MEASUREMENT AND INTERPRETATION OF CRUSTAL DEFORMATION RATES ASSOCIATED WITH POSTGLACIAL REBOUND

NAG5-1930

Semiannual Status Report No. 2

For the Period 15 September 1992 through 14 March 1993

Principal Investigator

Dr. James L. Davis

February 1993

Prepared for
National Aeronautics and Space Administration
Washington, D.C. 20546

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory
is a member of the
Harvard-Smithsonian Center for Astrophysics

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. Jaldehag, 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

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

Harvard-Smithsonian Center for Astrophysics

60 Garden St., MS 42, Cambridge, MA 02138

R.T.K. Jaldehag, G. Elgered, and B.O. Rönnäng

Onsala Space Observatory, Chalmers University of Technology

S–439 92 Onsala, Sweden

B. Jonsson, G. Hedling, and M. Ekman

National Land Survey of Sweden

S–801 82 Gävle, Sweden

AGU Fall Meeting, San Francisco, Dec. 1992

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 apperent land uplift). The monumentation has been carried out by the National Land Survey of Sweden. High precision GPS receivers and complementary eqipment are being purchased.

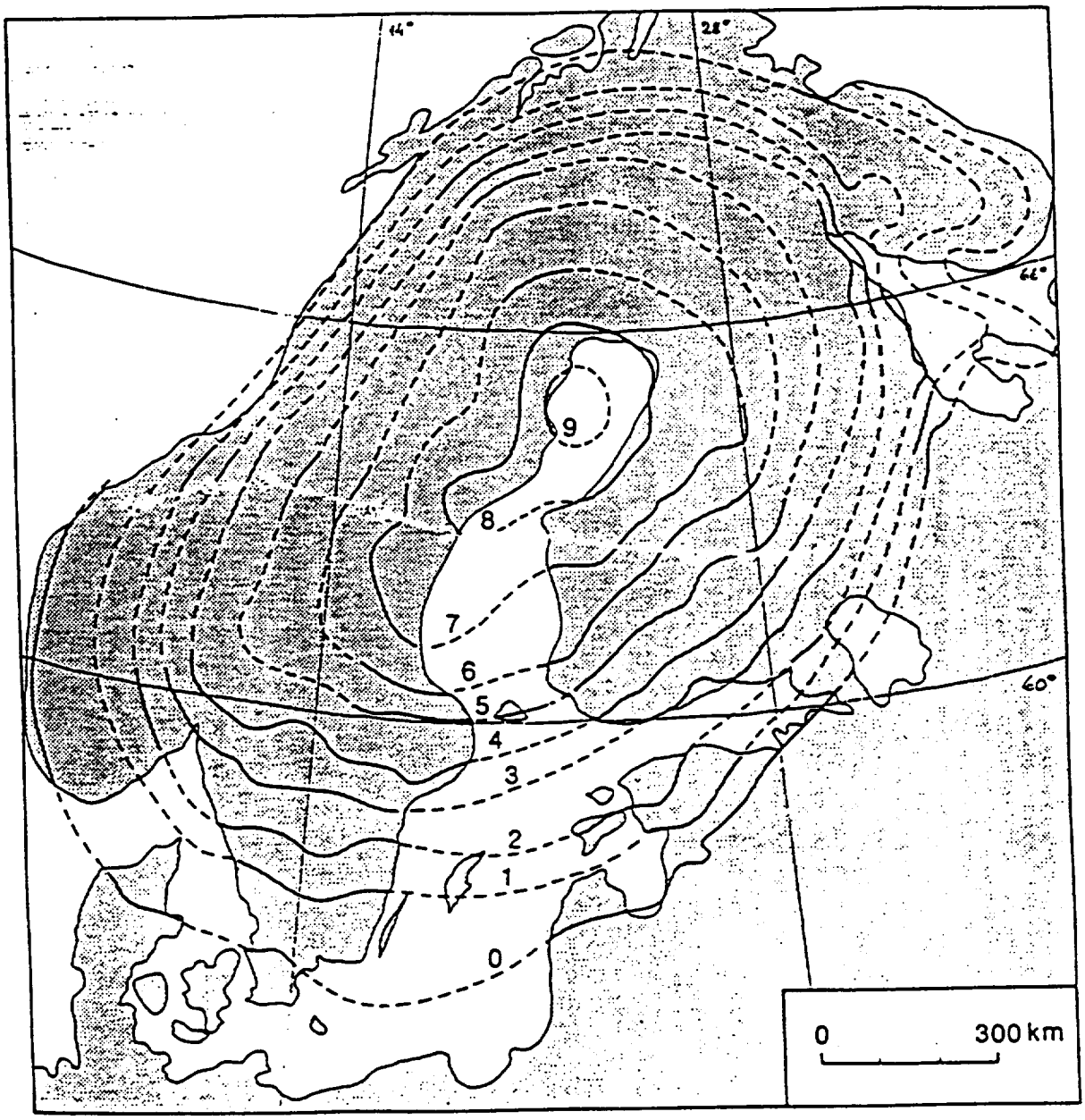


Fig. 1. *Apparent land uplift (mm/yr)*

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:

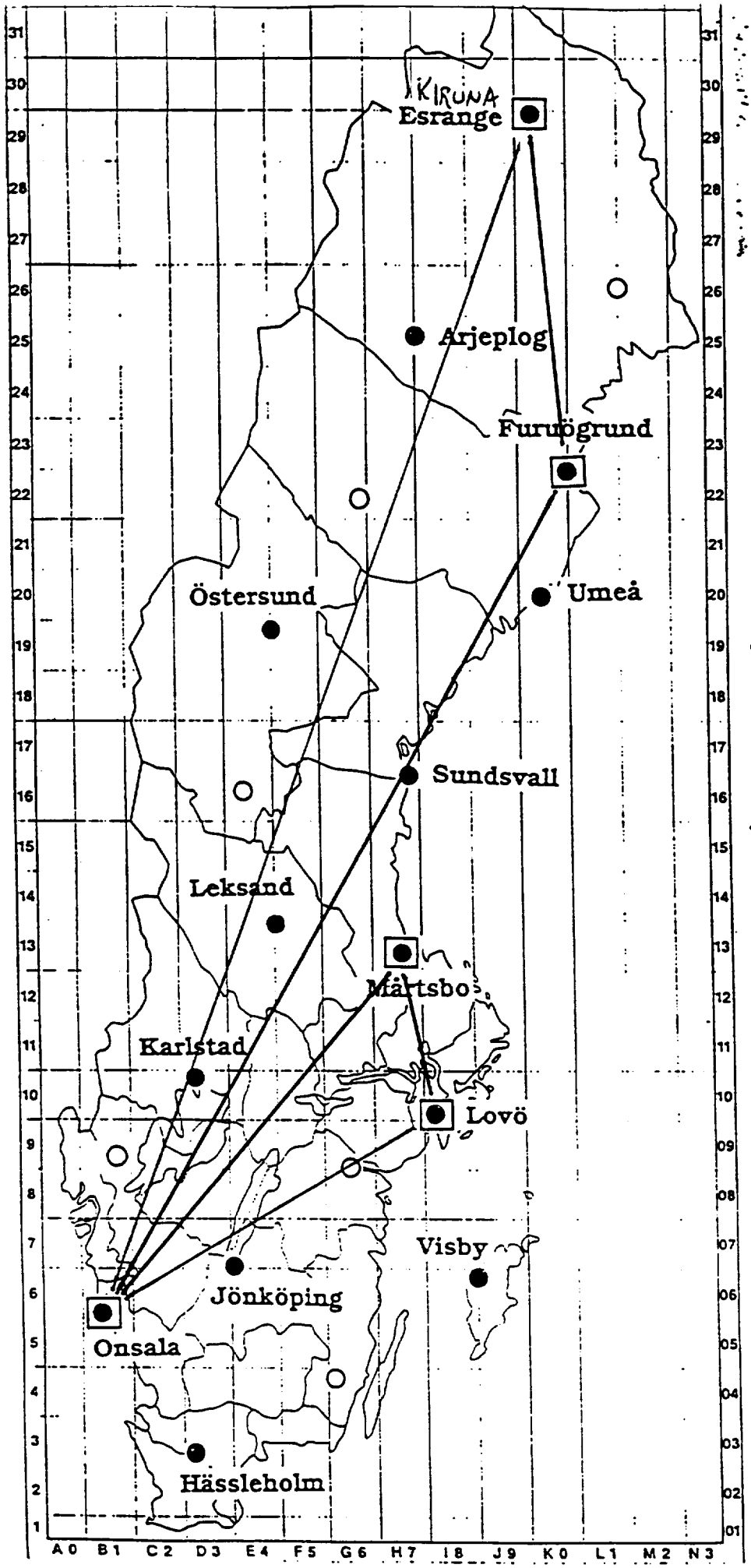
Rogue receiver at Onsala

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.



— 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.

