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UK plans for drifting buoy experiments during the NIMBUS-F (TWERLE) programme

by

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INTRODUCTION

In 1972 the Fisheries Laboratory, Lowestoft conducted three experiments which were designed to monitor deep-water movements in the Norwegian Sea using satellite tracking techniques. During these experiments, scaled-up parachute drogues deployed at 1000 m depth were tracked for extended periods using the French EOLE satellite (see Dickson and Baxter, 1972). Apart from the continuous monitoring of transponder battery voltage no sensors were employed during these initial experiments.

The launching of the NIMBUS-F satellite by NASA in October 1974 will provide a second opportunity for experiments of this type, and this paper describes the joint plans for participation by the four British agencies listed below:

Agency	Investigators	Principal experimental interest
MAFF, Fisheries Laboratory, Lowestoft	R. R. Dickson (P.I.) H. W. Hill D. J. Ellett	Ocean current investigation using parachute drogues
Institute of Oceanographic Sciences, Wormley	C. H. Clayson J. Crease	Statistical wave parameters
Meteorological Office, Bracknell	G. J. Day	Meteorological parameters (real time). Sea surface temperature
Ministry of Defence (Navy)	Lt Cdr MacAndrew	Thermistor chain observations

A total of eleven experiments are planned using the Random Access Measurement System (RAMS) of the satellite to locate and retrieve sensor data from the drifting buoys. This system differs from the EOLE system in that the drifting platforms carry a continuously-operating transmitter rather than a satellite-activated transponder. A one second signal at 401.2 MHz, modulated with an identifying signature and a subframe of four 8-bit channels of sensor information, is transmitted once per minute.

By subcommutating, up to four subframes can be sent on successive transmissions, giving a maximum possible cycle of 16 sensor channels repeating once every four minutes. In practice, the UK experiments described below are based on a maximum of two subframes (8 channels) of sensor data per buoy with the cycle repeating every two minutes. The platforms will be located with an accuracy of about 5 km by measuring doppler shifts of the carrier frequency as the satellite passes the platform on two successive orbits. The data are later transmitted to the Goddard Space Flight Center, Maryland for processing and onward transmission to the user.

METHOD

In each planned experiment the buoy and drogue assembly will be similar to that employed during the EOLE exercise, but with the addition of a variety of environmental sensors selected according to the purpose of the experiment. A diagram of the buoy and sensor placements is shown in Figure 1. In any given experiment the sensors are chosen from the following list of options:

1 Wire load: Strain gauge load-cell located in wire immediately below the buoy as a check on damage or loss of parachute. 8-bit word made up of 256 x 4 lb increments giving 1024 lb full scale. Resistance output.

2 Sea surface temperature: Thermistor located on lower buoy hull. 256 increments of 0.1°C giving 25.6°C full scale. Resistance output.

3-6 Thermistor chain of 4 thermistors: Total length of array 600 feet with thermistors grouped around likely thermocline depth. Again, each thermistor output graduated in 256 increments of 0.1°C giving 25.6°C full scale. Thermistor chain located in-wire (i.e. as part of drogue wire) with electrical connections to the buoy being tied-off in a bight to bypass the attachment point. Resistance output.

7 Air pressure: Aneroid with preferred accuracy of < 1 mb (though a lesser accuracy is expected above 1040 mb). Mounted on upper part of buoy hull. Fed to voltage interface with 0-5 V output. 256 increments of 0.5 mb gives 128 mb full scale. Sampled over 30 sec period and the result stored for the following $7\frac{1}{2}$ min.

8 Air temperature: Screened platinum resistance thermometer mounted on upper buoy hull. Fed to voltage interface with 0-5 V output. 256 increments of 0.1°C gives 25.6°C full scale.

9 Windspeed: Plastic cup anemometer mounted on top of buoy hull. Fed to voltage interface with 0-5 V output. 256 increments of 0.25 knots gives 64 knots full scale.

