Stable isotopic studies on monsoon vapour/clouds and precipitation over Kerala

A THESIS

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by

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UDAIPUR, INDIA

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CERTIFICATE

I certify that the thesis entitled "Stable isotopic studies on monsoon vapour/clouds and precipitation over Kerala" by Mrs Lekshmy P R was prepared under my guidance. She has completed the following requirements as per Ph.D. regulations of the University

(a) Course work as per the university rules.

(b) Residential requirements of the university.

(c) Presented her work in the departmental committee.

(d) Published/accepted minimum of one research paper in referred research journals,

I am satisfied with the analysis of data, interpretation of results and conclusions drawn. I recommend the submission of the thesis.

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DECLARATION

I Lekshmy P R, d/o Mr. P. V. Ravisankar, resident of A-5, PRL residences, Navrangpura, Ahmedabad - 380009, hereby declare that the research work incorporated in the present thesis entitled "Stable isotopic studies on monsoon vapour/clouds and precipitation over Kerala" is my own work and is original. This work (in part or in full) has not been submitted to any university or institute for the award of a Degree or a Diploma. I have properly acknowledged the material collected from secondary sources wherever required. I solely own the responsibility for the originality of the entire content.

Date:

Lekshmy P R

(Author)

Dedicating to

Amma, Achan and Hari

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Abstract

Stable isotopes of water provide a tool for studying the hydrological cycle and reconstructing past climate from proxies such as tree rings, speleothems, ice cores etc. It is important to understand the responses of the stable isotopic composition of rain and water vapour to various climate conditions for accurate paleoclimate reconstruction. In India, due to lack of sufficient observations, such studies were limited. The hydrological processes determining the isotopic composition of rain and water vapour and their importance in paleomonsoon reconstruction are studied here.

High resolution (spatial and temporal) rain and water vapour isotopic observations were done from the Kerala, south western peninsular India. The new results obtained from this work are as under: though the rainfall showed a large spatial heterogeneity in the study area, its isotopic composition remained coherent during the Indian summer monsoon period. The amount of rain had a very weak role in determining the isotopic composition of rain. Stronger ^{18}O and D depletion of rain is associated with large scale organised convection occurring in the south eastern Arabian Sea, near the Kerala coast. The intense moisture recycling occurring in the large scale convective area is responsible for the higher ^{18}O and D depletion of rain. Water vapour and rain are in isotopic equilibrium during Indian summer monsoon season and deviate more from equilibrium mainly during such large scale organised convective events. The fraction of stratiform rain from large scale convective area shows a significant negative correlation with the

$\delta^{18}O$ of vapour and rain; this signifies the role of stratiform clouds in moisture recycling during such events.

Varying seasonal rainfall amounts in peninsular India and Sri Lanka lead to a large spatial variation in the slopes of the rainfall amount -$\delta^{18}O$ relations. The stronger ^{18}O depletion of north east monsoon rainfall is likely caused by increased cyclonic activity over the Bay of Bengal, in addition to ^{18}O depletion of its surface waters by river discharge. This leads to significant negative correlations between monthly rainfall and its $\delta^{18}O$ chiefly in regions where the north east monsoon contributes more than, or at least as much rain as the Indian summer monsoon. Interannual variations in the amount effect due to varying interannual contributions of Indian summer monsoon and north east monsoon rainfall is also noted. Thus, a careful choice of sites for ^{18}O based monsoon proxies can be made so as to minimise noise in the paleomonsoon signal that could arise at sites with inverse amount effects. Using proxies capable of providing annual resolution (e.g., fast growing trees) past annual monsoon rainfall can be reconstructed at sites where the ratio of Indian summer monsoon season to north east monsoon rain continues to remain less than or comparable to unity, using the local amount effect.

Key words: Indian Summer monsoon, Oxygen and Hydrogen isotopes, large scale organised convection, amount effect.

