PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Summary of the JASIN 1978 Field Experiment

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Summary of the JASIN 1978 field experiment

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JASIN was designed to observe the physical processes causing mixing and to quantify aspects of the heat and momentum budgets in mid-latitude oceanic and marine atmospheric boundary layers. The multiplicity of processes to be sampled necessitated a large experiment, and JASIN involved 14 ships and 3 aircraft, with more than 50 teams of investigators from 9 countries. The experiment took place from July to September 1978 in the North Rockall Trough, an area of deep water several hundred kilometres off the west coast of Scotland.

Hydrographic surveys revealed eddies 100 km across, and intensive measurements on smaller scales revealed fronts in the confluence zones of the eddy field. The development of the mixing layer and seasonal thermocline, internal and inertial wave fields, and the Ekman response to winds are all complicated by the fronts and eddies.

The atmospheric boundary layer on scales of 200 km was non-steady and inhomogeneous. Surface-generated turbulence occupied the subcloud layer and transfers through the cloud layer occurred on scales greater than 50 km or intermittently. Possible driving factors were the variability in surface fluxes near the oceanic mesoscale eddies, radiative processes in the cloud layer and condensation processes. The lifting of warm sector boundary layer air from widely differing sources into the free atmosphere at a front resulted in well mixed moist layers that exhibited near-thermal wind equilibrium.

1. Introduction

A project to study the interaction of the atmospheric and oceanic boundary layers with the larger-scale motions of the sea and air was proposed in 1966 by the Royal Meteorological Society to the Royal Society as an appropriate U.K. contribution to the Global Atmospheric Research Programme (GARP). It was envisaged that the project, to be called the Joint Air–Sea Interaction Project (JASIN), would involve the intensive study, for about a month, of the atmospheric and oceanic boundary layers over an area in the North Atlantic about 150 km across, with use of buoys, ships, balloons, and aircraft to observe the structure of the layers and their interaction with the larger-scale synoptic features.

More than ten years later, and after a series of preparatory experiments (Royal Society 1971), this initially British proposal led to an international experiment, JASIN 1978 (Pollard 1978; Royal Society 1979). The need for a large joint experiment arose from the complexity of the air–sea interaction problem. No individual can gather all the data he needs to investigate any single aspect of the interaction process, and the development of numerical models to simulate the behaviour of the atmospheric and oceanic boundary layers has been hindered for many years by the lack of an adequate data base.

Four years after the field phase it is appropriate to survey what has been found so far, which is the function of this Discussion Meeting. The closer one studies geophysical phenomena, the more complex are the structures one observes. JASIN has proved no exception, and consequently it is only just beginning to be possible to synthesize the many components of JASIN into a coherent picture. But the jigsaw is complex and many of the pieces remain to be filled in.

Nevertheless, it is hoped that the papers presented here will stimulate discussion of the physical processes occurring in the oceanic and atmospheric boundary layers, and lead eventually to a significantly improved understanding of those processes and their consequences.

2. Aims

The primary aims of JASIN 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, and (ii) to examine and quantify aspects of the momentum and heat budgets in the atmospheric and oceanic boundary layers and fluxes across and between them.

