S Band Radar Target Detection in an Extreme Advection Duct Event

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***Abstract*— Mesoscale numerical weather prediction models coupled with modern parabolic equation radar performance models have allowed the resolution of four dimensional radar performance in challenging non homogeneous near surface refractivity fields at the time and location of the modeller's choice. Large scale offshore flow of warm and dry air over colder seas produces strong surface ducting. Large land-sea temperature differences can produce near shore sea breezes and surface based ducts. This paper describes modelled radar performance in such a complex ducting structure over the Persian Gulf during large scale northwest flow. The refractivity field was resolved by the Coupled Ocean Atmosphere Mesoscale Prediction System and the notional radar performance was modelled by the Advanced Refractivity Effects Prediction System. The results indicate strong spatially dependent enhancements and degradations in radar performance relative to a standard atmosphere.**

I. Introduction

Non-standard radio frequency (RF) propagation extends for hundreds of kilometers over the water when surface ducts are formed due to offshore flow of warm and dry air over colder sea surfaces [1]. Surface ducts are created when the vertical gradient of modified refractivity (*dM/dz*) is less than zero. The vertical gradient of M is dependent on the vertical gradient of potential temperature ($d\theta/dz$) and the vertical gradient of water vapor mixing ratio (*dw/dz*) as shown in equation 1. Depending on temperature and relative humidity, the w gradient term can be two to six times the θ gradient term.

$$dM/dz \approx 0.128 - c_1\, d\theta/dz + c_2\, dw/dz \qquad (1)$$

As the warmer air flows offshore over the colder water, a shallow thermodynamically stable internal boundary layer (SIBL) forms from the sea surface up to typically 50m above sea level (ASL). These layers are characterized by a positive gradient in θ that nudges the left side of 1 towards zero. If the water vapor content in the air flowing from the land is less than that over the water surface, the vertical gradient of w in the SIBL will be negative usually to the degree of nudging the vertical gradient of M well below zero. Mechanical turbulence tends to vertically mix the water vapor and potential temperature gradients supporting these advection ducts in the downwind direction. SIBL or surface duct height is approximately proportional to the square root of the offshore distance, proportional to wind speed, and inversely proportional to the square root of the land sea temperature difference. SIBL height is only slightly decreased for cases of higher water vapor content. The offshore distance to the location where the SIBL or surface duct is mixed to the point of normal propagation is proportional to wind speed and proportional to the square of the land sea temperature difference [2]. For rather common combinations of wind speed and land sea temperature differences, these surface ducts can exist for hundreds of kilometers offshore.

II. Models

For the past four years, the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) has exploited the technology for providing a 48 hour radar performance forecast capability. This has been accomplished by combining a modern parabolic equation RF performance tool with a mesoscale numerical weather prediction (NWP) model. This combination allows for a globally locatable 48 hour RF system forecast.

The Advanced Refractive Effects Prediction System (AREPS) is employed to model the performance of three notional radars at S, C and X band [3]. The notional radars are designed to have equal probability of detecting a notional target in free space allowing model output to be viewed in terms of wavelength influences due to refractivity fields. AREPS is capable of accepting three dimensional (3D) refractivity fields.

The 3D refractivity fields are provided by the Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS®) [4]. COAMPS® is the US Navy operational mesoscale NWP model. COAMPS® provides a 0 to 48 hour refractivity forecast. The (COAMPS®)/AREPS combination is run in a highly spatially resolved mode at NSWCDD in order to forecast radar and communication system performance at any location on the globe.

III. Case Study

On May 14, 2009, COAMPS® resolved SIBL structure in northwest flow over the Persian Gulf. At 1100UTC, the notional radars were modelled with AREPS and located in the COAMPS® refractivity field approximately 210km downwind in the middle of the Persian Gulf as shown by the star in figure 1. Figure 1 represents the surface temperatures at 1100UTC in degrees Kelvin. The large scale northwest (NW)