SIXTH TROPICAL CYCLONE RSMCs/TCWCs
TECHNICAL COORDINATION MEETING

Brisbane, Australia
2 to 5 November 2009

Final Report
1. ORGANIZATION OF THE MEETING (Agenda item 1)

1.1 Opening of the meeting (agenda item 1.1)

1.1.1 At the kind invitation of the Government of Australia, the Sixth Tropical Cyclone (TC) RSMCs/TCWCs Technical Coordination Meeting was held in Brisbane, Australia from 2 to 5 November 2009. The meeting was attended by the experts designated by TC RSMCs in Honolulu, La Réunion, Miami, Nadi, New Delhi and Tokyo and TCWCs Brisbane, Darwin, Jakarta, Perth, Port Moresby and Wellington. The list of the participants is given in Appendix I.

1.1.2 Mr Gary Foley, Deputy Director (Services), welcomed all participants on behalf of the Permanent Representative of Australia to WMO and Director of the Australian Bureau of Meteorology, Dr Greg Ayers. He noted that the countries represented at this meeting operate the major Tropical Cyclone RSMCs and TCWCs around the world. These centers share a common set of both problems and aspirations, which need to be addressed periodically. Many issues have been soluable through agreements and decisions made at such meetings while some issues persist until a solution can be found. Mr Foley then acknowledged WMO for their stewardship in tropical cyclone activities and noted the progress that has been achieved in our understanding of the science through the partnership of WMO, governments and academic institutions; and the advances made in warning systems and "behind the scenes" enabling protocols. He also noted the expectation of communities that they will be well warned of every tropical cyclone event affecting them and the consequences of warning centers not meeting those expectations. Nevertheless he expressed an overwhelming sense of optimism in achieving these goals and wished the meeting well in its deliberations.

1.1.3 Speaking on behalf of Mr Michel Jarraud, Secretary-General of WMO, Mr Koji Kuroiwa, Chief of Tropical Cyclone Programme Division, expressed his deep appreciation, and that of WMO, to the Bureau of Meteorology for hosting the sixth Tropical Cyclone (TC) RSMCs/TCWCs Technical Coordination Meeting. He emphasized that, as the world economy is becoming increasingly sensitive to weather and climate, new and more sophisticated types of meteorological and hydrological services are required by almost every sector of the economy. In this regard, it should be emphasized that the existing regional tropical cyclone early warning systems led by RSMCs and TCWCs are now serving as platform for developing the multi-hazard early warning systems in many regions. Such movement has proven that the cooperative frameworks for the TC warning are highly effective not only for tropical cyclone warnings but also as the bases for the multi-hazard approach to the various natural disaster risks based on the regional and global partnership. In this regard, Mr Kuroiwa stressed that this session has offered an outstanding opportunity for the exchange of views needed to develop appropriate strategies to coordinate actions in such new circumstances of the TC warning services.

1.2 Election of the Chairman and Vice-chairman (agenda item 1.2)

1.2.1 Mr Jim Davidson (Australia) and Mr Jim Wayman (USA) were elected as Chairman and Vice-chairman, respectively.

1.3 Adoption of the agenda (agenda item 1.3)

1.3.1 The meeting adopted the provisional agenda. The agenda, thus adopted, is reproduced as Appendix II to this report.

1.4 Working arrangements (agenda item 1.4)

1.4.1 The meeting agreed on the details concerning the organization of its work, including working hours.
2. FOLLOW-UP ACTION ON THE FIFTH TC RSMCs/TCWCs TECHNICAL COORDINATION MEETING (Agenda item 2)

The meeting reviewed the recommendations of the Fifth TC RSMCs/TCWCs Technical Coordination Meeting (TCM-5), particularly those relevant to the work to be done by this meeting and the follow-up actions taken.

2.1 Websites for Tropical Cyclone Warnings

2.1.1 Severe Weather Information Center (SWIC)

2.1.1.1 The meeting noted that, in 2005, the Severe Weather Information Center (SWIC) started to provide the official warnings of heavy rain, heavy snow and thunderstorms in addition to the tropical cyclone warnings. It noted with pleasure that the number of users of the SWIC website has grown steadily with about 16 Million page visits per year. SWIC is now cross-linked with EUMETNET’s METEOALARM Website (formerly known as the European Multi-service Meteorological Awareness (EMMA) WebPages) so that the users can more efficiently obtain information on severe weathers.

2.1.1.2 The meeting highly commended Hong Kong, China for hosting SWIC and for its continued effort to increase the utility of the website. The meeting recognized that SWIC is certainly serving as a unique and reliable source of the official information from NMHSs as requested by international media.

2.1.1.3 The meeting noted that, although the SWIC’s policy is clear, it is important to get the users to see the difference in status between the forecasts of RSMCs and of NMHSs; those of RSMCs as the first level information to be used as regional guidance and of NMHSs as the second level information which is more specific and informative to meet the national requirements. It urged the WMO Secretariat to arrange with SWIC for articulation of that difference in the SWIC website.

2.1.2 Websites of TC RSMCs/TCWCs

2.1.2.1 The meeting confirmed that all the RSMCs and TCWCs are running their own websites, except TCWC Port Moresby which is currently developing the website. The meeting underlined the importance of the websites in terms of distribution of the regional advisories as well as communication to the public and the media. Some centers also stressed the effective use of sub-websites such as NWP website of RSMC Tokyo for providing numerical predictions of tropical cyclones from the global NWP centers. The websites are as follows:

- RSMC Miami-Hurricane Center: http://www.nhc.noaa.gov/products.html
- RSMC-tropical cyclones New Delhi: http://www.imd.gov.in
- RSMC La Réunion-Tropical Cyclone Centre: http://www.meteo.fr/temps/domtom/La_Reunion/TGPR/saison/saison_trajGP.html
- RSMC Honolulu-Hurricane Center: http://www.prh.noaa.gov/hnl/cphc/
2.2 Minimum information issued by TC RSMCs/TCWCs

The meeting discussed this issue mainly from the following two aspects: 1) is the requirement being met? and 2) is the minimum requirement as set still valid? A discussion about whether the RSMC requirements also applied to TCWCs was tabled until discussion of agenda item 4.1. The meeting noted that all regions either were or would soon be compliant with the minimum requirement. Developing a graphical representation capability was still being accomplished.

As to the validity of the minimum requirement as set in 2005, the meeting agreed that the minimum forecast hours should be extended to 48 hours. The meeting also discussed second level elements (rainfall and storm surge) and concluded these were not to be included in the RSMC minimums, but a bullet would be added recommending where possible such information be included. The proposed revision was:

- A graphical depiction of the track, both past and forecast. The minimum time interval between locations should be 12 hours, and the forecast period at least 48 hours. The intensity at each location on the track should also be indicated. The graphic should also contain an indication of the uncertainty of the forecast in a format to be determined by the individual TC RSMC.
- A copy of the most recent advisories issued by the TC RSMC.
- Whenever possible, additional information should be provided concerning a depiction of any national warnings currently in effect within the RSMC area of responsibility.
- Whenever possible, certain second level information such as quantitative precipitation or storm surge should be provided.

2.3 Definition of maximum sustained wind speed of tropical cyclones

The meeting recalled that the TCM-5 in December 2005 reviewed the first draft of the WMO Wind Averaging Study submitted by Systems Engineering Australia (SEA) and requested SEA to give more consideration to the mean wind speed interpretation, to change some terminologies and to provide a succinct summary for inclusion in the regional Operational Plans/Manual and the Global Guide to Tropical Cyclone Forecasting. The second draft was circulated to the TCM Working Group (WG) on this study in January 2008. The third draft was circulated in October 2008 to the WG and also sent to WWW experts for review. In consideration of all the comments, the final report was prepared and submitted to WMO in June 2009. Further briefing on the report was provided by SEA at this meeting. The meeting was invited to review the report and consider incorporation of the summary into the Operational Plans/Manual and the Global Guide.

The briefing at the meeting by SEA defined what is meant by a “gust factor”. It is a theoretical conversion between an estimate of the mean wind speed and the expected highest or “gust” wind speed of a given duration within a stated observation period. To be representative, certain conditions must be met, many of which may not be exactly satisfied during a specific weather event or at a specific location. Isolated comparisons of measured mean winds and their associated gusts may show differences from the theoretical values. Theoretical gust factors are applicable only in a statistical sense and the semi-empirical theories available are based on many sets of observations.
2.3.3 The SEA briefing at the meeting also highlighted the following key points from the study:

- The wind speed can be averaged in many ways but care needs to be taken in how it is sampled;
- Wind averaging conversions are only applicable to “gusts” and not to “means”;
- Short term averages of the wind are not necessarily “gusts”;
- “Gustiness” is a function of “exposure”;
- Only wind “gusts” can be “converted” to the “mean”;
- Making a wind averaging conversion implies use of a “gust factor”, whereby a gust can be estimated from an estimate of the mean and the mean can be estimated from an estimate of the gust; and
- One estimate of the mean wind cannot be converted to another estimate of the mean wind.

2.3.4 The meeting proceeded to discuss the storm-wide maximum wind speed $V_{\text{max}}$ concept used in converting between agency estimates of storm maximum wind speed. Importantly, it was noted that the recommended conversion for at-sea exposure is about 5% higher at 0.93 than the “traditional” value of 0.88.

2.3.5 It was also recommended that all wind observation sites should meet WMO requirements and be directionally calibrated to provide “standard” exposure wind speeds which are truly representative. Numerical models need to be protected from assimilating gusts. The study provides a strong basis for future work as better wind data increasingly becomes available.

2.3.6 Following a robust debate, the meeting unanimously endorsed the SEA study and agreed that Sections 1.3 through 1.6 be incorporated into the Operational Plans/Manual and the Global Guide. With the addition of some minor changes requested by NOAA NHC in August 2009, the final version will be dated “November 2009”. WMO TCP and the meeting congratulated SEA and the co-authors on the quality of the study.

2.4 Standard format for verification of TC forecasts

2.4.1 The meeting recalled that establishment of the standard format for verification of TC forecasts has been a pending issue since the TCM-2. TCM-5 reviewed the standard format which was prepared by the representative of RSMC La Réunion taking account the comments from TC RSMCs and TCWCs. TCM-5 reserved acceptance of the format because parameters for verification were different between the centers and they also had different views about the measurement of gain in skill.

2.4.2 The meeting recognized the imperious necessity for all RSMCs and TCWCs to verify the official forecasts disseminated by these centres (both track and intensity forecasts) and to publicize the results. It moreover agreed upon the fact that all centres should not only publish their verification statistics but also the methodology used to verify the forecasts. However, the meeting viewed that it was still difficult to achieve a consensus regarding a standard format for verification of forecasts.

2.5 IWTC-VI recommendations

2.5.1 The meeting noted that wide-ranging recommendations arose from the Sixth International Workshop on Tropical Cyclones (IWTC-VI) which was held from 20 to 30 November 2006 in San Jose, Costa Rica. Among those, the meeting reviewed progress that has been made in the implementation of selected recommendations that are relevant to WMO Programmes. The meeting noted that the progress has been made as shown in the Appendix III.

2.5.2 The meeting recognized that the IWTC series has substantially enhanced the interaction between forecasters and researchers and has produced significant outcomes in
the form of major recommendations, research programmes and reference books. The meeting strongly recommended that the series be continued.

3. REPORT ON CURRENT AND PLANNED ACTIVITIES

3.1 Implementation of the TCP

3.1.1 On reviewing the whole range of activities being conducted under the Tropical Cyclone Programme (TCP), the meeting noted with satisfaction the achievements and progress accomplished in both the general and the regional components of the Programme since the fifth technical coordination meeting with special mention on the activities conducted under the auspices of the five regional tropical cyclone bodies and the regions centers, i.e. RSMCs and TCWCs.

3.1.2 The meeting noted with satisfaction the continuation of co-sponsorship by WMO for the annual RA IV Workshops on Hurricane Forecasting and Warning organized by NOAA at the RSMC Miami, the biennial Southern Hemisphere Training Courses on Tropical Cyclones by the Australian Bureau of Meteorology, and the biennial RA I Training Courses on Tropical Cyclones by Météo-France at the RSMC La Réunion. Attachment trainings have also been contributing to the development of capacity in tropical cyclone warning services, which are hosted by RSMCs Tokyo and New Delhi and the Indian Institute of Technology (storm surge).

3.1.3 Update of the Global Guide to Tropical Cyclone Forecasting was progressing with authorship of many distinguished experts and would be completed by the end of October 2010. The new Global Guide deals with almost all areas of forecasting of tropical cyclones and associated hazards, as well as societal impacts, assessment, warning and response strategies. It will be published primarily as a Web version in view of cost saving and easier access. Also, the WMO Tropical Cyclone Forecaster’s Website has been developed to provide a readily accessible source of forecast tools and analytical data necessary for operational forecasting. These two information sources will be linked with the TCP Website to serve as a comprehensive source of information/material/data that is expected to be of great value to operational forecasters (see item 4.7).

3.1.4 The meeting noted that Storm Surge Watch Schemes (SSWS) have been developing steadily in the tropical cyclone regional bodies as described in item 4.8.

3.1.5 The meeting also noted with pleasure that collaborations have been enhanced with the research community to transfer R&D results to operational forecasting through i) TCP/WWRP joint workshops such as IWTC and IWTCLP, ii) involvement of researchers in TCP regional bodies sessions, and iii) cooperation with researchers in research projects such as those related to THORPEX Interactive Grand Global Ensemble (TIGGE).

3.1.6 Concerning the training activities, the representative of WWRP illustrated the TIPS Workshop of the Typhoon Committee held in May 2009 as a good example for group training courses on the TC ensemble forecasting, which included intensive hands-on-trainings where participants run an actual operational system for data processing/display and produce ensemble-based forecasts. Discussion was also conducted on how to develop a forecasting system as well as ensemble products in forecaster- and user-friendly forms through a systematic and optimized approach.

3.2 Recent and Current Activities of the TC RSMCs/TCWCs

3.2.1 Representatives of the Centres made presentations on the current technical and operational aspects of monitoring and forecasting of tropical cyclones at their centres and on other topics including training and research. Major items presented are summarized below.
Activities reports submitted by the center are given in Appendix IV and their presentations are posted on WMO/TCP website at http://www.wmo.int/pages/prog/www/tcp/reports.html.

RSMC Honolulu

1) Tropical Cyclone Seasons (2007-2009)
2) Products and Services
   - Successful Evacuation
   - New Items for 2007 (IFPS, GFE, WRF, etc.)
   - National HazCollect
   - Hawaii Rain Gauge Collection Network Replacement
   - Performance Goals
   - Governor/Mayor Recognize RSMC Honolulu
   - Tropical Cyclone Seasons (2007-2009)

3) Training
   - FEMA Training
   - Pacific International Pacific Desk Program
   - Makani Pahihi Hurricane Exercise
   - Summer Science Programms
   - Weather Spotter Training
   - Hurricane Workshop

4) Preparedness/Outreach Activities
   - Outreach and Press Conference
   - Hawaii State Hazard Mitigation Forum
   - Hawaii Emergency Preparedness Executive Consortium
   - Hurricane Preparedness Workshops
   - StormReady/TsunamiReady

5) Research
   - Federal Emergency Management Agency (FEMA) and the State of Hawaii
     Civil Defense (CD) Catastrophic Disaster Event Planning
   - Probabilistic Tropical Cyclone Genesis
   - Ocean Vector Winds
   - Wind Probabilities

RSMC La Reunion

1) Introduction (mission and responsibilities)
2) Main achievements since last TCM-5 meeting
   - Increased access to TC-oriented NWP products
   - Developing our own Limited Area Model (LAM)
   - Important upgrade of the TC forecaster workstation
   - Major improvement of the official track forecasts performances
   - Quality certification and RSMC Survey
   - Development of a new specialized website
   - Implication in the RA I SWFDP project
   - Implication in the RAMA network

3) Future perspectives
   - 5-days forecasts
   - Towards probabilistic cones of uncertainty
   - Towards adopting a new pressure-winds relationship
   - Hosting IWTC-VII
   - Satellite re-analysis project
   - The SWICE project
RSMC Miami

1) Tropical Cyclones
   - Major Hurricanes Dean and Felix in 2007
   - Frequent landfall of storms in 2008
2) Changes in products and services
   - Expansion of graphical product development
   - Graphical Tropical Weather Outlook
   - Graphic depicting the current storm size, location, past track and active warnings
   - Providing all graphical products in GIS compatible formats
   - Second level products gaining use with decision makers
   - Storm surge forecast for the U.S. - graphics displaying inundation and probabilities
3) Ongoing Challenges
   - Key issues needing more work; continued growth in the coastal evacuation zones, lack of understanding of storm surge, lack of acceptance of probabilistic nature of forecasts and insufficient building codes
   - Hurricane Forecast Improvement Project (HFIP)
4) RA IV activities
   - Annual meetings of RA IV Hurricane Committee
   - Two week Hurricane 101 training at RSMC Miami.
   - Caribbean Hurricane Awareness Tour
   - RA IV Workshop on Hurricane Forecasting and PWS

RSMC Nadi

1) Area and responsibilities
2) TC Advisory System
   - Classification
   - Bulletins
   - Phase (Early Information, Alert, Warning)
   - Warning dissemination
3) Statistics of TC activities/Seasonal TC activities
4) Forecast position errors
5) New products
   - TC Threat Map
   - TC Forecast Track & Uncertainty Map
   - etc.
6) Training
   - Training Courses conducted under JICA Third Country Training Programme
   - Attachment Training to RSMC Nadi
7) Other Activities
   - Severe Weather Forecast & DRR Demonstration Project (SWFDDP)
   - Tsunami EWS
8) Recent & Planned Improvements
   - Main servers upgrade, Satellite receiving systems upgrade
   - Climate Network Upgrade, Outstation Upgrade, Weather Radar for Fiji’s Northern Division
   - Flood Early Warning System
9) RSMC Nadi Problems & Needs
   - Staffing, Integrated Met System, Forecasting tools, Maintenance of equipment, Upgrade of website, Quality management system (aviation)
10) Recommended Needs
    - Improved access to TC impact data and reports
    - Regular consultation with stakeholders
    - General education and awareness on the products
RSMC New Delhi

1) Responsibilities and functions of RSMC
2) Area of responsibility and climatology
   - Climatology of tropical cyclones over the north Indian Ocean
3) Observational System
   - Observations from basic network
   - Cyclone Detection Radars (CDR)
   - Satellite Monitoring
4) Telecommunication Network
5) Analysis and Prediction System in Operational Use
   - Analysis
   - Quasi-Lagrangian Model (QLM), etc.
   - Storm Surge Model
   - Mean Forecast Error
   - Improved performance of cyclone forecasting
6) New Initiatives in Cyclone Forecasting
   - Timeliness of cyclone warnings
   - Change in Format of Cyclone Warning Bulletin
   - Prediction of Storm surge/extremely heavy rainfall
7) Products Generated by RSMC New Delhi
   - Tropical Weather Outlook, etc.
   - Tropical Cyclone Advisories
   - Global Maritime Distress Safety System (GMDSS)
   - Tropical Cyclone Advisories for Aviation
   - Bulletin for Indian coasts
8) Disaster Prevention and Preparedness/Public Weather System
9) Data Archival
10) Implementation of Regional Cyclone Operational Plan
11) Publications/Verification of Warning
12) Research
   - Forecasting Manual on Cyclone
   - Implementation of WRF Model for cyclone prediction
   - etc.
13) Training
14) Forecast Demonstration Project on Landfalling Tropical Cyclones over the Bay of Bengal
15) Modernization Programme of IMD

RSMC Tokyo

1) Background
2) Products of RSMC Tokyo
   - RSMC bulletins via GTS
   - RSMC bulletins via AFTN
   - JMA website
   - RSMC Data Serving System
3) Improvement of TC Track Forecasts
   - Annual position errors
4) Improvement of TC Intensity Forecasts
5) RSMC Data Serving System
   - NWP products
6) JMA Numerical Typhoon Prediction (NTP) website
   - Track forecast of major NWP centers
   - JMA’s Typhoon Ensemble Prediction System (TEPS)
7) Publications
   - Annual Report on the Activities of the RSMC Tokyo - Typhoon Center
   - RSMC Tokyo - Typhoon Center Technical Review
8) Training activities
   - On-the-job training seminars for Typhoon Committee Members
9) RSMC products and its improvement in recent years
   - Global Spectral Model
   - Cloud motion wind data for the Northern Hemisphere
   - Ensemble mean data
   -
TCWCs in Australia

1) Significant Cyclones since December 2005
   - Larry – March 2006
   - Monica – April 2006
   - George – March 2007
   - Nicholas – Feb 2008
   - Hamish – March 2009
2) Verification of Forecasts
   - Intensity forecast error
   - Position forecast error
3) Products
   - Seasonal Forecasts
   - 7 Day/Intraseasonal Forecast
   - Daily TC Advice
4) Significant Service Improvements/Activities
   - TC Database – trends paper, re-engineering
   - TC Module – improvement, increased usage
   - Increased forecast timescale
   - Use of climatology for “grey zone”
   - International training – Jakarta, Vietnam, TC workshops
   - National TC Seasonal Outlook
   - ACCESS implementation
   - GFE implementation