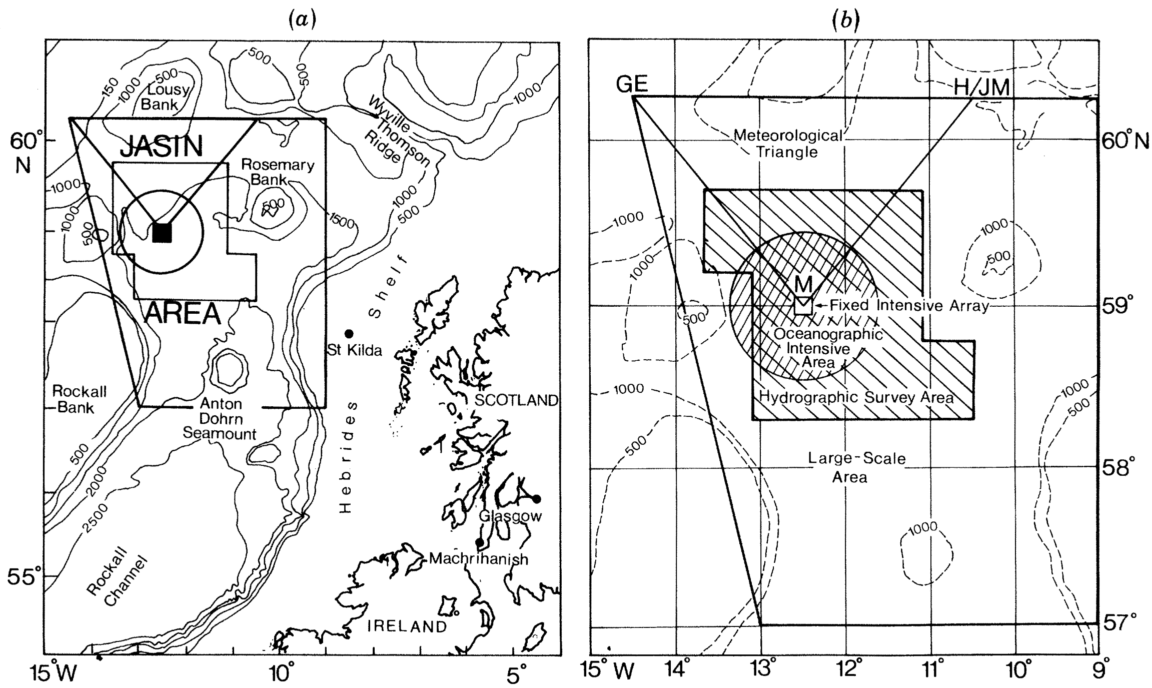

FIGURE 1. (*a*) The JASIN area in relation to the topography of the Rockall Trough. (*b*) The five nested areas, Large-Scale Area (300 km sides), Meteorological Triangle (180 × 180 × 220 km), Hydrographic Survey Area (150 km sides), Oceanographic Intensive Area (100 km diameter circle), and Fixed Intensive Array (6 km square). GE, H, JM and M mark the positions of *Gardline Endurer*, *Hecla*, *John Murray* and *Meteor*.

JASIN differed from previous experiments (e.g. the Atlantic Tradewind Experiment, ATEX (Augstein *et al.* 1973) and the GARP Atlantic Tropical Experiment, GATE (Siedler & Woods 1980)) in being an air–sea interaction study in the mid-latitude westerlies where the dominant physical processes might be expected to be significantly different from those in the tropics.

3. Logistic summary

JASIN 1978 took place for two months in summer 1978 in the North Rockall Trough, an area of deep (1000–2000 m) water several hundred kilometres across off the northwest coast of Scotland (figure 1). More than fifty teams of investigators from nine countries participated, using fourteen ships and three aircraft (table 1, figure 2). Thirty-five mooring systems were deployed (figure 3). The experiment lasted two months, from mid-July to mid-September, and was divided into three phases (figure 2), comprising two intensive measurement periods during phases 1 and 2 preceded by a preparatory testing period (phase 0).

Measurements were made in a number of nested and partially nested regions (figure 1*b*). Four meteorological ships (figure 2) occupied the corners (and, for phase 2, the centre) of the

