Science, State and Meteorology in India

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DIALOGUE
Science, Scientists, and Society

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Meteorology as a science developed from the middle of the nineteenth century in India in the government's cradle. This, in turn, has shaped its evolution, making public service its key focus and receiving government patronage in return. Examining this relationship through the evolution of cyclone warning services of India Meteorological Department (IMD), this paper argues that historically such meteorological service has developed without adequate emphasis on theoretical advancement inhibiting the growth of the particular science. Meteorology's entanglement with the state has resulted in its servicing of state's institutions rather than the society at large and creating a bureaucratic environment with poor research tradition both during colonial and in the post-Independence period. This association has ensured that there is no scope for the public's assessment of meteorological service even though it remains predominantly public-funded.

Keywords: Meteorology; Science and State; Cyclone Warning Service

This paper aims to examine the evolution of 'cyclone warning' as a meteorological service in India and through this, explicate the relationship between science and the state. This relationship was forged at a time when meteorology was in its embryonic stage, thus providing an ideal vantage point to understand the type of collaboration it engendered and the implication it had for the particular science. The paper focuses on the following: a) trace the historical context in which the idea of storm warning service was conceptualized in India b) trajectory through which India Meteorological Department (IMD)'s cyclone warning service has evolved over the years and c) the outcome of this relationship with the state has, for India Meteorological Department (henceforth IMD) and Science of Meteorology. The paper seeks to highlight the 'cyclone warning service' in India that played a major role in bringing together and sustaining the relationship of meteorology with the state. In what follows, the first part of the paper presents the global context during the eighteenth and nineteenth century that saw a transition in meteorology from theoretical to application-oriented goals. The second part delves into the evolution of cyclone warning in the Indian context, its initial conception and its shifting focus owing to political-economic considerations. The concluding part presents a discussion on the implication of IMD'S relation with the state, for its growth and development.

1 Early debates over 'sea storms'

During the period 1698 to 1810, sea storms were viewed as whirlwinds in all parts of the world including the Indian Ocean and the China Sea (Piddington 1848). Wiliam Redfield (1798-1857) a leading meteorologist from the USA postulated in 1831 that storms are not just whirlwinds but are progressive whirlwinds moving forward in curved tracks with considerable speed (Monmonier 1999: 31). By 1843, Redfield was engaged in an intense debate with his contemporaries on this feature of the advancing nature of storms (Redfield 1842). This idea was supported by Heinrich Dove in Germany and around the same time, Eedfiej. D and Colonel Eeid of Britain provided proofs that storms in the southern hemisphere revolve in a contrary direction compared to the northern hemisphere (Piddington 1848). During this period, the idea of 'storms' included a range of phenomena such as whirlwinds, tornadoes, water spouts, etc. One of the principal debates of this era was related to how storms gather energy and sustain it over a period of time. Espy (1785-1860) formulated a theory envisioning a moving air chimney at its centre to explain sea storms and related phenomena like tornadoes, volcanoes, snowfall, and rainfall, etc. (Espy 1841). The contentious issue in this debate was; what could be the driving force of a storm? Redfield and other whirlwind theorists argued that the air during a storm is drawn to a central point or a line through a spiral action. This, however, failed to explain how such a flow is sustained, or a continual fall in the barometric readings, despite the accumulation of air i.e., unless it is also shown that air-flows are thrown outward by greater centrifugal force (Espy 1841). To sum it up, while Redfield considered gravity and the Earth's rotation to be causing wind which in turn accounted for the differences in temperature, pressure and moisture, Espy's theory focused on heat or thermal process which caused air to rise and winds to rush in (Monmonier 1999: ch. 1). This theoretical debate among the leading meteorologists of the period, continued from the 1830s for the next few decades, seeking explanations for nature and sustenance of a sea storm (Espy 1841; Dove 1862; Walker 2011).

A key contributor to this debate was Henry Piddington (1797-1858), a British who in his early life worked in mercantile marine and commanded a ship until he decided to engage in his intellectual interests and hence opted for a shore job. During 1839-1848, Piddington published a great deal in the journal 'Asiatic Society' based on his analysis of thousands of logs obtained from various ships with much difficulty. These logs accounted for hundreds of cyclonic storm which occurred over the Bay of Bengal, Arabian and the Andaman Sea, China and Southern Indian Ocean (Piddington 1848). His publications included thirty articles or pamphlets, two books, one of which is his historic "The Sailor's Horn-Book for the Laws of Storms" that appeared in 1848. In this work, Piddington offered a clearer nomenclature of 'Cyclone' to distinguish it from a variety of terms used at the time and his principal focus was on developing practical tips for mariners so that they can negotiate the hazard on the sea. Piddington's early work reflected a conception of the storm from a mariner's point of view but in the later phase, he elaborated the impact of storms on land, or the phenomenon of 'storm wave', nature and severity of which was yet to be fully comprehended. He made considerable effort in making people aware of the danger posed from the storm's impact onshore and went on to advocate preparedness measures (Sarma 1997). For example, in 1853, when a new alternate port was being planned, 45 km to the south-east of Calcutta on an estuarine river called Matla, Piddington argued against its proposed location, pointing to its high vulnerability to a storm surge. He thus wrote a letter to the Governor-General of India in the form of a pamphlet, explaining in detail the phenomenon of 'storm wave'. Despite Piddington's objection, the port, however, was commissioned in 1864 at the same location and during a cyclone in 1867 it was inundated with six ft. of storm wave, leaving it crippled and was eventually abandoned four years later (Sarma 1997).