TCWC Wellington

1) Monitoring of the South Pacific tropics – I
   - Strategic importance to NZ - wide media interest when a tropical cyclone forms
   - Requirement under a contract between MetService and NZ Government
   - Temporary backup TCWC for Nadi
2) Monitoring of the South Pacific tropics – II
   - Daily Tropical Cyclone Potential Bulletin
   - Service for Ensure Radio New Zealand International (RNZI) and NZAID
   - Severe Weather Forecasting and Disaster risk reduction Demonstration Project (SWFDDP)
3) Monitoring of the South Pacific tropics – III
   - Advices to New Zealand’s Ministry of Civil Defence & Emergency Management (MCDEM)
   - Tropical Cyclone Watches & Warnings for Norfolk Island
   - SIGMETs for the Auckland Oceanic FIR
4) Other activities – I
   - 3x1 DAY WORKSHOPs for forecasters
   - WORKSHOP/MEETINGs with NZAid & Stakeholders
   - Outlook for 2009/2010 cyclone season
5) Other activities - II
   - Exchange best track data with Australia, Fiji & IBTrACS
   - Pending project to enhance cyclone tracking tools in “CyTRACK” & tidy up verification tool

**TCWC Jakarta**

1) Brief History of Jakarta TCWC
2) Operational Background
   - WMO Mandatory
   - Internal Interest of BM
3) Task and responsibility
   - Forecasts and warnings for the general population
   - Forecast and warning for open sea
4) Area of Responsibility
5) Activity and Planning
   - Short Term and Long Term Plan
   - Extension of Jakarta TCWC area of Responsibility
6) Jakarta TCWC Operational Design
7) Organizational Structure of Jakarta TCWC
8) Jakarta TCWC Products
   - Extreme weather warning
   - TC Technical Bulletin
   - TC Technical Bulletin
   - etc.
9) Infrastructures of Jakarta TCWC
   - Hardwares/Softwares
   - C-band Weather Radar Network
10) Staffs of Jakarta TCWC
11) First Activation of Jakarta TCWC
12) Inauguration of Jakarta TCWC
    - TCWC Website
13) List of TC Names

**TCWC Port Moresby**

1) Monitoring role in the tropics
   - Area of high strategic importance
   - Maintaining a weather watch
2) TCWC role
   - Responsible area
   - Actions for TC Monica and TC Guba
3) High Seas forecasts and warnings
   - Area for marine warnings
4) Non-meteorological information
5) Forecasting sytems
   - Dvorak Analysis
   - LRIT
   - Digital Atmosphere
6) Training and research
   - Annual mentoring workshops
   - Support of TCWC Brisbane
4. COORDINATION

4.1 Functions and responsibilities of TC RSMCs and TCWCs

4.1.1 The meeting noted that the overall responsibilities of RSMCs are outlined in the GDPFS manual. It underlined that TC RSMCs should meet the requirements set by the member countries they serve in their respective regions. Such requirements and arrangements are contained in the TC Operational Plans for each region. The meeting felt that the difference of roles and responsibilities between RSMCs and NMHSs should be clearly defined and documented, including the RSMC advisories as regional guidance and the forecasts/warnings from NMHS as official information to the nations.

4.1.2 The meeting recognized the need to review and develop the terms of reference (TOR) of TC RSMCs taking into account what was contained in the manual and what RSMCs were expected to do in the respective responsible regions. It was therefore of the view that the GDPFS Manual needs to be reviewed and updated as early as possible. The meeting requested the WMO Secretariat to keep the RSMCs informed of the actions being taken by WMO/WWW for the update of the GDPFS Manual.

4.2 Operational forecasts/advisories, watches and warnings – Requirements

4.2.1 Improved accuracy of the forecast of TC RSMCs/TCWCs

4.2.1.1 The meeting acknowledged the recent improvement in track forecasts and the challenge faced in making improvements to intensity forecasts. It is impractical to set the same standard for all basins so it is best that each RSMC and TCWC continues to do what suits its own requirements. What’s important is each centre should ensure there are continuing improvements in their track and intensity forecasts. The average position error in track forecasts for H+24 should fall below 100km and the intensity forecast errors should aim to be consistently less than 10hPa at H+24.

4.2.1.2 Overall, the goals for improving the average error should be better than the previous one by 1 to 3% per year. The meeting also acknowledged there are probably limits of predictability which aren’t really understood at the moment.

4.2.1.3 There were discussions about how ensemble prediction forecasts might help. Currently, the multi model ensemble information produced under GIFS_TIGGE is very experimental and the results are only available after H+48 hours. There is a perception that users lack an understanding of probability products and appear to prefer a simple ‘yes’ or ‘no’ answer to any forecast issues.

4.2.2 Requirements of the observational data and the NWP guidance

4.2.2.1 The Chairman introduced this topic by emphasizing the importance of the observations for TC forecasting. Noting the broadness of the topic, the meeting decided to focus on the importance of satellite data for NWP.

4.2.2.2 The representative of RSMC Honolulu reaffirmed the importance of QuikSCAT in the daily operations and reported that the instrument was expected to fail soon. It was brought to the attention of the meeting that Japan and the USA are planning to launch another instrument. There was a strong endorsement from the meeting.

4.2.2.3 The representative of RSMC La Reunion expressed that there is a possibility of the launch of a new France/India satellite with capabilities similar to TRIMM. He stressed the need of continued satellite coverage over the Indian Ocean by EUMESAT.

4.2.2.4 The meeting discussed that the new satellites will provide much more data and recognized the importance of the accessibility of such large volume of data. It also
emphasized that the data be available for both operations and research. Recognizing that some RSMCs and TCWCs require support for utilization of the new satellite data, the meeting stressed that actions need to be taken to ensure all the agencies of the availability of the data on an operational basis. WMO Secretariat indicated that the problem of accessing the new satellite data to be addressed at the CBS meeting in Namibia in 2010.

4.2.2.5 The meeting further discussed the importance of incorporating new satellite data and techniques into operations, particularly in developing countries that may have limited satellite infrastructure. As part of the increase in remote sensing data, new receiving technologies are required in some instances (eg for receiving X-Band), or access to new World Wide Web sites that data can be downloaded from. The meeting agreed with EC on the strategy of implementation of the revised Global Guide, and also suggested the need for RSMCs, including RSMCs with Geographic Specialization as well as RSMCs with specialization in tropical cyclones, to be proactive in assisting relevant NMHSs in attaining and using remote sensing observations.

4.3 Official forecasts from TC RSMCs/TCWCs vs. forecasts from other sources

4.3.1 There are various national and international agencies monitoring and forecasting tropical cyclones over a given basin as per their needs. The availability of the forecasts from different agencies in public domain for the same Ocean basin creates confusion in the minds of the users sometimes as the monitoring and forecast products differ on many occasions. As an example, the case of the north Indian Ocean was discussed, where two international agencies issue region-wide forecasts, viz., RSMC - Tropical Cyclones, New Delhi, as designated by WMO and Joint Typhoon Warning Centre (JTWC) of USA. In addition to RSMC New Delhi, JTWC also monitors and predicts the cyclonic disturbances over the north Indian Ocean. It provides its forecast on the website.

4.3.2 RSMC New Delhi has the official responsibility to monitor and predict the cyclonic disturbances over the north Indian Ocean and to issue Tropical Weather Outlook and Tropical Cyclone Advisories for the benefit of the countries in the World Meteorological Organisation (WMO)/ Economic and Social Co-operation for Asia and the Pacific (ESCAP) Panel region bordering the north Indian Ocean, namely, Bangladesh, Pakistan, Maldives, Myanmar, Sultanate of Oman, Sri Lanka and Thailand. The Center has also the responsibilities as a Tropical Cyclone Advisory Centre (TCAC) to provide Tropical Cyclone Advisories to the designated International Airways as per requirement of International Civil Aviation Organization (ICAO). RSMC New Delhi forecasts are available in the web site of the India Meteorological Department (IMD) apart from being disseminated to various users through different telecommunication channels.

4.3.3 The availability of the forecasts from these two different agencies in public domain like internet for the same Ocean basin creates confusion in the minds of the users as the monitoring and forecast products differ sometimes. Generally, it is observed that the intensity estimated by JTWC is higher than that by RSMC New Delhi. Sometimes, JTWC even declares TC, though it is not declared so by the RSMC.

4.3.4 After the intensive discussion, the meeting made recommendations as follows;

i) Good liaison may be maintained and briefings may be provided by the RSMCs/TCWCs to the regional press and electronic media during the TC period to avoid the confusion arising out of different forecasts issued by different sources.

ii) There should be a coordination mechanism among different forecasting agencies to minimize the difference.
4.4 Coordination on the transboundary storms

4.4.1 The meeting reaffirmed that a tropical cyclone is once named, it should retain the same name for its entire lifetime (and therefore should not be renamed when moving from an area of responsibility to another). If a named tropical cyclone decreases in intensity and is no longer classifiable as a tropical cyclone, then it intensifies and becomes an identifiable tropical cyclone, the same name should be retained if it can be verified that it is the same system.

4.4.2 Such a procedure (“one storm one name”) constitutes the best way to ensure a clear, consistent and unambiguous identification of named tropical systems for communication to the users and medias, best track and climatological referencing and archiving.

4.4.3 The meeting also reaffirmed the intent for all the tropical cyclone forecasts in a basin should be completed by the RSMC/TCWC responsible for that basin. It is acknowledged that RSMCs/TCWCs have users who required information in another RSMC's/TCWC's assigned area. In these cases, the RSMCs/TCWCs should use the official forecast from the responsible center and reformat/repackage the forecast as required for its users. Such a process ensures there is only one WMO official forecast and this official forecast is produced by the assigned responsible center. It also prevents possible confusion and misunderstandings produced if two different forecasts are issued for the same system by recognized RSMCs/TCWCs.

4.5 Tropical Cyclone Advisory for international civil aviation and coordination with WAFCs

4.5.1 The representative of the International Civil Aviation Organization (ICAO) expressed to the meeting its appreciation for the work of the Tropical Cyclone Advisory Centres (TCACs), which are located in Darwin, Honolulu, Miami, Nadi, New Delhi, Réunion and Tokyo. The TCACs, by providing advice on tropical cyclones, play an important role for the safety and efficiency of international air navigation, and their issuance, correct formatting, and correct dissemination (including to the uplink stations in the United Kingdom and the United States of the ICAO satellite broadcasts) are of prime importance to ICAO.

4.5.2 The meeting noted that, according to the information available from ICAO Regional Offices, the implementation of the issuance of these advisories in alphanumeric format by all the TCACs is satisfactory, and no specific action is required, although some matters were brought to the attention of the group.

4.5.3 An amendment related to the provisions governing the TC advisories has been developed with the assistance of the International Airways Volcano Watch Operations Group (IAVWOPSG) and Meteorological Information Data Link Study Group (METLINKSG), based on long-standing requirements by airline users (through IATA). This draft amendment includes additions of a specification for tropical cyclone advisory information in graphical format to be added in Appendix 1 to Annex 3 to the Chicago Convention, and a change of the identification of unnamed cyclones; the term “NIL” will be replaced by “NN” (since the term “NIL” was considered misleading by some users).

4.5.4 TC advisories in graphical format must include all the information included in the existing alphanumeric tropical cyclone advisory, together with areas affected by gale-force surface winds and frequent cumulonimbus clouds. This information, if provided in binary format, is expected to be in the BUFR code form although no BUFR code tables have yet been developed for such advisories. However, the migration of OPMET messages to the BUFR code form was suspended by the ICAO Air Navigation Commission; while the CBS/CAeM Expert Team on OPMET Data Representation (ET-ODR) has been addressing the possibility of using XML code form for OPMET data. The first results of a pilot project undertaken in July 2009 by the ET-ODR involving XML are promising.
circumstances, it appears that it is highly likely that in the medium and long term, most aeronautical MET data will migrate to the use of XML, including the tropical cyclone advisories.

4.5.5 The amendment proposal has been subject to consultation with all ICAO Contracting/WMO Member States and no adverse comments were expressed as far as the issues related to TCs are concerned. Therefore, it may be expected that the ICAO Council will adopt the amendment without changes in March 2010. The proposed applicability date will be 18 November 2010.

4.5.6 As an intermediate solution to the transition to XML, the meeting considered a suggestion that the TCACs might use the portable network graphic (PNG) chart form for graphical TC advisories. The PNG chart form is based on off-the-shelf decoding software (rendering it cost effective both for TCAC and users of the TC advisories in States). This software is already used for ICAO world area forecast system significant weather forecasts (as a back-up) and volcanic ash advisories issued within the ICAO international airways volcano watch (IAVW), with positive feedback. The ICAO aeronautical fixed telecommunication network (AFTN) cannot be used to transmit any PNG-coded data; however, the introduction of enabling clauses allowing the use of the Internet as part of Amendment 75 will resolve this problem.

4.5.7 Noting that it could be reasonably expected that the TCACs seek to address the new requirements by the time they come into effect, the meeting agreed:

(a) to fully implement the provisions related to the content, format and dissemination of tropical cyclone advisories contained in ICAO Annex 3/WMO Technical Regulations [C.3.1];
(b) to take note of the proposed amendments to Annex 3/Technical Regulations [C.3.1] to be applicable on 18 November 2010;
(c) to agree that, as an intermediate solution, the PNG chart form be used for the tropical cyclone advisories in graphical format;
(d) to request ICAO to assist in coordinating, through the ICAO Regional Offices in Bangkok, Nairobi, and Mexico, the implementation of the PNG chart form, and;
(e) to note the longer term plans concerning the migration to the use of XML for tropical cyclone advisories in graphical format, and the addition of a requirement to include forecast positions of TC beyond the current 24 hours.

4.6 Tropical cyclone best track data base

4.6.1 International Best Track Archive for Climate Stewardship (IBTrACS)

4.6.1.1 Dr Kenneth Knapp from NOAA’s National Climate Data Centre presented a summary of the work undertaken at NCDC under the IBTrACS project. IBTrACS has become the world’s single largest repository for tropical cyclone track and intensity data. Importantly IBTrACS has gathered together data from the various RSMCs to provide an easily accessible database not previously available to researchers. In addition to track data NCDC has developed the HURSAT data set of imagery associated with tropical cyclones which in due course will be valuable for reanalysis work deemed necessary in any of the tropical cyclone basins. In May 2009 NCDC hosted an international workshop in Asheville, NC to gather international experts in global tropical cyclone best-tracking to discuss a variety of topics that would serve to enhance the existing dataset and develop an agreed set of principles for the best track process.

4.6.1.2 The meeting acknowledged the excellent work that has been completed through the IBTrACS project and especially the establishment of the HURSAT dataset. The meeting identified the important unifying role IBTrACS plays in bringing together all track data across the globe and looks forward to further development of the entire dataset. The meeting acknowledged the role for IBTrACS as a diagnostic and research tool for use by all within
the tropical cyclone community. To support that role and to establish analysis and reporting procedures, the meeting recommended the establishment of an Advisory Panel comprising members from the RSMC/TCWCs and Research community. Further the meeting suggested that representatives from the RSMC/TCWCs to be included on that panel be Mr Philippe Caroff, Mr Jack Bevan, Mr Andrew Burton and a representative from Tokyo RSMC. The meeting saw the need for a review of the WMO format for reporting tropical cyclone best track information and recommended that the Advisory Panel should undertake that review for the Tropical Cyclone Programme.

4.6.2 Annual Summary of Global Tropical Cyclone Season

4.6.2.1 The meeting recalled that the annual summary of global tropical cyclone seasons, which contains the seasonal TC activities of all basins, was first published by WMO/TCP in August 2001. The summary is now posted on the TCP website and its publication in CD-ROM has been terminated.

4.6.2.2 On the basis of the needs of the TCP website users, WMO Secretariat requested the RSMCs and the TCWCs concerned to send their seasonal summaries to TCP as soon as completed. In this regard, the meeting was informed by the WMO Secretariat that TCP will cease posting the best track data on the website but develop a link with the IBTrACS website instead. The meeting was also informed that the seasonal forecasts are planned to be posted on the TCP website in consultation with the climate division of the Secretariat.

4.7 Global Guide to Tropical Cyclone Forecasting & TC Forecasters Website

4.7.1 The meeting noted the excellent work being undertaken by the authors of the revised Global Guide to Tropical Cyclone Forecasting, which is being led by Mr Charles Guard as Chief Editor. Although the project is running behind time, substantial progress has still been made. Recognising the importance of this work, the meeting urged WMO to make every effort to facilitate the completion of the Guide in a form suitable for incorporation into operations. The meeting reiterated that due consideration need to be placed on the utility in the operational forecasting.

4.7.2 In a related matter, WMO also presented the Tropical Cyclone Forecaster Website, which is under construction. The meeting commended the efforts being made and noted the importance of this work in assisting forecasters, particularly those in developing countries. It urged WMO to complete the site as soon as possible, in consultation with the TCWCs and TC RSMCs. The meeting also noted that such a site will need to be maintained on an ongoing basis to ensure relevance.

4.8 Storm Surge Watch Scheme

4.8.1 The meeting recalled that the Executive Council, at its sixtieth session (June 2008), requested the Secretary-General to facilitate the development of storm surge watch schemes (SSWS) for regions subject to tropical cyclones in consultation with UNESCO/IOC. It was recommended that such schemes should be incorporated in the tropical cyclone advisory arrangements and in the TCP Regional Operating Plans and/or Manual. In this regard, the meeting noted that all the regional TC bodies have already taken necessary actions in some way or other on the initiatives of RSMCs and TCWCs.

4.8.2 RA V SSWS Action Team held its first meeting in December 2008 and agreed that any watch scheme for RA V should address all of the marine weather-related threats for the Pacific Island Countries (PICs) including (i) storm surges associated with tropical cyclones; (ii) waves associated with tropical cyclones; and (iii) long-period waves (remotely generated swell).

4.8.3 WMO/ESCAP Panel on Tropical Cyclones agreed in March 2009 on the need for a regional storm surge watch scheme, and endorsed the commitment by the RSMC New
Delhi to incorporate such a scheme in its tropical cyclone advisory arrangements for the PTC region through close cooperation with Indian Institute of Technology.

4.8.4 RSMC Tokyo conducted a questionnaire survey in June 2009 on the present status of the Typhoon Committee Members in using storm surge models with a view to providing storm surge model guidances as part of the regional SSWS suitable for the Typhoon Committee region.

4.8.5 RSMC La Reunion informed the meeting that Meteo France owns a storm surge model and a cyclone swell model. Both do not have operational status and can only be run on request essentially the swell model when a cyclone threatens Reunion Island. Being able to provide storm surge guidance in real time for all territories within the RA I TCC area will require giving an operational status to the model. The National Marine Division in Toulouse has the capability to do the necessary developments but lacked manpower in the past years to do the job and develop an operational version of the model. It is hoped that this could be achieved within a reasonable date, provided that reliable bathymetric data will be available for Madagascar or Mozambique.

4.9 Severe Weather Forecasting Demonstration Project

4.9.1 Mr Terry Hart (Chair, Working Group on the Planning and implementation of the World Weather Watch in Region V) and Steve Ready (Chair of the Regional Subproject Implementation Team) presented a general overview of the WMO Severe Weather Forecasting Demonstration Project (SWFDP) and a report on the status of the Severe Weather Forecasting and Disaster Risk Reduction Demonstration Project (SWFDDP) in WMO Region V (South-west Pacific). They noted that the SWFDP has been designed as a series of regional subprojects whose scope is to test the usefulness of NWP products produced by global and regional meteorological centres, with the goal of improving severe weather forecasting services in developing countries. The first such project was carried out in southern Africa and proved very successful. It is now moving to a more operational stage and has been expanded in scope.

4.9.2 The subproject in RA V is known as the Severe Weather Forecasting and Disaster Risk Reduction Demonstration Project (SWFDDP) to emphasise that public weather services and disaster risk reduction are part of the project from the start. The initial aim was to focus primarily on severe weather associated with Tropical Cyclones. However, Pacific Island Countries (PICs) highlighted a need for improved forecasting and warnings of strong winds and heavy rain not associated with tropical cyclones and also significant marine effects such as long-period waves and storm surge.

4.9.3 The pilot field phase commenced on 1 November 2009 and involves four participating NMHSs (Fiji, Solomon Islands, Samoa and Vanuatu). These NMHSs have committed to involving their natural disaster management offices in development of severe weather services to their communities, and to evaluating the guidance products and their forecast performance. RSMC Wellington has developed a central web site and will provide overview guidance products to participating NMHSs.

4.9.4 RSMC Wellington has also conducted an in-country training program in the participating countries. RSMC Nadi will provide expanded tropical cyclone predictions services including graphical forecast track maps. RSMC Darwin will contribute an expanded range of regional NWP products. Global Centres (currently ECMWF and UK MetOffice) are providing NWP products, including EPS products, targeted at severe weather phenomena and tropical cyclones (including probabilities of genesis).

