



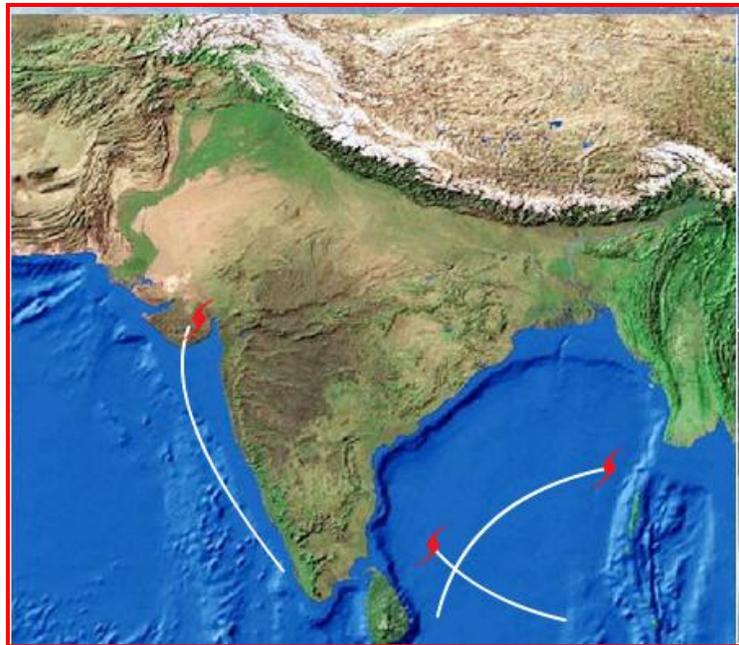
Cyclone eAtlas - IMD

Version 2.0 / 2011

Technical Note

Tracks of Cyclones and Depressions over North Indian Ocean

(from 1891 onwards)



Cyclone Warning & Research centre
India Meteorological Department
Regional Meteorological Centre, Chennai

CONTENTS

Preface	3
Acknowledgements	5
PART 1 - Excerpts from the past editions	6
1.1 Historical.....	7
1.2 1964 edition of the Atlas	11
1.3 1979 edition of the Atlas.....	12
1.4 1996 Addendum to the Storm track Atlas.....	13
1.5 Detailed contents of the 1979 edition	13
1.6 Preface to the previous editions	15
PARTS 2 to 7	20
2. Electronic version of IMD's Atlas of Tracks of Cyclones and Depressions (<i>Cyclone eAtlas – IMD</i>)	21
2.1 Introduction.....	21
2.2 Requisite for eAtlas	21
2.3 Objectives of the Electronic Version	22
2.4 Digitisation of the tracks of Cyclones and Depressions (C&Ds)	22
2.5 Software development	23
2.6 Output generated by the eAtlas.....	23
2.7 Saving and retrieving	31
3. Other information which might be useful to the user	32
3.1 Non-inclusion of short-lived CDs without a track	32
3.2 Frequency of formation and dissipation.....	32
3.3 Recurvature.....	34
3.4 Non- inclusion of origin of certain CDs.....	34
3.5 Date of formation and first date circle.....	34
4. Copyright Notice.....	36
5. Disclaimer.....	36
References	37
Appendix I - Illustrations.....	39
Appendix II - Abbreviations / Notations.....	45
Fig.1 Coastal boundaries of India and neighbourhood.....	47
Fig.2 Gridded map of India and neighbourhood	48

Preface

The first edition of Atlas of tracks of storms and depressions over the Bay of Bengal and the Arabian Sea was published by India Meteorological Department (IMD) in 1964 and an updated edition of the Atlas containing tracks of storms and depressions for the period up to 1970 was brought out in 1979. An Addendum to the 1979 edition containing tracks of storms and depressions for the period of 1971 to 1990 was published in the year 1996.

In view of the considerable demands from the civil administrators, disaster managers, navy, shipping industry, port authorities and other sister scientific organisations of the country as well as from the member countries of WMO/ESCAP Panel, an electronic version of the atlas, namely, *Cyclone eAtlas – IMD*, Version 1.0 was developed as a standalone PC application and brought out in CD form in the year 2008. The software contained digitised database for the period 1891-2007 and included large number of menu driven, user friendly interactive features to readily extract tracks of cyclones and depressions that occurred over Indian Seas and various other related statistics with provision for updating the database. Updated database were sent to all users of the software at the end of each subsequent year.

Response to the *Cyclone eAtlas – IMD* (Version 1.0) from the user agencies has been overwhelming with encouraging feedbacks to cater to the needs of a wider spectrum of users and hence, the software is now redeveloped as web based application, *Cyclone eAtlas-IMD*, Version 2.0 and ported in the web server of Regional Meteorological Centre (RMC), Chennai hosted by the National Informatics Centre, Chennai. The software is fully functional and completely free for all registered users. A detailed documentation section containing the *User's Guide* and a *Technical Note* on the software would help the users to easily access the various functionalities of the software.

The task of conceptualising the electronic version of the Cyclone Atlas (Version 1.0), was carried out by a team of officers and staff of Cyclone Warning & Research Centre (CWRC), Chennai under the leadership of Dr. Y.E.A. Raj, the then Director of CWRC, RMC, Chennai during 2006-2008. Now, the current web based application is developed at CWRC by a team led by Dr.S.Balachandran, Scientist-E, CWRC, RMC Chennai under the overall guidance of Dr.Y.E.A.Raj, Deputy Director General of

Meteorology, RMC, Chennai. The software development was carried out by M/s SVSS InfoTech Pvt. Ltd., Chennai.

I sincerely hope that this web based application software of the IMD's storm track Atlas will prove to be very useful to a wider spectrum of users including tropical cyclone forecasters, research workers engaged in cyclone research and also agencies involved in cyclone disaster management.

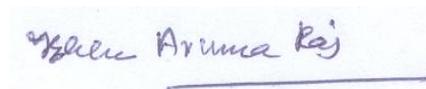
New Delhi
Jan 2012



Ajit Tyagi
Director General of Meteorology

Acknowledgements

1. The development of web based application of the electronic version of the Atlas of Cyclones and Depressions-India Meteorological Department (IMD) (2011 edition) named as *Cyclone eAtlas – IMD Version 2.0* was designed and executed at the Cyclone Warning Research Centre (CWRC), Regional Meteorological Centre (RMC), Chennai under the supervision of Dr.S.Balachandran, Scientist-E, CWRC, RMC Chennai.
2. The digitisation of nearly 1500 tracks of cyclones and depressions, which occurred over the Indian seas from 1891 onwards was carried out by the CWRC team comprising Shri A.Muthuchami, Meteorologist-I, Smt C.Savithri Assistant Meteorologist-I, Smt P.A. Subadra Assistant Meteorologist-II, Shri RM.A.N. Ramanathan and Smt B. Geetha, Scientific Assistants, S/Shri M.Bharathiar and N.Selvam Draughtsmen during 2006-2008 for the first version and subsequently updated every year by the existing CWRC team.
3. The web page design, documentation and testing of the current version of the software has been carried out by the present CWRC team comprising of Shri RM.A.N.Ramanathan, Assistant Meteorologist-II, Smt.B.Geetha, S/Shri K.Ramesh and N.Selvam, Scientific Assistants under the leadership of Dr.S.Balachandran, Scientist-E.
4. The following officers have been associated with the project as members of Local Advisory Committee:
 - i) Dr.Y.E.A.Raj, DDGM RMC Chennai, - Chairman
 - ii) Dr.S.Balachandran, Scientist-E, CWRC, RMC Chennai - Coordinator
 - iii) Dr. R.Suresh, Scientist-E, AMO Chennai }
 - iv) Dr. S.R.Ramanan, Scientist-E, ACWC, RMC Chennai }
 - v) Shri P.S.Kannan, Meteorologist-I CWRC RMC Chennai }- Members
5. M/s SVSS InfoTech Pvt. Ltd., Chennai developed the web based application of *Cyclone eAtlas – IMD*.



