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Research Paper

A Weather in the Empire's Cap: Henry Francis Blanford & the Indian Meteorological Observatories 1875-1890

Oyndrila Sarkar
(Presidency University, Kolkata)

ABSTRACT: *Henry Francis Blanford was a British geologist working on India's coal deposits in 1855. Within a decade, when unprecedented cyclones destroyed the eastern coast of India, Blanford was appointed chief meteorological reporter, and he took an active role in creating a network of meteorological observatories all over the Indian subcontinent. Building on existing scientific principles applied in observatories throughout the British empire, Blanford sought to replicate the same in the 'natural laboratory' of India by collaborating with diverse institutions like the Trigonometrical and the Geological Surveys. This paper examines the nature of networks created by Blanford's meteorological observatories, furthered by his instructional handbooks to understand the formative years of meteorology as a practical science in the nineteenth century.*
KEYWORDS*: Observatories, Cyclones, Meteorology, Weather*

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I. FROM GEOLOGICAL TO METEOROLOGICAL OBSERVATIONS

Henry Francis Blanford, educated at Henry de la Beche's Royal School of Mines was one of the few men appointed to the skeleton staff of the Geological Survey of India together with his brother William Blanford. Both of them arrived in Calcutta in 1855 and left immediately to examine and report upon coal fields in Orissa. This resulted in geological discovery that of the Talchir Boulder Bed where first steps were taken towards the classification of the remarkable series of beds associated with Indian coal bearing rocks (1855-1866). In 1857 he was again dispatched to Madras to examine Cretaceous beds near Trichinopoly and Pondicherry, till he retires from the survey partly because of health reasons and partly because of strained personal relations with Thomas Oldham the Superintendent of the Geological Survey. Transborder travel beyond the northern temperate hemisphere played a key role in the re-education of these geologists such that his older brother William Blanford writes in his memoir of the expeditions to Indian Subcontinent, 'it is to be regretted that all those geologists who disbelieve in the power of running water, as marine action and waves of translation, cannot see a few such marks of the handiwork of rain and rivers as are shown in gorges of the subcontinent'.

Henry Francis Blanford already displayed interest in the geography and climatology of the tropics, demonstrating his expertise in a balanced manner for the scientific and non-scientific crowd. He was already working on books aimed for school and college students, *The Rudiments of Physical Geography for the Use of Indian Schools* (1873), and *An Elementary Geography of India, Burma and Ceylon* (1890), while his academic scholarship included works like 'Palaeontologica Indica' in one of the earliest volumes of the *Memoirs of the Geological Survey of India*, and on 'the former existence of an Indo-oceanic continent' in the *Quarterly Journal of the Geological Society of London*. He continued to research and write while teaching physics at Presidency College Calcutta from 1864 to 1870. In 1864 just as he becomes one of the honorary secretaries of Asiatic Society of Bengal, Calcutta gets hit by one of the historical cyclonic storms of the time, and it is at this time that Blanford takes up the subject of Indian meteorology. In 1867 he becomes the Imperial Metrological Reporter to the Government of Bengal and the Indian metrological department is established with almost no staff and an annual budget of INR 45,000. His aim was to observe meteorological phenomenon, collect scientific facts for studying the physical changes in the atmosphere.

II. IMPERIAL OBSERVATIONAL PRINCIPLES IN INDIA

Balfour Stewart, the Director of the Kew Gardens, split meteorology into two investigative branches- climatic and physical. He writes in *Nature* (1869), "we are so mixed up with the earth and its atmosphere, and the motions of the latter are on so large a scale, that we find the greatest difficulty in grasping their true import." (B. Stuart: Physical Meteorology-I, p. 102). One needed to have, what Stewart called, 'A bird's eye view of the atmosphere, so that there could be a transparent distance between the measurer and what was being measured to gain a larger picture of the whole. This holistic perspective was taken up by Blanford, who realized the potential a synoptic chart had in order to showcase an observer's view, enabling them to further their knowledge of 'the laws that regulate the internal movements of the atmosphere'. (Henry Francis Blanford, Vade Mecum, p. 99). His 1875 Report to the Government of India after his appointment a year earlier can be summarized as following:

