface Drifters

## Enhanced surface drifters

- The team was funded by CPO/CVP to upgrade 10 regular drifters (SST, sfc. pressure) with wind sensor, ocean temp. at 5 m, 10 m, and conductivity at sfc., 5 m, 10 m.




**x 10**

G. Foltz et al. (NOAA AOML)


# NOAA RV Ronald H Brown During ATOMIC

## Schedule:

Jan 6: Depart Barbados for Leg 1
Jan 26 – 28: In port, open house
Jan 28: Depart Barbados for Leg 2
Feb 13: Arrive Barbados

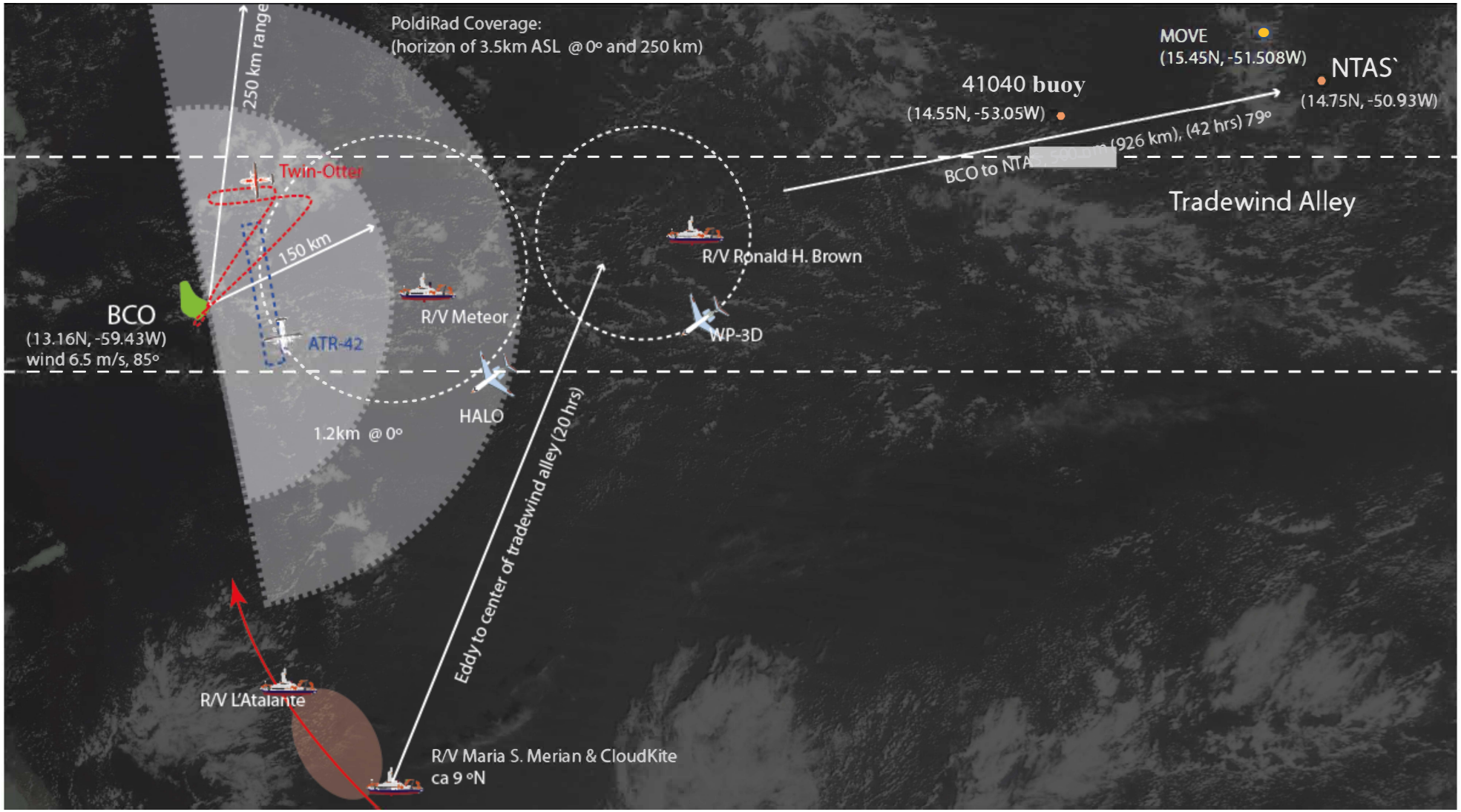
From P. Quinn NOAA PMEL


