# An Overview of LandProxiesofPaleomonsoon

**Abstract**

The monsoon circulation is at its best in this region of the world, with unusual characteristics such as its burst or abrupt change from the dry to the wet season and irrational patterns of rainfall. Historical monsoon records can be used to better understand monsoon dynamics, and pollen assemblage could also refer to land-use activities. The Indian subcontinent has a unique monsoon system that differs from other systems in terms of its focal points, air masses, and precipitation mechanism. This system disrupts and reverses the typical global atmospheric circulation, making it one of the world's most densely populated areas. Information about the most recent paleomonsoon was gathered via isotope studies, tree rings, and other natural archives like speleothem. Tropical teak trees from peninsular India may be able to recreate the sub-seasonal monsoon, according to oxygen isotope studies. Similar to how oxygen isotopes from Indian speleotherms have recently provided proxy evidence for rainfall. A speleothem with good coherence can be seen from a distance.

**Keywords:** Land Proxies, Monsoon, Speleothem, Tree-rings, India

## 1. Introduction

Palaeomonsoon term is derived from two words Palae Ancient, Monsoon Season. The word "monsoon" is derived from the Arabic "mausim" or the Malayan "monsim," both of which imply "season." A circulation that alternates between summer and winter every six months is referred to as a "monsoon". The word was first used by Arab navigators to describe winds that blow for six months from the northeast and for another six months from the southwest over the Arabian Sea between Arab and India. The monsoon is a symbol of the direction of the wind changing from one season to another. While a cold, dry wind that originates on land flows towards the sea during the winter, a warm, moist breeze from the ocean blows towards land during the summer. The wind direction changes 180 degrees during the monsoon circulation. However, if this seasonal winds reversal requirement is properly enforced, only a tiny portion of the world's landmasses have monsoon wind systems. It should be noted that the term "monsoon" was initially used to designate what is now known as monsoon Asia. The monsoon circulation is unquestionably at its best in this region of the world. Other continents, like the United States of America, Northern Australia, and West Africa, only show signs of pseudo-monsoon or monsoon tendencies.

1. The difference in temperature between land and sea was once thought to be the cause of

the monsoon wind phenomena and its distinctive reversing circulation. Also blamed for it was the seasonal movement of tropical and subtropical wind belts. However, there are several unusual characteristics of the monsoon circulation, such as its burst or abrupt change from the dry to the wet season and the irrational patterns of rainfall that are related to it, which cannot be entirely explained by the aforementioned factors alone. Long-term historical monsoon records can be used to better understand monsoon dynamics, particularly the interaction between the ocean and the atmosphere. Using various proxies, such historical monsoon records have already been reconstructed from both terrestrial and oceanic archives. Pollen assemblage could also refer to land-use activities. Land use could further be influenced by climate change, as has been the case for the agricultural pattern in some regions ( Demske et al., 2009; Yang et al., 2012).Precipitation over the Indian sub-continent received from different moisture sources (Roy et al., 2014) shows great diversity due to the seasonal shifting of the ITCZ. There may be biases in the monsoon records from these archives since the terrestrial and marine archives, as well as the proxy carriers included therein, are regulated by different sets of physical, chemical, and biological processes. An overall picture of monsoon changes in the Indian subcontinent and neighbouring maritime regions can be obtained by comparing historical monsoon records from both the terrestrial and marine realms. Based on historical monsoon data compiled from archives on both land (India) and sea (mostly the Indian Ocean).Paleomonsoon study based on different proxies by many researcher on different part of the word (Ali et al., 2019; Dubey et al., 2019; Zorzi et al., 2019; Ghos et al., 2018; Quamar, M. F., 2019; Clement et al., 2021; Breitenbach et al., 2012)

