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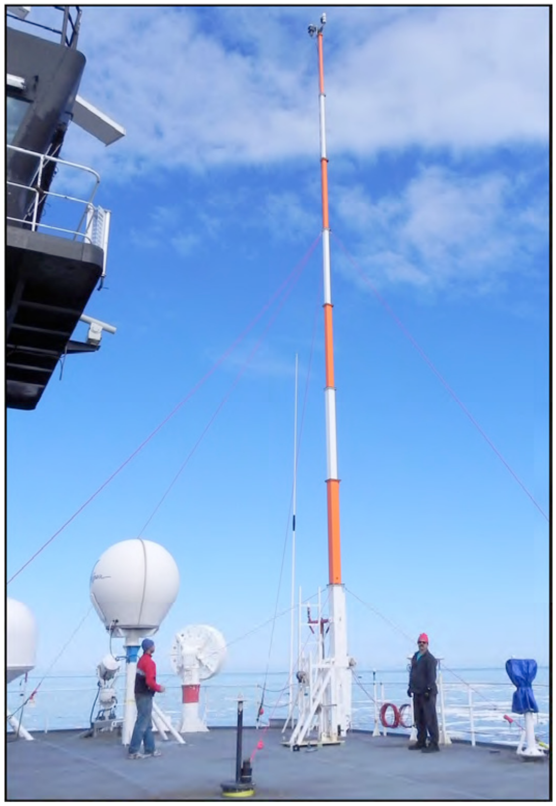

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Chapter 7

The Telescoping Mount for Advanced Solar Technologies (T-MAST)

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Abstract

The solar reference data collected with an *in situ* AOP observation must be at the highest point possible on the measurement platform and free from obstructions and reflection sources. Although this is easy to state, it is not always a straightforward operation to implement. On many research vessels, the highest spaces are usually already occupied with the ship's equipment and such spaces are frequently inaccessible at sea (because of safety concerns). Consequently, AOP observations are frequently made with the solar reference located in a less than ideal location. A quantification of the consequences of improperly siting the solar reference are presented along with field evaluations of a new Telescoping Mount for Advanced Solar Technologies (T-MAST). Field trials show T-MAST is an excellent solution for this problem while providing access to the sensor(s) for cleaning, servicing, and dark current measurements.

7.1 Introduction

Whether made using above- or in-water light sensors, the most significant problem with making AOP measurements is minimizing the perturbations from the sampling platform the light sensors are deployed on or from. In the case of large platforms, the reflections from the structure above and below the water line brighten the ambient light field, whereas the shadow cast by the platform darkens it. The latter affects instruments that are deployed directly into the shadow, but also those in near proximity to it, because photons that would normally be scattered into the adjacent unshaded waters have been blocked by the structure causing the shadow. In all cases, corrections can be produced, but they require significant modeling efforts involving a large dynamic range in solar illumination, sky conditions, and viewing geometries, which is not practical unless a platform is used for extensive periods of time. The simplest expedient, therefore, is simply to avoid the perturbation areas by sampling outside them.

In the case of the sampling platform being a research vessel, the in-water problem is easily solved by floating the sampling system far away from the ship and collecting data as the profiling package falls freely through the water column (Fig. 66). Currently, there is no reliable mechanism for floating an above-water system away from a ship, so the measurements are usually made on the bow of the vessel, which is a point reliably far away from the superstructure with good fields of view of the water. In both cases, the solar reference measurement is made at the highest point possible free from obstructions and reflection sources. If properly implemented, this avoids the platform perturbations, but it does not deal with all the perturbations. The data collected by the free-fall profiler is also subjected to self-shading, the correction for which is based on the in-water properties, the size of the sensors, and the above-water solar illumination. Indeed, the absence of a self-shading problem with the above-water approach is one advantage for this type of measurement.

