Mapana J Sci, 14, 1 (2015), 15-23
ISSN 0975-3303 | doi:10.12723/mjs.32.3

Study of Atmospheric Instabilities through Radioactivity

Charan Kumar K*, Kamsali Nagaraja†, Rajendra Prasad T‡, Narayana Rao T§ and Venkat Ratnam M**

Abstract

Radon and its progeny concentration are measured at 1m height from surface of Earth in the premises of National Atmospheric Research Laboratory, Gadanki to observe the changes in activity concentration of radon particularly during instabilities that are occurring in the atmosphere. The measurements were carried out using AlphaGUARD and Alpha Progeny Meter for the measurement of radon and its progenies, respectively. It has been observed that, the changes in daily and weekly atmospheric radon levels are related to the stability or turbulence of the lower troposphere. The analysis reveals that from sunny windless days indicates growth and dissolution of the inversion layer. The study of radon concentrations during several atmospheric instabilities including period during Nilam cyclone, has shown interesting features, which are correlated with the conditions of stability or turbulence in the atmosphere.

Keywords: Climate change; Satellite data; INSAT; Monsoon; Disaster management

---

* ASSR Lab, Department of Physics, Bangalore University(DoP-BU), Bangalore India; kamsalinagaraj@gmail.com
†ASSR Lab, (DoP-BU), Bangalore 560056
‡National Atmospheric Research Laboratory(NARL), Gadanki 517 112
§ (NARL), Gadanki 517 112
**(NARL), Gadanki 517 112

1. Introduction

The studies on the atmospheric stability in the lower layers of the earth's atmosphere are of great interest for understanding of the processes and also for modeling the distribution of pollutants. The Planetary Boundary Layer (PBL) is a part of the troposphere which is directly influenced by the activities on the earth's surface and responds to surface forces of time scale of an hour or less. Different devises are available like SODAR, LIDAR and several advanced instrumentation, for the study of the behaviour and structure of the PBL. Several analysis models are being developed by means of which it is possible to calculate the parameters essential for Boundary Layer description starting from meteorological station data. The main purpose of this study is to investigate the behaviour of a rare natural tracer in atmosphere i.e. radon and its progeny at the surface of earth and its variations with meteorological parameters, for atmospheric stability, such as ambient temperature, wind speed, relative humidity, precipitation and pressure.

2. Study Area

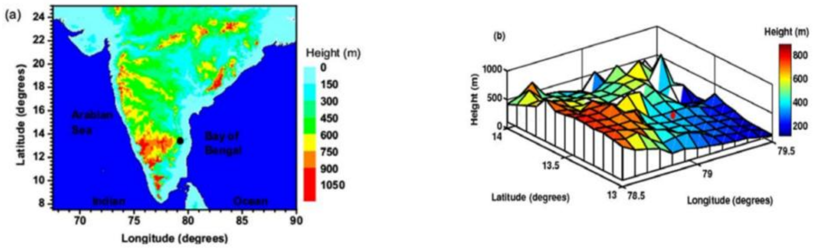

Fig 1: a) Location and b) topography of NARL, Gadanki

Continuous observations were carried out at the National Atmospheric Research Laboratory (NARL), Gadanki (13.5 ^{0}N, 79.2 ^{0}E), a rural tropical warm location in peninsular India, about 2 km away from main residential areas with no major industrial activities. The locative map and topography of NARL is shown Fig. 1 (a & b). Gadanki region experiences both Southwest and Northeast monsoons. Overall wind direction is southerly and southeasterly during April, westerly from May to September and northeasterly during October and November [1].

3. Methodology

Several techniques have been established for measuring the concentration of radon in air and are mainly based on the detection of emissions from radioactive decay products. Due to low concentrations of environmental radon, the precision, accuracy and detection efficiency of the techniques are of important issues. AlphaGUARD PQ-2000PRO is a compact portable measuring system for the continuous monitoring of the radon concentration as well as selected meteorological parameters such as temperature, relative humidity and pressure. This uses the principle of pulse ionization chamber and measures radon by 3D alpha spectroscopy technique with DSP technology. It consists of the cylindrical ionization chamber of active volume 0.56 L and is operated at a potential of +750 V. The center electrode is connected with the signal input of the highly sensitive preamplifier unit and then further fed to digital processing. The instrument is coupled to get synchronized results and then fed to a memory module for data acquisition [2].

