Operational Radar Performance Surfaces for RIMPAC 2008

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Introduction: A new system called Atmospheric Radar Performance Surfaces (ATPS) was designed in a joint effort between the Naval Research Laboratory (NRL), the Naval Postgraduate School (NPS), the Space and Naval Warfare (SPAWAR) Systems Center (SSC), and Fleet Numerical Meteorology and Oceanography Center (FNMOC), to provide spatio-temporal guidance about radar propagation conditions during Rim of the Pacific 2008 (RIMPAC08). The ATPS provides expected radar range guidance as a function of location, time, radar, and target type. Supplementary information was provided by ensemble forecasts to estimate the uncertainty associated with environmental ducting parameters impacting electromagnetic (EM) propagation. The ATPS provides range information and the environmental uncertainty enables a "range of ranges" to be communicated. Predicting EM propagation conditions in and around the Fleet during planning/execution of at-sea exercises and operations is of critical military importance. The ATPS enables decision-makers to gain a strategic advantage in placement and positioning of military assets. The inclusion of quantitative uncertainty information provides decision-makers with superior information, allowing for improved risk/opportunity management and more efficient operations.

Military operatives routinely use Numerical Weather Prediction (NWP) forecasts for predicting the spatio-temporal variability in atmospheric conditions that influence all facets of mission planning and execution. In addition to their forecasting capability, these fields are also used to initialize propagation codes to assess EM ducting conditions for various radar and target configurations. However, the current capability is limited by an inability to effectively communicate horizontal variability over a wide region of military activity.

The propagation environment is largely dependent upon vertical variations in water vapor, which often contain sharp discontinuities due to layering of the environment. Surface and boundary layer structure in the atmosphere can produce negative gradients in the modified refractive index (M) for which energy at microwave frequencies are trapped, producing extended detection and communication ranges for sensors operating within the ducting layer. Spatial variability develops due to changes in the sea surface temperature (SST), sea/land breeze and topographic forcing, and evolution of the synoptic and mesoscale conditions that add considerable complexity to the propagation environment. The Navy can exploit this variability for military advantage to ascertain locations within their operating domain for optimal placement of assets.

ATPS Components and Products: Figure 1 shows the components of the new ATPS in which radar and target information come from AREPS (Advanced Refractive Effects Prediction System) databases maintained by SSC, the NRL mesoscale forecast model COAMPS®* provides 3D environmental conditions, the NPS bulk surface model vertically resolves the surface layer providing modified refractivity profiles, and the SSC Advanced Propagation Model (APM) determines the propagation path loss. AREPS further provides probability of detection (POD) threshold values of propagation path loss below which a given target can be detected. The radar's performance is denoted by the maximum detection range and maximum continuous detection range (right and left asterisk, respectively, in Fig. 1(e)) computed for each point in the COAMPS model domain.

An example of a radar performance surface in the Arabian Gulf is shown in Fig. 2, depicting the maximum detection range of a small surface target using a shipboard X-band radar. The spatial complexity and structure originate from variability in the 9-km and 3-km resolution COAMPS fields, with the 3-km grid more faithfully resolving nighttime drainage flows from the steep mountainous coastline to the northeast. While these performance surfaces are for a generic X-band radar, the ATPS system has been made flexible and versatile such that the predicted performance can be obtained for a variety of radars and targets operating at any height within a COAMPS analysis or forecast domain.

RIMPAC08 Operational Demonstration: As a demonstration of the new radar performance surface capability and transition to operations at FNMOC, the complete end-to-end automated ATPS system was seamlessly run in real time twice daily for military exercises in and around the Hawaiian Islands during July 2008 (RIMPAC08). The performance of an X-band airborne radar at three flight levels was selected for evaluation of ATPS and follow-on validation efforts. Due to their differing radar cross sections, ship-sized targets have considerably different detection patterns than smaller surface targets, as shown in Fig. 3. The surfaces display the hallmarks of an island wake in the

*COAMPS® (Coupled Ocean/Atmosphere Mesoscale Prediction System) is a registered trademark of the Naval Research Laboratory.

