International Virtual Conference
on

Earth's Changing Climate: Past, Present & Future

15-17 October 2020

ABSTRACT BOOK

Organized by
The Society of Earth Scientists

Co-organized by
Birbal Sahni Institute of Palaeosciences, Lucknow
Indian Institute of Tropical Meteorology, Pune
National Centre for Polar and Ocean Research, Goa
National Institute of Disaster Management, Delhi
National Institute of Advanced Studies, Bengaluru

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Pre-Conference Expert Talks and Group Discussion (Online)
on
EARTH'S CHANGING CLIMATE
13.10.2020

A Pre-Conference Expert Talks and Group Discussion (Online) was organised on 13th October, 2020 in which experts from various domains were invited to deliver talks to know the status of knowledge and future scope of research addressing the Earth's changing climate. The day ended with an International Group Discussion highlighting global climate change scenario and way forward. The program received appreciation from every quarter. The expert talks will be available on YouTube channel of The Society of Earth Scientists. The details of Expert Talks and Group discussion is given below:

Moderator: Dr. K. J. Ramesh
Forenoon Session I: *Setting the Stage for the Conference: Global Climate Change: Context for Policy and Action*

Session Chair: Prof. A. Singhvi, Physical Research Laboratory, Ahmedabad
Speakers:

1) **Challenges for India in a climate constrained World**
   Sri Surya Sethi, Former Principal Adviser (Power & Energy), Plg. Com. & UNFCCC Negotiator
2) **New research questions in understanding climate change, policy response and societal change**
   Sri Mukul Sanwal, Retd. IAS, Formerly with UNEP & UNFCCC Negotiator
3) **Energy policy and mitigation**
   Prof. R. Srikanth, NIAS, Bangalore
4) **India's national communications and biennial update reports**
   Dr. J R Bhat, Adviser, MoEF & CC

Forenoon Session II: *Climate Science for Climate Action Strategy*

Session Chair: Dr. Akhilesh Gupta, Adviser, DST
Speakers:

1) **Understanding the observed and future projected changes in the Indian monsoon**
   Dr. R. Krishnan, IITM, Pune
2) **Science based tools for regional policy planning**
   Dr Ajay Mathur, Director General, TERI
3) **The climate change and biogeochemistry of the oceans**
   Dr Satish Shenoy, Former Director, INCOIS, Hyderabad
4) **Teleconnection between tropics and poles under changing climate**
   Dr. M. Ravichandran, Director, NCPOR, Goa

Afternoon Session I: *Impacts of Climate Change*

Session Chair: Prof. Ravi Shankar Nanjundiah, Director, IITM, Pune
Moderator: Dr. Rasik Ravindra
Speakers:

1) **Coastal inundation and shoreline changes**
   Dr M V Ramana Murthy, Director, NCCR
2) **Himalayan glacial change**
   Prof. Anil Kulkarni, IISc, Bangalore
3) **From nanometer to global scales: Aerosol influences on temperature, clouds and rainfall over India**
   Prof. Chandra Venkataraman, IIT Bombay

GROUP DISCUSSION

Panel:
Prof. Dame Jane Francis, Director, British Antarctic Survey
Prof. Kim Holmén, International Director, Norwegian Polar Institute
Prof. Ashok Singhvi, distinguished Scientist, PRL (Chairman Session-I)
Dr. Akhilesh Gupta, Adviser, DST (Chairman Session-II)
Prof. Ravi S. Nanjundiah, Director, IITM (Chairman Session-III)
Dr. Vandana Prasad, Director, BSIP, Lucknow
Dr. M. Ravichandran, Director, NCPOR, Goa
Dr. K. J. Ramesh, Former Director General, India Meteorology Department

Moderator: Dr. Rasik Ravindra**,** Former Director, NCAOR, Goa

The deliberations at Katowice, Poland summed up the grim situation, pertaining to climate change as follows:

- Earth's average surface temperature (Jan to Oct, 2018) was higher than 1850-1900 baseline
- 17 of the hottest years on record occurred since the start of 21st century
- The concentration of CO_2 in atmosphere reached 405.5 ppm in 2017. The current levels are 417ppm+.
  [This is highest in 3 million years and a 45% jump since preindustrial era. Last time the CO_2 was at this level; the oceans were 10-20 m higher].
- To limit the rise of temperature at 1.5^0 C, the emissions must drop to over half.

"Earth's climatic future is uncertain, but the world needs to prepare for change"- Carolyn Gramling.

The global concern on the climate change crises- rising temperatures, extreme weather events, increase in sea level and - their impact on the land, environment and its habitants is growing manifold.

The changes are real, now proved by the empirical evidences gathered from across the planet, especially the three Poles-Arctic-Antarctic - Himalaya and the oceans. There are reports of rapid thawing of permafrost, loss of over 30% of Arctic sea ice cover and massive retreat of Greenland ice sheet in the recent years.

Results of mass balance studies of the Antarctic Ice sheet, published in Nature in 2018 by Andrew Shepherd and others, has put the loss of Antarctic ice at 2,720 ± 1,390 billion tonnes between 1992 and 2017, which corresponds to an increase in mean sea level of 7.6 ± 3.9 millimetres.

The picture from Himalaya is equally grim with some smaller glaciers facing the risk of extinction by the end of century.

Our oceans are have seen change in pH- acidity and warmer. These changes are global and play a significant part in the coupled ocean-atmosphere-earth system.

In yet another study Winther and his co- workers (Nature, 2020) speak of the unprecedented pressure on the oceans due to rapidly evolving blue economy and climate change requiring implementation of integrated ocean management framework.

The UN FCCC (Framework Convention on Climate Change) in its 2019 Review on damages associated with Climate Change Impacts, has acknowledged that climate change is a common concern of humankind and urged that Parties when taking action to address climate change, respect, promote and consider their respective obligations on human rights, the right to health, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations and the right to development, as well as gender equality, empowerment of women and intergenerational equity.

The climate simulations are getting better at re-creating even the minute aspects of climate change, such as the complicated physics of clouds, the impact of aerosols and the capacity of the ocean to absorb heat from the atmosphere.

Five years ago, in the probable worst-case climate scenarios, the planet was projected to warm between 2.6 degrees and 4.80C relative to the average Earth temperature from 1986 to 2005 if no action was taken to abate greenhouse gas emissions, by 2100. The Global mean sea level was thought likely to increase by up to a meter in the same scenario, according to the 2014 report by the IPCC.

The Next Gen model simulations include estimates of Equilibrium Climate Sensitivity (ECS), which basically means how Earth's future climate is expected to respond to a new normal- specifically, an atmosphere that contains twice as much CO2 as during preindustrial times.

Several well-known simulations, developed by teams at NCAR, UK's Hadley Centre for Climate Prediction and Research and the Paris-based Institute Pierre Simon Laplace, or IPSL have higher ECS meaning the Earth was more sensitive to CO2, than in previous model generations. If real, that suggests that the gases can exert even more influence on Earth's atmosphere than thought, and ultimately, temperatures could get hotter than even the highest previous projections suggested.

In September, scientists with IPSL and CNRS, based on projections from two separate climate models, reported that average global warming by 2100 could be as high as 6 to 7oC relative to preindustrial times.

A study in GRL (Gettelman) emphasises the role of clouds in enhancing warming. The lower-altitude clouds can reflect sunlight back into space, while higher-altitude clouds can trap heat. Studies to examine effects of high-altitude clouds in the Arctic as well as lower-altitude clouds in the tropics are in progress.

Changing Paradigm

While the CMIP 5 (Coupled Model Inter-comparison Project) used for IPCC 2014 report used a concept called RCPs (Representative Concentration Pathways)- a scenario in which greenhouse gases trap radiation from the sun, the IPCC's upcoming sixth assessment report will rely on projections from CMIP6, the more sensitive models in which, RCPs will be replaced by SSPs or

"shared socioeconomic pathways,". The SSPs incorporate societal shifts, such as changes in demographics, urbanization, economic growth and technological developments.

Ice-Ocean-Atmosphere Interaction

Climate models are trying to simulate the physical interactions of ice and ocean and atmosphere, particularly in rising temperatures continue to rise, by coupling them.

Numerous sources of possible uncertainty remain when it comes to anticipating the so-called worst-case scenario. For example, how fast the seas will rise is linked to how quickly the great ice sheets of blanketing Greenland and Antarctica melt will be lost to sea. It is not understood well as to how the ice responds to climate change.

One of the largest uncertainties (Rignot), is how warming oceans can interact with the vast underbellies of glaciers fringing the ice sheets, eroding them. To identify how such erosion might occur requires detailed bathymetry maps, charts of the seafloor that can reveal deep channels that allow warmer ocean water to sneak into fjords and eat away at the glaciers.

How the continental glaciers will respond to warming in time and space and in volume is also not well understood.

Release of Greenhouse gases due to wild fires and permafrost thawing

The unprecedented wild fires in some parts of Arctic such as the eastern Siberian landscape have potential to release CO2 and methane that has been locked in the ground for thousands of years, much more that what thawing of permafrost would release. These factors have not been simulated in the climate models. The fires also produce black carbon suite that would further increase the Arctic warming, which is already warming at twice the global average rate.

The role of stubble burning in northern India, in causing changes in melt rate of Himalayan glaciers also need to be examined.

Marine Heat waves

Increasing incidences of long periods of high temperatures in the ocean (marine heatwaves) that used to occur once in hundreds to thousands of years before pre-industrial time, could become annual or decadal feature, if the global average temperatures were to rise by 30 C.

Loss of Biodiversity

The Great Acceleration (incredible growth in population, economic activities and consumption of resources) in last five decades has impacted the earth's intrinsic system and resulted in the loss of biodiversity in serval regions of our planet (Assessment of Climate Change over the Indian Region: A Report of the Ministry of Earth Sciences (MoES), Government of India Eds. R. Krishnan, J. Sanjay, C. Gnanaseelan, A. Kulkarni, S. Chakraborty; Springer Open (2020) 226p). The ecological footprints have grown at 190%in the last 50years as compared to bio- capacity rate of 10% (defined as ability of an ecosystem to renew itself) Only 30% of earth is covered by forests but they are home to 80% of all the terrestrial species of animals, plants and insects. Same is true of marine ecosystem, where Corals are at the brink of extinction.

**(Drawn largely from Carolyn Gramling's post dated Jan 07, 2020 (https://www. Sciencenews.org) and conclusions from panel discussions on Webinar on "Sustainability of Polar Ocean's organised by SaGHAA on 28-29 Sept, 2020).*

Points of discussion (leads for discussions)

- How good and useful are paleoclimatic data generated for the models in predicting the future climate? We are aware of the changes in the charactertistic of the Earth by anthropogenic activities.

- How good are our climatic models? Do they account for continous changing parameters on Arctic sea ice, thawing of permafrost, changing ice shelves, growing wild and peat fires, changing ice cover in Himalayas?

- Does the changed paradigm call for introducing SSP (shared socio-economic pathways) rather than RCPs (Representative Concentration Pathways)?

- Earth being a coupled system is witnessing changes/variability and getting amplified in terms of changes in marine biogechemistry to changes in biodiversity both terrestrial and marine. Research questions need to be framed to understand the processes.

- How effective is the teleconntion between Arctic and Indian Monsoon, do we know the cause and effect? Does it affect the way we predict changes in the Indian monsoon? Role of land use / land cover effect the monsoonal changes.

- Changing emissions, its feedbacks at local/city/state level to national level and its effects in agriculture sustenance

- Message to policy makers, the law makers and to the society at large. How to have an effective communication for informing and roping in indigenous population

PREAMBLE

Earth's climate varies even without human influence but the acceleration in the changing pattern with cause and effect by/to the civilisation is a matter of concern to scientists. These patterns are lessons to understand future trends and ways and means for mitigation. The extreme weather events in almost every region of the globe involving excessive loss of human life and property are causing anxiety in society and posing challenges before scientists and planners. Cyclical variations in the Earth's climate occur at multiple time scales, from years to decades, centuries, and millennia. Cycles at each scale are caused by a variety of physical mechanisms. In the last 65 Ma only, there have been several cycles of glacial advances and retreat, with the abrupt end of the last ice age about 11,700 years ago marking the beginning of the modern climate era and human civilization. A multidisciplinary approach in studying the Earth's changing climate will provide a holistic view and guide us in future planning and programming.

A multi-domain International virtual conference was organized wherein recent researches on palaeoclimatic changes, Quaternary climate variations and climate cycles, extreme weather events and meteorological studies, natural atmospheric climate forcing, ocean warming, and coastal ecosystem, disaster mitigation planning and management were presented and scope of mutual research cooperation in future was discussed. COVID-19 impact on the environment and future strategies to retain a positive impact on the environment by sustainable development were presented. Abstracts of a total of 98 papers are incorporated in this book. An Expert Talks and Group Discussion (online) was also organised on 13.10.2020 for a take away for upcoming conference.

Our sincere gratitude to Prof. Dame Jane Francis, Director, British Antarctic Survey; Prof. Kim Holmén, International Director, Norwegian Polar Institute; Prof. A. Singhvi, Physical Research Laboratory; Sri Surya Sethi, Former Principal Adviser (Power & Energy), Plg. Com. & UNFCCC Negotiator; Sri Mukul Sanwal, Retd. IAS, Formerly with UNEP & UNFCCC Negotiator; Prof. R. Srikanth, NIAS, Bangalore; Dr. J R Bhat, Adviser, MoEF & CC; Dr. Akhilesh Gupta, Adviser, DST; Dr. R. Krishnan, IITM, Pune; Dr Ajay Mathur, Director General, TERI; Dr Satish Shenoy, Former Director, INCOIS, Hyderabad; Dr. M. Ravichandran, Director, NCPOR, Goa; Prof. Ravi Shankar Nanjundiah, Director, IITM, Pune; Dr M V Ramana Murthy, Director, NCCR; Prof. Anil Kulkarni, IISc, Bangalore; Prof. Chandra Venkataraman, IIT Bombay for taking part in Pre-conference Expert Talks and International Group Discussions. Dr. Vandana Prasad, Director, BSIP, Lucknow; Prof. L. S. Chamyal, M S University of Baroda; Dr. K. A. S. Mani, FAO, World Bank & IFC Consultant; Prof. N. C. Pant, University of Delhi; Dr. R. H. Kripalani, Former Scientist, IITM, Pune chaired various technical sessions is thankfully acknowledged. Special thanks to the Director, BSIP, Lucknow for all round support in the virtual organisation of the conference. Sincere thanks to Dr. Binita Phartiyal, Dr. Anju Saxena, Dr. Santosh K. Shah and Dr. V. V. Kapur of BSIP for very skilfully managing the conference. Sri Syed Rashid Ali, BSIP helped in preparing final layout of the Abstract Book is thankfully acknowledged.

Dr. Satish C. Tripathi

General Secretary, SES

Content

Floristic changes during the Permian Period and its palaeoclimatic implications

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In India, Permian sediments are mainly known as Talchir, Karharbari, Barakar, Barren Measures and Raniganj formations. The flora of this period is known as *Glossopteris* flora and it came into existence after the onset of Gondwana glaciation during the late Carboniferous-early Permian sequences of Talchir Formation. The flora of Talchir Formation is meagrely known and represented by the few species of *Glossopteris* and 9 spp. of *Gangamopteris* together with the presence of *Arberia, Paranocladus* and some seeds. The limited occurrence of flora indicates that the cold condition prevailed during the deposition of Talchir sediments. The flora shows significant development during Karharbari, when climate became more suitable due to warmer condition in comparison to the Talchir. During this time, new elements namely *Buriadia, Botrychiopsis, Euryphyllum, Rubidgea* came into existence and the number of species of *Gangamopteris* also increased. The occurrence of *Noeggerathiopsis* leaves is quite common in Karharbari Formation and the flora is very distinct in having *Gangamopteris−Noeggerathiopsis* association together with the typical forms of *Buriadia* and *Botrychiopsis*. The study suggests that by the time of deposition of Karharbari sediments, cold condition diminished with warmer spell resulting into the proliferation of plant community. The study of plant fossils recovered from the lower Barakar indicates the continued presence of Karharbari forms and definite association of *Gangamopteris* and *Noeggerathiopsis*. The presence of Karharbari elements in the lower Barakar demonstrates the existence of same type of cool-warm climatic condition during this time, however, the assemblages reported from the upper Barakar shows the increased variety of the species of *Glossopteris.* The elimination of typical forms of Karharbari *i.e. Buriadia, Botrychiopsis* and variety of seeds in the Upper Barakar flora certainly suggests the shift in climatic condition. The condition became more severe during the deposition of Barren Measures as the flora is poorly known by 6-7 species of *Glossopteris*, 1 species of *Cyclodendron* and *Neomariopteris,* which suggests that during this time there was hot and dry spell which resulted into the limited growth of plants. The absence of coal seams in Barren Measures Formation supports the limited presence of plant. The adverse condition lasted for limited period and by the time of Raniganj Formation, climate became very suitable for the growth of variety of plants. The flora of Raniganj Formation is known as the acme of *Glossopteris* flora represented by number of glossopterid leaves, fructifications, equisetales, sphenophyllales, fertile and sterile forms of ferns besides number of fossil woods, sporangia and seeds. Such a rich assemblage has been attributed to the presence of warm-humid favourable climatic condition for the development of plants.

Cenograms technique: Historical review of cenogram methodology as a tool for environmental reconstructions sustained by several mammalian communities across the globe during the Cenozoic time-slice

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Profound effects in diversity and evolution of the Cenozoic (Paleogene–Neogene) floral and faunal (including mammalian) communities, as a consequence to the past climatic events, are known to have resulted in the establishment of the modern ecosystems on our planet. For instance, C4 vegetation (grassland ecosystem) dominated C3 vegetation during the late Miocene; consequently, grazers dominated the browsing mammals by making adaptations to their diet, while sustaining in the grassland habitats. Habitat reconstructions, by means of extinct fauna and flora, provide palaeontologists with an opportunity to study the change(s) in the community structure as a consequence of changes in environment (linked to climate change), during various geological intervals including the Cenozoic time-slice. In this regard, cenograms (developed in the 1960s) enable us to characterize the habitat sustained by mammals in deep time. Originally designed to analyze the trophic interactions between predators and prey, the cenogram methodology has been historically used for palaeoecological inferences by establishing different relationships between the cenogram structure and the characteristics of the environment. Furthermore, during the late 1980s, relationship between the canopy of the environment and the difference (offset) between the regression lines for the medium to large-sized and small-sized mammal species allowed this technique to be utilized in both a quantitative and qualitative context. Although earlier studies have argued against the correlation of cenogram patterns to palaeoclimate and/or temperature, palaeoenvironmental inferences have been well supported by the scientific community, particularly within the tropical realms. Interestingly, cenograms methodology is shown to be relevant even for assemblages with a random species loss of over 60–70%, being useful in palaeoenvironmental and palaeoecological analyses. Thus, over the years, cenogram analysis has proved to be a useful method for identifying the preferred biomes of various mammalian communities sustaining the globe at different time intervals within the Cenozoic.

Regional paleo climate and environment database: where paleo data meets socio-economic-political decision making

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Science has entered the big-data era, where statistical learning methods are applied to gigabytes of data to gain insights into complex problems. In the field of paleoclimate & paleoenvironment, investigators reconstruct capital-intensive records of past climate and environmental changes represented by calibrated, indirect observations that span long durations (centuries to thousands of years) and offer a wide spatial scope. Such records, going beyond the instrumental measurements, are critical not only in understanding complex climatic phenomena but also in assessing how climate and environmental factors impact socio-economic-political decision making (agriculture, water & land use, migration, famine, rise and fall of civilizations to name a few). As such paleoclimate and paleoenvironmental data needs to be systematically curated, standardized, quality controlled, and made accessible for use in modeling as well as climate and environmental services. Such datasets are unavailable for some regions that are at the forefront of climate and environmental changes.

Here we present an open-access database for paleoclimate and paleoenvironmental data. We have co-developed this database with multiple stakeholders as a service aimed at increasing visibility of and access to existing paleo data from the subcontinent, creating a platform for collaboration and providing climate and environmental products relevant to paleo-scientists, modelers, social scientists, and community practitioners. It is a paleo-community driven project that ensures transparent and equitable use of data using clearly laid data sharing policies. Currently, it hosts meta-data from more than 150 peer-reviewed articles, ~30 data records, and co-developed climate products. To the best of our knowledge, it is the first of its kind regional paleo data sharing and collaboration platform, and compiles ~20 new data records not available in the existing global databases, improving the coverage of the Indian subcontinent. Approx. 70 principal investigators were contacted by email to request the compiled data.

We believe this database would be pivotal in improving our understanding of past variability of the Indian Monsoon, consequently, future variability and historical climate-environment induced social-economic changes.

