Coastal Circulation and Water Column Properties along Kaloko-Honokohau National Historical Park, Hawaii

PART I:

Measurements of waves, currents, temperature, salinity and turbidity: April-October 2004

U.S. Department of the Interior
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Open-File Report 2005-1161

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U.S. GEOLOGICAL SURVEY

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http://walrus.wr.usgs.gov/infobank/a/a704hw/html/a-7-04-hw.meta.html

For an online PDF version of this report, please see:
http://pubs.usgs.gov/of/2005/1161/

For more information on the U.S. Geological Survey Western Region's Coastal and Marine Geology Team, please see:
http://walrus.wr.usgs.gov/

For more information on the U.S. Geological Survey's Coral Reef Project, please see:
http://coralreefs.wr.usgs.gov/

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INTRODUCTION

High-resolution measurements of currents, water levels, temperature, salinity and turbidity were collected in the marine portion of Kaloko-Honokohau National Historical Park (KAHO), Hawaii, in 2004. These data are intended to help researchers better understand the dynamics of the oceanographic environment in the park's coastal waters. Measurements were made through the emplacement of a series of bottom-mounted instruments deployed in water depths less than 15 m. This study was conducted in support of the National Park Service by the U.S. Geological Survey (USGS) Coastal and Marine Geology Program's Coral Reef Project. The purpose of these measurements was to collect hydrographic data to learn how currents and water column properties such as water temperature, salinity and turbidity in the vicinity of nearshore coral reef systems vary over the Trade wind season. These measurements support the ongoing process studies being conducted under the Coral Reef Project; the ultimate goal is to better understand the transport mechanisms of sediment, larvae, pollutants and other particles in coral reef settings.

Project Objectives:

The objective of these two deployments was to understand how currents, waves, tides, temperature, salinity and turbidity vary temporally and spatially along KAHO over the Trade wind season. These data were collected to support the studies being conducted off the KAHO as part of the USGS's multi-disciplinary Coral Reef Project that focuses on the geologic processes that affect coral reef systems. To meet these objectives, flow and water column properties off KAHO were investigated. These data will provide insight into the impact of terrestrial sediment, nutrient or contaminant delivery to the park's coastal waters. Two small instrument packages (MiniPROBEs) were deployed in the northern and southern area of the park to look at the variability in flow, tides, waves, temperature, salinity and suspended sediment flux for the different regions of the park. These data provide information on the transport dynamics during the Trade wind season off the Kailua-Kona coast, Hawaii.

Study Area:

The measurements were made at two locations in the marine waters of Kaloko-Honokohau National Historical Park on the Kona (leeward) coast of the island of Hawaii, USA (FIGURE 1). All of the measurements were on the inner shelf in water depths less than 15 m (FIGURE 2). The instrument stations were located near the northern and southern ends of the park. The northern station was located in an embayment offshore of the Kaloko Fishpond. The southern station was located off the outer edge of the basalt platform that extends offshore of the Aimakapa fishpond and to the northwest of the Honokohau Harbor. The seafloor sediment at both instrument locations is a poorly-sorted carbonate sand. All vessel operations, including mobilization and demobilization, were based out of Honokohau Harbor, Kona, Hawaii.

FIGURE 1. *Index map of Kaloko-Honokohau National Historic Park and its location on the Kona (leeward) coast of the Big Island of Hawaii, USA. Also shown are the locations of specific areas in the park discussed in the text.*

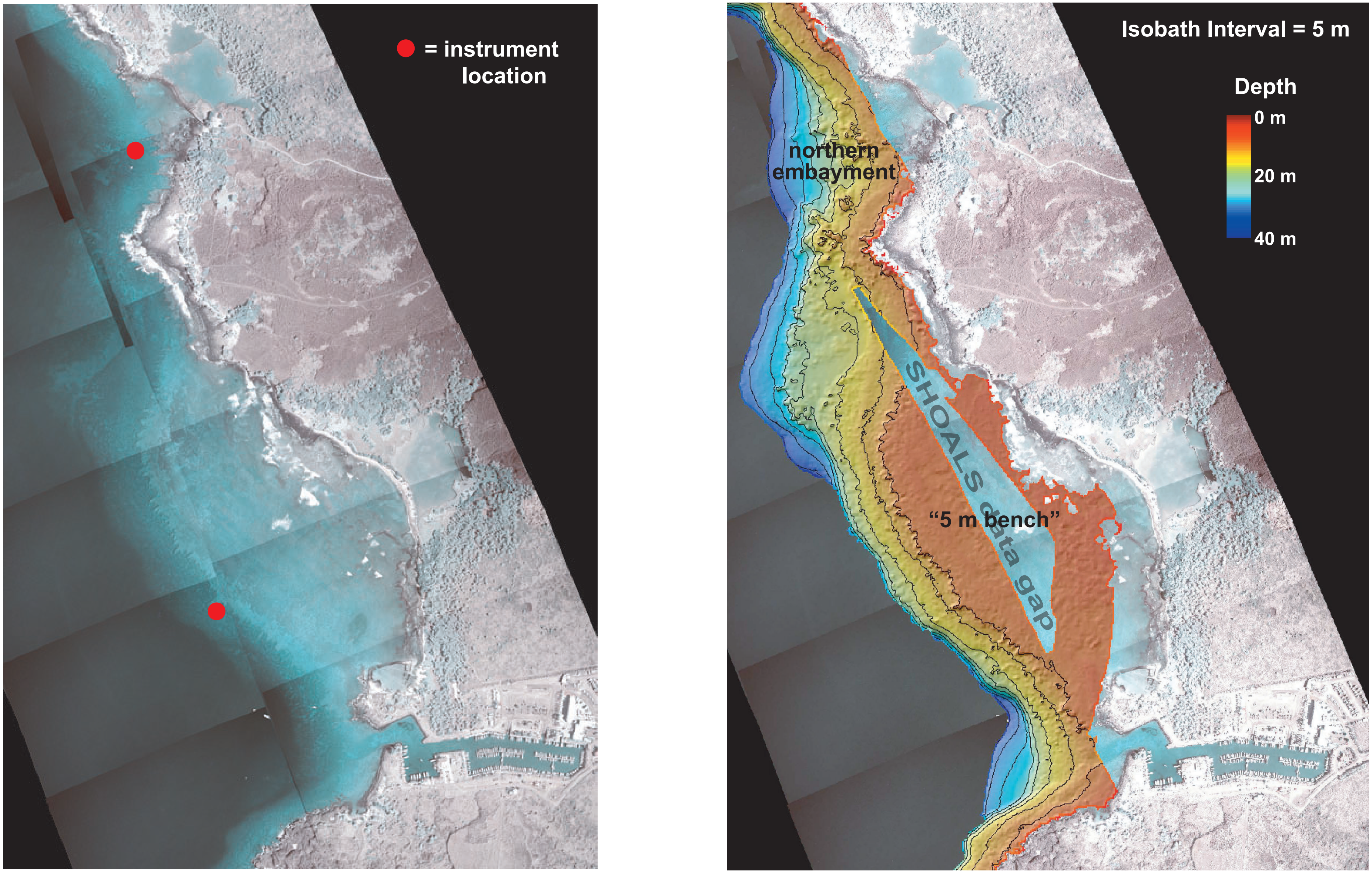


FIGURE 2. *Imagery of the park's coastline and nearshore waters. Left panel: Aerial photomosaic. Right panel: High-resolution SHOALS LIDAR bathymetry of the park's coastal waters overlaid on the aerial photomosaic. The park's coastal waters are dominated by an embayment (the "northern embayment") in the north and a subaqeous lava flow (the "5 m bench") in the south.*

OPERATIONS

This section provides information about the personnel, equipment and vessel used during the deployments. See TABLE 1 for a list of personnel involved in the experiment and TABLES 2 and 3 for complete listings of deployment information.

Scientific Party:

The scientific party for these deployments included a minimum of two scientists from the USGS Coral Reef Project and one from the National Park Service. During instrument deployment and recovery operations there was one vessel captain in addition to these scientists on board.

Equipment and Data Review:

Two MiniPROBE packages (FIGURE 3) were deployed to acquire flow, turbidity and water column data (TABLE 2). The packages included a RD Instruments 600 kHz Workhorse Monitor upward-looking Acoustic Doppler Current Profiler (ADCP) with WAVES Array package, an Aquatec/Seapoint 200-TY self-contained optical backscatter sensor (SCOBS) ~0.6 m above the bed, and a Seabird MicroCat conductivity temperature sensor (CT) ~0.05 m above the bed. The SCOBS and CT sensors collected single-point measurements on optical backscatter, and salinity and temperature, respectively.

The instrument packages were typically deployed for 90-100 day periods, as constrained by the power consumption. The upward looking ADCPs mounted on the the MiniPROBE sampled 36 0.5-m bins from 1.0 m above the seafloor up to the surface for 40 seconds at 2 Hz every 4 minutes to allow calculation of mean flows and higher frequency motions such as internal tidal bores and non-linear internal waves. Directional wave data were recorded for 1024 sec at 2 Hz every three hours; this data included water depth, current speed and current direction every 0.5 seconds to resolve significant wave height, dominant wave period, mean wave direction and directional spread. The SCOBS recorded an 8-sample burst every 4 minutes and was located high enough in the water column to be correlated with the acoustic backscatter data from the first bin of the ADCP. The CT sensor recorded data at a sample rate of every 4 min. The instrument package deployment and recovery log is presented in TABLE 3. The instrument specifics and sampling schemes are listed in APPENDIX 1 and APPENDIX 2.

Navigation equipment consisted of a hand-held WAAS-equipped global positioning system (GPS) unit. This system made it possible to very accurately deploy the instruments in the same location and to recover them without the need for a surface float to mark the instruments' locations.

