GEOSPATIAL CORRELATION OF ISOTOPES IN AIR MOISTURE ALONG THE SOUTHWEST MONSOON TRANSECT IN THE INDIAN SUB-CONTINENT

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Abstract: The isotopic data of atmospheric air moisture collected from Kakinada (Andhra Pradesh), Sagar (Madhya Pradesh), Kanpur (Uttar Pradesh), Roorkee (Uttarakhand), Jammu (Jammu & Kashmir) and Manali (Himachal Pradesh) measured in Isotope Laboratory of NIH, Roorkee and has been analysed using Matlab to find out the local/regional component of atmospheric moisture. The isotopic analysis confirms the continental and altitude effects which were earlier deciphered by the precipitation. Further, the isotopic data analysis validates the impact of local moisture on rainfall and help in resolving the moisture sources in different seasons. This analysis further concludes that the isotopic composition of air moisture can be applied for finding the onset of monsoon.

Keywords: *Air moisture, isotopes, southwest monsoon, geospatial correlation, Indian sub-continent.*

INTRODUCTION

Atmospheric moisture is an important component in the water cycle and major flux of moisture on the Indian subcontinent comes through southwest monsoon that arrives through Arabian Sea and Bay of Bengal branches (Gupta and Deshpande, 2005). The process of tracking the journey of water molecules using stable isotopes of oxygen and hydrogen can lead to quantitative understanding of the associated physical processes because of the isotopic fractionation being proportional to the extent the process has advanced.

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Monsoon is a large scale wind circulation phenomenon that brings large amount of moisture on the Indian sub-continent. Earlier some studies (Ajayamohan and Goswami, 2003; Gadgil and Sajani, 1998; Shukla, 1987) are carried out using conventional meteorological parameters on monsoon dynamics except timing of onset and withdrawal of monsoon due to the complexity between mixing of sub-regional moisture with continental scale moisture arising directly from Arabian Sea and/or Bay of Bengal and/or Indian Ocean.

In India, monsoon winds travels more than 2000 km from east coast to Northwest Himalayas and the movement of monsoon front on the isotope composition of precipitation was investigated by the Datta *et al.* (1991), Bhattacharya *et al.* (2003) and Peng *et al.* (2005). These studies although characterized isotopes in precipitation but, did not provide any details on isotopes in air moisture. Since, precipitation is an event based phenomenon and that too mainly during monsoon; the results of these works could not be used for modelling and prediction.

Observation of stable isotope variation of atmospheric water vapour, which is not same in all regions, has an important significance to indicate the moisture origins and its transport. Using the isotopic signatures of water molecules, it is possible to track the movement of air moisture and hence the southwest monsoon transect. This is due to fact that with the onward movement of the air moisture heavy isotopes get systematically depleted (Krishan *et al.*, 2012a) and the recycling of moisture due to condensation and subsequent evaporation cause a difference in relative enrichment in deuterium and oxygen isotopic composition. A few case studies on this philosophy were examined in coastal China (Xue-Fa *et al.*, 2010; Liu *et al.*, 2007).

In India, the studies on isotopic composition of air moisture were carried out at National Institute of Hydrology, Roorkee: (i) to identify the air moisture sources (Krishan *et al.*, 2012b); to study the climatological conditions (Krishan *et al.*, 2012c); to find the correlations between isotopic composition of air moisture at Roorkee with Hyderabad (Rao *et al.*, 2012), Sagar (Krishan *et al.*, 2012d), Jammu (Krishan *et al.*, 2012e) and Manali (Krishan *et al.*, 2013).

Department of Science and Technology, Government of India, initiated a National Programme on Isotope Fingerprinting of Waters in India (IWIN) in 2007 to collect groundwater, surface water and atmospheric waters to get the first level nationwide data on isotopic signatures of water resources of India. Under this, a network of stations have been established in the southwest monsoon transect by National Institute of Hydrology (NIH), Roorkee for collection of atmospheric moisture samples at Kakinada (2010) in coastal region (Andhra Pradesh), Sagar (2008) in Central India (Madhya Pradesh), Kanpur (2011) in Indo-Gangetic plains (Uttar Pradesh), Roorkee (2008) in foot hills of Shiwalik (Uttarakhand), Jammu (2010) in Sub-Himalayan region (Jammu & Kashmir) and Manali (2011) in Himalayan region (Himachal Pradesh) and the correlation is termed as southwest monsoon transect.

In the present study, an effort has been made for the first time to examine change in isotopic composition of atmospheric moisture at the stations located from coastal to Himalayas.

STUDY AREA

The samples were collected at Kakinada, Sagar, Kanpur, Roorkee, Jammu and Manali and the detail of the meteorological parameters of these stations is given in Table and Fig. 1.

