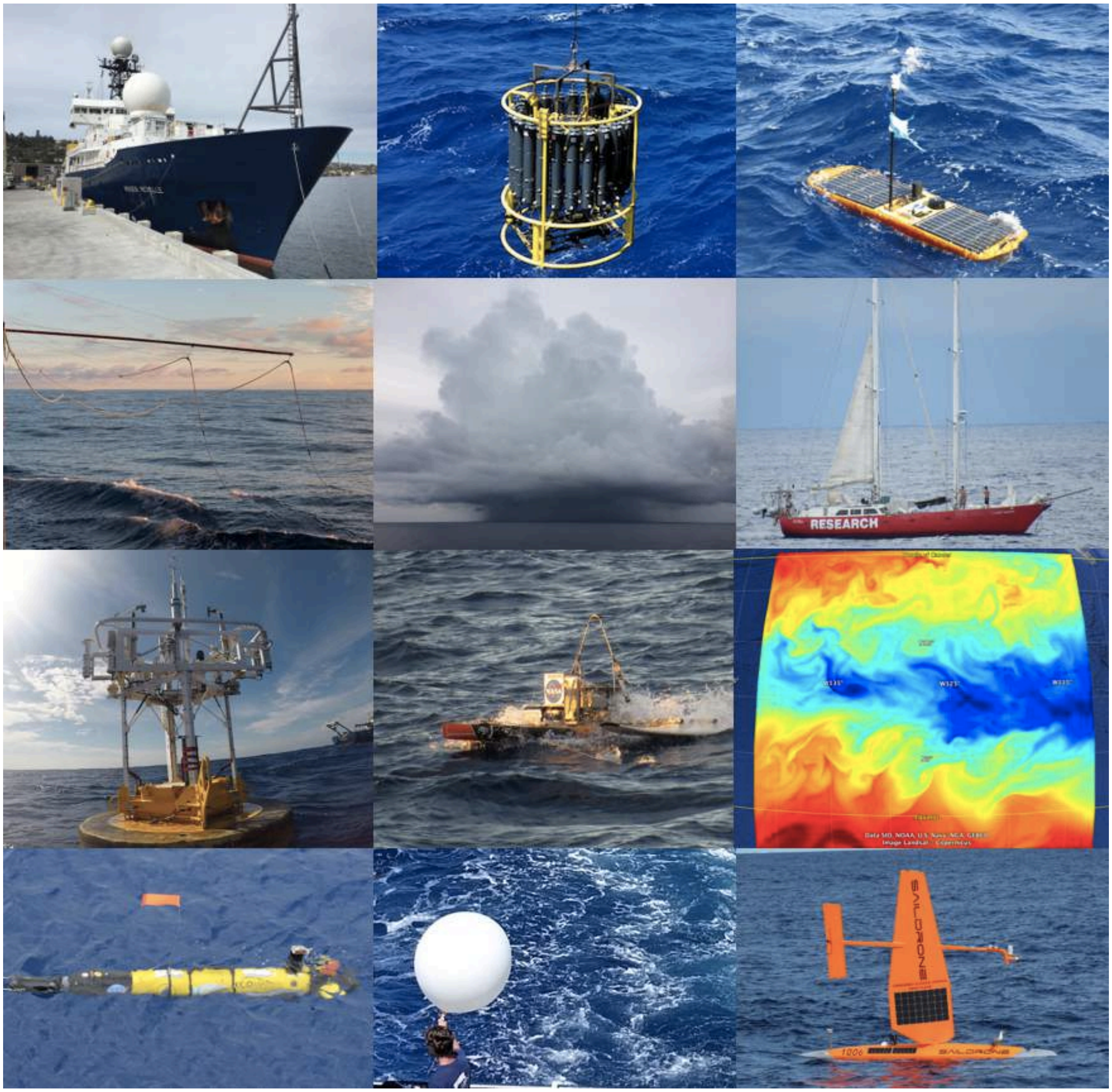
2017 SPURS-2 cruise report



Compiled by Kyla Drushka, Chief Scientist
9 March 2018

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Overview

The objective of the SPURS-2 experiment is to understand the fate of freshwater deposited on the sea surface as rainfall. The study site is the region around 125°W,10°N in the eastern tropical Pacific Ocean, within the rainy Intertropical Convergence Zone (ITCZ). The first of two SPURS-2 cruises took place in Aug-Sept 2016. This report describes the second SPURS-2 cruise, which took place from 16 October to 17 November, 2017 aboard the R/V Revelle.

The primary cruise activities were:

- Recovering moorings (central WHOI mooring plus two PMEL moorings)
- Recovering autonomous assets (2 Seagliders and 2 Wave Gliders)
- Continuous underway sampling from meteorological instruments, a Salinity Snake, the Underway Salinity Profiling System, a SEA-POL radar, and the WAMOS wave/rain radar
- Underway flow cytometry, optics, and chemistry (DIC, pH and DO_2) measurements
- Periodic CTD casts and A-sphere casts
- Surveying with an underway CTD
- Surveying with the Surface Salinity Profiler and the Controlled Flux Technique
- Rawindsonde launches
- A drifter experiment with CODE, S-ADOS, SVP, SVP-S, and Boyle drifters, as well as two EcoMapper surveys
- Deployment of Surpact drifters
- Joint sampling with two Saildrones and the Lady Amber
- Data management and shore support with modeling and satellite data
- Deployment of Argo floats

Major cruise activities are shown on the following page.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
October 15	**16** depart San Diego	**17**	**18** SSP and uCTD test. Exit Mexican EEZ.	**19**	**20** SSP and uCTD test	**21** Start uCTD survey
22 CTD, PMEL 11N recovery. Recover green Wave Glider. CTD at WHOI mooring. WHOI buoy battery replaced and met comparison. Saildrone sail-along near mooring.	**23** Recover yellow Wave Glider uCTD survey started SSP deployment	**24** uCTD, SSP	**25** CTD, uCTD.	**26** Wave Glider with rake deployed SSP uCTD	**27** uCTD survey south to 5°N 2 CTD casts SSP	**28** Survey northward with SSP uCTD
29 SSP uCTD	**30** SSP, uCTD; Drifter experiment, EcoMapper survey	**31** SSP around drifters. Recover drifters. EcoMapper survey	**November 1** SSP. uCTD. Recover Wave Glider. Replace DCFS on WHOI buoy.	**2** uCTD. PMEL 9N recovery and CTD. Deploy Wave Glider.	**3** uCTD survey northward to 12°30N, then southward.	**4** SSP, uCTD.
5 uCTD survey south to 6°06N	**6** Deploy Wave Glider with rake. Recover instruments from WHOI buoy. Recover 2 Seagliders. Survey with Lady Amber (with SSP).	**7** WHOI mooring recovery. Survey with Lady Amber. uCTD. SSP.	**8** SSP, uCTD. Survey with Saildrone. SSP (overnight)	**9** French drifter experiment. SSP. uCTD.	**10** Recover both Wave Gliders. SSP, uCTD.	**11** Begin transit home. Deploy three French drifters. CTD.
12 CTDs.	**13** CTD.	**14** CTD.	**15** CTD. Salinity Snake recovered.	**16** CTD.	**17** Arrive San Diego.	

WHOI Mooring Recovery

PI: Tom Farrar, Woods Hole Oceanographic Institution
At sea: Ben Pietro and Ray Graham

The WHOI surface buoy used in this project is equipped with meteorological instrumentation for estimation of air-sea fluxes, including two Improved Meteorological (IMET) systems. The mooring line also carried current meters, and conductivity and temperature recorders. This mooring was of an inverse-catenary design utilizing wire rope, chain, and synthetic rope and has a scope of 1.45 (scope is defined as slack length/water depth). The buoy is a 2.8-meter diameter foam buoy with an aluminum tower and rigid bridle. The watch circle is 3.8 nm in diameter.

The mooring, WHOI PO mooring #1282, was deployed 24 August 2016, at 10°03.0481'N, 125° 01.939'W. The mooring was recovered 444 days (14.6 months) later, on 11 November 2017. The water depth was 4769 m.

The surface instruments on SPURS II were unplugged and removed from the buoy on the morning of November 10, 2017. The decision to remove all meteorological instruments prior to recovering the buoy was to ensure all instruments would not be damaged during an A-frame recovery.

The SPURS II mooring was recovered on November 11, 2017. To prepare for recovery the vessel was positioned roughly ¼ mile to the side of the anchor position, with the buoy streaming down wind. The release command was sent to the acoustic release to separate the anchor from the mooring line at 13:50 UTC. After about 35 minutes, the glass balls surfaced. Once the glass balls were on the surface, the ship approached the cluster of balls along the starboard side. The ship's small workboat was deployed to connect a lifting sling into the glass ball cluster. A messenger line was used to pass the lifting line from the ship to the small boat, where the lifting sling and lifting line were shackled together.

The mooring was recovered starting from the bottom (glass balls), up until the Nortek AquadoppHR at 41.5 meters was recovered. Then a slip line, passed through the link at the bottom of the 18.35-meter wire shot was used to set the buoy and remaining 40 meters of instruments adrift. The buoy was recovered using the A-frame, and the remaining instruments were then recovered.

Preliminary evaluation indicates that data return was excellent. While some individual meteorological instruments failed, there is a complete record for all surface variables. Preliminary evaluation of precipitation measurements indicates that the two ASIMET RM Young self-siphoning gauges produced valid data for the duration of the experiment, but the Vaisala WXT520 and Hasse gauges failed about one month into the deployment. Beneath the surface, all SBE37s and RBR XR420s produced valid data. No SBE16s produced valid data, due to a human error in setup. All RDI ADCPs produced data. Both VMCMs stopped early. The Nortek HR data requires further evaluation.

Order of events on November 11, 2017 (UTC)

- Release fired- 13:50
- Glass Balls on deck – 16:18
- All synthetic rope recovered-19:10
- First instrument recovered (VMCM)- 20:21
- Buoy on deck- 22:26
- Last instrument recovered (SBE 37) 22:42

PMEL Mooring Recoveries and Saildrone Operations

PIs: Billy Kessler (moorings) and Meghan Cronin (Saildrone), PMEL
At sea: David Rivera

On October 22nd the ship arrived on site for the PMEL 11 N mooring recovery. The day started with a CTD cast to 500m. By 0530 local time, the small boat had been launched, and connected the working line to the buoy. The release code was sent at approximately 0600, and the buoy was on deck around 0630. This recovery along with the other PMEL mooring was done with a TSE winch and an air powered tugger that were provided by WHOI and operated by WHOI personnel. No problems occurred during operations for this recovery; the acoustic release was on deck before 1000.

There was minimal fouling on both the mooring and PRAWLER. The mooring had a small layer of algal growth and minimal barnacle growth; however, there was significant barnacle growth on the Microcat. The plastic jacketed wire rope (Nilspin) had no fouling and there was no visible damage, but there were visible indentations on the jacketing that resulted because of the PRAWLER's teeth.

Deck set up for the PMEL 9 N Recovery occurred on November 1st. Prior to this, it was discovered that both GPS units on the buoy had failed, so the buoy position was estimated based on buoy's overall average position along with the prevailing currents that were provided by the ship's ADCP. Like 11 N, a CTD cast to 500m was conducted prior to recovery. The mooring itself took under four hours to retrieve once the acoustic release was separated from the anchor. The recovery occurred without incident, and there was no visible damage to any sensors.

9 N also had limited growth on both the buoy and PRAWLER. The PRAWLER had a visible green layer of algal growth on most of the surface, but there was no growth on the sensors or pump. It should be noted that this PRAWLER, #006, was flooded on 7/3/2017. This flood likely resulted due to a crack in the housing near the pressure sensor. The nilspin looked clean and had no visible damage; however, it also had numerous indentations from the PRAWLER teeth. The Microcat also had fairly significant barnacle growth. While this mooring occurred without incident, several knots or "wuzzles" were discovered about midway through the 10mm Yalex line during recovery. There were two large ones and several smaller ones. While a couple of these were large, it was possible to continue to recover the mooring and pass the line through the block mounted on the A-frame though it did require that the deck crew tape the "wuzzles" to avoid any entanglements. All but one were untangled during the offspool from the TSE winch. It is unlikely that these formed during recovery based on conversations with Drew Cole, the lead technician. It is more likely that they formed after the acoustic release was freed from the anchor.

The recovery strategies for both 11 N and 9 N varied slightly. For 11 N, the ship preferred to connect to the buoy via the working line prior popping the release while for 9 N the ship decided it to instead connect to the buoy after it was freed from the anchor. The result from the latter strategy may have caused too much slack in the mooring line which resulted in "wuzzles."

It should also be noted that some heavy duty monofilament fishing line was discovered on the glass ball floats on 9 N. It is unlikely that this came from fishing activity on the mooring itself; it is more likely that the line drifted onto the floats as there was no other line found along the rest of the mooring. There was also no visible damage to the buoy or sensors including the UW PAL which was mounted at 650m. The PRAWLERS on these particular moorings were constructed with double extension springs on the cams which is a new feature in order to function properly with strong currents, and this addition proved to be successful for movement up and down the Nilspin.

PMEL also participated in a shipboard comparison operation with two Saildrones which were continuously sampling in the area. Several comparisons were conducted during moments of opportunity throughout the cruise. The ship maintained about 500m of distance during these operations from at least one of the drones typically, but was able to get as close as 200m and as far as 1000m. Saildrone operations occurred without incident which was in large part due to the ships WiFi connection. WiFi allowed for unlimited texting via iMessage with the pilot. Additionally, the ship was able to get limited access to the Saildrone portal which provided updates regarding heading, position, and speed over ground. The ship was also able to track the drones on AIS.