Chennai
Jan 2012

Y.E.A.Raj
Deputy Director General of Meteorology
Regional Meteorological Centre, Chennai

PART 1 - Excerpts from the past editions

1.1 Historical

1.1.1 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 Handbook for the Law of Storms*” and the fourth edition of the book appeared in 1864. In this book, he has given a detailed exposition of the then current knowledge relating to tropical storms in different parts of the world for the benefit of mariners. He has dealt with storms in the Bay of Bengal and the Arabian Sea and has 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.

1.1.2 To Piddington IMD owe the nomenclature “cyclone” for designating tropical storms. This word which is of Greek origin signifies among other things “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.

1.1.3 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. 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. The results of this study were incorporated in Part II of “*Indian Meteorologist’s Vade-Mecum*” published in 1883 by him.

1.1.4 A catalogue similar to that of Blanford was prepared for the Arabian Sea by F.Chambers and published in Volume II of the “*Indian Meteorological Memoirs*”. This list gives details of 70 cyclones for the period May 1648 to July 1881.

1.1.5 The systematic preparation of daily weather charts for the whole of India was commenced by the India Meteorological Department from August 1877 when arrangements were made for the daily transmission of 10 A.M. 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 India Meteorological Department 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. 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*”.

1.1.6 A list of 54 cyclones in the Arabian Sea from May 1648 to June 1889 together with description of the individual storms was published by W.L.Dallas in 1891 (“*Cyclone Memoirs*”, *Part IV*). This publication also gives cyclone tracks in the Arabian Sea for the different months.

1.1.7 From 1875 the India Meteorological Department 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.

1.1.8 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.

1.1.9 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*”

1.1.10 In 1890 Eliot published his “*Hand-book of Cyclonic Storms in the Bay of Bengal for the use of Sailors*”, in two volumes. The second edition of this appeared in 1900-1901. 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. Volume I of this publication dealt with the subject matter in four chapters; 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.

1.1.11 “*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.

1.1.12 In 1908 the India Meteorological Department 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.

1.1.13 In 1925-1926, the India Meteorological Department brought out two publications entitled “*Storm Tracks in the Bay of Bengal*” and “*Storm Tracks- in the Arabian Sea*” compiled by C.W.B.Normand. 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.

1.1.14 “*Climatological Atlas of India and Neighbourhood for Meteorologists and Airmen*” published by the India Meteorological Department in 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 in 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.

1.1.15 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*” (1908) Dallas 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*” (1925), Normand 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 the India Meteorological Department from about 1924.

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

<i>Types of Disturbances</i>	<i>Associated with wind speed</i>
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

1.2 1964 edition of the Atlas

1.2.1 Normand's atlas of storm tracks was intended to replace the earlier publications of the India Meteorological Department dealing with this subject which had by then gone out of print. As more than three decades had elapsed since Normand's atlas appeared, a revised and more comprehensive publication of the tracks of cyclonic disturbances in the Indian Seas was brought out in 1964.

1.2.2 The Atlas of *Tracks of Storms and Depressions in the Bay of Bengal and the Arabian Sea (1877-1960)* was published by the India Meteorological Department in 1964. This atlas includes the tracks of all cyclonic disturbances (depressions and storms) of tropical origin that occurred over the area bounded by latitudes 5°N and 35°N and longitudes 50°E and 100°E for the period of 84 years from 1877 to 1960. By and large, these disturbances originate over the Indian Seas and move in a westerly or northwesterly direction. Some of them recurve and move towards the north or northeast. In addition to these disturbances, the Indian area north of 20°N is also affected by disturbances of extra-tropical origin which move from the west to east, especially during the months November to April. The tracks of those disturbances known as "*Cold Weather Storms*" or "*Western Disturbances*" were not considered in the atlas. The publications mentioned in Section 1 formed the source of data of the first (1964) edition of this atlas. The main body of the earlier edition presented the tracks of all depressions and storms for the 70 year period 1891 to 1960. The tracks for the 14 year period from 1877 to 1890 were included as

supplement to the main atlas. This division of the whole period was considered desirable since the “*India Weather Review*” dated back to 1891 and it was felt that the material contained in these publications formed a homogenous series of data. The atlas thus gave within the scope of one volume the data relating to cyclonic disturbances in the Indian Seas collected from the time that daily weather charts began to be prepared by the India Meteorological Department in 1877 up to the end of 1960.

1.3 1979 edition of the Atlas

1.3.1 The 1964 edition of the Atlas contained information up to 1960. The publication had been in great demand in our country and abroad. The Atlas was therefore updated to include the available information up to 1970.

1.3.2 The 1979 edition of the atlas is therefore an updated version of the first edition containing tracks of all the cyclonic disturbances of tropical origin that occurred over the area bounded by latitude 5°N and 35°N and longitude 50°E and 100°E for the 80 year period from 1891-1970. It also includes the tracks of the cyclonic disturbances for the period 1877-1890.

1.3.3 For updating the atlas up to 1970, the tracks of all cyclonic disturbances for the period 1961 to 1970 have been added. But, the general lay out and presentation of the charts remained the same as that of the 1964 edition. The tracks in Parts I and II and the statistics in Part III of the Atlas are for the 80-year period from 1891-1970. As in the 1964 edition, Part I gives the tracks of all cyclonic disturbances in the Bay of Bengal and the Arabian Sea which reached “*cyclonic storm*” intensity. Printing of the 80-years’ tracks of cyclonic storms for each month on a single chart would have produced considerable congestion in the months of high disturbance frequency. For clarity of presentation, therefore, the 80-year tracks for the months May to December were divided into two periods of 40-years each 1891 to 1930 and 1931 to 1970. Part II contains 93 charts which presents the tracks of over 1050 cyclonic disturbances (depressions, storms and severe storms) for all the months and years during the period 1891-1970. Here again, to avoid congestion, the period has been divided into 5-year intervals for the months July, August and September; into 10 year periods for the months May, June, October, November and December as in the previous edition and in to two 40-year periods for

January to April. Part III of the Atlas contains 61 charts. These provide the statistics of relative frequencies of disturbances, directions and speeds of movement in every $2\frac{1}{2}^{\circ} \times 2\frac{1}{2}^{\circ}$ square and statistics of the formation and dissipation of disturbances derived from the tracks of cyclonic disturbances, for the period 1891-1970. Part IV is a supplement containing the tracks of cyclonic disturbances for the period 1877-1890. Appendices I and II give particulars of all cyclonic disturbances, the tracks of which appear in Parts II and IV respectively of the Atlas. Each of the Parts I to IV has a preface giving a brief explanation of the principal features of the contents. A short write up on the annual and monthly variation of the frequencies of cyclonic disturbances in the Indian seas during the 80-year period was given in section 5.

1.4 1996 Addendum to the Storm track Atlas

An Addendum to the Storm Track Atlas (1877-1970) was published in the year 1996. It contains the tracks of storms and depressions for the period 1971 to 1990. The contents of this Addendum are similar to the contents of 1979 Atlas but presenting tracks (in 42 pages) and statistics in Map form (in 57 pages) for the period 1971-1990.

1.5 Detailed contents of the 1979 edition

1.5.1 The contents of the 1979 edition can be grouped under the following categories;

- i) A brief write up on previous editions, historical information etc.
- ii) There are a few tables presenting various types of statistics. The contents of important tables are described below:

Table 1 – Presents yearly and monthly frequencies of cyclones and depressions. Output is in Matrix form (80×13) giving total number of cyclonic disturbances and cyclones that occurred over Indian Region for each year during the period 1891-1970, for each month and also annual total.

Table 3 – Presents annual variation of frequencies of cyclonic disturbances over Bay of Bengal, Arabian Sea and Land and all combined for each month and annual.

