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PROCESSING OF SEA GRAVITY DATA USING ON-LINE NAVIGATIONAL INFORMATION OF ICEBREAKER SHIRASE

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Abstract: The NIPRORI-1 gravimeter of icebreaker SHIRASE was modified so that the ship's navigational data were used in real time. Examples of measurement using the modified system during the 27th Japanese Antarctic Research Expedition are given to show the performance.

1. Navigational Data of the SHIRASE

The sea gravimeter of icebreaker SHIRASE is the NIPRORI-1 gravimeter developed in Japan under a co-operation between the National Institute of Polar Research (NIPR) and the Ocean Research Institute, University of Tokyo (ORI) (SEGAWA *et al.*, 1983). In the 27th Japanese Antarctic Research Expedition (JARE-27) a full system for real time use of the navigational data of the SHIRASE was first completed, and it became possible to process various correction data to be applied to raw gravity such as Eötvös correction, normal gravity subtraction and Bouguer correction. Table 1 shows the navigational data available on board the SHIRASE together with the devices which transmit the data, the types and formats of the signal and names of the ship's laboratories where the data are available. There are nine sorts of signals transmitted from the navigational and observational devices, *i.e.*, latitude and longitude with time (GMT), gyrocompass azimuth, ship's speed relative to water, wind direction, wind speed, air temperature, water depth, water temperature and ship's speed relative to the earth. These data are transmitted every one minute from the terminals equipped in each laboratory. Among the nine sorts of the navigational data the gravimeter needs only five of them, *i.e.*, latitude and longitude with time, azimuth, ship's speed relative to water and the earth, and water depth. The ship's position is primarily based on the satellite fixes provided from the NNSS receiver OPN-7B-3. Positions between two satellite passes are interpolated using the ship's speed (this is conducted by another computer equipped in the SHIRASE). Position and time signals have a digital ASCII format transmitted serially by a 20 mA current loop. The rate of transmission is 600 bits/s and the resolution is 90×2^{-22} degree/bit. The unit of time is in seconds. Azimuth or heading of the ship is measured by a gyrocompass Model MK 1 and transmitted by a synchro transmitter (AC 115 V, 60 Hz, 1X). The resolution of azimuth is 0.1°. Ship's speed relative to water is provided by an EM Log Model 7 through a synchro transmitter

Table 1. Navigational data available in real time on board the SHIRASE. Laboratories where the data are available are indicated by open circles.

Element	Device	Signal	Format	2nd Lab	Grav Lab	1st Lab	5th Lab
Latitude Longitude Time (GMT)	NNSS receiver OPN-7B-3	Digital	ASCII serial 20 mA current loop	○	○	○	
Azimuth	Gyrocompass MKI	Synchro transmission (AC 115V, 60 Hz, 1X)	Synchro 360°/Rev.	○		○	
Ship's speed wrt water	EM Log Model-7	same	same −5∼20 kt/Rev.	○		○	
Wind direction	Vane Model-1 ver. 2	same	same 360°/Rev.	○		○	
Wind speed	same	same	same 60 m/s/Rev.	○		○	
Air temp.	Remote sensing thermometer ver. 1	Digital Open collect. out	Parallel BCD 11 bit with sign. pos. logic	○		○	
Water depth	Precision deep sea echo sounder ver. 1	same	Parallel BCD 17 bit pos. logic	○	○	○	
Water temp.	Auto. water thermo salinometer	same	Parallel BCD 10 bit with sign. pos. logic	○		○	○
Ship's speed wrt earth	Ship's position tracer MK13	same	Parallel BCD 9 bit with sign. nega. logic	○		○	

with a resolution of 0.1 kt. Water depth is measured by a precision deep sea echo sounder and transmitted by 17-bit parallel BCD signals which cover a depth range up to 19999 m. Ship's speed relative to the earth is provided using 10-bit parallel BCD with a resolution of 0.1 kt through a rather complicated procedure: When water depth is very small a doppler log is used to measure the true speed. As the doppler log does not work in deep water the speed relative to the earth is calculated by the ship's computer on the basis of the position changes. In any case a true speed of a ship is difficult to obtain, and actually it is inevitable to improve the data by recalculation.

