

MEASUREMENT AND INTERPRETATION OF CRUSTAL DEFORMATION RATES ASSOCIATED WITH POSTGLACIAL REBOUND

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Principal Investigator

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The NASA Technical Officer for this Grant is Dr. Bruce Bills, Code: 921, Laboratory for Terrestrial Physics, Earth Sciences Directorate, NASA/Goddard Space Flight Center, Greenbelt, Maryland 20771.



Appendix A. Johansson et al. [1992]

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

- Johansson, J.M., J.L. Davis, J.X. Mitrovica, I.I. Shapiro, R.T.K. Jaldhag, G. Elgered, B.O. Rönnäng, B. Jonsson, G. Hedling, M. Ekman, Initial GPS measurements of Fennoscandian uplift (abstract), *Eos Trans. AGU*, 73(43), Fall Meeting Suppl., 123, 1992.
- Mitrovica, J.X., J.L. Davis, J.M. Johansson, I.I. Shapiro, Three-dimensional crustal deformations due to post-glacial rebound (abstract), *Eos Trans. AGU*, 73(43), Fall Meeting Suppl., 120, 1992.

Initial GPS Measurements of Fennoscandian Uplift

by

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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.

POSTGLACIAL UPLIFT OF FENNOSCANDIA

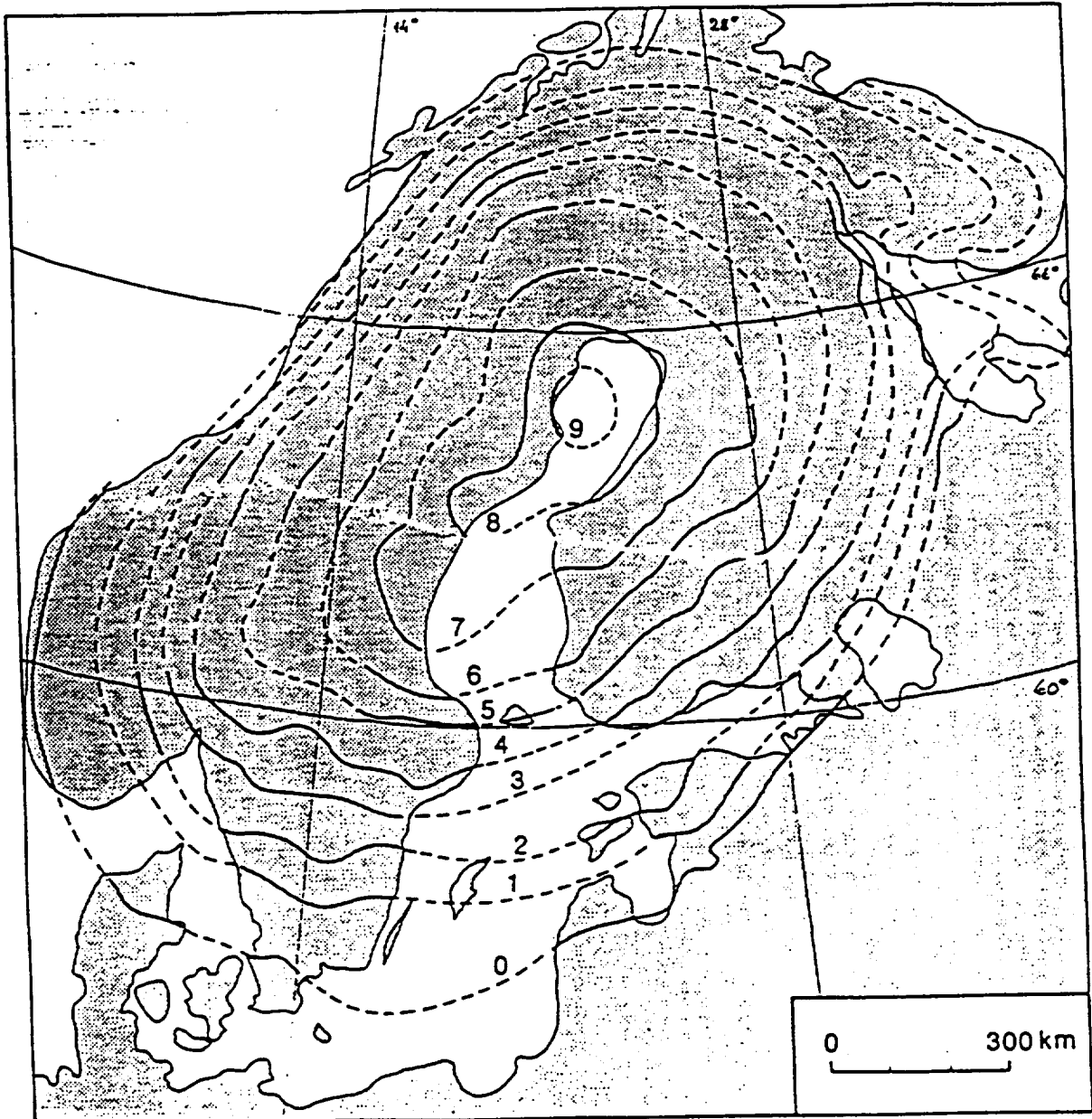


Fig. 1. Apparent land uplift (mm/yr)

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

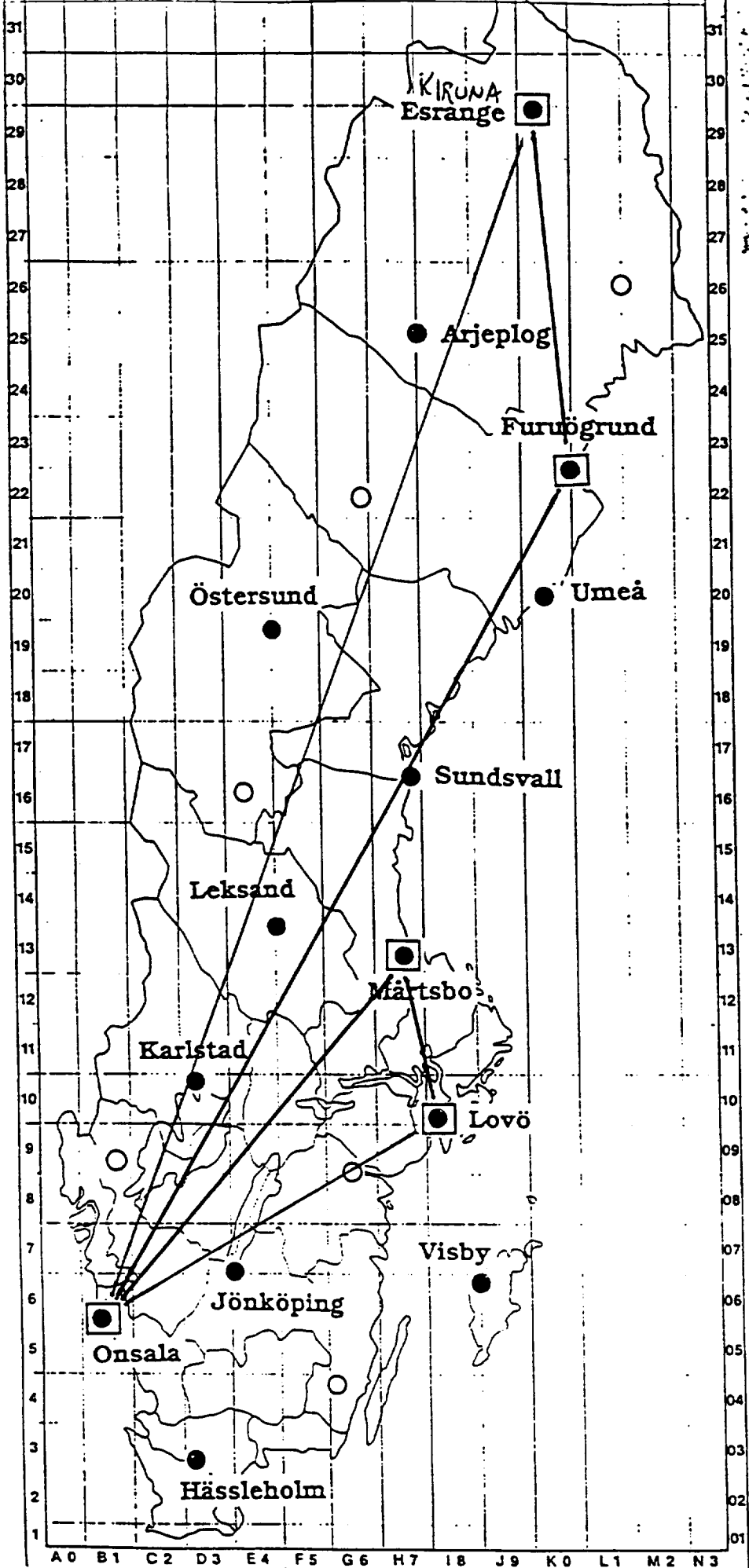
P-code Ashtech receivers at Lovö, Mårtsbo, Furuögrund, and Kiruna.