Time assessment of tectonic and climatic forcing on the formation of Khari bedrock gorge, Kachchh, western India: A mathematical approach

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Formation of large-scale deformations in the upper part of the crust during Quaternary resulted in the opening of cracks on the rising/bulging landscape of the E-W trending Kachchh basin. The present study pertains to the development of a deep Khari bedrock gorge (an open crack) in the mainland region of Central Kachchh, western India. The length of the crack, the narrow bedrock gorge is 220 m and the maximum depth is 27.3 m. The estimated results show the maximum dip dimension 49.9 m and a minimum 3.1 m. The study shows that there is a regular and direct connection between the size (length) of crack openings and the rate of displacement. However, the controlling dimension of displacement and widening of the fracture depends on volumetric fluid flow, overpressure of fluid, the ratio of length-displacement/width, and an elastic limit of sandstone, the host rock. The controlling dimension of a crack is geometrically denoted by the strike and dip of a fracture. The volume of water flow, the volumetric rate on the horizontal bedrock surface, and the subsequent crack opening is directed by the fracture aperture. The opening of a crack within the contact of two surfaces may have a variable aperture corresponding to the rate of volumetric fluid flow over the crack. The statistical parameter shows that the Young's modulus of sandstone is 6 MPa and the Poisson's ratio is 0.2 and the Tensile strength 14 MPa of the fault zone. Our estimates show that the initial opening displacement of Khari gorge is ~0.6–0.8 mm with an initial volumetric rate of fluid is 22 Qc indicates enhanced discharge. Further, it is noticed that the fluid passing through the crack caused its widening by 0.2 mm with a gradual decrease of volumetric fluid rate 3Qc through the cracks during the decline condition of fluid discharge. The empirical relation of fracture direction with time factor suggests that the initial stage of gorge formation took place around 125 ka (Late Pleistocene) ago during the effective climatic condition and continuous modification for shaping the gorge took place until around 8 ka (Holocene). After that, the modification through climate is completely ceased.

Extreme Flood Events and Erosional Hotspot of Tsangpo-Siang-Brahmaputra River valley

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Paleo-flood hydrology, not only preserves the reliable signature of climate variability but also tectonics and surface process relationship. The phenomena of megafloods are truly known to transport huge amount of sediments to a far distance and dump them at geomorphologically suitable locations as massive sand deposits and/or sand-silt couplets known as slack water deposits. In this study we focused on such extreme events in Siang- Brahmaputra basin by targeting 7 such deposits along the Siang River, in between Pasighat (at mountain front) and Tuting (Suture Zone), ~ 300 km stretch. To understand the depositional environment and provenance of the flood sediments we have used sedimentological, petrographic and geochemical approaches. Provenance study of these deposits can give information on hotspots of erosion and its controlling factors. Geomorphic indices including precipitation and a geomorphic swath profile across the Brahmaputra catchment were studied to understand the interplay of mountain relief and rainfall that determine potential zones of high erosion and sediment supply. Additionally, the Optically Stimulated Luminescence (OSL) dating technique is utilized to establish the chronology which indicated that the Siang River experienced at least 9 mega-floods between 8 and 1 ka under the influence of warm and wet climatic conditions. Different grain size parameters suggested high energy turbulent depositional conditions. Further, we calculated discharge at different sections using different pre-established equations. Except for the regular monsoon floods at Pasighat all other extreme event discharges are of the order of $>10^6$ magnitude. Again the peak discharge of the 5ka event at Bomdao is very much corroborates with the largest known late Pleistocene GLOFs reported from Siberia. The petrographic and geochemical analysis indicated that the eastern Himalayan syntaxis which has the highest uplift and exhumation rate is not most sediment producing source throughout the time, in some instances surface process i.e. GLOFs and LLOFs occurring at Tibetan plateau produces large flux of sediments from the plateau it-self . So the study has focused on different parameters that might be causing these extreme events and controlling factors of erosion during these flooding events.

Palynological and carbon isotopic signatures of early Eocene hyperthermal event from Kutch Basin, Western India.

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The early Eocene period is considered as overall global warm period, encompassing several transient extreme hyperthermal events, and is believed to have triggered a proliferation of angiosperms. During this period, transition of Indian subcontinent took place through palaeoequatorial position as an isolated island that caused significant paleogeographical and palaeobiological changes. The early Eocene lignites and associated sediments deposited pericratonic basin of western Indian archived the signatures of extreme global climate changes and their effects on palaeobiota.

The palynological study based on sporomorphs, dinoflagellate cysts, calcareous nannofossils and stable carbon isotope from Panandhro, Akri and Matanomadh lignite mine successions, western Kutch, Gujarat has done to decipher precise age of the successions and to identify hyperthermal events. In addition, palaeovegetation and palaeoenviromental interpretations have also done on the basis of diverse and well-preserved spore-pollen.

The dinoflagellate cyst assemblage from all lignite mines succession is characterised by dominance of the *Homotryblium* spp., *Thalassiphora* spp. and *Muratodinium* sp. indicate early Eocene (Ypresian-early Lutetian) age. Whereas, the top calcareous clay of Matanomadh lignite mine succession yielded diverse and age diagnostic calcareous nannofossils. Based on FAD of *Blackites inflatus*, *Coccolithus opdykei*, *Lanternithus minutus*, *Micrantholithus angulosus*, *Nannotetrina alata*, *Sphenolithus furcatolithoides* and LAD of *Discoaster kuepperi*, the top part of succession of Matanomadh lignite mine is dated early Lutetian (NP14 Zone, ~ 48-46 Ma). Furthermore, the carbon isotopic data reveals presence of sharp negative Carbon Isotope Excursion (CIE) of about 2.7‰ in Panandhro lignite succession and of 3.2‰ in the lower part of the Matanomadh lignite succession. This CIE are correlated to the globally recognized Second Eocene Thermal Maximum (ETM2) at 53.7 Ma.

The palynological assemblage is also diverse and rich, mainly dominated by pollen of Arecaceae and Araceaea family and members of typical tropical rain forest families such as Bombacaceae (*Lakiapollis ovatus* and *Tricolporopollis matanomadhensis)*, Dipterocarpaceae (*Dipterocarpuspollenites)*, Oleaceae (*Retitrescolpites*) and Ctenolophonaceae (*Retistephanocolpites* and *Ctenolophonidites*). The total 74 morphospecies recovered from Panandhro lignite mine were used to trace the changes in palaeofloristics and diversity pattern of palaeotropical vegetation across the ETM2. Various methods for estimation of biodiversity such as Range-through method, Shannon–Wiener index, Simpson Diversity index, Rarefied Richness Curve were used to determine the diversity pattern before, during and after the warming event. The standing diversity calculated using Range-through method yielded the mean diversity of 27.5 spore/pollen species per sample during pre-ETM2 warming, whereas this diversity increased to 44 spore/pollen species per sample during the ETM2 phase. Interestingly, the mean diversity per sample of post-ETM2 warming again decreased to 31.2 spore/pollen species. The same pattern is replicated by other diversity estimation methods after accounting for sample size, number of samples/time unit, lithofacies and depositional systems. The distinct increase in taxonomic diversity during high temperatures can be attributed to high level of soil moisture and CO_2 that contributed to proliferation of families typical of wet tropical rainforests in palaeotropical region during extreme warming events.

Palynofloral diversity and palaeoclimatic significance of striate disaccate pollen in Yellandu coalfield of Kothagudem sub- basin, Godavari graben.

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The present palaeopalynological study deals with the significance of striate disaccate pollen from bore hole Q - 563 of Yellandu coalfield (Jawahar Khani - 5 coal block), Kothagudem sub-basin and to determine the age and palaeoclimatic interpretations of the study area based on the pollen morphological characters. For the palynological investigation sixty samples were thoroughly analyzed. In which fairly diversified palynofloral assemblages of Gondwanic affinity were recorded. About 30 genera and 50 species of palynomorphs, belongs to Glossopteridales, Coniferales, Cordaitales of gymnospermous pollen, pteridophytic spores, few acritarchs and thecamoeibians were recorded. In the present communication the palynoflora belongs to Coniferales viz., *Faunipollentites varius, F. goriensis, Striatopodocarpites ovalis, Verticipollenites gibbosus, Striatites barakarensis, S. communis, S. rhombicus, Striatites medius, Crescentipollenites talchirensis, C. fuscus, C. globossus were* recorded. Frequency distribution pattern of the palynotaxa reveals that the assemblage is dominated by the non - striate disaccates followed by striate disaccates, monosaccates (gymnosperms) and pteridophytic spores. The diversified palynoassemblage of both non striate and striate disaccates pollen strongly signifies the Yellandu coal belt of Godavari graben belongs to Barakar Formation of Early Permian age (Late Sakmarian – Early Artinskian). Predominance of striate disaccate pollen in the palynozone - 2 recorded from the upper part of the Yellandu coalfields indicates a gradual increase of temperature from cool to warm and high humidity climatic condition prevailed with fluvial environment of deposition.

Paleoclimate reconstruction of the Aravalli Craton (Central Rajasthan, NW India) during Paleoproterozoic using geochemical proxies of metasedimentary rocks

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The Mangalwar Complex (MC) and Sandmata Complex (SC) constitute the Proterozoic basement (Banded Gneissic Complex; BGC) of the Aravalli Craton in Central Rajasthan, India. The MC is composed of varied lithologies, and on the basis of lithology it is classified into Mangalwar Gneissic Complex (MGC) and Mangalwar Metasedimentary Complex (MMC) composed of dominantly orthogneisses and supracrustal rocks (aluminous pelites, quartzite and marble), respectively. In this communication, we present whole-rock geochemical data to decipher the paleoweathering conditions of metasedimentary rocks from the MMC and use it for paleoclimate reconstruction of the Aravalli Craton.

The MMC is made up of varied lithologies like mica schist, garnet schist, chert, quartzite and paragneiss. Detrital zircon ages from metasedimentary rocks of the SC and MMC suggests that the MGC probably acted as their basement and source. Based on the geochemical data, most samples of the metasediments are classified as wacke and few samples as iron-bearing shale. Index of compositional variability (ICV) values for the samples are >1 suggesting their compositional immaturity, i.e., higher contents of non-clay silicate minerals as compared to the clay mineral contents. In Al_2O_3-(CaO^*+Na_2O)-K_2O ternary diagram (A-CN-K), weathering trends resulting from chemical weathering are roughly parallel to A-CN join projected towards the A-apex. Due to post-depositional metasomatism effect, weathering trend in the A-CN-K space makes the slope of the trends gentler. Chemical index of alteration (CIA) and plagioclase index of alteration (PIA) are useful to quantify the intensity of source area weathering. These indices suggest low to moderate weathering of the source indicative of cold and arid paleoclimate. However, at ~2.0 Ga the North Indian Block was situated in a tropical region (equator) where the extent of paleoweathering is usually high. So, to explain the decoupled paleoweathering and paleoclimate conditions we suggest that the transportation distance (small) and tectonics (rapidly uplifting basement) played the key roles. We propose that the chemical weathering was low to moderate due to rapid basement upliftment and sediment deposition in a proximal basin. This explains as to why the CIA values of the sediments are low/moderate despite the prevalence of equatorial climate (hot and humid) in the Aravalli Craton during the sedimentation process.

Oceanic Anoxic Events (OAEs): Causes, Consequences, and Records from India

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The Mesozoic era is one of the significant interval in the Earth's history. During this period the Earth experienced ice-free super greenhouse conditions. This interval evidenced multiple times extreme climatic perturbations. It is particularly noteworthy in terms of their impact on the chemistry of oceans. The global ocean was characterized by expanded and intensified Oxygen Minimized Zone (OMZ) (Jenkyns 2010). These Oceanic Anoxic Events (OAE's) are recognized as intervals in the geological timescale, lasted for about from a few 100-1000 years. This interval comprises of geochemically significant dark-colored, organic-rich, laminated marine sediments. It developed globally in several paleo -bathymetric settings from the oceanic plateau, basin, and continental shelf (Schlanger and Jenkyns 2014). A series of OAE's are recorded globally and regionally; which are T-OAE ~ 183 Ma (Posidonienschiefer event), OAE 1a ~ 120 Ma (Selli event), OAE 1b ~111 Ma (Paquier event) C/T OAE, OAE 2 ~ 93 Ma (Bonarelli event), OAE 1c (Late Albian), OAE 1d (Late Albian Breistroffer event), Weissert event (Late Valanginian), Faraoni event (Late Hauterivian) and OAE 3 (Late Coniacian to Santonian). Also, a repetitive similar anoxic condition interspersed with the oxic conditions is recorded from the Ordovician – Silurian boundary and Paleocene –Eocene Boundary (PETM). The major two reasons were behind the cause of this phenomenon are: first, greenhouse conditions and secondly, the decreasing strength of thermohaline circulation (Schlanger and Jenkyns 2014). There are several consequences of the OAE's. They are connected to mass extinctions throughout the geological time. An economical importance of the anoxia is related to the production of most of the world's petroleum and natural gas reserves. Several geological and palaeontological studies and also diagnostic geochemical fingerprints such as trace element abundances, organic geochemical markers, or various isotope records show evidence of OAE's. A number of OAE's are recorded from the Mesozoic successions exposed in different parts of India.OAE 1b, OAE 1d, OAE 2, and OAE 3 are recorded from the various formations (Terani Formation, Karai Shale Formation, and Dalmaipuram Formation) of the Cauvery Basin. A record of OAE 2 in the Chikkim Formation and preliminary evidence of OAE 1a from the Giumal Formation, Spiti Valley are present. Also, a possible Late Jurassic Oceanic Anoxia from the Jhuran Formation (Kachchh Basin) is indicated. Currently, there are several places on the Earth are showing similar anoxic conditions on a localized scale known as "dead zones" like the "Black sea" in the Mediterranean. Several studies on OAE's would help us in understanding the mechanism behind the ancient and modern OAE's. Also, information about the regions susceptible to the development of the anoxic condition in the future.

Post-LGM extreme flood record and provenance of Upper Indus River, Ladakh.

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After the Last Glacial Maximum (LGM), the recurrence of catastrophic flood events increases due to melting of several ice sheets and rise in temperature. Floods with discharge higher than a million cubic meters per second known as megafloods were documented globally in this time frame. The Himalaya is no exception that recorded extreme floods after LGM where megafloods were well documented in its eastern part. Few studies were done at the Western Himalayan Region where the records are still blurry to constrain its genesis. So we studied the extreme flood history of the Upper Indus River in Ladakh using slack water deposits (SWDs). SWDs are composed of stacks of sand-silt couplets deposited instantaneously during high flooding events in areas where a sharp reduction of flow velocity is encountered by local obstructions. Each couplet represents a flooding event constrained using Optically Stimulated Luminescence (OSL) of sand and AMS ^{14}C for charcoal specks from hearths layers. The study suggests occurrence of large floods during phases of strengthened ISM when monsoon might have penetrated into drier Ladakh. Detrital zircon provenance analysis of flood sediments indicates that sediment transportation along the Zanskar River is more efficient than in the main Indus channel. The hearth layers found within SWDs represents cultural signatures from which relationship between anthropogenic activity and flood is analyzed in context of post LGM human migration.

A Transformative Perspective on early Eocene Climate change of northern western India based on megaremains evidences.

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The earth has experienced multiple climatic transitions from cooling in Jurassic to gradual increase in temperature in cretaceous. The Paleogene witnessed the increase in temperature and concentration of carbon which enormously increases during the Eocene. The early Eocene had begun with much warmer, hot and humid climatic conditions with increase in concentration of CO_2. This resulted into the increased humidity which created a moist, wetter and humid environment and paved the way for the development of evergreen tropical forests in the tropics. The equatorial position (~10°) of the Indian subcontinent during the depositional period favored the growth of the luxuriant tropical evergreen forests. The Plaeogene plant megafossil assemblages of north western India depict a clear picture of climate dynamics of the Indian subcontinent and biotic exchange between the neighboring countries. Plant megafossil assemblages from the Gurha liginite mine (Early Eocene age) of northern western India were analyzed to reconstruct the climate of the early Paleogene. This is an open cast lignite mine exposed at Bikaner in the Bikaner-Nagaur basin (Rajasthan, western India). Based on the nearest living relatives (NLRs), it has been concluded that a highly diversified tropical evergreen forest was present in and around the Bikaner-Nagaur basin of western India. The modern analogs of the described fossils from most of the early Paleogene localities are mostly evergreen and native to wet humid climatic regions which show the presence of similar climate in during the Paleogene. Most of the NLRs described from the early Eocene exposure are not found in the area today and their extinction can be related to the further movement of the Indian subcontinent from south of equator to the north consequently accounts for the change in the climatic conditions.

Signatures of Mid-Miocene Climate Optimum from Kerala Basin, India: based on palynological records

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The sedimentary successions of Kerala Basin are the only onshore opportunity to study Neogene palaeoclimate of southwest India. Among the climatic events of the Neogene, MMCO (Mid-Miocene Climate Optimum) occurred around ~17-15Ma. It is considered to be the most recent extreme global warming episode. The global warming during MMCO, created annual surface temperature 3-4° C higher than the present and nearly equivalent to the warming predicted for the next century. Later to this event, the earth's climate experienced a gradual cooling with the increasing global ice volumes at the poles giving rise to modern world. Appraisal of such warming events particularly in the lower latitudes is perplexing. Palynological study is one of the most useful technique to reconstruct marginal marine and terrestrial climate change as climate directly governs the vegetation types in any given area.

In Malabar Super Group of Kerala Basin, Neogene sequence consists of Warkalli and Quilon Formation. For palynological studies, seven sediment samples have been processed from the 1.5 m exposure of Quilon Formation at Padappakara section near Ashtamudi Kayal in Kollam district. The assemblage consists of diverse and well-preserved terrestrial as well as marine components. The age-diagnostic assemblage of dinocysts recovered from Padapakkara succession includes *Cordosphaeridium cantharellus, Hystrichokolpoma cinctum* and *Distatodinium paradoxum*, dated the succession not younger than Burdigalian age. In addition, based on the presence of calcareous nannofossils such as *Rhabdosphaera clavigera*, *Sphenolithus disbelemnos* and Zonal marker *Sphenolithus belemnos* suggests NN3 of Burdigalian age (middle Miocene; 19.0-17.95 Ma).

The dominant palynomorphs present belongs to genera- *Palmaepollenites, Margocolporites, Dipterocarpuspollenites, Spinizonocolpites, Lakiapollis, Quilonipollenites, Warkallipollenites, Ctenolophonidites, Polyporina, Malvacearumpollis, Alangiopollis, Verrutriporites, Triporopollenites, Clavaperiporites, Retistephanocolpites, Proteacidites, Chenopodipollis.* Dominance of pollen belonging to typical rain forest family such as Ctenolophonaceae (*Retistephanocolpites* and *Ctenolophonidites*), Dipterocarpacaeae (Dipterocarpuspollenites sp.), Bombacaceae (*Lakiapollis* sp., *Dermatobrevicolporites* sp. and *Tricolporopollis* sp.) and Oleaceae (*Retitrescolpites*) indicate warm and humid climate at that time, receiving heavy rainfall throughout the year, unlike the modern climate of Kerala Basin is characterized by heavy precipitation in summer months and 3-7 dry months in winter season. Interestingly, a few families such as Ctenolophonacaea now extinct in India, were prevailing and diversified during extreme humid Miocene period. Overall palynological data from studied succession has provided vegetation scenario and corresponding climatic signatures of the Mid Miocene warming in south-western tropical region of India.

Plant fossils from the Bhadasar Formation of Jaisalmer Basin, Rajasthan, Western India: paleoclimatic interpretation

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The Jaisalmer basin is an integral part of the major tectonic province and is located in the west of Aravalli ranges. The Mesozoic succession of Jaisalmer basin has been divided into Lathi, Jaisalmer, Bhadasar, Pariwar and Habur Formation in ascending order. The rocks of Bhadasar Formation characterized by ferruginous sandstone with intercalations of thin beds of clay, siltstone, shale. Bhadasar Formation shows a gradation of marine to continental from bottom to top and is subdivided by Dasgupta, 1975 into two members such as lower Kolar Dungar Member (marine) and upper Mokal Member (non-marine). This formation represents variety of corals, Nautiloidea and Ammonoidea. The present study deals with the occurrence of plant fossils from Mokal member of Bhadasar Formation. Fronds of *Ptilophyllum* and *Pachypteris* is recovered from the Mokal Nala section situated about 1 km north of the Bhadasar ridge section. This section comprises of a thick sequence of variegated shale. Mokal member is typically exposed around Mokal Village and consists of brown hard, jointed, argillaceous sandstone with fossils wood, fish teeth and fragments of broken, reworked ammonites, gastropods, bivalve etc. However, wood fossils (Verma, 1982) and pollen assemblage (Mathur and Mathur, 1966) have been recorded from the Bhadasar Formation but plant fossils have not been reported so far. Overall evidence, when considered in totality, indicates that there must have thick plant vegetation during the Tithonian – Niocomian period in contrast to present-day desertic conditions Jaisalmer Basin.

Late Oligocene–Miocene climate and vegetation of northeast India: megafossil evidences

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Northeast India (NEI) envelops a vital biodiversity hot spot and receives the highest rainfall in the world. This region gets a major portion of rains during the summer monsoon season. However, the area also receives a significant amount of rain during the pre-monsoon season. After the collision and complete suturing of the Indian and Eurasian plates, NEI serves a corridor for the exchange of biota from Southeast Asia to the Indian subcontinent and vice-versa. The late Oligocene–Miocene plant megafossils have been recorded in the form of fossil leaves, wood, fruits, and seeds. The important plant families such as Thelypteridaceae, Pinaceae, Podocarpaceae, Arecaceae, Poaceae, Anacardiaceae, Annonaceae, Apocynaceae, Bombacaceae, Burseraceae, Calophyllaceae, Celastraceae, Clusiaceae, Combretaceae, Dipterocarpaceae, Ebebanaceae, Elaeocarpaceae, Euphorbiaceae, Fabaceae, Lauraceae, Lythraceae, Moraceae, Myristicaceae, Rhizophoraceae, Phyllanthaceae, Rhamnaceae, Rubiaceae, Salicaceae, Sapindaceae and Sapotaceae have been recorded from various localities of the Oligocene and Miocene sediments of NEI. The quantitative estimation of late Oligocene–Miocene climate has been done by using Coexistence Approach (CA) and Climate Leaf Analysis Multivariate Program (CLAMP). Both these methodologies are independent of each other in paleoclimate reconstruction. The CA is based on the philosophy of nearest living relative (NLR) approach which assumes that the plants that are growing in the modern world have similar climatic adaptations in the geological past. The CA can be done on any fossil assemblage having leaves, flowers, fruits, seeds, pollen, and wood. The CLAMP utilizes leaf morphological traits in palaeoclimate reconstruction and is based on the relationship between leaf physiognomy and climate. It is applicable to the leaf assemblages from the Cretaceous onwards. The CA analysis on the Miocene assemblage revealed that pre-monsoon rainfall was present in NEI since the late Miocene. The CLAMP analysis on the late Oligocene and Miocene assemblages indicates that a tropical warm and humid climate was present there during the period. The CLAMP study also suggests a monsoonal climate in NEI since the late Oligocene.