## 2. TheIndianMonsoon System

In comparison to the rest of Asia, the Indian subcontinent's monsoon system is very different. The Indian monsoon system differs greatly from other monsoon systems in terms of its focal points, associated air masses, and mechanism for precipitation. Even while other parts of the world experience pseudo-monsoons or monsoonal tendencies, monsoonal circulation in its truest sense is only seen in the area surrounding the Indian Ocean. The typical global atmospheric circulation appears to be seriously disrupted and reversed in this situation by the monsoon. One of the areas of the world with the densest population is the Indian subcontinent. One of the world's most densely populated areas is the Indian subcontinent. For most residents of this region, agriculture is their primary source of income and subsistence. Approximately 65% of the total land under cultivation in the Indian subcontinent, which accounts for over half of the total output of food grains, is solely dependent on rainfall for irrigation (Gadgil et al., 1999). The monsoon in this area has two distinct phases: the southwest monsoon (from June to September, also known as the Summer Monsoon), which brings the majority of precipitation over India, and the northeast monsoon (from November to February, also known as the Winter Monsoon), which brings heavy rains over the equatorial Indian Ocean and the region farther south of the equator. Gadgil et al. (1999) found that changes in monsoon precipitation had an impact on both the hydrological balance of the region and the production of food grains. (Kudrass et al., 2001; Ivanochko et al., 2005) The tropical monsoon has been proposed as a major modulator of the climate of the northern hemisphere. Additionally, a significant element at the end of an ice age globally is the tropical monsoon. According to current theories (Duan et al., 2023), conspicuous weak monsoon intervals indicate the end of an ice age. In order to improve the worldwide circulation models used to forecast future monsoon changes, it is crucial to comprehend the forces that control the monsoon. The Asian monsoon was first characterized as a massive sea breeze brought on by the temperature disparity between the land and the ocean (Niranjan et al, 2014). Although the land-ocean thermal differential may be the cause of monsoon commencement, it is not strong enough to support the persistent "sea breeze" that brings precipitation over several months, as evidenced by the cooling of the Asian continent after the initial precipitation (Simpson, 1921). Blanford (1884) first proposed an inverse association between snow cover over the Himalayas during the previous winter and spring seasons and summer monsoon precipitation, which was later supported by Walker (1910) and Vernekar et al. (1995). According to Flohn (1968), the atmospheric circulation that causes the monsoon is sustained by the western Tibetan Plateau, which serves as a source of sensible heat, and the orographically released latent heat over the southeast of Tibet. High mountains in the north are crucial for the monsoon's initiation and continuation, according to modelling studies (Hahn & Manabe, 1975). The impact of the Asian region's global and regional orography on rainfall during the Indian summer monsoon was further supported by modelling studies. The orography to the west of 80 degrees east has a greater influence on summer precipitation than that to the east of 80 degrees east. Without African orography, the amount of precipitation during the summer monsoon season rises by 28%, whereas without global orography, the amount of precipitation falls by 25%. Shankar (2007) made the suggestion that the monsoon is a manifestation of the north-south migration of the inter-tropical convergence zone, and Gadgil (2003) later corroborated this.

