MAGIC Leg0 CRUISE REPORT

2012-06-14

MAGIC Leg0 Cruise on the M/V Horizon *Spirit*

under the command of Captain Walt Rankin

Leg00a
Los Angeles, CA – Honolulu, HI
February 11-15, 2012

Leg00b
Honolulu, HI – Los Angeles, CA
February 16-23, 2012

Ernie Lewis (Brookhaven National Laboratory)
Brad Orr (Argonne National Laboratory)
Mike Reynolds (Remote Measurements and Research Company)

Abstract

MAGIC cruise Leg0 occurred on the M/V Horizon ***Spirit***, under the command of Captain Walt Rankin, during its routine voyage from Los Angeles to Honolulu (February 11-15, 2012) and back (February 16-23, 2012). Ernie Lewis of Brookhaven National Laboratory (BNL), Brad Orr of Argonne National Laboratory (ANL), and Mike Reynolds of Remote Measurements and Research Company (RMR Co.) traveled on ship from Los Angeles to Hawaii (Leg00a), and Ernie Lewis and Mike Reynolds continued on the ship for the return journey (Leg00b). The goals of this cruise as laid out in the Leg0 Cruise Plan were 1) to become familiar with ship operations, 2) to evaluate weather balloon launch conditions, 3) to characterize the ship motion, and 4) to evaluate wind flow conditions. The cruise was successful in each aspect. A variety of conditions were experienced, the instruments worked well for the entire cruise, and data was gathered that will prove valuable for the success of MAGIC. The crew was welcoming, interested, knowledgeable, and helpful. The purposes of this report are to describe how the above goals were realized, familiarize ARM and MAGIC personnel with conditions aboard the ship and those to which the instrumentation will be subjected, and present data collected during the cruise. Recommendations for future actions and important considerations are also presented and discussed.

Leg0 Schedule

Load ship	Los Angeles, CA	9-10 February, 2012
Depart Leg00a	Los Angeles, CA	11 February, 2012, 5:30 am (local)
Arrive	Honolulu HI	15 February, 2012, 11:00 pm (local)
Depart Leg00b	Honolulu, HI	16 February, 2012, 11:00 pm (local)
Arrive	Los Angeles, CA	23 February, 2012, 7:00 am (local)
Unload ship	Los Angeles, CA	23-24 February, 2012

Horizon *Spirit* Officers on Leg0

Walt Rankin	Captain
Eric Sinkevich	First Mate
John Starr	Chief Engineer

MAGIC/ARM Personnel Sailing

Ernie Lewis	Brookhaven National Laboratory
Brad Orr	Argonne National Laboratory
Mike Reynolds	Remote Measurements and Research Company

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Background

The MAGIC project of the Department of Energy's Atmospheric Radiation Measurement (ARM) Program will deploy the Second ARM Mobile Facility (AMF2) aboard Horizon Lines merchant vessel ***Spirit*** making regular trips between Los Angeles, CA (33.733N, 118.242W) and Honolulu, HI (21.314N, 157.883W) for a period of one year starting in October, 2012. Cloud radars, atmospheric lasers, radiosonde weather balloons, and a variety of other high technology instrumentation will be deployed, much of it contained in three modified 20' containers, called Seatainers, located on the bridge deck. Additionally, meteorological and other instrumentation will be located on the ship mast and bridge roof. The legs during MAGIC will be named sequentially as "Legxxa" for the trip from Los Angeles to Honolulu, and "Legxxb" for the return trip. The two parts of this preliminary cruise, Leg00a and Leg00b, are collectively designated "Leg0."

Several MAGIC and ARM personnel met with Mike Bohlman, Director of Marine Service of Horizon Lines, at Horizon headquarters in Kenilworth, NJ in October, 2011 to discuss this project. At his suggestion, several MAGIC/ARM personnel visited the Horizon ***Spirit*** and met with Captain Tom McCarthy at the Port of Los Angeles in November, 2011. It was decided that several people involved in the MAGIC project would go on an evaluation cruise to familiarize themselves with ship operations and gather information and data necessary for planning, and deploying the instruments for, MAGIC. This leg (Leg0) was undertaken in February, 2012 aboard the ***Spirit*** under the command of Captain Walt Rankin.

The Horizon ***Spirit*** is a steam ship 272 m long and 30.5 m wide, with gross tonage 34,000 tons. The bridge deck is ~20 m above the water level (the exact value will vary with loading of the ship), and the bridge roof another 2.5 m above that. The ***Spirit*** can accommodate 33 people and has a standing crew of 23 individuals. During Leg0, two cadets from United States Merchant Marine Academy and one Scripps Institution of Oceanography technician were also aboard. The ***Spirit*** carries approximately 900 40-foot containers, most of which are empty on the return trip. The 4100 km trip form Los Angeles to Honolulu takes 4.5 days at a speed of just over 10 m s^{-1} (~20 knots), and the return trip takes 6.5 days at a speed of just over 7 m s^{-1} (~15 knots); the slower return speed results in fuel savings and allows for a two-week schedule.

Goals of Leg0

The primary goals of Leg0 were:

1) to become familiar with the ship and its procedures, personnel, and routines;
2) to evaluate weather balloon launch conditions at various locations around the ship;
3) to obtain accurate information on the ship accelerations and rotations; and
4) to evaluate wind flow conditions.

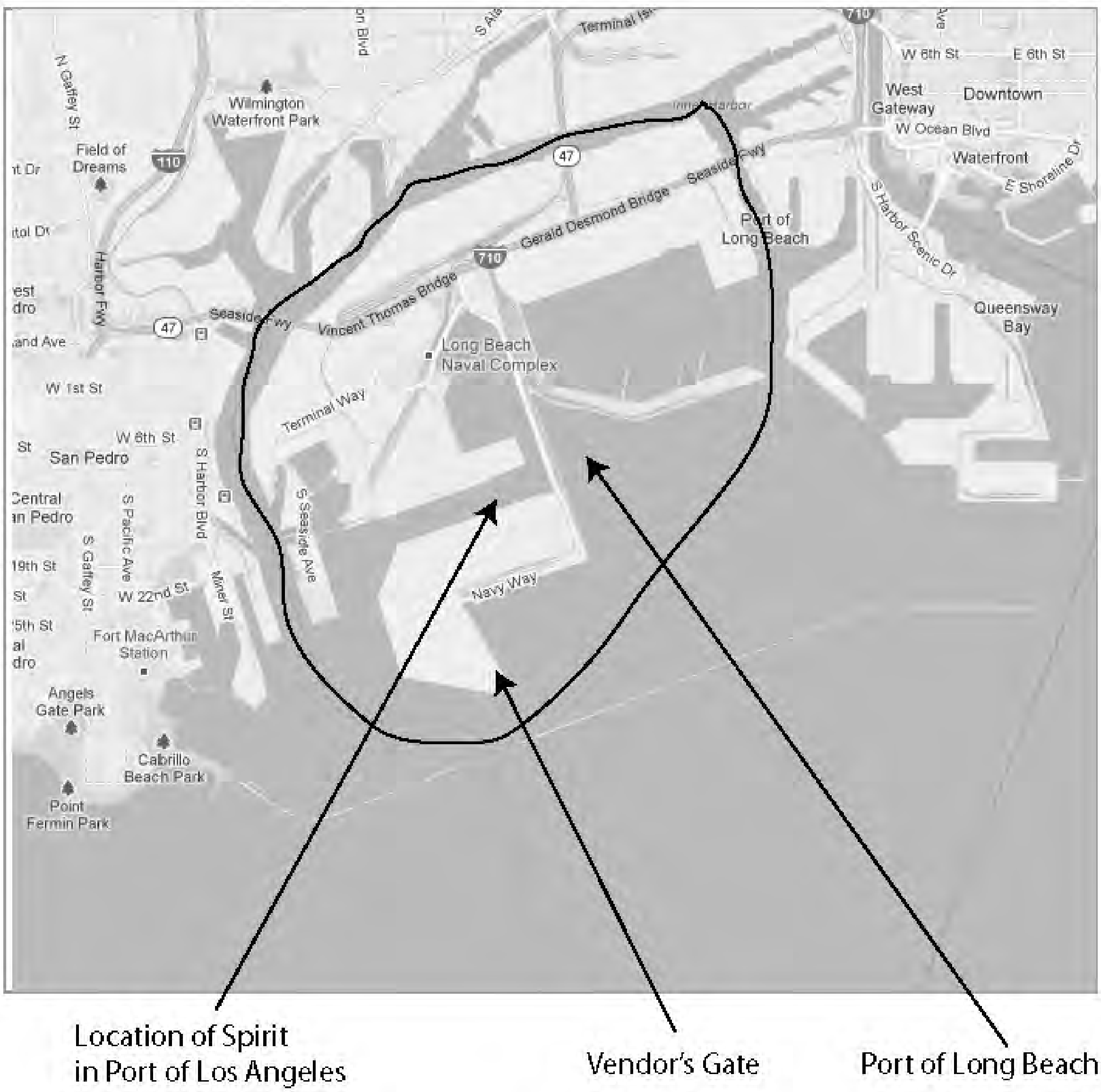
Additionally, Leg0 would provide opportunities to meet with the captain and crew to discuss locations for deployment of AMF2, power requirements, and other logistical details, and to obtain first-hand knowledge of conditions that would inform decisions for operations during the MAGIC deployment.

Procedures for equipment preparation and safe operations require advanced understanding of life at sea; this will be especially important as there will be at least two technicians on board at all times during MAGIC. Radiosondes launched from weather balloons will provide valuable data on properties of the marine boundary layer; thus it is important to find preferred launch locations during different wind conditions and directions. To this end, a set of dummy radiosondes were launched from different locations on the ship. Several of the AMF2 instruments require accurate knowledge of ship heading and motions (velocities, accelerations, and rotation rates), to allow for zenith pointing, to decide when fixed instruments are pointing vertically, and for other reasons; thus a high precision ring-laser inertial navigation system was employed to record the ship motion and provide estimates of what can be expected during the MAGIC deployment. Meteorological measurements were made from different locations on the mast using different instruments to evaluate perturbations by ship structures and to permit accurate determination of wind speed for winds from different directions.

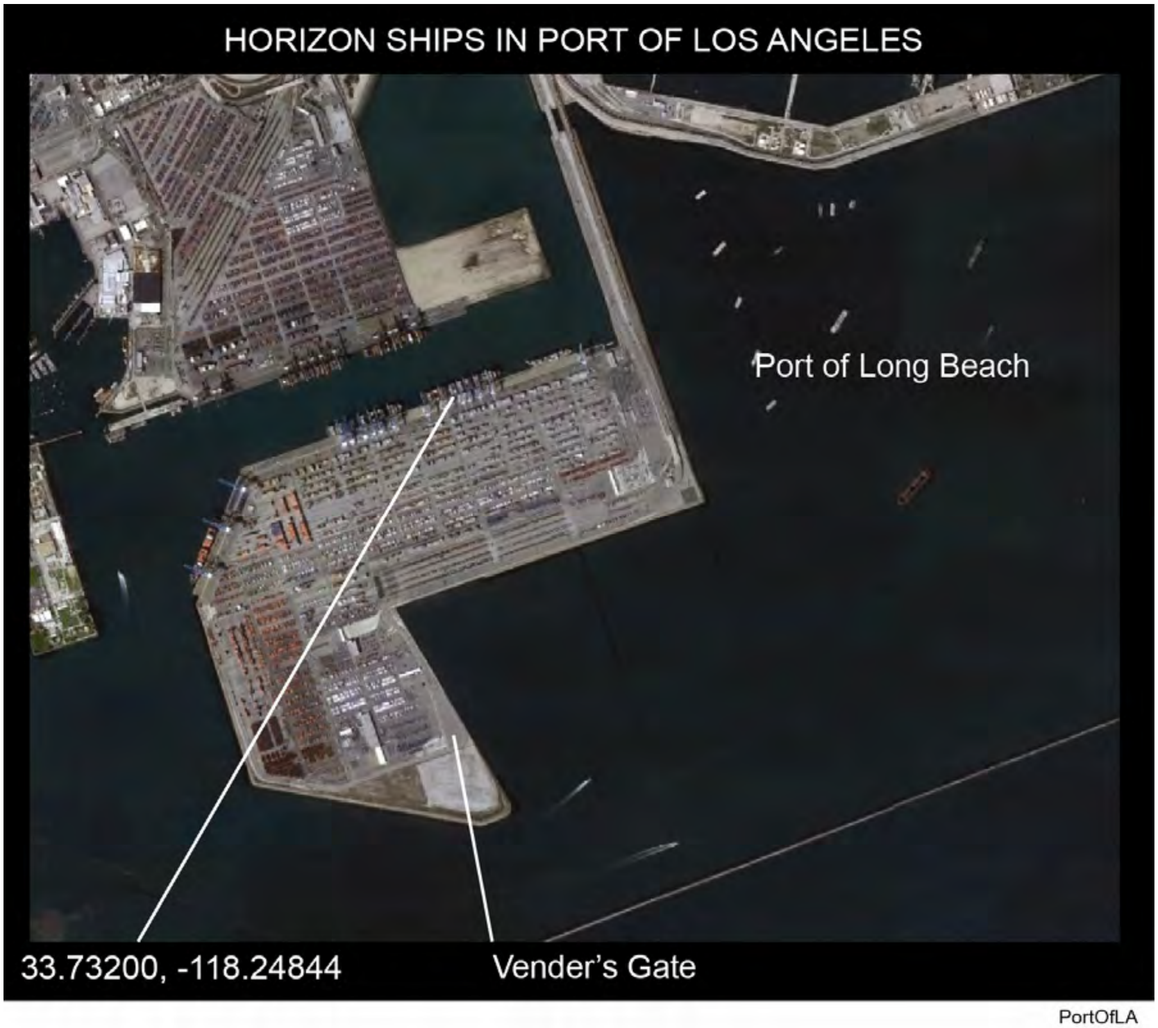
Location of the *Spirit* in Los Angeles

The ***Spirit*** docks at the Port of Los Angeles on Terminal Island. The western half of Terminal Island is the San Pedro area of the city of Los Angeles, and the eastern half is part of the city of Long Beach. The Port of Long Beach is across the road (on the east side of Navy Way) from the Port of Los Angeles, but is a separate port (this situation can be a bit confusing). MAGIC personnel stayed in Long Beach, which is nearby and probably the best place to stay.