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.



— Analyzed Baselines

- - - Presented Inferred Baselines

GPS ANALYSIS

All data were processed using the Bernese version 3.2 Software. The data were

divided into 3 subsets:

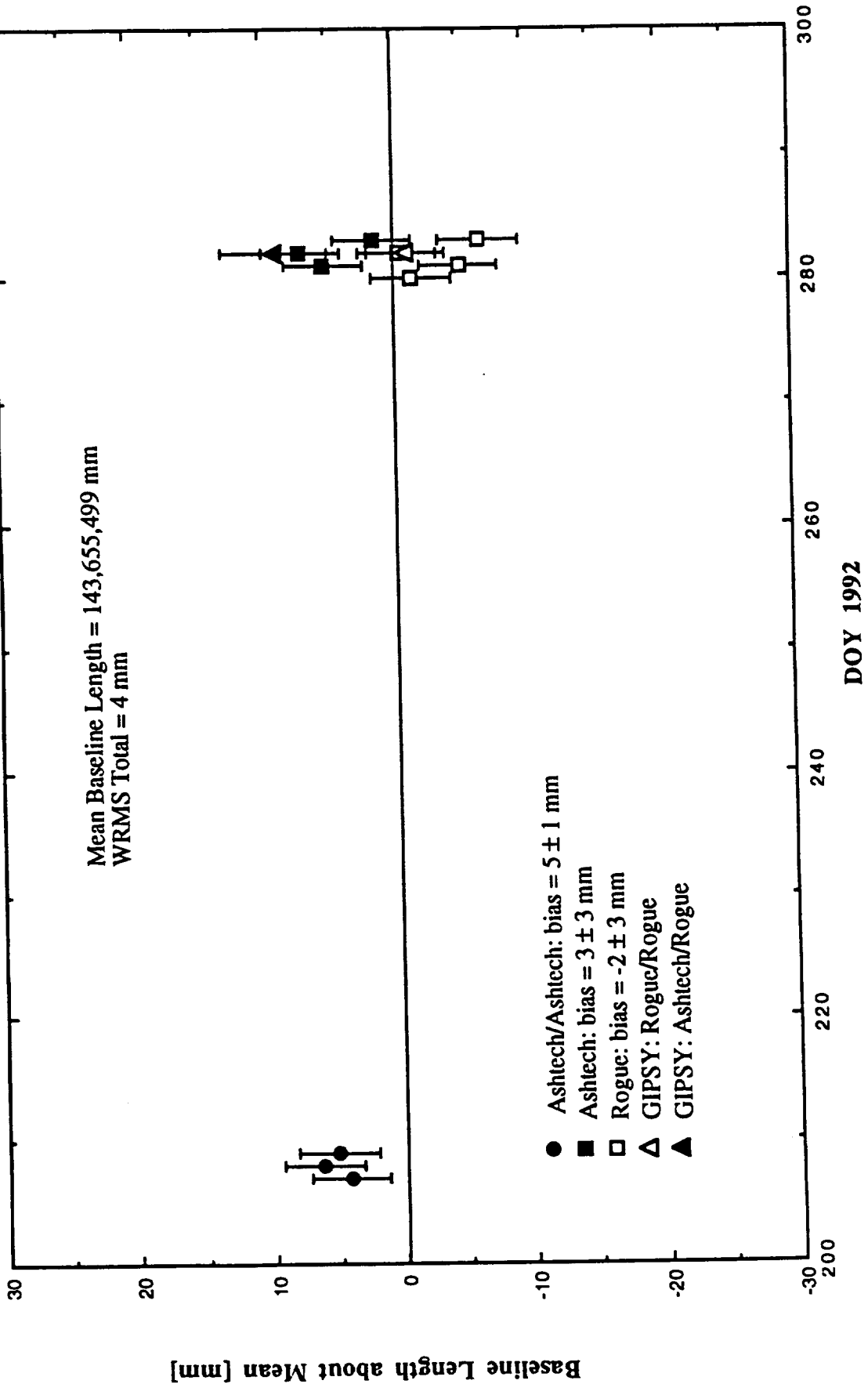
- 1) The 5 station network observed in July using a Rouge receiver at Onsala and Ashtech receivers at the other sites. These results are showed as filled circles below.
- 2) The 5 station network observed in October using Ashtech receivers. These results are showed as filled squares below.
- 3) The 3 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.

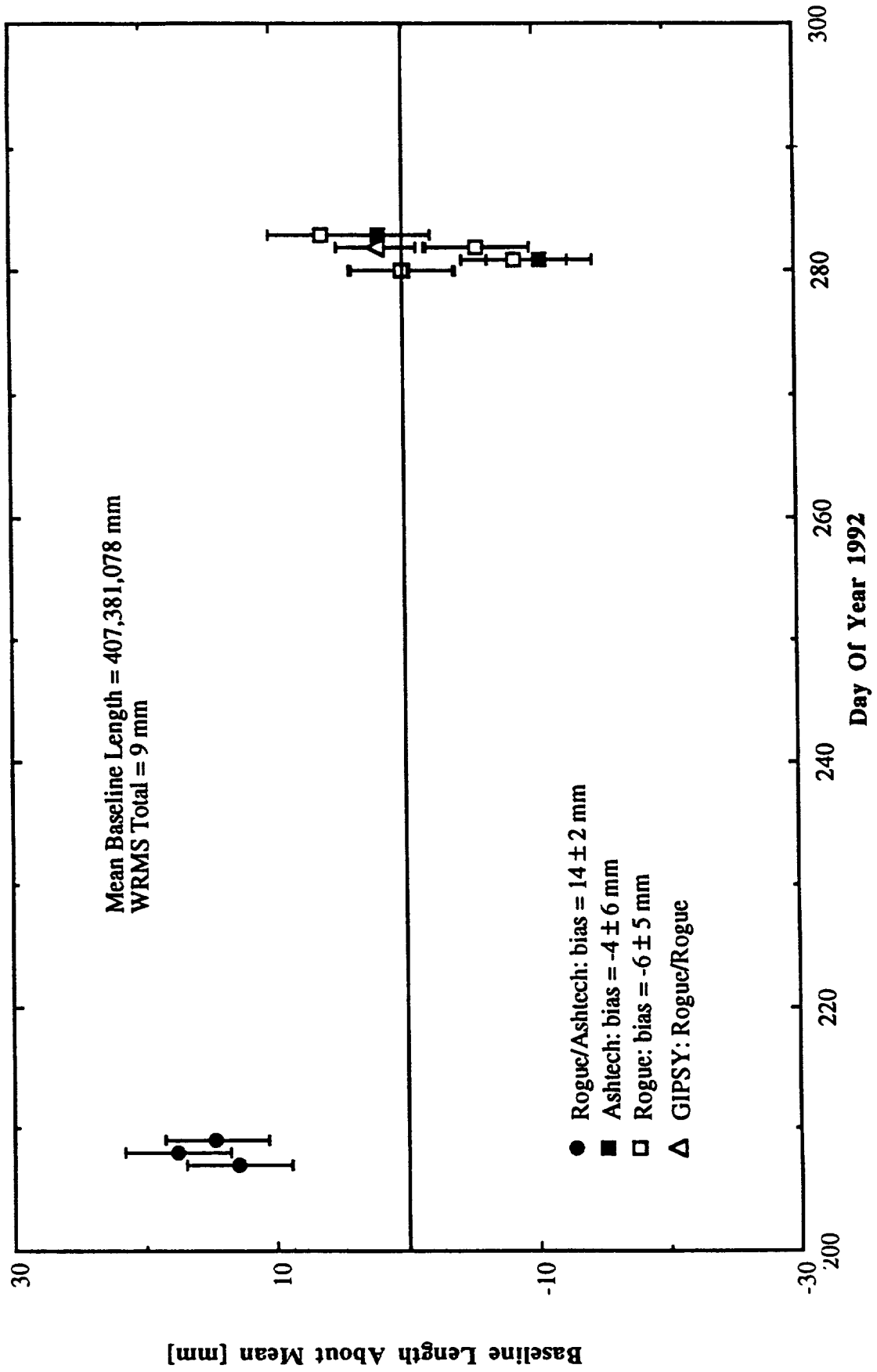
The ties between the collocated monuments at Onsala, Mårtsbo and Lovö are believed to be estimated with mm-level accuracy. All except 2 receivers were connected to external frequency standards. Four European sites with collocated VLBI/SLR and GPS monuments were used for satellite orbit determination, 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.