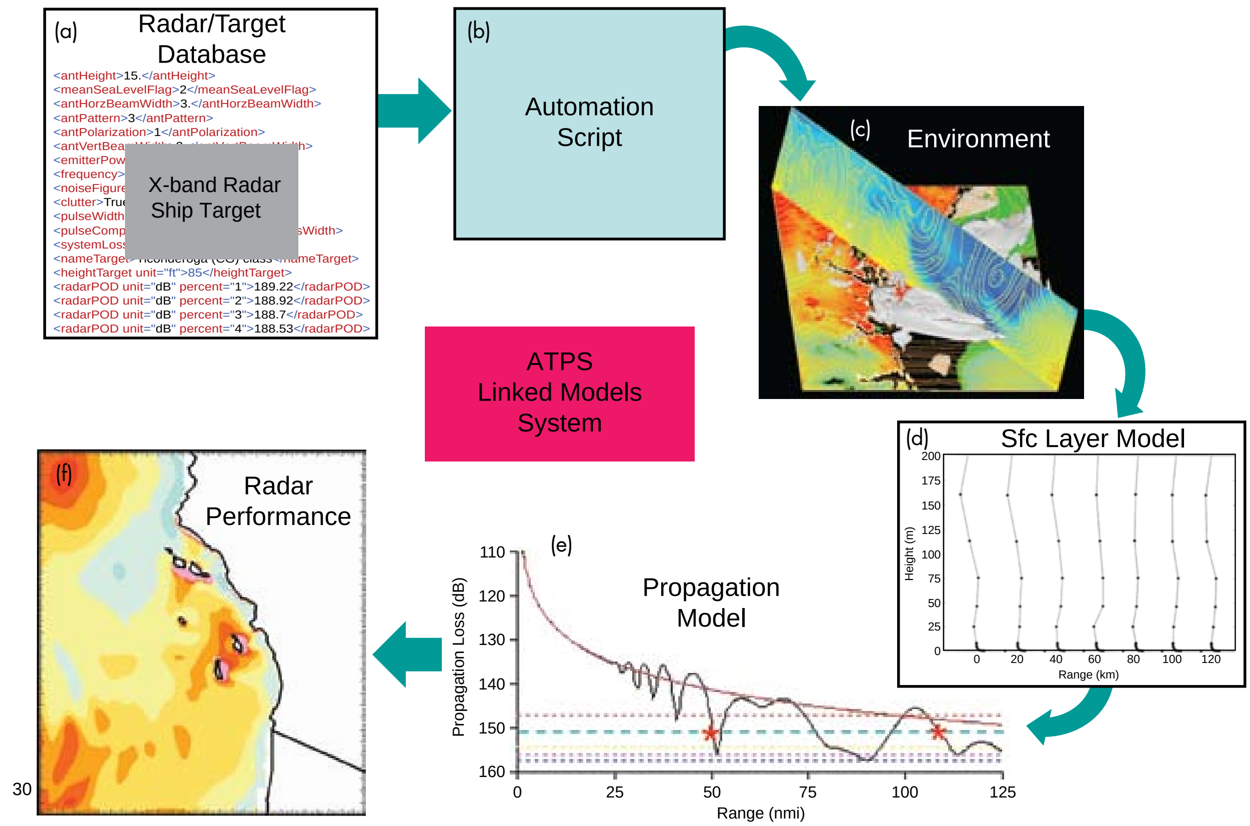

FIGURE 1
ATPS components. Radar/target/threshold input from AREPS database (a), automation script (b), three-dimensional environmental fields from COAMPS (c), high vertical resolution profiles of modified refractivity from the NPS bulk surface layer model (d), propagation path loss determined by APM (e), and the gridded ATPS radar performance output product (f). In Fig. 1(e), the dashed lines denote probability of detection (green line = 90% POD) and the right and left red asterisks are the maximum detection range and maximum continuous detection range, respectively.

