(3) Future of the Working Group: If the proposed further intercomparison experiment is approved, it will be necessary for the group to continue its existence until the analysis of the results of that experiment is completed. SCOR is invited to consider the desirability of enlarging the group by including Dr. F. Webster and a representative from Canada (Bedford Institute) in view of their present and proposed future activities on its behalf.

ANNEX IV

REPORT OF SCOR WORKING GROUP 28

IAMAP/IAPSO/SCOR COMMITTEE ON AIR-SEA INTERACTION

REPORT OF MEETING IN PRINCETON, NEW JERSEY, 21-23 JANUARY 1969

The Meeting was attended by the following:

K. Bryan, H. Charnock (Chairman), A.S. Monin, J. Namias, C.H.B. Priestley, R.W. Stewart, P. Welander, O.M. Ashford, V.A. Bugaev, J. Smagorinsky.

The report is extracted below. Apart from administrative matters, other items not reproduced here include a discussion of air-land interactions in relation to GARP.

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6. Air-sea interaction in relation to ocean circulation studies

Some models of ocean circulation take the surface fluxes as given, though coupled atmosphere-ocean models have been studied. The main difficulty appears to lie in representing turbulent transport within the ocean.

More realistic representation of the near surface transport of heat, salt and momentum is hindered by our ignorance of the velocity structure of the upper layers of the ocean. Any method of observing the current distribution while avoiding the effects of waves would be of great interest.

The study of the response of the ocean to the atmospheric forcing, on all scales will be helped by the increased amount of data available but a corresponding increase in oceanic data is also needed if the full benefit is to be obtained.

7. Air-sea interaction in relation to GARP

There was a wide ranging discussion of this topic, it being realized that the planning for GARP was still in such a formative state that unequivocal answers to many questions could not yet be provided. Nevertheless there was a growing need to start the development of instruments so as to allow their field testing before the main GARP Global Experiment.

The basic assumption made was that GARP would seek a realistic mathematical model of the whole atmosphere and of the upper layers of the ocean, with an observational grid of about 500 km in the horizontal and with about 10 levels in the vertical.

(a) General policy on boundary layer incorporation

It will be essential to take into account the transfer of heat, water vapor and momentun by processes on too small a scale to be resolved by the observational network. The transfers with which the committee is concerned are most important in the layers near the surface.

A frequently occurring case is when the heat gained at the surface is fairly uniformly redistributed through a boundary layer limited from above by a stable layer. In this case it may be possible to model the boundary layer using only the free atmospheric variables, provided by the model, and the sea surface temperature. The upper surface of the boundary layer would provide the bottom boundary of the model; its (variable) height and the implied vertical velocity could be specified by empirical means.

No experience has been gained using this explicit boundary layer formulation. It is at present only crudely developed but could possibly be refined to the extent that useful estimates of low cloud amounts would be possible.

Present large-scale models represent the boundary layer by specifying values of an exchange coefficient at various heights. Since the flux divergences are important at low levels this method requires that the lowest levels of the model be within the boundary layer, preferably within the surface (constant-flux) layer.

It may be possible to allow the exchange coefficients to vary not only with height but also with an appropriate stability parameter, itself determined by the variables (UVTr) of the model. In this case the methods are formally equivalent, if there is sufficient detailed computational resolution at many levels near the surface.

In both methods it is difficult to foresee the effects of motions on a scale greater than the height of the boundary layer but smaller than the grid size. Both also require a knowledge of the sea surface temperature.

(b) The treatment of mesoscale circulations

This is a general problem and we are concerned only with mesoscale circulations which affect the structure of the boundary layer. The difficulty is partly theoretical but more due to the lack of information as to the magnitude of the motions concerned and of their spatial correlation. In view of their importance to boundary layer structure and their relevance to the problem of the representation of volume averages by point observations the committee recommends that every effort be made to study their magnitude and their effects.

(c) Research needs

The need for study of mesoscale observations has already been stated.

The effective representation of boundary layer phenomena requires much more work on empirical methods for estimating turbulent transfer through a stratified atmosphere and on the mechanics of the boundary layer over the sea. Both theoretical and observational studies are needed.

The structure of the oceanic boundary layer is very badly known, especially the distribution of velocity in it. Any estimate of the distribution of turbulent fluxes in the upper layers of the ocean will be especially valuable not only for GARP but also for studies of the atmospheric circulation.

(d) Observational needs for initial conditions and for verification of long term model integrations

We take as an initial estimate that observations of UVTr will be needed, as initial conditions, at a spacing of about 500 km in the horizontal and at about 10 levels in the vertical. Since the initial conditions may include the time history of the observations, and for verification purposes, they will be taken twice daily for a period of a year or more.

Efforts are being made to extend the observational network to meet these requirements but difficulties are to be expected, especially in oceanic regions. We assume that a sufficient num-

ber of ocean weather ships, or large (manned or un-manned) buoys moored in the deep ocean, though desirable, will be prohibitively expensive. Tropospheric upper-air observations of UVTr can perhaps be made from merchant ships and supplemented in some areas by using large moored buoys (of the monster buoy type) as platforms for both sea-surface and upper-air observations. In this case every effort would be made to get detailed observations in the lower 150 mb and accurate observations of representative sea temperature, both at the sea surface and to a depth of at least 50 m.