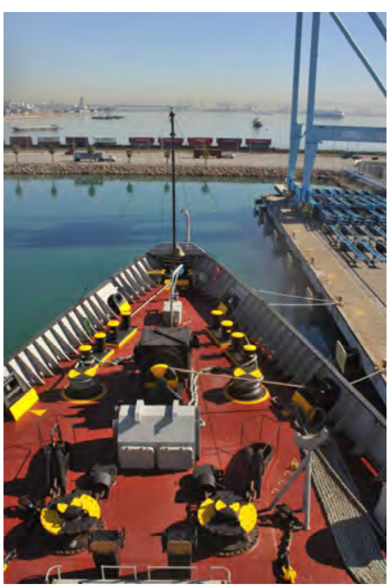
Access to the ship is through the Vendors Gate at the end of Navy Way, which is off the 710 Freeway. TWICs (Transportation Worker's Identification Credentials) were required for entry and should be obtained by all personnel who need access to the ship and to the port area (for staging, etc.). Information on TWICs can be obtained at http://www.tsa.gov/what_we_do/layers/twic/index.shtm. It might be a good idea to bring passports as well (and may be necessary; one captain said he would require this), although they are not a substitute for TWICs for port entry.



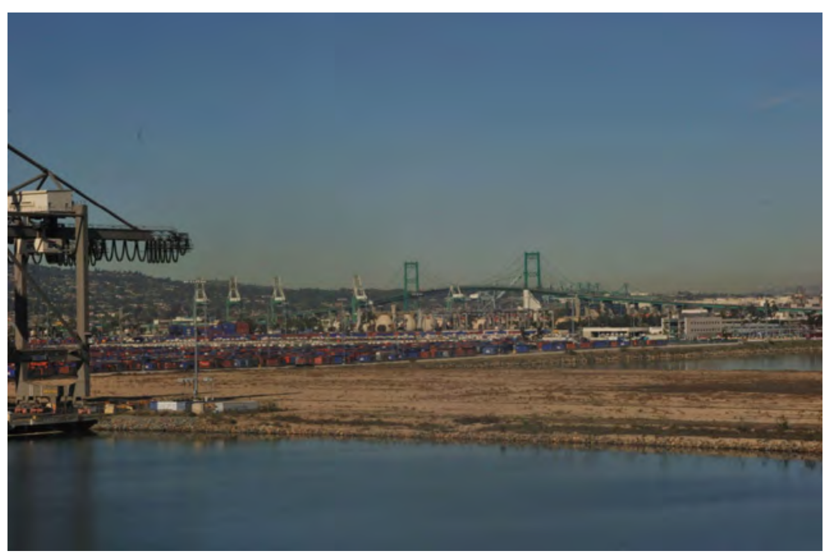
Terminal Island is circled.



Closeup of Terminal Island. The ***Sprit*** was docked in the Port of Los Angeles at 33.732N, 118.248W before and after Leg0.



View from bridge of the ***Spirit*** in the Port of Los Angeles; facing east. Water on the far side of road is the Port of Long Beach.

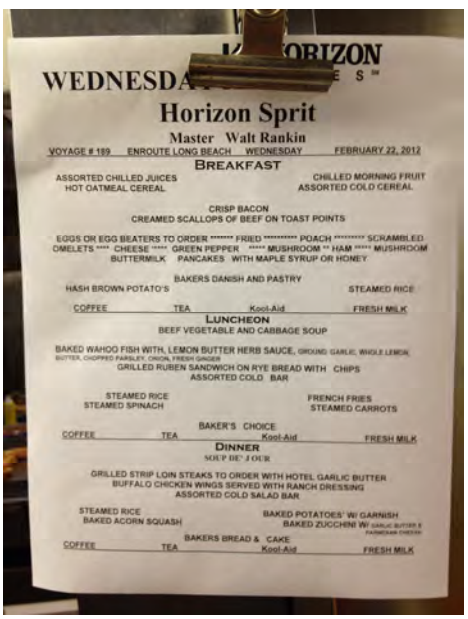


View from ***Spirit*** across harbor. This area could potentially be used for radar calibration.

Conditions Aboard Ship

Accommodations were as good as or better than those on most research vessels. The living quarters were spartan but pleasant, and food was abundant and good. All sheets and towels were provided. Laundry facilities, a weight room, and DVDs were available. There was no local internet, and limited ship-to-shore internet was available. It is not clear to what extent the internet should be used by MAGIC personnel, and ship-to-shore communications are still being decided. Alcohol and drugs are not permitted on board. The crew were interested in the project, anxious to help and offer advice, and fun to interact with. They are professionals and take pride in their work, and their advice and assistance will be of great help to MAGIC.

Cabin shared by two MAGIC scientists



Typical menu

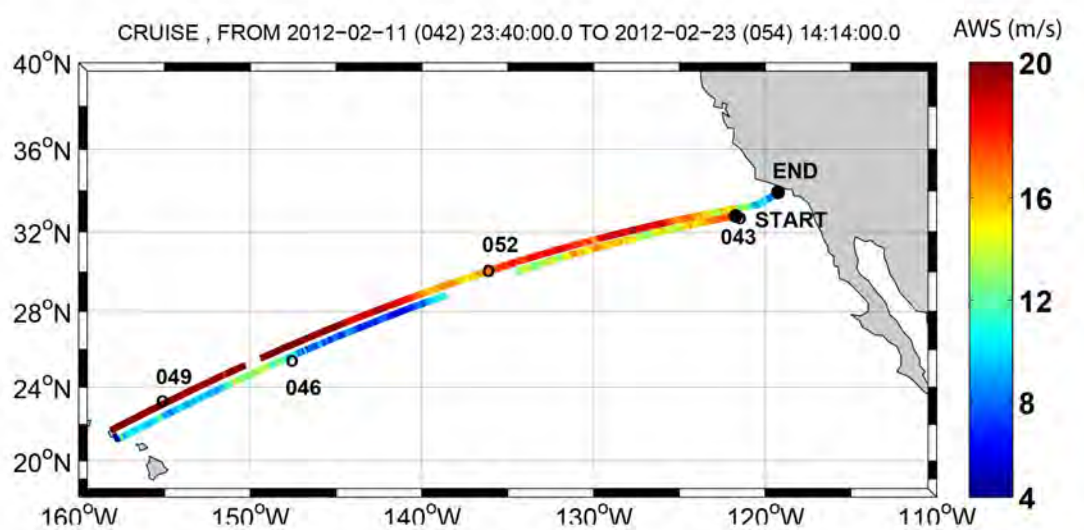
Weight room

Summary of Weather Conditions

The entire cruise was marked by partly to mostly cloudy conditions, mild to strong winds, and virtually no precipitation. Temperatures were typically pleasant, although there were few instances in which being out on deck in a chair would be comfortable, mostly due to the winds. There were a few instances of light drizzle lasting only minutes. The maximum precipitation rate was 0.12 mm h^{-1}. The ship motion was characterized more by pitch along the way to Hawaii, but more by roll on the return (mostly because the ship was lighter, returning with empty containers more than full ones). The motion was generally not such that it led to seasickness, and often the pitch and roll was rather gentle, although one night the motion was quite choppy, making for difficult sleep.

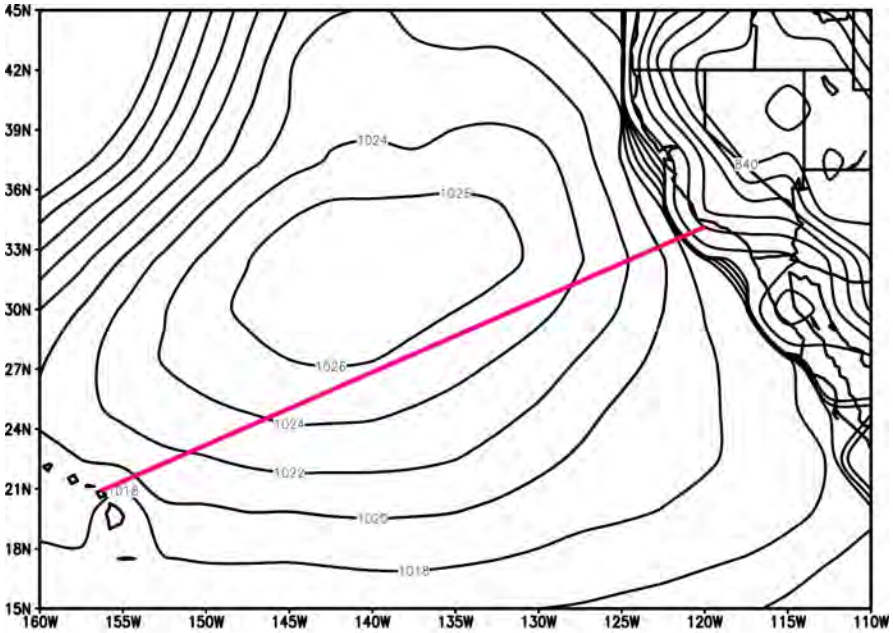
Cloudy conditions prevailed over most of the trip, such that only a few (three or four) readings of aerosol optical depths at several wavelengths were made using a Microtops Sunphotometer borrowed from the Marine Aerosol Network (MAN) of NASA. These measurements, which provide information on aerosol size and abundance, will be made routinely during MAGIC (when clear sky conditions exist). Often clouds were patchy, and during most of the cruise stratocumulus and cirrus were the common types present. There was only part of one day when puffy cumulus was the dominant cloud type.

Winds were mild to strong for most of the voyage. During both the outward and inbound trips there was a high pressure system to the north causing nearly constant winds. The central Pacific high deepened from about 1024 mbar to 1034 bar during the course of the cruise and moved against the California coast, which led to a tightening of the isobars and a strengthening of the easterly trade winds. When we departed Los Angeles the winds were from the NE. The ship speed was westerly around 10 m s^{-1} (~20 knots) which resulted in a low apparent wind speed. On the way back to LA the true winds were much stronger—greater than 10 m s^{-1} (~20 knots), and sometimes as high as 15 m s^{-1} (~30 knots)—and aligned almost exactly into the ship vector, resulting in apparent winds that were greater than 20 m s^{-1} (40 knots) for a substantial portion of the trip. The crew said that this was not atypical for this time of year. These conditions should be kept in mind with regard to instruments that are in the wind and to the aerosol inlet, and launching balloons in such conditions proved difficult. The meteorological system experienced no problems during these conditions, but such winds occuring on the outbound voyage would have resulted in winds from the stern to the bow, with implications for soot from the stacks (discussed below).



Apparent wind speed (ASW) during Leg0. Cruise tracks to and from Los Angeles to Honolulu are offset slightly to aid visualization. Numbers denote Julian Day.

The sea level pressure during Leg00a (2012-02-11 to 2012-02-15) and Leg00b (2012-02-16 to 2012-02-23) is shown in the two maps below, which were obtained from NCEP at http://www.esrl.noaa.gov/psd/data/histdata/.



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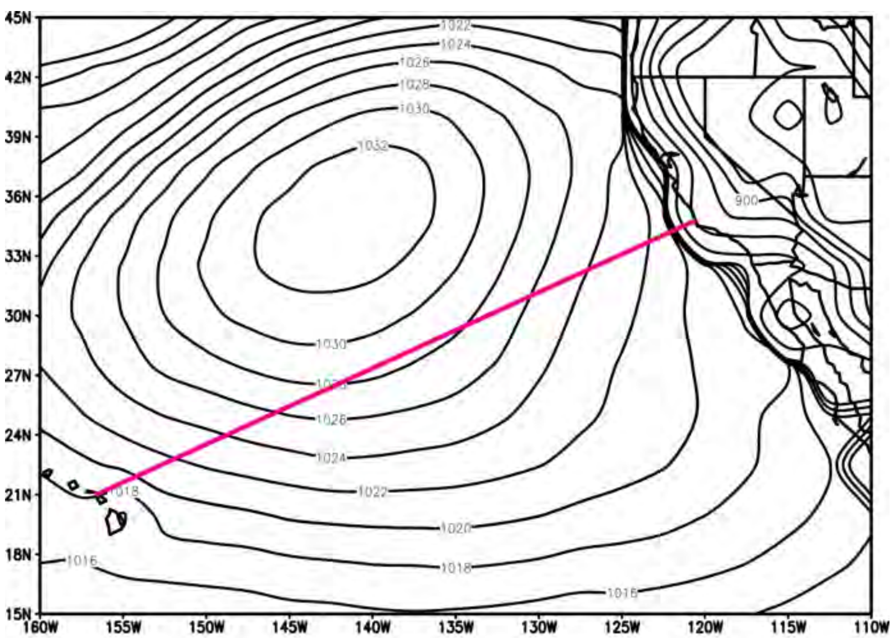

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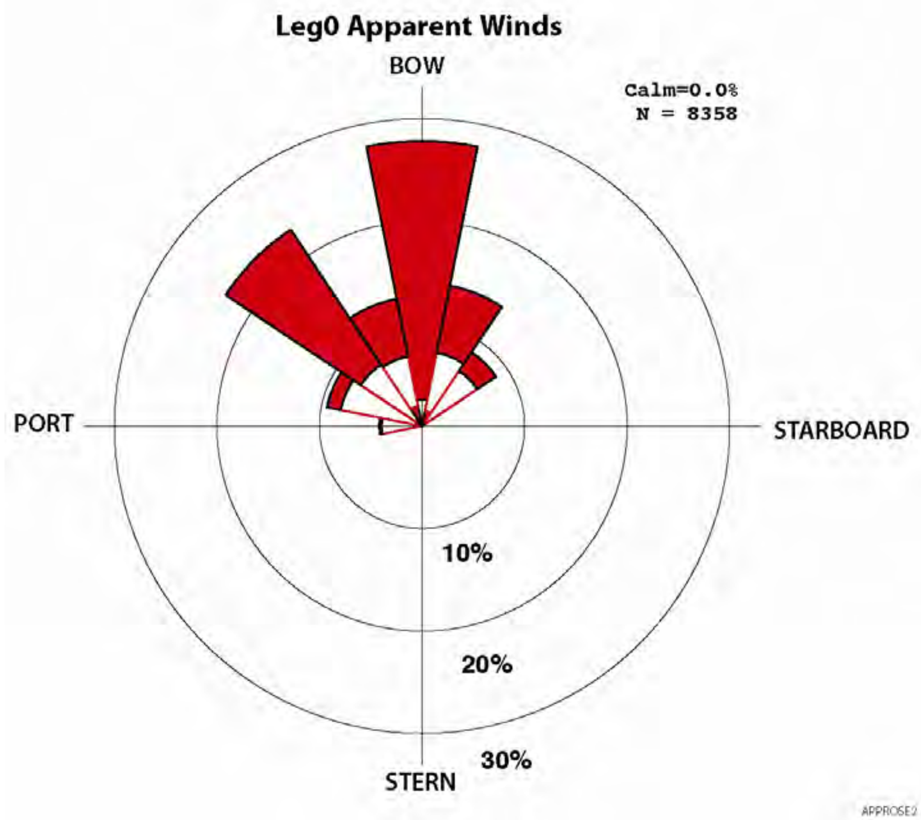
Sea level pressure maps during Leg00a and Leg00b, with cruise track shown.