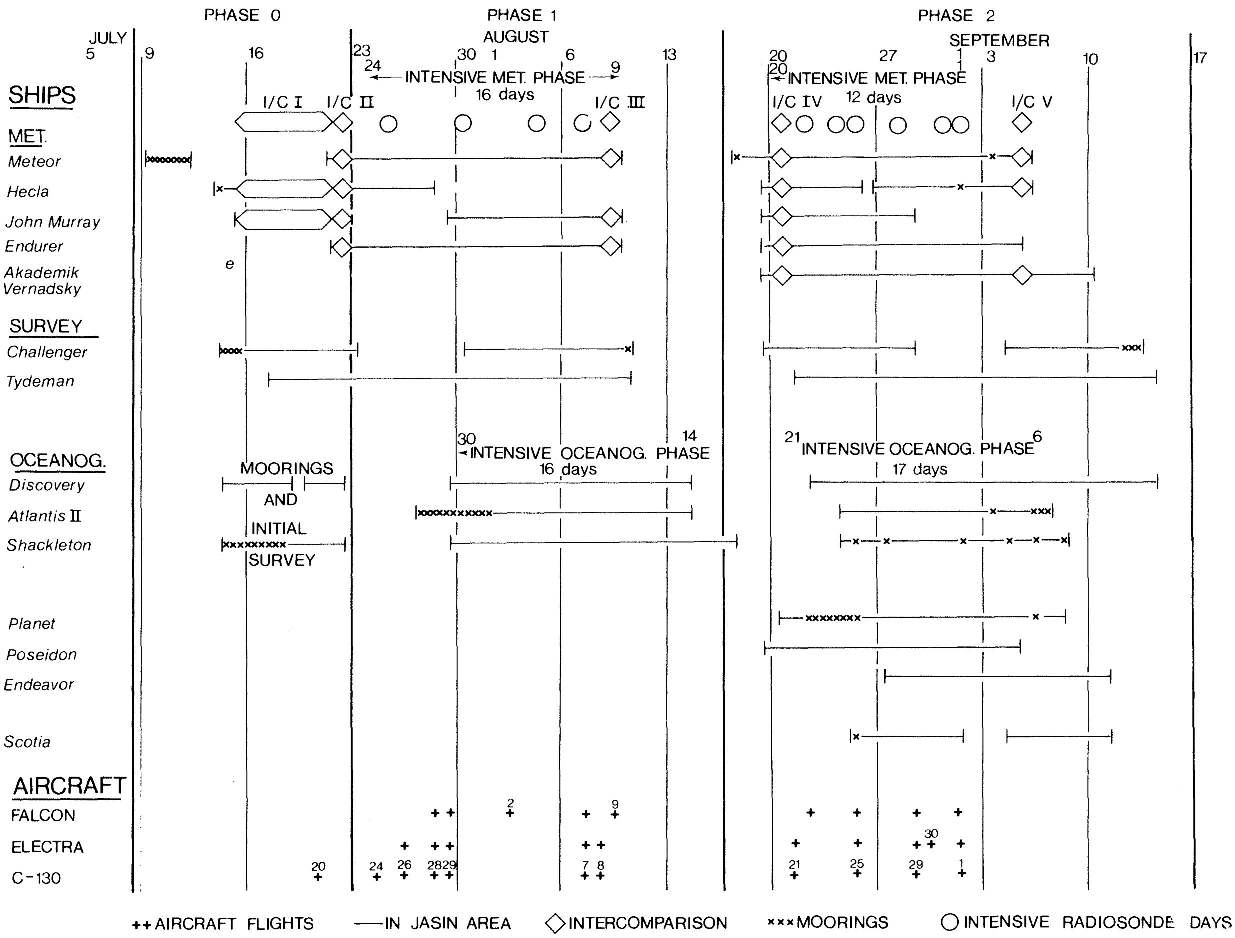

Figure 2. Ship and aircraft timetable, divided into primarily meteorological ships (met.), hydrographic survey ships (survey), and primarily oceanographic ships (oceanog.). The three main phases, intensive meteorological and oceanographic phases, intensive radiosonde days and intercomparison (I/C) periods are all shown.

200 km *Meteorological Triangle*. Surface meteorological parameters were manually sampled hourly, and were supplemented by meteorological instrumentation on ships, buoys, aircraft and satellites, providing a comprehensive data set discussed by Guymer *et al.* (this symposium). The meteorological ships carried facilities for launching and tracking LOCATE wind-measuring radiosondes. Three- or six-hourly flights were made for most of the experimental period, but on ten Intensive Radiosonde Days each ship launched at least twelve sondes between 06h00 and 21h00 G.M.T. at approximately hourly intervals. The IRDs have been used to calculate momentum and thermodynamic budgets for the lower layers of the atmosphere (Taylor *et al.* this sympo-

sium) and to study the three-dimensional structure of the boundary layer and of fronts (Taylor & Guymer this symposium).