The concentration of alpha emitting radon progeny attached aerosols was measured using Alpha Progeny Meter. Air is drawn through a glass microfiber filter paper of pore size 0.5 μm with a constant flow rate of 2 l/m and alpha counted using CAM300AM semiconductor detector with any desired sampling frequency. The air flow rate and sampling period were maintained constant throughout the campaign. At the end of the sampling period, the accumulated alpha counts are fed to the acquisition system.

The measurement on concentrations of radon and its progeny aerosols are first of its kind, and an effort is made to understand the activity concentrations of radon and its progeny during atmospheric instabilities.

4. Results and Discussion

The variation of radon and its progeny concentrations with temperature, relative humidity and wind speed are shown in Fig 2 for a typical day during October 2012. It is evident from the Fig 2 (a), that the concentrations of radon and its progeny show maxima during early morning hours and minima in the afternoon hours. This is due to the fact that as temperature increases, the saturation vapour pressure increases so that the given air parcel can take more water vapour, in turn reduces relative humidity [3].

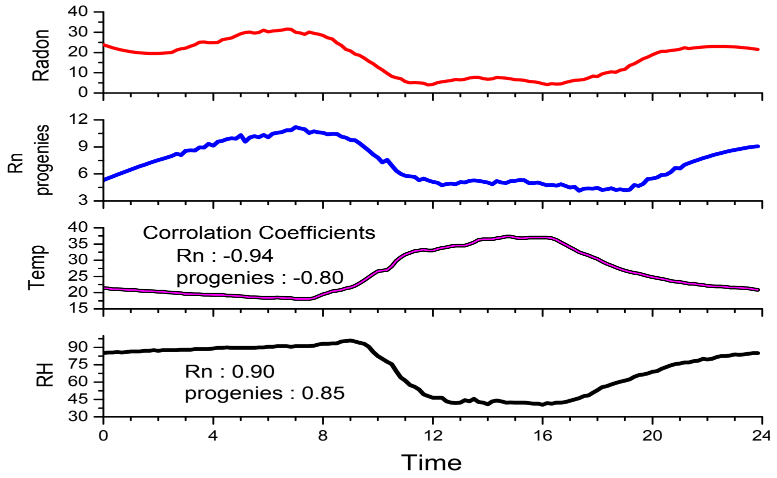

Fig 2a: Diurnal variation of radon and its progeny and ambient temperature and relative humidity for a typical day along with the correlation coefficients of radon and progeny with temperature and relative humidity.

The increase in temperature causes increased vertical mixing and uplift of air mass to the higher altitudes resulting in reduction of concentration of radon at the ground level. During nighttime, the ionization rates close to the ground is enhanced due to the accumulation of radioactive emanations from ground surface under temperature inversions and also due to their lesser dispersion because of low winds [4]. Also observed is the low concentration of radon and its progeny at noon hours when vertical mixing is relatively high compared to the nighttime and early morning hours, where mixing is low. The radioactive emanations from the ground are trapped below temperature inversions near to the surface of earth, and their accumulations cause an increase in ionization-rate in the lower stable atmosphere during the nighttime [5].

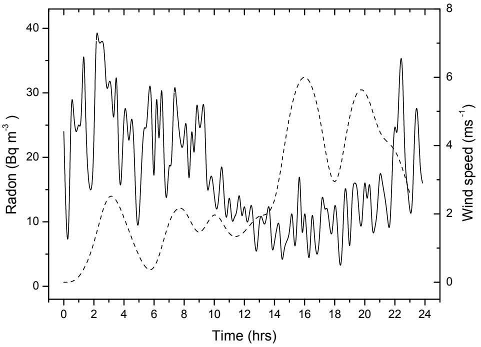

Fig 2b: Variation of radon with wind speed on 29 Oct 2012. Solid line represents variation of radon and dashed line for wind speed, respectively.

From Fig 2b, it is evident that radon concentration has anti-correlation with wind speed. This is due to the fact that the strong wind displaces air masses, which sweep the atmosphere and thereby reduces radon concentration [6]. This phenomenon is observed for all the months of observation and for the sake of brevity only limited data is reported here.

