Studying the effect of GPS radio occultation bending angle variations on the retrieval process of dry atmospheric temperature profiles: A sensitivity analysis

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The interest in studying the effect of Global Positioning System (GPS) radiowave signals bending angle variations on the retrieval process of dry atmospheric temperature increases, in response to the rising demands for accuracy improvements in atmospheric parameters retrieval with the launch of upcoming GPS radio occultation (RO) missions (e.g., COSMIC-II). Specifically, theoretical estimates and computation of GPS RO observational errors of radiowave signals' bending angle has already been conducted by various authors.

However, such theoretical studies and GPS RO observational error estimates of bending angle profiles were based on forecast models and early RO missions (e.g., CHAMP and SAC-C). With the launch of the Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) another set of error estimates was conducted revealing that the theoretical errors estimates predicted so far were underestimating the actual observational error on bending angle profiles. However, all these studies did not provide an insight in how atmospheric parameters might react on bending angle variations as function of altitude. On these grounds, based on the so-far theoretical studies and observational error estimates of bending angle profiles from various GPS RO missions, we conduct a set of sensitivity analysis by varying a reference case bending angle profile between 1.5×10^{-6} rad and 10^{-3} rad. We anticipate that such a rage of variations could cover the errors induced by multiple error sources such as, thermal noise, multipath, orbital velocity errors, spherical symmetry assumptions and un-calibrated ionospheric effects.

To perform such a task, we independently implement geometric optics techniques rather than using the widely-known Abel Inversion transform to invert bending angle into refractivity profiles. We observe that propagating bending angle variations of the order of $\pm$ 1 %, $\pm$ 3 % and $\pm$ 5 % into the atmospheric dry temperature retrieval process leads to $\mp$ 16 %, $\mp$ 44 % and $\mp$ 80 % variations in the dry atmospheric temperature profiles between 35 km and 60 km. Below 35 km, the atmospheric dry temperature retrieval process seems to be insensitive to bending angle variations. This indicates that the bending angle variations are not linearly correlated with the resulting variations of atmospheric dry temperatures. The results of our sensitivity analysis indicate that inducing a 10^{-5} rad uncertainty in bending angle profiles, we can estimate atmospheric dry temperature profiles within $\mp$ 3.2 K. Thus, in the upcoming event of launch of future GPS RO missions, estimating bending angle profiles to better than 1.5×10^{-6} rad in the middle stratosphere and above is a necessity. At such high altitude the primary source of bending angle errors is the un-calibrated higher-order ionospheric effect, which needs to be modeled and removed from the GPS RO observables.