Shipboard Meteorological and Near Surface Measurements

PIs: Carol Anne Clayson and Jim Edson, Woods Hole Oceanographic Institution
At sea: Benjamin Greenwood

Fluxes and Mean Meteorological Measurements

The Clayson-Edson-Greenwood group deployed a direct covariance flux systems (DCFS) with Licor 7500 open-path infrared hygrometers on the MET mast of the R/V Revelle as shown in Figure 1 (left panel). These measurements will be processed to compute direct estimates of the momentum, heat and moisture fluxes during the experiment. The MET mast also supported an optical rain gauge, aspirated temperature and humidity sensors, and pressure sensors. Solar and IR radiometers were deployed at the top of the MET mast to place them above the CSU radome and maximize their exposure to downwelling radiation. Additional instruments were deployed on the forward and aft O2 and O3 decks. These instruments included self-siphoning and manually read rain-gauges, pressure sensors, solar and IR radiometers, a sky cam, and data loggers. A "sea-snake" was deployed off the port side of the ship to measure near subsurface sea temperature. The sea-snake is comprised of a thermistor in heavy-duty tubing that is boomed-out and dragged approximately 5 cm below the sea-surface. The A-frame over the stern was instrumented with two 3-axis sonic anemometers and two RH/T sensors to provide improved measurements while traveling downwind (Figure 1, right panel). Lastly, four-time daily balloon born rawinsondes were launched each day during the 3-week period when the R/V Revelle was in the SPURS-2 experimental domain. Ben Greenwood oversaw the operation and initial analysis of the meteorological sensors during the five week cruise. All sensors were operated 24/7 during the experiment with little human intervention. Ray Graham supervised the balloon launches with help from the CSU rain radar team and other willing participants.

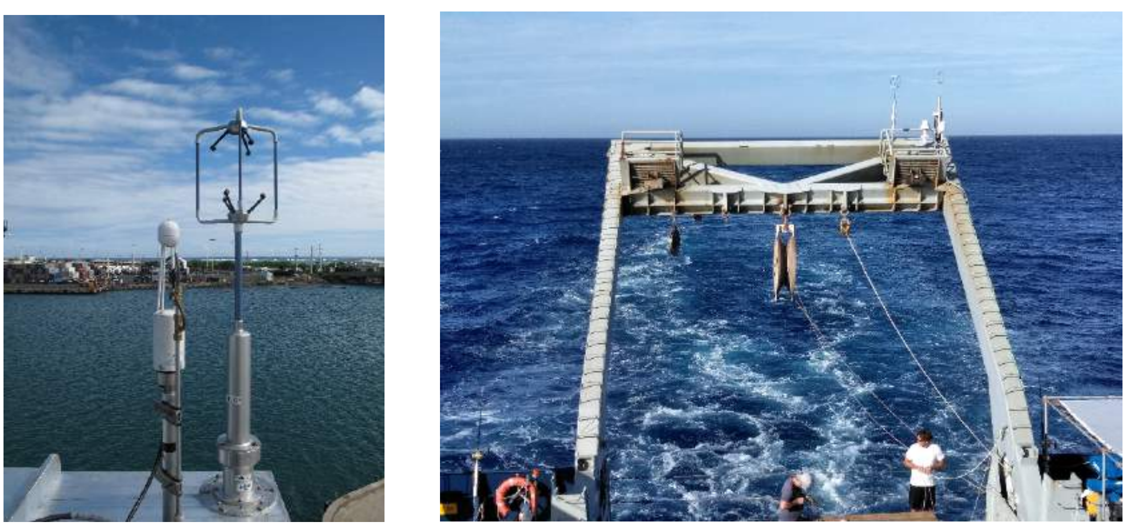


Figure 1. (left) The sonic and Li-COR from one of the DCFS systems on the MET mast. (right) The two sonic anemometers deployed on the Aframe aboard the Revelle as seen from the aft O2 deck. The two aspirated temperature/humidity sensors are visible below the sonics.

The preliminary meteorological and upper ocean data set is nearing completion. It will be made available through the SPURS data sharing site maintained by Fred Bingham. This initial data set is being put together to provide SPURS PI's with sufficient time to use the data to prepare for Ocean Sciences 2018. The variables are generally derived from more than one sensors and care is taken for inter-calibrate the data when multiple sensors are used. The sensors placed fore and aft of the ship are included or not in the calculation based on the relative wind direction. Some overlap is allowed for cross ship relative wind directions, i.e., the average of the fore and aft sensors are both used and averaged over a range of cross ship wind directions. The initial data files will include:

Yday	Decimal yearday (UTC)
Lat	Latitude (deg)
Lon	Longitude (deg)
SOG	Speed over ground (m/s)
COG	Course over ground (deg)
Heading	Ship's heading (deg)
WspdT	Wind speed (m/s) relative to earth at ~18 m
WdirT	Wind direction (deg) from relative to earth
U10	Wind speed (m/s) relative to earth adjusted to 10 m
U10N	Neutral wind speed (m/s) relative to earth adjusted to 10 m and neutral stratification
T10	Air Temperature (C) adjusted to 10 m
Tsea	Near surface sea temperature (C) at ~5 cm from the sea snake
SST	Sea surface temperature (C) from Tsea minus cool skin
Tsea5	Sea temperature (C) at ~5 m from the TSG
RH10	Relative humidity (%) adjusted to 10 m
Psurf	Pressure (mb) adjusted to the ocean surface
Q10	Specific humidity (g/kg) adjusted to 10 m
SSQ	Specific humidity (g/kg) at sea surface
Salt	Salinity (psu) from TSG.
SolarDown	Measured downwelling solar (W/m2)
SolarUp	Reflected solar (W/m2) estimated from Payne (1972)
IRdown	Measured downwelling IR (W/m2)
IRup	Upwelling IR (W/m2) computed from SST with sky correction
Precip	Accumulated precipitation (mm)
Prate	Precipitation rate (mm/hr)
Evap	Accumulated evaporation (mm)
Erate	Evaporation rate (mm/hr)
Ust	Friction velocity (m/s) from COARE 3.5
Tau	Surface stress (N/m2) measured relative to earth
Shf	Sensible heat flux (W/m2)
Lhf	Latent heat flux (W/m2)
Bhf	Buoyancy flux (W/m2)
Rhf	Sensible heat flux from rain (W/m2)

The near surface sea temperature at 5 cm, Tsea, is provided by the sea-snake after calibration with the μCTD operated by Janet Sprintall. The sea surface temperature (SST) is estimated from Tsea after correction for cool skin. This accounts for the difference between Tsea and SST due to evaporative cooling. The sea surface specific humidity, SSQ, is computed from the SST. The surface air pressure represents the average of barometers on the MET mast, forward O3 deck and Aframe. The pressure is adjusted to the surface using the hydrostatic equation before averaging. The air temperature is computed from four inter-calibrated sensors; two forward and two aft. The temperatures are all adjust to 10-m before averaging, i.e., using T10. The average of the two forward sensors are used for bow-on relative wind directions, while the average of the two aft sensors are used for stern-on wind directions. All four are used for a range of cross-ship relative wind directions. The specific humidity is computed from four inter-calibrated RH/T sensors using the same approach with fore and aft pairs. RH is reconstructed from the Q10, T10 and Psurf adjusted to 10-m.

The sonic anemometers on the MET mast and AFrame are used to measure the wind speed and direction. Relative wind speed is taken into consideration to minimize flow distortion. The winds are adjusted to 10-m before combining the fore and aft measurements. The wind directions are provided in meteorological convention (i.e., direction from). The latitude, longitude, speed-over-ground, course-over ground and heading are taken from the ship's data files. These are used to compute the wind speed relative to earth. Surface currents will be added to the data set to compute the fluxes and winds relative to the ocean surface ASAP. The wind speed relative to water will then be used to compute the fluxes in a future release. Estimates of the significant wave height will be included once the analysis of the DCFS surface fluxes is completed. Other variables (e.g., salinity from the salinity snake) will be added once they become available.

A five panel plot of the mean meteorological and heat budget terms are shown in Figures 2 and 3, respectively. A persistent sea-air specific humidity difference of approximately 5 g/kg drove a healthy latent heat (evaporative) flux of order a 100 W/m^2 during the experiment. Wind speeds were generally less than 10 m/s with a few moderate wind cases. Individual components of the IR radiative fluxes were large but closely cancelled. The resulting net heat flux followed the usual situation in the tropics with the downward solar radiative flux driving stabilizing ocean heating during the day and latent heat flux driving ocean surface cooling and enhance mixing during the night.

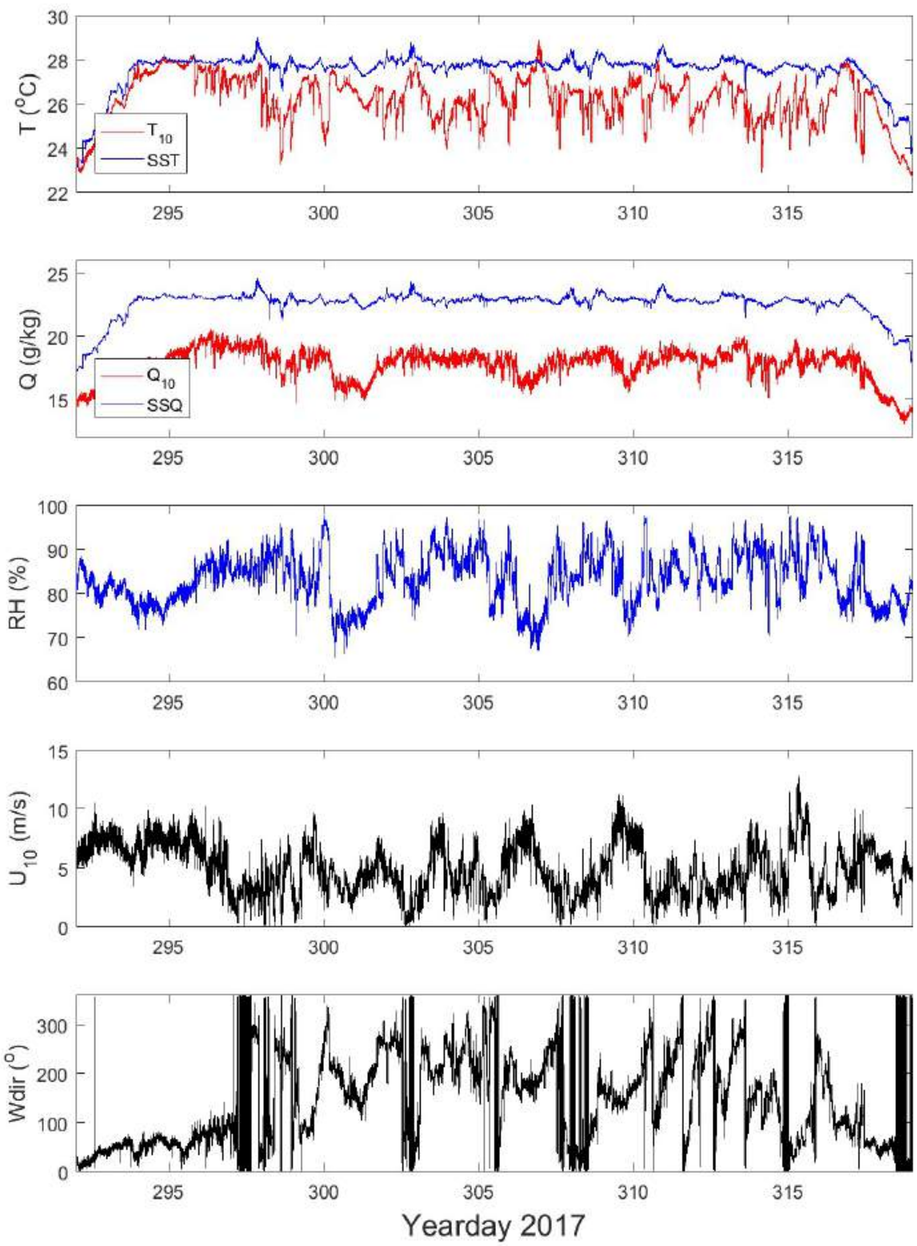


Figure 2. Mean meteorological variables as a funciton of Yearday 2017 during the Fall recovery cruise. The data represent 1 minute averages.

The bulk fluxes of stress (momentum), sensible heat, latent heat, buoyancy and the sensible heat due to rain are provided by the COARE 3.5 algorithm. The COARE 3.5 algorithm is also used to compute the 10-m values of wind speed, temperature and humidity. The downwelling solar and IR radiative fluxes are computed from the average of radiometers deployed on the top of the MET mast and on a shorter mast on the aft O2 deck. The MET mast IR radiometer (i.e., a purgeometer) is corrected for solar heating prior to averaging. The upwelling (reflected) solar radiation is computed from a commonly used parameterization of the surface albedo of the ocean (Payne, 1972). The upwelling IR radiation is derived from the SST measurements and a correction for reflected IR using the COARE 3.5 algorithm.