Abbreviations

α	Isotopic fractionation factor between product and source
$\delta^{18}O$	Oxygen isotopic composition of water relative to VSMOW standard
δD	Deuterium isotopic composition of water relative to VSMOW standard
ϵ	Isotopic enrichment factor i.e, $(\alpha - 1) \times 10^3$
‰	per mil (parts per thousand)
AS	Arabian Sea
BoB	Bay of Bengal
CRU	Climate Research Unit
EKM	Ernakulam
ENSO	El Nino Southern Oscillation
GDAS	Global Data Assimilation System
GDP	Gross domestic product
GISP	Greenland Ice Sheet Precipitation
GMWL	Global Meteoric Water Line
GNIP	Global Network of Isotopes in Precipitation
GPCP	Global Precipitation Climatology Project
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory
IAEA	International Atomic Energy Agency
IDK	Idukki
IRMS	Isotope Ratio Mass Spectrometer
ISM	Indian Summer Monsoon

IST	Indian Standard Time
ITCZ	Inter Tropical Convergence Zone
JJAS	June, July, August, September
KKD	Kozhikode
LLJ	Low Level Jet
LMWL	Local Meteoric Water Line
MCZ	Maximum Cloud Zone
MERRA	Modern Era Retrospective-Analysis for Research and Application
NARM	Narmada water standard
NBR	Nilambur
NOAA	National Oceanic and Atmospheric Administration
NCEP	National Centers for Environmental Prediction
NEM	North East Monsoon
OLR	Outgoing Longwave Radiation
OND	October, November, December
PKD	Palakkadu
PND	Ponmudi
PRL	Physical Research Laboratory
QBO	Quasi Biennial Oscillation
SL	Subcloud Layer
SLAP	Southern Light Antarctic Precipitation
SST	Sea Surface Temperature
TCR	Thrissur
TRMM	Tropical Rainfall Measuring Mission
TVM	Thiruvananthapuram
VSMOW	Vienna Standard Mean Ocean Water (IAEA water standard)
WICO	Interlaboratory comparison exercise for $\delta^2 H$ and $\delta^{18} O$ analysis of water samples
WYD	Wayanad

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List of Publications

Papers in Refereed Journals

1. R Ramesh, SR Managave, **PR Lekshmy**, AH Laskar, MG Yadava, RA Jani (2012) Comment on "Tracing the sources of water using stable isotopes: first results along the Mangalore-Udupi region, south-west coast of India", *Rapid Communications in Mass Spectrometry* 26 (7), 874-875, doi: 10.1002/rcm.6174.

2. M Midhun, **PR Lekshmy** and R Ramesh (2013), Hydrogen and Oxygen Isotopic Compositions of Water Vapour over Bay of Bengal during Monsoon, *Geophysical Research Letters* 40, 6324-6328, doi:10.1002/2013GL058181.

3. **PR Lekshmy**, M. Midhun, R. Ramesh, and R. A. Jani (2014), ^{18}O depletion in monsoon rain relates to large scale organized convection rather than the amount of rainfall, *Nature Scientific Reports*, 1-5, doi:10.1038/srep05661.

4. **PR Lekshmy**, M. Midhun and R. Ramesh (2015), Spatial variation of amount effect over peninsular India and Sri Lanka: role of seasonality, *Geophysical Research Letters* 42, doi:10.1002/2015GL064517.

5. **PR Lekshmy**, M. Midhun and R. Ramesh (2015), Influence of stratiform clouds on δD and $\delta^{18}O$ of monsoon water vapour and rain in a tropical hill station ,*Journal of Atmospheric Chemistry* (under review).

Abstract presented in conferences

1. **P.R.Lekshmy**, M.Midhun, R.Ramesh, and R.A.Jani (2013) Is the Isotopic Composition of Rainfall of the South west coast of India Independent of Local Rainfall Amount? 12th ISMAS Triennial International Conference on Mass Spectrometry, March 4-8, Dona Paula, Goa..

2. M.Midhun, **P.R.Lekshmy**, R.Ramesh, and R.A.Jani (2013) Stable isotopic composition of atmospheric vapour over the Bay of Bengal and its relation with ocean surface conditions, 12th ISMAS Triennial International Conference on Mass Spectrometry, March 4-8, Dona Paula, Goa.

3. Band S, AH Laskar, **PR Lekshmy**, M Midhun, MG Yadava and R Ramesh (2014) Holocene monsoon variability derived from speleothems, Mini Symposium on Reconciliation of Marine and Terrestrial Records of Summer Monsoon Variability during the Holocene, 80^{th} INSA Anniversary General Meeting, December 19-21, Goa.

4. **Lekshmy, PR**, M.Midhun and R.Ramesh (2015),Rain- vapour isotopic interaction over the south-west coast of India, European Geophysical Union General Assembly, April 12-17,2015, Vienna, Austria.

5. Midhun M, **PR Lekshmy** and R.Ramesh (2015),Short-term Variability of Indian Summer Monsoon Rainfall $\delta^{18}O$, European Geophysical Union General Assembly, April 12-17,2015, Vienna, Austria.