# COAMPS Refractivity Forecast Evaluation Using LATPROP-UWB Propagation Loss Data

Luyao Xu[1], Caglar Yardim[1], Tracy Haack[2], Robert Burkholder[1], and Qing Wang[3]
[1]ElectroScience Laboratory, The Ohio State University, Columbus, OH, USA
[2]Naval Research Laboratory, Monterey, CA, USA
[3]Department of Meteorology, Naval Postgraduate School, Monterey, CA, USA

***Abstract*— Lower Atmospheric Propagation Ultra Wide Band (LATPROP-UWB) system is deployed during Coupled Air-Sea Processes and Electromagnetic Ducting Research (CASPER) East campaign to measure range-dependent propagation loss for 2–40 GHz. Couple Ocean/Atmosphere Mesoscale Prediction System (COAMPS) is used to obtain refractivity forecasts during CASPER East. Range-dependent forecast refractivity profiles are used with a parabolic wave equation code to get simulated propagation loss. The simulated and measured propagation loss are compared to compute COAMPS forecasting accuracy.**

## I. INTRODUCTION

Changes in vertical temperature and humidity profiles can result in atmospheric ducts that cause the trapping of electromagnetic (EM) waves, significantly affecting system performance [1]. To explore the effects of non-standard conditions on EM propagation, the Coupled Air-Sea Processes and Electromagnetic Ducting Research (CASPER) East campaign was conducted in October/November 2015, offshore of Duck, NC where extensive concurrent atmospheric and EM propagation loss (PL) data are collected. Two research vessels, R/V Huge R. Sharp (R/V Sharp) and R/V Atlantic Explorer (R/V AE) were operated with frequent rawinsonde launches from both vessels and the shore site. In addition, high-rate measurement of wind, temperature, humidity, and pressure were recorded by fixed height sensors on the bow masts of both R/V Sharp and R/V AE [2].

These are coupled with numerical weather predictions using the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). The COAMPS is a mesoscale modeling product developed at the Naval Research Laboratory, Marine Meteorology Division that can provide both the current time analysis and short-term forecast for any given region of the Earth in both the atmosphere and ocean. The initial fields are specified using an analytic function and empirical data. All of the available observations from all of the research platforms since the last analysis are blended with the previous forecast to generate the current analysis. Then the model runs forward in time to produce the new forecasts where the time interval between successive analyses is called the update cycle [3].

Next, the parabolic wave equation (PWE) method is used to calculate electromagnetic wave PL along the experiment track using the simulated refractivity profiles from COAMPS output. Then the simulated PL are compared with measured PL.

## II. LATPROP-UWB DATA

The Lower Atmospheric Propagation Ultra Wide Band (LATPROP-UWB) measurement system is designed to measure PL from 2-40 GHz. A total of 64 frequencies were measured during CASPER East. The transmitter was installed at the end of the Army Corps of Engineers Field Research Facility Pier, emitting towards the sea. A receiver was installed on bow of R/V AE. The transmitter and receiver were synchronized via GPS to lock to the same frequency at the same time. Range-dependent PL at multiple frequencies were measured as R/V AE moved toward the shore along an east-west path.

For this work, 21 sets of range-dependent PL measurements at 25 frequency points ranging from 2 GHz to 18 GHz were used. The PL at each frequency is a function of both time and range since each measurement took several hours.

## III. IMPLEMENTATION

COAMPS provides analysis data twice every day (noon and midnight). Each of these COAMPS fields are run for consecutive 48 hours afterwards creating the forecast data. Because of 48 hours forecasts with 12 hour intervals, there are always 4 COAMPS fields for each time that can provide anticipated PL at each UWB measurement. Horizontal dimension is defined towards

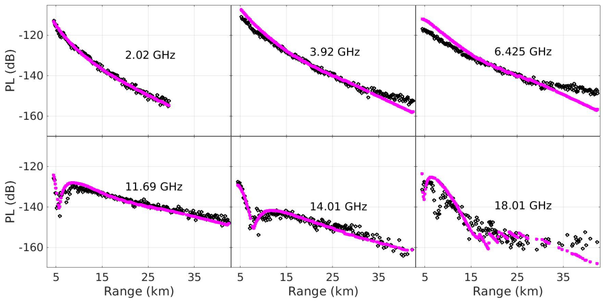

Fig. 1: Simulated and measured PL at 2.02, 3.92, 6.425, 11.69, 14.01 and 18.01 GHz. Black dots are measurement, solid lines are PWE simulations from COAMPS forecast fields.

east away from the Duck Pier, extends to 60 km with 2 km grid spacing. Vertical profiles have been blended with the surface layer using 1 m vertical resolution up to 100 m height, then reverted to COAMPS resolution up to around 30 km.

