CHAPTER 5
CONCLUSIONS AND FUTURE RECOMMENDATIONS

The present thesis deals with the development of the algorithms to retrieve the temperature and humidity profiles using space-borne microwave observations. The rationale to pursue this study was the improvement in the atmospheric temperature and moisture profiles in not only in clear sky conditions but also in cloudy conditions. The atmospheric temperature and moisture are the most crucial parameters which form the initial conditions or first guess to run the numerical weather prediction models for weather forecasting purpose. The accuracy of the forecast is dependent on the accuracy of the first guess. Therefore, to improve the weather forecasting skills the accuracy of the first guess has to be better. Also atmospheric temperature and moisture govern most of the meteorological phenomena like formation of convective clouds etc. Hence, we have chosen the retrieval of these two atmospheric variables to carry out our research work. Since both of these variables can be retrieved from space-borne infrared observations also but the retrieval can be done in clear sky conditions only, because of the heavy absorption of infrared radiation in cloudy environment. Hence, to retrieve the temperature and moisture profiles in all weather conditions microwave observations provide a good opportunity as these are not affected by the clouds.

In the first chapter of thesis we have provided a background relevant to the
present work, in which the importance of the satellite based observations has been shown. A brief history of weather research is also discussed. Then the role of atmospheric variables in various climatological as well as meteorological phenomena has been described briefly. Next, a brief history of the atmospheric sounding has been described which tells about the evolution of the science of the atmospheric sounding. The next section of the chapter devoted to the basic principles of atmospheric remote sensing. The classification of the remote sensing techniques based on their working principle has also been described. Since the present thesis is concerned with passive microwave remote sensing only, the merits and demerits of the microwave remote sensing over infrared remote sensing has also been discussed. After that the focus shifted to the basic principles of passive remote sensing in microwave regime. Thereafter, details of the important processes involved like radiative transfer, absorption and emission spectra of various atmospheric gases etc., have been provided. In the subsequent section various mathematical techniques like statistical regression analysis, artificial neural network, integrated profiling techniques etc., for retrieving the temperature and humidity profiles from various satellite observations have been described. And finally the applications of profiles of the retrieved atmospheric variables have been mentioned.

The second chapter has been devoted to the detailed description of the radiative transfer theory underlying the present work. In this detailed description each and every component of radiative transfer has been described. The radiative transfer theory tells about the various processes responsible for interaction of the electromagnetic radiation with the earth's atmosphere. It forms the basis for the relationship between the physical properties of an object and the radiation emitted or absorbed by the object. This relationship is expressed by an equation known as radiative transfer equation (RTE). The solution of RTE provides the knowledge about the physical properties of any object being probed. RTE has
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many terms like upwelling and down-welling atmospheric radiation, the contributions from the earth’s surface and the cosmic background etc. These terms have been explained in details. The theory of absorption and emission spectra of oxygen used for temperature profile retrieval and water vapour gases for estimating the humidity profiles have also been given in the appropriate section. Then details of various absorption models for oxygen and water vapour gases available have been presented. Finally, the detailed description of the RTM used in the present thesis has been provided.

The development of the artificial neural network based algorithm to retrieve the atmospheric temperature profiles (Gangwar et al. (2014b)) has been discussed in chapter 3. To prepare a diverse training data set for tuning the ANN a matchup data set has been made by taking the concurrent observations of NCEP model temperature profiles and AMSU-A brightness temperatures for the whole year of 2010. Due to strong latitudinal variations of the atmospheric temperature the training data set have been divided into three geographical regions viz. tropical, mid-latitude and polar regions. Since in microwave region of electromagnetic spectrum the surface emissivity is highly variable over land as compared to over ocean, the dataset is further segregated into two categories based on land and ocean surface. After that the ANNs are established for each sub-sets of the training dataset. To test this algorithm an independent validation dataset consisting of NCEP model profiles of 2012 has been used. To check the performance of the algorithm in various seasons the retrieval has been performed for four different months representing different seasons of 2012. In general for all the months the minimum errors are found in the tropical regions. The lower atmospheric altitudes show the larger errors in comparison with levels corresponding to upper atmospheric pressures. Also the retrieval accuracy is better over ocean as compared to over land surface for each geographical region. In our analysis the same trend has been found for all the months indicating the capability of the
retrieval algorithm to capture the seasonal variability with almost similar accuracies.

Finally, chapter 4 describes the development of a new algorithm to retrieve the relative humidity in terms of layer averaged relative humidity (LARH) of six layers from the earth’s surface (1000 hPa) to tropopause level (100 hPa) for tropical regions. Gohil et al. (2013) describes the LARH retrieval for six layers viz. 1000-850 hPa, 850-700 hPa, 700-550 hPa, 550-400 hPa, 400-250 hPa, and 250-100 hPa using simulated brightness temperatures of SAPHIR. Mathur et al. (2013) performed post-launch retrieval of LARHs from actual SAPHIR observation on-board Megha-Tropiques and validated it with concurrent model as well as in-situ radiosonde observations for the period of July-November 2012. The errors in all the six layers are found to be \( \sim 20\% \) which is well within the mission goal. The further validation of LARH from SAPHIR with three different numerical models for the period of January-June, 2013 has also been carried out by Kumar et al. (2014) in which the same errors have been found in all the LARH layers. Gangwar et al. (2014a) developed the retrieval algorithm for the same LARHs using MHS observations on-board MetOp-A. They have developed the algorithm using simulated brightness temperatures of MHS through Liu (1998) RTM and NCEP model LARHs. After that the algorithm has been tested on the actual MHS observations for the year 2010 and compared with concurrent LARHs observations from NCEP model as well as radiosonde measurements. In validation exercise they have found the less than 20% errors in all the six layers in both the comparisons.

Hence, from this work it can be concluded that the retrieval of the atmospheric temperature and humidity profiles using satellite based microwave observations can be done with reasonable accuracy in all weather conditions. Therefore, the retrieved products can be utilized in numerical weather prediction models for
forecasting as well as now-casting purposes with better efficiency.

5.1 Future Recommendations

To further improve the accuracy in temperature profiles over land surfaces the accurate modelling of the emissivity over land should be properly addressed. Also, efforts are required to distinguish between clear-sky and cloudy-sky brightness temperature using comprehensive radiative transfer models in the cloudy atmospheres. In future the retrieval of the relative humidity at different pressure levels instead of layer averaged relative humidity should be attempted. The humidity values at specific pressure levels can be utilized more efficiently to explain many meteorological phenomena which are difficult to explain through LARHs.


S. Ajil Kottayil, Pradeep Kumar Thapliyal, Munn V. Shukla, Pradip K. Pal, Prakash C. Joshi, and Ranganath R. Navalgund. A new technique for temperature and humidity profile retrieval from infrared-sounder observations using

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Publications related to the Thesis


