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JASIN 1978

Field activities on the research vessels “Meteor”, “Planet”, “Poseidon” and the research aircraft D-CMET

by

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With 10 figures and 7 tables

JASIN 1978. Beobachtungen auf den Forschungsschiffen „Meteor“, „Planet“, „Poseidon“ sowie mit dem Forschungsflugzeug D-CMET

Zusammenfassung

Es werden Übersichten zu den Forschungsprogrammen der deutschen Arbeitsgruppen bei JASIN 1978 gegeben, die Untersuchungen zur planetarischen Grenzschicht, zum Strahlungshaushalt, zur ozeanischen Deckschicht und Sprungschicht und zum Spurenstoffaustausch umfassen. Die Namen der wissenschaftlichen und technischen Mitarbeiter sind in Tabellen zusammengefaßt. Es folgen kurze Darstellungen zu den Beobachtungen auf den drei Schiffen und an Bord des Flugzeugs mit Karten und Stationslisten.

Summary

The research programmes of the German groups in JASIN 1978 are summarized, comprising projects that concern the planetary boundary layer, the radiation budget, the oceanic mixed layer and thermocline and the trace element exchange. Lists of the participating scientists and technicians are included. Brief descriptions of the field activities on board the three ships and the aircraft are given, including maps and stations lists.

1. Introduction

JASIN 1978, the Joint Air-Sea Interaction Project, was part of a series of experiments started by the Royal Society as a U.K. programme in 1970. The 1978 experiment was an international oceanographic and meteorological investigation, and part of GARP (Global Atmospheric Research Programme). The main objectives of the 1978 measurements in the eastern North Atlantic west of Scotland were:

- i) to observe and distinguish between the physical processes causing mixing in the atmospheric and oceanic boundary layers and relate them to mean properties of the layers,
- ii) to examine and quantify aspects of the momentum and heat budgets in the atmospheric and oceanic boundary layers and the fluxes across and between them.

To some extent the international GATE C-Scale Experiment in the tropical Atlantic had been forerunner of JASIN 1978. The principal difference to GATE was the choice of a region where the structures of both the atmospheric and oceanic boundary layers are different and where the inertial period is shorter. Furthermore it was hoped that frequently passing atmos-

pheric fronts would produce effective forcing of the ocean.

A total number of 14 vessels and 4 research aircrafts with participants from 7 nations joined for the field phase from July to September 1978. The experiment had been planned by informal working groups, with the international coordination being conducted by the JASIN Project Office at the Institute of Oceanographic Sciences, Wormley, England. Five documents resulted from these planning activities (Royal Society 1975, 1977, 1978, 1979; Deutsche Forschungsgemeinschaft 1978). The following report summarizes the scientific programmes and the field activities of the groups on board the German research vessels and the aircraft.

2. Scientific programmes

2.1 Planetary boundary layer

The investigations were aimed at determining the structure of the marine atmospheric boundary layer and the dominating perturbations of smaller scales in relation to the mean field, and at specifying criteria which can be applied to model simulations of boundary layer processes. Special interest centered on the relation between stochastically distributed perturbations and organized flow patterns like helical rolls or three-dimensional symmetrical cells. The horizontal and vertical structure and the life cycle of organized flow as well as its dependence upon the synoptic conditions was a further subject of investigation. It was finally intended to determine the heat, moisture and momentum budget of the atmospheric boundary layer.

The main methods to be used included: Tethered balloon measurements, aerological soundings with radiosondes from board R.V. "Meteor" and two other ships, profile measurements on anchored spar buoys and 3-dimensional turbulent fluctuation measurements on the airplane D-CMET.

2.2 Radiation budget

In this programme it was intended to determine the influence of cloud structures on the radiative fluxes and to provide an improved understanding of the processes which have to be parameterized in models dealing with average properties of the atmosphere. The main observations consisted of radiative flux measurements with pyranometers, pyrgeometers and radiation thermometers as well as liquid water sampling on board the aircraft D-CMET and radiation measurements and cloud photographs on board R.V. "Meteor".

The average atmospheric conditions inferred from observations and radiative flux measurements can be used in computational algorithms to estimate the tropospheric radiation budget.

2.3 Oceanic mixed layer and thermocline

Assuming that information on the turbulent structure of the "mixed layer" of the ocean can be gained by observing the temperature structure alone, it was intended to monitor this layer by a special moored thermistor array. Furthermore, it was planned to test some basic assumptions and predictions of one-dimensional mixed layer models such as slab-like motion, Richardson-Number, change of some components of the energy and momentum budget by measurements with CTDs, current profilers, a drifting thermistor chain and moored current meters. Surface wave measurements with waverider buoys should supply information on the momentum and energy flux from the atmosphere to the mixed layer and thermocline through the surface wave field.

The thermocline studies were aimed at studying linear processes related to internal waves and non-linear processes related to eddies, fronts, internal waves and billows. It was planned to determine the thermocline displacements due to internal waves, to investigate the vertical distribution of kinetic and potential energy of internal waves in the JASIN area and to attempt finding causes for these energy changes in the atmosphere and the mixed layer of the ocean. The main tools were CTDs and current meter moorings, including an anchored spar buoy. The study of non-linear transport processes tried to relate observed distributions of natural and artificial tracers to distributions predicted by models of individual transport processes in order to identify those transport processes that are affected by atmospheric forcing. Here the key instrument was an undulating CTD towed behind the ship.

2.4 Trace element exchange

Gas transfer across the air-sea interface is related to mixing and exchange processes in the upper oceanic mixed layer and the lower part of the atmospheric planetary boundary layer. The trace element exchange investigations were partly aimed at supporting the core programme of small-scale air-sea interaction studies, but also were intended to contribute to the understanding of the more general role of the ocean as a source and sink for atmospheric trace compounds.

Gas transfer rates across the air-sea interface were to be measured by determining the concentration deficit of radon-222 relative to radioactive equilibrium with its parent substance radium-226. Two systems were available, a towed device on "Poseidon" and a lowered apparatus on "Meteor".

As a contribution to the study of the atmospheric H₂-cycle, measurements of deuterium/hydrogen ratios in the marine atmospheric boundary layer and of hydrogen dissolved in the oceanic surface layer were being planned, as well as CO₂-gradient determinations in the atmosphere. Particle measurements in the

marine atmosphere concentrated on the distribution of the mass on different particle radii of ammonium, sulphate and nitrate, the total organic particle mass, the various compounds and the total organic carbon. Measurements of Aitken particles were also conducted with a new differentiating electrostatic separator.

3. Participants

Participating institutions and personnel including their scientific affiliations are summarized in Tables 1, 2, and 3.

Table 1. Participating institutions.

Tabelle 1. Beteiligte Institute.

BMVg	Bundesministerium der Verteidigung, Haardthöhe, 5300 Bonn
DHI	Deutsches Hydrographisches Institut, Bernhard-Nocht-Straße 78, 2000 Hamburg
DFVLR	Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, Post Wessling/OBB, 8031 Oberpfaffenhofen
IAP	Institut für Angewandte Physik an der Universität Kiel, Olshausenstr. 40–60, 2300 Kiel 1
IfM	Institut für Meereskunde an der Universität Kiel, Düsternbrooker Weg 20, 2300 Kiel 1
IGMK	Institut für Geophysik und Meteorologie der Universität zu Köln, Kerpener Straße 13, 5000 Köln 41
IUP	Institut für Umweltphysik der Universität Heidelberg, Im Neuenheimer Feld 366, 6900 Heidelberg
KFA	Kernforschungsanlage Jülich GmbH, Postfach 1913, 5170 Jülich
MIK	Meteorologisches Institut der Universität Karlsruhe, Kaiserstr. 12, 7500 Karlsruhe
MPIfC	Max-Planck-Institut für Chemie, Saarstraße 23, 6500 Mainz
MPIfM	Max-Planck-Institut für Meteorologie, Bundesstraße 55, 2000 Hamburg
SWA	Deutscher Wetterdienst, Seewetteramt Hamburg, Bernhard-Nocht-Straße 76, 2000 Hamburg
UBC	University of British Columbia, Institute of Oceanography, 2075 Westbrook Place, Vancouver B. C., Canada
UG	Universität Göteborg, Oceanografiska Institutionen, Box 4038, 40040 Gothenburg, Sweden

Table 2. Participating scientists and technicians.

Tabelle 2. Beteiligte Wissenschaftler und Techniker.

Name	Working Group	Platform	Institution
Augstein, E., Dr.	1	Meteor	MPIfM
Behrend, W.	3	Meteor	IfM
Bock, R.	3	Poseidon	IfM
Bösenberg, J., Dr.	1	Meteor	MPIfM
Brückner, C., Ms.	3	Meteor	IfM
Brümmer, B., Dr.	1	Meteor	MPIfM
Carlsen, D.	3	Planet	IfM
Carlson, H.	3	Meteor	DHI
Clauss, E.	1	Meteor	IfM
Dunckel, M.	1	Meteor	MPIfM
Fechner, Dr., H.	1	Meteor	IfM
Fiedler, F., Prof. Dr.	1	D-CMET	MIK
Fimpel, H.-P.	1/2	D-CMET	DFVLR

Name	Working Group	Platform	Institution
Fischer, K.-H.	4	Meteor	IUP
Franken, H.	4	Planet	KFA
Froideveaux, B.	1/2	D-CMET	DFVLR
Gube, M., Ms.	2	Meteor	IGMK
Günther, H.	1	Meteor	MPIfM
Haaf, W.	4	Meteor	MPIfC
Hauf, T.	1	D-CMET	MIK
Hansen, H.-P., Dr.	3	Poseidon	IfM
Henschel, K.	1	Meteor	SWA
Hofmann, H.	1	Meteor	SWA
Hubrich, L.	3	Planet	BMVg
Johannes, V.	4	Meteor	MPIfC
Joyce, T., Dr.	3	Planet	IfM
Käse, R., Dr.	3	Meteor	IfM
Knoll, M., Ms.	3	Planet	IfM
Kramm, G.	1	Meteor	IGMK
Kromer, B.	4	Meteor,	IUP
		Poseidon	
Kuhn, H., Dr.	3	Planet	IfM
Kulessa, G.	4	Meteor	KFA
Kullenberg, G., Prof. Dr.	3	Poseidon	UG
Langhof, H.-J.	3	Meteor	IfM
Large, W.	1	Meteor	UBC
Leach, H., Dr.	3	Poseidon	IfM
Lentz, U.	3	Planet	IfM
MacVean, M., Dr.	3	Poseidon	IfM
Mahrt, K.-H., Dr.	3	Planet	IPA
Meinke, C.	1	Meteor	IfM
Mews, K.	1	Meteor	SWA
Meyer, P.	3	Planet	IfM
Minnett, P., Dr.	3	Poseidon	IfM
Mittelstädt, R.-U.	3	Planet	IAP
Müller, K.-P.	4	Planet	KFA
Müller, T.	3	Meteor	IfM
Müller, W.	4	Meteor	IUP
Münster, H.	1	Meteor	IPIfM
Neumann, G., Ms.	1	D-CMET	MIK
Olbrück, G., Dr.	1	Meteor	SWA
Onken, R.	3	Meteor	IfM
Peters, H.	3	Meteor	IfM
Petersen, H.	3	Poseidon	IfM
Petersohn, U., Dr.	3	Planet	IAP
Petow, M.	3	Meteor	IfM
Raschke, E., Prof. Dr.	2	D-CMET	IGMK
Regensburger, P.	1	D-CMET	DFVLR
Roether, W., Prof. Dr.	4	Poseidon	IUP
Rubach, H.-J.	3	Meteor	DHI
Schebeske, G.	1	Meteor	MPIfC
Schloß, A.	1	Meteor	MPIfM
Schmetz, J.	2	D-CMET	IGMK
Schriever, D.	1	Meteor	MPIfM
Schütz, L., Dr.	4	Meteor	MPIfM
Siedler, G., Prof. Dr.	3	Planet	IfM
Speth, P., Prof. Dr.	1	Meteor	IGMK/IfM
Timm, P.	1	Meteor	IfM
Uhlig, K., Dr.	1	Meteor	IfM
Websky, T.	3	Planet	IfM
Wendel, M.	1	Meteor	MPIfM
Willenbrink, E., Ms.	3	Planet	IfM
Woods, J., Prof. Dr.	3	Poseidon	IfM
Zapf, T.	4	Meteor	IUP
Zenk, W., Dr.	3	Machrihan-	ish Air Base

Table 3. Working groups.