Research Platform:

The instrument deployments and recoveries were conducted using the 28-ft-long *R/V Alyce C.*, owned and operated by Alyce C. Sport Fishing. The *R/V Alyce C.*, which was designed as a sport-fishing boat, was modified for scientific studies. The port beam was adapted for instrument deployment and recovery. The port beam was allocated for

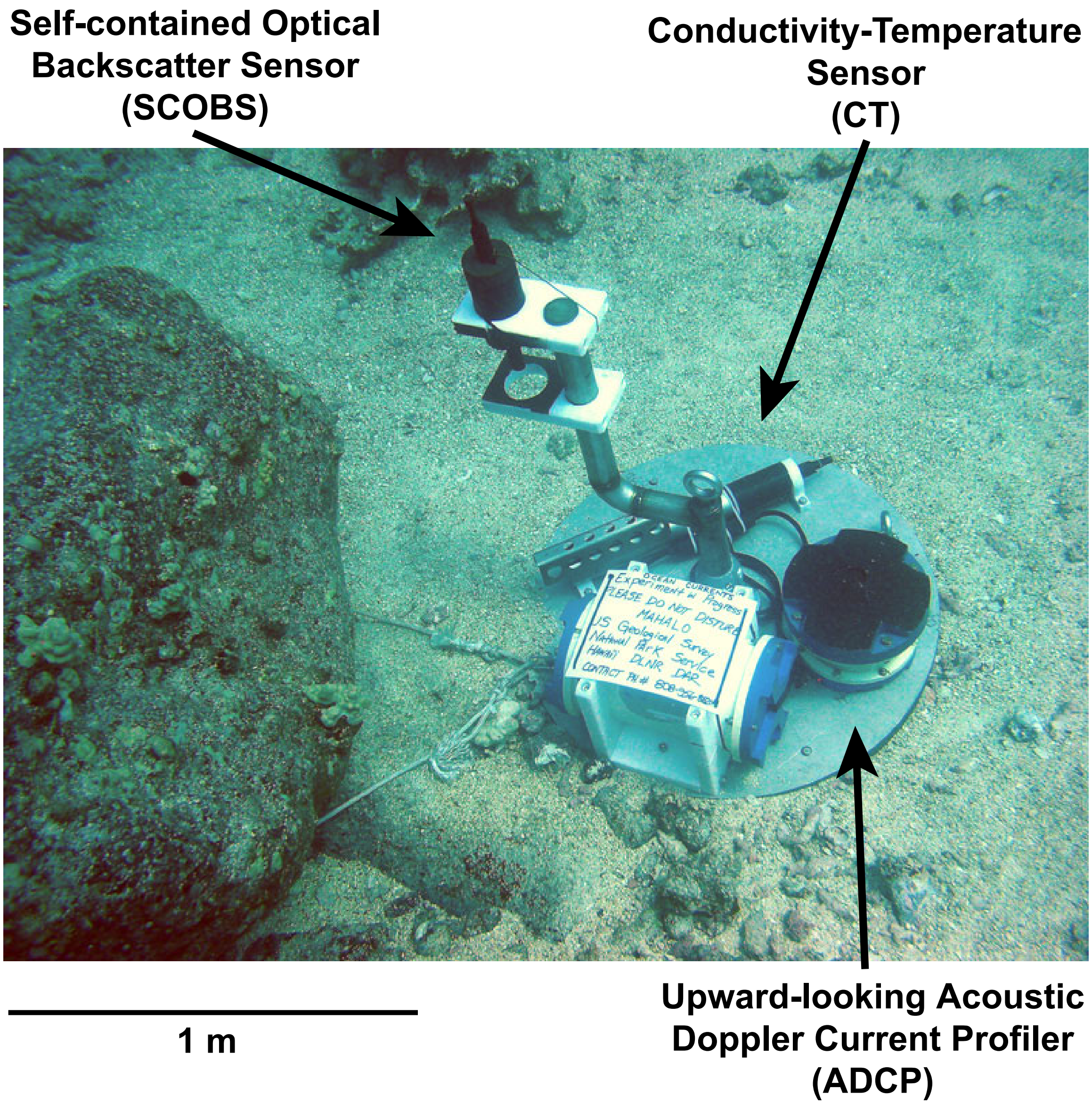


FIGURE 3. *Photograph of the MiniPROBE instrument package showing the location of specific sensors discussed in the text. This photograph was taken in 14 m of water in the southern portion of the park.*

instrument package deployment and recovery operations, which included the use of an electric winch and an overhead davit.

Deployment/Recovery Operations:

The instruments were deployed by attaching a removable bridle to the instrument package with a connecting line through the davit and down to the winch. The instruments were lowered to within a few meters of the seafloor, where the scuba divers would attach a lift bag and detach the lifting line. The divers would then move the instrument package into place. After determining the package's location, the divers emplaced sand anchors into the seafloor and attached them to the instrument package using cables and turnbuckles. Recovery operations employed the same techniques.

DATA ACQUISITION AND QUALITY

Data were acquired for 182 days during the 6 month period between 4/28/2004 and 10/30/2004; this was more than 98% data coverage over the experiment time period. The instruments were out of the water for only 3 days during these 6 months for data recovery and instrument refurbishment.

More than 75% of the data were recovered from the ADCP on the MiniPROBE platforms. Data quality was generally very high. The battery case for the ADCP at the northern site flooded during the first deployment rendering no current or wave data from the northern site for the first deployment from 4/28/2004 to 8/1/2004. The ADCP data near the surface displayed slightly lower correlation due to bubble interference with the transducers. This loss of data from the bins closest to the surface is common to most upward-looking ADCPs and was expected. The raw ADCP current profile data and the raw ADCP wave data were archived and copies of the data were post-processed to remove all "ghost" data from above the surface. All data from times when the beam correlation dropped below 70% were discarded for visualization and analysis. Post-processed data were saved and copies were then desampled to hourly intervals to better visualize longer-term variability; these desampled copies of the data were also saved and archived.

There were problems with the SCOBS sensors. The SCOBS sensors, although coated with a transparent antifouling coating on the optics, tended to biofoul towards the middle to end of the deployments, rendering portions of the data unusable. The SCOBS sensor at the northern site fouled within the first 40 days of the first and second deployments, resulting in very limited high-quality data. Unfortunately the National Turbidity Units (NTU) values from the OBS sensors did not significantly correlate with the acoustic backscatter data from the ADCPs.

RESULTS AND DISCUSSION

This section reviews the data collected by both systems during the deployments and addresses the significance of the findings to better understand the local oceanographic conditions in the study area.

Tides and Waves

The tides off KAHO are micro-tidal (< 2 m) of the mixed, semi-diurnal type with two uneven high tides and two uneven low tides per day; thus the tides change just over every 6 hours. The mean daily tidal range is approximately 0.6 m, while the minimum and maximum daily tidal ranges are 0.4 m and 1.0 m, respectively.

Significant wave heights, dominant wave periods and mean wave directions at the northern site ranged from 0.23-0.78 m, 3.3-21.3 sec and 0-360°, respectively, with a mean ± one standard deviation of 0.39 ± 0.08 m, 12.86 ± 3.71 sec and 203 ± 166.8°, respectively. Significant wave heights, dominant wave periods and mean wave directions at the southern site ranged from 0.26-1.03 m, 3.3-21.3 sec and 186-334°, respectively, with a mean ± one standard deviation of 0.51 ± 0.12 m, 13.42 ± 3.30 sec and 239 ± 16.3°, respectively. Overall, the southern site is more exposed to the large, long-period North Pacific swell while the northern site is more protected from these waves by Wawahiwaa Point and thus has smaller significant wave heights and shorter dominant wave periods. The northern site's sheltering by Wawahiwaa Point also results in its greater influence by more southerly swell, as apparent in the more southerly mean wave directions.

Currents

Most of the daily variability in current speed and direction at the study site are due to the tides. In general, as the tide rises (floods), currents along the park flow to the north, generally parallel to shore; conversely, as the tides fall (ebb), the currents reverse and flow to the south alongshore. This pattern is set by the location of the tidal node (amphidrome) to the west of the Hawaiian Island chain and the counter-clockwise sweep of the tidal bulge around the amphidromic point. Current speeds at the northern site ranged between 0.00-0.38 m/sec, with the mean speed ± one standard deviation 3 m below the surface being 0.09 ± 0.05 m/sec and 0.04 ± 0.03 m/sec 12 m below the surface (FIGURE 4). Current speeds at the southern site ranged between 0.00-0.42 m/sec; the mean speed ± one standard deviation 3 m below the surface was 0.09 ± 0.07 m/sec and 12 m below the surface was 0.05 ± 0.05 m/sec.

Overall, the current speeds are typically greater near the surface and offshore the 5 m bench at the southern site than in the embayment at the northern site. Flow is primarily alongshore at the southern site and cross-shore at the northern site. The principal axes and net directions of flow at the northern and southern sites at different elevations above the sea floor are shown in FIGURE 5. Both the principal axes of flow and the net direction of flow are considerably different at the northern and southern sites. Near-surface flow at both sites is primarily oriented alongshore with net onshore flow. Flow 7 m above the seafloor (mid-water column) at the northern site is primarily oriented cross-shore, with net flow offshore, while flow 7 m above the seafloor at the southern site is primarily oriented alongshore, with net flow to the southeast.