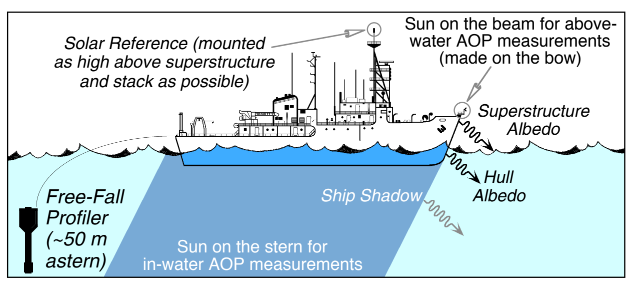

Fig. 66. A schematic representation of the platform perturbations associated with a ship and deployment locations for AOP measurements.

How far a free-fall profiler needs to be deployed away from a ship is a function of not only avoiding the light field perturbation, but also of incorporating the influence of the ambient currents, which can carry the instrumentation back into the perturbation field. A sensible compromise is to use a distance of approximately 50 m for a large ship and about 30 m for a smaller vessel. Kite-shaped profilers tend to *pop upwards* when they are hauled in, so the

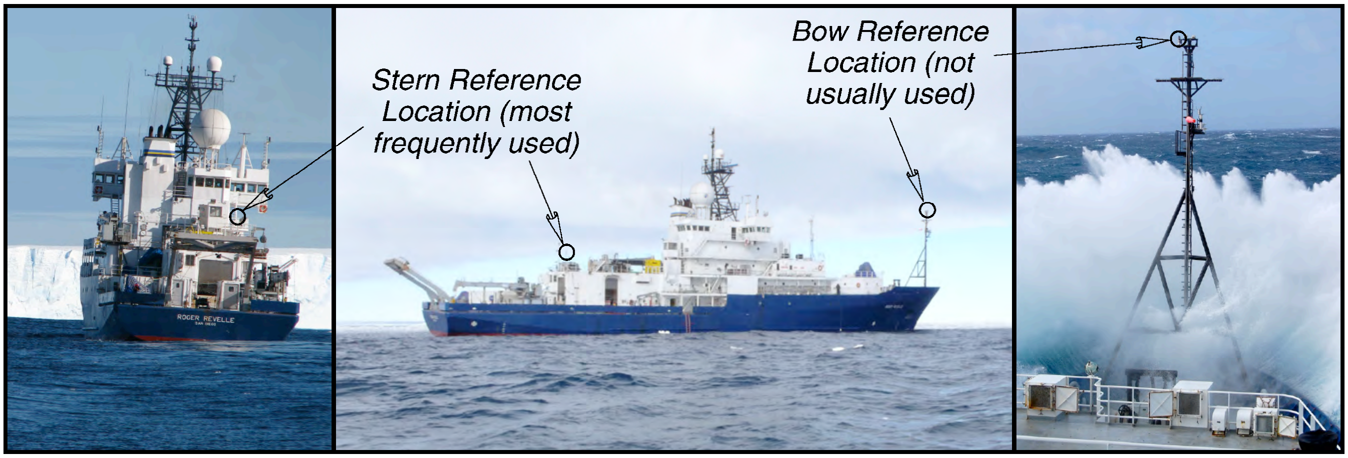

Fig. 67. Stern (left), side (middle) and bow (right) views of the R/V *Roger Revelle* showing a typical location for a solar reference towards the stern and the preferred (but more difficult) location on the bow. Although not as high as the tallest mast on the ship, the latter is substantially above and far away from the most substantial part of the superstructure, and provides significant shelter for the reference even in high sea states.

relative position of the profiler when it returns to the surface after being retrieved usually gives a good indication of local current effects. If the profiler returns not too far from where it was released, the distance from the ship need not be adjusted; if the profiler returns much closer to the ship, then a farther release distance is likely appropriate.

Very large, so-called *ocean-class*, vessels are needed for many types of oceanographic research. Arctic field campaigns, for example, require large icebreakers. A significant difficulty with icebreakers is the oversized box-shaped superstructure that is placed forward of the typical location in ocean-class research vessels. It is very difficult to measure the solar irradiance—which is a requirement for AOP measurements—on large vessels, because the light sensor needs to be far away from the light-field perturbations caused by the associated superstructure and the contamination caused by the ship's exhaust stack. Usually, this means the solar reference needs to be mounted on the highest point of the ship. Unfortunately, on many research vessels, the highest spaces are usually already occupied with the ship's equipment and such spaces are frequently inaccessible at sea (because of safety concerns).