Piddington generally refrained from attributing causes to cyclones, but provides an excellent summary of various theoretical perspectives of his time including the random ones such as the role of the magnetic and electric field or even volcanic eruption etc., for causing a storm (Piddington 1860). A key idea which Piddington attributes to William Redfield is; cyclones are caused by a clash of atmospheric currents at different strata resulting in a circular motion which increases and expands into a storm. This view was refined further by Alex Thom who studied the nature and course of storms in the Indian Ocean. There are also others such as Kametz who argued that when North East wind prevails below and South-West wind above, violent whirlwinds are formed at their limits, which descend to the surface of the earth and often endowed with prodigious force (Kametz 1845, 47 as cited in Piddington 1860: 21). John Herschel one of the most distinguished scientists of the period raised doubts about the possibility of such an upper atmosphere collision of air currents causing a cyclone in the lower atmosphere and proposed instead that two or more barometric waves moving in different directions intersect to cause rotatory storms (Piddington 1860:15-18).

Theoretical debates spanning over the first three-quarters of nineteenth-century offered an alternative meteorological explanation for causes of cyclonic storms, its nature, movement, etc., and they were generally aimed at deriving general laws to understand the phenomena and apply that understanding to societal benefits. Piddington believed that postulated laws are to be the outcome of adequate verification of theories and such suppositions are meant to be of value to the public. Other contemporary meteorologists, for example, HW Dove shared a vision of storms with similar goals for example in believing storm may look violent or disturbed atmospheric states but there are some general principles for its formation and movement which are to be discovered (Dove 1862).

1.1 Theories of Storms to Warning Services

Parallel to the period of aforementioned debate i.e., 1830-70, a decisive shift was underway globally vis-à-vis meteorology. This was in the form of government playing a central role in expanding observational network; both in their organization as well as in operation. It was a departure from the earlier practice of weather observation being undertaken either at an individual level or through the formation of meteorological societies (Walker 2011). Two principal reasons generally attributed, for the rationale for such a network of observation stations are: a) the need to observe weather phenomena from different locations to supplement or construct theoretical perspectives and b) the need for a collective effort of individuals, collaboration and exchange instead of individual subjective opinion or conjectures

- a philosophy that was in line with the contemporary vision of a 'new science' [1] (Anderson 2000). These coupled with the idea of requirements of calibration and standardization for observation instruments, created a favourable ground for the state to take up the responsibility (Walker 2011:10). Furthermore, the availability of telegraphy in the 1850s provided the catalytic effect, for faster telegraphic communication not only enabled meteorologists to create snapshots of observations taken over large areas, it also gave them the ability to prepare weather forecast and send it in quick time as well. By the end of the nineteenth century, most nations with telegraphic networks had established national weather service (Edward 2006: 231). For example, Britain and Holland formalized national weather office in 1854, Italy in 1863, France in 1863, etc. (Anderson 2000). Soon enough, it was also realized that the need for collaboration goes beyond national boundaries leading to the conception of the first international maritime conference in 1853 at Brussels and subsequently the first international meteorological congress in Vienna in 1873.

Storm warning as a service, in particular, played an important role in effecting this change in metrological science's relationship with the state. As weather phenomenon 'storms' allowed observation scope during its growth and advancement phase and faster telegraphic communication to areas which are likely to be affected. Catastrophic effects resulting from storms' impact, together with society's ability to mitigate the same risk through meteorological means legitimized the direct involvement of the state. As was evident in the number of cases, the occurrence of a high impact storm often would be a catalyst, creating an environment which is a prerequisite to achieve political and financial commitment for storm warning services. In Britain, for example, the storm warning system was prompted by a severe sea storm in 1859 in which 343 ships were destroyed. Following extensive media coverage of the storm's impact, a system of warning based on telegraphic communication was operationalized and the first warning was issued in 1861. Robert Fitzroy the architect and first head of British storm warning service was a mariner in his early career and one who faced much criticism for giving precedence to the practical application of meteorological knowledge over the collection of accurate observation or providing emphasis to theoretical constructs (Anderson 2000:112; Walker 2011).

1.2 Meteorology as 'Government Science'

The changes heralded a new era in meteorological science, driven by a network of observation stations, coordinated and supported by the agencies of state with its larger goal-oriented towards public service. Anderson 2000: 235 views it as 'meteorology embodied the promise of state science in two different ways: as an example of government funding for research, but also as a model of control, both natural and social'. The collaboration was indeed distinct from the perspective of its immediate demonstration of 'science for public interests' and pioneered the idea of *government science* (Resnik 2008; Manning 1967). In its distinction from the idea of a 'regulatory science' (Jasanoff 1990: 40), 'government science' had an explicit mandate of

[1] 'New science' refers to western societies' new approach to study nature; characterized by instrumentation, cooperation, secularity, professional societies, openness and a t drive towards an eventual prediction and control.

producing scientific knowledge at the time of their inception, though they were as much entangled with public administration. Subsequent development during the middle decades of the nineteenth century consolidated the role of the state in providing support to meteorology and to weather service in particular. This catapulted the state to assume a commanding role not just in terms of financial support rather it made meteorology a state-led science. This could be easily justifiable on account of its public service character and from the same perspective; the devastating potential of storms made it an ideal candidate for warning service.