The wind rose below shows the apparent winds (i.e., relative winds as measured by the ship) during Leg0. For most of the cruise the winds were near or directly on the bow at speeds greater than 15m s^{-1} (~30 knots), with gusts considerably higher (up to ~50 knots). The strongest winds occurred during Leg00b when the ship was steaming directly into strong easterly true winds.



Wind rose of apparent wind speed and direction measured from the mast. White denotes wind speeds less than 7 m s^{-1}; black wind speeds greater than 7 m s^{-1} but less than 15 m s^{-1}; red wind speeds greater than or equal to 15 m s^{-1}.

Equipment Deployed

Equipment for balloon launching, a motion sensor system, and a mast meteorological (met) package were deployed on Leg0. The balloon launching equipment consisted of five helium cylinders that were located in different places around the ship for convenience (two cylinders were placed on the bridge, port side, two on the bridge, starboard side, and one on the stern), regulators and balloon inflation equipment, 20 weather balloons, and biodegradable dummy radiosondes (potatoes and other vegetables of approximate mass 0.27 kg). The motion sensor system consisted of a SeaNav inertial navigation system, power supply, and computers for running the system and logging data. The met package consisted of a 3 m long horizontal frame member with a wind sensor at each end and two other sensors that measured wind speed (WS) and direction (WD), temperature (T), pressure (P), and relative humidity (RH). This was located on the mast at approximately 35 m above sea level.

SeaNav System

The motion data for AMF2 was measured with a Kerfott Seaborne Navigation System (SeaNav) Monolithic Ring Laser Gyro, model KN-5050, with GPS (more information can be found at http://www.kearfott.com/images/stories/pdf/DATASHEETS_KGN_NJ/SEA/kn-5050_seanav.pdf). All six components of motion (accelerations in three directions and pitch, roll, and yaw) were measured. Data are available from the SeaNav at 50 Hz, however, such high rates are not necessary for a shipboard application and for the Leg0 cruise it was decided to subsample at 10 Hz, which is generally acceptable for shipboard motions. The data below demonstrates that this is a reasonable choice.

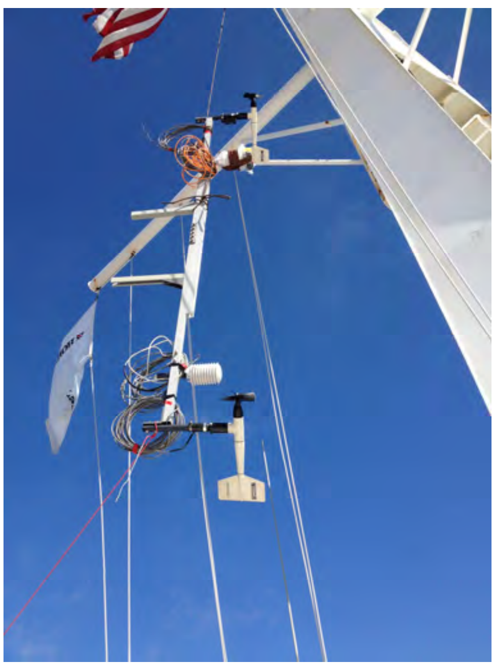
The SeaNav and support computers were placed on a table in the radio room, which was directly below (2.3 m) the intended location for the radar van. The cable for the GPS was strung through a hole in the window from which a bolt was removed (this was replaced at the end of the cruise). Two laptops were required for this system: a DOS computer to operate the interface software and a Linux laptop to run the data collection software.

L ro R: SeaNav unit, 24 V power supply, DOS laptop, Linux netbook.

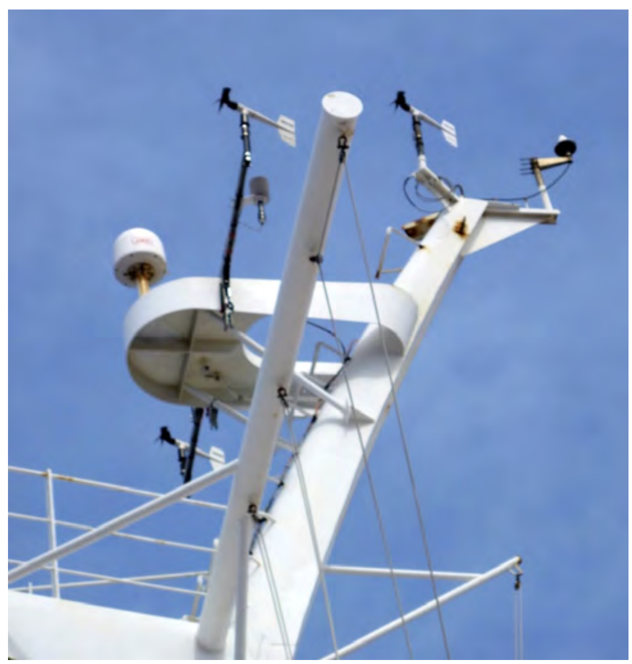
Mast Meteorology Package

A meteorological system was assembled for this cruise using sensors from RMR Co., BNL, and ARM. These sensors were integrated into a single package that was installed on the top platform of the main mast, 35 m (±2 m, depending on ship loading) above the sea surface. This package consisted of a horizontal frame member 3 m long with wind sensors (WM1 and WM2) a WXT (which measured T, RH, P, precipitation, and wind speed and direction by sonic anemometer) on one side, and a T/RH sensor on the other side. Flow distortion is expected from the satellite radome on the platform, and multiple sensors were employed to help determine the extent of this effect.

Sensor		**Measurements**	**Sampling interval**
WM1	Wind monitor 1	Wind speed (WS1) and direction (WD1)	1 s
WM2	Wind monitor 2	Wind speed (WS2) and direction (WD2)	1 s
WXT	Vaisala weather transmitter	Wind speed (vs) and direction (vd)	1 s
		Air temperature (T), relative humidity (RH), barometric pressure (P), rain intensity (ri)	5 s
GPS	Garmin GPS17x	Latitude (lat), longitude (lng), speed over ground (SOG), course over ground (COG), and magnetic variation (var)	5 s
T/RH	Vaisala HMP45D probe in passive solar shield	Air temperature (T) and relative humidity (RH)	1 s
TCM	PNI TCM-2.6 fluxgate compass with pitch & roll from MEMS acceleration sensors	Flux gate compass (fcomp), pitch (pitch), roll (roll), magnetic flux in east (xmag), north (ymag), and up (zmag) directions, and the board temperature (temp)	



Met system being hauled up to mast.



Met system installed on mast. Radome is at left, center. Ship's nonfunctional wind sensor is on right.

Cables from the sensors were run down the mast to a data acquisition system (DAQ) mounted on the ship rail on the bridge roof and housed in a weatherproof non-corrosive enclosure with 316 stainless steel hardware. Heyco compression fittings allowed sensor cables weatherproof entry. A Zeno data logger was used on Leg0, although the final AMF2 system will probably use the Campbell data logger that is in common use in ARM programs. DIN rail mounting provides flexibility for design changes.

Mast Meteorological Package. The sensors on the cross arm are, from port to starboard (L to R): wind monitor 1 (WM1), temperature and relative humidity sensor (T/RH) in a passive solar radiation shield, a weather transmitter (WXT), and wind monitor 2 (WM2).

Wind monitor WM1 and T/RH sensor on cross arm.

For Leg0 the DAQ was connected to ship AC power and an ethernet cable was run down to a netbook computer on the bridge, although wireless communications will probably be used in the final design. A small Linux PC runs all data collection software. For Leg0, the DAQ incorporated an ethernet hub which converged five serial lines to a single ethernet cable that connected to the netbook. Software in the netbook collected 1-sec raw data from the different sensors and computed 2-min averages. All raw 1 Hz data are stored. The 1 Hz GPS and apparent wind measurements were converted to true winds as described below.

Data Acquisition Module on bridge deck

Data Aqusition Module, open

A small computer was placed in the bridge displaying 2-minute average met data. This was quite handy for both the ship's crew and the MAGIC personnel, and it is recommended that a similar system be put in place for the MAGIC deployment.

Weather Balloons Launches

During MAGIC four radiosonde launches per day are scheduled. During Leg0, a total of 18 balloons were released from various locations around the ship; two balloons burst during filling. Only one balloon went into the ocean, and none collided with the containers. As there was no enclosure during Leg0, filling was done on deck. As the purpose was to investigate the feasibility of launching balloons from the ship and to determine the best location(s), radiosondes were not launched but instead, potatoes and other vegetables of roughly the same mass as sonde packages were used. These were attached approximately two meters below the balloons, instead of ~20 m as is typical for sondes.

For a radiosonde substitute we selected root vegetables all weighing 260-280 g.

Launching weather balloons proved to be quite challenging, especially on the return leg when the relative winds were consistently near 20 m s^{-1}. Handling the balloon while filling, and transporting the balloon to a location from which it could be launched, were difficult; the use of an enclosure will certainly help with this. One balloon popped, probably from contacting the rough surface of the bridge deck; after this we used a sheet on which to lay the balloon when filling began, then we put the sheet around the balloon to help control and contain it while transporting it to the location for release. This procedure required several people, including someone to turn the helium off.

It proved difficult to find a good location from which to release the balloons, especially under the wind conditions encountered. There were large downdrafts around the ship that were not expected. When the winds were directly on the ship, as occurred several times, launches from either wing would cause the balloon to initially lift then drop when it reached the containers, and remain low and sometimes very near the water until the balloon was past the ship, after which it rose at a normal rate. The captain offered to turn the ship 20-30 deg during these conditions, and this doesn’t seem to be a problem for the ship’s operations, as it would need last only a few minutes. However, this didn’t alleviate all the problems. When the winds were not on the ship (i.e., from the bow) there was still considerable downdraft from the ship, and balloons launched from the wings would often drop near the water and remain there for a few ship widths before rising at a normal ascent rate. Were the sondes to unroll to a distance of 20 m or below the balloons, several of them would have been in the water or would have collided with containers during ascent.

Most of the launches were attempted from the bridge deck, as this location would be most convenient for the technicians, who would be housed and already working near this location. Several launches were attempted from the stern. Although one launch from this location worked well, during another attempt under heavy winds (17 m s^{-1} relative) the balloon was sucked in behind the containers 5-10 m above the deck and remained there without gaining or losing elevation for approximately 30 s before finally getting away from the ship long enough to start a normal ascent. For this reason and others it was determined that the stern would not be a good location for launches. It is far (200-250 m) from the bridge and would require two people for launching (for safety purposes, especially during nighttime). The deck was extremely dirty and rather slippery from soot (discussed below), and there was sometimes little room to work; the stern area was open on Leg00a, but filled with containers on the return leg.

The best location in some situations seemed to be near the front dodger (railing) near the bridge house. It seemed that if a balloon could gain some elevation before reaching the location of the containers it would continue to ascend well. Launching from the bridge would also be most convenient for the technicians. Ship's crew would be nearby, eliminating the need for both technicians to be present (for safety) during night launches, and minimizing time required for launches. As noted above, the stern is not recommended, as it would require a long trip for the technicians and still would not necessarily provide good launch conditions, in addition to safety concerns.

More work is required to determine how launches with radiosondes that unroll after release can be successfully performed. Use of a portable enclosure, such as one made from canvas, to provide shelter from the wind will make filling easier, but finding how and where to launch so that the balloon isn't caught by a downdraft from the ship remains an issue that needs to be investigated. It is recommended that MAGIC personnel go on another leg to attempt to resolve this issue before the deployment commences.

A sheet used to provide an enclosure for filling the balloon.

Small balloons were used in an attempt to find good launch locations, although without success.

Balloons in high winds. This sequence of photos shows a balloon launch during a very strong wind period on February 19 when relative winds were ~20 m s^{-1} directly over the bow. We found no good places on the bridge during such conditions.