Modern pollen analogue from the Majuli Island (ramsar site) of Assam: implications to decipher the palaeoecology and palaeoflood episodes in northeast India

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The present communication is the preliminary study from any Indian wetland, where palynological data is assessed to understand the flooding histories of the Sakali and Duboi wetlands in the Majuli River Island, a part of the Indo-Burma hotspot (world largest river island). Palynological analyses of surface soil samples from these wetlands were carried out in order to explore the ecology and signature of recent flooding from this island. The occurrence of scattered tropical mixed deciduous forest was evident from the pollen records of both the wetlands. The presence of extra-local taxa such as *Rhododendron*, *Tsuga* and *Castanopsis*, in the Sakali wetland is strongly suggestive of river water transportation and flooding on the Majuli Island in the recent past. In contrast, dominance of local arboreal taxa and low abundance or absence of extra-local pollen taxa in the Duboi wetland does not indicate flooding. Correspondence analysis (CA) was applied on the present dataset to reveal possible correlations between the surface samples of the wetlands and the major group of palynotaxa. The CA successfully discriminated the samples from the two wetlands and also marked strong correlations between flood indicators extra-local taxa with the samples of the Sakali wetland and local arboreal elements with the Duboi samples. The present result will not only provide a baseline for the palaeovegetation and palaeoclimate reconstructions, but will also help in deciphering the palaeoflood episodes from these wetlands.

The Kashmir Loess record and its significance for reconstruction of Middle to Late Pleistocene climate change in north-Western Himalaya, India

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The Kashmir Loess represents the most significant terrestrial proxy record of Quaternary climatic history in north-western part of Himalaya. Loess is extensive in south-western part of the Kashmir valley. Palaeoenvironmental multi-proxy data (micromorphological, lithological and SEM) from high-resolution loess-palaeosol sections provide evidences for a subtle climatic change in this part of the Himalaya during Middle to Late Pleistocene. The pedological observations revealed that these paleosols are weak to moderately developed representing cold arid to warm semi-arid climatic conditions. Evidence for periodic atmospheric shifts is provided by degree of pedogenesis in different loess-paleosols profiles. It also revealed that the loess deposits of Kashmir Valley formed syndepositionally when both loess deposition and pedogenic processes were coeval. However, balance between the rate of sedimentation and rate of pedogenesis changed in a cyclic pattern. Four periods of relatively warm conditions occurred in the Kashmir Valley. However, this rule out sharp glacial or interglacial conditions during the development of these loess- paleosol sequences. The occurrence of the relatively higher sediment accumulation rates in stadial stages and depressions during interstadial stage indicates that the aeolian dust deposition followed the pedogenesis during which paleosols were formed. The upper most loess horizon in the valley probably represent the last glacial maximum (LGM) in Kashmir valley and the Last Glacial was interrupted by arid and warm semi-arid intervals.

Centennial scale teleconnection between the Indian Summer Monsoon and the North Atlantic Region during the last two millennia

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The last two millennia showed to have had periods with sea surface temperature (SST) ~1 ºC warmer and cooler than present in Europe and surrounding regions (i.e. North Atlantic Region, NAR), which are well known as "Medieval Climatic Anomaly (MCA)". Several studies have also discussed the millennial scale synchronization between the strength of the Indian Summer Monsoon (ISM) and the NAR events. The key question which needs to be debated is, how synchronous are these abrupt climatic variations occurring in the North Atlantic Region with that of the Indian Summer Monsoon? In order to assess this, we studied a shallow core from the Gulf of Kachchh coast (~palaeomudflats) which span last two millennia (~ based on AMS ^{14}C). Based on a multiproxy investigation of monsoon responsive proxies (Environmental magnetism, organic carbon and geochemical analysis), we documented the signatures of Roman Warm Period, Cold Dark Ages and the Medieval Warm Period. We compare our record with regional as well as global MCA records and are of the opinion that the ISM also exhibits centennial scale correlation with the NAR events most likely driven by the atmospheric circulation.

Evolution of glacial landforms in ISM dominated eastern Himalaya: Review study from Sikkim, India, emphasising climate change

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Geological exploration in and around eastern Himalaya started nearly two centuries ago, when humans started to learn about the importance of geomorphology in daily life. Since then various expeditions have been carried out to ascertain different aspects of mighty Himalaya. Now with the changing climate we have to emphasize our efforts towards mitigating its adverse effects.

Tectonically Himalaya can be broadly divided into three zones. Each zone has individual upliftment characteristics. Prolonged upliftment of higher Himalayan sequence caused river dominated landforms to get altered by glacial activity. Whereas in central and lesser Himalaya fluvial action is more dominating force in geomorphic evolution. Availability of agents, steeper gradient and less vegetation in the northern part of Sikkim leads to high erosion of landforms. Whereas in the central and southern part erosion is substantially low. This further creates a denudation gradient from north to south.

In fault dissected Sikkim Himalaya, the southern slope is steeper than the northern slope. From south to north the average height of Himalaya is also increasing. This differential elevation is the main reason behind differential distribution of Indian Summer Monsoon (ISM). Along with orographic precipitation of ISM winter precipitation at different altitudes feed eastern Himalayan glaciers. In the northern part of these ranges (higher Himalaya) where very little precipitation occurs, rivers are formed by deglaciation. In central and lesser Himalaya rivers are fed by deglaciation as well as surface runoff caused by precipitation.

In geological history, climate change has an insignificant role in geomorphic evolution. But millennial erosion is controlled by precipitation. Climate change plays a huge role in energy resourcing of geological agents. Warmer climate leads to rapid deglaciation and downslope movement of the glaciers. In a deglaciating valley evolution of geomorphology mainly controlled by paraglacial processes. Correlating the lateral and terminal moraines one could easily get an idea of previous glacial extents. Whereas recessional moraines depict the melting of glaciers. Recent geochemical studies and moraine stratigraphy confirms that the last quaternary glacial maxima over the eastern Himalaya was patchy. Terminal moraines a few kilometres ahead of present day glacier snout also help us to calculate retreat rate of glaciers.

Glacial landforms, especially those formed by deglaciation readily react to climate change. The more the glacier shrinks the more the glacial lake gets bigger, after a certain time two different lakes get adjoined and produce bigger moraine dam lakes. Continuous anthropological modifications like deforestation, construction lead to landslides in southern Sikkim which further alters the natural geomorphology of the area.

Enamel Isotope Data from the Domesticated Animals at Kotada Bhadli, Gujarat, Reveals Specialized Animal Husbandry During the Indus Age

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During the Urban/Mature phase (2600-1900 BCE) of the Indus Civilization, Gujarat was occupied by two types of settlements, the settlements with predominantly Classical Harappan traits and the settlements with predominantly Sorath traits. Most reconstructions of the data conclude that the settlements with Classical Harappan traits in Gujarat were engaged in the production and trade of non-perishable Harappan-style goods, while the settlements with Sorath traits focused on agro-pastoralism. To date, no major attempt has been made to understand the nature of the agro-pastoralism practiced in these Sorath settlements. This pilot study based on the oxygen and carbon isotope data from cattle/buffalo, sheep, and goat/sheep teeth from the Sorath settlement of Kotada Bhadli (2300-1950 BCE) suggests that this settlement was indeed engaged in specialized seasonal herding of the domesticated animals. Comparing these data with published data on cattle/buffalo, sheep and goat from the nearby Harappan settlement of Bagasra indicates that a distinct form of sedentary animal husbandry was practiced at the site of Kotada Bhadli, the nature of which is considerably different from that practiced at the permanent settlement of Bagasra. At Kotada Bhadli both wild flora and agricultural waste were utilized as fodder, depending on their seasonal availability. Such seasonal availability, and the diversification of fodder selection may suggest a regional adaptation to the local climate by the agro-pastoralists during the Late Mature phase (2300-1900 BCE) of the Indus Civilization. The strontium isotopes from the tooth enamel suggest the domesticates consumed at Kotada Bhadli were most likely raised locally, with a grazing catchment not extending far from the settlement. The results also suggest that at least in Gujarat during the Mature phase of the Indus Civilization, carbon isotope values along with tooth morphology might be used to distinguish between sheep and goats, due to human practices involving the deliberate use of millets as fodder for sheep but much less so for goats.

Late Quaternary variations in Indian Summer Monsoon inferred from the morphotypes of *Globigerionides ruber* (white) from the NE Indian Ocean

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Globigerinoides ruber (white), a tropical to sub-tropical planktic foraminiferal species which dwells in the mixed layer, has garnered significant attention for palaeoceanographic investigations. Recent studies on *G. ruber* (w) morphotypes (*G. ruber* sensu stricto (s.s.) and *G. ruber* sensu lato (s.l.)) have inferred differences in seasonal calcification depths and offsets in isotopic and elemental data. To decipher if the morphotype abundances vary in response to changes in Indian Summer Monsoon (ISM), two well-dated sediment cores from the Andaman Sea, a core monsoon area in the Northeastern Indian Ocean, are investigated. The abundance variations of *G. ruber* s.s in this study are very similar to total *G. ruber* (w), whereas *G. ruber* s.l. is found to be very sensitive to the hydrologic changes linked to the ISM variability. Increased abundances of *G. ruber* s.l. were witnessed during periods of weak stratification and deepened mixed layer. The last glacial maximum (LGM), deglacial, Younger Dryas (YD) and late Holocene (4.2 to 1.5 cal ka BP) periods with weak ISM are characterized by a high abundance of *G. ruber* s.l. Conversely, this morphotype abundance decreased from 30 to 23 cal ka BP, Bølling/Allerød (B/A), early and mid-Holocene when the ISM was enhanced. The elevated abundances of this morphotype during the glacial period in the Andaman Sea closely match with the available records from other regions, possibly making them climatic markers. This study, suggests that isotopic and geochemical analyses should preferably be carried on a single morphotype over that on a non-selective mixture for reconstructing past ISM.

Stable C and N isotopes of carbonized seeds/ soil-sediments to gauge hydrological status and manuring practices during Indus urbanism

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Agriculture has a major role in influencing landscapes, soils, vegetation and subsistence since its inception. Though agriculture is a human effort but, it has intimate link(s) with contemporary environment. Charred seeds recovered from archaeological excavations reveal wealthy information about past agricultural practices. Likewise, stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes of charred seeds obtained from different cultural deposits of an archaeological site along with the host soil-sediments can provide important clues about the hydrological status of agri-fields and manuring practices. Utilizing $\delta^{13}C$ values of charred crop-remains, 'carbon isotope discrimination factor' ($\Delta^{13}C$) could also be computed and used to compare past hydrological conditions with other contemporary data as well as modern analogues. As habitational layers of the archaeological sites are mainly composed of soil-sediments of nearby arable landscapes, $\delta^{13}C_{SoilOrganicMatter}$ values also could be used to gauge environmental conditions. In addition, quantity of water consumed by crops could also be assessed by evaluating 'intrinsic water-use efficiency (WUEi)'of the seeds which has significant link to contemporary atmospheric CO_2 concentrations. In addition to watering, manuring of agri-fields is another important human effort employed to enhance agricultural productivity. $\delta^{15}N_{soil\text{-}sediment}$ and $\delta^{15}N_{seed}$ values could be utilized to assess past manuring practices and agricultural intensifications. The dataset from Indus (Harappan) archaeological sites of western Rajasthan and Gujarat have been generated. A brief overview of combined results of stable isotopic studies and macro-botanical data from these archaeological sites will be presented to draw inferences on past ecological status and human efforts in prevailing climate.

Using geochemical tracers for paleoenvironmental reconstruction from tropical montane peat, Nilgiris, India

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Mineral dust, especially from the Middle-East, has been known to affect monsoon circulation in India, a country whose economy is heavily contingent on the timely arrival of the monsoon. Reconstruction of dust circulation in the past and its relationship to the monsoon has never been attempted in India although inorganic geochemical proxies from peat have been used in various parts of the world. Finding a suitable peat archive to use inorganic geochemical proxies in the largely tropical and sub-tropical Indian environments is a challenge but the Sandynallah montane peat formation in the Nilgiris, southern India, offers such an opportunity. The peat accumulation here is one of the oldest in the world (>50 ka) and has been shown to record climatic and vegetation changes of at least 30,000 yrs of the past. We explored the usefulness of inorganic geochemical proxies for the first time here to reconstruct dust circulation. Inorganic geochemical analysis was carried out on acid digested peat samples analyzed using Inductively Coupled Plasma-Mass Spectrometry and Optical Emission Spectroscopy at EcoLab, Toulouse. We see that the major (e.g., Al, Fe, Mn, K, Na, Mg, Ca) and commonly used trace (Cu, Zn, Pb) elements do not show many significant trends for paleoenvironmental interpretation. Preliminary analyses indicate that lithogenic elements Ti and Zr are stable through time and in good agreement with each other. In this study, we used scaled Rare Earth Element (REE) concentrations and Zr as a reference to calculate enrichment factors (REE EFs) and found that the Lanthanide series showed promise for identifying potential sources of atmospheric dust and weathered material. We specifically looked at depths of exceptional enrichment of REE and see that they correspond to known periods of global climatic shifts. We find strong enrichments in some sections of the last glacial (the strongest enrichment is observed at ~30 ka), indicative of environmental conditions that supported increased dust input, possibly related to the higher dust circulations in the glacial periods as evidenced by ice core studies. We propose that the lanthanide group could be established as a useful proxy even in the tropics for atmospheric dust circulation of the past and this requires careful analyses of the various components of peat and records from various parts of the subcontinent.

A high-resolution record of past environmental variations during the mid-holocene from an east antarctic lake

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There is a dearth of high-resolution records of environmental changes during the Holocene in Schirmacher Oasis, East Antarctica. In this study, we present and discuss the environmental magnetic properties of a 94 cm long sediment core obtained from a land-locked lake (Lake L6) in Schirmacher Oasis. Magnetic measurements were made on the samples and inter-parametric ratios were calculated. The data provides information on the abundance and type of magnetic minerals and their grain size.

Magnetic susceptibility (χ_{lf}) is a measure of the total concentration of the iron oxide minerals present in the samples. The χ_{lf} values vary from a minimum value of $20.44\times10^{-8}m^3kg^{-1}$ to a maximum of $390.11\times10^{-8}m^3kg^{-1}$ with an average (± s.d.) value of 95.49 (±66.67) $\times10^{-8}m^3kg^{-1}$. The moderate to high values of χ_{lf} suggests a high concentration of iron oxides. The parameter χ_{ARM} is indicative of the proportion of stable single domain (SSD) grains in the samples. The Lake L-6 sediments show a mean (±s.d.) value of around 22.9 (±35.58) $\times10^{-8}m^3kg^{-1}$. A statistically significant correlation is observed between χ_{lf} and χ_{ARM} (R^2=0.654 p<0.0001) indicating a strong control of SSD grains on the magnetic susceptibility. The SIRM values reflect the concentrations of all the remanence carrying ferrimagnetic minerals. Our samples show SIRM values ranging from a minimum 7.25×10^{-5} Am^2kg^{-1} and a maximum of 509.76×10^{-5} Am^2kg^{-1} with a mean (±s.d.) of 41.04 (±65.2) $\times10^{-5}$ Am^2kg^{-1}. The parameters χ_{lf} and SIRM show significant correlation (R^2=0.746, p<0.0001) indicating significant proportion of ferrimagnetic grains in the samples. The S-ratio values for our samples vary between 0.92 and 0.98 reflecting the predominance of magnetically soft minerals like magnetite/titanomagnetite. From the IRM acquisition curves, it is clear that most of the samples saturate at fields < 300 mT, suggesting that the dominant remanence carrier may be magnetite/titanomagnetite. The HIRM values remain relatively low indicating insignificant contributions from magnetically hard minerals such as hematite/goethite. The L-ratio values remain fairly constant varying between 1 and 1.2 and show no significant correlation with HIRM, giving validity to the traditional interpretation of S-ratio and HIRM. Our samples have χ_{ARM}/SIRM values of 65.30×10^{-5} mA^{-1} on an average with the values remaining well below 200×10^{-5} mA^{-1}, the threshold for bacterial magnetite. χ_{ARM}/χ_{lf} values remain low for all the samples with a maximum value of 1.92 reflecting coarser magnetic grain sizes. Also, it exhibits a good correlation with χ_{ARM}/SIRM (R^2=0.572, p<0.0001). The inter-parametric ratio, IRM_{20mT}/ARM ranges from 2.3 to 40.33 indicating mixed assemblages of SSD and MD grains. The preliminary data shows several peaks in the χ_{lf} data suggesting colder climatic conditions in the Schirmacher Oasis which would have led to more pronounced physical weathering in the Lake L-6 catchment. Periods representing low χ_{lf} values relate to warmer climate which would have accentuated the chemical weathering thus producing fine-grained magnetite (SSD grains). The data is of high significance as important climate events which occurred during the mid- to late-Holocene such as the mid-Holocene Hypsithermal, Neoglaciation, Medieval Warm Period and the Little Ice Age can be resolved.

Quaternary climate: A case study on Alluvium Geochemistry from Tawa Basin, Hoshangabad district Madhya Pradesh

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The evolution of earth and its environment is a continuous and ongoing process and are well documented within the components of terrestrial and aquatic ecosystems. The quaternary riverine sediments is one of the robust indicator for the study of gradational environmental variation. In the present study an attempt is made for understanding the quaternary climatic variation using the geochemistry of Narmada Alluvium from Tawa basin, Hoshagabad District, Madhya Pradesh. The study area is bounded by latitude 22°30' to 22° 45' and longitude 77°45' to 78° 00'. The elevation within the study area ranges from 314m to 228m with the over all slope towards northwest. The representative stream sediment samples were collected from the 1st or 2nd order streams within the study area, in a systematic grid pattern and were analyzed for major and trace elements by XRF and ICPMS method at Chemical Lab, GSI Nagpur. Lithologically the five distinct formations of Alluvium are exposed; these are Pilikankar, Surajkund, Baneta, Hirdepur and Ramnagar Formation. The fluvial, erosional and structural morphological units are present and the stream sediments were grouped as per the geomprohological units, i.e. Piedmont Slope, Pediplain, Older Flood plain and Younger Flood plain. The Chemical Index of Alteration (CIA) of the samples varies between 61.05 and 77.98 with an average of 72.83 and is comparable with the average CIA values for global shale. This reflects the presence of muscovite, illites and smectite within the Narmada Alluvium.

The smooth and co-linearity trends of major & trace elements, on Harker plots with Al_2O_3 / Zircon as differentiating index reflects that all belongs to single / related populations. The positive correlation of iron, manganese, magnesium with aluminum indicates predominance of clay minerals whereas the negative correlation of silica, titanium, sodium and phosphorus with aluminum indicates predominance of quartz, opaques and phosphate minerals (Monazite?). The distinct chemical characteristics of the alluvium form old and new flood plain suggests that the Holocene environmental fluctuation is well recorded in the form of elemental signatures within these sediments. The bivariate plots SiO_2 wt. % versus (Al_2O_3 + K_2O + Na_2O) wt. % (*Suttner and Dutta, 1986) indicates the* sequential transition in the depositional climatic from semi-arid to arid with the overlapping phases within the quaternary succession. The reduction in oxygen saturation over the time is further suggested by the Cu/Zn and V/Cr ratios. The visible compositional variation, within the alluvium from Older & Younger Flood Plain is attributed to chemical, mineralogical and textural maturity of the sediments from the same precursor. This elemental enrichment and transition is influenced by flow hydraulics and the environmental factors i.e. oxygen fugacity, humidity, CO_2 concentration, biological productivity.

Stable- and radio- isotopic measurements of faunal remains from archaeological sites: Implications to achieve absolute chronology and retrieve palaeo-environmental information

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Stable isotopes of light elements and radiocarbon based dating have extensively utilized by geoscientists for studying variety of earth-environmental processes occurring on different timescales up to late-Quaternary. Almost all palaeoclimate reconstructions, qualitative as well as quantitative have divulged potential of stable isotopes for decoding the 'process' and radio isotope for obtaining time information. Most of the good palaeoclimate reconstructions are from repositories where only integrated environmental signature is preserved, making it difficult to link the captured proxy imprint to a particular civilization. Archaeological excavations provide, in contrast, materials belonging to identifiable human cultures. Among commonly found material artefacts (pottery, coins, pots etc.), often faunal remains (bones and teeth) are found abundant belonging to contemporary human/ animal lives. A detailed isotopic investigation of their different fractions (enamel, dentine, and bone-collagen) not only provides a method to date it (using AMS ^{14}C dating) but also to assess palaeo-diets which are intimately linked to contemporary climate. Stable C, N and O isotopic analyses ($\delta^{13}C$, $\delta^{15}N$ and $\delta^{18}O$) of appropriate fractions of these faunal remains can provide important clues about palaeo- dietary patterns and palaeo-hydrology. We have recently measured these proxies in a few human as well as animal (herbivore) burial remains of central and northern India, a brief overview of combine results of stable isotopes and radiocarbon dating from these archaeological sites will be presented for an illustration purpose to draw inferences on past ecological status and climate.