Tabelle 3. Arbeitsgruppen.

1	Planetary boundary layer	Planetarische Grenzschicht
2	Radiation budget	Strahlungshaushalt
3	Oceanic mixed layer and thermocline	Ozeanische Deckschicht und Sprungschicht
4	Trace element exchange	Spurenstoffaustausch

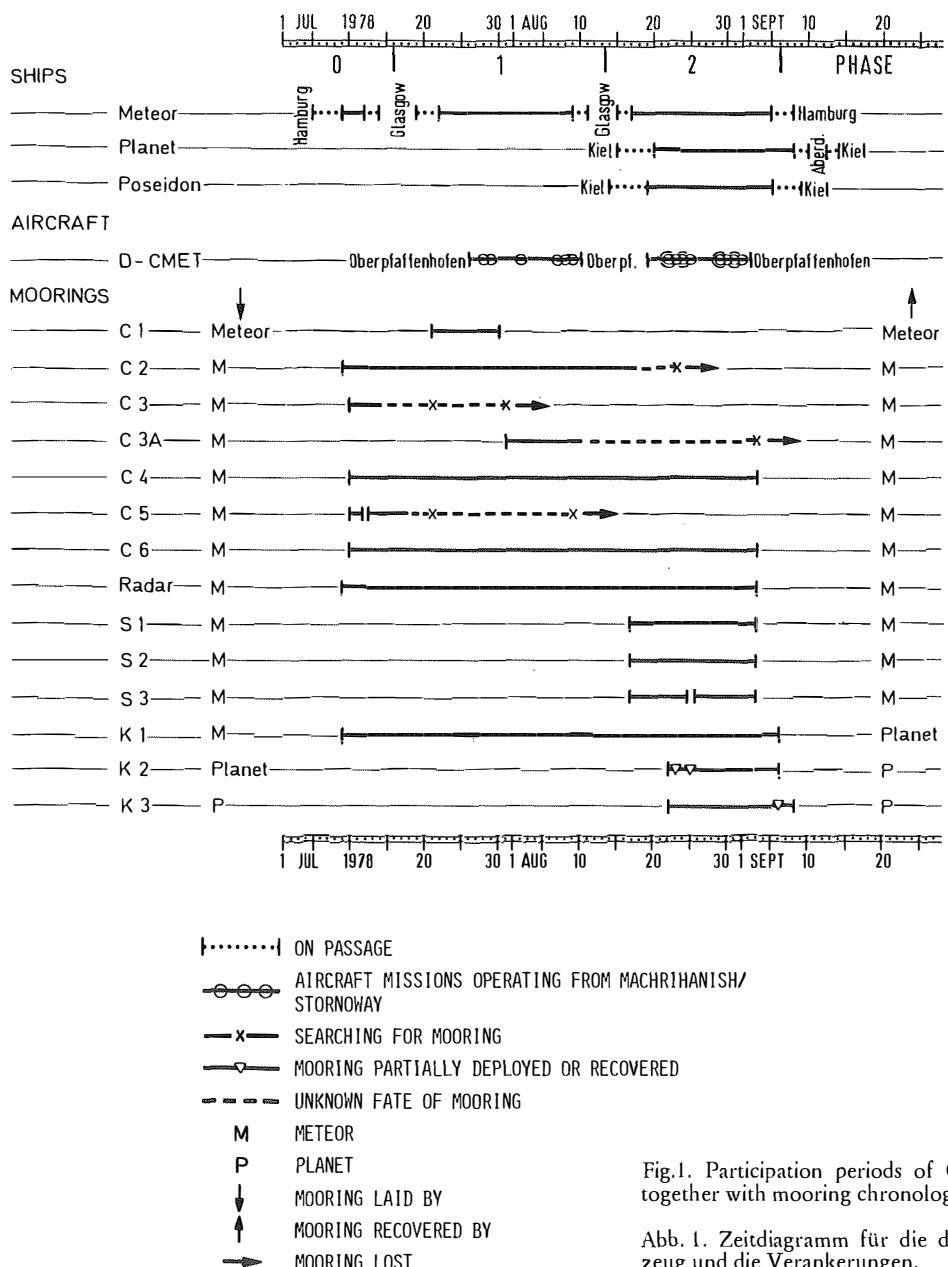


Fig. 1. Participation periods of German vessels and aircraft together with mooring chronology.

Abb. 1. Zeitdiagramm für die deutschen Schiffe, das Flugzeug und die Verankerungen.

4. Field phase

4.1 Field phase summary

The field experiment had been divided into three parts called "Phase 0, 1 and 2" (see Fig. 1). The participation periods of the German vessels and the aircraft are shown in Fig. 1. Fig. 2 schematically displays the track lines of the German ships to and from the central JASIN area northeast of Rockall. The nested working areas in the JASIN region of observations and the airport of Machrihanish are shown in Fig. 3.

Three stationary vessels formed a triangle with 180 km sidelength during phases 1 and 2 as shown in

Fig. 4. Approximate positions of other quasi-stationary and mobile vessels are indicated in the same figures. "Meteor" belonged to the quasi-stationary ships during phases 1 and 2 while "Planet" and "Poseidon" were in the area in Phase 2 as mobile ships.

In addition to the shipboard observations a large amount of data was obtained through moored instrumented buoys and sub-surface recording current and temperature meters (see Fig. 1). Particularly, a "Fixed Intensive Array" (FIA) of moorings for the study of small horizontal scales was placed near the southern corner of the large triangle. This array is shown in full size in Fig. 5, including the three German oceano-

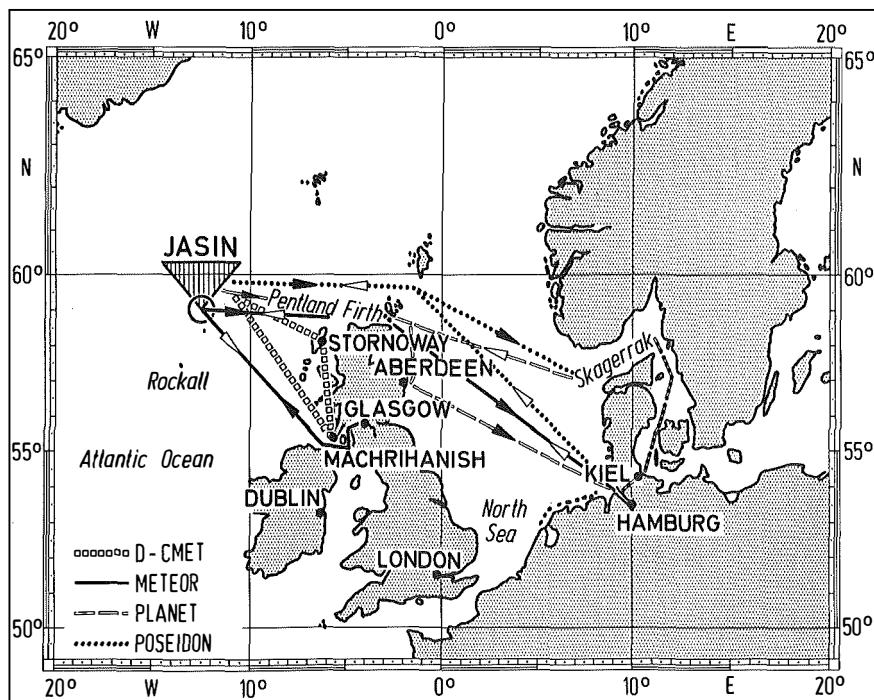


Fig. 2. Tracklines of German JASIN-ships. The research airplane D-CMET was based in Machrihanish.

graphic moorings K1, K2 and K3 (Fig. 6) as well as the meteorological buoys S1, S2 and S3 and the anchored waverider buoy C1.

The participating airplanes used the Royal Air Force Base at Machrihanish in western Scotland as their airport. The German aircraft's participation periods are summarized in Fig. 1. More details of the activities on board the ships and the aircraft are described in the following chapters.

4.2 Activities on R.V. "Meteor"

"Meteor" left Hamburg for the JASIN area on 5 July 1978. After passage through the North Sea where hourly XBT probes were dropped, she reached central position $59^{\circ} 00' N, 12^{\circ} 30' W$ on 9 July 1978. Most of the activities on board the "Meteor" during the preparation phase 0 were performed at this location in the FIA (see Fig. 5). First, mooring K1, containing eight recording current meters and an ambient noise listener of the University of Rhode Island, was launched at $58^{\circ} 59.7' N, 12^{\circ} 30.5' W$ within the FIA at a depth of 1577 m. Mooring work continued during the night and the following day, 10 July, with launching of five waverider buoys on a circle of 37 km radius centred at K1 (partly shown on Fig. 5, top half). During all three phases of the experiment data from these radio buoys were received on board the "Meteor" and stored on magnetic tape in four-hour intervals.

The oceanographic programme of phase 0 contained 6 deep CTD-stations and Aanderaa profiler test runs down to 130 m depth.

Abb. 2. Routen der deutschen JASIN-Schiffe. Das Forschungsflugzeug D-CMET war in Machrihanish stationiert.

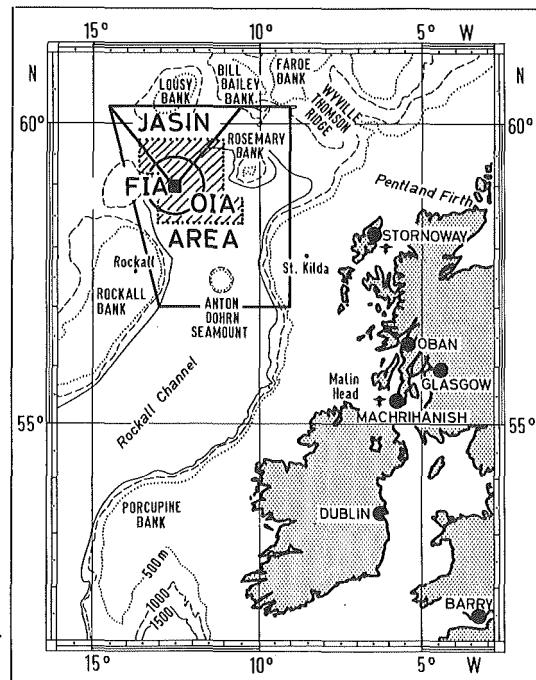


Fig. 3. Nested JASIN areas and location of Machrihanish air field. Abbreviations: FIA = Fixed Intensive Array, OIA = Oceanographic Intensive Array. The Large Scale Array including the meteorological triangle is also plotted.

Abb. 3. Die ineinander geschachtelten JASIN-Gebiete und die Lage des Flughafens Machrihanish. Abkürzungen: FIA = Kleinräumiges Meßgebiet mit zahlreichen Verankerungen, OIA = Größeres Meßgebiet mit zahlreichen ozeanographischen Schiffsmessungen. Das großräumige Meßgebiet einschließlich des meteorologischen Dreiecks ist zusätzlich eingezeichnet.