The currents' energy spectra (FIGURES 6-7) during the deployments, while dominated by the semi-diurnal and diurnal tidal components, do not show increased energy in the 55-65 hour island-trapped wave (ITW) band as suggested by Flament and Lumpkin (1996), modeled by Merrifield et al. (2002) off the Big Island, and observed by Storlazzi and Jaffe (2003) off West Maui. We do not have enough information at this

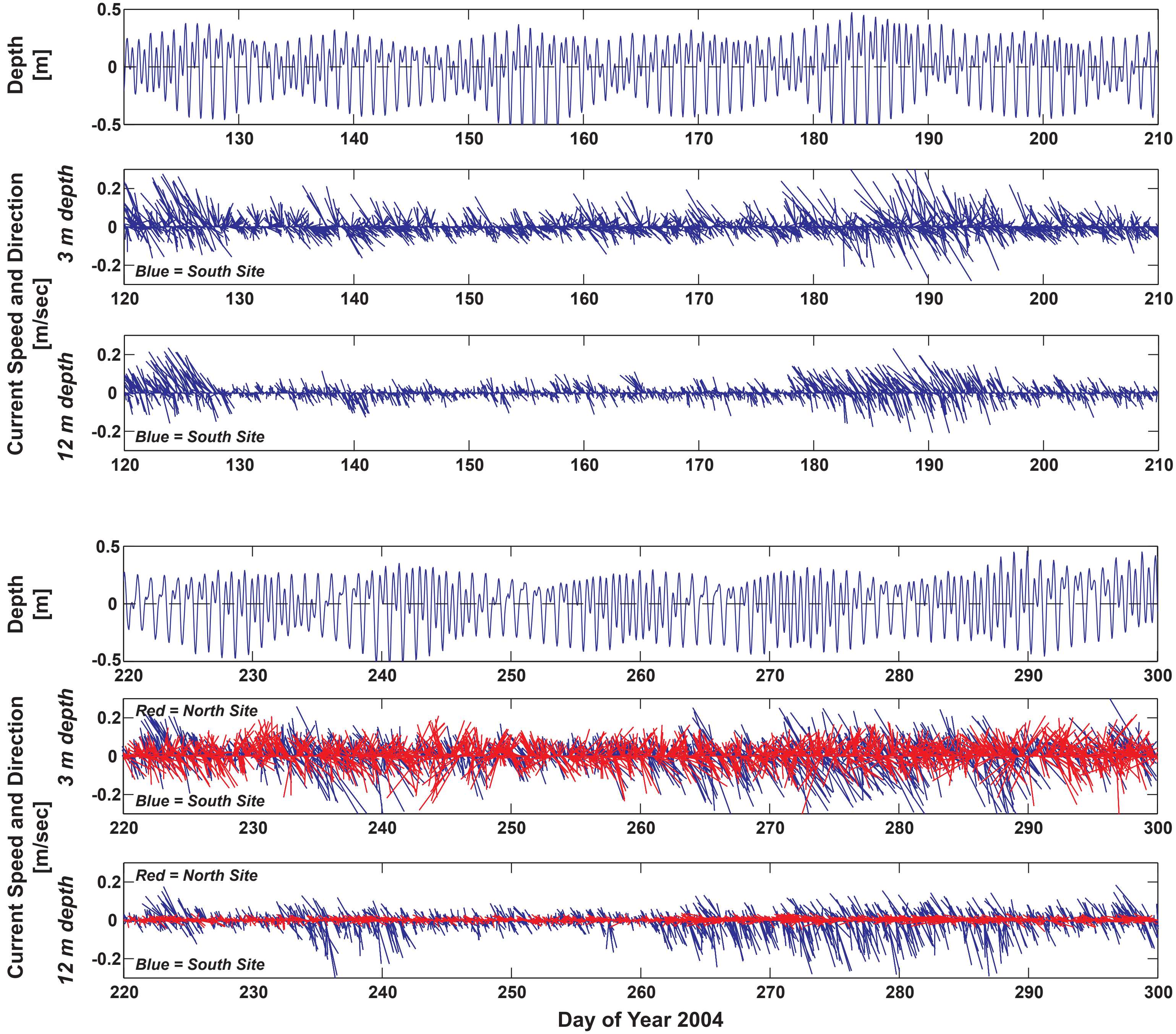


FIGURE 4. *Tides and hourly mean and current speeds and directions at 3 m and 12 m below the surface during the two deployments. Blue data are from the instrument package at the southern site while the red data are from instrument package at the northern site. The current speeds are typically greater near the surface and are much higher off the 5 m bench at the southern site than in the embayment at the northern site. Flow is primarily alongshore at the southern site and cross-shore at the northern site.*

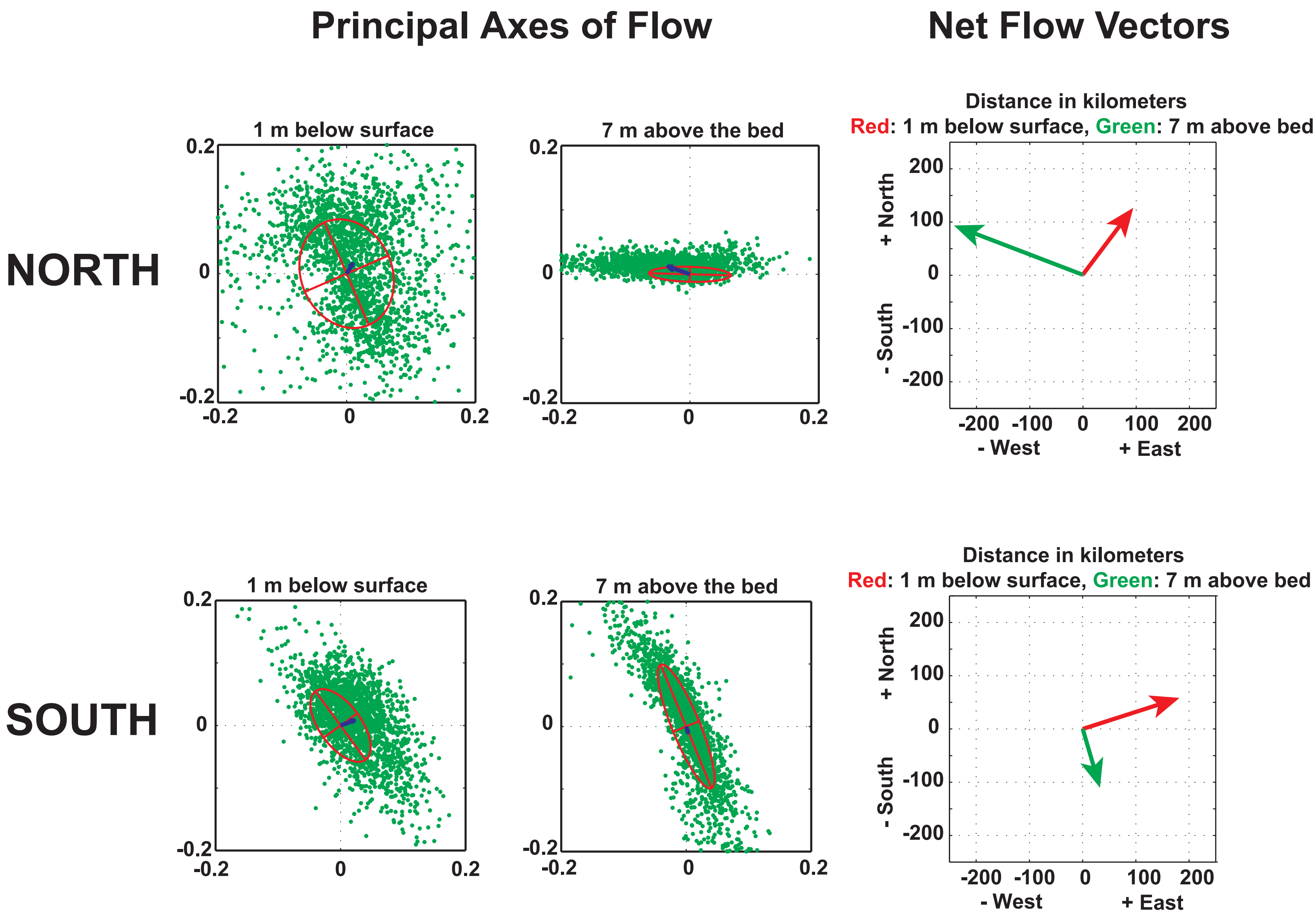


FIGURE 5. *Principal axes and net directions of flow at the northern and southern sites at different elevations above the sea floor. Each green dot displays the easterly (u) and northerly (v) current speed in map view of a single current measurement. The red ellipses denote the major (longer) and minor (shorter) axes of flow. Note the different orientations in the principal axes of flow and the net direction of flow between the sites. Near-surface flow at both sites is primarily oriented alongshore with net onshore flow. Flow 7 m above the seafloor at the northern site is primarily oriented cross-shore, with net flow offshore, while flow 7 m above the seafloor at the southern site is primarily oriented alongshore, with net flow to the southeast.*

