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Assimilative Real-time Models of HF Absorption at High Latitudes

Abstract:
HF radio wave absorption in the high-latitude ionosphere results from ionisation by precipitating energetic particles. A UK/Canada research programme is therefore developing online tools to assist fixed-mobile HF communications frequency management for aircraft on trans-polar routes. These will help to plan the re-routing of communications links or, where necessary, the re-routing of aircraft to maintain communications during absorption events. We describe new polar cap absorption models that assimilate real-time measurements of zenithal cosmic noise absorption (at 30-38 MHz) from a distributed network of up to 30 riometers in Canada and Finland. Type 1 models (based on DRAP [1]) relate absorption to the square-root of near-Earth proton flux above an energy threshold. The day- and night-time scaling coefficients and energy thresholds are optimised by regression to riometer measurements. Further optimisation is available by introducing terms dependent on magnetic local time and season. Type 2 models (based on [2]) incorporate altitude profiles of neutral densities and temperatures from the NRLMSISE-00 model [3] and the full spectrum of proton energies. These are optimised by varying the night- and daytime scale heights of the recombination coefficient profile in the D-region. An assessment of 13 large, multi-day solar proton events (SPE) in Solar Cycle 23 demonstrates that real-time optimisations at a single polar cap location improves root-mean-square errors (RMSE) from 2-3 dB to less than 1 dB and mean errors to within +/-0.2 dB over a wide latitude range. Assessing the performance of two rigidity cutoff latitude models ([4], [5]) during SPEs, we find that the model derived from POES satellite measurements [4] gives lower RMSE than the model [5] currently used in DRAP. The latter model [5] requires a 2-3° equatorward shift to best-fit riometer measurements, and this shift may be optimised in real-time by regression to distributed riometer measurements. Further improvements to model accuracy near the solar terminator are obtained by optimising the dependence on solar-zenith angle independently at dawn and dusk. Continuous energetic particle flux measurements from the geostationary GOES satellite may be complemented by localised measurements from POES satellites in low, polar orbits, subject to assumptions on the pitch angle distribution. During SPEs the POES measurements provide a direct measurement of the rigidity cut-off latitudes. We discuss the integration of an optimised absorption model into HF ray-tracing propagation predictions [6] relating to measurements of HF signal strengths on a network of HF transmitters and receivers in the high northern latitudes.

References
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