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# CONSIDERATIONS CONCERNING GPS SOFTWARE DEVELOPMENT: STRUCTURE, MODELS, ALGORITHMS

**G.Beutler, S. Fankhauser, W. Gurtner, M. Rothacher, U. Wild**
**Astronomical Institute University of Berne**
**Switzerland**

**Abstract:**: We discuss some important aspects of developing post-processing software for geodynamic use of the Global Positioning System (GPS). Different tasks (orbit determination, network processing, simulation, etc) are defined, the structure of a general purpose program system is discussed, design principles are introduced. Using the material of the lAG GPS data set (prepared by the Special Study Group 1.104 of the International Association of Geodesy (lAG)) some processing algorithms are presented.

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## Kinematic Experiences with GPS and LaserTracker

by Marc Cocard
Institute for Geodesy
ETH-Zurich Hoengerberg
CH - 8093 Zurich

Abstract : Some kinematic experiences using simultaneously two GPS-receivers (TRIMBLE 4000ST) and an automatic tracking system (GEODIMETER 140T) were carried out. The results of a first, rather rough evaluation of the data show a good agreement between both systems. The GPS-results presented here have been obtained by a single point- or a differential C/A-Code -Solution. After transformation the RMS of the residuals range between 1.3 to 7 meters. The next step will be taking into account the GPS-phase measurements.

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## THE INFLUENCE OF NON-GRAVITATIONAL FORCES ON GPS-SATELLITE ORBITS

Joachim Feltens
Institute of Physical Geodesy
Technical University Darmstadt
Petersenstrasse 13

D-6100 Darmstadt, F.R. Germany

**Abstract:**. The disturbing force of solar radiation pressure has a considerable influence on GPS satellite orbits. Because of the irregular shape of the GPS spacecraft, solar radiation

force modelling is rather complicated. Additionally to the direct force pointing away from the Sun, also other components must be considered, e.g. components acting in the normal directions of the spacecraft's surfaces coming from specular and diffuse reflection. Furthermore thermal emission must be accounted for.

This paper describes the principles of several mathematical models and compares some results obtained with them. Also principles and some results of a new extended solar radiation pressure model, which was recently developed, will be presented.

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## Changes of station coordinates with Earth tides and oceanic loading

B. DUCARME, B. JANSSEN
Chercheur Qualifié FNRS Faculteit Geodesie
Observatoire Royal de Belgique Technische Universiteit
Delft Avenue Circulaire, 3 Thijsseweg 11
B-1180 BRUXELLES NL 2629 JA DELFT

*SUMMARY:* The tidal displacements at the surface of the Earth are not negligible reaching up to 40cm in the radial direction but only 5cm in the horizontal ones. From celestial mechanics it is easy to compute them for an oceanless elastic Earth. However the oceanic tides are producing additional displacements by "loading" the Earth. This effect can reach up to 10cm in unfavorable locations. Its computation requires the knowledge of digital cotidal maps for the main oceanic tidal waves. Their precision is rather poor leading to errors of the order of ten per cent on the load displacements.

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## ON THE ESTIMABILITY OF RESIDUAL TROPOSPHERIC PATH DELAYS IN THE GPS NETWORK ADJUSTMENT

K.Kaniuth, H. Tremel and M. Suarez*
Deutsches Geodätisches Forschungsinstitut ~GFI), Abt. I
Marstallplatz 8
D-8000 München 22

Federal Republic of Germany

**Abstract:**. Systematic errors in predicting the wet component of the tropospheric path delay significantly affect geodetic positioning with the Global Positioning System (GPS). Apart from improving the prediction models, stochastic, correlated stochastic and deterministic modelling of residual troposphere effects has been proposed. In this analysis systematic tropospheric delay errors were generated and applied to a real and a simulated GPS network. By including appropriately chosen parameters in the network adjustment it should then be possible to recover the intentionally introduced systematic errors. The results of this exercise indicate that in case of the simulated data set the applied biases could be accounted for to a level limited by data noise and mathematical correlations. With the real data this kind of deterministic modelling turned out to be not feasible and yielded results biased by several centimeters. Besides the high correlation in particular between estimated heights and tropospheric refraction this seems to be due to the presence of any other unmodelled systematic effects in the real GPS data.

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## PRECISE GPS POSITIONING WITH THE MULTISTATIONIMULTISESSION SOFTWARE - TOPAS

Herbert Landau
Institute of Astronomical and Physical Geodesy
University FAF Munich
D-8014 Neubiberg, Federal Republic of Germany

**Abstract:**. This paper is introducing a software tool named TOPAS (Terrestrial and Orbital Positioning Adjustment Software) and related utilities. TOPAS is modular data reduction software providing relative positioning of static or moving receivers in a network mode. It is using a multistation I multisession model based on a sequential formulation with a recursive filtering technique and is well suited to process the undifferenced sequential GPS data. The models to handle all major error contributions are implemented in the TOPAS software resulting in a high

accuracy GPS data reduction tool for geodetic and geodynamic purposes.

The second part of the paper describes the combination of GPS data from different receiver types in a multistation mode with TOPAS. A stochastic clock model is introduced and tested with simulated data.

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## KINEMATIC POSITIONING BY GPS

J. Westrop, P Summerfield and V Ashkenazi
Institute of Engineering Surveying and Space Geodesy
University of Nottingham
University Park
Nottingham, NG7 2RD
United Kingdom

**ABSTRACT.** Current GPS relative pseudo range positioning accuracies are of the order of 3-10 m. By using GPS phase measurements in conjunction with the pseudo range measurements, one can achieve much better relative positioning accuracies. If the problems of cycle slips and the unknown initial integer ambiguities can be resolved, then kinematic positioning with only the phase measurements becomes a distinct possibility, and the accuracies are improved to the centimetre level.

This paper describes two techniques for kinematic positioning using phase smoothed pseudo ranges and double difference carrier phases. Positioning results for a test network are presented and discussed.

