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Report of Scientific Discussion Meeting on the Physical Oceanography of the Great Barrier Reef Region

Held at the University of New South Wales

5–6 July 1982

Jason H. Middleton

AUGUST 1983

GREAT BARRIER REEF MARINE PARK AUTHORITY

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REPORT

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SCIENTIFIC DISCUSSION MEETING ON THE PHYSICAL OCEANOGRAPHY OF THE GREAT BARRIER REEF REGION

Held at the University of New South Wales

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with support from the Great Barrier Reef Marine Park Authority

and the Australian Academy of Science

JASON H. MIDDLETON

SUMMARY

A scientific discussion meeting was held in July 1982 to generate a statement concerning the physical oceanography of the Great Barrier Reef region. The statement was to be framed by answering the questions below:

(a) What is the present state of knowledge?
(b) What appear to be the most important unanswered questions?
(c) With regard to (a) and (b), what methods would be most effective in answering the questions posed in (b)?
(d) What routine monitoring measurements would appear to be of most scientific value in increasing our knowledge of the region?

This report summarises the discussions of the meeting.

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1. SUMMARY OF IMPORTANT SCIENTIFIC QUESTIONS

The meeting identified a number of important scientific questions. These were of two types:

(i) What is the description of certain events? and

(ii) Which model is needed to predict these events.

Considering events in decreasing time scale, the following statements summarize the important questions addressed in the body of the report.

(a) Climatology and Large Scale Circulation

In order to construct a model of the mean circulation we need to parameterise flow across the outer boundary reef (in terms of swell, tides and topography) and also to parameterise the internal friction and bottom friction due to the reefs within the Lagoon. To operate or test a model we need a description of the wind forcing (climatology), fresh water inflow,dynamic height and baroclinic motions at the shelf edge (Coral Sea).

From a validated model might come knowledge of the rate of mixing of coastal water and the transfer rate of water across the Lagoon ocean boundary.

(b) Long Period Motions

We need a description of the circulation that results from the forcing at the Lagoon boundaries (open ocean, wind forcing, river inflow) which occurs at periods of a few days to many months (seasonal).

We need to know which are the dominant forcing mechanisms for the currents on these time scales. Wind forcing is one candidate but geopotential anomalies which impose alongshore pressure gradients may also be important. We also need to know the effect on Lagoon circulation of baroclinic (internal) motions in the Coral Sea. How well can long period waves be explained by wind forced models, if the effects of reefs are appropriately parameterised?

(c) Episodic Events

Two obvious transient events are floods and tropical cyclones. We need to determine from measurements how large is the storm surge response from these events (particularly from strong winds and cyclones). Can existing models of storm surge and the surface wave field from these episodic events explain the observations?

(d) Tidal Motions

We require a descriptive study of tide height, current and internal motion to facilitate modelling and eventually model testing.

We need to demonstrate that non-linear tidal effects (such as reef induced mixing) in the Great Barrier Reef Lagoon are important and also need to develop models of these non-linear effects.

(e) Surface Waves and Swell

We need to parameterise the propagation of swell across the coral reefs. It would be useful to know the climatology of surface waves for input to models of circulation that use swell as a parameter.

2. INTRODUCTION TO WORKSHOP REPORT

The impetus for this meeting stemmed from discussions with Professor John Swan (Australian Marine Sciences and Technologies Advisory Committee) and Mr Graeme Kelleher (Great Barrier Reef Marine Park Authority) who saw the need for an overview of knowledge in the rapidly accelerating research effort aimed at understanding the physical oceanography of the Great Barrier Reef region.

The meeting focussed solely on physical oceanography as the range of issues within this field are complex and occur over a wide variety of spatial and temporal scales. The scope therefore does not extend to multidisciplinary aspects, although it is hoped that this report may help in the identification of areas of physical oceanography relevant to other disciplines.