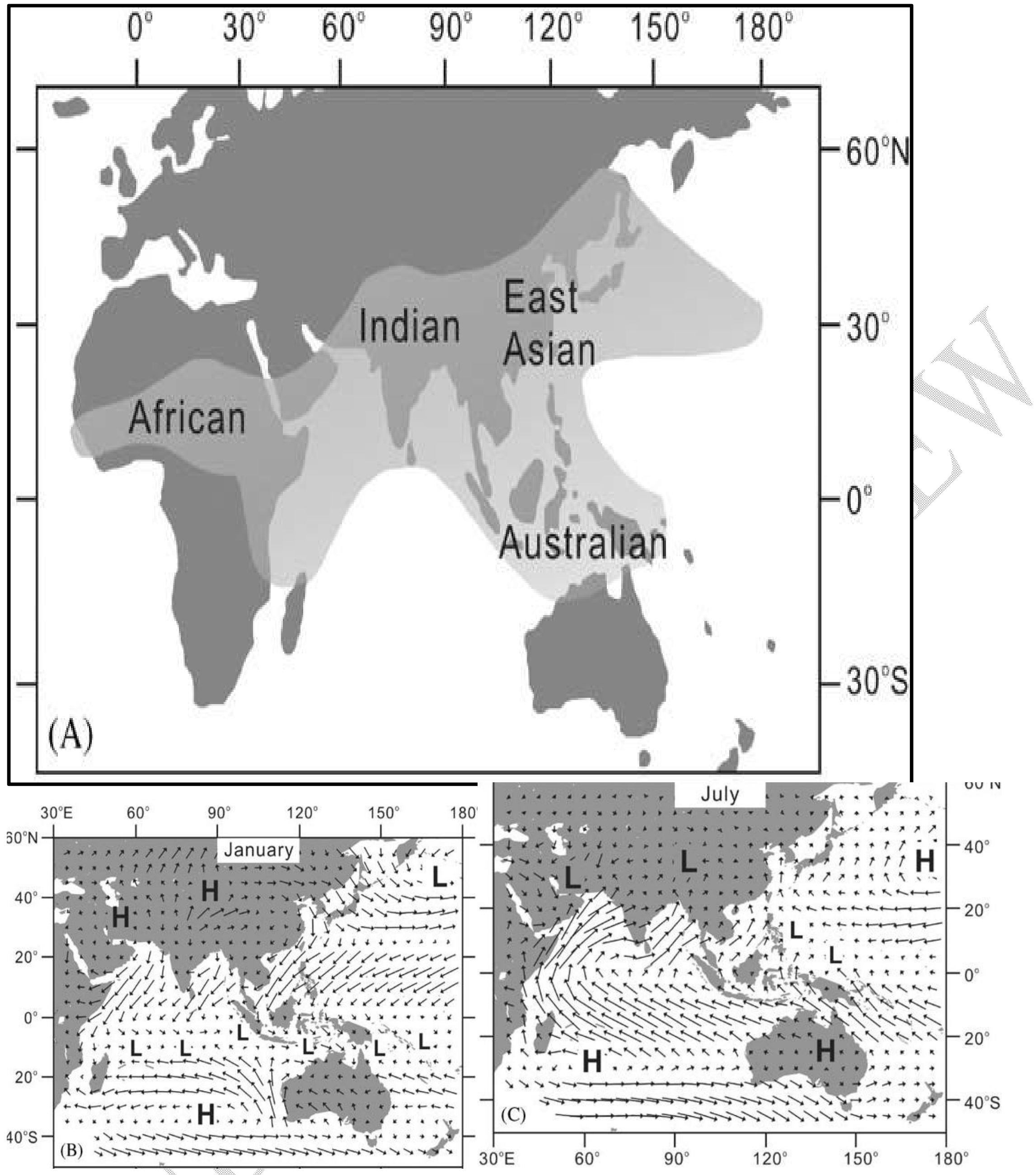

Fig.1.ModernAsianmonsoonsystem:(A)distributionofmodernmonsoonalregionsinAsia,AfricaandAustralia;(B)pressureandsurfacewindpatterninwinterand(C)insummer.

## 3. Methodology

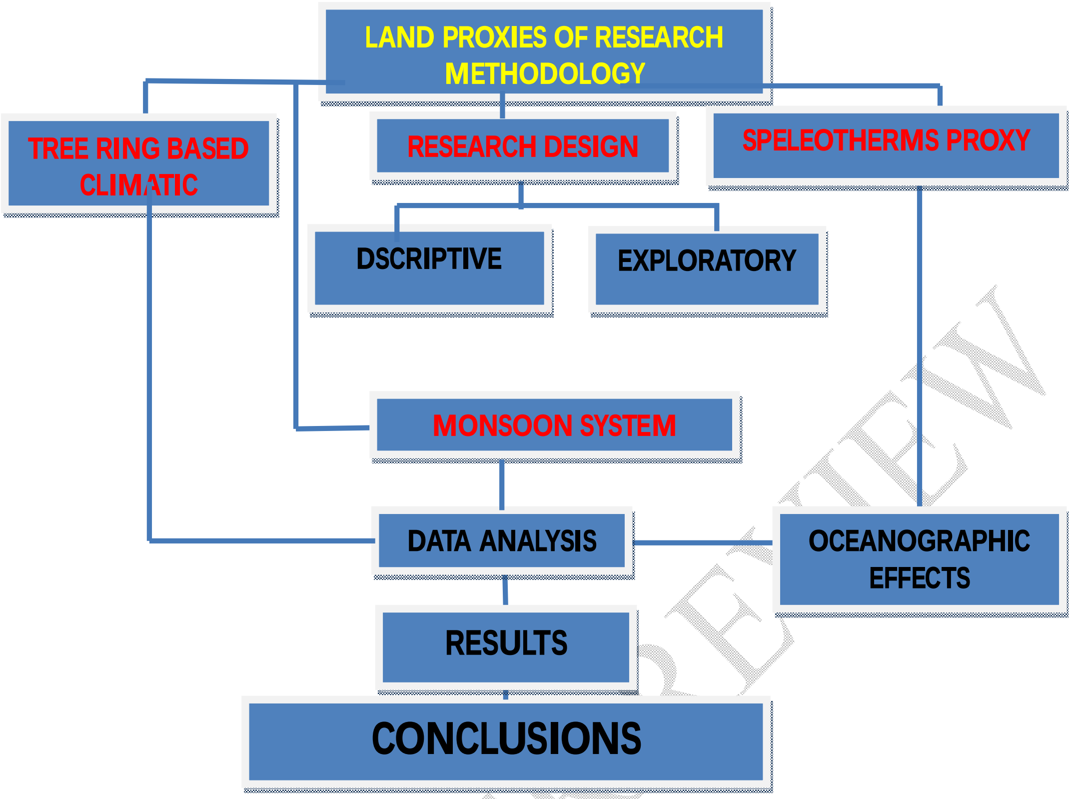

Fig.2. Flow-chart of adapted methodology

## 4. LandProxiesofPaleomonsoon

Recent paleomonsoon information was collected from isotope investigations, tree rings, and other natural archives like speleothem. According to oxygen isotope research, tropical teak trees from peninsular India have the potential to reconstruct the sub-seasonal monsoon. Similar to how Indian speleotherm oxygen isotopes have provided proxy rainfall data for recent years. From a distance, a speleothem, good coherence can be seen.