2. Modification of Gravimeter System

A special interfacing device was prepared to introduce the navigational data to the mini computer of the gravimeter. The mini computer system and its software were also modified to match the new system. Figure 1 shows the block diagram of the interfacing device. The data of water depth consisting of a 17-bit BCD and the ship's speed relative to the earth consisting of 9 bits are introduced to a digital input/output module of the mini computer through buffer amplifiers. The signals from synchro transmitters of gyrocompass and EM Log are digitized by synchro digital converters and converted further to BCD code. Then these signals are fed to the digital input/out-

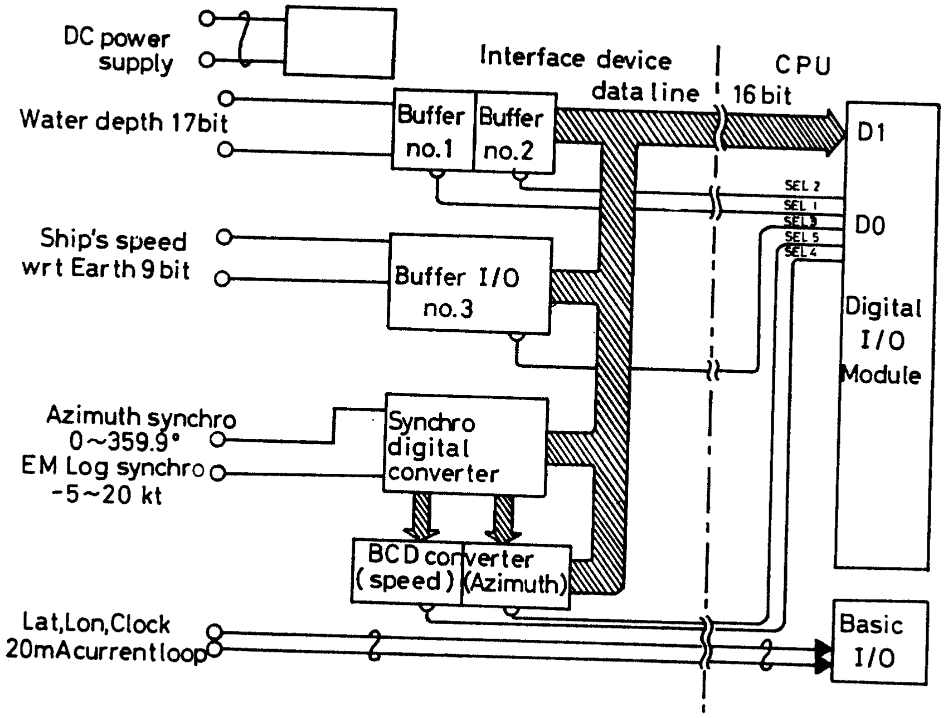

Fig. 1. Block diagram of the interfacing device that receives the navigational signals and converts them to a form acceptable for the CPU unit.