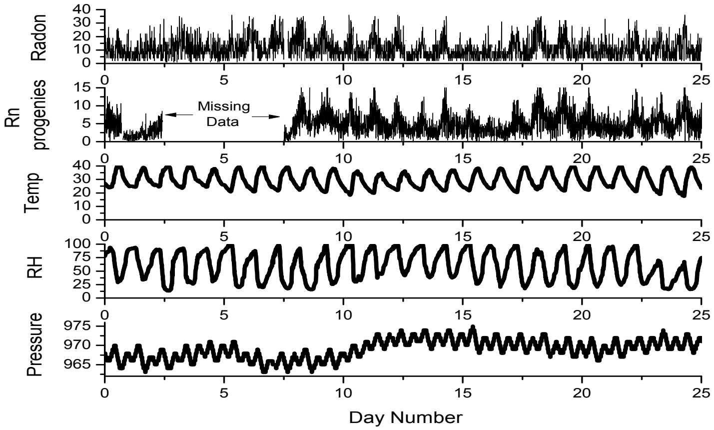

Fig 3: Continuous variation of radon and its progeny and meteorological parameters such as ambient temperature, relative humidity and pressure during March 2012

Fig 3 represents continuous changes in radon, progeny and meteorological parameters for three weeks during March 2012. It is clear that, even a slight variation in temperature and relative humidity causes appreciable change in radon and its progeny concentrations. This shows sensitivity of radon and its progenies with the variation of meteorological parameters. During the study period, several instabilities in the atmospheres were seen through the remarkable changes in the values of temperature, wind speed, relative humidity and precipitation. It is assumed that, during instability, the diurnal trend in temperature and relative humidity was not followed and during this period concentration of radon and its progenies were measured continuously. Two such instabilities including Nilam cyclone are studied and reported.

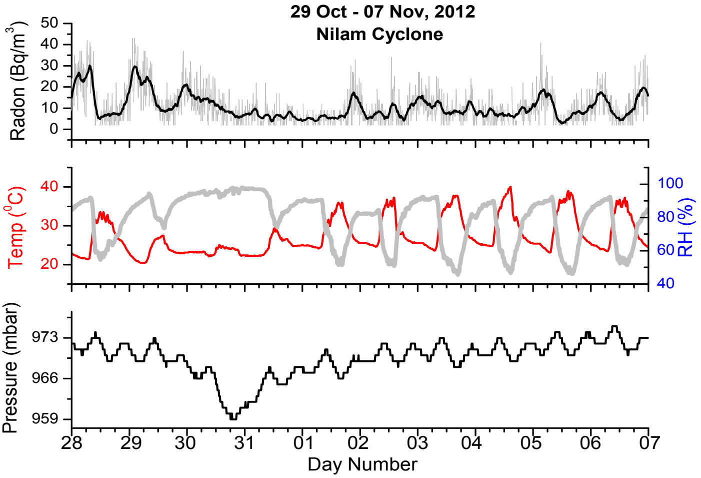

Fig 4a: Variation of radon with temperature, relative humidity and pressure during Nilam cyclone that occurred during 29 October to 02 November, 2012.

From the figure 4b, it is evident that during cyclonic activity, the precipitation and wind speed shown higher values (as highlighted in box) and indicates that the atmosphere is unstable and lead to decrease in concentration of radon concentration significantly. The reduction is mainly due to the convective activity and radon might be diffused both horizontally and vertically from the site of observation. The radon took few days to recover to its normal trend.

The statistical variations such as minimum, maximum, range, average and standard deviation of radon concentration before, during and after the event, i.e. Nilam cyclonic clearly shows that due to instability, there is a significant decrease in activity concentration of radon during cyclonic activity and is mainly due to meteorological variations [7]. Radon can be used as tracer for the possible prediction of these types of events at least few hours in advance. Pearson correlation coefficient of radon with ambient temperature and relative humidity during pre-cyclone, cyclone and post-cyclone period indicates that, during unstable atmosphere coefficient is low and during stable atmosphere it is high, both during before and after the cyclonic activity.

The radon concentration shows 55 – 60% of positive correlation with relative humidity and negative correlation with ambient temperature during pre-cyclone and post-cyclone period, and drops to 13-15%, during the event. The reduction in activity concentration is 75-80% of its original concentration before the event.

