

VASCO–CIRENE MEASUREMENTS

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The Vasco–Cirene field experiment, in January–February 2007, targeted the Seychelles–Chagos thermocline ridge (SCTR) region, with the main purpose of investigating Madden–Julian Oscillation (MJO)-related SST events. The Validation of the Aeroclipper System under Convective Occurrences (Vasco) experiment (Duvel et al. 2009) and Cirene cruise were designed to provide complementary views of air–sea interaction in the SCTR region. While meteorological balloons were deployed from the Seychelles as a part of Vasco, the Research Vessel (R/V) *Suroît* was cruising the SCTR region as a part of Cirene.

During Vasco, six Aeroclipper prototypes were launched from Mahé Island (Seychelles). The Aeroclipper is a streamlined balloon, vertically stabilized at a ~ 50-m height by a guide rope floating at the ocean surface (see Duvel et al. 2009 for a complete description). Aeroclippers move under the influence of surface wind. The Aeroclipper sensors measure pressure, temperature, wind, and humidity in the atmosphere, and temperature and salinity at the ocean surface. The Aeroclipper is designed to measure low-level dynamics and surface turbulent heat flux perturbations produced by organized deep convection over the tropical oceans. These balloons were attracted toward convective regions by the low-

level wind convergence generated by associated low surface pressure. As a result, the balloons maximized the number of measurements in the vicinity of active convective systems. Pressurized balloons flying at about 850 hPa were also deployed during Vasco, which recorded pressure, temperature, humidity, and wind on quasi-Lagrangian trajectories.

The Cirene cruise, onboard the R/V *Suroît* (www.ifremer.fr/fleet/navires/hauturiers/suroit/index.htm), comprised two legs (8–28 January and 1–20 February) starting from and returning to Seychelles (see Fig. 1 in Vialard et al. 2009). The cruise involved three types of operations: underway shipboard measurements, measurements in station, and deployments of autonomous measurement systems.

UNDERWAY SHIPBOARD MEASUREMENTS. Underway shipboard measurements included near-surface (about 4-m depth) temperature and salinity monitored through the ship’s thermosalinograph. The 150-kHz ship acoustic Doppler current meter (S-ADCP) recorded upper-ocean currents, down to about 300 m in favorable conditions. Expandable bathy thermograph (XBT) sections (with most profiles down to 800 m) were conducted during all transits at a spatial resolution of 50 km or better.

The underway measurements also included less routine observations. Air–sea fluxes were monitored using a dedicated flux platform installed on a mast 17 m above sea surface on the bow of the ship. The mast reduces the impact of the ship structure (flow distortion and thermal island) on the measurements. A sonic anemometer provided 50-Hz measurements of temperature and the three components of the wind. A motion package allowed for the correction of the wind fluctuations for vessel motion. A microwave refractometer provided measurements of the humidity at the same rate. These high-frequency measurements were completed by classical meteorological measurements on the mast, using a Météo France weather station (pressure, temperature, humidity, horizontal wind, and downward infrared and shortwave radiation). Turbulent fluxes were computed from three methods: the inertial dissipative method (IDM; Dupuis et al. 1997), eddy correlation method (ECM; Pedreros et al. 2004), and bulk method (Dupuis et al. 2003). One of the constraints from this system is that the ship needs to be facing the wind (with an angle < 35°), which was not possible at all times for logistical reasons. Preliminary estimates of the flux accuracy suggest a relative error less than 16% for heat, momentum, and freshwater fluxes.

An instrumental suite providing measurements of the sea surface and marine boundary layer complemented the Air–Sea flux estimates from the mast. The Marine–Atmosphere Emitted Radiance Interferometer (M-AERI; Minnett et al. 2001) collected radiometric sea surface skin temperatures. Atmospheric temperature and humidity profiles up to 3 km were retrieved at 12-min intervals, except during mostly cloudy periods.