10-13 Statistical wave parameters: Four 8-bit words (sensors 10-13) will monitor the following parameters: (a) the distance of highest crest from mean water level (b) the distance of lowest trough from mean water level (c) the number of zero crossings in an upward direction (d) the number of crests, each calculated during a record-length of 10 minutes at two samples per second. The basic sensor is a pendulous accelerometer and double integrator having a 4th order high pass filter with a cut-off at 15 sec period mounted within the upper instrument compartment near the metacentre of the sparbuoy so as to reduce roll and pitch errors. During each sample the wave displacement is converted from analogue (± 10 V full scale) to 8-bit binary store "NOW" (256 increments of 5/16 ft equalling a full-scale wave of ± 40 ft, with zero at increment 128). Two 8-bit stores "MAX" and "MIN" are compared with "NOW" and updated if appropriate. A further 8-bit store "LAST" is then compared with "NOW", setting a slope latch to 0 or 1, depending upon whether "LAST" is greater than or less than "NOW". Two counters are incremented by 1 when (a) the slope latch changes from 1 to 0 (wave crest) or (b) when a sign latch changes from 1 to 0 (corresponding to a transition through the wave displacement zero in an upward direction).

Owing to power constraints the feasibility of using sensors 7-9 (meteorological parameters) and 10-13 (wave parameters) will depend upon intermittent sensor activity, using either the crystal oscillator in the TWERLE encoder or an autonomous timing system to regulate the record length and sampling rate. Each of these sensors will obtain time-averaged data over a period of 5 or 10 minutes, but this will be repeated only once every 3 hours with circuitry being switched off between records. Transmission of the data from store will occur normally however (one second per minute) to ensure successful acquisition of signal during each satellite pass.

As shown in Figure 1 the hollow instrument chamber in the upper part of the sparbuoy will be sealed by seating the vertical dipole antenna on to a 3.2 mm thick neoprene gasket. Within the instrument compartment the transmitter electronics will be housed in ABS plastic sleeves, equipped with dessicators, and sealed with end-caps and O-seals. The internal location and waterproofing of the transmitter electronics should reduce the influence of external temperature changes, and the outside of the ABS sleeves will be silvered to minimize internal temperature changes due to the start-up of sensor electronics on each cycle of activity. The transmitter electronics will be suspended on mild steel rods from the steel reinforcing ring which forms the entrance to the instrument chamber; thus some provision is made for the reduction of wave shock.

All sensor electronics within the buoy will be splash-proofed. The accelerometer will be mounted on a removable steel plate held in place by lugs fixed to the internal bulkhead and the battery packs are stowed below this bulkhead in three ABS plastic tubes so as to reduce the top-weight of the buoy. For 6 months' operation each buoy is equipped with three packs of 60 RM42R primary mercury cells (rated capacity 14 A.h.) divided so as to supply the transmitter and sensor electronics separately. For safety, diodes are placed between each bank of transmitter batteries. If excess battery life is available beyond 6 months it will be used to prolong transmitter life only.

The drogues to which the buoy is attached are nylon cargo parachutes with a flat diameter of 19.2 m (12.8 m shaped) and with a load capacity of 1 ton (1016 kg). During deployment the parachute and shrouds are bound into a parcel with ropes of twisted plasticized polyvinyl alcohol film (seawater soluble) to ensure that the parachute can be lowered to the required depth before the canopy opens. According to the purpose of each experiment, the drogues will be deployed at different depths between 50 and 1000 m. In four experiments using relatively shallow drogues a thermistor chain (steel cored; 3 ton breaking strain) will form the drogue "wire". In all other experiments, 4 mm diameter 6 x 7 construction wire (minimum breaking load 957 kg or 0.942 ton) will be used to link parachute and buoy. During the EOLE experiments in 1972 an abrupt change in the behaviour of the buoys after 2½ months was thought to indicate breakage of the drogue wire; in the current experiments a load cell located in wire will provide direct confirmation of wire break.

Table 1 provides more specific details as to the arrangement of sensors, drogue depths and data format in each of the 11 experiments planned. The primary site numbers (underlined) refer to sites chosen for the initial deployment of the six buoys. The five secondary sites are those chosen for the second deployment of the buoys.

