ESTIMATING THE PHASE SIGNATURE OF THE EARTH'S IONOSPHERE USING GPS CARRIER PHASE MEASUREMENT

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1. INTRODUCTION

Interferometric Synthetic Aperture Radar (InSAR) and the Global Positioning System (GPS) are commonly used to obtain surface topography and surface motions for the study of crustal deformation. Because both of these systems operate from satellites high above the Earth's surface, the arrival time of the propagating signals is delayed as the signals travel through the Earth's ionosphere. As a result, it is necessary to consider the total electron content (TEC) of the ionosphere, and predict the corresponding ionospheric delay in interferograms or GPS data, to properly interpret the measurements.

2. APPROACH

There have been many investigations of the ionospheric delay of GPS data and its correction. For example, the Wide Area Augmentation System (WAAS) uses a network of ground-based reference stations, in North America and Hawaii, to measure small variations of the ionospheric delays in the GPS satellites' signals in the western hemisphere [1]. However, the quantized correction message produced by that system is only available every 5 degrees in latitude and longitude over North America, and much more local estimation of the vertical TEC (TECV) is needed to correct interferograms. In addition, the absolute delay is not well characterized in this data set, as the uncertainty can be several meters of delay. Similar uncertainties result from the use of ionospheric models such as the IRI [2], and they also suffer from the same lack of positional resolution.

We have used carrier phase measurements of dual-frequency GPS data to estimate the absolute ionospheric group delay referenced to the GPS L1 frequency and thus the TECV. The carrier phase measurement is precise to the cm level but has an integer ambiguity as the total number of cycles of phase is not known a priori. Previous techniques attempt to solve the integer ambiguity by combining code and carrier phase measurements; however, the dual frequency code measurement itself has a constant bias due to the unknown phase delay. This leads to an error in the estimate of TECV after we apply the vertical correction (obliquity factor) to the slant path measurements. Therefore, we used the most local WAAS data as a reference and computed the ambiguity in the carrier phase measurements by shifting the data over a series of possible missing cycles, and minimizing the difference of the phase data corrected for the obliquity factor and the reference.

The difference of the optimized results and the reference yields the time variation of TECV, which we can relate to spatial variation using the known sky tracks of the GPS satellites. We compared the TECV variations of two different times at which two sets of SAR data are used to form interferograms over California and Iceland. WAAS data were not available over Iceland, so we used one satellite data as a reference, varied the reference from 0 meters to 10 meters additional ambiguity error, applied the obliquity factor, and compared the result to the pseudoreference. Again we optimized our results by choosing the ambiguity that minimized the total variations of all satellite results.

3. RESULTS

We present our residual TECV variations of two different times at which two sets of SAR data are used to form interferograms over California. We observed more rapid TECV changes in Iceland data set, which in turn predict a greater azimuth pixel shift and accompanying decorrelation. Figure 1 shows the inferred TEC variation with time; Figure 2 shows the corresponding interferograms.

The SAR data were acquired at 23:16 UTC. During 23.2UTC-23.3 UTC, the ionospheric delay of ALOS signal predicted by satellite 9 (green curve) has a slope of 2.1meters/hour. The corresponding change of the ionospheric delay over one aperture length is 10.5 cm, which is equal to a Doppler shift of 0.33 Hz or 1.17 pixels shift. However, the pixel shift for California data set is only 0.14 pixels. The Iceland interferogram shows clear ionospheric artifacts while the California interferogram does not. This corresponds directly to the high level of observed Iceland TECV variation on September 2nd, 2007 which shows rapid changes over a synthetic aperture sky trace.