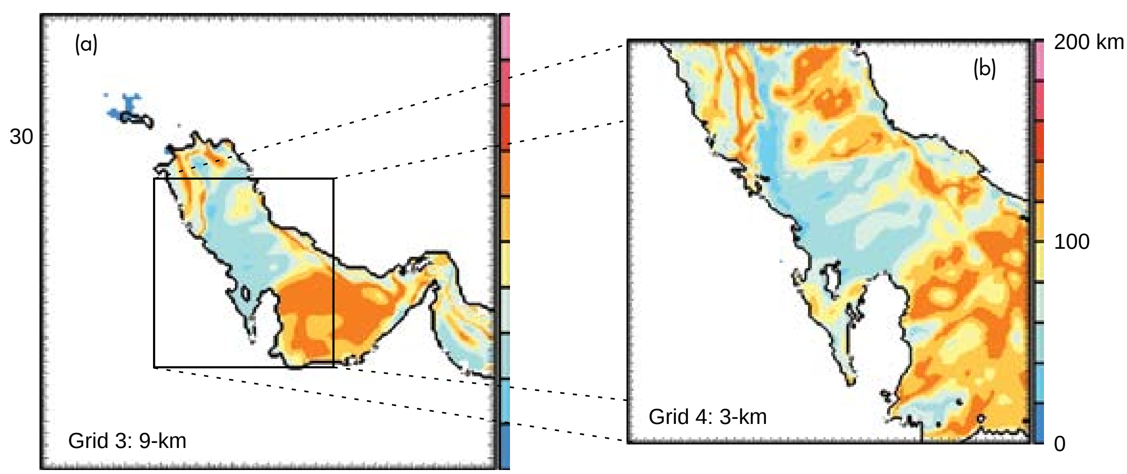

FIGURE 2
Comparison of the radar performance surface for an X-band shipboard radar showing maximum detection range (km) for a 90% POD of a small surface target from COAMPS 9-km resolution fields (a) and 3-km resolution fields (b).

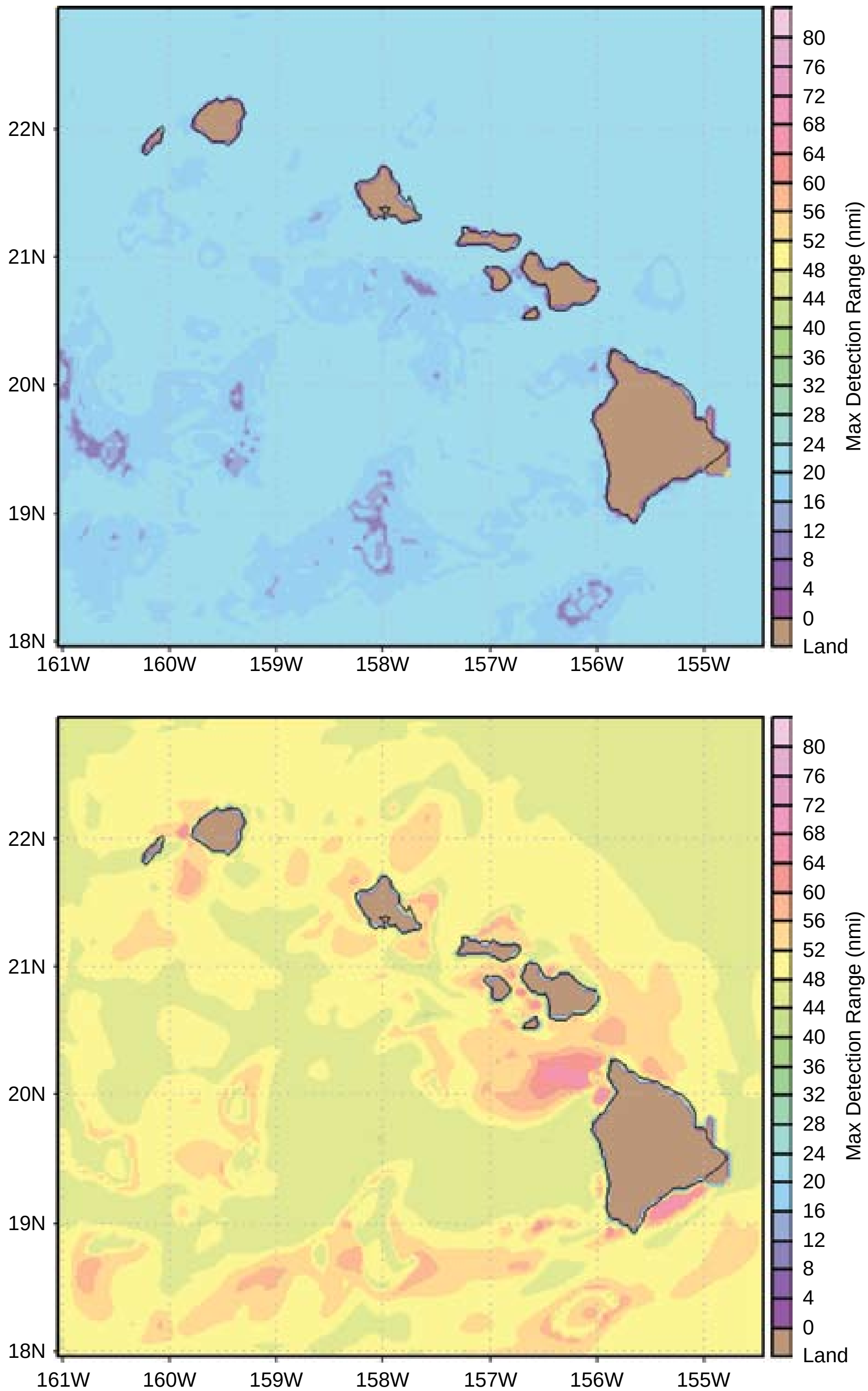

FIGURE 3
Performance surface for an X-band airborne radar at 1000 ft showing maximum detection range (nmi) for 90% POD of a small surface target (top) and a ship-sized target (bottom).