The CVO participated in CLIVAR I6S to not only fill in the current undersampling of high latitudes, but also to understand what problems might be degrading AOP data and, hopefully, provide solutions. Although the R/V *Roger Revelle* provides many advantages for oceanic sampling, it is not very attractive for optical measurements: the highest point on top of the main mast is not readily available to scientists, and the bow mast cannot be accessed at sea. Consequently, a solar reference is usually mounted in a less than ideal location (Fig. 67).

The importance of properly siting a solar reference is quantified by comparing the bow and stern references on CLIVAR I6S. The bow sensor is assumed to provide the best data (i.e., the closest to truth), because it is mounted at the highest elevation and the farthest from superstructure perturbations, so the RPD (5) is computed as

$$\psi = 100 \frac{E_d^S(0^+,\lambda) - E_d^B(0^+,\lambda)}{E_d^B(0^+,\lambda)}, \qquad (14)$$

where E_d^B and E_d^S are the global solar irradiances measured by the bow and stern sensors, respectively.

Figure 68 presents the RPD between the bow and stern solar references. If properly sited, two solar references should agree to within the calibration uncertainty (about 2.5%). The stern sensor exceeds this threshold about 49% of the time and has only a few examples wherein all the data agree with the bow sensor to within 2.5%. In many instances, the differences are quite large, worse than ±15%.

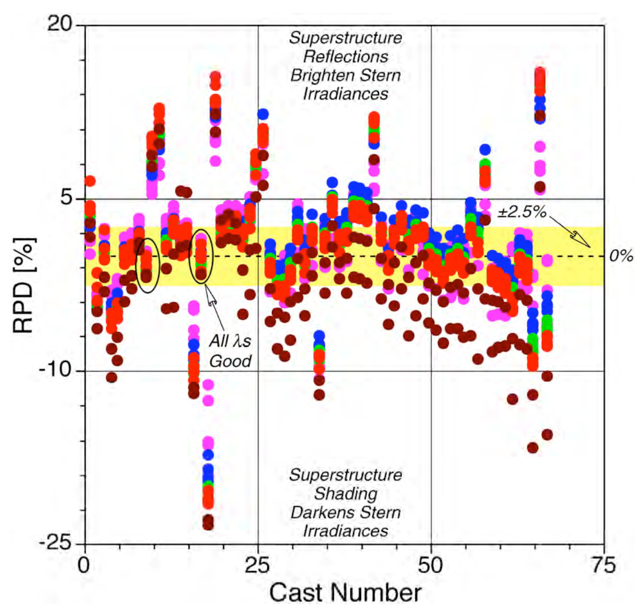

Fig. 68. The RPD between the bow and stern solar references on the R/V *Roger Revelle* (the former is the reference in the RPD calculations).

The most troubling aspect of the Fig. 68 results, however, is the introduction of a persistent bias as the ship steams farther towards the South Pole and the recurring overcast conditions lead to a steady worsening in negative RPD values. The occasional sunny stations show up as large positive excursions. This type of significant bias can have a seriously detrimental effect on data products that use the solar reference data for normalization, e.g., $R_{\mathrm{rs}}(\lambda)$ or $\left[L_W(\lambda)\right]_{\mathrm{N}}$.

7.2 Description

For ships that do not have or permit access to high superstructure locations free of significant perturbations, the only solution for the data bias problem is to either a) use contaminated data, or b) install a device that will elevate the solar sensor to a height were contamination is not possible. The latter is a potentially difficult requirement on a large vessel, because of the height of the superstructure. There are also the difficulties of wind loading, ice loading, ship motion, and the corrosive environment of conditions at sea. If a device is going to be practical, it needs to be easy to install and easy to take down—especially if foul weather is forecast.