The transition, however, raises a number of questions such as, how did this involvement by the state impact the nature of science? What were the consequences, what kind of influences it had on its institutions? What research it did not allow? Or how did it link to politics? (Doel 2003; Randall 2010, Whitehead 2009). Patronage, as Carlsson-Hyslop 2010 points out, is just not about money but values about research and identity. These questions assume significance as theoretical meteorology subsequently diverged from the more practice-oriented newly established national weather service, and developed separately, mostly in academic institutions (Edward 2006). Collaboration with the state enhanced the scale and broadened the scope for observation and that of weather services while relatively much less was seen in terms of theoretical advancement. Reed 1977 terms the period of 1860-1920, as an empirical era when experience gained in the use of weather maps constituted almost the sole basis of prediction. Forecasting in this period was largely an exercise in isobaric geometry. Lynch 2002 makes the same point about tropical cyclonic forecasting to be based on subjective judgments and extrapolation of current trends. This in itself is ironical as, despite significant theorization efforts before the commencement of storm warning services, very little of them found application, and forecasters often relied on guesswork than theoretical insights (Cox 2002). Edward 2006 further informs that the trend did not change significantly until the 1940s with barely any theoretical input and during this period, the predictive technique was largely a form of pattern matching with previous weather maps.

1.3 Cyclone warning service in India

Astronomical observatories were established in India during the late eighteenth century. Fort William, Calcutta, for example, was set up in 1774 while that of Madras came up in 1790. These were mainly in aid of the colonial government's surveying activities though subsequently used for the meteorological purpose (IMD 2000). With the commencement of the trigonometric survey at the turn of the century, the utility of these observatories was diminished. The one at Madras, for example, was on the verge of closure by early Nineteenth Century, serving as a venue of Public Works Department's workshop. It was used later for meteorological and magnetic observations (Kochhar 1991). The revival was further extended to new places and during the period 1820-30, meteorological observatories were founded in Colaba, Bombay (1823); Surveyor's General Office, Park Street, Calcutta (1829); Trivandrum (1836); Simla (1841-45), etc. (IMD 2000: 4). Radhanath Sikdar, who was earlier associated with Trigonometric Survey, became the first Indian superintendent of Calcutta Observatory in 1852 and credited to have developed a methodology to record weather observations (IMD 2000). By the mid-nineteenth century, places such as Saharanpur, Darjeeling, Mysore, Agra, Roorkee, Benares, Bijonore, Kathmandu, etc. were added to the observation station network (Sikka 2011). Weather data were valuable to the colonial government for its sanitation, agriculture, general administration department and also for their commercial usefulness. Colonial interest in meteorological science has a ring of similarity with other sciences such as Geology, Astronomy etc.; conceived primarily as a tool and for their economic and administration utilities (Kochhar 1991). Following an instruction from the Court of Directors of East India Company, Great Britain, meteorological observations were taken at the principal station of European troops and sanitation, such as Belgaum, Mahabaleshwar, Panchgani, Purandhar, Poona, Ahmednagar, Hyderabad, Zanzibar, Muscat, etc., under the supervision of senior medical officer at each of these stations (IMD 1976:16).

The mutiny in 1857 resulted in the suspension of meteorological observation over most of the country during 1857-1860. Concurrent with the transfer of administration from East India Company to the British Government, new interests were seen in meteorological observations. A German company 'Von Schlaginweit' was invited to India, which collected a vast amount of meteorological records during 1861-63 and took them to Munich for its analysis. It was however found to have very little value, mainly due to quality of data (IMD 1976). In a series of events that reminds of how storm warning service was formulated in Britain, two catastrophic cyclones during 1864, the first of which hit Bengal on 4-5th October, 1864 killing more than 80,000 people and the second within a week, struck Machhlipatnam, resulting in the death of nearly 40,000 people (IMD 1925: 4). The scale of the impact caused much unrest, especially among the mercantile traders and shipping community and triggered a demand for a cyclone warning service along the lines of Fitzroy's British system. The colonial government constituted a committee in 1865, to develop a system of cyclone warning and on its recommendation; Calcutta became the first port in India in 1865 to have a storm warning apparatus. This service was subsequently placed under the Bengal Meteorological Department that was established in 1867 with a twofold objective: "to give cyclone warning for the protection of shipping and to collect and record systematic meteorological observations throughout the presidency" (IMD 1925: 3). H. F. Blanford, then a Professor of Science at Presidency College, Calcutta was appointed in 1867 as the Meteorological Reporter for Bengal while being permitted to retain his professorship. Two severe monsoon failures in 1866 and 1871 consolidated the demand for coordinated and effective weather service. Blanford on the request of the then government prepared a report in July 1875 in which he identified three broad objectives for a centralized meteorological organization; a) systematic study of climate and weather of India as a whole b) application of the knowledge thus acquired to issue storm and other warnings and daily weather forecasts and c) subsequent history keeping, assessing the extent to which the above aims were achieved (IMD 1925: 4). The government of the period approved this proposal in its entirety and constituted the India Meteorological Department (IMD) in the same year and promoted Blanford to become its first head or Imperial Meteorological Reporter.

