NAVGRAV, A COMPREHENSIVE COMBINED NAVIGATION AND GRAVIMTERY EXPERIMENT ON THE NORTH SEA; OBJECTIVES AND FIRST EXPERIENCES

M.A. Salzmann
G.J. Husti
G.L. Strang van Hees
P.J.G. Teunissen[x]
Department of Geodesy
Delft University of Technology
Thijsseweg 11
2629 JA Delft
The Netherlands

ABSTRACT

During spring 1986 a unique NAVigation GRAVimetric experiment (NAVGRAV) took place on the North Sea. An overview of the objectives, the experiments performed and some experiences are given.

1. INTRODUCTION

The NAVGRAV project, a combined NAVigation and GRAVimetric experiment, was carried out successfully in the period April 23 - May 13 1986. Summarizing the main objectives of the project are:
- to establish the perspectives of the Global Positioning System (GPS) for positioning at sea.
- to investigate the quality of terrestrial navigation systems in the North Sea region.
- to establish the achievable resolution and (internal and external) accuracy of the gravity field characteristics, derived from sea gravimetry, in comparison with results obtained from satellite altimetry.

The oceanographic vessel H.M.S. Tydeman of the Royal Netherlands Navy was made available for the experiments.
The experiment was carried out in two parts. The first period (April 23 - April 29) was mainly directed at the navigation experiment (see fig. 1). The second period (April 30 - May 13) concentrated on the sea gravimetry experiment (fig. 2).
The NAVGRAV project is the result of a joint effort of the Dutch survey community and several German universities.

x) supported by Z.W.O, Netherlands Organization for the Advancement of pure Research

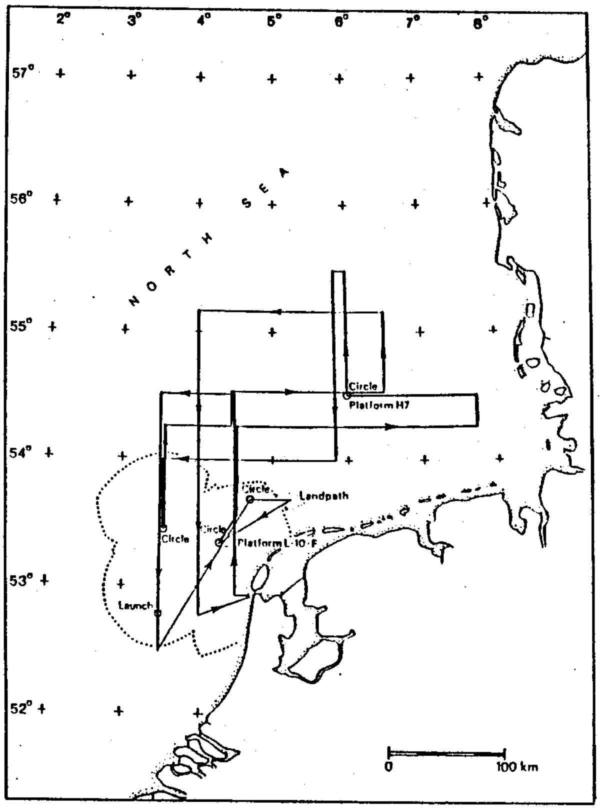

figure 1.

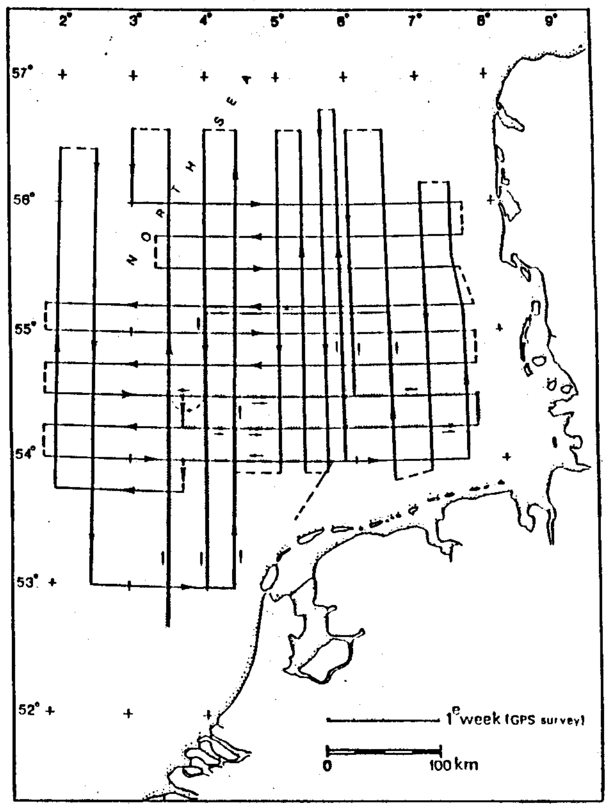

figure 2.

