Hundredth birth anniversary of
Professors P. C. Mahalanobis, S. K. Banerji
and
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1. Introduction and early careers

The present year marks the hundredth birth anniversary of three celebrated Indian Scientists, namely, Professors P.C. Mahalanobis, S. K. Banerji and K. R. Ramanathan. Meteorologists in India and abroad will remember them with respect and affection on this occasion. During their lifetime they helped us to build an edifice which had small dimensions at the turn of the present century, but is today a major meteorological centre in the tropics.

By a strange coincidence they were all born in the same year (1893), so their centennials fall concurrently in 1993. We may recall that Professor Meghnad Saha was also born in 1893, while Professor Satyendra Nath Bose was born a year later in 1894. Professor C.V. Raman was born a little earlier in 1888. These dates are relevant because the last decade of the nineteenth century saw the arrival of several illustrious scientists in India. The decade between 1920 and 1930, when they reached their youth, was one of remarkable resurgence in Indian science. Let us consider the situation as it prevailed then.

Professor Raman started his work on light scattering at Calcutta in 1920. It won him the Nobel prize in 1930. In the same year Professor Saha communicated his paper on "Ionization of the solar chromosphere" to the British scientific journal "*Philosophical Magazine*". It became a landmark in the theoretical astrophysics. Professor Bose sent his famous letter, and his work on quantum statistics to Albert Einstein in 1921. It laid the foundations of the Bose-Einstein statistics. Professor Mahalanobis joined the Meteorological Observatory at Alipore in 1922. The experience he gained there led him to set up the Indian Statistical Institute at Calcutta in 1930.

There was an air of excitement and great expectations in Indian science.

Viewed in this historical context, Professors Mahalanobis, Banerji and Ramanthan were the poducts of an exceptional period. In the early part of their career both Professors Ramanathan and Banerji were closely associated with Professor C. V. Raman. It was Professor Ramanathan's early work on the scattering of light in liquids, and his observation of a "feeble fluorescence", that ultimately led to the discovery of the Raman effect. He was a talented experimental physicist. On the other hand, Dr. Banerji was a gifted applied mathematician with a brilliant academic record. His theoretical work on acoustics and the diffraction of light was widely acclaimed.

Professor Raman had the vision to encourage his younger colleagues to extend their talent to other areas of research. The beneficiary in this case was meteorology, because Dr. Banerji joined the Indian Meteorological Department in 1922 and Professor Ramanathan followed him shortly thereafter in 1925.

Professor Mahalanobis was a close associate of Professor S. N. Bose. They held each other in high esteem. Many important features of the Mahalanobis distance, or the D^2 statistics, were subsequently extended and enlarged by Professor Bose. Professor Mahalanobis's interest in meteorology was kindled by Sir Gilbert Walker, a remarkable English Scientist who gave up a Professor's position at Cambridge to become the Director General of the Indian Meteorological Department from 1904 to 1926. It was he who introduced Ramanujam, the Indian mathematical prodigy, to Professor G.H. Hardy, an eminent mathematician at Cambridge. Ramanujam and Professor Mahalanobis were contemporaries at Cambridge and, as the Professor later recalled, they enjoyed each other's company by solving mathematical puzzles on weekends.

After completing a tripos in both Mathematics and Physics with a first in Part II, Professor Mahalanobis came back to India in 1915. He was immediately appointed a Professor of Physics at the Presidency College of Calcutta University. It was the custom in those days that the Professor of Physics at the University was also made the Superintendent Meteorologist at Alipore Observatory. It was thus a case of fortuitous circumstances that introduced Professor Mahalanobis to meteorology. Rabindranath Tagore, who had won the Nobel prize for literature in 1913, often stayed with the Mahalanobis family during their tenure at Alipore from 1922 to 1926. They were both devout members of the Brahmo Samaj, a religious movement founded by Raja Rammohan Roy in 1828.

2. Scientific contributions

A full description of the scientific contributions of these three eminent scientists will be beyond the scope of this article. We will confine outselves to their work in meteorology, and we will try to show how their work made them ahead of their times.

2.1. *Professor P. C. Mahalanobis (1893-1972)*

Professor Mahalanobis had a very brief spell as a meteorologist; his obvious forte was statistics. But, he wrote two papers in 1923, which provided early evidence of his statistical insight. They were published as Memoirs of the India Meteorological Department.