1. The establishment of a central meteorological observatory at Calcutta an important part of the work of which would be the verification and comparison with standard instruments of all instruments issued to metrological observatories in India,
2. An increase of the number of observatories in India by the establishment of observatories in certain parts not adequately represented and the redistribution of all existing observatories in other provinces.
3. An arrangement of the observatories into 3 classes. At stations of the first and second classes special observations were to be recorded for the study of the diurnal variation of pressure temperature and other elements of meteorological observations.
4. The provincial systems with that then meteorological reporters were to be retained in Bengal the northwestern provinces the Punjab and Madras but to be subordinate to the imperial reporter a special reporter was to be appointed for Bombay and Rajputana in which areas the work of meteorological observations was way behind and outdated.
5. Front of the storm warning system of the Calcutta and Madras coasts
6. The discussion of the meteorological data of the whole of India in annual volumes by the Reporter General for India and the publication of special investigations of a purely scientific character in a series which would be called 'The Indian metrological Memoirs'.

All these proposals were approved and sanctioned by the Government; the establishment of additional observatories started only in full swing in 1876.

Scholars can see examples of the various kinds of daily weather reports published, and of synoptic charts compiled from observatories and recording stations across the subcontinent, and the promise kept to deliver the Indian Meteorological Department (hereafter IMD) memoirs, this is the first volume**.** Monitoring and cataloguing Indian weather were unsystematic and unorganized. Aided by a short-staffed department and no standardized patterns of observations or instruments to rely on, Blanford managed to direct a coordinated system of recording temperature, pressure, and rainfall in meticulous detail. This created a comprehensive record of meteorological service across these observatory sites, their objectives, and their practical application to weather knowledge, the usage and maintenance of instruments by trained workers, as is evident in the existing meteorological archive.

III. OBSERVATORY SITES & THE COLLECTION OF SCIENTIFIC DATA

As the Imperial Reporter, Henry Francis Blanford had a clear two-fold objective – the systematic study of the climate and weather of India's a whole, and the application of the knowledge acquired, to the issue of storm and flood warnings of weather forecasts. What he needed was the adoption of uniform methods of observation and the recording of these observations in all parts of India in order to get continuous as well as accurate data for the scientific study of meteorology of India (Eliot: CAI, p. xi).

1. To record meteorological observations and provide current met information and forecast met information for optimum operation of weather-dependent activities like agriculture, shipping.
2. To issue storm warnings against heavy storms, heavy rainfall, heavy snow and record variations in solar observations
3. To provide information in the form of synoptic charts, handbooks for use at ports, general information in the form of articles in dailies and gazettes

The paramount objective set before the IMD was to collect scientific data about the meteorology of India based on which, meteorology could be used for societal purpose.

IV. PRACTICAL APPLICATION

The result of getting information of the progress of the monsoon in 1878 was the introduction of the system of daily telegrams of weather from all parts of India and Burma, and the publication of a Daily Weather Report of the whole of India. Blanford was approached to provide much needed help to the Famine Commission as well. The Madras Famine of 1876-1877 caused havoc – modern statistics go up to 8.2 million lives– the Famine Commission made known that very little was known about the rainfall distribution in India and the reasons for less rain or more rain was even less know. Their report also mentioned that there was sufficient evidence to indicate that there was some relationship between the season distribution of rainfall in India and the sunspot periodicity, and there needed to be some consistent documentation of solar observations. Blanford's 'very satisfactory system of meteorological observations' needed to remain efficient – to be strengthened, improved, so as to provide a punctual supply of information to the government/relevant people handling agriculture and famine relief activities. With such observational knowledge, one could form a forecast of the future, so that such disasters could be avoided or be less severe on any account.