# Ship Measurement Overview

- *In situ* and remote sensing measurements of aerosol and cloud properties, air-sea fluxes, and meteorological parameters
- Launching pad for UASs with aerosol, cloud, and flux payloads
- Launching pad for SWIFTS, wave gliders, and radiosondes
- Recovery and deployment of the NTAS buoy
- Servicing of the MOVE buoy

From P. Quinn NOAA PMEL

# ATOMIC ship operations play a role in larger coordinated ship + aircraft + autonomous sensing plan with EUREC$^4$A



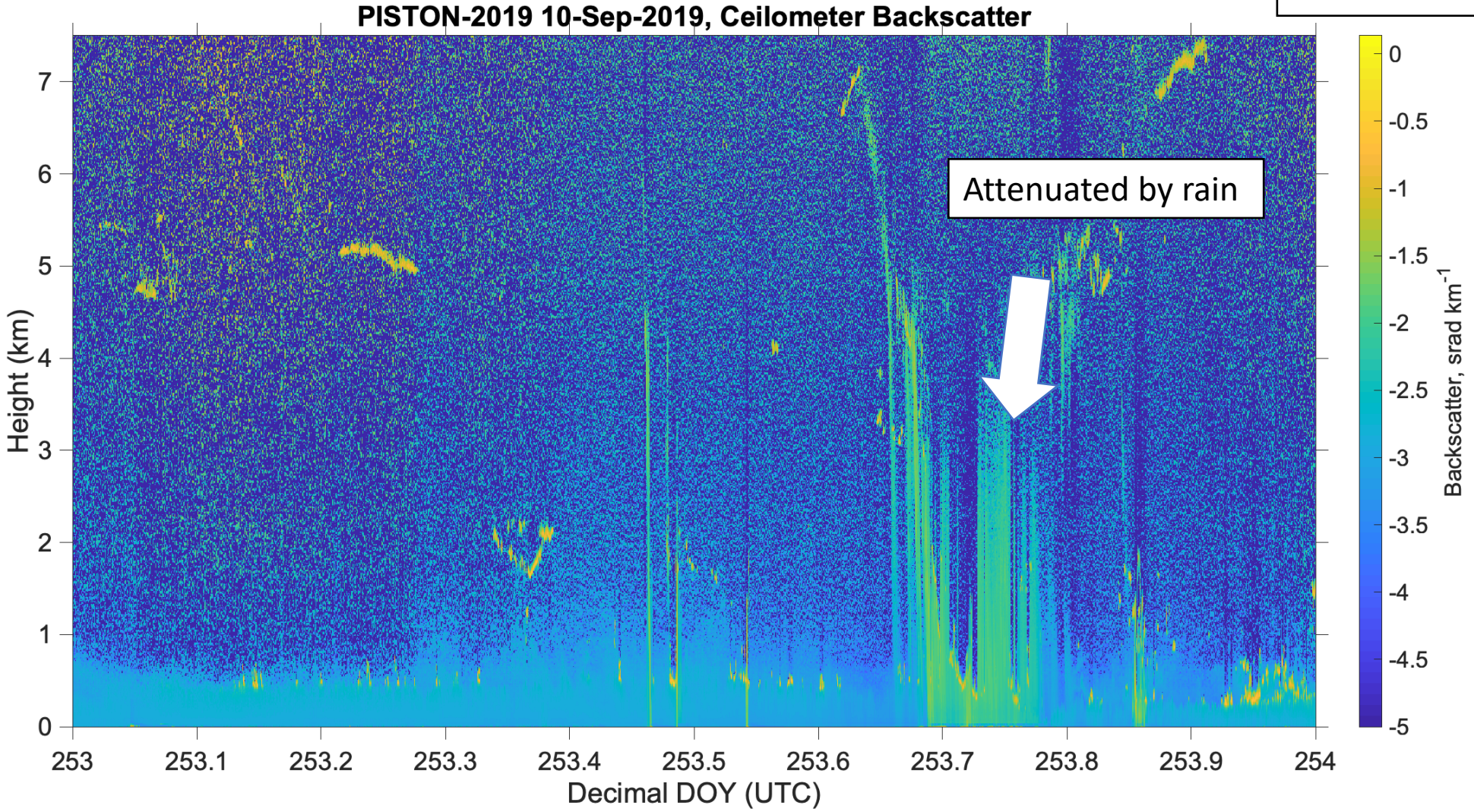
# ship met / air-sea / ocean observations