4.9.5 Bandwidth limitations affecting access to the MetConnect Pacific web site had been encountered in one or two of the NMHS but steps are being taken to resolve the problem.
4.9.6 An expanded range of NMHS will participate in the expanded demonstration phase of the Project scheduled to commence in November 2010.

4.9.7 The meeting commended Steve Ready and the Regional Subproject Implementation Team on the impressive progress to date, particularly the establishment of the MetConnect Pacific web site and the programme of in-country training.

4.9.8 The meeting noted that it was important that the Disaster Risk Reduction and Public Weather Services objectives of the project be considered from the start, and requested the participating NMHS to ensure that these objectives were realised.

4.9.9 The meeting noted that the in-country training had been a very successful programme that was well-received by the NMHS and the natural disaster management offices (NDMOs). The meeting recommended that in-country training be included in the expanded demonstration phase.

4.9.10 The meeting also noted that financial resources for the SWFDDP were very small. Given the high impact potential of the project, and its focus on a key strategic objective for WMO, the meeting reemphasises requests made at CBS-XIV for WMO to explore options to make funds available for this high priority project.

4.10 Research

4.10.1 Collaboration with WWRP

4.10.1.1 The meeting was informed of an overview of the World Weather Research Program (WWRP) and THORPEX activities relevant to the WWW/TCP. This overview included brief reports of the combined WWRP Tropical Cyclone Panel Tropical Cyclone Structure (TCS08) and THORPEX Pacific Asia Campaign (T-PARC) field experiment in the western North Pacific that observed typhoons from the formation stage to the extratropical stage and its related downstream impacts. The possible involvement of WWRP/THORPEX in the Southwest Indian Ocean (SWICE) field experiment planned for January-February 2011 was also mentioned. Other WWRP and THORPEX-related initiatives for using ensemble prediction systems for tropical cyclone prediction were described, and the Year of the Tropical Convection (YOTC) was mentioned as a source of high resolution numerical model analyses and forecasts and satellite products for tropical cyclone research studies during the period 1 May 2008 through 30 April 2010.

4.10.1.2 The meeting also noted that the second International Workshop on Tropical Cyclone Landfall Processes (IWTCLP-II) in Shanghai during October 2009 had a strong participation by operational forecasters. These forecasters had summarized the operational needs for improved forecast guidance that could serve as guidance for the WWRP Tropical Cyclone Panel in planning their future activities. In turn, the forecasters had an opportunity to hear of the research opportunities and commend on some planned WWRP research programs. The meeting concurred with the IWTCLP-II summary of operational needs that reflected the differences between the developed countries and those of the developing countries, and concurred that the improved track forecasts for landfalling tropical cyclones continues to be a high priority.

4.10.2 Research activities at TC RSMCs/TCWCs

4.10.2.1 Research activities at the Australian TCWCs were presented under this agenda item.

4.10.2.2 It showed the recent research activities of the TCWCs related to; i) Prediction, ii) Ocean Coupling and extended prediction, iii) Climatology, iv) Larch-mesoscale Structure and Processes, v) Case studies by operational staff and vi) Operations and research needs to meet service demands as follows;
- Operational implementation of research outcomes: There appears to be a “missing link” between getting good research results and applying them in operations. In Australia, increased interaction between forecasters and researchers is necessary to ensure research meets the service requirements of the organization. Also, better data viewing tools to address increased data streams.
- Storm Surge: need for a consistent storm surge methodology.
- A probabilistic output that gives the worst-case scenario (0% Exceedence).
- Need the ability to create “what if” scenarios in real time.
- Cyclogenesis: need to develop a systematic forecast process that utilizes the state of the art science (eg. Okubo-Weiss) - needs to include cyclogenesis diagnostic tools.
- Also improved conceptual models of decay after landfall.
- Next Generation Forecasting System (NGFE) – need for incorporation of TC forecasts.
- Intensity Forecasting - work needs to be done on a consensus/ensemble approach to intensity forecasting.
- Rainfall Forecasting - utilise the existing eTRaP data being produced.
- Improved wave guidance through coupling of ocean wave model with TC NWP
- Improved TC database to enhance the capabilities of risk assessments.
- Improved observational systems / platforms within the TC and its environment.

4.11 Capacity building

4.11.1 The meeting stressed that an important aspect of the TCP continues to be the training of tropical cyclone forecasters, which is essential for a sustained augmentation of the tropical cyclone warning services provided to the public by NMHSs. To this effect, the meeting agreed that TCP should give greater attention to capacity building, through training activities, mainly in the form of dedicated courses and workshops, and forecaster training attachments to the TC RSMCs. Specifically, forecasters of the least developed countries (LDCs) and Small Island Developing States (SIDS) in the tropical cyclone basins were seen as a priority target group.

4.11.2 In considering a list of training activities conducted under the Tropical Cyclone Programme, the meeting agreed that it would be useful to also have access to a consolidated list of significant activities undertaken on a bilateral or VCP basis by the TCWCs and TC RSMCs. It was agreed that a list of these activities would be coordinated by WMO as part of the report to the meeting, and in future such activities would be reported as part of the members’ reports to the meeting.

4.12 Review of terminology/classification of tropical cyclones

4.12.1 The meeting reviewed the list of terminologies and classifications of tropical cyclones adopted during previous coordination meetings (see Appendix V), and noted that a few words such as “EXTRA-TROPICAL CYCLONE” and “EXTRATROPICAL TRANSITION” have slightly different definitions in respective RSMC/TCWC basins. It is suggested that WMO should pay adequate attention to these differences among the basins in the international use of the terms.

4.12.2 The meeting recalled that at IWTC-VI in Costa Rica, a paper was presented to discuss definition of the terminology of 4 related terms - TC strike, TC impact, TC coastal crossing & TC landfall. Although consensus was not reached at IWTC-VI, the meeting agreed to discuss these definitions at TCM-7 to include them in the list of terminology. It was also recommended that the list should simply be called “List of Tropical Cyclone Terminology” and not as “standard”.

4.13 Recommendations to IWTC-VII
4.13.1 Prof. Russell Elsberry presented an overview of the seventh International Workshop on Tropical Cyclones (IWTC-VII) that will be held in La Reunion during 15-20 November 2010 and asked for recommendations from the TCM-6 participants.

4.13.2 The meeting was informed that an international organizing committee has been appointed, and Prof Chris Velden of U. S. and Dr Jeff Kepert of Australia are the co-chairs. The meeting noted that duration of IWTC-VII is a Monday-Saturday period and is only six working days rather than the prior eight working days over a ten-day period. The key issue at the present time is what topics are to be covered at IWTC-VII given the reduction from eight working days to only six. Some previous topics (e.g., tropical cyclone motion) will have to be combined with other topics. Present thinking is that formation, structure and structure change (including intensity change), and mitigation and social-economic considerations are likely to be topics.

4.13.3 The meeting emphasized that, as was the case for previous workshops in the series, this workshop be designed to serve as a forum for the interaction between forecasters and researchers in the area of tropical cyclones, and to encourage the application of research results to operational usages.

4.13.4 The meeting noted the following several factors that would lead to the decision for a shorter period:

I. A significant number of researcher participants, especially from the U. S., were only coming for the first week due to academic teaching schedules and the usual overlap with the U. S. Thanksgiving holiday.

II. Major initiatives from IWTC-VI are only being completed in 2010: (i) The update of the book Global Perspectives on Tropical Cyclones is expected to be published in January 2010 and many of these chapters will have been updated through mid-2009. (ii) Update of the Forecaster Guide to Tropical Cyclones will not be completed until shortly before IWTC-VII. (iii) A journal publication that is a new assessment on Tropical Cyclones and Climate Change is expected to be published in January 2010, and this considers all publications through September 2009. An update of the Statement on Tropical Cyclones and Climate Change is under preparation and will be released in conjunction with the publication of the assessment article described above. Thus, it is expected that this topic will require less time than at IWTC-VI. (iv) Establishment of WMO website for tropical cyclone seasonal forecasts. (v) The second International Workshop on Tropical Cyclone Landfall Processes (IWTCLP-II) was held during 19-23 October 2009 and covered several topics that have previously been topics at the IWTCs.

III. La Reunion is a more expensive venue and air travel will be rather expensive for a large fraction of the expected participants in IWTC-VII. Various sources of additional funding are being explored, especially to ensure that a substantial number of forecasters are able to attend.

4.13.5 Recommendations from TCM-VI are requested as to topics and subtopics that are to be covered in the daily plenary and discussion sessions, or for the special focus sessions that will be organized for forecasters at IWTC-VII. These special focus sessions (attendance-optional) are organized each late afternoon to present and discuss in detail a topic that may be of special interest to the researchers (e.g., planning for a field experiment) or forecasters (e.g., Andrew Burton of BoM organized a session on consensus forecasting at IWTC-VI). These recommendations from the RSMCs and TWCs might be similar to the topics proposed at the recent IWTCLP-II: (i) Hydrological perspectives on tropical cyclone precipitation be a key topic for discussion with researchers and forecasters; (ii) Tropical cyclone wind structure (e.g., including pressure-wind relationships) be a key topic for discussion and a special focus topic for forecasters; and (iii) Address key issues related to air-sea interaction at high wind speeds and the design of optimum sampling strategies for ocean probes as an integral part of the program, and to include a special focus session on the ITOP and Gulf of Mexico field experiments.
4.13.6 One recommendation was to focus on the need for accurate long-term records of tropical cyclone activity with the objective of developing a global database, perhaps in conjunction with the CBS. A special focus session on the recent improvements in the Dvorak technique was suggested. Either an overview or a special emphasis on uncertainties in forecasting all tropical cyclone variables and in the use and interpretations of probabilities would address new research and operational practices of interest in many WMO Regions.

4.13.7 The meeting noted that this is an optimum time for providing input to the organizers of IWTC-VII. In addition to recommended topics and special focus sessions, the meeting requested the TCM members to continue to provide any suggestions for organization of the IWTC-VII that will make it more beneficial for the tropical cyclone forecasting community to the organizing committee through the WMO Secretariat.

5. CLOSURE OF THE MEETING

5.1 At the closing ceremony, Mr Koji Kuroiwa, the representative of the WMO Secretariat, expressed the appreciation of WMO to the Bureau of Meteorology in particular TCWC Brisbane for hosting the meeting and for the excellent facilities provided. He expressed his gratitude to Messrs Jim Davidson and James Weyman for their excellent leadership as Chairman and Vice-chairman, respectively, and the local secretariat, for the excellent work they did. Mr Kuroiwa also thanked all participants for their active participation in the discussions throughout the meeting. The Chairman of the meeting thanked all participants for their support and declared the meeting closed at 1230 hours on 5 November 2009.
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APPENDIX IV  Activity reports of RSMCs and TCWCs

APPENDIX V  List of standard terminologies
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APPENDIX II

AGENDA

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       4.2.1 Improved accuracy of the forecast of TC RSMCs/TCWCs
       4.2.2 Requirements of the observational data and the NWP guidance
   4.3 Official forecasts from TC RSMCs/TCWCs vs. forecasts from other sources
   4.4 Coordination on the transboundary storms
   4.5 Tropical Cyclone Advisory for international civil aviation and coordination with WAFCs
   4.6 Tropical cyclone best track data base
       4.6.1 International Best Track Archive for Climate Stewardship (IBTrACS)
       4.6.2 Annual Summary of Global Tropical Cyclone Season
   4.7 Global Guide to Tropical Cyclone Forecasting & TC Forecasters Website
   4.8 Storm Surge Watch Scheme
   4.9 Severe Weather Forecasting Demonstration Project
APPENDIX II

4.10 Research
   4.10.1 Collaboration with WMO/WWRP
   4.10.2 Research activities at TC RSMCs/TCWCs
4.11 Capacity building
4.12 Review of terminology/classification of tropical cyclones
4.13 Recommendations to IWTC-VII

5. CLOSURE OF THE MEETING
IWTC-VI Recommendations reviewed by TCM-VI

- IWTC-VI urges the WMO Space Program convey to all consortiums and entities involved in the development of satellite programs the importance of maintaining and even increasing the level of remote sensing coverage, with specific attention given to instruments that provide data for monitoring and prediction of tropical cyclones (microwave data, scatterometer data, altimeter data, total precipitable water data, etc…). (HP) In particular the issue of decreased scatterometer data availability in the near-future is a matter of crucial importance to the tropical cyclone community.

(Progress)
- Like last year, the draft recommendation seems motivated by the wish to support Quikscat follow-on. NOAA is trying to negotiate such a follow-on in partnership with Japan, and this should be encouraged. However we should not deny the other scatterometer missions. ASCAT on METOP is an operational mission which is secured for the next decade at least. ISCAT on Oceansat-2 (ISRO) was launched last month and ISRO announced last week at CGMS that the data will be available after the commissioning and validation phase. HY-2A from China (State Ocean Administration) will be launched next year and the availability of data was mentioned last year but needs to be confirmed.
- As concerns geostationary microwave instrument (passive) our efforts have been stopped as decided by the Consultative Meeting on High-level Policy on Satellite Matters. The technology is not mature enough and the countries are not ready to cooperate on this sensitive technology.
- There is no information about a plan for active microwave instruments in GEO orbit. In any case the principle of the RRR (Rolling Requirements Review; the process to review users’ requirements for observations) is that users express requirements for physical parameters they need, rather than suggesting a technical solution. GEO active microwave missions are not foreseen in the vision for the GOS in 2025 approved by the last CBS and EC. So I would not support such a recommendation.

- WMO should therefore take action to ensure the operational, timely availability and dissemination of all satellite data of major interest to the tropical cyclone community.

(Progress)
- WIS has been developed.

- WMO should explore all possible means to maintain, restore, and even expand, the existing upper-air network, especially in developing countries. Targeted observation strategies could be used to optimize the implementation of rawinsonde stations.

(Progress)
- Over the past few years GCOS has funded and managed the renovation/upgrade of 10-15 upper air stations. These upgrades have included the provision of hydrogen generators, upper air equipment and consumables.
- The activities with the WWW has included technical workshops such the one held in Namibia in 2007 in which all GUAN stations in Africa were training in correct observing techniques. These activities along with the competitive procurement process employed have lead to a rich competition among the suppliers and thus an overall cost reduction for users.
- We have further established a good number of additional performance reports which further results in improved operation.
• GUAN network has gone from 30 silent stations (out of 160) 6 years ago to literally none silent today. The only silent ones today are those that just failed or ran out of consumables.

- WMO should coordinate with the NWP and major operational centres (RSMCs and TCWCs) in order to define a set of resolvable tropical cyclone characteristics to be provided and timely disseminated by the NWP centres through the GTS (e.g. centre location, minimum sea level pressure, max wind, wind radii by quadrants, etc...) and define the appropriate standardised format. and/or find a WMO-sponsored dedicated reference centre (similarly to what has been done with the Severe Weather Information Centre for the dissemination of the analysis and forecast products issued by the main operational centres) able to host and maintain a single global data base of the tropical cyclone forecasts originating from the different NWP centres.

(Progress)
• It is our understanding that several NWP centres now place tropical cyclone track information on the GTS in a standard format, but that the parameters included may vary with the centres. The ECMWF, for example, includes not only position but central pressure, while other centres do not include this information. A central site for ensemble forecasts can be found at THORPEX TIGGE web sites:
  - This site contains links to tropical cyclone tracks forecasts provided by seven centres that allows access with some centres operating in a password protected mode. I am not aware of any single data base of tropical cyclone forecasts.

- Interaction with the TIGGE initiative could be considered (see TIGGE item thereafter).

(Progress)
• Links have been established through the proposed North Western Pacific Tropical Cyclone Ensemble Forecast Research Project in 2010.

- WMO/CAS could ask, in cooperation with WWRP, the Working Group on Forecast Verification to put in place a formal mechanism for this purpose, defining a common methodology and set of parameters appropriate to tropical cyclones to be verified (e.g. genesis, tropical cyclone tracks – including provision of along track and cross track error statistics –, intensities or intensity changes, size – wind radii –, rainfall prediction, etc...).

(Progress)
• Activities on tropical cyclone verification are underway by the Joint WGNE/WWRP Working Group on Forecast Verification Research in support of Shanghai MHEWS. I will inquire about the status of such efforts and formally propose that this Working Group take on this task more fully at next week's WGNE meeting.

- Where there exist multiple “best tracks” for a specific basin, these need to be incorporated into a unified, reanalyzed tropical cyclone database. Such reanalysis efforts will by nature enerally create a heterogeneous time series because of differing available observations; however, it is also crucial that homogeneous tropical cyclone climate databases be developed.

(Progress)
• IBTrACS has been developed.
We suggest that WMO should facilitate a meeting between the interested operational and research experts to encourage interaction and collaborative research in this field.

(Progress)
- IWTCLP, IWTC, TCP training course/workshop, TCP regional body session.

It is recommended that the various tropical cyclone wind scales in use globally be identified and a summary of their features published for reference by WMO/RSMCs/TCWCs.

(Progress)
- Study on the conversion factors for wind speeds.

As a major initiative an international database should be developed to track the loss of human life and socio-economic impacts of tropical cyclones as well as the costs associated with tropical cyclone forecasting and disaster mitigation initiatives. A small multi-disciplinary task force should be formed to monitor the development of the database and to liaise with other groups with a similar goal.

(Progress)
- There are 4 global databases that document impacts on loss of life and economic losses associated with disasters including tropical cyclones. What is needed from our end is standardization of Hazard database (tropical cyclones and related hazards). Also, there is need for tools for mapping of tropical clones and related hazards (storm surge, tropical cyclone related tornadoes, land slides, etc). We have initiated an ad hoc task team in CBS to look into these issues with CAS. This needs to be established and linked to CAS.

IWTC-VI asks WMO to continue to support all initiatives aimed at that purpose: sponsoring of small focus thematic workshops, training courses, attachment of forecasters at the main operational centres (RSMCs and TCWCs), development of Computer Assisted Learning, etc.

(Progress)
- WGNE has taken on the task of examining the performance of NWP models in predicting intensity. They have found growing skill in this area, particularly for those models with relatively higher resolution. The WWRP Tropical Cyclone Panel also launched a major field effort called the Tropical Cyclone Structure 2008 experiment to advance understanding and develop strategies to improve forecast skill in these areas.

Specific training focused on the following topics should be promoted:
- Ensemble and consensus approaches and related forecasting and probability forecast interpretation
- Identify effective methods and tools to better communicate the forecasts, warnings and the realistic threats to emergency managers, media and the public.

(Progress)
- TIPS Workshop conducted in Jeju, Korea in May 2009 by the joint effort by Typhoon Committee and WMO/TCP.
- Training on tropical cyclone rainfall and storm tide forecasting.
- Storm surge workshop in Melbourne in December 2008.
APPENDIX III

- RA IV Workshop on Hurricane Forecasting in Miami, RA I Tropical Cyclone Training Course in La Reunion, and Southern Hemisphere Workshop in Melbourne.

- The IWTC-VI also recommends that WMO hosts a dedicated tropical cyclone web page including tutorials, training modules, frequently-asked-questions and links to useful related sites.

  (Progress)
  - Tropical Forecasters Website has been developed.

- The IWTC-VI reiterates the urgent need to issue a revised and updated version of the Global Guide to Tropical Cyclone Forecasting and endorses the content of the major WMO recommendation already made on this topic at the previous IWTC-V meeting (refer to the related Proceedings), except that the chapter “The Total Warning System” should be expanded into “Effective Warning System and societal impacts”. A small multidisciplinary task force should be formed to prepare the new section.

  (Progress)
  - Ongoing.

- IWTC-VI also asks WMO to rapidly initiate the process towards a follow on publication of an updated version of the Global Perspectives on Tropical Cyclones.

  (Progress)
  - Ongoing.
Activity Reports of RSMCs and TCWCs
Recent and Current Activities of RSMC Honolulu

1. Tropical Cyclone Seasons

1.1 2009 Tropical Cyclone Season. Developing El Niño conditions across the equatorial Pacific Ocean in 2009 translated into above normal tropical cyclone activity in the Central North Pacific. From 1 January 2009 through 31 October 2009, seven tropical cyclones formed within or moved into the Central North Pacific. An active MJO (Madden Julian Oscillation) phase contributed to five tropical cyclones around the month of August, which is typically the most active month as well. The normal for the basin is four to five tropical cyclones each year. The remnants of Hurricane Felicia produced significant flooding in Hawaii. The system produced widespread 3 to 6 inches of rain across several islands and flash flooding on Oahu. The highest rainfall amounts recorded were 13.46 inches and 14.63 inches over the mountains of Kauai and Oahu, respectively. RSMC Honolulu coordinated the deployment of Air Force Reserve WC-130 and NOAA Gulf Stream hurricane reconnaissance aircraft as Hurricane Felicia headed toward the main Hawaiian Islands. The flights provided crucial data which greatly assisted RSMC forecasters.

1.2 2008 Tropical Cyclone Season. Tropical cyclone activity in the Central Pacific from 1 January 2008 to 31 December 2008 was much below normal. Only one occurred, Tropical Storm Kika. It was the first tropical cyclone since 2006 which formed in the central Pacific. All of the others moved into the area from the east Pacific.