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## ANALYSIS OF KINEMATIC AND STATIC GPS-OBSERVATIONS

K.Sauermann, M. Becker, Z. Hou
Institute of Physical Geodesy
Technical University Darmstadt
Petersenstrasse 13
D-6100 Darmstadt
F.R. Germany

**Abstract:**. The Institute of Physical Geodesy in Darmstadt has performed several GPS-Observations during spring and summer 1989 in static as well as in kinematic mode. The GPS-Observations were made in a small network with point distances of hundred meters nearby the Technical University and in a part of the German Main Triangulation Network (DHDN) with an average point distance of 40 kilometers. The accuracy of GPS-Baselines observed in kinematic mode in comparison to terrestrial reference distances is analysed and leads to residuals of about 1-3 cm.

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## RECENT RESULTS IN HIGH PRECISION KINEMATIC GPS POSITIONING

G. Baustert
G.W. Hein
H. Landau
Institute of Astronomical and Physical Geodesy (IAPG)
University FAF Munich
8014 Neubiberg, F.R.Germany

**ABSTRACT.** Many fields, such as geodetic surveying, positioning of airborne sensor:
(photogrammetric cameras), laser bathymeter, airborne gravimetry, and hydrographic( surveys, require accuracies in the decimeter or even centimeter range in differential positioning. Using the full potential of the GPS in a dynamic environment, IAPG has carried( out several Kinematic tests with respect to land-based, shipborne, and airborne applications.

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## Status of the ROB - GPS Software. Application to Belgian EUREF Observations.

Bruyninx C., Warnant R., Paquet P.
Royal Observatory of Belgium
B-1150 Brussels
Belgium

January 1990

Abstract: The present status of a GPS software developed at the Royal Observatory of Belgium is presented together with preliminary results of the analysis of data collected in Belgium during the first european GPS campaign.

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## THE GENERAL RELATIVITY EFFECTS IN THE COMPUTER SOFTWARE OF ARTIFICIAL SATELLITE POSITIONING

H.J. Yan*, E. Groten
(Institute of Physical Geodesy
Technical University Darmstadt, West Germany)
W.Y. Zhu, C.G. Feng
(Shanghai Observatory, Academia Sinica, China)

* on leave from Shanghai Observatory, China

**Abstract:**. The calculation procedure of general relativity effects in the computer software of artificial satellite positioning has been reviewed and re-discussed in this paper. In section 1, we have mentioned the convenience and the reasonableness to discuss the general relativity effects in the framework of geocentric frame. The special attention has been paid to the problems on the geodesic procession and that how to select Earth gravity constant C in section 3 and 4 respectively while the general relativity was concerned . We choose some satellites as the examples to show our results, but the main idea in this paper is essentially apt to other space techniques such as VLBI, LLR and others.

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## THE GEOID IN EUROPE: STATUS, REQUIREMENTS, PROSPECTS

Wolfgang Torge
Institut für Erdmessung
Nienburger Str. 6
D - 3000 Hannover 1

Fed. Rep. of Germany

**Abstract:**. The rapid advance of GPS-techniques in the last

years included GPS heighting, with a few cm accuracy over distances from some km to 1000 km and more. In order to meet the demands of practice and to combine GPS-heights with leveling, regional geoid resp. quasigeoid determinations are required with comparable accuracy. The paper summarizes early geoid calculations for the European area, and the more recent results obtained at IfE (Institut für Erdmessung), University of Hannover. Those European gravimetric and astrogravimetric quasigeoids calculated in the beginning of the 1980's, have a spatial resolution of about 20 km, and an accuracy of some decimeters. The necessary improvement of one order of magnitude seems to be possible now, with new data sets as global or regional long-wave geopotential models, high-resolution point gravity data, and digital terrain models. Corresponding test calculations have been successfully performed at I~, applying the "remove-restore" technique, with least squares collocation and integral formulas. From the comparison of a new quasigeoid of the Federal Republic of Germany with GPS/leveling control points, r.m.s. discrepancies of a few centimeters over some 100 km have been found. Based on this experience, a strategy for calculating a new quasigeoid for Europe is presented, which will be followed by IfE in the next years.

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## GPS MEASUREMENTS OF ABSOLUTE MEAN SEA LEVELS

T F Baker
Proudman Oceanographic Laboratory
Bidston Observatory
Birkenhead
Merseyside IA3 7RA
UK

**Abstract:**. A review is given of the important contribution that future GPS (and absolute gravity) measurements can make in separating vertical crustal movements from true sea level rise at tide gauges. These measurements will be of interest to geophysicists concerned with isostatic and tectonic vertical crustal movements, to oceanographers trying to improve estimates of real sea level rise and to geodesists

concerned with defining a vertical datum reference surface.

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## PROPOSAL FOR THE ESTABLISHMENT OF AN EUROPEAN HEIGHT SUPERVISION SYSTEM (HSS-WE)

W. Augath
Niedersächsisches Landesverwaltungsamt (NLVA)
Landesvermessung -
[) 3 0 0 0 Hannover 1 F. R . G.

**Abstract:**. The determination of changes in the horizontal vertical or gravity component of points is an important geodetic contribution to the solution of geo -dynamic questions. Especially height changes are of special interest for a lot of tasks. The following paper proposes the use of existing methods of measurements (precise leveling") and new possibilities (repeated 30"- and gravity-observations) on an European level.

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## LEVELLING With GPS

Alan Dodson and Sara Gerrard,
Institute of Engineering Surveying and Space Geodesy,
University Park,
Nottingham, NG7 2RD.

**Abstract:**: As GPS is being implemented more and more for high accuracy 3 dimensional positioning, the need has been seen in the U.K. for a precise local geoid. This would facilitate the conversion of ellipsoidal heights to the more commonly used orthometric heights. Using Least Squares Collocation, a geoid database is being prepared such that geoid height differences will be good to a few centimetres over distances of up to *50km,* a magnitude in line with at least third order levelling tolerances (at 12 mm *v*km). Several GPS networks, based on levelling stations, have been observed across the country in order to test the predicted geoid. Already, the results are pleasing. This paper describes the work behind the geoid prediction (data, covariance function, etc.), the GPS schemes and the results obtained so

far.