During the intensive meteorological periods (figure 2), three aircraft operated from the JASIN Base at R.A.F. Machrihanish (figure 1). They flew on 18 days, generally in formation at different heights, repeatedly surveying 100 km box-patterns and 50 km L-patterns contained mostly within the meteorological triangle. Measurements made included direct fluxes (Nicholls *et al.* this symposium) and radiation (Slingo *et al.* 1982; Schmetz *et al.* this symposium).

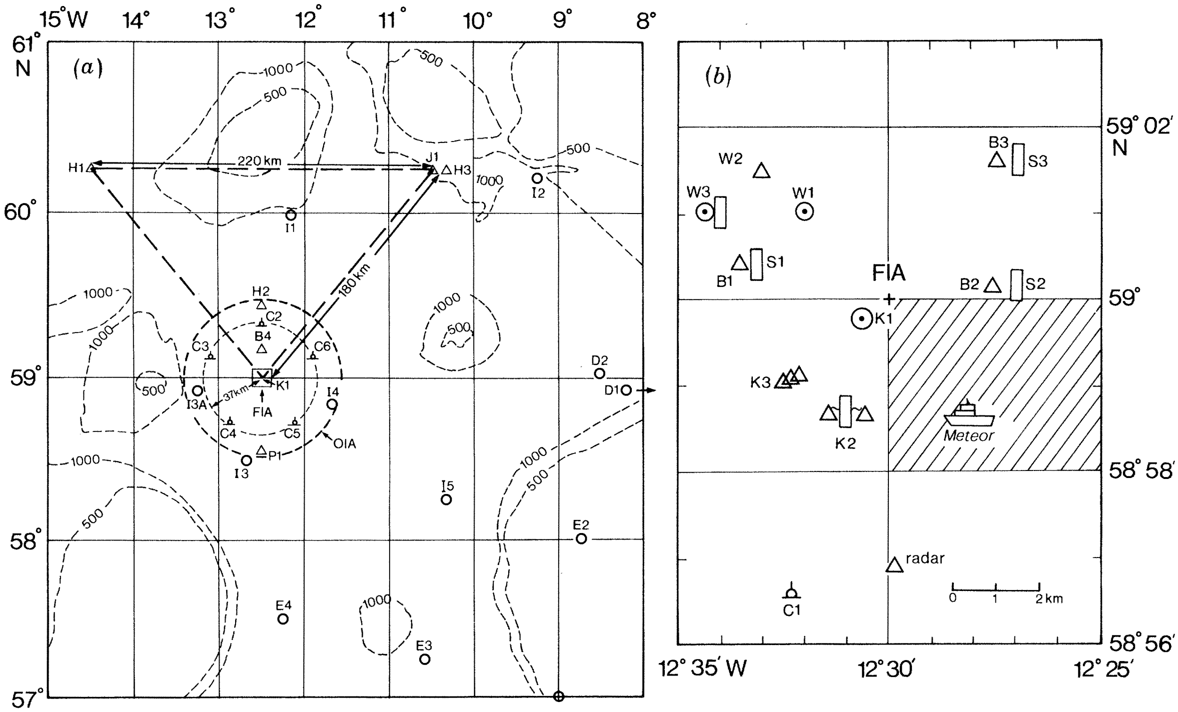

FIGURE 3. Moorings in (*a*) the Large-Scale Area, (*b*) the Fixed Intensive Array (FIA). Surface (triangles), spar (rectangles), subsurface (circles) and waverider (semicircles) buoys are shown. The spar buoys were tethered to adjacent surface moorings.

The *Large-Scale Area* (figure 1) covered most of the North Rockall Trough. It contained a number of moorings (figure 3) intended to reveal the synoptic velocity field in the ocean, but detailed salinity and temperature surveys were confined to the *Hydrographic Survey Area* (figure 1) in which R.R.S. *Challenger* repeatedly surveyed a grid of 15 km triangles 45 km apart (Ellett *et al.* this symposium). Hr.Neth. Ms. *Tydeman* also surveyed the *Hydrographic Survey Area*, partly to improve R.R.S. *Challenger*'s deep-station coverage, but mostly using repeated 'yoyo' sampling of the upper 300 m to study the distribution and storage of heat in the upper layers of the ocean (Prangsma *et al.* this symposium).

