Identification of Sources of Atmospheric Vapour using Isotopic Signature of Air Moisture at Roorkee, Uttarakhand, India

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1. Introduction

As a result of research and applications of isotope hydrology in the country during the last few decades, it has become possible to study continental scale hydrological cycle and trace the movement of water molecules from their origin on the surface of the ocean through rain bearing clouds to precipitation to evapo-transpiration and groundwater recharge and back to ocean and atmosphere. It is also realized that this process of tracking the journey of water molecules using stable isotopes of oxygen and hydrogen can lead to quantitative understanding of the involved physical processes because of the isotopic fractionation being proportional to the extent the process has advanced [1].

The annual hydrological cycle begins with the onset of Southwest (SW) monsoon over Lakshadweep, Minicoy and Kerala [1, 2]. The monsoon current slowly advances over the entire Western Ghats and the southern peninsular region and crosses over to the east coast in the Arabian Sea (AS) branch of the SW monsoon. Over the Bay of Bengal (BOB), the monsoon current turns anti-clockwise and re-enters India across the central and northern parts of the east coast, giving rise to the BOB branch. During winter and spring, winds originating in east and central Asia and moving towards south-west direction pass over the BOB before entering the Southeast (SE) parts of India in the form of Northeast (NE) monsoon, while around the same period, north and Northwest (NW) part of the country receive rains due to Western Disturbances that originate over the Mediterranean and West Asia [1, 2].

The main sources of precipitation/atmospheric vapours in India are Arabian Sea, Bay of Bengal and locally/regionally derived vapours or continental vapours transported over long distance due to Western Disturbances, e.g., vapours from Mediterranean Sea affecting North India during winter. The origin of precipitation/ atmospheric vapour can be understood through tracking cloud movement but the contribution of various sources cannot be differentiated. The isotopes can be used as a potential tool to identify the source of precipitation/ atmospheric vapour as well as to find out contribution of various sources. The heavy stable isotopes of oxygen and hydrogen, (^{18}O and ^{2}H), are particularly useful tracers of climatological and hydrological processes because of the systematic mass-dependant partitioning of the three isotopomers $^{1}H^{1}H^{16}O$, $^{1}H^{2}H^{16}O$ and $^{1}H^{1}H^{18}O$ among solid, liquid and gaseous phases as water passes through the hydrological cycle. Variations in the relative abundances of these isotopomers, measured as $^{18}O/^{16}O$ and $^{2}H/^{1}H$ ratios and expressed conventionally as $\delta^{18}O$ and $\delta^{2}H$ values often provide characteristic labeling of a water molecule for studies ranging from tracing of the origin and distillation history of atmospheric moisture parcels to the analysis of runoff generation. In the present paper, the wind trajectory data (NHAC-NWP, IMD) and water vapour data obtained from Kalpana Satellite data (IMD, New Delhi) with the isotopic data ($\delta^{18}O$) were correlated for establishing similarities in the wind trajectory, water vapour data and corresponding changes in the isotopic signature of air-moisture.

2. Material and Methods

The isotopic composition of water, in general, is extremely sensitive to evaporative loss. Therefore, condensed atmospheric vapour/ground level vapour (GLV) samples for isotopic analyses are collected on daily basis at Roorkee, Uttarakhand, India by condensation method. In this method, the air moisture sample is collected using the conical condensation device. The conical condensation device comprises; (i) Aluminium cone; (ii) metallic stand for holding and vertically aligning the Aluminium cone at desired height; (iii) a lid with knob for covering the Aluminium cone; and (iv) a cylindrical wire-mesh cover for protecting the cone and the sample bottles. The Aluminium cone is aligned using the 8-screws provided for it, such that the tip of the cone is positioned just above the bottle and the droplets of the moisture condensed on the surface of the cone falls straight into the bottle. A 5-ml sampling bottle is placed into the groove at the base of the stand and ensured that the bottle is open (stub and cap removed), completely inserted into the groove and not shaking freely. The ice cubes are put into the cone up to the top, leaving little more space required for fixing the lid. The Aluminium cone (filled with ice cubes and sealed by lid) in the stand is placed such that the axis of the Aluminium cone is vertically aligned with the bottle placed in the groove. The position of the cone is adjusted such that the tip of the Aluminium cone is centred at 0.5 cm above the mouth of the bottle. This will ensure that droplets of moisture condensing outside the Aluminium cone can fall straight into the bottle and the falling droplets can be seen. Depending on prevalent relative humidity, it takes 30 minutes to 60 minutes for collecting 5 to 10 ml of liquid condensate. However, during the rainy season when relative humidity is very high, the sampling bottle is filled even within 30 minutes. After setting up the conical condensation device the date, time, temperature and relative humidity are recorded using thermo-hygrometer [1,3, 4].

The isotope (^{18}O) in GLV was analyzed using GV-Isoprime Dual Inlet Isotope Ratio Mass Spectrometer. The $\delta^{18}O$ of the sample is measured by equilibrating 400 µl of water with CO_2 gas at 40°C for 7 h and the equilibrated gas is introduced into the mass spectrometer. The measured values are converted into the delta (δ) values with respect to Vienna Standard Mean Ocean Water (VSMOW) using a triple point

calibration equation [5]. The precision of measurement for δ ^{18}O is ± 0.1‰.

The wind trajectory data was procured from NHAC-NWP, IMD-Delhi and satellite data from Satellite Meteorology Department, IMD, New Delhi.