Shell size variation of pteropod *Limacina inflata* as a proxy for Paleoceanography

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In order to better constrain the factors controlling the calcification rate in pteropods, and to assess shell size reliability as a calcification rate proxy, changes in shell size of *Limacina inflata*, one of the major subtropical cosmopolitan warm water epipelagic species have been studied in core samples from the Andaman Sea for the past 35 ka.Because of their shell chemistry, pteropods have been proposed as biological indicators of aragonite saturation of the seawater column. The results suggest that *L. inflata* calcification rate is mainly controlled by atmospheric CO_2 and water chemistry. Shell size is directly related to optimum growth conditions since larger shell size coincides with a more absolute abundance of this species due to optimum temperature conditions. Therefore, the pteropod shell size should be used carefully as an atmospheric CO_2 proxy. The surface water that is supersaturated with carbonate ions resulted in higher calcification rates to produce thicker shells. The calcification proxy complements with each of the dissolution proxies and reveals that the most intense aragonite dissolution happened during the Holocene period. The intense aragonite dissolution during interglacials could be due to undersaturation of CO_3^{2-} concentration in the bottom waters. Though there are secondary factors which trigger the dissolution of fragile aragonitic shells, the undersaturation of carbonate ions can be consider being the 'first order' factor to determine calcification rate and shell size.

Holocene climate anomaly of the Kashmir valley, Northwestern Himalayas

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The Holocene Epoch started at around 11700 yr BP marking the end of the Pleistocene Epoch. The Holocene Epoch is characterized by commencement of noticeable rapid deglaciation. However, cyclic dry/cold climate events tentatively linked to climate fluctuations due to North Atlantic ice rafting, known as Bond events have also been reported in Northern hemisphere during this Epoch. The Kashmir Valley is a subtropical area in Northwestern Himalayas, and its climate is dominantly influenced by westerly disturbance. We collected multiple sediment cores and excavated sediment trench on the margins of the Wular lake to study the Holocene paleoclimate and hydrological regime of the Wular lake. The chronology was formulated using AMS ^{14}C dating and we retrieved a complete Holocene sedimentation sequence. The sediment samples from all the sites are dominantly fine grain size indicating sediment deposition in usually calm and deeper water column. The multi-proxy analysis revealed phases of dry/cold climate from 10,800 to 10,200 yr BP, 8700 to 7700 yr BP, 6200 to 5700 yr BP, 4600 to 3750 yr BP, 3100 to 2750 yr BP, 2000 to 1800 yr BP, 500 to 350 yr BP. Our observations reveal that the Kashmir Valley has been profoundly influenced by westerly disturbance during the Holocene. Records of dry climate events reveal that, out of total nine Bond events reported, the lake sediments have endured signatures of the seven.

Holocene hydroclimate variability in the Bengal Basin: a lake archive record

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Lake sediments are one of the excellent archives for paleoclimatic studies. A 2 m deep sedimentary profile (c. 10.2 and 0.1 ka) dug out in a dried lake bed at Mahananda Sanctuary Forest, Upper Bengal Basin, West Bengal has been subjected to multiproxy analyses (non-pollen palynomorphs, phytoliths stable isotope, grain size and environmental magnetic properties) to understand the Holocene climate variability in the area. This study helps us to understand the trend of past climate changes and also throws light on the regional monsoonal variations since the early Holocene. The results showed that the area had experienced alternate stages of wet and dry phases since the last 10 ka. From the variability of both biotic and abiotic data it can be inferred that during 10.2 and 5.4 ka the climate prevailing was warm-humid under a strong monsoonal regime as suggested by the environmental magnetic data (high χ, low χARM and variable S-ratio) and low percentage of dry-loving algal cyst *Pseudoschizaea*. Whereas the phytolith data suggests that the region was inhabited by mixed C3/C4 moist loving grasses. This warm period could be related to the Holocene Climate Optimum (HCO) period. Between 4.3−3.8 ka, the climate was relatively drier as shown by the gradual increase in *Pseudoschizaea* and the sharp increase in sand percentages. This dry and cooler climate perhaps favoured the expansion of C3 pooid cold loving grasses as revealed by abundance of pooid grass indicator phytoliths in the assemblages and may be corresponding to the 4.2 ka event. Appearance of a cool-indicator fresh water alga *Pediastrum* during this phase is also in conformity with the fact. Between 3.8ka to 1.5 ka, the climate prevailed was wetter than the earlier phase with an increasing trend in monsoon precipitation. A significant decline in monsoonal strength has been observed after c. 2 ka which continued until 1 ka. This decline in monsoon strength might have supported the growth of considerable amount of C4 dry loving grasses in the region and also the water stress conditions shown by the higher value of a water-stress indicator phytolith index (i.e. Fs%), and abundance of dry loving *Pseudoschizaea* in this time span. Environmental magnetic data also shows a wet to dry transition phase between 2.1 ka to 1.4ka as suggested by the higher values of χlf, low χARM & S-ratio. Between 1ka–0.7ka, there was a gradual increase in the monsoon strength as indicated both by biotic and abiotic data. Surprisingly, despite the increase in monsoonal strength the lake started drying during this phase possibly due to the infilling of shallow lake by leaf litter (deduced by non-pollen palynomorph data) from the surrounding forest. Between 0.5–0.1ka, a warm and humid environment may be inferred by the dominance of warm-moist loving grass phytoliths, depletion in $\delta^{13}C$ value and the increase in χlf values.

Reconstructing Crop economy and based on archaeobotanical evidence and radiocarbon dates from Rithi Rajana: An Early Iron Age site in semi-arid Vidarbha, Maharashtra, India

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Here we present the results of macro-remains from Early Iron Age site Rithi Rajana, in the Vidarbha region of Maharashtra, India. Analysis of thirty-four floated samples indicates that the likely staple food grains were *Oryza sativa*, *Hordeum vulgare*, and *Triticum aestivum.* Besides, few minor crops (*Panicum* sp., *Paspalum* sp., *Echinochloa* sp., *Setaria* sp.), pulses (*Pisum sativum*, *Lathyrus sativus*, *Lens culunaris*, *Lablab purpureus*, *Cajanus cajan*, *Vigna* sp., *Macrotyloma* sp.) and oil/fibre yielding (*Linum* sp., *Gossypium* sp.) plants have been recorded. In addition, there is evidence for gathered fruits of *Carissa* sp., *Grewia* sp., *Ziziphus nummularia*, and *Emblica officinalis*, which may have been gathered by the ancient settlers for consumption. The macro-botanical finds indicate the presence of winter and summer crops. Few weeds and other wild taxa which turned up as an admixture with the above economically important remains were also retrieved. The AMS radiocarbon dates of the plant remains and recovered archaeological artifacts support the identification of cultural period at the site. The well dated charred macro-remains (cultivated, minor crops and few weeds) from Rithi Rajana uncover the founder elements of Chalcolithic subsistence in the region continued and existed in the crop economy of Early Iron Age settlers.

Quaternary sea level fluctuation along with sedimentation pattern of different sectors of north-eastern coast, India

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The Udaipur- Shankarpur - Junput coast is characterised by gently sloping intertidal zone. The width of Udaipur, Shankarpur and Junput beach is from 237m to 426m, from 224m to 376m and from 347m to 514m respectively. In Junput and Shankarpur coasts there are two units of sand dune namely neo dune and older dune whereas Udaipur coast is characterised by three sets of dune namely neo dune, older dune and older dune ridge. In Junput mean size of beach, neo dune and older dune sediments are 3.1φ to 3.6φ, 2.8φ to 3.6φ and 2.1φ to 2.7φ respectively. In Shankarpur mean size of beach and older dune sediments are 2.2φ to 3.2φ and 2.4φ to 2.9φ respectively. In Udaipur mean size of beach, neo dune, older dune and older dune ridge sediments are 3.0φ to 3.8φ, 3.2φ to 3.9φ, 2.4φ to 2.9φ and 2.1φ to 2.2φ respectively. The beaches are composed of very fine to fine sands. By comparing the low water line (LWL) over last 80 years it has been reflected that LWL has shifted in phases. Prior to the earlier data has indicated that there was a retreat of beach of 1050m from 1877 to 1968. Comparative study revealed that the shoreline gradually moves towards landward direction from 1932 onwards. Landward shifting of shoreline is higher in the eastern sector i.e. near Shankarpur coast compared to the western part i.e. Udaipur coast during the period from 1932 to 1972. Landward movement of LWL is about 1.5km during this time period in the eastern part whereas in the western part the shifting is up to about 1km. After that there was no as such change of the LWL in next 10 years. The study further shows that during 1982 to 2014 the landward shifting of shoreline is higher in the western sector i.e. at the near Udaipur region compared to the eastern part Shankarpur region. It is about 300m in Shankarpur coast whereas in the Udaipur coast the shifting is comparatively more up to about 500 m. These areas have experienced sector-wise erosion-accretion in different phases. Signatures of erosion are prominent by the presence of eroded tree stumps, clay balls. Due to erosion the pockets of sticky clayey zone have been exposed in the intertidal zone. But the clayey zone is covered by sandy materials through modern sedimentation by the action of wave and near shore current. Analyses of shoreline fluctuation map and field observation shows that presently the Udaipur and Shankarpur coasts are still undergoing erosion. Erosion in these coastal areas is mostly caused during high intensity events like storms and/or cyclones especially when their landfall coincides with the spring tides. As the area is influenced by meso- to macro-tidal environment, surges during monsoon or spring tide or storms inundates the vast low lying area. High amplitude waves for short duration might have removed beach materials and these eroded materials have been transported seaward leading to seasonal beach retreat.

Control of Sea Surface temperature on the isotopic composition of coastal precipitation

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Recent studies have revealed that the Indian Ocean is warming at a faster rate than the other oceans of the world. From 1901 to 2012, the summer mean sea surface temperature (SST) of the western Indian Ocean was increased by 1.2 °C. As a result, there has been an increase in the frequency of extreme weather events in the region, especially in the Arabian Sea. In this context, an attempt has been made in the present study to understand the influence of SST on the stable isotopic composition ($\delta^{18}O$ and D-excess) of Indian Summer Monsoon (ISM) precipitation in the coastal city of Mumbai. For this, the stable isotopic data ($\delta^{18}O$ and $\delta^{2}H$) of ISM precipitation available at the GNIP station, Mumbai (1961-1977), and those measured during 2018 were analysed along with the SST data obtained from NOAA satellite for 5° – 25°N/50°-77°E sector of the Arabian Sea during April to September. Furthermore, the isotopic values of ISM precipitation were also compared with those of an intense cyclonic event of 2017. The observations reveal that the SST in the Arabian Sea is increasing in the recent years and is found to be positively correlated with $\delta^{18}O$ (r=0.70) and D-excess (r=0.44) of the coastal precipitation indicating the influence of equilibrium and kinetic fractionation at the time of phase changes. Despite the high SST during the cyclone period, the $\delta^{18}O$ values of precipitation were found to be depleted; however, its D-excess values were high indicating prevalence of convective activities. This study is first of its kind and provides a better insight into the assessment of climate change and the genesis of extreme rainfall events

Understanding of the Himalayan monsoon system: Past to present

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Paleoclimate reconstructions have become an important focus in global climate research as it facilitates our understanding of the Earth's system feedbacks on time scales longer than a few decades/centuries. The Himalayas located north of the Indian subcontinent hold a key status in not only modulating the Asian climate system but also in sustaining the socio-economic activities of the region. Considerable efforts have been directed towards developing past monsoonal records from Himalayan region to improve our understanding of the Himalayan Climate System (HCS). Previous records have shown that small changes in the climate, including shifts in the regional precipitation and temperature patterns will have large consequences on the landscapes, Himalayan Rivers, glaciers and the regional livelihood as monsoonal precipitation is vital for sustaining the regional water stocks and supporting agriculture and rapidly growing economy. The synthesis of these records have mostly relied on lacustrine sediments, Quaternary aeolian outcrops, tree rings and ice core records. Additionally, instrumental records suggest that the region has experienced a steep decline in the monsoonal precipitation during the last few decades, which would generated socio-economic hardships under the present warming world. In the present research work, we seek to understand the variations/cyclicity in paleoclimate and sediment provenance changes using multiproxy records from aeolian loess and lacustrine geoarchives to better understand the Himalayan climate system. Several of these past climate records reveal near synchronous fluctuations (within dating uncertainties) with other regional and global palaeoclimate events. The results highlight the importance of studying Himalayan lake and loess/paleosol archives to constrain the driving forces modulating the Himalayan climate system.

Role of tectonic-climate interaction in formation of the terraces in the Chamba region, NW Himalaya

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The genesis of the Quaternary river terraces is generally controlled by the climate due to sediment supply and/or water discharge and tectonic upliftment. In an active mountain range like Himalaya, the formation of the river terraces are generally showing a close relation of the both climate as well as tectonic interaction. The valley-fill terraces with/without underlying thin bedrock are considered as a result of climatic episodes, whereas the thin alluvial cover over a thick bedrock represents a tectonic control for the formation of the strath terraces. The study area Chamba lies between the Pir Panjal range to the north and the Dhauladhar range to the south. Two major thrusts, MBT and MCT are located at the southern basal margin of Dhauladhar range. The Ravi river flows largely E-W, SE-NW and SW directions in a narrow gorge. However the river gorge broadens to form a wide valley in SE-NW direction between Rakh and Kiyani including the Chamba town. In the narrow gorge, no Quaternary terraces are preserved, whereas 18 km long and upto 3 km wide wider segments of the river valley i.e in Chamba basin, the Quaternary deposits are very well preserved in the form of river terraces and fan deposits. The Chamba basin was evolved as a pull-apart basin. A E-W trending strike slip fault jumped right laterally and formed NW-SE oriented Chamba basin. Pull apart basins are formed as a result of strike slip motion along the bend-segment of the fault. There are eight levels of terraces preserved along the Ravi river in the Chamba area. The aggradation of terraces occurred in two major stages: 72.5─46.4 ka and 38.8─22.7 ka; followed by incision phases between <22.7─7.4 ka. The first phase (72.5─46.4 ka) of aggradation was regional and occurred in a pre-existing river valley whereas the later phases (38.8 ka onward) occurred as cut-and-fill and degradded terraces. The formation of pull apart basin was tectonically induced whereas the aggradation-incision of terraces deposits were mainly climatically induced.

The role of the orbital parameters in the Indian monsoon during the Mid-Holocene, as deciphered from atmospheric model experiments

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Proxy, and modelling-based studies show that the Indian summer monsoon (ISM) varied on multiple time scales. In this study, by applying the PMIP3/CMIP5 boundary conditions on the CESM1 atmospheric general circulation model, we carried-out multiple ensemble AGCM simulations for the Mid-Holocene (MH; ≈ 6 kyr BP), Medieval Warm Period (MWP; ≈ 1 kyr BP), Little Ice Age (LIA; ≈ 0.35 kyr BP), and Historical (HS; ≈ CE 2000) periods. These simulations ascertain claims from the proxy studies that during the MH ISM was stronger compared to HS. The experiments also indicate that the MWP received higher ISM rainfall (ISMR) relative to the LIA. Our model studies suggest that these slow changes in the ISMR, and associated large scale circulation changes, result from changing incoming solar insolation induced by changes in the orbital parameters.

Role of solar insolation and high latitude climate in Indian summer monsoon variability since MIS3

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Important socio-economic changes and shaped different human history phases during the late Quaternary in the Indian subcontinent. Understanding monsoon-societal linkages are one key area of interest for paleoclimate workers. We present a new high-resolution speleothem-record of Indian summer monsoon (ISM) variability ranging from ~ 45,000 to 34,000 yr B.P. combined with a published record up to 5,500 yr B.P. from Mawmluh cave, northeastern India. Statistical analysis of the $\delta^{18}O$ time series reveals the dominant cyclicity of 2745, 1647, 135, 88, 68, and 45 yrs from 45000 to 33400 B.P. The 135, 88, 68, and 45 yr cycles have earlier been documented in the Holocene records from the Indian subcontinent, demonstrating the role of solar insolation in modulating ISM intensity on multidecadal to centennial time scale during the last glacial period. Our new δ18O time series shows high-frequency shifts in the ISM during MIS 3, similar to Dansgaard-Oeschger (D-O) oscillations recorded at high northern latitudes, which mimick the Greenland ice sheet record. These findings suggest that the insolation and Northern Hemisphere high latitude climate anomalies played an active role in driving ISM variability and changes in the regional hydrological cycle on centennial to millennial time scales.

Heatwave driven atmospheric Carbon dioxide variability over India perceived by satellite and surface measurements

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Terrestrial biosphere plays a pivotal role in removing carbon from the atmosphere. The removal processes are largely affected by heatwaves in the atmosphere. A little information is available on the response of carbon removal by the terrestrial biosphere during the occurrence of heatwaves over India. It is due to the limited observations of continuous surface flux and atmospheric CO_2 measurements in

India. India witnessed the occurrence of frequent heatwaves in the recent past and there is a potential of increased frequency in the future. The recent year 2015 was one such year to witness the intense and longer spells of heatwaves occurrence over India, resulting in the loss of more than two thousand human lives. In the climate perspective, here in this study, we used surface CO_2 flux and satellite retrieved CO_2 concentrations to understand atmospheric CO_2 variability and its transport patterns during the heatwave and non-heatwave conditions over Indian region. Moderate intensification of temperature seems to have increased the atmopshere-biosphere CO2 fluxes (carbon sink). But further intensification such as observed during heatwaves, makes the ecosystem a source to atmopshere. The heatwave period of year 2015 is analyzed in this study. The satellite observed atmospheric CO_2 concentration is observed to be elevated by 2 to 3 ppm during the heatwave conditions in India. This is examined using surface CO_2 flux or Net Ecosystem Exchange observations from MetFlux India Project funded by Ministry of Earth Sciences, Atmospheric Infrared Sounder and Orbitting Carbon Observatory-2 satellites retrieved atmospheric CO_2 concentrations, and ECMWF Re-Analysis interim meteorological parameters such as surface temperature and winds during heatwave conditions over India. Analysis is also extended to study anomalous circulation patterns, which may have been responsible for changes in CO_2 concentrations over the country. In a changing climate scenario, where the intensity and frequency of heatwaves are projected to increase, it becomes vital to understand the response of biosphere in the presence of heatwaves as this might affect the carbon sequestration capacity of the biospheric sink processes which are a key component in absorbing the global anthropogenic and natural CO2 emissions. The impact of heatwaves on the biospheric component of the carbon cycle is one of the major outcomes of this study.

Role of Atmospheric Wind Pattern in Extreme Weather Condition

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The Atmosphere plays a major role in the Earth's climate condition. Extreme weather condition has been observed in each year as summer and winter having long and extreme, rainfall having less frequent with high quantity and less snowfall in higher altitude. Indian continent has a unique position compared to global wind circulation. Hedley cell winds were getting cold at 30° N latitude and Ferrell cell wind getting hot/ loosed their cold near the 30° N latitude and back to North pole, but Himalayan mountain obstructed the Ferrell cell winds and save India from polar winds. Wind circulation pattern depends on Earth tilting, rotation, atmospheric composition and thickness. Due to emission of high amount of greenhouse gases from last 50 years, Earth albedo affected the vertical height of the atmosphere troposphere and shifted the wind pattern. We are observing that cold desert of Himalaya is getting vegetation cover and variation in permanent snow line. Event of Meteorological disaster has increased rapidly. All these events are affected by atmospheric wind circulation at regional and local level. For better understanding of extreme weather pattern, we have to monitor the change in atmospheric wind circulation and anthropogenic factors for the local weather condition.

Assessment of agricultural drought using rainfall deviation at district level for Tamil Nadu, India

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This study is concentrated during the major rainfall season of Tamil Nadu during northeast monsoon (October – December) for the period of 2016 (as extremely drought year) at district level using rainfall departure indicator with rain gauge data to assess the drought due to the climate change variations. The analysis showed that 12, 3 and 15 districts were identified under moderate condition whereas 20, 29 and 5 districts were severe drought condition during October, November and December 2016.

Characteristics of Aerosol Optical depth (AOD) using satellite approach over Surat

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Aerosol Optical Depth (AOD) observed at Surat, Gujarat (INDIA), Coastal region near the Tapi River at the Gulf of Khambhat. Using MODIS Satellite data for Aerosol Optical Depth (AOD) have been collected from the Giovanni site (http://giovanni.gsfc.nasa.gov/giovanni/) developed by NASA. Results of the data for the 5-year period (January to December 2015-2019) have been discussed here. Seasonal variations of Aerosol Optical depth (AOD) in relation to changes in the regional meteorological conditions. The data collected during January to December 2015-2019 indicated that annual average AOD variation. The mean annual variations of Aerosol Optical Depth (AOD) seen the maximum around the monsoon. The seasonal mean Aerosol Optical Depth (AOD) is lowest values are observed during the pre-monsoon and relatively moderate AOD is observed during the winter season. Variation of aerosol optical depth (AOD) in Post-monsoon season shows similar variation as of winter and pre-monsoon in 2016 while values get increased afterwards and reaches maximum in both Aqua and Terra observations which are mostly related to the changes in the local boundary layer.