Mårtsbo-Lovö Baseline Length

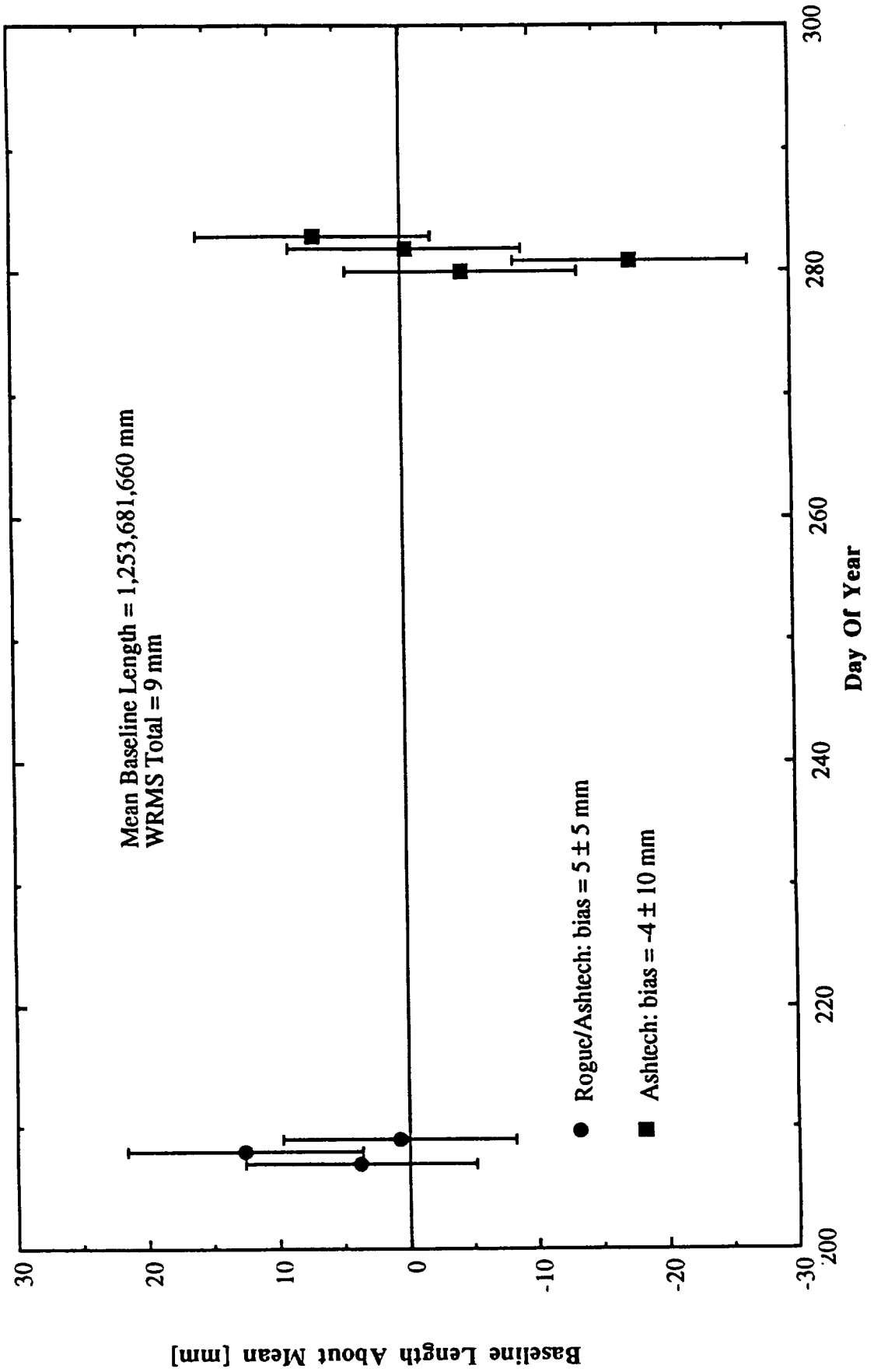
Mean Baseline Length = 143,655,499 mm
WRMS Total = 4 mm