DEPLOYMENTS OF AUTONOMOUS MEASUREMENT SYSTEMS. As a contribution to the Argo network (Gould et al. 2004), 12 Argo profilers were deployed along 67°E (Fig. 1 in Vialard et al. 2009). The profilers were deployed in groups of three at 3°, 5°, 7°, and 9°S, and they were programmed to make 0–2000-m profiles every 5 days. The profilers in each group of three were set to profile sequentially at 2 days' separation. This strategy allowed for good temporal resolution of the SCTR meridional structure during the cruise. After 90 days, the profilers drifted apart from each other and provided a more uniform spatial coverage.

Three drifters with a series of self-recording thermometers (SRT) over the upper 50 m were also deployed to monitor the detailed thermal structure of the mixed layer, the diurnal cycle of the SST, and

its spatial heterogeneity. The drifters consisted of a steel frame with three glass ball floats and an Argos transmitter for location. A single SRT was attached to the frame at 0.5 m, followed by a 24-node temperature chain with sensors at 0.5-m spacing. Below this, there were additional SRTs at intervals of 5 m and two pressure sensors (15 and 60 m). The drifters were drogued with 1000 m of nylon rope to reduce the susceptibility to wind drag.

MOORING AT 8°S, 67°E. The last significant deployment during Cirene was that of a heavily instrumented next-generation ATLAS mooring supplied by National Oceanic and Atmospheric Administration (NOAA)/Pacific Marine Environmental Laboratory (PMEL) at a nominal location of 8°S, 67°E. The mooring was anchored to the ocean floor in 4,065 m of water depth and was in place for 35 days beginning on 13 January 2007. The purpose of this component of Cirene was to provide high temporal resolution time series data as a complement to other observations during the field campaign to document and diagnose ocean–atmosphere interactions and upper-ocean variability. Measurements included ocean temperature, salinity, and velocity, air temperature, relative humidity, wind velocity, downwelling shortwave and longwave radiation, barometric pressure, and rain rate. Ocean temperature was measured at 20 depths between 1 and 500 m, with 3–20-m resolution in the upper 140 m. Salinity was measured at 11 depths between 1 and 140 m, with 5–20-m resolution in the upper 100 m. Five Sontek Argonaut current meters were deployed at depths of 10, 20, 30, 40, and 60 m to measure horizontal velocity. Air temperature and relative humidity were measured at a height of 3 m above sea level, shortwave and longwave radiation and rainfall were measured at 3.5 m, and wind velocity at 4 m. Daily averages of most data were transmitted to shore in real time, while high temporal resolution data were internally recorded. These high-resolution data (1–10-min samples in most cases, except for barometric pressure, which was sampled at 1-h intervals) were available for analysis when the mooring was recovered. More detailed information on ATLAS mooring design, sensors, and instrument accuracies can be found online at (www.pmel.noaa.gov/tao/proj_over/mooring.shtml).

In addition to PMEL instrumentation on the mooring, P. Bouruet-Aubertot from the University of Paris VI deployed 10 RBR model TR-1050 temperature recorders, which recorded data at 5-s intervals between depths of 5 and 300 m to study internal wave processes. Two WET Labs fluorimeters, provided by

Ajit Subramaniam of Columbia University, were also deployed at depths of 18 and 44 m on the mooring to measure chlorophyll-a fluorescence, which is an indicator of active phytoplankton biomass and chlorophyll concentrations.

The R/V *Suroit* deployed a PMEL ADCP mooring in close proximity to (i.e., within 5.5 nautical miles of) the ALTAS mooring on 13 January 2007. The ADCP was an RD Instruments (RDI) 76.8-kHz instrument programmed for 4-m bin widths and 10-min ensemble averages. The ADCP provided velocity data between about 20 and 180 m during the field campaign.