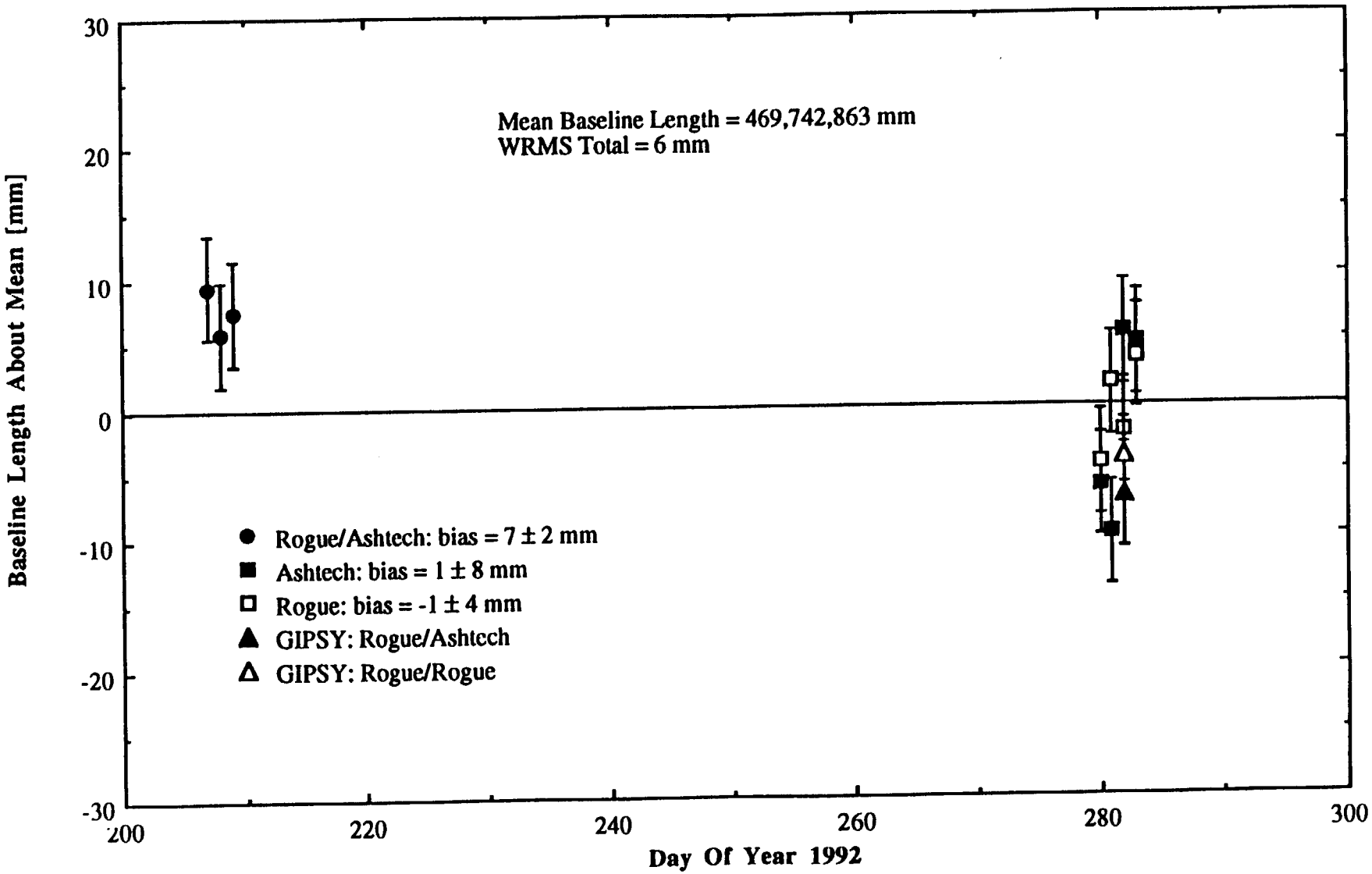
2) The 5 station network observed in October using Ashtech receivers. These results are showed as filled squares below.

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

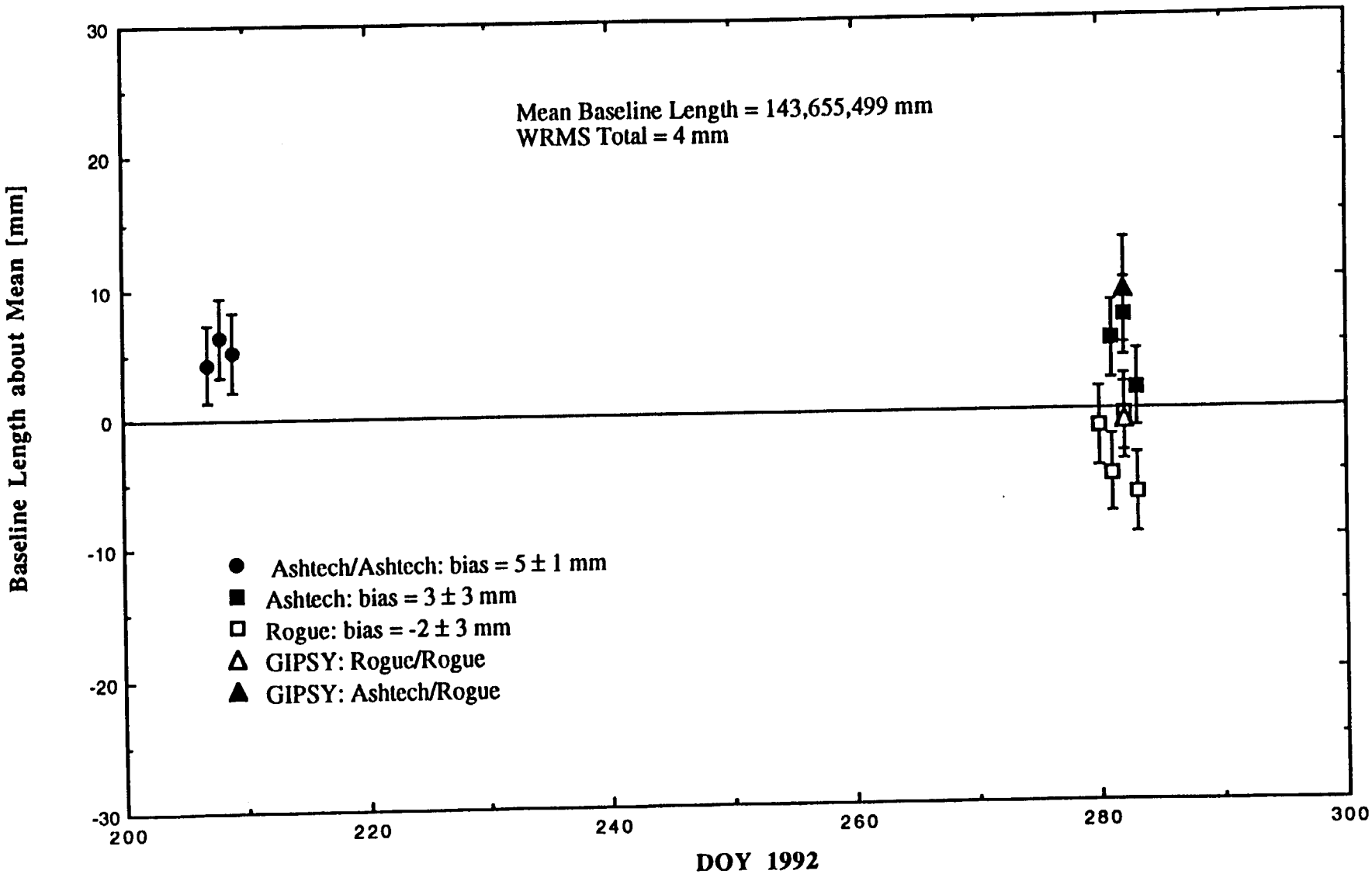
In addition a sample of the October data set has also been processed with the GIPSY software. These results are showed as triangles below.

The ties between the collocated monuments at Onsala, Mårtsbo and Lovö are belived 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.