Figure 1. Navigation experiment NAVGRAV. The dotted line indicates the Syledis three way fix area.
Figure 2. Gravity survey NAVGRAV.

A list of all participants in the project is given in the appendix.
The NAVGRAV project was sponsered by the Dutch Council of Ocean Sciences (Nederlandse Raad voor Zeeonderzoek, NRZ). Additional financial and material support was obtained from participating universities, government agencies and private companies.

2. OBJECTIVES OF THE NAVGRAV PROJECT

The objectives of the navigation and gravimetric experiments will now be viewed in more detail.
First of all the perspectives of GPS for positioning at sea have to be established.
- Comparison of GPS with classical radio positioning systems (e.g. Syledis).
- Absolute (single point) positioning for the purpose of navigation and and velocity determination.
- Relative positioning between the vessel and a reference point on land.
- Relative positioning between two receivers on board.
- Relative positioning between two moving objects.

In addition the limitations and perspectives of the existing classical radio positioning systems, concentrating on the physical aspects of these systems, are investigated.

The purpose of the gravimetric experiment is to investigate to what extend satellite altimetry can replace sea gravimetry in the future (see e.g. Rummel et al, 1983).

Part of the region was already surveyed in 1979 (Strang van Hees, 1983). By partly re-measuring and densifying this gravity network, it becomes possible to investigate the spatial resolution, external accuracy and systematic biases of sea gravimetry. The measurements were carried out by two gravimeters to investigate the internal accuracy and instrumental characteristics.

3. EXPERIMENTS AND FIRST EXPERIENCES

The experiments concerning GPS, radio positioning systems and gravity measurements will be reviewed seperately.

During most of the navigation experiment Syledis was used as a reference system. As a consequence of ideal weather conditions first-class data were obtained. The sea gravimetry measurements were mainly carried out on the northern part of the Dutch Continental Shelf. An overview of the available navigation systems during the first week of the project is given in table 1.

Available navigation systems during NAVGRAV, April 23 - April 29.

on board	on land
GPS receivers	the Netherlands
2 TI 4100	1 TI 4100 Delft and Haarlem
1 Sercel TR5S	1 Sercel TR5S Delft and Haarlem
1 Trimble 4000S	
1 Cesium standard	1 Rubidium standard
	Norway
	1 TI 4100 Stavanger
Radio positioning systems	
Syledis	
Hifix-6	
Hyperfix	
Loran C	
Other systems	
Gyro	
Log	
Pitch and Roll sensor	
Echosounder	

table 1.

3.1 GPS experiments. The availability of three types of receivers on board enabled a comparison of the different receivers. During the entire navigation experiment always at least one GPS antenna was installed in the front mast of the ship.

The following experiments were performed:

- Single point positioning and velocity determination with a single receiver. A velocity estimate of 0.1 m/s was achieved during good coverage with the Trimble 4000S. Using a cesium standard it was investigated how long GPS observation intervals could be enlarged during unfavourable satellite coverage.
- Relative positioning between the vessel and reference points on land. For this purpose receivers were installed ashore. One receiver was installed in Stavanger (Norway) about 600 km. from the test area. Two receivers were installed at Haarlem and Delft (The Netherlands) much closer (± 100 - 200 km.) to the test area. Both pseudo range and carrier phase were observed. These experiments for longer baselines supplement the already performed experiments (e.g. Seeber et al.,1986). First analysis of the data of the shorter baselines shows that an accuracy, which is equal or better then the reference system Syledis (3 m.) can be obtained.
- Short distance differential GPS in order to determine the ships dynamics. During the experiment antennas were installed in the main and front mast of the H.M.S. Tydeman at a relative distance of 40 m.
- Relative positioning between two moving objects. A TI 4100 receiver was installed in a launch, which was also equipped with Hifix-6. The distance ship-launch varied between 0 - 3 km.

Up to now mainly single point solutions have been computed. The quality of the data is such that good differential positioning results can be expected.

3.2 Experiments concerning radio positioning systems. These experiments mainly relate to the physical aspects of medium frequency systems (Hifix-6 and Hyperfix) and on the possible future use of interchain Loran-C in the North Sea area.

