

A Technique to Estimate Outer Scale of Turbulence from Numerical Weather Prediction in the Atmospheric Boundary Layer

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Atmospheric refractive turbulence can affect the ability of RF, IR, and optical sensor systems to detect or resolve an object or image due to signal intensity fluctuation (scintillation), beam spreading, image blurring, and other effects. Many sensor metrics quantify these atmospheric propagation effects via the refractive index structure constant (C_n^2). Methods for deriving C_n^2 from numerical weather prediction (NWP) that employ vertical gradients in mean atmospheric pressure, temperature and moisture commonly follow Tatarskii (V.I. Tatarskii, *Wave Propagation in a Turbulent Medium*, McGraw-Hill, New York, 1961. 285 pp), whose formulation is valid within the inertial subrange:

$$C_n^2 = a M^2 L_0^{4/3} \quad (1)$$

$$a = c Kh / Km \approx 2.8 \quad (2),$$

where M is the vertical refractive index gradient ($\partial n / \partial z$), c is an empirically derived constant, and the ratio of heat and momentum eddy coefficients (Kh / Km) is approximated by unity. L_0 is the outer scale over which the Kolmogorov spectrum is valid and is employed as a scaling parameter representing the largest isotropic adiabatic eddy motions. Techniques for measuring L_0 directly or inferring L_0 from meteorological data are characterized by large errors and uncertainties. Many techniques are empirically-based. Other techniques are valid for specific atmospheric layers or are subject to restrictions in turbulence regimes (e.g. bounded by critical Richardson number).

The Propagation Measurement and Analysis Group (PMAG) at the Naval Surface Warfare Center Dahlgren Division (NSWCDD) has implemented a set of C_n^2 algorithms for use with the Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS[®]) NWP model. The technique incorporates several L_0 derivations based on their applicability and availability for operational use. Results will be compared with optical C_n^2 measurements within the atmospheric boundary layer and evaluated in terms of relevant sensor metrics and meteorological context. The impact of vertical and horizontal model resolution, integration of different L_0 algorithms, and assumptions of the technique will be discussed.