Validation of an Inverse Technique to Retrieve Intermediate-Scale Structure Statistics from Time Series of Ionospheric Scintillation

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In a 2016 paper, we presented a phase screen theory for the spectrum of intensity scintillations when the ionospheric irregularities follow a two-component power law [Carrano and Rino, DOI: 10.1002/2015RS005903]. More recently we have been investigating the inverse problem, whereby equivalent phase screen parameters are inferred from scintillation time series. This is accomplished by fitting the spectrum of intensity fluctuations with a parametrized theoretical model using Maximum Likelihood (ML) methods. The Markov-Chain Monte-Carlo technique provides a-posteriori errors and confidence intervals. The Akaike Information Criterion (AIC) can provide justification for the use of one- or two-component irregularity models. We refer to this fitting as Irregularity Parameter Estimation (IPE) since it provides a statistical description of the irregularities from the scintillations they produce.

The self-consistency of the IPE technique has been verified using simulated scintillation data produced by forward phase screen propagation calculations [Carrano et al., Proc. IES, 2017]. In this paper, we use the IPE technique to analyze simulated scintillation data produced by propagating waves through high resolution physics-based simulations of equatorial plasma bubbles [Yokoyama and Stolle, DOI:10.1007/s11214-016-0295-7]. A recent analysis of the intermediate-scale irregularities in these simulations has shown them to follow a two-component power law [Rino et al., submitted to PEPS, 2017] with a systematic relationship between turbulent intensity, large scale spectral slope, and break scale.

The purposes of this study are several-fold. First, we aim to validate the self-consistency of IPE retrievals (and their inherent limitations) for scintillation produced by an extended and inhomogeneous random medium. Second, it is widely assumed that scintillation is dominated by irregularity structure near the F-region peak. To the extent that this approximation is useful, we attempt to establish whether IPE retrievals reflect the statistics of structure near the F-region peak as well. Third, can IPE provide useful information about the altitude development within an EPB? Lower frequency signals are modulated by irregularities spanning a wider range of altitudes than higher frequency signals. By considering multiple propagation frequencies we can simulate IPE retrievals under conditions for which irregularities at different altitudes contribute to the scintillation. These questions may be addressed most effectively with the use of simulated EPB data since the statistics of the medium are known in detail.