

CONVENERS' SUMMARIES

Convener's Summary of the Sessions on 'Socio-Economic Factors'

- Session Convener: Professor J. Oliver, James Cook University of North Queensland
- Review paper: Mr R.L. Southern, Regional Director, Bureau of Meteorology, Perth
- Keynote address: Professor Robert H. Simpson, University of Virginia, Charlottesville

The socio-economic aspects of tropical cyclones were covered in three separate paper presentation sessions (2, 14 and 17) together with displays in the poster session (7). The chairmanship of the lecture sessions was shared between Professor J. Oliver, Mr R. Southern and Professor Robert Simpson.

All the papers listed in the lecture part of the program were offered, except for that by Mr P.J. Herbert who was unable to be present. This gap in the program was filled by Dr Neil L. Frank who gave a stimulating exposition of 'Lessons from hurricanes'. Circumstances prevented the presentation of two of the poster session items dealing with socio-economic factors, namely those from Dr W.J. Gibbs and Mrs S. Leivesley.

The discussion on the socio-economic impact of tropical cyclones represented an important aspect of the whole conference, providing as it did one of the major justifications, in addition to the purely scientific significance of tropical cyclone phenomena, for studying tropical cyclones; that is the applied or practical aspects of their environmental impact.

Mr Southern provided a comprehensive and impressive account of the magnitude, nature and distribution of the damage arising from tropical cyclones. His review of their global socio-economic impact was a very effective opener for the whole conference. He demonstrated dramatically that in the tropical areas exposed to these storms their potential or actual threat could not be ignored. If any reasons for holding the conference were required Mr Southern provided them.

The second session of the socio-economic discussion was initiated by a keynote address from Professor Robert H. Simpson on the impact of tropical cyclone winds. This address followed easily from the broader picture painted by Mr Southern and indicated the significance of the high winds associated with tropical cyclones. The effect of the winds at sea in generating destructive waves, and contributing to the full impact of storm surges, led into an analysis of the consequences of high velocity and gusting winds upon buildings. The importance of terrain and the limitation of much of the severest wind damage on land to the coastal fringe were also considered.

The other papers presented in this second session provided a coherent group. Dr Leicester presented the results of a multi-authored analysis of the variations of the wind damage potential from cyclone force winds for different parts of coastal Australia. This paper offered a valuable basis for some of the desirable planning for response to cyclonic winds. Mr R.A. Wittenoom brought the discussion nearer to home in his survey of the ways in which community housing in northwest Australia had been engineered to adapt it to the tropical cyclone threat. His analysis was reinforced by a variety of well-chosen illustrations. Professor J.E. Minor reinforced the impression of the significance of the wind threat and pointed to some interesting United States experience and its possible guidance to those concerned with wind engineering in Australia.

Dr Neil Frank's message from his treatment of 'Lessons from hurricanes' was, 'Do as we say, not do as we do'. With dramatic impact he was able to draw even from sober meteorologists in his audience expressions of awe at the striking before and after illustrations he presented. The main message was the seriousness of the threat to life and property of the storm surge in unwisely developed coastal fringes of the Atlantic and gulf coasts of the United States of America. Professor Aminul Islam made a comparative analysis of the surge impact on the coastal regions of the delta lands of Bangladesh. He indicated the importance of cultural factors in influencing the perception of the tropical cyclone danger and in determining the form of response.

The tropical cyclone hazard can be planned for in several ways. Insurance offers the opportunity to spread the burden of loss. Mr J.P. Dawson presented a 'snapshot of the insurance situation' which, with admirable clarity, covered in the short time available the relevant aspects - the Insurance Act, spreading the risk, re-insurance, building codes, market forces, the need for information on the cyclone threat, problems of non or under-insurance and the question of compulsion.

The conventional complex of tropical cyclone effects groups them under the headings of wind, flood and surge. Dr J. Gentilli showed how a combination of unexpected circumstances occurring in an unusual convergence of happenings produced major disruption out of what had seemed likely to be a relatively unremarkable tropical cyclone. Tropical cyclone Alby produced in Western Australia in April 1978 severe soil erosion, sand blasting, unmanageable growth of normally controllable burning-off, and widespread electrical short-circuits from dust covered insulators. The lesson was that we must be prepared for the unexpected.