Blanford proposed to improve the Daily Weather Reports by increasing the number of stations from which daily telegrams were received. He also required the establishment of additional observatories which were not sufficiently represented in the metrological system. The collection of weather information from the ship logs entering the ports of Calcutta and Bombay would need to be undertaken, added to which would be a series of selected observations taken on-board the vessels in the Indian seas which were being collected by the English Metrological Office and by the Indian Metrological Office (twenty years of data 1856-1875). Blanford also proposed the improvement of the work of solar observation to get accurate measures of the sun's heating power at the earth surface and record its periodic variations. The proposals were sanctioned and became operational during 1880-1882 (p. xii). Discussion and reduction of twenty years of data from the EMO and the IMO resulted in the publication of 1) monthly weather charts of the Bay of Bengal and adjacent sea north of the equator showing pressure, winds and currents, (2) Monthly weather charts of the Arabian Sea and the adjacent portion of the north Indian Ocean showing pressure, winds and currents., (3) Charts of the bay of Bengal and adjacent sea north of the Equator showing specific gravity, temperature and currents of the sea surface. A system of storm signals for warning the Port of Calcutta of cyclones approaching from the Bay of Bengal became defunct, instead issuing warnings to the lower reaches of the Hooghly River became a priority whenever storms appeared – as well as in certain cases to indicate the probable course the storm would take, whether to the east or west of the mouth of the Hooghly. This became functional from 1882. A Daily Weather Report for the Bay of Bengal was also issued, the first of its kind, by the Meteorological Department, which would provide observations, brief summary of the weather in the Bay and adjacent coasts, a weather chart of the Bay showing the chief features of the weather in a form of infographics. In 1888, the time to record daily rainfall, wind direction and air pressure was designated to 8 AM.

The need to obtain metrological data from the Bay of Bengal, the Arabian Sea and Indian Ocean from vessels navigating the seas intensified with the IMD's increasing activities and this information was urgently required so as one could trace the origin and track storms in these seas to be able to throw some light on the causes of the variations in the southwest monsoon rainfall. An important practical addition to the IMD's work was made during 1885 and this was due to very destructive floods in the lower values of the Narmada and Tapti rivers in 1884. No warnings were issued to officers to prevent or even be prepared for this disaster. Blanford proposed an arrangement by which all District and Political Officers in charge of Surat, and Baroda would receive early notice of any unusual and heavy rainfall in the drainage basins of these rivers and he also proposed that one should have the information of conditions which were likely to give rise to severe floods in these rivers so in an attempt to estimate the prospects of the monsoon rainfall based on the results of snowfall reports, the general wind direction, the air pressure distribution in the period was made by Blanford in each of the individual years from 1882-1885. Now the forecast for the Southwest Monsoon of 1885 was the first in the set of annual forecasts which had been issued and published in The Gazette of India.

Other than collecting metrological information from the vessels navigating in the Bay of Bengal the government also sanctioned the collection of information to give an adequate view of the general weather conditions in the Indian seas and a publication of a daily chart which would be based on the observations in both the Bay of Bengal and the Indian see and also at certain Indian and Extra-Indian stations which included Port Blair, Aden, Perim, Bushire, Baghdad and a few others.

The second case of massive losses was in the west coast of India after this became successful in Bengal. Previously warnings were given to a comparatively small number of ports the Burma port was not warned at all, Madras and Bombay coasts were inadequately warned. So during 1886, Blanford to takes up the

question of extending the system of storm warnings to all Indian ports including those in Burma. He introduces a general system of signals for the Burma and the Madras ports and instructions for port officers to use. The apparatus for hoisting the storm signals was not ready until much later and this entire system became effective only in 1888, and even then it was found to be defective and unsatisfactory for the West Coast ports of India.