1.3 2007 Tropical Cyclone Season. Tropical cyclone activity in the Central Pacific from 1 January 2007 to 31 December 2007 was below normal. Three occurred: 1 tropical depression, 1 tropical storm, and 1 hurricane. Tropical Storm Cosme which entered RSMC Honolulu’s area of responsibility (140W to 180, north of the equator) on 18 July passed south of the Big Island as a tropical depression bringing heavy rain to the windward slopes. The most serious threat to the state of Hawaii occurred in August when Hurricane Flossie passed 95 nautical miles south of the southern tip of the Big Island of Hawaii bringing tropical storm force winds to the southernmost part of that island.

2. Products and Services

Successful Evacuation

2.1 Active coordination between RSMC Honolulu forecasters, NOAA Marine Fisheries, NOAA Office of Marine and Aviation Operations, the U.S. Coast Guard, and the U.S. Fish and Wildlife Service resulted in the successful evacuation of three remote islets in the Papahanaumokuakea National Monument (NW Hawaiian Islands) in advance of Hurricane Neki. A total of 17 people were safely evacuated in October 2009.

New Tropical Cyclone Products for 2009

2.2 RSMC Honolulu implemented several new tropical cyclone products and changes to current products for the 2009 Central Pacific Hurricane Season. The first was the addition of a three tiered and color coded scheme to describe probability of development for areas described in the graphical Tropical Weather Outlook introduced in 2008. The second was the tropical cyclone Wind Field Graphic which displays the areas affected by tropical storm and hurricane force winds. A graphical display of Tropical Cyclone SIGMETS was also added to the RSMC product suite and the Maximum Wind Speed Probability Wind Table was extended from 72 to 120 hours. In addition, RSMC Honolulu extended the lead time for tropical storm/hurricane watches from 36 to 48 hours and extended the lead time of tropical storm/hurricane warnings from 24 hours to 36 hours in 2009.
New Tropical Cyclone Products for 2008

2.3 RSMC Honolulu implemented several new tropical cyclone products for the 2008 Central Pacific Hurricane Season. The first was a graphical Tropical Weather Outlook which showed areas of disturbances and then a discussion on their structure and potential for development. The second was a specific, separate product which is issued when either a tropical cyclone watch or warning is issued. Previously, the watches and warnings when issued were “Headlined” in the standard tropical cyclone products, but a separate product was not issued.

New Items for 2007

2.4 Interactive Forecast Preparation System (IFPS) and the Graphical Forecast Editor (GFE): This is the main forecast system in the U.S. NOAA National Weather Service which produces the forecast by first having the meteorologists prepare a set of gridded data for all elements of the forecast and then use automatic formatters to take these gridded data to generate a worded forecast. The meteorologists have new tools to edit the digital forecast database in this system, which can import the tropical cyclone maximum sustained wind and wind radii from RSMC Honolulu’s tropical cyclone track and intensity forecast and apply them to the local domain of gridded data which has a resolution of 2.5 km. Forecasters can apply an appropriate eye diameter for the tropical cyclone, and a wind speed reduction factor over land. This provides higher resolution spatial and temporal weather information to local disaster preparedness personnel.

2.5 High Resolution Weather and Research Forecasting (WRF) Model - Nonhydrostatic Mesoscale Model (NMM) data: RSMC Honolulu began ingesting high resolution WRF-NMM data from the University of Hawaii Mesoscale Modeling Group into the Interactive Forecast Preparation System approximately 20 July 2007. The model is comprised of several different domains, with a maximum spatial resolution of 3 km over Maui and the Big Island of Hawaii, and 1.5 km over Kauai and Oahu. The model will provide forecasters with high resolution wind fields over the islands and provide insight into meso beta and gamma-scale terrain-forced local wind effects.

2.6 Hurricane WRF: Forecasters at RSMC Honolulu began utilizing and evaluating the new Hurricane WRF model provided by the National Centers for Environmental Prediction (NCEP) during the 2007 tropical cyclone season. The Hurricane WRF is eventually expected to replace the Geophysical Fluid Dynamics Laboratory (GFDL) model.

2.7 Probabilistic Wind Guidance: RSMC Honolulu began generating graphical and text products of probabilistic guidance of 34, 50, and 64 knot winds for discrete and cumulative time periods from 0-120 hours in 2006. However, there were no significant land-based threats to Hawaii in 2006. With the approach of Hurricane Flossie, this was the first opportunity that land-based users had to evaluate the guidance during a significant threat to the Hawaiian Islands.

2.8 Graphical Watches and Warnings: RSMC Honolulu implemented graphical depiction of tropical cyclone watches and warnings on the RSMC Honolulu webpage. This is in addition to graphical depiction of tropical cyclone track forecasts, both deterministic and probabilistic.

2.9 Targeted Email Notification: RSMC Honolulu began targeted email service (listserv) to those key customers requesting delivery of RSMC Honolulu products via email. The mailing list allows subscribers to receive RSMC Honolulu bulletins via email within minutes of being issued. Approximately 2200 customers signed up for the service thus far.

2.10 RSMC Honolulu implemented software tools within the Gridded Forecast Editor (GFE) system to facilitate easier quantitative precipitation forecast (QPF) production. The tools, also known as “Smart Tools”, allow for the adjustment of forecasted physical
parameters to determine precipitation totals quickly for all 2.5 x 2.5 km grid points in the Honolulu Forecast Office's domain. Production of experimental QPF grids started in late 2006 and continues through 2007. Grids covering all the main Hawaiian Islands are available through 7-days.

2.11 National HazCollect: RSMC Honolulu served on the national HazCollect Implementation Team. HazCollect is a system which allows Emergency Managers to send Civil Emergency Messages directly to NOAA Weather Radio for broadcast in regions of the USA or throughout the entire USA. WFO Honolulu and State of Hawaii Civil Defense Agency jointly participating in the initial alpha testing starting in late 2008 and was one of the first offices to implement HazCollect operationally in 2009.

2.12 Hawaii Rain Gage Collection Network Replacement: NOAA NWS Pacific Region received funding to replace the entire rain gage collection network system in the state of Hawaii. The new system is replacing the aging rain gages with new technology and will use HF radio line of sight communication system rather than land or cell phone lines. The project commenced in January 2009 to install the communication infrastructure. Eighteen new gages have been installed to date.

2.13 Performance Goals: RSMC Honolulu surpassed the USA NOAA NWS’s 48 hour Government Performance and Results Act tropical cyclone forecast track error goal of 110 nautical miles for 2007 with a documented track error of 92 nautical miles and the 2008 goal of 108 nautical miles with an error of 94. The average track error is based upon the calculated 5-year running mean errors.

2.14 Governor Recognizes RSMC Honolulu: Governor Linda Lingle hosted an appreciation reception for CPHC/WFO Honolulu, State and County Civil Defense, Red Cross and others at the historic Washington Place on September 10, 2007. She held the event to recognize and express her appreciation to all the agencies involved in forecasting and preparing for Hurricane Flossie as it approached the Hawaiian Islands in August 2007. She praised CPHC for their accurate forecasts, timely updates, extensive coordination, and for the reassurance to the public which clearly stated the hurricane was going to pass to the south of the islands and not curve as destructive Hurricane Iniki did in 1992.

2.15 Mayor Recognizes RSMC Honolulu: The Mayor of the City and County of Honolulu presented a certificate of recognition for being an “Outstanding Community Partner” to RSMC Honolulu at a press conference on May 13, 2008. The certificate was “Presented in recognition of your dedicated and faithful community service to the residents of the City and County of Honolulu.”

3. Training

3.1 FEMA Training. RSMC Honolulu hosted a 3 day class for 19 Emergency Managers and First Responders on April 14-16 2009: The 3-day pilot course was a specialized training opportunity to build the capacity of the civil defense/emergency manager to understand hurricanes and make effective protective action decisions during a hurricane threat. Through hands-on and interactive instruction with specialists at RSMC Honolulu, the course provided participants with an intensive instruction on all aspects of tropical cyclone forecasts and products, along with local National Weather Service forecast office products.

3.2 Pacific International Pacific Desk Program: From 1 January 2009 to 31 October 2009, the Pacific International Desk Training Programme, RSMC Honolulu, Hawaii Islands, USA trained 6 forecasters from 6 different members of WMO RA V regions, including Samoa, Vanuatu, New Guinea, Philippines, Solomon Islands, and Tonga. Since its inception in 2001, 52 people from 15 Members of WMO Regional Association V and 2 Members from the Typhoon Committee have attended this programme. The USA government, through NOAA NWS funded the training programme.
3.3 Makani Pahili Hurricane Exercise: The annual Makani Pahili Hurricane Exercise, coordinated by Hawaii State Civil Defense in partnership with the National Weather Service Forecast Office in Honolulu was held from 26 May to 4 June. This year’s exercise was the culmination of a year long effort to develop, exercise, and validates the Hawaii Catastrophic Hurricane Readiness Response Plan. RSMC Honolulu exercised coordination procedures with civil defense and military partners around Hawaii during the event.

3.4 Summer Science Programs: RSMC Honolulu participated in three summer science programs for elementary and high school students. One was for students from the “How to be a Weather Wiz Kid” class at Kamehameha Schools to learn about tropical cyclones and severe weather and the second were students from the “Discovering Science through Aerospace” class at Mid Pacific Institute to learn about tropical cyclones and climate in Hawaii. The third was the Sky and Space Class taught at the University of Hawaii Lab School.

3.5 Weather Spotter Training: RSMC Honolulu provided basic and advanced weather spotter training to 25 volunteers of the City and County of Honolulu Department of Emergency Management (DEM) on December 8, 2007. The volunteers are trained to identify and report to the weather offices significant weather events. Most of the group also provides emergency communications and coordinates relief efforts in rural areas on Oahu.

3.6 Hurricane Workshop: In May 2008, RSMC Honolulu presented a day-long hurricane workshop for Emergency Managers and Media. The director, deputy director, and the Warning Coordination Meteorologist provided information on historical events, tropical cyclone threats, lessons learned, tropical weather outlooks, and probability forecasts. Attendees included members of local television stations, radio stations, print media, police,

4. Preparedness/Outreach Activities

4.1 Outreach and Press Conference: A comprehensive tropical cyclone outreach program for the 2009 Central Pacific Hurricane Season generated a heightened awareness of emergency preparedness in the State of Hawaii. The theme of the 2009 campaign, Hawaii’s First Responders are Prepared, Are You?, focused on maintaining awareness of tropical cyclone hazards, preparing emergency kits, and developing action plans for individuals, families, and businesses. RSMC Honolulu hosted a press conference to announce the 2009 Central Pacific Hurricane Season Outlook on May 20, 2008. Following opening remarks from the RSMC Honolulu Director, guest speaker Fire Chief Kenneth Silva of the Honolulu Fire Department spoke on the role of first responders in a disaster and keynote speaker Mufi Hanneman, Mayor of the City and County of Honolulu touched on personal responsibility for emergency preparedness. All 4 local television and the 2 statewide newspaper attended press conference and featured stories that evening and/or the next day on hurricane preparedness. The theme for the 2008 campaign was “Be prepared, be empowered! The theme of the 2007 campaign, Stay in Touch: Stay Prepared, focused on maintaining awareness of tropical cyclone hazards, preparing emergency kits, and emphasized action plans for individuals, families, and businesses.

4.2 Hawaii State Hazard Mitigation Forum: The Hawaii State Hazard Mitigation Forum, of which RSMC Honolulu is a member, is tasked with maintaining and updating the Hawaii State Hazard Mitigation Plan. Forum members met regularly and to discuss hazard threat, risk assessment, and actions which can be taken to mitigate the hazard risk to protect lives and property from loss and destruction during a natural hazard.

4.3 Hawaii Emergency Preparedness Executive Consortium: RSMC Honolulu is a member of the Hawaii Emergency Preparedness Executive Consortium (HEPEC). HEPEC is comprised of emergency managers and disaster mitigation personnel from local, state, and federal agencies. HEPEC meets quarterly to provide updates on current and outstanding threats, both natural and manmade, to the State of Hawaii. The RSMC
Honolulu Director provided a hurricane presentation to the group during the June 2009 meeting.

4.4 Hurricane Preparedness Workshops: RSMC Honolulu personnel conducted 17 hurricane related workshops including the annual CPHC Press Conference and staffed booths at 5 emergency fairs. Overall, RSMC Honolulu participated in a total of 111 education or outreach events to internal partners and external customers at all levels. These included Hawaii Fishing and Seafood Festival (15,000 people attended); Waianae Elementary School Career Day (300); as judges at the Hawaii State Science and Engineering Fair (500); University of Hawaii School of Earth and Ocean Science and Technology Open House (4,000 students).

4.5 StormReady/TsunamiReady: Maui and Hawaii counties of Hawaii, USA successfully renewed their StormReady/TsunamiReady recognition through 2011. StormReady and TsunamiReady are programs of the U.S. National Weather Service (NWS). In conjunction with emergency managers, the NWS completes a checklist of various items that are necessary for a county or community to be prepared for hazardous weather situations. The items on the checklist include ensuring the community has a 24 hour point of contact, multiple ways of receiving NWS watches and warnings, multiple ways to dissemination the NWS watches and warnings once they receive them, and adequate plans for various types of hazardous weather. In 2004, Hawaii was the first state in the United States to be StormReady and TsunamiReady statewide.

5. Research

5.1 Federal Emergency Management Agency (FEMA) and the State of Hawaii Civil Defense (CD) Catastrophic Disaster Event Planning: FEMA, Hawaii State CD, the University of Hawaii, Pacific Disaster Center, and the USA NOAA NWS RSMC Honolulu completed the development, exercise, and validation of the Hawaii Catastrophic Hurricane Readiness Response Plan in 2009. As part of this planning, the University of Hawaii and RSMC Honolulu developed a very sophisticated storm inundation for island communities with coral reefs composed of 6 different models at varying resolutions. To test this plan, RSMC Honolulu developed 12 hurricane tracks with varying tracks, speed of movement, intensity, and size for the plan. The plan featured a strong Category 4 hurricane hitting the most populated area of Honolulu, Hawaii. USA Federal Emergency Management Agency executes part 1b of the plan with a hurricane in the central Pacific approaching Hawaii, and 1c either when a watch is issued for the islands or the probability of hurricane force winds are between 10 and 20 percent for any place on the islands. At stage 1b, FEMA expends significant funds by pre-locating people and resources, because of the isolated nature of the Hawaiian Islands.

5.2 Probabilistic Tropical Cyclone Genesis: As part of the Hollings Scholar program a student from Florida State University spent 9 weeks at RSMC Honolulu. This scholar along with the Deputy Director of RSMC Honolulu conducted studies of probabilistic tropical cyclone genesis in the central Pacific. All available data on tropical cyclones were used with Dvorak fixes as one of the major data sources. This research continues and in the future may involve RSMC Miami and the Atlantic Ocean.

5.3 Ocean Vector Winds: RSMC Honolulu continues to advocate for real time ocean vector winds for the future. The Deputy Director is part of the Operations Team associated with the planning, development, and coordination with NASA, Japan, and others on replacements to QuikSCAT winds.

5.4 Wind Probabilities: Wind probabilities for tropical storm and hurricane force winds out to 120 hours play an important part in the ability of RSMC Honolulu to communicate risks to emergency managers and other decision makers. RSMC Honolulu is working with RSMC Miami on a Joint Hurricane Testbed project to continue to improve the beneficial use of these probabilistic winds.
APPENDIX IV
(Le Reunion)

Review of recent (2005-2009) main activities and achievements at RSMC La Réunion

Introduction

The Direction of Météo-France in La Réunion has been formally designated as the Regional Specialized Meteorological Centre (RSMC) - Tropical Cyclones for the South-West Indian Ocean during the 45th session of WMO/Executive Council (Geneva, June 1993), with effect on 1 July 1993.

The area of responsibility of the RSMC includes the tropical and subtropical areas of the South-West Indian Ocean from the Equator to 40°S and west of 90°E to Africa (therefore including the Mozambique Channel).

The primary mission of the RSMC/La Réunion is to provide appropriate guidance information (analyses, forecasts, prognostic reasoning,...) to the 15 Members of the AR 1 Tropical Cyclone Committee (Botswana, Comoros, France, Kenya, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zimbabwe) for all the tropical disturbances occurring in its area of responsibility. However, beyond this fundamental operational function, the RSMC has the role to become the regional focal centre for all the other activities conducted in the field of tropical cyclones such as, for instance, Training and Research/Development.

In addition to its responsibilities as an RSMC, Météo-France La Réunion has numerous other national and international responsibilities. Within the GTS, it is a hub in the regional telecommunication network. In the framework of GMDSS, it has the responsibility of preparing marine forecasts and warnings for extensive portions of the METAREA VII-OI and METAREA VIII-S areas. Furthermore, with the role of assisting the MWO's of the whole region in the preparation of SIGMET messages for tropical cyclones, ICAO has designated RSMC/La Réunion as its Regional Tropical Cyclone Advisory Centre.

Météo-France La Réunion takes also an active part in the International Buoys Programme in the Indian Ocean (IBPIO), implementing pressure recorders for instance and regularly organizing the deployment in tropical or polar areas of drifters from ships calling at La Réunion.

Main achievements since last TCM-5 meeting

II-1. Increased access to TC-oriented NWP products

Before 2006 (prior to the previous TCM-5 meeting in Hawaii) a certain stagnation in the performances of the RSMC was noticed with a levelling off in the reducing trend of the track forecast errors. It was considered a priority to remedy to this situation.

Big efforts have been made to get access to an increased number of various NWP-TC guidance and track forecasts in order to make a better profit from the new techniques (like the consensus technique).

In parallel, operational access to ensemble prediction has become the routinely standard.

II.2. Developing our own LAM

Aiming to also improve the Météo-France offer and performances in terms of numerical modelling of tropical cyclones, a dedicated high resolution Limited Area Model (called ALADIN-Réunion) has been developed for the RSMC. Being run at Toulouse (where the super-computer of Météo-France is located) it is however followed and managed by the Cyclone Research Cell based at Météo-France La Réunion.
First implemented in October 2006, it has been specifically designed to better handle the tropical storms with a vortex bogussing technique introduced. The method was refined in December 2007 with a wind bogus technique which led to very significant improvements: much better location of the initial position of the TCs, improved accuracy in track forecasts and improved skill for intensity prediction (outperforming other models).

Last evolutions of ALADIN-Réunion include extension of the domain (June 2008), which now covers most of the RSMC’s area of responsibility, and of the forecast range (84h), inclusion of own SST analysis and important modifications to the physics (parameterisations of the surface fluxes and turbulent vertical mixing) in February 2009.

Next step will be in January 2010 with the increase of the resolution of the model both horizontally (from 10 to 8 km) and vertically (from 60 to 70 levels).

II.3. Important upgrade of the TC forecaster workstation
At the same time the availability of numerical model TC track forecasts was highly increased in-house operational tools were developed in order to facilitate their visualization and best use by the tropical cyclone forecasters at the RSMC.
In this purpose the Synergie workstation has been the subject of an important upgrade with the tropical cyclone module becoming fully operational while new added functions and facilities have been included associated to a better ergonomy of the software. Recently, the display of graphical products captured on specialized internet websites (NRL, CIMSS) has been rendered possible on our Synergie workstations using the Google Earth technology that enables to get access to geo-localized imagery.

II.4. Major improvement of the official track forecasts performances
Benefiting from all the aforementioned efforts and also from the major improvements demonstrated in the recent years by some global numerical models in the handling and forecasting of TCs, the results have surpassed all the hopes with a big step downward being achieved in reducing the errors of the official TC track forecasts disseminated by RSMC La Réunion. The gains have been outstanding with an up to 40% reduction for the longest range track forecasts errors (72h forecasts) when verifying the 2006-2007 cyclone season official forecasts.
RSMC La Réunion has thereby recovered the – temporary lost – leadership in TC track forecasting for its area of responsibility (the SouthWest Indian Ocean). And while raw seasonal track forecasts errors seem to go through another stalling phase since then, the reality is that improvements keep on as witnessed by the skill against persistence which still shows a positive trend during the past two seasons (which were more difficult in terms of track forecasting).

II.5. Quality certification and RSMC Survey
The imperious necessity to come up to the highest possible standard was also a requirement in the framework of the certification iso 9000 : 2001 that was awarded to Meteo-France (and to its regional Centre based in La Réunion) in 2005/2006. Another requirement is to regularly check the quality of the services provided with our main users, which are the National Meteorological and Hydrological Services. In that purpose a survey has been prepared and will be submitted to the NMHSs of the RA I region (members of the SouthWest Indian Ocean Tropical Cyclone Committee) by the end of the coming 2009-2010 cyclone season.