3. Results and Discussion

The wind trajectory data can be used for interpreting the isotopic data of the GLV. Due to the Westerlies wind source (Figure 1. a, c and f), the isotopic data of GLV starts depleting from δ ^{18} O= -8.39‰ (Figure 1.a) to δ ^{18} O= -12.20‰ (Figure 1.c) and it further depletes to a maximum of δ ^{18} O= -14.71‰ (Figure 1.f) from June to September. Similarly, the same trend is observed in the winds coming from the Arabian Sea, where the isotopic values of δ ^{18}O depletes from -24.67‰ (Figure 1.b) to -27.79 ‰ (Figure 1.e). This is due to the *Seasonal effect*.

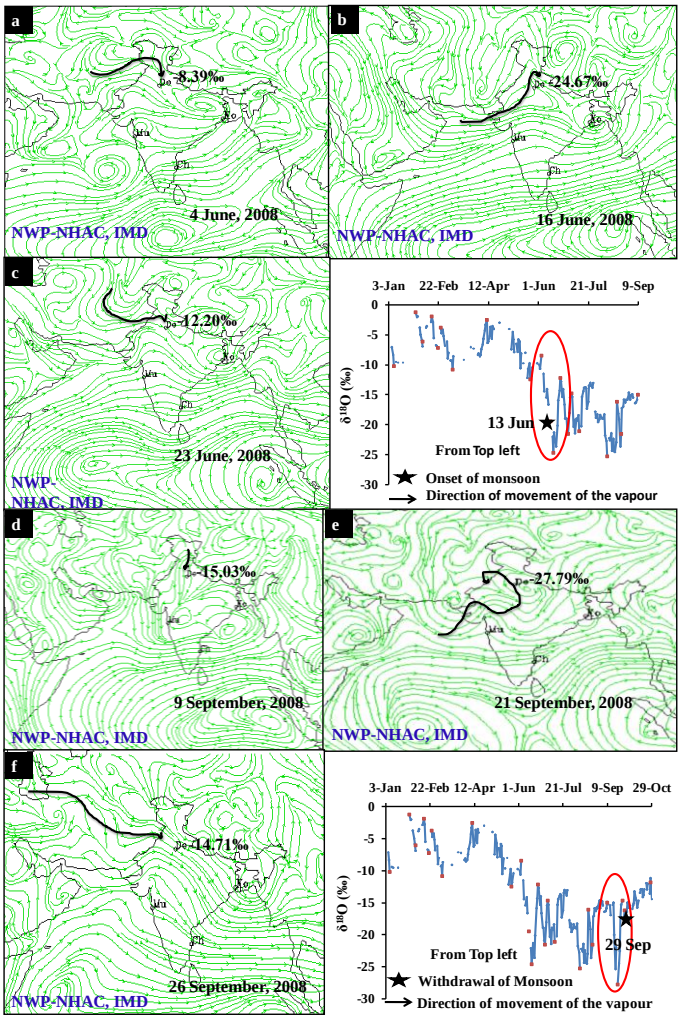

Figure 1. Use of Wind Trajectory Data for interpreting the isotopic data of GLV.

The isotope data was correlated with the wind trajectory and water vapour data (Figure 2). The atmospheric vapour/air moisture from the local/regional source is enriched (δ ^{18}O= -11.18‰; Figure 2a.) as compared to atmospheric vapour/air moisture originating from Arabian Sea & Bay of Bengal (δ ^{18}O= -18.94‰; Figure 2b.). This is due to the *Continental effect*.

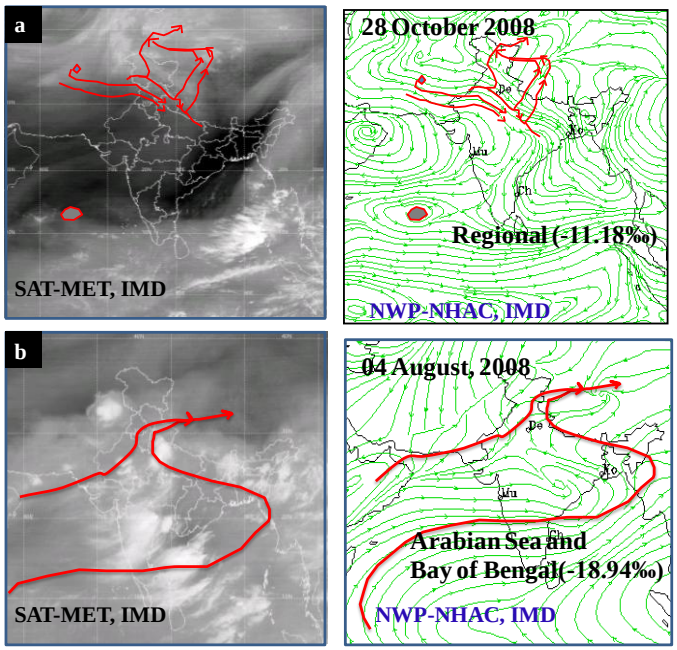

Figure 2. Correlation of isotopic data with water vapour data and wind trajectory

Therefore, it can be inferred from the δ^{18}O values of the air moisture that it varies with time (months and seasons) which indicates the activeness of different sources of atmospheric vapours such as -15‰ corresponding to the Western Disturbances, -20‰ Bay of Bengal and Arabian Sea, while -11‰ corresponding to local/regional vapours. Therefore, on the basis of isotopic signatures of air moisture, it can be concluded that Roorkee (Uttarakhand, India) receives the rainfall during the monsoon from Arabian Sea and Bay of Bengal while winter season rains are influenced by the atmospheric vapours originating in Mediterranean Sea. During summer, the precipitation occurs due to water vapours originate locally or at regional scale.

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