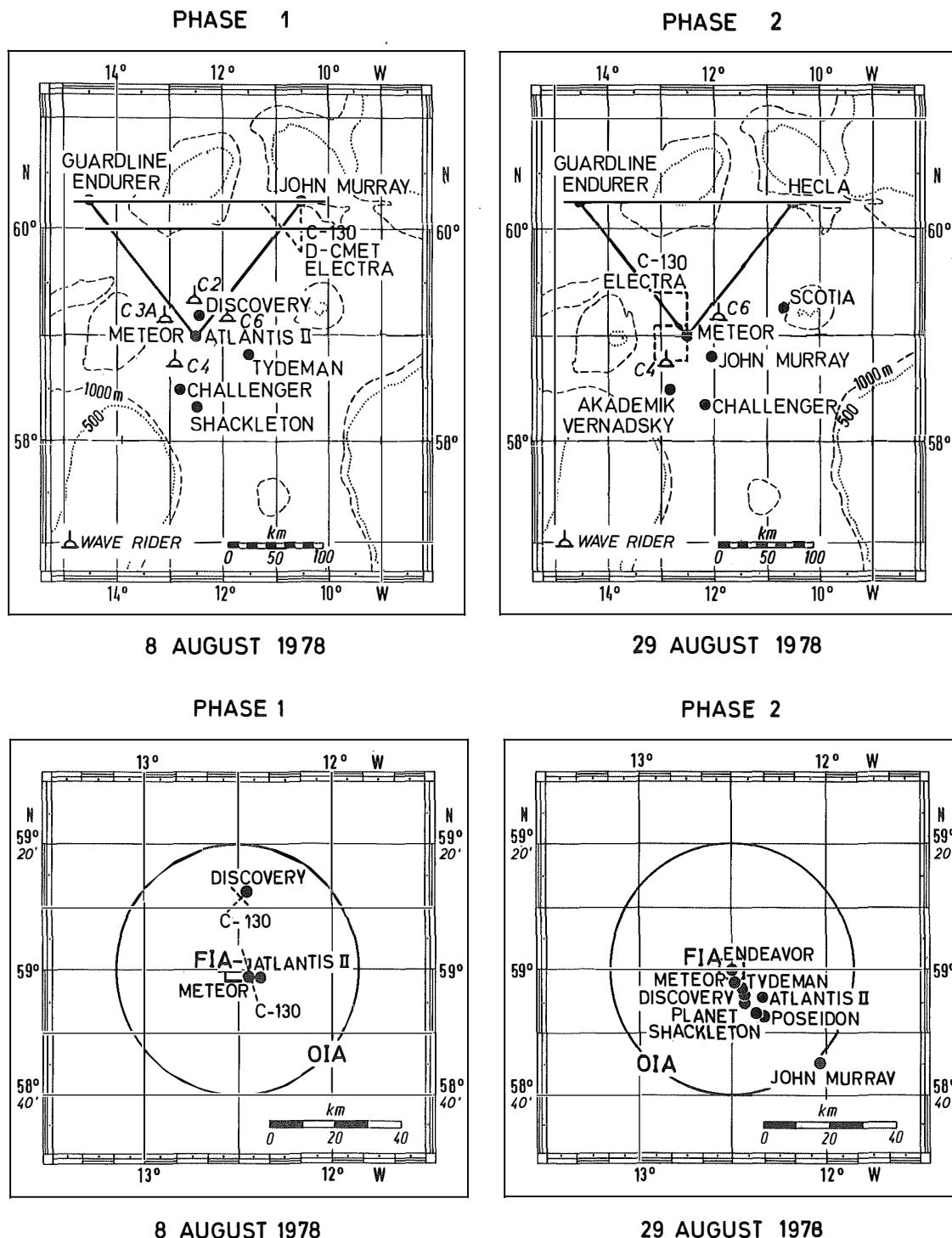


Fig. 4. Two examples for the distribution of ships and wave-rider buoys together with observation flight tracks near the meteorological triangle (top) and the OIA including the FIA (bottom).

Abb. 4. Zwei Beispiele für die Verteilung von Schiffen und Waveriderbojen mit den Meßkursen der Flugzeuge im Bereich des meteorologischen Dreiecks (oben) und des OIA bzw. FIA (unten).

The meteorological and gas exchange programmes included 6 aerological ascents, continuous radiation and quasi-continuous cloud observations, 48 hours of turbulence measurements in the planetary boundary layer and two 90 m deep radon profiles. In all cases

instruments and equipment were tested to be prepared for the phase 1. The air chemistry groups started the analysis of marine aerosols. Samples for the determination of the following trace elements were taken: H₂, CO, CO₂, CH₄, N₂O, CF₂Cl₂, and CFCI₃.

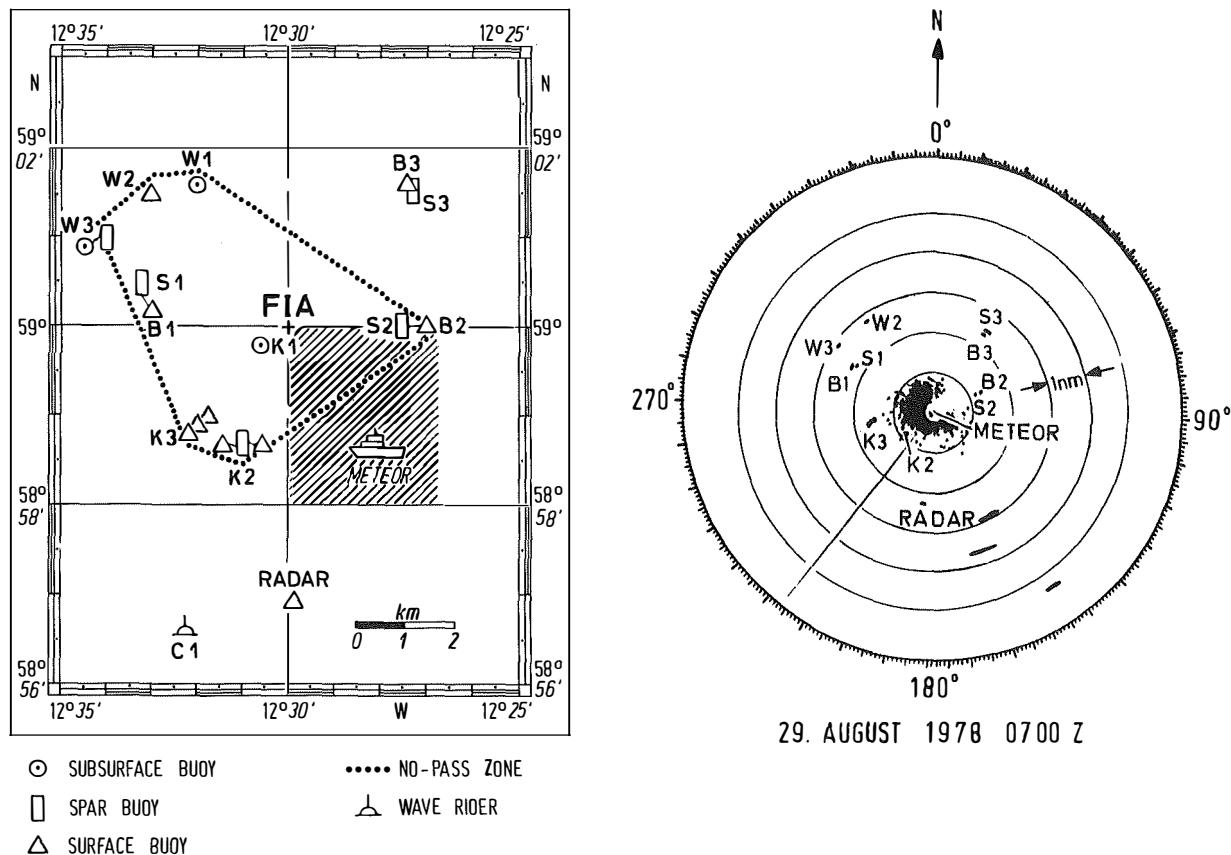


Fig. 5. Distribution of various JASIN moorings within the FIA, from the Woods Hole Oceanographic Institution (W1–W3), Oregon State University (B1–B3), Deutsches Hydrographisches Institut (C1), Institut für Meereskunde Kiel (K1–K3), and Cologne University (S1–S3). R.V. "Meteor" was predominantly positioned in the hatched area SE of K1 (left). "Radar" indicates the position of a navigational buoy with radar reflector. The radar photograph, taken by R.V. "Meteor", shows an instantaneous situation. In the SE corner other JASIN ships are displayed (right).

All working groups were thus prepared for the main observation period when "Meteor" left the area on the evening of 12 July 1978 for her first port call to Glasgow (14–19 July).

The second leg of the cruise (phase 1) was devoted to intensive station work within the FIA. The turbulence probe device, deployed for the first time with a tethered balloon, operated satisfactorily. During 135 hours up to four probes between 200 and 1000 m measured turbulent fluxes of momentum, heat and water vapour. Additional sensors were installed on the ship's mast and on a bow boom. Radiosonde ascents including LORAN-C-wind observations were carried out during the whole period. A summary of all radiosonde launches on board the "Meteor" is given in Fig. 7. The JASIN operational plan required radiosonde launches at three-hourly intervals. Further flights were performed during Intensive Radiosonde Days between 6 and 21 GMT and during the meteoro-

logical intercomparison days 22, 28 July and 9 August. Numerous comparisons between observations on "Meteor" and the research aircrafts were made as part of the turbulent structure and radiation programmes between 28 July and 1 September when the aircrafts flew close to each other over the ship. In addition to continuously measuring radiation sky-photographs were taken every 10 minutes between 7 and 20 GMT.

The oceanographic programme consisted of observations of the hydrographic structure of the upper thermocline as a background data set for the analysis of current and temperature time series from moored instruments. Yo-yo type profiles by the multisonde (CTD) were obtained twice a day in selected depth ranges at 2–4 min intervals. Supplementary deep casts were taken every three hours. A summarizing list of the oceanographic activities besides the mooring work is given in Table 4. Because of the high variability of the upper ocean structure detected by the multisonde,