Balloon Launches

Date	UTC	Relative wind		Payload	Location[1]	Comments
		Speed (m s^{-1})	Direction (°)			
2012-02-12	18:00	14	30	Potato	Port side, cabin deck[2]	
2012-02-12	22:00	15	30			Popped balloon
2012-02-12	22:00	15	30	Acorn squash	Port side, cabin deck[2]	Went into ocean
2012-02-13	19:00	9	25	Potato	Port wing	
2012-02-14	00:00	9	50	Avacado	Port side near bridge house	
2012-02-14	18:45	11	330	Turnip	Starboard wing	
2012-02-14	19:00	8	340	Rhutabaga	Stern, starboard	
2012-02-15	02:30	9	310	Potato	Starboard wing	
2012-02-15	19:30	7	290	Sweet potato	Starboard wing (about half way out)	
2012-02-17	21:00	21	5	Sweet potato	Starboard wing	
2012-02-19	22:00	18	0	Cayote squash	Port wing	Squash broke up when launching
2012-02-19	22:30	18	0	Potato	Port wing	
2012-02-20	00:00	18	20	Potato	Port wing	Ship turned for us
2012-02-20	18:00	18	340	Sweet potato	Starboard wing	
2012-02-20	18:20	15	340	Acorn squash	Starboard wing	
2012-02-20	18:40	15	340	Acorn squash	Starboard wing	
2012-02-20	23:00	17	330	Sweet potato	Stern, starboard	
2012-02-20	23:10	17	330	Potato	Stern, starboard	
2012-02-22	19:10	17	310			Popped balloon
2012-02-22	19:15	17	310	Turnip	Starboard wing	

[1] All launches from bridge deck unless otherwise noted
[2] Cabin deck is one level below bridge

Meteorological Measurements

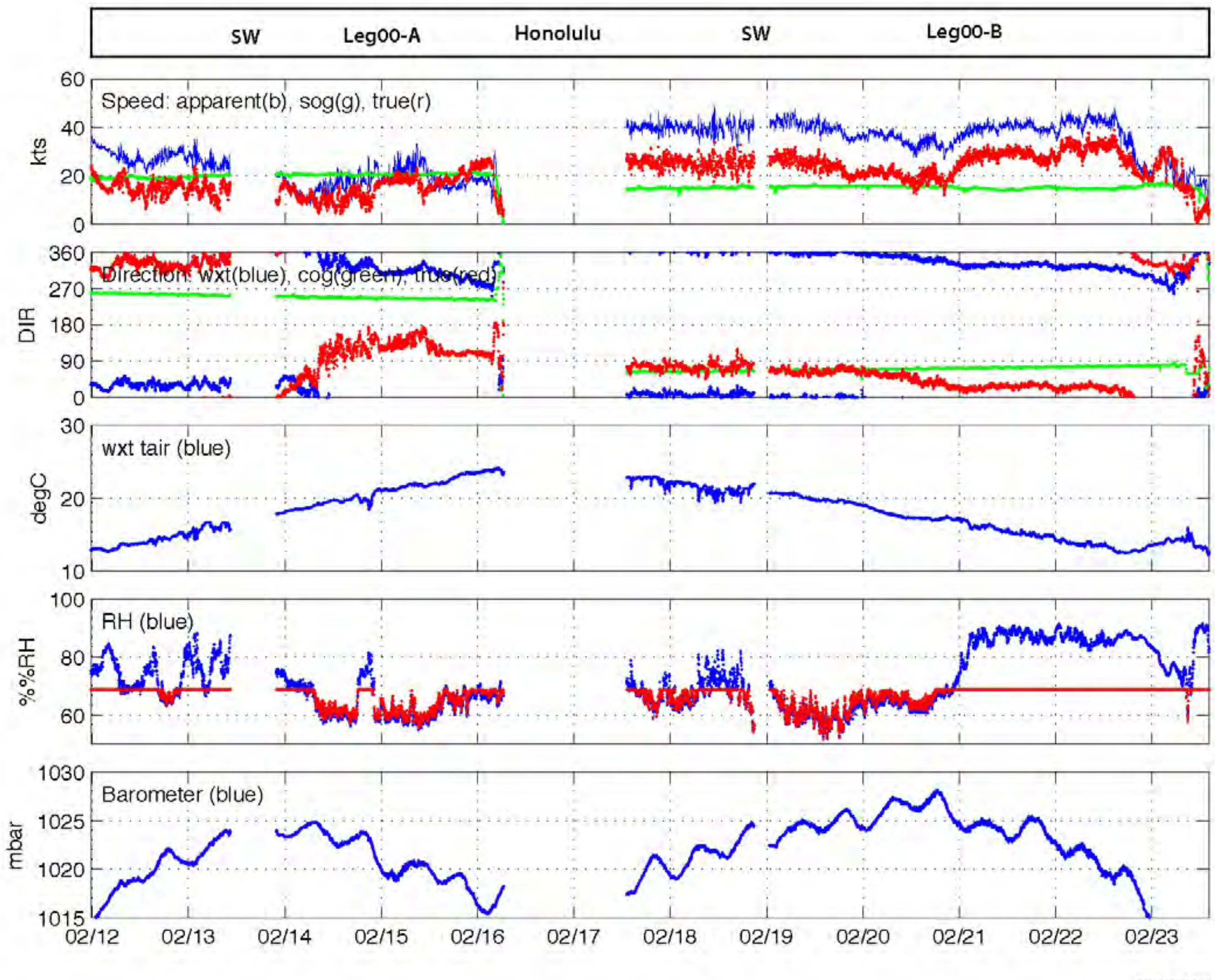
The mast meteorological package, consisting of the crossbar mounted on the mast with wind monitors WM1 and WM2, a WXT, and a T/RH sensor, worked very well for the entire cruise. There were brief periods of missing data (labeled “SW,” for “software,” on the graphs below) on Leg00a (2/13) due to a software update and on Leg00b (2/18) due to a ship’s system power issue, but these should not be a problem during MAGIC, when Uninterrupted Power Supplies (UPS) will be employed. As wind directions from WM1 and WM2 were not zeroed in Los Angeles, they did not provide correct values on Leg00a, but they were aligned in Hawaii. However, they exhibited extremely good agreement, even at relative wind speeds of more than 20 m s^{-1}, except for a short time near Hawaii when the wind was directly along the crossbar and distortion around the radome (or from a perched bird) may have affected the readings. The met system was checked in Hawaii by climbing the mast and inspecting it, and it was found to be secure. The wind speed from WM2 was not working during the cruise, probably because of a minor wiring issue. The RH signal from the T/RH sensor appeared to cut off at ~69% RH, although below this value there was good agreement in relative humidity between the T/RH sensor and the WXT. The rest of the instrumentation worked well and there was very good agreement among different instruments measuring the same quantity. No interference with ship’s radars was observed during the leg.

Data were processed by the following procedures. Raw data, taken directly from the sensors, were merged and interpolated as necessary to 1-s time series and these were further averaged to 2-min time series. Vectors were vector-averaged, and standard deviations were computed.

The apparent winds are the winds measured by a wind sensor mounted on the ship. The wind direction follows the meteorological convention in that it is the direction from which the wind blows, measured from the bow in a clockwise direction. In a fast moving ship the apparent wind is almost entirely over the bow, as shown by the wind rose above. True winds were computed using the ship heading (HDG) to rotate the ship coordinate system to a geographic coordinate system with *x*-axis to East, *y*-axis to North and *z*-axis up, yielding the relative wind vector. The ship speed vector is determined from the speed over ground (SOG) and the course over ground (COG), determined by the GPS. This is subtracted from the relative wind vector to yield the true wind speed. The ideal true wind is computed each second and vector averaged for the standard two-minute mean. The heading, HDG, must come from a gyro compass or inertial navigation system (INS). When the ship is steaming at a good speed, COG is a good approximation to HDG and the resulting error in true winds is small, although when the ship is on station, or moving slowly in a strong wind or current, this might not be such a good approximation. During Leg0, two-minute averages of the difference between HDG and COG varied between ±4°, depending on the incident winds and currents. With this in mind the COG might be substituted for the HDG in case that is not available, but this should be done with caution.

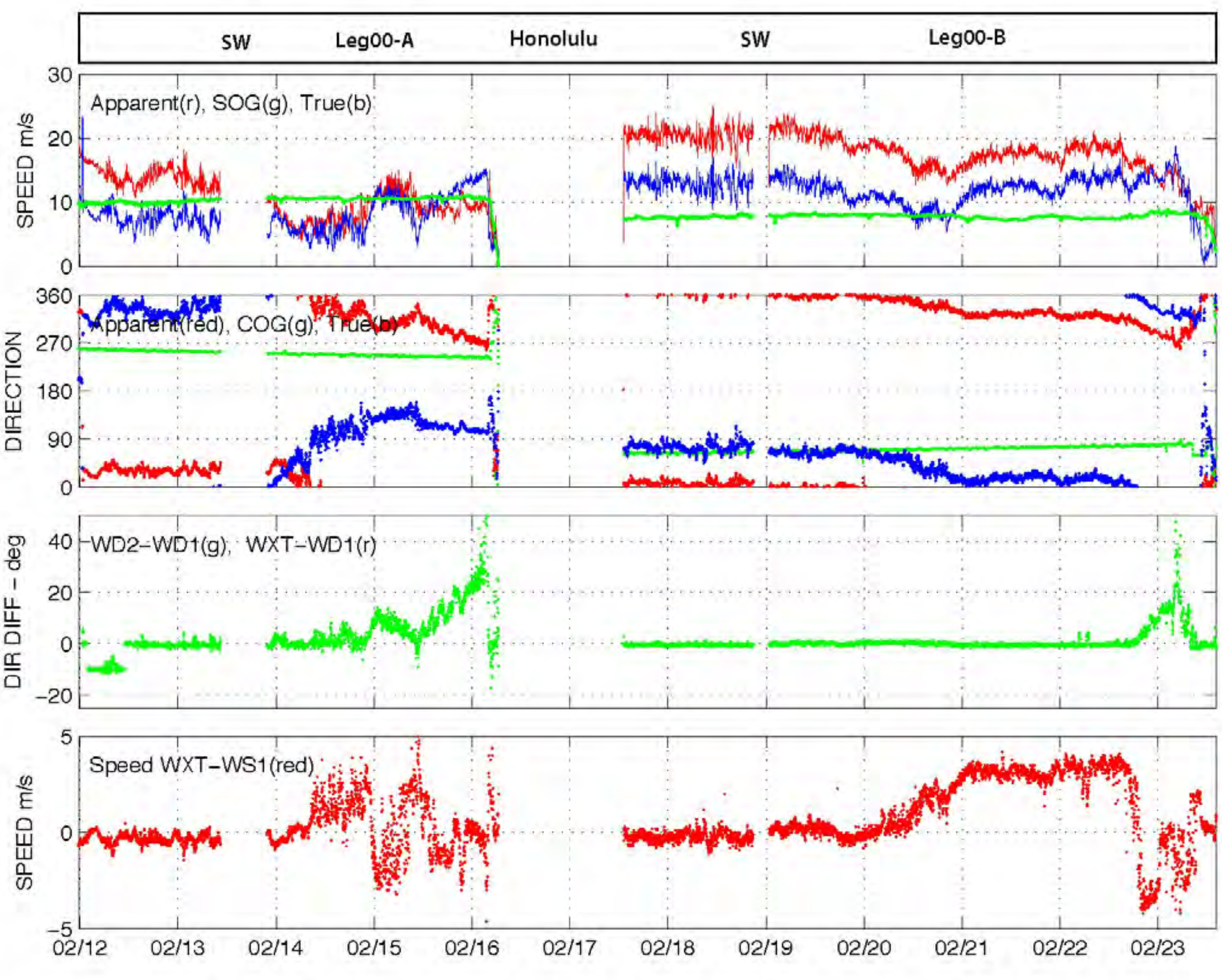
A summary plot of the meteorological data is shown below. The top panel shows the apparent wind speed, the GPS speed over ground (SOG) and the computed true wind speed. The SOG shows the ship averages about 20 kts (~10 m s^{-1}) going to Hawaii and returns more slowly, approximately 15 kts (~7 m s^{-1}). During Leg00a, the apparent winds were light, <10 m s^{-1}, and the apparent direction moved from directly over the bow to starboard, 20º (NE) to 300º (NW). During the return, the apparent winds were much stronger.

The second panel shows the apparent wind direction, the GPS course over ground (COG), and the computed true wind direction. The third panel shows the air temperature measured by the T/RH sensor and the WXT. These two measurements agreed to better than 0.2°C, which is reasonable considering the WXT had been several years without a calibration and the output of the WXT had a resolution of only 0.1°C. The fourth panel shows the relative humidity (RH) measured by the T/RH, which was calibrated at the ARM SGP facility, and by the WXT, which was out of calibration. Nevertheless the RH measurements agreed to 1.2%. RH is a crucial measurement for flux estimates and great care should be made to ensure uncertainties better than 1%. The final panel shows the barometric pressure as measured with the WXT; this was in good agreement with the ship's barometer on the bridge. At a height of 35 m above sea level, the barometer is corrected by +4.4 mbar for sea level pressure. Note the diurnal variations in the barometer from the atmospheric tides. The pressure during the cruise was quite high (> 1015 mb) because of the central Pacific high.



Top two panels show the apparent winds at the mast top (blue), the ship vector (speed over ground, sog, and course over ground, cog; green) from the GPS, and computed true winds (blue). Apparent winds during most of Leg00b were near ~20 m s^{-1} (40 knots) and directly from the bow. (1 knot = 0.514 m s^{-1} = 1.85 km hr^{-1}; 1 m s^{-1} = 1.95 knots). Third panel shows air temperature measured by WXT (blue); fourth panel shows relative humidity measured by T/RH sensor (blue) and WXT (red); and lowest panel shows barometric pressure measured by WXT (blue).

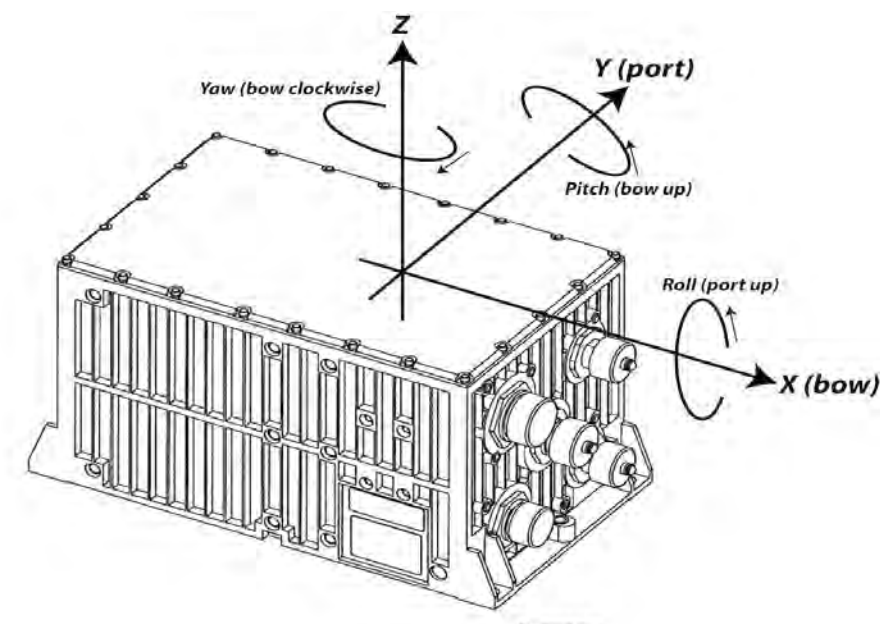
One goal of the Leg0 cruise was to assess the severity of the air flow distortion around the mast so that an algorithm by which the true, undisturbed wind can be derived. The measurements show indeed that there may be a pronounced distortion. Wind speed and direction differences between the two wind monitors at the ends of the met package (WM1 and WM2) are shown in the third and fourth panels of the figure below (the top two panels are repeated from above to show the nominal speeds and directions). The difference in directions increased considerably to almost 30º, and the speeds showed considerable variability, ±3 m s^{-1}. After 02/21, again with 320º wind direction and with extremely high apparent wind speeds (>20 m s^{-1}), the difference exceeded 4 m s^{-1}, or 20%. Clearly, use of multiple wind sensors and conditional sampling will be necessary to ensure only unperturbed winds are measured.