The solution for the data bias problem presented here was to have a telescoping mast currently being used by the US military (Fig. 69) and have it modified for use on a ship. The masts are made by Floatograph Technologies (Silver Spring, Maryland), and are available in a wide variety of sizes. The masts are also offered in two different classes of ruggedness: heavy duty (steel) and light duty (aluminum). Installations to-date include 50 ft and 60 ft steel masts, and a 25 ft aluminum mast. The 50 ft and 25 ft masts were used on the Canadian Coast Guard Ship (CCGS) *Amundsen*, and the 60 ft and 25 ft masts were used on the United States Coast Guard Cutter (USCGC) *Healy*.

Fig. 69. A telescoping mast, with surveillance equipment on top, is mounted to the bumper of a humvee.

The installation of the telescoping masts on the CCGS *Amundsen* took place in 2009 and was in cooperation with the *Laboratoire d'Océanographie de Villefranche* (LOV) in France and the University of Laval in Canada as part of the Malina† field campaign to the Canadian waters of the Beaufort Sea. The installations on the USCGC *Healy* took place in 2010 as part of the Impacts of Climate on Ecosystems and Chemistry of the Arctic Pacific Environment (ICESCAPE‡) expedition to the U.S. waters of the Chukchi Sea.

For both the Malina and ICESCAPE campaigns, the EM25 telescoping mast was installed on a smaller vessel that was launched from the ice breaker (Fig. 70). The small boats deployed from the CCGS *Amundsen* and USCGC *Healy* were rather similar, and both could have the bow lowered for immediate access to the sea. The latter was useful for deploying free-fall optical sensors and was critical for finer-scale sampling, because the icebreakers and the large sampling systems deployed from them significantly mixes the upper portion of the water column to a depth of many meters. The small boat, in comparison, was allowed to drift into the areas to be sampled and minimally perturbed the near-surface layer.

Fig. 70. The EM25 telescoping mast extended on the small boat (port side, stern) launched from the CCGS *Amundsen* during C-OPS deployment operations. Note the red cable extending from the port bow and the white streak (top right corner) from the cable being hauled in.

Although a simpler mast arrangement could have been used with the small boats, the deployment and recovery scenarios for the smaller vessels on both icebreakers required a telescoping design to ensure the collapsed height

† Information about the Malina field campaign to the Canadian waters in the Beaufort Sea is available from the following Web site: `http://www.obs-vlfr.fr/Malina/`.

‡ Information about the ICESCAPE field campaign in 2010 to the U.S. waters in the Chukchi Sea is available from the following Web site: `http://www.espo.nasa.gov/icescape/`.

was below the height of the wheelhouse of the small boats being launched.

7.3 Design

The masts described here are models FM50, FM60, and EM25. The former two are heavy-duty steel masts and the latter is a light-duty aluminum mast. The FM masts are rated for 50 lb *payloads* on top of the mast, while the EM mast is rated for a 25 lb payload. All of the masts can be used in winds up to 60 mph and are equipped with *guy lines* to stabilize the upper parts of the mast against bending (Fig. 71). For the deployments described here, the guy lines were only used with the large masts, because the small masts were only extended for the short periods of time associated with the small boat operations.