Around 1919 W. H. Dines expressed the connection between different meteorological variables of the atmosphere by correlation coefficients. He found a high correlation between the pressure at 9 km (p_9) and (a) the surface pressure (p_o), and (b) the mean temperature of the atmosphere (T_m). This led him to suggest that the dynamics of motion at 9 km controlled events at the earth's surface. Mahalanobis approached the problem differently. Using an equation for hydrostatic balance, he worked out a relation to link the standard deviations of the different meteorological variables, and the correlation coefficients between them, at an altitude Z. By a variational approach he then computed the height (Z) at which the correlation should reach a maximum. He found this to be about 4 km. It later transpired that

the discrepancy between Dines and Mahalanobis arose out of a difference in the interpretation of T_m. Dines considered the mean temperature between 1 and 9 km, while Mahalanobis considered the mean between 0 and 9 km. Notwithstanding this discrepancy Mahalanobis's approach had an advantage. It enabled him to ascertain how the true correlation between two variables (x, y) could be distorted by errors (a, b) in the observed values of x and y. It was a useful study on the errors of upper air observations.

Although Mahalanobis later turned to statistics, especially on D^2, which won him much recognition, he did return, albeit briefly, to study the hydrometeorology of the Mahanadi catchment in Orissa. This was published in an article in *"Sankhya"* around 1940. He found a prediction formula for the level of the Mahanadi at a place named Naraj.

The later phases of Professor Mahalanobis's work were largely devoted to planning and organisation. The growth of the Planning Commission was largely due to his initiative. It is now widely known that Professor Mahalanobis was also responsible for setting up India's first electronic computer, "URAL", at the Indian Statistical Institute around 1960. He was one of the earliest to see the vast potential of electronic computers in India. But for constraints on its memory, the "URAL" could well have been the first computer on which a barotropic model could be used for weather prediction in India.

2.2. *Dr. S. K. Banerji (1893-1966)*

Dr. Banerji's work in meteorology and allied fields was of a much longer duration. His best contributions were on: (a) the impact of mountain ranges on the monsoon circulation, (b) seismology, and (c) several aspects of physical meteorology related to the precipitation mechanisms.

His work on the impact of mountains was largely confined to non-divergent flow. He computed the distortion of streamlines in the vicinity of the mountains along the northeast and the northwestern sectors of the Indian subcontinent. This was later extended to the Western Ghats. He found reasonably good agreement between his computed streamlines and the normal isobaric pattern over India during the monsoon. But, he did not consider the thermal stratification of the fluid as expressed by the first law of thermodynamics. However, if we consider the fact that his work was done over sixty years ago, we must recognise his originality. His demonstration of a centre of cyclonic vorticity over Sind (now in west Pakistan) was particularly impressive. This is the western centre of the monsoon trough, and Dr. Banerji was the first to compute the streamlines generated by the alignment of mountains in this region.

Dr. Banerji's main contributions lay in theoretical seismology where his mathematical insight stood him in good stead. In a classical paper published in the *"Philosophical Magazine"* in 1925, Dr. Banerji computed, on theoretical grounds, the relation between the amplitude of waves as they reached the earth's surface from the earth's interior, and the depth of their focus. This had an important practical application because the long waves (surface waves) are more rapidly attenuated than the primary or secondary waves. The rate of attenuation of different waves thus provides an indication of the depth of the focus of an earth tremor. Subsequent to Dr. Banerji's discovery of this result, it was found that most earthquakes on the earth had a shallow depth of focus of about 70 km; but in a few isolated regions of the world the earthquakes had a deep focus. The Pacific is a region of deep earthquakes.

Dr. Banerji later extended his theory to the study of microseisms. By a careful analysis of microseisms he was able to postulate that they were an outcome of gravity waves impinging on a seabed. These waves were set up by tropical cyclones and similar disturbances at the sea surface. Another viewpoint that was suggested by Longuet Higgins favoured the lateral, instead of the vertical, propagation of wave energy set up by tropical cyclones. It transpired that primary microseisms (periods of 12-14 s) favoured Banerji's hypothesis, while the secondary microseisms (of periods 6-7 s) were more in conformity with the theory of Longuet Higgins.

Towards the end of his career, after his retirement from the Meteorological Department in 1950, Dr. Banerji was invited to join the Jadavpur University as a Professor in the Department of Mathematics. He took up his new assignment with the same zeal and enthusiasm that marked his earlier work. He engaged himself on a study of electrical charges on raindrops and on the electricity of thunderstorms. He was also enthusiastic on investigating the possibility of inducing rain from clouds by ground seeding.

Apart from originality of thought, a characteristic feature of Dr. Banerji's work was his mastery over theory. This he imparted generously to all who were fortunate enough to have known him and who understood his work.