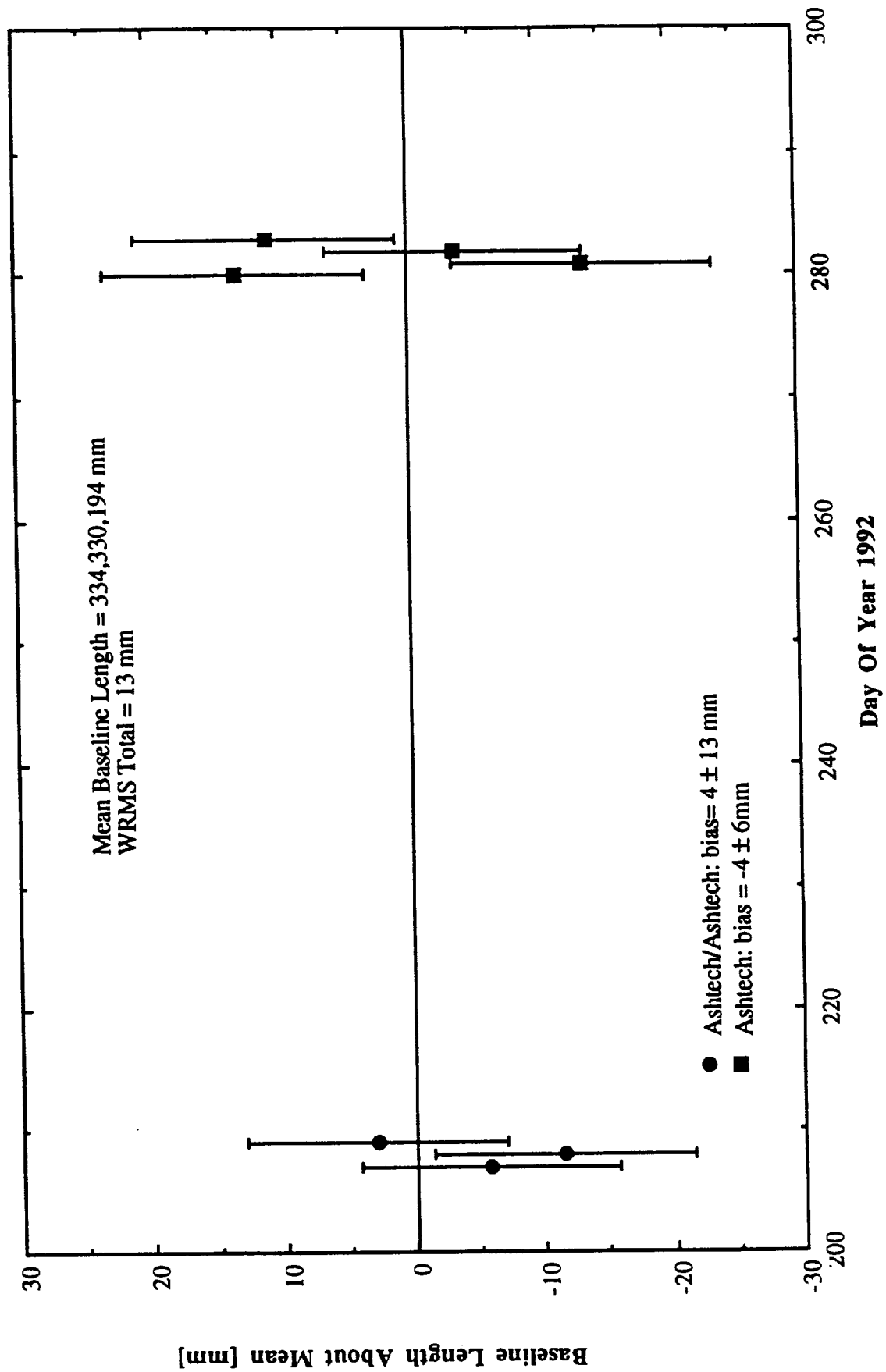
Onsala-Lovö Baseline Length



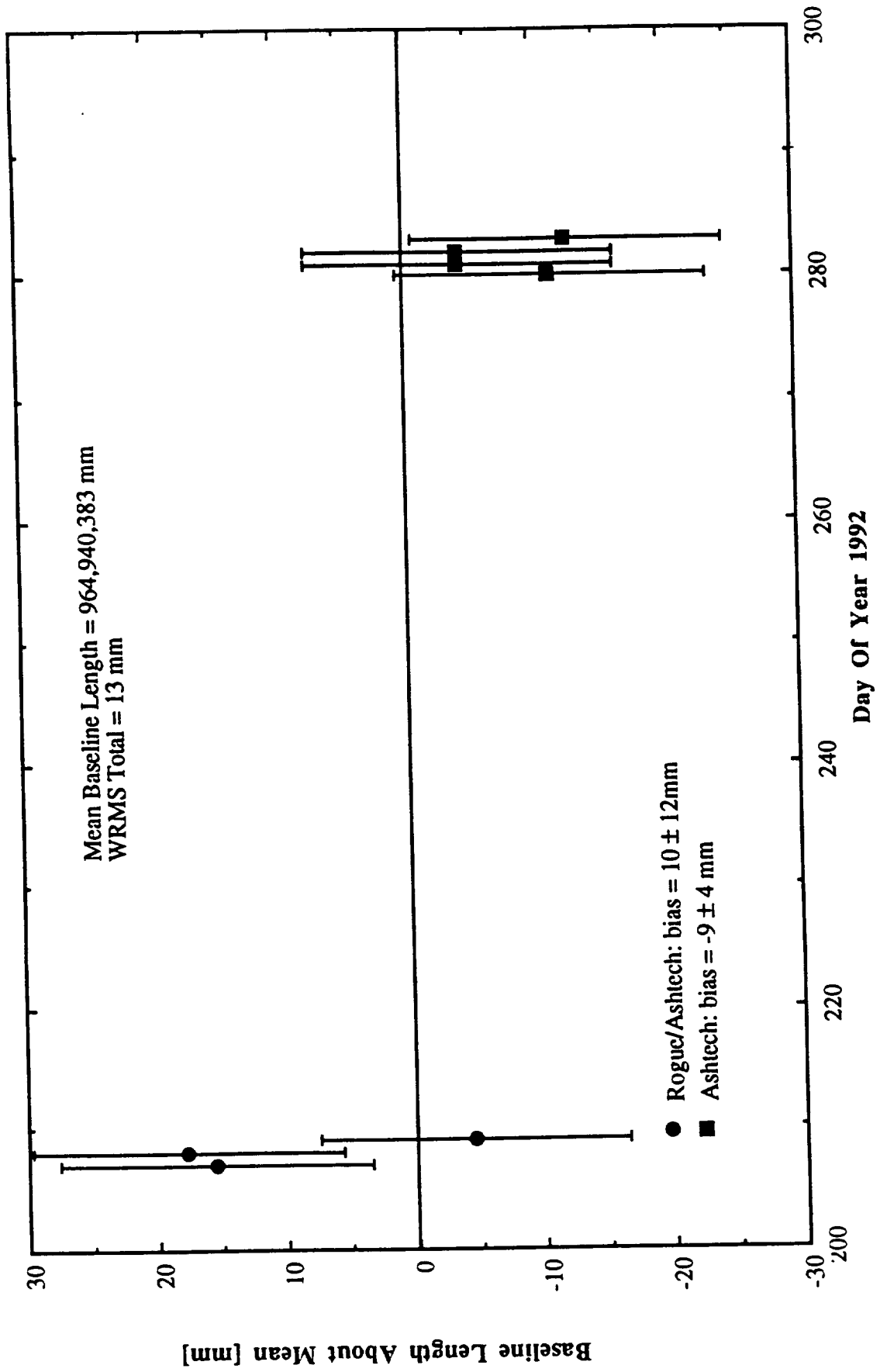
Onsala-Kiruna Baseline Length



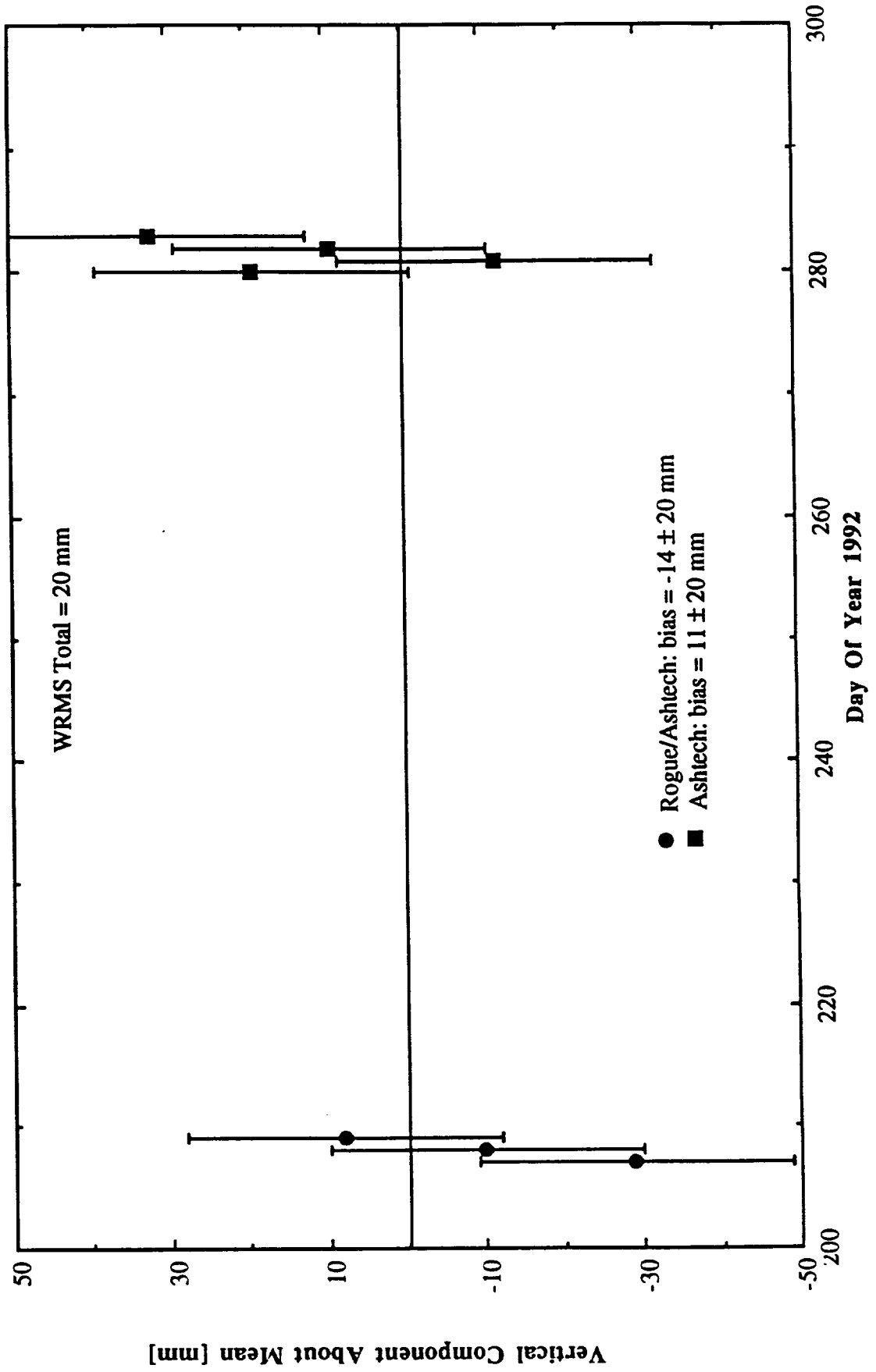
Furuögrund-Kiruna Baseline Length



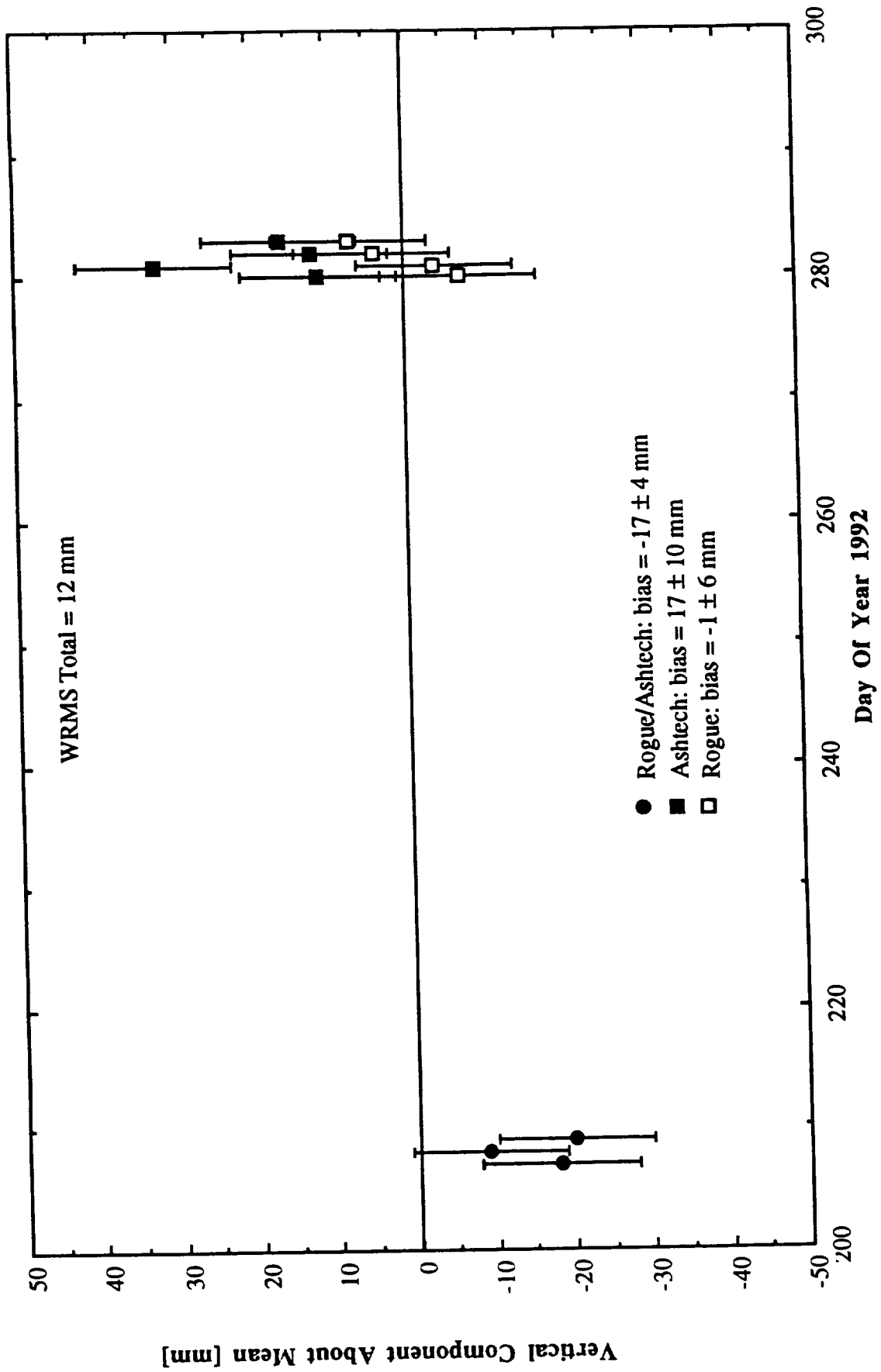
Onsala-Furuögrund Baseline Length