Oceanographic measurements concentrating on small-scale processes were confined to the *Oceanographic Intensive Area* (OIA, figure 1), and carried out by up to eight ships (figure 2, oceanographic ships plus R.V. *Meteor*). The highest concentration of instruments was in the *Fixed Intensive Array* (FIA, figure 3*b*) of moorings, which was designed to study the structure and propagation of surface-generated internal waves (Briscoe, this symposium; Levine *et al.* this symposium; Weller 1982) and the structure of the mixed layer and upper thermocline on scales from centimetres to kilometres, extended to tens of kilometres by using mooring H2 also (Weller & Halpern this symposium). Within the OIA, roving ships equipped with towed undulating conductivity–temperature–depth sensors, towed thermistor chains, and acoustic profilers surveyed fronts (Minnett *et al.* this symposium; Pollard 1982*a*) and examined mixed-layer dynamics (Pollard this symposium). Other observations included dissipation measurements (Oakey 1982), surface wave measurements, and gas transfer rates (Kromer & Roether 1981).

Table 1. International participation in JASIN 1978

country	number of ships (ships' days on station)	number of aircraft (aircraft flights)	number of participating groups	number of moorings
Australia	0	0	1	0
Canada	0	0	2	0
Denmark, Sweden	0	0	1	0
F.R.G.	3 (82)	1 (14)	13	12
Republic of Ireland	0	0	1	0
Netherlands	1 (50)	0	2	½
U.K.	7 (256)	1 (14)	13	13½
U.S.A.	2 (50)	1 (14)	18	9
U.S.S.R.	1 (23)	0	2	0
totals	14 (461)	3 (42)	53	35

4. Synoptic weather summary

At the start of phase 1 (20–29 July) depressions crossing the Atlantic from the southwest became slow-moving to the south of Iceland (figure 4*a*), and the fronts affecting the JASIN area were generally occluded. Wind speeds were 5–12 m s^{-1}. The complex low moved north and filled, and the period 30 July to 8 August was characterized by a slow-moving depression over the southern U.K. and a weak ridge to the west of the JASIN area (figure 4*b*). Convection in the cold northeasterly surface airstream was inhibited by potentially unstable warm air aloft. Weak fronts moved slowly westwards with occasional light rain and, on 4 August, a thunderstorm (Guymer *et al.* 1981). Wind speeds were 5–10 m s^{-1}.

On 9 August the ridge gave way and, until 21 August, there was a period of mobile westerlies with active fronts and troughs (figure 4*c*) and winds exceeding 10 m s^{-1} on several days. By the start of phase 2 on 22 August the situation was similar to that which had existed during phase 0 (14–19 July). A ridge extended northwestwards from high pressure south of JASIN (figure 4*d*) and weak disturbances propagating eastsoutheastwards initially passed north of JASIN. However, the synoptic pattern shifted very slowly westwards so that, by 30/31 August, JASIN was near the more active part of the systems and for a time experienced cold-sector conditions. After 1 September the fronts became quasi-stationary lying northwest–southeast across the area with waves travelling southeastwards along them. Then on 4 September a strengthening southeasterly flow developed ahead of an active occluded front, which approached from the southwest. Cyclonic conditions (similar to figure 4*a*) persisted until about 8 September followed by a return to mobile westerlies (figure 4*c*) at the end of the experiment.

5. Synoptic state of the ocean

The OIA (figure 1) was chosen, on the basis of surveys in preceding years, as the region within the North Rockall Trough where horizontal variability was expected to be a minimum. In 1978, however, mesoscale eddies and fronts were dominant features of the flow, and must be accounted for in all attempts to examine aspects of air–sea interaction.