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## GPS-Levelling Experiments for the Connection of the Denish and German Levelling Systems in the Fehmarn-Belt-Region

Rainer Heer and Andreas Bagge
Geodetic Institute
University of Hannover
Nienburger Str. 1
D - 3000 Hannover 1

**Abstract:** In 1987 a hydrostatic levelling across the Fehmarn Belt had been carried out. The purpose was to connect the German island Fehmarn and the Denish island Lolland in a coastal part of the Baltic Sea extending the northern part of the european levelling network. During this field campaign a GPS levelling experiment with four TI 4100 GPS receivers was performed as joint project of the Denish Geodetic Institute, Kopenhagen and the Geodetic Institute, University of Hannover. The computed geocentric coordinates of the GPS bench marks were converted to orthometric heights using the available geoidal information in this region. These orthometric heights were compared with the orthometric heights of the local levelling networks. These results and strategies for solving the problems of connecting different height systems in land surveying are shown.

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## Precise Differential Kinematic Positioning for Hydrographic Surveying Tasks

U. VAN TWEMBEKE
A. MULS
Ecole Royale Militaire
Chaire de Géodésie
30, Avenue de la Renaissance
BRUXELLES

20 December 1989

**Abstract**: In June 1988 the *Fonds National de la Recherche*

*Scientifique (FNRS) de Belgique* sponsored a test project of precise kinematic GP5 marine positioning on the North Sea near the seaport of Zeebrugge **(3011;** 5102o~). Until now, the detection of the variations in seabottom morphology was performed from bathymetric vessels using classic radio positioning systems. However in coastal areas with rapidly changing conditions the survey takes too long and only the use of a fast moving platform can provide an effective solution.

In 1983 the Belgian Government instructed the Belgian company *Eurosense* to start the development of a specially designed hovercraft-based sounding system. The objective of the Zeebrugge experiment was to examine if GP5 precise kinematic p0-sitioning is a full reliable substitute for the classic radio positioning of a fast moving platform.

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## TRENDS IN EUROPEAN MEAN SEA LEVELS AND PATTERNS OF VERTICAL LAND MOVEMENTS

P.L.Woodworth and G.Alcock
Proudman Oceanographic Laboratory
Bidston Observatory
Birkenhead IA3 7RA
United Kingdom

**Abstract:** OF Poster. The figures in this poster were intended to complement the invited talk at this conference by T.F.Baker on GPS measurements of absolute mean sea levels. They were taken from three papers published or in press (Flemming and Woodworth, 1988; Woodworth, 1989; Woodworth et al., 1990) and one in preparation (Alcock et al., 1990) and all were derived from data obtained from the Permanent Service for Mean Sea Level (Pugh et al., 1987).

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## $M_2$ WORLD OCEAN TIDE FROM TIDE GAUGE AND GRAVITY LOADING MEASUREMENTS

0.FRANCIS
Observatoire Royal de Belgique
Avenue Circulaire 3

B-1180 Bruxelles
BELGIQUE

P. MAZZEGA
UMR39/GRGS/CNES
Avenue Edouard Belin 18
31055 Toulouse Cedex
FRANCE

**Abstract:**. The perturbations of geophysical and geodetical measurements caused by the variable load of the oceanic tide and the way to model them are briefly described. Finally, a new approach based on Inverse Theory to model the ocean tides in relation with the loading effects computation is discussed.

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## REFLEXIONS ON HEIGHT NETWORKS AND GEOID MODELLING

U.VAN TWEMBEKE
Astronomisch Instituut
K.U.Leuven
Belgium

**Summary**: Positional geodesy based on geometrical and gravitational measurements has to solve the fundamental questions of definition and realisation of geodetic datum. Traditionally, the problem has been splitted up into horizontal and vertical components. The geoid has been regarded by geodesists as the natural and universal height datum. At present there is no doubt that GPS survey methods can replace classical horizontal survey methods, the question is "what is the part of GPS observations in height determination, can we derive classical heights from precise ellipsoidal heights". Height determination constitutes the most tangible service provided by geodesy to the scientific and engineer community.

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## REFERENCE SYSTEMS RELATED TO GPS

C. BOUCHER

Institut Géographique National
2, Avenue Pasteur
94160 ST-MANDE (France)

The Global Positioning System (GPS) already plays and will play even more in the next future a primary role in Geodesy, Geodynanics, Surveying and Navigation. Reference System issues are therefore particularly important to investigate, either for the wide range of users, from decameter to millimeter, or for the proper use of GPS to improve the realization of terrestrial reference frames, from a global to a local scale.

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## High Precision GPS Relative Positioning on a Regional Scale

V. Ashkenazi, G. Ffoulkes-Jones, T. Moore and S. Whalley
Institute of Engineering Surveying and Space Geodesy
University Of Nottingham
University Park, Nottingham, NC7 2RD, UK
Telephone 0602484848 Ext. 2680 Telex 37346 UNINOT C
Fax 0602 508616

**Abstract:** A campaign to monitor tectonic motions in central and southern California using repeated measurements of the Global Positioning System was initiated by the Massachusetts Institute of Technology (MIT) in December 1986. Five days of observations between the 3rd and 7th of January 1987 was the most ambitious part of the campaign involving 14 receivers in the California region and five more receivers at other continental sites in North America. It is this data set that was selected by the International Association of Geodesy (IAG) Special Study Group 1.104 on 'Static and Geodynamic Positioning with GPS' as the 'Standard Data Set'. This data set has been processed by MIT producing baseline accuracies of a few millimeters +0.01 ppm horizontally and 1-2cm vertically (*Dong and* Bock,1989). A portion of this same data set is being processed at Nottingham using the in house software PANIC and ORBIT to produce five independent daily solutions. To date preliminary computations have been performed on four of the five days' data. A full fiducial strategy has been

implemented, solving for the satellite orbits and the unknown station locations simultaneously, followed by the constraint of the carrier phase ambiguities to integers. The preliminary results obtained show baseline and coordinate repeatability's of a few centimeters This paper presents the techniques used for the GPS phase processing and ambiguity resolution in the PANIC software. The repeatability statistics of the results are presented, as well as a comparison with MIT's solution.