Table 1 Arrangement of subframes and sensor channels in each of the 11 proposed experiments. Primary site numbers are underlined

Subcommutation mode	Mode bits	Sensor channels			
(a) Sites 1 and 3: 4 channels [i.e. 4 words (word parallel, bit parallel)], 50 m drogue					
1	00	Maximum wave height	Minimum wave trough	Number of wave crests	Number of zero crossings
(b) Sites 2 and 4: 8 channels [i.e. 8 words analog], 350 m drogue					
1	00	SST	Air pressure	Air temperature	Wind speed
2	10	Thermistor chain 1	Thermistor chain 2	Thermistor chain 3	Thermistor chain 4
(c) Sites 5 and 7: 8 channels [i.e. 4 words analog, 4 words (word parallel, bit parallel)], 350 m drogue					
1	00	Maximum wave height	Minimum wave trough	Number of wave crests	Number of zero crossings
2	10	Thermistor chain 1	Thermistor chain 2	Thermistor chain 3	Thermistor chain 4
(d) Sites 6 and 8: 8 channels [i.e. 4 words analog, 4 words (word parallel, bit parallel)], 50 m drogue					
1	00	SST	Air pressure	Air temperature	Wind speed
2	10	Maximum wave height	Minimum wave trough	Number of wave crests	Number of zero crossings
(e) Sites 9, 10 and 11: 8 channels [i.e. 8 words analog], 1000 m drogue					
1	00	Wire load	SST	Wind speed	Air pressure
2	10	Wire load	SST	Wind speed	Air pressure

LOCATION AND PURPOSE

Figure 2 illustrates the location of the 11 experiments, with primary sites shown as dots and secondary sites as open circles. The four Atlantic buoys occupying primary sites will be launched in November/December 1974 while the initial deployment of two buoys in the northern Norwegian Sea will take place in the spring of 1975. Recovery will be attempted between the end of their expected useful life as current followers (*c.* $2\frac{1}{2}$ months) and the end of their planned battery life (*c.* 6 months).

The Norwegian Sea bottom-drift experiments, sites 9 and 10 (primary) plus site 11 (secondary), are designed to continue the 1972 EOLE investigations of the deep water circulation in the Norwegian Sea. Drogues will be set at 1000 m depth close to the continental slope of the eastern Norwegian Sea. The specific purpose is to investigate the theoretical possibility that a south-going deep flow exists along the slope from Spitsbergen to southern Norway as part of a general anticyclonic gyre which is suspected (from the distribution of hydrographic properties) to occupy the deeper layers of the Norwegian Sea basin. It has been suggested that such a current would assist the migration of adult Arcto-Norwegian cod from the Barents Sea to their spawning ground off Lofotens (Dickson and Baxter 1972). The fact that EOLE did not locate surface targets north of 70°N with any great certainty limited the 1972 Lowestoft experiments to exercises in the southern half of the Norwegian Sea basin; using NIMBUS-F, it is now possible to investigate the deep flow between Spitsbergen and Lofotens where the principal interest lies.

The North Atlantic deep-drift experiments, sites 2 and 5 (primary) plus sites 4 and 7 (secondary) are designed to investigate the basic oceanography of the area where the North Atlantic Drift divides into three branches, one part turning south along the western coast of Britain and Ireland, a second part moving through the Faroe-Shetland Channel to form the Norwegian Atlantic Current, and a third part turning west to pass to the south of Faroes and so to Iceland. For this purpose the drogues will be set at 350 m.

Wave and surface-drift experiments will be carried out at sites 1 and 6 (primary) plus sites 3 and 8 (secondary). Although statistical wave parameters will also be monitored at sites 5 and 7, sites 1, 3, 6 and 8 are primarily designed to provide surface wave data and to investigate the existence of any useful correlation between the wave and surface-current conditions. Near-surface water movements will be monitored by means of drogues deployed at 50 m depth. Their deployment in locations close to deep drogue sites will also provide the surface current data required to correct the drift of the deep drogues.

The location of buoys 4 and 8 is not yet decided but will depend upon the behaviour of buoys 1, 2, 5 and 6 in the earlier experiments.

REFERENCE

DICKSON, R. R. and BAXTER, G. C., 1972. Monitoring deep water movements in the Norwegian Sea by satellite. ICES C.M. 1972/C:9, Hydrography Committee, 9 pp. plus 8 figs (mimeo).

