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Trident Warrior 2013 RF Data Analysis

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Award Number: N0001414WX20073 and N000141310360

LONG-TERM GOALS

Determine the suitability of signals-of-opportunity (SOO's) for evaluating the goodness of electromagnetic (EM) propagation estimates.

OBJECTIVES

Using data from Trident Warrior 2013 (TW13) to show suitability of SOO's for evaluating EM propagation estimates. Show ability to estimate system constants from model-based processing of far-field power measurements where terrain has impacted the propagation. Identify and mitigate contaminants in the signals. Compare to propagation estimates based on other sources.

APPROACH

Data from TW13 includes time series of power measurements from SOOs taken onboard the Research Vessel Knorr. The SOO's included two FM stations, three airport terminal information service (ATIS) stations, four TV stations, and one VOR station. Other TW13 data taken on the Knorr includes high-resolution radionsondes and surface layer meteorology.

NWP output for TW13 was provided by the Naval Research Laboratory, Monterey. The Coupled Ocean and Atmospheric Mesoscale Prediction System (COAMPS) model was run with an inner nest resolution of 1.33 km $\times$ 1.33 km and 60 vertical points. The first level in the COAMPS is 10 meters, and the initial vertical grid spacing is 20 meters.

The overall process was to estimate a system constant for the SOOs. The system constant and quality control processing was then used to map the power measurements into propagation loss. The loss values were compared to loss values estimated from radisondes and NWP.

WORK COMPLETED

The work this year consisted of two major components:

1. Reducing the noise in RF measurements: Initial analysis of the SOO power measurements used peak power as measured by the spectrum analyzer. Simultaneous with the recording of the peak power, full spectrums were recorded as well. Spectrum plots for WHRO-TV (482.31 MHz carrier frequency) are shown in Figure 1. Three bars in the upper left plot indicate the times of measuremetns corresponding to locations at ranges in the upper right plot and individual spectrum plots below. A first quality step was performing machine analysis and visual inspections of this data to ensure that the peak in the spectrograms was signal (vice noise). Note that the "floor" of the spectrograms in the upper plot is only the noise floor when it is at about -100 dBm; at larger values it is payload signal for the 6 MHz wide TV signal. A more complex element of the data quality was to mitigate effects of the shipboard receiving antenna pattern. The result of the processing is shown in 2. Figure 2 also shows the comparisons to radiosondes and NWP as well.

2. Compare radio-inferred propagation loss to values estimated by radiosondes and NWP: Figure 2 also shows the these comparisons High resolution radio sondes and range-dependent refractivity profiles were input into the Advanced Propagation Model (APM). Because the propagation paths were partially overland, APM was operated without the troposcatter flag "on." The NWP based predictions over-estimated the propagation loss (equivalently, estimated lower signal levels) vis a' vis the quantities derived from the SOO observations.

3. Preliminary analysis: To provide a qualitative indication of the root cause of the differences, we compared high-resolution radiosonde refractivity profiles with profiles calculated from the output of COAMPS for the location in space and time closest to the radiosonde. These are shown in Figure 3. Three key observations stand out: (a) The overall change in refractivity from the value at the surface to the value at 1000 meters is roughly the same. (b) The soundings, particularly those up to day 15.6 have large variations in refractivity as would be characterized by the refractivity structure function index C_n^2. (c) Up to Day 15.6, it appears the model is showing a well defined layer wheras the soundings migh be interpreted as reflecting a turbulent interface extending from the surface to 800 meters or so. Future work will include having troposcatter "on" in APM as well as varying the statistics of that model.

   The difference in propagation calculations based on four sets of radiosondes and that based on contemporaneous NWP are shown in Figures 4 and 5. In 4, it is seen that NWP is generally predicting lower signal levels at ranges beyond 60 or-so km. In Figure 5, such a statement cannot be made.

RESULTS

Results for four other stations appear consistent with the behavior seen with WHRO-TV. The data shown corresponds to a single run where the Knorr went to ranges well beyond line-of-sight. It would take multiples of such runs to make a general conclusion about the goodness of the NWP.

IMPACT/APPLICATIONS

We have demonstrated the use of SOOs to provide feedback on the use of numerical weather prediction models for estimating propagation. This also indicates their suitability as a new form of data to be used in algorithms to invert refractivity.

TRANSITIONS

None.