The object of the meeting was to generate a statement concerning the physical oceanography of the Great Barrier Reef region, this statement to be framed by answering the following questions:

(a) What is the present state of knowledge?

(b) What appear to be the most important unanswered questions?

(c) With regard to (a) and (b), what methods would be most effective in answering the questions posed in (b)?

(d) What routine monitoring measurements would appear to be of most scientific value in increasing our knowledge of the region?

All present and past researchers in the field were invited to attend, as were the more experienced Australian physical oceanographers without direct Barrier Reef experience. The participants and their addresses are listed in Appendix 1. Brief summaries were presented by some participants (indicated in the list by an asterisk) after which the participants broke up into groups to draft sections of the report. An edited version of the material written during the workshop was circulated widely for comment, and all comments have been incorporated into this report. As far as possible it has been editorial policy to retain original wording and to preserve the emphasis placed on topics by the workshop participants.

The workshop has concentrated on that research conducted in the last five years, and the extensive review by Pickard *et al* (1977) provides many of the foundations for this report.

The reference list has been largely restricted to publications in refereed journals, and those references prior to 1976 do not appear here as they appear in Pickard *et al* (1977). Internal reports have also been included where these are a sole reference, while conference proceedings have not been included.

Towards the end of the workshop, the possibility of a large scale multi-institutional experiment arose in discussion since many participants felt that such an experiment was the only way of answering some of the questions posed.

The following four sections comprise the answers to the posed questions, while references and the list of workshop participants follow.

3. THE PRESENT STATE OF KNOWLEDGE

(i) Bathymetry

Substantial bathymetric surveys have been undertaken in recent years by the Navy using both ship-borne depth sounders and airborne laser. These have enhanced knowledge of reef topography and of selected channels, but there remains some need for more detailed bathymetry in areas far from shipping routes and particularly on the continental slope. Landsat processing, involving work by David Jupp (CSIRO), ASO and DMS will give bathymetric data for the top 15 m in two years for the entire Great Barrier Reef Region.

(ii) Meteorology

Several offshore meteorological stations are maintained by the Bureau of Meteorology, but these are mainly in the southern region and most physical studies are obliged to set up their own automatic stations if wind and mean sea level pressure are required. The Bureau has available mean sea level pressure analyses on a 3^{o} x 3^{o} grid at 6 hourly intervals but it is not known whether the interpolated surface wind (calculated from the geostrophic approximation) or the interpolated mean sea level pressure would be sufficiently accurate for studies of, for example, wind driven circulation or wind wave generation and associated erosion or sedimentation. Such a calculation has proved adequate on the North American West Cost. Wolanski (1983) has made a study of the trade winds over the Coral Sea and the Great Barrier Reef.

(iii) General Hydrography and Large Scale Circulation

Since the review by Pickard et al (1977) there has been additional work in the Coral Sea by CSIRO in the region immediately adjacent to the Great Barrier Reef showing an East Australian Current starting at about $18^{o} \pm 2^{o}$, strengthening as it goes south. Andrews and Gentien (1982) found the East Australian Current off Townsville pulses four times a year. Church and Boland (1983) describe the existence, at 18°S, of a southward flow in the top 300 m of the Coral Sea immediately adjacent to the reef with a permanent northward flowing undercurrent between 400 m and 1000 m. Church and Golding (1983) describe the data collected in the western Coral Sea by CSIRO during 1980 and 1981. There exists sufficient data to give a reasonable seasonal climatology of temperature and salinity and Ridgway has determined mean and seasonal temperature-salinity relationships for the western Coral Sea, and shown that these relationships are sufficiently reliable that the dynamic height may be computed from the temperature field along.

