GNSS RADIO OCCULTATION INTERPOLATED BY MACHINE LEARNING AND BAYESIAN INTERPOLATION

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GNSS radio occultation (RO) is a space-based remote sensing technique that profiles microwave refractivity, temperature, and pressure in the atmosphere by measuring the refractive bending of signals transmitted by the Global Navigation Satellite Systems (GNSS) transmitters as they transect the Earth's limb. Long-term stability, all-weather capability, and high accuracy make RO very attractive to the meteorological community. Indeed, RO profiles at a global scale are routinely assimilated into numerical weather prediction models. However, constructing RO-based climatologies is complicated because the sampling density is non-uniform and so low that it does not resolve synoptic variability in the atmosphere.

Bayesian interpolation (BI) is a state-of-the-art approach to construct RO climatologies in which the occultation data are fit — but not over-fit — using spherical harmonics as basis functions on constant height surfaces. In this presentation, we investigate a neural network machine learning (ML) algorithm to generate maps of RO-retrieved products based on sparse RO data. We produce RO climatologies using ML and compare them to the performance of BI. Furthermore, we train the ML models using the residuals of BI in a combined BI+ML approach. We map microwave refractivity on six constant geopotential height surfaces (2, 3, 5, 8, 15 and 20 km), representing diverse atmospheric dynamical regimes. We focus most of our evaluation at the lowest layer (i.e., 2-km), where RO is sensitive to small horizontal scale structures associated with boundary layer clouds and correlated variations in water vapor density. We use the forecasts of the operational numerical weather prediction system of the European Centre for Medium-range Weather Forecasts (ECMWF) as a nature run, interpolate the forecasts to the times and locations of COSMIC-2 RO data over a period of 10 days, apply BI-only and ML-only, and combined BI+ML to map the simulated data. Then the results are compared to the gridded products of ECMWF to evaluate the performances of these three approaches. COSMIC-2 produces approximately 3500 RO soundings daily spanning 46°S to 46°N latitude only.

We find that the performances of BI in interpolating RO data and of ML in interpolating RO data are comparable; however, we find that ML when applied to the residuals of BI offers further improvement in interpolating RO data in the form of increased temporal and horizontal resolution. BI is able to provide maps of refractivity at a cadence of a few days whereas BI+ML provides maps of refractivity at a cadence of 3 hours. The posterior uncertainties in microwave refractivity at each iso-height surface for BI-only are 10.9, 9.1, 5.3, 1.6, 0.6 and 0.3 N-unit. The posterior uncertainties for the same for BI+ML are 8.7, 6.6, 3.6, 1.1, 0.3 and 0.2 N-unit.