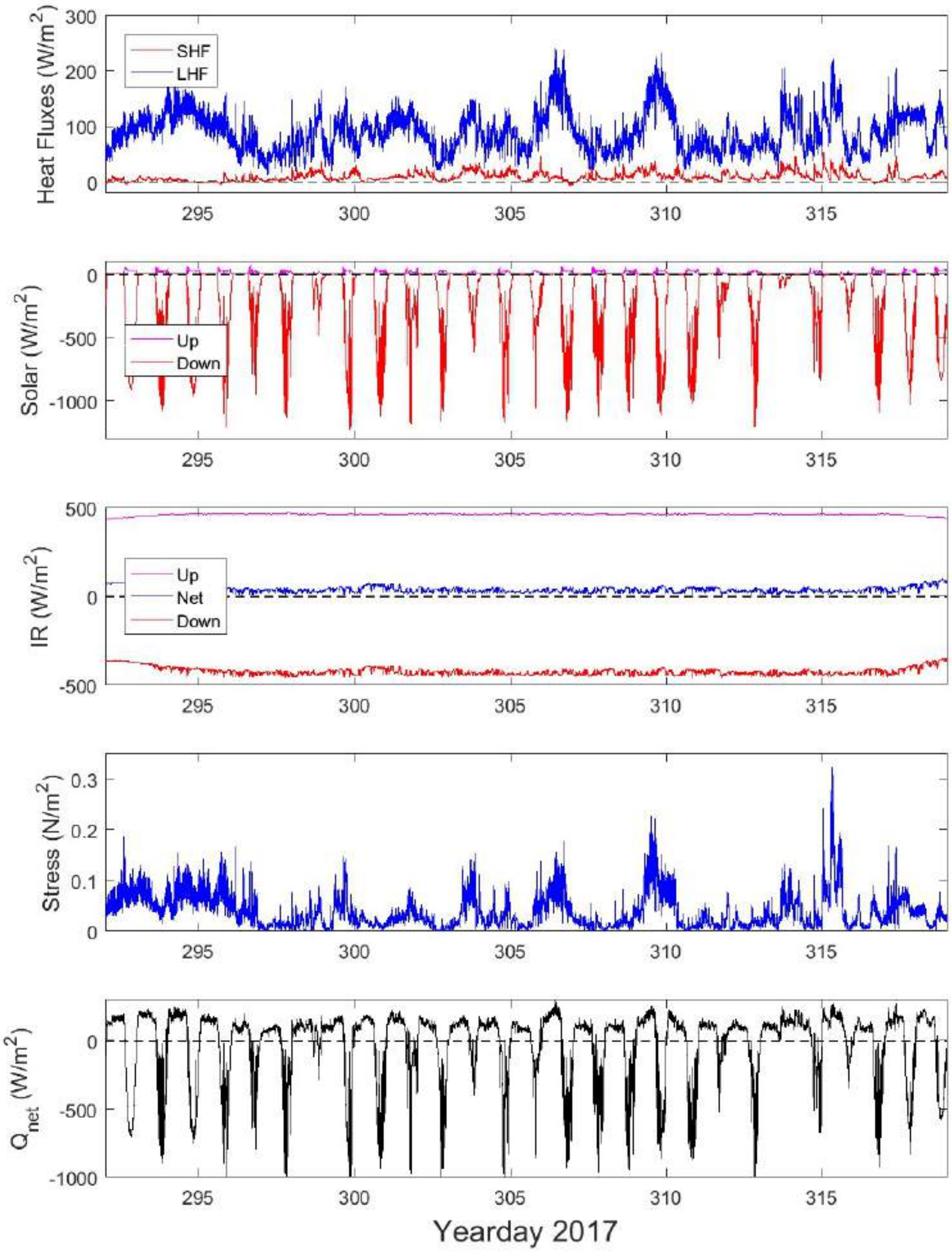


Figure 3. Heat budget terns and the surface stress as a funciton of Yearday 2017 during the Fall recovery cruise. The data represent 1 minute averages. The sum of the radiative and heat flux terms provide an estimate of the net heat flux, Q_{net}, as shown in the lower panel.

Optical Absorption in the Ocean

Approximately 25 casts of the a-sphere spectrophotometer were performed onboard the Revelle during the cruise to measure the optical absorption by sea-water. The casts were generally conducted just prior to CTD casts. The instrument has been calibrated and absorption length scales have been calculated for all of the casts. We intend to collaborate with Sophie Clayton and the ocean optical properties team to calculate variability in the upper ocean extinction profiles and its effects on upper ocean heating.

Rawinsonde Launches

Ray Graham and the CSU radar group with other volunteers launched rawinsondes every 6-hours to provide profiles of temperature, humidity, wind speed and direction through the marine atmospheric boundary layer and beyond. The new Vaisala sounding system purchased for the deployment cruise was again used during the experiment. It performed extremely well and provided approximately 85 profiles of the marine boundary layer. The average profile of all launches is shown in Figure 3 and height-time series of water vapor is shown in Figure 4. These profiles are being used to provide estimates of precipitable water and its storage and convergence over the SPURS-2 array, and to validate reanalysis products such as MERRA-2 for our investigations.

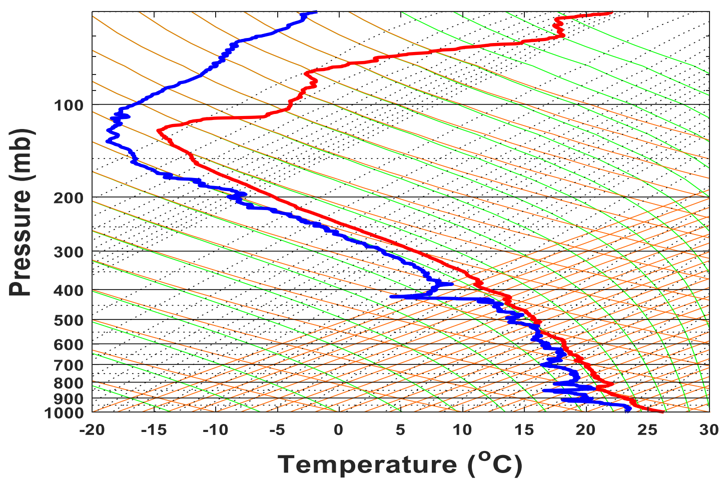


Figure 4. Mean profiles of air and dewpoint temperatures during the cruise.

WHOI mooring

The WHOI surface buoy used in this project is equipped with meteorological instrumentation for estimation of air-sea fluxes, including two Improved Meteorological (IMET) systems. The mooring line also carries current meters, and conductivity and temperature recorders. This mooring is of an inverse-catenary design utilizing wire rope, chain, and synthetic rope and has a scope of 1.45 (scope is defined as slack length/water depth). The buoy is a 2.8-meter diameter foam buoy with an aluminum tower and rigid bridle. The watch circle is 3.8 nm in diameter.

The mooring, WHOI PO mooring #1282, was deployed 24 August 2016, at 10°03.0481'N, 125° 01.939'W. The water depth was 4769 m. The anchor was released from the ship at 18:38:58 UTC and was settled on the seafloor before 20:00 UTC. The anchor position was estimated by performing an 'acoustic anchor survey', pinging the acoustic releases from several positions to triangulate the anchor position. The buoy was successfully recovered 7 November 2017

There are two independent IMET systems (Hosom et al., 1995; Payne and Anderson, 1999) on the buoy provide the measurements listed in Table 1. All IMET modules are modified for lower power consumption so that a non-rechargeable alkaline battery pack can be used. In addition to the IMET measurements, the buoy also carries an instrument to measure the height and direction of surface waves. Near-surface temperature and conductivity are measured with two SeaBird MicroCat (SBE37) instruments with RS-485 interfaces attached to the bottom of the buoy. One-hour averages of data from the IMET modules were transmitted via Iridium during the deployment for initial investigations. The recovered data is being post-processed and calibrated to develop a "best" time series of the surface meteorology for estimation of air-sea fluxes.

Table 1: Types of measurements collected on the WHOI-SPURS2 air-sea interaction surface mooring.

Surface Measurements	**Subsurface Measurements**
Wind speed	Temperature
Wind direction	Conductivity
Air temperature	Current speed
Sea surface temperature	Current direction
Barometric pressure	
Relative humidity	
Incoming shortwave radiation	
Incoming longwave radiation	
Precipitation	
Surface wave height and direction (buoy pitch, roll, heave, and yaw)	
Turbulent fluctuations of humidity, temperature, and wind	

The buoy also carried an atmospheric turbulence packages for measuring turbulent sensible and latent heat fluxes and wind stress. This instrument package, known as a Direct Covariance Flux Systems (DCFS), includes a fast-response infrared hygrometer (Li-COR 7500 model), Gill 3-axis sonic anemometer, and a motion package. The DCFS high frequency wind and platform motion information is used to compute air-sea fluxes. The high power Li-COR 7500 operated into January 2017 when power levels dropped below that needed for operations. The sonic anemometer continues to operate until May 14th when it began to transmit faculty data. The motion system continued throughout. The DCFS was successfully recovered with the buoy on 7 November, 2017. Inspection of the system showed that the sonic had lost one of its transducers; likely on 14 May, 2017 due to bird activity. Overall, we expect to be able to compute direct covariance latent heat fluxes for the first 5 months, and stress and buoyancy fluxes for the first 9 months of the deployment.

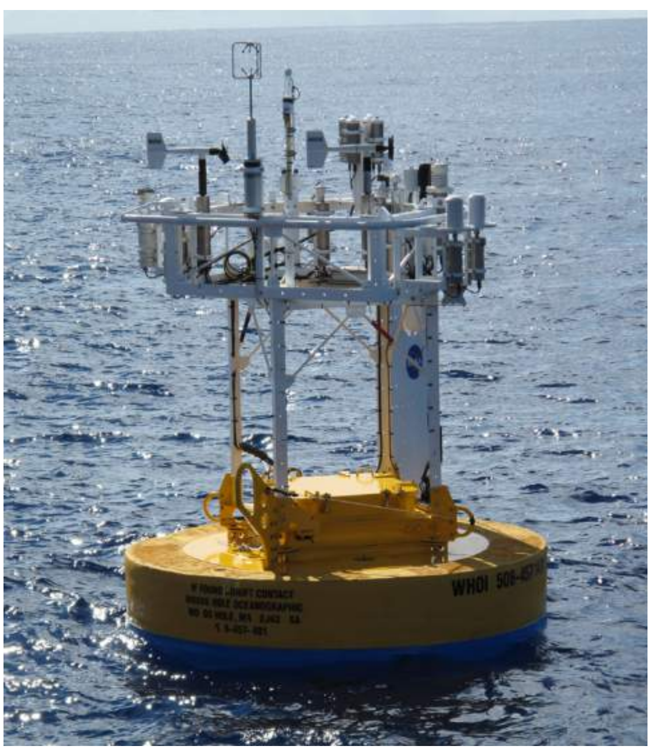


Figure 6: WHOI-SPURS2 surface mooring sonic Anemometer and Li-COR 7500 are in foreground.

SEA-POL Radar

PI: Steven A. Rutledge, Colorado State University
At sea: Steve Rutledge, Francesc Junyent, Jim George, Brody Fuchs

The SPURS-2 cruise marked the first deployment of the CSU SEA-POL (seagoing-polarimetric) radar. SEA-POL is a C-band, Doppler polarimetric radar. The transmitter, signal processor, operating consoles, inertial stabilization system, and data recording system are housed in an air-conditioned seatainer. The 1 degree beamwidth antenna, antenna mounted receiver and positioning system are set on top of the radar using a rugged, custom designed mechanical interface. The antenna is enclosed in a high performance radome. For SPURS-2, SEA-POL was located in the inner-starboard seatainer position on the forward 02 deck (Fig. 1). The transmitter, with a peak power of 250 kW (therefore 125 kW to each polarization channel, horizontal and vertical) was automatically blanked when the antenna swept across the solid angle of the ship. Therefore, SEA-POL covered a 240-degree sector centered on the ship's bow. The radome did obstruct the forward view from the bridge to some extent. But watch standers felt the blockage was not a hindrance to ship operation and safety.

Fig. 1. Picture showing the SEA-POL radar installed on the forward 02 deck of the R/V Roger Revelle.

SEA-POL operated very well during the entire cruise. The assembly and disassembly of SEA-POL at MAR-FAC went very well, aided by their excellent facilities and staff. The only problem that was encountered at sea was that the Seapath 200 INU failed due to the loss of a GPS receiver (the same receiver that had been replaced by the manufacturer just prior to the cruise). This failure occurred several days into the cruise. The Revelle ship personnel (mainly Mary Huey) quickly helped us to obtain the ship's Seapath 330 data stream, which provided excellent stabilization.

SEA-POL was deployed to address two scientific foci. The first objective was to map rain and therefore locate and track fresh water puddles to further understand the fate of freshwater deposited on the ocean's surface (fresh water lens). The second objective was to document convection in the ITCZ and attendant mesoscale convective systems associated with cloud clusters. Objective 1 was successfully achieved. Objective 2 was also achieved, but with slightly less success. This was simply due to fact that the big cloud clusters were just out of range of the radar at times. Overall, both objectives were satisfactorily achieved.

An example of a particularly intense convective cell is shown in Fig. 2. This event occurred during a period when the CAPE (Convective Available Potential Energy) was at a cruise maximum of approximately 2600 J/kg.