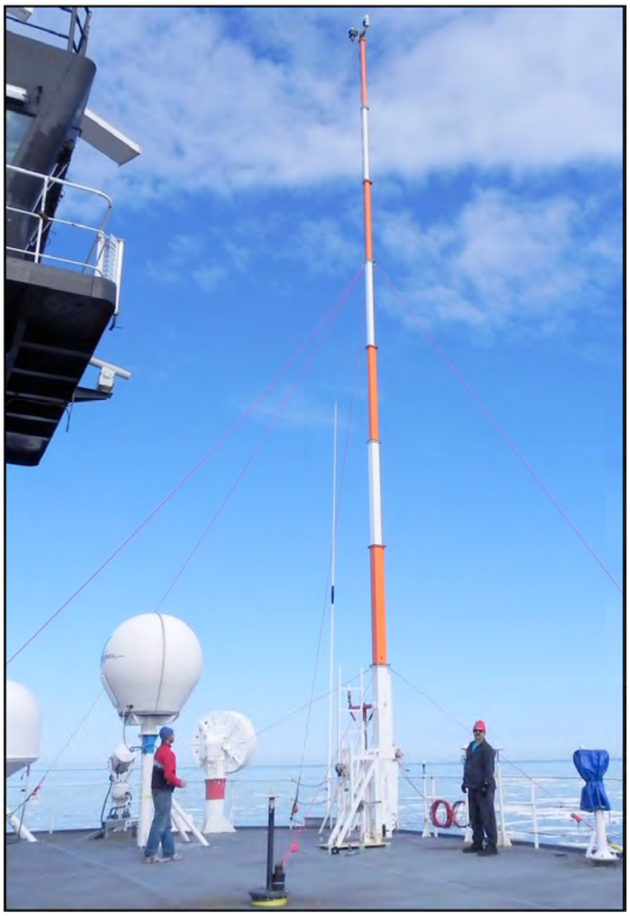

Fig. 71. The FM60 telescoping mast mounted on top of the USCGC *Healy* with Kevlar guy lines attached.

Another distinction of the large masts is they *break down* after being collapsed, so they lie horizontally and fit into a cradle. This places the entire mast at an accessible height, so the sensors mounted at the top can be cleaned or serviced. The latter also permits caps to be put on the radiometers, so dark measurements can be made. The FM60 has a partially detachable ladder as part of the base unit, so it is possible to access the payload when the mast is collapsed, without having to break it down into the horizontal resting position (Fig. 72).

Fig. 72. The FM60 telescoping mast collapsed, with the solar references being cleaned prior to the recording of dark measurements (caps on).

7.4 Modifications and Operation

Technical drawings of the FM50 and EM25 masts are presented in Figs. 73 and 74, respectively. The masts were used primarily as originally designed, but some modifications were made to accommodate their use in the marine environment:

- Some of the hardware was replaced with stainless steel (SS).
- The top stage had a 1 in national pipe tapered (NPT) coupler welded to it, so the standard 1 in NPT 316SS pipe used for mounting solar references in the field could be attached directly to the top of the mast.
- The winches were replaced with an SS marine compliant winch.
- The base of the small EM25 mast was modified, so it could be bolted against standard ship railing using mounting plates that would compress the mast against the railing.

The last item proved important for the small boat deployments during both Malina and ICESCAPE, because the