Appendix I – A Table form given in Appendix I which provides the list of storms and depressions for the period 1891 – 1970, monthwise. This list provides year, first date circle and longitude/ latitude of the beginning position, for each system.

Appendix II – Provides similar list for the period 1877-1890.

1.5.2 In part I of the Atlas the tracks of cyclonic storms alone are presented in 20 charts. In Part II, the tracks of storms and depressions are presented in charts Nos. 21 to 113 (93 charts).

1.5.3 In Part III, various types of statistics are presented in map form in $2\frac{1}{2} \times 2\frac{1}{2}$ longitude/ latitude grid. The following types of map are presented.

- i. Annual variation of Storms and Depressions (in chart 114)
- ii. Frequencies of Storms and Depressions (in charts 115 to 126)
- iii. Frequencies of formation and dissipation of Storms and Depressions
(in charts 127 to 138)
- iv. Percentage frequency of direction of movement of storms and depressions
(in pages 139 to 150)
- v. Percentage frequency of speed of movement of Storms and Depressions
(in pages 151 to 162)
- vi. Points of recurvature and number of Storms and Depressions striking coastal belt
(in pages 163 to 174)

1.5.4 Part IV of the 1979 Atlas contains the tracks of Storms and Depressions for the period 1877 to 1890 and a few statistics/ details.

1.6 Preface to the previous editions

1.6.1 Preface to the 1964 edition

The two departmental publications entitled “*Storm Tracks in the Arabian Sea*” and “*Storm Tracks in the Bay of Bengal*” compiled by Dr. C.W.B. Normand and issued in 1925-1926 have been out of print for some years. The need to bring out a more up to date Atlas of Tracks of Cyclonic Storms and Depressions in the Bay of Bengal and Arabian Sea in one single publication with an introduction and some auxiliary information regarding frequencies etc., has been felt for some time. This work was entrusted to Dr. R. Ananthkrishnan, Deputy Director General (Forecasting), Poona, who, with the assistance of Shri A. Thiruvengadathan, Assistant Meteorologist and other members of staff of Poona Meteorological Office has completed the work in March 1964. This Atlas of Tracks of Storms and Depressions includes information up to 1960 and will, I am sure, be found useful by Meteorologists, Hydrologist, Irrigation and Power Engineers, Geographers and others who are concerned with, or interested in, the weather and rainfall of India and the surrounding areas. This Atlas is being issued on March 23, 1964, which is the fourth World Meteorological Day, the special theme for which is “Meteorology as a factor of economic development with special emphasis on hydrometeorology”.

I wish to express my thanks to Dr. R. Ananthkrishnan for the special interest he has taken in the preparation of this Atlas.

New Delhi
March 1964

sd/-
P.R.KRISHNA RAO
Director General of Meteorology

1.6.2 Preface to the 1979 edition

The Atlas of *Tracks of Storms and Depressions in the Bay of Bengal and the Arabian Sea 1877-1960* was published in 1964. It contained information up to 1960, and was well received. There was considerable demand for this publication from the Navy, the Shipping Industry, Port Authorities, Public Works and a number of other user agencies. Considering its value as a useful reference work, it was decided to up-date the Atlas, so as to include information about all storms that have hit the Indian Coast up to 1970.

The present edition of the Atlas contains this updated information. For greater clarity, the tracks of cyclonic storms have been presented in two parts for those months which experience a high frequency of storms and depressions.

The task of updating this publication has been largely the work of officers and staff in the office of the Deputy Director General of Meteorology (Weather Forecasting). Dr. P.S. Pant, who is currently the Deputy Director General in charge of weather forecasting, supervised this work during its later stages. His personal attention, alongwith those of his officers and staff, helped to get the publication ready in time.

I hope that the second edition of the Atlas will prove as useful as the first edition was to research workers and operational meteorologists engaged in the prediction of tropical cyclones.

New Delhi
January 10, 1979
Pausa 20, 1900 SE.

G.K. Das.
10/1/79

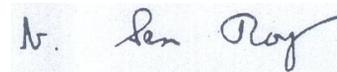
P.K. DAS
Deputy Director General of Meteorology

1.6.3 Preface to the 1996 addendum

The first edition of the Atlas of “*Tracks of Storms and Depressions in the Bay of Bengal and the Arabian Sea*” was published in 1964 and contained information from 1877 to 1960. The publication has been in great demand in the country and abroad. It was, therefore, decided to update the Atlas to include the information available up to 1970, and an updated version was brought out in 1979.

The present publication provides information from 1971 to 1990 as an addendum to the Atlas of ‘*Tracks of Storms and Depressions - 1877-1970*’. The most important technological development that took place during the period was the advent of satellite, which enhanced the capability for detection and monitoring of storms on high seas. The general layout and presentation of the charts remain the same as that of the 1979 edition. It has been prepared by the Investigation and Development Section of the Office of the Deputy Director General of Meteorology (Weather Forecasting), Pune under the guidance of Dr. U.S. De, the then DDGM (WF).

Date: November, 1996
New Delhi



N.SEN ROY
Director General of Meteorology

1.6.3 Preface to the 2008 electronic edition (Cyclone eAtlas – IMD, Version 1.0, standalone PC application)

The first edition of Atlas of tracks of storms and depressions over the Bay of Bengal and the Arabian Sea was published by India Meteorological Department in 1964 and an updated edition of the Atlas containing tracks of storms and depressions for the period upto 1970 was brought out in 1979. An Addendum to the 1979 edition containing tracks of storms and depressions for the period of 1971 to 1990 was published in the year 1996. The above editions of the Atlas have been in considerable demand in the country, especially from the Navy, Shipping Industry, Port authorities, Public works and other sister scientific organisations. They have also been sought after by the member countries of WMO/ESCAP Panel.

The present electronic edition of the Atlas named as Cyclone eAtlas – IMD completely differs in concept when compared to the older editions. The past editions were published in the form of hard copy whereas the current edition is an electronic version. It is based on updated and digitised data for the period from the year 1891 upto the year 2007 and includes large number of menu driven, user friendly interactive features. The user can readily extract tracks of cyclones and depressions that occurred over Indian Seas and also the various other related statistics. The tracks / statistics could be generated by exercising basic or advanced options and by feeding different types of input parameters such as year and month of occurrence, basin of formation or dissipation, intensity of landfall of the cyclonic disturbance. A detailed write up is separately supplied and a help file has also been included in the menu to familiarise the user with the past editions of the Atlas and the various features of the current electronic version.

The task of conceptualising the electronic version of the Cyclone Atlas, its designing and the digitisation of tracks have been carried out by the officers and staff of Cyclone Warning Research Centre, Chennai under the able guidance of Shri S.Sridharan, Deputy Director General of Meteorology, Regional Meteorological Centre, Chennai (retired), Dr. R.V.Sharma, currently Deputy Director General of Meteorology, Regional Meteorological Centre, Chennai and Dr. Y.E.A. Raj Director, Cyclone Warning Research Centre, Regional Meteorological Centre, Chennai.

The software development was carried out by CMC Ltd., Chennai.

I sincerely hope that the electronic edition of the IMD's storm track Atlas will prove to be very handy to a wide spectrum of users including tropical cyclone forecasters, research workers engaged in cyclone research and also agencies involved in cyclone disaster management.

New Delhi
June 2008



Ajit Tyagi
Director General of Meteorology

PARTS 2 to 7

Electronic version of IMD's Atlas of
Tracks of Cyclones and Depressions
(from 1891 onwards)

(Cyclone eAtlas - IMD)
Ver 2.0 (Nov 2011)

2. Electronic version of IMD's Atlas of Tracks of Cyclones and Depressions (*Cyclone eAtlas – IMD*)

2.1 Introduction

This Technical Note discusses and describes the various aspects of the current electronic version of IMD's Atlas of Tracks of Cyclones and Depressions (*Cyclone eAtlas – IMD, Version 2.0*) and compliments the User's Guide (*Cyclone eAtlas – IMD, Version 2.0*) for correct understanding and interpretation of input parameters, their stratifications and methodologies of computations involved.