Cyclone warning system in India in its early phase revolved around the interests of mariners. The port warning services introduced in Calcutta in 1865 were extended to sixty-five Indian ports by 1929-30. Also, for smaller boats plying on the river deltas, eight river ports and seventeen river police stations were added to the warning network. In due course, cyclone warning signals for ports were standardized. To communicate a warning to ships at deep sea, wireless messages were transmitted for their safe navigation (IMD 1930). The emphasis given to port warning and marine establishment, in general, was indeed considerable which should be seen in the light of the importance of mercantile trade and related colonial interests. At the same time, sailors provided weather observations from the sea, transmitting information through wireless communication and their logbook records were invaluable for theoretical exploration. Together these factors ensured that the storm warning service was placed under 'marine meteorology' as a sub-disciplinary category (IMD 1939). In addition to marine establishments, warning for storm and flood were issued for various government agencies. Telegraphic messages were disseminated to District officials, and that of Railways, Irrigation, Military and other Departments. This idea to warn public officials was first considered in the wake of a severe flood in 1885 in the lower valley of Nerbuda and Tapti Rivers. The concept drew from linking forecasts for heavy rainfall with the movement of cyclonic depressions from the Bay of Bengal and based on it, issuing a warning to the concerned government officials. A series of floods during the southwest monsoon of 1889 resulted in the Public Works Department (PWD) issuing a circular to this effect to all its officers (IMD 1925: 5-9). This practice continued and during the period 1908-22, special forecasts and warnings were issued as many as 2,500 to nearly 12,000 number of times a year (Fig 1). During the same period, the number of officers who received such warnings varied between 175 to a maximum of 425 (IMD 1922). In one particular year 1921, an additional 461 officers from the inland habitats of Bengal were added to the warning list keeping in view the high risk posed to them from a land-falling cyclonic storm (IMD 1925: 26).

During this early phase of IMD warning services, procedures were laid out to assess the satisfaction of user groups which effectively meant government officials in charge of undertaking precautionary measures. Instructions were issued accordingly in 1898 that every officer who received storm or flood warnings should send feedback to IMD in the first month of every year (IMD 1922: 5). The total number of replies received during 1908-1921 indicates that the number of response in the best case scenario was less than one hundred seventy-five. Replies received were largely positive endorsement of the service though there were critical remarks as well. For example, during the year 1924-25, feedback reports were received from fifty-four officers, forty of whom stated that the warning received were satisfactory, seven provided no definite remarks while the remaining seven made either suggestions or minor criticism. A specific criticism, for example, was received from the Deputy Port Conservator of Calcutta dated 4th August 1924, which said: "Yesterday it was very obvious to everyone that weather was very unsettled at the head of the Bay but no warning of any description was received either from Simla or locally" (IMD 1925: 24). IMD assessed its overall warning services 'to be of value to recipients' based on a) feedback received from users i.e., officials and b) comparison made *post facto* through a survey of inland tracking of the storm and rainfall (IMD 1925: 26).

For people living on the coast and who bore the brunt of a cyclonic storm's impact, the warning was provided through newspaper and radio bulletins (IMD 1919). The later in particular was the chief means of warnings during cyclonic conditions when bulletins were issued periodically. For example, during 1930-31, as many as 9,712 weather bulletins were issued (IMD 1931: 5). However, unlike user groups such as officials, feedback of the general public was neither considered to be an important dimension nor did it form part of the overall IMD's evaluation framework. The utilitarian framework appears to have little value for the importance of public assessment of warning service, at par with that of administrators. In the absence of any systematic study, the extent to which such warnings were useful for the coastal populations remains uncertain. Considering that no major effort was made by the colonial government to construct sturdy public buildings or what is popular as 'cyclone shelters' at vulnerable locations to which people can move into, at the time of a cyclone, it can be argued that the focus of cyclone related radio bulletins was mainly for the marine establishment and officials to take some preventive measures than coastal population.