PUBLICATIONS

Caglar Yardim and L. Ted Rogers, Verification of Trident Warrior 2013 Radiosonde and Numerical Weather Prediction Results with Passive Low Frequency RF Measurements, Internal Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, Memphis, TN, July 6-11, 2014

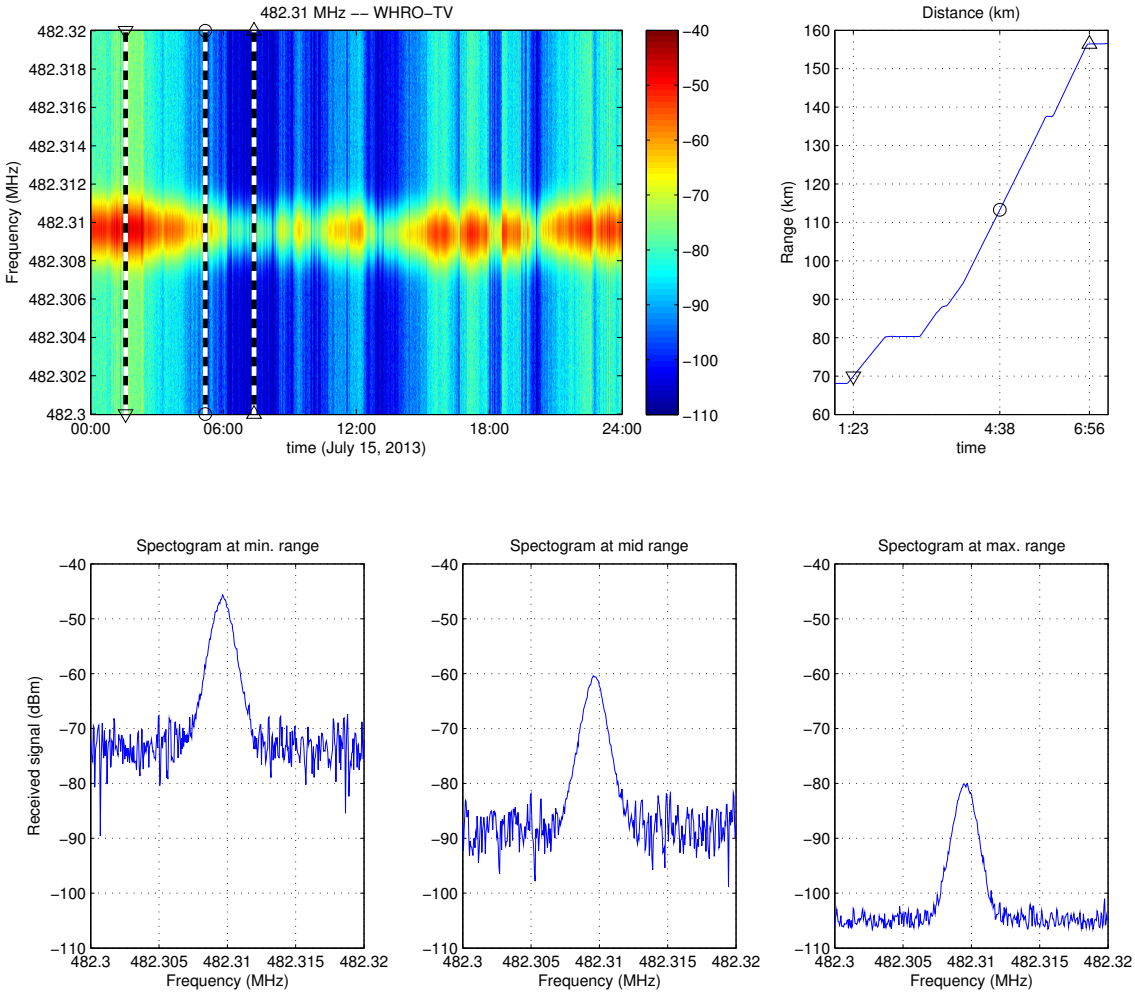

Figure 1: Received power spectrum for July 15, 2013, WHRO-TV (482.31 MHz), distance to the station as a function of time, and spectogram of the TV signal measured at minimum, mid, and maximum ranges from the deck of the outgoing R/V Knorr.