### 4.1 Tree-Ring-BasedClimaticRecords

Since the first rain gauge station was constructed at Chennai in AD 1813, the Indian Meteorological Department (IMD) has been recording instrumental rainfall data. A respectable network of 312 rain gauge stations had been constructed by 1871. Utilizing climate proxies like tree rings are required to examine the fluctuations in rainfall before 1871. The ability of high altitude as well as tropical trees to reconstruct past climate has been shown by dendroclimatological investigations conducted at the Birbal Sahni Institute of Palaeobotany (BSIP), Lucknow, Indian Institute of Tropical Meteorology (IITM), Pune, and Physical Research Laboratory (PRL), Ahmedabad. Dendroclimatic studies throughout the Indian subcontinent have shown several facets of global climate change. Dendroclimatic temperature reconstruction in the Himalayas is characterized by the absence of a pronounced temperature increase during the early

20th century, a global warming trend seen in the majority of locations in the Northern Hemisphere (Mann et al. 1999; Crowley and Lowery 2000; Esper et al. 2002). Additionally, the temperature in the Himalayan region, particularly in Tibet and central Asia, has been declining since the late 20th century. The lack of evidence for the Little Ice Age (LIA), a fact it shares with the record recorded at Tibet and other central Asian places, is another striking difference between the western Himalayan temperature record and the Northern Hemisphere record. These indicators may indicate that there were regional and temporal variations in the previous climate. However, observations of hydrogen's isotopic abundances unequivocally support LIA (Ramesh 2000). Additionally, a major Himalayan glacier contained evidence of the LIA, according to Nijampurkar et al. Therefore, it seems that the detrending method used to create ring-width indices partially removes the climatic signal.

Cook et al. (2003) reported the existence of the Little Ice Age and the warming trend of the 20th century based on their findings in Nepal more recently. Singh et al. (2006) provided evidence of the Little Ice Age's existence in the western Himalayas. Despite the fact that mid-altitude tree-ring chronologies do not reveal any long-term trends, some high-altitude and periglacial tree-ring chronologies seem to provide proof of global warming. According to Tiwari et al. (2017), the recent rise in tree growth may be a sign that the area is warming up. Only a few tropical trees have accurate growth rings and are long-lived; therefore, the dendroclimatological potential of trees in central and southern India has not been adequately utilized. A few chronologies have been successfully constructed for teak (Tectona grandis) and toona (Cedrela Toona), two species with significant potential for reconstructing historical climate (Borgaonkar et al, 2010). Teak ring-width variations can be utilized to reconstruct historical monsoon rainfall, according to recent studies (Borgaonkar et al. 2010,). Bhattacharyya & Shah (2009) demonstrated that the mean vessel area of the early wood in southern Indian teak is connected with the previous year's northeast (N.E.) monsoon rainfall and, based on this relationship, reconstructed past N.E. monsoon rainfall. Managave et al. (2017) have shown that sub-annual monsoon rainfall can be reconstructed using the high-precision 18O composition of teak trees. Using isotope and ring-width research, further chronologies for peninsular India must be created in the future. To comprehend and document the geographic heterogeneity of rainfall, future work may focus on comparing the tree-ring 18O record with that of speleothems.

### 4.2 Tree-ringδ18OasaHydrologicProxy

An important recent development is the hydroclimatic reconstructions from the rare and long-lived Fujian Cypress (Fokienia hodginsii) growing in Vietnam (Cook, et al. 2010). These data, based on measurements of ring width, showed that the area has previously endured decadal-scale droughts, which are unmatched in the instrumental period. It's interesting that these severe droughts occurred at times when there was societal instability (Cook et al. 2010). Along with this development, other recent research suggested that oxygen isotope ratios of tree-ring cellulose can aid in bettering our comprehension of monsoon activity (Xu et al. 2013). In this succinct note, we highlight a few benefits of employing tree-ring 18O as opposed to the more conventional ring width and wood density in dendroclimatology. It is generally recognized that endogenous disturbance pulses, such as competition with nearby trees, also influence tree-ring width and wood density in addition to climate. To minimize such perturbations, climatically sensitive trees are mostly examined at the species' ecological boundaries, such as close to the frontiers of deserts or cold forests. Utilizing oxygen isotope ratios can get around this spatial restriction because ecophysiological activities have little impact on the isotopic ratio of the wood. According to several studies (e.g. Robertson et al. 2002), the relative humidity and the source water's 18O content, which are both closely tied to monsoon activity in South and Southeast Asia, are the two climatic elements that theoretically govern tree-ring 18O. Tree-ring 18O is clearly more strongly linked with precipitation, relative humidity, temperature, and the Palmer Drought Severity Index (PDSI) than ring width or wood density, according to our preliminary analysis of samples from the Himalayas and Laos (Xu et al. 2013). PDSI is a drought indicator that is based on a model of water balance. The PDSI's positive and negative values correspond to dry and wet circumstances, respectively. Example from the four-year span between 1871 and 1874 in a sequence of four Douglas-fir tree rings from southwestern New Mexico. Darker latewood (L.W.) and lighter earlywood (E.W.) make up each annual growth ring. False rings with density changes are present in both 1871 and 1872, which are most likely the effect of seasonal drought during the pre-monsoon season.