Grid-wise Correlation of Long Term Monthly Average Temperature of Meghalaya, India

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We use Random Matrix Theory to describe eigenvalue spacing of historical monthly average temperature (T_{avg}) of Meghalaya in grids. For this purpose, data set for T_{avg} has been extracted from 0.5º x 0.5º grid boxes of CRU TS 4.04 over Meghalaya. Data set for 10 out of 11 grids from 1901 to 2019 were arranged in a matrix form in such a way that the first matrix for January 1901 has 5 values (grid no 1 to 5) in one row (center latitude: 25.75ºN; center longitude: 90.25ºE, 90.75ºE, 91.25ºE, 91.75ºE, 92.25ºE) and the rest 5 values (grid no 6 to 10) in the second row (center latitude: 25.25ºN; center longitude: 90.25ºE, 90.75ºE, 91.25ºE, 91.75ºE, 92.25ºE). Thus a total of 1428 matrices (W_{2x5}) were arranged for the complete data set. The largest eigenvalue (λ_i) of each correlation matrices $C_{2x2} = \frac{W^T W}{5}$, were then arranged in ascending order. From these eigenvalues the Nearest Neighbor Spacings (S_i) were found out as $S_i = \frac{\lambda_{i+1} - \lambda_i}{<\lambda_{i+1} - \lambda_i>}$, where i =1, 2…..1427 and $< \lambda_{i+1} - \lambda_i >$ denotes average value over 1428 consecutive eigenvalue pair differences. It is found that the distribution of S_i follows a combined distribution of Brody and Weibull distribution at a correlation value $\beta = 0.45$. However many has reported earlier that Nearest Neighbor Spacing Distribution (NNSD) can be well described by Brody Distribution, $P(S_i)$. So we checked a stable value of β for which the slope of $P(S_i)_{max}$ at different values of S_i is zero. For that we found out $P(S_i)_{max}$ from Poisson to Gaussian Orthogonal Ensemble (GOE) fluctuations (changing β from 0 to 1 in a step size of 0.1). Ultimately Cumulative Distribution Function (CDF) of all S_i nearly fits with a combined Brody and Weibull distribution (CDF_C) in the range $0 \leq S_i \leq 1$ as $CDF_c = 1 - \frac{e^{-\alpha S_i^{1+\beta}}}{2} - \frac{e^{-\alpha\beta S_i^{\beta}}}{2}$, where $\alpha = [\Gamma(\frac{2+\beta}{1+\beta})]^{1+\beta}$. The value of $\beta(0.45)$ indicates a presence of weak repulsion among the eigenvalues, which means that there is a weak correlation among the grids. Hence, the Meghalayan climatic system can be considered as dynamical subsystem although the statistical fluctuations are weak.

Temperature Forecasting over North-East Region of India using Artificial Neural Network: A comparison-based study

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Forecasting weather parameters in North East Region of India (NER) is a great challenge due to its unique location and typical landscape. In NER, temperatures in the orographically dominated locations and also in other locations where the diurnal variations are large always difficult to predict accurately. In present study, a comparative study based on Artificial Neural Network (ANN) is performed on minimum and maximum temperatures of northeast region. Two approaches are performed; first one uses daily minimum-maximum temperatures as input and predicts daily minimum-maximum temperatures. While in second approach, season-based daily minimum-maximum temperatures is used as input to predict season-based daily minimum-maximum temperatures. Past 30 years daily maximum and minimum temperatures data of 10 locations of NER have been utilized to formulate the ANN model. Due to varied model parameters, optimum one is selected based on mean square error (MSE). From total available data, 80% are used for training, 10% are used for validation and remaining 10% are used for model testing. Training data set is selected randomly, so that model can fetch all the possible relationship in the data. Validation is used to handle the issue of overfitting. Finally, testing phase identifies the model accuracy. An individual model has been devised for each of the station.

Extreme rainfall trends and their statistical significance

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Atmospheric temperature is likely to increase due to increase in greenhouse gases concentration (Global Warming), which in turn is likely to impact evapotranspiration and atmospheric water content there by significantly changing the rainfall magnitude, frequencies and its intensities. Global warming may also affect the seasonal, inter-annual variabilities and spatial distribution of rainfall. The implication of these changes are significant for climatically and ecological sensitive Himalayan regions as small changes in the climate can relatively produce large changes in the probabilities of extreme events, which might have severe consequences in this region. Therefore, an understanding of climate related extremes in the region is important to mitigate the negative impacts of climate change. This study investigates the extreme rainfall events observed over a period of 25 years in a small town in the foothills of Himalaya. Consecutive day extreme rainfall i.e. annual one day, two days and three days maximum rainfall values are extracted from daily rainfall data. These extreme rainfall values are investigated for trend analysis using parametric (linear regression) and non-parametric (Man-Kendall) tests. Results show an increasing trend in the extreme rainfall events over the time. However, inferences from significance test show that these trends are not significant at 95% level of confidence. The study estimates the regression, Mann Kendall, and "Sen Slope Estimator" statistics to infer the above results.

Geographical dependence of cloud process over India: A comparative study between coastal and inland region

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Due to advancement in global warming, irregular rainfall patterns have become very often specially at regional scale. Such studies are essential for monsoon dependent region such as Indian subcontinent wherein 70% of the population directly or indirectly depends on agriculture. Additionally, due to its geographical location, being surrounded by water bodies from three sides, make its weather more diversified and thus rainfall patterns. Study of cloud microphysical property along with atmospheric parameter play a significant role to determine rainfall pattern. This also could vary with geographical location, so present study focus on two types of heterogeneous regions- a region closer to coast and an inland region at high spatial resolution (0.5°x0.5°) with the help of regional climate model (RegCM 4.4). Long-term (1990-2017) analysis show high range ($4.26x10^{-6}$-$1.08x10^{-5}$kg/kg) of specific humidity (995-25hPa) over coastal region, whereas it reduces ($4.07x10^{-6}$-$1.01x10^{-5}$kg/kg) over inland region may due to more number of influencing parameters during monsoon. The rate of change of specific humidity decreases faster with time ($y=(-1.34E^{-7} \pm 2.63E^{-8})x+(3E^{-4} \pm 5.29E^{-5})$; $r^2=0.50$; $P<0.05$) for coastal and it gets delay ($y=(-1.17E^{-7} \pm 2.17E^{-8})x+(2E^{-4} \pm 4.35E^{-5})$; $r^2=0.52$; $P<0.05$) for land region, which is again may be due to the role of affecting parameters. Variability in moisture content is observed at fine scale and would influence amount of liquid water in the clouds through evaporation and condensation. It may cause heterogeneity in cloud properties, which in turn lead to alter cloud formation processes as well as rainfall patterns. Like specific humidity, rate of cloud liquid water content also decreases with time ($y=(-6.27E^{-9} \pm 1.64E^{-9})x+(1.27E^{-5} \pm 3.29E^{-6})$; $r^2=0.38$; $P<0.05$) over inland region may be due to less availability of moisture in the atmosphere. Thus, low rate of specific humidity and cloud liquid water impede condensational growth of liquid droplets in the atmosphere. Further study needs to investigate dependency of rainfall with the help of decreasing trends of specific humidity and cloud liquid water over both the selected regions. Thus, any variation in source parameters of rainfall would lead to influence cloud formation processes at regional scale. Such long-term observations can be included in climate models to improve weather predictability and also would be helpful to project future climate scenarios. Such results can be strengthen statistically by adding more number of atmospheric/cloud parameters and more number of regions.

Impact of the climate change on the water resources of the Brahmani Basin of Odisha

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Impact of climate change on hydrological responses of river basins require detailed examination to ensure sustainable management of water resources. This study evaluated the impacts of climate change on water resources availability of the Brahmani basin of Odisha and analysed climate-hydrology relationships. For this study, the annual rainfall, temperature, water discharge, evaporation and ground water flux are used. The trend patterns were analysed to ascertain the impact of climate change on rainfall and runoff. The annual rainfall-runoff shows decreasing trend, though inter annual and interdecadal variations exist. The temperature shows increasing trend due to the impact of mining and industrial activities in the basin. The rainfall analysis of 120 years (1901-2020) and all other parameters are for a period of 40 years (1980-2020) are used for the study .The basin receive about 57698 MCM annual rainfall and about 20384 MCM (35%)drains in to the sea. The basin is facing water scarcity due to decrease in rainfall and demand of water increasing for industries as the basin has maximum mineral resources and industrialised. Hence adequate surface water storage is the need of the hour to overcome the water scarcity in the age of climate change.

Groundwater responses to climate variability in Punjab, India

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Groundwater has the potential to show resilience to the climate variability due to its residence times in the aquifer systems which makes it difficult to find climate change effects on groundwater systems. The recently recharged water near to the surfaces or shallow groundwater is susceptible to the climate variability than the very old water in the deep will have a little effect. However, irregular patterns of rainfall and change in its frequency and intensity over a period of time can influence the groundwater storage through variable recharge. Northwestern states of India - Punjab, Haryana and Rajasthan fall in arid to semi-arid regions with mean annual rainfall ranging from 500-600 mm/year and the region is underlain by Indus river aquifer. The present paper highlights groundwater responses to rainfall variations during 1901 to 2019 using a simplistic empirical relationship of annual rainfall and recharge in Punjab. It has been found that 20% decrease to the annual normal rainfall volume of 600mm results to 65% decrease in recharge. From this it is inferred that there are possible impacts of climate change in respect of projected change in mean annual precipitation on groundwater resources.

Snow Cover Changes and its Impact on Hydrological Flow Regime: A Study of Tons River Basin

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Tons river originating from Bandarpunch Mountain of Uttarakhand, is a major tributary of Yamuna River. Covering a stretch of 148 km, the river contributes a runoff from 5146 km^2 area. The water availability in river depends on the precipitation received in different forms. The present study is principally concerned with snow cover changes over the Tons river basin at monthly, annual, and seasonal basis over two decades (2000-2019) and their impact on hydrological flow regime. In the present study, MODIS data and discharge were used with a non-parametric Mann-Kendall test (MK test) and Sen's slope estimator. The results from the monthly analysis indicates insignificant variations in snow cover except for July month, which follows a significant upward trend with 1.85 Z-statistics and 0.25 Sen's slope. Further, annual analysis shows the snow cover area (in percent) over the basin is temporally increasing, followed by 0.12 magnitude of the slope. The seasonal study indicates that there is insignificant change in the snow cover during 2000-2019.

Geographical study of wetland area in north Bihar plain using remote sensing and GIS tools

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Present articles sketches out the geographical study of wetland area in North Bihar Plain. It is the playground of many rivers originating in Nepal which characteristically carry water during monsoon far beyond their carrying capacities with massive silts. Wetlands are areas that are seasonally or permanently inundated with water. It includes marshes, swamps, lakes, flood plains, bogs, shallow ponds and littoral zones of water bodies. The region shows the district wise wetland areas altogether in 21 districts of north Bihar. It has 2,59,418 ha area under wetlands, comprising an average of 4.96% of its total geographical area. Most of the wetlands of North Bihar are 100 to 200 hectares (ha) in area, but some exceed even 1000 ha. These are fed by overflow from the rivers and local monsoon flows. In the present study, district wise wetland area relating to the region has been statistically analysed as a result it is found that when the rainfall shows a declining trend in the same way, the area of wetland also shrinks. The finding indicates the future danger and calls for comprehensive research for a conclusive and definite result.

Groundwater management strategies in a rural catchment area: A case study of Chattisgarh

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In the rural Indian context, while groundwater is objectified as the main source for fulfilling the water related demands, fluctuations in the hydrological patterns and rise in water demand create an intensified pressure on groundwater resources. This study aims to characterize and analyze the water demand for Mandri river catchment area in Kanker district, Chhattisgarh with the help of water balance modelling.

The characterization of catchment displays that it lies on the crystalline rock, mainly banded-gneissic complex, as the principal aquifers present in the study area. Due to the presence of almost all the wells in the same aquifer and exhaustive paddy cultivation in the region, it imposes great stress on it. In this study, the water balance modelling is conducted through Water Evaluation and Planning System (WEAP) to analyze and compare the existing and future water conditions in different climate change and population growth scenario till 2050.

The WEAP modelling in this study indicates that for the future eras, surface water is more reliable to meet the agricultural demands while groundwater can be of dependence for domestic demands. Hence, WEAP results indicate that superintendence of the groundwater level in the watershed could be possible with the help of identifying appropriate sites for water harvesting structures. Such observations offer a strong premise to help planners for recommending and formulating water management strategies in future.

Glacier loss in response to climate change in selected basins of Western Himalaya

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Glaciers are located at high altitude mountain areas and serve as an important storehouse of water supply for the downstream areas. But, due to the ongoing drastic climatic changes, these resources are under a huge threat of wastage and disappearance. In this study, we represent few case-studies of recent glacier changes in parts of Satluj basin, Zanskar basin, Jhelum basin and Indus basin, Western Himalaya, India. The assessment of the glacier resources has been carried out using Satellite and Geographic Information System techniques. As per the availability and suitability, the data sources used in this study includes the Landsat images (MSS, TM, ETM+, OLI/TIRS), Survey of India toposheets (SoI), Google earth images, Corona KH-4B and ASTER DEM. In Satluj basin, Baspa and Tirungkhad highly glaciated sub-basins have been selected as benchmark for analysis. The study indicated that the glaciers in Baspa basin are losing an area of 41.2 km^2 (18.1%) at a rate of 1.18 km^2/year from 1976 to 2011 whereas in Tirungkhad the glaciers are losing an area of29.1 km^2 (26.1%) from 1966 to 2011. In Zanskar basin, three representative glaciers Dalung, Padam and Parkachik were selected for the analysis. The Dalung and Padam glaciers indicated a loss of 2.6 km^2 (19.2%) at a rate of 0.05 km^2/year and 3.4 km^2 (12.7%) at a rate of 0.06 km^2/year from 1962 to 2015. However, the Parkachik glacier in this basin showed a very little area loss of 740 m^2 (1.5%) at a rate of 74 m^2/year from 1971 to 2015. Within the Jhelum basin, Kolahoi glacier is the main and large glacier and hence has been analyzed as a bench mark for the basin. The Kolahoi glacier has indicated a loss of 1.74 km^2 (13.63%) at a rate of 48 m^2/year from 1979 to 2016. For the representation of Indus basin, the glaciers around Leh and Nubra catchments have been selected and analyzed. The study indicated a loss of 5.1 km^2 (21.2%) at a rate of 93 m^2/year from 1962 to 2017 with respect to SOI glaciers. However, the glaciers indicated a loss of 2.7 km^2 (12.5%) at a rate of 160 m^2/year from 2000 to 2017 with respect to TM-2000 data. From these studies, it is observed and concluded that the glaciers in Western Himalaya are losing within the range of 10-20% with certain exceptions like the Parkachik glacier. Due to this glacier wastage or loss, water resources in Himalayan region are losing and have implications on the future water availability. Therefore, suitable strategies have to be evolved to manage this type of water resource.

Glacier Response to Changing Climate in the past half a century in the Lidder Basin, Western Himalayas

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Although its large area covered by seasonal snow and glaciers, detailed glacier inventory data is not yet available for most parts of Himalayas. Due to the inaccessibility, remoteness and presence in hostile environmental conditions, frequent field visits is a limitation to most of the glaciers in the region, however, remote sensing is an effective tool in the mapping of such glaciers. In the present study, a multi-temporal glacier inventory has been prepared for the Lidder basin Kashmir Himalayas for the last 50 years from 1969 to 2019 using a map of 1969 and multi-temporal satellite data. The satellite data used include Landsat, LISS III, and Sentinel 2 along with the Aster digital elevation model. The glaciers were coded and named as per the names of the places around the glacier. The number of glaciers has increased and decreased over time with a maximum number of 64 glaciers found in 1969. Total deglaciation of 9.1 km^2 has taken place in the study area during a period of 50 years, with an overall recession rate of 0.233 km^2 per year. The glacier slope and aspect have also changed over the period of observation and glaciers with a slope between 25 to 35 degrees and northwest aspect have witnessed a negative change.

Reconstructing the glacier dynamics since Little Ice age (LIA) using multi-proxies or data integrate approach in the Chandra-Bhaga basin, northwestern Himalaya

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The Little Ice Age (LIA), ca. CE 1250–1850, was a cold period of global extent, with varying intensity and timing of reduced temperatures across regions. In recent years, dendrochronological dating has been explored to provide the nature of glacier behaviour during the LIA and post-LIA mainly across the Tibetan region but the adjacent region in the southern part of the Himalaya is comparatively less explored. Additionally, studies pertaining to the nature of long-term glacier fluctuations since LIA and particularly deglaciation following the LIA maxima are virtually non-existent for the Himalayan region. Such gaps have been tried to be filled-up by multi-proxies/data integrated approach (MDIA) that mainly includes tree rings, remote sensing, and historical records with the supplement of field based geomorphological mapping in the Chandra-Bhaga valley of North-western Himalaya. The analyses are under way and the overall response of climatic and non-climatic factors on the long-term glacier behaviour since LIA across this region will be addressed.

Accelerated decline of the Arctic sea-ice associated to the global climate change

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The Arctic is an integral part of the global climate system, which controls the global surface energy balance and ocean-atmospheric circulation by heat exchange between the ocean, atmosphere and sea ice. Arctic sea-ice decline has been reported throughout the year since the 1970s, but significant decrease in sea-ice extent and sea-ice concentration are observed each September, every year. Different datasets of passive microwave satellite imagery and model reanalysis were used to investigate the accelerated decrease in the Arctic sea ice. The study enumerates the magnitude of Arctic sea-ice loss during the boreal summer (July-September), particularly at different timescales (daily, monthly, annual and decadal) during the month of September. The dramatic sea-ice decline in the summer during the past few years and its linkages with global climate change (natural and anthropogenic influences) is further assessed to decipher the impact on sea-ice concentration, sea-ice thickness, sea-ice volume and multiyear ice coverage. The study reveals the minimum sea-ice extent and the warmest September records in the last twelve years of the satellite era. The average air temperature of the Arctic has increased four times higher than the global air temperature during the last four decades, which resulted in Arctic Amplification and is linked to the northward heat advection into the Arctic Ocean. Over the past four decades, Arctic sea ice has declined rapidly at a rate of -4.7% decade^{-1}, leading to an ocean heat flux imbalance. The study reported that the warmest month in the Arctic was July 2019, leading to a significant loss of sea ice in the last 41 years. The present study demonstrates the land-ocean warming processes intensifying the sea-ice loss due to persistent low pressure, high air-ocean temperatures, supplemented by the coupled ocean-atmospheric forcing. The detailed outcomes of this study will be presented and discussed.

Impact of changing climate over Polar ice sheet located south of Larsemann Hills, East Antarctica

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Changing climate and its impact on the polar cryosphere is one of the prime concern of researchers and decision makers. The Antarctic Ice-Sheet and the surrounding Southern Ocean are key components of global climate regime. The Antarctic ice sheet, potentially contains ~60 m of sea-level equivalent and is a critical factor in regulating, modifying and forcing the global climate Present study (2018-19) is focused on the insitu observations of impact of climate change over the Larsemann Hills area situated in Prydz Bay region at 76° east longitudes of East Antarctica. The study area covers an area of 216 km2 of ice sheet bound by the ice stream called Polararboken on the west and Dalk glacier on the east. Annual and monthly accumulation/ablation rates have been estimated with the help of a total 149 stakes distributed evenly in the region. Movement of the ice sheet is monitored with the help of Differential-GPS (DGPS) for precisely locating the stakes at fixed interval. Snow/ice thickness at the ice sheet margin have been estimated using Ground Penetrating Radar with variable antenna array from 400 MHz to 40 MHz. On the basis of measured parameters, the annual surface mass balance has been calculated for the region. Except SN1 stake farm which is towards the margin of the bay, all the stakes show net annual accumulation. Snow accumulation increases away from the shore. The observation with the high confidence shows more than 3.5-fold average accumulation during 2019-20 in the region. The average regional annual ice sheet velocity of 24.3 m/y is calculated integrating the data from all 13 stake-farms. The range of the average ice-sheet velocity varies from 0.78 m/y (SN1) to 61 m/y (SN13). The pattern shows highest velocity along the margins of Polararboken and Dalk Glaciers. The general direction of the ice sheet movement in the study area is towards NNW to North. GPR survey was carried out in the marginal part of the ice sheet indicates a thickness of 125 m up to bedrock. The net Surface Mass Balance for 2019-20 is estimated 80304204 m3 SWE and specific surface mass balance is estimated 0.37 m SWE. The study points towards increase in accumulation resulting in positive SMB as compared to recent years. Recent observations in the Princes Astrid coast have also indicated a positive bias in cumulative surface mass balance. The mass balance trend is confirming the majority results which is concluded using different methodologies and data. A good understanding of the Late Quaternary glacial and climate history of Antarctica will help to constrain the contribution of Antarctic ice to the global sea-level.