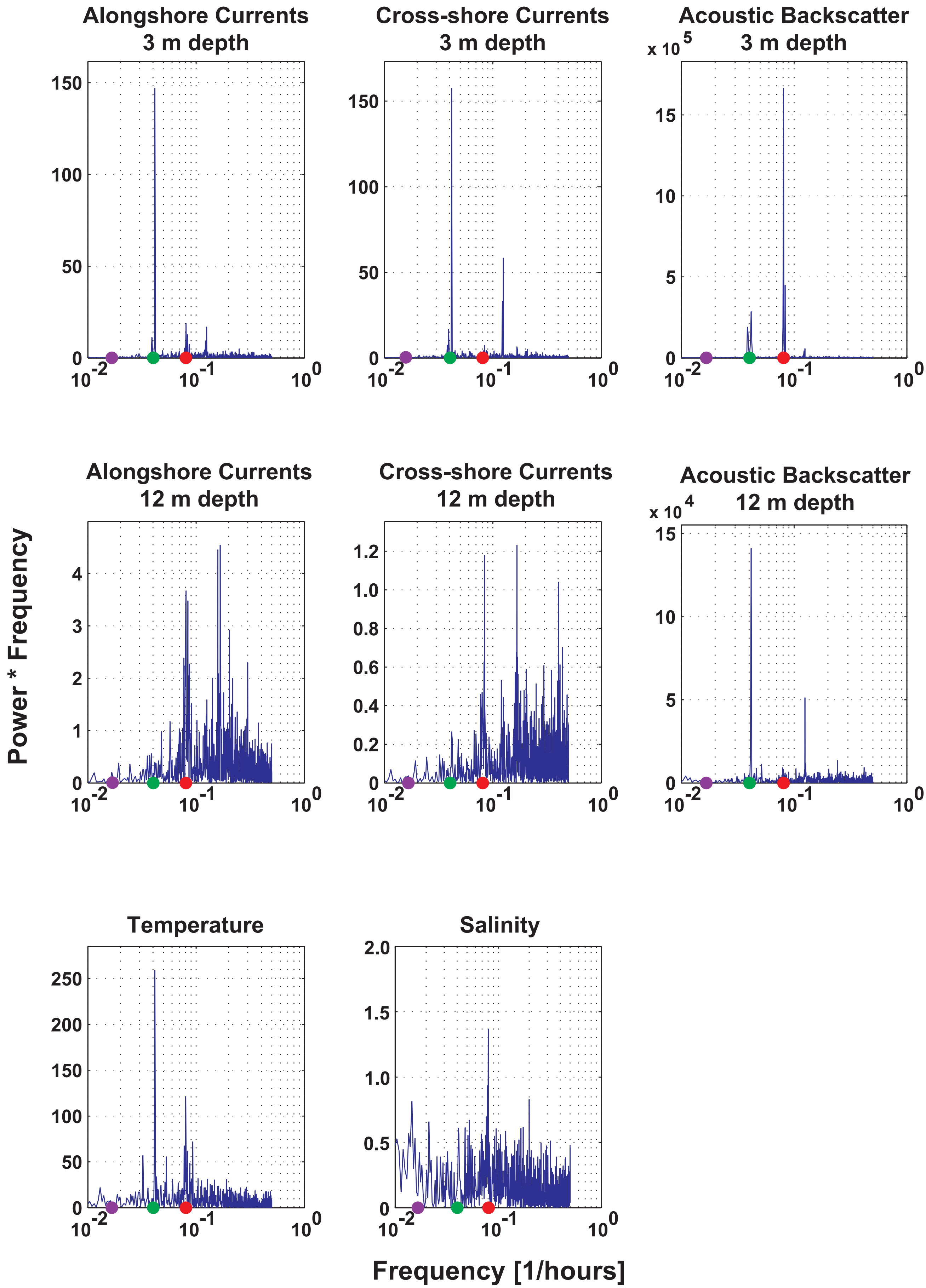


FIGURE 6. *Variance-conserving power spectra for parameters at the northern site during the second deployment. The red dots along the x-axis denote the peaks in energy at the semi-diurnal tidal period (~ 12.4 hours), the green dots denote the peaks in energy at the diurnal tidal period (~ 24.8 hours) and the purple dots denote the peaks in energy in the island-trapped wave period band (55-65 hours). Note the varying magnitude of the y-axes.*

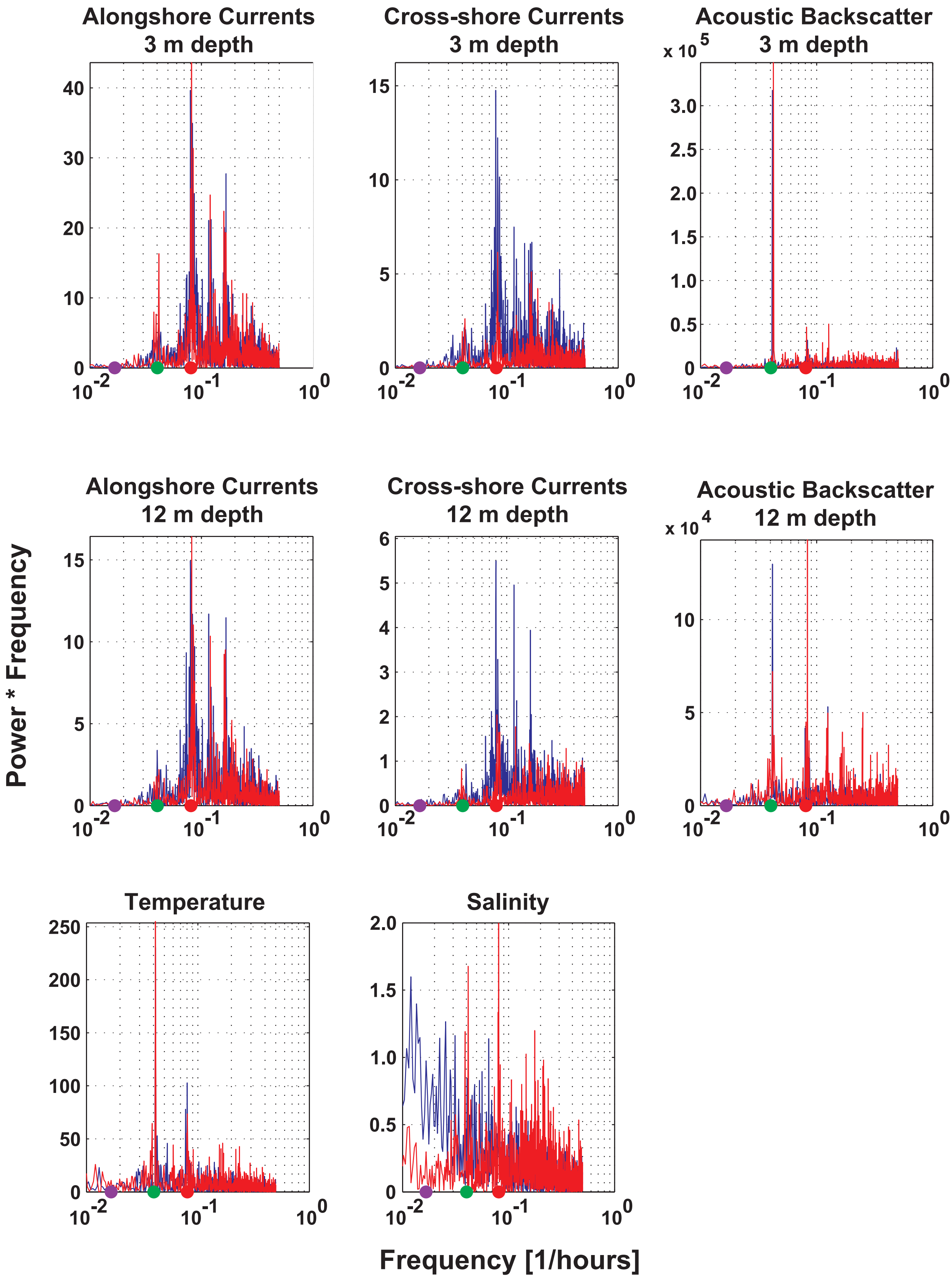


FIGURE 7. *Variance-conserving power spectra for parameters at the southern site during the two deployments. The red lines denote the results from the first deployment while the blue lines denote the results from the second deployment (See FIGURE 8 for data from the northern site for the same time period). The red dots along the x-axis denote the peaks in energy at the semi-diurnal tidal period (~ 12.4 hours), the green dots denote the peaks in energy at the diurnal tidal period (~ 24.8 hours) and the purple dots denote the peaks in energy in the island-trapped wave period band (55-65 hours). Note the varying magnitude of the y-axes.*

time to indicate which process or combination of processes is responsible for the lack of a well-defined peak in the ITW band.

Water Column Properties

The water column properties that were collected included variations in temperature (ºC), salinity (PSU) and optical backscatter (NTU).

***Temperature*:**

Over the period of study, the water temperatures roughly 0.05 m above the bed at the northern site ranged between 25.29 °C and 28.47 °C, with a mean ± one standard deviation of 27.02 ± 0.62 °C (FIGURE 8). At the southern site the water temperatures ranged between 25.15 and 28.40 °C, with a mean temperature ± one standard deviation of 27.03 ± 0.60 °C. At both sites, the water typically warmed 0.2-0.4 °C during the day due to insolation. At tidal periods (12-24 hours), water temperatures typically increased when the tidal elevation fell. Over the course of the deployments, the water temperature increased ~2 °C through the middle of the summer and then decreased by 1.5 °C into the late fall.

***Salinity*:**

Over the period of study at the northern experiment site, the water salinities roughly 0.05 m above the bed ranged between 31.02 PSU and 34.71 PSU, with a mean ± one standard deviation of 34.32 ± 0.13 PSU (FIGURE 9). At the southern experiment site, the water salinities roughly 0.05 m above the bed ranged between 32.68 PSU and 34.83 PSU, with a mean ± one standard deviation of 34.26 ± 0.17 PSU. Higher-salinity water typically moved onshore with the rising tide. Infrequent low-salinity pulses were observed and correlated with offshore flow; these may have been the signal of freshwater discharge from onshore drainages or fresh submarine groundwater discharging out of the shallower portions of the reef and being advected out past the instrument site along the 14 m isobath. These periods of low salinity could not be correlated with rainfall at the Kona Airport approximately 4 km to the north of KAHO, suggesting that the freshwater emanating from the coast is derived from distant (upland?) sources.