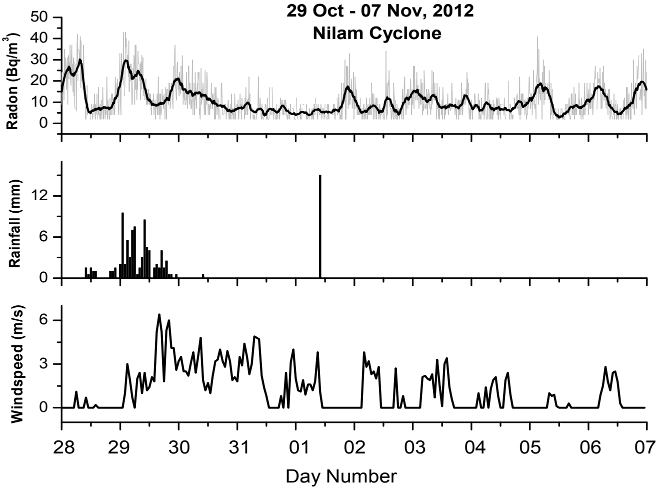

Fig 4b: Variation of radon with rainfall and wind speed during Nilam cyclone that occurred during 29 October to 02 November, 2012.

Similar phenomena was also observed during 05-20, December 2013 and shown in Fig 5. It is clear that a slight change in temperature or humidity trend disturbs the radon concentration. The changes in meteorological parameters reflect on the variation of radon concentration near to the surface of earth and the applicability of usage of radon as tracer is highly significant.

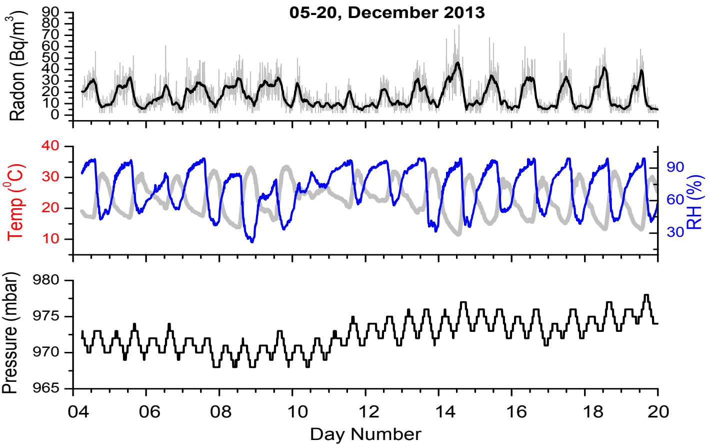

Fig 5: Variation of radon with temperature, relative humidity and pressure during an event during 5-20, December, 2012.

Acknowledgment

Authors are thankful to the Director, National Atmospheric Research Laboratory (NARL) for the constant encouragement and extending all the facility to carry out the experiments at Gadanki and financial support from the Indian Space Research Organization (ISRO), Government of India is acknowledged.

References

[1] Gadhvi H, Jayaraman A, Absorbing aerosols: contribution of biomass burning and implications for radiative forcing, 28, pp. 103-111, 2010.

[2] Nagaraja Kamsali, Sathish L.A., Preliminary results of radon levels at Bangalore University, Bangalore, Solid State Nuclear

Track Detectors and Their Applications, Ed. NL Singh, Narosa Publications, New Delhi, India, pp. 71-77, 2013.

[3] Porstendorfer J., Butterweck G., Reineking A., Diurnal variation of concentration of radon and its short-lived daughters in the atmosphere near the ground. Atmospheric Environment, 25, pp. 709–713, 1991.

[4] Hoppel W.A., Anderson R.V., Willet J.C., 1986, National Academy Press, Washington, DC, USA, 149–165.

[5] Nagaraja K., B.S.N. Prasad, M.S. Madhava, M.S. Chandrashekara, L. Paramesh, J. Sannappa, S.D. Pawar, P. Murugavel, A.K. Kamra, Rad Meas (2003), 36, 413-417.

[6] Podstawczynska, K Kozak., W. Pawlak, J. Mazur, Seasonal and diurnal variation of outdoor radon (^{222}Rn) concentration in urban and rural area with reference to meteorological conditions, Nukleonika, 55(4), pp. 543-547, 2010.

[7] D. Jasaitis, A. Daunaravičienė, A. Girgždys, Variation of activity concentration of radon decay products in the Curonian Spit, Ekologija, 58, pp. 405–412, 2012.