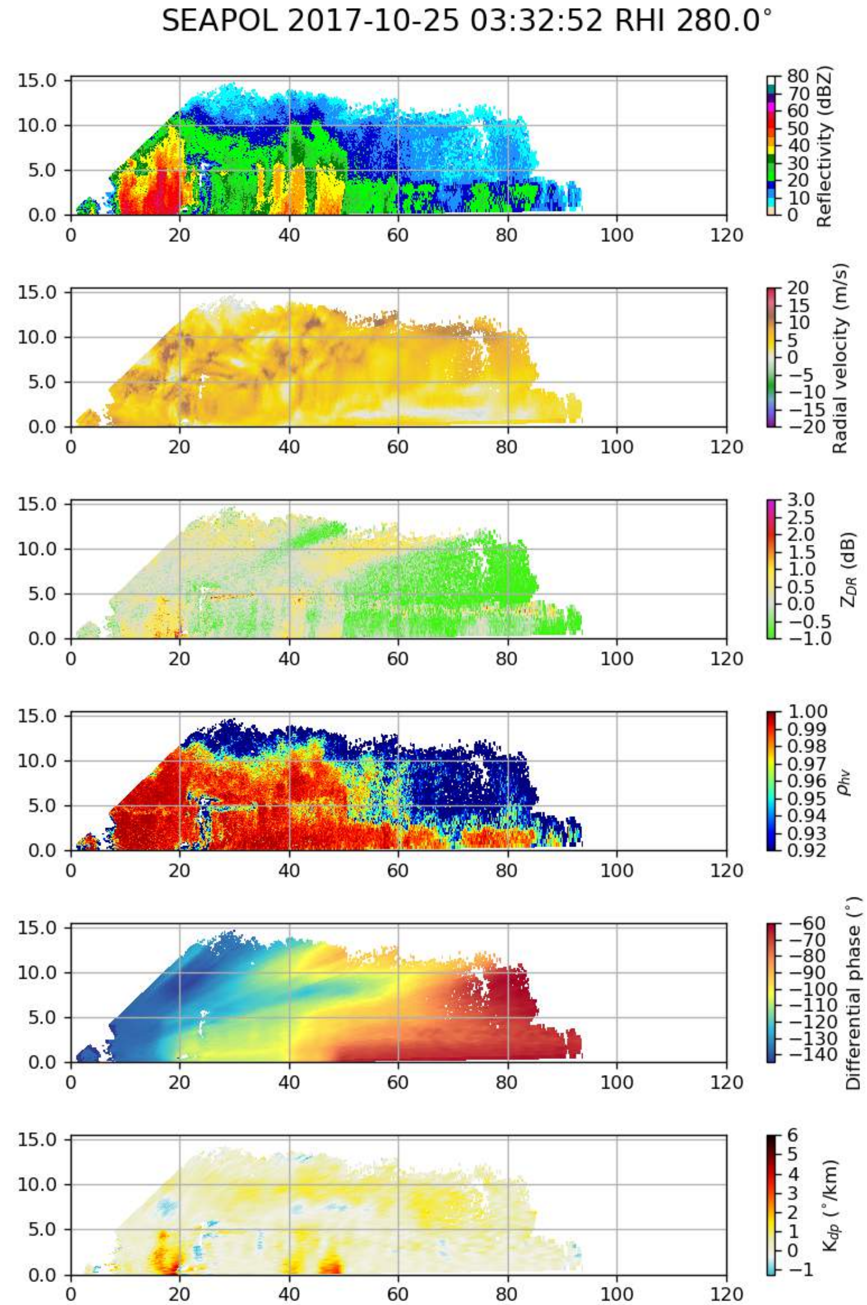


Fig. 2. RHI cross section at 03:32:52 on 25 October 2017. The upper most panel shown the reflectivity field (Z). The cell at 20 km range is very intense, especially for oceanic convection. The new Geostationary Lightning Mapper on GOES-R observed lightning in association with this cell during the time of this RHI.

In closing, the CSU radar team would like to thank Dr. Kyla Drushka, who was a very effective and supportive Chief Scientist. The radar team would also like to thank Capt. Murline and the entire R/V Roger Revelle crew for also playing a huge role in making the SEA-POL deployment so successful.

Very-Near Surface Salinity Measurements

PI/at sea: Julian J. Schanze, Earth and Space Research

1. Scientific Background

With the advent of space-borne L-band radiometers capable of measuring sea surface salinity (SSS), such as Aquarius/SAC-D, SMOS and SMAP, a new challenge of calibrating such measurements has arisen: While most measurements of salinity are performed at levels of 3-5 m or deeper by means of Argo floats and ship-mounted thermosalinograph (TSG) systems, the radiometric depth (or the 'measured depth') of L-band (~1.4GHz) microwave remote sensing is 1-2 cm (Lagerloef *et al.*, 2008). While this difference is often negligible in well-mixed conditions, it can be substantial in regions of high precipitation and relatively low surface mixing due to the formation of freshwater lenses or 'puddles' at the ocean surface. The measurement of salinity at depths as shallow as 1-2 cm is challenging from vessels and autonomous platforms due to bubble entrainment, vessel stirring, and the ship-time required for dedicated missions

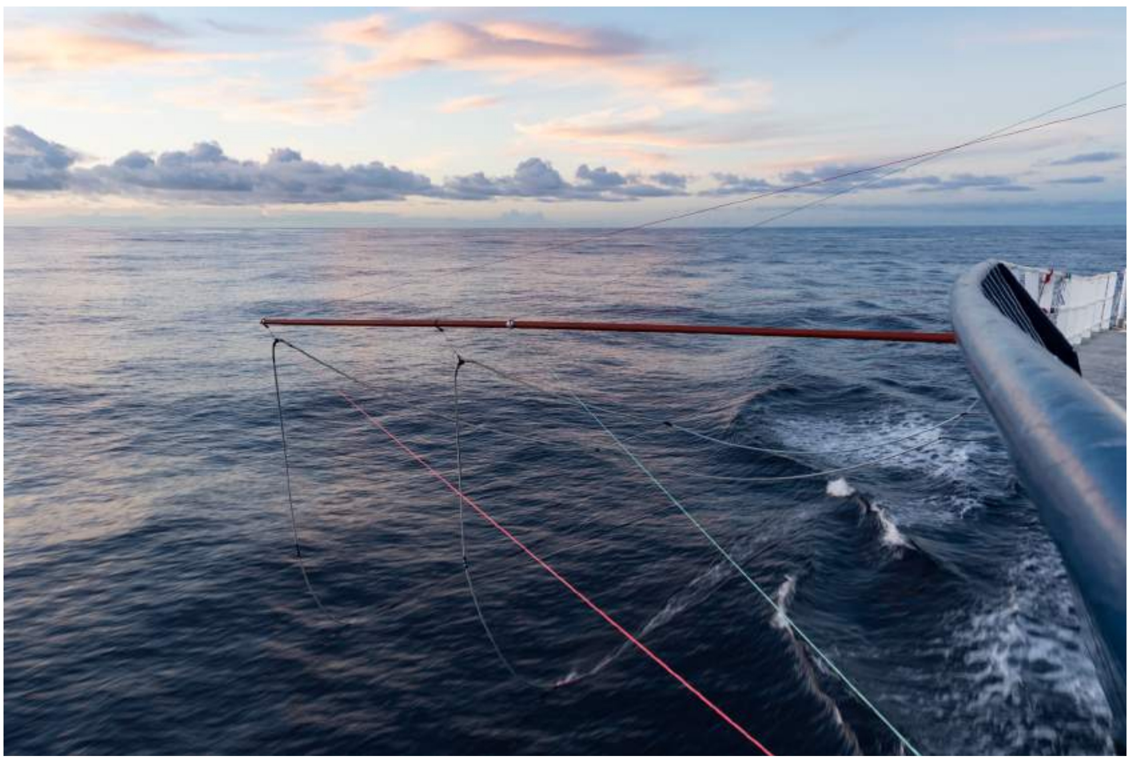


Figure 1: Intake System during RR1720 deployment, showing 42ft boom deployed on starboard bow with dyneema SK-78 stays, both intake hoses and out associated outhaul systems.

2. The Salinity Snake System

The first version of the system ('Salinity Snake Mk 1') was deployed successfully aboard the R/V Endeavor for SPURS-1 in 2013, but significant changes were made to account for the increased suction height from a global class research vessel such as the R/V Revelle, which were implemented during tests aboard the NOAA ship Okeanos Explorer in April 2015 and the first deployment during RR1610. These changes include a much more powerful peristaltic pump capable of dry-priming to 9.5m suction height as well an improved de-bubbling apparatus, and comprise the ‘Salinity Snake Mk 2’.

For RR1710, the boom mounted on the starboard bow was extended to a length of 42 ft and stayed with 2 sets of 3 Dyneema stays each (8600 lbs avg. breaking strength for the outboard set), attached at attachment points located at 30 ft and the head of the boom (*Fig. 1*). Each of these attachments also hangs the outboard block of two outhaul systems with attached hoses. The hose attached 30 ft outboard is designed to be positively buoyant and is optimized for slow vessel speed (generally less than 12 km/h), while the hose located at the end of the boom is optimized for fast vessel speeds, being negatively buoyant, extremely flexible, wave-following, and hydrodynamically streamlined. A control apparatus continuously monitors vessel speed using the ship-provided GPS feed, which is read in by a microcontroller. Depending on the speed, an electrically actuated valve housed on the starboard O1 deck is thus switched to select the appropriate intake hose. Both hoses a number of 6mm intake holes in the last meter of hose, and are sealed at the ends with internally recording WOCE-quality SBE56 temperature recorders. This allows the recording of true in-situ surface temperature, as thermal exchanges occur inside the hoses, pump, and the de-bubbling apparatus.

The salinity snake control system houses both the aforementioned microcontroller-based system as well as an embedded Linux system (Beaglebone Black), for redundant data logging and diagnostics. The system furthermore monitors intake vacuum and discharge pressure to aid in data quality control, e.g. to determine a blocked intake hose or other no-flow conditions, such as manual pump overrides.

3. Recorded Data and Data Format

The main data recorded by the salinity snake control system are provided as comma-separated values from the time of arrival at the SPURS-2 area until before the entry into the Mexican EEZ. Data are available before that, but are recorded in different formats due to the assembly, construction, and testing of the system during the transit to the SPURS-2 area.

The raw data format is as follows:

```
1510538272.808,2017,11,14,8,53,47,19.676963,-119.999992,21.9,
25.37300,34.56990,0,1.400,0.701,0.236,35,19.400,1015.750
```

With fields: timestamp (erroneous due to a known BeagleBone real-time-clock bug), year (UTC, GPS derived), month (UTC, GPS-derived), day (UTC, GPS-derived), hour (UTC, GPS-derived), minute (UTC, GPS-derived), second (UTC, GPS-derived), Latitude (WGS84, decimal degrees, N=positive), Longitude (WGS84, decimal degrees, E=positive),Vessel Speed (km/h, GPS-derived, over ground),Temperature (from SBE45, ITS-90, modified by heating and cooling inside hoses, de-dubblers, pump etc. and should not be used for science),Salinity (from SBE45, PSS-78),SlowSnakeOn (Intake hose used, 0=heavy, flexible outside hose mounted at 42ft outboard attachment point, 1=positively buoyant hose mounted at 25ft outboard attachment point), Flow rate (at SBE45, after all de-bubblers, liters per minute, using Seametrics flow meter), Hose suction vacuum (in bar, gauge, 1=full vacuum, measured at pump intake), Pump discharge pressure (in bar, gauge), Pump speed (in Hz, as provided to VFD controlling an Albin ALP-30 pump), Control board temperature (degrees C, for diagnostic purposes only), Control board atmospheric pressure (in mbar, for diagnostic purposes only but clearly shows even minor ship roll etc.).d

The raw data format for records from the SBE56 temperature recorders is given both in the Seabird-native xml format and converted to comma-separated variables (CSV). All times are in GPS time in UTC+0 time-zone (i.e. are not corrected for differences between UTC and GPS time due to leap seconds, but are left as GPS time).

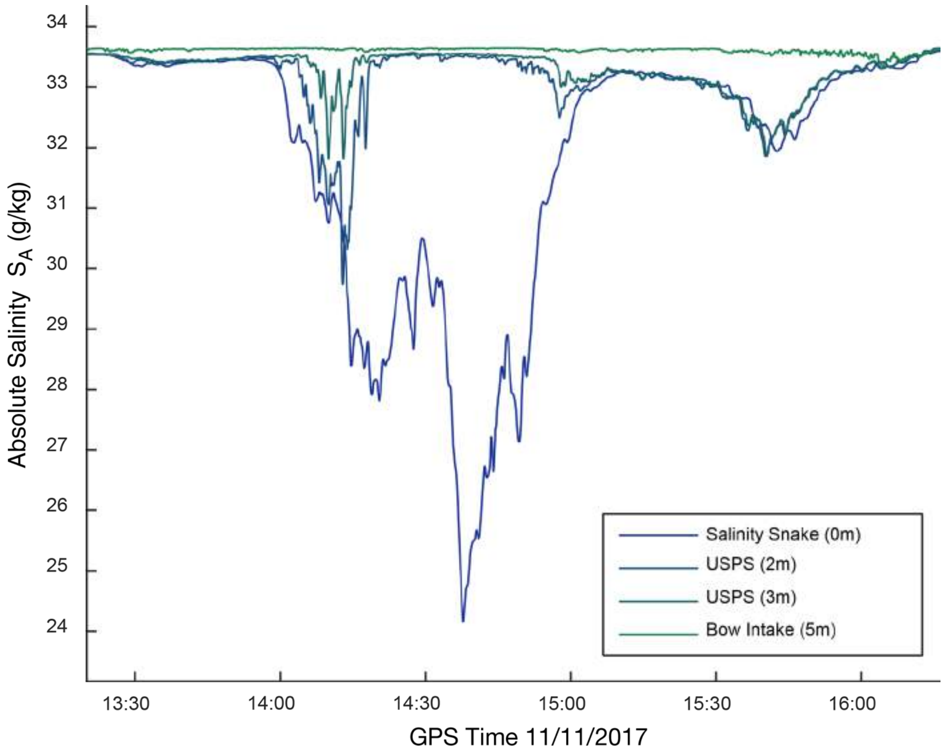


Figure 2: Example of salinities in freshwater lens encountered during RR1720 on 11/11/2017, with ΔSSS (radiometric depth – 5m salinity) exceeding 9 g/kg

4. Scientific Results

An example of a freshwater lens is provided in Figure 2. Here, surface salinity from the salinity snake is shown in blue, while the bow intake (5m) is shown in green, and USPS intakes at 2m and 3m are shown in different hues of blue-green. A clear near-surface stratification is evident, which at first is similar at 2m depth, but is soon mostly visible in the salinity snake data only.

The seawater gathered by the salinity snake was collected daily for a 10-day period for analysis in a Guildline Autosal salinometer. As during RR1610, the water was analyzed (PI David Ho at the University of Hawaii, Manoa) for pCO2, Dissolved Inorganic Carbon (DIC), pH, and dissolved oxygen (DO). As a novum for RR1710, the seawater was furthermore pumped into an imaging flow cytometer and its optical properties were measured (PI Sophie Clayton, Applied Physics Laboratory at the University of Washington).