The sea surface temperature would be known. For short period forecasts (up to 4 days) the climatological values can perhaps be taken. Three to seven day forecasts require recent observations to map any large (exceeding 0.5°C) sea surface temperature anomaly. Longer period forecasts will need a calculation of the temperature structure of the upper ocean, to an increasing depth as the period of the forecast increases.

Whether observations would be essential at a height below 10 m depends on the method adopted for the incorporation of the boundary layer. They would be more desirable if the model used had several levels within the boundary layer. Such observations are technically difficult but they would allow reasonably direct estimates of the initial surface fluxes (T_o, H_o, E_o). Their main purpose would probably be for verification. They could be used to check that the surface fluxes produced by a model were sufficiently realistic, both for climatological purposes and for studies of the ocean circulation.

At this stage it is impossible to foresee what the near surface observational need of GARP will be. Many combinations of methods, techniques and platforms are possible; nevertheless it seems prudent to investigate the potential performance and cost of some of those which seem likely to be useful.

The committee therefore recommends a design study of prototype buoys of the following kinds:

(i) a simple, disposable drifting buoy which will observe and telemeter a near sea-surface temperature to an accuracy of 1/4°C or better.

(ii) a similar buoy with an added capability for observing and telemetering surface pressure, to 0.5 mb or better.

(iii) a similar buoy which will observe and telemeter sea temperature at ten or more levels between the surface and, say, 50 m, with an accuracy of 0.1°C or better.

(iv) a similar buoy to observe and transmit surface pressure (to .5 mb) as well as the sea temperature to 50 m (to 0.1°C).

(v) a fixed or drifting buoy which would observe and transmit:

pressure to 0.5 mb.
sea temperature (surface to 50 m) to 0.1°C.
difference between sea temperature and air temperature (at a height between 2 and 10 m) to 0.5°C.
difference between sea temperature and wet bulb temperature (at a height between 2 and 10 m) to 0.5°C.
mean hourly wind speed (at a height between 2 and 10 m) to 1 m/sec or 10% of the wind speed.
wind direction (averaged over up to 1 hour) to 10° or 15°.

The capability of such a buoy for recording the duration of bright sunshine should be investigated, as should the possibility of monitoring some characteristics of rainfall.

It can be assumed that the signals will be transmitted via satellite and that drifting buoys will be located and their position relayed by satellite also. Some useful information on surface currents could be obtained from buoys with suitable sea anchors.

It would be an advantage if these buoys were sufficiently compact and robust to permit launching from aircraft. Their desirable life expectancy depends on their unit cost and the cost of launching: no detailed calculation has been made but a rough estimate is that they should survive for 100 days.

The committee recommends that the need for buoys of these types be made known to commercial firms, perhaps through a notice (from the JPS of the JOC for the GARP) in suitable journals such as Oceanology and Marine Technology. It will be clear that no firm estimate of the numbers which will be needed can be made at the present time, though a relatively small number will surely be useful for special projects.

9. Air-sea-land interactions

It was agreed that important processes of energy transfer took place in and over relatively narrow strips of ocean bordering land masses and often over the continental shelves.

The committee recommended that particular attention be paid to these areas, both theoretically and by observation, in the hope that they could be well represented in numerical models of the atmosphere and the ocean. This might need a reduction of the grid size in these areas since the processes were often intense but on a relatively small horizontal scale.

10. Air-surface interaction in relation to seasonal and long-term developments

It was appreciated that the increased density of observation associated with the GARP developments would provide a stimulating input to research on this aspect.

As these longer term developments would be difficult to simulate numerically the committee recommends that a group or groups be formed to study the incoming data, in real time, by existing empirical and statistical methods. Experience has shown the important role played by such groups in isolating and clarifying the new problems to which new sorts of data provide access.

It was assumed that attention would be paid to the archiving of the data so that it would be readily accessible to future workers. Correspondingly, in order to optimize the usefulness of past data, considerable weight should be given to the WMO Historical Sea Surface Temperature Project. The Committee was informed of this project, but its present status was not known.

12. The WWW and IGOSS network

The WMO representative gave a brief report of the increase in upper air observing stations. These included 100 more stations before 1971, mainly overland but some on small islands. Apart from some in Latin America most were in the Northern Hemisphere and it was felt that the provision of observation from the Southern Hemisphere would present grave problems.

Every effort was being made to install radio sonde and wind finding gear in merchant ships. The USSR was contemplating providing 3 ocean weather ships whose positions were not yet decided, though it was possible that one would be sited in the Atlantic, one in the Pacific and one in the Indian Ocean.

Little information was available about the IGOSS network. It was hoped that it would be integrated with that of WWW so far as was possible. Some of the possible IGOSS components might well be situated in places where air-sea-land interactions were of great importance.