Hull-mounted sea surface measurements in the North Atlantic for RF performance predictions

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***Abstract*—In the fall of 2015, research groups from both the United States Navy and the Royal Netherlands Navy collaborated in a continued effort to validate and refine the extended Radar Threshold Model (RTM) capabilities of the Advanced Refractive Effects Prediction System (AREPS). For several weeks, scientists were given permission to collect both sea surface temperature (SST) and radiosonde data aboard the Dutch air defense and command frigate, HNMS De Zeven Provinciën during its long transit and participation in a multi-national military exercise. In this analysis we focus the effort on the logging and analysis of sea surface temperature (SST), discuss the efficacy of several methods used to collect this data and determining a metric by which we might determine acceptable accuracy in operational situations when more accurate measurements cannot be taken.**

I. Introduction

In the Fall of 2015, researchers from Space and Naval Warfare Systems Center Pacific (SSC Pacific) and NSWC Dahlgren Division (NSWCDD) were invited to ride-along during a multi-national military exercise in the North Atlantic. Supported by Dutch collaborators from the Defense Materiel Organisation(DMO/KIXS), Netherlands Defense Academy(NLDA) and Maritime Warfare Center(MWC), observations of sea surface temperature (SST) and radiosonde data were made during the long transit and operations. This data was collected to continue our efforts to evaluate and validate the new AREPS Radar Threshold Model (RTM) that has now been extended to the operation of modern phased-array radars.

During the deployment the scientists were given access on a non-interference basis. Unlike the initial effort in the previous year, our team did not have any control over the movement and orientation of the ship. Access to the deck of the ship was controlled so trusted manual methods of data collection were not guaranteed. While little could be done to automate the proper launch and operation of the radiosondes, several passive methods were considered to collect SST data and maximize sensor uptime with minimal direct interaction. Of these, a hull-temperature reading was chosen to be compared against two established methods of SST temperature readings. Here we analyze SST data collected by all three methods in order to determine if any meaningful results can be inferred.

TABLE I
Sea temperature readings collected

Source	Collection Interval	Total Readings
Infrared Sensor	*intermittent* [1]	59
Seawater Intake	1 hr	226
In-hull Sensor	0.5 hr	661

II. Sea temperature readings

The three different temperature sources recorded during this campaign are (1)Shipboard seawater intake temperature, (2)Infrared gun readings and (3)Hull-temperature sensor readings.

A. Seawater intake temperature (SWIT)

Recorded hourly in the ship's logs the seawater intake temperature, sometimes called ship-injection temperature, is the standard value given for SST when sea temperature is requested from the bridge. The reading is taken from a sensor located somewhere along a path from an inlet to the surrounding ocean to a central location, usually the engine room, where seawater can be used as cooling fluid for the machinery therein. Often ships include a reservoir called a sea chest, which is isolated from the surrounding water by gratings and baffle plates in order to protect ship internals from ship movement and sea state. This may also result in a relatively stagnant reservoir of water from which successive temperature readings may be taken. Readings in this case can also be altered by proximity of the sensor to heat sources, e.g. engines, depth on the water inlet, etc.

During normal operation SWIT values are often used to determine water safety risk thresholds from hypothermia and can be used as an indicator for the need to restrict topside access for shipriders. For this purpose, a SWIT reading can be sufficient, however for more sensitive applications such as the initialization of weather and propagation models, this reading is expected to lack the necessary fidelity.

[1] *Handheld readings taken concurrent with radiosonde launches and at regular intervals while sonde remained in flight.*

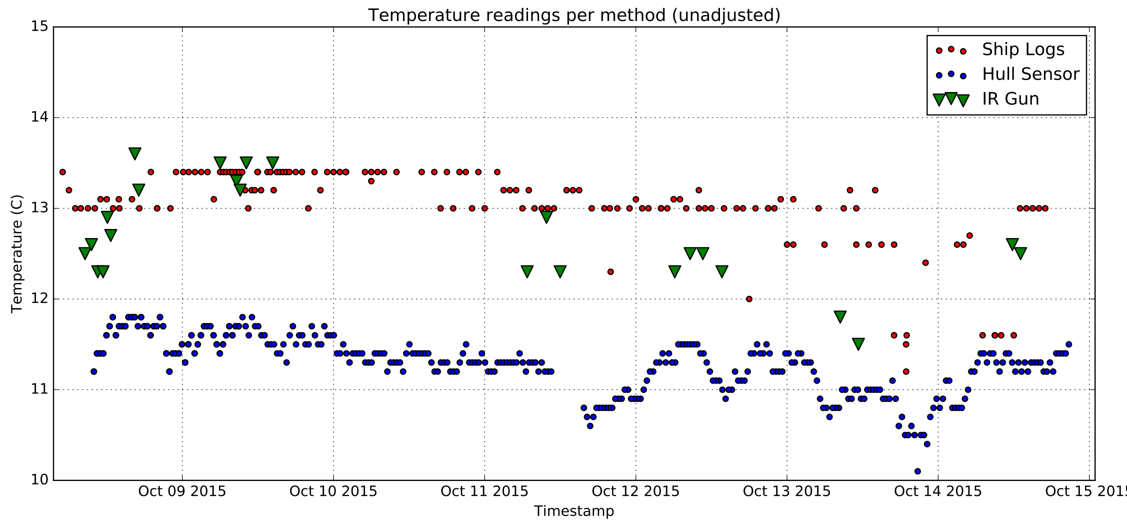

Fig. 1. Sample portion of raw data collected by all sensors.

B. Handheld infrared readings

Following strict protocol as that outlined by NSWCDD, the values recording with this method will be considered the ground truth against which our additional methods will be compared and adjusted. Readings were recorded using a handheld Cole Parmer 39800 gun at regular intervals following the launch of all radiosonde flights. In order to take valid readings, strict criteria must be kept when measuring. Any slight variation in angle, poor target selection (e.g. in the ship's wake or on a whitecap) could result in vastly different results. Additionally, access to the ship's deck is necessary to perform each reading, which was heavily restricted by the bridge especially during times of heightened sea state and live fire events.

C. Hull SST

The hull SST sensor was chosen to guarantee that a passive SST reading could be recorded even at times when it was unsafe or disallowed to take manual readings topside on deck. Intended to be non-destructive and uncomplicated, the sensor package consists of a custom IR sensor measuring the surface temperature of the ships inner-hull. The measurement chamber of the IR sensor was isolated from the ships interior, in our case engine room, by a layer of expanding foam. Opposite the sensor, on the wet side of the plate the opposite surface was exposed to the surrounding ocean water at a height reported by crew as roughly that of the sea surface.

As expected, a direct reading from this sensor would likely not be indicative of SST, given the more complicated process of heat transfer through the thickness of the hull to the sensor. Instead we focus on the possibilty of a measured bias or possible formula, which might be used to quickly determine an acceptable estimation of true SST given this reading.

III. Comparing differences in SST values

We will review through direct comparison the results of raw data from each of three distinct SST collection methods. We then attempt to determine how the data might be meaningfully corrected with respect to the measured IR gun 'ground truth.' The pros and cons of each method will be discussed, ideal usage conditions for each will be discussed, and we will try to identify a metric for the sensitivity of our models to each methods temperature variations.

A. Propagation effects due to SST source

At this stage, analysis of the radar data collected during the 2015 measurement campaign is ongoing. As in phase 1 of this study, APM models driven by both NWP and in-situ measurements will be generated. These models will then be compared against radar observations recorded by operational radars, mounted on the mobile platform HNMS De Zeven Provincien.

Acknowledgement

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