# Dynamics of the Solid Earth
# Summary Report

Prepared by
Dr. Curt Knight
Co-Investigator
Interferometrics Inc.
8150 Leesburg Pike #1400
Vienna, VA 22182

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## 1.0 Introduction

This report summarizes the work done under contract NAS5-31747 and its subcontract with NVI, Inc. For details, consult the monthly reports prepared and submitted directly by NVI, Inc.

## 2.0 Tasks

The tasks intended to be performed during the present investigation can be summarized:

1. Perform comparisons of station position and atmospheric zenith path determinations by VLBI and GPS methods.
2. Investigate the use of GPS data to calibrate the atmospheric variations in VLBI data.
3. Investigate the detectability of atmospheric zenith path gradients.
4. Determine a means for judging the quality of a set of observing conditions regarding atmospheric zenith path variations.
5. Attend DOSE investigators meetings.

By far the bulk of the effort was expended on tasks 1 and 3.

## 3.0 Work Summary

In preparation for the fall 1994 AGU meeting, MacMillan and Elowitz compared the tropospheric zenith delays estimated from GPS data and from VLBI data during the two-week CONT94 observing series in January 1994. This comparison resulted in a paper presented at the AGU meeting. MacMillan used the GPS atmospheric results to calibrate the VLBI data, with the result that it was not clear that GPS was better than a standard 7 degree cutoff VLBI solution in terms of station position consistency.

In a further investigation of the accuracy with which atmospheric zenith delays can be estimated with GPS receivers, MacMillan compared the measured atmospheric delays from an ensemble of GPS receivers located near GGAO. He also began an investigation into the question of atmospheric gradients by looking into how the gradients could be estimated using GIPSY. More regional GPS data were obtained. These data were converted to RINEX format using the Berne software and were reduced using a version of GIPSY that had been modified by MacMillan to incorporate the multipath tools from K. Jaldehag at Onsala.

The further analysis of CONT94 data resulted in a poster talk for the UNAVCO GPS meeting in Boulder.

MacMillan investigated the regional GPS data for the possible effects of multipath and atmospheric errors by determining the height of a station using many different elevation cutoff angles. He found that the height estimate changed approximately linearly with

elevation angle cutoff over the range 7.5 to 40 degrees. In a further effort to reduce the effect of multipath propagation, MacMillan investigated different methods for reducing the effects of scattering from the pillar supporting the GPS antennas and the surrounding earth. The effect of this scattering was apparent in the signal amplitude and the behavior of amplitude vs. Elevation angle was successfully modeled in terms of the mount geometry by Knight, using a simulation program which also predicted the effect on measured pseudorange. A brief investigation by Knight into the use of maximum entropy estimation techniques to aid in determining the correct pseudorange in the presence of multipath was inconclusive.

More data were obtained using 12 GPS receivers running during the August 30 1995 VLBI experiment. Gipson completed a theoretical study of atmospheric modeling errors.

Future effort will include applying GPS atmospheric calibrations to more VLBI experiments to further determine the conditions under which this technique is useful. This will involve analysis of the GPS data obtained in August 1995. Further, the atmospheric gradients inferred from VLBI data will be compared with gradients inferred from GPS data reduced using a version of GIPSY that hopefully will be released by JPL within the next few weeks.

Additional presentations for the AGU will be prepared on the subjects of the results from the GPS receiver array and the investigation of multipath.

## 4.0 Publications and Papers Given

D. S. MacMillan and R. M. Elowitz, "Atmospheric Delays Estimated from GPS and VLBI During CONT94", Abstract for AGU Fall Meeting, San Francisco, 28 Sep 1994.

D. S. MacMillan and T. A. Clark, "Optimum Elevation Limits for GPS Observing", Presented at IUGG XXI General Assembly.

D. S. MacMillan and T. A. Clark, "Modeling Tropospheric Delay in VLBI and GPS Analysis", Poster paper at UNAVCO GPS meeting, Boulder, CO.

D. S. MacMillan and T. A. Clark, "Atmospheric Delays Estimated from an Array of GPS Receivers", Abstract for fall AGU meeting, San Francisco, 1995.

T. A. Clark and D. S. MacMillan, "Mitigation of Effects of Multipath Signal on GPS Position Estimates", Abstract for fall AGU meeting, San Francisco, 1995.

J. Gipson, "How Low Should You Go? Atmospheric Modeling Errors and Elevation in Space Geodesy", draft

D. S. MacMillan, C. Ma, and T. A. Clark, "Atmospheric Gradients in VLBI and GPS Analysis", presented at DOSE investigators meeting, Pasadena, 31 Oct 95.

J. Gipson, "Atmospheric Modeling Errors and Space Geodesy", presented at DOSE investigators meeting, Pasadena, 31 Oct 95.

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**16. Abstract**

The work performed under this contract provides for the improvement of modeling of troposphere propagation delay in VLBI data, defining of required accuracy of ancillary data type(s) to measure tropospheric behavior and to develop a clear correspondence between tropospheric behavior and the quality of geodetic VLBI measurements.

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