Comparison of measured winds for different apparent winds. Top two panels show apparent (relative) winds, i.e., measured (red) and calculated true wind (blue) speeds and directions, and ship vector (GPS speed over ground, SOG, and course over ground, COG, in green). Third panel shows wind direction differences at each end of the cross arm, i.e., from WM1 and WM2 (green), as a measure of flow distortion. Strong direction differences of as much as 30º occurred when the apparent winds come from port along the axis of the package, probably due to distortion from the radome. In the last panel, the wind speed difference between the WXT and the port wind monitor WM1 (red) shows pronounced overspeeding at the WXT for apparent wind directions from the port bow (300-350º).

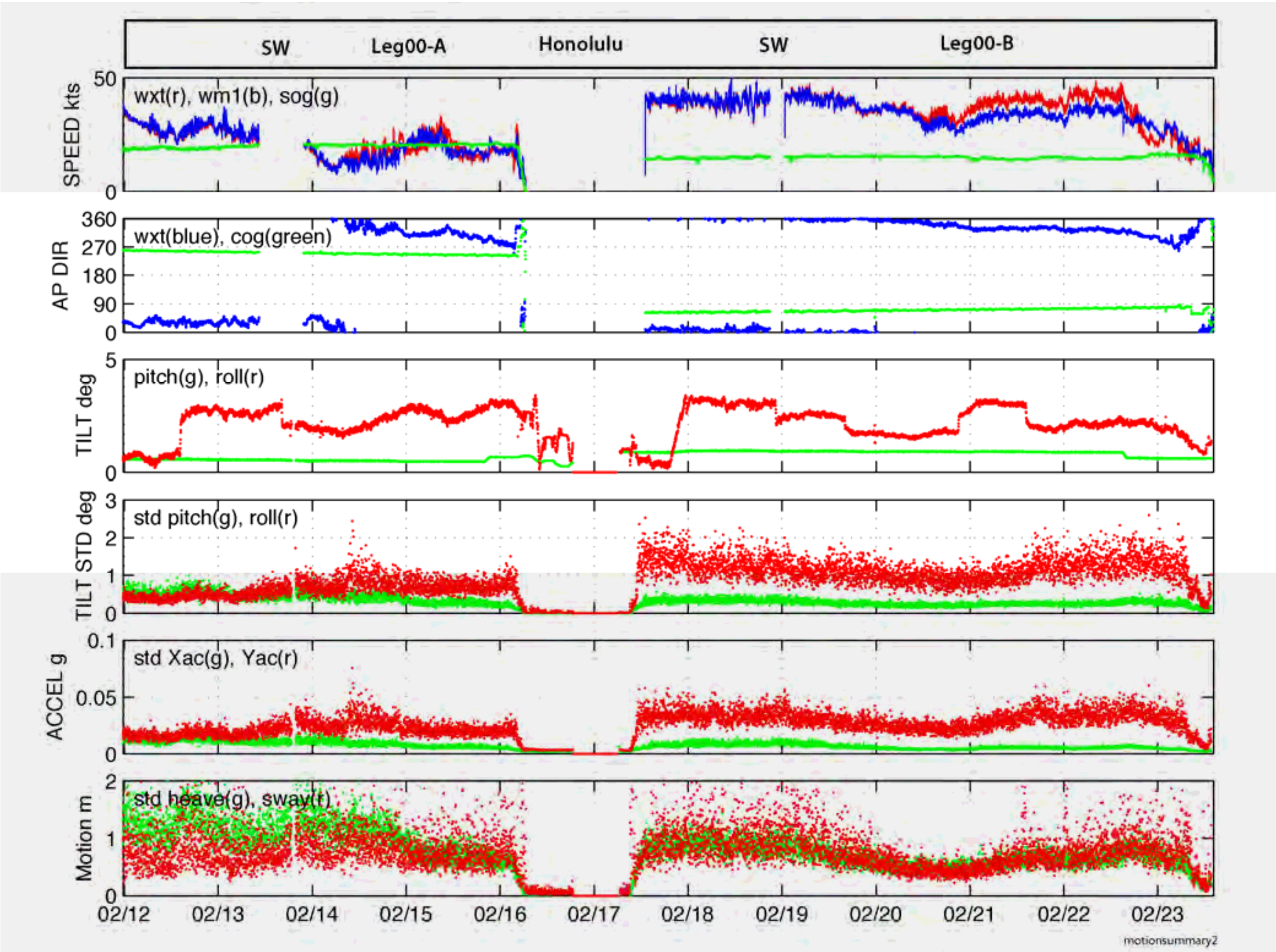
Ship Motion

The SeaNav motion system provided 10 Hz measurements of year/month/day, hour/min/sec (UTC); lat/long/altitude; roll/pitch/yaw (rotations around the three axes: along the ship length–port up positive, across the ship starboard to port–bow up positive, and vertical-positive clockwise, respectively); surge/sway/heave (displacements from the *x*-, *y*-, and *z*-axes, corresponding to along the length of the ship–positive forward, across the ship from starboard to port–positive to port, and along a vertical axis–positive up, respectively); velocities along the three axes; angular velocities of roll/pitch/yaw; and accelerations along the three axes (including gravity). The quantities will be required for numerous other instruments during MAGIC.



SeaNav coordinate system: yaw angle corresponds to a compass direction and is thus a left-handed rotation. Pitch and roll angles, bow up and port up, respectively, are standard right hand convention.

The Seanav data were streamed into a Linux PC as binary data. The 10 Hz raw data were saved as hourly binary files (2 MB/hr). Every day the binary files were converted to a single text file (173 MB) for processing. A PERL program performed a quick quality check and filter, then the text files were converted to Matlab binary "mat" files for processing (84 MB/day). In addition to the original 10 Hz data, 1 Hz data to be used with meteorological data (especially computation of true winds) and 2-min averages (with standard deviations) were produced. In computing averages, it was assumed that the motions are small so that simple averages of angular variables such as yaw are accurate.

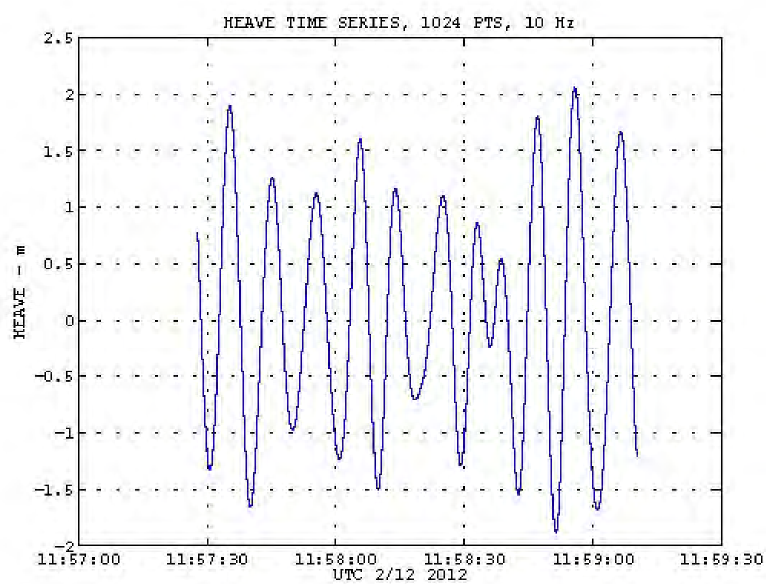


Time series of ship motion data for the Leg0 cruise from two-minute statistics from the raw (10 Hz for SeaNav, 1 Hz for winds, 0.2 Hz for GPS) samples. Leg00a was from Los Angeles to Honolulu; Leg00b was the return. The two gaps in the data, SW1 and SW2, resulted from the system being down for software upgrade and testing. In the top panel, WXT (red) and WM1(blue) are wind speed sensors; "sog" (green) is "speed over ground." In the second panel, "AP DIR" is apparent direction from the WXT (blue); "cog" is "course over ground" (green). In the third and fourth panels, pitch (green) and roll (red) mean and standard deviations are shown. In the fifth panel, the standard deviations of accelerations in the along-ship (X) direction (green) and across-ship (Y) direction (red) are shown. In the final panel, the standard deviations of heave (green) and sway (red), i.e., the displacements in the along-ship and across-ship directions, are shown.

Each data point on the above graph is a mean or standard deviation of 10 Hz data over a two-minute period. During Leg00a, the ship is headed toward Hawaii with a heavy load. During the Leg00b, the ship is returning to Los Angeles with mostly empty containers. The response of the ship to the sea and winds is different for these two legs. The apparent wind speed from two sensors (WXT and WM1) and the speed over ground (sog) are shown in the top panel, and the apparent wind direction from the WXT and the calculated course over ground (cog) are shown in the second panel.

The mean pitch and roll, and their standard deviations, are shown in the third and fourth panels, respectively. These quantities are important for many measurements in the AMF2. During Leg0 the mean pitch was small and steady at approximately 0.6°, with standard deviation generally <0.7°; the minimum and maximum values were -2.74° and 3.32°, respectively. The roll was not steady, and the mean exhibited large excursions, ±3°, with a standard deviation generally <0.7°; the minimum and maximum values were -5.4° and 8.6°, respectively. All ships, including cruise ships, can list (i.e., experience a nonzero roll value) due to weather conditions (wind pressure or incident waves) or operational adjustments to the ship's ballast. During Leg0 the mean roll was always positive (i.e., port up) and experienced several abrupt changes, probably caused by routine shifting of ballast fuel and water. These non-zero mean values will affect instruments that are fixed to the ship, and these instruments may not experience views to zenith if the amplitude of roll is not greater than the mean value. The abrupt changes in the mean value of roll means that it would be necessary during the deployment to change the orientation of instruments that require zenith pointing. One possibility which will allow this is to install these instruments with the ability to change their orientation, such as might be done with an adjustable jack under one side, to offset the man roll so that on average they point to the zenith, thus minimizing the effect of list. It would appear that this correction would not have to be made more than once per day.

The standard deviation of pitch and roll (the RMS amplitude of the tilts over the two minute period) are called simple "sea." These are what one generally feels and what causes sea sickness. The standard deviations of the accelerations and the displacements (heave and sway) in the two horizontal directions were generally steady and small.



Typical time series of heave (vertical displacement).

The graphs above and below show typical time series of heave. The ***Spirit*** has a dominant heave frequency of 0.1 Hz, meaning that the period is ~10 s. This is generally sufficiently slow that motion sickness is unlikely. An amplitude range of ±2 m corresponds to a vertical motion of near 1 m s^{-1}. This motion has implications for Doppler radars and for vertically-pointing instruments.

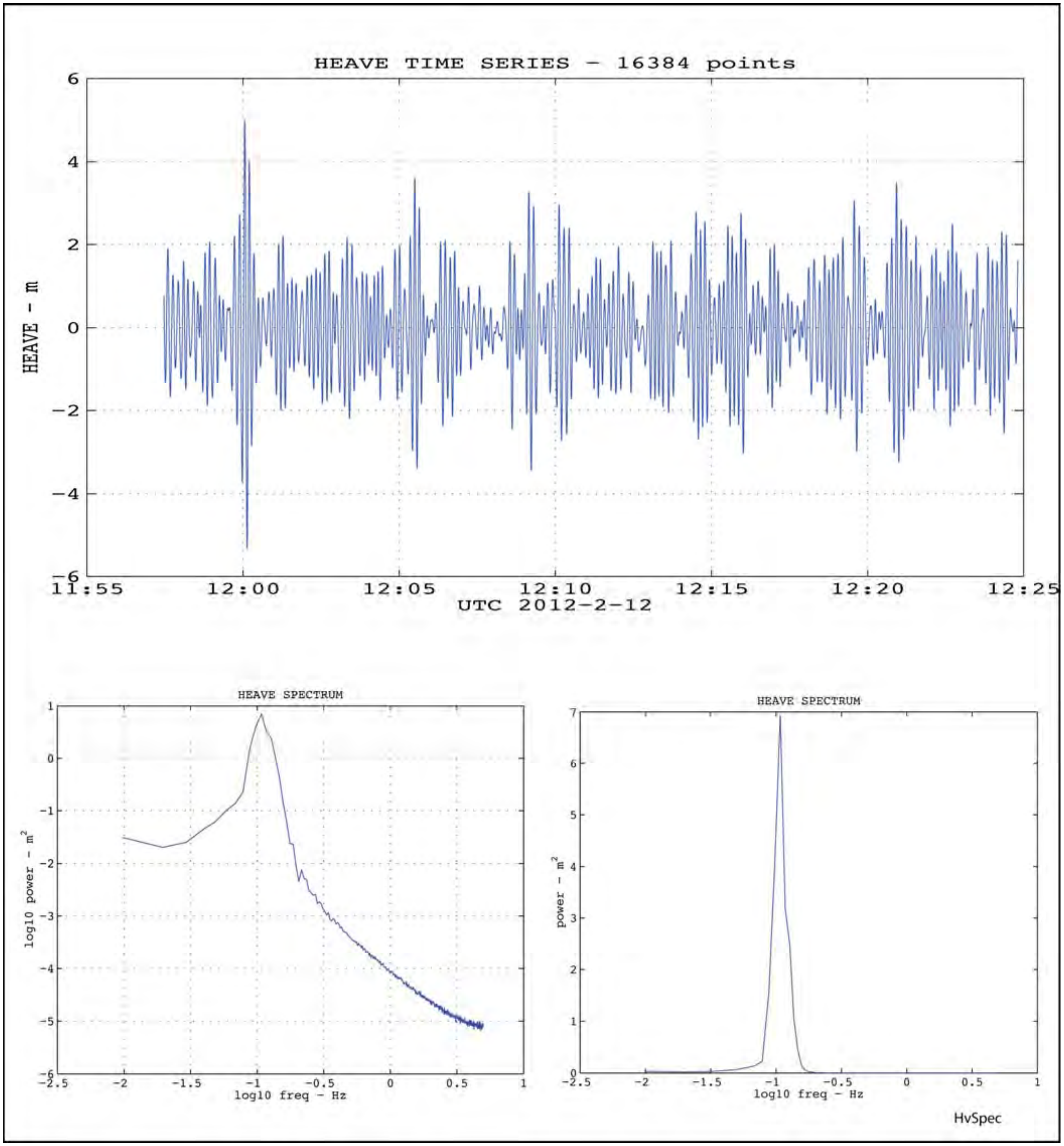
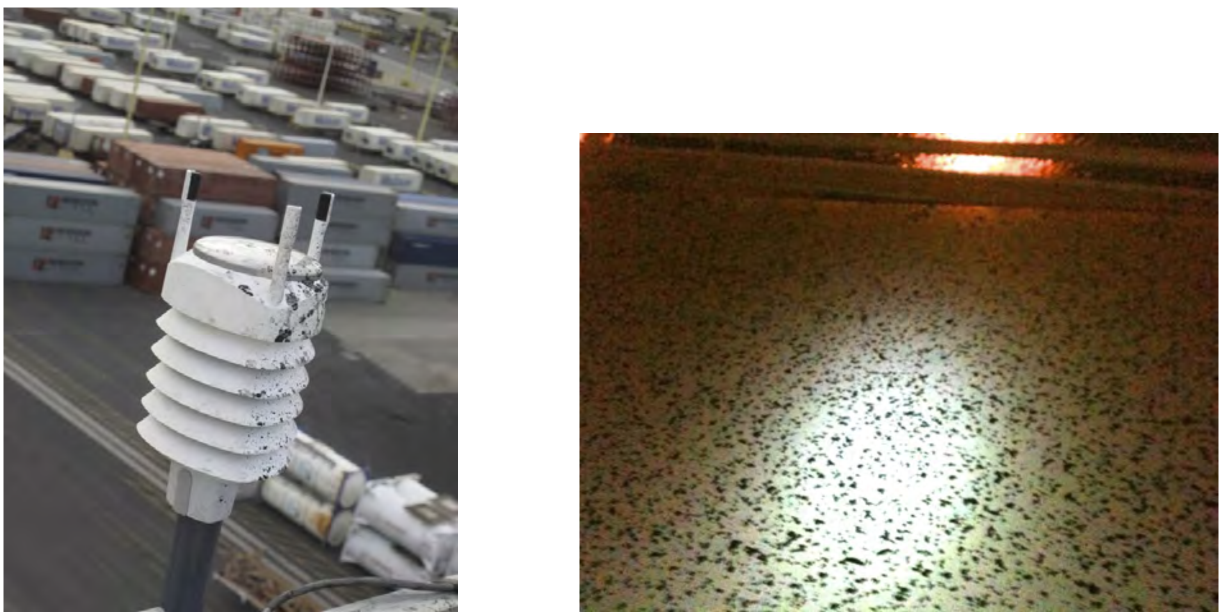