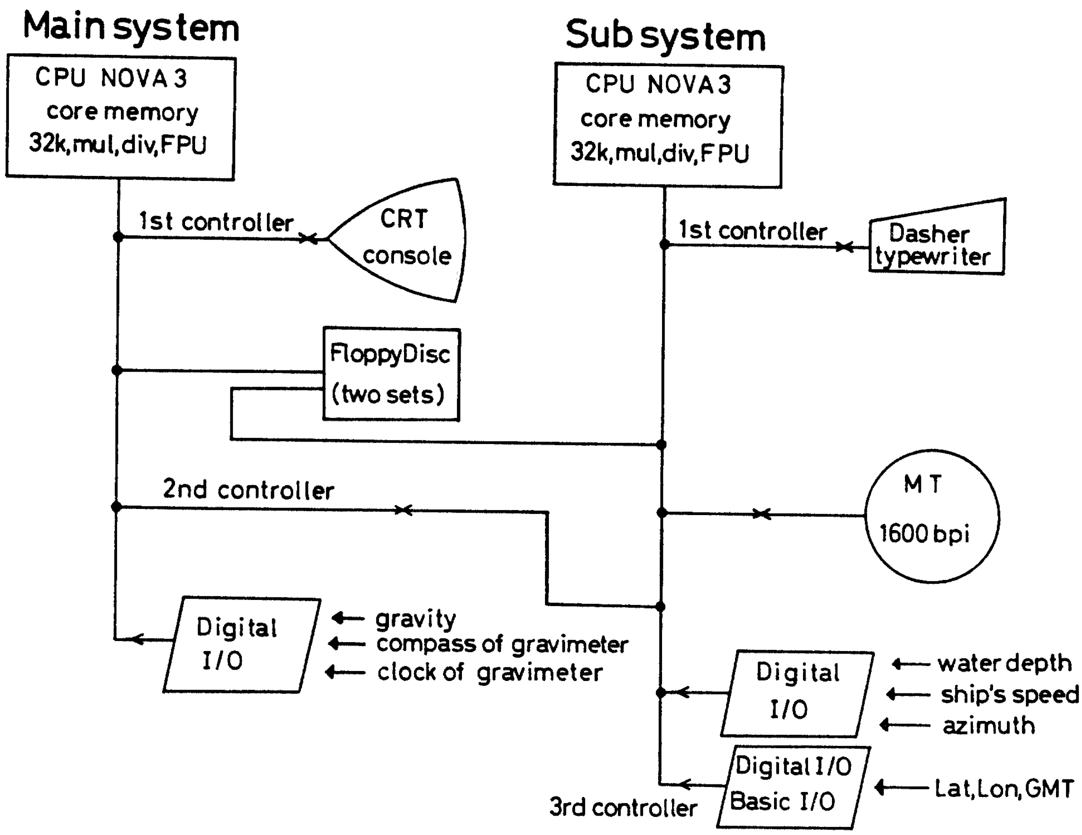

Fig. 2. Interconnections between the units of the computer system.

put module of the mini computer. Position and time signals are directly fed to the basic input/output board of the computer.

Interconnection or data flow in the mini computer system was changed as seen in Fig. 2. The computer system of the NIPRORI-1 gravimeter had back-up devices with two sets of identical NOVA-3 CPU unit and two sets of floppy disc unit. In the new system these units were connected and used together so that they shared the function. The main CPU unit has a primary mission to process the signals from the gravimeter unit, *i.e.*, gravity acceleration, indication of gyrocompass of the gravimeter itself and clock signal. The subsidiary CPU unit has a mission of processing the navigational data. A CRT console unit is connected to the main CPU. A dasher typewriter and a magnetic tape unit are connected to the subsidiary CPU. Two sets of the floppy disc unit are connected to both CPU's, and the main and subsidiary CPU are connected together by the 2nd controller terminals.

3. Real Time Processing of Gravity

In the old gravimeter system the read-out of instantaneous gravity acceleration and digital low-pass filtering was conducted in real time. The gravity value obtained by this processing is a raw gravity which is affected by Eötvös effect. In order to correct for the Eötvös effect continuous data of ship's position or speed is necessary. As the navigational data of SHIRASE is provided every one minute this is almost sufficient. In a vehicle moving with a speed as low as a surface ship the Eötvös effect E which is the vertical component of Coriolis force is represented by

$$E=2\omega v\cdot\cos\varphi, \tag{1}$$

where ω is the angular velocity of the earth rotation, v the west-to-east component of ship's speed relative to the earth, and φ the geographical latitude. Then the true gravity g on the spot is expressed by

$$g=G+E, \tag{2}$$

where G is the raw gravity. If gravity anomaly is to be calculated the normal gravity has to be obtained from the following internationally approved formula:

$$\gamma=978.03185(1+0.005278895\sin^2\varphi+0.000023462\sin^4\varphi). \quad \text{(unit in gal)} \tag{3}$$

The free air gravity anomaly $\Delta g'$ is obtained by

$$\Delta g'=g-\gamma. \tag{4}$$

In order to get Bouguer gravity anomaly Bouguer correction value is necessary. Simple Bouguer correction B is obtained from

$$B=2\pi k^2(\rho_c-\rho_w)D, \tag{5}$$

where k^2 is the universal constant of gravity, ρ_c the density of the earth crust, ρ_w the density of sea water, and D the water depth just beneath the gravity measuring point.

In the present calculation the simple Bouguer correction is used to obtain the simple Bouguer anomaly $\Delta g''$ which is expressed as

$$\Delta g'' = \Delta g' + B. \tag{6}$$

Bouguer gravity anomaly, if it is to be used to estimate the structure of the earth interior, needs to be corrected for the topographic effect. The topographic or bathymetric correction will be considered for the future system.