M-profiles generated by COAMPS need to be processed before compared to measurement. Here we applied PWE to compute PL. Then, basing on the actual location of our vessel at that time, we extracted corresponding PL and combined them together to form the anticipated PL. For example, 1014 run1 PL is recorded on Oct 14, 2015 between 14:50-17:50. 21 M profiles sets are calculated from 14:40-18:00 and each set contains 31 range dependent profiles with 2 km unit length. Four COAMPS fields started at Oct 14 12:00, Oct 14 0:00, Oct 13 12:00 and Oct 13 0:00 create forecast M profiles for 1014 run1 at 3-6, 15-18, 27-30 and 39-42 hours forecasting length, respectively. The PL generated from farthest (first) to closest (last) forecast cycle are labeled as forecast 1–4.

## IV. RESULTS

The comparison of measured and simulated PL at selected frequencies is illustrated in Fig.1. Measurement data are from Oct 14, 2015 15:50-17:50. Simulated PL is calculated from COAMPS forecasting sets started at Oct 14 12:00. Mean correction have been made in this figure. Notably, there is excellent match between two lines in 2.02 GHz. The simulated PL curves successfully capture the quick dips at 11.69 GHz and 14.01 GHz. It also follows the descending trend at 18.01 GHz. As expected, the mismatch between simulation and measurement increase as frequency increases. Simulation also provides better agreement at closer range.

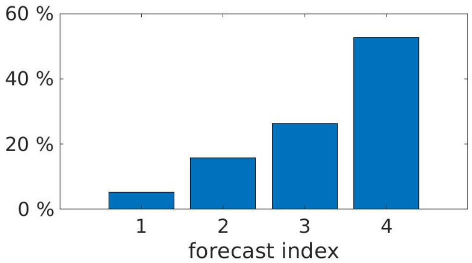

Fig. 2: Comparison of forecasts: Percent times that the PWE simulated PL match the measured data best.

Error analysis of simulated and measured PL is shown in Fig. 2. The index of measurement set is labeled in chronological order. PL in each set is a function of range for 25 frequency points. The error term is the frequency average of RMS PL error in range:

$$\phi = \frac{1}{N_f} \sum_{1}^{N_f} \sqrt{\frac{\sum_{1}^{N_r} \left(PL(r,f) - PL_{obs}(r,f)\right)^2}{N_r}} \qquad (1)$$

where $PL(r,f)$ is the simulation, $PL_{obs}(r,f)$ is the observation, $r$, $f$, $N_r$ and $N_f$ are range, frequency, number of range and frequency points, respectively.

The RMS error averaged over PL data for 5-40 km, 2-18 GHz over the entire October-November 2015 campaign corresponds to 4 dB for 0-12 h forecasts. Best and worst case frequency-range averaged RMS values are 2.5 and 7 dB while the typical RMS error is around 5 dB. Figure 2 shows the percentage of minimum error in each forecast. Over 50% of the cases the frequency and range averaged error is minimum for forecast 4 (0-12 h forecast). The match decreases with increased forecast time with forecast 1 (36-48 h forecast) only producing the best results less than 10% of the time.

## V. CONCLUSION

The refractivity output from COAMPS is converted to propagation loss and then compared with measured radio frequency loss from LATPROP-UWB system during CASPER East. The good agreement of simulated and measurement validated that COAMPS has good prediction in short term forecasting.

## REFERENCES

[1] A. Karimian, C. Yardim, P. Gerstoft, W. S. Hodgkiss, and A. E. Barrios, “Refractivity estimation from sea clutter: An invited review,” *Radio Science*, vol. 46, no. 6, pp. 1–16, 2011.

[2] Q. Wang, D. P. Alappattu, S. Billingsley, B. Blomquist, R. J. Burkholder, A. J. Christman, E. D. Creegan, T. de Paolo, D. P. Eleuterio, H. J. S. Fernando, *et al.*, “Casper: Coupled air-sea processes and electromagnetic (em) ducting research,” *Bulletin of the American Meteorological Society*, no. 2017, 2017.

[3] S. Chen, J. Cummings, J. Doyle, R. Hodur, T. Holt, C. Liou, M. Liu, A. Mirin, J. Ridout, J. Schmidt, *et al.*, “Coamps version 3 model description: General theory and equations,” *NRL Publ. NRL/PU/7500-03*, vol. 448, p. 145, 2003.