Glacial to proglacial and paraglacial landscape transformations in Arctic, Ny-Alesund area, Svalbard: sedimentary archives

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The Arctic region is very sensitive to climate change and the transformation from largely ice covered to relatively ice free has been rapid during the Holocene. This rapid warming in the Arctic has a significant impact on the development and evolution of landforms. In glaciated Arctic region, abrupt climatic shifts are captured in the landforms developed and their modification from glacial to proglacial region through entering in paraglacial processes due to rapid glacier retreat along glacier margin. These transformations are evident in the form of systematic progression morainic ridges (evidence of past glacial advance/retreat), proglacial lakes (recent glacial melt) as well as permafrost and outwash plains (periglacial deposition). The evolution of the landforms, in response to the varying climate, provide the long-term proxy records which are valuable for evaluating climate change trends. Proper characterization of these landforms in field and understanding of various sedimentary processes are important to understand the temporal extent of such geomorphic transformations and indicate substantial palaeoclimatic variations. The characteristic landforms distribution in Ny-Alesund area is studied documented and interpreted as dramatic shifts in palaeoclimatic changes. In the proglacial areas, evidences of enhanced solifluction/gelifluction processes within the diamictite deposits are clear indication of enhanced sediment readjustment from proglacial region together with permafrost degradation. Extensive solifluction lobes mark transformation from glacial environment to paraglacial conditions that controls the meltwater sediment transportation and sediment aggradation in outwash plain. Characterization of the geomorphic attributes in vicinity of present glacial margin as evidences of such transformations that clearly indicate significant warming during the Late Quaternary i.e. post LGM (~18ka and 15ka time period) at least around Ny-Ålesund, Svalbard. This study provides a fresh outlook to understand the glacial-paraglacial transition in the arctic region associated with concomitant sediment readjustment processes.

Prevalent Climate variables during summer season around Gangotri Glacier

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Hydrometeorological data for the Gangotri Glacier was collected for 4 ablation seasons (May- September) during 2014, 2015, 2016 and 2017 and analysis was made to understand the weather conditions of the glacier. Average monthly rainfall for June, July, August and September has been computed to be 34.8, 87.6, 54.6 and 32.6, respectively. The total rainfall and its distribution over the summer season are found to vary from year to year. Based on 4 years data average seasonal rainfall for the Gangotri Glacier was observed to be about 221.2 mm. The average daily maximum and minimum temperatures over the summer season were computed to be 15.7^{o} C and 4.7^{o} C, respectively, whereas average mean temperature was 10.2^{o} C. Analysis of wind data shows that on an average the daytime wind speeds are much stronger (4 times) than the night time winds. On the seasonal scale daily mean sunshine hours were 4.7 hours. Monthly total pan evaporation was 118, 125, 107, and 121 mm for the month of June, July, August and September respectively. Mean daily evaporation for the summer season as a whole is found to be 3.9 mm, which is comparable to the pan evaporation data observed at foothill station of the Himalayas.

Influence of the Arctic sea-ice melt on the Summer Pacific Tropical Cyclone is modulated by Pacific Ocean decadal variability

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The influence of the Arctic sea ice melt on low latitudes is not well understood. Here, we have examined the relationship between the Arctic sea ice concentration and the North Pacific tropical cyclone (TC) activity in the near about past seven decades (1951 to 2018) of the observational record. The July-August sea ice concentration is significantly correlated with the North-West and East Pacific TC activity. The Arctic sea ice variability modulates the influence of Pacific Decadal Oscillation (PDO) on the Pacific TC activity. A combination of positive PDO and low sea ice summers have heightened TC activity and a poleward shift in the genesis while the negative PDO and low sea ice summer lead to a slightly diminished TC activity with an equatorward shift in the genesis.

Impact of ENSO on tropical cyclone season over north Indian Ocean

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Tropical cyclones are possibly the most devastating of all the natural disasters. There is a growing interest in knowing the long-term variation in vulnerability to tropical cyclone activities over North Indian Ocean (Arabian Sea and Bay of Bengal) due to warming climate and changes in sea surface properties. Based on an analysis of 35-years (1982–2017) data, the influence of El Niño-Southern Oscillation (ENSO) on tropical cyclone (TC) activity has been examined over the North Indian Ocean (NIO) comprising the basins of Arabian (ARB) Sea and Bay of Bengal (BOB) as the El Niño–Southern Oscillation (ENSO) phenomenon is perhaps the most leading regulator of the interannual climate variability on a global scale. We address this issue by the issue of through study with accumulated cyclone energy (ACE) index. ACE is an important measure of cyclonic activity which combines storm intensity over the life time of each storm as well as over all the storms occurring during a season or year. The result shows that during post-monsoon season tropical cyclone activity measured in terms of ACE is more over ARB Sea during El Nino phase while ACE is more over BOB during the La Nina phase. Conversely, in the pre-monsoon season the ACE is more over BOB during the El Nino years while ACE is more over ARB Sea during the La Nina phase. The total ACE value over the NIO during the study period is observed to be more during the La Nina phase. The higher sea surface temperature (SST) during the post - monsoon season combined with positive sea surface height (SSHG) anomaly and low vertical wind shear during El Nino phase led to high ACE over the ARB Sea. The SST, on the other hand, is not responsible for greater ACE over BOB during La Nina phase in the post-monsoon season but, high SSH and low wind shear is observed to be significant during La Nina phase. However, the wind shear does not show any significant variation between La Nina and El Nino phases. This research may have the potential to improve the background knowledge of short-term forecast of the local TC activity and intensity on a seasonal basis for public awareness and disaster preparation.

Spatial modifications of Gulf of Mannar Islands due to rising sea level, Tamil Nadu

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Recently, the Intergovernmental Panel on Climate Change estimated a rise in sea level from 0.18 to 0.59 m at the close of the present century. This is well documented in the oceanic set up of Gulf of Mannar 21 group of islands bordering the southeast coast of Tamil Nadu (Rameshwaram to Thoothukudi). Typical geomorphological changes accompanied by erosional and depositional disposition are well illustrated when outlines of GoM islands of two different time stamps overlaid. In this work, it is analysed from spatial point of view. The emerging modified scenario of GoM islands could be attributed to the rise of sea level attenuated by global warming. Attendant rise in the sea surface temperature (SST) not only causes the warming of GoM but also enhances the volume of sea water. This study stems important as these islands and surrounding GoM ocean harbour rich biodiversity calling for the first Marine Biosphere Reserve in the South and Southeast Asia. The region forms a unique ecosystem with aprons of coral reefs, algae communities, mangroves and sea grass in a salt marsh lay.

In the analyses, outlines of GoM isles (21) digitized from Landsat 4 (1980) and Landsat 8 (2018) with 30m resolution were placed one (latest) over the other (oldest) using ArcGIS. And overlaps and gaps in outlines and geographic coordinate mismatch as well were spotted. It further enabled inference of fluctuating phases of submerging and emerging states of GoM isles. Two islands were lost. It is concluded that sea water inundation – an effect of SLR could have induced spatial modifications such as reshaping and migration of GoM isles including obliteration of islands, in too.

Modeling Sea Surface Temperature over Indian Ocean and its influence on Indian Monsoon rainfall

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This research demonstrates Sea Surface Temperature (SST) analysis of Modular ocean Model version 3.0 (MOM 3.0) for the period 1992-2015 over the Indian Ocean (IO) region (45°E-100°E, 10°S-25°N) including Arabian Sea and Bay of Bengal (BoB). An effort has been made to understand the relationship between SST and monsoon wind pattern on seasonal as well as annual time scales. We have focused on various studies, mainly on significant features of SST arises from model output such as its spatial and temporal variability using EOF, SST climatology & anomalies, tendency of seasonal SST's and standard deviation, regression analysis between 850 mb wind and precipitation against the EOF; and finally concluded the study based on the pattern of correlation between Bay of Bengal (BoB) SST and Indian Summer monsoon rainfall (ISMR). It is observed that SST has dominant features in the Indian monsoon system as revealed by various analyses, e.g. SST anomalies over IO which provides valuable information about the local Indian monsoon system and warmer SST enhances the strength of the monsoon component in India. It is also observed that the cooling in the southeastern IO may be because of higher latent heat loss which may indicate the possibility of polarity reversal in the context of the Indian Ocean dipole (IOD), and is believed to exert a great impact on Indian monsoon variability. Standard deviation of SST also gives complete idea about the Indian monsoon system and reduces the SST variability in the northern IO. The linear positive correlation between BoB SST and ISMR shows more than 55% positive correlation in peninsular India, North Eastern India with correlation confidence level up to 95%.

Increased cyclone destructive potential in the Southern Indian Ocean

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The Southern Indian Ocean (SIO) showed significant warming trend during the period 1999-2016. The warming is caused by the advection of warm waters from the western Pacific to the SIO through Indonesian Thorough Flow (ITF). Consistent with this SIO warming, the cyclone destructive potential, i.e., the Power Dissipation Index (PDI) during 1999-2016 is found to have doubled compared to the same during 1980-1998. The increasing trend in PDI during the 1999-2016 period is primarily due to an increase in the intensity of cyclones and their duration. The increasing PDI is associated with a sea surface temperature warming and an upper ocean heat content increase associated with a significant slowdown in translation speeds. The increase in upper ocean heat content during the recent decades enhances the intensification of cyclones and their duration which is consistent with the slowdown of cyclones. We show that in the SIO, ocean-driven processes play a major role in PDI rise during the recent period. Any continued increase in PDI will cause more loss of life and socio-economic damage to the island countries such as Mozambique, Mauritius, Mascarene Islands and Madagascar, as well as the coastal inhabitants along East Africa.

Recent changes in Different modes of Indian Ocean in warming climate

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The present study evaluates the change in prominent seasonal pattern of significant modes of Indian Ocean (IO) in warming climate. For analysis, sea surface temperature (SST) from Hadley centre for 1950-2019 has been used. Analysis of monthly SST anomaly clearly shows a continuous increase in SST over Tropical Indian Ocean (TIO) since 1984. Hence based on warming scenario, 70 years has been divided into two epochs 1950-1984 and 1985-2019. Composite difference and trend (mankendall) analysis of seasonal SST over TIO depicts that every season have different warming scenario. Although in every season, equatorial IO manifests warming but southern Indian Ocean manifest different warming pattern. In winter (JF), western SIO has warmed while in pre-monsoon (MAM), SIO centered at 30°S has warmed more. During Monsoon (JJAS), Along with equatorial IO, South eastern IO has observed to increase more while during post-monsoon (OND) warming has observed to bind between 10°N to 10°S. Based on this warming scenario, Basin wide Mode, Indian dipole mode has been evaluated by analyzing first three EOF of SST over Indian Ocean. Also EOF of SST for season has been analyzed for three time period 1950-2019, 1950-1984 and 1985-2019 respectively. EOF 1 which corresponds to IO basin wide mode shows continuous increase against long term trend and that is also supported by spatial structure. This picture is more or less similar for all season. EOF 2 which corresponds to IOD mode depicts a weakening pattern for all season. During winter season, epoch 1950-1984, EOF 3 shows a dipole and this converted into single mode (Central SIO warming). During pre-monsoon season, EOF 2 shows nIOD (negative IOD) pattern while EOF 3 depicts SIO mode (SIOM). During Monsoon season, EOF 2 and EOF 3 both depicts dipole pattern. During post-monsoon a nIOD pattern has observed in recent epoch (1985-2019) while EOF 3 also depicts SIOD mode which changes its pole in recent epoch. Hence Seasonal Variability in spatial pattern of IO has been noted.

Response of ocean water chemistry on impact of increasing atmospheric Carbon di Oxide

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Anthropogenic forcing of global warming, owing to the addition of greenhouse gas in the atmosphere, has induced considerable increase in the atmospheric and ocean temperatures. It is a constant source of concern of modern-day research on global climate change since it impacts the global ocean chemistry and terrestrial ecosystem including the livelihood of human being. Different models have been proposed to understand the carbon exchange among the atmosphere, the hydrosphere, and the biosphere to delineate the impacts of different domains of the global ecological system. A gap of ~2 Gigatons of carbon between the process of intake of carbon in global ocean and returning it back to atmosphere is recognized as a missing sink in global carbon cycle. Researchers have identified this gap in their global carbon cycle modeling (Tans et al, 1990; Slegenthaler et al, 1993). Tans et al (1990) assigned this missing sink is located at terrestrial biosphere. However, Slegenthaler et al. (1993) reported that earlier models (Tans et al, 1990) were assigned with unrealistic value to tropical deforestation which should be less than the estimated value. However, none of the work could pinpoint the missing sink. Considering the model proposed by Holman, (2000) for the distribution of carbon in different sinks, its interaction with other sinks and associated residence time in Global Carbon Cycle, there is also a missing 2 Gigatons of carbon exchange from atmosphere to global ocean. Towards this, the report of The Royal Society (2005) on Ocean acidification due to increasing atmospheric carbon dioxide and other greenhouse gases has proposed that the average pH of ocean water lies within 8.2±0.3. This minute change in special distribution pattern of pH in global ocean is due to local, regional, and seasonal factors which influence differential partial pressure of carbon di oxide at atmosphere and sea water. Global Ocean has different domains which can act as source and sinks of global carbon cycle (Milliman and Droxler 1996, Wollast 1994). This work attempts to identify the missing sink of 2 Gigatons of carbon in global carbon cycle as buffer of decreasing pH of global ocean which influences the carbonate dissolution and holding capacity, particularly above the carbon compensation depth (CCD). The global ocean acidification process is difficult to model quantitatively due to its spatial heterogeneous distribution and therefore it remains open to conclude where this 2 Gigatons of carbon in global ocean is hidden.

Did the Meghalayan sea stand fluctuations play a role in deurbanization of the coastal Harappan settlers, Lothal (Gujarat, India)?

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Ancient Indus (Harappan) civilization, well known for its town-planning, maritime trade and organized living, flourished during its mature phase i.e. between ~ 2600-1900 (BCE) along the alluvial plains of the north-western (undivided) India. Cause(s) of decline of this ancient civilization are intensely debated. Interestingly, the sudden decline also marks beginning of a distinct sub-division of the Holocene being termed as the Meghalayan age (last ~4200 Cal years). Whether this beginning marks a holistic change in hydro-climate together with regional sea level changes that collectively resulted in ending the mature phase of Indus civilization is not yet well corroborated with suitable regional geological records. Lothal (an oldest Harappan dockyard), located ~23 km from the present-day shoreline of western India could be an ideal locale to find the clues. We present here a detailed geochemical, stable isotopic, mineralogical and sedimentological proxy-based record from ~5000 yr (BP) to ~2000 yr (BP), revealing evidences for a marginally higher sea stand (+1.6m above the High Water Line). This relative higher sea stand could have pushed the estuarine zone close to the Lothal site, facilitating ship-movements. The period around 1900 BCE, practiced a relative fall in sea stand, and brief arid phase, which led to the stream being water scarce and for that reason couldn't support the movements of ships. This would have unfavourably affected the settlers at Lothal as their dockyard would have been rendered defunct, could have led to the fall in trade. As a result, the settlement at Lothal as recommended by the archaeological evidences became smaller in size and most occupants migrated to nearby water rich sites. Sea retreat in downstream regions of Indus area resulting in Lothal dockyard dysfunctional for business and trade, and the coincident monsoonal aridity in upstream regions appear to be collectively responsible for demise of Indus culture at the dawn of Meghalayan era (~4.0±0.4 ka).

Isotope fingerprinting of precipitation over Indian region

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Precipitation stable isotopes are used as tracers in the water cycle and for interpretation of paleo-climatic archives. This study focuses on isotope information in precipitation and deriving a relationship between geographical and meteorological controls on isotope information such as latitude, air temperature and precipitation amount. This work used dataset from IAEA's Global Network of Isotopes in Precipitation (GNIP) over the period 1960-2012 at different temporal scales and is based on *Köppen*-Geiger climate classification system.

The spatial correlation parameters for isotopic composition (deuterium and O^{18}) over the Indian region have been determined. Further a good correlation is found to exist between isotopic composition of precipitation and climate variables such as air temperature and precipitation, suggesting the use of isotopic signal as a monitor and record of climate change regime. Isotopic composition is preserved in materials related to meteoric water cycle such as fossils, sediment cores, speleothems, tree rings, ice sheets etc. which can be used as proxies for past climate reconstruction and for interpretation and validation of hydro-climatic phenomenon and models respectively.

Climatological interlink study of rapid urbanization and extreme rainfall events over megacities in India.

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In India from past two decades, the rate of migration of people, industrialization, and rise of population in metro cities are burgeoning, which has led to exponential growth of urbanization and sprawling, stressing over the utilities of natural ecosystem. Hydro-meteorological disasters particularly the extreme rainfall events (EREs) associated with flash floods, frequency, intensity and duration has increased unprecedentedly. As a result, megacity city of India has faced artificial water logging, traffic congestion, inundation of low lying areas, which leads to massive destruction of life and property, and in long run makes adverse socio-economic impacts over the country. The objective of this study is to find out the role of rapid urbanization in modulating the frequency and intensity of EREs over megacity of India. Moreover, factors affecting changes in short duration EREs over urban environment are even less known because of complex dynamics of destabilization caused by urban heat Island, induced thermal perturbation. An approach combining modelling, computing and data analysis is essential tool for developing advanced prediction system as well as finding the climatological link of urbanization with EREs. Mesoscale models are considered as one of the most widely used tools in the simulation and advance prediction of EREs. The prediction of EREs and its mechanism of evolution in an urban city is generally difficult using numerical models because of the challenges in capturing the effect of urban heating and local convection arising due to large spatial inhomogeneity. Climatological study of urbanization with long-term high resolution observed data and mesoscale simulation of various EREs can find out possible link of various thermodynamic parameters role in inducing and enhancing the frequency and intensity of EREs is a major scientific challenge. The present study is aimed at improving the simulation of urban extreme events and to understand its linkages with rapid urbanization for Indian megacities.

Isotopic composition of daily precipitation from Kashmir Valley, NW Himalaya: Insights on the role of meteorological parameters and dual moisture transport pathways

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Understanding the temporal processes controlling water stocks in Himalayan region becomes fundamental in the current greenhouse world. The recent reports on isotopic composition of monthly and seasonal variability in high Himalayan precipitation have highlighted and identified the control of dual atmospheric circulation patterns associated with Western Disturbances (WDs) and Southwest Monsoon (SWM) derived precipitation. However, being the monthly composites, these studies were not capable of resolving the short-term processes that govern the individual rainfall events corresponding to the WD and SWM moisture sources. Additionally, the role of several meteorological parameters (temperature, relative humidity, and surface pressure) which are known to significantly affect the Himalayan hydrology have not been addressed so far. We provide daily-scale precipitation isotope record from the Kashmir Valley, northwestern Himalaya with an aim to better quantify the relationship between the precipitation isotopes and the meteorological variables separately for WD and SWM seasons. The records indicate that precipitation isotopic composition in this region is strongly modulated by temperature and relative humidity during the periods of WDs while as a weak dependency was observed for the SWM season. Moisture transport pathways calculated from HYSPLIT back trajectory analysis suggest moisture sources restricted to Mediterranean region during the WD period but a wide spatial variability was seen during the SWM period. The present isotope record will help operational meteorologists to observe the role of regional synoptic-scale processes for a better understanding of the regional hydrology.

Rainfall Trends (1901-2019) and last 100Year's Drought Intensity Assessment (DIA) in Varanasi district, Uttar Pradesh

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Present study analyzes the daily rainfall data series used of the last 119 years (1901-2019), to understand the long-term trends in annual, seasonal (e.g. winter, pre-monsoon, monsoon and post-monsoon) and mean monthly rainfall in Varanasi district. Two non-parametric statistical tests including the Mann-Kendall test (MK) and Sequential Mann-Kendall test (SQ-MK) was used for the analysis. Trend analysis of rainfall data series for 1901-2019 did not show any a clear trend for the region as a whole, Sen's slope estimator tests describing the rising positive trend is observed in the monsoon season (0.02mm/year) during 1901-1920 time scale which is statistically significant at 95% confidence level. After 1920 the trend is negative but during the 19th century (2000 to 2019) the monsoonal rainfall trend increasing with positive value but not statistically significant. Similarly annual as well as monthly rainfalls as well as temperature (maximum & minimum) data from June to October for100 (1901-2000) years were used to compute the Standardized Precipitation Index (SPI) and Reconnaissance Drought Index (RDI) values based on two-parameter gamma distribution in the same district, for drought intensity assessment. As a result, the annual SPI and RDI in the worst drought observe in the years of 1953-54 (SPI = -2.38) and RDI = -2.32) and 1991-92 (SPI = -2.08 and RDI= -2.03) in the low rainfall, the district indicated only moderate dryness instead of extreme dryness. On the other hand, monthly data of SPI and RDI results showed an extended range compared to that of 1 month, but the sensitivity in drought years have not improved significantly. Consequently, the present study has a huge water and agricultural potential and analysis of rainfall trends and drought intensity assessment would be of interest to water and agriculture planners.