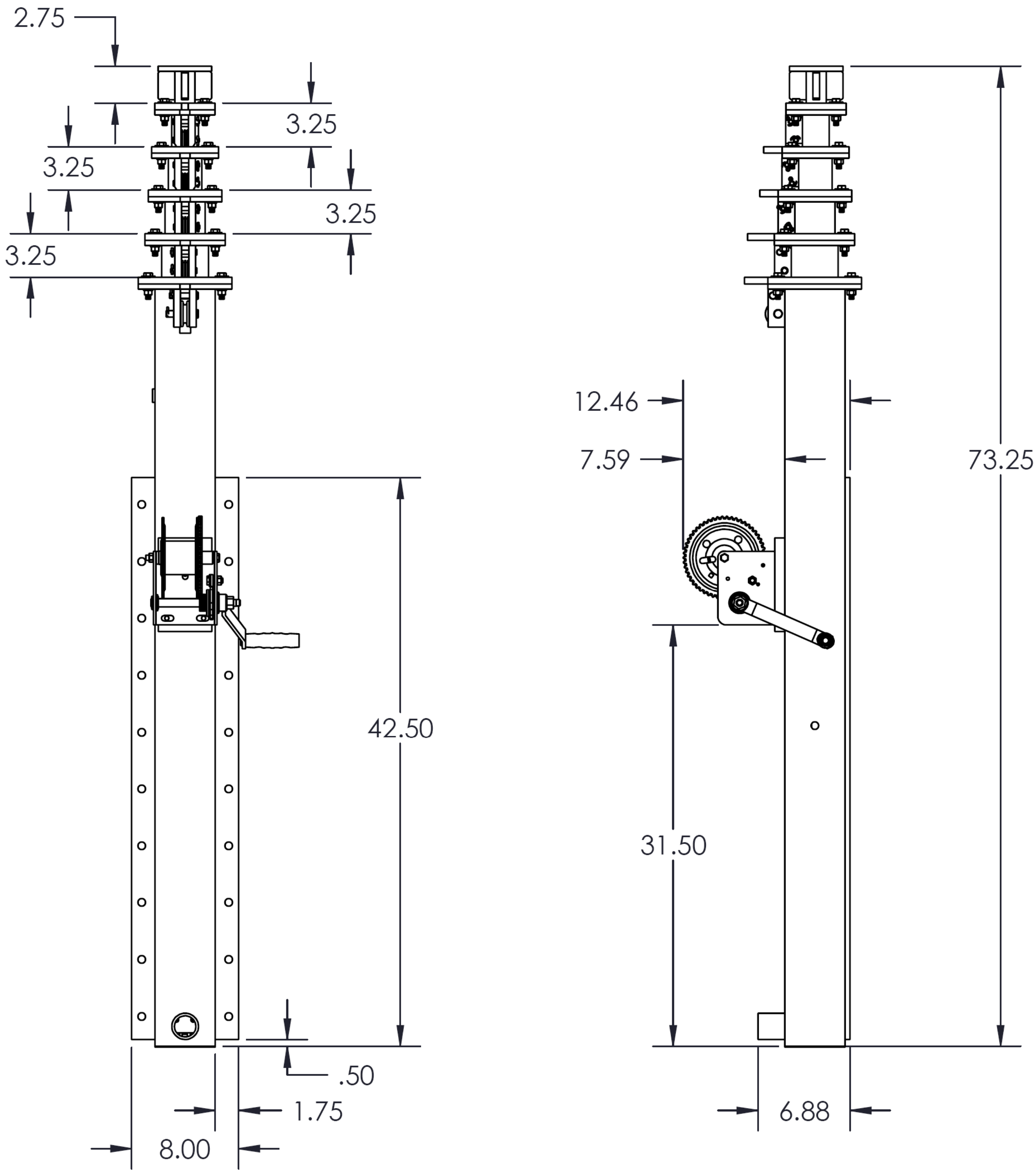

Fig. 73. A schematic of the EM25 mast showing it in the collapsed (stowed) configuration, which has an overall height of a little more than 6 ft, from two different angles. The small pipe pointing to the left and protruding from the bottom of the lowest stage associated with the telescoping mast unit (right schematic) is for pumping hot air into the mast in the event it gets frozen into place as a result of very cold and wet conditions. All dimensions are given in inches.