### 4.3 SpeleothemsProxiesofPaleomonsoon

Theterm ─speleothem‖means ─cavedecoration‖ and in a broader senseto the–content ofa cave‖ (old-Greek: ζπηλαιον[spelaion]means ─cave‖; υεμα[tema]– means ─content‖;Latin: spelaeum – –cave‖; thema – –content‖).Speleothems refer to minerals precipitated in cave environments. Among the differentvarietiesofspeleothemsfoundincaves,stalagmites(growingonthecavefloor)andflowstones(sheet-likeprecipitatesoncavewallsandfloors)arecommonlyusedinpaleoenvironmental research. Both types often occur and were extensively studied relative toother varieties. Moreover, stalagmites show less complex growth behaviour than most otherspeleothems, as they typically originate from a point drip source. Nevertheless, stalactites andsoda straws (both growing on the cave ceiling) have relevance regarding specific questions.

Studies of the last few decades have shown that speleothems can reliably record information on temperature and precipitation patterns of past climates. This information is transferred to a speleothem by infiltrating water, chemical and isotopic composition, and solid particles and colloids. Cave monitoring is increasingly used to get insight into the ruling factors determining speleothem growth and composition at a given cave site. The climate information is transferred to a speleothem in multiple ways, such as by infiltrating water, chemical and isotopic composition, and solid particles and colloids. Additionally, there is a temperature relationship between the cave interior and the atmosphere outside the cave, which corresponds to the mean annual air temperature outside in caves that are not deep enough. Speleothems are a multi-proxy climate archive. In thisway,theyprovidevariousanduniquepossibilitiestoindirectlyuncoverpastclimateconditionsFairchildetal.,2006).Incontrasttooceandrillcoresandicecores, they represent a continental archive found in all continents of the globe, although speleothemgrowth is reduced in cooler and drier climates – i.e. with increasing latitude and altitude.Further,speleothemsforminanenvironmentlargelyprotectedfrommajordestructingagents.Althoughsecondary alteration(e.g.diagenesisor dissolution)may existinsomecases, it is commonly of minor importance. Most speleothems constitute a well-preservedarchive. New technical developments allow for sampling and investigation of speleothems athigh spatial resolution (Treble et al., 2005; Spötl and Mattey, 2006) and, as a consequence, toextract climate information of high temporal resolution. Therefore it is possible to unraveldecadal,annualandevensub-annualoscillationsofclimateparametersinmanycases.Absolute chronologies based on dating methods and, in particular, on uranium-series datingtechniques are routinely and effectively set up to integrate the environmental information intoa solid absolute time frame. As these cave deposits offer an exceptional capability regardingdating purposes, this undoubtedly represents one of the outstanding strengths of speleothemsasa climatearchive.

The term "speleothem" describes minerals that have precipitated in a cave environment. Through the examination of changes in the stable oxygen isotopic composition (18O) of the carbonate, it can be utilized to reconstruct paleoclimates (Yadava and Ramesh 2005). Paleoclimatologists have recently become more interested in exploring the potential of speleothem deposits because (i) they are well protected from physical damage (erosion by rain or wind action), and (ii) U-Th dating methods using mass spectrometry have been improved and applied to speleothem dating, making it possible to date small quantities (100mg) of even young speleothems with reasonable precision. Paleoclimatic reconstruction cannot be used with all speleothems growing in a cave. The dissolved ionic species (mainly calcium and bicarbonate) swiftly recombine and precipitate carbonate when a cave has multiple entrances through which outside dry air can enter and enable fast evaporation of seepage water. There is not enough time left to achieve isotopic equilibrium, which calls for a complete ion exchange across various species. Interpreting isotopic data from these speleothems becomes challenging as a result. The majority of samples that "promise for climate interpretation" do occur in the heart of caves where there is the inadequate air ventilation, assuring sluggish carbon dioxide emission and little water evaporation that isotope equilibrium. We examine how the stable isotope ratios of oxygen (18O) and carbon (13C) are impacted by the cave environment while CaCO3 precipitates separately. Seepage water in caves has an isotopic makeup similar to the typical isotopic makeup of meteoric water dropping on the cave's surface. Due to the high thermal inertia of the land mass (soil and bedrock), the air inside the cave is the same temperature as the average annual surface air temperature outside. The speleothem and tree-rings provided the high-resolution decadal to annual-scale climate records of the past few centuries, with speleothem records extending beyond the late Holocene. But such high-resolution long-term climate records are less from the Himalayan and other regions of the Indian subcontinent. This is due to the limited existence of old forest patches and less number of explored speleothem sites. However, the biotic and abiotic proxy-based hydroclimatic records from different regions of the Indian subcontinent lack the comparative proxy response analysis toward precipitation dynamics.