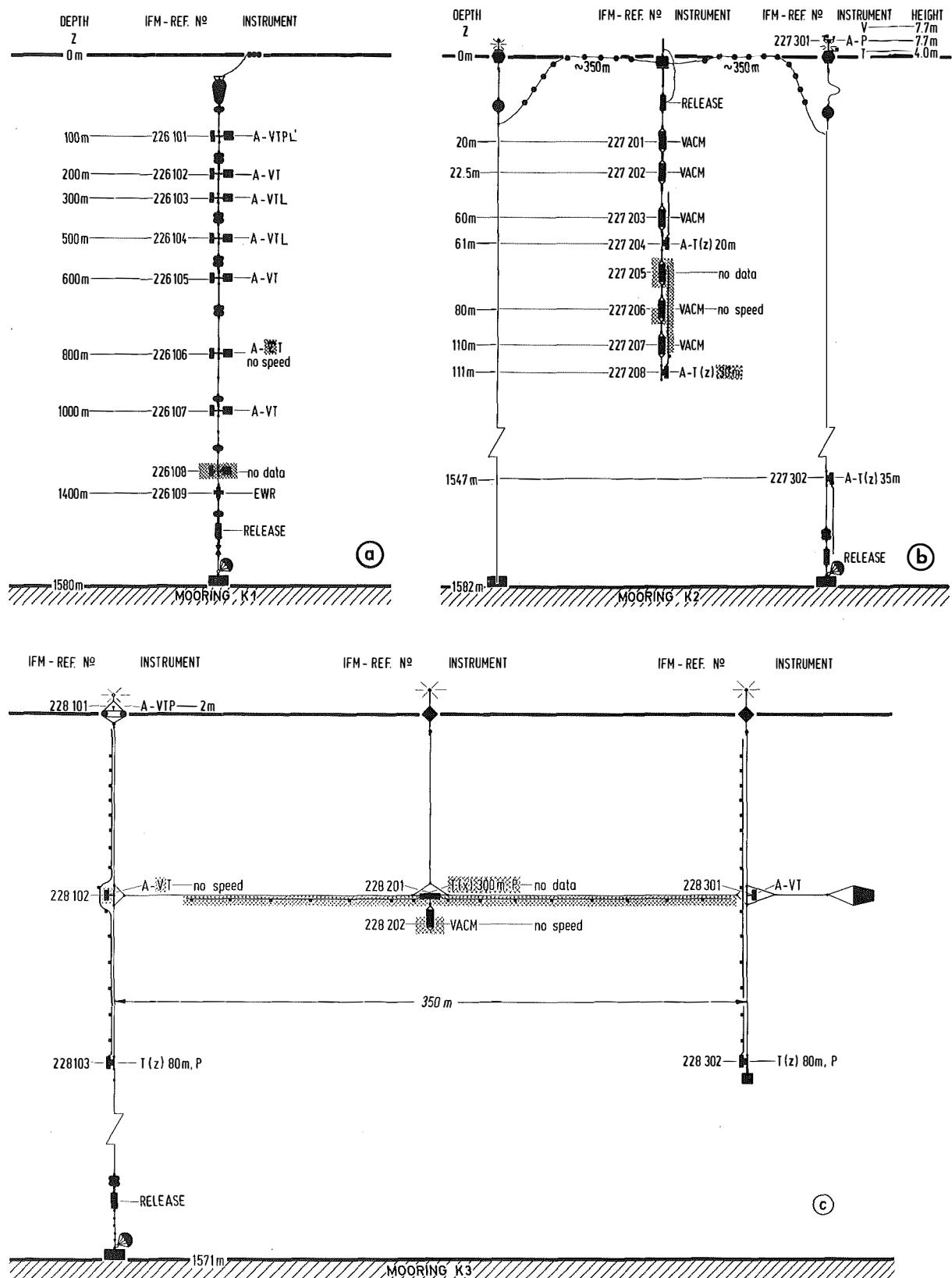


Fig. 6. Schematic diagrammes of JASIN-moorings K1 (a), K2 (b), and K3 (c).

Abb. 6. Schematische Darstellungen der JASIN-Verankerungen K1 (a), K2 (b) und K3 (c).

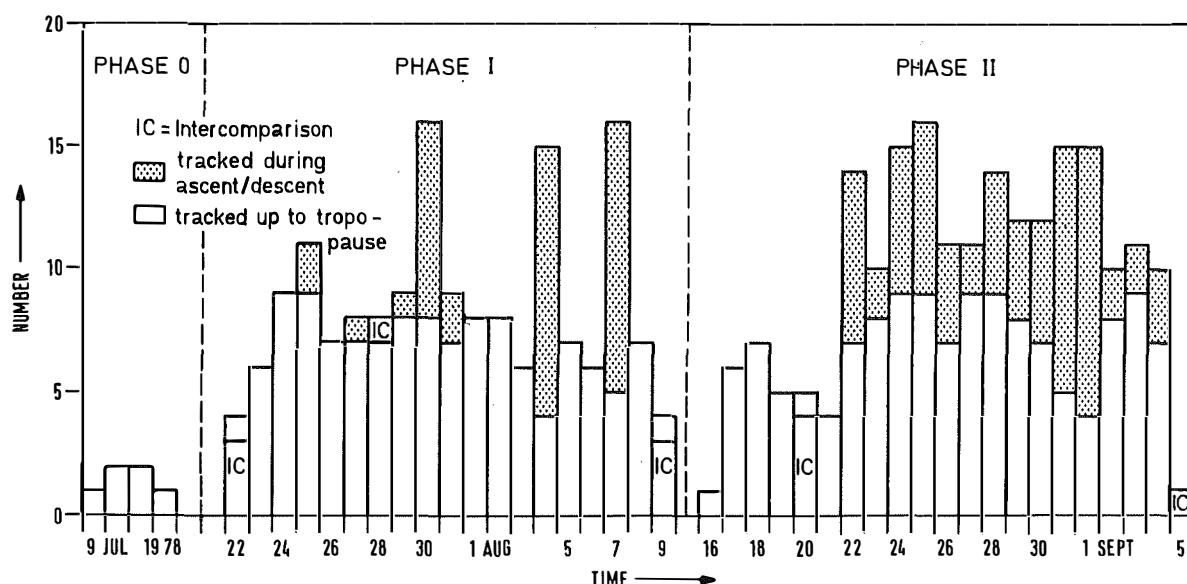


Fig. 7. Radiosonde launches from board R.V. "Meteor".

Abb. 7. Radiosondenaufstiege von Bord F. S. "Meteor".

Table 4. Summary of oceanographic activities on R.V. "Meteor"

Tabelle 4. Zusammenfassung der ozeanographischen Arbeiten auf F. S. „Meteor“.

JASIN Phase	Station No.	Date 1978 Day/Month	CTD Multisonde Single Profiles	Yo-yo	Bathysonde Single Profiles	Yo-yo	Aanderaa Profiles	Remarks	Standard sequense
0	0	11—12/7	6				5	all measurements within the FIA, nominal area under investigation see Fig. 5	Test
1	1	23/7—7/8	161	27	12	1			3-hourly and Yo-yo for 3 hours at 0900 and 1500
2	2	17/8—30/8	82	156					30 min yo-yo each hour
3		2/9	1	1				Position $\varphi = 59^\circ 25' N$ $\lambda = 12^\circ 30' W$ near buoy H2	

the radon measurements had to be repeated more often than planned. 57 three-hourly profile series in the depth range 5–60 m could be obtained. Some problems were caused by the waverider buoys which were partly lost or interfered with other radio transmitting equipment. Details about the operative phases of various waveriders can be seen in the mooring chronology (buoy code letter C in Fig. 1).

When phase 1 ended on 11 August, port time in Glasgow was used for the exchange of observational material with other JASIN ships for the planning of phase 2 and for a reception on board the "Meteor". The air chemistry group left the ship and was replaced by the meteorological mesoscale turbulence group.

After reaching the FIA this group launched 3 spar buoys and tethered them to surface buoys which had

already been moored by "Atlantis II" from Woods Hole. Because of limited range of these buoys' transmitters "Meteor" stayed close to them during most of phase 2 (Fig. 5). All groups were able to perform their experiments essentially as planned. During 120 hours measurements of atmospheric turbulent fluxes were carried out with up to 4 probes. 156 multisonde yo-yo operations with over 3300 dips were performed. Only during the second multiship experiment (Fig. 10) on 2 and 3 September (cf. section 4.3) "Meteor" left the FIA and occupied a position near buoy H2 ($59^\circ 25' N$, $12^\circ 30.0' W$). After this rendezvous the 3 meteorological buoys and the remaining 2 waverider buoys were recovered. Finally intercomparison observations were performed on 5 September near buoy B3.

On the way back to Hamburg, XBT probes were

dropped hourly when crossing the North Sea. "Meteor" finished her cruise no. 49 on 8 September 1978.

4.3 Activities on R.V. "Planet"

Research activities on board the "Planet" were part of the studies of the oceanic mixed layer and thermocline and the trace element exchange. Thus, except for the air chemistry investigations, all the activities on board were aimed at determining the temperature, salinity and current structure of the ocean on scales from a few meters to approximately 30 km in the horizontal and to approximately 500 m in the vertical and to observe their variations in relation to atmospheric events.

The principal instrumentation used was: CTDs (bathysonde, multisonde), wire-guided or free-fall current profilers (Aanderaa, Mahrt, Kuhn) and the moorings (Fig. 6) K1 (sub-surface mooring with 8 Aanderaa current meters spanning the whole water column), K2 (two-leg surface mooring with tether lines holding a spar buoy with 6 vector averaging current meters and 2 thermistor chains down to 110 m plus 1 thermistor chain near the bottom at one leg) and K3 (surface mooring with 3 surface buoys carrying an H-shaped thermistor chain array including 1 vector averaging current meter, spanning the mixed layer down to 80 m). Furthermore, a drifting ocean platform (DOPY) was used. For air chemistry investigations a CO₂-detection unit and impactors for marine aerosols and for bacteria and ice condensation nuclei, teflon-flask gas absorption units and rain and sea water samplers were installed.

"Planet" left Kiel on 15 August 1978. On passage to the experiment site, some instrument testing was performed in the Skagerrak, and XBTs were dropped hourly when crossing the North Sea. Upon arrival in the JASIN area on 20 August, repeated CTD and current profiling was performed near the positions of the K-moorings. After improvement of the weather conditions, launching of the moorings started, and the deployment of K3 and K2 was finished on 25 August. K1 had been set earlier by "Meteor". During the nights between the mooring activities and during several days following this period, CTD and current profiling was done near the K-moorings in order to obtain information on temporal variations of the mixed layer and thermocline structure and to provide reference data for the moored temperature sensors. Spatial variations of the thermohaline structure were investigated on a "small box" pattern (6 × 4.5 nautical miles, station distance 1.5 nautical miles), repeating this pattern twice within one semi-diurnal tidal cycle. In order to obtain information on smaller horizontal scales and shorter time scales, yo-yo type CTD profiling over several hours with a repetition rate of 5 minutes was performed 0.4 nautical miles off "Meteor" and later 1

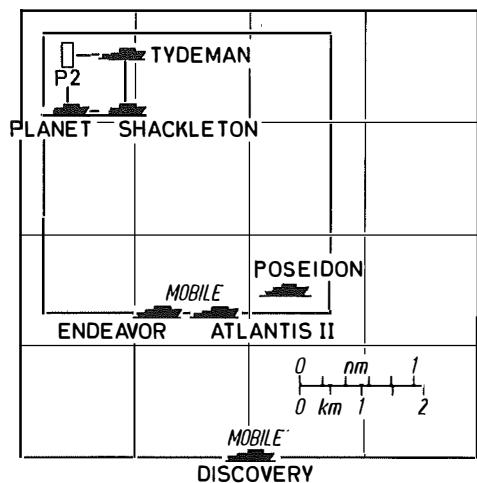


Fig. 8. Distribution of drifting and roving ships during the first Multiship Experiment (29/30 August 1978). The centre of the shown area was about 14 km south east of the FIA.

Abb. 8. Verteilung der driftenden und fahrenden Schiffe während des ersten Mehrschiff-Experiments (29.—30. August 1978). Die Mitte der dargestellten Fläche lag etwa 14 km südöstlich vom FIA.

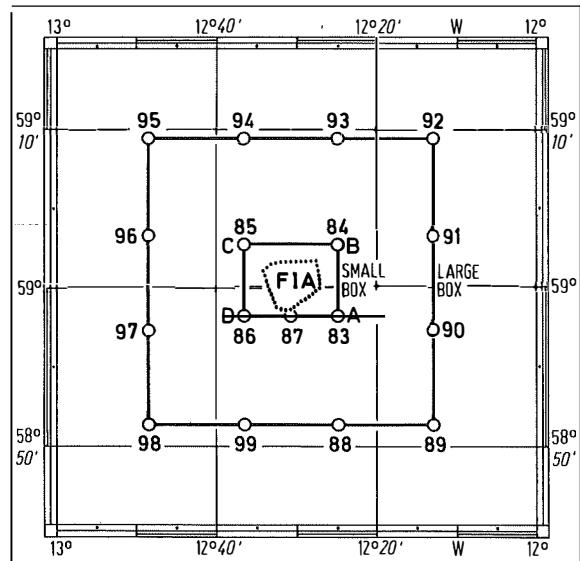


Fig. 9. Distribution of "Planet"-stations outside the FIA.

Abb. 9. Verteilung der "Planet"-Stationen außerhalb des FIA.

nautical mile off "Meteor" and "Discovery" in a triangular array. Unfortunately, no atmospheric front passage occurred except at the end of the main observation period of "Planet", and most of the data will be characteristic for weak air-sea interaction.