2.2 Requisite for eAtlas

2.2.1 In this note and also in the various menus, tables, maps and charts generated by the eAtlas, the term '*Cyclonic disturbance*' (CD) or some times mere '*Disturbance*' is used to describe either a Depression (D) or Cyclonic Storm (CS) or Severe Cyclonic Storm (SCS) which have been defined in Section 1. The term '*Cyclones and Depressions*' (C&Ds) is also used frequently. The term '*Storms and Depressions*' is frequently used in the 1979 & 1996 editions of IMD's Storm Track Atlas and occasionally in the current electronic version also. This term has the same meaning as the term C&Ds.

2.2.2 The Atlases presenting tracks of C&Ds over the Bay of Bengal and the Arabian Sea and associated statistics have been periodically published by India Meteorological Department (IMD). Details of the past editions and the corresponding period of C&Ds are given below:

- i) 1964 edition for the period 1877-1960
- ii) 1979 edition for the period 1891-1970
- iii) 1996 edition for the period 1971-1990
- iv) For the period since 1991 – Annual Cyclone Review reports, Regional Specialised Meteorological Centre (RSMC) reports published by IMD and periodical articles in IMD's Quarterly journal *Mausam* published under the title "*Cyclones and Depressions over the North Indian Ocean during the (year)*" provided the tracks and associated details.

2.2.3 Substantial amount of statistical information on C&Ds and their tracks could be / have been extracted from the above publications by research workers. Based on such data, large volume of research work has already been published. However the hard copy editions of the Atlas may not be able to supply the information in the format as exactly desired by the user. For example the tracks of C&Ds, which occurred during a specific year within the period 1891-1990, are not available in a single chart. The electronic version is much more versatile and supplies the tracks and statistical data as per choice of the user. Innumerable number of charts, tables and maps can be generated from the eAtlas, stored and retrieved.

2.3 Objectives of the Electronic Version

The broad based objectives of the eAtlas are:

- ✚ To replicate the present Atlas in an electronic form.
- ✚ To provide the Electronic Atlas with a large number of user-friendly menu driven features.
- ✚ Easy and ready display of tracks for any given month/season/year, for any given intensity, given area of formation and dissipation.
- ✚ Provision for numerous choices in the display of tracks.
- ✚ Generation of storm statistics by feeding various input parameters.
- ✚ Saving and retrieving the output products.

2.4 Digitisation of the tracks of Cyclones and Depressions (C&Ds)

2.4.1 For the development of the eAtlas, digitised data of each and every track of large number of C&Ds has formed the major input. The digitisation of tracks has been carried out by scanning the charts of the existing hard copy versions of the Atlas and then by adopting an objective procedure to convert the pixel coordinates of large number of points lying on the tracks in the displayed image in to longitudinal and latitudinal coordinates.

Coordinates selected

Coordinates of the following positions were selected for each CD.

Date(s) and Position(s) of: -

1. Formation
2. 03 UTC every day
3. Dissipation
4. Significant points

The following positions lying on the track of a CD have been taken as the significant points.

- ✚ Position at which the CD changes its direction of motion
- ✚ Coastal crossings - either from ocean to land (landfall) or land to ocean (re-emerging into sea).
- ✚ Position at which the CD changes its intensity
- ✚ Point of recurvature of the CD
- ✚ Representative position after the CD entered a different basin and
- ✚ Any other position(s) which are necessary to retain the shape of the track of the CD.

When all the selected points are plotted on a standard W-3 map used by IMD and successive points joined by a smooth and continuous line, the track obtained should exactly resemble the track of the CD as presented in the existing Atlas. Sufficient number of positions to satisfy such a requisite were selected and coordinates determined.

2.5 Software development

The generation of data files for the eAtlas, by digitisation of the tracks of C&Ds, has been carried out at Cyclone Warning Research Centre, Regional Meteorological Centre, Chennai. M/s CMC Ltd., Chennai developed the first standalone PC application of the software and M/s SVSS InfoTech Pvt. Ltd., Chennai developed the current web based application.

2.6 Output generated by the eAtlas

2.6.1 Types of output

Three different types of output (displays) can be generated through the various menus provided in the software. These are briefly described below. For further and

minute details, reference may be made to the help file or user manual supplied along with the software.

- (i) Tracks of Cyclones and Depressions
- (ii) Statistics of Cyclones and Depressions in map form
- (iii) Tables and Diagrams

2.6.2 Tracks of C&Ds – Display options

Display option 1 (with markings)

The tracks of C&Ds will be displayed with details such as indication of *month and year* at the beginning of the track and *month* only at the end of the track, by an *arrow*. All the consecutive *03 UTC* positions are marked by circles and the corresponding date is marked inside each circle in double digits. The segments of the tracks corresponding to the three different stages of a CD are indicated by dotted line, thin continuous line and thick continuous line respectively for the Depression, CS and SCS stages of the CDs which is similar to the methodology adopted in the existing Atlas.

Display option 2 (without markings)

Tracks are displayed as dotted / thin / thick lines with arrows at the end **without** details such as *03UTC* positions and dates. This option can be invoked by the user if tracks of large number of C&Ds are to be displayed.

2.6.3 Display of tracks of C&Ds through dialogue boxes

There are two distinct ways whereby the display of tracks can be effected. These are described below.

i) Display of tracks through the Main Menu: View of C&Ds by General Selection

A dialogue box for the display of tracks can be invoked from the menu (*Different Views-View by Parameters*). First *New Input* button provided in the dialogue box is to be clicked. The dialogue box provides the following three options viz. *Basic options*, *Advanced options 1 & 2*.

(a) Basic options: Under the basic options Year, Month & Basin of formation, Type of intensity (either maximum or at crossing) are the four input parameters.

Basin of formation (Basin(F)-B_f): Choice can be made through check boxes for all the basins namely Bay of Bengal, Arabian Sea and Land. If all the three are to be chosen the check box 'All' must be clicked.

Type of Intensity, either *maximum* or *at crossing*, can be chosen with the help of option button. Only one type of intensity can be chosen at a time. The level of intensity i.e. D, CS and SCS can be chosen through check boxes

Year: (1891-2010*, to be invoked as Y₁-Y₂ where 1891 ≤ Y₂ ≤ 2010*, Y₁ ≤ Y₂)

(*or the current year up to which the data base is updated)

Month: To be invoked as M₁-M₂ where M₁ and M₂ are the months and M₁ must precede or be the same as M₂.

Now *View output* is to be clicked to enable view of the tracks of the C&Ds for the selected options.

Tracks of C&Ds satisfying the selected basic options would get displayed. By running the mouse pointer over the displayed chart, the corresponding longitudinal and latitudinal positions can be noted.

The dialogue box contains provision for invoking *Advanced options 1 & 2*, which helps the user to narrow the search further.

(b) Advanced options 1:

In addition to *Basic options*, the following parameters could be prescribed under *Advanced options 1* (i) Basin of dissipation: Bay of Bengal, Arabian Sea, Land and All; (ii) Specific area of formation and dissipation: in terms of longitude and latitude.

Click on the *Advanced options 1* check box. Under this option, an area of formation (say area *F*) bounded by longitudinal and latitudinal positions within the range 50-100°E and 5-35°N can be defined. Basins of dissipation and, in addition, an area of dissipation (*Di*) could also be defined. Tracks of C&Ds that formed in area *F* and satisfying the basic options and dissipated in the chosen basin(s) of dissipation within area *Di* would then be displayed. If choice of *Advanced options 1* is invoked but area *Di* and area *F* are not defined by the user then default values of longitude and latitude viz., full range (50-100°E, 5-35°N) are assumed.