***Turbidity*:**

During the first deployment at the northern site, the burst-averaged turbidity approximately 0.6 m above the bed ranged between 1.7 NTU and 21.91 NTU, with a mean ± one standard deviation of 2.43 ± 0.87 NTU (FIGURE 10). During the first deployment at the southern site, the burst-averaged turbidity ranged between 0.61 NTU and 25.91 NTU, with a mean turbidity ± one standard deviation of 2.19 ± 2.61 NTU approximately 0.6 m above the bed. At both sites the turbidity was slightly lower during the second deployment. At the northern location, the turbidity ranged between 0.708 NTU and 13.70 NTU, with a mean ± one standard deviation of 1.168 ± 1.24 NTU. The turbidity at the southern site ranged between 0.824 NTU and 20.31 NTU, with a mean ± one standard deviation of 3.03 ± 2.12 NTU. While most of the variability in turbidity was due to the tides, the highest turbidity values were related to large wave events, as discussed later in the text.

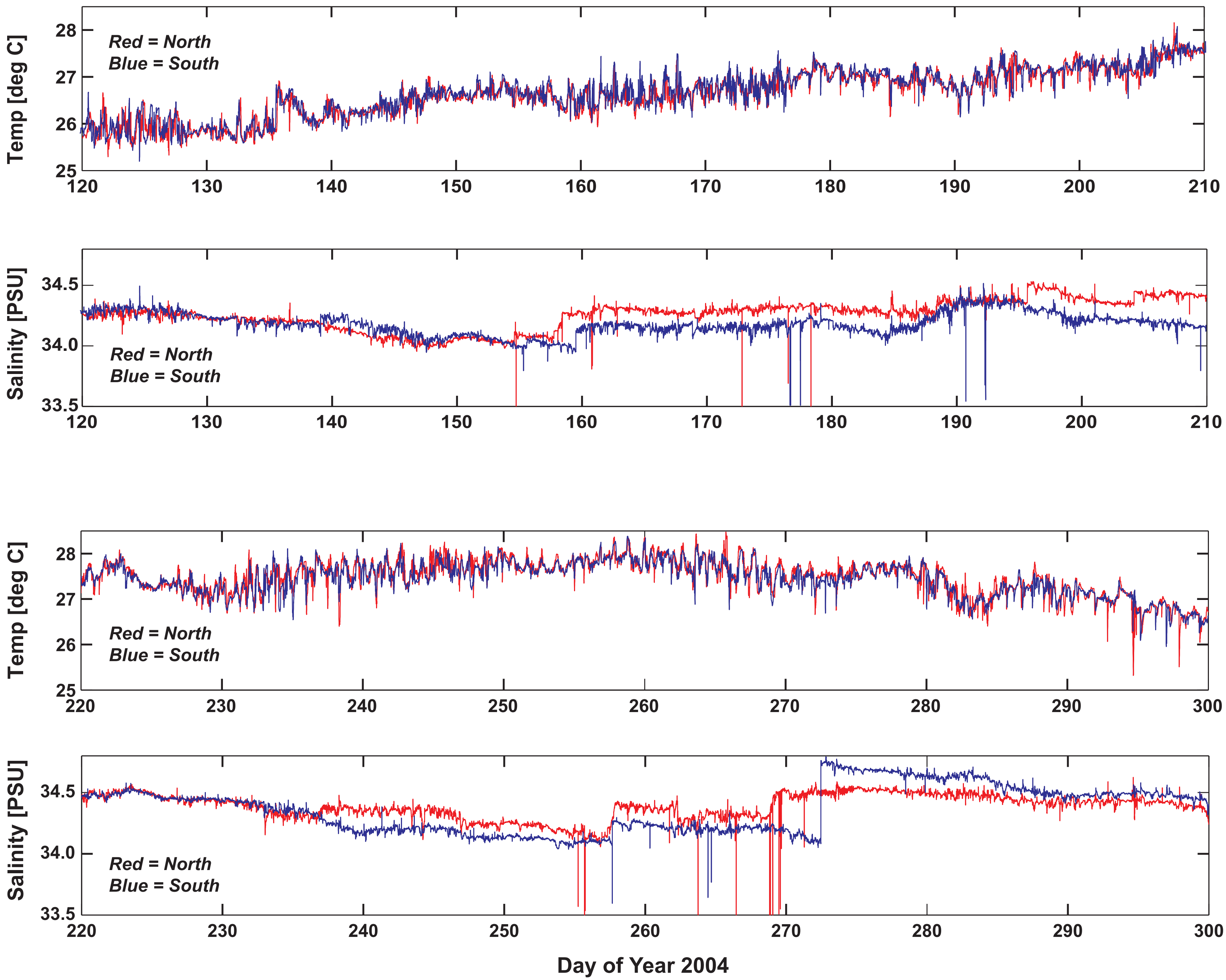
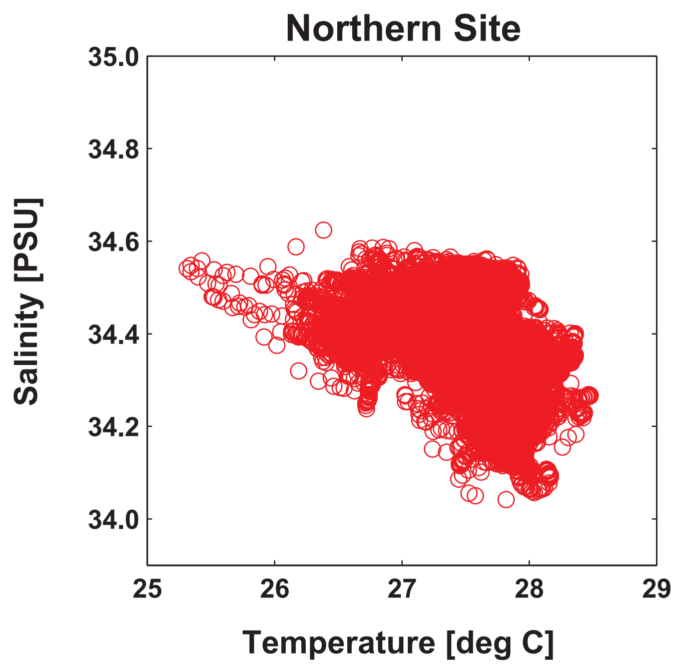


FIGURE 8. Hourly mean near-bed water temperatures and salinities in the study area during the two deployments. Temperature at both sites increased throughout the summer due to insolation. Note the semi-diurnal 0.25-0.50 °C and 0.01-0.05 PSU fluctuations due to the tides and the infrequent larger rapid decreases in salinity that are likely due to submarine groundwater discharge.



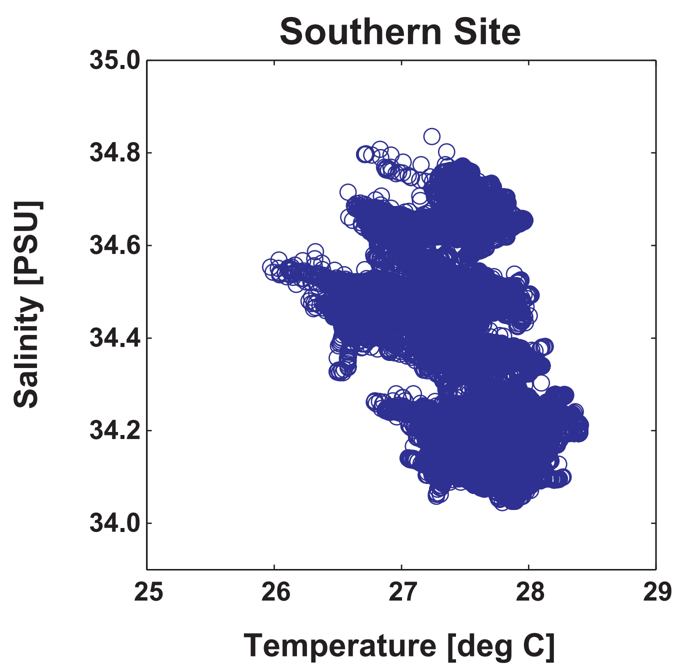


FIGURE 9. *Plots of variation in salinity as a function of temperature. The data from both sites display high scatter rather than the typical inverse relationship between temperature and salinity; this suggests more than one distinct water mass in the study area. These variable water mass signatures are likely heavily influenced by submarine groundwater discharge into the coastal waters. Overall, the data from the southern site shows greater scatter due to more influence from terrestrial freshwater, insolation and wave-induced mixing.*