Water properties are known to be different inside the Lagoon compared with those of the Coral Sea. In the Lagoon the water appears to be well mixed in the vertical direction, except for depths greater than 40 m during October through December when weak stratification may exist. Pickard et al give typical values of temperature and salinity as a function of season, but the only study of differences either side of the Reef has been made by Andrews et al (1982) in a rectangle (at 18°S 100 km along the reefs, from the Lagoon to the Coral Sea. There are no studies of differences in hydrographic properties at any other latitudes. Andrews and Gentien (1982) found that meanders of the East

Australian Current occur with 90 day period and force upwelling on the slope to the shelf break. Nutrients are pumped inshore from the shelf break in a bottom Ekman layer forced by periodic (about 20 days) reversals in the longshore wind component. Upwelling intrusions penetrate the entire reef zone, but rarely enter the Lagoon. These two processes (East Australian Current and wind stress) produce an enrichment equivalent to about 175 g cm^{-2} yr^{-1} in a 50-60 km strip in from the shelf break.

Cross shelf baroclinic transport has been studied in a 200 km longshore strip, by correlating thermoclinic waves (created by onshore surges of shelf break water) with winds, atmospheric pressure and mean sea level (Andrews, 1982). Longshore winds produce thermal waves of periods near 4 days in summer and 8 days in winter which travel northwest at 50 km/day. Longer period (10 to 70 day) waves do not travel, but form a standing wave with an antinode east of Townsville.

On a smaller scale there have been studies related to the following:

1. Mixing of river plumes showing persistence of sharp fronts and large separate patches of order 30 km (Wolanski).

2. Flushing of small lagoons inside reefs, indicating flushing times of a few days (Wilson), to a few hours (Andrews _et al_, 1982).

3. Observations of cold water upwelling onto the shelf and mixing with shelf water (Andrews).

4. Mixing associated with low Richardson Number has been observed over the slope outside the reef (Wolanski).

5. Mixing within Reef structures (Andrews and Muller, 1982).

6. Mixing behind islands and reefs due to the wake (Wolanski, Jupp, Heron).

(iv) Tidal Currents and Heights

A sea level data bank is archived at F.I.A.M.S. Constants have been analysed for many stations and are archived by Lennon at the Tidal Laboratory at Flinders University. In addition, tidal height data is being collated by Hamon.

Current data has been collected by several institutions: AIMS (Andrews, Wolanski), BMR (Davies), CSIRO (Church), DOT (Crossing), LIRS (Goldman), QU (Orme), UNSW (Middleton) and some of these data analysed for tidal currents. There appear to be no present plans for collation of current tidal data as is being done for heights. There is evidence that tidal currents are not as regular or predictable as tidal heights but an explanation is lacking. For some locations it may not be meaningful to list amplitude and phase "constants" for tidal currents.

Numerical models of tides (Apelt, Bode, Easton) are in various stages of development but are all depth integrated (barotropic). Numerical models are generally recognised to provide tidal heights and currents to a reasonable predictive level provided reasonable data is available as boundary forcing, and an appropriate parameterization of the reef on the flow is made.

Aspects of flow across and around reefs are being investigated theoretically (Middleton, Buchwald, and Huthnance (1983), Church and Wilson).

Baroclinic tides have been observed by Boland and Church in the continental slope region at 18°S.

(v) Longer Period Currents and Heights

A drift card study centred at Townsville shows most strong southeast winds generate a northwestward surface flow, but that flow is to the southeast during other wind conditions (Walker and Collins, 1980, 1983). Observations during 1982 show that northwestward flow during southeast winds occurs along the whole GBR (Walker and Collins, 1983). Surface drift-cards (Walker and Collins) and surface drogues (Woodhead, 1970) suggest that during periods of non-southeast winds a complex surface circulation may occur in the region of the Capricorn Channel. Belperio (1978) released four series of bottom drogues within 15 m near Townsville. Three of these were during southeast winds and the drogues moved to the northwest. The fourth was during light northwest winds and moved to the southeast. Finally, MacFarlane (1980) released surface drogues in the Gulf of Papua and a number of these landed on the northeast Queensland coast as far south as 25°C.