Figure 2. Typical time series power spectrum of heave. Spectral smoothing is done by averaging 10 1024-point spectra. A strong peak at 0.1 Hz (10 sec) is present in all spectra and in different wave fields. Bottom panels show the power spectrum of the heave time series on both logarithmic and linear scales.

Soot

The ship blows soot out of its stacks daily as a routine maintenance procedure, and this can result in dirty conditions and possible containimination of optics and aerosol instrumentation, especially when the apparent wind is from behind. On the night before leaving Los Angeles, during light winds, the entire bridge was covered with soot. Such occurrences can be expected, and will require cleaning of the optics and aerosol filters, and logging such instances, during which aerosol measurements may not be worth using. Special consideration must be given to the mast equipment. We had initially thought that the mast would be a good location for some optical instruments, but after observing the soot this was discounted, as it is necessary that there be easy access to these instruments while underway. Technicians should be advised to exert caution and to ensure that they are not tracking this soot back to living and working quaters. During conditions of headwinds, the path to the stern becomes extremely dirty with soot and somewhat slippery, requiring caution as well. Efforts should be made to communicate with the chief engineer before legs to see if advanced notification of this procedure can be obtained.



The event shown here occurred during the night in port before we departed. The entire ship was coated by soot. Sensor on left was on the mast, ~15 m above the bridge deck.

Looking down at the deck when covered with soot (left) and when clean (right).

Horizon ***Reliance*** cleaning its stack. Picture taken from the ***Spirit***.

Spray and Corrosion

The bridge deck, on which the vans will be located, is approximately 20 m from the water line (the exact value depending on ship loading). During Leg0 there was no indication of spray on the bridge, even under extreme wind and sea conditions. The crew said that this does occur, however, and that there is residue built up. This will require that optical instruments are cleaned routinedly. Additionally, corrosion may be an issue and care should be taken to ensure that to the extent possible instruments are protected from marine air.

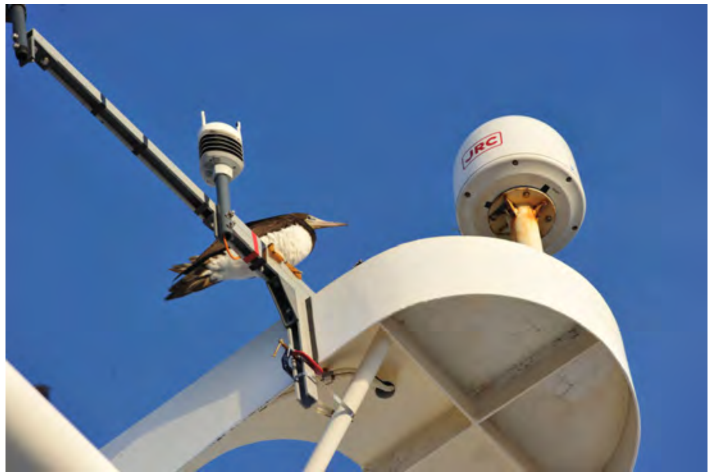
Bridge roof of ***Spirit***.

Smoking

There are crew members who smoke on the bridge, but it is unlikely that this will be noticable or cause problems with or contamination of aerosol measurements.

Birds

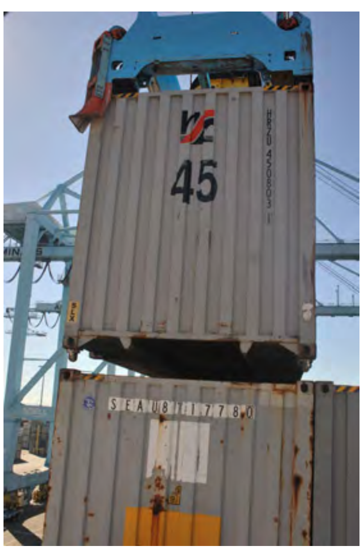
Few birds were seen during Leg0, but near Hawaii one perched on the meteorological system, during which time the leeward wind vane was seen rotating rapidly about its vertical axis. Turbulence generated by the bird (the wind was directly along the axis of the meteorological system at this time; the leeward vane was rotating) could have been a contributing factor. Some of the other instrumentation (such as the aerosol inlet) might provide perches for birds.



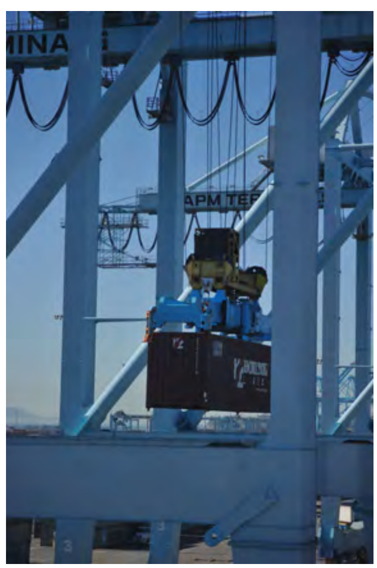
Brown Booby (*Sula leucogaster*) on mast meteorological package

Loading of Containers

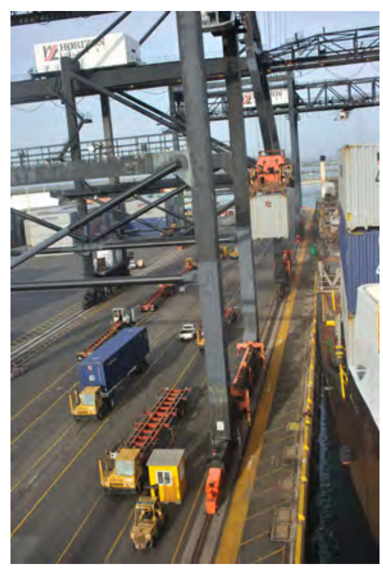
We were able to observe the cargo being loaded in both Los Angeles and Honolulu, with the same cranes (and probably the same crew) that would load the AMF2 SeaTainers onto the ship. Some of the containers experienced considerable impact when being loaded, and it is likely that the AMF2 will also. Thus, extreme care should be expended into securing everything inside, and thought should be given to loading delicate equipment separately.



Los Angeles



Los Angeles



Honolulu

MAGIC Route

The ***Spirit*** follows a great circle between Los Angeles and Honolulu and back. The distance along this route (one way) is approximately 4100 km long. The ***Reliance*** runs a rhumb line (a straight line on a Mercator projection such that longitude lines are intersected at a constant angle) from Los Angeles to Honolulu, and a great circle on the return. The rhumb line route is ~18 km longer than the great circle route. The distance between these two routes at their midpoints is 85 km. This distance is such that parts of the routes might fall in different grid cells for models, but it is unlikely that conditions between the two routes will ever differ appreciably.

Safety

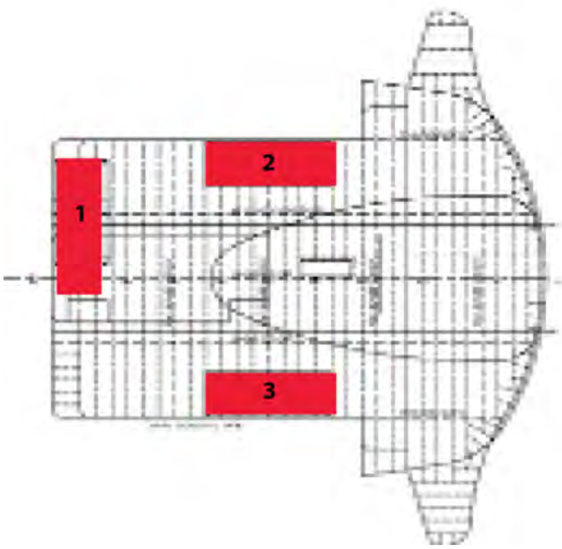
Horizon takes safety very seriously and all Horizon procedures for safe operations were followed while on Leg0. These procedures required that hard hats and steel-toed shoes be worn on the bridge deck when the ship was in port (as containers were being loaded and unloaded during those times). We were required to sign a HHA (hold harmless agreement), and ARM personnel will also be required to sign this. There were no incidents during Leg0.

Signs posted in ***Spirit***

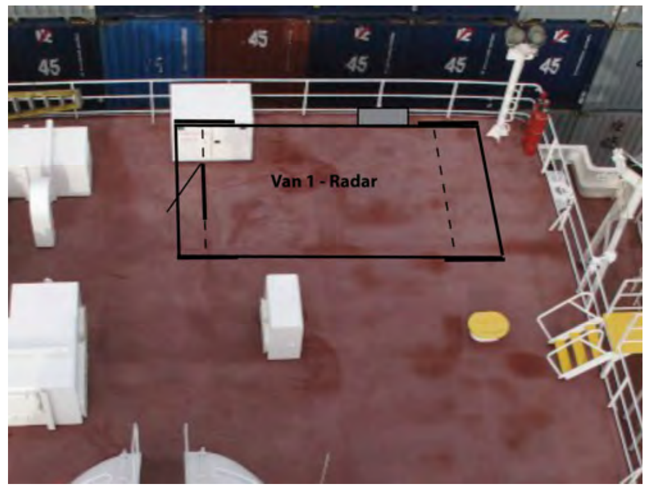
Safety concerns during the MAGIC deployment include slips, falls (including overboard), bumping into objects, and being hit by unsecured or falling objects. Ship motion, slippery decks (due to soot or other factors), wind, weather, and fatigue could possibly contribute to hazardous situations, but there were no obvious concerns that would require more than common sense.

Location of SeaTainers

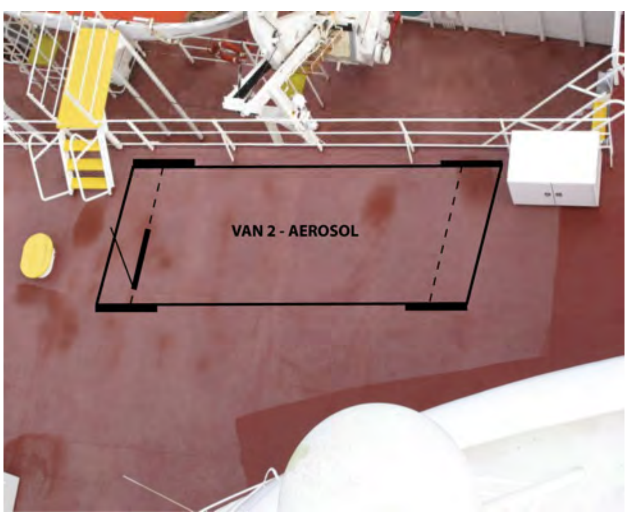
During Leg0 we discussed the layout of the SeaTainers on the deck with Captain Rankin and he marked possible locations with chalk which we measured to ensure that there was plenty of access to emergency equipment, life rafts, etc. There were several obstacles and containers that he said could easily be moved. It appears that three SeaTainers can be accommodated in the locations shown below. We discussed power requirements with the Chief Engineer; no serious issues were apparent. We also discussed possible installation of a salinograph with the Chief Engineer.