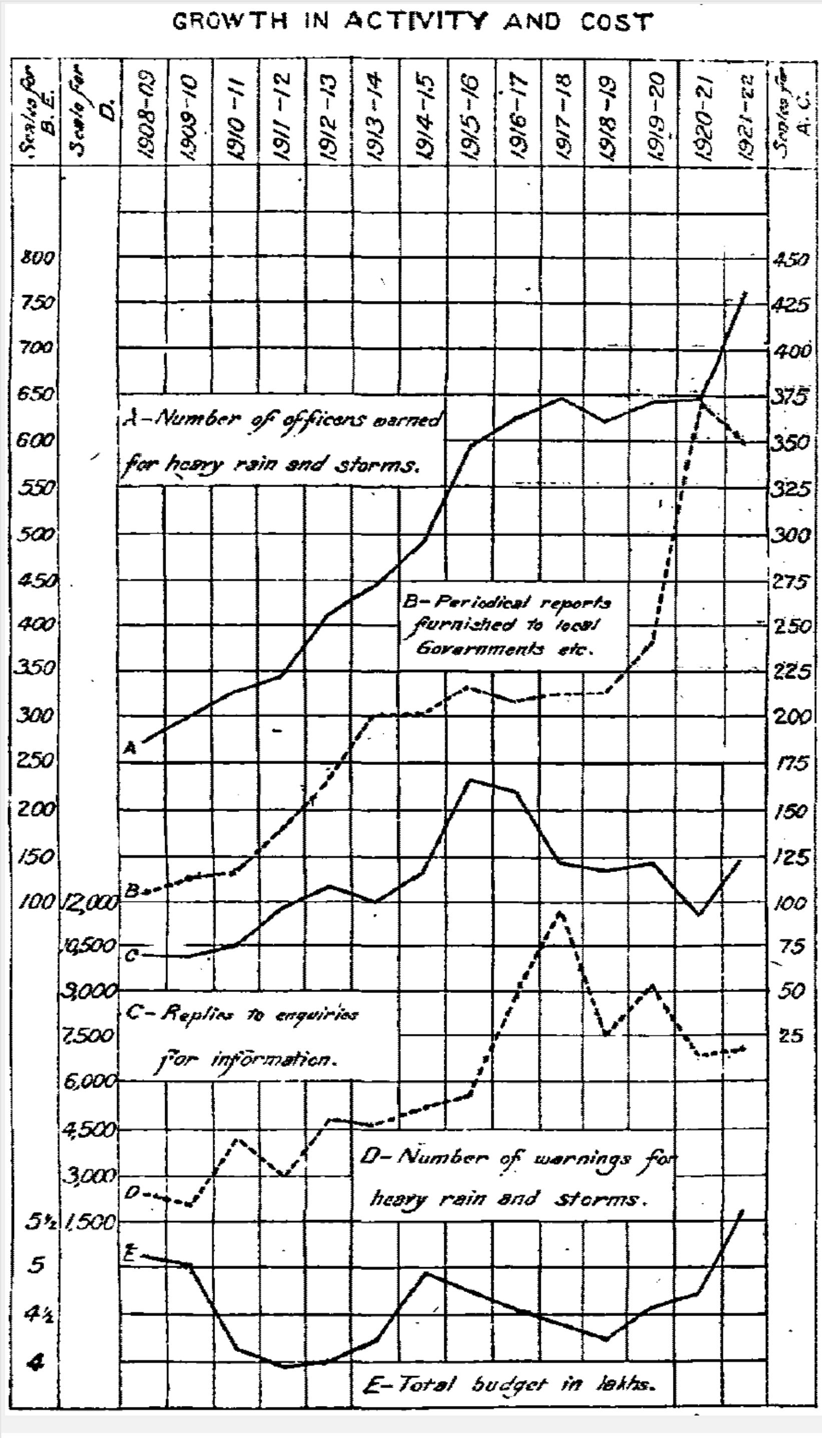

Fig 1 Growth of IMD during 1908-1922 (IMD 1922:15)

1.4 Declining research support

Following the establishment of IMD in 1875, theoretical work related to cyclonic phenomena and weather science, in general, continued within the organization though in very limited form. John Eliot succeeded Blanford in 1889 as head of IMD, and like his predecessor was also a Professor of Science and in charge of Bengal meteorological system before his IMD appointment. During his tenure in Bengal, he investigated the 1876 Backergunj cyclone in which more than 200,000 people died. Eliot developed and extended the theory of cyclone formation and his publication 'Report on Vizagapatnam and Backergunj cyclones of 1876' generated much interest and a request was made by the British House of Commons for this report to be laid on its table (IMD 1925: 6). Eliot's' interests, however, were not limited to tropical cyclones and he wrote more than fifty papers on various aspects of meteorological science. He succeeded in expanding the network of observation stations to native ruled states such as Hyderabad, Kashmir, Upper Burma and Persia (IMD 1925). Towards the end of his tenure, there were several severe drought occurrences, for example in 1896, 1899, 1902, etc. and growing public unrest over the failure of administration in tackling hunger and unemployment. In this backdrop, improvement of long-range monsoon forecasts appeared to be a viable strategy and eventually led to the appointment of Gilbert T Walker in 1904 as the new head of IMD. Walker, a trained mathematical physicist who was teaching at Cambridge, was expected to contribute to the 'long range monsoon forecast' though he had very little expertise in meteorology as such. He focused on the 'long range monsoon forecasts' examining possible causes of monsoon failure and its global pattern (Sikka 2011). During this period, an upper air observatory was founded at Agra in 1914, though this demand was long pending from the perspective of cyclone warning services. This requirement of observation of upper air was raised as early as 1877 by H. Blanford and was further reiterated by his successor John Eliot but failed to receive financial allocation until 1905 (IMD 1925). Studying a cyclone in 1903 over the Bay of Bengal, C. Little Esq. the official meteorologist in Bengal, for example, argued that 'the only remedy is the investigation of the upper strata of the atmosphere because ground-level observation fails to display the causes and, therefore, fails to indicate the occurrence beforehand' (Esq: 37). Upper air observations finally commenced in 1910s though received much greater impetus during the 1920s, due to its usefulness to aviation services that started with Royal Air Force opening a meteorological office at Quetta and Peshawar aerodromes in 1926 (Sikka 2011).

In an overall sense, research suffered during the early decades of twentieth-century due to severe resource constraints which IMD faced leading to budget cuts and pressure on the hiring of personnel. The agency in a review of its own performance for the period 1875-1925, acknowledges the same and observes that owing to acute financial crisis some of the observatories were reduced in the scale of operation or wherever possible they were abolished altogether. The total budget allocation for IMD in its first year of existence i.e., 1875-76 was rupees one lakh (Sikka 2011) and its annual budget remained less than rupees five lakh for the entire period of 1908-25, except during 1921-22 when it was seven lakh (IMD 1925: 36). Importantly during this period, barring a sanction of three lakhs rupees for engaging two officers to observe 'upper air' at Agra, no significant financial support was accorded to any new research project. So much so that it prompted J. H. Field in 1925, then head of IMD to observe that its officers are mostly engaged in routine organizational and service functions without any time for scientific research. This being in sharp contrast to their British counterparts who had much greater scope to undertake research (Sikka 2011: 402). Reviewing its own performance over first fifty years, IMD 1925 is rather candid and open about its lack of research focus both theoretical as well as applied:

"The more purely scientific work suffered grievously, and all attempts at improving methods of forecasting and storm warning, or gaining more insight into Indian weather were temporarily abandoned. It seemed, in fact, that any scientific enquiries with the object of improving practical methods would be rendered impossible, and that the work of the department would be confined to the mere supervision and publication of meteorological statistics" (IMD 1925: 25).