| Project | Parameter | PIs | Method |
|---|---|---|---|
| **Evolution of the cloudy boundary layer** | Cloud properties, precipitation, atmospheric moisture, air/sea temperatures | Zuidema | Microwave radiometer, IR SST from M-AERI, disdrometers, sky camera |
| **Atmospheric vertical structure** | Profiles of T, RH, wind, pressure | de Szoeke | Radiosondes: 6/day |
| **Atmospheric cold pools, isotopes** | H2O, dD, d18O water vapor | Noone / deSzoeke | Picarro gas analyzer |
| **Air-sea fluxes, waves, clouds, SST** | Cloud properties, flux measurements, SST | Fairall / Thompson | Wband radar, Doppler lidar, air-sea flux system, IR and solar flux sensors, sea snake, wave altimeter, ceilometer, IR SST from ROSR |
| **Impacts of aerosol properties on regional radiation and SSTs** | Aerosol number concentration and size distribution, chemical composition, scattering, absorption, cloud nucleating properties | Quinn / Bates | Shipboard in situ observations, including photometer |
| **Ocean vertical structure** | salinity, temp, currents | Bigorre | underway CTD, ADCP, TSG |

# Ceilometer: a vertically-pointing lidar (laser of visible light) that detects refractive index gradients. Measures non-raining cloud base and depth of atmospheric boundary layer.

Backscatter is processed into time series of:

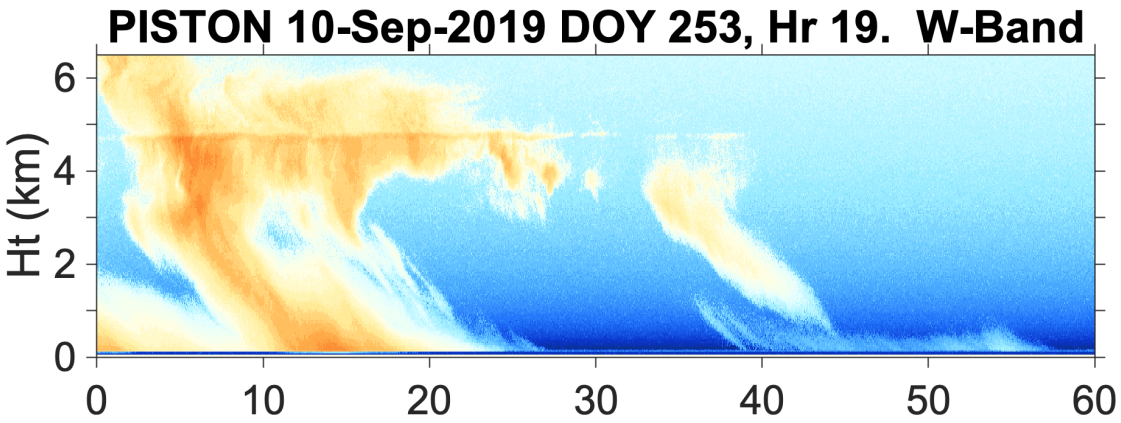
- Height of non-raining cloud base
- Intensity of cloud layer
- Depth of atmospheric mixed layer