Finally, there was a need to extend the work to flood warnings. There were a series of floods during the south-west monsoons occurring in the lower Indus valley suspended traffic for days, breached bunds and railways tracks and flooded Quetta, Baluchistan, Lahore and Karachi. This was brought under discussion of issuing flood warnings to officers in the Public Works Department and arrangements were made by which telegraphic information of heavy rainfall and warnings were sent. This enabled to minimize destruction and loss of life and public property due to the heavy floods.

V. GRADATION AND CLASSES OF OBSERVATORIES

A first-class observatory came up in Bangalore in 1891. Smaller observatories were set up at 3 other stations, i.e., Mysore, Hassan and Chitradurg. 14 additional third-class observatories were established in 1892-1893 at Mainpuri and Bahraich in the North-West, Four at Minbu, Yamethin, Fort Stedman and Lashio in Burma. The remaining 8 observatories were located at stations on the North-West Frontier at Gilgit, Kabul, Chaman, Cherat, and in Persia at Jask, Muscat, Teheran and Isfahan. During 1891-1896, observatories were opened at Srinagar, Dras, Skardu, Gulmarg and Sonamarg in Kashmir.

The *Vade Mecum* provided a guide to those who keep a meteorological register, additional laws of pneumatics and thermotics that regulate meteorological phenomena, additional sketch of what is known of Indian Meteorology both for current groundwork and for the future. First class stations (Calcutta and Colaba) had either self-recording instruments (barographs, thermographs as in Kew) register continuously, or at short intervals the pressure, air and evaporation temperatures, wind movements are read off hourly. Metereographs are soon to be supplied (1875 report). Second class stations, two sets of observations are recorded on all days (diurnal variation of chief elements), 10 am and 4 pm, and hourly observations starting and ending with a midnight observation on 4 days of a month. These stations would be supplied with Beckley's or Casella's anemometers to obtain continuous registers of the wind's movement. Third class stations carried out two sets of observations of principal instruments recorded daily.

Some of the instruments which were being used by the observers at the observatories were Barometers and its associated rules of how to pack, carry and position them; Thermometers and its associated rules and principles of graduation, degrees, placement on open corridors and on instrument stands, the different types of thermometers ranging from radiation to solar radiation ones and the restoration of graduation in case of maintenance; Actinometers and their associated principles, types, uses, and reduction; Hygrometers and their associated principles, Rain gauges and their object, principle, construction and rules for sites for building them; Wind vanes and Anemometer along with their associated norms for construction, compass, site, types, readings. Rules for cloud observation and its different types, proportions, movements, velocity; General weather observation rules, different kinds of symbols to be used when and for which purpose; Rules for recording hours of observation; reduction of observations, and the many other associated activities.

There were clear-cut rules for observers at government observatories in India. One had to be absolutely punctual and maintain a frequent record. Cleanliness was of utmost importance. There could be no break of instruments while handling them or changing them for repair and maintenance. Observers would have to be very careful so as not to disturb the position of an instrument. Each instrument had a separate set of instructions on its packing, unpacking, verticality, place, level, maintaining benchmark of the GTS, night readings, and a further manual in case of unforeseen injuries and accidents to the instruments. Separate sections on Telegrams were also found in these rulebooks pertaining to the times of despatch and its content of every date, hour, reading, brief verbal report, and/ weather initials.

VI. PAN-INDIAN METEOROLOGICAL OBSERVATIONS FOR COMPREHENSIVE RECORD

Two different systems of storm signal work – one for the East Coast Ports, and one for the West Coast Ports – at first confused men at sea, leading to errors in readings. The Government of India referred this question to a smaller committee consisting of the Director of the Marine Survey of India, the Bombay Port Officer, and the Meteorological Reporter to the Government of India to revise the system, which would satisfy both land and sea observations simultaneously. The committee recommended with some changes a uniform system proposed by the Imperial reporter for use at all the larger and more important ports came into being. It became mandatory

that the storm signals used at small ports frequented by local vessels, small steamers should be made simple. And this could be done using a selection from the uniform system of storm signals proposed for all the larger ports. Smaller ports should be warned only of storms likely to affect them directly. And this could be done by use of a 'Three Day-Three Night' signals. This system was accepted by the Government of India with all local authorities being consulted and was introduced on 1st of April 1898. All the observatories were also placed under the general Superintendence of the Metrological reporter to the Government of India who was appointed Director General of Indian Observatories. All provincial met systems came under this pan-Indian system.

