MEASUREMENT AND INTERPRETATION OF CRUSTAL DEFORMATION RATES ASSOCIATED WITH POSTGLACIAL REBOUND

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I. Introduction

This project involves obtaining GPS measurements in Scandinavia, and using the measurements to estimate the viscosity profile of the Earth's mantle and to correct tide-gauge measurements for the rebound effect. Below, we report on several aspects of this project.

II. GPS Measurements

The DSGS has not yet been fully occupied, due to a delay in the acquisition of GPS receivers by NASA. Preliminary measurements have been obtained in order to test the practicalities of receiver "mixing" and to obtain an idea of the expected accuracies in estimates of intersite vectors. The analysis of these measurements was presented in Johansson et al. [1992], a copy of which is contained in Appendix A.

III. Theoretical Advances

An important technical advance we intend for this project is to use the full three-dimensional site velocity information for inferring geophysical parameters. To this end, we have investigated the sensitivity of the estimates of the mantle viscosity profile to horizontal deformations, and presented this work in Mitrovica et al. [1992], a copy of which is contained in Appendix D.

References


Initial GPS Measurements of Fennoscandian Uplift

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INTRODUCTION

A Swedish network consisting of twenty GPS stations has been proposed in support of an ongoing investigation, supported by the NASA DOSE project, to study postglacial rebound in Fennoscandia (see map with apparent land uplift). The monumentation has been carried out by the National Land Survey of Sweden. High precision GPS receivers and complementary equipment are being purchased.
Fig. 1. Apparent land uplift (mm/yr)
PRESENTLY USED SUB-NETWORK

A subnet consisting of five stations has been in use since the start of the International GPS Service (IGS) campaign in the summer of 1992. The five sites, also shown on the map, are Onsala Lovö, Mårtsbo, Furuögrund, and Kiruna. The Furuögrund site is near the regional maximum of Fennoscandian uplift.

The data analyzed for this presentation have been acquired as follows

July 25–27:

Rogue receiver at Onsala

P-code Ashtech receivers at Lovö, Mårtsbo, Furuögrund, and Kiruna.

October 6–9:

Rogue receiver at Onsala, Mini-Rogue receiver at Lovö, and Turbo-Rogue receiver at Mårtsbo

P-code Ashtech receivers at Onsala, Lovö, Mårtsbo, Furuögrund, and Kiruna.
GPS ANALYSIS

All data were processed using the Bernese version 3.2 Software. The data were divided into 3 subsets:

1) The 5 station network observed in July using a Rouge receiver at Onsala and Ashtech receivers at the other sites. These results are showed as filled circles below.

2) The 5 station network observed in October using Ashtech receivers. These results are showed as filled squares below.

3) The 3 station network observed in October using Rogue receivers. These results are showed as open squares below.

In addition a sample of the October data set has also been processed with the GIPSY software. These results are showed as triangles below.
The ties between the collocated monuments at Onsala, Mårtsbo and Lovö are believed to be estimated with mm-level accuracy. All except 2 receivers were connected to external frequency standards. Four European sites with collocated VLBI/SLR and GPS monuments were used for satellite orbit determination, namely Wettzell, Kootwijk, Metsähovi, and Tromsø. The estimated orbit parameters were compared with the Precise Ephemeris produced by Jet Propulsion Laboratory (JPL) based on data from the Global GPS Tracking Network in order to check the quality. No significant difference was found. The following pages present plots of variation in the station-to-station baseline length and the vertical component using 24 hour data sets.
Onsala-Mårtbo Baseline Length

Mean Baseline Length = 469,742,863 mm
WRMS Total = 6 mm

- Rogue/Ashitch: bias = 7 ± 2 mm
- Rogue/Ashitch: bias = 1 ± 8 mm
- Rogue: GIPSY: Rogue/Ashitch
- GIPSY: Rogue/Rogue

Baseline Length About Mean (mm)
Mårtsbo-Lovö Baseline Length

Mean Baseline Length = 143,655,499 mm
WRMS Total = 4 mm

- Ashtech/Ashtech: bias = 5 ± 1 mm
- Ashtech: bias = 3 ± 3 mm
- Rogue: bias = -2 ± 3 mm
- GIPSY: Rogue/Rogue
- GIPSY: Ashtech/Rogue