## 5. MonsoonandAssociatedOceanographicEffects

By shifting wind patterns, the surface oceanic circulation in the northern Indian Ocean (the Arabian Sea and the Bay of Bengal) changes direction throughout the summer and winter monsoons (Wyrtki 1973; Schott and McCreary Jr 2001). With a transport of 1.5–2 Sv in the upper 50m, there is intense upwelling around the Somalian and Omani coasts. The water upwelled typically ranges in temperature from 19 to 24 C (Schott and McCreary Jr. 2001). The Ekman divergence caused by the movement of strong winds parallel to the coast is blamed for the intense coastal upwelling. Under the influence of Ekman pumping and Findlater jet wind stress loading, the middle Arabian Sea shows a bowl-shaped mixed layer that is deepening. In the northern Arabian Sea, the high salinity surface waters are subducted as a result of the cold, dry northeast monsoon winds and Ekman pumping. Sea surface temperature (SST) falls by four °C when nutrient-rich deeper water surfaces, significantly increasing sea surface biological production. These upwelling zones along the Somalian and Omani coasts produce dramatic biological and geochemical changes in this region. Along southwest India's coastline, there is also weak upwelling. Minor upwelling is seen in the northeastern Arabian Sea during the Northeast monsoon (Wyrtki 1973). Due to convective mixing in the northern Arabian Sea caused by the cold and dry N.E. monsoon winds, the mixed layer deepens to a depth of 100–125 metres. This results in nutrient injection and high productivity during the winter monsoon in this area. For the S.W.

monsoon, N.E. monsoon, and intermonsoon periods, respectively, the usual values for productivity in the western Arabian Sea are 2.0, 1.0, and 0.5g C/m2/day. The normal productivity values for the eastern Arabian Sea are 0.6, 0.3, and 0.2g C/m2/day during the S.W. monsoon, N.E. monsoon, and intermonsoon periods, respectively. As the moisture-laden S.W. monsoon winds are compelled to ascend as they approach the Western Ghats, this results in heavy precipitation and runoff into the coastal Arabian Sea, greatly lowering the sea surface salinity (Tiwari et al. 2009).

The Arabian Sea's entire depth range, from 250 metres to 1250 metres, has a very low oxygen content, which leads to denitrification. This oxygen minimum zone (OMZ) is a result of the high oxygen consumption required for the oxidation of organic matter, which is provided by the high overhead surface productivity below the thermocline. A strong tropical thermocline (caused by relatively high SST, which inhibits the mixing of the oxygen-rich surface waters with the deeper waters) and the sluggish flow of the intermediate water that is deficient in oxygen also contribute to the maintenance of the OMZ (Morrison et al. 1999).Thus, monsoon winds, the productivity they provide, other climatically controlled variables like ocean ventilation rate, and OMZ and denitrification interact to produce. The Arabian Sea is a great place to study past changes in monsoon severity because of the seawater's significant changes in properties. The surface productivity, which takes many different forms, including organic, calcareous, and siliceous productivity, also affects the carbon isotopic composition of the saltwater, which is recorded in the calcitic shells of different foraminifera. Similar to how the oxygen isotopic composition of these shells is altered by SST and sea surface salinity, these changes are documented in the marine sediments. The denitrification intensity associated with changes in productivity can be determined by the nitrogen isotopic composition of sedimentary organic matter. In order to better understand previous variations in monsoon strength and the associated climatic shifts, it may be useful to look at the downcore variations of such proxies.

## 6. Conclusions

The origins and long-term development of the monsoon have been extensively documented by numerous researchers. High-resolution centennial to sub-centennial scale records of qualitative changes in previous monsoons have been reconstructed using data from the Arabian Sea, Bay of Bengal, and the Indian subcontinent. On the basis of seawater 18O, continuous quantitative estimations of the paleomonsoon intensity covering the last glacial-interglacial transition have also been made. Centennial or subcentennial scale quantitative records of the paleomonsoon (paleosalinity) and temperature over the glacial-interglacial terminations are needed to assess the link between low and high latitude processes. It is crucial to concentrate on regions with large sedimentation in order to collect high-quality cores, including the northern Bay of Bengal, the regions in front of important rivers like the Irrawaddy, Ganga-Brahmaputra, and Mahanadi, the northern Arabian Sea (Indus Fan region), and a few selected lakes.