Changing patterns of historical rainfall and temperature in a river basin of the desert state of India

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Study of the changing patterns of rainfall and temperature are essential for the assessment of the impacts of climate change on the water resources of a region. A higher or lower rainfall or changes in its distribution would influence the spatial and temporal distribution of runoff, soil moisture, groundwater reserves and would alter the frequency of droughts and floods. From an agriculture perspective, it is very important to understand the seasonal and monthly variations of rainfall for correct estimation of crop water requirements as well as correct crop sowing time especially in the in rain-fed area. Temperature on the other hand is the driving force for all the climatic variability. Manifestations of a changing climate are being observed as the duration of seasons change. It is observed in Rajasthan that summers are expanding and the winters are shrinking. Rising temperatures are resulting in crop failures during the sowing stage of Mustard crops and milking stage of Wheat crops. The farmers are facing loss of crop yield due to rising temperatures and the curtailed irrigation supplies. The study area namely, Banas River basin is the largest basin in the state of Rajasthan with over 45,000 km^2 area. The basin has a very low water availability and faces recurrent droughts. The annual average rainfall of the basin is 585.6 mm (varying from 416.80 mm to 861.90 mm). The Bisalpur dam constructed across the Banas River in 1999 is used for drinking water supplies to nearby major cities and irrigation to the command area downstream. The water availability in the reservoir in coming years will play a crucial role in the overall economy of the entire region including other socio-economic issues, therefore, it is important to understand variations in rainfall and temperature trends which could influence the future availability of water. The paper presents analysis of long-term rainfall (also rainy days) and temperature (maximum, mean, minimum, diurnal) trends using statistical techniques (regression and Mann-Kendall) with daily rainfall data at thirty raingauge stations over 30 years (1990-2019) and gridded temperature data of IMD. Rainfall, rainy days and temperature data have been analysed in annual, monthly and seasonal series. On the basis of regression and Mann-Kendall test, rising and falling trends in rainfall, rainy days as well as temperature and anomalies at various stations have been analysed. The results show that many of these variables demonstrate statistically significant changes occurred in last three decades. Such changes have direct implications on water availability and crop production in the region. Some stations show statistically significant increase in the monthly as well as monsoon rainfall including rainy days which is a good indicator of increased water availability for this semi-arid region and the Bisalpur reservoir. However, the temperature (mean and minimum) also shows an increase (statistically significant) indicating more evaporation from reservoir, delay in sowing of winter crops and more ET from agriculture fields, thereby enhancing the crop water demands.

An Appraisal of Seasonal Precipitation distribution pattern over the newly formed union-territory of Ladakh in North West Himalayan Region

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The Northwest Himalayan (NWH) region has one of the most unique geophysical significance along with a very complex interaction between atmospheric and topographical properties. The precipitation pattern over the NWH region is mostly controlled by the two major atmospheric circulations: one is the Indian summer monsoon (ISM) which lasts from June to September and the other one is Western disturbances occurring during the winter season activated from December to March. But the distribution pattern and intensity of precipitation is different for all the states and Union territories of NWH, where the orographic arrangement of each of the states and union territories plays a vital role in the precipitation distribution pattern.

Ladakh, being separated from the Jammu and Kashmir union territory, has its own meteorological, geophysical, socio-economic significance. The orographic arrangements and physiographic aspect of Ladakh are absolutely different from that of any other mountain states of NWH in terms of elevation, arrangements of hill shade, Slope aspect and Slope factor. Thus the seasonal, annual, and decadal precipitation pattern are absolutely as well. Ladakh is called the clod desert of India and being situated at the lee side of the Himalayan orography, the precipitation intensity and amount is extremely low for Ladakh. The maximum precipitation observed here is based on the snowfall conditions in DJF months of winter season, directly associated with the arrival of the Western Disturbances. Focussing on the newly formed Union Territory of Ladakh, the present study will focus on the precipitation trend and pattern in the last 40 years (1979-2019) using the ERA-5 reanalysis datasets. ERA-5, the fifth-generation datasets, The European Centre for Medium Weather Forecasts has been released based on their consistent performances over a regional scale. Based on the performance evaluation of them over the hydro-climatic regime of the Indian Subcontinent, it has been investigated that ERA-5 outperforms the other reanalysis products for the monsoon season precipitation in India. Now its performance is also evaluated in the present work over the complex terrain of NWH at a finer regional scale. They are also quite better in terms of spatial resolution compared to other reanalysis dataset products.

From the spatial plots of seasonal precipitation pattern over the NWH, we can easily infer that the western side of Ladakh Union Territory receives more amount of rainfall than the eastern side due to orographic arrangements and maximum precipitation is concentrated during the non-monsoon period. The snowfall peak has received an early shift in the later decades (1999-2019). The concentration of the hydrometeors at the surface level is also representing a similar trend with the change in the annual cycle of rainfall. The trend analysis at 95% Confidence Interval shows that the DJF season is showing almost similar pattern of snowfall and the trend has a sharp increase in the JJAS season where the rainfall amount is getting higher in the monsoon period. The precipitation pattern in MAM and ON season are showing a sharp negative trend which indicates a shift of rainfall towards the JJAS season over the year. Finally the study is going to give a brief investigation of the all-over changes in the trend of precipitation pattern around the year. Results obtained from the present study are encouraging and would be helpful in understanding the state level investigation seasonal precipitation dynamics over the NWH region.

Spatio-temporal rainfall analysis of Goa State

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Precipitation is one of the most important climate elements directly affecting the availability of water resources. Recently, it has been suggested that one of the most noticeable consequences of global atmospheric warming is water cycle modification, precipitation being the primary component. The AR-5 of IPCC reports that, the Indian sub-continent would be experiencing a large variation in the rainfall in terms of short duration high intensity rainfall. It also suggested that, the sub-regional variability in rainfall should be analyses in depth. Any change in the pattern of rainfall at the sub-regional level have a greater impact on agricultural, industrial, hydro-power generation and domestic water supply. The suffering of any of these sector will directly impact the regional economy. These analysis require a long term spatial datasets of the region of consideration.

The state of Goa, located in the west coast of India surrounded by Western-Ghats on west and Arabian sea on the east. There are nine major rivers in Goa which supply fresh water for domestic as well as agricultural purposes. Many of these river also used for navigational purposes to transport ore. The spatio-temporal variation of rainfall in the state has a greater impact on the water resources of these nine rivers. In view of this, the daily rainfall data of IMD grids (0.25^o x 0.25^o) from 1960 to 2018 were analysed for homogeneity, precipitation concentration index (PCI) and trend.

The PCI was estimated for annual, monsoon and post-monsoon season. The analyses of the two sub-periods show significant changes in the precipitation occurred towards the mountain area from 1989-2017, and precipitation concentration increased across most of the grids. At an annual scale, PCI increases mostly due to an increase in precipitation concentration during the monsoon season. At a seasonal scale significant changes were detected between 1960–1988 and 1989–2017, particularly in post-monsoon (increase of PCI values) season. While the homogeneity analysis of rainfall indicate that, most of the grids covering the plains show no significant changes. These changes in PCI and homogeneity seem to be complex and appear to be related to global atmospheric features and synoptic and local factors affecting precipitation trends. These analysis will be important for planning of water resources project for irrigation, hydro power and flood control in the state.

Investigating the effect of environmental variables on the isotopic composition of transpiration

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The isotopic composition of precipitation and plant sap water has been studied extensively. Yet the knowledge of ecosystem water pools, such as soil water and transpiration remains poorly constrained. We propose an alternative method to study the effect of environmental variables on the isotopic composition of transpiration.

A small scale field experiment was carried out to collect transpiration water samples from Cassia tree along with rain water samples throughout the monsoon season of 2018. Transpiration samples were collected by enclosing plant leaves with transparent plastic bags. Isotopic analysis of these samples as well as rainwater was carried out using a laser based water isotope analyser. Humidity and air temperature data was collected using a weather sensor.

It was observed that relative humidity and temperature play an important role in governing the isotopic characteristics of plant transpired water. Isotopic composition of rain water shows a large variability during monsoon season. This variability was well captured by plants as evident by isotopic signatures of transpiration samples. The study of Local Meteoric Water Line (LMWL) reveals that raindrops are undergoing evaporative enrichment as the slope of LMWL is 6.61 which is lower than 8, the slope of the Global Meteoric Water Line. Difference between $\delta_{18}O$ of rainfall and $\delta_{18}O$ of transpiration water is more during low rainfall (break phases of monsoon) events and less during high rainfall events (active phases of monsoon). This characteristics feature provides a means to delineate the active and break conditions of monsoon using a bio-physical parameter.

Quality assessment of water-bodies around an oil refinery, Bina, district Sagar, Central India

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The aim of this work is a first attempt to assess presence and intensity of anthropogenic stress is causing pollution/contamination on water-bodies (surface and sub-surface) around an oil refinery at Bina, district Sagar, Madhya Pradesh (established 2011), in a 'quality-wheat' producing region of central India. Assessment of groundwater's quality for irrigation was achieved using several indices as sodium adsorption ratio (SAR), percentage of sodium (Na%) and residual sodium carbonate (RSC).

Temporal Trends in Water Discharge of the Large Peninsular Rivers: Assessing the Role of Climatic and Anthropogenic Factors

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In recent years there has been increased discussion about the regional and global water balance, particularly concerning its response to changing climate and societal use. For the Indian peninsula, summer monsoon accounts for more than 80% of annual rainfall, and rain-fed peninsular rivers serve as an important source for domestic and agricultural uses. Therefore, this study aims to examine the trends of annual water discharge (WQ) of peninsular rivers. We computed location-specific trends of more than 300 locations covering ten large and several coastal river basins using daily WQ data provided by the Central Water Commission, India. The results are based on 50 years' annual discharge data for 7 locations, more than 30 years of data for around 150 locations, and more than 20 years of data for additional 100 locations spread across the Indian peninsula. The trend in discharge for these rivers is calculated by linear regression and the non-parametric Mann-Kendall test statistics, to identify rivers with significant changes in discharge. In the case of large rivers, the percentage of change varies between -79.1 and 29.5. Except for Mahi and Sabarmati, showing an increasing trend, the rest of the rivers experience a systematic decline in their annual water discharge. Rivers such as Brahmani (-13.7%), Mahanadi (-12.2%), Godavari (-10.6%) and Sabarmati (-20%) experienced a small decline, whereas Krishna (-79.1%; $p<0.001$), Pennar (-77.9%; $p<0.05$), Cauvery (-53.7%; $p<0.01$), Tapti (-27.8%; $p<0.1$) and Narmada (-62%; $p<0.01$) exhibit a significant reduction of their annual water discharge. On the other hand, Mahi exhibit an insignificant increase in discharge. Overall, large rivers registered about a 30% decline in water discharge. Studies suggest that despite a significant increase in the frequency and the intensity of extreme monsoon rain events, there is no appreciable upward trend in average annual rainfall in most of the peninsular basins. The peninsular region hosts 45 mega and more than 3800 large dams and several thousand minor structures. Therefore, diversion of water from dams for various purposes could be one of the major reasons resulting in a decline in annual WQ in these basins. Based on location-specific discharge trends, we anticipate that local or sub-basin-scale changes in rainfall patterns might be another important factor for observed trends in water discharge. Data reduction techniques such as factor analysis revealed that in the case of large rivers, three factors (storage capacity, rainfall, and evapotranspiration rates) have eigenvalue> 1 and explain 87.6% of the variance. The statistical analysis confirms that (i) human intervention in the form of construction of reservoirs have significantly impacted the discharge regimes particularly of large basins; (ii) though rainfall is the prime source of water, it becomes a secondary factor in the case of large rivers, followed by evapotranspiration.

A comparative study of ecohydrology of a tropical mangrove and a broadleaf deciduous forest in India

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Mangroves are wetland ecosystems found in the coastal area near the confluence of rivers at the juncture of soil, water and atmosphere. These ecosystems provide livelihood to the local population through fishery, shrimp farming, firewood etc. and also act as natural barriers for dampening the oceanic eddies such as tsunami, cyclone etc upon their landfall. Apart from these socioeconomic values they also offer high carbon sequestration potential which can even be larger than the inland 'dry' terrestrial ecosystems, crucial for the land-based climate change mitigation. The ecohydrology of mangroves is an amalgamation of complex biogeophysical and biogeochemical processes between the plants and environmental variables which requires careful attention to be disentangled, as essential for their proper representation in weather prediction, climate and ecosystem models. Evapotranspiration is the gross measure of water loss by an ecosystem to the atmosphere through biotic (transpiration) and abiotic (evaporation) mechanisms which also denotes the amount of moist heating provided to the atmosphere by the ecosystem. In comparison with other natural ecosystems, studies on evapotranspiration and their dependencies on environmental variables in mangroves are rather sparse in literature due to the complexity in measuring and modelling those because of the submerged nature of these ecosystems, and more so over the Indian subcontinent. In our study we compare the hydrological cycle of a mangrove on the Bay of Bengal coast in southeast India with a broadleaf deciduous forest in northeast India using high-frequency in situ eddy covariance flux measurements, in a first of its kind of study over this region. Evapotranspiration from the mangrove is dominated by the dry sensible heat flux throughout the year, in similarity with a semi-arid ecosystem except pre-monsoon when it replicates a well-watered ecosystem with evapotranspiration dominating the sensible heat flux. Such behaviour, however, is in stark contrast with the broadleaf deciduous forest that acts as a well-watered ecosystem and provides larger evapotranspirative heating than sensible heat throughout the year including the dry seasons. Transpiration contributes the larger share to the evapotranspiration of mangrove even in the dry seasons, whereas transpiration and evaporation contribute maximum to the evapotranspiration of broadleaf deciduous forest periodically in a year. Using principal component analysis we show that the salinity is the major regulating factor of both transpiration and evaporation at the mangrove, followed by net radiation. It is much different from the broadleaf deciduous forest where root-zone soil moisture and wind speed exert strongest controls on transpiration and evaporation, respectively. The salinity regulation of transpiration has an important implication for the carbon cycle of mangrove and an appropriate assessment of climate change impact on the same. Our study will be useful to the modelling community in these regards for better parameterizing the ecophysiological processes in the models.

Study of carbon transfer processes in a semi-evergreen forest of Northeast India

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Long term and precise monitoring of the forest carbon cycle in different climatic zones around the globe is essential for proper quantification of forest carbon dynamics. The carbon dynamical processes of the major forest ecosystems in India have not been adequately documented yet. The north-eastern part of India is unique in terms of biodiversity and climate characteristics. To investigate the forest carbon transfer processes of this region, CO_2 and energy fluxes are being measured using an eddy covariance (EC) system in a semi-evergreen forest of Kaziranga National Park (KNP), in Assam. Three years of EC measurements from 2016 to 2018 indicates that on an annual scale, the KNP is not a strong sink of CO_2. The diurnal scale net ecosystem exchange (NEE) shows a high amount of respiration component relative to other forested environments in India, apparently driven by heterotrophic respiration in this forest ecosystem. KNP acted as a source of CO_2 during the winter and gradually shifted towards a CO_2 sink during the pre-monsoon season. Forest management practices such as the burning of wild grasses during the winter season also generate a substantial amount of CO_2, resulting in a net source of carbon especially in the winter. The NEE has been partitioned into gross primary productivity (GPP) and total ecosystem respiration (TER). The annual NEE of the forest is estimated as +177 and -31 gC m^{-2} yr^{-1} for the year 2016 and 2018 respectively.

Interannual variability of the physico-chemical parameters around the coral reef ecosystem of Lakshadweep Sea

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The integral parameters which assist sustaining the coral reef ecosystem are being influenced by ocean warming and any small variations in these parameters are known to cause huge physical damage to this susceptible ecosystem (NOAA). Lakshadweep Sea encompasses with number of atoll based islands in Arabian Sea and is known for its coral wealth. The observation was made on physico-chemical parameters and air-sea pCO_2 inter-annually at the coral reef ecosystem of Lakshadweep Sea over a period of years (2014-2018) to understand their influence on this ecosystem. The Sea Surface Temperature (SST), Salinity and pH were measured *in situ* by a calibrated water quality instrument (Model: Quanta-Qd04193), Dissolved Oxygen (DO) was measured by Winkler's method and Primary Productivity (PP) was estimated using light and dark bottle method. The air-sea pCO_2 measurements were made using LI-COR 820-CO_2 gas analyzer. The annual mean values were calculated from the monthly average values for all the parameters and presented.

The obtained results were noticed with variations as the SST (26.68-30.36ºC) and salinity (34.06-36.15psu) were recorded with higher side of mean values in majority cases of assessment and lower range of pH (8.17-8.22) during the observational period of 2014-2018. The DO was found with normal range of 3.96-4.51 ppm as the Lakshadweep water is well mixed and aerated by localized currents. The primary productivity was found with lower range (0.68-1.96 $mgC/m^3/hr$) and the elevated partial pressure of air-sea pCO_2 (388-402 ppm) was recorded during the study period. About 1.5ºC raise in SST over ~5 decades could be noticed when compared with previous studies at Lakshadweep Sea. The low level of pH is envisaged the acidification process and reduced the CO_3 ion available for coral building. Therefore, the increase of SST coupled with low pH is believed to have expelled the symbiotic zooxanthellea from the polyp of corals and resulted in coral reef destruction. The sequestration of air-sea pCO_2 in the Lakshadweep Sea was found to be insignificant due to the damages of coral reef ecosystems and lessens primary production. Overall, some vital physico-chemical parameters of Lakshadweep Sea were found with variations which have notable impact on this sensitive ecosystem.

Assessment and conservation approaches of degradation hotspots in three leading Indian rivers

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River and riparian ecosystem restoration have significantly become the new approach to reverse the past degradation activities and prevent the future losses. There are factors such as clearing of riparian zones, construction on wetlands, degrading river water quality by human activities etc. that are contributing to deterioration of the river and riparian ecosystem. These activities cumulatively pose challenges to the short term and long-term agendas proposed by various organizations. It is important to look for solutions that will help reduce the extent of the degradation caused by the key drivers. The current restoration practices that are taken as the action plans for rejuvenation of rivers and associated riparian zones are not available to achieve the legally mandated goals, which are meant for the improvement of the structure and function of the degraded units.

Three identified leading rivers of India to assess the degradation hotspots are the Ganga, Brahmaputra and Godavari. For each identified river, degradation hotspot has been recognized based on four parameters viz. population, sources of economy, river water quality, and biodiversity. Based on their geographical location with respect to the particular river selected and the extent of secondary data available regarding the river and riparian ecosystem degradation in a particular district, rivers are studied in certain aspects to evaluate degradation issues and monitoring implementation on the same grounds.

While conditions of riverine ecosystem at specific location are also determined by the status of the riparian zone and vice-versa, conditions of upstream and downstream of particular riverine ecosystem are interdependent. Thus, degradation of upstream and downstream of the river is interlinked, which also connects their revival solutions. Individual rivers can be affected by similar or different key drivers of degradation; therefore, the restoration schemes differ in the magnitude of their exposure to these certain factors. This study is an approach to assess the degradation factors and its extent along with looking at the causal factors in degradation hotspots of three rivers in India namely Ganga, Brahmaputra and Godavari so that the existing conservation approaches are modified and new action plans are accordingly designed taking in account their existing mortified scenario.

Examination of historical trends and future projections for climate and land-use variables and its impact on Kalna River flow in Goa, India

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There is always pressure on water availability due to increasing levels of societal demand and from economic activities. Hence, understanding the effect of climate change on various components of the water cycle is crucial in management of this resource. To devise sustainable water resource strategies, seeing how much change in climate and land-use/land cover (LULC) affects hydrologic regimes can help decision-makers to incorporate necessary measures in the policy instruments. The objective of this study was to analyze the impact of climate coupled with land-use change on Kalna river flow situated in North Goa. The assessment involved temporal rainfall analysis to understand the historical trends. Further, future climate and land-use change projections were evaluated to comprehend the impact on the river flow. An ensemble of models was used for future predictions. For climate modeling, the Norwegian Earth System Model (NorESM) was used under two scenarios that included RCP 4.5 and RCP 8.5. The land-use change was simulated using the Land Change Modeler (LCM). Finally, hydrological modeling was done using the Soil and Water Assessment Tool (SWAT) model. The results from NorESM and LCM were used as an input to SWAT model to predict future flow for Kalna River.

The historical trend in rainfall was statistically scrutinized using Mann-Kendall Test and Sen's Slope method. Average annual rainfall data from India Meteorological Department rain gauge station at Mapusa for the period between 1980 and 2018 was used. An increasing linear trend was observed which was supported by Kendall's tau and Q (Sen's slope) indicating strong positive correlation between rainfall and duration. The land-use change analysis was done using satellite images of 1993, 2014 and 2019 map for validation. A Kappa co-efficient of 0.73 indicated acceptable accuracy. Multi-Layer Perceptron neural network was used for prediction of land-use for 2030 and 2040. These two future land-use maps were used as an input and SWAT model was calibrated for the years 2011 to 2015 and validated for 2016 to 2018. Two statistical measures, Nash Sutcliffe Efficiency (NSE) and R^2 with value of 0.7 showed goodness of calibration. It was then used to predict the future streamflow till 2050. As compared to baseline average monsoon rainfall data (26.87mm), the future projections under both RCPs (4.5 and 8.5) scenarios indicate an increase in rainfall and streamflow. This increase in average streamflow is more pronounced in RCP 4.5 as compared to RCP 8.5. As per the LCM projections, the forest area is likely to decrease by 2040 with a distinct increase of 14% in barren land owing to quarrying and mining activities. The decrease in the forest cover along with changing climate decreases the streamflow clearly demonstrating the importance of the green cover. Currently, around 10% of the water required by the water treatment plant at Chandel is extracted from Kalna River. Based on the simulations, site-specific recommendations are given to aid in the strategic planning of this watershed.

Assessment of physicochemical parameters of the Ganga river water between Prayagraj and Varanasi

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In recent years, due to rapid population growth in urban areas, rivers have been associated with water quality problems. Due to the discharge of domestic and industrial waste, without any proper treatment, into the surface water bodies, which leads to the contamination in river water. The present work is focused on the two important pilgrim cities of India situated on the bank of the Ganga river. Various factors influence water quality in the river Ganga. The main influence comes from the domestic sewage, and industrial effluents, and anthropogenic activities discharge into the river Ganga. The Physico-chemical parameters of River Ganga and their tributaries were determined between Prayagraj and Varanasi and compared for possible interaction and correlation. Water samples were analyzed by aqua meter kit and ion chromatography methods. Results obtained indicate that apart from the pH variation (7.8- 9.3), variation was observed in other parameters such as turbidity (1390-2936 NTU); TDS(370-1039 mg/L); ORP(228-273 mV); DO(>7 mg/L); salinity (0.24-0.79 PSU); EC(577-1600 μS/cm). Similarly, major cations (Na^+, K^+, Mg^{2+}, Ca^{2+}, etc.) and major anions (F^-, Cl^-, SO_4^{2-}, Br^-, PO_4^{2-}, etc.) were measured. Arsenic concentration was very less in the study area. The result shows that the water quality degrades along with the downstream. The high pollution level was noted near Assi Ghat and river Varuna confluence in Varanasi. This is attributed to the disposal of untreated sewage and industrial wastewater.