2.3. *Professor K. R. Ramanathan (1893-1985)*

Professor Ramanathan's contributions to science were spread over a much longer period. A remarkable feature of his career was his phenomenal memory, and his grasp over the essentials of a subject, even after he was well past eighty. Indian meteorologists were proud to have him in their midst.

In the early part of his career, Professor Ramanathan and K. P. Ramakrishnan were the first to investigate the structure of the upper atmosphere over India. Professor Ramanathan was the earliest to demonstrate that the height of the tropopause was highest over the tropics, and gradually diminished from 18 km over the equator to 9 km over the poles. This had an important bearing on studies of the stratosphere, especially on the meridional gradient of temperature, in later years.

Professor Ramanathan's best contributions were perhaps on the study of ozone. It was his initiative that led to the development of a network for ozone measurements over India. By utilising the Umkehr effect he and his associates were able to study the vertical profiles of ozone at different locations in India. Corrections for scattering by dust particles and aerosols were determined by him for the Umkehr effect. They revealed deep physical insight into the physics of the ozone layer. At a later stage, the development of a balloon borne ozonsonde in India was another triumph for his initiative.

A characteristic feature of his work was an assiduous analysis of the data that he collected. This enabled him to recognise many patterns of symmetry in global weather for which he is widely remembered. He narrowly missed discovering the now well established quasi-biennial oscillation, a 26-month oscillation of temperatures and winds in the lower stratosphere, although this was implicit in some of his earlier publications. In the context of shorter period equatorial waves acting as a forcing mechanism for the quasi-biennial oscillation, Professor Ramanathan's observations were perceptive.

Professor Ramanathan was also one of the earliest to draw attention to the Southern Oscillation. During a symposium on "Monsoons of the World" in 1958 at New Delhi, Professor Ramanathan repeatedly stressed the importance of the Southern Oscillation, a see-saw pattern of pressure changes between the Pacific and Indian Ocean, for long range seasonal forecasting in India. This was over 35 years ago. It needed a man of his intellect to discern the importance of this oscillation much before others.

After his retirement from the Meteorological Department, Professor Ramanathan joined the Physical Research Laboratory at Ahmedabad. This had been set up by the late Professor Vikram Sarabhai as a Centre of excellence for research on atmospheric physics and allied fields. Professor Ramanathan was the first Director of this Institute. Here again his guidance and enthusiasm led to the very rapid growth of this Institute in the last four decades.

3. Honours and recognition

Academic honours and recognition sat lightly on the shoulders of the three scientists whom we remember today. We will mention a few outstanding achievements.

Professor Mahalanobis was elected to the Royal Society of London in 1945. He was made an Honorary Fellow of the Royal Statistical Society of the United Kingdom in 1954 and of King's College at Cambridge in 1959. He received the Weldon Medal from Oxford University in 1944 and several similar honours from prestigious academic institutions in India and abroad. The Government of India presented him with one of the highest civilian awards, the "*Padma Vibhushan*", in 1968. The United Nations (UN) made him the Chairman of its sub-commission on Sampling from 1954 to 1958. The Indian National Science Academy (INSA) elected him to be its President for the period 1957-1958, and he presided over the Indian science congress in 1950.

Dr. S. K. Banerji, as mentioned earlier, was the first Indian Director General of the Meteorological Department. He won the prestigious Premchand Raychand Scholarship of the Calcutta University in 1915, winning also the Mouat Gold Medal. For his able assistance as the Head of the Indian Meteorological Department during the war he was awarded the O.B.E. in 1943. The Royal Meteorological Society of London made him an Honorary Fellow during its centenary year. He was the first Indian to receive this honour. In addition to being a fellow of several academic institutions abroad, he was also a fellow of the Indian National Science Academy.

Professor Ramanathan was awarded the "*Padma Bhushan*" by the Government of India in 1965 and "*Padma Vibhushan*" in 1975. He was the first Indian to receive the prestigious IMO Prize from the World Meteorological Organization in 1961. Many international awards were conferred on him during his career. He was again the first Indian to be elected the President of the International Union of Geodesy and Geophysics (IUGG) for the period 1954-1957. He was also President of the International Association for Meteorology and Atmospheric Physics (IAMAP) in 1957. The Royal Meteorological Society also made him an Honorary Fellow in 1960. The Indian National Science Academy awarded the "*Aryabhata*" medal to him in 1962. The Indian Academy of Sciences at Bangalore elected him to the Raman Chair in 1980.

It would be unwise to complete this article by further enumerating awards, because the three men whom we honour today were above honours and public acclaim. The best tribute that one can pay them on this occasion would be to say that they enriched the lives of all who knew them by their knowledge and ability. They leave behind indelible footprints on the sands of time.

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