## References

1. Ali, S. N., Dubey, J., Shekhar, M., &Morthekai, P. (2019). Holocene Indian Summer Monsoon variability from the core monsoon zone of India, a pollen-based review. *Grana*, *58*(5), 311-327.
2. Bhattacharyya, A., & Shah, S. K. (2009). Tree-ring studies in India past appraisal, present status and future prospects. *IAWA journal*, *30*(4), 361-370.
3. Blanford, H. F. (1884). II. On the connexion of the Himalaya snowfall with dry winds and seasons of drought in India. *Proceedings of the Royal Society of London*, *37*(232-234), 3-22.
4. Borgaonkar, H. P., Sikder, A. B., Ram, S., & Pant, G. B. (2010). El Niño and related monsoon drought signals in 523-year-long ring width records of teak (Tectonagrandis LF) trees from south India. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *285*(1-2), 74-84.
5. Breitenbach, S. F., Lechleitner, F., Plessen, B., Marwan, N., Cheng, H., Adkins, J. F., &Haug, G. H. (2012, December). Reconstructing Monsoon Variations in India-Evidence from Speleothems. In *AGU Fall Meeting Abstracts* (Vol. 2012, pp. PP13D-02).
6. Clement, C., Desprat, S., Martinez, P., Thirumalai, K., Prasad, S., Anupama, K., ...& Clemens, S. (2021, December). Indian Vegetation and Summer Monsoon Changes across the Last Two Interglacials: The First Pollen-Based Holocene-Eemian Comparison in the Core Monsoon zone from IODP Site U1446. In *AGU Fall Meeting Abstracts* (Vol. 2021, pp. PP15D-0950).
7. Cook, E. R., Anchukaitis, K. J., Buckley, B. M., D'Arrigo, R. D., Jacoby, G. C., & Wright, W. E. (2010). Asian monsoon failure and megadrought during the last millennium. *science*, *328*(5977), 486-489.
8. Cook, E. R., Krusic, P. J., & Jones, P. D. (2003). Dendroclimatic signals in long tree-ring chronologies from the Himalayas of Nepal. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, *23*(7), 707-732.
9. Crowley, T. J., & Lowery, T. S. (2000). How warm was the medieval warm period?. *AMBIO: A Journal of the Human Environment*, *29*(1), 51-54.
10. Demske, D., Tarasov, P. E., Wünnemann, B., & Riedel, F. (2009). Late glacial and Holocene vegetation, Indian monsoon and westerly circulation in the Trans-Himalaya

recorded in the lacustrine pollen sequence from TsoKar, Ladakh, NW India. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *279*(3-4), 172-185.

11. Duan, P., Li, H., Ma, Z., Zhao, J., Dong, X., Sinha, A., ...& Cheng, H. (2023). Interdecadal to centennial climate variability surrounding the 8.2 ka event in North China revealed through an annually resolved speleothem record from Beijing. *Geophysical Research Letters*, *50*(1), e2022GL101182.
12. Esper, J., Schweingruber, F. H., &Winiger, M. (2002). 1300 years of climatic history for Western Central Asia inferred from tree-rings. *The Holocene*, *12*(3), 267-277.
13. Fairchild, I. J., Smith, C. L., Baker, A., Fuller, L., Spötl, C., Mattey, D., & McDermott, F. (2006). Modification and preservation of environmental signals in speleothems. *Earth-Science Reviews*, *75*(1-4), 105-153.
14. Flohn, H., & Reiter, E. R. (1968). *Contributions to a meteorology of the Tibetan Highlands* (Doctoral dissertation, Colorado State University. Libraries).
15. Gadgil,S.,2003.TheIndianmonsoonanditsvariability.AnnualReviewsofEarthandPlanetary Science31,429-467.
16. Gadgil, S., Abrol, Y. P., &Rao, P. S. (1999). On growth and fluctuation of Indian foodgrain production. *Current Science*, 548-556.
17. Ghosh, R., Biswas, O., Paruya, D. K., Agrawal, S., Sharma, A., Nautiyal, C. M., ...&Bera, S. (2018). Hydroclimatic variability and corresponding vegetation response in the Darjeeling Himalaya, India over the past~ 2400 years. *Catena*, *170*, 84-99.
18. Hahn, D. G., &Manabe, S. (1975). The role of mountains in the south Asian monsoon circulation. *Journal of the Atmospheric Sciences*, *32*(8), 1515-1541.
19. Ivanochko, T. S., Ganeshram, R. S., Brummer, G. J. A., Ganssen, G., Jung, S. J., Moreton, S. G., & Kroon, D. (2005). Variations in tropical convection as an amplifier of global climate change at the millennial scale. *Earth and Planetary Science Letters*, *235*(1-2), 302-314.
20. Kudrass, H. R., Hofmann, A., Doose, H., Emeis, K., &Erlenkeuser, H. (2001). Modulation and amplification of climatic changes in the Northern Hemisphere by the Indian summer monsoon during the past 80 ky. *Geology*, *29*(1), 63-66.
21. Managave, S. R., Shimla, P., Borgaonkar, H. P., Bhattacharyya, A., & Ramesh, R. (2017). Regional differences in the carbon isotopic compositions of teak from two monsoonal regimes of India. *Dendrochronologia*, *44*, 203-210.
22. Mann, M. E., Bradley, R. S., & Hughes, M. K. (1999). Northern hemisphere temperatures during the past millennium: Inferences, uncertainties, and limitations. *Geophysical*

*research letters*, *26*(6), 759-762.