II.6. Development of a new specialized website
A new specialized website completely dedicated to the RSMC has been developed. The first version which is planned to open for the coming 2009-2010 cyclone season will be highly operationally oriented with access to all the real-time and archived products disseminated by the RSMC.
APPENDIX IV

II.7 Implication in the RA I SWFDP project
Meteo-France and RSMC La Reunion are active partners of the Severe Weather Forecasting Demonstration Project (SWFDP) that has been implemented with WMO for southern African countries. Meteo-France is involved through the RSMC products (for the cyclone hazard) and through the provision of NWP fields from the ALADIN-Réunion Limited Area Model.

II.8 Implication in the RAMA network
The RAMA (Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction) network is an instrumented moored buoys network deployed in the near-equatorial Indian Ocean. It is an important contribution to the Indian Ocean Observing System (IndOOS) and the counterpart of the TAO/TRITON and PIRATA networks of the Pacific and Atlantic Oceans.
Meteo-France has decided to join this programme considering that the RAMA network is a great opportunity to improve the surface observing coverage of the RSMC’s area of responsibility. Hence, Meteo-France will provide pressure recorders for 4 moored buoys deployed for the southwestern portion of the network while RSMC La Reunion has been involved in the geographical definition of the network.

Future perspectives

III.1. 5-days forecasts
Considering the recent increased skill in TC track forecasting it has been decided to move towards 5-days forecasts (shifting from the current 3-days forecasts) since 120h forecasts are now as good as were the 72h forecasts when we started to disseminate them in 2003.

III.2. Towards probabilistic cones of uncertainty
Something which is lacking in the present production of La Reunion’s Centre is providing a degree of uncertainty of the track forecasts. Instead of including a cone of uncertainty based on the average errors climatology, like what is done by most centres, it was considered to try to develop a more sophisticated method through an innovative probabilistic approach which would more realistically take into account the real degree of uncertainty of each individual TC track forecast situation. The idea was to use the spread information included in the ensemble forecasts (EPS from the ECMWF) to better assess the uncertainty and construct an EPS-based probabilistic adaptive cone. The related developments are close to their end so that we do hope to be able to start testing a first pre-operational version during next southern hemisphere cyclone season.

III.3. Towards adopting a new pressure-winds relationship
In 2007 Knaff&Zehr have proposed a new "universal" pressure-winds relationship (PWR) that would take into account most of the parameters influencing the pressure winds relationship within tropical systems (i.e. storm size, environmental pressure, latitude, speed of movement). In 2008 a modified version was then proposed by Courtney&Knaff and is now in use by all Australian TCWCs. An evaluation of these new PWRs against the currently used Atkinson&Holiday PWR has been undertaken at RSMC La Réunion using a set of joint pressure-winds observations obtained during storms’ events having directly affected islands in the SouthWest Indian Ocean region.
Following this evaluation a proposal will be made at the next RA I Tropical Cyclone Committee meeting to adopt the K&Z pressure-winds relationship.

III.4. Hosting IWTC-VII
The organization of the next International Workshop on Tropical Cyclones (IWTC-VII) has been awarded to Meteo-France La Reunion. This important meeting will be hosted at La Réunion from 15 to 20 November 2010. For the first time it will take place in the Indian Ocean a unique occasion to highlight this basin, probably the one which is the less known and studied. And it will also be the first time that it is organized and hosted by an RSMC.
III.5. Satellite re-analysis project
RSMC La Réunion has decided to start a re-analysis project based on the Dvorak re-analysis of past satellite imagery. This project, strongly supported by the last IWTC-VI and IBTrACS Workshop recommendations, has now become feasible thanks to the disposal of an archive of TC-dedicated satellite images developed by the NCDC (NOAA National Climate Data Center – Asheville). This so called HURSAT database contains both geostationary and AVHRR imagery from polar orbiting satellites. Preliminary actions have already been undertaken like the treatment of the NetCDF format for internal visualization of the geo-localized images on our workstations.

III.6. The SWICE project
RSMC La Réunion is highly involved in the definition and design of a tropical cyclone field experiment to be conducted in the SouthWest Indian Ocean hopefully in January-February 2011 if the funding is granted. The main components of the project called SWICE (for SouthWest Indian Cyclone Experiment) will rely on a dense upper-air stations network and air reconnaissance missions operated with an instrumented French research aircraft in the surrounding environment of developing or mature storms evolving within the proposed field area. The whole set of data and targeted observations collected from the radio-soundings, released dropsondes, microphysical probes, will serve different scientific goals. Among them are: the assessment of sampling strategies and evaluation of the impact of targeted observations for TC prediction by the numerical models, the validation of the sensors and measurements from the Megha Tropiques mission (to be launched in June 2010).
Tropical Cyclones

Activity since 2005

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RMSC Miami totals:
#NS 111
#H 49
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Major Hurricanes Dean and Felix in 2007 caused damage and loss of life in the Eastern Caribbean, Mexico, and Nicaragua. The 2008 hurricane season produced many landfalls in the regions, resulting in over 1000 fatalities and over $25B USD damage. About 85% of the fatalities were due to fresh water flooding and mudslides.

Changes in products and services
The rapid progression of internet driven information service continued since the last meeting. Graphical product development expanded accordingly. Miami introduced a Graphical Tropical Weather Outlook that includes a three tiered (low, medium, high) probability of tropical cyclone genesis. Also introduced was a graphic depicting the current storm size, location, past track and active warnings. Work continues on providing all graphical products in GIS compatible formats. Mostly cosmetic changes have been made to the text products. Based on internet statistics, the Tropical Cyclone Discussion was the most viewed text product.

Second level products gaining use with decision makers include our wind probability graphics (34, 50, 64kt) and maximum intensity probability tables. These are used in briefings after presenting the deterministic information. Another area where advancement in information has just started is storm surge. For the U.S., graphics displaying inundation and probabilities have been introduced.

Ongoing Challenges
Continued growth in the coastal evacuation zones, lack of understanding of storm surge, lack of acceptance of probabilistic nature of forecasts and insufficient building codes are key issues needing more work. Storm surge technology for other nations within the basin are still in need of detailed development work. While skill in forecasting track continues to improve, intensity and size forecasts still show little gain.
The Hurricane Forecast Improvement Project (HFIP) has been launched to address forecast issues. An ambitious goal of 50% improvement in track and intensity forecast within the next decade has been set. Much debate is underway on the way forward. Modeling efforts with global and high resolution storm scale are moving forward. Basic science and observation requirements needed to run high resolution models are challenges.

**RA IV activities**
Annual meetings have been held which has continued to advance collaboration and coordination among the member nations in the basins. A two week Hurricane 101 training session has been held each year at RSMC Miami. Feedback from attendees indicates the value of the training received. A Caribbean Hurricane Awareness Tour is conducted each March visiting up to 5 cities in the region using the Hurricane Hunter C-130 and crew as a draw for schools and the public. Over 25,000 people visited during the 2009 tour.
ACTIVITIES OF REGIONAL SPECIALIZED METEOROLOGICAL CENTRE – TROPICAL CYCLONES, NEW DELHI

INTRODUCTION

Regional Specialized Meteorological Centre (RSMC) - Tropical Cyclones, New Delhi has the responsibility of issuing Tropical Weather Outlook and Tropical Cyclone Advisories for the benefit of the countries in the WMO/ESCAP Panel region bordering the Bay of Bengal and the Arabian Sea, namely, Bangladesh, Pakistan, Maldives, Myanmar, Sultanate of Oman, Sri Lanka and Thailand. It has also the responsibilities as a Tropical Cyclone Advisory Centre (TCAC) to provide Tropical Cyclone Advisories to the designated International Airports as per requirement of International Civil Aviation Organisation (ICAO).

The broad functions of RSMC- Tropical Cyclones, New Delhi are as follows:

- Round the clock watch on weather situations over the entire north Indian Ocean.
- Analysis and processing of global meteorological data for diagnostic and prediction purposes.
- Detection, tracking and prediction of cyclonic disturbances in the Bay of Bengal and the Arabian Sea.
- Running of numerical weather prediction models for tropical cyclone track and storm surge predictions.
- Interaction with National Disaster Management Authority and National Disaster Management, Ministry of Home Affairs, Govt. of India to provide timely information and warnings for emergency support services. RSMC-New Delhi also coordinates with national Institute of Disaster Management (NIDM) for sharing the information related to cyclone warning.
- Implementation of the Regional Cyclone Operational Plan of WMO/ESCAP Panel.
- Issue of Tropical Weather Outlook and Tropical Cyclone Advisories to the Panel countries in general.
- Issue of Tropical Cyclone advisories to International airports in the neighbouring countries for International aviation.
- Collection, processing and archival of all data pertaining to cyclonic disturbances viz. wind, storm surge, pressure, rainfall, damage report, satellite and Radar derived information etc. and their exchange with Panel member countries.
- Preparation of comprehensive annual reports on cyclonic disturbances formed over North Indian Ocean every year.
- Preparation of annual review report on various activities including meteorological, hydrological and disaster preparedness and prevention activities of panel member countries.
- Research on storm surge, track and intensity prediction techniques.
- Coordination with the panel member countries during cyclone period (list of the nodal officers is given in enclosure – 1)

1.1 AREA OF RESPONSIBILITY AND CLIMATOLOGY

The area of responsibility of RSMC Tropical Cyclones, New Delhi (hereafter referred to as RSMC- New Delhi) covers Sea areas of north Indian Ocean north of equator between 45° E and 100° E and includes the member countries of WMO/ESCAP Panel on Tropical Cyclones viz, Bangladesh, India, Maldives, Myanmar, Pakistan, Sri Lanka, Sultanate of Oman and Thailand as shown in Fig. 1. The centre issues Tropical Weather Outlook daily at 0600 UTC in normal weather. If a depression forms over north Indian ocean a Special Tropical Weather Outlook is issued additionally at 1700 UTC. The Tropical Cyclone Advisories are issued on tropical cyclones at three hourly intervals when they develop over
the north Indian Ocean. RSMC New Delhi has also been issuing Tropical Cyclone Advisories for Aviation as per requirements of ICAO.

RSMC- New Delhi is continuing the naming of Tropical Cyclones formed over North Indian Ocean since October 2004.

1.1.1 Climatology of tropical cyclones over the north Indian Ocean

The havoc caused by tropical cyclones to shipping in the high seas and coastal habitats along the Indian coasts have been known since hundreds of years. The tropical warm Indian Ocean, like the tropical North Atlantic, the South Pacific and the NE Pacific, is a breeding ground for the disastrous tropical cyclone (TC) phenomenon. TCs are accompanied by very strong winds, torrential rains and storm surges. Historically, in terms of loss to human life, the Bay of Bengal TCs have accounted for deaths ranging from a thousand to three hundred thousands.

It is now a well known fact of climatology that about 5 to 6 TCs occur in the North Indian Ocean prominently during the pre-monsoon season (March-April-May) and the post-monsoon season (October-November-December). Nearly 7 percent of the global TCs form in the North Indian Ocean. The maximum frequency is in the two months of May and November (Fig.2). The Bay of Bengal TCs more often strike Orissa-West Bengal coast in October, Andhra coast in November and the Tamilnadu coast in December. Over 60 percent of the TCs in the Bay of Bengal strike different parts of the east coast of India, 30 percent strike coasts of Bangladesh and Myanmar and about 10 percent dissipate over the sea itself. The tracks of cyclones over the north Indian Ocean during 1891-2007 are shown in Fig.3. The cyclones crossing different coastal states are shown in Fig.4. Several efforts have been made in the IMD to update climatological records on TCs of the North Indian Ocean. Atlases showing tracks of individual cyclones are also published. Recently an electronic atlas has been published for tracks of cyclonic disturbances over the Bay of Bengal and Arabian Sea. Analyses of storm tracks with reference to their genesis, recurvature and landfall points on 1°x1° scale along the Indian coasts have also been produced.
Fig. 2. Monthly frequency of cyclonic disturbances during 1891-2007 over north Indian Ocean

Fig. 3. Tracks of cyclones over the north Indian Ocean during 1891-2007
Fig. 4(a). Frequency of TCs over the Bay of Bengal landfalling over different coastal states during 1951-2000

Fig. 4(b). Frequency of TCs over the Arabian Sea landfalling over different coastal states during 1951-2000
1.2 OBSERVATIONAL SYSTEM

A brief description of different types of observational network of IMD and observations collected from networks are given below.

1.2.1 Observations from basic network

The network of stations adopted for regional exchange by the world weather watch is considered adequate for routine tracking of weather systems. However in the cyclone season particularly when a tropical disturbance exists in the region special efforts are made by the national meteorological services (NMS) to improve the collection and distribution of surface synoptic reports from the coastal stations. National Meteorological services have established a large number of meteorological observing stations, in addition to those in the regional basic synoptic network, observations from which are received by the NMS. When there is tropical cyclone in the north Indian ocean, observations from these stations particularly from coastal stations are exchanged on real time basis on priority. Detail list of surface and upper air stations of the panel countries are given in TCP-21.

A number of Automated Weather Stations (AWS) are also in operation along the Indian coast and provide surface observations on hourly basis which are utilised in cyclone monitoring and forecasting.

1.2.2 Cyclone Detection Radars (CDR)

There are 11 Nos. of S-band Radar for Cyclone Detection located at Kolkata, Paradip, Visakhapatnam, Machilipatnam, Chennai, Sriharikota, Karaikal, Kochi, Goa, Mumbai, and Bhuj, (Fig. 5) in India. Out of these 11 stations, 6 stations (except Chennai, Kolkata, Sriharikota, Visakhapatnam and Machilipatnam which are Doppler radar) are using conventional S-band radars. there are 4 radar in Bangladesh, 5 in Thailand and one each in Myanmar, Pakistan and Sri Lanka.

Doppler Weather Radars (DWRs) provide vital information on radial velocity within tropical cyclone which is not available in conventional radars. Conventional radar provides information on reflectivity and range only, whereas a DWR provides velocity and spectral width data along with various meteorological, hydrological and aviation products which are very useful for forecasters in estimating the storm’s center, its intensity and predicting its future movement. The DWR generates these products through a variety of software algorithms.
India Meteorological Department is modernizing its observational network in the phased manner. In the first phase, four existing old conventional CDRs located at Paradip, Karaikal, Goa, and Mumbai will be replaced by Doppler Weather Radars soon. India Meteorological Department is also procuring 2 S-band Doppler Weather Radars which will replace cyclone detection radars at Bhuj and Kochi.

1.2.3 Satellite Monitoring

Under INSAT-3D program, a new Geostationary Meteorological Satellite INSAT-3D is being designed by ISRO. It will have an advanced imager with six imagery channels (VIS, SWIR, MIR, TIR-1, TIR-2, WV) and a nineteen channel sounder (18 IR & 1 Visible) for derivation of atmospheric temperature and moisture profiles. It will provide 1 km. resolution imagery in visible band, 4 km resolution in IR band and 8 km in water vapour channel. This new satellite is scheduled for launch in 2009 and will provide much improved capabilities to the meteorological community and users. In preparation for the reception and processing of this data, ISRO has installed a data reception and processing system to process the data from the INSAT 3A and Kalpana 1 satellites.

1.2.3.1 Web Products:

The Satellite Meteorology Division updates twelve images on the IMD website every half hour from the VHRR payload of INSAT and Kalpana satellites. It also updates jpeg images of various geophysical products as and when available. The division has also began maintaining an archive of all products of the web which is available to all users.

1.2.3.2 Meteorological Data Dissemination

IMD transmits processed imagery, meteorological and facsimile weather charts to field forecasting offices distributed over the country using the Meteorological Data Dissemination (MDD) facility, through INSAT in broadcast mode. The bulletins providing
description of the cloud organization and coverage are also sent as advisory to forecasting offices every synoptic hour. When cyclones are detected in satellite imagery, these bulletins are sent every hour. Such advisories are also transmitted to the neighbouring countries.

Processed satellite imagery, analyzed weather charts and conventional synoptic data are up-linked to the satellite in C-band. Satellite broadcasts these data to MDD receiving stations in S-band. MDD receiving stations analyse weather imagery and other data to generate required forecast. The processing system is also being used for generating analogue type of cloud imagery data which are transmitted through INSAT-3C to field stations using S-band broadcast capability of the satellite along with other conventional meteorological data and fax charts. There are about 33 MDD receiving stations in the country being operated by different agencies. Two MDD receiving stations are also operating in neighbouring countries at Sri Lanka and Male. In general, the processed images are sent to these stations every hour during cyclone periods. These stations are receiving direct broadcast of cloud imagery, weather facsimile charts and meteorological data on an operational basis.

1.3 TELECOMMUNICATION NETWORK

- The automated centre of Regional Telecommunication Hub (RTH), New Delhi is the Principal Meteorological Telecommunication Centres in South Asia and its zone of responsibility extends roughly from Saudi Arabia in the west to Thailand in the East and the adjoining sea areas. It collects data from this areas and feeds on to the Global Telecommunication System for Global and Regional Exchange. Other meteorological services in the Middle East and South East Asia also depend for their data requirements on RTH, New Delhi.
- it maintains Telecommunication Circuits with Moscow, Tokyo, Cairo, Jeddah, Bangkok, Colombo, Dhaka, Tehran, Karachi, Male, Yangon and Kathmandu. The circuit with Moscow and Beijing operates on 128 kbps speed, Dhaka, Pakistan, Jeddah, Cairo operates on 64 kbps, Melbourne, Male, Srilanka, Yangoon operates through Internet.
- India Met. Deptt. maintains a very extensive Telecommunication Network with Central Hub in its National Meteorological Telecommunication Centre (NMTC) at New Delhi connected with Five State of the art Regional Automatic Messages Switching Systems (AMSS) at Delhi, Kolkata, Chennai, Mumbai and Guwahati. AMSS at RTH New Delhi is under the process of upgradation (replacement) by the latest –state- of the art technology. For collection of Meteorological Data from the entire country, and the neighbouring NMTC, various modes of communication viz dedicated leased line circuits, fax, internet, high speed data terminals, VPN connectivity, VHF / Walkie-Talkie have been installed at various locations dispersed throughout the country.
- The Regional Telecom Hub (RTH) New Delhi maintains point to point Global Telecom System (GTS Ten links) and Five circuits through internet connectivity.
- For public weather informations Interactive Voice Response Systems (IVRS), popularly known as ‘Weather on Telephone’ have been installed at 26 stations (mainly state capitals) throughout the country.
- 28 Stations have been provided VPN Connectivity.
- 26 Stations have been equipped with 64 kbps high speed data terminals.
- A network of 26 V-SATs is being installed at selected seismological observatories, Cyclone Detection Radar stations, Cyclone Warning Centres for reception of observational data utilizing communication transponder of INSAT.
- A Satellite Data Dissemination System (SADIS) (receive only) is in operation at New Delhi to receive aeronautical meteorological information from International Civil Aviation Organization (ICAO) Centres.
1.4 ANALYSIS AND PREDICTION SYSTEM IN OPERATIONAL USE

1.4.1 Analysis

The analysis of synoptic observations is performed four times daily at 00, 06, 12, and 18 UTC. During cyclone period, synoptic charts are prepared and analysed every three hours to monitor the tropical cyclones over the north Indian Ocean.

Cloud imageries from Geostationary Meteorological Satellites INSAT-3A and METSAT (KALPANA-1) are the main sources of information for the analysis of tropical cyclones over the data-sparse region of north Indian Ocean. Data from ocean buoys also provide vital information. Ship observations are also used critically during the cyclonic disturbance period.

The direction and speed of the movement of a tropical cyclone are determined primarily from the three hourly displacement vectors of the centre of the system and by analyzing satellite imageries. When the system comes closer to the coastline, the system location and intensity are determined based on hourly observations from Cyclone Detection Radar and Doppler Weather Radar stations as well as coastal observatories. The AWS stations along coast are also very useful as they provide hourly observations on real-time basis. The water vapour derived wind vector and cloud motion vectors in addition to the conventional wind vectors observed by Radio Wind (RW) instruments are very useful for monitoring and prediction of cyclonic disturbances especially over the Sea region.
1.4.2. Quasi-Lagrangian Model (QLM)

The QLM, a multilevel fine-mesh primitive equation model with a horizontal resolution of 40 km and 16 sigma levels in the vertical, is being used for tropical cyclone track prediction in IMD. The integration domain consists of 111x111 grid points centred over the initial position of the cyclone. The model includes parameterization of basic physical and dynamical processes associated with the development and movement of a tropical cyclone. The two special attributes of the QLM are: (i) merging of an idealized vortex into the initial analysis to represent a storm in the QLM initial state and (ii) imposition of a steering current over the vortex area with the use of a dipole. The initial fields and lateral boundary conditions are derived based on global model (T-80 and T254) forecasts obtained online from the National Centre for Medium Range Weather Forecasting (NCMRWF), India. The model is run twice a day based on 00 UTC and 12 UTC initial conditions to provide 6 hourly track forecasts valid up to 72 hours. The track forecast products are disseminated as a World Weather Watch (WWW) activity of RSMC, New Delhi.