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## TANGO:TRANSATLANTIC GPS NET FOR GEODYNAMICS AND OCEANOGRAPHY

H. Landau and G. W. Hem
Institute of Astronomical and Physical Geodesy
University FAF Munich, 8014 Neubiberg, F. R. Germany

M. L. Bastos and J. P. Osorio
Observatorio Astronomico, Centro de Astronomia
Universidade do Porto, Monte da Virgem, 4400 Vila Nova de Gaia, Portugal

**Abstract**: The TANGO GPS campaign, carried out from November *25* to December 5, 1988, was the first step towards the realization of a project whose main goals are: (i) Definition of a unified 3D-datum of the Portuguese and the European network and connection to the American continent via the Azores and Bermuda islands by using GPS and satellite altimetry; (ii) Establishment of a high precision network to monitor the Kinematics of the Azores volcanic region, located in the area of convergence of the North American, African and Eurasian plates (Azores triple junction), and to assess GPS potentialities to measure continental drift

For the measurement of epoch zero 10 TI 4100 GPS receivers were used at selected stations and tide gauges in Portugal, Spain, French Caribbean and on the Bermuda island. Through international cooperation, connection to the CIGNET network was established by pre-optimized observation schedule and selected satellite tracking for the purpose of precise orbit determination using phase data.

The paper presents the detailed description of the measurements and discusses the methodology adopted in the processing of the data. The specific problems due to intercontinental size of the network (non-intervisibility) and the bad satellite geometry at the Azores islands are outlined. Preliminary results are reported.

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## GPS FOR THE STUDY OF CRUSTAL DEFORMATIONS: METHODOLOGY AND PROJECTS

P. Briole and J.C. Ruegg
*Institut de Physique du Globe – Laboratoire de Sismologie – 4 Place Jussieu – 75252 Paris – Cedex 05- France*

**Abstract:** GPS is a tool of particular interest for the study of geophysical problems involving ground deformation. In the specific case of studies of subduction, extension or graben kinematics, a typical dimension of the area is 50 x 50 km with possible height difference of 1500 m. In such a region, the same order of magnitude is expected for both horizontal and vertical displacements with possible relative velocity between points in the range 1-10 cm/yr and metric displacements in case of earthquakes. In general, modelling such deformations requires a large data set (20-200 points). Then, the first two questions we encountered with the use of GPS, were estimation of the tropospheric delay, and how to get many data in a few number of days. We present in this paper our first conclusions after two experiments carried out to investigate these two questions. Additionally, we developed our own software of phase resolution. We present the principal characteristics of this software. Finally, we present our actual projects including GPS measurements.

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## MONITORING DISPLACEMENTS BY GPS: A CALIBRATION TEST

B. Coulon & Y. Caristan
CEA/RCP, B.P. 12, 91680 Bruyères-le--Châtel, France

**Abstract:** In April 1988, the position of three stations located

near Paris were monitored with single frequency GPS SERCEL receivers. The three base lengths were 30.030 km, 28.168 km and 2.715 km. One station was equipped with an antenna mounted on a stage and free to move in three directions. The displacements were known with a precision of one millimeter through the stage micrometers. Repeated measurements were done, first without displacements, then by steps varying from 1 to 50 cm. A priori coordinates were obtained from the pseudo-range data. Large differences between results obtained with or without satellite 8 are probably due to satellite 8 clock problems.

Baseline vector was determine by phase inversion. Comparisons between GPS and stage measurements show that the inversion result quality is function of two parameters : the r.m.s. of the residuals after inversion and the number of data taken into account during the inversion. When the displacements are computed from UPS baseline vector components, the scatter reach 10 ppm. Repeatability baseline measurements have a scatter of 1-3 ppm on the baseline length and reach 5 ppm on the baseline vector components. However, the r.m.s. on the repeatability measurements is less than one ppm on the baseline length and varies up to 2 ppm on the baseline vector components.

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## LAND SURFACE DISPLACEMENT INDUCED BY WATER-LEVEL VARIATIONS

M. Delcourt-Honorez
Observatoire Royal de Belgique
Av. Circulaire 3
1180 Brussels, Belgium

**Abstract:** We study the vertical land surface displacement induced by water-level variations. We show that the effect of water-level variations registered in three wells at the Royal Observatory of Belgium in Brussels is negligible on the GPS station. We nevertheless conclude that the "hydrogeological environment" of a GPS station has to be taken into account, e.g. in subsidence areas caused by intensive fluids withdrawals.

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## GLOBAL TRACKING NETWORK FOR A GPS EXPERIMENT IN THE INDIA-EURASIA COLLISION ZONE

G. Peltzer, S. Kornreich Wolf and T. H. Dixon
Jet Propulsion Laboratory,
California Institute of Technology
Pasadena, CA 91109, USA

**Abstract:**. From the perspective of a large scale Global Positioning System (GPS) geodetic experiment in the India-Eurasia collision zone, the problem of fiducial and global tracking networks is addressed. A global tracking network is necessary to define a reference frame for the experiment region, and to minimize errors on long baselines associated with uncertainties in the orbits of the GPS satellites. In order to test different configurations of a global tracking network, we have performed covariance analyses. A global tracking network formed of pairs of sites located in Europe, North America and Australia, supplemented by three additional sites in the periphery of the experiment region seems to be robust for the planned experiment. With such a network, total errors on horizontal components of baselines in China are on the order of a few millimeters plus 1 part in $10^8$ of baseline length. Baseline solutions appear to be sensitive to the occupation of sites south of the experiment region. Such a precision appears to be adequate to measure displacement rates on large faults in China (1-4 cm/yr). The importance of distributing fiducial sites evenly within the global tracking network is also emphasized in order to avoid an increase of errors due to uncertainties on their positions.