An anticyclonic eddy (figure 5*a*) propagated westward across the OIA during JASIN, with its centre to the north of the FIA (Pollard 1982*b*). An anticyclonic meander of North Atlantic water (Ellett *et al.* this symposium) lay south of the FIA throughout the experiment. During phase 1 the FIA lay in the confluence zone between the anticyclonic eddy to the north, and the meander and a cyclonic eddy to the south (figure 5*a*). The resultant northwestward flow advected tongues of relatively saline water from the meander through the FIA (figure 5*b*)

Table 2. Summary of JASIN studies

topic	main data sources (scale)	references
	Atmosphere	
BL budgets	radiosondes (200 km)	Taylor *et al.*†, Günther & Olbrück (1983)
	aircraft (50 km)	Nicholls *et al.*†
turbulent structure of BL	aircraft (50 km), tethered balloons (hours)	Nicholls *et al.*†
radiation	aircraft (50 km)	Schmetz *et al.*†, Gube *et al.* (1980), Schmetz *et al.* (1981), Slingo *et al.* (1982), Devault & Katsaros (1982)
	ship (200 km)	Lind & Katsaros (1982)
fronts	radiosondes (200 km, 1 day)	Taylor & Guymer†, Taylor *et al.* (1981)
surface flow	ship, buoy, aircraft, Seasat (10s–100s km, days–weeks)	Guymer *et al.*†, Large & Pond (1982), Brown *et al.* (1982)
	Ocean	
large-scale water-mass structure	CTD/STD surveys, current meters (200 km)	Ellett *et al.*†, Pollard (1982*b*), Van Aken (1981)
upper ocean temperatures	Tydeman shallow CTD (200 km)	Prangsma *et al.*†
	FIA moorings	Siedler *et al.* (1982), Joyce *et al.* (1980)
internal waves	FIA current meters (km)	Briscoe†, Levine *et al.*†, Peters (1982)
fronts	Sea-Soar, drifting spar, CTD surveys, current meters (20 km)	Minnett *et al.*†, Pollard (1982*a*), Van Aken (1982)
mixed-layer dynamics	spar buoy, Sea-Soar, floats (km)	Pollard†, Saunders (1980)
	W2, H2 current meters (40 km)	Weller & Halpern†
dissipation	octuprobe (cm)	Oakey (1982)
surface waves, aerosols and gas transfer	waveriders, pitch–roll buoys	Stewart (1980)
	whitecap photographs	Monahan & O'Muircheartaigh (1980), Monahan *et al.* (1982)
	HF radar	Dexter & Theodoridis (1981)
	Radon 222 measurements	Kromer & Roether (1981)
	Seasat	
general	—	JPL (1980)
wind, stress	scatterometer (50–500 km)	Jones *et al.* (1981), Guymer *et al.* (1981), Guymer (1983), Liu & Large (1981)
water content	microwave radiometer (50–600 km)	Katsaros *et al.* (1981), Taylor *et al.* (1982), Taylor (1983)
wind, waves	altimeter and synthetic aperture radar	Allan & Guymer (1981), Allan & Guymer (1982), Webb (1981), Webb (1983), Thomas (1982), Vesecky & Stewart (1982)

Abbreviations: BL, boundary layer; CTD, conductivity–temperature–depth; STD, salinity–temperature–depth.
† Papers appearing in this volume.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

causing horizontal variability in the temperature–salinity relation. By phase 2 the anticyclonic eddy lay northwest of the FIA and both the FIA and the mooring H2 (figure 3) lay on its eastern flank, experiencing southward flow and advection of cooler fresher water from the north. Maps of mixed-layer temperature show the tongue of relatively warm saline water to have been advected in a nearly complete circuit around the eddy (Guymer *et al.* this symposium) forming a thermoclinic but only weakly baroclinic front with the cooler fresher water at H2 (Minnett *et al.* this symposium).