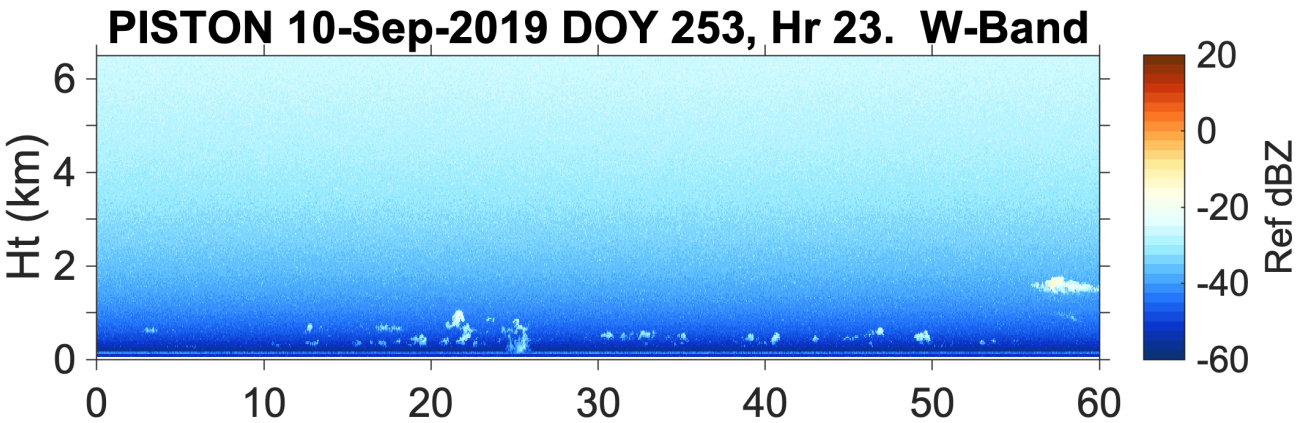


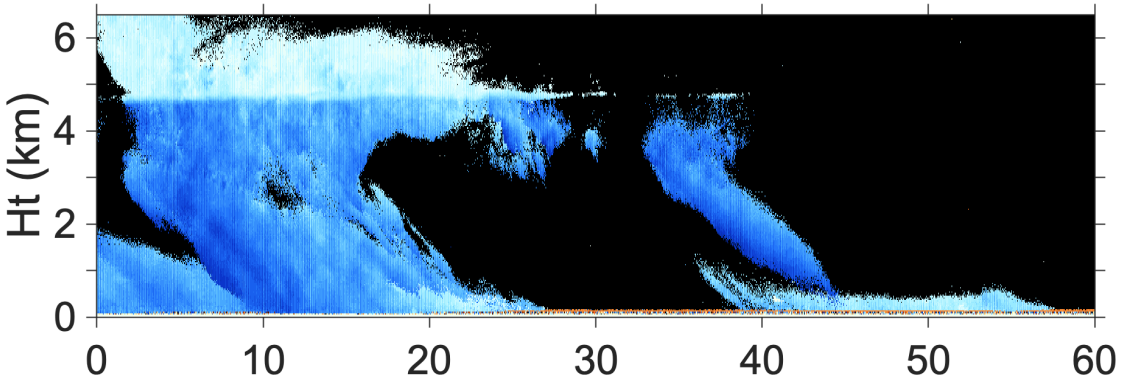
# W-band radar: measuring the vertical structure and vertical velocity of clouds (raining and non-raining)