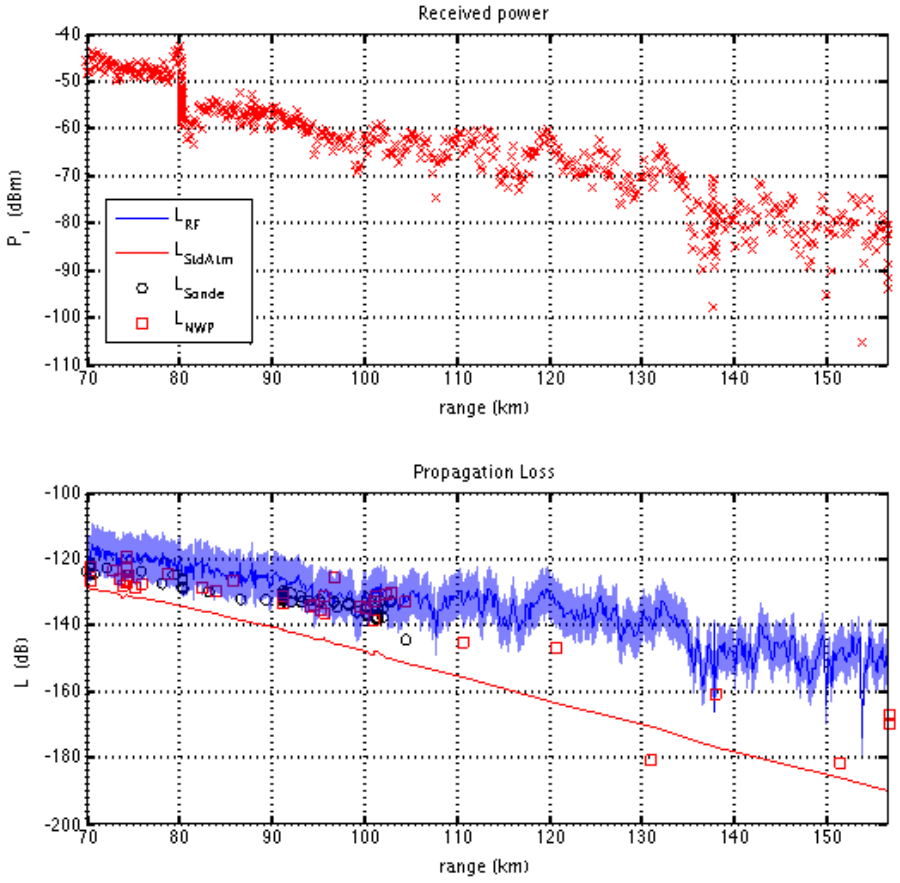

Figure 2: (Upper plot) Received raw RF power from WHRO-TV (482.31 MHz carrier frequency) before calibration and antenna pattern correction. (Lower plot) Negative propagation loss estimated from the passive RF system (dark blue line and blue envelop), sonde measurements (black circles), NWP forecasts (red squares), and standard atmosphere assumption (solid red line).

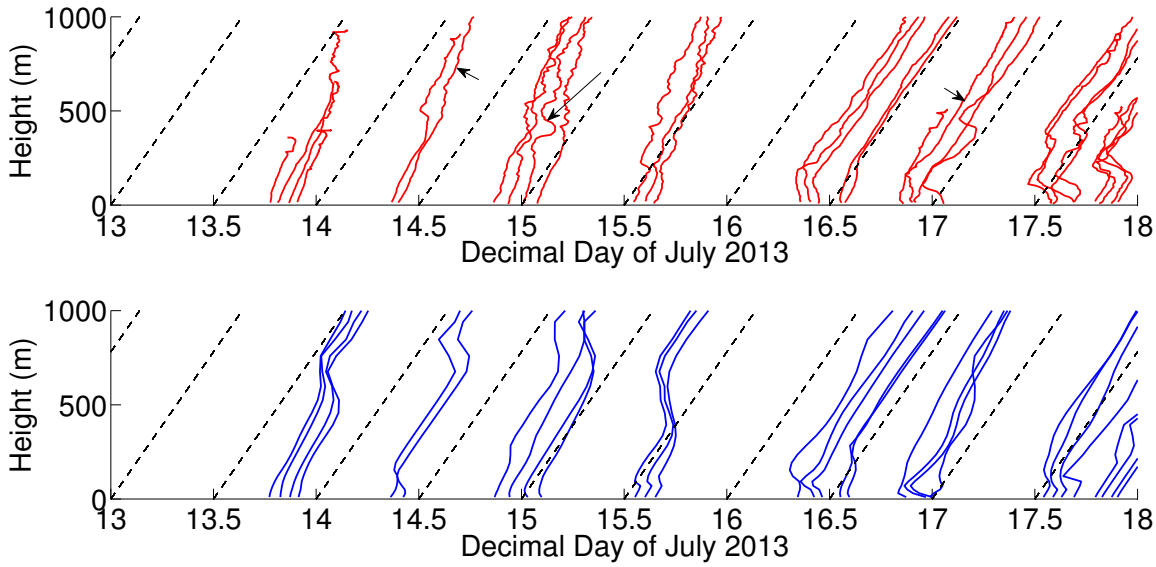

Figure 3: Soundings time series. (upper plot): Soundings taken from R.V. Knorr, the location of receiving system used during Trident Warrior 2013, shown in red. 0.128 M-units/meter modified refractivity (typical of developed MABL mixed layer shown on black dashed lines for reference. (lower plot) COAMPS-generated seaward path end-point soundings shown in blue with same mixed-layer reference. Modified refractivity and Decimal Day on same axis with ratio of 1 M-unit = 0.005 days.