1.5 **Cyclone Warning Service in 'Disaster Management' Framework**

Post-independence, recognition grew of the insufficient emphasis given to cyclone warning and accordingly a major organizational change was effected. IMD was bifurcated into aviation and marine meteorological services (IMD (n.d. b.), IMD (n.d.a.)). The increasing role of aviation meteorology from 1920s onwards expanded its scope and operation in India. Globally too, it received much attention as well, particularly during the war period. For example, in India, twenty-seven aviation forecasting centres were operating in 1944 (Sikka 2011: 404). Under marine meteorology, separate storm warning centres were established at Mumbai in 1956 and Madras in 1969. This was also the period when cyclone warning benefitted immensely from technological up-gradation, specifically from radar and satellite applications. These technologies primarily developed for their use outside of meteorology but soon enough found much use as weather observational tools. Interestingly, when IMD acquired its first meteorological radar from the USA in 1957, it was deployed at New Delhi airport to provide aviation support, though subsequently it was also used for cyclone detection and monitoring. Further expansion took place based on the recommendation of 'Cyclone Distress Mitigation Committee' constituted in 1969 for Orissa, and Andhra Pradesh and based on its recommendations, Cyclone warning centres were established at Bhubaneswar and Vishakapatnam.

The cyclonic disaster in 1977, popularly known as the 'Diviseema cyclone', Andhra Pradesh created much uproar over inadequacies in the existing cyclone warning services. The central government ordered a comprehensive review of all aspects of cyclone prediction and warning in the country and constituted Cyclone Review Committee (CRC) in 1979. The terms of reference for this committee included a review of various warning facilities, telecommunication support, community preparedness and development of operating procedures *vis-a-vis* other countries (Agrawal 1994). This Committee felt that the existing system of cyclone warning services needs to be improved through a range of measures which include

a) strengthening, up-gradation and introduction of new observational technologies, for example, carrying out aircraft probes b) thrust on modelling exercises to improve the accuracy of forecasts c) robust communication mediums for issuing a warning to remote locations especially during adverse weather conditions, d) centralized coordination from the IMD head office in Delhi and e) dedicated institutional mechanism at various levels, preparation of emergency plans, and action plans for community preparedness etc. Based on this committee's recommendations a cyclone warning directorate was established in the head office of IMD, New Delhi to coordinate and supervise the formation of the cyclone warning network in the country; a practice that continues up to the present times.

As far as improving the services from general public's point of view is concerned, one specific recommendation was that the term 'cyclone' should be replaced by 'toofan', i.e., its Hindi translation to which people could relate better for giving them a better sense of its magnitude. Beyond these specific recommendations, a much larger achievement of the Cyclone Review Committee was to provide a direction for future development that is underpinned by a distinct emphasis to disaster management. It received further impetus during the early 1970s, in the aftermath of large scale losses caused by one of the most severe cyclone, 'Bhola' which struck Bangladesh (Frank and Husain 1971). There was widespread global concern over the efficacy of meteorological warning services and their utility in preventing such disasters. Regional bodies of the World Meteorological Organization such as the Panel on Tropical Cyclones (PTC) were created by 1973 and explored for finding new ways to mitigate cyclone related disasters. In the new approach, the interface between meteorological warning systems and its users was seen to be crucial to improve the performance of services.

Overall, it emphasized significant management challenges for a possible scenario wherein a large number of people's lives are at stake before the cyclone has crossed the coast, and post-landfall, how to ensure efficient and effective rescue, relief and restoration of public services. In this new schema, it is a disaster which if it cannot be averted then must be managed better. In the overall framework envisaged by Cyclone Review Committee, IMD's warning service is to play an anchoring role by guiding various agencies of the state administration such as irrigation, fisheries, police, ports and shipping, civil defence, etc. Their coordinated effort is necessary to prevent cyclones from becoming a deadly disaster and to ensure that the public is protected through the state's intervention. This perspective was supplemented by the construction of a number of public 'cyclone shelters' in India in the late 1970s. The idea of such a designate shelter first experimented in Bangladesh during the 1960s (Mallick and Rahman 2008: 61), which involved the construction of specially designed concrete structures in remote locations that can withstand cyclone's impact. Later these shelters took the form of 'multi-purpose' to ensure their upkeep and proper maintenances. This approach remains popular to date and forms the principal risk mitigation strategy (National Disaster Management Authority 2008). At the same time, it also embodies what Deville, et al 2014 term as a form of *concrete governmentality.*