1.4.3. Limited Area Model (LAM)

The operational forecasting system known as Limited Area Forecast System (LAFS), is a complete system consisting of data decoding and quality control procedures, 3-D multivariate optimum interpolation scheme for objective analysis and a semi-implicit semi-Lagrangian multi-layer primitive equation model. The model is run twice a day based on 00 UTC and 12 UTC observations. The horizontal resolution of the model is 0.75°x0.75° lat. / long. With 16 sigma levels in the vertical. First guess and boundary conditions for running the LAFS are obtained online from global forecast model being operated by the NCMRWF. During cyclone situation, the model is run by including Holland vortex scheme. The forecast products are disseminated as a WWW activity of RSMC, New Delhi.

1.4.4. Non-hydrostatic Meso-scale Model MM-5 (Version 3.6)

The non-hydrostatic model MM-5 is being run on operational basis daily once based on 00 UTC initial conditions for the forecast upto 72 hours. The horizontal resolution of the model is 45 km with 23 sigma levels in the vertical. The domain of integration covers the area between lat. 25.0° S to 45.0° N and long. 30° E to 120.0° E. National Centre for Environmental Prediction (NCEP) analysis and six hourly forecasts are used as initial and boundary conditions to run the model. During cyclone situations, the model is run by including Holland vortex scheme. The forecast products are disseminated as a WWW activity of RSMC, New Delhi.

1.4.5. Non-hydrostatic mesoscale model WRF

Weather Research and Forecast (WRF) model has been implemented based on 00 UTC initial and boundary conditions from NCEP model outputs for the forecast up to 72 hours. The model is run with a single forecast domain covering Indian subcontinent at the horizontal resolution of 27 km. The performance of the model is found to be reasonably skilful for cyclone genesis and track prediction.

1.4.6. Statistical Dynamical model for Cyclone genesis and intensity Prediction

A statistical-dynamical model has been implemented for real time forecasting of cyclone genesis and intensity. The approach consists of (a) Analysis of Genesis Potential Parameter (GPP) and (b) 12 hourly Intensity Prediction for forecasts up to 72 hours. The model parameters are calibrated based on model analysis fields of past cyclones. For the real-time forecasting, model parameters are derived based on the forecast fields of MM5 model. The method is found to be promising for the operational use.

1.4.7 MME Technique
APPENDIX IV

Development of Multi-Model Ensemble Prediction Scheme for cyclone track prediction has been introduced experimentally since 2009. This MME is based on five global and regional models.

1.4.8. Storm Surge Model

For the operational storm surge prediction, IMD uses both nomograms developed by IMD and Dynamical Storm Surge Model developed by Indian Institute of Technology (IIT), Delhi. The nomograms are based on the numerical solution to the hydro dynamical equations governing motion of the Sea. The nomograms are prepared relating peak surge with various parameters such as pressure drop, radius of maximum wind, vector motion of the cyclone and offshore bathymetry. The dynamical model of IIT Delhi is fully non-linear and is forced by wind stress and quadratic bottom friction following the method of numerical solution to the vertically integrated mass continuity and momentum equations. The updated version of the model currently in operational use covers an analysis area lying between lat. 2.0° N and 22.25° N and long. 65.0° E & 100.0° E. The method uses a conditionally stable semi-implicit finite difference stair step scheme with staggered grid for numerical solution of the model equation. The bottom stress is computed from the depth-integrated current using conventional quadratic equation. The bathymetry of the model is derived from Naval Hydrographic charts applying cubic spline technique.

1.4.9. Mean Forecast Error

The mean forecast errors of RSMC, New Delhi based on data of last five years are given below.

- 12 hrs track forecast error: 87 km
- 24 hrs track forecast error: 139 km
- 12 hrs landfall point forecast error: 72 km
- 24 hrs landfall point forecast error: 81 km
- 12 hrs landfall time forecast error: 4 hrs
- 24 hrs landfall time forecast error: 4 hrs
- 24 hrs Intensity forecast error: T 0.5 (as per Dvorak classification)

1.4.10. Improved performance of cyclone forecasting

Comparing the landfall forecast errors, the 24 hour mean error has been significantly less during last two years (2008-2009, six cyclones). It is about 90 km (Nargis-110 km, Rashmi-20 km, KhaiMuk-150 km, Nisha-100 km, Bijli-40 km and Aila-110 km) against the long period average error of about 150 Km. The average 24 hrs wind forecast error has been about 10 knots for these cyclones.

1.5 NEW INITIATIVES IN CYCLONE FORECASTING

1.5.1 Timeliness of cyclone warnings

All the bulletins/warnings is being issued within 2 hours of observations, which is an improvement in lead time available to disaster management agencies.

1.5.2 Change in Format of Cyclone Warning Bulletin
The format of bulletins has been changed with inclusion of forecast track and intensity at +6, +12, +18, +24, +36, +48, +60 and +72 hours. The cyclone warning bulletins containing the above information is being issued for the first time in the history of IMD since December 2008. The Sample copies of bulletins issued during AILA are enclosed (Appendix A).

1.5.3. Inclusion of diagnosis and prognosis.

The physical reasoning describing the diagnosis and prognosis of cyclonic disturbances over the north Indian Ocean is being mentioned in the RSMC bulletin.

1.5.4. Prediction of Storm surge

IIT Delhi Storm surge prediction model has been introduced operationally since 2002. RSMC, New Delhi is issuing storm surge guidance in its advisory bulletin to member countries with effect from 2009.

1.5.5. Introduction of new cyclone forecasting system

Improvement in forecast and research with respect to cyclones are likely with upgradation of forecasting activity through Modernisation of Indian Meteorological Observational Systems and Applications (MIMOSA)/ VARSAMANA Project.

1.5.6. Prediction of extremely heavy rainfall

The prediction of extremely heavy rainfall (25 cm or more in 24 hours) over a district has been introduced since 2006. Prior to that the heavy rainfall warnings were issued in two categories only, viz., heavy rainfall (7-12 cm) and very heavy rainfall (13cm or more).

1.6 PRODUCTS GENERATED BY RSMC, NEW DELHI

RSMC, New Delhi prepares and disseminates the following RSMC bulletins.

1.6.1 Tropical Weather Outlook

Tropical Weather Outlook is issued daily at 0600 UTC in normal weather for use of the member countries of WMO/ESCAP Panel. This contains description of synoptic systems over north Indian Ocean along with information on significant cloud systems as seen in satellite imageries and ridge line at 200 hPa level over Indian region. In addition, a special weather outlook is issued at 1700 UTC when a tropical depression lies over north Indian Ocean.

1.6.2 Tropical Cyclone Advisories

Tropical cyclone advisories are issued at 3 hourly intervals based on 00, 03, 06, 09, 12, 15, 18 and 21 UTC observations. The time of issue is HH+03 hrs. These bulletins contain the current position and intensity, central pressure of the cyclone, description of satellite cloud imagery, expected direction and speed of movement and forecast of winds, squally weather and state of the Sea in and around the system upto 72 hrs. It also contains the diagnosis and prognosis of the system. Tropical cyclone advisories are transmitted to panel member Countries through global telecommunication system (GTS) and are also made available on real time basis through internet at IMD's website: http://www.imd.ernet.in and http://www.imd.gov.in. RSMC, New Delhi can also be contacted through e-mail (cwdhq@imdmail.gov.in) for any real time information on cyclonic disturbances over north India Ocean.
1.6.3 Global Maritime Distress Safety System (GMDSS)

Under Global Maritime Distress Safety System (GMDSS) scheme, India has been designated as one of the 16 services in the world for issuing Sea area bulletins for broadcast through GMDSS for MET AREA VIII (N), which covers a large portion of north Indian Ocean. As a routine, two GMDSS bulletins are issued at 0900 and 1800 UTC. During cyclonic situations, additional bulletins (up to 4) are issued for GMDSS broadcast. In addition, coastal weather and warning bulletins are also issued for broadcast through NAVTEX transmitting stations located at Mumbai and Chennai.

1.6.4 Tropical Cyclone Advisories for Aviation

Tropical Cyclone Advisories for aviation are issued for international aviation as soon as any disturbance over the north Indian Ocean attains or likely to attain the intensity of cyclonic storm (sustained surface wind speed ≥ 34 knots) within next six hours. These bulletins are issued at six hourly intervals based on 00, 06, 12, 18 UTC synoptic charts and the time of issue is HH+03 hrs. These bulletins contain present location of cyclone in lat./long., max sustained surface wind (in knots), direction of past movement and estimated central pressure, forecast position in Lat./Long and forecast winds in knots valid at HH+06, HH+12, HH+18 and HH+24 hrs in coded form. The tropical cyclone advisories are transmitted on real time basis through GTS and AFTN channels to designated International Airports of the region prescribed by ICAO.

1.6.5 Bulletin for Indian coasts

These bulletins are issued on every three hourly interval based on the standard 8 synoptic observations at 00, 03, 06, 09, 12, 15, 18 and 21 UTC when the system intensifies into a cyclonic storm over north Indian Ocean. This bulletin contains present status of the cyclone i.e. location, intensity; past movement and forecast intensity & movement, likely landfall point and time and likely adverse weather including heavy rain, gale wind & storm surge. Expected damage and action suggested are also included in the bulletins. This bulletin is completely meant for national users and these are disseminated through various modes of communication including All India Radio, Telephone/Fax, Print and electronic media. It is also posted on cyclone page of IMD website.

1.7 DISASTER PREVENTION AND PREPAREDNESS

1.7.1. Cyclone Warning Services

The extensive coastal belts of India are exposed to cyclonic storms, which originate in the Bay of Bengal and the Arabian Sea every year. These cyclones, which are accompanied with very heavy to extremely heavy rain, gales and storm surges cause heavy loss of human lives and cattle. They also cause extensive damage to standing crops and properties.

It is the endeavour of India Meteorological Department (IMD) to minimise the loss of human lives and damage to properties due to tropical cyclones by providing early warnings against the tropical cyclones. Cyclone warning is one of the most important function of the IMD and it was the first service undertaken by the department in 1865. The cyclone warnings are provided by the IMD from the Area Cyclone Warning Centres (ACWCs) at Kolkata, Chennai & Mumbai and Cyclone Warning Centres (CWCs) at Vishakhapatnam, Bhubaneswar and Ahmedabad.

The complete Cyclone Warning Programme in the country is supervised by the Cyclone Warning Division (CWD) at Head Quarter Office of the Director General of Meteorology at New Delhi. The CWD monitors the cyclonic disturbance both in the Bay of Bengal and Arabian Sea and advises the Government of India at the Apex level. Information on cyclone warnings is furnished on a real time basis to the Control Room in the Ministry of Home Affairs, Government of India, besides other Ministries & Departments of the Central
APPENDIX IV

Government. This Division provides cyclone warning bulletins to Doordarshan and All India Radio (AIR) station at New Delhi for inclusion in the National broadcast/telecast. Bulletins are also provided to other electronic and print media and concerned state govt. The Deputy Director General of Meteorology (Cyclone Warning) and Deputy Director General of Meteorology (Weather Forecasting) Pune monitor technical aspects and review the standard practices in the area of cyclone forecasting.

1.7.2. Cyclone warning bulletins

The following is the list of bulletins and warnings issued by ACWCs/CWCs for their respective areas of responsibility:

1. Sea area bulletins for ships plying in High Seas.
2. Coastal weather bulletins for ships plying in coastal waters.
4. Bulletins for Indian Navy.
5. Port Warnings.
6. Fisheries Warnings.
7. Four stage warnings for Central and State Govt. Officials.
8. Bulletins for broadcast through AIRs for general public.
9. Warning for registered users.
11. Warnings for Aviation (issued by concerned Aviation Meteorological Offices).

The cyclone warnings are issued to state government officials in four stages. The First Stage warning known as "PRE CYCLONE WATCH" issued 72 hours in advance contains early warning about the development of a cyclonic disturbance in the north Indian Ocean, its likely intensification into a tropical cyclone and the coastal belt likely to experience adverse weather. This early warning bulletin is issued by the Director General of Meteorology himself and is addressed to the Cabinet Secretary and other senior officers of the Government of India including the Chief Secretaries of concerned maritime states.

The Second Stage warning known as "CYCLONE ALERT" is issued at least 48 hrs in advance of the expected commencement of adverse weather over the coastal areas. It contains information on the location and intensity of the storm likely direction of its movement, intensification, coastal districts likely to experience adverse weather and advice to fishermen, general public, media and disaster managers. This is issued by the concerned ACWCs/CWCs and CWD at HQ.

The Third Stage warning known as "CYCLONE WARNING" issued at least 24 hours in advance of the expected commencement of adverse weather over the coastal areas. Landfall point is forecast at this stage. These warnings are issued by ACWCs/CWCs and CWD at HQ at 3 hourly interval giving the latest position of cyclone and its intensity, likely point and time of landfall, associated heavy rainfall, strong wind and storm surge along with their impact and advice to general public, media, fishermen and disaster managers.

The Fourth Stage of warning known as "POST LANDFALL OUTLOOK" is issued by the concerned ACWCs/CWCs and CWD at HQ at least 12 hours in advance of expected time of landfall. It gives likely direction of movement of the cyclone after its landfall and adverse weather likely to be experienced in the interior areas.

Different colour codes as mentioned below are being used in since post monsoon season of 2006 the different stages of the cyclone warning bulletins as desired by the National Disaster Management.

<table>
<thead>
<tr>
<th>Stage of warning</th>
<th>Colour code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclone Alert</td>
<td>Yellow</td>
</tr>
</tbody>
</table>
During disturbed weather over the Bay of Bengal and Arabian Sea, the ports likely to be affected are warned by concerned ACWCs/CWCs by advising the port authorities through port warnings to hoist appropriate Storm Warning Signals. The Department also issues "Fleet Forecast" for Indian Navy, Coastal Bulletins for Indian coastal areas covering up to 75 km from the coast line and sea area bulletins for the sea areas beyond 75 km. The special warnings are issued for fishermen four times a day in normal weather and every three hourly in accordance with the four stage warning in case of disturbed weather.

The general public, the coastal residents and fishermen are warned through State Government officials and broadcast of warnings through All India Radio and Doordarshan telecast programmes in national and regional hook-up. A system of warning dissemination for fishermen through World Space Digital Based radio receivers is being planned.

1.8 PUBLIC WEATHER SYSTEM (PWS)

1.8.1. Cyclone Warning Dissemination

In addition to the conventional network, for quick dissemination of warning against impending disaster from approaching cyclones, IMD has installed specially designed receivers within the vulnerable coastal areas for transmission of warnings to the concerned officials and people using broadcast capacity of INSAT satellite. This is a direct broadcast service of cyclone warning in the regional languages meant for the areas affected or likely to be affected by the cyclone. There are 352 cyclone warning dissemination system (CWDS) stations along the Indian coast; out of these 100 digital CWDS are located along Andhra coast. The IMD’s Area Cyclone Warning Centres (ACWCs) at Chennai, Mumbai and Kolkata and Cyclone Warning Centre (CWCs) at Bhubaneswar, Visakhapatnam and Ahmedabad are responsible for originating and disseminating the cyclone warnings through CWDS. The bulletins are generated and transmitted every hour. The cyclone warning bulletin is up-linked to the INSAT in C band. The warning is selective and will be received only by the affected or likely to be affected stations. The service is unique in the world and helps the public in general and the administration, in particular, during the cyclone Season. It is a very useful system and has saved millions of lives and enormous amount of property from the fury of cyclones. The digital CWDS have shown good results and working satisfactorily.

1.8.2 Upgradation of cyclone page of IMD website

The cyclone page of website has been upgraded with inclusion of many static and dynamic informations. The present cyclone page includes following:

Static information
(a). Frequently asked questions (FAQ)
(b). Terminology
(d). Reports on latest Cyclone.
(e). TCP-21 2008 edition

Dynamic information
(a). Bulletin for Indian Coast
(b). RSMC Bulletin
(c). Observed and forecast track
(d). QLM Track
(e). Satellite imagery
(f). Ocean state forecast
1.8.3 **Creation of RSMC website**

At present a common website (www.imd.gov.in) exists for both national and international use. A new website is being created for RSMC New Delhi with defined static and dynamic pages and link to the websites of the member countries.

1.8.4 **Introduction of new PWS**

A new PWS is being set up in IMD with the collaboration of Meteo France International for automatic production of bulletins, graphical display of warnings and automatic warning dissemination to various users through different telecommunication channels. For this purpose, the people have been trained in France also.

1.9. **DATA ARCHIVAL**

1. Six hourly best track data of cyclones over north Indian Ocean since 1990 in digital form are available and put up in website
2. 12 hourly data in cyclone electronic Atlas during 1891-2008 has been published.
   - India Meteorological Department has brought out an electronic version of the hard copy editions of its widely referred atlas “Tracks of Storms and Depressions in the Bay of Bengal and the Arabian Sea”, which were published by IMD in the years 1964, 1979 and 1996.
   - Designed with User friendly Menu driven interface
   - Incorporates 3 Basins viz. Bay of Bengal, Arabian Sea and Land (India & Neighbouring countries) and 16 pre defined Coastal belts
   - The eAtlas which could be installed in a personal desktop computer with Microsoft Windows Operating System would prove to be handy to Tropical Cyclone forecasters, research workers and disaster managers.
   - The eAtlas generates three different types of output viz:
     1. Display of Tracks of C&Ds
     2. Statistical data of C&Ds in map form
     3. Tables / Bar diagrams
   - Tracks can be saved and printed
   - Digital data of tracks also can be saved as document or excel file with the following options
     (i) Save as image, (ii) Save as document, (iii) Save as Excel
3. Data from 1877-1890 are also available in hard copies in 1979 edition of cyclone Atlas
4. Adverse weather including rainfall, wind and storm surge and damage reports for all cyclones are also available as publications

1.10 **IMPLEMENTATION OF REGIONAL CYCLONE OPERATION PLAN OF WMO/ESCAP PANEL**

Tropical cyclone operational plan for the north Indian Ocean has been published for the year 2008. The same for the year 2009 will be published soon. This report is available in IMD’ website (cyclone page)

1.11 **PUBLICATIONS**

The following publications are made by RSMC New Delhi:

1. Annual Report on Cyclonic Disturbances over the North Indian Ocean
2. Annual cyclone review report
3. Input for Panel News published by TSU, Pakistan
4. Publication of best track digital data
5. Meteorological Monographs
6. Preliminary reports on Cyclones
   All the cyclones over the north Indian Ocean have been individually documented and the document was made available to public and research communities through IMD website and e-mail with effect from cyclone, Nargis during April-May 2008.

1.12 Verification of Cyclone Warning

Systematic verification of operational cyclone track and intensity forecasts issued by IMD has been introduced. The verification of forecasts issued by RSMC, New Delhi has been included for the first time in the ‘Report of Cyclone disturbances over the north Indian Ocean during 2008’ which is published by RSMC-Tropical Cyclone New Delhi.

1.13 RESEARCH
1.13.1 Forecasting Manual on Cyclone

In view of the developments in observational tools and analysis and prediction techniques, the monitoring and prediction methodology w.r.t. cyclones over north Indian Ocean has undergone several changes. All these above facts have been documented as forecasting manual or cyclone manual. These manuals have undergone several changes in the past considering the requirements of forecasters and disaster managers. The last review of the cyclone manual was carried out and published by IMD during 2003.

In the recent years, there have been many developments in observational and prediction aspects including deployment of Doppler Weather Radar (DWR), Automatic Weather Station (AWS) and meteorological satellites and development of prediction models including Quasi Lagrangian Model (QLM), Weather Research and Forecast (WRF), Hurricane WRF(HWRF) models etc. in addition to various synoptic and statistical methods. Hence, the review of the forecasting manual on cyclone has been taken up and will be completed soon.

1.13.2. Implementation of WRF Model for cyclone prediction

There is a need to improve tropical cyclone intensity, track and associated rainfall prediction. The Weather Research Forecasting Model (WRF) is a general purpose, multi-institutional mesoscale modeling system. A version of the WRF model called the HWRF/WRF-NMM modeling system, developed at the National Center for Environmental Protection (NCEP) was recently adopted for hurricane forecasting by the National Hurricane Center (NHC).

Studies shows that higher resolution WRF model forecast was able to capture the movement and intensity of tropical disturbances in a better way. Research is going on for further improvement of this model and its operationalisation.

1.13.3 Introduction of MME technique for track prediction

- WMO has suggested to introduce MME technique for cyclone track prediction
- Research is going on for further improvement and operationalisation of the MME technique

1.13.4 Storm surge prediction

1.13.4.1 Probable Maximum Storm Surge (PMSS)

The probable maximum storm surge has been calculated for each district of India based on historical data, nomograms developed by IMD and simulation studies based on IIT Delhi storm surge model. A monograph has been published in this regard. The results are also
incorporated in the Vulnerability Atlas of India published by Ministry of Urban Affairs, Govt. of India.

1.13.4.2 Storm surge model

IIT, Delhi storm surge model has been installed in RSMC, New Delhi and a few people have been trained.

1.13.5. Cyclone prone districts of India

A project has been taken up by National Disaster Management Authority for identification of cyclone prone districts of India.

1.13.6 Seasonal prediction of cyclonic disturbances over the north Indian Ocean

A research project has been taken up for developing a statistical method for prediction of seasonal frequency of cyclonic disturbances. The preliminary study has been completed to find out the potential predictors.