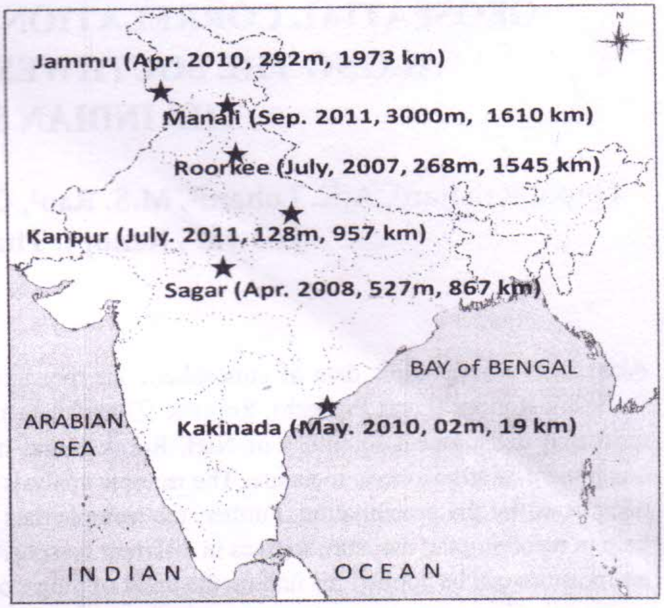

Fig. 1: Stations established by NIH, Roorkee for collection of air moisture

METHODOLOGY

Sample collection

The condensed air moisture samples for isotopic analyses were collected on daily basis at all the stations from 9.30 am to 10.30 am by condensation method (Krishan *et al.*, 2011). In this method, the air moisture sample is collected using the conical condensation device. After setting up the conical condensation device the date, time, temperature and relative humidity are recorded using thermo-hygrometer (Krishan *et al.*, 2011).

Table 1: Meteorological Parameters of All the Sample Collecting Stations

Sr. No.	Station Name	Altitude (m)	Coordinates		Monthly Average Temperature (°C)		Normal rainfall (mm)	Average relative humidity (%)
			Latitude (N)	Longitude (E)	Min.	Max		
1	Kakinada	02	16°59′	82°15′	18.7-24.9	29.5-37.2	1113.0	91
2	Sagar	527	23°50′	78°50′	11.6-24.5	24.5-40.7	1234.8	52
3	Kanpur	128	26°28′	80°24′	8.5-28.5	23.0-41.3	850.9	66
4	Roorkee	268	29°52′	77°53′	6.1-24.9	20.4-39.2	1156.4	78
5	Jammu	292	32°42′	74°51′	7.8-26.9	18.6-39.8	1193.0	58
6	Manali	3000	32°19′	77°10′	-1.7-15.3	10.6-27.2	1363.8	67

The samples are collected at Kakinada (2010-12), Sagar (2008-12), Kanpur (2011-12), Roorkee (2008-12), Jammu (2010-12) and Manali (2011-12). The samples at Manali could not be collected during the period December to April due to heavy snowfall.

Data concerning daily meteorological variables, including surface air temperature (minimum temperature, maximum temperature and mean temperature) and relative humidity was also recorded at all the stations.

Sample Analysis

Stable isotopes (2H or D) in water were analysed using GV-Isoprime Dual Inlet Isotope Ratio Mass Spectrometer. For δD analysis, 400 μλ of the water sample is equilibrated with H2 along with Pt catalyst at 40°C for 3 hours and then the equilibrated gas is introduced into the mass spectrometer. The measured values are reported as delta (δ) values (Coplan, 1996). The precision of measurement for δD was within ± 1‰.

Data Analysis

Before carrying out the statistical analysis processing of isotopic values of air moisture obtained for various stations has been carried out. The period of collected samples of air moisture varies from 2 to 5 years and there is a variation of data collection dates in each year. Therefore, a programme is developed in Matlab to compute average values of the isotopic composition (δD) on different dates from the observed data. Further, the isotopic data was statistically analysed by computing the cumulative isotopic values (δD) of all the stations using Matlab software.

RESULTS AND DISCUSSION

The cumulative isotopic composition (δD) of air moisture of all the stations (Manali, Sagar, Kakinada, Kanpur, Jammu and Roorkee) is shown in Fig. 2. It is observed that the slope of all the stations changes with time except Kakinada station where it remains constant whole year due to the continuous air moisture supply received from the Bay of Bengal. On the basis of change in slope, the equations were developed for all the stations (Table 2), which are different in case of all the stations due to the difference in air moisture sources. The most depleted values for cumulative δD were observed at Roorkee which is followed by Kanpur, Jammu and Sagar which may be deciphered due to the Continental effect.