(c) Advanced options 2

Under *Advanced options 2*, tracks of C&Ds which crossed specific coast(s), as chosen by the user, would be displayed. Coastal crossing can happen in two ways, viz., *Sea to Land* or *Land to Sea*. The coastal belt(s) can be chosen from a *Pre-defined* list of coasts of maritime states of India and other coasts of North Indian Ocean provided in the menu. Another option is for *Custom* definition by the user by choosing longitudinal and latitudinal belts. In this case the user may name the coast by entering the name in the text box provided, for identification of the coast defined.

It is possible to invoke *Advanced options 1&2* either separately or simultaneously with the *Basic options*. Appendix I which provides examples may be referred to for demonstrating the use of these options.

(d) Display of a subset of tracks of C&Ds from amongst the tracks displayed

The menu provides easy selection and display of C&Ds from amongst the tracks displayed by using the *Select* option in the menu. In the chart displaying tracks, the menu *C&Ds* is to be selected. The popup window displays the identifiers in chronological order, of all the displayed tracks of C&Ds. There is a check box against each identifier. By clicking in the check box of the required identifier and by pressing the ‘*View*’ button, the track(s) of selected subset of C&Ds are displayed.

A map (Fig.1) presenting the geographical locations of the basins of North Indian Ocean and the various coasts defined in the menu can also be accessed through the menu. Another map (Fig.2) which displays the locations of several important stations and also displays 1° longitude and latitude grid squares can also be accessed.

The input parameters corresponding to the various options exercised by the user to generate the tracks are displayed in two boxes within the displayed chart. The parameters corresponding to basic options along with the number of C&Ds are displayed on the top right hand side of the chart (Display I) and those corresponding to the *Advanced options* are displayed on the top left hand side (Display II). When a subset of the tracks of C&Ds is displayed by invoking the *Select* option, the display also indicates the number of C&Ds displayed along with the total number of C&Ds displayed without invoking the *Select* option.

(e) Correct interpretation of the option “Crossing Intensity”

The term “*Maximum Intensity*” denotes the highest intensity of the CD during its entire life cycle and so unambiguous. The term “*Crossing Intensity*” (CI) is also clearly defined when there is only one coastal crossing. However when there are multiple crossings in respect of a single CD there would be more than one crossing intensity. Suppose the CI is invoked as CS in Basic Options. CDs which crossed from Sea to Land with the intensity CS alone would be displayed. In the event of more than one coastal crossing the CD is selected for inclusion if one of the CIs (corresponding to crossing from Sea to Land) is CS. Crossings from Land to Sea are not considered.

However when *Advanced Options 2* is invoked, the user can choose the options *Sea to Land* or *Land to Sea*. If Land to Sea is opted, the CI at the time of crossing from Land to Sea is also taken in to consideration and such a CD is included in the display.

For the abbreviations used, reference may kindly be made to the list provided in Annexure II or by clicking *Abbreviations* directly from the menu.

ii) Display based on Identifier

The dialogue box can be selected from the menu, viz., *Different View-View by Identifier*. As mentioned in section 2.3.2 every CD formed over Indian seas has been assigned a unique identifier. If this Identifier is entered in the dialogue box, subsequent commands could be used to display the associated CD. If the identifier is not known, the same can be selected by making a search based on any of the following four parameters:

- o Year (F:Formation)
- o Month (F)
- o Basin (F) and
- o Intensity (Maximum)

For example, say for 1974, all the identifiers of the C&Ds which formed during the year 1974 get listed in chronological order in the window provided beneath. Selection of any identifier can be made.

The selected identifier gets highlighted and is displayed in another window provided below. The buttons ‘*Details*’ and ‘*View*’, when pressed, provide display of complete data block of the selected CD as described in section 2.3.2 and track of the selected CD respectively.

Suppose month is chosen for the selection of identifier, search can be made by entering the number of the respective month i.e. 01 for January, 02 for February,12 for December. If Basin is chosen, search is made by entering 1 for Bay of Bengal, 2 for Arabian Sea and 3 for Land. In case of intensity selection, search is to be carried out by entering 1 for depression, 2 for CS and 3 for SCS. It may be noted that, track of only one CD can be displayed at a time through the Identifier dialogue box.

2.6.4 Statistics of cyclones and depressions in the map form

2.6.4.1 Charts 114 to 174 of the 1979 edition and charts 43 to 99 of the 1996 edition display a large number of C&D statistics in map form. The eAtlas generates the following statistics in map form, displayed in $2\frac{1}{2}^\circ$ longitude \times $2\frac{1}{2}^\circ$ latitude squares. The software displays a window with the following six choices when 'Statistics in Map form' is selected.

- i. Frequency of C&Ds.
- ii. Frequency of formation and dissipation of D, CS and SCS.
- iii. Percentage frequency distribution of the direction of motion of CDs.
- iv. Mean speed of the CDs (direction of motion in degrees, vector or/and scalar mean speed).
- v. The frequency of recurvature of D+CS+SCS, CS+SCS, SCS at various $2\frac{1}{2}^\circ$ squares towards north east direction
- vi. Frequency of C&Ds that crossed between two coastal stations.

The features associated with the above options are discussed below.

i. Frequency of C&Ds

Frequency of C&Ds gets displayed by selecting *year* and *month* and then clicking *View* button. In each $2\frac{1}{2}^\circ$ square, monthly frequency of D+CS+SCS is displayed at the top, that of CS+SCS in the middle and of SCS in the bottom.

ii. Formation / Dissipation Frequency

Under this choice, frequency of formation and dissipation of C&Ds is displayed. The *year* and *month* can be chosen through list boxes and *formation* or *dissipation* through option buttons. If *formation* option is chosen, in each $2\frac{1}{2}^\circ$ square three frequencies corresponding to D(top), CS (middle) and SCS (bottom) are displayed. In the case of dissipation the frequencies corresponding to dissipation of D, CS and SCS are

given in top, middle and bottom respectively. Here formation of CS means intensification from D to CS and formation of SCS means intensification from CS to SCS. Similarly, dissipation of SCS means weakening of SCS to CS and dissipation of CS means weakening of CS to D.

iii. Direction of movement

The percentage frequency distribution of the direction of movement of CDs is displayed in the map. The *year* and *month* can be chosen. For each $2\frac{1}{2}^\circ$ square, the percentage frequency distribution of the direction of movement of CDs towards various directions in each square is displayed through shafts with origin as the centre of the square. Single shaft in a square indicates 100% frequency. However, if there are multiple shafts, the corresponding frequencies add up to 100%. A scale indicating shaft length of 25%, 50% and 100% frequency is displayed within the display box. The frequency of CDs that passed through each square is also displayed.

iv. Scalar & Vector speed

Year and *month* can be chosen through the dialogue box. In each $2\frac{1}{2}^\circ$ square the top figure indicates the direction of motion in degrees in accordance with meteorological convention (i.e. measured clockwise from the northern direction). The figure in the middle indicates the mean vector speed of the CD and the bottom figure indicates the mean scalar speed. The speeds are expressed in kmph.

[The mean speed both scalar and vector, are given instead of frequency distribution (as given in the 1979 version) as it is felt that mean speed is amenable for easy interpretation compared to the frequency distribution].

v. Frequency of Recurvature towards Northeast

The *year*, *month* and *basin* can be chosen through the dialogue box. If the user wants to prescribe an area of formation, the same can also be done by selecting longitude / latitude values. If no selection, the default values i.e. $50-100^\circ\text{E}$ / $5-35^\circ\text{N}$ for longitudes and latitudes are automatically chosen. The frequencies of C&Ds that formed in the selected basin and specific area and re-curved towards the northeast direction, in the various $2\frac{1}{2}^\circ$ squares are presented in the map.

vi. Frequency between two stations

Frequency of C&Ds crossing coast between two successive stations from amongst the stations indicated in the India map of 1979 Atlas, will be displayed in this chart. The *year, month, basin* and restricted area of formation, the type of *intensity* either *maximum* or at *crossing* and also the level of intensity i.e. *D+CS+SCS, CS+SCS, SCS* can be chosen. The coastal stations along the eastern coast of India are Kanyakumari, Nagapattinam, Chennai, Machilipatnam, Visakhapatnam, Gopalpur, Kolkata etc.

