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The formation of level 3 climatologies of radio occultation (RO) data from level 2 retrievals of refractivity, dry temperature, and other inferred atmospheric quantities is greatly complicated by the sparsity of the data and nonuniform sampling in the horizontal, in time, and in local (solar) time. Two approaches are currently being applied: sampling error removal (SER) and Bayesian interpolation. The former accounts for even extreme nonuniformity in the sampling density in space and time and greatly reduces the noise of synoptic variability of the atmosphere in level 3 RO climatologies by subsampling numerical weather prediction (NWP) forecasts to the times and locations of RO soundings. The latter accounts for the nonuniformity by fitting basis functions to the data without over-fitting the data, inferring the effective horizontal resolution of the data set in the process. There is some risk in SER, however, in that it relies on the NWP model not containing systematic flaws in the variability that SER seeks to remove. In this work we address the role of the diurnal cycle in the atmosphere as it pertains to the formation of climatologies of RO data.

Bayesian interpolation with an extension into the diurnal cycle domain is applied to retrievals of refractivity, dry temperature, and geopotential height from COSMIC RO data from 2007 through 2016 and to the difference between RO data and the forecasts of ERA-Interim. The RO retrievals are provided by the Climate Data Record generated by the Radio Occultation Meteorology Satellite Application Facility (ROM SAF). The tropical atmospheric migrating tides are prominent as is the trapped mode at the mid-latitude stratopause. The forecasts of ERA-Interim replicate the downward propagating tides almost perfectly but not the trapped mode at the mid-latitude stratopause: ERA-Interim overestimates its amplitude and produces a maximum about 1 hour too early in the diurnal cycle. This implies error in SER climatologies based on RO data that irregularly span the diurnal cycle, and the magnitude of the effect is ~0.2 K in the upper stratosphere. Finally, a comparison of the analyzed diurnal cycle between solar maximum (2012–2015) and solar minimum (2007–2011) reveals no empirical evidence for the existence of ionospheric residual as a source of error in RO climatologies, contrary to theoretical predictions.
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