5. Future Developments and Improvements

While the deployment of the salinity snake was a complete success on all SPURS cruises thus far, there are a number of potential future improvements, particularly regarding the deployment of the boom. During the deployment of the 42 ft long boom, several attempts and a pushing device made from 2x4"x10' lumber were required to achieve a successful swinging out of the boom. Furthermore, due to the heavy stresses of unsuccessful attempts to swing the boom out, the aluminum mounting point for the boom base experienced some material fatigue. While still operating normally, in the future, several systems could be used to deploy the boom more successfully, and will be implemented to achieve a smoother boom deployment. Such systems could consist of a central pivot point mounted to the attachment point ('paddock door system'), or

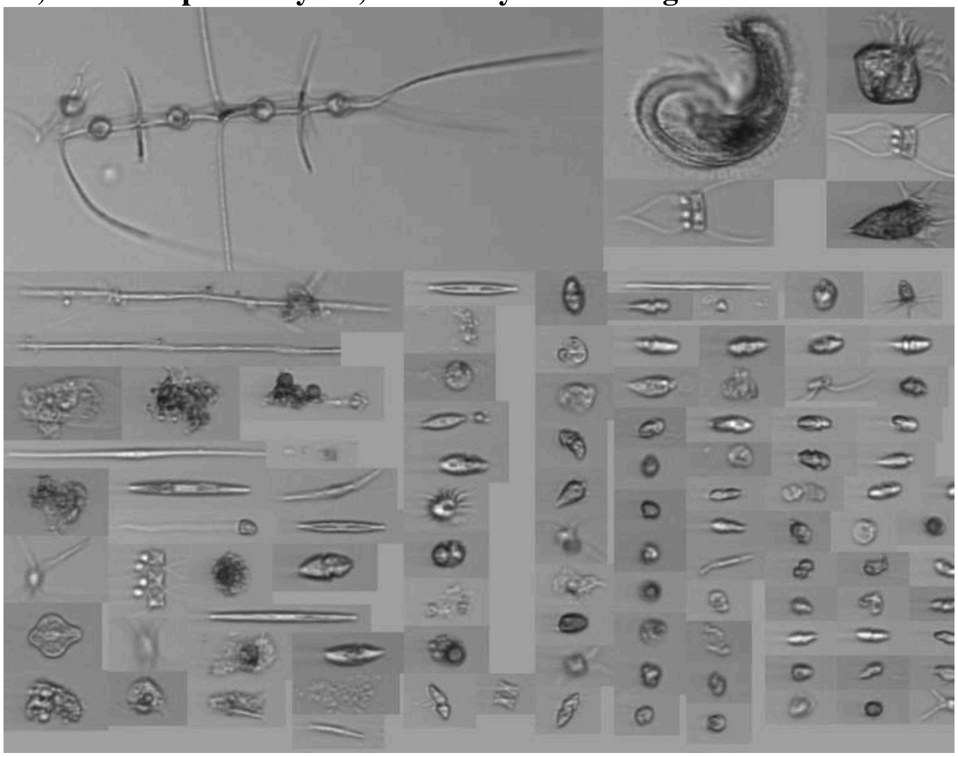
may involve lowering the boom into the water with a floatation device at the mast head, upon which it would be swung out, lifted up using an air tugger and secured.
From a scientific perspective, the current configuration of slow and fast snake in combination with the current pump and de-bubbling setup and length of boom allow the sampling of completely undisturbed surface water outside of the influence of the wake of the ship at any speed, and can thus be considered the final design iteration. xx

References

Lagerloef, G., F. Colomb, D. Le Vine, F. Wentz, S. Yueh, C. Ruf, J. Lilly, J. Gunn, Y. Chao, A. Decharon, G. Feldman, and C. Swift (2008). The Aquarius/SAC-D mission: Designed to meet the salinity remote-sensing challenge. Oceanography 21(1), 68–81.

Spatial Variability in Phytoplankton Community Structure From Underway Optics

PI, at sea: Sophie Clayton, University of Washington



1 Motivation

Phytoplankton form the base of the oceanic food chain, mediate the biogeochemical cycles of climatically important elements including carbon, and are responsible for nearly half of global primary production. In light of their global significance, elucidating the mechanisms driving phytoplankton variability, both spatially and phenotypically, represents a fundamentally important research theme for the climate sciences. Observations of phytoplankton variability at scales from hundreds of meters to tens of kilometers (the oceanic submesoscale) are exceedingly rare and limited to a handful of regionally targeted process studies. Global-class research vessels are equipped with flow-through systems that already make submesoscale-resolving measurements of physical variability.

Shipboard underway systems, equipped with modern optical and imaging instruments, represent a platform by which high-resolution observations of planktonic ecosystem variability may be collected. Current underway systems take measurements of physical properties every 1-2 seconds, resulting in a horizontal resolution < 1 m at standard transit speeds. Multi-spectral scattering and fluorescence measurements can be made at comparable scales, resulting in submesoscale-resolving observations of phytoplankton biomass, growth rate, and physiological state. To directly estimate biodiversity, underway cytometers and imaging instruments, which aggregate samples over 20 minutes, generate observations with horizontal resolution of O(10 km). Combining these two data-streams will enable us to develop optical proxies of phytoplankton variability and diversity. Furthermore, these high-resolution optical observations of biological tracers will be used to diagnose submesoscale physical processes.

The SPURS-2 expedition presented a unique opportunity to test such a system, to measure surface ocean inherent optical properties (IOPs), and to collect direct observations of phytoplankton community structure at high spatial resolution in the tropical North Pacific Ocean.

2 Description of cruise activity

Bio-optical properties were measured using two flow-through systems, a WetLabs BB3 scatterometer run inline with a coloured dissolved organic matter (CDOM) fluorometer, and a McLane Imaging FlowCytobot (IFCB). The BB3 continuously measures backscatter of particles present in seawater, and the CDOM fluorometer is used to measure the concentration of CDOM in seawater. The IFCB uses a combination of flow cytometric and imaging technology to capture high resolution images of planktonic organisms. These instruments were all supplied seawater from the Salinity Snake intake at the sea surface. The BB3, IFCB and CDOM fluorescence data was all collected concurrently with the standard ship TSG and fluorometer data from the 5m intake port. In addition to the underway data, discrete samples for flow cytometric analysis, DNA extraction and pigment determination were collected at the surface and from CTD casts. These analyses are to be done back on shore.

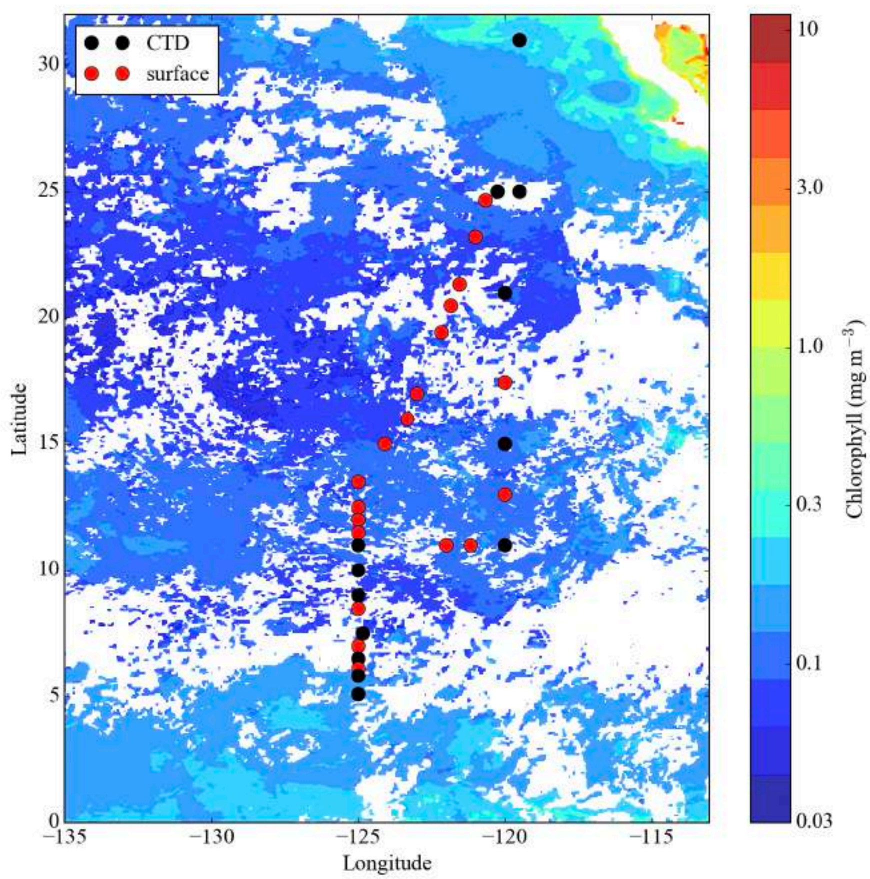


Figure 1: Map of the SPURS2 study region showing the location of surface samples (black circles) and CTD deployments (red circles).

3 When and where measurements were made

Underway optical and imaging measurements were taken continuously while the ship was underway and the Salinity Snake was in the water. There were minor interruptions to sampling, e.g. when passing through the Mexican EEZ and when small boat operations were underway. Discrete samples were collected periodically from the Salinity Snake surface intake, and the ship's 5m intake. We also collected samples from the deep chlorophyll maximum (DCM) and 5-10m depth from each of the 14 CTD stations sampled during the cruise. The cruise track and location of discrete sampling stations are shown in Figure

4 What to do differently next time

The optical instruments and the IFCB were fed with water collected using the Salinity Snake at the sea surface. We did not utilize the ship's seawater supply as the impeller pump used to supply that system is likely to damage larger phytoplankton cells that we were hoping to detect with the IFCB. However, we relied on the fluorescence measurements taken from the ship's underway system (from the 5m intake). As a result, our backscatter, CDOM and cell count data collected from the sea surface are offset from the fluorescence data from 5m. In future deployments of this system, either a fluorometer should be incorporated into the inline system, which could then be fed from any source, or we should ensure that the ship's pump is of a type that will minimize damage to large phytoplankton cells.

Underway measurements of surface pCO_2, DIC, and pH

PI/at sea: David Ho, University of Hawaii

During the cruise, measurements of partial pressure of CO_2 (pCO_2), dissolved inorganic carbon (DIC), and pH were made in the Main Lab on water pumped continuously from the Salinity Snake operated by Julian Schanze of Earth and Space Research. In addition, pCO_2 and pH, were made in the Hydro Lab on water from the Revelle's uncontaminated seawater intake.

The pCO_2 systems use showerhead equilibrators coupled to nondispersive infrared (NDIR; LI-740) analyzers. The DIC system takes a small volume of water, acidifies it with phosphoric acid to drive all the DIC to pCO_2, and sends the resulting gas to an NDIR analyzer (LI-7000) for quantification. pH was measured with an ion sensitive field effect transistor (ISFET)-based pH sensor. The pCO_2 and pH measurements on the Salinity Snake had a temporal resolution of 3 s, and the pCO_2 and pH measurements in the Hydro Lab has a temporal resolution of ca. 1 min. The DIC system has a temporal resolution of ca. 3 min.

Calibration for pCO_2 was done with two compressed gas standards; calibration for DIC and pH were made with certified reference material (CRM) from Andrew Dickson's lab at Scripps.

In the Main Lab, measurements were made from the Salinity Snake whenever it was deployed. At other times, water from the Revelle's uncontaminated seawater intake was measured in order to compare results with measurements made in the Hydro Lab.

A total of 592,452, 9,883, and 650,418 measurements of pCO_2, DIC, and pH, respectively, were made from the Salinity Snake in the Main Lab, and a total of 30937, and 17529 measurements of pCO_2 and pH, respectively, were made from the ship's uncontaminated seawater intake in the Hydro Lab.

Preliminary results show a clear dilution of pCO_2 and DIC due to rain (see Figures 1 and 2).

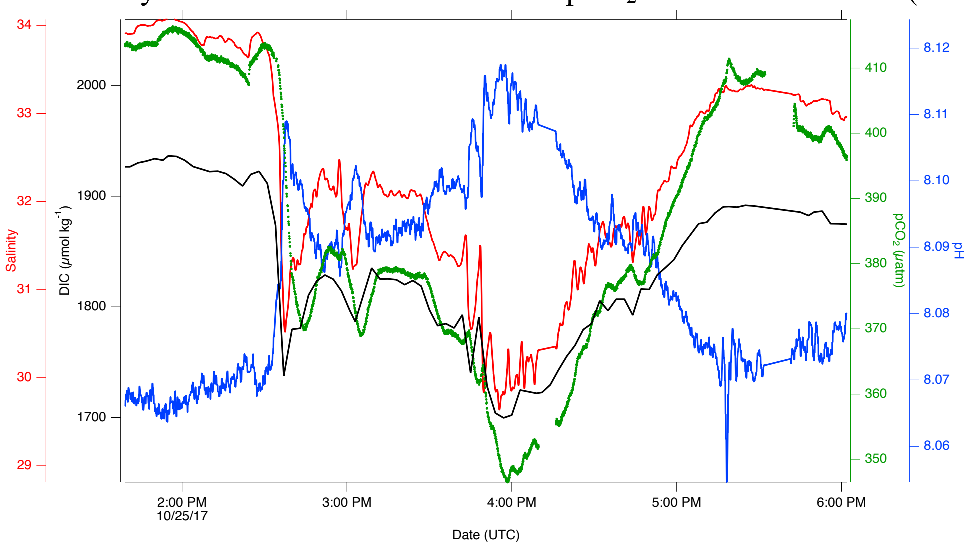


Figure 1. An example of continuous measurements of pCO_2, DIC, and pH across a "puddle", showing a decrease in pCO_2, DIC and increase in pH when salinity decreased.