2.6.4.2 The statistics presented in map form and described in (i) to (vi) above pertain to the month of actual occurrence. For e.g., a CD that formed in July and dissipated in August would get included in the statistics for *dissipation* in August only. In the case of *Frequency of C&Ds*, the frequency during July would be accounted against July and that against August would be accounted against August. Similar conventions have been followed in respect of other maps also.

In case of the map depicting monthly frequency of CDs, the frequencies that correspond to a $2\frac{1}{2}^{\circ} \times 2\frac{1}{2}^{\circ}$ square give the number of CDs which travelled through that selected square for the given period. Similarly, in the case of maps depicting mean speed and frequency of recurvature assigned to various squares, all the CDs that travelled through the given square have been considered.

2.6.4.3 For generating each of the above maps detailed methodologies had to be adopted which also involved several assumptions. By and large, the Climatology generated by the maps should be quite accurate if the period of generation is kept at least 10 years.

2.6.5 Tables and pictorial representation

In the main menu, *Different Views* and then *Table View* are to be invoked by the user. The software provides a window with three choices when '*Table View*' is selected. Once input is provided, the required table gets displayed. In some cases, *bar diagram* could also be generated.

The following tables and bar diagrams can be generated.

(i) Yearly and Monthly/Seasonal frequency of C&Ds (Table I of the existing Atlas)

Yearly and monthly / seasonal frequency of the CDs (two different types of outputs for 'by Month' and 'by Season') get displayed. The parameters *year, basin* and *intensity* (maximum intensity of the CD) and *statistics required* for *month* or *season* are

to be selected. The required statistics get displayed in three different ways; if *Table* option is invoked, the output gets displayed in table form; for *bar diagram* option, a specific choice of month / or season is to be made in the given list box.

(ii) Monthly and Seasonal variation of frequencies of C&Ds

The following frequency / probability is displayed:

- ✚ Monthly and seasonal frequency of CDs in various basins - Depressions which intensified into CS or CS which intensified into SCS.
- ✚ Monthly / seasonal frequency expressed as percentage of annual frequency and Probability of intensification. The output gets displayed in the form of *tables* or *bar diagram*.
- ✚ In case *bar diagram* is chosen, another portion of the dialogue box is enabled wherein *frequency, percentage frequency & probability of intensification* can be chosen and viewed. In some cases the probability of intensification could be indeterminate and this is depicted by negative probability in the bar diagram.

(iii) Consolidated list of C&Ds

Only *year* interval can be chosen. The C&Ds pertaining to all the twelve months of the year are listed. (Refer Appendix I of IMD's storm track Atlas). It may be noted that the frequency of a CD gets assigned to the month of formation only.

Example: An SCS, which formed on 28th November 1996 and dissipated on 7th December 1996, is assigned to the month of November only, for the purpose of counting the frequency even though most of the life cycle of the CD belongs to December. The same methodology has been followed while depicting the tracks. The track of the above SCS would get displayed only if November is fed as s input against month.

2.7 Saving and retrieving

The various types of output of the eAtlas viz: track display, map display and tables can be saved using the Browser options.

3. Other information which might be useful to the user

3.1 Non-inclusion of short-lived CDs without a track

In Table III of the 1979 edition, annual variation of frequency of C&Ds during 1891-1970 is given for the three basins i.e Bay of Bengal, Arabian Sea, Land and also for the complete area. The frequency for each basin obtained from the eAtlas for the period 1891-1970 and taken from the 1979 edition are given below:-

Area	Frequency from eAtlas software, for 1891-1970	Frequency as given in 1979 edition, for 1891-1970
Bay of Bengal	860	1034
Arabian Sea	112	196
Land Area	85	120
All	1057	1303

As seen from the above table the frequency generated by eAtlas is lower than the frequency given in the 1979 edition. This is due to the fact that Table III of 1979 edition presenting the above data included a good number of CDs which were short lived and did not have a track. Such CDs were still included while generating Table III of 1979 edition but have not been included in the eAtlas as the 1979 edition of the Atlas did not include such CDs in the set of tracks presented through various charts and that input data for the eAtlas was the various editions of the IMD's Atlas only. Such short lived CDs are numbered about 250 as mentioned in page iv of the 1979 edition under section 3.

3.2 Frequency of formation and dissipation

The frequency of formation and dissipation of C&Ds for all the twelve months has been presented month wise in charts 127 to 138 of the 1979 edition based on data for the period 1891-1970. In the eAtlas, however charts can be generated for any selected month(s) / year(s) and the displayed figures are the frequencies of formation and dissipation depending upon the selection.

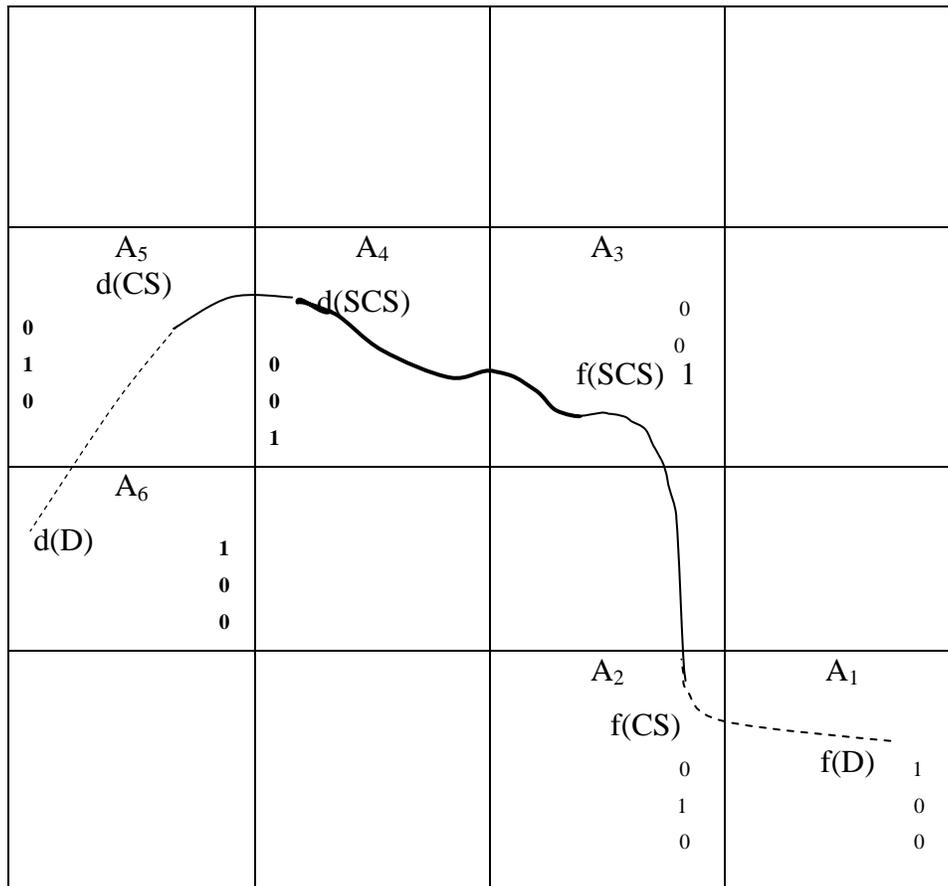
If a depression originates in a particular area square $2\frac{1}{2} \times 2\frac{1}{2}$ degree, (say A1- in the accompanying figure) and dissipates in another area square A6, then the displayed

figure gives the frequency of formation of depression in A1 and dissipation of depression in A6.