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## GPS PROJECTS OF DEUTSCHES GEODÄTISCHES FORSCHUNGSINTITUT (DGFI) RELATED TO GEODYNAMICS RESEARCH

Hermann Drewes, Klaus Kaniuth, Klaus Stuber, Herbert Tremel
Deutsches Geodätisches Forschungsinstitut, Abt. I
Marstallplatz 8
D-8000 München 22

F.R. Germany

**Abstract:**. There are two principal GPS projects of the German Geodetic Research Institute, Dept. I (DGFI/I) related to geodynamics research: The Calabrian Arc Project (CAP) in the Central Mediterranean and the Venezuelan part of the Central and South American (CASA) Project. Both networks have been observed in a zero-epoch campaign.

The objectives and first results are summarized in this paper.

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## A HIGHLY PRECISE GPS-EPOCH MEASUREMENT IN THE NORTH-EAST VOLCANIC ZONE OF ICELAND

Cord-Hinrich Jahn
Institut für Erdmessung
University of Hannover Nienburger Strasse 6 D - 3000 Hannover 1
Federal Republic of Germany

Abstract: In 1987 a geodetic GPS survey was conducted in the Northern and Eastern Volcanic Zone of Iceland covering an area of 300 x 280 km. In total, 63 ground control points were observed between the 2nd and 24th of August using 7 TI 4100 receivers. Data were collected for a period of 3.5 hours each day. The entire network may he divided into three parts, the Kraal, Ask and Vatnajökull network.

The network covering the Krafla region consists of 42 stations with spacings varying from a few km to 100 km in the rift zone resp. up to 150 km in the stable plate interior to the west and east. Some points of this network are identical with the pre-existing terrestrial control network established by the University of Braunschweig, FRG. Six points of this network are identical with absolute gravity stations observed by Institut für Erdmessung (IFE) in 1987. Furthermore, at least 12 points are identical with GPS stations observed in 1986 by other groups.

A dense network of altogether 15 GPS points within and flanking the Askja volcanic system was measured in a 4-day period. The Vatnaj5kull network consisting of 14 stations

with spacings of approx. 100 km was observed in two sessions. 6 stations of this network are also identical with the first order terrestrial control network of Iceland. The three parts of the entire network are connected by common stations.

The 1987 GPS project was a cooperation between the Icelandic GPS Coordinating Committee, the Dept. of Geological Sciences, the University of Durham, UK, and the Institut für Erdmessung. The goals of this project are:

-to perform a first epoch measurement and create a precise three-dimensional network,

-to compare GPS results with results from existing terrestrial and GPS control,

-to create highly accurate coordinates for absolute gravity stations,

-to analyse the applicability of GPS for the determination of recent crustal movements.

In this paper results from the GPS analysis and a comparison with electronic distance measurements are presented. The evaluation of the GPS measurements was done with the multi-station, multi-session, multi-receiver and multi-frequency software package GEONAP developed at IFE. The standard deviations in the north, east, height, and distance components are in the order of 1...2 cm over distances up to 100 km. The comparison of the GPS results with slope distances obtained from the terrestrial network yields a systematic scale difference of about 3 ppm and a standard deviation of about 0.5 ppm. A remeasurement of the GPS network is planned for 1990.

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## GPS NETWORKS IN SEISMIC AND VOLCANIC AREAS IN CENTRAL AND SOUTHERN ITALY

M.Anzidei C.Gasparini F.Riguzzi
Istituto Nazionale di Geofisica. Rome, Italy

V.Achilli

Dipartimento di Ingegneria Civ. Ed. Universita di Roma "Tor Vergata". Rome, Italy

P.Baldi
1st. Scienze della Terra. Universita di Udine. Udine, Italy

P. Marsan
Presidenza del Consigho. Servizio Sismico. Rome, Italy

**Abstract:**: The Italian peninsula is a region interested by great geodynamical processes and by a recent and active tectonic. The observation of the deformation field associated with earthquakes is important to define the processes which take place in the earth's crust. Geodetic measurements are capable of delineating the feature of the earthquake deformation cycle, monitoring movement patterns and can provide precise estimates of present day fault slip rates and irregularities in deformation rate. GPS networks can be used to outline the broad scale deformation patterns, surveys are less expensive than the conventional techniques and the verteces do not need to be placed on the mountain tops to ensure mutual visibility. In this contest three geodetic networks were realized: the Calabrian Arc and the Messina Strait networks, the L'aquila network and the Albani Hills (volcanic area) network. The Calabrian Arc, the Messina Strait and L'Aquila networks are both terrestrial and GPS, while the Albani Hills network is a GPS network only. The comparison of the terrestrial and GPS data are shown for the Messina Strait network while for the others projects and strategies for the GPS campaigns are shown.

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## INVESTIGATION OF THE GPS MONITORED CRUSTAL MOVEMENTS NETWORK I N HUNGARY

M. Varga-Lang - J. Töth
Department of' Geodesy, Geodetic Institute
Technical University of Budapest
H-1521 Hungary

**Abstract:**. On the basis of the results of the test measurements per-formed in SGO in May, l989, two kinds of geodynamical networks are planned in Hungary. The first

one is the testnet of the TU Budapest, being a small-scale, regional network established in Soskut. Second one is a global, national network consisting of 10-12 points.