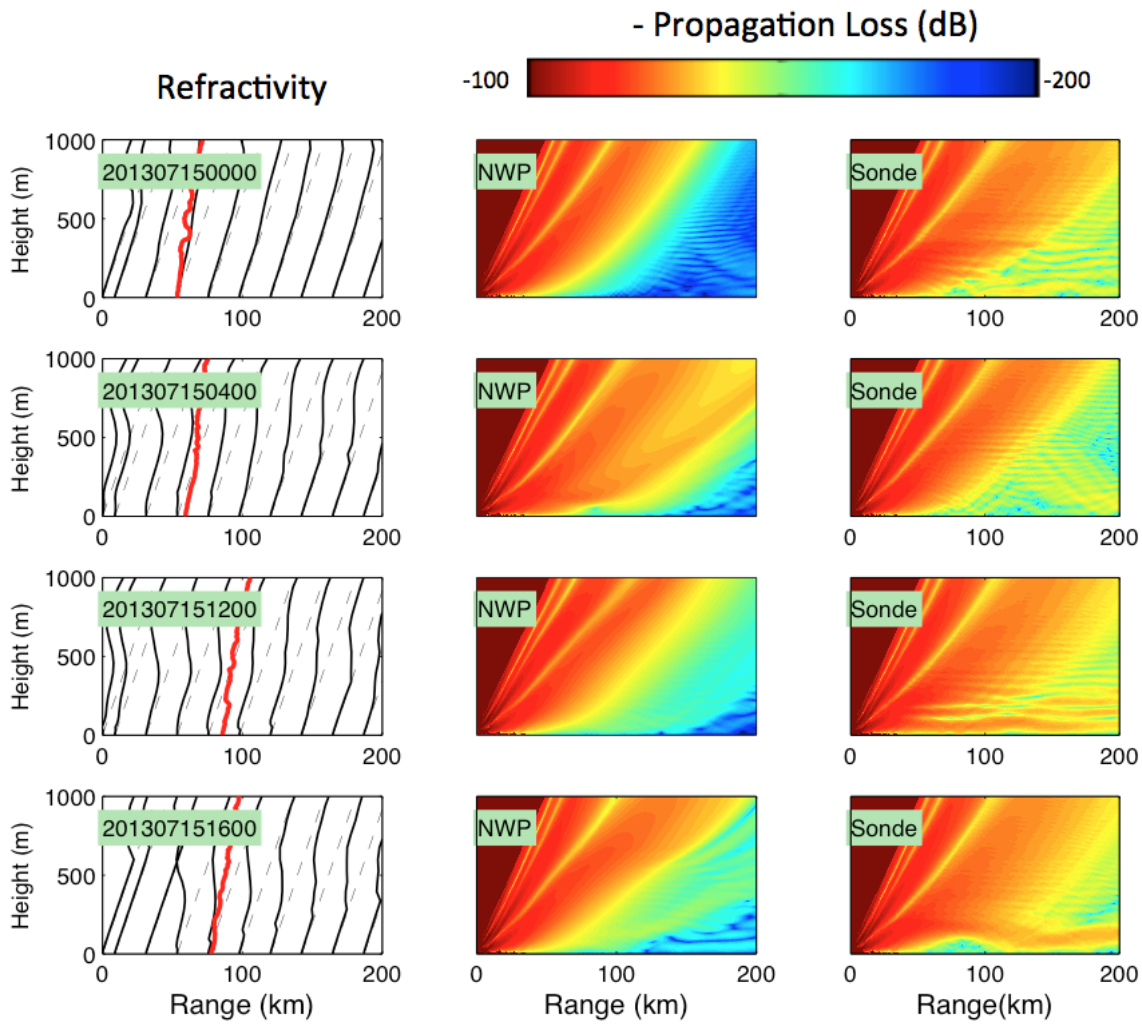

Figure 4: Differences between NWP and radiosonde propagation effects at 500 MHz. Left column of picklets show range series of COAMPS (NWP) modified refractivity profiles from July 15, 2013 for 0000Z, 0004Z, 0012Z and 1600Z in black. Nearest (in time) radiosonde profile is shown in red. The profiles are on a path from (36.75N, -76.35E) in a due-east direction. Two additional columns of "picklets" in Figures 4 and 5 show inverse propagation loss (inverted so lower loss and higher signal levels are depicted in warmer colors) for COAMPS (NWP) and Radiosondes (assuming a horizontally homogeneous atmosphere) respectively. The loss values are based on a hypothetical emitter located at the West end of the path at a height of 80 meters above mean sea level. The location of the hypothetical transmitter corresponds roughly to the location of the star in Figure ?? and the eastward track in the same region as the Knorr's track.