Hyperfix proved to be very unstable during dawn and dusk. Hyperfix was also highly affected by skywave during night. Part of the efforts in the first week have been directed to the calibration of the relatively new Hyperfix chain.

The following experiments were carried out:

- In order to investigate the effects of landpaths on Hyperfix positioning some special lines were surveyed.
- On medium and low frequencies the combination antenna-ship may cause heading dependent additive errors to the measured (pseudo-)distances. De Jong and de Munck (1986) propose to develop corrections in a fourier series. To obtain these corrections gyro and (pseudo-)distance observations, uniformly spaced over the horizon, have to be made. For this purpose several circles were steamed. First computations show that the effect occurs with periods of π and 2π radians, which is in accordance with the expectations. Harmonics higher than order 2 do not seem present.
  These results should be handled with care, because the total effect (for the H.M.S. Tydeman) was of the same magnitude as the accuracy of the reference system. Also the antenna lay-out on board could have caused some interference.
- The reflection of signals of all frequencies caused by oil platforms was investigated by circling around two platforms at close range.
- The effects of skywave on medium frequency systems were monitored at night by observing lane values from distant stations.

-Loran-C interchain measurements. Pseudo ranges were measured to two station in the Norwegian, and one in the French chain. A cesium standard was used to synchronize the chains. This feasibility test for the use of Loran-C in the North Sea area proved that the system is reliable. An assessment of the accuracy of the measurements cannot be made yet.
Despite the 100 kHz frequency, during the experiment no interference of importance was encountered, even in the busy North Sea region.

3.2 Sea gravimetry experiments. 3500 Nautical miles of gravity lines were surveyed. The Delft gravimeter (an Askania Bodensee sea gravimeter KSS-5) was supplemented during the second period by the gravimeter of Hamburg University (Bodensee sea gravimeter KSS-30).

This set-up enables the assessment of mean instrumental biases of the gravimeters, since external effects like the Eötvös correction (vertical component of the Coriolis acceleration) and errors in positioning are eliminated in the difference between the two measured gravity values.

During a preliminary comparison about 200 points were used with a maximal range in gravity anomalies. The root mean square (rms) of the difference was 0.9 mgal in good weather conditions. During a few lines, measured under slightly worse weather conditions, the rms of the differences was about 2 mgal.

The external accuracy of the gravity measurements at sea is strongly influenced by the quality of the navigation; especially the velocity in East-West direction has to be determined very accurately. An uncertainty in the East-West velocity of 0.1 m/s (0.2 knot) corresponds to an uncertainty of 1 mgal in the Eötvös correction. As the determination of the Eötvös correction is seen as one of the main error sources in sea gravimetry, velocity measurements with GPS could help to bring sea gravimetry accuracy down to 1 mgal worldwide.

4. CONCLUSIONS

The NAVGRAV project yielded a large amount of data. All data have been catalogued and stored in a data-base. Preliminary computations show that real time differential GPS at sea can bring position accuracy down to the meter level. Sea gravimetry will benefit from the velocity determination capabilities of GPS.

Phase errors caused by the ship-antenna combination seem present, but need further investigation.

Actual processing of the data is presently underway. Interest is mainly focussed on differential GPS with a reference station on land and sea gravimetry. The gravity data will be processed independently at Delft University of Technology and Hamburg University. Further detailed investigations (e.g. concerning the radio positioning systems) will be performed in the near future.
All research results will be published.

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APPENDIX

List of participants in the NAVGRAV project

-Delft University of Technology, Department of Geodesy	Delft	the Netherlands
-Hydrographic Service of the Royal Netherlands Navy	Den Haag	the Netherlands
-Rijkswaterstaat, Survey Department, section Marine Geodesy	Delft	the Netherlands
-Shell Internationale Petroleum Maatschappij	Den Haag	the Netherlands
-Intersite Surveys	Haarlem	the Netherlands
-Osiris Seaway	Heemstede	the Netherlands
-NeSA	Rotterdam	the Netherlands
-NHS	Leidschendam	the Netherlands
-Radio Holland	Amsterdam	the Netherlands
-Oretech	Vijfhuizen	the Netherlands
-Utrecht University, Institute of Earth Sciences	Utrecht	the Netherlands
-Hannover University, Institute of Geodesy (IFE)	Hannover	FRG
-München University of Technology, Institute of Astronomical and Physical Geodesy	München	FRG
-Hamburg University, Institute of Geophysics	Hamburg	FRG
-Norwegian Hydrographic Service	Stavanger	Norway