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## TIME TRANSFERS BY GPS

B. Guinot
Bureau International des Poids et Mesures
Pavillon de Breteuil
92312 Sèvres Cedex France

**Abstract:** The GPS directly disseminates the Coordinated Universal Time (UTC) with uncertainties of a few microseconds. It can be also used as a very accurate means of time comparisons. In the latter case, the uncertainties, without the Selective Availability (SA), are usually in the range 10-30 ns. However, it will be shown that the uncertainties can drop to 1-2 ns. The implementation of SA is a major concern for time laboratories. May be a first idea of its impact can be given by experiments made in Spet. Oct. 1989. There are means to overcome the SA, but this will require delays and work.

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## LIST OF PARTICIPANTS

Anzidei Marco
Istituto Nazionale di Geofisica
Via di Villa Ricotti 42
1-0061 Roma
Italie

Ashkenazi Vidal
Univ, of Nottingham
University Park
Nottingham NG7 2R0
Grande Bretagne

Augath Wolfgang
NLVA-Landesvermessung
Warmbuchenkamp 2
D-3000 Hannover 1

R.F.A.

Baker Trevor
Proudman Oceanographic Lab.
Bidston Observatory
Birkenhead Merseyside
L43 7RA Grande Bretagne

Bastos Luisa
Astron. Obs.-Univ. of Porto
Monte da Vi rgem
4400 U.N. Gaia
Portugal

Bauch Alfred
Inst. Astr. U Phys. Geod.
Arcisstrasse 21
D-8000 Munchen 2
R.F.A.

Baustert Gerald
Univ. FAF Munich
Werner-Heisenberg Weg 39
D-8014 Neubiberg
R.F.A.

Beutler Grard
Astronomical Institute
Sidlerstr. 5
CH-3012 Bern
Suisse

Bordley Ron
Ordnance Survey
Romsey Road -Maybush
GB-Southampton
S09 4DH Grande Bretagne

Boucher Claude
SGNM/IGN
Av. Pasteur 2
F-94160 St Mand
France

Breger G.
Service gomtre-Centre E. Hamilius
51 Bld Royal
L-2449 Luxembourg
Grand Duch de Luxembourg

Briole Pierre
Institut Physique du Globe
4 Place Jussieu
F-75252 Paris Cedex O5
France

Bruyninx Carine
Royal Observatory of Belgium
Ringlaan 3
B-1180 Bruxelles
Belgique

Chares N.
Service Gomtre-Centre E. Hamilius
51 Bld. Royal
L-2449 Luxembourg
Grand Duch de Luxembourg

Cocard Marc
Inst. Geod. & Photogrammetry
Federal Inst. Technology
CH-8093 Zurich
Suisse

Collin Fabienne
Observatoire Royal de Belgique
Av. Circulaire 3
B-1180 Bruxelles
Belgium

Coulon Bruno
Service RCP
CEA/DAM B.P.12
91680 Bruyres-le-Chatel
France

Cross Paul
University of Newcastle
Department of Surveying
Newcastle upon Tyne
Grande Bretagne NEl 7RU

De Chevalier J.-B.
Institut de Physique du Globe I
4 Place Jussieu
F-75252 Paris Cedex O5

De Jong Kees
Dept. of Geodesy - TUD
Thijsseweg 11
NL-2629 JA Delft
Nederland

Dehant Vronique
Observatoire Royal de Belgique
Avenue Circulaire 3
B-1180 Bruxelles
Belgique

Delcourt Micheline
Observatoire Royal
Av. Circulaire 3
B-1180 Bruxelles
Belgique

Demonie Luc
National Geographic Institute
Terkamerenabdij 13
B-1050 Brussel
Belgique

Drewes Hermann
DGFI
Marstallplatz 8
D-8000 Munchen 2
R.F.A

Ducarme Bernard

Observatoire Royal
Av. Circulaire 3
B-1180 Bruxelles
Belgique

Engen Bjorn
Statens Kartver
Monserudvejen
N-3500 Hoenefoss
Norway

Feltens Joachim
Inst. Physik. Geod.
Petersenstrasse 13
D-6100 Darmstadt
R.F.A.

Ferrer Sebastian
Univ. de Zaragoza-Dpt. Fis. Astr.
Ciudad Universitaria
50009 Zaragoza
Espagne

Ffoulkes-Jones Geraint
Univ. of Nottingham
University Park
Nottingham NG7 2RD
Grande Bretagne

Flick Jean
Rue Louis XIV, 25
L-1948 Luxembourg
Grand Duch de Luxembourg

Flouzat Mireille
CEA
Service RCP - BP12
F-91680 Bruyres-le-Chatel
France

Folmer N.
Adm. Cadastre et Topographie

Av. Gaston Diederich 54
L-1948 Luxembourg
Grand Duch de Luxembourg

Francis Olivier
Observatoire Royal de Belgique
Avenue Circulaire 3
B-1180 Bruxelles
Belgique

Friedhoff Harald
Inst. fr Angewandte Geodsie
Richard Strauss Allee 11
D-6000 Frankfurt/Main 70
RFA

Galas Roman
Sternwarte der Universitat Bonn
Auf Dem Hugel 71
D-5300 Bonn 1
RFA

Gerrard Sara
Univ. of Nottingham
University Park
Nottingham NG7 2RD
Grande Bretagne

Guinot Bernard
Bureau Int. Poids et Mesures
Pavillon de Breteuil
F-92312 Svres Cedex
France

Gurtner Werner
Astronomical Institute
Sidlerstrasse 5
CH-3012 Berne
Suisse

Hill Chris
Univ. of Nottingham
University Park

Nottingham NG7 2RD
Grande Bretagne

Horn Detlef
Adm. Cadastre et Topographie
Av. Gaston Diederich 54
L-1948 Luxembourg
Grand Duch de Luxembourg

Hou Zangwei
Instit. Physikalische Geodasie
Petersenstrasse 13
D-61 Darmstadt
RFA

Jahn Cord-Hinrich
Inst. Erdmessung-Univ. Hannover
Nienburgerstrasse 5
D-3000 Hannover 5
R.F.A.

