Evaluation of wind turbine clutter detection and suppression in dual-pol weather radar observations

Amit Dutta[2], *Evan Ruzanski[1], V. Chandrasekar[2]

1. Vaisala, 2. Colorado State University

A particularly challenging weather radar problem is the identification and separation of wind turbine clutter (WTC) from weather signals and suppressing them. The problem is challenging because WTC is comprised of a stationary component (tower and nacelle) and a non-stationary component (rotating wind turbine blades). The frequency content of the quasi-periodic non-stationary WTC component overlaps that of precipitation making simultaneous suppression of WTC and preservation of the precipitation signals difficult, especially for operational use. Plan Position Indicator (PPI) scans are preferred for operational uses. They display rapidly evolving precipitation events over all azimuths within the radar’s range. The WTC mitigation algorithm presented in this paper consists of two steps: a detection step followed by a signal separation step.

In the detection step, a Generalized Likelihood Ratio Test (GLRT) is used to locate the clutter-contaminated range bins. A single hypothesis test was found to be ineffective at separately detecting both ground clutter (GC) and WTC. Hence, a new GLRT based on the distributions of WTC and GC is performed on the range bins where clutter was detected by the previous hypothesis test. Prior knowledge of the turbine locations and a corresponding clear air reflectivity scan at low elevation are used for evaluation of the performance of the detector. Detection performance includes the empirical estimation of the receiver operating characteristic curve, which depends on detection and false alarm rates for different thresholds of the test statistic. Empirical deflection coefficient for the new GLRT is estimated which is used to determine how well the detector can distinguish between GC and WTC.

Next, in the signal separation step, both the clutter and weather signals are estimated. This is based on sparse signal recovery as used in the compressive sensing domain. The signal separation partly follows the algorithm proposed by Uysal et al. (2016). The separation is done only on the range bins detected as WTC. The algorithm has a signal-modeling step where radar returns are modeled by sparse representations with appropriate regularization parameters and a solution step where the optimization problem is solved and the signals are separated. Various transforms (e.g. Fourier, Wavelet and Discrete Cosine) are analyzed for both weather and clutter signals where they exhibit sparsity. These transform domain representations essentially aid in the construction of the signal dictionary from which the sparse coefficients to determine the underlying signals are estimated. Regularizations including total variation and structured group sparsity are done in order to obtain a converging solution. According to the performances of the regularization parameters, the best signal separation technique is selected. The evaluation is done using a PPI PPI data set scanned at the lowest elevation angle (0.5 degrees) as recorded by CSU-CHILL radar. The amount of clutter suppressed is also quantified.

Uysal, F., I. Selesnick, and B.M. Isom, 2016: “Mitigation of wind turbine clutter for weather radar by signal separation”, *IEEE Trans. Geosci. Remote Sens.*, 54, 2925–2934.

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