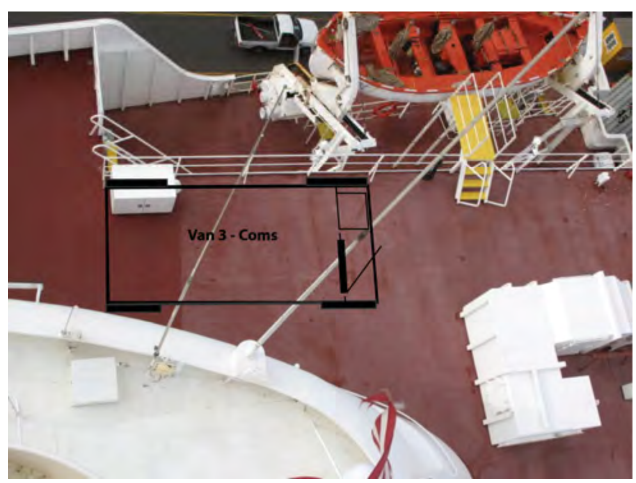
Layout of the Spirit bridge deck, with forward to the right.



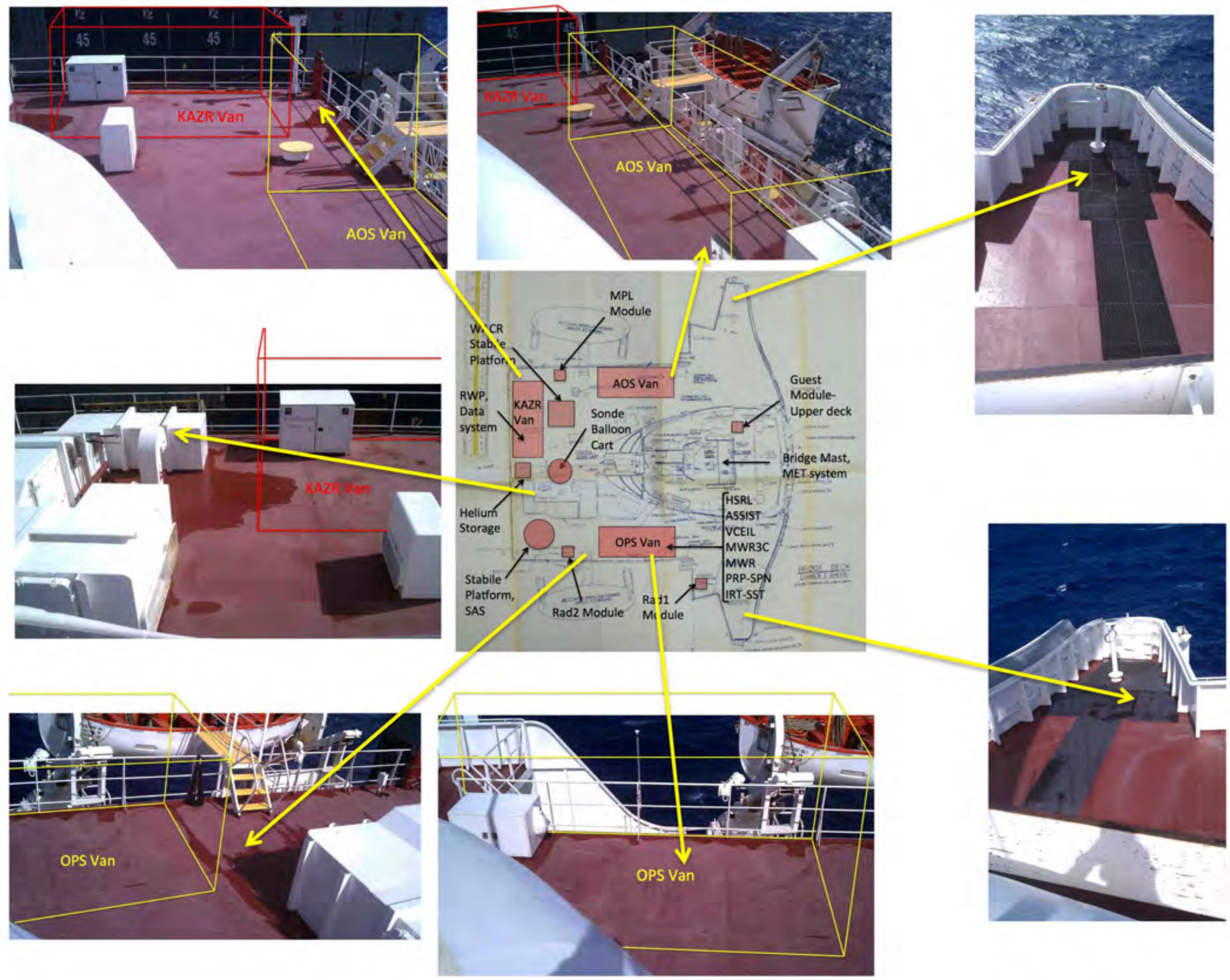
The location for van 1, with the radar, and ASSIST is athwart ships along the aft rail of the bridge deck. There will be good views to the horizon from the top of this van. The storage box will need to be moved. Note the rail stanchions are spaced 60 +/- 0.25" Facing back.

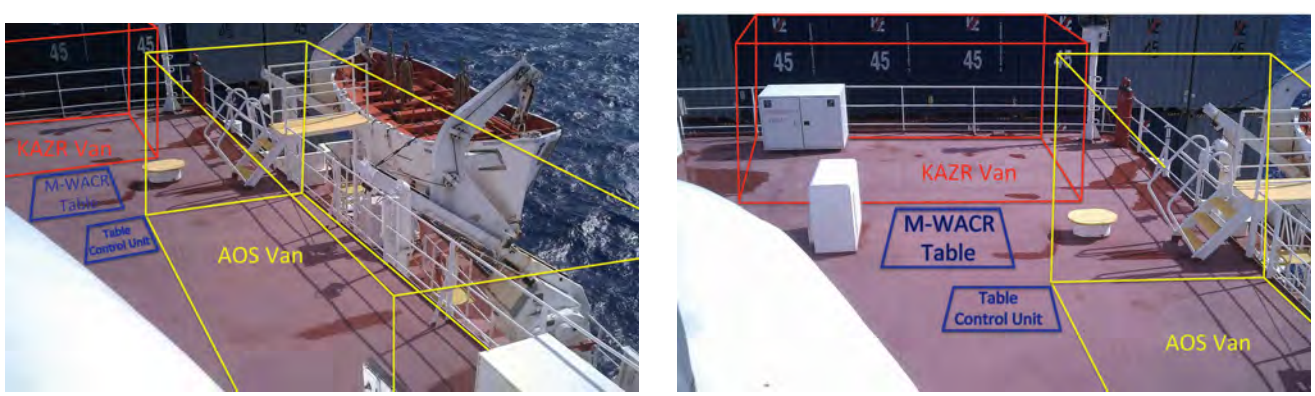


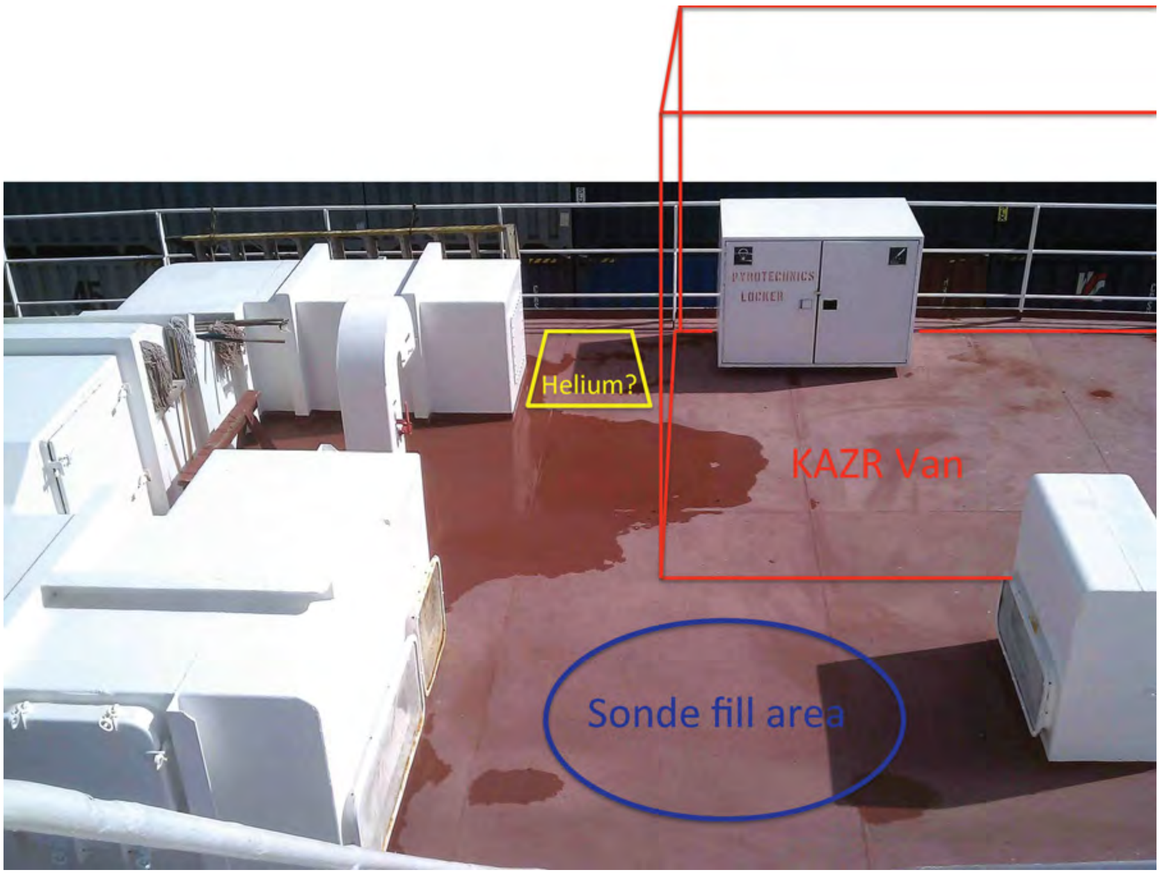
The Van 2, Aerosol, will be mounted along the port rail. Note rail stanchions are 60 +/- 0.25". The bow is to the right.