The ATLAS and ADCP moorings were recovered on 15 February 2007. The ATLAS mooring was then redeployed on 16 February 2007 with a slightly reduced set of PMEL instrumentation (also minus fluorometers and RBR temperature sensors) as a contribution to the RAMA (McPhaden et al. 2009). This second ATLAS deployment is scheduled for recovery and redeployment in mid-2008. In combination with satellite and in situ measurements from the basin-scale IndOOS (Meyers and Boscolo 2006), moored time series measurements from this ATLAS mooring will provide a long-term climate context for interpretation of the January–February 2007 Cirene cruise observations.

MEASUREMENTS IN STATION. Detailed measurements of the upper-ocean and atmospheric evolution were collected during two long stations (from 1200 UTC 14 January 2007 to 0100 UTC 26 January 2007 and from 0430 UTC 4 February 2007 to 0000 UTC 5 February 2007) at 8°S, 67°30'E. In addition to the continuous measurements performed above, we launched four radiosondes per day (at 0000, 0600, 1200, and 1800 UTC) and collected temperature, pressure, humidity, and wind measurements up to 300 hPa for most profiles. The data were transmitted in real time and assimilated into most major operational center analyses. CTD profiles of the upper ocean were also taken at high temporal resolution. Profiles down to 500 m, including temperature, salinity, pressure, dissolved oxygen, photosynthetically available radiation, and fluorescence, were performed every 20 min. One profile down to 1000 m was performed every 6 h, together with additional current measurement from two coupled 300 kHz lowered-acoustic Doppler current profilers (L-ADCP) and the collection of water samples. The air–sea interaction profiler (ASIP) was deployed on several occasions during the long stations (see below for more details).

Biogeochemical measurements were also performed during the long stations. Water samples were collected during the CTD upcast at five different depths. These depths were chosen according to the inflection points of the downcast fluorescence profile, because biogeochemical processes are drastically different in the mixed layer, in the deep chlorophyll maximum (DCM) and in the deeper ocean. The water samples were archived and will be analyzed for photosynthetic pigments (chlorophylls and carotenoids) and nutrients (nitrate, nitrite, phosphates, and silicates).

THE AIR–SEA INTERACTION PROFILER.

The ASIP is an autonomous profiling instrument for upper ocean measurements, whose design was based on the successful Skin Depth Experiment (SkinDeEP) profiler (Ward et al. 2004). The Cirene cruise was the first time ASIP was deployed in the open ocean.

The measurements from ASIP are well suited to enhancing research on air–sea interfacial and near-surface processes. Autonomous profiling is accomplished with a thruster, which submerges ASIP to a programmed depth. Once this depth is reached, the thruster will switch off, and the positively buoyant instrument will ascend to the surface acquiring data. ASIP can profile from a maximum depth of 100 m to the surface, allowing both mixed layer and near–surface measurements to be conducted.

The sensor payload on ASIP during Cirene included microstructure sensors (two shear probes and a thermistor) to provide an estimate of dissipation rates; a slower-response accurate thermometer for absolute temperature measurements; a pair of conductivity sensors—one for high resolution and the other for accuracy; pressure for a record of depth; fluorescence/turbidity for chlorophyll and water clarity; and photosynthetically active radiation (PAR) for measurements of light absorption in the water column. Other nonenvironmental sensors on ASIP were acceleration rate and heading for determination of vehicle motion. Power was provided with rechargeable lithium–ion batteries, supplying 1000 W h, allowing approximately 300 profiles. ASIP also contained an iridium/GPS system, which allowed real-time reporting of its position, as well as some crucial instrument parameters (profile depth, profile interval, and remaining battery charge). This involved acquiring a GPS position and then transmitting it along with the instrument information to the Iridium satellite network using the short-burst data (SBD) mode. This message was delivered as an e-mail, whereupon a script running on the server

retransmitted the message to the shipboard Iridium modem.

The upper section of ASIP contains the sensors and electronics, while the lower section contains the batteries. The thruster is located at the bottom of the instrument, surrounded by a stainless steel cage on which the instrument can stand for staging. The photograph (Fig. SBI in Vialard et al. 2009) was taken during CIRENE and shows the instrument ascending to the surface at about 5-m depth.

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