1.13.7 Modulation of genesis and intensity of cyclonic disturbances by Madden Julian Oscillation

A study has been taken up of the study of modulation of genesis and intensity of cyclonic disturbances over north Indian Ocean by Madden Julian Oscillation. The results of this study will be utilized for extended range prediction (10-20 days) of genesis of cyclonic disturbances over the north Indian Ocean.

1.13.8 Meteorological Monographs on characteristics of specific cyclones

The met Monograph on “Cyclone OGGI” has been published and the same for cyclone “GONU, SIDR and NARGIS” is in progress.

1.13.9 Individual research papers published in reviewed journals and proceedings of seminar/symposium

A number of papers are published every year in various journals and proceedings. However, the abstracts of the papers published in Mausam Journal are documented in Annual Cyclone Review Report published by RSMC, New Delhi.

1.13.10 Damage Potential

Damage potential of cyclonic disturbances with different intensities has been analysed and published by IMD.

1.14 TRAINING

- RSMC, New Delhi is imparting training on cyclone warning to the WMO sponsored forecasters of various WMO/ESCAP Panel member countries since 2005. This year, the forecasters from Maldives and Bangladesh were attached with RSMC, New Delhi during Feb. 2009 for similar training.
- RSMC New Delhi conducts lecture series on cyclone warning during April and September, 2008 every year as a part of pre-cyclone exercise.
- A special lecture series was conducted during October 2008 for the benefit of the forecasters and researchers in HQ.
- Refresher courses are also conducted for the cyclone forecasters in regular intervals, especially for interpretation of satellite, radar and NWP products.
Two cyclone forecasters were trained from National Hurricane Centre, Miami, USA under USAID project during 2006. A new forecasting system is being introduced in IMD with the collaboration of Meteo France International. The cyclone forecasters have undergone training this year in France on cyclone forecasting.

1.15 SIGNIFICANT IMPORTANT MEETINGS AND CONFERENCES

- Director, RSMC regularly participates in the annual meeting Panel on Tropical Cyclones. Mr. B. K. Bandyopadhyay, Director RSMC, New Delhi participated in WMO/ESCAP Panel meeting at Oman during 2-5 March 2009 and presented a status paper on ‘Activities of RSMC-Tropical Cyclone, New Delhi
- Various officers participate in the seminars and workshops organized nationally and internationally on cyclone forecasting and allied subjects
- In the recently held First International Conference on Indian Ocean Tropical Cyclones and Climate Change during 08-11 March 2009 in Muscat. India’s viewpoint on the issue i.e. ‘Impact of Climate change on Indian Ocean Tropical Cyclones’ was prepared and sent to WMO. Six research papers on ‘Indian Ocean Tropical Cyclone and Climate Change’ submitted by IMD were accepted for presentation in the conference.

1.16 SIGNIFICANT INTERNATIONAL CO-OPERATION

1.16.1 Expert Member in WMO Fact Finding Mission to Myanmar

Dr M Mohapatra Participated as an expert member from India in the WMO’s Fact Finding Mission to Myanmar, Yangon during 9-13 February 2009 with the purpose of: (a) further detailed assessment of Department of Meteorology and Hydrology (DMH) actions during and following Nargis and needs for priority activities for capacity development; (b) provision of guidance to PR of Myanmar in working with the government authorities in development of effective early warning systems for cyclone and storm surge forecasting and warning to minimize impacts of future cyclones; (c) implementation of some key/priority proposed assistance (e.g., installation of priority equipment; demonstration of storm surge models and training); (d) familiarization of DMH staff and partners with WMO/ESCAP/PTC activities and potential opportunities for capacity development; and (e) formulation of recommendations to PR of Myanmar on the enhancement of DMH meteorological and hydrological activities, in general. The mission team was composed of representatives and experts in tropical cyclone and storm surge forecasting and warning from WMO (Dr T. Toya and Ms A. Soares); ESCAP (Dr Le Huu Ti), India (Dr M. Mohapatra and Prof. S. Dube), Pakistan (Dr Q. Chaudhry: PTC TSU Coordinator), Thailand (Dr W. Kanbua), and worked in full collaboration with Dr Tun Lwin and DMH staff. The following presentations were made by Dr Mohapatra during the Mission.
1. Regional Specialised Meteorological Centre (Tropical Cyclone), New Delhi
2. Review of cyclone Nargis – Monitoring/tracking and advisory/warning services : RSMC New Delhi Regional services
3. Standard operation procedure for Cyclone Warning Services In India
4. Modernisation of forecasting system and disaster management
5. Cyclone warning system.

Apart from the above, provided training to DMH cyclone forecasters about the operational cyclone warning system the Cyclone e-Atlas developed by IMD was installed and explained its usefulness.
1.16.2 Development of International Best Track of cyclones Archives for climate Stewardship (IBTrACS).

RSMC, New Delhi provided inputs for the development of international best track archives of tropical cyclones which is being developed in World Climate Data Centre (WCDC), located in National Climate Data Centre (NCDC), National Ocean and Atmospheric Administration (NOAA), Asheville, USA. Six hourly best track data of cyclones over the north Indian Ocean during 1990-2008 has been provided and the same is available in the website of WCDC/NCDC, USA.

Dr. M. Mohapatra also participated in the International workshop on IBTrACS held in USA during 5-7 May 2009 and gave a presentation on ‘Availability and quality of best tracks of cyclones over the north Indian Ocean’.

1.17. Forecast Demonstration Project (FDP) on Landfalling Tropical Cyclones over the Bay of Bengal

A Forecast Demonstration Project (FDP) on landfalling tropical cyclones over the Bay of Bengal has been taken up. It will help us in minimizing the error in prediction of Tropical Cyclone track and intensity forecasts. The programme has been divided into three phases

(iii) Final phase : Oct-Nov 2012

During pre-pilot phase (15 Oct-30 Nov 2008), several national institutions participated for joint observational, communicational & NWP activities. A report on implementation of prepilot phase has also been published.

1.18. Modernisation Programme of IMD

During the past 133 years, IMD has undergone several instances of modernization helping it to harmonize with emerging technologies and societal demands. The present phase of modernization which is underway is to adopt of technologies enabling Observational Upgradation , Advanced data communication and processing Technology, Advanced Computing Systems, Installation of specific purpose Numerical Prediction Models and Human Resource Development.
PERFORMANCE OF RSMC, NEW DELHI IN TRACK AND INTENSITY PREDICTION OF THE CYCLONES DURING 2008

The performance of RSMC-New Delhi in track and intensity prediction of the 4 cyclones during 2008 are presented and discussed below:

2.1. Very severe cyclonic storm, ‘NARGIS’

Likely formation of low pressure area over southeast Bay of Bengal and its further intensification was indicated in the daily bulletin issued from NHAC from 23 April onwards. The first special tropical weather outlook for the WMO/ESCAP Panel member countries including Myanmar intimating the formation of depression over the Bay of Bengal was issued at 0600 UTC of 27 April based on observations of 0300 UTC.

The tropical cyclone advisories to WMO/ESCAP Panel member countries including Myanmar were issued in every three hourly intervals from 28 April onwards till 0000 UTC of 3 May.

The first tropical cyclone advisory indicating landfall over Myanmar coast was issued at 0600 UTC of 1 May based on observations of 0300 UTC. It was indicated in the bulletin that the system would cross Myanmar coast between lat 16°N and 18°N around night of 2 May 2008. On 2 May morning, it was indicated in the bulletin that the system would cross Myanmar coast near 16°N around evening of the same day.

The forecast for maximum intensity (T 5.0) corresponding to maximum sustained wind speed of 90 knots was predicted and maintained in the tropical cyclone advisories for WMO/ESCAP Panel member countries from 2100 UTC of 1 May based on observations of 1800 UTC. The number of bulletins issued is as follows.

International
Special Tropical Weather Outlook – 3
Tropical Cyclone Advisories – 41
Tropical Cyclone Advisories for international civil aviation – 19

According to operational bulletin issued by RSMC, New Delhi there is 64 Kms forecast average error in 12 hrs and 112 kms in 24 hrs. In 24 hrs predicted intensity forecast there is about T0.5 average error.

<table>
<thead>
<tr>
<th>Landfall error</th>
<th>Point error</th>
<th>Time error</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) 12 hrs landfall error</td>
<td>55 kms</td>
<td>1 ½ hrs</td>
</tr>
<tr>
<td>(ii) 24 hrs landfall error</td>
<td>110 kms</td>
<td>2 hrs</td>
</tr>
<tr>
<td>(iii) 36 hrs landfall error</td>
<td>110 kms</td>
<td>3 ½ hrs</td>
</tr>
</tbody>
</table>

The performance of RSMC, New Delhi compared to various NWP models guidance is shown in Fig. 2.1.
Fig. 2.1. (a) 24 hours track forecast error based on 00 UTC of 01.05.2008 (km), (b) landfall time error (km) based on 00 UTC of 01.05.2008 (km) and (c) 24 hours landfall forecast error

2.2. Cyclonic storm, ‘RASHMI’

The system was monitored by IMD and warnings were issued to various national and international agencies and to the public through its cyclone warning organizations. The warnings issued by RSMC, New Delhi are given below.

- Special Tropical Weather Outlook – 05
- Tropical cyclone advisories – 06
- Tropical Cyclone Advisories for international civil aviation– 03

Based on 250300 UTC observation and analysis, it was predicted that the system was likely to move in a northerly direction initially. Based on 250900 UTC observation and analysis, it was predicted that the system is likely to move in a north-northeasterly direction towards West Bengal-Bangladesh coast. As per the actual track, the system moved initially in a northeasterly direction and then in a north-northeasterly direction towards Bangladesh coast. The performance of RSMC, New Delhi compared to various NWP models guidance is shown in Fig. 2.2.
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Fig.2.2. (a) 24 hours landfall time error (km) based on 00 UTC of 01.05.2008 (km) and (b) 24 hours landfall forecast error

2.3. Cyclonic storm, ‘KHAI MUK’

The system was monitored by IMD and warnings were issued to various national and international agencies and to public through its cyclone warning organizations. The warnings issued by RSMC, New Delhi are given below.

- Special Tropical Weather Outlook – 04
- Tropical cyclone advisories – 07
- Tropical Cyclone Advisories for international civil aviation– 04

Formation of a low pressure area over southeast Bay of Bengal and its westwards movement was firstly forecasted on 5th November. On 12th November, it was predicted that low pressure area is likely to intensify into a depression and move in west-northwesterly direction. Based on 131200 UTC observations and analysis, it was predicted that the system will intensify further and move in west-northwesterly direction towards north Tamilnadu-south Andhra Pradesh coasts. Based on 140300 UTC observations and analysis, it was predicted that the system will intensify further into a cyclonic storm and move in northwesterly direction towards Andhra Pradesh coast. As per the actual track, the system moved in a northwesterly/west-northwesterly direction towards Andhra Pradesh coast. The performance of RSMC, New Delhi compared to various NWP models guidance is shown in Fig. 2.3.

**Fig.2.2.**

(a) RASHMI TIME F/C ERROR (HRS) BASED ON 2610/00 UTC

(b) RASHMI 24 HRS LANDFALL F/C ERROR
2.4. Cyclonic storm, ‘NISHA’

The system was monitored by IMD and warnings were issued to various national and international agencies and to public through its cyclone warning organizations. The warnings issued by RSMC, New Delhi are given below:

- Special Tropical Weather Outlook – 03
- Tropical cyclone advisories – 07
- Tropical Cyclone Advisories for international civil aviation– 04

On 19th November, it was predicted about the formation of a low pressure area over southeast Bay of Bengal around 25th. Based on 250900 UTC observation and analysis, it was predicted that the system is likely to intensify further and move slowly in a northwesterly direction and cross Tamil Nadu coast between Pamban and Nagapattinam by 26th November 2008 night. As per the actual track, the system moved in a northerly/northwesterly direction and crossed Tamilnadu coast north of Nagapattinam near
APPENDIX IV

(lat. $11.3^\circ$ N between 0000 & 0100 UTC. The performance of RSMC, New Delhi compared to various NWP models guidance is shown in Fig. 2.4.

![NISHA LANDFALL F/C ERROR BASED ON 26/00 UTC](image)

![NISHA TIME ERROR BASED ON 26/00 UTC](image)

**Fig.2.4.** (a) 24 hours landfall forecast error (km) and (b) 24 hours landfall time error (km) based on 00 UTC of 26.11.2008

The average landfall error of cyclonic storms during 2008 are given below.

<table>
<thead>
<tr>
<th>Landfall error</th>
<th>Point error</th>
<th>Time error</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) 12 hrs landfall error</td>
<td>43 kms</td>
<td>3½ hrs</td>
</tr>
<tr>
<td>(ii) 24 hrs landfall error</td>
<td>95 kms</td>
<td>10 ½ hrs</td>
</tr>
<tr>
<td>(iii) 36 hrs landfall error</td>
<td>137 kms</td>
<td>10 hrs</td>
</tr>
</tbody>
</table>

The average landfall error was less than the long period average error for the landfalling cyclones over the north Indian Ocean.
Recent and Current Activities of the RSMC Tokyo - Typhoon Center

1. Background

The RSMC Tokyo - Typhoon Center (referred to below as the Center) is a Regional Specialized Meteorological Centre (RSMC) that carries out specialized activities in analyzing and forecasting of tropical cyclones (TCs) in the western North Pacific and the South China Sea (100E - 180, 0 - 60N) within the framework of the World Weather Watch (WWW) Programme of the World Meteorological Organization (WMO). The Center was established at the headquarters of the Japan Meteorological Agency (JMA) in July 1989, following a designation by the WMO Executive Council at its 40th session (Geneva, June 1988).

2. Products of RSMC Tokyo

The Center prepares and disseminates the RSMC bulletins listed below as long as a TC keeps tropical storm (TS) intensity or higher within the area of responsibility via the GTS and the AFTN when:
- a TC of TS intensity or higher exists in the area of responsibility
- a TC is expected to reach TS intensity or higher in the area within 24 hours
- a TC of TS intensity or higher is expected to move into the area within 24 hours

**RSMC bulletins via GTS**
1. RSMC Tropical Cyclone Advisory: TC analysis and forecast
2. RSMC Guidance for Forecast: Numerical Weather Prediction (NWP) output
3. SAREP: satellite analysis using Dvorak method
4. RSMC Prognostic Reasoning: brief reasoning for TC forecast
5. RSMC Tropical Cyclone Best Track: TC post-analysis

**RSMC bulletins via AFTN**
6. Tropical Cyclone Advisory for SIGMET: analysis and forecast to support ICAO’s Meteorological Watch Offices in preparing SIGMET

In addition to the RSMC bulletins above, JMA provides a wide range of TC related information by such means as JMA website, NTP website, RSMC Data Serving System, and WMO information system (WIS). The details of the NTP website are described at section 6 while RSMC products and its recent improvement at section 9.

3. Improvement of TC Track Forecasts

Annual mean position errors of JMA’s operational TC track forecasts are shown at Figure 1. TC track forecasts of 24-hour (from 1982), 48-hour (from 1988) and 72-hour (from 1997) are steadily improving although with some annual fluctuations.
4. Improvement of TC Intensity Forecasts

In contrast to the TC track forecasts, JMA’s operational TC intensity forecasts presently issued up to 72-hour ahead, do not have notable improvements. Rapid development and decaying of TC in particular remain difficult to forecast with adequate accuracy.

5. RSMC Data Serving System

The Center operates the RSMC Data Serving System (DSS) to provide Typhoon Committee Members with NWP products such as GPVs and observational data through the Internet. The System is used by nine Members as of the end of November 2008.

6. JMA Numerical Typhoon Prediction (NTP) website

The Center operates the Numerical Typhoon Prediction (NTP) website in cooperation with eight NWP centers in the world:

- BoM (Australia)
- MSC (Canada)
- CMA (China)
- DWD (Germany)
- KMA (Republic of Korea)
- UKMO (UK)
- NCEP (US)
- ECMWF

The NTP website provides predictions of TC tracks derived from the models of major NWP centers in order to assist NMHSs in their TC forecasting and warning services. The website is available only to registered organizations including NMHSs of Typhoon Committee Members and participating NWP centers. The main contents of the website are as follows:

- TC track forecast, in table and chart format, from the participating NWP centers
together with JMA’s predictions. Ensemble mean prediction with any combination of products is also available

- NWP model outputs, in chart format, from the participating NWP centers
- TC track forecast using JMA’s Typhoon Ensemble Prediction System (TEPS)
- Satellite analysis: CI (Current Intensity) number of Dvorak analysis including Early-stage Dvorak Analysis (EDA)

Figure 2 and 3 show actual examples of multi model ensemble and satellite analysis for T0914 and T0915 on NTP website.

7. Publications

The Center issues the following publications both available at RSMC Tokyo website.

- Annual Report on the Activities of the RSMC Tokyo - Typhoon Center (yearly basis)
- RSMC Tokyo - Typhoon Center Technical Review (as-needed basis, available online from 2007)
8. Training activities

One of the activities of the Center includes providing on-the-job training seminars inviting forecasters of NMHSs of Typhoon Committee Members. This annual training seminar, started in 2001, gives opportunities to participants to learn TC operations such as cloud analysis, Dvorak analysis including Early-stage Dvorak Analysis (EDA) and TC forecast using JMA’s GSM and TEPS.

9. RSMC products and its improvement in recent years

Table 1 shows the JMA’s products related to TC analysis and forecast in 5 years time-series from 2007 to 2011. GSM (TL959L60), upgraded on 21 November 2007, has approx. 20 km horizontal resolution and 60 vertical layers while TEPS (TL319L60), became operational in February 2008, has 11 members with approx. 60 km horizontal resolution and 60 vertical layers. This upgrade of GMS together with TEPS makes it possible to terminate the operation of the previously used Typhoon Model (TYM). The Center terminated the HiRID/WEFAX broadcast service in March 2008, and started providing cloud motion wind data for the Northern Hemisphere in BUFR format every three hours in August 2009. In May 2009, the Center started issuing five-day track forecasts (example of RSMC Tropical Cyclone Advisory for T0918 (MELOR) is shown below). Ensemble mean data of TEPS track prediction up to 132 hours ahead are also provided through the NTP website and the GTS. In addition, the results of the early stage Dvorak analysis and conventional Dvorak analysis are posted on the NTP website.

Example of RSMC Tropical Cyclone Advisory for JMA’s five-day track forecast

```
WTPQ52 RJTD 051800
RSMC TROPICAL CYCLONE ADVISORY
NAME TY 0918 MELOR (0918)
ANALYSIS
PSTN 051800UTC 21.2N 132.5E GOOD
MOVE NW 15KT
PRES 920HPA
MXWD 105KT
GUST 150KT
50KT 90NM
30KT 300NM NORTHEAST 210NM SOUTHWEST
FORECAST
24HF 061800UTC 25.5N 130.3E 80NM 70%
MOVE N 11KT
PRES 925HPA
MXWD 100KT
GUST 140KT
48HF 071800UTC 31.3N 133.4E 180NM 70%
MOVE NNE 16KT
PRES 935HPA
MXWD 095KT
GUST 135KT
72HF 081800UTC 37.3N 139.3E 250NM 70%
MOVE NE 19KT
PRES 980HPA
MXWD 055KT
GUST 080KT
96HF 091800UTC 43.1N 147.4E 350NM 70%
MOVE NE 21KT
120HF 101800UTC 47.2N 157.2E 375NM 70%
MOVE ENE 20KT =
```
## Table 1 RSMC products and its improvement (2007 - 2011)

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
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<td><strong>Satellite Observation</strong></td>
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<tr>
<td>MTSAT HiRIT</td>
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<td>All observed cloud images</td>
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<tr>
<td>MTSAT HRIT</td>
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<td>All observed cloud images</td>
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<tr>
<td>MTSAT WEFAX</td>
<td></td>
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<td></td>
<td></td>
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<td>24 times/day</td>
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<tr>
<td>MTSAT LRIT</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>24 times/day (full-disk) 24 times/day (polar-stereo East Asia)</td>
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<tr>
<td>MTSAT SATAID (WIS)</td>
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<td></td>
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<td>8 times/day</td>
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<tr>
<td>SAREP (TAC)</td>
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<td></td>
<td></td>
<td></td>
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<td>8 times/day CSC Position etc.</td>
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<tr>
<td>SAREP (BUFR)</td>
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<td>4 times/day Dvorak analysis</td>
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<tr>
<td>RSMC Tropical Cyclone Advisory</td>
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<td>4 times/day up to 72 hrs ahead</td>
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<td>(5-day track forecast)</td>
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<td>8 times/day up to 24 hrs ahead 4 times/day up to 120 hrs ahead</td>
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<td>RSMC Prognostic Reasoning</td>
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<td>RSMC Guidance for Forecast</td>
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<td>4 times/day up to 84 hrs ahead (TYM) twice/day up to 90 hrs ahead (GSM) 4 times/day up to 84 hrs ahead (GSM) 4 times/day up to 132 hrs ahead (TEPS)</td>
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<tr>
<td>NWP products (RSMC DSS)</td>
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<td>mostly updated twice/day 4 times/day up to 132 hrs ahead (TEPS) Dvorak analysis</td>
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<td>RSMC Annual Report</td>
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<tr>
<td>Technical Review</td>
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<td>(as necessary, available online from 2007)</td>
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<tr>
<td>RSMC monitoring of data exchange</td>
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<td>twice/year</td>
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<tr>
<td>Data archive (incl. EBT)</td>
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(Tokyo)
Introduction

At the 9th session of WMO CBS in 1988, Wellington was designated as a RSMC with geographic specialization. The geographical area for which Wellington is responsible is not explicitly defined other than a related reference to zones of responsibility, listed by countries (including Cook Islands, Fiji, Kiribati, Niue, Tokelau, Tuvalu and Samoa), in the Annex to Appendix I-5 of the Manual on the Global Data-Processing and Forecasting System (GDPFS), WMO-No. 485 Volume I with respect to backup services to UN Humanitarian Missions.