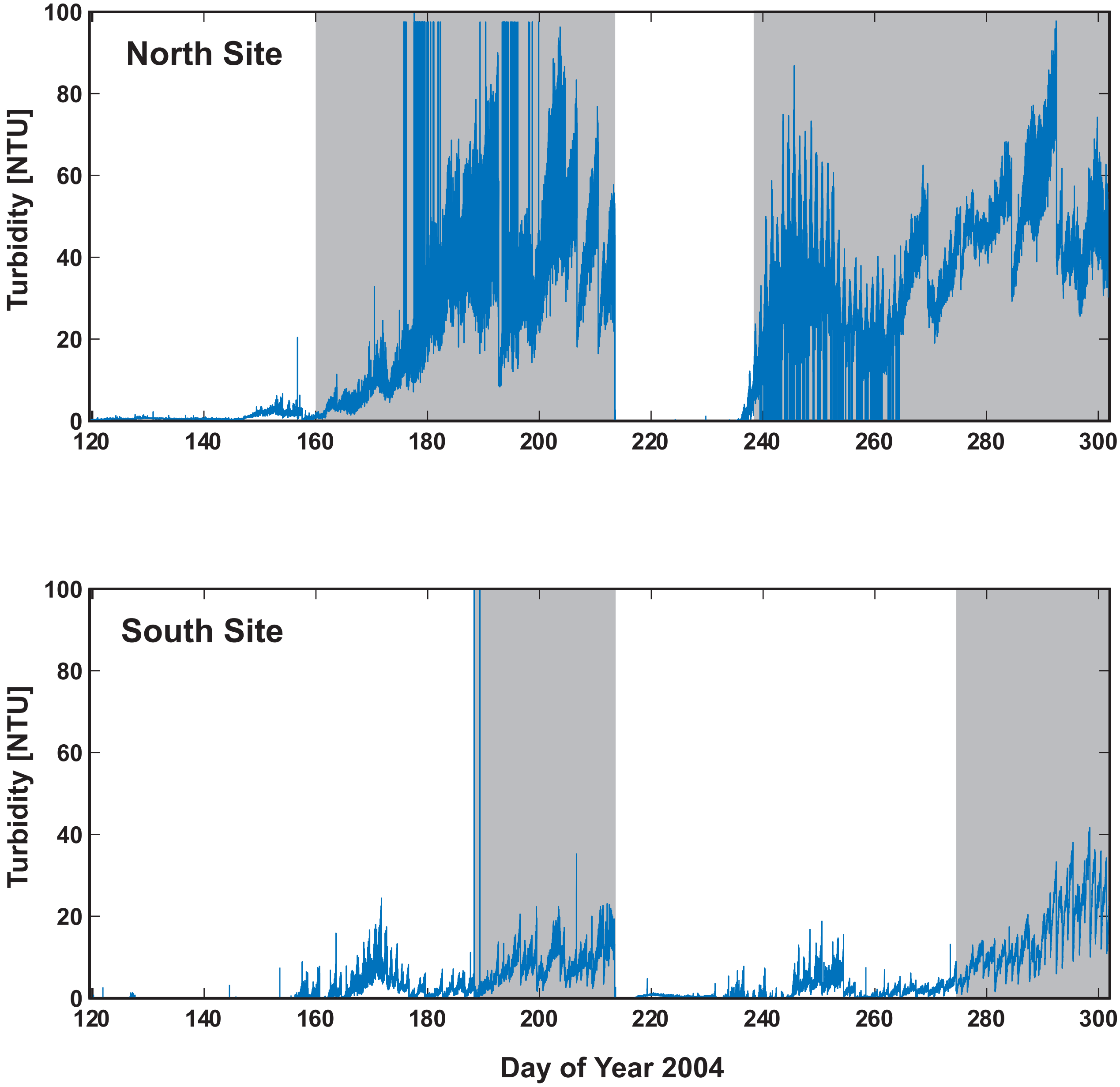


FIGURE 10. *Hourly mean near-bed turbidity data in the study area during the two deployments. Gray regions denote period of biofouling or infra-red beam obstruction. There is no clear correlation between the different sites nor with the winds or waves.*

Forcing Mechanisms and Their Resulting Fluxes:

Tidal

As noted earlier, the tides are the dominant control on flow at both the northern and southern study sites. This movement of water, both cross-shore and alongshore, results in advection of different water masses past the instrument sites. As shown in FIGURE 11, as the tide rises, near-bed flow is onshore and the water temperature decreases and salinity increases. This appears to be the advection of deeper, subthermocline water from offshore up on to the coral reefs in the park's waters. Conversely, when the tide falls, near-bed flow is offshore, water temperature increases and salinity decreases. This is likely due to the advection of shallow, low-salinity water from submarine groundwater discharge warmed by insolation and then advected offshore as the tide falls, similar to the observations of West Maui by Storlazzi and Jaffe (2003). Leichter et al. (2003) has shown the onshore advection of subthermocline waters that contain elevated nutrient loads from submarine groundwater discharge supply a large percentage of nutrients to the shallow coral reefs in the US Florida Keys. We have no evidence of elevated nutrient loads and without concurrent, co-located nutrient sampling, we cannot determine if these internal tidal bores are actively delivering nutrients to the reefs along the Kona Coast. However, this may be a mechanism for the onshore transport of deeper waters if nutrients loads were to increase in the future.

Wind

Although Kaloko-Honokohau lies on the leeward or Kona coast of the Big Island of Hawaii, regional wind forcing appears to exert some influence on the advection of water in the park over subtidal (>36 hours) periods. The Northeast Trade winds in the Hawaiian Islands typically blow to the southwest and are topographically steered around the large volcanoes of the Hawaiian Islands. This forces the surface water offshore and forces the near-bed water to move onshore in an upwelling-type of configuration, carrying deeper, cooler waters onshore (FIGURE 12). Conversely, when the Trade winds slacken or reverse direction and blow strongly onshore, this causes onshore surface flow and offshore near-bed flow, resulting in greater near-bed water temperatures as warmer, shallower water from inshore is carried offshore in a relaxation motion, similar to the observations off the US West Coast by Storlazzi et al. (2003).

Waves

The acoustic backscatter records show that when the significant wave height exceeds 0.6 m for more than a few hours, the acoustic backscatter increases (FIGURE 13). This is likely due to the resuspension of seafloor sediment either at the instrument sites or inshore in shallower areas and its advection out past the instrument packages in 13-14 m of water. Another interesting phenomena associated with the large wave events is that when the wave height exceeds 0.6 m for more than a few hours, the cross-shore tidally-driven flows are substantially reduced. Similar observations were made by Storlazzi and Jaffe (2003) off West Maui and Storlazzi et al. (2003) off South Molokai.

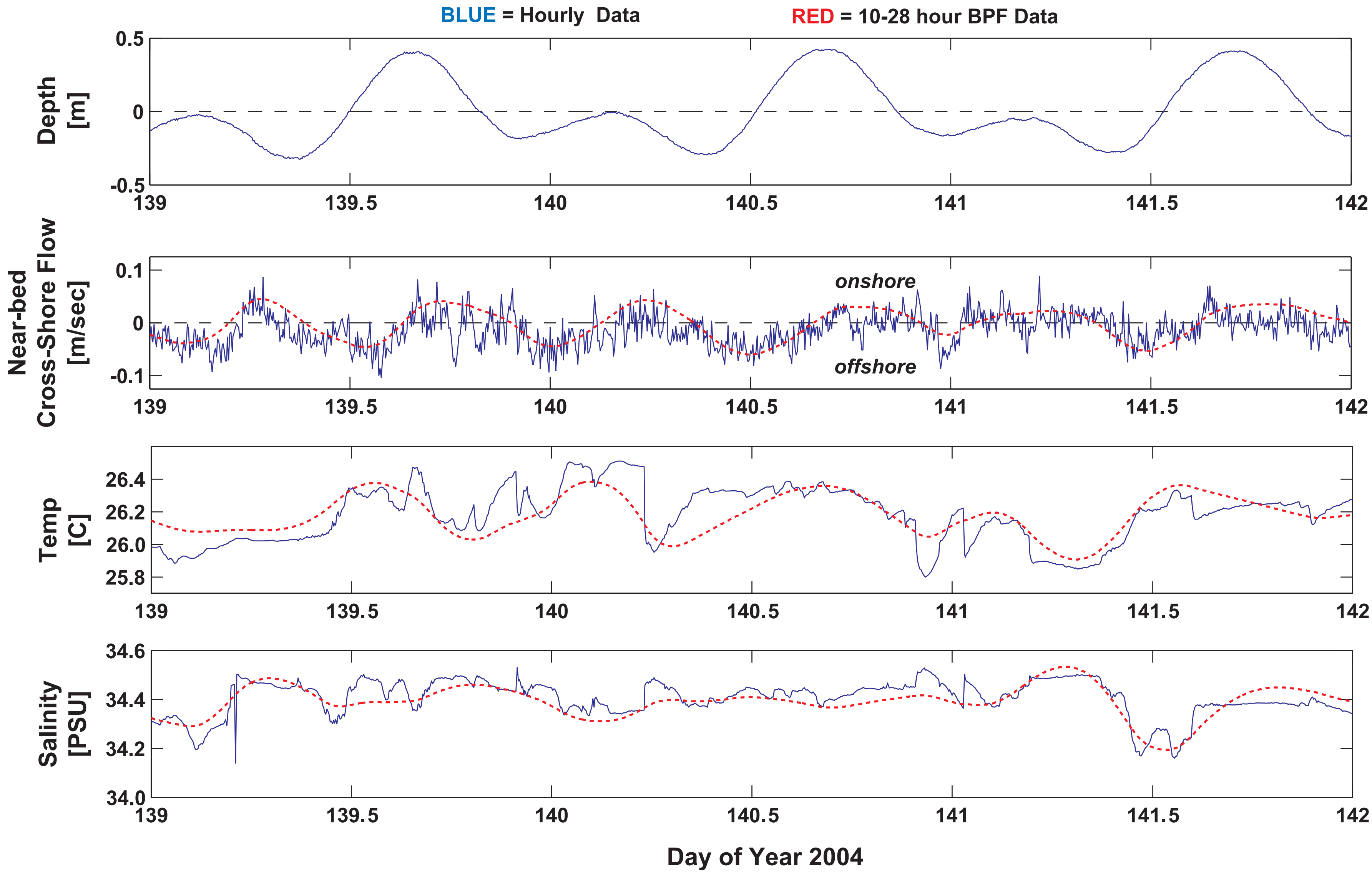


FIGURE 11. *Tidal forcing of cross-shore currents, temperature and salinity at the southern site. As the tide rises, flow is onshore, temperature decreases and salinity increases as deeper cold, saline water is advected onshore. Conversely, as the tide falls, flow is offshore, temperature increases and salinity decreases as shallow warm (due to insolation), less saline (due to submarine groundwater discharge) water is advected offshore.*