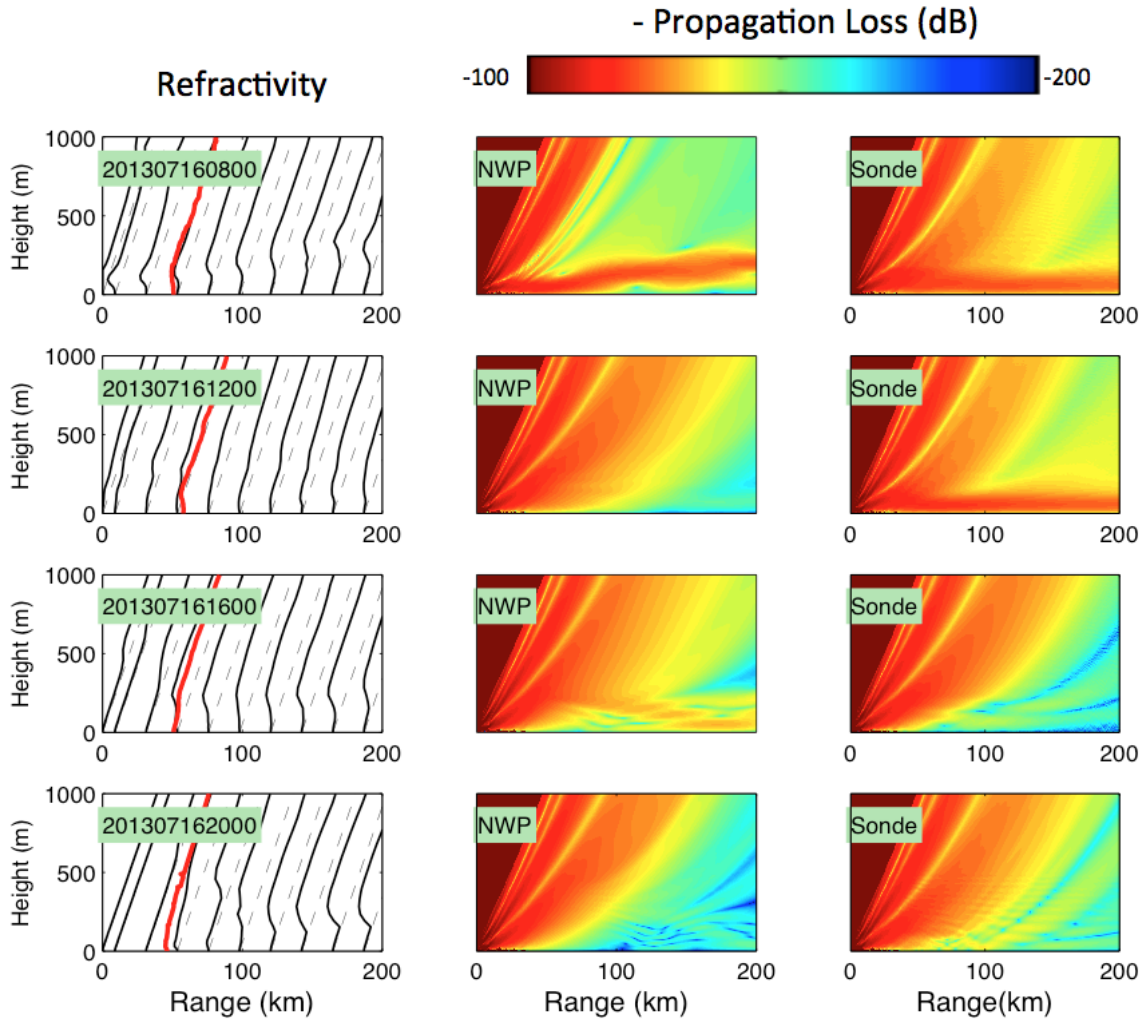

Figure 5: Same as Figure 4 but at later times.