In the case of cyclonic storm and severe cyclonic storm, the formation of CS in the given area square (say A2) is considered as intensification of CS in A2 and for SCS, intensification of CS to SCS in A3.

Similarly, weakening of a SCS into CS in a given area square (say A4) is considered as the dissipation of SCS in A4 and that of CS into depression in a given area square (say A5) is taken as dissipation of CS in A5.

The corresponding frequencies (as generated in the eAtlas display for a single track) are given in the following figure (bold figures represent frequencies of dissipation of the CD)



Note : f(D), f(CS), f(SCS) –formation of depression, cyclonic storm and severe cyclonic storm;
d(D), d(CS), d(SCS) –dissipation of depression, cyclonic storm and severe cyclonic storm;

The above methodology that has been followed in the eAtlas are same as the methodology followed in the 1979 edition, described in Para 4 of Part III.

3.3 Recurvature

The recurvature of a CD over Indian seas is normally taken as a well-defined change of direction of movement from westerly to easterly and in rare cases from easterly to westerly. Frequencies of CDs which recurved towards northeast can be obtained from the eAtlas.

3.4 Non- inclusion of origin of certain CDs

The eAtlas does not provide the initial positions of tracks in respect of CDs which originated outside the region of consideration i.e. 50°E-100°E and 5°N –35° N. In respect of such CDs which originated elsewhere and entered into the above region, the tracks have been shown from the point of entry to the region only. Similarly in case of the CDs which exited out of the region of consideration, the tracks have been shown up to the point of exit only. In such cases, the arrows of the tracks may not indicate point of dissipation.

3.5 Date of formation and first date circle

Date of formation of a CD has been defined as the exact date on which the CD originated. However in respect of the C&Ds that occurred during the period 1891 to 1990, the first date circle i.e., the first 0830 hrs IST position (03 UTC in track) after the originating point is only available in the tracks and not the exact date /time of formation. For example consider a hypothetical case of a CD formed on 3rd August at 2030 hrs and travelled nearly 200 kms but the track indicates a position of 0830 hrs on 4th August as the first date circle. In this case it is not possible to decide whether the CD originated on 4th itself or on the previous day. The date of first date circle has therefore been taken as the date of formation of the CD. However care has been taken to verify the date of formation from the consolidated list of storms and depressions available in Annexure I of IMD's Storm Track Atlas while giving the formation position. In respect of the CDs that

occurred since 1991 the tracks also contain positions at 1730 hrs (12 UTC) and in some cases the exact time of formation. For example, the track of a CD that originated on 3rd August might contain such information even though the first date circle is dated 4th August. In case of such authentic information being available, the actual date of formation has been taken as the date of formation and the subsequent date of first date circle taken as the subsequent date position. In such cases, the identifier date will differ from the first date circle and the track would contain the first date circle only.

The above methodology may lead to following type of situation of track display.
Example: A CD which eventually intensified into SCS formed on 30th September 2004 at about 1430 hrs but its first date circle is on 1st October 2004 only. The track of this CD will get displayed only against September and not against October.

Feedback from users

Users, should they come across any errors in the tracks / charts / maps generated and displayed by the eAtlas, can communicate the same to RMC Chennai to the email ID cwrcrmchennai@gmail.com. The errors will be checked at RMC Chennai and duly corrected data will be incorporated into the database during the subsequent session of updating. Suggestion for improvement also may be communicated to the above email ID.

4. Copyright Notice

The software *Cyclone eAtlas – IMD, version 2.0*, an electronic Atlas of *Tracks of Cyclones and Depressions in the Bay of Bengal and the Arabian Sea* and its related documentation (including maps) is subject to copyright vested with India Meteorological Department. Any other reproduction of copies of the software and its documentation are in violation of the Copyright Act.

5. Disclaimer

The basic data for the *Cyclone eAtlas – IMD, Version 2.0* software on the *Tracks of Cyclones and Depressions in the Bay of Bengal and the Arabian Sea* was generated based on the official records of India Meteorological Department, containing the tracks of cyclones and depressions which occurred over Indian seas during the period 1891-2010. IMD has undertaken all steps to ensure that the information contained in this software is true and correct at the time of production. However, IMD does not accept any responsibility for any loss suffered by the user as a result of reliance upon or use of this information. The Department will not be responsible or liable for the outcome of a decision based on the products generated through the use of *Cyclone eAtlas – IMD*.

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Appendix I - Illustrations

Examples of various categories of displays of cyclones and depressions(C&Ds) over the Indian seas which can be generated through the dialogue box when the option ‘View of C&Ds by parameters’ is invoked.

I. Basic options

1. *Year* : 1991-2000; *Month* : October to December;

Basin of formation: Bay of Bengal

Type of Intensity: Maximum;

Level of Intensity: cyclonic storms and severe cyclonic storms (CS and SCS)

The above options will generate tracks of all the CS & SCS that formed over Bay of Bengal during October to December months for the period 1991 to 2000.

2. *Year* : 1991-2000; *Month* : October to December;

Basin of formation: Bay of Bengal

Type of Intensity: coastal crossing

Level of Intensity: CS and SCS

The above options will display all the tracks of the CDs that formed over Bay of Bengal during October to December months for the period 1991 to 2000 and then crossed the various coasts with the intensity of CS & SCS. Obviously a CS/SCS (maximum intensity) that has not crossed coast would not get displayed under the above option.

3. *Year* : 1991-2000; *Month* : June to September;

Basin of formation: Bay of Bengal

Type of Intensity: Maximum;

Level of Intensity: Depression

The tracks of all the depressions formed over Bay of Bengal during June to September in the period 1991 to 2000 alone get displayed with the above option. CDs which reached maximum intensity of CS / SCS would not get displayed.

II. With Advanced Options 1 and 2:

1. *Year* 1971-2000; *Month* : October to December

Basin(F): Bay of Bengal;

Type of Intensity: Maximum;

Level of Intensity : D,CS, SCS;

Basin(Di): AS

The tracks of all the CDs that formed over Bay of Bengal and dissipated over Arabian Sea during the above period would be displayed.

2. In the above example we may also choose in addition, specific areas for formation and dissipation. For example,

Formed over: longitude 80°E-90°E and latitude 5 °N - 15°N ...area *f*

Dissipated over: longitude 65°E-75°E and latitude 15°N - 25°N ... area *d*

The above options would display C&Ds which formed over Bay of Bengal in area *f* (i.e., intersection of BOB and area *f*) and dissipated over Arabian Sea in area *d* (i.e., intersection of AS and area *d*)

3. In (1) above if Basin (of dissipation) is chosen as land then CDs which dissipated over land would be displayed.

4. *Year* 1971-2005; *Month* : October to December,

Basin(F): Bay of Bengal; *Type of Intensity*: Maximum;

Level of Intensity: CS and SCS;

Advanced Options 1:

Formed over: longitude:80-90°E latitude: 5-15°Narea 1

Dissipated over: longitude:92-100°E latitude: 15-25°Narea 2

Under the above option the tracks of all CS and SCS that formed over Bay of Bengal over the area 1 above during October to December, 1971 - 2005 and dissipated over the area 2 would get displayed.

5. *Year* 1971-2005; *Month* : October to December,
Basin(F): Bay of Bengal;
Type of Intensity: Maximum;
Level of Intensity: CS and SCS;
Advanced Options 1:
Formed over: longitude:80-90°E latitude: 5-15°Narea 1
Dissipated over: longitude:70-80°E latitude: 15-25°Narea 2
Advanced Options 2:
Sea to Land: Coastal belt: AP & Orissa

Tracks of all the CS and SCS that formed over Bay of Bengal in area 1 during October - December, 1971-2005, crossed Andhra Pradesh and Orissa coasts and dissipated over area2 would get displayed.