The new approach for cyclone risk management appealed to meteorologists for it viewed the accomplishment of the overall warning system's goal as a shared responsibility in which they are the lead agency (Kalsi 2003). New initiatives during the 1990s, a decade that was declared by the UN as the international decade for natural disaster reduction, demonstrated the linkages of cyclone warning with disaster mitigation and management which in a sense further consolidated the approach (Obasi 1994). The changing focus consequently brought its own set of tools, in seeking to aid management objectives. For example, maps of vulnerable areas based on the cyclone's probable path; issuing precautionary advisories such as 'watch' and 'post-landfall outlook'; development of standard operating procedures for emergency control rooms etc. became the new avenues to improve warning services. An unintended consequence of this transition was; public were seen more as vulnerable groups needing timely evacuation as part of state's obligation than individuals needing specific input on cyclone's path or the danger level posed to take their own decision. In this framework, the public's interests are represented through agencies of the state and if at all the meteorological organization's service is to be evaluated, it should be from the perspective of those agencies. In short, it transformed the overall system to one in which IMD is a key government agency alongside many others to perform a public service – that of ensuring the reduced loss of life and minimum damage to properties. Paradoxically, in doing so the meteorological agency finds itself catering largely to requirements of other agencies, and resulting in its growing distance from the public.

2 **Weather Service and Science**

In the foregoing discussion, the evolution of cyclone warning service in India points to two interrelated aspects a) the shifting emphasis over the years from catering to the requirements of mariners to that of state agencies and b) development of service without engaging with the general public in terms of their direct assessment or enabling them to express their level of satisfaction in any form. From that point of view, state patronage has proved to be instrumental in defining what kinds of warning services are required and for whom? In this concluding section, the focus shifts to exploring the extent to which this close association with the state has benefited meteorological science in its overall research endeavour?

The creation of a centralized organization such as IMD entailed that the same agency had much influence over the development of the corresponding discipline. IMD had not only control over the vast amount of data which were routinely collected from across the country, but it also had the authority to initiate new observation stations as per its requirement. Data repository coupled with IMD's core mandate of improving weather service placed it in an advantageous position to research as envisaged at the time of inception. Yet in the pre-independence period, the department could barely give attention to research owing to its preoccupation with routine public service mandate and lack of adequate fund. Further during this period, meteorology like other scientific fields of inquiry suffered from a 'metropolitan tradition' in which Indians were trained to perform subordinate tasks such as surveying, data gathering, etc. (Sikka 2011). This character of IMD did not change much even after independence and despite various organizational changes and a discernible drive to promote research. Soon after independence, Atmospheric Research Committee that functioned under the Board of Science and Technology promoted a number of research projects within IMD. Lamenting on the absence of research culture in IMD, D R Sikka (Sikka 2011: 416) a leading Indian meteorologist who also served the organization in various capacities observes "the strong tradition of a bureaucratic system in the IMD remained entrenched for nearly seven decades. Despite some efforts from time to time during 1970-2000, to promote vibrant scientific culture in the IMD, no remarkable achievement could be achieved even in post-independence India." He goes on to add, during this period, IMD worked like a 'science enterprise' inhibiting its progress in scientific terms, whereas other scientific organizations which came up after independence such as Department of Space, Atomic Energy, CSIR labs, etc., succeeded, mainly due to their non-bureaucratic culture.

What indeed compounded the overall problem is that very little meteorological science was carried out outside of IMD. Subjects like atmospheric science or meteorology could not be made part of master's courses or PhD program until the country's independence. To fill this gap, professionals with a background in physics, chemistry, mathematics, statistics etc. were recruited who were then trained in-house to perform service functions. In 1948, Postgraduate courses in meteorology were introduced in India, with the establishment of Department of Meteorology and Oceanography at Andhra University by NK Sur who had retired earlier from IMD. Around the same time, Department of Geo-Physics and Meteorology was also formed at Benares Hindu University (BHU) (Sikka 2011). In 1975 Department of Physical Oceanography and Meteorology was established in Cochin University of Science and Technology and started a master's program in meteorology. Subsequently, two Centres for Atmospheric Sciences (CAS) came up in 1979, one in Indian Institute of Technology (IIT) Delhi and the other in IIT Kharagpur. A similar centre was also set up in 1982 at Indian Institute of Science, Bangalore which later became the Centre for Atmospheric and Oceanic Science. These centres were seen to complement IMD's mandate in terms of fundamental research as well as application-oriented goals. However, the scale of financial support to these centres from IMD over the years has remained modest. For example, during the period 2002-2007, only two Centres received assistance; CAS, IIT Delhi had a grant of approx. nineteen lakh and Jadavpur University got a total of little over ten lakh in three instalments (IMD (n.d. b.)). In comparison, the IMD budget for the financial year 2007-2008 alone was Rs 301 crore with an additional 153 crore for maintenances [2]. Notwithstanding the large disparity between investment in university research and predominantly service-oriented activities of IMD, efforts are underway to promote the former and announcements have been made accordingly for supporting academic institutions to undertake applied research in various areas including cyclone (IMD 2011).

Beginning from the establishment of IMD, meteorology in India was conceived as a public service instrument, a character to which it remained inseparable, despite several attempts from time to time to incorporate within it a culture of scientific research. IMD's in-house journal publication if considered as a pointer to its overall research culture, there is barely any accomplishment here as well. The *Journal of Meteorology and Geophysics* was launched in the year 1950 and since then it has been renamed twice; first as 'Indian Journal of Meteorology, Hydrology and Geophysics' in 1975 and subsequently as 'Mausam' in 1979. This journal continues up to present time with impact factor at lowly score of 0.152 (IMD 2014: 91). Until

[2] This includes Rupees 122 crore that IMD received from the Airport Authority of India for providing aviation meteorological services.

