

**Best track data of tropical cyclonic disturbances
over the north Indian Ocean**

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1. Introduction

Regional Specialised Meteorological Centre (RSMC) - Tropical Cyclones, New Delhi which function in Cyclone Warning Division, India Meteorological Department (IMD), New Delhi has the responsibility of monitoring and predicting cyclonic disturbances over the north Indian Ocean and issuing Tropical Weather Outlook and Tropical Cyclone Advisories for the benefit of the World Meteorological Organisation (WMO) / Economic and Social cooperation for Asia and the Pacific (ESCAP) Panel member countries including Bangladesh, Pakistan, Maldives, Myanmar, Sultanate of Oman, Sri Lanka and Thailand. It is also responsible for collection, processing and archival of all data pertaining to cyclonic disturbances and preparation of best track data over the north Indian Ocean, RSMC, New Delhi also exchanges the same data with WMO/ESCAP Panel member countries.

The historical background of collection and archival of the data related to cyclones over the north Indian Ocean are presented in Sec.1. The best track and intensity estimation procedure and quality of data at RSMC, New Delhi are presented and discussed in Sec.2. Various kinds of best track data available in RSMC, New Delhi are presented in Sec.3. The six hourly best track data during 1990-2008 are presented in Sec.4.

2. Historical background

The systematic scientific studies of tropical storms in the Indian seas commenced by Henry Piddington, President of Marine courts, Calcutta towards the middle of the 19th century utilising meteorological logs of vessels navigating in these waters. A series of Memoirs were published by him in the “*Journal of the Asiatic Society of Bengal*” during the years 1839 to 1858 dealing with accounts of individual storms in the Bay of Bengal and the Arabian sea. Piddington also wrote his famous book entitled “*The sailor’s Hand- Book for the Law of Storms*” and the fourth edition of the book appeared in 1864 (Piddington, 1864). He has dealt with storms in the Bay of Bengal and the Arabian Sea. He has also given at the end of the book a chart showing the tracks of 38 storms in the Bay of Bengal during the period 1800 to 1848 and 7 storms in the Arabian Sea during the period 1811 to 1847. To Piddington, IMD owes the nomenclature “cyclone” for designating tropical storms. This word which is of Greek origin means “the coil of a snake”. Piddington has stated in his book that “cyclone” is an appropriate term for this class of disturbances in which the air motion is circular or spiral. He felt that

the use of terms such as 'gale', 'storm' and 'hurricane' to designate such disturbances was apt to lead to confusion since these terms are used to indicate wind strength on the Beaufort scale.

In 1877, H.F. Blanford (Meteorological Reporter to the Government of India) published in the "*Journal of the Asiatic Society of Bengal*" a catalogue of 112 recorded cyclones in the Bay of Bengal for the period October 1737 to November 1876 (Blanford, 1877). This list was drawn up by him by making reference to various sources. His object was to find out the seasonal distribution of cyclones in different parts of the Bay of Bengal. The results of this study were incorporated in Part II of "*Indian Meteorologist's Vade-Mecum*" (Blanford, 1883). A catalogue similar to that of Blanford was prepared for the Arabian Sea by F.Chambers (1882-85). This list gives details of 70 cyclones for the period May 1648 to July 1881.

The systematic preparation of daily weather charts for the whole of India was commenced by IMD from August 1877, when arrangements were made for the daily transmission of 0430 UTC observations. Telegraphic transmission of weather observations began in 1878. Printed copies of Indian Daily Weather Reports and Daily Weather Maps are available in the Library of the IMD commencing from 15th June 1878. Based on the daily weather charts, J. Eliot compiled and published in Volume II of the "*Indian Meteorological Memoirs*" an account of 46 storms in the Bay of Bengal for the period 1877 to 1881. The storm tracks for the different years have also been given in Eliot's paper Eliot (1882-85). A similar account and tracks of 55 storms for the period 1882 to 1886 was published by him in Volume IV of the "*Indian Meteorological Memoirs*". A list of 54 cyclones in the Arabian Sea from May 1648 to June 1889 together with description of the individual storms.