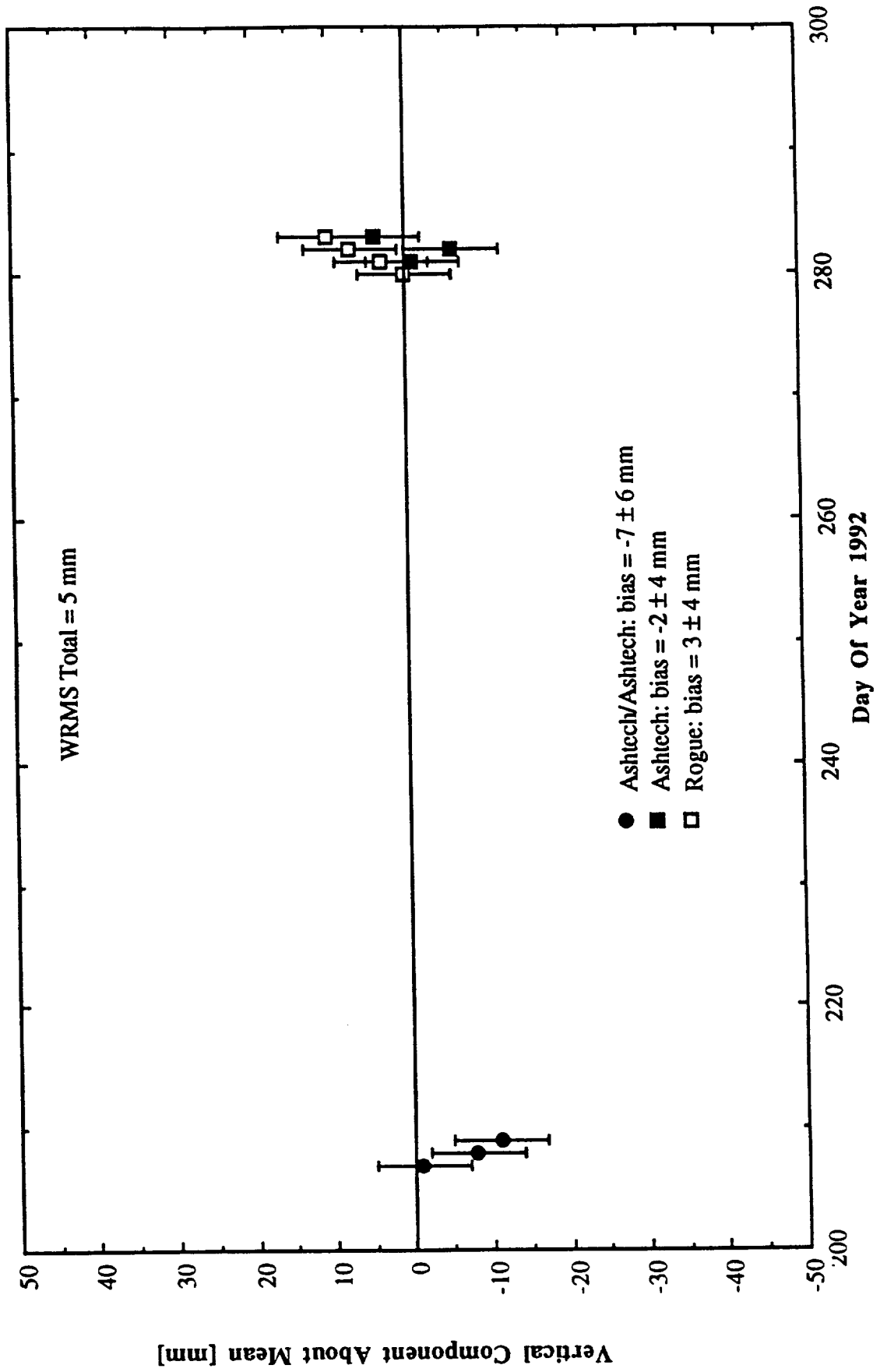
Onsala-Furuögrund Vertical Component



Onsala-Mårtsbo Vertical Component



Mårtsbo-Lovö Vertical Component

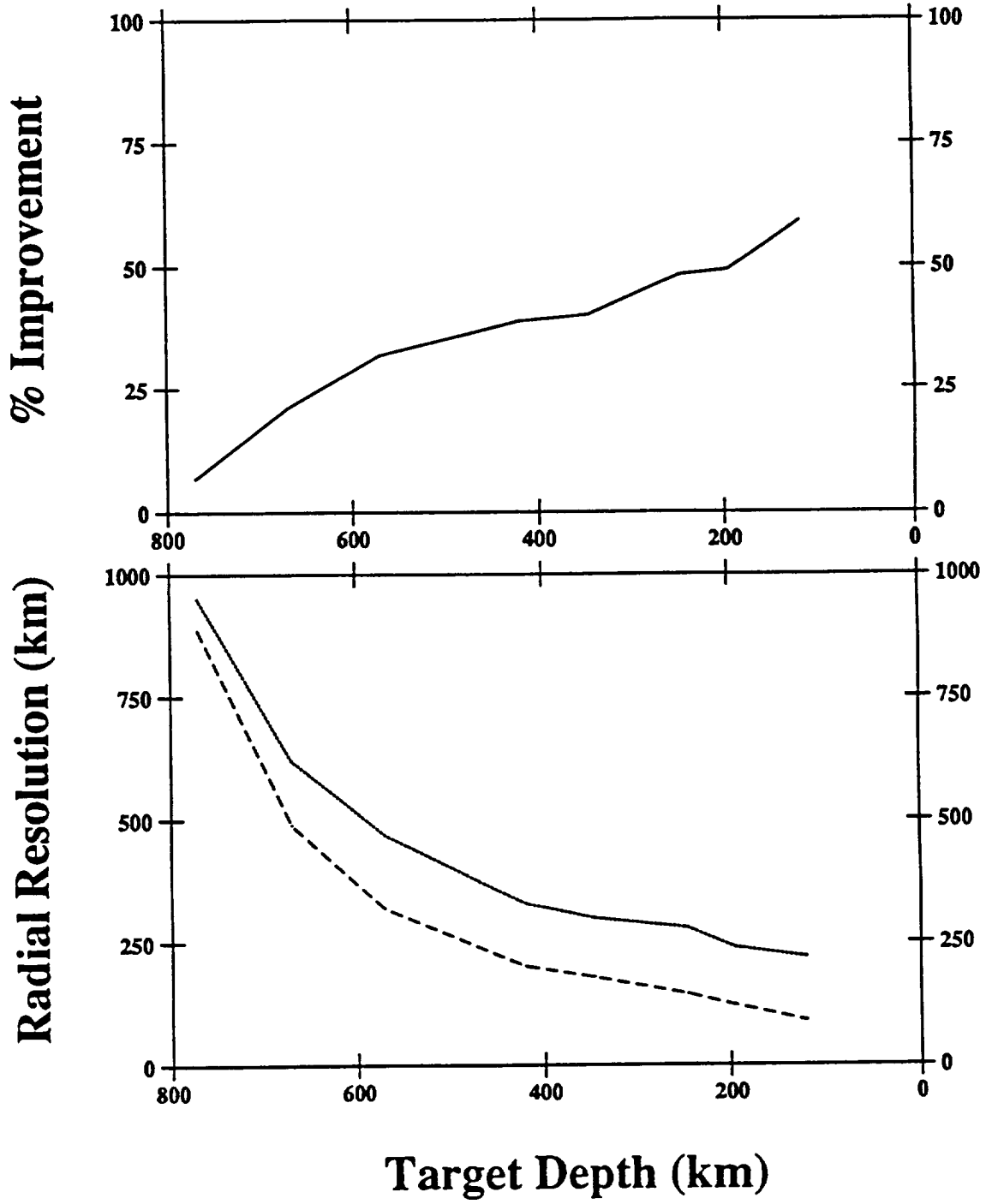


RESULTS AND CONCLUSION

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]