2008, it was not even part of the Science Citation Index-Expanded and is generally seen to have very limited influence (Garg, et al 2008).

In recognition of its own limitation in promoting research within its framework has led IMD to establish 'Institute of Tropical Meteorology' in Pune in 1962 under UNDP Special Fund Project. This institute was made autonomous and re-designated as Indian Institute of Tropical Meteorology in 1971 (IITM 2001). Its aim included conducting studies in all related areas with special emphasis to monsoon meteorology (MOES 2007 a). IITM like its parent entity IMD initially worked under the Ministry of Tourism and Civil Aviation, an arrangement that signifies its orientation and specific service requirements. Reorganization, however, took place in 1985 during which IMD and IITM both were brought under the Ministry of Science and Technology and from 2006 they are working under the Ministry of Earth Science. Employment pattern at IITM over the period 1971-2000 show that there were around a hundred scientific staff in 1971 against sixty administrative/support staff. By 2000, this ratio of scientific staff to administrative/support staff changed to130:30. Most of the 1980s, there were nearly equal number of staff from both categories. The financial support to this institute was barely few lakhs in the initial years, touching a figure of one crore in the early 1980s, and has shown an upward increase since 1990s to reach figures of six crores in 2000 (IITM 2001).

Early work on Numerical Weather Prediction (NWP) in India was launched from IITM itself but under very limited facilities. Sikka (Sikka 2009:16) describes how during the late 1960s, for want of better computer, personnel of the institute would carry punched cards with the program on a special box and travel by morning train from Pune to Bombay every day and return in the evening after collecting computer printouts of the program that had run the night before on Tata Institute of Fundamental Researchs' (TIFR) computing facility. Despite these constraints, consolidation of NWP efforts in subsequent years led to the establishment of National Centre for Medium Range Weather Forecasting (NCMRWF) in 1988 along the lines of European Centre for Medium Range of Weather Forecasting (ECMRWF). Launched amidst several drought years, NCMRWF was conceptualized under a mission mode and its key mandate includes providing weather forecast for three to ten days and develop application especially for the needs of agriculture (Sikka 2009). Despite its stated accomplishments in the face of various challenges, the centre has struggled for most period of its existence for apathetic government policies. For example, notwithstanding its infrastructure, it's hosting of the country's first supercomputer, etc. NCMRWF operated until 2009 on a project mode and as a result, found it hard to retain scientific talents. The central government at the time of NCMRWF inception, had announced to fill two hundred forty-one position in batches but even at the peak level i.e., during 1995-99, only around seventy positions were occupied and by 2009 this figure went further down to twenty-five (Sikka 2009: 88).

Limited importance to research has remained an important concern for meteorology which is recognized by the government too. For example, a committee was appointed in 2006 under the Chairmanship Rodham Narasimha with a task to redefine the mandates of key meteorological bodies and propose an appropriate restructuring of IMD. The committee urged "Government should recognize IMD as a scientific department" (MOES 2007 a: 13) and further recommended that for future, IMD should become the primary agency to provide weather forecasts and all type of weather services. IITM, on the other hand, can focus on climate research and climate modelling in addition to its other ongoing research programs and NCMRWF should be renamed as National Centre for Numerical Modelling of the Atmosphere (NCAM) that need to concentrate on model development which has operational use for IMD’s various services (MOES 2007 a). In a sense, it tried to formulate a clearer division of role and mandate, and a framework for their complementarity.

Conclusions

To conclude, historically meteorological research has failed to find due emphasis or has not been treated at par with that of weather service functions despite their stated conjoined relationship from the beginning. The foundational mandate of IMD included two key objectives; systematic study of climate and weather and its application for providing weather services such as forecasts and storm warning. Interestingly these have undergone subtle changes wherein the present official IMD mandate emphasizes observation, provision of the forecast for weather-sensitive activities such as irrigation, offshore oil exploration, etc. and warning services for severe weather. Though research continues to be one of its key mandates the agency’s preoccupation with weather services is quite unambiguous. The key question is, can there be an improvement in weather services beyond a point without theoretical advancement? For example, in case of a cyclone warning, questions which Henry Piddington raised in the mid-nineteenth century such as causes and explanation for curving or recurving of tropical cyclone or the nature of the interaction between cyclonic storms and its surrounding weather system for its path projection are as much relevant even in the contemporary period (Sarma 1997: 191). During this period, much has changed globally as well in terms of the underlying science, though limitation in our understanding of the cyclonic phenomena is as truer for most other countries. For example, general understanding related to factors determining cyclone's intensity remain poorly understood (Ginis 2002) which in particular has much significance from the perspective of how the public respond to cyclonic forecast. Far from being a coincidence, this present state of affairs is a direct consequence of umbilical relationship meteorological science shares with the state. The association has ensured- a) the weather service dimension remains the predominant goal, b) evolution of services from the perspective of the state and its agencies and c) ordering of various function through rigid bureaucratic norms. Development of science is no doubt valued and as such is always stated to be a key objective but largely from the point of view of its application relevance. Such an overall approach works rather well until the occurrence of a major weather-related disaster; a time when limitations of the services find their way to a public forum in a much-magnified form. Even in such period of scrutiny, it is the state which takes charge of criticism, with a response that ranges from employing new observational technology to organizational restructuring, procedural refinement or at times funding of new research projects.

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