From 1875, IMD commenced an annual publication entitled "*Reports on the Meteorology of India*" to bring together in one report the Meteorological data of the whole India and adjacent areas. Accounts of depressions and storms in the Indian Seas as well as a chart showing the tracks of these disturbances began to be included in these reports from 1886. The Annual Report on the Meteorology of India was replaced in 1891 by the "*India Weather Review*" giving a summary of the chief features of the weather, month by month and an annual summary. The Monthly Weather Reviews contained accounts of depressions and cyclonic storms while the Annual Summary gives a consolidated list of these disturbances with particulars of the greatest observed barometric depth, intensity of the disturbance and certain other details. A chart containing tracks of all the depressions and storms was also included in the Annual Summary. The publication of the "*India Weather Review*" with modifications and additions has gone on uninterruptedly since 1891. From 1923 onwards tracks of storms and depressions are separately included in the Annual Summary portion of the "*India Weather Review*".

In 1890 Eliot published his “*Hand-book of Cyclonic Storms in the Bay of Bengal for the use of Sailors*”, in two volumes (Eliot 1890). The second edition of this appeared in 1900-1901(Eliot, 1900-01). The object of this publication was to give the mariners navigating in the Bay of Bengal an account of dangerous storms that occur in the Bay, the indications by which the proximity of a cyclone may be recognised, the paths which these disturbances follow and rules for the practical guidance of sailors. The Volume II gave mean monthly sea level pressure and wind charts for the different months of the year and monthly tracks in respect of 93 storms for the period 1877 to 1887 and 119 storms for the period 1888 to 1899. “*Climatological Atlas of India*” by J. Eliot was published in 1906. In this atlas monthly storm tracks for the period 1877 to 1901 have been included as insets in the normal rainfall maps for the different months.

In 1908, IMD published “*Meteorological Atlas of the Indian Seas and the North Indian Ocean*”. This was prepared by W. L. Dallas under the direction of Sir Gilbert Walker. This atlas contains 12 charts showing the monthly conditions of pressure, wind and sea currents, 9 charts showing the monthly tracks of the more important cyclonic storms over the Arabian Sea and the Bay of Bengal and 15 daily weather maps illustrating cyclonic storms in the Indian Seas.

In 1925-1926, IMD brought out two publications entitled “*Storm Tracks in the Bay of Bengal*” and “*Storm Tracks- in the Arabian Sea*” (Normand 1925-26). Normand’s atlas for the Bay of Bengal includes the tracks of storms that occurred in the Bay in the years 1891 to 1923; the atlas for the Arabian Sea includes the tracks of all fairly known storms up to the year 1924.

“*Climatological Atlas of India and Neighbourhood for Meteorologists and Airmen*” (IMD, 1943) gives mean tracks of the storms and depressions in the Bay of Bengal and the Arabian Sea for the different months of the year. It also incorporates charts showing the number of these disturbances that crossed different coastal belts during the period 1891 to 1940. A companion volume entitled “*Climatological Charts of the Indian Monsoon Area*” published by IMD (1948) contains monthly charts giving typical tracks of cyclonic storms in the Indian Ocean and the surrounding areas and average frequencies of their occurrence over the respective regions.

3. Nomenclature of cyclonic disturbances

The terminology used for designating cyclonic disturbances in IMD required certain classifications. From the earlier publications of the department, it is seen that the term “*depression*” was used in a general sense to indicate an area where the barometric pressure is low compared with the surroundings. Thus we often come across descriptions in which a depression is referred to as a small storm, a feeble storm etc. In the introduction to “*Meteorological Atlas of the Indian Seas and the North*

Indian Ocean” (Dallas, 1908) stated as follows:- “In the description which follows in the body of this atlas a cyclonic circulation in which the winds do not exceed force 10 is termed a ‘Cyclonic Storm’, while a circulation in which the winds are of hurricane force, 11 to 12, is called a ‘Cyclone’. Thus the term ‘Cyclone’ is restricted to the fiercest and most dangerous storms of tropical seas”. In the body of the Atlas where tracks of representative storms for the Arabian Sea and the Bay of Bengal are reproduced, we come across the following explanation of the tracks:- “thick lines indicate severe cyclonic storms or cyclones; thin lines indicate moderate cyclonic storms”. In the preface to his Atlas of “*Storm Tracks in the Bay of Bengal,*” Normand (1925) has stated as follows:- “Technically depressions may include all cyclonic circulations ranging from those of small barometric depth and weak circulation up to the severe cyclone with its ring of hurricane winds and central barometric deficiency of, perhaps, two inches. In practice, however, the Meteorological Department tries to limit the use of the word ‘depression’ to those cyclonic circulations in which the wind does not reach gale force, i.e., force 7 or less on the Beaufort scale; the depression becomes a storm when the wind in a part of the cyclonic area rises to gale force (force 8); when it rises to force 10, with occasional hurricane squalls, the storm is severe”. These criteria used by Normand to classify the storm tracks reproduced in his atlas, have been in vogue in IMD from about 1924.