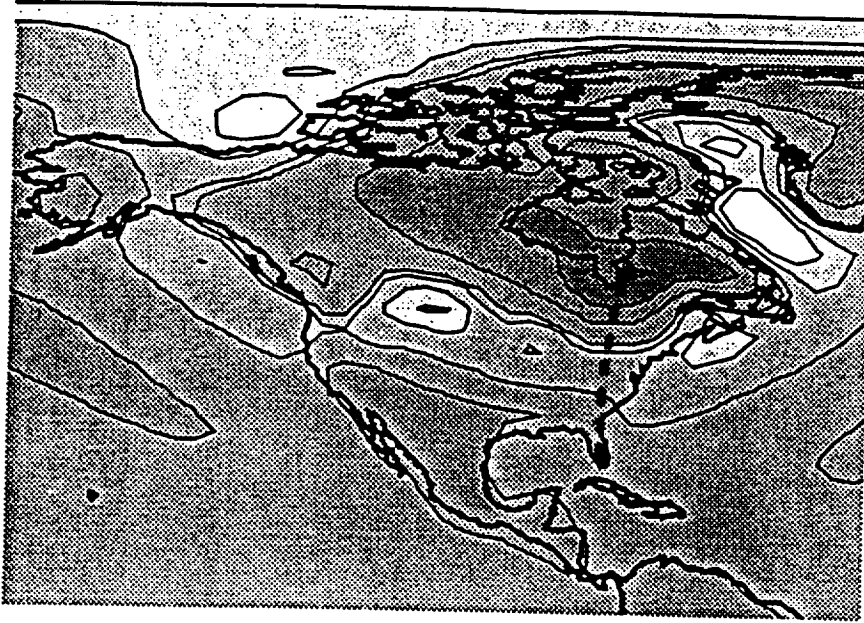
**Three-Dimensional Crustal Deformations
Due to Post-Glacial Rebound**

J. X. Mitrovica, J. L. Davis, J. M. Johansson, & I. I. Shapiro

Harvard-Smithsonian Center for Astrophysics

RADIAL VELOCITY

HUDSON BAY
↓
RICHMOND,
FL



NORTH
AMERICA

LULGA, SW.
↓
WETTZELL,
GERM.



