Effects of Assimilation of Surface Temperature Data on the Evaporation Duct and Propagation Predictions

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***Abstract*— The evaporation duct is an ubiquitous feature over the world's oceans responsible for trapping electromagnetic energy from surface emitters. The height of the evaporation duct (EDH) is often used to determine if ship-board radars and communications systems will be adversely affected by the environment. EDHs typically range from 2 to 40 meters and can vary substantially with surface stability, wind speed, and low-level humidity, particularly within 100 km from shore where temporal and spatial variations in the environment are the norm. A study was conducted to measure sea surface and air temperature from a specially instrumented ocean glider during a 30-day deployment off of San Diego, California. Improvements to the surface layer and evaporation duct modeling resulted from assimilation of the glider measurements into a numerical weather prediction (NWP) model. We show the impact of these data on the prediction of electromagnetic energy propagating from a surface radio frequency (RF) sensor.**

Keywords—evaporation duct, propagation, sensor performance

I. INTRODUCTION

Current fleet sea surface temperature observations are primarily collected via the ship's intake temperatures which are notoriously inaccurate. These data are used to calculate EDHs that are critical to ascertaining radar performance and communication vulnerability when evaporative ducts are present. Duct height calculations are exceptionally sensitive to small variations in the sea surface and air temperatures. We describe research to instrument an unmanned underwater glider with a new low-cost sensor to augment the in-situ data void over oceans, and explore viability for increasing the range and accuracy of evaporative duct calculations by assimilating these new data sources into NWP weather models.

II. GEDI PROJECT OVERVIEW

The Glider Evaporative Duct Height Initiative (GEDI), a multi-agency collaborative in 2016 and 2017, included an engineering upgrade to the glider instrumentation, two validation sea tests and a 30-day data collection demonstration, a data assimilation and NWP modeling component, and analysis of the impacts of such data on predictions of EDH and propagation. Two commercial Slocum G2 ocean gliders were mounted with an extended thermistor sensor to record sea and air temperature. The gliders were deployed near the coast of San Diego, California, navigated 45 nautical miles west toward buoy 46086 and returned back to shore for a 30-day period in Feb/Mar 2017. The gliders surfaced every 4 hours to expose the thermistor to the air yielding 12 new in-situ air temperature measurements per day. These data were assimilated every 6 hours into the U.S. Navy's NWP model, COAMPS®[1] (Coupled Air-sea Mesoscale Prediction System) [1], through data assimilation systems for the atmosphere, NAVDAS [2], and for the ocean NCODA [3].

COAMPS generated real-time forecasts for the GEDI sea tests on a high resolution domain situated over Southern California (SOCAL). The inner grid (Fig. 1), having resolution of 1.33 km in the horizontal and an average of 32 m in the lowest 1 km in the vertical, was capable of capturing the mesoscale structure and diurnal variability in this complex coastal zone. This 'CNTL' experiment ingested traditional observations from radio sondes, aircraft, buoys, satellites, and ships, and a concurrent identical 'GEDI' run additionally included the new glider data.

III. GEDI DEMONSTRATION AND RESULTS

COAMPS forecasts of air temperature, sea surface temperature (SST), pressure and winds were compared to measurements at buoy 46086, and showed good agreement in synoptic (weekly) patterns as well as diurnal (daily) variability. The GEDI experiment generally captured the overall trends better than CNTL indicated by a reduction in the bias and root mean square error (RMSE) statistics for each variable (not shown). In particular, the GEDI improved the prediction of air-sea temperature difference (ASTD), a key parameter in

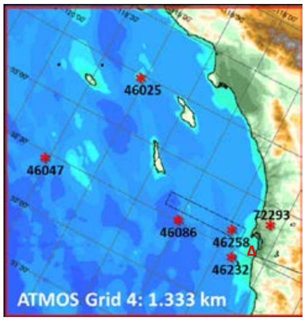

Fig. 1. COAMPS inner grid. The rectangle shows the operational area of the GEDI gliders and the buoys are labeled with red asterisks. The triangle (Δ) marks the location of an X-band emitter.

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[1] COAMPS is a registered trademark of the Naval Research Laboratory

determining atmospheric stability that drives low-level mixing, thus influencing vertical gradients of temperature and moisture. The glider data reduced errors in stability by effectively cooling the near-surface atmosphere in COAMPS. In Fig. 2, we note the improvement in the SST forecasts relative to SST measurements from buoy 46258 and from the GEDI gliders.

The model-derived EDHs at buoy 46086 are given in Fig. 3. The EDH is the minimum in modified refractivity computed from a surface layer model seeded with NWP values. This figure also shows the correlation between the EDH and the air and sea surface temperatures. GEDI air temperatures were notably lower than in the CNTL. During the few periods of stable surface forcing (ASTD>0), the EDH varied widely and was considerably higher than the more typical weakly unstable forcing (ASTD<0) in which EDH values hovered near 5 m. The most significant divergence in EDH predictions occurred on 16 Feb. which is examined in greater details. Vertical profiles of modified refractivity along the glider path are shown in Fig. 4 and reveal substantial difference in the surface layer portion of the profiles (below 50 m) between the CNTL and GEDI experiments, as well as the upper layers of the atmosphere. On this day the GEDI predicted atmospheric constituents were in better agreement to the buoy observations.