Locations of meteorological, pressure gauge and current meter stations within the shelf and offshore regions of the northeast Australian coast up to mid 1981 are presented in various publications including Cresswell and Greig (1978), Church (1982), Wolanski and Ruddick (1981), Wolanski and Jones (1982), Wolanski and Bennett (1982) and Middleton (1983). More recent wind, current and pressure gauge moorings covering November 1981 to October 1982 are now in place from Cape Upstart to Cape York under a joint experiment by AIMS, UNSW and IOS.

On seasonal time scale, flow within the Lagoon tends to be northward north of about 18°S and southward at higher latitudes. During the summer season the flow may be variable in the north. These features are probably the result of differing balances between wind stress and imposed pressure gradient (due to variation in dynamic heights in the Coral Sea).

On subseasonal time scales, wind forcing is known to produce fluctuations of the order of days to months in the central reef section (Cape Upstart to Carter Reef). Wolanski and Bennett (1982) argue that fluctuations are predominantly first mode wind driven barotropic shelf waves, while Middleton and Cunningham (1983) identify first mode wind driven shelf waves in the region from the Capricorn Channel to the Whitsundays, although the evidence indicates that the presence of the extensive Swain Reefs substantially modifies the flow (Middleton, 1983).

Wind stress and friction appear to be important everywhere on the shelf in regions already studied. Wolanski and Ruddick (1981) have discussed the evidence for shelf waves in the far north, while Wolanski and Hughes (1982) have argued the case for wind-driven kinematic waves at about 10-12^{o}S.

Numerical models of wind driven circulation (Bode) have been initiated for the southern section but these are in the preliminary stage. These need time dependent wind forcing as an input and, as for tides, good bathymetric parameterization of the reef.

The radar scanning system of Heron (COSRAD) is able to provide data on surface currents and directional wave spectra over a swath of 60^{o} and to distances of 100 km from the location of the mobile transceiver. While this system is still in the testing phase, the potential for detailed studies of circulation is large.

(vi) Wind Waves and Swell

Wave measurement buoys have been deployed by the Beach Protection Authority at sites off Cairns, Townsville, Bowen, Mackay, Gladstone and Bundaberg (Cook, 1981). Details are becoming progressively available from that Authority. These buoys are located reasonably close to shore and no information is available on the outer edges of the continental shelf or in the Coral Sea. Substantial theoretical and numerical work is outlined in the many references by Sobey, Stark, Harper and Young.

(vii) Tropical Cyclones

Predictability of tropical cyclones as events is not yet satisfactory. The effects of tropical cyclones on flow in general within and outside the reef has been studied extensively by Sobey, Harper and Stark (1977) with numerical and theoretical methods. Field studies of cyclones (as being undertaken off the North West shelf by Imberger and Steedman) would provide much needed information.

4. THE MOST IMPORTANT UNANSWERED QUESTIONS

(i) Bathymetry

A knowledge of the precise topography and character of the reef and continental slope is lacking in many areas particularly those away from shipping routes. This knowledge is important to circulation and mixing studies on the shelf, and on the slope where circulation is strongly controlled by local bathymetry (submarine canyons).

(ii) Meteorology

The nature of the wind forcing over the Coral Sea and Great Barrier Reef Region needs to be known as a function of location in order to determine wind driven circulations. In addition, the mean sea level pressure needs to be known in order to remove the "inverse barometric effect" when calibrating sea level data. Wind velocity is required when investigating wind waves, and air and sea surface temperatures are needed to specify boundary layer stability in wind-drag and wind wave generation models.

(iii) General Hydrography and Large Scale Circulation

The following appear to be the most important scientific questions:

1. How does the reef affect transfer, diffusivities etc. as boundary conditions for analytical and numerical models? How much transfer occurs in channels and across reef flats?

2. What are the surface fluxes of heat, salt and momentum?

3. How much mixing occurs to coastal water (including that from mangrove swamps and rivers) before it reaches and influences the local reefs? What is the nature of sediment transport?