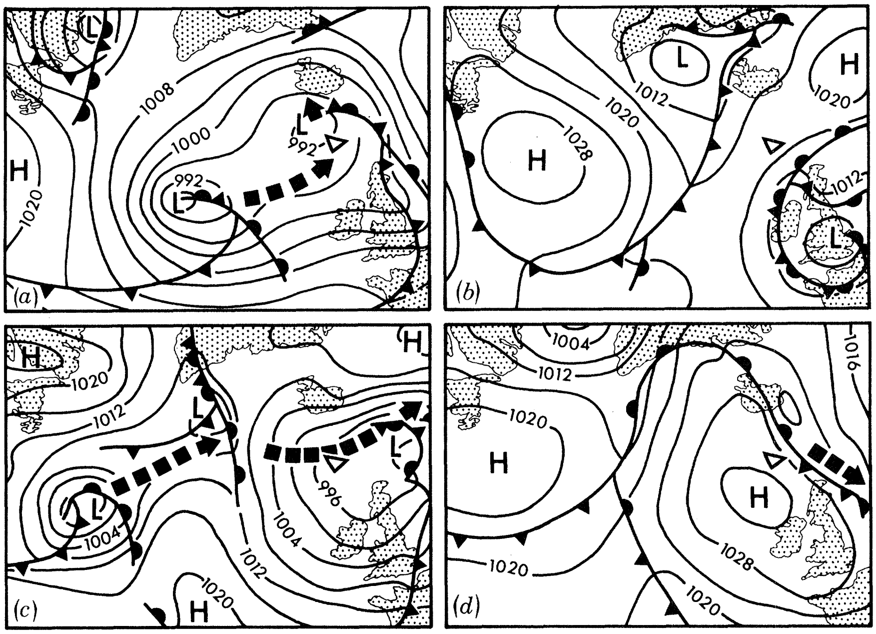

FIGURE 4. Synoptic charts illustrating the different weather types during the JASIN experiment. The bold arrows indicate the movement of the systems. The examples shown are (*a*) 26 July (cyclonic southwesterly); (*b*) 2 August (blocked); (*c*) 15 August (mobile westerly); (*d*) 26 August (moist anticyclonic).

In calculating heat budgets for the upper ocean throughout JASIN, Prangsma *et al.* (this symposium) find that averaging over the eddy scale reduces the contribution of horizontal advection to generally 20% or less of the surface flux, though the role of the eddy in stirring the surface layers can be seen by comparing surface-temperature and dynamic-height contour maps (Prangsma *et al.* figure 5). On smaller scales, Pollard (this symposium) finds slopes in mixed-layer depth after wind mixing and consequent geostrophic shears related to the horizontal density gradients across the eddy. Both Weller (1982) and Pollard (this symposium) find that the amplitudes of wind-generated inertial oscillations are modified by the mesoscale flow.

6. Seasat and JASIN

Fortuitously, JASIN took place during the three-month period in which Seasat was operational (Allan & Guymer 1980), and the detailed JASIN surface measurements were used to provide extensive 'ground truth' to evaluate and improve the algorithms used to convert Seasat sensor readings to geophysical units (Jones *et al.* 1981; Webb 1981, 1983; Katsaros *et al.* 1981; Taylor 1983). In turn, JASIN has benefitted from the spatial coverage afforded by Seasat,

