A comparative study of precipitable water in the atmosphere by radio, optical and other methods

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U. N. Maiya
Raman Research Institute
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DECLARATION

I hereby declare that the thesis was composed by me independently and that it has not formed the basis for the award of any Degree, Diploma, Associateehip, Fellowship or other similar title.

U. NARASIMHAMURTHI MAIYA

'CERTIFIED'

Research Supervisor

CERTIFICATE

This is to certify that the thesis submitted is a bonafide record of the research work done by Sri. U.N. Maiya during the period of his study under me and that the thesis has not formed the basis of the award to the candidate of any degree, diploma, associateship or other similar title of any University or Society.

The material presented in this thesis represents the original and independent work of Sri. U.N. Maiya under my supervision and guidance.

(V. RADHAKRISHNAN)

U.N. MAIYA

A COMPARATIVE STUDY OF TEE PRECIPITABLE WATER IN THE ATMOSPHERE BY RADIO, OPTICAL AND OTHER METHODS

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SYNOPSIS

The vertically integrated water vapour content or precipitable water in the atmosphere is a parameter of great importance in studies of the atmosphere and its properties, and in all measurements of extra-terrestrial radiation received at the earth's surface, in which absorption by water vapour plays an important role. This is particularly true of the infrared and microwave regions of the spectrum where water vapour has strong absorption bands.

The amount of precipitable water in the atmosphere was originally computed by integration from radiosonde measurements of absolute humidity in the atmosphere. Techniques have since been developed for its measurement using the abeorption of infrared and microwave regions of the spectrum by water vapour; and infrared spectral hygrometers and microwave radiometers have been developed for the measurement of precipitable water in the atmosphere, both from the ground and from orbitting and geostationary meterological satellites. In all cases, the measurements are verified against radiosonde mea-

surements or by calibration of the instruments in the laboratory.

Although measurements of precipitable water have been made at a number of locations in the world and extensive computations of precipitable water over India have been made from radiosonde data for a large number of stations, no systematic measurements have been made of precipitable water and its variations at low latitudes. The main purpose of the work described in the thesis was therefore the development of experimental techniques for the continuous measurement of precipitable water using optical, radio and other techniques and a study of ita variations in time and with altitude. The original motivation for the study was the selection of a suitable site for a millimetre wave telescope in southern India. The thesis therefore covers studies of precipitable water at two stations at 13^{o}N 77^{o}E and describes instruments designed and constructed by the author for the continuous measurement of precipitable water in the atmosphere. The calibration of the instruments and the evaluation of the data are described, followed by a report

on the diurnal and annual variations of precipitable water at the two stations and a critical assessment of the different techniques used, their source of error and possible accuracy of the measurements.

The thesis is divided into five chapters. Chapter 1 gives a brief account of the importance of atmospheric water vapour in meteorological, hydrological and other scientific investigations and for studies in infrared and short wavelength radioaetronomy. A section on the terminology and unite used for defining atmospheric water vapour and the relationship between the various parametere, is followed by a short description of the different techniques used to measure water vapour and precipitable water in the atmosphere and the purpose of the present study.

Chapter 2 describes in detail the two techniques used for the computation of precipitable water in the atmosphere, one from surface humidity values and the other from radiosonde measurements. The firet method was found to be unsatisfactory except as a qualitative

indication of the amount of precipitable water in the atmosphere. The second remains the most reliable method, not only for computing precipitable water but for the calibration of direct measuring instruments such as the infrared spectral hygrometer and the microwave radiometer. Results of computation of precipitable water over two stations, Bangalore and Nandi Hills from radiosonde measurements are presented, and the inherent sources of error in the method discussed. A section on the computation of precipitable water scale heights concludes the chapter.

Chapter 3 deals with the measurement of precipitable water using infrared absorption techniques and describes in detail the infrared spectral hygrometer designed and constructed by the author at the Raman Research Institute, Bangalore, for precipitable water measurement in the atmosphere. Brief sections on the physical concepts and the nature of water vapour absorption in the infrared regions of the spectrum follow. The instrument uses two wavelengths 0.935μ and 0.881μ, absorption of water vapour in the former being much higher than in the latter. From the ratio of intensities of the solar infrared radiation

at the two wavelengths received at the ground, precipitable water in the entire atmosphere is calculated. Results of observations made at Bangalore during 1980-81 are presented and the accuracy and sources of error and the limitations of the method discussed in detail.

Chapter 4 describes a microwave radiometer designed and constructed by the author for the measurement of precipitable water in the atmosphere by measuring atmospheric radiation at the frequency of 22 GHz. The principle of the radiometer is described and the relationship between the antenna temperature of the microwave radiometer and the absorption ooefficient of water vapour in the microwave region is illustrated using the radiative transfer equation. It is a frequency-switched system, noise from broad-band sources being injected in the IF stage during alternate half periods in the switching sequence and the output continuously monitored. The chapter concludes with a discussion of the sources of error and accuracy of measurement of microwave radiometers.

In Chapter 5 the results of the computations and measurements of precipitable water in the atmosphere over Bangalore and Nandi Hills during the four year period

1977-1981 are discussed and compared with results of observations made at other stations in India and elsewhere. A fairly clear picture of the diurnal, seasonal and interannual variation of precipitable water vapour over Bangalore and its surrounding areas is now available. The chapter concludes with a discussion on the variation of precipitable water with altitude and the evaluation of Nandi Hills as a suitable location for a millimeter wave telescope.

The importance of the work reported in the theeis may be summarised as follows. Two instruments, using water vapour absorption techniques in the infrared and microwave regions of the spectrum, have been designed and constructed by the author for the continuous measurement of precipitable water in the atmosphere. Both instruments were calibrated against radiosonde data and were found to record precipitable water with almost the same accuracy as the radiosonde method. Systematic measurements of precipitable water made over a period of four years from 1977 to 1981 at the two stations with these instruments and the analysis of the data have provided for the first a time a detailed picture of the

precipitable water climatology at the two stations and its variation on both short and long time scales. An evaluation of the data at the two etations shows that Nandi Hills, where the precipitable water amounts are relatively small in the non-monsoon clear months, is suitable for the location of a millimetre wave telescope.