4. What factors significantly affect transfers between lagoon water and ocean water? What is the heat and salt balance for the whole Lagoon?

5. What are the effects of tropical cyclones on mixing?

6. What is the relative importance of various mixing processes, such as surface mixing, bottom stirring and reef effects? How much mixing occurs in wakes etc. behind reefs?

(iv) Tidal Currents and Heights

The most important scientific questions are as follows:

How does the tide progress: on the shelf break?
across reefs of varying topography?
in the Coral Sea?

What is the transparency of the reef to long waves?

What is the nature of the tidal response/resonance of the Coral Sea?

Why does there appear to be a seasonal nature to the response of the tide in the Lagoon?

What is the nature of internal tides on the continental slope as a function of latitude?

What are the characteristics of tidal components of current measurements already made?

What are the irreversible effects of tides such as residual circulation and mixing?

There are inadequate measurements in the region north of 13^{o}S and south of Townsville at present although presently deployed instruments will rectify this to some extent.

(v) Longer Period Currents and Heights

As for tides and general hydrography, the nature of flow across and around reefs is required in order to be able to parameterize the reef successfully in theoretical and numerical models. Other important questions are:

On a seasonal time scale, what is the dominant forcing mechanism? Wind stress and geopotential anomalies are the most likely candidates, but how do these mechanisms vary with season and location?

On subseasonal scales, what is the general nature of wind forcing, propagation and dissipation of topographically trapped waves (edge waves, Kelvin waves, shelf waves) as a function of latitude?

These characteristics have been determined for several regions of the reef for shelf waves but the relation between regions is unknown.

What is the effect of the abrupt change in shelf width at the Capricorn Channel on the equatorward propagation of trapped waves?

(vi) Wind Waves and Swell

What is the wave climate in deep water outside the reef and within the reef on the outer edge of the shelf?

How does the presence of the reef affect transmission of swell?

How does the swell act physically on the reef?

(vii) Tropical Cyclones

What is the effect of tropical cyclones on deepening of the mixed layer in the Coral Sea?

How do cyclones transport water across reefs?

To what extent do cyclones generate storm surge and the associated currents?

What are the wave fields generated by, and propagating from, tropical cyclones?

5. METHODS

(i) Bathymetry

Naval systems are best suited to continue bathymetric work, although Landsat also appears to be useful in determining topography for depths less than 15 m or so. Landsat would be particularly useful in delineating areas that dry at low water.

(ii) Meteorology

Although there appears to be a need for automatic weather stations in more remote areas of the reef (especially north of Cairns), the validity of the Bureau's 3^o x 3^o grid mean sea level pressure analyses for the determination of surface (10 m) winds and pressures at selected points remains to be examined. Should the data prove sufficiently accurate, then the time and expense involved in deploying and maintaining automatic weather stations would be minimized.

There appears to be a need to compile a general climatology of the Reef region from existing data in order to rationalise further the need for weather stations.

(iii) General Hydrography and Large Scale Circulation

A sound knowledge of the general seasonal features of the Coral Sea is already available, however, at any particular time and location, these cannot be adequately predicted and measurements would need to be taken with CTD instruments for any particular experiment. As for the Coral Sea, general features of the hydrography in the Lagoon are also known, but there appears to be a need for more work examining the seasonal dependence of the hydrographic structure from the Lagoon to the Coral Sea as a function of latitude.

Long time series of sea level, temperature, salinity, nutrients, O_2 from pairs of instruments on both sides of the Reef (or from CTD casts) are useful in estimating permeability of the reef, and mixing rates on the inflowing and outflowing tide.

Satellite observations of sea-surface temperature, water colour (chlorophyll) and turbidity would aid hydrographic studies particularly in the vicinity of reefs and at various stages of the tide. In addition, aerial colour photography in conjunction with a passive tracer (rhodamine) might be used to study horizontal mixing in the reef and Lagoon areas, particularly in determining the role of flow through channels and across reefs in the dispersion of tracers.