6. *Year*: 1971-2005; *Month* : October to December,
Basin(F): BOB;
Type of Intensity: Maximum;
Level of Intensity: SCS;
Advanced Options 1: longitude: 80-90°E, latitude: 5-25°N
Advanced Options 2:
Sea to Land :longitude: 79-81°E, latitude: 11.8 – 14.2°N
 Coastal strip (user defined): CDL-NLR

By exercising the above options tracks of all the severe cyclonic storms that formed during the above period over Bay of Bengal within the region bounded by 80-90°E and 5-25°N and crossed the coastal strip of Cuddalore to Nellore in the area bounded by 79-81°E and 11.8-14.2°N get displayed.

7. *Year*: 1971-2005; *Month* : October to December,
Basin(F): BOB,
Type of Intensity: Maximum;
Level of Intensity: SCS;

Advanced Options 1:

Formed over: longitude: 80-90°E, latitude: 5-15°N

Dissipated over: longitude: 75-85°E, latitude: 20-25°N

Advanced Options 2:

Sea to Land : Coastal belt :Andhra Pradesh

The above multiple options would display the tracks of all CS and SCS for the above period originated over the area 80-90°E & 5-15°N, crossed into Andhra Pradesh coast and then dissipated over the area 75-85°E and 20-25°N.

8. *Year:* 1971-2005; *Month* : June to September;

Basin(F): Land;

Type of Intensity: Maximum;

Level of Intensity: D, CS and SCS;

Advanced Options 2:

Land to Sea - Coastal belt: K&G, Gujarat

The above options would display the tracks of all the depressions, CS and SCS which originated over land and crossed the above coasts and then re-emerged into the sea.

9. *Year:* 1971-2005 *Month* : October to December

Basin(F): Bay of Bengal;

Type of Intensity: Maximum;

Level of Intensity: CS and SCS;

Advanced Options 2:

Sea to Land :longitude:71-81°E, latitude: 11.8 – 14.2°N

Name of the Coastal strip: (user defined): CDL-NLR

The above options would display tracks of all CS and SCS which crossed the Cuddalore-Nellore coast.

In the above examples if we define the coastal belt as Gopalpur to Puri, area bounded by longitude 86-87°E and latitude 18-23 °N can be named as Gopalpur - Puri,

Appendix II - Abbreviations / Notations
used in *Cyclone eAtlas – IMD* and their expansions

I Commonly used abbreviations and their expansions

JF	-	Jan-Feb
MAM	-	Mar-May
JJAS	-	Jun-Sep
OND	-	Oct-Dec
Ann	-	Annual
UTC	-	Universal Time Coordinate
C&Ds	-	Cyclones and Depressions
CD	-	Cyclonic Disturbance
BOB	-	Bay of Bengal
AS	-	Arabian Sea
D	-	Depression
CS	-	Cyclonic Storm
SCS	-	Severe Cyclonic Storm
F	-	Formation
Di	-	Dissipation
MI	-	Maximum Intensity
CI	-	Crossing Intensity
lon	-	Longitude
lat	-	Latitude

II Abbreviations used to denote various coastal belts

East coast of India

cap	-	Andhra Pradesh
or	-	Orissa
tnn	-	Tamilnadu North
tns	-	Tamilnadu South
wb	-	West Bengal

West coast of India

ck	-	Karnataka
gu1 & gu2	-	Gujarat
ker	-	Kerala
kg	-	Konkan & Goa

Countries to the east of India

ar	-	Arakan
bd	-	Bangladesh
sle	-	Srilanka East
slw	-	Srilanka West

Countries to the west of India

pak	-	Pakistan
iaa	-	Iran, Arabia & Africa

Fig.1 Coastal boundaries of India and neighbourhood

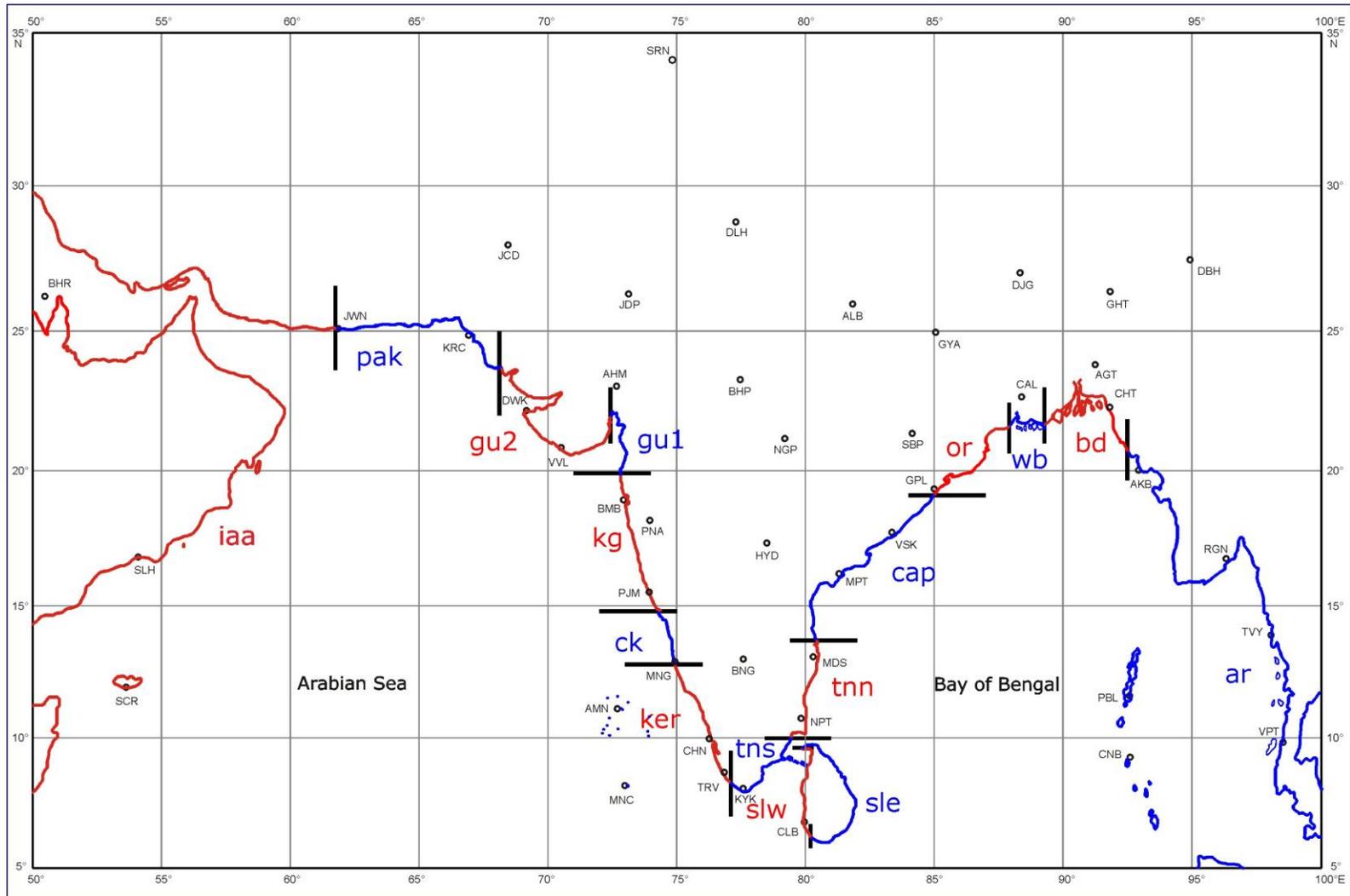


Fig.2 Gridded map of India and neighbourhood