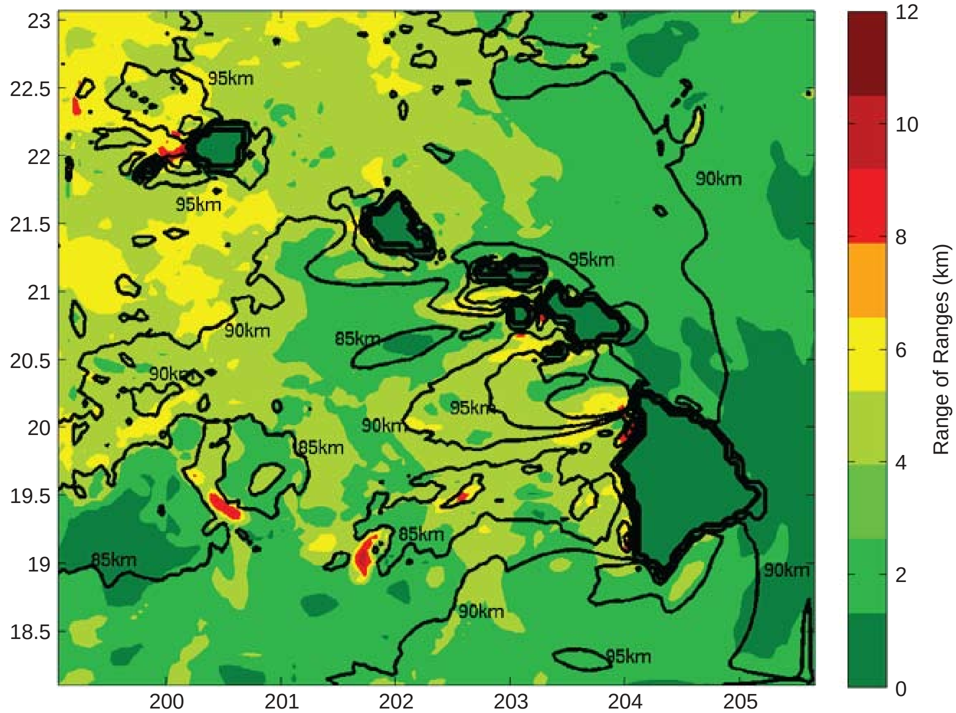

FIGURE 4
The mean detection range (km, solid contours) and 1 standard deviation (km, color fill) of ship-sized target obtained from a 33-member ensemble of COAMPS forecasts communicating environmental uncertainty and the "range of ranges." Green colors denote high confidence in the mean value, and red denotes low confidence.

lee of the islands,[1] for which atmospheric effects can have opposing influence on detection depending upon target size. Note that a ship-sized target has shorter detection ranges in the wake region relative to surrounding locations, whereas a smaller surface target has longer detection ranges.

The deployment of ATPS enables for the first time domain-wide coverage of environmental effects on radar performance and an opportunity to efficiently assess and exploit spatio-temporal variability over broad regions. A complementary RIMPAC08 demonstration project estimated and communicated the uncertainty associated with atmospheric ducting by running a 33-member ensemble of COAMPS integrations for each forecast period. Detection range uncertainty is obtained by computing ATPS fields for each member of the ensemble, yielding the mean maximum detection range and first standard deviation, an example of which is given in Fig. 4. The variability communicates the "range of ranges" that can be used to add confidence to deterministic forecasts or be used to objectively optimize decisions.

Summary: The work presented here represents the combined efforts of several Navy organizations to design, develop, and transition ATPS, which automates the computation of atmospheric radar performance surfaces using COAMPS three-dimensional forecasts as input to describe the environmental effects on EM propagation. This system was successfully deployed as a demonstration product during RIMPAC military exercises in 2008.

[Sponsored by SPAWAR PMW-120]

References

[1] S.D. Burk, T. Haack, L.T. Rogers, and L.J. Wagner, "Island Wake Dynamics and Wake Influence on the Evaporation Duct and Radar Propagation," *J. Appl. Meteoro*. **42**, 349–367 (2003).