Jonsson Bo
National Land Survey Sweden
National Land Survey
S-80182 Gavle
Suede

Kaniuth Klaus
DGFI
Marstallplatz 8
D-8000 Munchen 2
RFA

Klees Roland
Geodatisches Institut
Postfach 6380 Englestr. 7
D-7500 Karlsruhe
RFA

Kohnen J.
Service gomtre-Centre E. Hamilius
51 Bld. Royal
L-2449 Luxembourg

Grand Duch de Luxembourg

Kosters Anton
Technical University Delft
Thijsseweg 11
NL-2629 JA Delft
Nederland

Kumpel Hans-Joachim
Inst. Geoph.-Univ. Kiel
Leibnizstrasse 15
D-2300 Kiel 1
R.F.A.

Landau Herbert
Univ. FAF Munich
Weiner Heisenberg weg 39
D-8014 Neubiberg
R.F.A.

Lisboa M. Manuela
Inst. Geog. e Cadastral
Praca da Estrela
P-1200 Lisboa
Portugal

Louis Luc
Observatoire Royal de Belgique
Av. Circulaire 3
B-1180 Bruxelles
Belgique

Magirus Andr
Adm. Cadastre et Topographie
Av. Gaston Diederich 54
L-1948 Luxembourg
Grand Duch de Luxembourg

Melchior Paul
Observatoire Royal de Belgique
Av. Circulaire 3
B-1180 Bruxelles
Belgique

Molitor Mathias
Adm. Cadastre et Topographie
Av. Gaston Diederich 54
L-1948 Luxembourg
Grand Duch de Luxembourg

Moore Terry
Univ. of Nottingham
University Park
Nottingham NG7 2RD
Grande Bretagne

Morujao Daniela
Dept. Mat.-Univ. Coimbra
Univ. Coimbra-Apartado 3008
3000 Coimbra
Portugal

Muls Alain
Royal Military School
Renaissancelaan 30
1040 Brussels
Belgique

Paquet Paul
Observatoire Royal de Belgique
Av. Circulaire, 3
B-1180 Bruxelles
Belgique

Peltzer Gilles
Jet Propulsion Lab.-Calif.Inst. Tec
4800 Oak Grove Drive
Pasadena California 91109
U.S.A.

Pesec Peter
Observatory Lustbuehel
Lustbuehelstrasse 46
A-8042 Graz
Austria

Poder Knud
Geodaetisk Institut
7 Rigsdagsgarden
DK-1218 Copenhagen
Danemark

Poitevin Christian
Observatoire Royal de Belgique
Av. Circulaire 3
B-1180 Bruxelles
Belgique

Richardus Peter
Heimanslaan 10
NL-6705 AG Wageningen
Nederland

Rius Antonio
Instituto de Astronomia y Geodesia
Universidad Complutense
E-28040 Madrid
Espagne

Romero Pilar
Instituto de Astronomia y Geodesia
Universidad Complutense
E-28040 Madrid
Espagne

Ross Christie
Ordnance Survey
Romsey Road - Maybush
GB-Southampton
GB-s09 4DH Grande Bretagne

Saint-Crit Liliane
CERGA
Avenue Copernic
F-06130 Grasse
France

Sauermann Knud

Institut fur Physikalische Geodasie
Petersenstrasse 13
D-6100 Darmstadt
RFA

Schlesser Emile
Adm. Cadastre et Topographie
Av. Gaston Diederich 54
L-1948 Luxembourg
Grand Duch de Luxembourg

Schluter Wolfgang
Inst.Angew.Geod.-Satell .Weltzell
Bayer. Wald
8493 Kotzling
RFA

Seeger Hermann
Director IFAG-Inst.Angew.Geod.
Richard Strauss Allee 11
D-6000 Frankfurt am Main 70
R.F.A

Sillers Paul
University Newcastle
Department of Surveying
Newcastle upon Tyne NEl 7RU
Grande Bretagne

Silva Antonio
University of Nottingham
University Park
Nottingham NG7 2R0
Grande Bretagne

Smeets Ingeborg
Astron. Inst.-K.U. Leuven
Celestijnlaan 200 B
B-3030 Heverlee
Belgique

Smets Edouard
Lange Lozanastraat 134

2018 Antwerpen
Belgique

Smit Jeroen H.M.
Faculty of Geodesy - TUD
Thusseweg 11
NL- 2629 JA Delft
Nederland

Souriau Annie
GRGS
18, Av. Ed. Belin
F-31055 Toulouse Cedex
France

Temple John
Univ. of Nottingham
University Park
Nottingham NG7 2RD
Grande Bretagne

Torge Wolfgang
Inst. Erdmessung-Univ . Hannover
Nienburgerstrasse 6
D-3000 Hannover 1
R.F.A.

Tremel Herbert
DGFI
Marstallplatz 8
D-8000 Munchen 2
R.F.A

Van Der Marel Hans
Faculty of Geodesy -DUT
Thusseweg 11
NL-2629 JA Delft
Nederland

Van Dijck L.J.
Sokkisha Europe

Flevolaan 4
1380 AJ Weesp
Nederland

Van Gelder Boudewijn
TUD/Faculty of Geodesy
Thusseweg 11
NL-2629 JA Delft
Nederland

Van Twembeke Urbain
Royal Military Academy
Hortensialaan 13
B-1970 Wezembeek-Oppem
Belgique

Varga Marta
Dept. Geodesy TU Budapest
Muegyetem rkp 3.1.61
H-1521 Budapest XI
Hongrie

Visser Hans
RH Survey
Trawiwerkade 64
NL-1676 Cl Ijmuiden
Nederland

Wagner Ren
Adm. Cadastre et Topographie
Av. Gaston Diederich 54
L-1948 Luxembourg
Grand Duch de Luxembourg