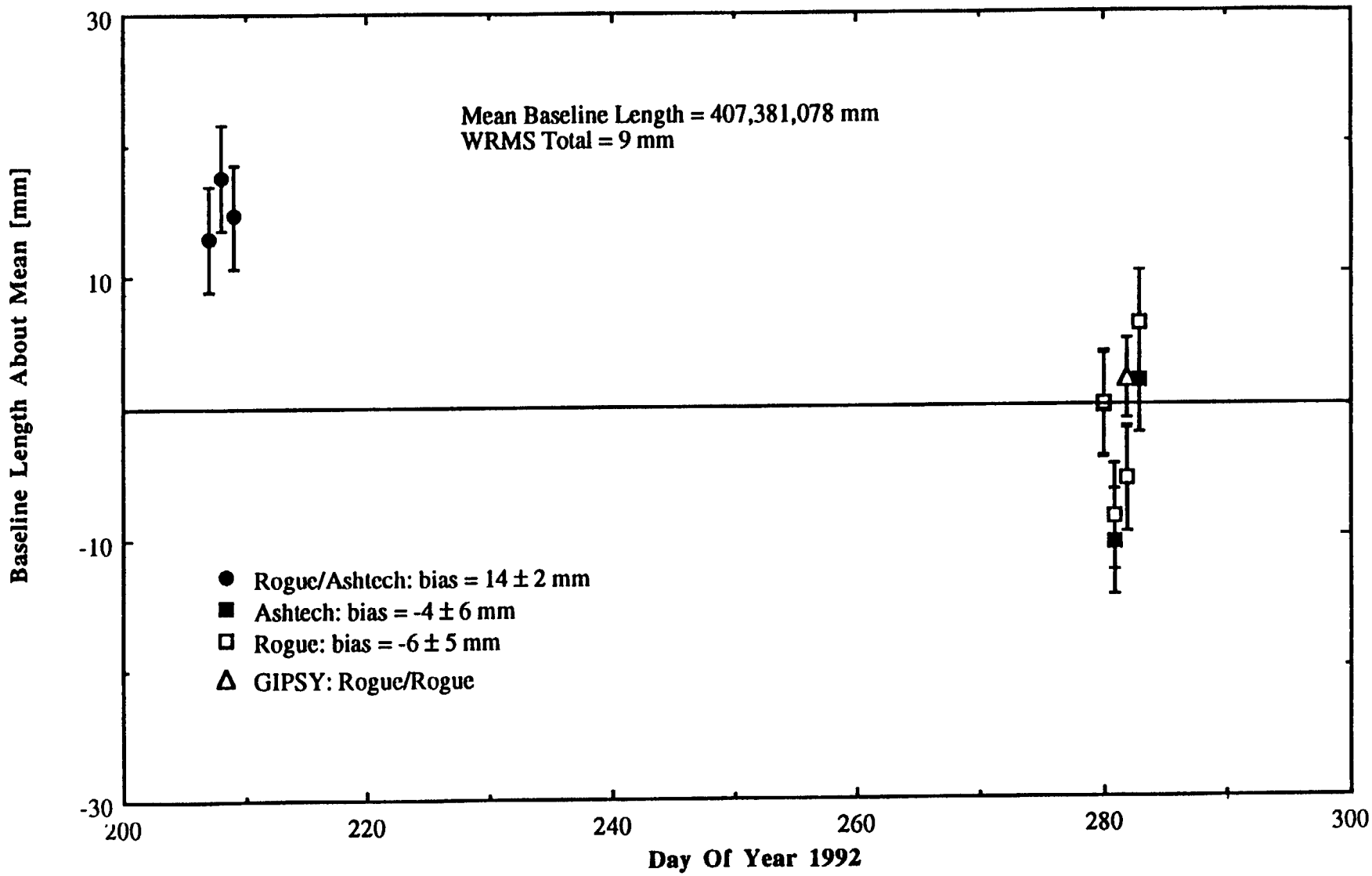
Onsala-Mårtsbo Baseline Length



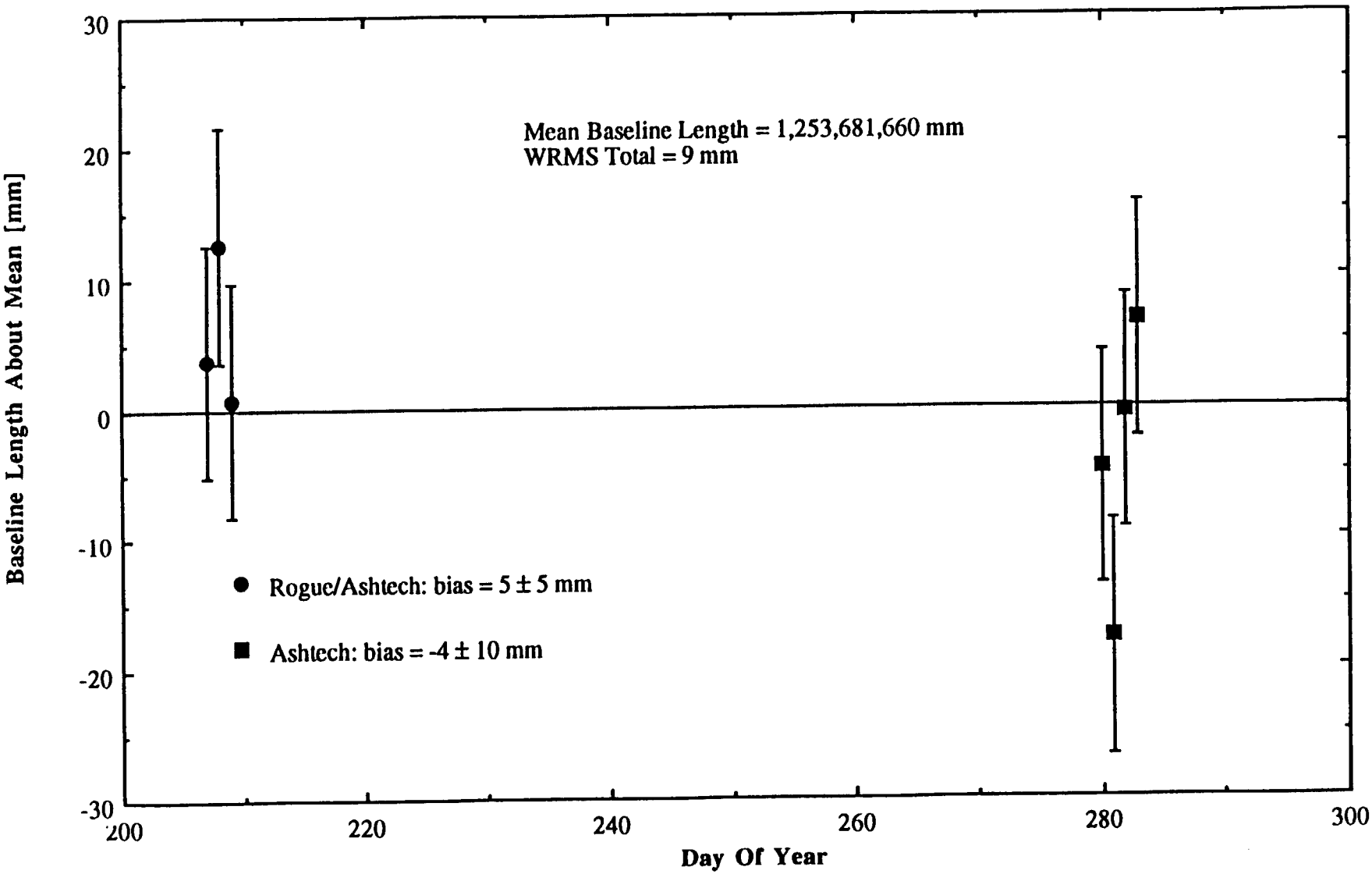
Mårtsbo-Lovö Baseline Length



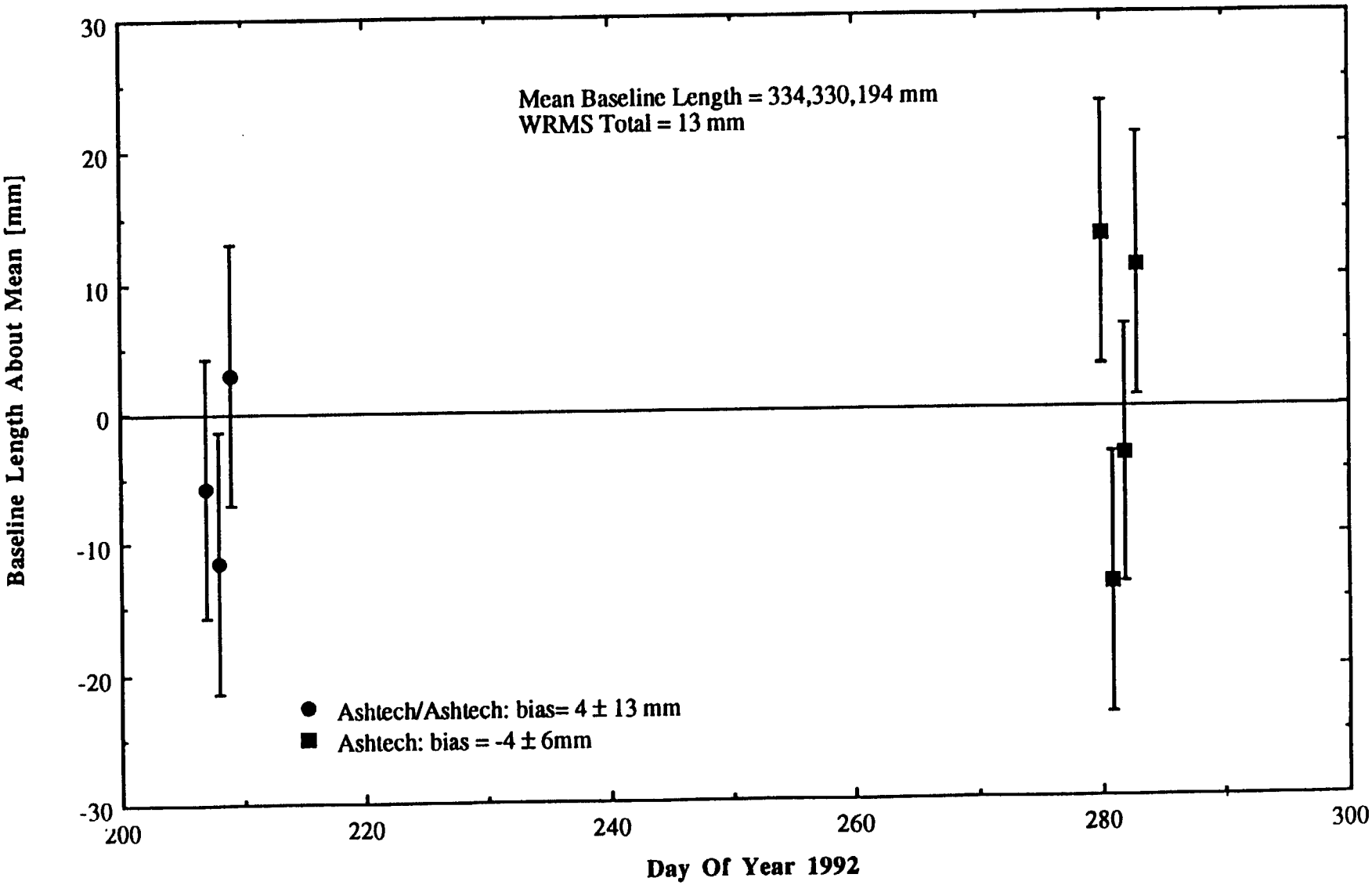
Onsala-Lovö Baseline Length



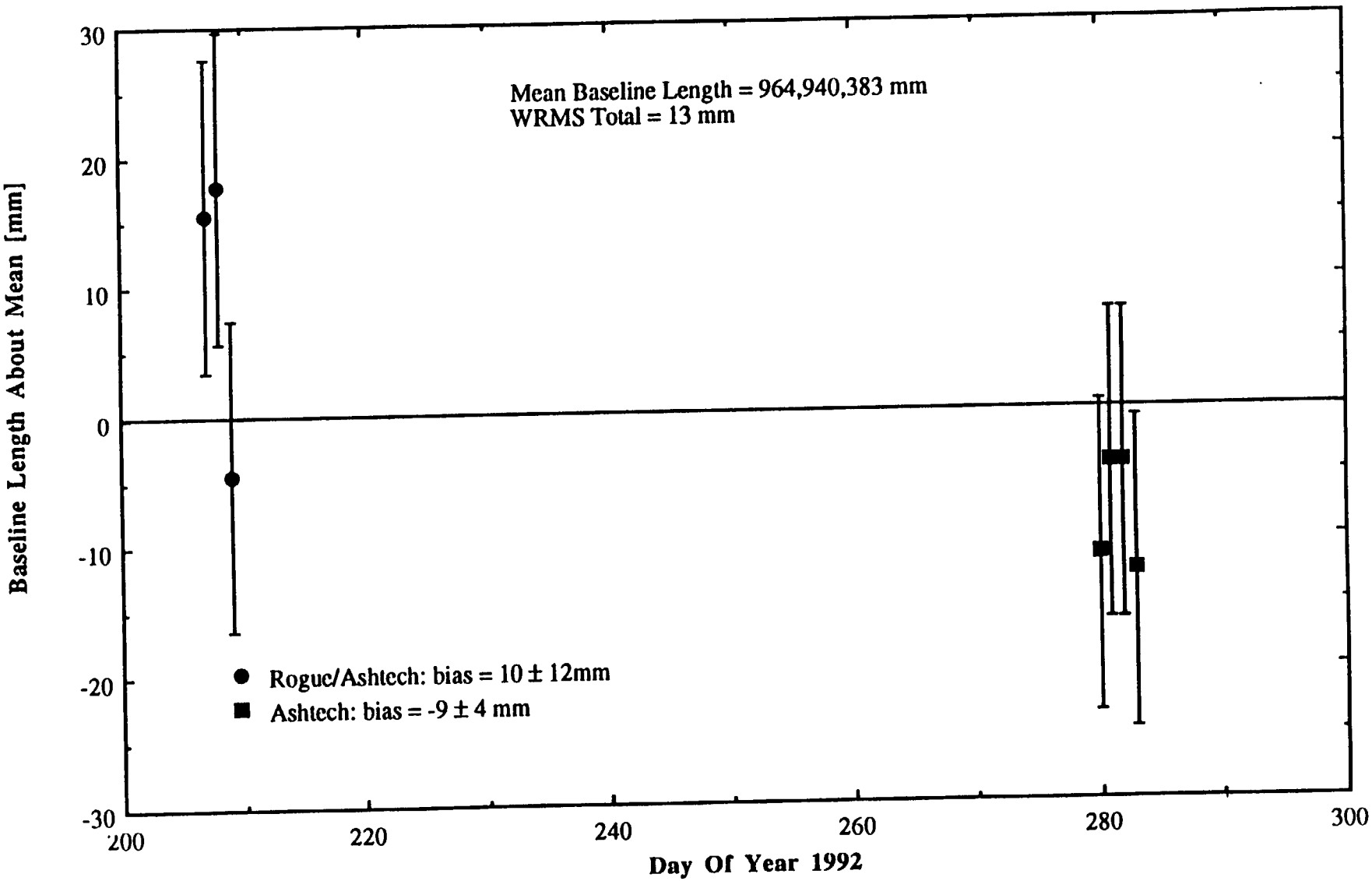