4. Conclusion

The NIPRORI-1 sea gravimeter used on board icebreaker SHIRASE was improved so that the position of the measurement, water depth, and gravity anomaly were obtained in real time. Figure 3 shows examples of free air gravity anomaly profiles which

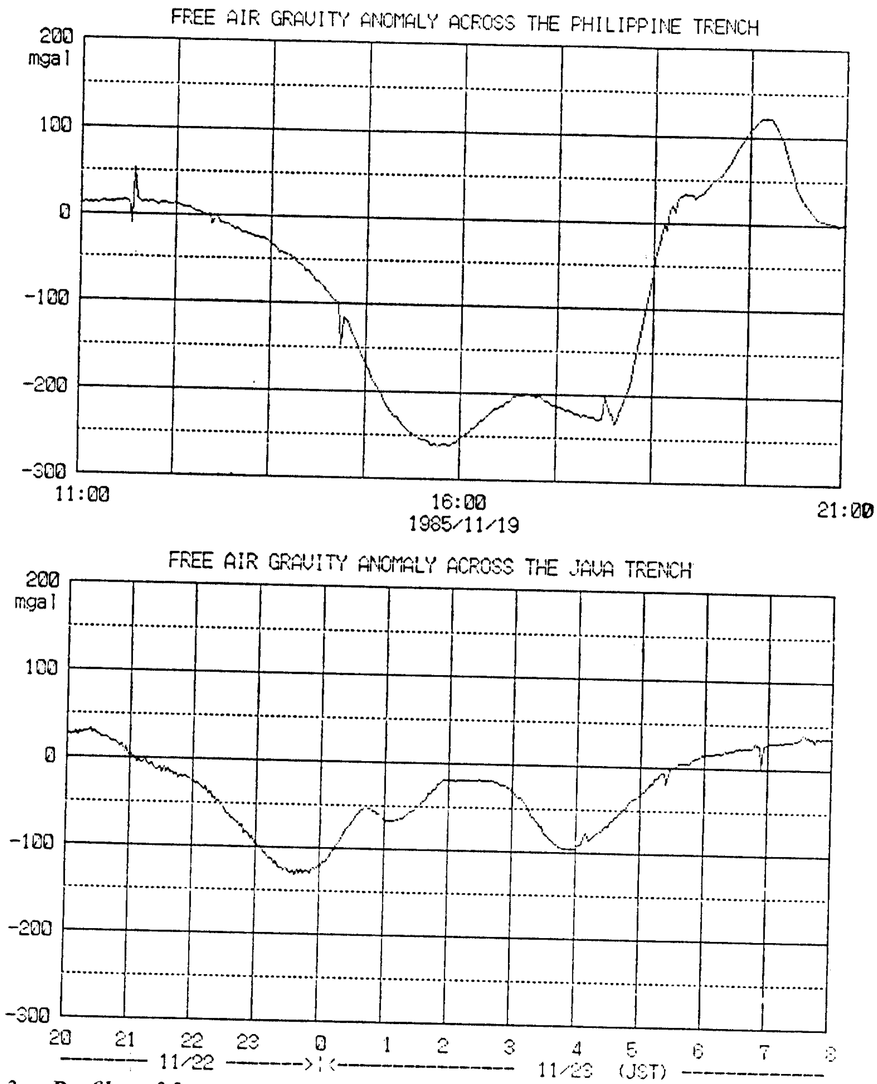

Fig. 3. Profiles of free air gravity anomaly across the Philippine trench (upper) and the Java trench (lower). The abscissa shows the time of measurement in hours. The ordinate shows gravity anomaly in mgal.

are the raw output from the gravimeter. The upper profile is the anomaly across the Philippine trench and the lower one across the Java trench. Spike-like changes of the anomalies observed in the profiles were caused by sudden changes of the ship's speed or direction in a short period that occurred during hydrographic observations or other operations. This kind of short change has an undesirable effect on gravity either because the vertical gyroscope of the gravimeter is affected by horizontal accelerations or because the ship's navigational data are erroneous. In any case such erroneous gravity can be corrected by additional data processings.

Reference

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