The Classification of the low pressure systems by India Meteorological Department, currently in force is mentioned below (IMD, 2003):

Low pressure system	Sustained maximum surface wind
I. Low Pressure Area	Less than 17 knots
II. Depression	17-27 knots
III. Deep Depression	28-33 knots
IV. Cyclonic Storm	34-47 knots
V. Severe Cyclonic Storm	48-63 knots
VI. Very Severe Cyclonic Storm	64-119 knots
VII. Super Cyclonic Storm	more than or equal to 120 knots

The above definition came into existence in 1999 based on the decision taken during the Annual Cyclone Review meeting held during early part of the year. It superceded the earlier decision of 1988. During the period 1988-1998, the above mentioned categories of VI and VII constituted one category, viz., severe cyclonic storm with core of hurricane winds (SCS(H)) with associated wind

speed of 64 knots or more. Prior to 1988, the cyclones were classified into two categories only, viz., (i) cyclonic storm (34-47 knots) and severe cyclonic storms (48 knots or more).

4. Best track and intensity estimation procedure

The procedure followed in IMD for estimating the best track and intensity of a cyclonic disturbance over the north Indian Ocean is discussed in the cyclone manual (IMD, 2003). This manual is under revision in view of the developments in the observation, analysis and prediction system in recent years. To determine the best track, the operationally finalized tracks of past one year are reviewed by committee of experts in the annual cyclone review meeting of IMD, usually held in January/February. The committee takes account all available surface & upper air observations from land and ocean, satellite observations and radar observations. The tracks finalized by the committee is presented in annual cyclone review meeting and adopted as best track after the correction/modification if any. This committee also looks into the intensity of the system and other parameters for review. The finalized best track, intensity and other parameters are published and shared by IMD/ RSMC, New Delhi.

5. Six hourly Best track data set of cyclones over the north Indian Ocean

The best tracks have been published in the form of atlas by IMD from time to time since 1964 containing the data from 1877 onwards. However, six hourly best track data sets containing various characteristics of the cyclonic disturbances were prepared since 1990. It is available in the Annual Cyclone Review reports and Annual RSMC reports published by IMD. It includes the every six hourly position (lat/long), stage of intensity along with T/CI No., estimated central pressure, pressure drop at the centre and sustained maximum surface wind. These data are also shared with WMO/ESCAP Panel member countries, WMO and other research institutes. Prior to 1990, only the information on 12 hourly track positions and intensity were available in the published cyclone atlases. The six hourly best track data sets are given in Appendix I. This best track data sets are based on the latest definition of cyclonic disturbances as discussed in Sec. 3.

6. Problems and perspectives

North Indian Ocean, being the data sparse region, the best track estimates are subject to errors. The mean best track error may be considered as 50 km. In the absence of the observations over the north Indian Ocean, the best track of the cyclone is mostly estimated with the satellite imagery interpretation with the help of Dvorak's technique. This technique has been applied over the north

Indian Ocean since its inception during 1970s. However, this technique, which has been developed for north Atlantic Ocean basin needs to be validated for north Indian Ocean with aircraft reconnaissance. Further automated Dvorak's technique has to be validated/ developed for north Indian Ocean to minimize the human error and evaluate its efficiency.

There is also scope for improvement in future, as evident from the recent past cases, due to existing and proposed buoy network over the north Indian Ocean, ongoing modernization plan of IMD resulting in improved observational system like DWR and AWS along the coast, improved modeling technique with installation of high power computing system, ongoing forecast demonstration project on landfalling cyclone over the Bay of Bengal.

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