The session was completed by an important presentation by Professor K.P. Stark on behalf of himself and Professor G.R. Walker. The contribution that could be made from the computer simulation of surge and cyclone damage was shown to offer a very practical and significant solution to the problems of planning for serious community threats, in particular the development of satisfactory evacuation schemes.

The two poster presentations were both directed to the question of finding a suitable basis for defining tropical cyclone severity by a number of indices representative of the damage impact of wind or rain. The achievement of an effective means of classifying the damage potential of tropical cyclones would be a major contribution to counter-disaster planning decisions.

J.Oliver

Convener's Summary of the Sessions on 'Observational Aspects'

Session Convener: Mr R. Falls, Bureau of Meteorology, Darwin

Review Paper: Professor W. Gray, Colorado State University

The five talking sessions and the poster presentation dealing with observational aspects included contributions from scientists of nine different countries.

Presentations dealing with relationships between cyclone genesis or intensification and the broad scale provided the major thrust of the session; seven papers as well as Professor Gray's review paper dealt with this aspect. There is clearly a wide body of opinion that the way larger scale patterns interact with tropical disturbances have important, if not crucial, influences on cyclogenesis. We seem to be getting closer to the answers but, nevertheless, the precise mechanisms of tropical cyclone genesis remain a subject of controversy.

We noted a degree of rivalry (and some nice gamesmanship), between the compositing school and the case study people. I suggest this is indicative of healthy competitiveness in observational research. To me the two approaches are complementary, both providing valuable insights into the mechanisms of cyclones. Studies utilising both methodologies were well represented and provided new knowledge.

Five papers discussed observational *techniques*. With the alarming depletion of fixed surface and upper air networks, the development and extension of remote sensing and other techniques is vital for both operations and research. In this context, I was particularly impressed with the potential of the over-the-horizon radar.

The simple maximum gust recorder and the aircraft deployable instrument package designed to measure surge, waves and current, display ingenious approaches to the problems of gathering extreme event 'ground truth' data effectively. We also heard how ships of the USSR have gathered very valuable new tropical cyclone data sets.

A landmark in Australian region cyclone research is studies in these and other sessions utilising the very detailed data sets collected by the NOAA Orion aircraft. For the first time it has been possible to study an Australian region cyclone in great detail. We have, also, a valuable new climatology of tropical cyclone tracks in the South Pacific Ocean, that will have many uses for research and planning.

I am grateful to all the contributors to the sessions on observational aspects for helping to make this a fine meeting, and particularly to Professor Gray for his review presentation, and Peter Webster, Geoff Crane and Mal Lamond for helping to chair the sessions.

R.Falls

Convener's Summary of the Sessions on 'Modelling'

Session Convener: Dr R.K. Smith, Monash University, Melbourne

Review Paper: Professor R. Anthes, Pennsylvania State University

The session began with an excellent review of numerical models by Professor Anthes and this led to a very lively discussion. Professor Anthes showed how models could be used to test ideas about basic processes in hurricanes, and as an illustration of this he showed that an alternative explanation for the observed isothermal boundary layer is that warm subsiding air between clouds may be much more important than sensible heat transfer from the surface. This idea has some support from recent analyses of data from cyclone Kerry described at the conference by Dr Black.

Dr Jones described what is perhaps the most sophisticated numerical model to date, which he is developing at NHEML. It is a three-dimensional, non-axisymmetric model with nested movable grids and includes an explicit representation of latent heat release on the resolvable scales. The trend away from cumulus parameterisation schemes is an exciting new development in hurricane modelling since, as Dr Rosenthal has recently pointed out, the adoption of cumulus parameterisation tacitly assumes that there is cooperation between the synoptic and cumulus scales and thereby precludes the ability to describe the genesis process in which an initial cloud cluster becomes organised into a vortex. Dr Jones showed that the model can simulate realistic hurricane structure in considerable detail with individual deep cumulus cells in the cloud bands being resolved. We also heard about simpler models designed more for prediction purposes, i.e. those of Madala and Chang and the Russian model described by Dr Petrossiants.