Onsala-Kiruna Baseline Length



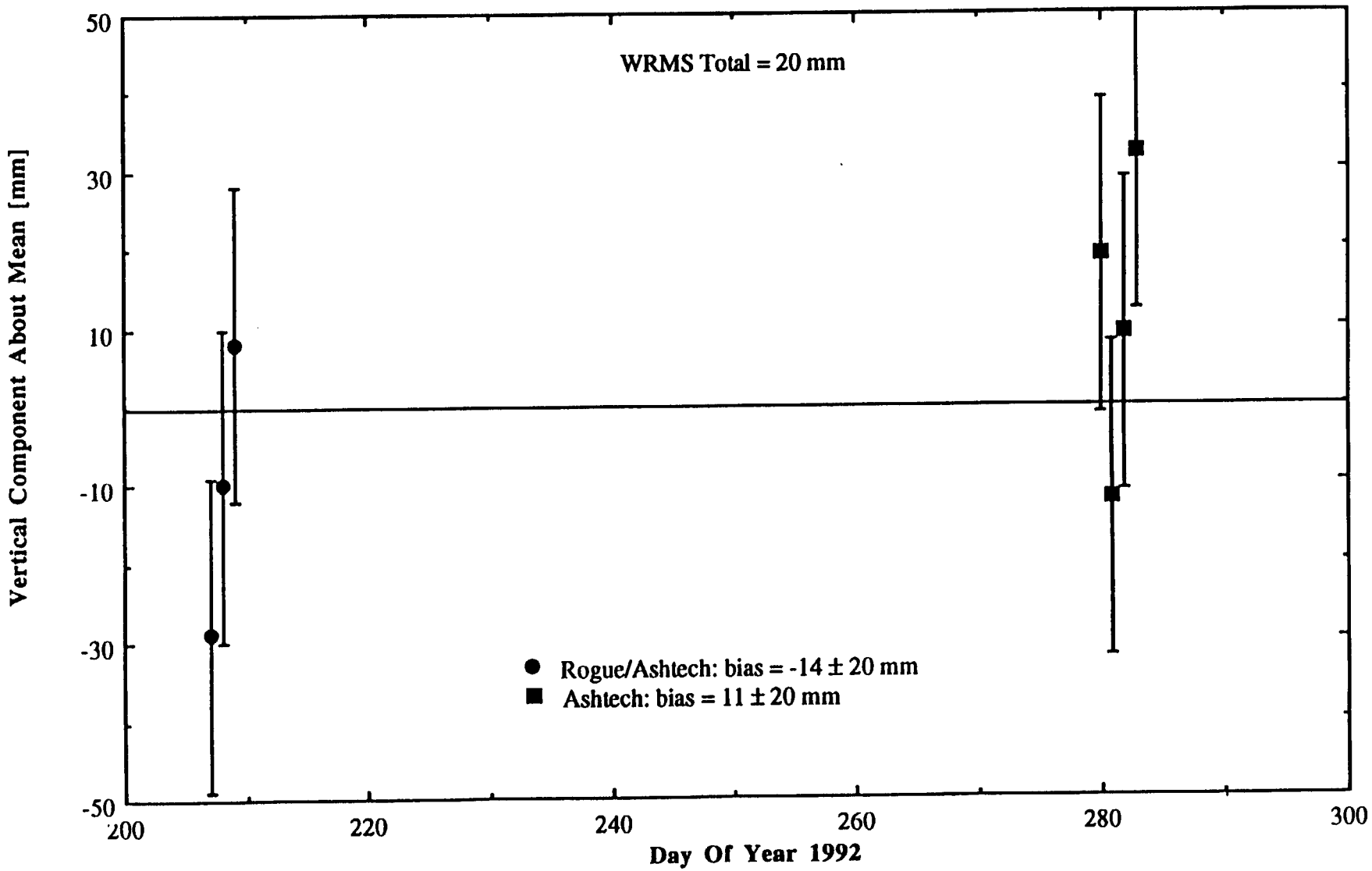
Furuögrund-Kiruna Baseline Length

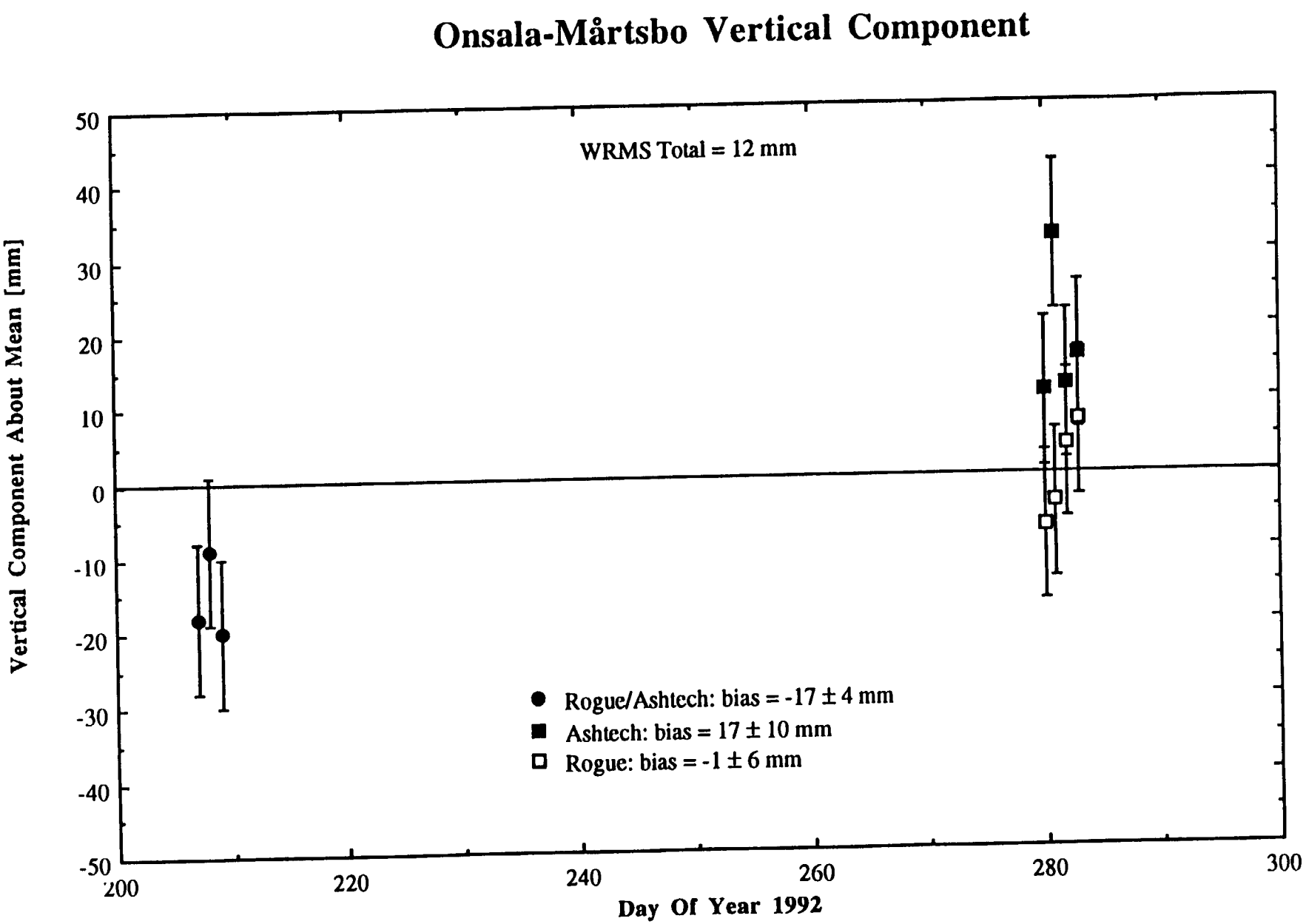


Onsala-Furuögrund Baseline Length

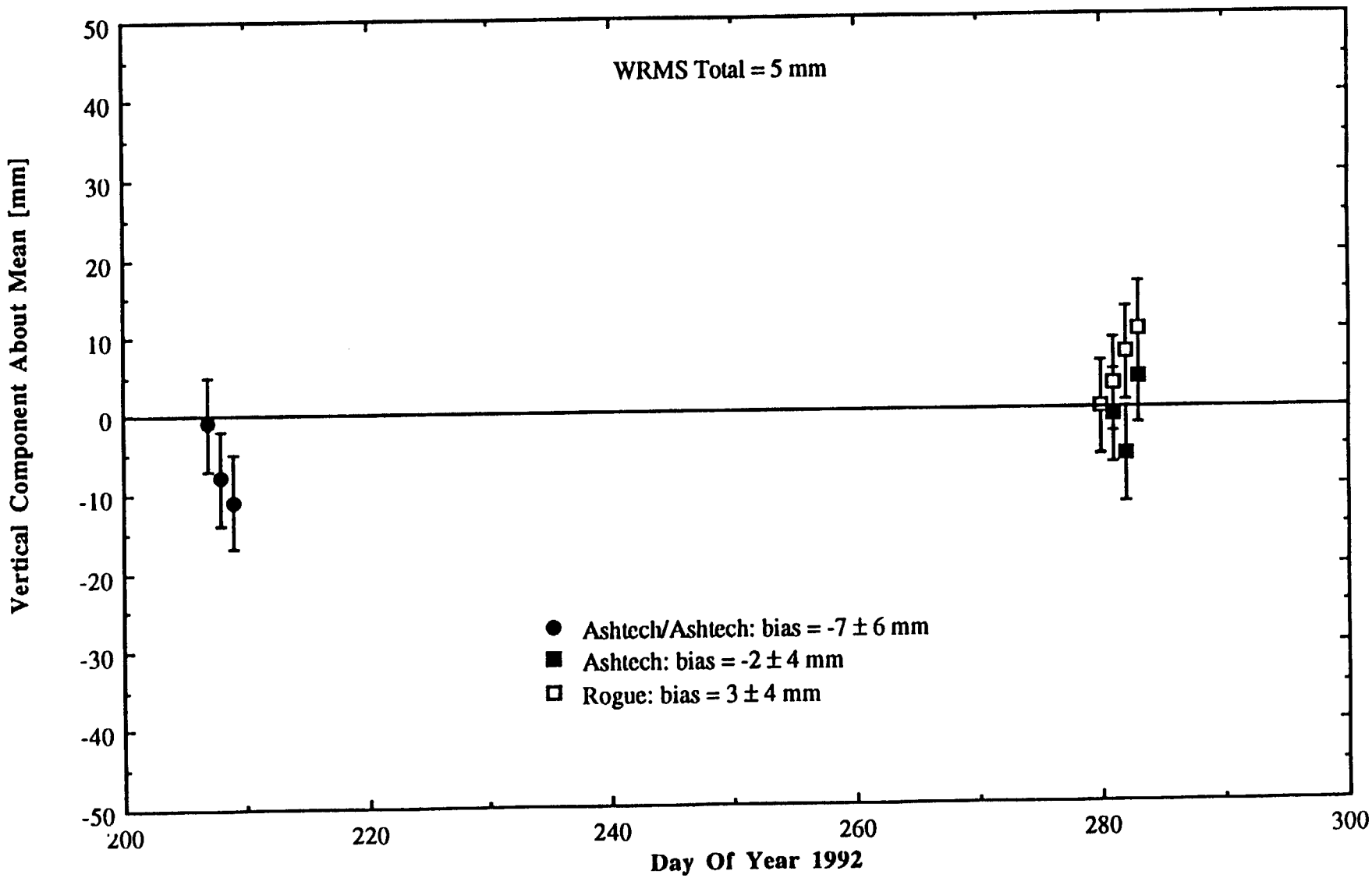


Onsala-Furuögrund Vertical Component




Onsala-Mårtsbo Vertical Component
WRMS Total = 12 mm
Vertical Component About Mean [mm]
50
40
30
20
10
0
-10
-20
-30
-40
-50
200
220
240
260
280
300
Day Of Year 1992
Rogue/Ashtech: bias = -17 ± 4 mm
Ashtech: bias = 17 ± 10 mm
Rogue: bias = -1 ± 6 mm