23. Morrison, J. M., Codispoti, L. A., Smith, S. L., Wishner, K., Flagg, C., Gardner, W. D., ... &Gundersen, J. S. (1999). The oxygen minimum zone in the Arabian Sea during 1995. *Deep Sea Research Part II: Topical Studies in Oceanography*, *46*(8-9), 1903-1931.
24. Niranjan, V., Kumar, M. D., &Bassi, N. (2014). Climate variability in South Asia. *Climate Variability and Its Impacts on Water, Energy and Food Systems in South Asia: Adaptive Water Management Approaches within the*, *32*, 8.
25. Quamar, M. F. (2019). Vegetation dynamics in response to climate change from the wetlands of Western Himalaya, India: Holocene Indian Summer Monsoon variability. *The Holocene*, *29*(2), 345-362.
26. Ramesh, K. (2000). Digital photoelasticity. *Measurement Science and Technology*, *11*(12), 1826-1827.
27. Robertson, J. A., Stemke, G. W., Davis Jr, J. W., Harasawa, R., Thirkell, D., Kong, F., ... & Ford, D. K. (2002). Proposal of Ureaplasmaparvum sp. nov.and emended description of Ureaplasmaurealyticum (Shepard et al. 1974) Robertson et al. 2001. *International Journal of Systematic and Evolutionary Microbiology*, *52*(2), 587-597.
28. Roy, I., Tomar, N., Ranhotra, P. S., &Sanwal, J. (2022). Proxy Response Heterogeneity to the Indian Monsoon During Last Millennium in the Himalayan Region. *Frontiers in Ecology and Evolution*, *10*, 512.
29. Schott, F. A., & McCreary Jr, J. P. (2001). The monsoon circulation of the Indian Ocean. *Progress in Oceanography*, *51*(1), 1-123.
30. Shankar, D., Shetye, S. R., & Joseph, P. V. (2007). Link between convection and meridional gradient of sea surface temperature in the Bay of Bengal. *Journal of Earth System Science*, *116*(5), 385-406.
31. Simpson, G. C. (1921). The south-west monsoon. *Quarterly Journal of the Royal Meteorological Society*, *47*(199), 151-171.
32. Singh, J., Park, W. K., &Yadav, R. R. (2006). Tree-ring-based hydrological records for western Himalaya, India, since AD 1560. *Climate Dynamics*, *26*, 295-303.
33. Spötl, C., &Mattey, D. (2006). Stable isotope microsampling of speleothems for palaeoenvironmental studies: a comparison of microdrill, micromill and laser ablation techniques. *Chemical Geology*, *235*(1-2), 48-58.
34. Tiwari, A., Fan, Z. X., Jump, A. S., Li, S. F., & Zhou, Z. K. (2017). Gradual expansion of moisture sensitive Abiesspectabilis forest in the Trans-Himalayan zone of central Nepal associated with climate change. *Dendrochronologia*, *41*, 34-43.

35. Tiwari, M., Managave, S., Yadava, M. G., & Ramesh, R. (2009). Spatial and temporal coherence of paleomonsoon records from marine and land proxies in the Indian region during the past 30 ka. *Platinum Jubilee publication of the Indian Academy of sciences, Bangalore, India*, 1-19.
36. Treble, P. C., Chappell, J., Gagan, M. K., McKeegan, K. D., & Harrison, T. M. (2005). In situ measurement of seasonal δ18O variations and analysis of isotopic trends in a modern speleothem from southwest Australia. *Earth and Planetary Science Letters*, *233*(1-2), 17-32.
37. Vernekar, A. D., Zhou, J., &Shukla, J. (1995). The effect of Eurasian snow cover on the Indian monsoon. *Journal of Climate*, *8*(2), 248-266.
38. Walker, B. (1910). The distribution of Margaritanamargaritifera (Linn.) in North America. *Journal of Molluscan Studies*, *9*(2), 126-145.
39. Wyrtki, K. L. A. U. S. (1973). Physical oceanography of the Indian Ocean. *The biology of the Indian Ocean*, 18-36.
40. Xu, C., Zheng, H., Nakatsuka, T., & Sano, M. (2013). Oxygen isotope signatures preserved in tree ring cellulose as a proxy for April–September precipitation in Fujian, the subtropical region of southeast China. *Journal of Geophysical Research: Atmospheres*, *118*(23), 12-805.
41. Yadava, M. G., & Ramesh, R. (2005). Monsoon reconstruction from radiocarbon dated tropical Indian speleothems. *The Holocene*, *15*(1), 48-59.
42. Yang, L., Wei, W., Chen, L., & Mo, B. (2012). Response of deep soil moisture to land use and afforestation in the semi-arid Loess Plateau, China. *Journal of Hydrology*, *475*, 111-122.
43. Zorzi, C., Desprat, S., Lauterbach, S., Krishnamurthy, A., Prasad, S., Andersen, N., ...& Martinez, P. Indian vegetation and monsoon response to millennial and orbital climate variability during the last glacial period. In *The Mediterranean Palynological Societies Symposium 2019. Abstract book*. (p. 129). Université de Bordeaux.