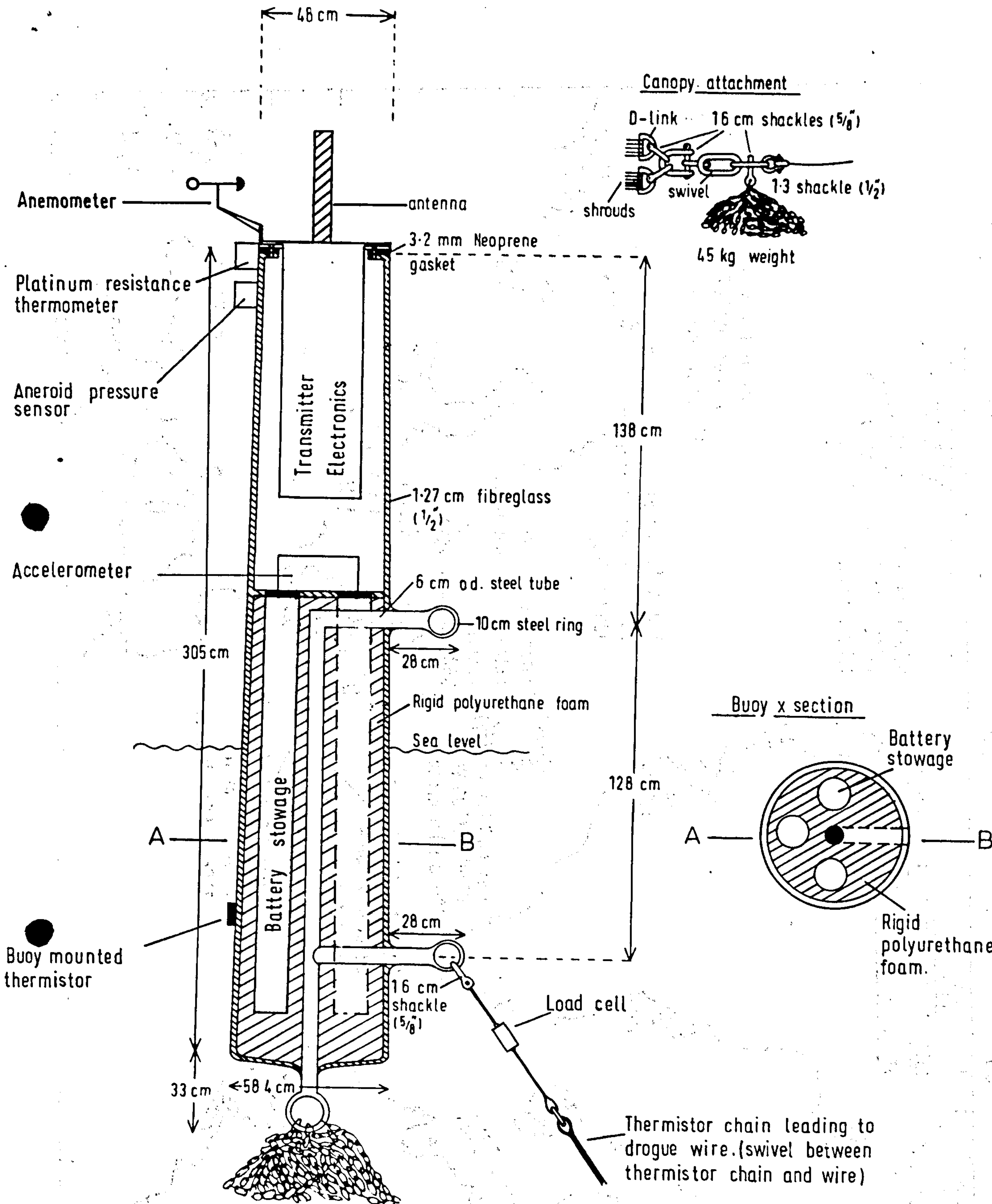

Fig 1 Diagram of sparbuoy and drogue wire attachment

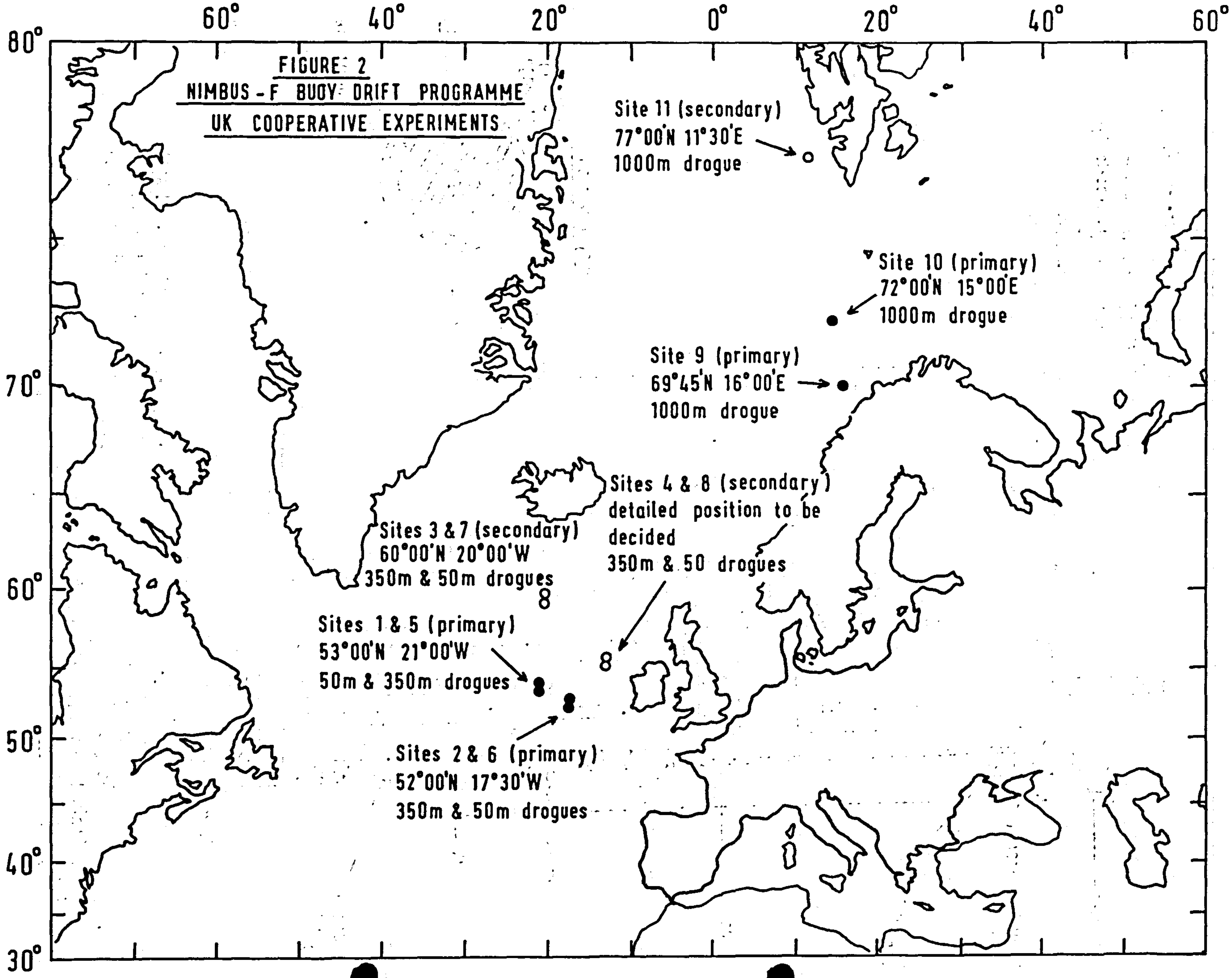
FIGURE 2
NIMBUS - F BUOY DRIFT PROGRAMME
UK COOPERATIVE EXPERIMENTS
Site 11 (secondary)
77°00'N 11°30'E
1000m drogue
Site 10 (primary)
72°00'N 15°00'E
1000m drogue
Site 9 (primary)
69°45'N 16°00'E
1000m drogue
Sites 4 & 8 (secondary)
detailed position to be
decided
350m & 50 drogues
Sites 3 & 7 (secondary)
60°00'N 20°00'W
350m & 50m drogues
Sites 1 & 5 (primary)
53°00'N 21°00'W
50m & 350m drogues
Sites 2 & 6 (primary)
52°00'N 17°30'W
350m & 50m drogues
60°
40°
20°
0°
20°
40°
60°
80°
70°
60°
50°
40°
30°