Assimilation of GPS Radio Occultation Observations

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In a local refractivity assimilation (Kursinski et al 2000, Poli et al 2002), a simulated refractivity profile is interpreted as a vertical profile at the averaged position of all tangent points of a radio occultation (RO). In the bending angle assimilation, the along-track refractivity and its gradient determines the bending of each individual ray-path through the integration of the ray-trajectory equation (Zou, 1999). The bending angle calculated from such an operator is physically consistent to the way the Global Positioning System (GPS) RO observations are obtained and processed. Such a consistency renders the bending angle assimilation more desirable when accuracy is a priority. However, the integration of the ray-trajectory equation is expensive, especially for its applications in operational weather forecasts. Aiming at achieving both accuracy and computational efficiency, a new observation operator that simulates the GPS excess phase delay was proposed and tested for GPS RO data assimilation. The GPS excess phase delay is approximated in the assimilation forward operator as a integration of the local refractivity along the tangent link of a ray-path of the radio signal transmitted from a GPS satellite to a low Earth Orbit (LEO) satellite, occulted by the Earth (Figure 1).

The National Centers for Environmental prediction (NCEP) spectral statistical interpolation (SSI) system at a resolution of T170L42 was used. The forward operator and its adjoint model for the assimilation of the excess phase delay were developed and incorporated. The forward simulation and assimilation experiments using the system were conducted (PHA) for the time period from May 20 to 31, 2002. A total of 1158 the German CHAllenging Minisatellite Payload (CHAMP) RO sounding observed in the time window during the period were used. Two more experiments, local refractivity simulations and assimilations (REF) and a control run without the assimilation of GPS data (NOGPS) were also carried out. The results from PHA, REF and NOGPS were compared. Based on the same background of refractivity, the excess phase delay simulated by PHA has less bias from its observation value than the local refractivity simulated by REF from its observation (Figure 2). After assimilations of GPS data, PHA results in a smallest bias of the GPS refractivity than REF and NOGPS, indicating that the analysis from PHA is more accurate than those from the other two experiments. The impacts of the assimilation of the excess phase delay observations were studied in terms of both the general statistical mean and STD and case studies. We found that PHA tends to produce a warmer and moister atmosphere than REF. It also introduces a finer structure with a larger radius of influence to the temperature and specific humidity analysis fields (Figure 3 and 4).

Under the assumption of the spherical symmetry of the local refractivity, an alternative form of the excess phase delay, symmetric excess phase delay, and its observation operator were derived. Simulation and assimilation experiments using the forward operator were carried out (PHA-sym). It shows that PHA-sym produces intermediate results between PHA and REF. Since it is simpler than PHA, and meanwhile keeps most information for the alongtrack refractivity gradients, it may be more desirable in a operational numerical model implemented via a localized parallel algorithm without any changes of the model structure. However, when and where this symmetric excess phase delay can substitute the excess phase delay are yet to be studies further.

Computations were performed on the IBM SP4 at the FSU. GPS radio occultation data were provided by COSMIC at UCAR. This research was supported by NSF project: ATM-0101036.

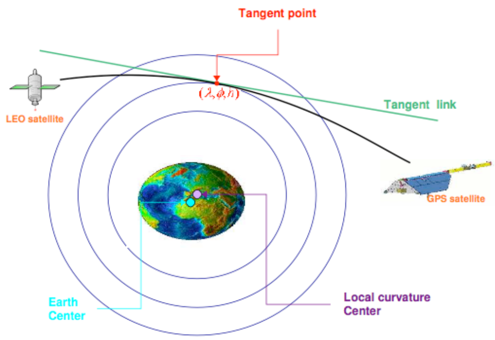

Figure 1: Schematic illustration of the definition of a tangent link. Assume the earth is an ellipsoid. Given a GPS measurement at a tangent point (λ, φ, h), a tangent line (referred to as the tangent link) is constructed so that it goes through the point (λ, φ, h), tangent to the local curvature and coplanar to the plane containing the GPS and LEO satellites (occultation plane).

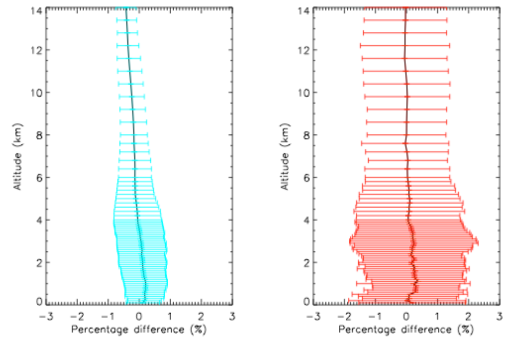

Figure 2: Vertical profiles of the mean and standard deviation (error bars) of fractional difference between the simulation and the observed values of GPS excess phase delay (left panel) and local refractivity (right panel). The quantities are calculated from 1158 simulated soundings during May 24-31 2002.

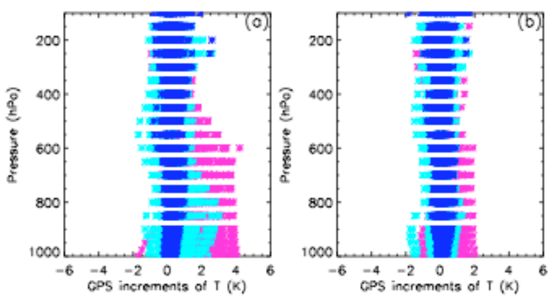

Figure 3: Spaghetti plots of the GPS increments of T for (a) PHA and (b) REF. The profiles have been color-coded according to their corresponding occultation latitudes: blue represents soundings in the tropics (30°S − 30°N), cyan represents soundings in mid-latitudes (30°S − 60°S and 30°N − 60°N) and magenta represents soundings in high-latitudes (60°S − 90°S and 60°N − 90°N).

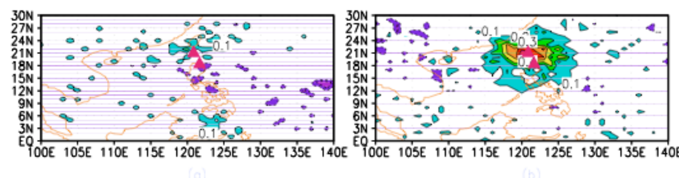

Figure 4: Distribution of the GPS increments of the 850hPa specific humidity in the subdomain (10° − 140°E, 90° − 10°S) at 06UTC May 30, 2002 for REF (left panel) and PHA (right panel). The triangles indicate the GPS occultation points.

References

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