"Planet" participated in a first multiship experiment (Fig. 8) on 29 to 30 August as one of the vessels with fixed position relative to the drifting spar buoy P2. This experiment, like the second multiship experiment, was aimed at observing the small-scale short-term variation of the mixed layer and thermocline structure.

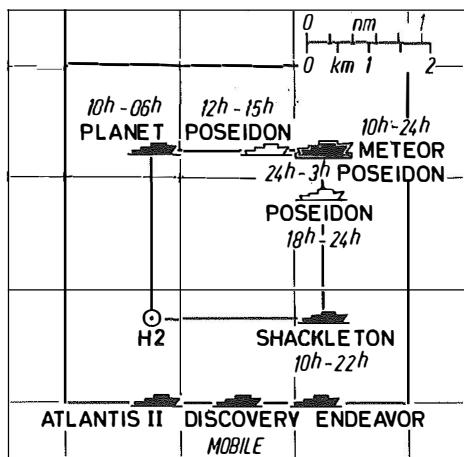


Fig. 10. Distribution of fixed position and roving ships during the second Multiship Experiment (2/3 September 1978). Buoy H2 was moored at $59^{\circ} 25' N$, $12^{\circ} 30' W$ about 47 km north of the FIA.

Abb. 10. Verteilung der ortsfesten und der fahrenden Schiffe während des zweiten Mehrschiff-Experiments (2.—3. September 1978). Die Boje H2 war bei $59^{\circ} 25' N$, $12^{\circ} 30' W$ etwa 47 km nördlich von FIA verankert.

After the first experiment repeated current and CTD profiling was carried out close to P2 and then close to K3. A repeated "small box" station pattern was followed by a "large box" (18×18 nautical miles, station distance 6 nautical miles) around the FIA moorings (Fig. 9).

In the second multiship experiment on 2 to 3 September north of the FIA the "Planet" again participated as fixed position ship (Fig. 10), then returned to the K-moorings for further profiling work. Moorings K2, K3 and finally K1 were recovered on 6 September. After another repeated "small box", "Planet" joined in for a third multiship experiment on 7 to 8 September to observe spatial variations in the thermocline related to internal tides.

In addition to the work described, DOPY was deployed on several occasions, and CO₂ measurements and air chemistry sampling was conducted on board almost continuously.

Information on stations and moorings are presented in Figs. 1 and 9 and in Table 5. "Planet" left the JASIN area on 8 September. She stayed in the port of Aberdeen, Scotland, from 10 to 12 September, then crossed the North Sea doing hourly XBTs and arrived in her homeport Kiel on 14 September 1978.

4.4 Activities on R.V. "Poseidon"

The work on board the "Poseidon" was also part of the studies of the oceanic mixed layer and thermocline and the trace element exchange. A summary of stations is presented in Table 6. The cruise programme included only a modest contribution to the measure-

Tabelle 5 a—h. Stationsliste W.F.S. „Planet“.

Station No.	No. of Dips	Date 1978 Day/Month	Time (Z) Start/End	DECCA chain	Coordinates	Nav-Sat Start-End	λ (E) Start-End	Depth (m) corr. Start-End	CTD Multi-sonde	Bathy-sonde	Profiler Aand. Mahrt Kuhn	DOPY	Remarks	Stat. No.
1	4	16/8	16.11/19.23	BLO	rF17.90 rF16.06	9D38.20 9D38.91	58°07'.5' -58°07'.5'	09°46'.6' -09°47'.9'	1			2	Test	1
2	1	17/8	05.23	B 7	gF32.43	pE62.64	57°53'.3'	07°50'.3'					Test	2
3	1	17/8	07.07	B 7	gF41.50	pE50.90	57°51'.5'	07°26'.6'					Test	3
4	4	17/8	08.21/11.12	B 7	gG31.00 -gG31.30	pD75.70 -pD76.00	57°51'.6' -57°52.3'	07°09'.9' -07°07'.1'	3				Test	4
Start of air chemistry, until 14/8/78 (except port time)														
XBTs hourly when crossing North Sea														
—														
17-18/8 11.30/16.30														

Table 5 a—h. Station list R.V. "Planet".

Table 5 b

Station No.	No. of Dips	Date 1978 Day/Month	Time (Z) Start/End	LORAN-C SI3-W	Start - End SI3-Y	DECCA chain E8 green	ϕ (N) Start-End	λ (W) Start-End	Nav-Sat corr.	Depth (m) Start-End	CTD corr.	Multi-Bathy sonde	Profiler Aand. Mahrt Kuhn	DOPY	Remarks	Stat. No.
5	71	20-21/8	03.00/22.00	32969.3 -32970.1	50324.4 -50315.6	J 32.55 -J 32.19	58°58'.5' -58°58'.9'	12°32'.2' -12°33.5'	1570 -1590	7	21	43			5	
6	20	21-22/8	22.44/15.09	32969.7 -32972.0	50324.1 -50323.0	J 32.58 -J 33.32	58°58'.9' -58°59'.2'	12°33.5' -12°32.3'	1570 -1584						6	
7	26	22-23/8	19.00/07.30	32974.3 -32970.6	50313.5 -50319.5	J 32.55 -J 32.45	58°58'.7' -58°58'.6'	12°24.5' -12°33.4'	1563 -1572		26				Deployment mooring K3 and first leg K2 near K 3	7
8	8	23/8	14.25/19.40	32959.2 -32959.4	50315.7 -50314.3	x -J30.75	58°56'.7' -58°57'.2'	12°34.1' -12°34.1'	1) x)	1		7			CTD-Test))))	8
9	107	23-25/8	20.30/06.45	32970.2 -32969.6	50323.0 -50318.2	J32.66 -J32.18	58°57'.2' -58°58'.3'	12°34.1' -12°33.2'	1575 -1572		69	38			near K3))))	9
10	8	25/8	14.52/18.38	32960.2 -32953.1	50316.5 -50315.6	J31.00 -J30.08	58°58'.7' -58°55.9'	12°30.6' -12°34.3'	1579 -1584		4	4			Deployment sparbuoy K2))))	10
11	25	25-26/8	19.00/07.30	32953.6 -32964.7	50316.5 -50310.6	J30.12 -J31.10	58°55.7' -58°57.5'	12°34.3' -12°33.8'	1584 -1569		12	13) near K3))))	11
12	1	26/8	08.35			J32.40	58°57'.3'	12°35.8'	1563		1					12
13	49	26-27/8	16.48/07.00	32956.9 -32953.8	50350.8 -50348.4	J33.30 -J32.60	58°57.7' -58°57.9'	12°25.1' -12°25.6'	1608 -1606		49				position A of small box	13
14	1	27/8	07.30	32967.1	50352.3	J34.48	58°59.9'	12°24.6'	1602		1				Stat. 14-41 Two small boxes	14
15	1	27/8	07.55	32975.6	50351.0	J35.40	59°01.2'	12°25.0'	1592		1					15
16	1	27/8	08.28	32984.6	50352.0	J36.55	59°02.65'	12°24.75'	1584		1					16
17	1	27/8	08.47	32987.1	50340.0	J35.96	59°02.5'	12°27.9'	1569		1					17
18	1	27/8	09.10	32991.4	50329.0	J35.64	59°02.6'	12°30.7'	1558		1					18
19	1	27/8	09.35	32996.5	50317.0	J35.33	59°02.8'	12°33.85'	1543		1					19
20	1	27/8	10.00	32999.5	50307.0	J34.93	59°02.8'	12°36.4'	1534		1					20
21	1	27/8	10.25	32990.0	50306.7	J33.84	59°01.25'	12°36.5'	1544		1					21

Table 5 c

Station No.	No. of Dips	Date 1978 Day/Month	Time (Z) Start/End	LORAN-C Start - End SL3-W	DECCA chain E8 green	ϕ (N) Start-End	Nav-Sat λ (W) Start-End	Depth (m) corr. Start-End	CTD Multi-sonde	Bathy-sonde	Profiler	DOPY	Remarks	Stat. No.
22	1	27/8	10.50	32980.7	50306.9	J32.79	58°59'.7'	12°36'.5'	1553	1				22
23	1	27/8	11.15	32971.5	50306.8	J31.69	58°58'.2'	12°36'.5'	1562	1				23
24	1	27/8	11.40	32968.4	50317.5	J32.07	58°58'.3'	12°33'.7'	1571	1				24
25	1	27/8	12.05	32963.9	50330.6	J32.50	58°58'.7'	12°34'.2'	1586	1				25
26	1	27/8	12.30	32960.1	50340.5	J32.75	58°58'.7'	12°34'.2'	1598	1				26
27	1	27/8	12.55	32956.5	50351.7	J33.23	58°58'.0'	12°27'.9'	1611	1				27
28	1	27/8	13.30	32966.1	50352.0	J34.35	58°58'.0'	12°27'.9'	1603	1				28
29	1	27/8	13.56	32.975.0	50351.9	J35.4	58°58'.0'	12°27'.9'	1595	1				29
30	1	27/8	14.20	32964.3	50351.5	J36.50	58°58'.0'	12°27'.9'	1584	1				30
31	1	27/8	14.45	32988.2	50339.2	J36.0	59°02'.8'	12°24'.9'	1568	1				31
32	1	27/8	15.10	32992.4	50328.1	J35.67	59°02'.8'	12°24'.9'	1558	1				32
33	1	27/8	15.35	32995.9	50318.1	J35.27	59°02'.4'	12°29'.5'	1545	1				33
34	1	27/8	16.00	32999.0	50307.4	J34.90	59°02'.7'	12°36'.5'	1536	1				34
35	1	27/8	16.25	32999.4	50306.9	J33.80	59°01'.3'	12°36'.4'	1545	1				35
36	1	27/8	16.50	32980.1	50306.6	J32.70	58°59'.7'	12°36'.5'	1553	1				36
37	1	27/8	17.15	32971.1	50306.7	J31.60	58°58'.2'	12°36'.4'	1563	1				37
38	1	27/8	17.40	32966.4	50318.8	J32.0	58°57'.7'	12°34'.5'	1574	1				38
39	1	27/8	18.05	32964.4	50329.3	J32.46	58°58'.2'	12°30'.5'	1585	1				39
40	1	27/8	18.30	32959.0	50340.1	J32.65	58°57'.8'	12°27'.7'	1597	1				40
41	1	27/8	18.55	32956.5	50351.7	J33.21	58°58'.2'	12°24'.8'	1610	1				41
42	1	27/8	20.30	32962.4	50329.3	J32.24	59°36'.6'	11°58'.9'	1585	1)				42
43	1	28/8	00.35	32966.7	50335.3	J33.00	58°57'.7'	12°30'.3'	1585	Y				43
44	2	28/8	03.00/07.30	32964.7	50327.7	J32.20	58°58'.8'	12°29'.0'	1581	2Y				44
45	2	28/8	09.54/11.45	32961.3	50321.2	J31.38	58°57'.2'	12°32'.7'	-1584	x				45
				-32958.6	-50322.6	-J31.26	-58°57'.0'	-12°33'.2'		2	near K3			