(1) The number of observatories working under, or in connection with, the Department furnishing information for inclusion in the Daily Weather Reports and Monthly Reviews was increased from 135 on the 1st April 1887 to 230 on the 31st March 1901. The increase is hence 95 in number, or 70 per cent, of the number in 1886-87.

(2) The number of ports warned on the Indian coast was increased from 15 in 1886-87 to 45 in 1900-1, an increase of 200 per cent. The system of storm signals was improved and additional signals introduced to meet defects shown by actual working and experience.

(3) The number of officials and other authorities to whom flood and weather warnings are sent whenever necessary by special urgent (storm signal) messages has increased from *Nil* in 1886-87 to 77 in 1900—1. The number of these warnings issued in the former year was *Nil* and in the latter year 509.

(4) In 1886—87 there were only three Daily Weather Reports issued for the information of Government and the public, viz., the Simla and Bay of Bengal Reports, of which only the latter was illustrated by a chart. There were issued five Daily Weather Reports and Charts of which the following compilation of data can be provided:

	Number of Stations 1886-1887	Number of Stations 1900-1901
India-Daily Weather Report	97	158
Bengal: 1) Bay of Bengal Daily Weather Report 2) Bengal Daily Weather Report	 20 41	 28 66
Bombay Daily Weather Report	NIL	54
Madras Daily Weather Report	NIL	39

Current weather information was placed as rapidly before the more important Governments and public as is possible under the conditions of Indian telegraphic and postal facilities.

(5) The introduction of a uniform system of the registration of rainfall throughout India (more especially the adoption of a common type of rain gauge, common hour of registration and methods of inspection) and of the publication of the data of observation. The number of rain gauge stations has been increased to some extent, chiefly by increase in Rajputana, Central India, Baluchistan, Kashmir, and other districts in which the work was previously very imperfectly performed. An important improvement in connection with this was the introduction of weekly rainfall telegrams to Simla from District Officers for the preparation of weekly rainfall reports and of charts showing the distribution of the rainfall of each season to date for the information of the Government of India.

(6) A large extension of the work of collecting meteorological information relating to the Indian Seas. The data now systematically collected are sufficient to enable daily weather charts to be prepared which show the character of the weather changes in the sea area almost as fully as is done for the land area by the charts in the Daily Weather Reports. Pilot charts for the Indian Seas are, as a result of this, now prepared and issued by the office.

(7) The establishment of a Solar Physics Observatory for the systematic examination and study of the changes in progress in the sun and their correlation with the larger features of Indian meteorology, and the transfer of the Magnetic Observatory at Colaba and the Astronomical Observatory at Madras from Provincial to Imperial control.

(8) A full list of the observatories, with their latitude and longitude, furnishing meteorological observations regularly to the India Meteorological Department, the date of establishment, the elevation of the level of the mercury in the barometer-cistern above the sea, the position of the anemometer, and approximate elevation of the cups of the anemometer above ground.