On a smaller scale, the mixing studies outlined earlier have only just begun to highlight the importance of these mesoscale mixing processes, and much more work needs to be done in these areas before they can be said to be properly understood. In addition to CTD measurements, current mapping by ground based radar (Coastal Ocean Surface Radar, or COSRAD) is a potentially useful tool for these smaller scale studies.

(iv) Tidal Currents and Heights

The most important and effective methods appear to be the following:

Make and maintain a data register of current data.

Make a systematic program of simultaneous data observations on the coast, in the Lagoon, immediately inside and outside the reef, and in the Coral Sea. These data observations should include sea level, current, weather and ocean temperature, for the larger scale studies. Coastal ocean surface radar would help identify smaller scale effects of tidal currents.

Encourage analytical and numerical models as aids to understanding and as predictive tools.

(v) Long Period Currents and Heights

As for tides, current and sea level fluctuations of subseasonal period can best be examined by long time series of current and sea level data, ideally at locations inside and outside the reef. In particular, wind stress measurements are required for full analysis of these motions since they are predominantly wind driven (see Meteorology). In addition, for an analysis of flow within the reef, imposed pressure gradients (geopotential anomalies in the Coral Sea) would ideally be required and these would be obtainable from sea level measurements at the outer reef and in the Coral Sea. While there is substantial knowledge of shelf waves in some regions of the reef, the role of other coastally trapped waves (Kelvin waves, edge waves, baroclinic waves in the Coral Sea), has not been resolved. Also there has been no very large scale study examining the coherence of propagation of such waves along the entire length of the reef.

Baroclinic motions in the Coral Sea appear to be important in raising deeper, nutrient rich water to a level where it can be advected onto the continental slope. While current moorings on the steeper parts of the slope (greater than 45^{o}) are a difficult proposition, CTD measurements from vessels can determine a great deal about the climate of internal waves and intrusive effects. Little is known of inertial effects which may also be studied using current, height and CTD measurements.

The general hydrography and the baroclinic current field are closely related.

Numerical and theoretical models should be encouraged as an aid to understanding measurements.

(vi) Wind and Waves and Swell

Investigate swell wave dissipation by reefs and swell wave penetration through reefs by a combination of controlled laboratory experiments and field observation.

Supplement these studies with numerical hindcasting/forecasting of the wave field to build up a picture of offshore wave climatology.

Encourage the Beach Protection Authority to extend their regular monitoring program further offshore.

(vii) Tropical Cyclones

These might best be studied using techniques implemented by Imberger and Steedman on the north west shelf, and require relatively dense arrays of instrumentation before, during and after the passage of a Tropical Cyclone.

6. ROUTINE MEASUREMENTS

(i) Bathymetry

These are being undertaken by the Navy and the Hydrographic Office on the continental shelf, but data on the bathymetry of the continental slope is lacking in most areas not associated with regular shipping routes.

(ii) Meteorology

An up to data climatology of the reef region together with a comparison on existing meteorological data with mean sea level pressure and wind speed data evaluated from the Bureau of Meteorology's 3^{o} x 3^{o} grid of mean sea level pressure would ascertain the need for offshore automatic weather stations.

At present the need for such stations cannot be properly evaluated.

(iii) General Hydrography and Large Scale Circulation

Long time series of hydrographic measurements as a function of depth on both sides of the reef (that is, in the Coral Sea and the Lagoon proper) and at a selection of positions along the reef (latitudes) would be useful in determining general hydrography.

These measurements could readily be supplemented with remotely sensed sea surface temperatures and chlorophyll. The feasibility of obtaining synoptically consistent data from either side of the reef would need evaluation as it cannot be easily achieved except in limited regions.