Table 5 d

Station No.	No. of Dips	Date 1978 Day/Month	Time (Z) Start/End	LORAN-C Start - End SL3-W	DECCA chain SL3-Y	Nav-Sat Start-End	Depth (m) corr. Start-End	CTD Multi-Bathy-sonde	Profiler Aanderaa bathy-sonde	DOPY	Remarks	Stat. No.
46	1	28/8	13.30	32969.3	50320.6	J32.48	58°58'.4'	12°33.7	1572	y	Yoyo near K3	46
47	1	28/8	16.13	32958.3	50320.8	J31.08	58°56.9'	12°30.9'	x		close to dye patch of POSEIDON	47
48	1	28/8	20.11	32953.9	50342.5	J32.20	58°56.2'	12°33.0'	x			48
49	1	28/8	21.00	32961.5	50336.7	J32.72	58°56.2'	12°33.0'	1599	y	Yoyo, drifting joint experiment with METEOR	49
50	1	29/8	00.10	32955.3	50341.8	J32.26	58°57.4'	12°28.5'	1605	y	Yoyo, joint experiment with METEOR and DISCOVERY on fixed position	50
51	7	29-30/8	09.00/08.45	32942.9	50349.3	J31.42	58°57.9'	12°26.4'	1605		Yoyo, first multiship experiment near drifting-buoy P2	51
52				-32930.6	-50363.0	-J30.88	-58°54.5'	-12°23.4'	-1641		close to drifting buoy P2	52
53	2	31/8	00.10/06.10	32914.9	50368.9	J31.18	58°54.2'	12°21.5'	1593			53
54	18	31/8	08.44/19.30	32916.2	50392.4	J31.48	58°53.7'	12°14.8'	1699	2y	Yoyo	54
55	1	31/8	22.00	32898.3	-50400.9	-J30.12	-58°51.5'	-12°11.8'	-1699			55
56	1	31/8	23.15	32896.4	50403.2	J30.05	58°51.3'	12°10.6'	1699			56
57	1	31/8	23.40	32878.3	-50415.1	-J16.84	-58°49.0'	-12°08.8'	14			57
58	1	01/9	00.04	32957.5	50350.1	J33.04	58°55.1'	12°25.6'	1607	y	Yoyo, pos A of small box	58
59	1	01/9	00.29	32966.0	50351.9	J34.31	58°57.8'	12°25.9'	x	1	stat. 56-83: Two small boxes	59
60	1	01/9	00.53	32975.0	50352.1	J35.30	58°57.8'	12°25.9'	1593	1		60
61	1	01/9	01.19	32984.2	50351.1	J36.44	58°57.8'	12°25.9'	1588			61
62	1	01/9	01.44	32988.0	50340.6	J36.11	59°02.6'	12°25.5'	1569	1		62
63	1	01/9	02.08	32992.1	50329.8	J35.65	59°02.6'	12°25.5'	1556	1		63
64	1	01/9	02.32	32999.0	50307.0	J34.92	59°02.6'	12°25.5'	1534	1		64
65	1	01/9	03.00	32990.0	50306.5	J33.68	59°02.6'	12°25.5'	1544	1		65

Table 5 e

Station No.	No. of Dips	Date 1978 Day/Month	Time (Z) Start/End	LORAN-C Start - End SL3-Y	DECCA chain E8 green	Nav-Sat Start-End	ϕ (N)	λ (W)	Depth (m) corr. Start-End	CTD Multi-Start-End	Bathy-sonde	Profiler Aand. (Mahrt Kuhn)	DOPY	Remarks	Stat. No.
66	1	01/9	03.24	32967.6	50319.6	J32.05	59°02'.6'	12°25.5'	1575	1					66
67	1	01/9	03.50	32965.3	50329.2	J32.50	59°02'.6'	12°25.5'	1583	1					67
68	1	01/9	04.16	32960.6	50342.0	J32.90	59°02'.6'	12°25.5'	1600	1					68
69	1	01/9	04.36	32956.0	50351.7	J31.18	59°02'.6'	12°25.5'	1613	1					69
70	1	01/9	05.25	32965.8	50353.3	J34.38	59°02'.6'	12°25.5'	1606	1					70
71	1	01/9	05.50	32975.8	50351.0	J35.35	58°59'.6'	12°25.1'	1592	1					71
72	1	01/9	06.15	32984.5	50351.2	J36.40	58°59'.6'	12°25.1'	1584	1					72
73	1	01/9	06.40	32989.6	50340.5	J36.10	58°59'.6'	12°25.1'	1569	1					73
74	1	01/9	07.05	32991.9	50330.9	J35.85	58°59'.6'	12°25.1'	1558	1					74
75	1	01/9	07.30	32995.2	50319.0	J35.30	58°02'.5'	12°31.7'	1545	1					75
76	1	01/9	07.55	32999.2	50308.0	J34.95	59°02'.5'	12°31.7'	1535	1					76
77	1	01/9	08.20	32989.0	50306.3	J33.60	59°02'.5'	12°31.7'	1545	1					77
78	1	01/9	08.45	32980.5	50306.9	J33.65	59°02'.5'	12°31.7'	x	1					78
79	1	01/9	09.10	32970.3	50306.1	J31.46	58°59'.3'	12°31.0'	1563	1					79
80	1	01/9	09.36	32966.3	50318.0	J31.77	58°59'.0'	12°32.6'	1574	1					80
81	1	01/9	10.01	32963.0	50328.8	J32.24	58°59'.0'	12°32.6'	1584	1					81
82	1	01/9	10.26	32960.2	50339.5	J32.70	58°59'.0'	12°32.6'	1595	1					82
83	2	01/9	10.52/11.05	32956.5	50350.7	J33.12	58°59'.0'	12°32.6'	1599	2					83
				-32956.3	-50349.7	-J33.01	-58°59'.2'	-12°28.2'	-1607						
														Stat. 83.2-86: corners off small box	
84	1	01/9	14.15	32985.1	50353.0	J36.70	58°59'.2'	12°28.2'	1585	1					84
85	1	01/9	15.12	33000.5	50306.2	J34.95	58°59'.2'	12°28.2'	1533	1					85
86	1	01/9	16.00	32972.0	50306.6	J31.64	58°59'.2'	12°28.2'	1562	1					86
87	1	01/9	16.50	32962.2	50329.8	J32.20	58°57.8'	12°30.0'	1588						87
88	1	01/9	18.10	32914.6	50352.1	I46.20	58°51.4'	12°24.7'	1641	1					88
89	1	01/9	19.08	32898.1	50395.9	I47.70	58°51.4'	12°13.0'	1689	1					89

Table 5 f

Table 5g

Station No.	No. of Dips	Date 1978 Day/Month	Time (Z) Start/End	LORAN-C Start SL3-W	End SL3-Y	DECCA chain E8 green	ϕ (N) Start-End	Nav-Sat λ (W) Start-End	depth (m) corr. Start-End	CTD Multi- Bathy- sonde	Profiler Aand. Mahrt Kuhn	DOPY	Remarks	Stat. No.
112	1	06/9	22.55	32989.1	50341.2	J36.20	59°02.8'	12°27.2'	1572	1				112
113	1	06/9	21.22	x	50329.8	J35.80	59°03.1'	12°31.1'	1559	1				113
114	1	06/9	21.48	32996.1	50318.5	J35.45	59°03.2'	12°33.8'	1546	1				114
115	1	06/9	22.17	33000.7	50303.6	J34.82	59°03.2'	12°38.2'	1530	1				115
116	1	06/9	22.41	32989.8	50306.2	J33.60	59°01.5'	12°35.4'	1546	1				116
117	1	06/9	23.04	32980.1	50306.4	J32.56	58°59.7'	12°33.7'	1555	1				117
118	1	06/9	23.28	32971.6	50306.3	J31.59	58°58.0'	12°31.6'	1563	1				118
119	1	06/9	23.54	32968.0	50318.0	J31.88	58°58.2'	12°26.9'	1573	1				119
120	1	07/9	00.23	x	50328.2	J32.20	58°57.9'	12°21.8'	1583	1				120
121	1	07/9	00.57	x	50339.5	J32.45	58°58.0'	12°23.0'	1595	1				121
122	1	07/9	01.26	x	50351.6	J32.90	58°58.2'	12°16.7'	1611	1				122
123	1	07/9	01.52	x	50352.3	J34.08	58°59.9'	12°15.6'	1604	1				123
124	1	07/9	02.22	x	50352.2	J35.26	59°01.5'	12°14.6'	1596	1				124
125	1	07/9	02.50	x	50352.4	J36.43	59°03.3'	12°13.8'	1584	1				125
126	1	07/9	03.20	x	x	J35.85	59°02.5'	12°28.8'	1566	1				126
127	1	07/9	03.45	x	50328.6	J35.50	59°02.4'	12°31.2'	1559	1				127
128	1	07/9	04.13	x	50316.9	J34.80	59°02.1'	12°33.8'	1547	1				128
129	1	07/9	04.40	x	50306.4	J34.35	59°02.2'	12°35.7'	1538	1				129
130	1	07/9	05.07	x	50306.1	J34.48	59°00.6'	12°35.3'	1550	1				130
131	1	07/9	05.35	x	50305.3	J32.45	58°59.3'	12°36.6'	1553	1				131
132	1	07/9	06.07	x	50306.7	J31.30	58°57.6'	12°36.6'	1566	1				132
133	1	07/9	06.32	x	50319.0	J31.85	58°57.5'	12°33.9'	1576	1				133
134	1	07/9	07.00	x	50329.5	J32.40	58°57.9'	12°30.8'	1586	1				134
135	1	07/9	07.18	x	50341.2	J32.75	58°57.9'	12°27.8'	1601	1				135
136	1	07/9	07.40	x	x	J33.00	58°57.6'	12°26.6'	1611	1				136

Table 5 h

Station No.	No. of Dips	Date 1978 Day/Month	Time (Z) Start/End	LORAN-C Start - End	DECCA chain SL3-W	DECCA chain SL3-Y	ϕ (N) E8 green	Nav-Sat Start-End	λ (W) Start-End	Depth (m) corr. Start-End	CTD Multi-sonde	Bathy-sonde	Profiler Aand. Kuhn	DOPY	Remarks	Strat. No.
137	49	07-08/9	15.00/15.30	33002.4 -33004.5	50330.2 -50329.5	536.98 -537.15	59°06'.1' -59°04'.2'	12°34'9" -12°29'.6"	1546 -1544	45				2	third multiship experiment Recovery of release of K3 XBTs hourly when crossing North Sea	137
37		12-14/9	20.00/06.00	-												

Notes

- 1) Y = yoyo
- 2) x = not known

ments of vertical profiles of temperature, salinity and velocity. Instead it was planned to spend most of the time towing an undulation fish, in which was housed a CTD, fluorometer and water pump. Thus, by executing a series of hydrographic surveys, it should have been possible to simultaneously monitor the dye spreading from a point injection below the wind mixed layer. The aim was to determine transport rates on horizontal scales up to 30 km in the zone between the surface entrainment layer and the seasonal thermocline by direct observation of natural (radon) and artificial (rhodamine) tracers. Parachute drogues were to be used as markers in the dye experiments. Unfortunately, the towing cable of the undulating fish frequently broke down at an early stage of the ship's participation in the experiment, and the programme had to be changed to vertical CTD profiling and water collection for radon analysis with a pipe lowered on the hydrowinch wire while the ship drifted.

"Poseidon" left Kiel on 14 August 1978. The passage out to the JASIN area was interrupted by system trials in the Baltic, in the North Sea and on the Shetland shelf. Upon arrival in the JASIN area on 19 August tests were performed of the undulating fish with its new water pump, fluorometer and Neil Brown CTD. A first four-hour radon trial was completed on that day, with the fish towed at a series of constant depths. A first run with the fluorometer followed, passing back and forth through a small quantity of rhodamine dye injected in the mixing surface layer. This work ended when a conductor broke in the towing cable.

A 24-hour time series of XBTs was started on 20 August which discovered sharp inversions suggestive of frontal interleaving to the northeast of the moored FIA. On 21 August, after a testing of the fish, dye was pumped into the sea at 40 m for a first dye experiment. All went well with the mapping until after 5 hours the cable broke down again. The fish was recovered, and work continued with a standby fluorometer lowered by winch while the ship motored very slowly. Starting in the evening of 21 August, water for radon profiling was collected using a hose attached to the hydrowire with the ship drifting. After some drogue tracking while repairing the fish the second dye experiment was started on 22 August, with cable problems occurring again during the experiment. In order to save the remaining spare conductors of the undulator cable for a joint experiment with other ships, towed measurements were stopped for the time being. The CTD was extracted from the fish and used for standard vertical profiling during the following days.