The Tropical Cyclone Warning Centre (TCWC) Wellington role is carried out by a section of the forecasting centre known as "Wellington RSMC" in addition to the RSMC responsibilities. For the remainder of this report, "Wellington RSMC" will be referred to as "Wellington".

Monitoring role in the tropics

The tropical region to the north of New Zealand is of high strategic importance to New Zealanders since weather systems originating there may have a high impact on us, and tropical cyclones in that region receive high coverage in the NZ media. Consequently Wellington maintains a very close watch on the activity in the RSMC Nadi area of responsibility (160°E to 120°W and the equator to 25°S) at all times and ensures forecasts and warnings are always available for dissemination to maritime or Pacific Island communities. This role of maintaining a weather watch over the tropical South Pacific is enshrined in a contract between MetService and the New Zealand Government. Under this contract, MetService makes available special weather bulletins related to hazardous weather in the South Pacific region, normally received from the Nadi Tropical Cyclone Warning Centre to Radio New Zealand International (RNZI), to
APPENDIX IV

(NZAID, New Zealand's International Aid & Development Agency and to the Ministry of Civil Defence and Emergency Management. RNZI operates a shortwave service and serves as an alternate for broadcasting forecasts and warnings to various Pacific Island countries & territories.

From 1 November to 30 April, Wellington produces a daily Tropical Cyclone Potential Bulletin for NZAID to keep them abreast of the latest expectations of cyclone activity in the South Pacific and to help them with their disaster relief planning. Additional advisories are also provided as necessary during the life of a tropical cyclone to fill any information gaps. During this same period, a routine weekly forecaster-to-forecaster conference call is carried out between Nadi and Wellington forecasters to discuss the situation and developments over the next few days.

Wellington also provided forecasting advice to NZAID for Samoa and northern Tonga for several days following the disastrous earthquake and Tsunami on 29 September (UTC).

Wellington also issues SIGMETS for the Auckland Oceanic FIR which extends as far north as 5°S and is sandwiched between the Nadi FIR and the Tahiti FIR and encloses the Pacific Island countries - Samoa, Tonga and the Cook Islands.

TCWC role

Wellington is responsible for forecasts and warnings on tropical cyclones south of 25°S and from 160°E to 120°W. Nearly all tropical cyclones have been reclassified as an extratropical depression before crossing 30°S. The very few that keep their tropical cyclone status to 30-35°S are usually found east of 180°.

In the 4 seasons from 2005/2006 to 2008/2009, 15 out of the 29 tropical cyclones that formed in the Coral Sea-South Pacific crossed 25°S into the Wellington area of responsibility. Of these, Wati made landfall over the north of the North Island on 28 March 2006 as a weak depression and Funa decayed as an extra-tropical depression as it approached the South Island West Coast on 22 January 2008 after giving gales and heavy rain to some parts of the North Island. Gene left the tropics with its eye obscured by thick cirrus in the IR-imagery but became well-defined for a time before Gene was re-classified as an extra-tropical system and evolved into a significant mid-latitude system east of New Zealand.

Wellington is the backup TCWC for RSMC Nadi

Under a contract between MetService and the New Zealand Government, Wellington is required to maintain the ability to assume temporary (no more than a week) back-up for the Nadi TCWC in accordance with WMO Technical Document WMO/TD-No 292 "Tropical Cyclone Operational Plan for the South Pacific and the South East Indian Ocean" and to carry out the obligations in the Plan.

MetService has not been required to effect a back up for meteorological reasons since 1984/1985. However, assistance has been provided for other operational reasons.

Tropical Cyclone Warnings for Norfolk Island

Under the same "Tropical Cyclone Operational Plan…", whenever Norfolk Island comes under threat from a tropical cyclone, Wellington will issue Watch or Warning advices as necessary. This
is carried out in close cooperation with the Australian Bureau of Meteorology who is responsible for the routine forecasts and warnings for Norfolk Island.

During the last 4 cyclone seasons, Norfolk Island came under threat only twice - from Wati which passed about 300 kilometres to the southwest on 26 March 2006 with northerly gusts to 35 knots and Funa, about 200 kilometres to the southeast on 20 January 2008, with southwesterly gusts to 50 knots.

**Dissemination of forecasts and warnings**

As part of its support to countries in the tropical South Pacific, Wellington relays automatically routine weather and Special Weather Bulletins received from the RSMC Nadi to Radio New Zealand International, NZAID and the New Zealand Ministry of Civil Defence and Emergency Management.

**High Seas forecasts and warnings**

Wellington routinely prepares oceanic warnings (including tropical cyclones) for the area between 25ºS and the Antarctic ice edge and from 160ºE to 120ºW every 6 hours or so and issued for the full METAREA XIV (enclosed by the black hatched lines on the map), as directed in the WMO Manual on Marine Meteorological Services (WMO-No 558) as part of the Global Maritime Distress and Safety System (GMDSS). This usually results in 500 to 600 warnings per month. RSMC Nadi is responsible for the preparation of warnings across the same longitude range between the equator and 25ºS. As METAREA X - Pacific Ocean Region overlaps the area for which Wellington provides high seas forecasts and warnings, Wellington is classified as a preparation service (refer to Sub-Tropic and Forties areas in map above). In these sea areas, Wellington strives to maintain consistency with the Australian warnings. The forecasts and warnings are provided to Maritime New Zealand for broadcast over high frequency (HF) and very high frequency (VHF) radio, and through the Pacific Ocean Region Inmarsat satellite as part of the Global Maritime Distress and Safety System ("GMDSS").

**Severe Weather Forecasting and Disaster risk reduction Demonstration Project (SWFDDP) - RAV**

Wellington is playing the lead RSMC role in this Project which starts off as a Pilot on 1 November 2009. Wellington is hosting the Project website called MetConnect Pacific which contains a lot of information from various Global and Regional centres, and National Meteorological and Hydrological Services {only Fiji (playing a dual role as regional and national centre), Samoa, Solomon Islands and Vanuatu involved at the start). Wellington also produces the main severe weather guidance for the South Pacific target area between 2ºN and 25ºS and from 150ºE to 150ºW. The South Pacific Guidance charts outline areas of heavy rain (>50mm in 24 hours NOT associated with tropical cyclones), strong wind (25 knots or more NOT associated with tropical cyclones), large waves (2.5m or higher NOT associated with tropical cyclones) and tropical cyclones (only in the form of a reference to the RSMC or TCWC that has primary responsibility for the tropical cyclone). Wellington will also continue to provide guidance on tropical cyclones whenever they cross into its area of responsibility south of 25ºS. There also a link between SWFDDP and the global research programme, THORPEX (The Observing system Research and Predictability Experiment) which will make additional Ensemble Prediction Products (EPS) available to MetConnect Pacific in due course.
Non-meteorological information

Wellington also relays information received from international sources concerning nuclear incidents (MetService is the National Warning Point under the Emergency Notification and Assistance Conventions as facilitated by the International Atomic Energy Agency and liaises closely with the National Radiation Laboratory in the Ministry of Health) and seismic events (an important link during the recent earthquake and disastrous Tsunami in Samoa) for customers within New Zealand.

Forecasting systems

SNOWIE stands for System for Natural Onscreen Weather Information Exploitation and is the primary instrument for assisting forecasters with their analysis and diagnosis work, and in helping to generate a number of outputs in the forecasting process. SNOWIE also links to the cyclone database and possesses the functionality to generate tropical cyclone forecast tracks. There is an IT project in the pipeline to improve its tropical cyclone tracking capability. SNOWIE also has the ability to generate high seas warnings using the built-in tool known as the "Oceanic Warning Generator" which converts a forecaster's graphical display into a text output.

A new, high-powered system for managing and viewing NWP data has become available to forecasters. It is known as SAGE (= Serve Any Gridded data Engine) and the interactive part is a java application called ENVISAGE (Enterprise Visualisation of SAGE).

There are also other tools that help with the animation of graphical fields like satellite imagery, the managing and viewing of observations and the display and analysis of upper atmospheric soundings.

Training & research

It is important to note that the Meteorological Service of New Zealand is primarily focused on operational forecasting, and the research and development work undertaken is focused in the area of modeling and the provision of tools that improve the knowledge and skills of forecasters, and the quality and efficiency of the output.

Wellington conducts annual workshops for forecasters in preparation for the coming cyclone season. The input to these workshops has been given added value with the help of meteorologists who have had recent experience in the deep tropics.

Special workshops have also been organised for Lead forecasters who are directly involved in SWFDDP.

An IT project is about to be embarked on to improve our cyclone tracking and verification tools in SNOWIE.
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TCWC Port Moresby activity report for 6th RSMC/TCWC Technical Coordination Meeting in Brisbane, 2-5 November 2009

Introduction

Port Moresby is designated as a TCWC with geographic specialization EQ 141E, 10S 141E, 09S 144E, 12S 147E, 12S 155E, 08S 155E, 05S 160E, EQ 160E, EQ 141E. The geographical area for which Port Moresby is responsible is not explicitly defined other than a related reference to zones of responsibility, listed by countries in the Annex to Appendix I-5 of the Manual on the Global Data-Processing and Forecasting System (GDPFS), WMO-No. 485 Volume I.

The Tropical Cyclone Warning Centre (TCWC) Port Moresby role is carried out by a section of the Forecasting and Warning Centre known as "Port Moresby TCWC" in addition to the nations forecasting responsibilities. For the remainder of this report, "Port Moresby TCWC" will be referred to as "Port Moresby".

Monitoring role in the tropics

The Solomon and Coral Seas are the tropical cyclone prone areas within tropical region of Papua New Guinea. These areas are of high strategic importance since weather systems originating there may have a high impact on the country and its neighbors Australia and Solomon Islands. The tropical cyclones in these regions often receive high coverage in the PNG media. Consequently Port Moresby maintains a very close watch and contact on the activity in the Brisbane TCWC at all times and ensures forecasts and warnings are consistent and always available for dissemination to maritime or Island communities within the cyclone prone areas. This role of maintaining a weather watch over Papua New Guinea has been mandated to National Weather Service of the Department of Transport by the Government of Papua New Guinea. PNG National Weather Service is the sole Government organization and makes available special weather and climate bulletins related to hazardous weather and
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climate in Papua New Guinea. These warning of Tropical Cyclones, Tsunamis, and drought are disseminated through the media (Radios, TV, and Newspapers).

Annually, from 1 November to 31 May, Port Moresby produces a daily Tropical Cyclone Potential Bulletin for National Disaster Centre (NDC) to keep them abreast of the latest expectations of cyclone activity in the South Pacific and to help them with their disaster relief planning. Additional advisories are also provided as necessary during the life of a tropical cyclone to fill any information gaps. During this same period, a routine weekly forecaster-to-forecaster conference call is carried out between Brisbane TCWC and Port Moresby forecasters to discuss the situation and developments over the next few days.

Port Moresby also provided forecasting advice to NDC for disastrous earthquakes and Tsunamis.

TCWC role

Port Moresby is responsible for forecasts and warnings on tropical cyclones south of EQ 141E, 10S 141E, 09S 144E, 12S 147E, 12S 155E, 08S 155E, 05S 160E, EQ 160E, EQ 141E, 25ºS.

In the 4 seasons from 2005/2006 to 2008/2009, 4 out of the 10 tropical depressions that formed in the Coral and Solomon Seas-South Pacific became tropical cyclones and crossed into the Port Moresby area of responsibility. Of these, Ingrid a small intense cyclone formed on 6th March 2005 as a weak depression in the western Coral Seas and tracked east and become a tropical cyclone. Large sea swells generated by Ingrid were felt along the southern coasts of Papua New Guinea. On 16 April a tropical low developed just to the east of Papua New Guinea, and began to drift southwest into the Coral Sea. It developed into a tropical cyclone on 17 April, and took a more easterly track towards the north Queensland coast.

TC Monica continued to develop as it approached Queensland, and crossed the coast just to the south of Lockhart River, as a Category 3 cyclone, on the afternoon of 19 April. TC Kate formed as a Tropical Depression on the 22 February 2006, reached Category 2 on the 23rd February and slipped into the Papua New Guinea waters later that afternoon. TC Pierre formed as a tropical depression in the south eastern Solomon Seas on the 15th May 2006 and tracked west into PNG. It developed into a category 1 on the 17th May and made landfall on the 19th May. There were no casualties.

Guba formed on November 13, 2007 in the northern Solomon Sea, close to the island of New Britain, and reached tropical cyclone intensity the next day by the Tropical Cyclone Warning Centre (TCWC) in Brisbane, with the TCWC in Port Moresby assigning the name Guba. It meandered in the northern Coral Sea for the next week, strengthening to a Category 3 severe tropical cyclone on November 16. It posed a threat to the Australian Cape York Peninsula, but remained offshore, and finally dissipated on November 20.

Guba was a classical example of the split system due to the mountain (Owen Stanley range) barrier. TC Guba was in the Coral Sea and not over Oro, however, due to the maintain range barrier, a large cloud build was observed to the north eastern sector and was over Oro Province for 3-4 days and caused the flooding there.

Flooding in Papua New Guinea led to at least 200 deaths. In the Oro Province, about 2,000 people were evacuated as a result of the flooding. Roads, bridges and 40 houses were washed away, as tides in the area reached two metres high. In the provincial capital, Popondetta, the water supply and electrical infrastructure was damaged, and road access was blocked. Papua New Guinea's national airline, Air Niugini, suspended flights to Popondetta's main airport.
The Rabaraba district in Milne Bay Province was also hit by flooding, with 30 houses and food gardens washed away, and forcing the evacuation of about 100 people. The government in Papua New Guinea reported that an estimated 145,000 people were affected from the flooding in Oro Province. Six days of torrential rain led to a damage total of 200 million kina ($71.4 million USD). The torrential rain was the worst seen in the region in 30 years, according to the local people.

**High Seas forecasts and warnings**

Port Moresby routinely prepares marine warnings (including tropical cyclones) for the area between EQ 141E, 10S 141E, 09S 144E, 12S 147E, 12S 155E, 08S 155E, 05S 160E, EQ 160E, EQ 141E every 6 hours or so as directed in the WMO Manual on Marine Meteorological Services (WMO-No 558) as part of the Global Maritime Distress and Safety System (GMDSS). Approximately 100 warnings are issued per month. In these sea areas, Port Moresby strives to maintain consistency with the Australian warnings. The forecasts and warnings are provided to all media (Radio, TV, Newspapers) for broadcast over high frequency (HF) and very high frequency (VHF) radio.

**Non-meteorological information**

Port Moresby also relays information received from international sources concerning nuclear incidents (National Weather Service is the National Warning Point under the Emergency Notification and Assistance Conventions as facilitated by the International Atomic Energy Agency and liaises closely with the National Disaster Centre and the Ministry of Health) and recently added responsibility of Tsunami warning for Papua New Guinea.

**Forecasting systems**

Port Moresby is yet to acquire specialised software and equipment for monitoring Tropical Cyclones and wave surges. It continues to use very basic forecasting tools which are mostly
APPENDIX IV

(Port Moresby)

web based (Models/ Satellite Pictures, etc.). For Topical Cyclone tracking, we still use manual Dvorak analysis.

A new, WMO LRIT system for managing and viewing satellite imagery data is now available to forecasters.

The installation of Digital Atmosphere has really helped with the animation of graphical fields like satellite imagery, the managing and viewing of observations and the display and analysis of upper atmospheric soundings, however, this system is very basic and does not allow the forecaster to really track and monitor any severe weather systems that may develop within Papua New Guinea.

**Training & research**

Importantly, PNG National Weather Service is primarily focused on operational forecasting, and the research and development work undertaken is focused in the area of improving tools, knowledge and skills of forecasters, and the quality and efficiency of the output.

Port Moresby conducts annual mentoring workshops for forecasters and pre seasonal briefings in preparation for the coming cyclone season. The input to these workshops and briefings has been given added value with the help of very experienced forecasters from Brisbane TCWC who have had vast experience in forecasting and tracking of tropical cyclones.
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LIST OF STANDARDIZED TERMINOLOGY

CENTRAL PRESSURE OF A TROPICAL CYCLONE – Surface pressure at the centre of the tropical cyclone as measured or estimated.

CENTRE FIX OF THE TROPICAL CYCLONE – The estimated location of the centre of a tropical cyclone.

CENTRE OF THE TROPICAL CYCLONE – The centre of the cloud eye or, if not discernible, the wind/pressure centre.

CONFIDENCE IN THE CENTRE POSITION – Degree of confidence in the centre position of a tropical cyclone expressed as the radius of the smallest circle within which the centre may be located by the analysis.

“Position good” – implies a radius of less than 30 nautical miles (55 kilometers)
“Position fair” – implies a radius of 30 to 60 nautical miles (55 to 110 km) and
“Position poor” – implies a radius of greater than 60 nautical miles (110 km).

DIRECTION OF MOVEMENT OF THE TROPICAL CYCLONE – The direction towards which the centre of the tropical cyclone is moving.

EXTRA-TROPICAL CYCLONE – Low-pressure system which develops in latitudes outside the tropics.

EXTRATROPICAL TRANSITION – is an evolutionary process by which a symmetric warm-core tropical cyclone transforms to an asymmetric cold core extratropical cyclone. This process includes a change in the distribution of clouds, winds, and precipitation. Also, the primary energy source changes from latent heat release in deep convective clouds of the tropical cyclone to baroclinic conversion of available potential energy in the extratropical cyclone.

EYE OF THE TROPICAL CYCLONE – The relatively clear and calm area inside the circular wall of convective clouds, the geometric centre of which is the centre of the tropical cyclone.

GALE FORCE WIND – maximum sustained surface wind speed of 34 to 47 knots

HURRICANE/TYPHOOON FORCE WIND – maximum sustained surface wind speed of 64 knots or more.

LOW PRESSURE AREA – Region of the atmosphere in which the pressures are lower than those of the surrounding region at the same level.

MAXIMUM SUSTAINED WIND SPEED – Averaging period of one, three or ten minutes depending upon the regional practices.

RECONNAISSANCE AIRCRAFT CENTRE FIX OF THE TROPICAL CYCLONE, VORTEX FIX – The location of the centre of a tropical cyclone obtained by reconnaissance aircraft penetration.

SPEED OF MOVEMENT OF THE TROPICAL CYCLONE – Speed of movement of the centre of the tropical cyclone.

STORM FORCE WIND – maximum sustained surface wind speed of 48 to 63 knots
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STORM SURGE – The difference between the actual water level under influence of a meteorological disturbance (storm tide) and the level which would have been attained in the absence of the meteorological disturbance (i.e. astronomical tide).

STORM TIDE – The actual sea level as influenced by a weather disturbance. The storm tide consists of the normal astronomical tide and the storm surge.

SUB-TROPICAL CYCLONE – A low pressure system, developing over sub-tropical waters which initially contains few tropical characteristics. With time the sub-tropical cyclone can become tropical.

TROPICAL CYCLONE – Generic term for a warm-core non-frontal synoptic scale cyclone originating over tropical or sub-tropical waters with organized deep convection and closed cyclonic surface wind circulation. The term is also used for a storm in the South-West Indian Ocean in which the maximum sustained wind speed is estimated to be in the range of 64 to 90 knots and in the South Pacific and South-East Indian Ocean with the maximum sustained surface wind speed greater than 33 knots.

TROPICAL DEPRESSION WIND – maximum sustained surface wind speed less than 34 knots

TROPICAL DISTURBANCE – A non-frontal synoptic scale cyclone originating in the tropics or sub-tropics with enhanced convection and light surface winds.

TROPICAL STORM WIND – maximum sustained surface wind speed of 34 to 63 knots

TROPICAL WAVE – A trough or cyclonic curvature maximum in the trade wind easterlies or equatorial westerlies. The wave may reach maximum amplitude in the lower middle troposphere, or may be the reflection of an upper-troposphere cold low or equatorial extension of a mid-latitude trough.

ZONE OF DISTURBED WEATHER – A zone in which the pressure is low relative to the surrounding region and there are convective cloud masses which are not organized.

WEATHER WARNING – Meteorological message issued to provide appropriate warnings of hazardous weather conditions.