Mårtsbo-Lovö Vertical Component

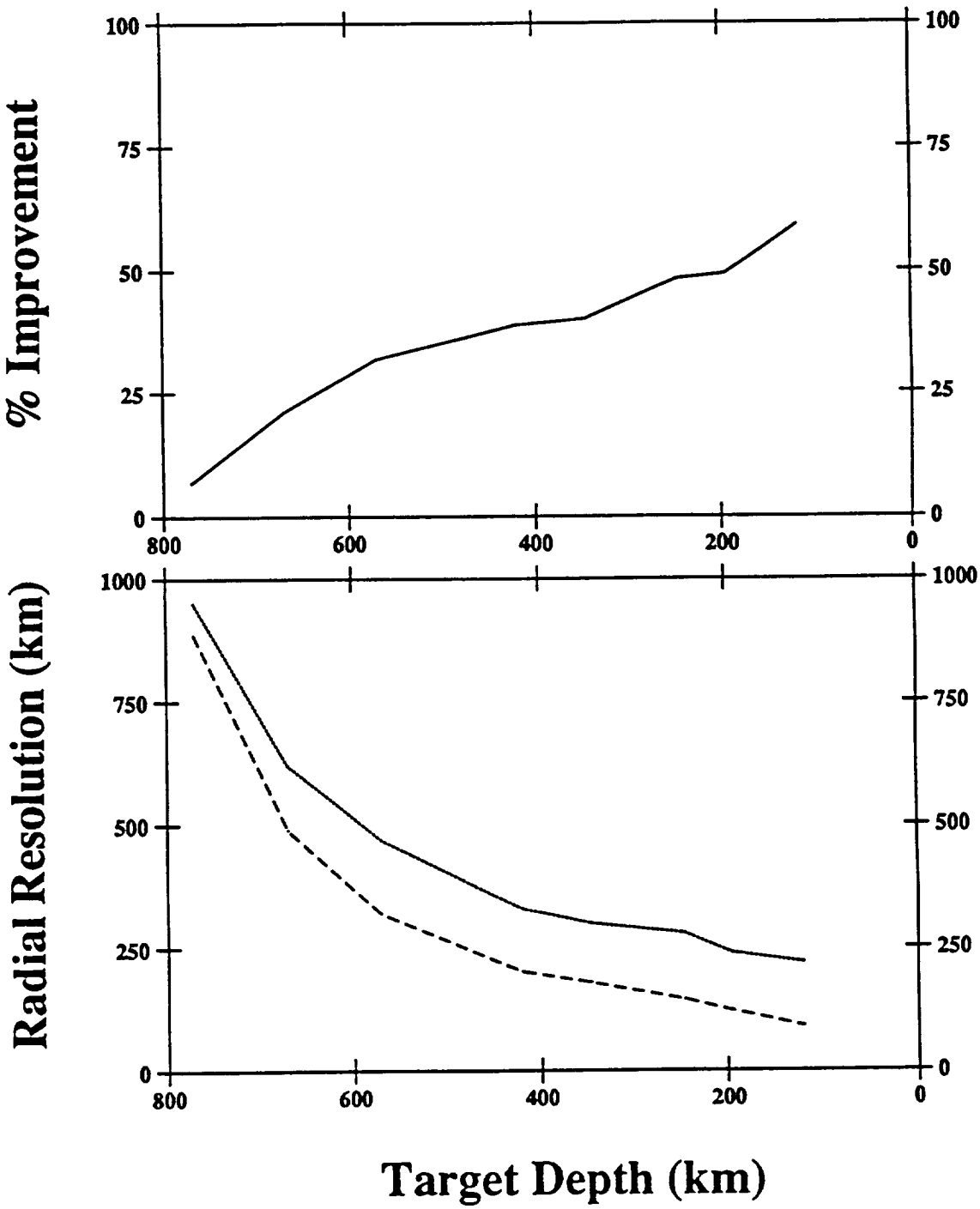


RESULTS AND CONCLUSION

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.


% Improvement
100
75
50
25
0
800
600
400
200
0
Radial Resolution (km)
1000
750
500
250
0
Target Depth (km)

Appendix B. Mitrovica et al. [1992]

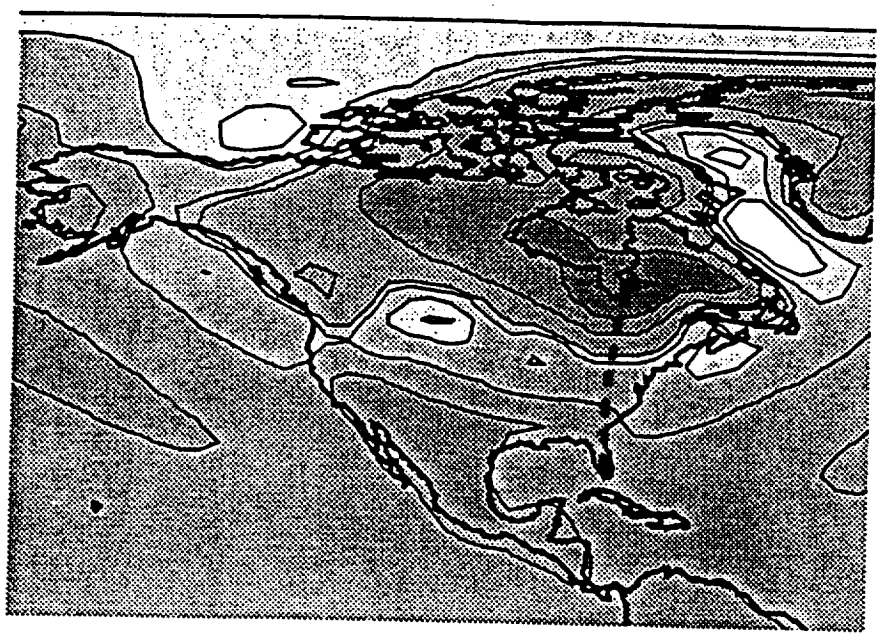
Three-Dimensional Crustal Deformations Due to Post-Glacial Rebound

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

Harvard-Smithsonian Center for Astrophysics

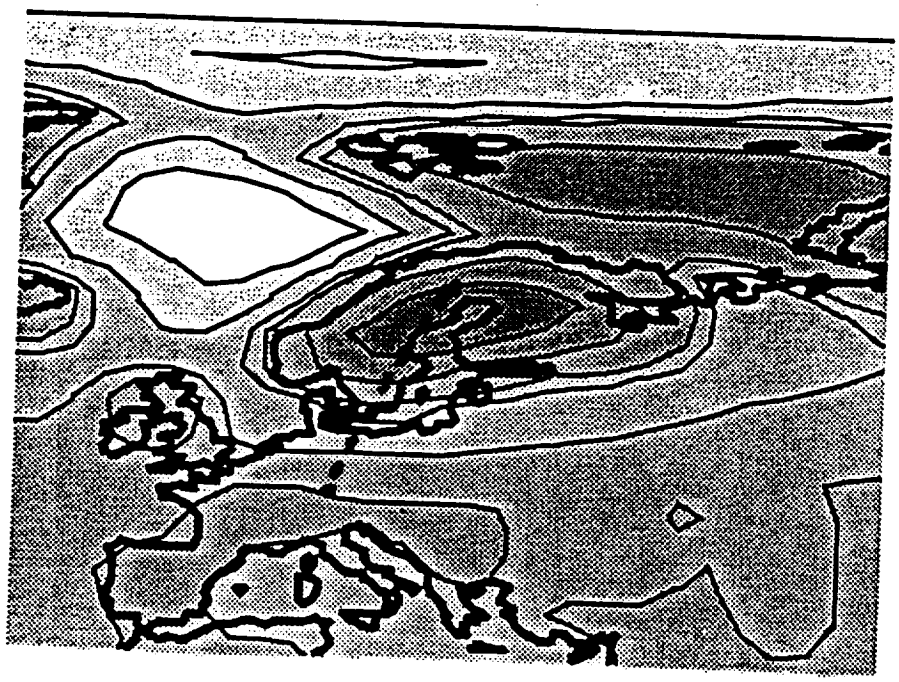
RADIAL VELOCITY

HUDSON BAY
↓
RICHMOND, FL



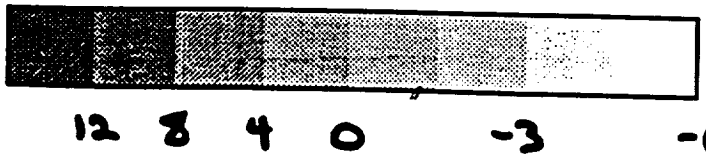
NORTH AMERICA

LULEA, SW.
↓
WETTZELL, GERM.