Other approaches to modelling involve laboratory simulations and analytical models and we have heard about both these approaches. Professor Wei Ding-Wen and Dr McEwan described laboratory simulations and Professor Pearce described an analytical model that attempts to explore some of the ideas of hurricane genesis advanced by Professor Gray and his students. Dr McEwan's laboratory simulation is a particularly exciting one and explores the idea of Scorer many years ago that mixing of angular momentum by an area of deep convection can generate a vortex.

Mr Webb talked about the similarities and differences between hurricanes and whirlwinds, an approach that I think can be enlightening and has been done all too seldom in the past. I believe much can be learned by attempting such comparisons since many aspects of vortex behaviour are common to 'tall thin' vortices such as tornadoes, waterspouts and dust-devils, and to 'broad shallow' vortices such as tropical cyclones. This is because the azimuthal and meridional components of vortex flows are tightly coupled through the pressure field and the constraints imposed are similar irrespective of aspect ratio.

I have been a little surprised that there was not a good deal more mentioned concerning the application of models to testing modification hypotheses. It is also distressing that the models have not been able to do better at predicting actual development and tracks. Clearly we have a long way to go - but it is not yet clear to what extent the paucity of data is responsible for this.

R.K.Smith

Convener's Summary of the Sessions on 'Boundary Layer and Moist Convection'

Session Convener: Mr R.H. Clarke, University of Melbourne

Review Paper: Professor M. Garstang, University of Virginia

I feel I should record some disappointment at the response to this portion of the conference. There are important questions to be answered under this heading, and these comprise some problems whose solutions are vital to an understanding of the formation and maintenance of cyclones. Some of these were addressed during the conference, especially in the review by the invited speaker, Professor M. Garstang. Others probably cannot be attacked until better data become available.

GATE observations were used by Dr E. Zipser to describe mesoscale convective rain bands. With the data available it was possible to describe the structure of two kinds of rain bands in considerable detail, including wind flow in three dimensions relative to moving systems. Temperature and static energy decreases behind a gust front, with strong down draughts, are of great interest in the tropical cyclone context.

This matter was given considerable prominence by Professor Garstang in his review 'The tropical atmospheric boundary layer: role in the formation and maintenance of hurricanes'.

He showed from recent observations over the ocean the quite dramatic modification of the mixed layer and result of active cumulus convection. In the absence of such convection, a well mixed layer, in terms of potential temperature and humidity, extends through the first 500 to 700 m of the atmosphere. After precipitation occurs, the mixed layer is cooler (by $\sim 1^{\circ}\text{C}$), drier (by ~ 0.5 g/kg) and shallower (by several hundred metres). Near strong convective systems the mixed layer can disappear entirely, leaving clear air in contact with the ocean surface. Low and modified mixed layers (characteristic of about 30 per cent of observed mixed layers) can persist for some hours in the wake of a travelling squall line or disturbance. Suppression of the mixed layer results from penetrative down draughts, while its recovery depends on the wind being sufficiently strong to restore it against the influence of mesoscale subsidence.

Very little information is available about the structure of the boundary layer in the inner region of cyclones, and such information is urgently needed if the boundary layer is to be adequately modelled. It is important especially to know the extent of boundary layer modification in the vicinity of precipitation.

No models adequately treat the boundary layer in cyclones; especially do they not simulate the cooling and drying due to down draughts. Model boundary layers are unrealistically deep. This may not matter too much in the mature stage of storms, but is quite inappropriate in the developing stages. If the wind speeds are too low (< 3 m/s) and the lapse rate high at the top of the mixed layer, *it is most unlikely that a disturbance will grow.*

The critical velocity is most likely near 10 m/s, which must be exceeded if convection is to be maintained in a cohesive fashion. How this occurs is perhaps the crucial question.

An attempt to treat more adequately the subgrid scale turbulence in conditions appropriate to cyclones was described by Dr G. Sommeria. This is an extension of the work of Deardorff, using higher order closure methods to represent the effects of turbulence. It is likely that, in the future, methods such as these will be considered necessary to properly take account of turbulent processes. The importance of using quasi-conservative variables, the representation of condensation, and estimation of correlations between moisture and temperature was emphasised. Third moment terms are not included in the closure system.