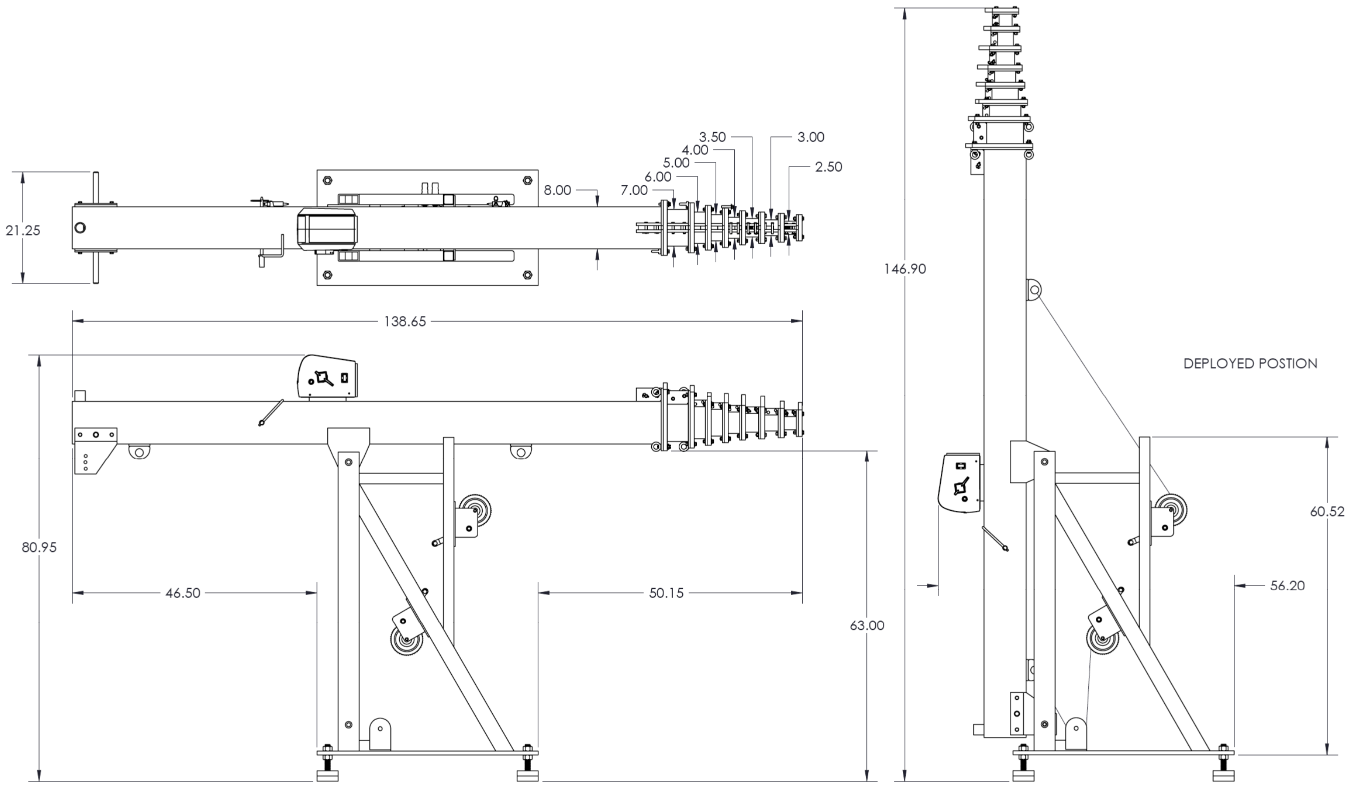

Fig. 74. A schematic of an FM50 mast (with an electronic winch for the extension and retraction functions) showing it in the stowed configuration (left) and the deployed, but collapsed, position (right). As with the EM25 mast, the small pipe pointing to the left and protruding from the bottom of the lowest stage associated with the telescoping mast unit (right schematic) is for pumping hot air into the mast in the event it gets frozen into place as a result of very cold and wet conditions. All dimensions are given in inches.

small boats involved could not be modified in any way without extensive recertification by the appropriate agencies.

The large masts have two extra hand-operated winches associated with the base unit to deploy or stow the collapsed mast into, or out of, the cradle. The primary difference between the FM50 and FM60 models is the addition of a ladder for the FM60; otherwise, the two masts are deployed and stowed in the same fashion. Once a mast is vertically oriented, it is raised and lowered with the hand-operated winch attached to the immovable lowest stage of mast. Cable guides are attached to the sides of the various telescoping stages to ensure the data telemetry cable is properly restrained.

7.5 Summary

At-sea deployments of the FM50, FM60, and EM25 masts during the Malina and ICESCAPE field campaigns established the robustness of the basic design. Throughout both campaigns, there was only one occasion when the combination of relative wind and ship headway was expected to produce winds in excess of the design limit, and the mast was lowered. There were no failures of any part of either system and all deployments resulted in the collection of excellent solar irradiance data. For the large icebreakers, vertical tilts on-station were almost always less than 2.5°, and for the small boats—which are livelier platforms—no solar irradiance data was outside the expected thresholds and all data were usable.

Chaffing of the cable from wind luffing was anticipated in the larger masts, which were left extended for significant periods of time. Split tubing with an inner diameter close to the outer diameter of the cable was used to protect the cable from rubbing against the cable guards mounted on each telescoping stage. In one instance, the tubing slipped below the cable guard and the outer braid of the cable was worn through over the course of many days of wear; the next layer of insulation was not degraded. This event showed the importance of properly applying chaffing protectors on the cabling.