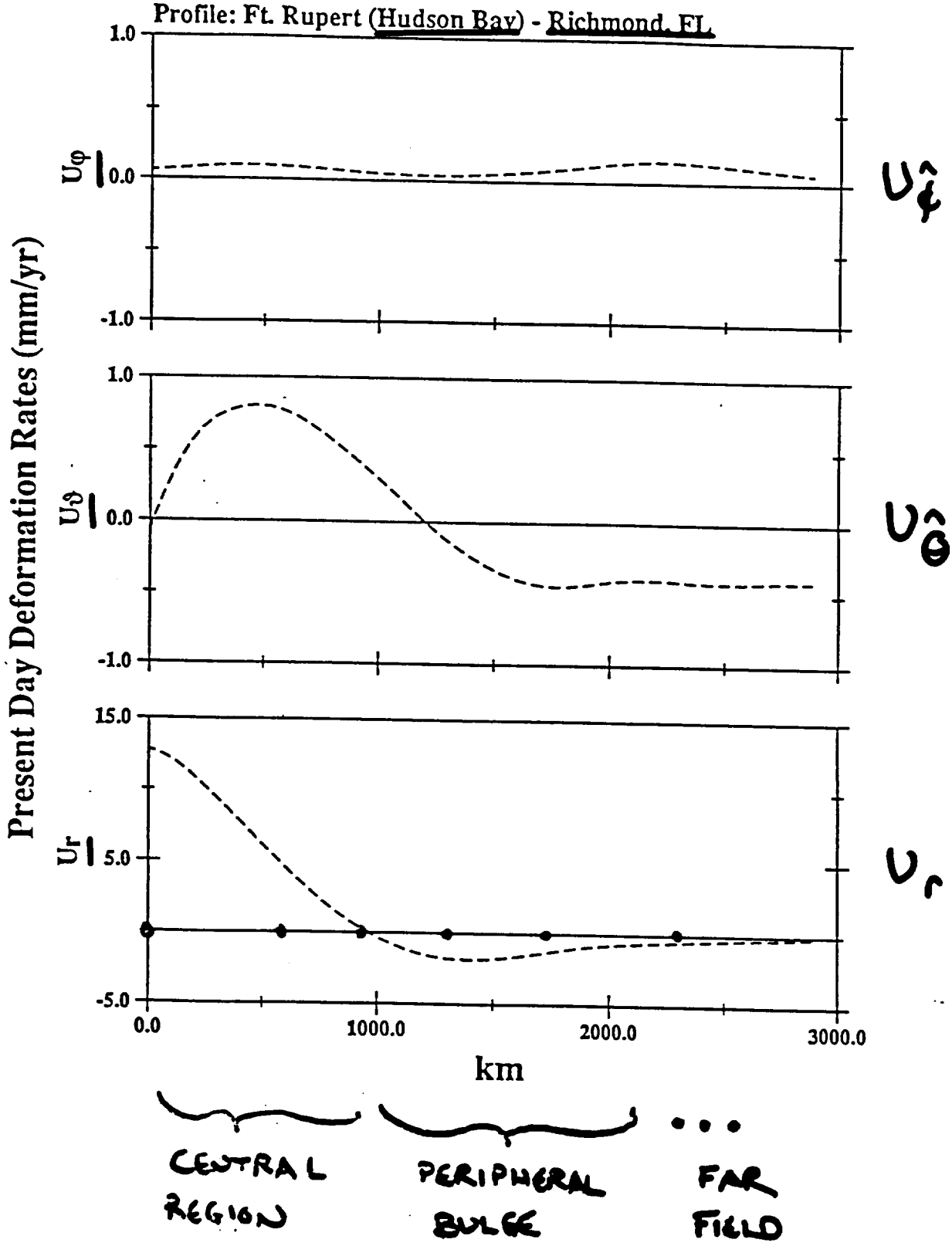


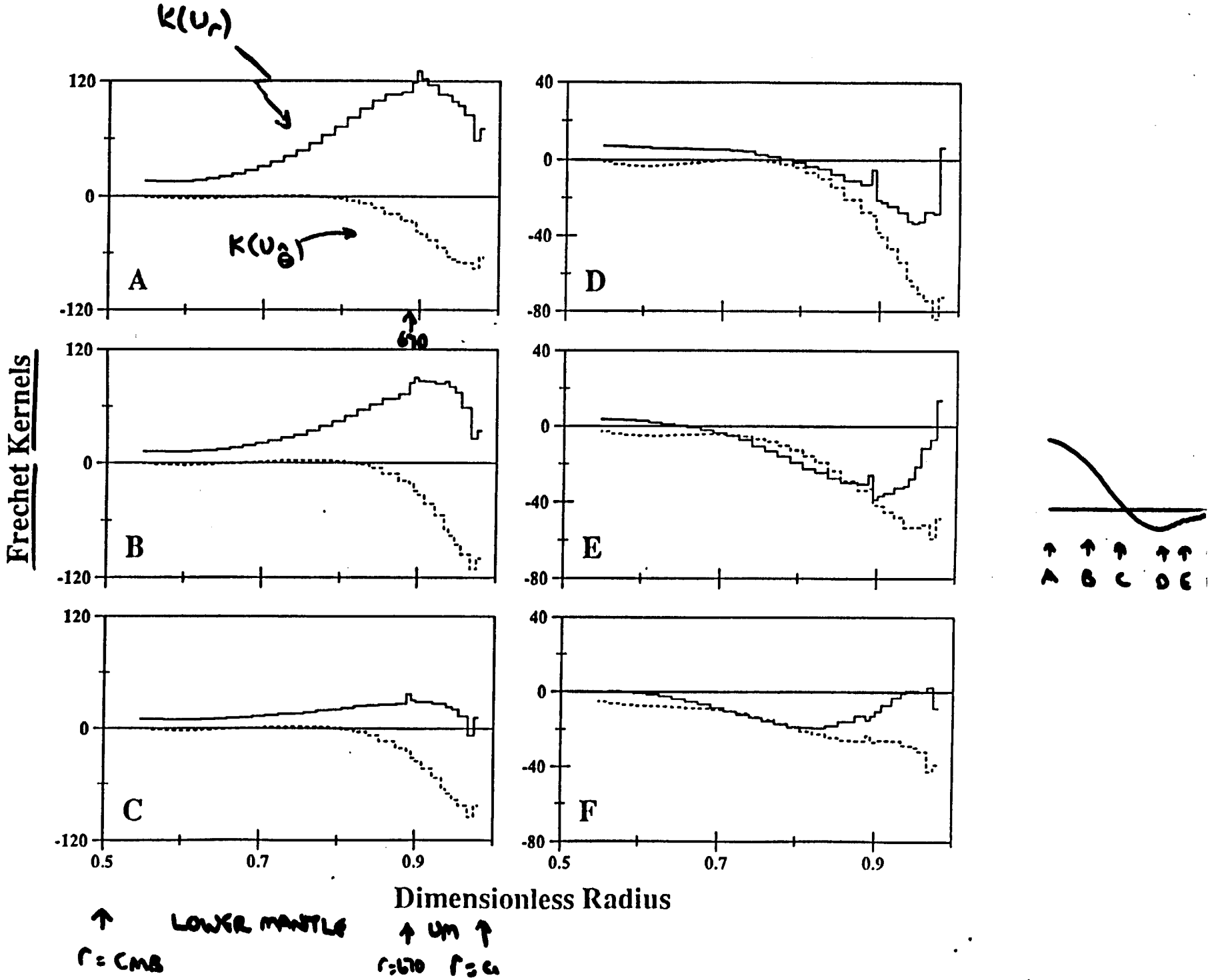
NORTHERN EUROPE

mm/yr

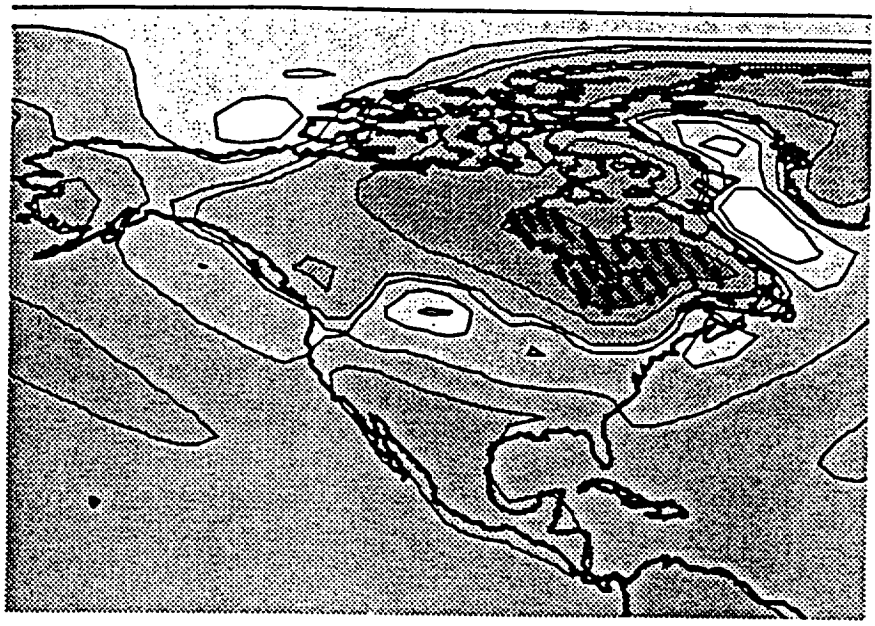


mm/yr

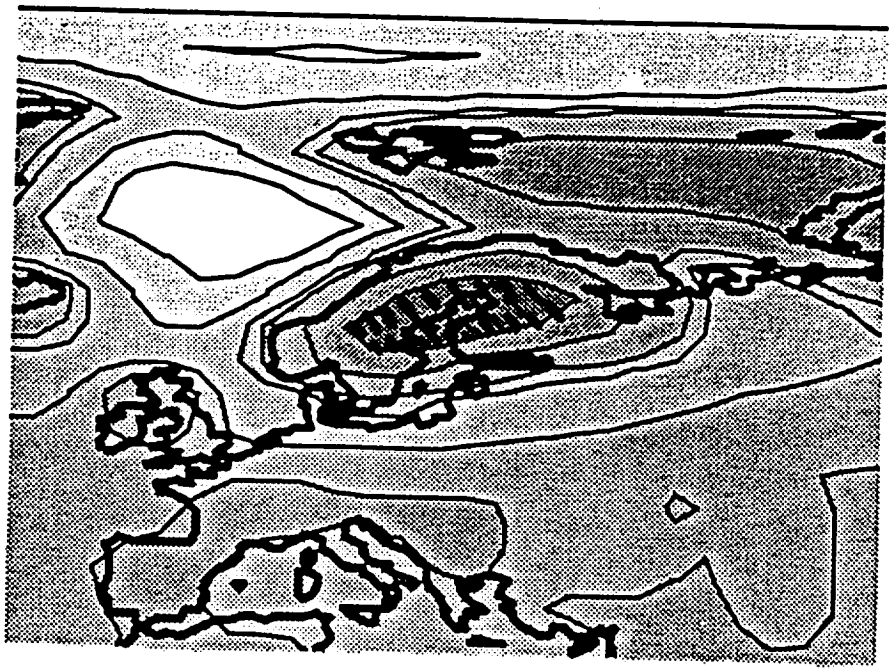

Profile: Ft. Rupert (Hudson Bay) - Richmond, FL
Present Day Deformation Rates (mm/yr)
1.0
0.0
-1.0
U_φ
$\hat{u}_\varphi$
1.0
0.0
-1.0
U_ϑ
$\hat{u}_\theta$
15.0
5.0
-5.0
U_r
u_r
0.0
1000.0
2000.0
3000.0
km
CENTRAL REGION
PERIPHERAL BULGE
FAR FIELD


K(Up)
K(Us)
120
0
-120
40
-40
-80
A
B
C
D
E
F
670
Frechet Kernels
0.5
0.7
0.9
Dimensionless Radius
LOWER MANTLE
UM
r = CMB
r=670
r = ca
A B C D E

RADIAL VELOCITY

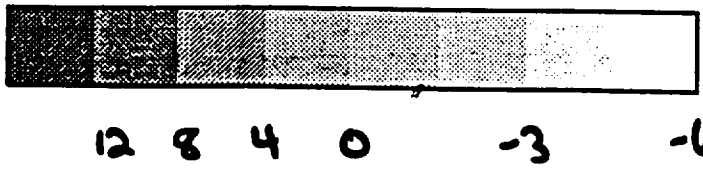


NORTH AMERICA



NORTHERN EUROPE

mm/yr



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

NORTH AMERICA: 19 BASELINES

including sites ...