DOY 1992
Onsala-Lovö Baseline Length

Mean Baseline Length = 407,381,078 mm
WRMS Total = 9 mm

- Rogue/Ashtech: bias = 14 ± 2 mm
- Ashtech: bias = -4 ± 6 mm
- Rogue: bias = -6 ± 5 mm
- GIPSY: Rogue/Rogue

Day Of Year 1992

Baseline Length About Mean [mm]
Onsala-Kiruna Baseline Length

Mean Baseline Length = 1,253,681,660 mm
WRMS Total = 9 mm

- Rogue/Ashtech: bias = 5 ± 5 mm
- Ashtech: bias = -4 ± 10 mm
Onsala-Furuögrund Vertical Component

WRMS Total = 20 mm

- Rogue/Ashtech: bias = -14 ± 20 mm
- Ashtech: bias = 11 ± 20 mm

Day Of Year 1992
Mårtsbo-Lovö Vertical Component

WRMS Total = 5 mm

Vertical Component About Mean [mm]

- Ashtech/Ashtech: bias = -7 ± 6 mm
- Ashtech: bias = -2 ± 4 mm
- Rogue: bias = 3 ± 4 mm

Day Of Year 1992
RESULTS AND CONCLUSION

Even though the processed data set is small and spans a relatively short time period it is possible to draw some general conclusions. The agreement between the two measurement epochs and the two receiver types is good. The day-to-day repeatability is on the order of 10 ppb. The quality of the collected data were good and more than 80% of the total amount of data was used every day. Unfortunately, the quality of the data collected in the northern part of Sweden are slightly worse due to the satellite constellation and ionospheric effects. The global tracking network can be used for orbit estimation with high-precision results.
IMPlications FOR THE ESTIMATION
OF THE MANTLE VISCOSITY PROFILE

One of the main applications of the three-dimensional crustal deformations estimated from data collected by the GPS network will be an inference of the radial profile of mantle viscosity below the region. The radial resolving power of the data to be collected by the GPS network has been estimated using a sensitivity analysis, and is shown in the plot below. The plot suggests that the network will be capable of resolving structure on a variety of radial length scales on the top 800 km of the mantle, and that horizontal and vertical motions both important contributors to the resolving power of the full data set.
Appendix B. Mitrovica et al. [1992]
Three-Dimensional Crustal Deformations Due to Post-Glacial Rebound


Harvard-Smithsonian Center for Astrophysics
VLBI BASELINES

What is the potential information provided regarding mantle rheology given the spatial coverage of a set of VLBI Baselines in N. America & Europe??

What is resolving power of VLBI baseline coverage?
What is radial length scale that we can resolve \( v(\tau) \) & how does this vary with depth?

NORTH AMERICA: 19 BASELINES
including sites...
ALCOPARK
GILCREASE
PENTICTON
WESTFORD
WYTHORSE

FT. DAVIS
NRAO
PARRPOINT
RICHMOND

EUROPE: 5 BASELINES
including sites...
ONCALA, SW
WETZELL, GERM.
EFLSBERG, GERM.
MEOLINA, IT.
NOTU, IT.
MADRO, SPAN.
RESOLVING POWER: VLBI BASELINE RESULTS

Radial Resolution (km)

Target Depth (km)

- Lower Mantle
- Upper Mantle

European Baselines

North American Baselines

Surface
SWEDISH GPS NETWORK

SWEDEN
- Arjeplog
- Furuögrund

NORWAY
- Östersund
- Umeå

GULF OF BOTNIA
- Leksand
- Mårtåbo
- Karlstad
- Lovö
- Jönköping
- Visby
- Onsala
- Hasselholm

14 SITES MONUMENTED
L = PROPOSED
TOTAL = 20

REGION OF MAXIMUM UPLIFT

GPS NETWORK
SWEDISH LAND SURVEY
ONSALA SPACE OBS.
HARVARD-SMITH, CFA
UNIV. OF TORONTO
RESOLVING POWER: NORTHERN EUROPE

Target Depth (km)

Radial Resolution (km)

VLBI +
GPS NETWORK

VLBI BASELINES

LOWER MANTLE

UPPER MANTLE