NORTHERN
EUROPE

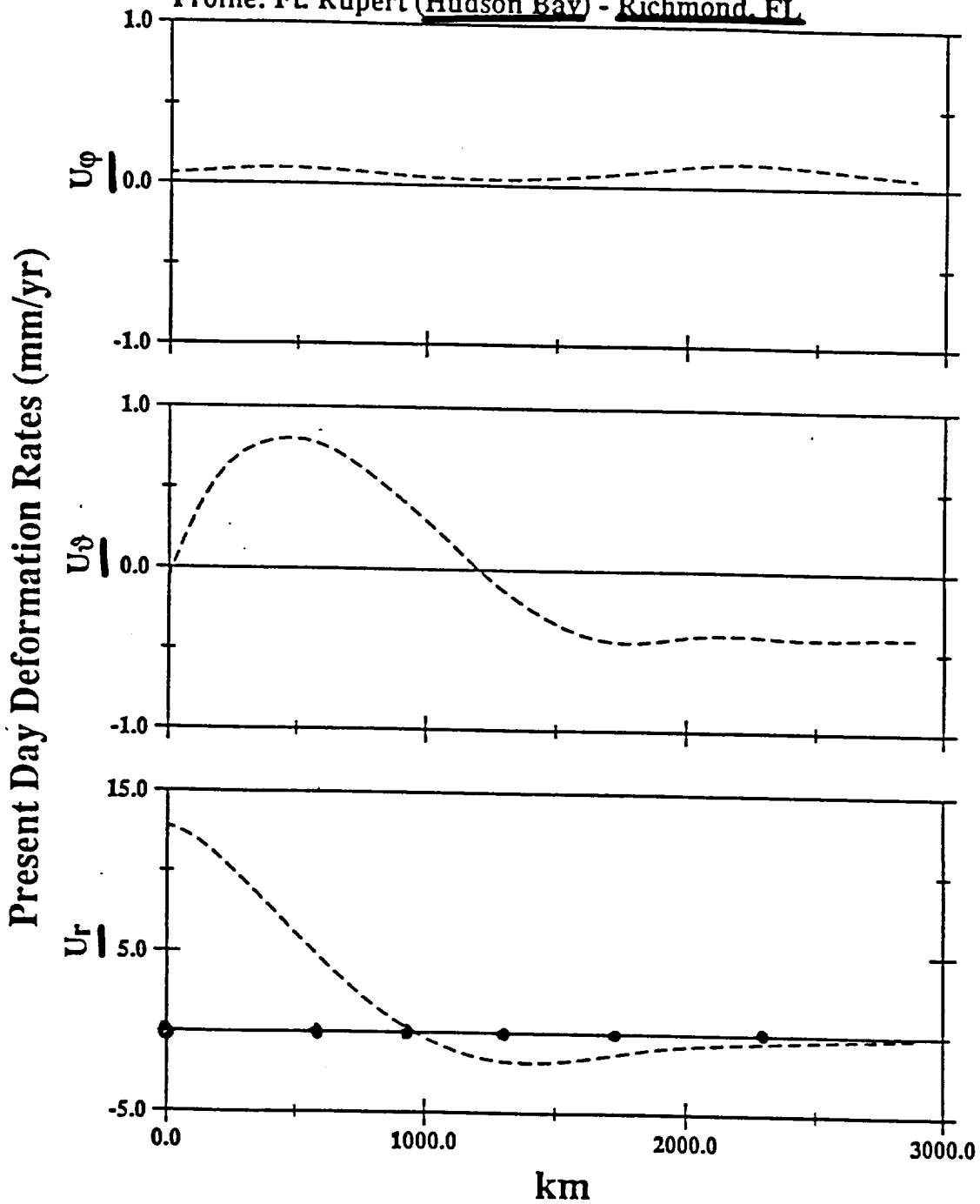
mm/yr



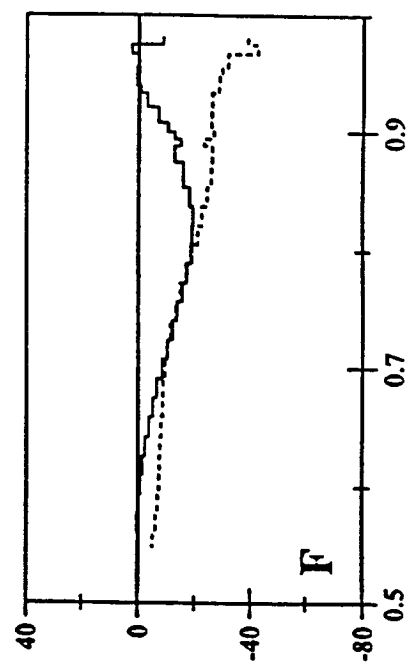
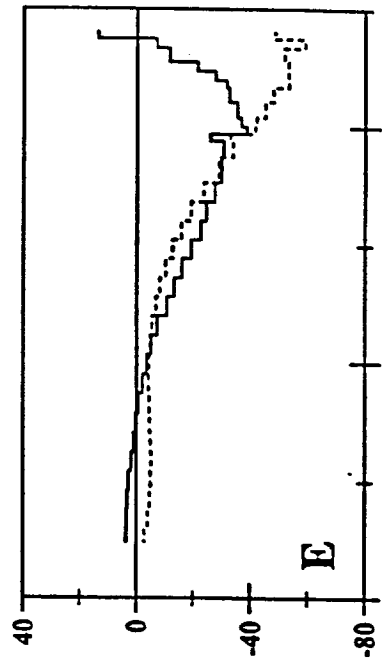
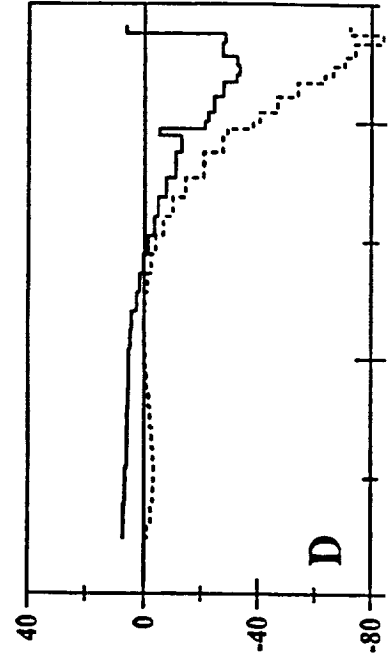
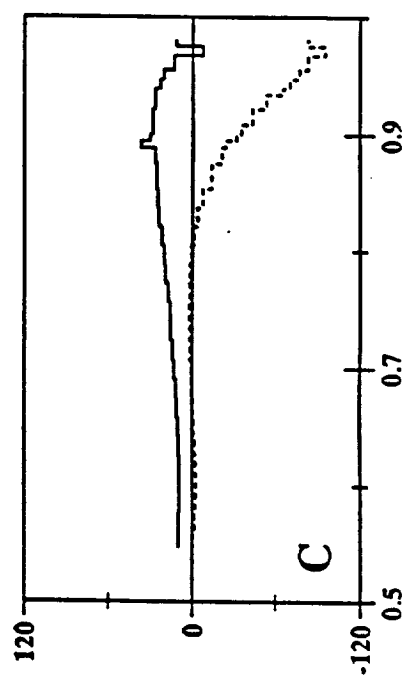
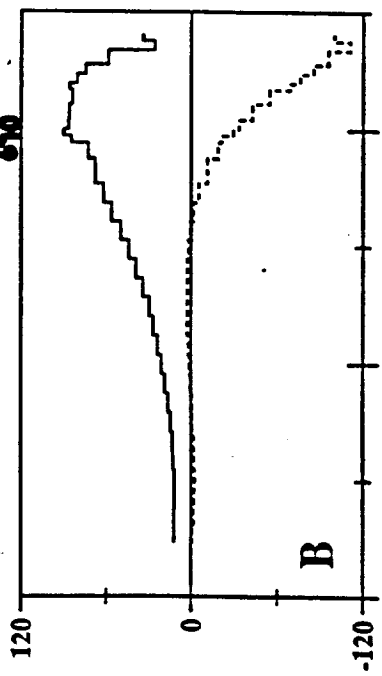
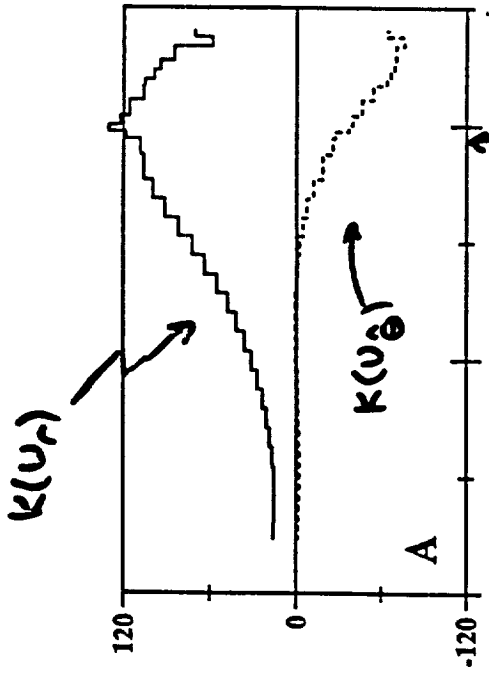
12 8 4 0 -3 -6

mm/yr

Profile: Ft. Rupert (Hudson Bay) - Richmond, FL



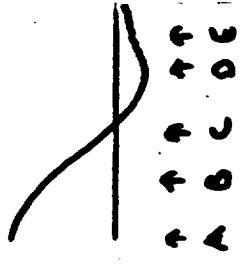
CENTRAL REGION PERIPHERAL BULGE ... FAR FIELD



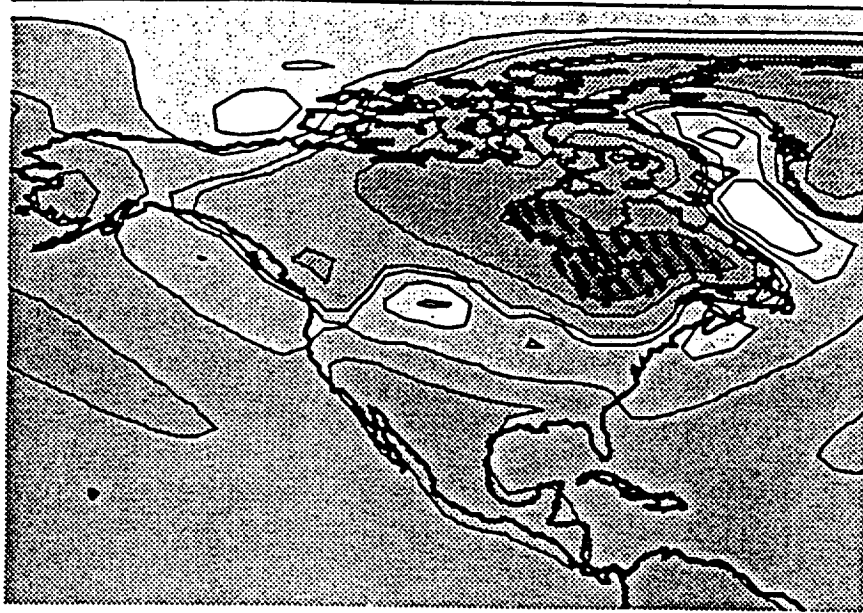
Frechet Kernels

Dimensionless Radius

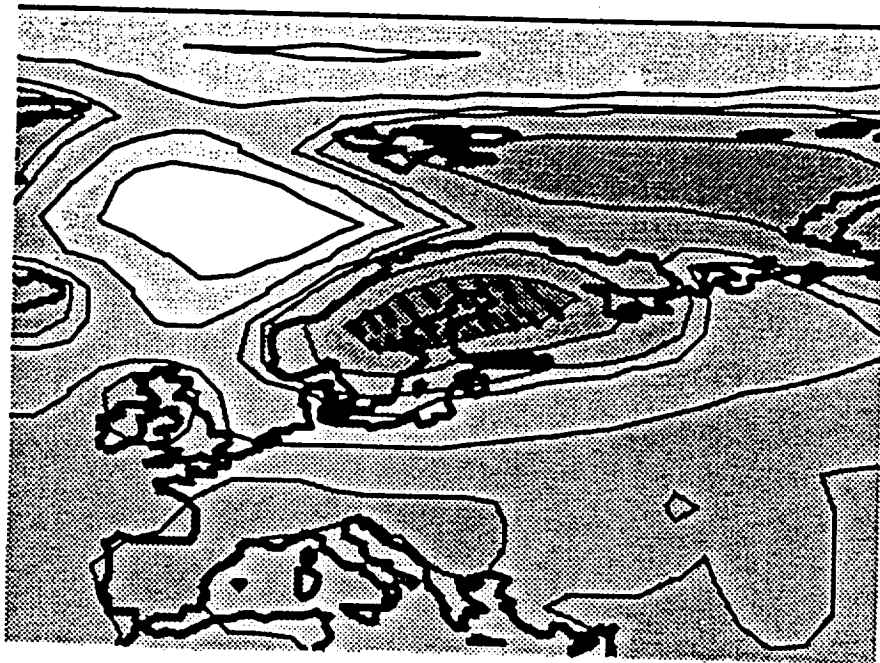
↑ LOWER MANTLE ↑ 4M ↑
 r = 6MB r = 50 r = 6



RADIAL VELOCITY

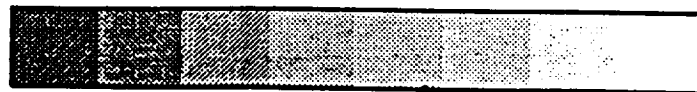


NORTH
AMERICA



NORTHERN
EUROPE

mm/yr



12 8 4 0 -3 -6

mm/yr

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 $\rightarrow(r)$ & how does this vary with depth?