VII. LOCAL & GLOBAL NETWORKS OF THE INDIAN METEOROLOGICAL DEPARTMENT

If one considers internal collaborations, sources amply demonstrate how the Indian Meteorological Department was always in league with the Great Trigonometrical Survey of India, and the Geological Survey Department. However, outside the ambit of these institutions, two other major institutions of the scientific world, the Royal Society, and the British Association for the Advancement of Science, were at once involved with the IMD'S foundation and its early years of work (1860-1870). We also find mention of the crucial nature of meteorological and weather reports by Hermann von Schlagintweits in the Mission to India & High Asia, where the mission reports contained *Numerical Elements of Indian Meteorology* (1863). What started off as the ten branches of Scientific Service in India, at first included the Surveyor General of India (GTS), Civil Veterinary Department, Botanical Survey of India, Geological Survey of India, Reporter on Economic Products, Department of Agriculture, Archaeology, Forest, Mines, and the Office of the Meteorological Reporter. This later coalesced into a 'Scientific Advisory Committee' (1875) as proposed by Alexander Strange and Norman Lockyer.

VIII. CONCLUSION

The Scientific Advisory Committee emphasized the extension of meteorological knowledge among officials and among all classes in India. Blanford introduced a system of publication of results of researches conducted by the staff of the IMD as 'Memoirs of Indian Meteorological Department'. He coined the terms the IMD uses even today, as the Bay of Bengal Branch of Monsoons, and the Arabian Sea branch of monsoons / introduced tropical meteorology and storm signal warnings. He integrated the provincial met system of India with a subcontinental system under the IMD. He increased the network of surface observatories, set up new observatories in difficult regions like Leh, Kashmir and equipped them with standard instruments. Firmly established snow registration in the Trans-Himalayas, rainfall registration all over India and promoted setting up of observatories in the Native States of India. With regard to creating an archive of scientific knowledge, we also find several publications – administrative reports, Indian Daily Weather Reports, Indian Monthly Weather reports, Annual Summaries, Memoirs promoted the diffusion of met knowledge to a wide class of users in India. Blanford's main agenda was also to prioritize a warning system, which would be able to avert and prevent the repetition of a disaster like the ones India faced. He visualized creating a storehouse of meteorological data, and a somewhat institutionalized centre where scientists could carry out the calculation and the processing of such data. With such ambitions, he pursued knowledge in his many publications of books and pamphlets. In addition to these observational interests, Blanford also sought to popularize astronomy meteorology, expand the rural urban networks. He campaigned for administrative changes as well, where the state would be responsible for the meteorological functions of the provincial observatories. All in all, Blanford opened channels that linked the observatories to a global community of scientists, colonial officers and a reading public. The value of overseas meteorological investigation was recognized by the British government, investment was piecemeal and progress relied on the commitment and enthusiasm of individuals. These efforts connect meteorology with the history of science and empire, and how research undertaken in these observatory sites in the Indian subcontinent sheds light on the operation of transnational networks in the exchange of scientific knowledge.

By the 1890s, these expectations had borne some fruit. The Meteorological Department of India was highly praised for its scientific output; Blanford's textbook was one the most up-to-date summaries of meteorological theory available in English; and no one could fault Blanford or his successors on the scientific standards of their analysis. Cullen and Geros, writes how following Blanford, Eliot published a *Climatological Atlas of India*, which positioned the monsoon within a well-defined geographical region, 'constructing a notion of the climatological solidarity of the British Empire around the Indian Ocean' (Cullen & Geros, 2020, p. 14). From 1904 to the end of British operation of the IMD in 1944, it was realized that atmospheric phenomena could not be considered in geographic isolation, and regionally defined scientific constructions of the monsoon began to expand their territory of inquiry, including a shift into the upper-atmosphere. However, the department was also noted for its practical labours: its cyclone warning service and, more uniquely, the June long-term monsoon forecasts, which gave an estimate of the general character of rainfall for the following four months. These rains determined the quality of the principal Indian harvest, so the forecast of regions where rainfall was expected to be significantly lower than average marked out those that were vulnerable to drought. Meteorological research, it seemed, could control the anarchy of the weather just as the Raj controlled its chaotic and immense possessions. In return, the prospects of meteorological science in India suggested the importance of command in science. The atmosphere, like empire, required discipline on a monumental scale (Anderson, p. 284). I argue that Henry Francis Blanford's contribution extended to defining Indian Meteorology to both the Empire and colonial science. The nature of meteorology networks was furthered by instructional

handbooks to understand the formative years of Indian meteorology as a practical science in the colonies in nineteenth century.