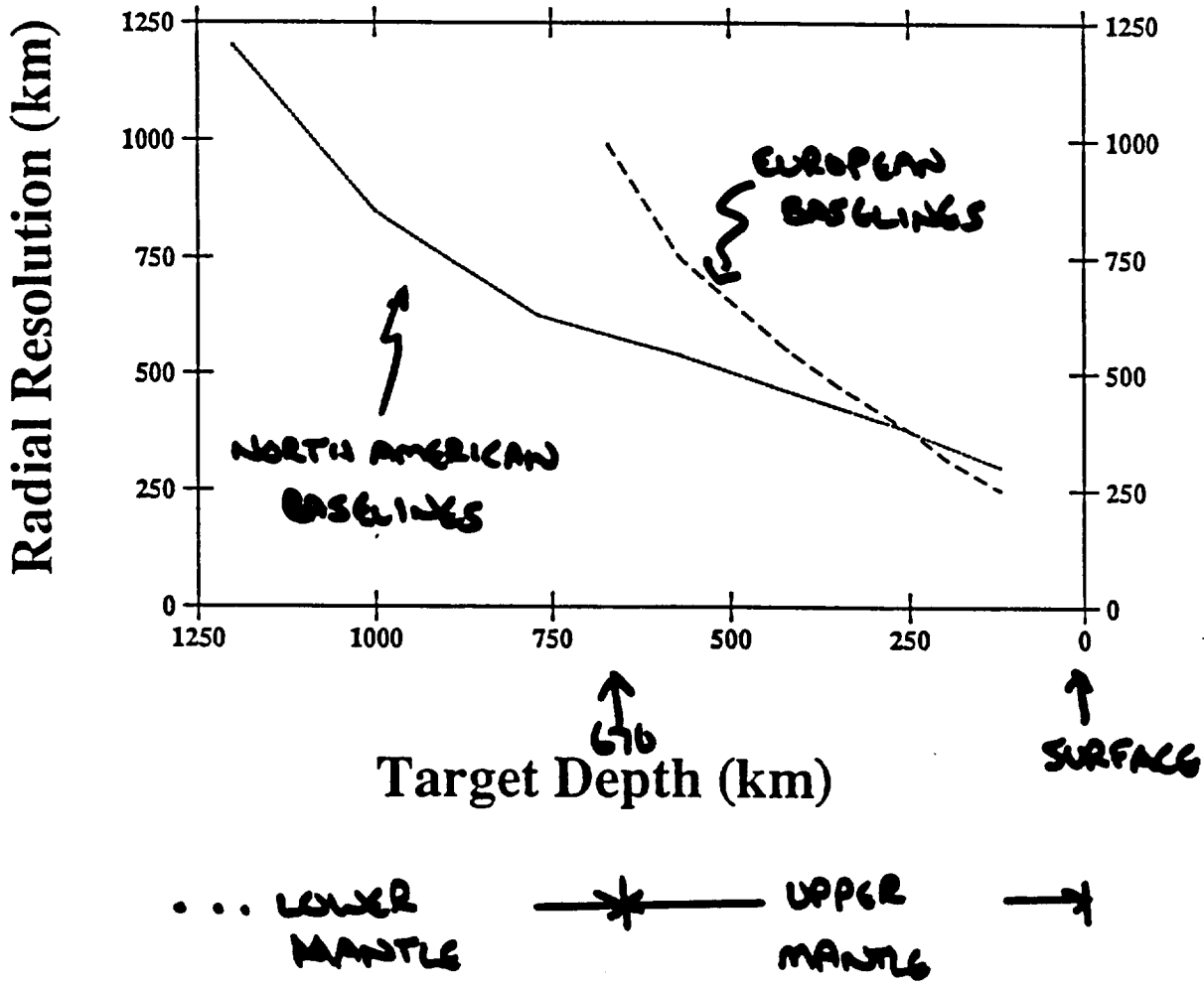
ALGOPARK
GILCREEK
PENTICTN
WESTFORD
WHITHORSE
FT. DAVIS
NRAO
PIETOWN
RICHMOND

EUROPE: 5 BASELINES

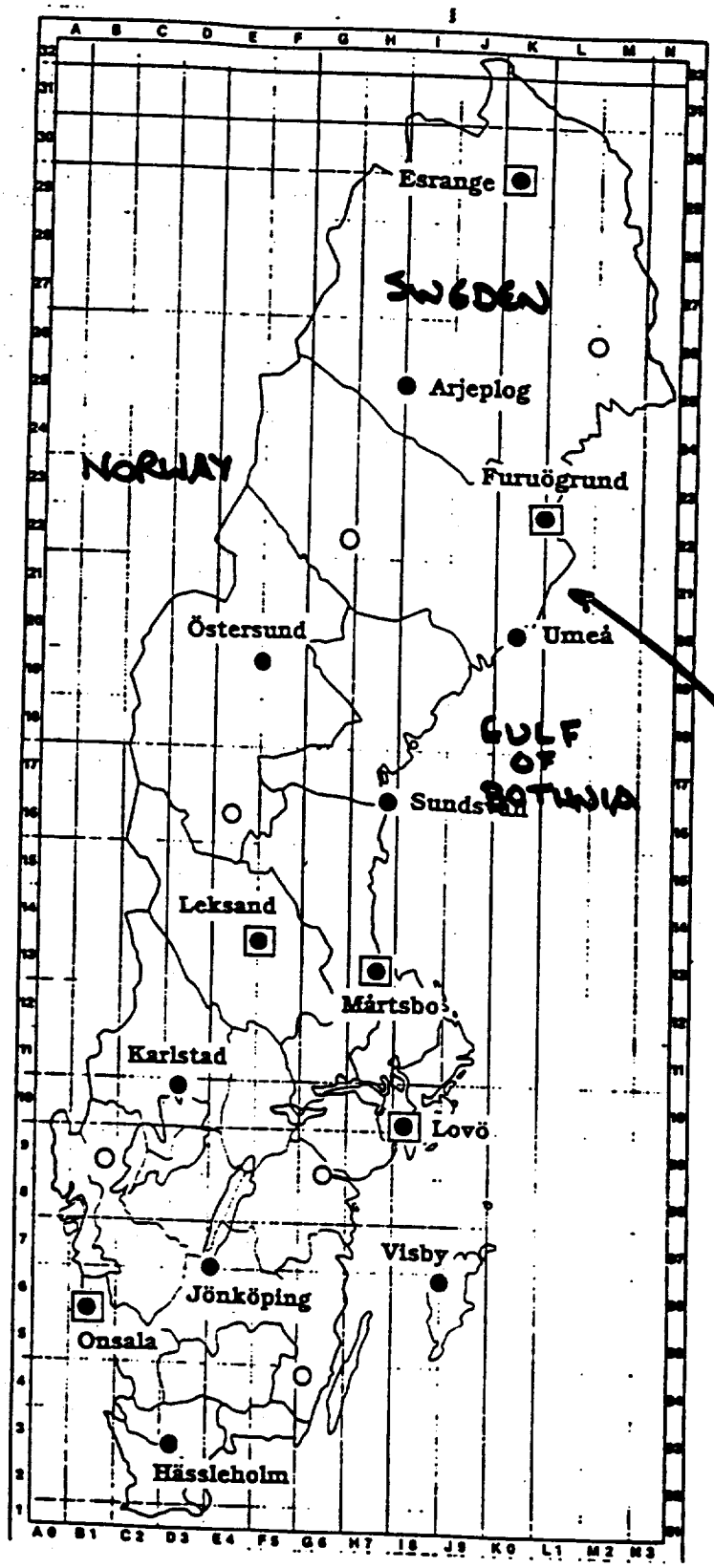
including sites ...

ONSALA, SW
WETTZELL, GERM.
EFLSBERG, GERM.
MEDICINA, IT.
NOTO, IT.
MADRID, SPAIN.

RESOLVING POWER: VLBI BASELINE RESULTS



SWEDISH GPS NETWORK



14 SITES MONUMENTLE
6 " PROPOSED

TOTAL = 20

REGION OF MAXIMUM UPLIFT

GPS NETWORK

SWEDISH LAND SURVEY
ONSALA SPACE OBS.
HARVARD-SMITH. CFA

RESOLVING POWER: NORTHERN EUROPE