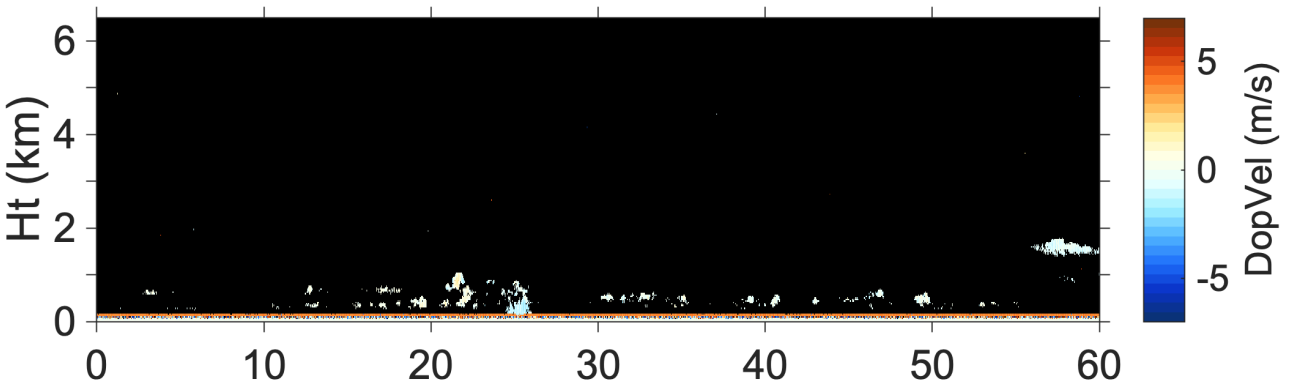
*Clouds raining throughout troposphere*

*Non-raining clouds growing from the atmospheric boundary layer*



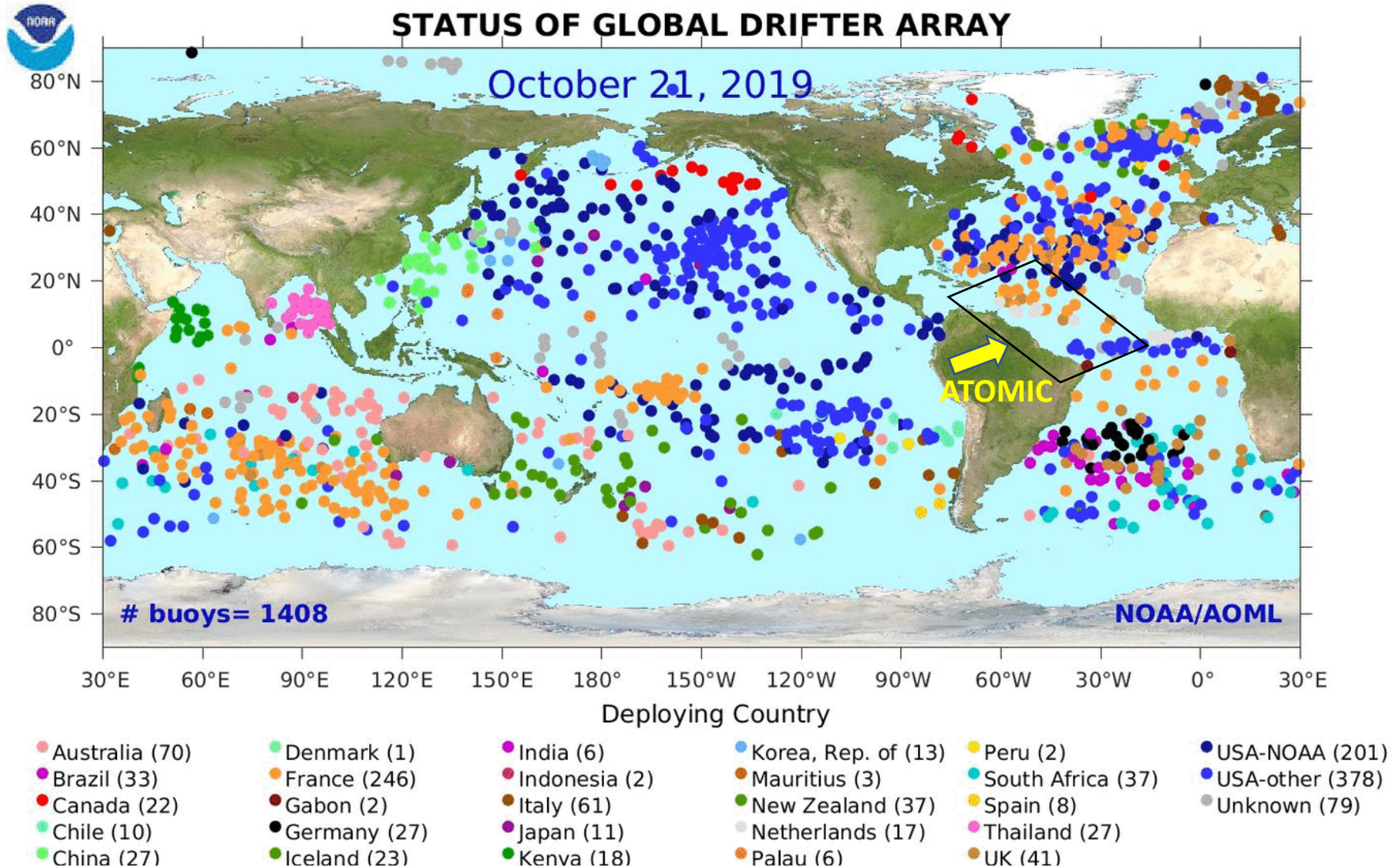



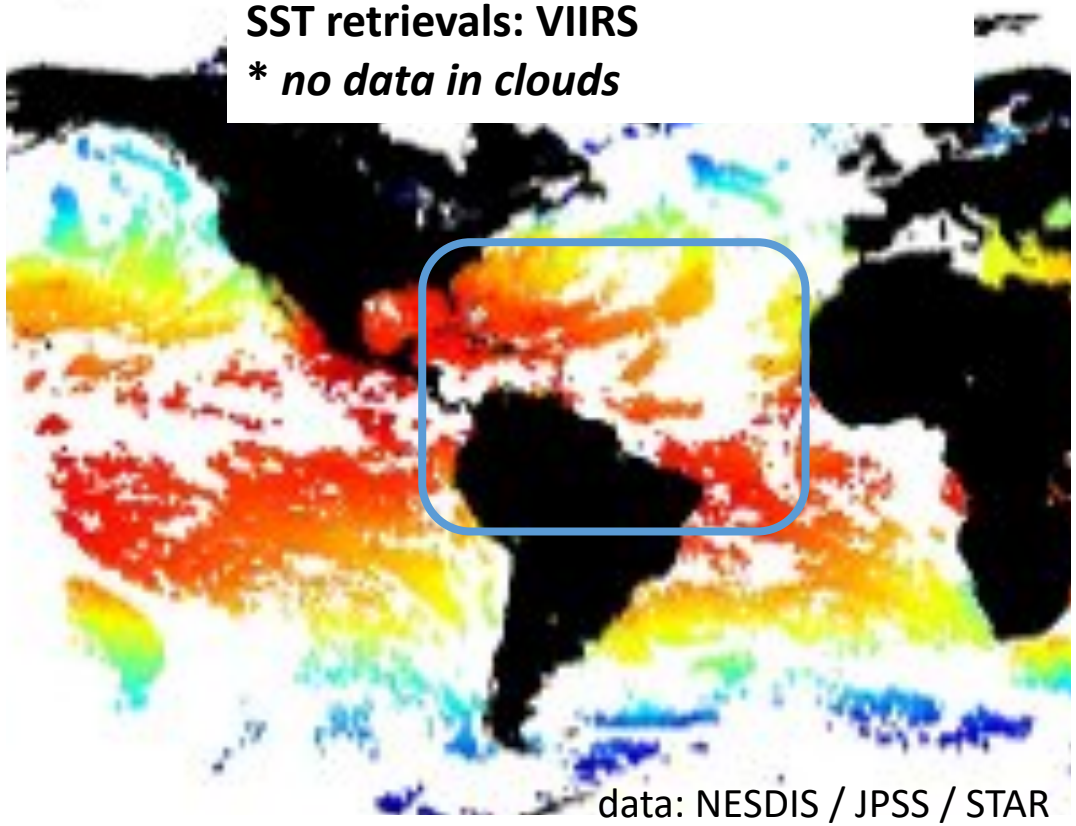
The ATOMIC array of ocean drifters, wave gliders, buoys will measure superior spatial and temporal detail compared to in-situ global ocean observing system, where satellites offer poor coverage of air-sea interaction, the upper ocean, and low clouds.