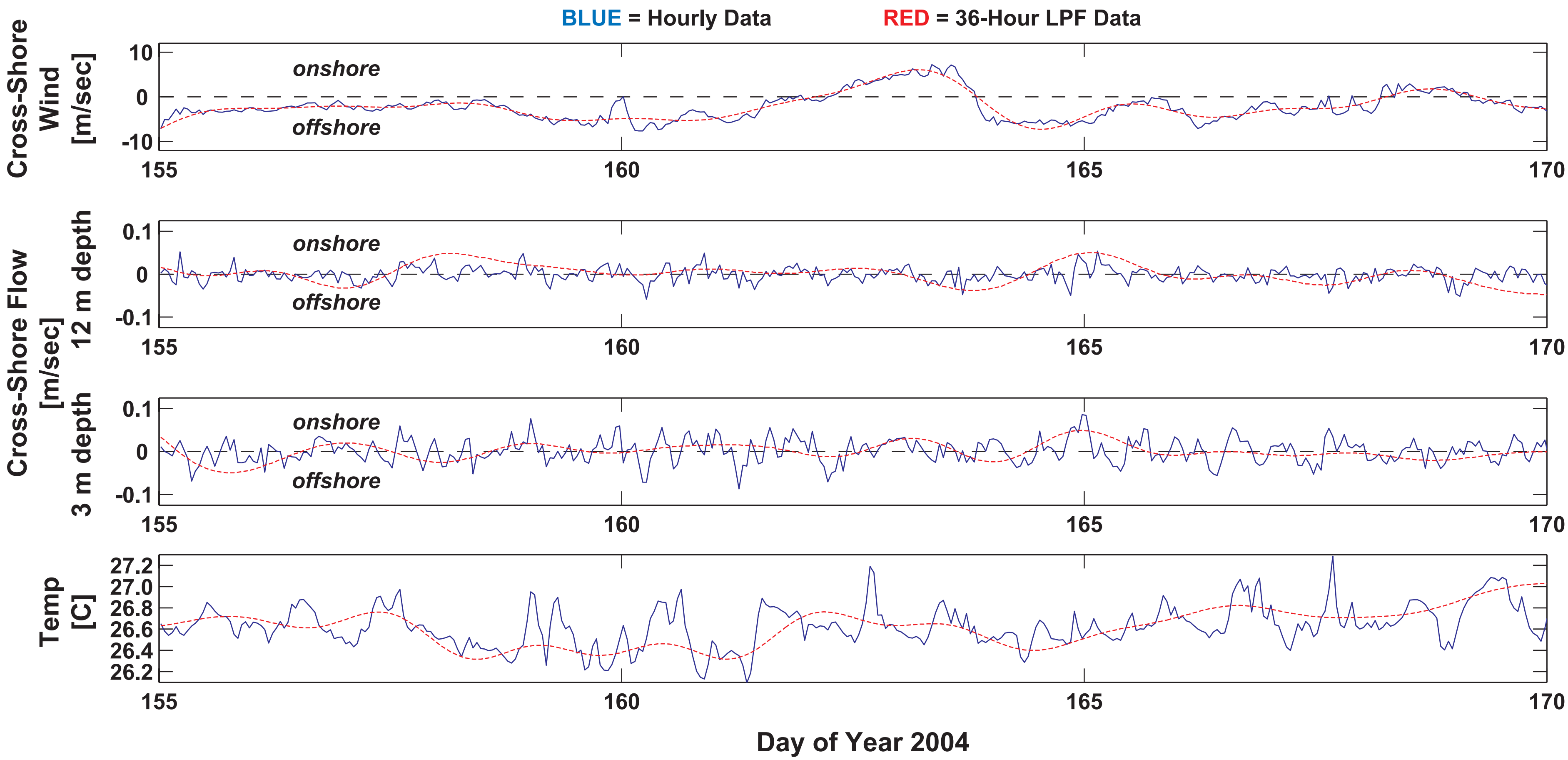


FIGURE 12. *Wind forcing of cross-shore currents and temperature at the southern site. When the winds blow strongly offshore, it appears to drive flow onshore that results in decreased water temperatures as deeper cold water is advected onshore in an upwelling configuration. Conversely, when the winds weaken or blow onshore, net flow is offshore and warmer near-bed waters are observed.*

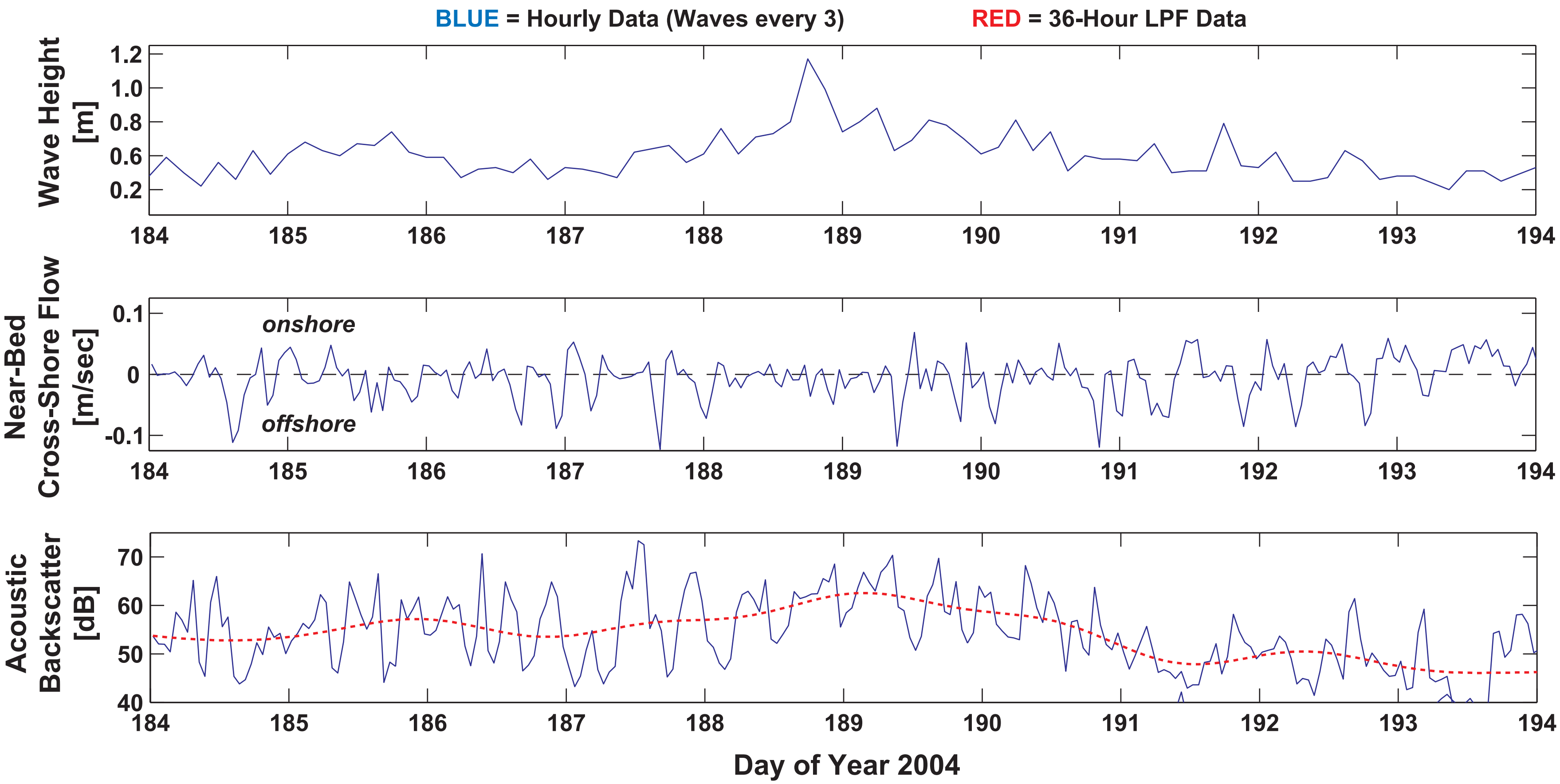


FIGURE 13. Wave forcing of cross-shore currents and acoustic backscatter at the southern site. While there is some low background acoustic backscatter (a measure of turbidity), note that when the significant wave height exceeds 0.6 m for more than a few hours the acoustic backscatter increases. Also note that when the wave height exceeds 0.6 m for more than a few hours, the cross-shore tidally-driven flows are substantially reduced.

Anomalous Mid-Water Column Acoustic Backscatter

Interesting features were often observed in the high-frequency (every 4 min) acoustic backscatter and temperature records recorded at the instrument sites. During spring and summer when the Trade winds blew consistently and wave heights were low, anomalously high acoustic backscatter was observed during the daytime (FIGURE 14). Instead of the typical high acoustic backscatter near the bed that decreases exponentially towards the surface and is due to the resuspension of seafloor sediment, anomalously high acoustic backscatter was observed in the middle of the water column during the daylight hours. These observations of elevated mid-water column acoustic backscatter occurred concurrently with high-frequency fluctuations in water temperature. These high-frequency temperature fluctuations signify the passage of high-frequency internal waves past the instrument site, similar to the observations of the US West Coast by Storlazzi et al. (2003). The measurement of anomalous mid-water column acoustic backscatter during the daytime along with the concurrent observation of high-frequency internal waves suggests the presence of biological thin layers, which were observed under similar conditions off the US West Coast by McManus et al. (in press).