(iv) Tidal Currents and Heights

Some routine measurements of tidal height are already being made. The coastal tide gauge network (Department of Harbours and Marine) and the storm surge network (Beach Protection Authority) provide extensive coverage of the coast as far north as Cooktown. Routine access to digitized data is required for effective use by scientists other than those in these two organisations. Further north, coastal stations should ideally be located at about 100 km interval along the coast. In addition, several stations are needed at selected locations near the outer reef itself in order to determine phase and amplitude relationships for those areas not yet studied. Although there appears to be some slight seasonal dependence of tides, measurements of tides (once made) remain valid and predictable for future times.

(v) Long Period Currents and Heights

Any array designed to measure tides would also be useful for a study of longer period currents, but in addition, wind stress forcing and forcing due to geopotential anomalies in the Coral Sea (pressure gradients imposed at the reef edge) are required. Hydrographic measurements exterior to and within the reef would aid in the determination of along-shore gradients due to varying density. Any planning of routine measurements would probably need to await results of the northern Barrier Reef study since this addresses dynamics in the most remote region.

(vi) Wind Waves and Swell

Remote sensing methods (for example, synthetic aperture radar) are best for studies of similarities and differences in wave climatology over a large region.

Directional wave recording measurements, especially in outer reef areas and the Coral Sea would also be useful.

(vii) Tropical Cyclones

Routine measurements would not appear to be suitable for a study of Tropical Cyclones due to the lack of predictability. Although almost any routine measurements would aid in the study of a tropical cyclone, a separate individual study plan would seem necessary.

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APPENDIX II

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APPENDIX III

DOCUMENT-CONTROL DATA

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1. Document Type: Technical Memorandum

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2. Document Date: August, 1983

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3. Title: Report of Scientific Discussion Meeting on the Physical Oceanography of The Great Barrier Reef Region.

   Sub-title:

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4. Author(s) and affiliations if from different establishments.

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5. Summary:

The meeting identified a number of important scientific questions. These were of two types:

(i) What is the description of certain events? and

(ii) Which model is needed to predict these events.

Considering events in decreasing time scale, the following statements summarize the important questions addressed in the body of the report.

(a) Climatology and Large Scale Circulation

In order to construct a model of the mean circulation we need to parameterise flow across the outer boundary reef (in terms of swell, tides and topography) and also to parameterise the internal friction and bottom friction due to the reefs within the Lagoon. To operate or test a model we need a description of the wind forcing (climatology), fresh water inflow,dynamic height and baroclinic motions at the shelf edge (Coral Sea).

From a validated model might come knowledge of the rate of mixing of coastal water and the transfer rate of water across the Lagoon-ocean boundary.

(b) Long Period Motions

We need a description of the circulation that results from the forcing at the Lagoon boundaries (open ocean, wind forcing, river inflow) which occurs at periods of a few days to many months (seasonal).

We need to know which are the dominant forcing mechanisms for the currents on these time scales. Wind forcing is one candidate but geopotential anomalies which impose alongshore pressure gradients may also be important. We also need to know the effect on Lagoon circulation of baroclinic (internal) motions in the Coral Sea. How well can long period waves be explained by wind forced models, if the effects of reefs are appropriately parameterised?

(c) Episodic Events

Two obvious transient events are floods and tropical cyclones. We need to determine from measurements how large is the storm surge response from these events (particularly from strong winds and cyclones). Can existing models of storm surge and the surface wave field from these episodic events explain the observation?

(d) Tidal Motions

We require a descriptive study of tide height, current and internal motion to facilitate modelling and eventually model testing.

We need to demonstrate that non-linear tidal effects (such as reef induced mixing) in the Great Barrier Reef Lagoon are important and also need to develop models of these non-linear effects.

(e) Surface Waves and Swell

We need to parameterise the propagation of swell across the coral reefs. It would be useful to know the climatology of surface waves for input to models of circulation that use swell as a parameter.

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6. Keywords: Great Barrier Reef Marine Park Authority; Great Barrier Reef, Oceanography.

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7. Descriptors

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8. Classification Codes