Weightman Jack
150 St Vincent Str.
Glasgow G2 5LJ
Grande Bretagne

Westrop Jane
Univ. of Nottingham
University Park
Nottingham NG7 2RD

Grande Bretagne

Willis Pascal
IGN/SGNM
Av. Pasteur 2
F-94160 St Mand
France

Woodworth Philip
Proudman Oceanographic Lab.
Bidston Observatory
Birkenhead Merseyside
L43 7 RA Grande Bretagne

Wubbena Gerhard
Inst. fur Erdmes sung-Univ. Hannover
Nienburgerstrasse 5
D-3000 Hannover 1
RFA

Yan Haojian
Inst. Physikalische Geodasie
Petersenstrasse 13
D-61 Darmstadt
RFA

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## PROGRAMME

### SESSION 1: SOFTWARE DEVELOPMENT

*CHAIRMAN: PROF. V. ASKHENAZI*

Oral Presentation

*Beutler G., Fankhauser S., Gurtner W., Rothacher M., Wild U.*
Considerations Concerning GPS Software Development:Structure, Models, Algorithms.

Posters

1.01 *Cocard M.*
Kinematic Experiences with GPS and Laser Tracker.

1.02 *Feltens J.*
The Influence of non-Gravitational Forces on GPS-Satellite Orbits.

1.03 *Ducarme B., Janssen B.*
Changes of Station Coordinates with Earth Tides and Oceanic Loading.

1.04 *Kaniuth K., Tremel H., Suarez M.*
On the Estimability of Residual Tropospheric Path Delays in the GPS Network Adjustement.

1.05 *Dodson A., Hill C. (*)*
Atmospheric Refraction Correction to GPS Measurements.

1.06 *Landau H.*
Precise GPS-Positioning with the Multistation/Multisession Software TOPAS.

1.07 *Ashkenazi V., Napier M., Westrop J*
Kinematic and Pseudo-Kinematic GPS Positioning.

1.08 *Sauermann K., Becker M., Hou Z.*
Analysis of Kinematic and Static GPS Observations.

1.09 *Hem C., Baustert C., Landau H.*
Recent Results of High-Precision Kinematic GPS Positioning.

1.10 *Bruyninx C., Paquet P., Warnant R.*
Status of ROB-GPS Software. Application to Belgian EUREF Observations.

1.11 *H.J. Yan, Groten E.*
The General Relativity Effects in the Computer Software of Artificial Satellite Positioning.

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## SESSION 2:
## GEOID AND MEAN SEA LEVEL
*CHAIRMAN: DR. W. AUGATH*

Oral Presentation

*Torge W*
The Geoid in Europe : Status, Requirements, Prospects.

*Baker T.*
GPS Measurements of Absolute Mean Sea Levels.

Posters

2.01 *Augath W*
Proposals for an European Height Control System.

2.02 *Pesec P., Sunkel H. (*)*
Geoid Determination and Crustal Monitoring by GPS Methods in Austria.

2.03 *Dodson A., Gerrard S.*
Levelling with GPS.

2.04 *Heer R., Bagge A.*
GPS - Levelling Experiments for the Connection of the Denish and German
Levelling Systems in the Fehmarn Belt Region.

2.05 *Muls A., Van Twembeke U.*
GPS Positioning for Hydrographic Surveying Tasks.

2.06 *Woodworth P., Alcock G.*
European Vertical Land Movements.

2.07 *Ashkenazi V., Dodson A., Davison M., Basker G. (*)*
Mean Sea Level Determination by Using GPS.

2.08 *Francis 0., Mazzega P.*
$M_2$ World Ocean Tides from Tide Gauge and Gravity Loading Measurements.

2.09 *Van Twembeke U.*
Geoid and Orthometric Height Determination.

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## SESSION 3:
## REFERENCE SYSTEMS, CRUSTAL DEFORMATIONS

*CHAIRMAN: DR. G. PLETZER*

Oral Presentations

*Boucher C.*
Reference Systems Related to GPS.

*Cross P. (*)*
Use of GPS for Crustal Deformation Studies.

Posters

*3.01 Ashkenazi V., Moore T., Ffoulkes-Jones G., Whalley S., Aquino M.*
High Precision GPS Relative Positioning on a Continental Scale.

3.02 *Hem C., Landau H., Bastos L.*
TANGO - Transatlantic GPS Net of Geodynamics and Oceanography.

3.03 *Ruegg J.C., Briole P.*
Coupled Spatial-Terrestrial Geodesy in Seismic Areas : Strategy and Projects.

3.04 *Coulon B., Caristan Y*
Monitoring Displacements by GPS.

3.05 *Van Gelder B. (*)*
GPS for Geodynamics : Are Fiducial Networks Really Necessary?

3.06 *Delcourt M.*
Land Surface Displacement Induced by Water-Level Variations.

3.07 *Peltzer C.*
Global Tracking Network and Fiducial Network for a GPS Experiment in the India-Asia Collision Zone.

3.08 *Drewes H., Kaniuth K.*
GPS Projects of the Deutsches Geodaetisches Forschungsinstitut (DGFI) Related to Geodynamics Research.

3.09 *Jahn C.H.*

A highly Precise GPS-Epoch Measurement in the North-East Volcanic Zone of Iceland.

3.10 *Achilli V., Anzidei M., Gasparini C., Riguzzi F., Strollo R.*
GPS Methods in Seismic and Volcanic Areas in Central and Southern Italy.

3.11 *Varga-Lang M., Toth A.*
Investigation on GPS-Monitored Crustal Movements Network in Hungary.

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## SESSION 4: TIME TRANSFERTS. EUREF.

*CHAIRMAN: DR. K. PODER*

Oral Presentations

*Guinot B.*
Time Transferts by GPS.

*Seeger H.*
The Aims of EUREF/GPS/VLBI.

*Schluter W., Gurtner W.*
EUREF-GPS Observation-Campaign.

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## SESSION 5:FUTURE EUROPEAN GPS PROJECTS (*)

(*) no paper included

BACK TO PUBLICATIONS