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

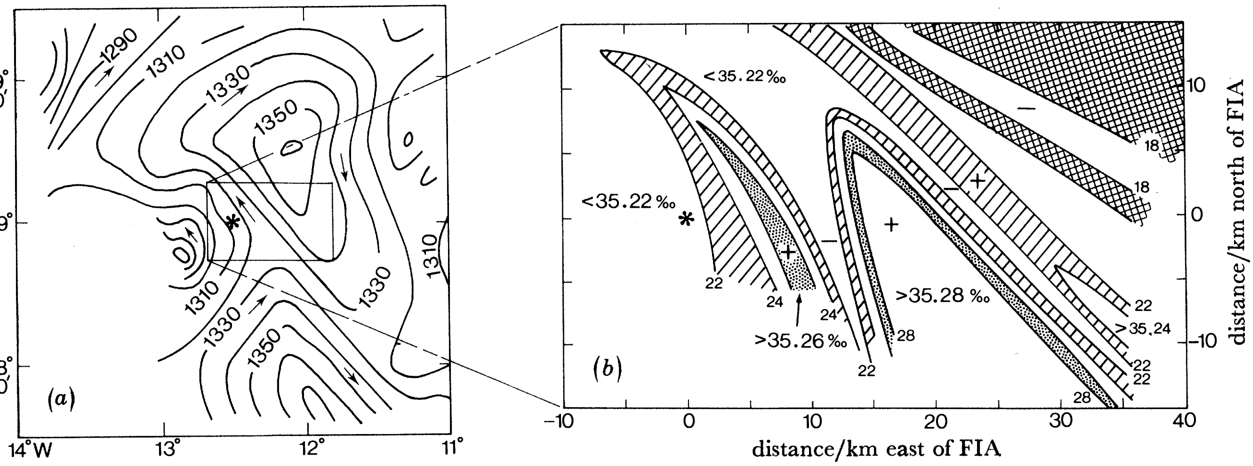

FIGURE 5. (Adapted from Pollard 1982*a*.) (*a*) Dynamic height contours in dynamic mm for the 10 dbar pressure level (i.e. the surface layer) relative to the bottom. (*b*) Salinity contours on the 26.9 kg m^{-3} density surface, which lies in the seasonal thermocline. The FIA (59° N, 12° 30′ W) is marked by an asterisk.

in particular for obtaining fields of surface wind velocities, wind stress curl (Guymer *et al.* this symposium; Guymer 1983) and atmospheric water content (Taylor *et al.* 1981, 1982).

7. Discussion

In this paper we have provided a brief logistic background and general synoptic descriptions to serve as a context within which to place the many JASIN studies. Space does not permit individual mention of the many studies not discussed elsewhere in this volume, but they are summarized together with the main publications to date in table 2. Subsequent papers in this volume (also included in table 2) give further details of measurement systems and analysis methods, and attempt a synthesis, mostly by the joint analysis of several investigators, of the main scientific points to emerge from the various sub-programmes to date.

Some impressions of the scientific results of JASIN, four years after the field experiment, are given by Businger & Charnock in the final paper of this volume. In addition to evaluating the success of JASIN they examine its wider relevance within GARP and attempt to identify problems that remain to be solved before more satisfactory mathematical models of the atmosphere and oceans can be constructed. It is perhaps appropriate to point out that JASIN was administered differently from other large experiments in that it had a very small overall management team and relied heavily on individual participants accepting organizational responsibilities. Without this close cooperation a successful experiment could not have been mounted.

It is anticipated that further analysis will be undertaken by participants with opportunities to pursue interesting features of the analyses in more detail. Others not directly involved with the experiment will also wish to use the data, especially members of the modelling community, for the data set provides a unique opportunity for formulation of models of air–sea interaction and links with larger scales. For these reasons a substantial effort is being made to archive a large proportion of well documented JASIN data in a form that is readily accessible. Responsibility for this phase is being undertaken by the Marine Information and Advisory Service of the Institute of Oceanographic Sciences, Wormley.

It is our hope that this volume of scientific results will alert meteorologists, oceanographers and others to the existence of a new and comprehensive data set and that many will be stimulated by it.

The JASIN experiment took place in the summer of 1978, more than a decade after it had been conceived by Professor Henry Charnock, F.R.S., and the late Dr Tom Ellison, and after three preliminary field trials and experiments in 1970, 1972 and 1977. Many people have assisted the Project in that long period. The Royal Society, through the Atmospheric Sciences Panel (Chairman, Professor Peter Sheppard, F.R.S.) and the Air–Sea Interaction Subcommittee (Chairman, Professor Charnock; Secretary, Mr Chris Argent) of the British National Committee for GARP, has sponsored and guided the Project throughout. Many institutes and funding agencies have made large contributions of personnel, ship and aircraft time to the Project.

The logistics of the two-month long field experiment were carried out with remarkable success, owing in no small measure to the tireless efforts of the Project Manager, Mr Arthur Fisher and the Aircraft Coordinator, Dr Chris Readings. In the field, the wholehearted cooperation of the officers, engineers and crew of all ships and aircraft, the staff of the Clyde Port Authority, R.A.F. Machrihanish, the JASIN Ship Base, Adair Distribution and Storage Ltd, Oban Radio, Denholm Ship Agency Ltd, Glasgow University, the City of Glasgow District Council and many other bodies and individuals contributed to the smooth running of the Experiment.

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