On 24 August "Poseidon" met with "Meteor" for an intercomparison of the radon systems operating on the two ships and for an intercomparison of the meteorological systems. Vertical CTD profiling started

Table 6 a-d. Station list R.V. "Poseidon".

Tabelle 6 a-d. Stationsliste F. S. „Poseidon“.

Stat. No.	Date 1978 Day/Month	Time (Z) Start/End	Position at Beginning		CTD			XBT	Gas- Exchange	Droge Exp.	Dye Exp.	Remarks
			ϕ (N)	λ (W)	Fish	Vert. Prof.	Yoyo					
1394	14/8	15.35-17.17	54°29.9'	10°02.8' East	x							Test
	17/8	15.48-17.18	59°23.0'	03°56.1' West	x							Test
	18/8	15.07-15.30	59°19.0'	08°20.0'	x							Test
1396	19/8	08.30-11.40	59°04.0'	11°20.0'	x				x			
	19/8	13.58-16.38	59°00.0'	12°03.0'	x					x		Test
	19/8	19.45-19.59	59°02.5'	11°19.0'	x							
	20/8	07.10-08.38	58°56.1'	12°00.7'					x			
JX001	20/8	09.00	58°57.0'	12°00.0'				1				
	20/8	09.04-17.11	58°56.1'	11°58.4'					x			
JX002 - 026	20-21/8	10.00-09.00	58°58.0'	11°56.8'				24				frontal inter- leaving studies
	21/8	09.48-11.56	58°56.0'	11°33.0'	x							
100101 - 103	21/8	12.56-21.39	58°57.7'	11°38.0'	x					x		
	21/8	22.00	58°55.6'	11°39.5'				1				
JX027	22/8	08.00	59°02.3'	11°49.4'				1				
JX028	22/8	08.23-11.18	59°02.1'	11°50.0'				.		x		
JX029 - 034	22/8	09.00.-18.10	59°02.0'	11°51.2'				6				
	22/8	12.39-15.34	59°03.1'	11°49.3'	x							
200101 - 104	22/23/8	18.33-00.35	59°02.5'	11°48.0'	x					x		
	22-23/8	22.30-01.00	58°55.0'	11°31.0'					x			
200201	23/8	00.35-01.18	59°02.5'	11°47.0'	x					x		
1406A	23/8	05.30-07.30	59°04.0'	11°46.0'					x			
1413	23/8	11.00-13.00	59°02.0'	11°45.0'					x			
20030	23/8	14.45-16.03	59°01.2'	11°43.4'	x					x		
1413 A	23/8	19.00-21.00	59°01.0'	11°38.0'					x			
1414	24/8	08.00-10.30	58°58.0'	12°27.0'					x			Intercomparison with Meteor
1415	24/8	13.37-14.05	58°55.4'	12°37.8'		500m						
1416	24/8	15.54-16.25	58°55.4'	12°26.5'		"						
1417	24/8	16.48-17.16	58°55.9'	12°26.8'		"						
1418	24/8	17.32-18.01	58°56.4'	12°26.6'		"						
1419	24/8	18.16-18.45	58°56.9'	12°26.6'		"						
1420	24/8	18.59-19.29	58°57.3'	12°26.4'		"						
1421	24/8	19.41-20.11	58°58.0'	12°26.4'		"						
1422	24/8	20.24-20.51	58°58.5'	12°26.8'		"						
1423	24/8	21.01-21.32	58°58.9'	12°26.5'		"						
1424	24/8	21.46-22.16	58°59.4'	12°26.7'		"						
1425	24/8	22.31-23.01	58°59.9'	12°26.5'		"						
1426	24/8	23.22-23.50	59°00.8'	12°26.2'		"						

after this rendez-vous, working on a box around the FIA with 0.5 nautical mile spacing of stations until 26 August. For the next 48 hours "Poseidon" did parachute drogue and CTD measurements to help deciding on the location of the first multiship experiment, breaking at intervals for radon profiling. Then the undulator was tried again, giving an uninterrupted 3-hour section near the FIA. A third dye experiment was started on 28 August.

From 29 August to 1 September "Poseidon" participated in the first multiship experiment (Fig. 8) as a stationary ship with CTD yo-yo profiling. On 1 September there followed a fourth dye experiment, then the ship participated from 2 to 3 September in the second multiship experiment, again as a stationary ship (Fig. 10). With breaks for radon profiles, the remaining days in the JASIN area were devoted to a second CTD box around the FIA (corresponding to the "small

Table 6 b

Stat. No.	Date Day/Month	Time (Z) Start/End	Position at Beginning		CTD			XBT	Gas- Exchange	Drogue Exp.	Dye Exp.	Remarks
			ϕ (N)	λ (W)	Fish	Vert. Prof.	Yoyo					
1427	25/8	00.37-01.23	59°01.6'	12°25.7'		1000m						
1428	25/8	03.18-03.52	59°02.9'	12°26.7'		500m						
1429	25/8	04.06-04.37	59°02.4'	12°26.5'		"						
1430	25/8	04.52-05.23	59°02.4'	12°27.6'		"						
1431	25/8	05.30-06.05	59°02.4'	12°28.5'		"						
1432	25/8	06.21-06.49	59°02.4'	12°29.7'		"						
1433	25/8	06.59-07.29	59°02.4'	12°31.4'		"						
1434	25/8	07.38-08.08	59°02.5'	12°31.4'		"						
1435	25/8	08.25-08.54	59°02.4'	12°32.4'		"						
1436	25/8	09.26-09.55	59°02.5'	12°33.4'		"						
1437	25/8	10.15-10.43	59°02.5'	12°34.1'		"						
1438	25/8	11.05-11.34	59°02.5'	12°35.4'		"						
1439	25/8	11.48-12.48	59°02.4'	12°36.3'		"						
1440	25/8	13.05-13.35	59°01.9'	12°36.3'		1000m						
1441	25/8	13.52-14.22	59°01.4'	12°36.3'		500m						
1442	25/8	14.38-15.07	59°00.9'	12°36.3'		"						
1443	25/8	15.21-15.52	59°00.4'	12°36.4'		"						
1444	25/8	16.08-16.39	58°59.9'	12°36.4'		"						
1445	25/8	16.56-17.26	58°59.4'	12°36.4'		"						
1446	25/8	17.43-18.11	58°58.9'	12°36.4'		"						
1447	25/8	18.33-19.03	58°58.5'	12°36.4'		"						
1448	25/8	19.19-19.47	58°57.9'	12°36.5'		"						
1449	25/8	20.04-20.33	58°57.4'	12°36.2'		"						
1450	25/8	20.58-21.28	58°56.9'	12°36.4'		500m						
1451	25/8	21.50-22.46	58°56.4'	12°36.3'		1000m						
1452	25/8	23.05-23.34	58°56.2'	12°34.9'		500m						
1453	25-26/8	23.53-00.23	58°56.0'	12°34.3'		"						
1454	26/8	00.40-01.11	58°55.8'	12°33.9'		"						
1455	26/8	01.21-01.51	58°55.6'	12°32.5'		"						
1456	26/8	02.07-02.38	58°55.4'	12°31.5'		"						
1457	26/8	02.55-03.26	58°55.3'	12°30.6'		"						
1458	26/8	03.42-04.13	58°55.1'	12°29.7'		"						
1459	26/8	04.29-04.57	58°55.0'	12°28.9'		"						
1460	26/8	05.17-05.46	58°54.8'	12°27.9'		1000m						
1461	26/8	06.01-06.55	58°54.6'	12°26.9'		500m						
1462	26/8	07.30-07.58	58°55.4'	12°26.5'		"						
1463	26/8	08.14-08.43	58°55.9'	12°26.5'		"						
1464	26/8	09.00-09.29	58°56.4'	12°26.6'		"						
1465	26/8	10.00-12.30	58°56.0'	12°26.0'				x				
1466	26-27/8	14.40-10.53	58°53.2'	12°20.5'					x			including Stat. 1468, 1471, 1473
1467	26/8	18.30-21.00	58°52.0'	12°30.0'			x					
1469	27/8	00.30-03.00	58°53.0'	12°23.0'			x					
1472	27/8	06.30-08.30	58°52.0'	12°22.0'			x					
1474	27/8	10.55-11.31	58°51.5'	12°17.9'					x	x		
1475	27/8	13.37-16.02	58°50.7'	12°16.6'					x	x		
IWO35	27/8	13.45	58°51.2'	12°16.0'			1					
1476	27/8	19.00-21.00	58°51.0'	12°15.0'			x					

Table 6 c

Stat. No.	Date 1978 Day/Month	Time (Z) Start/End	Position at Beginning		CTD			XBT	Gas- Exchange	Droge Exp.	Dye Exp.	Remarks
			ϕ (N)	λ (W)	Fish	Vert. Prof.	Yoyo					
1477	28/8	06.30-09.00	58°51.0'	12°14.0'				x				
1478	28/8	09.10-12.25	58°50.6'	12°14.3'	x				x			
1479	28/8	13.00-15.00	58°55.0'	12°27.0'								
300101 - 301	28-29/8	16.48-05.38	58°56.9'	12°24.5'	x					x		
1481	29/8	10.00-12.00	58°55.0'	12°22.0'					x			
1482	29-30/8	11.55-06.11	58°53.8'	12°20.4'			x					Multiship Experiment near buoy P2
1484	30/8	07.00-09.00	58°54.0'	12°21.0'					x			
1485	30/8	09.49-14.30	58°53.9'	12°20.7'			x					
1486	30/8	15.30-17.30	58°54.0'	12°21.0'					x			62 - 122 m
1487	31/8	06.30-09.00	58°51.0'	12°08.0'					x			
1488	31/8	10.00-15.00	58°51.1'	12°11.6'			x					
1489	31/8	15.00-18.00	58°50.0'	12°07.0'					x			
1490	31/8-01/9	18.25-02.52	58°48.9'	12°05.7'			x					
	01/9	07.25-23.00	58°47.0'	12°04.1'						x	x	
1491	01/9	03.30-06.00	58°48.0'	12°08.0'					x			
1492	01/9	16.47-17.19	58°47.1'	12°04.0'			x					
1496	02/9	00.00-03.00	58°49.0'	12°00.0'					x			
1497	02/9	11.23-15.03	59°26.0'	12°27.5'			x					
1498	02/9	15.30-18.00	59°26.0'	12°28.0'					x			
1499	02-03/9	18.44-02.59	58°45.6'	12°02.5'			x					
1500	03/9	04.00-06.00	59°27.0'	12°23.0'					x			
1501	03/9	08.28-08.51	59°02.4'	12°24.1'		500m						
1502	03/9	09.10-09.33	59°01.9'	12°24.1'		"						
1503	03/9	09.50-10.13	59°01.4'	12°24.1'		"						
1504	03/9	10.29-10.52	59°00.9'	12°24.0'		"						
1505	03/9	11.03-11.26	59°00.4'	12°24.1'		"						
1506	03/9	11.42-12.07	58°59.8'	12°24.0'		"						
1507	03/9	12.21-12.47	58°59.3'	12°24.1'		"						
1508	03/9	13.01-13.25	58°58.8'	12°24.0'		"						
1509	03/9	13.40-14.05	58°58.2'	12°24.0'		"						
1510	03/9	14.17-14.40	58°57.6'	12°24.1'		"						
1511	03/9	14.57-15.21	58°57.6'	12°25.0'		"						
1512	03/9	17.00-21.30	58°57.0'	12°25.0'					x			52 - 122 m
1513	03/9	22.05-22.27	58°57.6'	12°25.0'		"						
1514	03/9	22.49-23.13	58°57.6'	12°25.9'		"						
1515	03/9	23.32-23.55	58°57.6'	12°26.9'		"						
1516	04/9	00.10-00.31	58°57.6'	12°27.9'		"						
1517	04/9	00.49-01.10	58°57.6'	12°28.9'		"						
1518	04/9	01.23-01.44	58°57.6'	12°29.8'		"						
1519	04/9	02.04-02.28	58°57.6'	12°30.8'		"						
1520	04/9	02.42-03.03	58°57.6'	12°31.8'		"						
1521	04/9	03.15-03.38	58°57.6'	12°32.7'		"						
1522	04/9	03.55-04.16	58°57.6'	12°33.7'		"						
1523	04/9	04.33-04.56	58°57.6'	12°34.7'		"						
1524	04/9	05.16-05.39	58°57.6'	12°35.7'		"						