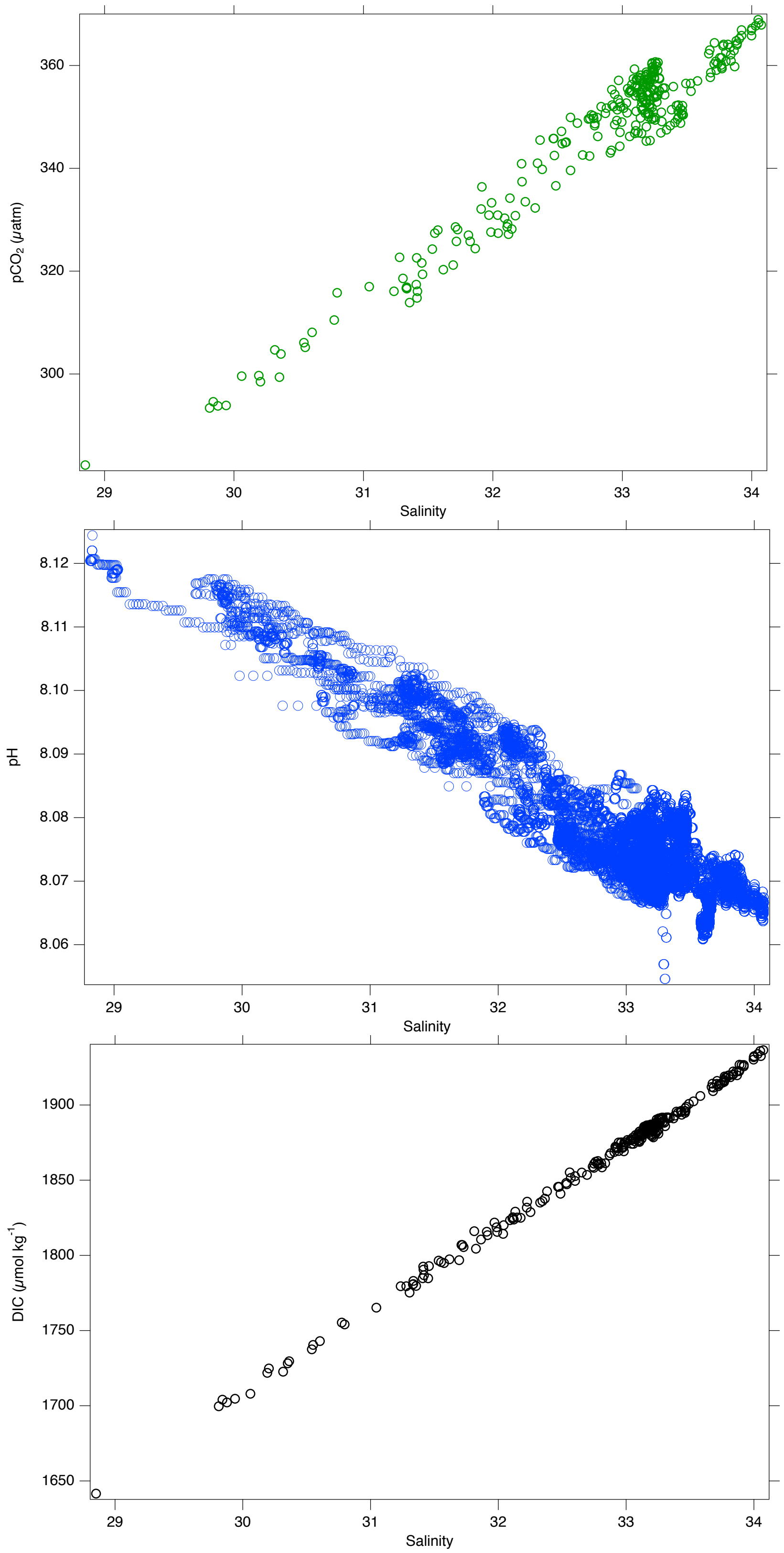


Figure 2. pCO_2, pH and DIC as a function of salinity for the data shown in Figure 1.

Surface Salinity Profiler and Controlled Flux Technique

PIs: Kyla Drushka, William Asher, Andrew Jessup
At sea: Kyla Drushka, William Asher, Elizabeth Thompson, Trina Litchendorf

Research approach and objectives:

As in 2016, the research directed by the team of Drushka, Asher, and Jessup was focused on examining the effect of rainfall on stratification of salinity, temperature, and turbulent kinetic energy (TKE) dissipation in the upper few meters of the ocean. In the tropics, rainfall deposits cooler, freshwater at the sea surface and this freshwater input can lead to a fresher ocean surface layer that affects calibration/validation of remote measurements of salinity and temperature and modulates air-sea interaction and mixing in the upper ocean. The modulation of air-sea interaction, in turn, affects the salt budget, heat content, surface currents, and TKE dissipation throughout the ocean bulk mixed layer. It is necessary to understand how these fresh lenses form and decay in order to assess their role in air-sea interaction and their impacts on satellite validation. The primary objective of the measurements made during SPURS2 was to quantify the horizontal, vertical, and temporal evolution of rain-formed fresh lenses at the ocean surface.

There were three main measurements made by APL-UW scientists on the *R/V Roger Revelle* during the 2017 SPURS2 cruise. Datasets from 2017 SPURS2 are:

(1) vertical profiles of temperature, salinity, and turbulent dissipation measured in the upper meter using a towed surface salinity profiler (SSP);

(2) net heat transfer velocity and TKE dissipation at the ocean surface measured using the controlled flux technique (CFT); and

(3) continuous underway profiles of salinity and temperature at depths of 2 m, 3 m, and 5 m made using an underway salinity profiling system (USPS) mounted in through-hull ports in the bow of the ship.

The observations from these systems will be used to quantify the vertical and horizontal structure of the salinity, temperature, and TKE dissipation fields at the ocean surface as a function of rain and wind. This information will be used to quantify the role of different processes in driving the build-up and decay of fresh lenses; to investigate the relationship between rain rate and the structure of ocean skin temperature; to understand how rainfall affects TKE dissipation at the air-sea interface and within the top meter of the ocean; in modeling studies to assess the impacts of rainfall on the upper ocean throughout the tropics; and to assess the impact of fresh lenses on satellite salinity measurements.

The SSP, CFT system, and USPS all functioned as designed during the cruise and provided data that will be used to achieve the research goals. To date, preliminary analysis has begun on data from the SSP, CFT, and the USPS and it is known the systems successfully collected data.

Hydrographic Surveys

PI: Janet Sprintall, Scripps Institution of Oceanography
At sea: Janet Sprintall, Spencer Kawamoto, Peter Hacker, Clifford Hoang

The principal aim is to characterize, measure and understand what drives surface layer variations in the low salinity/high precipitation regime of the eastern tropical Pacific Ocean. Our goal is to better understand the characteristics and variability of the upper ocean salinity stratification in the vicinity of the ITCZ and identify the main mechanisms that are responsible for this variability. The specific objectives are:

1. Determining the role that barrier layers may play in salinity stratification and in producing the warm SSTs found under the ITCZ in the eastern Pacific
2. Assessing the processes responsible for the spatial mismatches in salinity, temperature, winds and precipitation in the eastern Pacific

This project makes use of a full-suite of remotely sensed observational data sets, along with other *in situ* data from existing archives and importantly from direct measurements as part of fieldwork associated with the SPURS-2 campaign. Our contribution to the SPURS-2 field campaign focused on the "mesoscale" box (10-300 km) spatial scale, undertaking upper ocean stratification and velocity measurements that will help provide some regional context for the nested small-scale and single-point moored measurements.

We completed 15 CTD stations and 501 uCTD stations (Figure 1; Table 1) Some of these surveys were in conjunction with SSP deployments (at ~4 knots) and hence represent near surface to 500 m time series, while other surveys were continuous (at ~10 knots) along 125°W and will be used to examine upper ocean variability.

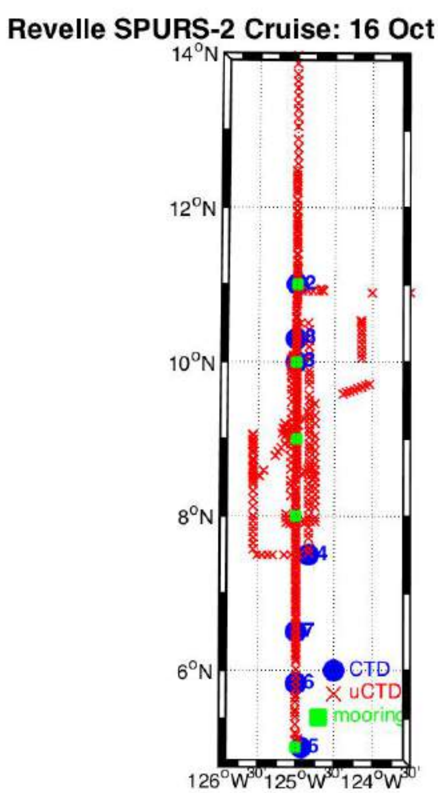


Figure 1: Location of hydrographic CTD stations (blue); uCTD transects (red), and moorings (green) during the SPURS-2 cruise.

Table 1: Event Log: Chronology of CTD stations and uCTD transects

Station	Cast	Lat (Start)	Long (Start)	Type	(u)CTD Depth (m)	NOTES	Start cast (GMT)
001	01	25° 02.85N	120° 15.44W	CTD test/fire all 24 bottles at 1000	1000	3885m	18 October 2017 18:11
T1beg	u001	13°58.2N	125°W	uCTD start	500		21 October 2017 12:03
T1end	u030	10° 52'N	125° W	uCTD end	500		22 October 2017 08:25
002	01	11° 00.2N	124° 58.2W	CTD at PMEL north	500	4626m	22 October 2017 13:03
003	01	10° 01.87N	125° 00.32W	CTD Full depth at WHOI Buoy	4650	4671m	23 October 2017 00:58
T2beg	u031	10° 48'N	125°W	uCTD start	500		23 October 2017 16:38
T2end	u064	8° 32'N	125° 28.8W	uCTD end	500		24 October 2017 15:34
T3beg	u065	8° 25.3N	125° 34W	uCTD start	500	SSP-2 (65-76)	24 October 2017 17:04
T3end	u079	9° 4N	125° 34.3W	uCTD end	500		25 October 2017 04:30
T4beg	u080	9°N	125° 34.4W	uCTD start	500		25 October 2017 04:51
T4end	u095	7° 34'N	125° 34W	uCTD end	500		25 October 2017 12:46
T5beg	u096	7° 30N	125° 30.4W	uCTD start	500	east	25 October 2017 13:27
T5end	u102	7°30N	125° W	uCTD end	500		25 October 2017 16:32
004	01	7° 29.9N	124°49.8W	CTD	500		25 October 2017 17:25
T6beg	u103	7° 32'N	124° 50W	uCTD start	500	North bound	25 October 2017 18:19
T6end	u143	10° 30N	124° 51W	uCTD end	500		26 October 2017 13:53

T7beg	u144	10° 30N	124° 57W	uCTD start	500	SSP-3 (148-158)	26 October 2017 14:28
T7end	u208	5° 7.2N	124 57.9°	uCTD end	500	South bound	28 October 2018 05:44
005	01	5° 4.02N	124° 56.1W	CTD	500	TAO Buoy	28 October 2017 07:03
T8beg	u209	5° 5.4'N	125°W	uCTD start	500	SSP-5 (246-255)	28 October 2017 08:30
006	01	5°49.97N	124° 59.9W	CTD	500		28 October 2017 13:33
007	01	6°29.99N	124°59.9W	CTD	500		28 October 2017 18:51
T8end	u263	9° 27.6N	124° 45'W	uCTD end	500	North Bound	29 October 2017 23:26
T9beg	u264	9° 18'N	124° 45'W	uCTD start	500	South bound	30 October 2017 00:22
T9end	u278	7° 58'N	124° 45W	uCTD end	500		30 October 2017 08:37
Tbeg	u279	7° 55.7'N	124° 45W	uCTD start	500	SSP-6 (279-288)	30 October 2017 09:23
Tend	u288	8° 1.7N	125° 8W	uCTD end	500		30 October 2017 18:13
Tbeg	u289	8° 29'N	124° 47W	uCTD start	500	SSP-7 (289-295)	31 October 017 10:03
Tend	U295	8° 32N	124° 55W	uCTD end	500	Drifter expt	31 October 2017 15:29
Tbeg	u296	8° 15'N	125° 4W	uCTD start	500	SSP-8 (310-312)	1 November 2017 01:01
Tend	u318	10° 3.8N	125° 3.5W	uCTD end	500		1 November 2017 17:08
Tbeg	u319	9° 58'N	125° 4W	uCTD start	500		1 November 2017 22:56
Tend	u337	8° 24.7N	125°W	uCTD end	500		2 November 2017 08:46
008	01	9° 3.67N	124° 58.05W	CTD	500		2 November 2017 16:41
Tbeg	u338	9° 6.7'N	125°W	uCTD start	500		2 November 2017 20:37
Tend	u378	12° 28N	125°W	uCTD end	500		3 November 2017 18:56

Tbeg	u379	12° 24'N	125°W	uCTD start	500	SSP-9 (419-428)	3 November 2017 19:17
Tend	u460	6° 11.2N	125°W	uCTD end	500	WHOI buoy recover	5 November 2017 18:26
009	01	6° 5.9N	124°59.9W	CTD	500		5 November 2017 19:15
Tbeg	u461	9° 7'N	125° 2.4W	uCTD start	500	SSP-11 (461-470)	8 November 2017 05:14
Tend	u470	9° 11.6N	125°8.4W	uCTD end	500		8 November 2017 14:37
Tbeg	u471	10° 3'N	124 8.8°W	uCTD start	500	SSP-12 (471-481)	9 November 2017 06:01
Tend	u481	10° 31.6N	124° 9.4W	uCTD end	500		9 November 2017 15:23
Tbeg	u482	9° 42.6'N	124°2.6W	uCTD start	500	SSP-13 (482-489)	10 November 2017 00:30
Tend	u489	9° 35.1N	124° 23.4W	uCTD end	500		10 November 2017 07:32
Tbeg	u490	10° 55.2'N	124° 55.5W	uCTD start	500	SSP-14 (490-501)	10 November 2017 21:48
Tend	u501	10° 55.N	124° 20W	uCTD end	500		11 November 2017 07:29
011	01	11° 0.9N	119°59.9W	CTD	500		12 November 2017 07:33
012	01	14° 59.9N	120°W	CTD	500		13 November 2017 06:41
013	01	20° 59.9N	119°59.9W	CTD	500		14 November 2017 16:50
014	01	25° N	119°32.3W	CTD	500		15 November 2017 17:04
015	01	31° N	119°59.9W	CTD	500		16 November 2017

Wave Gliders and EcoMapper
PI/at sea: Ben Hodges, Woods Hole Oceanographic Institution

Wave Gliders:

Pre-cruise operations

Three Liquid Robotics, Inc. SV2 Wave Gliders were deployed in August 2016 from the R/V Revelle (SPURS2 deployment cruise, RR1610). Each Wave Glider (WG) was equipped with two Sea-Bird GPCTD's: one at nominally 25 cm depth beneath the upper portion of the vehicle (the "float") and a second at approximately 6.6 m depth on the lower portion (the "sub"). Each of the six CTD's was configured to sample at 2-minute intervals. Additionally, each WG carried an Airmar WX200 Weather Station on a one-meter mast measuring wind speed and direction and air temperature and pressure, and an Airmar CS4500 ultrasonic water speed sensor, which, in conjunction with GPS, allows computation of surface current velocity. These auxiliary sensors were configured to sample at 10-minute intervals. Each WG also carried an SBE-56 temperature logger on the sub, sampling at 5-second intervals. (SBE-56's mounted to the floats were lost).