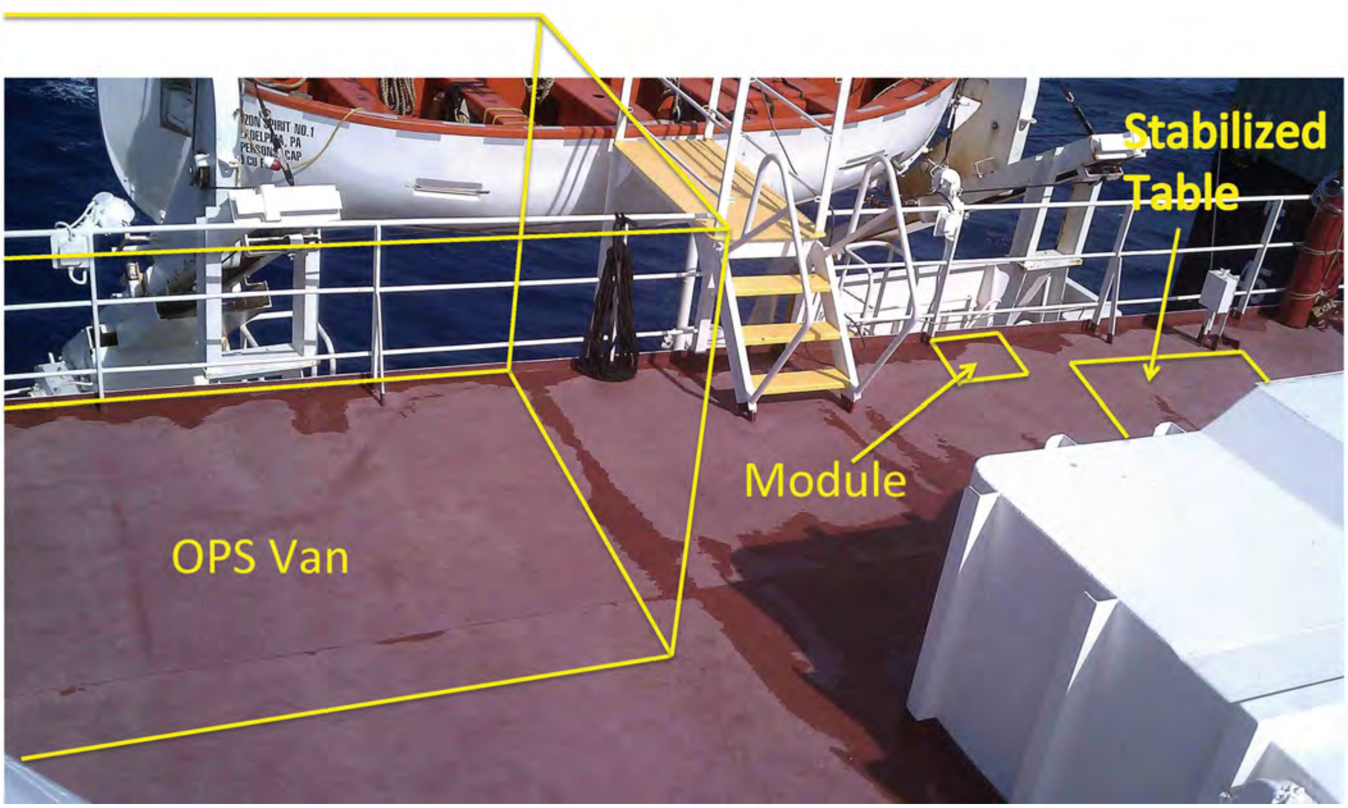


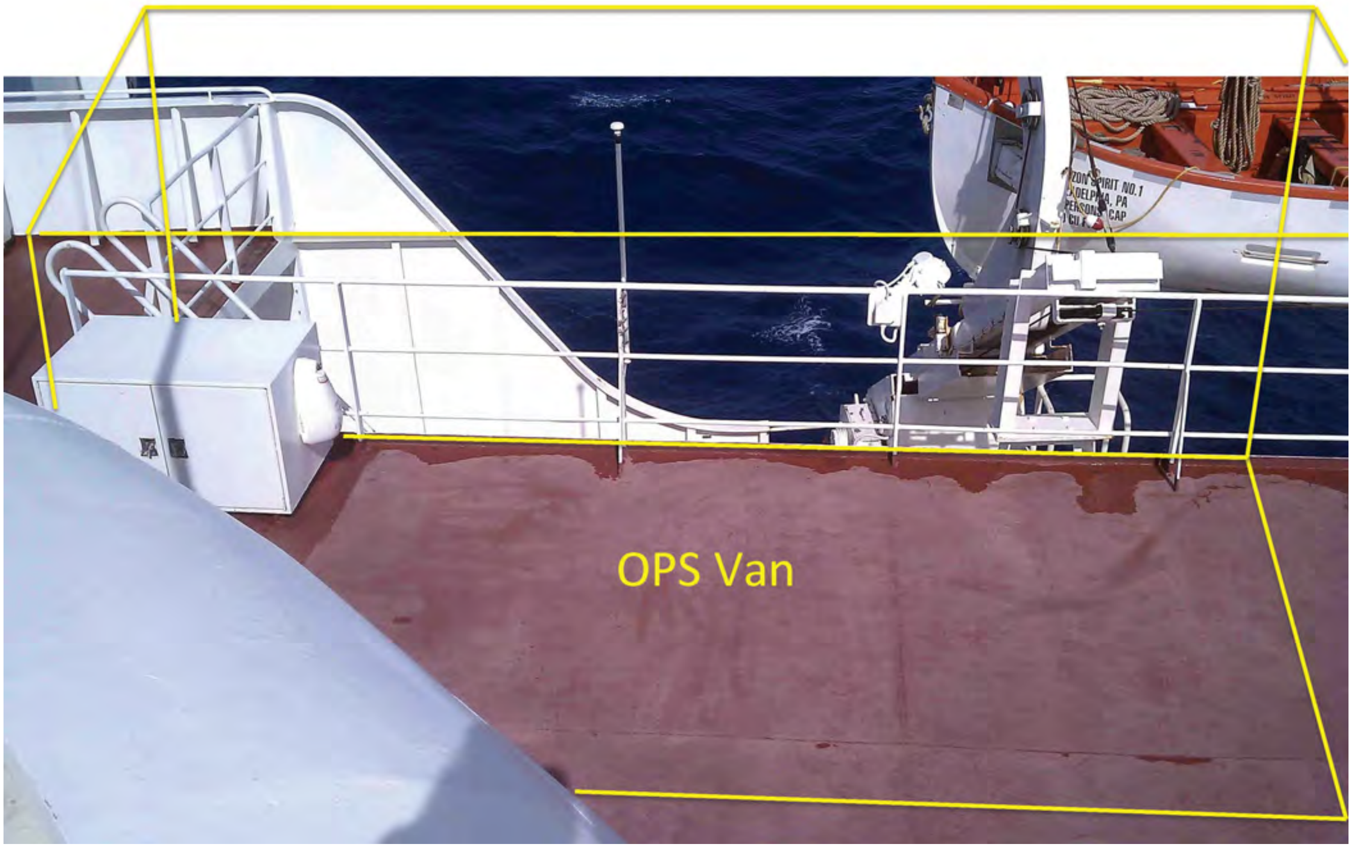
Van 3, Coms, will be located on the starboard rail The storage box will need to be moved. Bow is to the left.


KAZR Van
AOS Van
MPL Module
RWP, Data system
Sonde Balloon Cart
Guest Module- Upper deck
Bridge Mast, MET system
Helium Storage
OPS Van
HSRL
ASSIST
VCEIL
MWR3C
MWR
PRP-SPN
IRT-SST
Stabile Platform, SAS
Rad2 Module


KAZR Van
M-WACR Table
Table Control Unit
AOS Van

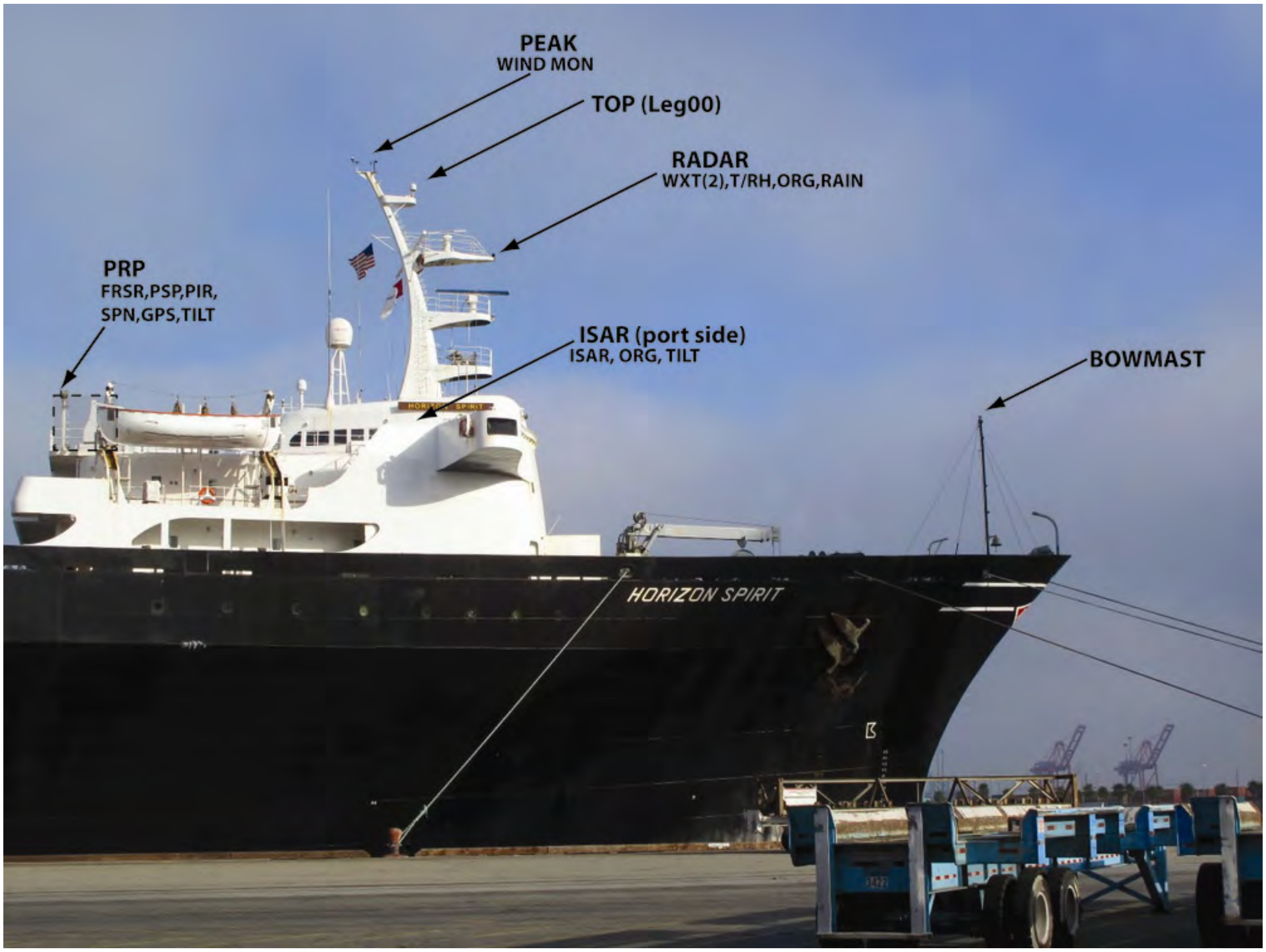

PYROTECHNICS
LOCKER
Helium?
KAZR Van
Sonde fill area


Stabilized
Table
Module
OPS Van


OPS Van

Possible MAGIC Meteorological Measurement Locations

The information gathered during the preliminary two week cruise on the ***Spirit*** was very useful in evaluating locations for meteorological measurements. We determined that our first choice for these measurements, that used for the met system, was not optimal, but we found locations that would be better and where we propose to install them during MAGIC. These are shown in the figure below.



The **TOP** location was used during Leg0 and is not recommended for the final system, as there was a surprising amount of flow distortion around the small radome there. Although it is possible to obtain good measurements of apparent winds by using two wind sensors and selecting the windward sensor, we found good alternatives where distortion should be virtually non-existent.

The **BOWMAST** is an ideal location for measuring undisturbed air flow. The bowmast is hinged and can be lowered in order to attend to the sensors. However, access to the bow is restricted, especially during port maneuvers, and the bow is subject to heavy spray. In the final deployment we will plan to make use of the peak and radar platforms with redundant instrumentation.

The **PEAK** is at the very top of the mast. Currently an R. M. Young wind monitor is located there (on the ***Spirit***), but it hasn't operated in three years. During Leg0 we tested the sensor and confirmed that the cable is bad. We discussed with the Captain Rankin the possibility of removing that sensor and replacing it with ARM sensors. We propose to install a small platform at that location with a wind monitor, which will provide measurements of wind speed and direction. The wind monitor is also very useful as it will allow the technicians to see the direction of the apparent wind for balloon launches, for instance.

The location named **RADAR** is a large landing that holds the ship's small radar but has a long forward extension that is unused and will easily hold instrumentation. This is a good location to deploy a second HMP45 (T/RH) sensor and rain sensors. Rain is an important measurement; rain under marine stratus is often light drizzle yet it is important indicator of breakup. The rain sensor for the WXT is not totally proven and there is some indication from prior cruises that it does a poor job with drizzle. However, the miniORG is an exceptionally sensitive rain detector. The ISAR system has a miniORG but it would be a good idea to add an optical rain gauge at the tower top. The RADAR platform is a good location for this. An R. M. Young siphon rain gauge would provide a good quality check on the other rain detectors.

The location called **PRP** shown here will be at the top of the radar van at the aft part of the bridge deck, almost at the top level of the containers. This location has almost complete exposure to the sky yet is convenient for technicians to clean the optics with minimal safety risk.

The **ISAR** will be on the port rail in the same location as in the diagram where it is shown on the starboard side. The ISAR uses a Heitronics IR radiometer in a self-calibrating system to measure the sea surface skin temperature (SST). Included in the basic ISAR system is a miniORG rain gauge, a GPS, and a tilt sensor.

Summary and Recommendations

The goals set out in the Leg0 Cruise Plan were accomplished During Leg0. We became familiar with the ***Spirit*** and its operations, and the information gathered will prove valuable to the success of MAGIC. Several important facts were learned that were not expected and could not have been foreseen.

Weather balloon launches were attempted from several places aboard the ship, and although for the vast majority of these attempts the balloons remained airborne, they were not optimal launches and they might not have been successful if the balloons had radiosondes attached. It was determined that stern is not a good location for such launches for several reasons discussed earlier. However, considerable work still needs to be done to find a location and procedure for filling and successfully launching balloons with radiosondes attached under the wind conditions experienced. It is likely that the bridge deck will provide such a location, but this should be determined well before MAGIC starts. It is recommended that another voyage on the ***Spirit*** by MAGIC/ARM personnel be undertaken soon to investigate how successful launches can be accomplished.

The ship's motion was characterized using the SeaNav during Leg0 and these data were presented. Heave, the vertical motion resulting mainly from pitch, had a dominant frequency of 0.1 sample rate of 10 Hz will probably provide sufficient accuracy for all measurements. Typically pitch and roll varied nearly sinusoidally over a few degrees. These resulted in vertical motion at the bridge (where the AMF2 containers would be located) of several meters, and vertical velocities of 1 m s^{-1} or more. Such motions will have implications for Doppler radars and other vertically-pointing instruments. Often the ship had a mean nonzero roll which changed several times during the cruise due to adjustments to the ship ballast. This offset will affect instruments that require zenith views, although if they are deployed with the ability to change their orientation, such as might be done with an adjustable jack under one side, then they can be made to go through zenith as the ship rolls, as discussed above.

Meteorological conditions were measured, and the met system proved robust and functioned well. Wind speed and direction was measured at several locations and some ship effects were determined to exist. Based on this knowledge, good locations for deployment of meteorological instrumentation during MAGIC were found. These were discussed above. It is recommended that a computer display be placed on the bridge so that ship's crew and MAGIC personnel can readily see meteorological conditions. Strong winds were encountered during Leg0, and these can also be expected during many if not most legs.

We found the crew to be interested and enthusiastic about our project. Several times they offered to help, and their assistance and advice was, and will be, of great value. However, it is imperative that ARM/MAGIC scientists and technicians show utmost respect for our hosts. ARM/MAGIC personnel are essentially being invited into their home as guests and, as guests, we should act in such a way that we will be invited back. Our goal should be to minimize the shipboard impact as much as possible. We cannot expect them to help us do our jobs. We need to be knowledgeable about the ship's operations and routines such as meal times, which often correspond to shift changes. Thus, for instance, every effort should be made to schedule meals so as to not interfere with crew schedules. Above noted all, we should never forget the basic rules of respect. Ship riders should always remember that they are professionals involved in the collection of important scientific information and they not only represent themselves but also the ARM program. It is also imperative that sensitivity be used when engaging in discussions with ship's crew, especially with regard to topics such as global warming or climate change. MAGIC is investigating climate, not climate change—an important distinction. It is recommended that training procedures be instituted for all ARM and MAGIC personnel, both technicians and scientists, who will be on board during the deployment. Information used by other institutions that have scientists and technicians on voluntary observing ships is available and can be used as a template.

Soot can be a problem for optics and other instrumentation. We will want to establish communications with the Chief Engineer to see if we can get daily times for when the stacks will be cleared. Such notification will provide time to cover optics, etc., if wind conditions are such that this will be necessary. Optics should not be placed on the mast, a location we originally thought might be a good one. After reviewing the configuration of a fully loaded ship, and after experiencing a “soot incident,” it is recommended that every effort be made to mount the optical equipment in exposed yet accessible locations, such as the top of one of the vans. These locations will probably provide excellent sky coverage with little shading or sky occlusion. As the marine environment is harsh, corrosion due to marine air should be given serious consideration, and marine hardening of instruments will be necessary.

Acknowledgements

Tim Martin of Argonne National Laboratory prepared the SeaNav system for this cruise. His data collection software worked well with little training.

Jeremiah Reynolds assisted in preparing and installing the mast meteorological system. His diligent and hard work was greatly appreciated.

Barry Pettyjohn and his staff at Dockside Machine provided support in loading and offloading all of our equipment.

Captain Rankin and all the crew of the ***Spirit*** were extremely supportive and interested in our work. It was a pleasure to ride with each of them.

Mike Bohlman and Don Watters of Horizon Lines have been supportive and helpful in the entire MAGIC project, and we thank them and Horizon for their hospitality and support.