In Manali, the depletion is found only in the monsoon season due to the air moisture (Krishan *et al.*, 2013). However, no depletion was found in the pre (May-June) and post monsoon (October-December) seasons.

No change in slopes is observed in Kakinada (whole year) and pre and post monsoon months in Manali due to recycling of air moisture received from the SW monsoon, clearly indicating Continental and altitude effect as air moisture in other seasons is mostly received due to the sublimation of snow on the basis of data and change in slope, the dates where the slope is changing can be recorded which is helpful in finding the onset and withdrawal dates of the monsoon for all the stations. The dates of air moisture originating from local/regional sources can be easily differentiated from the air moisture received through the SW monsoon.

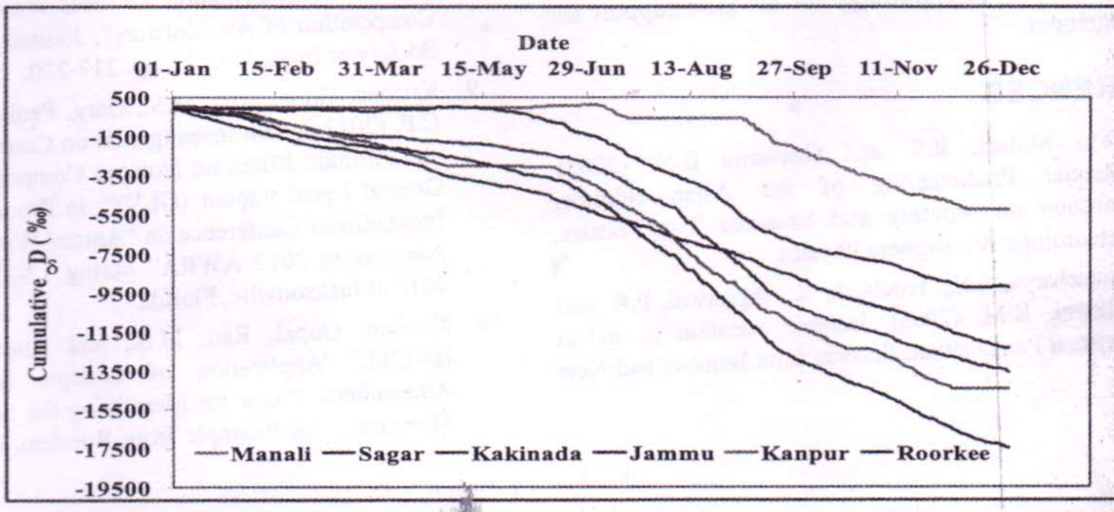

Fig. 2: Cumulative isotopic composition (δD) of air moisture

Table 2: Sources of air moisture at all the sample collecting stations

Sources	Manali	Sagar	Kakinada	Jammu	Kanpur	Roorkee
Local	Y=-0.77x	Y=-3.41x	Y=-33.78x	Y=-13.79x	Y=-18.33x	Y=-22.26x
SW Monsoon	Y=-43x+7685	Y=-54x+7596	Y=-34x+3378	Y=-65x+7487	Y=-71x+8838	Y=-88x+11445
Local/Regional	Y=-5x-3267	Y=-42x+4380	Y=-34x+3378	Y=-38x+64.2	Y=-58x+4830	Y=-50x+1240

Table 3: Dates for change in slopes at all the sample collecting stations

Sources	Manali	Sagar	Jammu	Kanpur	Roorkee
Local	May 1 to Jul 2	Jan 1 to May 31	Jan 1 to May 31	Jan 1 to Jun 15	Jan 1 to Jun 20
Monsoon	Jul 3 to Oct 18	Jun 1 to Sep 20	Jun 01 to Sep 24	Jun 16 to Oct 05	Jun 21 to Sep 21
Local/Regional	Oct 19 to Dec 31	Sep 09 to Dec 31	Sep 25 to Dec 31	Oct 06 to Dec 31	Sep 22 to Dec 31

As per IMD, New Delhi the normal dates for onset of monsoon in Kanpur, Roorkee and Jammu are observed between 25th June to 1st week of July but as per the isotopic data the dates observed ranged from 26th May to 3rd July indicating that the air moisture arrives earlier than the actual precipitation, which is helpful in predicting the onset of monsoon.

CONCLUSION

The isotopic analysis confirms the continental and altitude effects which were earlier deciphered by the precipitation.

Further, the isotopic data analysis validates the impact of local moisture on rainfall and help in resolving the moisture sources in different seasons. This analysis further concludes that the isotopic composition of air moisture can be applied for finding the onset of monsoon.

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