Valuable wind data for several cyclones from an instrumented tower were presented by Mr K. Wilson. An unexpected feature was a wind maximum at 60 m elevation, which may be due to the short land trajectory.

Heat, water vapour and momentum fluxes in cyclone Kerry, and some derived budgets, were presented in a paper read by Dr P. Black. This forms a unique and invaluable data set.

A theoretical paper explaining the spiral bands observed in cyclones was read by Dr Liu of Peking University. The bands are the result of internal gravity waves moving out from the centre.

R.H.Clarke

Convener's Summary of the Sessions on 'Operational Forecasting'

Session Convener: Mr W.R. Wilkie, Bureau of Meteorology, Brisbane

Review Paper: Mr G. Bell, Royal Observatory, Hong Kong

Keynote Address: Dr N. Frank, National Hurricane Center, Miami

This topic was discussed in four sessions comprising a total of 15 papers, nearly all of which dealt with the most important aspect of operational forecasting, namely the prediction of movement. In addition to the review and keynote address, five papers concentrated on the application of satellite data, four on statistical/synoptic methods, three on the modelling approach, and one on the utility of aircraft reconnaissance.

In summary the main findings were:

- . Over the last 10 years little or no improvement has been made in the accuracy of determining tropical cyclone movement notwithstanding the development and use of sophisticated technology such as satellite cloud imagery and high speed computers.
- . Emphasis was placed on the need to evaluate techniques in relation to community impact rather than as a purely statistical exercise. A method consistently free of large errors is more acceptable than one having smaller average errors but containing some large ones.
- . Time-scales for prediction are usually 'up to 24 hours' and beyond 24 hours. Because saving of life involved the shorter term predictions concentrating of effort should be in this area. Nevertheless, pressures for longer term predictions are increasing in areas of heavy coastal industrial development. The most likely way seen for longer term predictions (beyond 24 hours) to be made is by improved and extended numerical modelling over a very large area.
- . The importance of the use of satellite data in operational work was reflected in the number of papers presented on this subject and planned developments in satellite technology should give the forecaster an even greater observational tool by means of which improvement in the short term forecasts can be expected.
- . The statistical/synoptic type studies are an attempt to quantify prediction and are perhaps most helpful to the forecaster provided sufficient (accurate as distinct from interpolated) grid data are available. In general, however, these accurate data are not available except by aircraft reconnaissance and therefore the usefulness of these techniques, and those others based on specific grid-point data input, is minimised.

To achieve improvements in short period cyclone prediction there is a need to concentrate research on the intensification processes and application of pressure profiles. More real-time data will need to be gathered or inferred from satellites to enable better use of statistical and dynamic models.

Longer term prediction (24 hours or more) has application to a lesser number of persons and so is probably of secondary importance. Any serious work in this field must involve large scale movement of systems, particularly those in the subtropics, and therefore of necessity falls to the lot of the numerical weather predictor.

Regardless of any efforts to improve accuracy there is an immediate need for a strong public relations program to correct public misconceptions about such things as the degree of accuracy achievable in cyclone warnings and other aspects of the warning service.

It was inferred from the address by Dr Frank that a hurricane warning centre in the 1980s should comprise a team of specialists who eat, breathe and sleep tropical cyclones. Responsibilities cannot be discharged or any improvements made unless this function is regarded as being something other than 'an extra job' for the forecaster. In this regard he should be directly involved in developmental, testing and evaluation functions and be fully exposed to the latest techniques used successfully by other centres.

W.R.Wilkie

Convener's Summary of the Sessions on 'Artificial Modification'

- Session Convener: Mr J. Warner, CSIRO Division of Cloud
Physics, Sydney (now with WMO, Geneva)
- Session Chairman: Dr J.W. Zillman, Bureau of Meteorology,
Melbourne
- Review Paper: Dr R.C. Sheets, NHEML, Miami
- Keynote Address: Professor J.S. Simpson, University of
Virginia, Charlottesville

There were only two sessions on artificial modification, one at the beginning of the conference, the other at the very end. I found it significant that Dr Sheets' opening presentation spoke of hurricane modification but three days later, after discussing the scientific, operational, social and economic aspects of the hurricane problem, we closed the meeting with a stirring keynote address by Professor Joanne Simpson on tropical cyclone moderation - not *modification*, but *moderation*.