REFERENCES

[1] Administration Report of the Meteorological Reporter to the Government of Bengal for the year 1903-04. [National Archives of India, Revenue and Agriculture (No. PR_000000065214)].

[2] Anderson, Katharine. *Predicting the Weather: Victorians and the Science of Meteorology* (University of Chicago Press, 2005).

[3] Ansari, S. M. R. "Astronomical Archives in India". *Journal of Astronomical Data*, Vol 10, 7, 2004.

[4] Balfour, Stewart, "Meteorological Research". *Nature*, 1876.

[5] Balfour, Stewart, "Physical Meteorology I: It's Present Position", Nature, 1869.

[6] Balfour, Stewart, "Physical Meteorology II: Suggestions, *Nature*, 1869.

[7] Blanford H. F. *A Practical Guide to the Climates and Weather of India, Ceylon, and Burmah and the Storms of Indian Seas based chiefly on the Publications of the Indian Meteorological Department* (Macmillan and Co., London, 1889).

[8] Blanford, H. F. *Indian Meteorologist's Vade-Mecum: Part 1: Instructions to Meteorological Observers in India* (Office of the Superintendent of Government Printing, Calcutta: 1876).

[9] Carson, Sarah, "Anticipating the monsoon: The Necessity and Impossibility of the Seasonal Weather Forecast for South Asia, 1886-1953", *The British Journal for the History of Science* (2001), 1-21.

[10] Cullen, B. and Geros, C.L., "Constructing the monsoon: Colonial Meteorological Cartography, 1844–1944". *History of Meteorology*, 9 (2020).

[11] Eliot, John. *Climatological Atlas of India* (Indian Meteorological Department, 1906)

[12] Eliot, John. *Instructions to Observers of the Indian Meteorological Department* (Office of the Superintendent of Government Printing, Calcutta, 1902).

[13] Eliot, John. *Hand-Book of Cyclonic Storms in the Bay of Bengal for the Use of Sailors*, Vol. 1-Text (Office of the Superintendent of Government Printing, Calcutta, 1900).

[14] Kingsbury, Benjamin. *An Imperial Disaster: The Bengal Cyclone of 1876* (Oxford University Press, 2018).

[15] Leviton, A. E. and Aldrich, M. L., "The impact of travels on scientific knowledge: William Thomas Blanford, Henry Francis Blanford and the Geological Survey of India, 1851-1889". *Proceedings of the California Academy of Sciences*, Vol. 55, S II, No. 9, pp. 117-137. (2004).

[16] Meadows, A. J., *Science and Controversy: A Biography of Sir Norman Lockyer* (Palgrave Macmillan, New York, 2008).

[17] Naylor, Simon, and Simon Schaffer. "Nineteenth-century survey sciences: Enterprises, expeditions and exhibitions." *Notes and Records* 73.2 (2019): 135-147.

[18] Report on the Administration of the Meteorological Department of the Government of India in 1879-1880 (Meteorological Office, 1879).

[19] S. Boileau, A Letter from Captain Boileau, Superintendent of the Magnetic Observatory at Simla, in India, Proceedings of the Royal Irish Academy (1836-1869), Vol. 2 (1840 - 1844), pp. 300-305.

[20] Schaffer, S., 2012. "The Bombay Case: Astronomers, Instrument Makers, and the East India Company." *Journal for the History of Astronomy*, *43*(2), pp.151-180.

[21] Schlagintweit, H. "Numerical Elements of Indian Meteorology." *Philosophical Transactions of the Royal Society of London*, Vol. 153 (1863), pp. 525-542.