NORTH AMERICA: 19 BASELINES

including sites ...

ALGONK

FT. DAVIS

GILBERT

NRAO

PENTICTN

PARPOINT

WESTFORD

RICHMOND

WINTHROP

EUROPE: 5 BASELINES

including sites ...

ONSALA, SW

WETZELL, GERM.

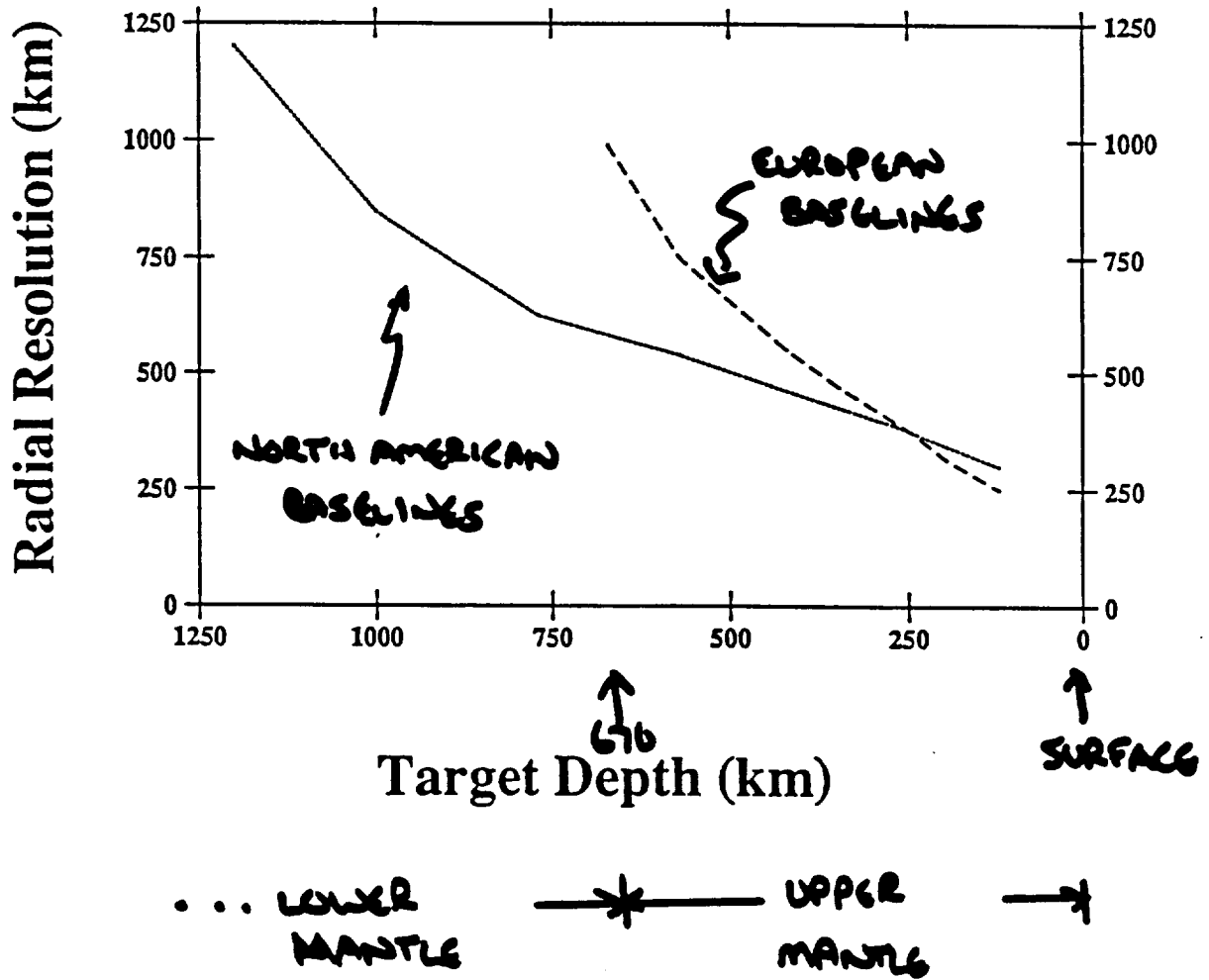
EFLSBERG, GERM.

MEDICINA, IT.

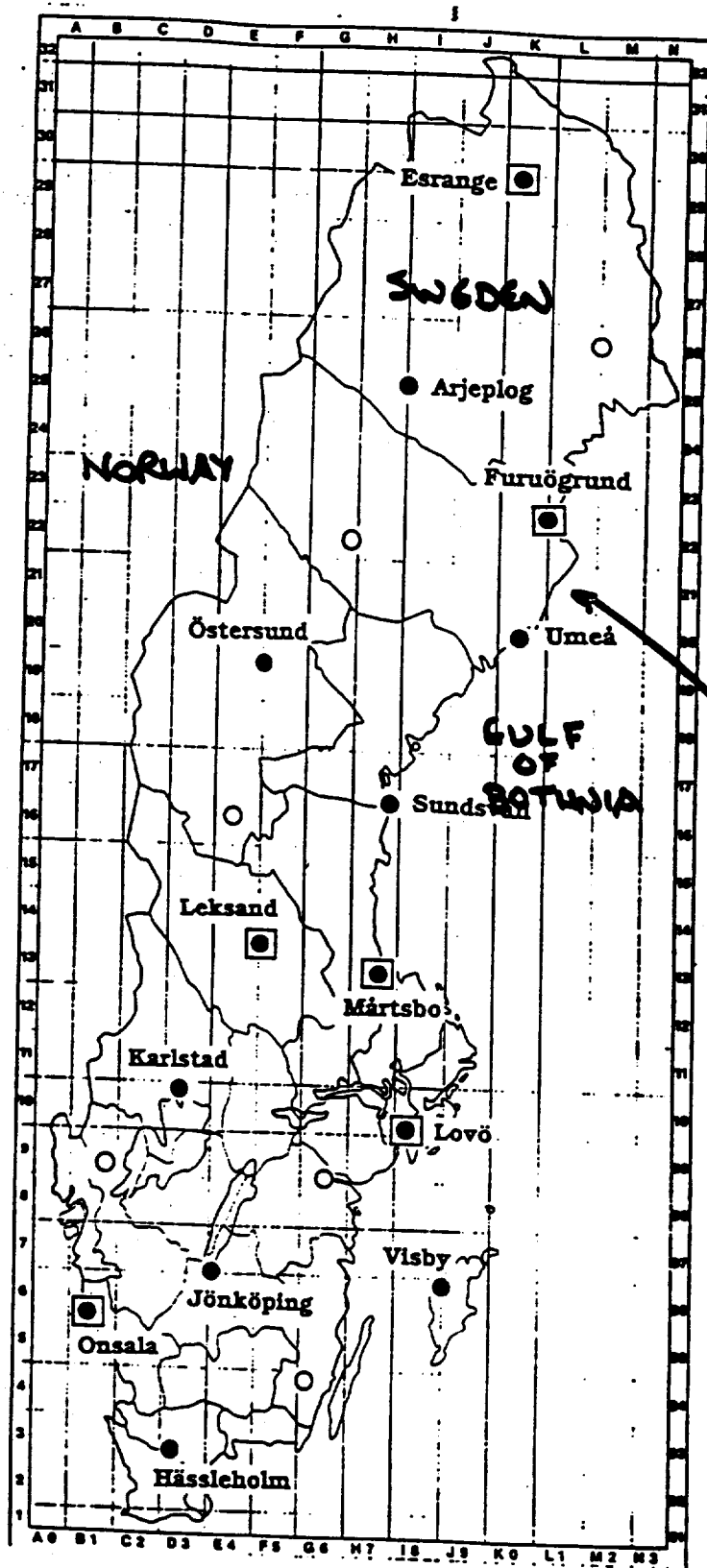
NOTU, IT.

MADRID, SPAN.

RESOLVING POWER: VLBI BASELINE RESULTS



SWEDISH GPS NETWORK



14 SITES MONUMENTAL

6 " PROPOSED

TOTAL = 20

REGION OF
MAXIMUM
UPLIFT

GPS NETWORK

SWEDISH LAND SURVEY
ONKALA SPACE OBS.
HARVARD-SMITH, CFA
UNIV. OF TORONTO

RESOLVING POWER: NORTHERN EUROPE