Dr Sheets' survey of the enormity of the global hurricane problem revealed vividly that a capacity for even minor moderation has such large potential economic and social benefits that we cannot afford not to pursue the possibilities suggested by the Stormfury hypothesis. As he explained it to us, the concept is that seeding the developed hurricane outward from the eyewall will stimulate convection and induce ascent of the inflowing low level air further out from the centre such that, by partial conservation of angular momentum, the eyewall will be displaced outwards by, say, a few kilometres and the maximum winds reduced by say 10 to 15 per cent.

Dr Sheets' review focused on such key questions as the impact of seeding on the wind speed, the hurricane track and the total precipitation from the storm, and he discussed the implications for the future of the Stormfury program. From both modelling studies and the experimental data available so far, it is evident that we can be fairly confident on several points concerning the effects of seeding:

- . as far as wind is concerned, there has been no suggestion of any increase in the winds;
- . with respect to the track, modelling studies suggest any track changes will be small. While we cannot resolve differences in track to the last 100 km or so we can rule out the prospect of major change in the motion of the hurricane;
- . considerations of both model results and intensity-rainfall correlations from actual hurricanes lead to the conclusion that it is unlikely that Stormfury could significantly affect the total rainfall.

In the light of this initial scientific assessment we then looked at the legal questions posed by research on hurricane modification. The basic question was need we, or should we, proceed to develop or implement a sophisticated legal framework to cover hurricane modification research or should we put all our efforts into designing our experiments, as is being done with Stormfury, with such care that legal considerations should not be a major issue. It became clear that we need to work on the problem of communication between the scientist and lawyer to ensure, in particular, that progress is not impeded by legal obstacles based on an inadequate understanding of the implications of the science, and to ensure that the scientist in designing his experiment does so with an appreciation of the legal issues involved.

We had a productive dialogue. Mr Ernst Willheim canvassed, in a sense, the worst possible situation and looked at the legal and political implications at domestic and international level. In the Australian situation he saw liability as a problem. He felt some kind of legislation would be needed and suggested that seeding decisions and the like should be made at senior government rather than technical level. At the international level he saw the need for some kind of legal framework but he felt it should be relatively simple, loose and flexible.

Professor Ray Davis, on the other hand, looked at the specific situation of the proposed Stormfury-Australia program and sought to identify practical ways of handling the kind of liability and other problems raised by Mr Willheim. Professor Davis, too, looked at a worst case situation (his 'horrible hypothetical') but he seemed to me to be suggesting that much of the necessary legal framework is already in place at the international level and that, given the nature of the Stormfury project and an adequate understanding all round, many of the potential issues could be adequately covered by appropriate advance agreements and understandings.

We had a lively discussion between the 'bush scientists' and 'bush lawyers' with Professor Fred Sanders raising the interesting proposition of the fellow who would sue if the hurricane were seeded, but would also sue if it were not seeded because the Government failed to protect him.

Then we got back to the science.

Dr Smith took us back to more basic questions related to the dynamics of the cyclone eye and offered some insight to eye generation and maintenance and implications for cyclone modification hypotheses. Dr Fukuta looked into the importance of microphysics-dynamics interactions under the seeded supercooled cloud mass in terms of the Stormfury hypothesis and, on the basis of his interpretation of the physics, suggested a strategy to optimise the effects of the seeding.

The compelling message of Professor Joanne Simpson's keynote presentation was that the time has come to move forward with a total program of hurricane moderation research including both modelling studies, supporting field work and soundly conceived moderation experiments. She then gave us a clear overview of the proposed Tymod experiment (whose basic

concept is similar to Stormfury), summarised recent relevant results on response of cumulus clouds to dynamic seeding in the storm environment, stressed the need for phased experimentation, and identified some key research thrusts to advance typhoon modification. She then quickly surveyed some other possible concepts for typhoon moderation and ended with a clear call and statement of resolve for solid progress over the next decade of hurricane moderation research.

J.W.Zillman