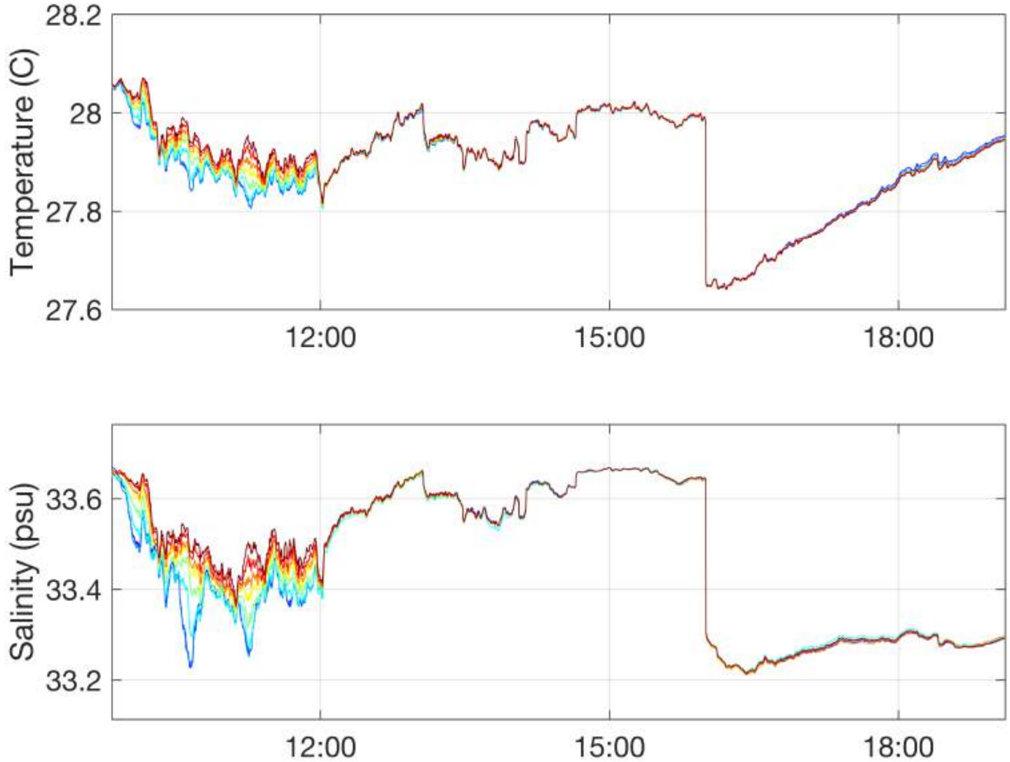
One WG suffered a float-to-sub communication failure in November 2016 which eventually resulted in the loss of the sub. The float was recovered by the R/V Lady Amber in December 2016. The other two Wave Gliders continued to sample, assigned to complementary transects along 125°W: one from the WHOI mooring (10.05°N) to the northern PMEL mooring (11.00°N), and the other from the WHOI mooring to the southern PMEL mooring (9.00°N). Their ability to stick to these lines varied with the prevailing current. All three WG saw air temperature and pressure data quality degrade early in the deployment and remain spotty throughout. The SBE-56 batteries from both surviving subs failed in March 2017. Otherwise data return was complete (CTD, wind velocity, surface current velocity).

Cruise activities

Both WG were recovered on October 23, 2017. Worn parts were replaced and biofouling removed. One WG was redeployed on October 26 carrying a "salinity rake" developed by Ray Schmitt: 10 NBOSI CT sensors spaced along a faired vertical fin at 10-cm intervals over the upper meter, sampling at 1 Hz, with data logged onboard. It made several laps around the WHOI mooring. The WG with rake was recovered for evaluation on November 1. Half the sensors (20, 40, 60, 80, and 100-cm) had returned good data, while the other half, for reasons as yet unknown, were swamped by noise. On November 3, the other WG was redeployed to resume sampling along 125°W, carrying SBE-56's on the sub and just below the waterline on the float, each sampling at 1 Hz. On November 6, the WG with rake was redeployed. Both WG were recovered for the final time on November 10. For this second deployment, three of the formerly noisy sensors returned good data, leaving malfunctioning sensors only at 30- and 50-cm depths.

Data access

Raw data is available upon request (bhodges@whoi.edu).



A 9-hour snippet of temperature and salinity recorded near the WHOI mooring by the rake on November 6 (during the second deployment). Sensor depths vary from 10 cm (blue) to 1 m (red). A fresh puddle forms and decays in the first couple of hours; later a sloping, 0.4-psu front, less than 1 m across, is encountered.

EcoMapper:

An EcoMapper carrying an NBOSI CTD, a suite of YSI sensors, and a SonTek DVL was deployed on two missions during the cruise, each about 3 hours in duration, and each done at a speed of 3 knots (for a track length of ~20 km). The deployments took place on October 30 and October 31, and were carried out in each case in conjunction with a drifter release experiment. Designed to map out small-scale vertical and horizontal temperature-salinity variability, the missions were successful horizontally, but found very little vertical stratification. Raw data is available upon request (bhodges@whoi.edu).

SIO Drifters

PIs: Verena Hormann and Luca Centurioni, Scripps Institution of Oceanography

In addition to 2 standard (SVP) and 2 salinity (SVP-S) drifters, a fleet of 5 CODE-type drifters (COastal Dynamics Experiment) equipped with a Valeport conductivity sensor were deployed during the recent R/V Roger Revelle cruise in October/November 2017 to measure the response of the near-surface freshwater layer to the wind and the spread of patchy "puddles". The Lagrangian Drifter Laboratory (LDL) at the Scripps Institution of Oceanography (SIO) further fabricated a so-called "Super Drifter" where the surface buoy was configured with a ~30-m thermistor chain instead of a drogue. It was equipped with a total of 20 subsurface nodes including 4 salinity sensors as well as an ADCP and was successfully used during the 2017 R/V Roger Revelle drifter experiment.

LOCEAN Drifters

PIs: Gilles Reverdin, Emilie Dassié, Antonio Lourenco, Denis Dausse and Jacqueline Boutin.
At sea: Alexandre Supply

Equipment:

- 4 CARTHE drifters: position, 50 centimeter anchor;
- 2 NKE drifters: salinity and temperature measurement near 50cm depth; 15-meter anchor (50 centimeter anchor during drifter experiment); Can be run at 5-minute acquisition rate, or to save energy at 30 minutes' rate.
- 4 SURPACT wave riders: continuous mode (3 second resolution; Sea Surface Salinity (SST), Sea Surface Salinity (SSS), acoustic intensity for rain (7 channels at different frequency) and accelerometer for wave spectrum; argos mode (15 minutes resolution);
- 1 "micro-chaîne": salinity and temperature at 5 depths from sensors on chips at 20 cm, 40 cm, 60 cm and 80 cm.

1. WHOI mooring experiment

One Surpact and the "micro-chaîne" were deployed attached to the WHOI mooring. The SURPACT recorded more than 3 and half days of data from November 1 to 5. The "micro-chaîne" was able to make measurements during only a little less than 10 hours due to an issue with it waterproof abilities. There might have been some banging on the mooring structure, as indicated by wear on the SURPACT float.

During this experiment, 4 significant freshening events were recorded with the SURPACTs. First look to the data allow to see correspondence between decrease of SSS and increase of acoustic intensity for different frequency channels, corresponding to rain, especially for channel 4.

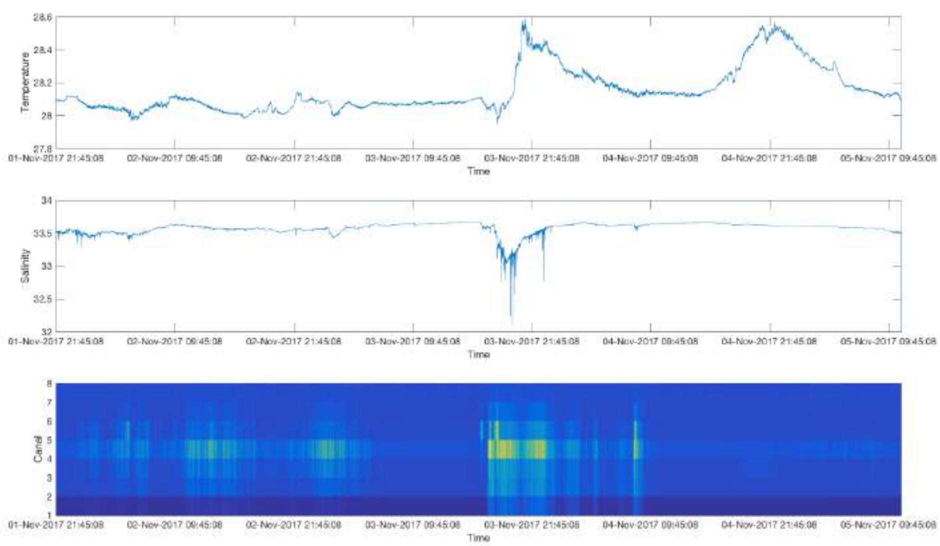


Figure 1: Time series of temperature, salinity (at 5cm) and acoustic intensity (blue to yellow : lower to higher) recorded with a SURPACT attached to the WHOI mooring from 01 November to 05 November.

2. Drifter experiment

The deployment of two Surpact (attached to NKE and the 50cm CARTHE drogue) started early in the morning of 9 November (Local Time) with a large meso-scale rain system coming from the south-east. The two sets of drifters were deployed roughly 500 m apart. The drifter experiment started under non-rainy, low wind speed conditions and finished under high wind speed, non-rainy conditions, but was also able to record the very large freshening associated with the heavy rainfall. As a consequence, even if the drifter experiment was temporarily short, SURPACTs experiences very different conditions during this deployment.

Figure 2 shows how the drifters were prepared. Each SURPACT wave rider was hooked on one NKE drifter and each NKE drifter was hooked on one CARTHE drifter. During this drifter experiment, SSP instrument and Salinity Snake were also recording in several loops a few miles at most from the drifters, allowing future promising comparisons with SURPACTs and NKEs. First look on the two SURPACTs data (Figure 3) and Salinity Snake data show values and dynamics in the same range (the two instruments indicate close to 10 pss freshening). Notice also how the data collected 500m apart are different. The NKE data at 50 cm depth indicate much less maximum freshening (and cooling).

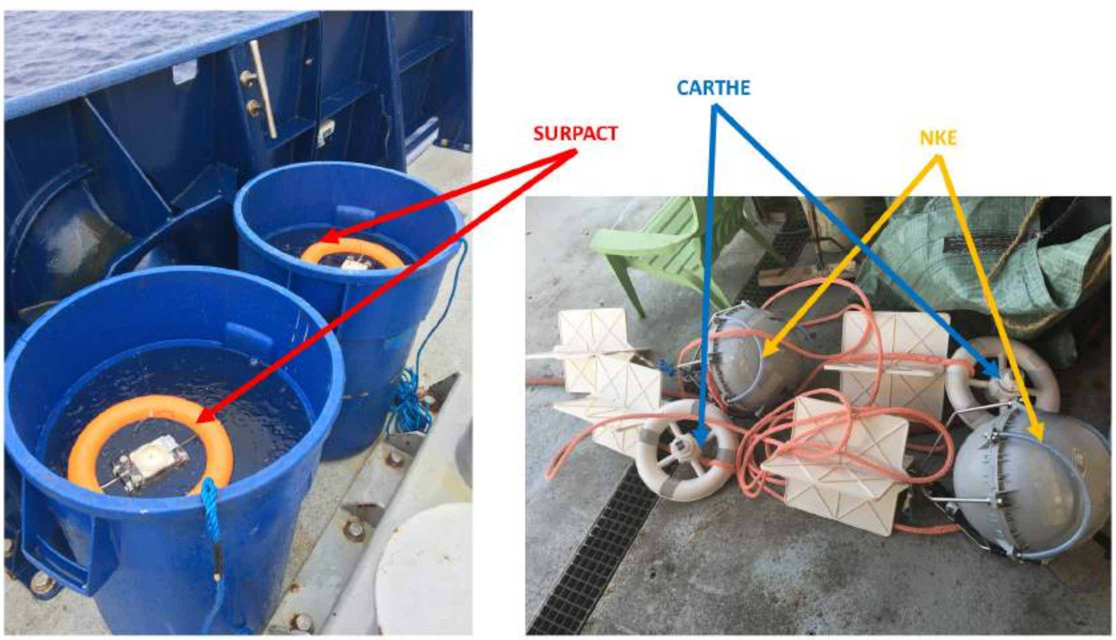


Figure 2: Left) SURPACT in salty water before drifter experiment; Right) NKE and CARTHE before drifter experiment.