Table 6 d

Stat. No.	Date 1978 Day/Month	Time (Z) Start/End	Position at Beginning		CTD			XBT	Gas- Exchange	Droge Exp.	Dye Exp.	Remarks
			ϕ (N)	λ (W)	Fish	Vert. Prof.	Yoyo					
1525	04/9	05.53-06.17	58°58.1'	12°35.8'			500m					
1526	04/9	06.41-07.04	58°58.6'	12°35.8'			"					
1527	04/9	07.20-07.42	58°59.1'	12°35.8'			"					
1528	04/9	07.55-08.19	58°59.6'	12°35.8'			"					
1529	04/9	08.38-09.00	59°00.2'	12°35.7'			"					
1530	04/9	09.19-09.43	59°00.6'	12°35.6'			"					
1531	04/9	10.03-10.25	59°01.2'	12°35.8'			"					
1532	04/9	10.44-11.06	59°01.6'	12°35.9'			"					
1533	04/9	11.28-11.52	59°02.4'	12°35.7'			"					
1534	04/9	12.13-12.35	59°02.3'	12°34.7'			"					
1535	04/9	12.58-13.19	59°02.4'	12°33.9'			"					
1536	04/9	13.40-14.03	59°02.4'	12°32.9'			"					
1537	04/9	14.27-14.50	59°02.4'	12°31.9'			"					
1538	04/9	15.11-15.32	59°02.4'	12°31.0'			"					
1539	04/9	16.06-16.29	59°02.4'	12°30.0'			"					
1540	04/9	16.45-17.07	59°02.4'	12°29.1'			"					
1541	04/9	17.21-17.44	59°02.4'	12°28.1'			"					
1542	04/9	18.07-18.30	59°02.4'	12°27.2'			"					
1543	04/9	18.46-19.40	59°02.4'	12°26.2'			"					
1544	04/9	19.21-19.44	59°02.4'	12°25.3'			"					
1545	04/9	19.56-20.20	59°02.4'	12°24.1'			"					
1546	04/9	21.00-23.00	59°03.0'	12°24.0'				x				62-122m
1547	05/9	00.38-01.02	59°02.4'	12°35.7'			"					
1548	05/9	01.29-01.53	59°02.4'	12°34.8'			500m					
1549	05/9	02.09-02.27	59°02.4'	12°33.8'			"					
1550	05/9	02.49-03.12	59°02.4'	12°31.8'			"					
1551	05/9	03.28-03.51	59°02.4'	12°30.8'			"					
1552	05/9	04.02-04.25	59°02.4'	12°29.8'			"					
1553	05/9	04.55-05.17	59°02.8'	12°28.8'			"					
1554	05/9	05.35-05.59	59°02.4'	12°28.0'			"					
1555	05/9	10.47-11.15	59°02.3'	12°27.4'			"					
1556	05/9	11.37-12.19	59°02.4'	12°26.8'			1000m					
1557	05/9	12.35-12.57	59°02.4'	12°25.9'			500m					
1558	05/9	13.10-13.33	59°02.3'	12°24.8'			"					
1559	05/9	13.45-14.08	59°02.3'	12°24.1'			"					
1560	05/9	14.24-14.47	59°02.3'	12°23.1'			"					

box", see Fig. 9), again with 0.5 nautical mile spacing of stations.

On 5 September the "Akademie Vernadsky" joined "Poseidon" for a CTD intercomparison, then "Poseidon" left the JASIN area and arrived in her homeport Kiel on 9 September 1978.

4.5 Activities on D-CMET (Mystère)

Observations on board the German research aircraft were part of the planetary boundary layer and the radiation budget studies. This was the first mission of the aircraft within a major international experiment. The JASIN base at Machrihanish, Scotland, was the principal airport, and in addition Stornoway airport on the Isle of Lewis was sometimes used for intermediate landings. Flight patterns included:

- (a) Horizontal L-pattern, side length 40 km (turbulent structure, radiation, surface waves),
- (b) Horizontal box pattern, side length 50 km (turbulent structure, fronts, radiation, surface waves),
- (c) Vertical saw tooth pattern (inversions, clouds),
- (d) Vertical step-like pattern (turbulent structure, radiation),
- (e) Horizontal butterfly pattern (sea surface temperature).

The German participants' observational programmes as well as the short flight duration in comparison to the "Electra" (U.K.) and the C-130 (U.S.A.) required an emphasis of the D-CMET operations on pattern (a) and (b). Usually one L-pattern for radiation measurements above the clouds and two L-patterns for turbulence measurements at low levels

Table 7 a—b. Summary of D-CMET missions.

Tabelle 7 a—b. Zusammenfassung der D-CMET-Einsätze.

Flight JASIN No.	DFVLR No.	Date 1978	Start		Return		Mission types (x,y,z denote daily varying working positions)
			Airport	GMT	Airport	GMT	
1	193	28.07.	M	11.28	M	15.01	1) Fixed L pattern: X1, X2, Z1 L(X1 → Y1 → Z1) at 1000 ft L(Z1 → Y1 → X1) at 1200 ft 2) Tethered balloon intercomparison
2	194	29.07.	M	12.30	M	16.05	1) Fixed L pattern: X1, Y1, Z1 L(Z1 → Y1 → X1) at 8500 ft L(X1 → Y1 → Z1) at 300 ft L(Z1 → Y1 → X1) at 500 ft 2) Aircraft intercomparison
3	195	02.08.	M	12.04	M	15.45	1) Fixed L pattern: X1, Y1, Z1 L(X1 → Y1 → Z1) at 12500 ft L(Z1 → Y1 → X1) at 500 ft L(X1 → Y1 → Z1) at 1100 ft 2) Tethered balloon intercomparison
	196	07.08.	M	11.02	S	14.43	Fixed L patterns: X1, Y1, Z1; X2, Y2, Z2 L(Z1 → Y1 → X1) at 12500 ft L(X2 → Y2 → Z2) at 3900 ft L(Z2 → Y2 → X2) at 700 ft L(X2 → Y2 → Z2) at 500 ft
5	198	08.08.	M	11.24	M	14.58	Fixed L pattern: X1, Y1, Z1 L(Z1 → Y1 → X1) at 3500 ft L(X1 → Y1 → Z1) at 500 ft L(Z1 → Y1 → X1) at 500 ft Ascent → 8000 ft
6	199	09.08.	M	07.48	S	11.05	1) Fixed L pattern: X1, Y1, Z1 L(X1 → Y1 → Z1) at 3500 ft L(Z1 → Y1 → X1) at 1000 ft 2) Mooring L pattern: X2, Y2, Z2. L(X2 → Y2 → Z2) at 500 ft
7	207	22.08.	M	08.06	S	11.41	1) Radiation L pattern: X1, Y1, Z1 L(Z1 → Y1 → X1) 2) Stepped descent 8000 ft → 2800 ft → 300 ft 3) Fixed L pattern: X1, Y1, Z1 L(X1 → Y1 → Z1) at 300 ft L(Z1 → Y1 → X1) at 300 ft L(X1 → Y1 → Z1) at 600 ft 4) Ascent → 8000 ft 5) Radiation I pattern: A, B I(A → B) at 8000 ft
8	208	22.08.	S	13.26	M	16.30	1) Radiation L pattern: X1, Y1, Z1 L(X1 → Y1 → Z1) at 8000 ft 2) Fixed L pattern: X1, Y1, Z1 L(Z1 → Y1 → X1) at 650 ft L(X1 → Y1 → Z1) at 300 ft 3) Ascent → 8000 ft
9	209	23.08.	M	11.03	S	14.44	1) Fixed L pattern: X1, Y1, Z1 L(Z1 → Y1 → X1) at 8000 ft L(X1 → Y1 → Z1) at 450 ft L(Z1 → Y1 → X1) at 600 ft 2) Aircraft intercomparison

were performed, complemented by intercomparisons with the tethered balloon observations of "Meteor" or with the other airplanes' measurements. Consecutive

quick-look data analysis was performed with a small computer at Machrihanish base. The 18 observational flights are summarized in Table 7.

Table 7 b

Flight JASIN No.	DFVLR No.	Date 1978	Start		Return		Mission types (X, Y, Z denote daily varying working positions)
			Airport	GMT	Airport	GMT	
10	211	24.08.	M	08.32	S	12.12	1) Fixed L pattern: X1, Y1, Z1 L(X1 → Y1 → Z1) at 8000 ft L(Z1 → Y1 → X1) at 300 ft L(X1 → Y1 → Z1) at 500 ft 2) Aircraft intercomparison 3) Tethered balloon intercomparison
11	212	24.08.	S	13.35	M	16.37	Fixed L pattern: X1, Y1, Z1 L(X1 → Y1 → Z1) at 8000 ft L(Z1 → Y1 → X1) at 300 ft L(X1 → Y1 → Z1) at 600 ft
12	213	25.08.	M	10.31	S	14.00	Fixed box pattern: A, B, C, D L(A → B → C) at 500 ft L(C → D → A) at 300 ft Saw tooth traverse (A → D) at 1200-1700 ft L(D → C → B) at 600 ft
13	215	29.08.	M	08.26	S	11.25	Fixed box pattern: A, B, C, D Box (A → B → C → D → A) at 300 ft Ascent (A → B) → 9000 ft Radiation L(B → C → D) at 9000 ft
14	216	29.08.	S	13.08	M	16.10	1) Aircraft intercomparison 2) Fixed box pattern: A, B, C, D Box (A → B → A → D → C) at 300 ft I(C → D) at 8000 ft
15	217	30.08.	M	12.30	M	15.57	1) Fixed L pattern: X1, Y1, Z1 L(Z1 → Y1 → X1) at 6000 ft 2) Aircraft intercomparison
16	218	31.08.	M	08.30	S	11.52	1) Fixed L pattern: X1, Y1, Z1 L(X1 → Y1 → Z1) at 5000 ft L(Z1 → Y1 → X1) at 300 ft L(X1 → Y1 → Z1) at 500 ft L(Z1 → Y1' → Y1'' → X1) at 750 ft 2) Tethered balloon intercomparison
17	219	31.08.	S	13.29	M	16.28	1) Fixed L pattern: X1, Y1, Z1 L(X1 → Y1 → Z1) at 5000 ft L(Z1' → Y1' → X1) at 300 ft L(X1' → Y1' → Z1) at 1500 ft 2) Tethered balloon intercomparison
18	220	01.09.	M	09.19	M	12.46	1) Fixed L pattern: X1, Y1, Z1 L(X1 → Y1 → Z1) at 5500 ft L(Z1 → Y1 → X1) at 300 ft L(X1 → Y1 → Z1) at 800 ft 2) Tethered balloon intercomparison

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Appendix: Planning documents

- Royal Society (1975): Plans for the Joint Air—Sea Interaction Experiment JASIN 1977 and 1978. — London.
- Royal Society (1977): Joint Air—Sea Interaction Project Scientific Plans for 1977 and 1978. — London.
- Royal Society (1978): Joint Air—Sea Interaction Project Operational Plan for 1978. — London.
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