CONCLUSIONS

In all, more than 29,300 hourly observations of currents, waves and water column properties were collected per day for 182 days over the course of 7 months between April, 2004, and October, 2004, in Kaloko-Honokohau National Historic Park (KAHO) off the Kona coast of Hawaii, USA. Key findings from these measurements and analyses include:

(1) Flow at the instrument sites is primarily controlled by the tides and the Trade winds. Flow is faster higher up in the water column and generally greater at the southern site. Flow at the southern site is primarily alongshore and net flow is to the southeast, while flow at the northern site is primarily cross-shore and net flow is offshore.

(2) Tidal currents rise to the north and fall to the south. As the tides fall, they typically draw warm, fresher water offshore and drive it downcoast to the south. When the tides rise, they bring deeper, cooler, more saline water into shallower water.

(3) Slacking or reversal of the Trade winds appears to drive relaxation motions, causing low-frequency warming of the near-bed waters in the park.

(4) Higher acoustic backscatter, a proxy for turbidity, is typically observed close to the seafloor during large wave events, suggesting either the local resuspension of seafloor sediment or the suspension closer to shore in shallow waters and its subsequent advection out past the instrument sites.

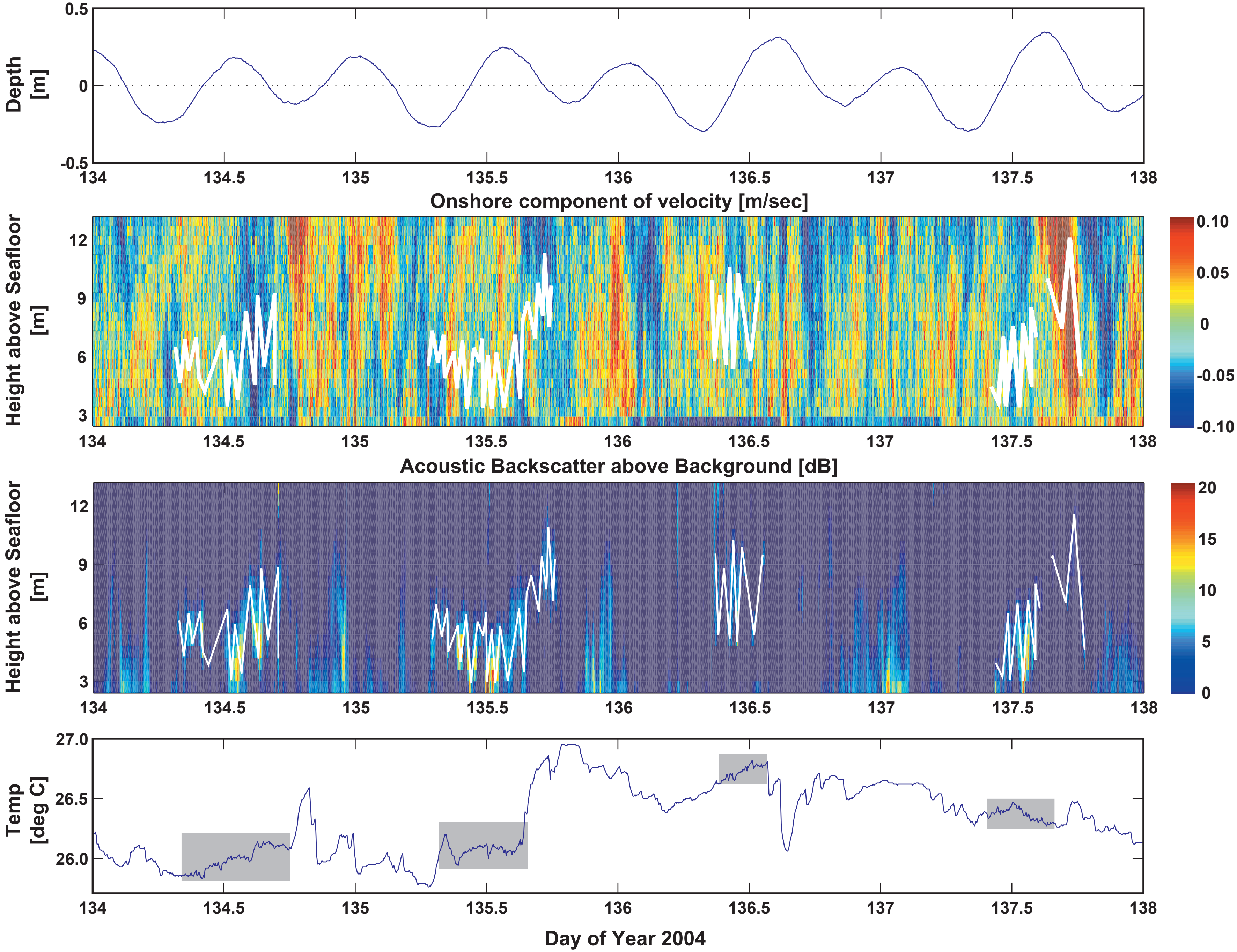


FIGURE 14. *Observations of anomalous mid-water column acoustic backscatter and high-frequency internal waves at the southern site. Instead of the typical high acoustic backscatter near the bed that decreases exponentially towards the surface that results from the resuspension of seafloor sediment, anomalously high acoustic backscatter was observed up in the middle of the water column on Year Day 134.3-134.7, 135.3-135.7, 136.3-136.4 and 137.3-137.5 following periods of high cross-shore shear (when flow flows in different directions at different elevations in the water column). These periods of high mid-water column acoustic backscatter were observed at the same time as very high-frequency fluctuations in water temperature (grey boxes) due to the passage of high-frequency internal waves.*

(5) What are interpreted to be biological thin layers were acoustically imaged during the spring and summer when the waves were small and the Trade winds were consistent. These biologic thin layers occurred only during the day and were observed during the passage of high-frequency internal waves.

These data provide us with a much clearer picture of the nature of and controls on flow and the flux of material in the study area. A number of interesting phenomena were observed that indicate the complexity of coastal circulation in the waters of KAHO and may help to better understand the implications of the processes on the health of the park's resources.

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TABLE 1. Experiment personnel

Person	Affiliation	Responsibilities
Curt Storlazzi	USGS	Chief scientist, diver
Joshua Logan	USGS	Information specialist, diver
Jill Zamzow	UH/DAR	Field Assistant
Larry Basch	NPS	NPS-PICRP Chief, Field Assistant
Sallie Beavers	NPS	NPS-KAHO scientist and liaison, Field Assistant
Rebecca Stamski	UCSC	Field Assistant

TABLE 2. Instrument package sensors

Instrument	Sensors
MiniPROBE(S)	RD Instruments 600 kHz Workhorse Monitor acoustic Doppler current profiler (upward-looking)
	Aquatec/Seapoint 200-TY optical backscatter sensor
	Seabird SBE-37SI Microcat conductivity-temperature sensor
MiniPROBE(N)	RD Instruments 600 kHz Workhorse Monitor acoustic Doppler current profiler (upward-looking)
	Aquatec/Seapoint 200-TY optical backscatter sensor
	Seabird SBE-37SI Microcat conductivity-temperature sensor

TABLE 3. Instrument package deployment log: 04/2004 - 10/2004

Instrument	Island ID	Depth (m)	Deployment Date	Recovery Date	Latitude (dd)	Longitude (dd)
MiniPROBE (N)	HA	13	04/28/04	08/01/04	19.6877265	-156.0361913
MiniPROBE (S)	HA	14	04/27/04	08/01/04	19.6738057	-156.0334821
MiniPROBE (N)	HA	13	08/04/04	10/30/04	19.6877265	-156.0361913
MiniPROBE (S)	HA	14	08/04/04	10/30/04	19.6738057	-156.0334821

APPENDIX 1

MiniPROBE Acoustic Doppler Current Profiler (ADCP) Information

Instrument:

RD Instruments 600 kHz Workhorse Monitor (north 04/04-08/04); s/n: 2432

RD Instruments 600 kHz Workhorse Monitor (south 04/04-08/04); s/n: 2074

RD Instruments 600 kHz Workhorse Monitor (north 08/04-10/04); s/n: 2074

RD Instruments 600 kHz Workhorse Monitor (south 08/04-10/04); s/n: 3648

Transmitting Frequency:	614 kHz
Depth of Transducer:	12.7 m/14.6 m
Blanking Distance:	0.25 m
Height of First Bin above Bed:	0.73 m
Bin Size:	0.5 m
Number of Bins:	36
Operating Mode:	High-resolution, broad bandwidth
Sampling Frequency:	2 Hz
Beam Angle:	20 deg
Time per Ping:	00:00:00.30
Pings per Ensemble:	1
Ensemble Interval:	03:00:00.00
Sound Speed Calculation:	Set salinity, updating temperature via sensor

Data Processing:

The data were averaged over 36-bin (1 hour) ensembles, all of the spurious data above the water surface were removed and all of the data in bins where the beam correlation dropped below 70% were removed for visualization and analysis.

Position Information:

Garmin GPS-76 GPS; s/n: 80207465; USGS/CRP unit#1
RDI internal compass/gyroscope, set to –10 deg magnetic offset

APPENDIX 2

MiniPROBE External Sensor Information

Instruments:

Seabird Microcat SBE-39SI CT; s/n: 1161; calibrated 11/2001

Seabird Microcat SBE-39SI CT; s/n: 2792; calibrated 11/2001

Aquatec/Seapoint 200-TY OBS; s/n: 371-013; calibrated 08/17/2002

Sampling Frequency:	2 Hz
Measurements per Burst:	30
Time Between Bursts:	00:04:00.00

Aquatec/Seapoint 200-TY OBS; s/n: 371-026; calibrated 08/17/2002

Sampling Frequency:	2 Hz
Measurements per Burst:	30
Time Between Bursts:	00:04:00.00

Position Information:

Garmin GPS-76 GPS; s/n: 80207465; USGS/CRP unit#1