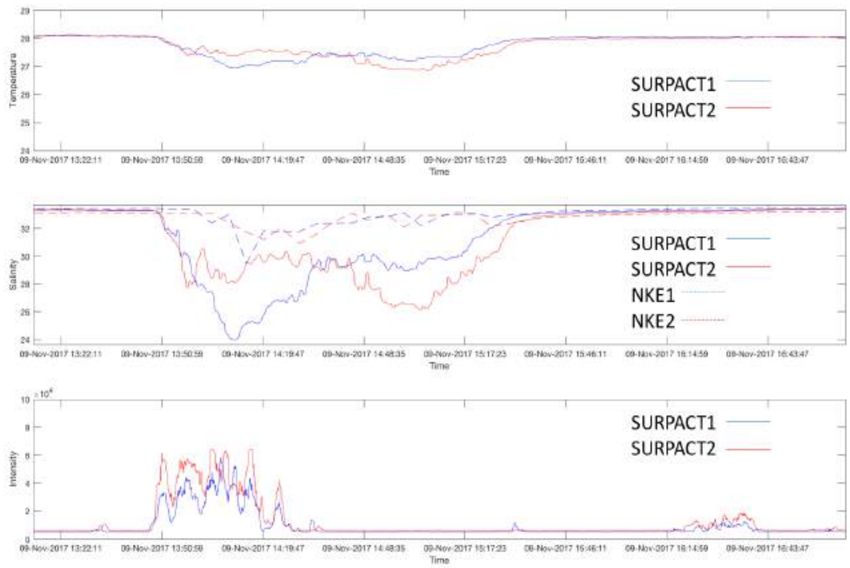


Figure 3: Time series of temperatures, salinity and acoustic intensity recorded with two SURPACTs during drifter experiment the day of 05 November.

3. Argos deployment

At the end of the cruise (11 November), 3 drifters and attached SURPACT wave riders were deployed. The 3 SURPACTs were in argos mode (15-minute data resolution), two attached with NKE drifters (drogued at 15 m depth) and one with a CARTHE drifter. These 3 drifters traveled over large areas and did several loops (the trajectories differ because of drogue depth). Numerous freshening/rain events were recorded from the start of the experiment.

Today, we always obtain data from each drifters, but since 14 November no new data are sent from one of the SURPACT attached to a NKE drifter and large salinity bias is recorded on the other SURPACT attached with the other NKE drifter (certainly due to an external element). Other sensors (rain noise, accelerometer work, temperature) from the SURPACT work well, as well as the sensors from the two NKE drifters.

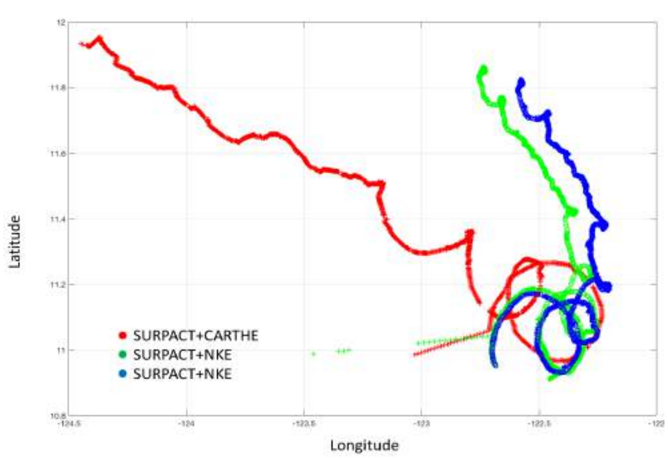


Figure 4: Motion of drifters deployed in argos mode at the end of SPURS-2 cruise from 11 November to 28 November.

4. Sample collection

In order to analyze δ[18]0 of seawater, 45 water samples from 5m depth R/V Roger Revelle TSG were sampled from October to November. These measurements will be compared to both $\delta^{18}O$ measurements of rain water collected from the ship's rain gauge and SSS measured on board.

5. SMOS and SMAP data

Salinity measurements from SMOS and SMAP, and derived products (salinity anomalies and 7 days SMOS/SMAP combined products) were provided during the cruise in order to make comparisons with in-situ measurements and radar data. Some freshening events was recorded with in-situ and satellite measurements. For example, Salinity Snake and SMAP data are able to sense the same freshening event during the 25th of October.

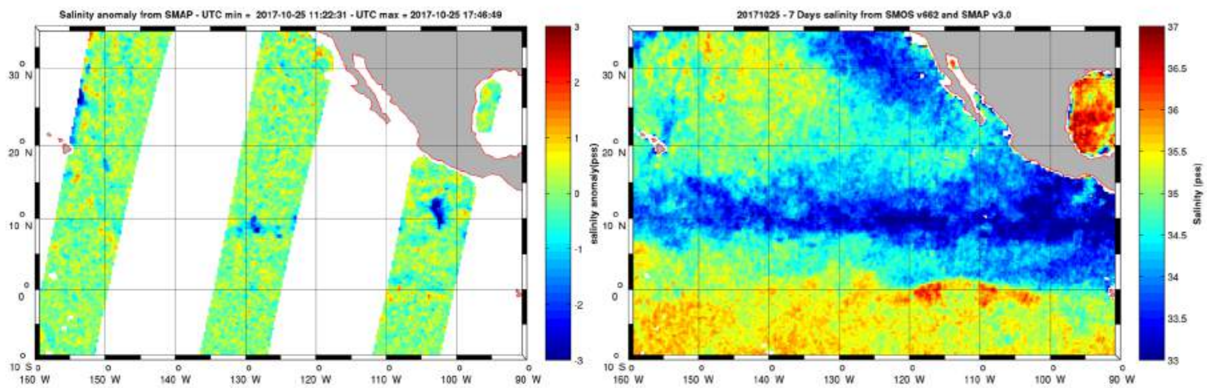


Figure 5: Sea Surface salinity measurement from space for one case study (25/10/2017).

6. Various tests

During the cruise, numerous test was done with SURPACTs on the boat recording salty water. The tests should provide information allowing to better understand SURPACT salinity measurements. It also rained during one of these tests, which should provide further data to validate the microphone rain records.

Data management and modeling

PIs: Frederick Bingham, Zhijin Li and Peggy Li
At sea: Frederick Bingham

During the 2017 Revelle cruise, RR1720, the data management and modeling (DMM) group helped with field support and provided model output to interpret in situ data that was collected. In addition, the member of the group that was on the ship (Bingham) aided with deck operations for the SSP and hydrography groups when time permitted.

Support for operations was mainly provided through the “daily tarball”. This was a set of data, sent daily to the ship, which included 1) ROMS (Regional Ocean Modeling System) model output, 2) precipitation, wind and wave height forecasts from the GFS model at NCEP, 3) various datasets such as drifter tracks, waveglider data, float data, wind fields, precipitation, saildrone positions and 4) kml documents for visualizing and analyzing much of the above.

During the cruise, the DMM group monitored the positions of various observational assets, the Revelle, the Lady Amber, saildrones, wavegliders, drifters, etc. We produced animations showing the positions of the assets in Google Earth. A screenshot of one animation is included in figure 1. The figure shows several drifters having just been deployed heading east while the ship heads west. The DMM group helped track the positions of the drifters so some could be retrieved later. A final version of the animation was shown to the science party on the ship on the last day of the cruise, 16-November.

As stated above, the DMM group also provided model output helping to give oceanographic context to the measurements, particularly the hydrography, being collected. Figure 2 shows and example of this. The model gives a best estimate of these quantities assimilating sea surface height, surface winds, SST and some argo data. The model shows the position of the north equatorial countercurrent as a broken set of filaments and the SSH ridge that separates it from the south equatorial current. Tropical instability waves are clearly evident in both the velocity and salinity fields. A presentation was given to the group on the ship on 10-November showing some of the model output and the context of the data collection.

Figure 1. Partial screenshot of an animation produced by the DMM group. This comes from 30-Oct-2017. The Revelle, in green, having just deployed several drifters, heads west to put out an ecomapper. The red "C" drifters are CODE-type, the "S" are SVP or SVP-S-type and the A is an A-DOS drifter.

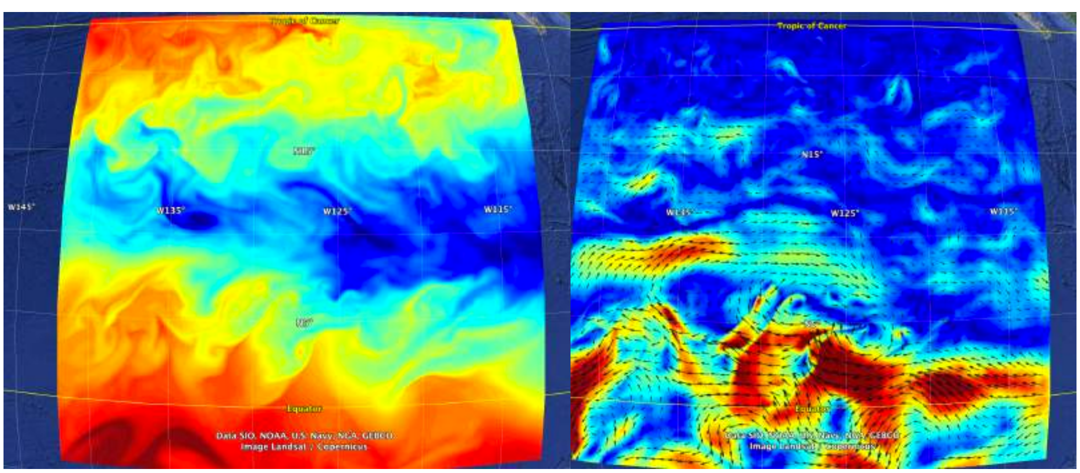


Figure 2. Screenshots of (left) surface salinity and (right) surface velocity vectors (arrows) and speed (colors). Date is 4-Nov-2017.

University of Washington School of Oceanography Argo Lab

PI: Steve Riser, University of Washington

During the SPURS-2 cruise in the fall of 2017 11 University of Washington-built Argo-type floats were deployed. 9 of these floats were in a standard Argo configuration, with a SeaBird Electronics 41CP CTD unit. The other 2 floats were a new design built for the Tropical Pacific Observing System (TPOS) pilot program, that carried (in addition to CTD sensors) sensors for dissolved oxygen, chlorophyll fluorescence and particle backscatter, and a hydrophone capable of making ambient acoustic noise measurements that can be used to estimate wind speed and rainfall. All floats are presently cycling between 0-2000 m on 10-day cycles and operating normally. A summary of these deployments is provided in the following table.

UW float ID number	WMO ID	Deployment Date	Deployment Latitude (°N)	Deployment Longitude (°W)	Comments
12619	5905365	10/27/17	9.01	124.79	Argo float; operating ok
12636	5905363	10/26/17	9.51	124.80	Argo float; operating ok
12637	5905358	11/3/17	9.06	124.93	Argo float; operating ok
12650	5905362	10/31/17	8.59	124.91	Argo float; operating ok
12651	5905360	10/26/17	8.49	124.83	Argo float; operating ok
12653	5905357	11/3/17	9.48	124.95	Argo float; operating ok
12654	5905359	11/2/17	8.50	125.93	Argo float; operating ok
12656	5905361	11/3/17	10.02	124.98	Argo float; operating ok
12659	5905364	10/26/17	10.02	124.80	Argo float; operating ok
12717	5905139	10/28/17	4.98	124.96	TPOS float; operating ok
12728	5905140	10/26/17	7.38	124.70	TPOS float; operating ok

Lady Amber

PI: Luc Rainville
At sea: Kyla Drushka and Julian Schanze

The sailing vessel R/V Lady Amber (Fig 1), which has been carrying out cruises between San Diego, La Paz (Mexico) and Honolulu as part of the SPURS-2 experiment, was at the SPURS-2 site during the 2017 cruise. From 5 to 9 November 2017, the Lady Amber deployed SPURS-2 drifters and carried out joint sampling operations with the R/V Revelle, as shown in Fig. 2. The Lady Amber was equipped with a meteorological package as well as with CTDs at 1 and 2m depth and a pumped salinity snake. During the cruise, the Revelle spent more than 24 hours within 5 km of the Lady Amber. This will allow us (a) to evaluate the uncertainties arising from collecting data from a sailboat, and (b) examine the small-scale spatial variability in the ocean and atmosphere.

Fig. 1: R/V Lady Amber at sea during the 2017 SPURS-2 cruise. (Photo credit: Eric Lindstrom).

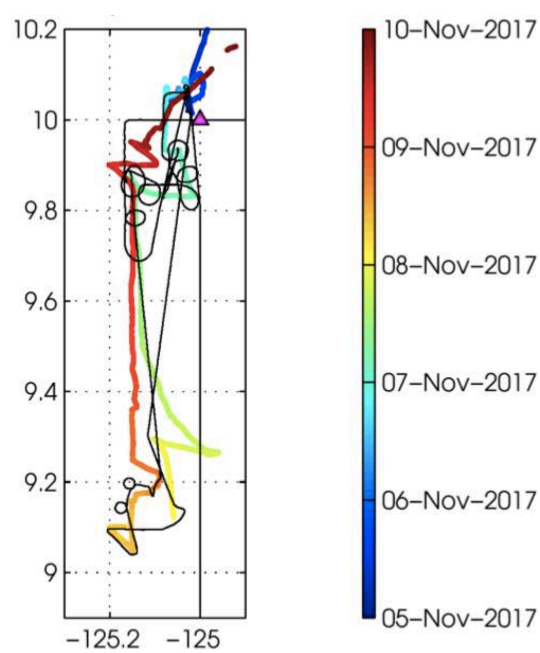


Fig. 2: Track of R/V Lady Amber (colors represent date) and R/V Revelle (black lines) during SPURS-2.