ATOMIC datasets will be ripe for future opportunities with coupled modeling groups and observationalists!



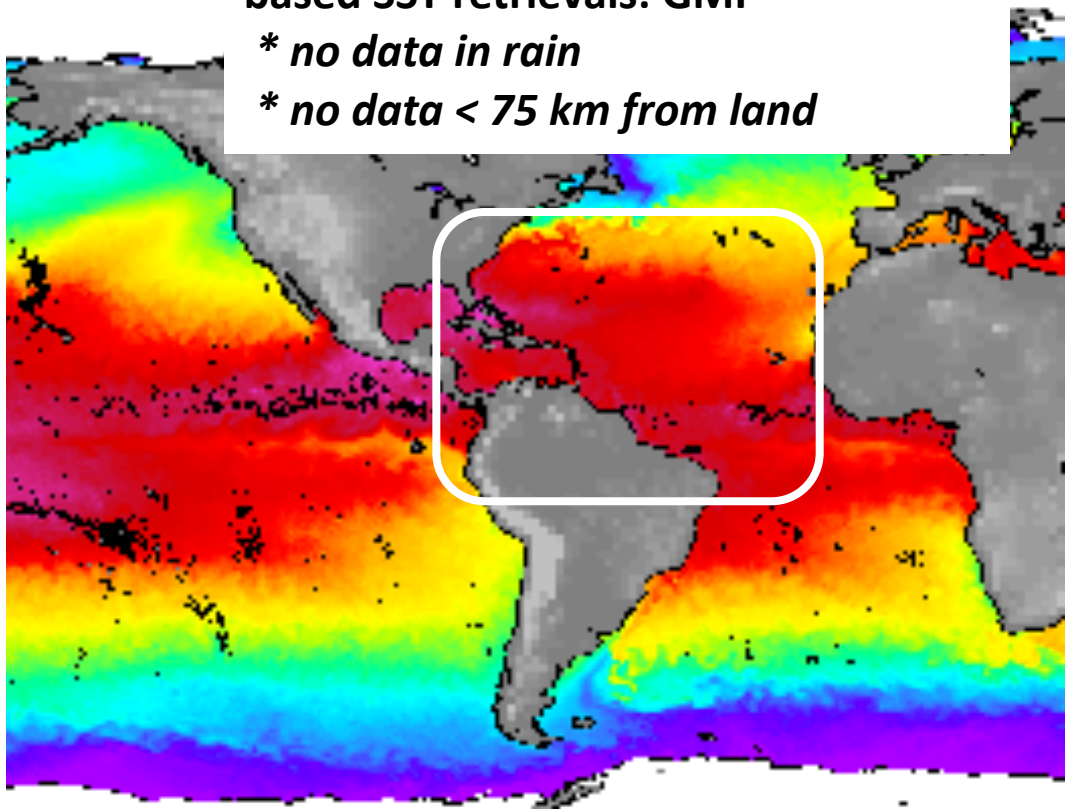
The ATOMIC array of ocean drifters, wave gliders, buoys will measure superior spatial and temporal detail compared to in-situ global ocean observing system, where satellites offer poor coverage of air-sea interaction, the upper ocean, and low clouds.

**1 day of infrared satellite-based SST retrievals: VIIRS**
**** no data in clouds***



data: NESDIS / JPSS / STAR

**3 days of passive microwave satellite-based SST retrievals: GMI**
**** no data in rain***
**** no data < 75 km from land***



data: Remote Sensing Systems

SST, SSS, Chl, clouds, and rain cannot be observed with satellites *simultaneously*
SST, SSS, Chl cannot be observed with satellites *on atmospheric mesoscale*