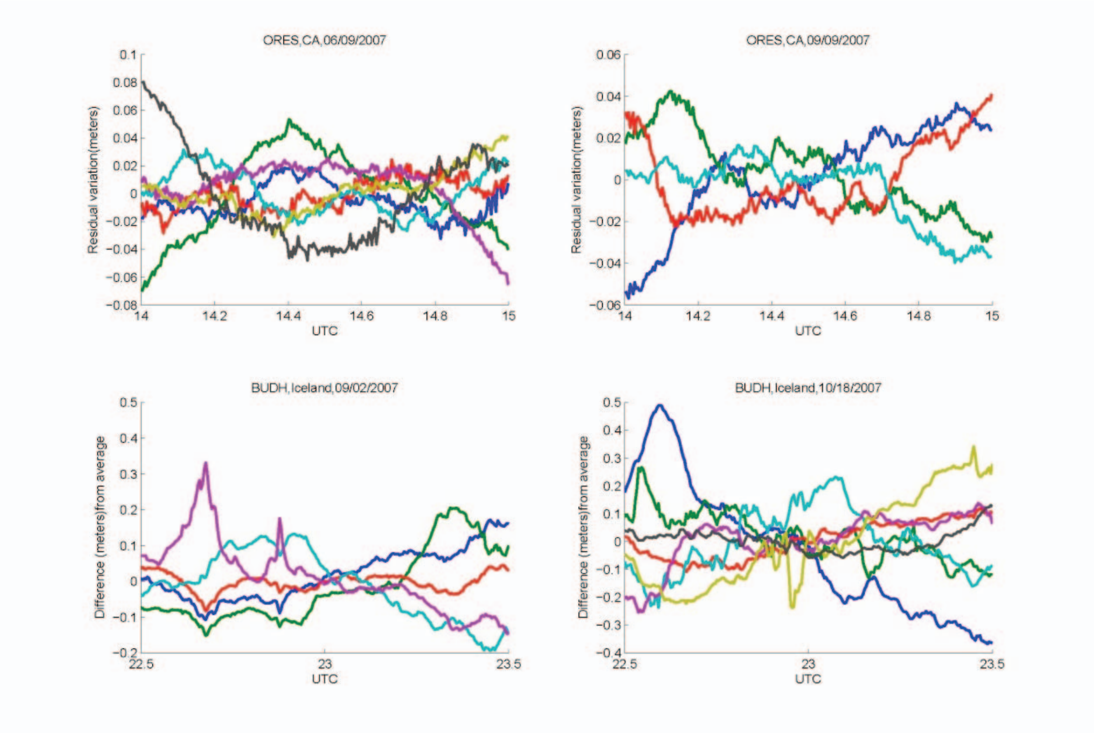

Figure 1. Observed changes in vertical TEC over Iceland and California.

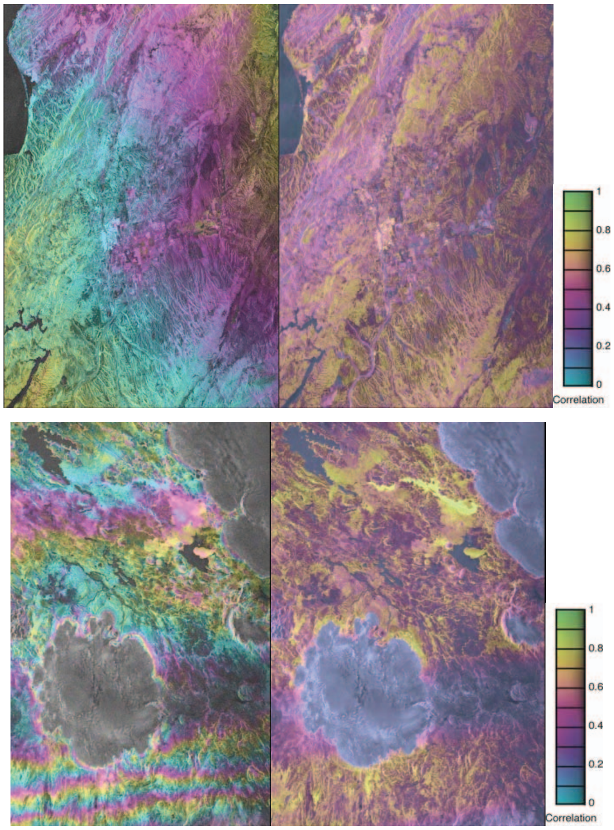

Figure 2. Interferograms, correlation for the California data set (upper).

Interferograms, correlation for the Iceland data set (bottom).

4. CONCLUSION

In conclusion, GPS dual frequency carrier phase measurements can be used to estimate the variation of TECV. The rapid TECV changes in Iceland data set lead to about one pixel shift in interferograms while the worst TECV changes in California can only cause 0.14 pixel shift, sufficient to decorrelate the region in the Iceland data but not a significant error for the California data set.

5. REFERENCES

[1] U.S. Department Of Transportation & Federal Aviation Administration, Specification for the Wide Area Augmentation System (WAAS).

[2] D. Bilitza and Reinisch, B., International Reference Ionosphere 2007: Improvements and new parameters, J. Adv. Space Res., 42, #4, 599-609, doi:10.1016/j.asr.2007.07.048, 2008.

6. ACKNOWLEDGEMENT

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