The effect of the environment and of variations in EDH on RF propagation modeling is represented in Fig. 5 comparing propagation loss (PL) for a near-shore X-band transmitter located at a height of 15 m sensing a small surface target at a height of 4 m. For the higher EDH modeled by the CNTL, the PL pattern displays less loss, more lobing, and a remarkable 35 km difference in maximum continuous detection range relative to GEDI. While the RMS difference in PL, 27 km down range of the transmitter, was near 5 dB, several periods had much larger differences in PL as shown in Fig. 6.

IV. CONCLUSIONS

The GEDI ocean glider demonstration offered a unique opportunity to augment the traditional observations fed to the Navy's high resolution weather model with new, in-situ air and sea temperature measurements. The impact of these data on atmospheric forecasts of low-level refractivity gradient and the height of the evaporation duct produced RMS differences ranging between 4 and 6 m. These parameters were used to predict the propagation of electromagnetic energy from a surface emitter yielding operationally significant differences in propagation loss as high as 20 dB with an RMS difference near 5 dB for the duration of the 30-day GEDI experiment.

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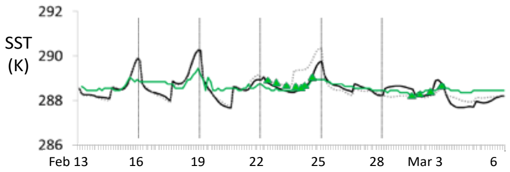

Fig. 2. Time series of sea surface temperature (K) at buoy 46258 from the CNTL (dotted black), the GEDI (solid black), buoy data (green), and the GEDI glider data (green triangles).

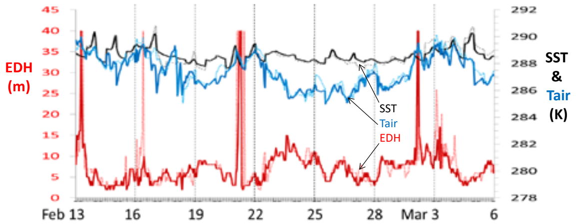

Fig. 3. Time series of EDH (red), air temperature (blue), and SST (black). The CNTL is dashed and GEDI is solid.

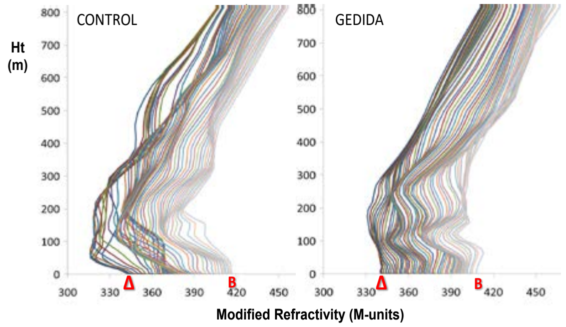

Fig. 4. Modified refractivity profiles from the coast (Δ) to buoy 46086 (B) for the CNTL (left panel) and GEDI (right panel) on 16 Feb 3 UTC. The range has been added to each profile to create an offset.

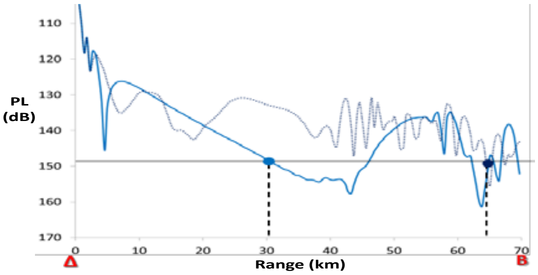

Fig. 5. X-band propagation loss at height of 4 m vs. range. The CNTL is dotted and GEDI blue solid. Shown are the detectability threshold of a small surface target (black solid line) and maximum continuous detection ranges (black dashed lines).

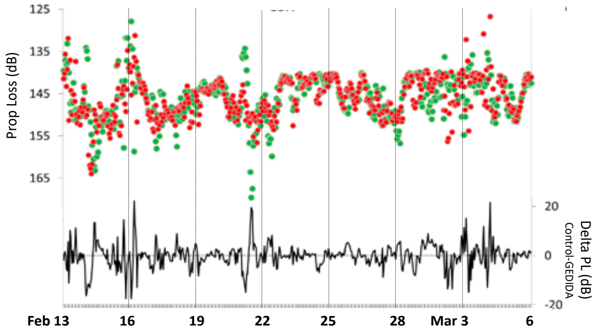

Fig. 6. Time series of propagation loss 27 km down range from the X-band emitter for the CNTL (green) and the GEDI (red), and the difference (Delta) PL (black).