Probability of flooding and vulnerability assessment in the Damodar River, Eastern India: implications for mitigation

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The estimation of flood magnitude for a specific return period is prime importance for flood management through flood plain zoning. Flood frequency analysis enables estimation of the probability of occurrence of a certain hydrological event of practical importance by fitting a probability distribution that is empirically obtained from recorded annual maximum discharge data. This case study considers the use of four probability distributions, namely Gumbel's extreme value distribution (EVD-I), extreme value distribution-III (EVD-III), log-normal (LN) and Log-Pearson Type III (LPT-III) in flood modelling of monsoon dominated Damodar River and illustrates the applicability of goodness of fit (GOF) and D-index tests in identifying the distributional model for the specific data. Eighty-nine years (1823–2007) of existing and estimated annual peak discharge (Q_{max}) data have been used for analysing the trend of flood occurrence. After identifying the best fit model, analysed combining with geographic information systems (GIS) for predicting flood affected area and preparation of inundation map at a specific return period (T).

Flood data for Rhondia gauge station Results of the study showed the EVD-I, EVD-II, LN and LPT-III distribution including better suitability for modelling flood data for Damodar River including computed Q_{max} for vulnerability assessment. This finding provides a clear picture for the pattern of hydrological fluxes and aftermath in the next decades in the lower Damodar River Basin (DRB). The Sustainable planning and developmental measures that consider the modelled pattern of hydrological fluxes of this study area were also recommended for decision making.

Identification of climate change impacts by glacial lake changing aspects in Arunachal Pradesh over the last four decades

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Climate changes have a significant impact in various part of the Himalayan glacial environment. Quick melting of glaciers has resulted in the formation and expansion of various types of glacial lakes, creating a potential danger from glacial lake outburst floods (GLOFs). Most lakes have started increasing in size and numbers from the 20th century. Therefore, glacial lakes play an important role in the cryosphere, climate change and alpine hazards. The issues of glacial lake were systematically discussed, from the view of glacial lake inventory and glacial lake hazards study, the glacial lake is defined as natural water mainly supplied by modern glacial meltwater or formed in glacier moraine's depression. The present study includes mapping of glacial lakes with an area greater than 1 sq. km above 3500 m above using time series LANDSAT 5, 7 & 8 satellite data ranging from 1990 to 2019. The image enhancement techniques such as Pan Sharpening, Digital Elevation Model (DEM), and NDWI have been implemented on Landsat imagery and glacial lakes were delineated. Furthermore, a complete classification system of the glacial lakes was proposed based on its mechanism of formation, topographical feature, and geographic position. Glacial lakes were classified as, glacial erosion lake (including cirque lake, glacial valley lake, and other glacial erosion lakes), moraine-dammed lake (including end moraine-dammed lake, lateral moraine-dammed lake, and moraine thaw lake), ice-blocked lake (including advancing glacier-blocked lake and other glacier-blocked lakes), a supraglacial lake, subglacial lake, and other glacial lakes. Meanwhile, Lakes were also assessed on the basis of growth rate at various altitude ranges. The result of the study can help in carrying out a downstream riskassessment, spatial planning, and better preparedness for future GLOF hazards.

Multi- hazard risk mapping and assessment of housing adaptability: a geo-statistical analysis from Indian Sundarban

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Deltas are always being favourite destination for human due to rich biodiversity and abundant resources yet at the same time; they are highly vulnerable to the impacts of natural hazards. With a coastline of 157.5 km, West Bengal is prone to high intensity weather events including cyclone, storm surges, inundation, land erosion. These hazards are associated with material loss, destruction of houses and civic properties. Despite their proneness to hazards, coastal people make relentless efforts to cope with severe impacts through age-old indigenous knowledge and practices. Dwelling structures are directly being influenced by extreme events. The purpose of this study is to delineate the multi- hazard risk zones and find out the association between natural hazards and housing pattern to combat extreme consequences in the islands of Indian Sundarban Delta (ISD). The western boundary of the ISD is the major focus of this study specifically Sagar, Ghoramara and Mousani Islands which are prone to regular occurrence of erosion, cyclone, and inundation/ flooding. Integrated study on risk zonation and community adaptability is limited in this deltaic region. This study tries to fill this gap using Multi- hazard risk maps by GIS platform to identify hazard specific vulnerable areas. Result shows that Sibpur, Doblat, Beguakhali, Sumatinagar, Kachuberia and Muriganga and Ghoramara of Sagar Block and Baliara of Mousani Block are worst affected due to erosion; Beguakhali, Dhablat, Kastala, Sapkhali, Companir char, Sumatinagar, Shibpur, Baliara, Ghoramara, Mousani are mostly affected from cyclonic storm; and coastal mouzas are mainly vulnerable from inundation. This study attempts to estimate the influence of particular hazard on the housing structure by means of multinomial regression using collected primary survey data from randomly selected households within these islands. The result suggests that seawater ingression often collapses the mud wall of the coastal houses and houses having thatched roof are vulnerable to cyclonic storms. The survey findings show that finished materials are preferable for roofs to that for wall and floor to protect houses form the cyclonic storm. The result further suggests that mud is commonly used for wall and floor due to easy availability from river, creeks, and ponds. Comparatively Sagar Island has lowest percentage of kachcha houses than other two islands which can be explained by the fact that Sagar has a better infrastructural setup. Given the importance of delta regions as centre of attraction for diverse anthropocentric activities, this study also tries to offer a number of concrete policy recommendations to reduce housing vulnerability from natural hazards.

Innovation in Rain water Harvesting to mitigate risks due to Climate Change

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The extreme weather events in India involving excessive loss of livelihood and property are causing much trouble in society and posing challenges before government, scientists, professionals and policy makers to mitigate risks. Every year some parts in India face droughts and some parts face floods situation due to erratic rainfall. It is very much difficult to characterised any are comes under drought or flood. It means same area can be affected by drought as well as floods in same year.

Significant part of district Patan in Gujrat is severely affected due to salinity. The district has semi-arid climate. Extreme temperatures, erratic rainfall and high evaporation are the characteristic features of this type of climate. Below 40 feet depth there is huge amount of water available but due to high level of salinity it can't be used not for drinking neither for irrigation. Almost every year people of Patan facing drought or flood situation. In both situation crops damaged left farmers in debt cycle. Major crops are coarse grained Cereals, Castor, Cumin and fodder crops to support animal husbandry to survive the people.

Reliance Foundation under its flagship program BIJ (Bharat India Jodo) selected a cluster comprising 16 villages in Radhanpur block in year 2013. Detailed situation analysis revealed that water is major issue for the people. Every year floods and droughts posed challenge to survive them and cattle's. Team observed a dilapidated practice of drawing water for drinking at a very few farms through a small hand pump from shallow aquifer (the system named "Holiya"). Taking it forward we designed an improved version of Holiya with arrangement for recharging rain water during floods and use recharged water for irrigating crops.

Design of Holiya System: In low lying area of farm, 8 inches dia. 40 feet deep bore drilled and inserted a 6 inches dia. perforated pipe. Filled the gravels around pipe in the bore and at top constructed soak pit of 2 m dia. And 2.0 m depth. Flood water diverted towards the soak pit and facilitated to percolate in the shallow aquifer through this recharge mechanism. Testing on ground done in year 2015, results found as per expectations. Next year piloting of the Holiya done in some of villages. Farmers found it very much helpful protecting Kharif crop during long dry spells and have some water to irrigate Rabi crops.

Results: Reliance Foundation supported farmers for construction of more than 700 Holiya's till Mach 2020. Farmers found it game changer as it protects crops by recharging stagnant water during high floods and draw same water from aquifer to irrigate Rabi crops. The cost of whole systems comes around Rs.10,000 to 15,000. Count of milching animals increased as green fodder is available. Income of farmer households has been crossed level of Rs.1.5 Lakhs / Annum. District collector appreciated the innovation and advised to DRDA to scale up in entire district. Current year DRDA is supporting farmers through online application system by using MGNREGS funds for 1000 nos.

Waste Management and Its Effect on Global Warming

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Waste is an unwanted natural byproduct that has been disposed, after primary use by the Society. It is of various types and is classified, based on its different parameters such as state, nature, source, decomposition and future use. Due to diverse and numerous types of waste like garbage, sewage, construction-/chemical-/medical-/sanitary-/e-(electronic)/nuclear-waste, etc., its genera-tion is of the order of millions of tons per year in many countries. Hence, its proper disposal has become critical for tackling the major societal problem of global warming (GW) that has direct impact on climate change (CC). For example annually, Americans alone produce ~ 220 million tons (mt), the highest in the world, and Indians ~ 62 mt of waste of which 45 mt remain untreated and 75% is recyclable. Waste Management (WM) is all the activities and actions required to manage waste from its inception to its final disposal, which includes, amongst other things, its collection, transport, treatment and disposal together with monitoring and regulation, besides encompassing the legal and regulatory framework, related to guidance on its recycling, reuse, etc., The 5Rs (Refuse, Reduce, Reuse, Recycle and Recover) principle is usually followed for WM. Important methods of WM are landfill, incineration, plasma arc gasification & vitrification, compaction, composting & vermicomposting, biogas-generation and recycling, with the first being the least desirable, except for hazardous waste like mercury and asbestos.

Effect of WM on GW: The major causes of GW - power plants, transportation, industrial-farming, deforestation, fertilizer-use, oil/gas-drilling, permafrost, garbage and volcanic eruptions – are driving to CC, mainly due to increase in the emissions of greenhouse gases. GW and CC lead to many catastrophic events such as large-scale melting of polar ice, rising of sea-level, posing submergence-problems to low-lying coastal areas/countries, and frequent occurrence of natural disasters such as floods, drought, cyclones, hurricanes, tsunamis, earthquakes, etc., WM, in terms of reduction, separation and recycling, is the best option to reduce GW of the Earth, and the waste that remains would be burnt to create energy. Furthermore, WM, in terms of generation of bio-energy and conversion of plastics into liquid hydrocarbons and energy for diverse end-users of industries, agriculture, etc., can have positive effect in reducing GW and ill-effects of CC, besides saving millions of dollars for importing crude oil. Worldwide implementation of composting can reduce emissions by 2.3 billion tons over the next 30 y. Reducing food waste is one of the most important things to reverse GW and could have nearly the same impact on reducing emissions over the next three decades as onshore wind turbines. Furthermore, WM can generate both wealth [e.g., extraction of Cu-Au-Ag-Sn-REEs by recycling of e-waste; diamond batteries from ^{14}C (from nuclear waste); and jarofix (Zn-byproduct) for road construction] and employment due to diverse WM-services, which result in a big boon to a developing country like India.

Seeing the Unseen: Changing Climate affecting microbes and their ecological services

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Climate change is a serious, socioeconomic, geopolitical and defining global issue of varied visible effects on present century. The UN Intergovernmental Panel on Climate Change (IPCC) in its fifth assessment report stated that from 1880 to 2012, the global mean temperature increased by 0.85°C. If the current rate of GHG emission is not curtailed, temperatures may rise by up to 1.5°C between 2030 and 2052. Carbon dioxide (CO_2) accounts for two thirds of the total greenhouse gases (GHG), and its atmospheric concentration have reached to 405.5ppm in 2019 (Moana Loa Earth observatory). Climate change has direct as well as indirect adverse effects on all life forms including microorganisms. The microorganisms play significant role in maintaining ecosystem balance and crucial for various ecosystem services such as nutrient cycling and biodegradation of pollutants. Additionally, microbes interact with different life forms such as plants and animals and plant-microbial, soil-microbial and microbe-microbe interactions and are important for the proper functioning of the ecosystem. However, these interactions are very sensitive in nature and susceptible to change in environmental parameters such as elevated CO_2 concentration and rise in atmospheric and soil temperatures. In fact, altered plant activities shifts the plant-microbes interactions due to climate change (elevated temperature and CO_2). We have reviewed that climate change leads to alteration in microbial activity, composition and diversity present in different ecosystems. For example, rhizosphere microbes play important roles in nutrient cycling and protect plants from harmful effects of abiotic and biotic stresses. High temperature and CO_2 affects the nutrient cycling, decomposition and mineralization processes of rhizosphere due to altered microbial activities. Moreover, large number of phyllosphere microbes predominantly bacteria and fungi, mutualistically help the host plant in their growth, function and provide tolerance to environmental stresses. In turn, they get plant habitat for their own growth, reproduction and development. This phyllosphere microbes and plant interactions get significantly affected due to climate change. Oceans are among the highly dense microbial pools in the environment and ocean acidification due to climate change have led to increased CO_2 concentration in oceans which caused effect on abundance, structure, function as well as results in loss of microbial diversity. In the same sense, Antarctica and arctic microbial communities have also diverged under climate change. The intricate and diverse microbial communities of these various ecosystems showed astonishing results under climate change. Thus, we here reviewed the impact of climate change on functioning, diversity and composition of microbial communities associated with various ecosystems and their forbidden impact on ecosystem. In light of this, we are discussing about unseen effect of climate change on microbial communities and in turn their major impact on the environment.

Engendered climate risk analysis: a precursor to gender equality and empowerment

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As Climate Change continues to wreak havoc around the globe in the form of climatic disasters such as increased frequency and intensity of floods, droughts, cyclones and wild fires, vulnerable sections of the population continue to bear the brunt of its impacts. Studies have shown that determinants of risk/vulnerability of men and women are gendered. As natural resources become scarce, women are the most affected since they are the prime managers of natural resources. Due to increased time required to fulfil their gender based roles, women continue to remain disadvantaged leading to high gender inequalities in different domains thus failing to achieve the Sustainable Development Goals of gender equality and empowerment as well as the achievement quality education, poverty alleviation, clean energy, good health and clean water and sanitation, economic growth and most importantly, climate action.

The Conference of Parties of the UNFCCC have emphasized time and again the need for gender balance and gender equity in climate action as well as negotiations. The LIMA work program on gender and consequently the Gender Action Plan have highlighted one of the priority areas as the need for metrics to create evidence of differential vulnerability and risk to climate change. The present study uses an index based approach using a new index called Gender based Climate Risk Index (GCRI) to capture the vulnerability and resultant risk faced by both men and women at the sub-national (state) level in India. A combination of the IPCC's risk assessment framework and Caroline Moser's Gender Analysis Framework has been used to arrive at the index. GCRI has been validated and tested for reliability keeping the availability of data at the required spatial scales. It comprises of 54 indicators for which data has been collected from a variety of sources. GCRI been computed for all states and Union Territories across the country for both men and women.

GCRI values for females ranged from 0.25 (low risk) in Goa to as high as 0.62 (high risk) in Bihar. By comparison, males faced much lower level of risk as the GCRI values ranged from as low as 0.16 in Goa to 0.51 in Bihar. A weighted average of GCRI scores reflect a ten percent point difference between the climate-based risk faced by males and females. Despite experiencing the same level of hazards and exposure, females experienced much greater level of sensitivity to climate change and extremes and had much lower capacity to adapt to climate change leading to their greater vulnerability and consequently risk to climate change and hazards. If the national and the global goals (SDGs) have to be met, it is important that climate related policy making is more gender sensitive and gender transformative to enable women to lead climate resilient lives.

Understanding the lockdown impact on Air Quality in Delhi due to COVID-19

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Coronavirus disease 2019 (COVID-19) has become a more severe public health problem globally. The COVID-19 cases are increasing day by day. Government of India has initially decided for 21 days complete lockdown which had extended to further more phases. The comparative study between the characterized air pollutants over Delhi and prevailing lockdown impact has been addressed by the trend analysis of Air Quality Index. It is noticed that O_3 rather than SO_2, CO, PM10, PM2.5 and NO_2 was more dominant in this region during the lockdown period. We have considered daily 24 hourly average data of PM10, PM2.5, NO_2, SO_2, and 8 hourly average data of O_3 and CO as collected from Central Pollution Control Board (CPCB) between March 25, 2019 to April 24, 2019 (before lockdown) and from March 25, 2020 to April 24, 2020 (during lockdown). Our results indicate that the average concentration of NO_2, CO, SO_2, PM10 and PM2.5 have been reduced but the concentration of O_3 has increased during the lockdown period. The trend analysis shows that the trends of NO_2, SO_2, PM2.5, PM10 and O_3 have been increasing constantly, except CO before the lockdown period.

COVID-19 Lockdowns Improve Air Quality in the South-East Asian Regions, as Seen by the Remote Sensing Satellites

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The appearance of COVID-19 in December, 2019 in China and its rapid spread all over the globe, forced the governments to severely curb the social and economic activities of their respective countries. Barring the essential services, most of the business activities and transport sectors have been suspended and an unprecedented lockdown imposed over major economies in the world. South-East Asian regions, such as India and China, were no different. As a result, the pollutant level has gone down over these regions, and the air quality improved somewhat better than it was before the lockdown. This study uses satellite retrievals and attempts to estimate the extent of the reduction of major pollutants, like carbon monoxide (CO), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) in India and China during January to April, 2020. We have calculated anomalies of pollutants during the lockdown period relative to their long-term records. NO_2, which has significant emissions from the transport sector, is reduced on an average by 17% over India and 25% over China. SO_2, which mainly emits from power plants, shows significant reductions (approx. 17%) especially over the Eastern sector of India. CO is found to be reduced by 6.5% over north-central China. The differential reduction was attributed to manmade versus natural activities. This study is helpful to policy makers in mitigating the air-pollution on a long-term perspective.

Black carbon in Arctic: Impact of COVID-19

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Black Carbon (BC) can trap radiation and warm the atmosphere; and are reported to be the second strongest contributor to global warming after carbon dioxide. BC is mainly generated by burning of biomass and combustion fossil fuel. BC has crucial impact over the polar regions. The global radiation balance was altered by complex feedback mechanisms which can reduce the surface albedo. More rapid ice loss can exhibit in the Arctic due to positive feedback mechanism. BC also contributes to melting of snow through another process, in which BC deposited over snow and sea ice, darkens the snow and give rise to enhancement in solar absorption by snow and ice. The residence time of BC in the lower atmosphere is about a week. Arctic region is a receptor of aerosols (tiny particles suspended in air) including BC from different source regions at lower latitudes. Aerosols and their properties are being contentiously measured under the Indian POLar AERosol NETwork (POLAERNET) program since August 2018. Black Carbon mass concentration and aerosol absorption coefficients are being measured at seven wavelengths (370, 470, 520, 590, 660, 880 and 950 nm) using seven channel Aethalometer (model AE33) at temporal resolution of 1-minute temporal resolution over Ny Ålesund (78.92°N, 11.91°E; Norwegian Arctic) under POLAERNET. The contributions of biomass burning and fossil fuel combustion on BC mass are estimated using the spectral behaviour of BC mass at seven wavelengths.

In order to reduce and stop the pandemic situations due to Corona Virus Infection Decease -2019 (COVID-19), most of the countries had locked down almost all the activities except emergency services. Therefore, the vehicular and many industrial activities had stopped from mid of March 2020 to Mid of May 2020. There are 40% and 30% decrease in BC mass during March and April 2020 respectively with respect to masses during same months in 2019. The reduction of anthropogenic activities can have significant impact on BC mass over the pristine Arctic region. However, the BC produced by forest fires contributed to BC. The detailed results of the study will be presented and discussed.

COVID-19 and Pollution and Meteorology: A Convoluted Relationship

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Corona virus disease 2019 (COVID-19) which emerged from Wuhan, China, the spreading dynamics of which is not fully understood, is highly vague and intricate in time and space. The pandemic poses a brutal choice to the society and economy. The vulnerabilities and strengths of every country have been revealed making us to understand a series of lifelong lessons. Studies found that an increase in particulate matter concentration causes more COVID-19 cases and mortality. Gaseous pollutant and COVID-19 cases are positively correlated. Local meteorology plays crucial role in the spread of corona virus and thus mortality. Decline in number of cases with rising temperature was also observed.

Environmental beneficial effects include improvement in Air Quality as a result of lesser travelling done by people, which includes road, rail, sea and air transport. Air quality tremendously improved during lockdown. A significant reduction was observed in PM10, PM2.5, BC, NOx, SO_x, and VOCs concentration. Wind-speed plays a crucial and important role in spread of corona virus, however Rainfall was not related to the spread of COVID-19 whilst, the places with lower solar radiation showed the high exposure rate of corona virus. Humidity showed negative or no relationship with COVID-19 cases recorded worldwide. The rivers and waterways has cleared up because of the lesser human footfall even the oceans are recovering and marine life is thriving as noticed in many places across the world. Environmental deleterious effects include increase in the production of solid waste as a result of quarantine policies, established by most of the countries. Bio-Medical waste is also on the rise and on an average five times more production was recorded across the world during the period of outbreak. Various studies showed that aerosols generated by sneezes and coughs are major route for spread of corona virus however practicality of novel COVID-19 stuck on the surface of particulate matter is not yet confirmed. The present review study made us to understand the impact of weather and atmospheric pollution on morbidity and mortality and made us to rethink and re-assess our developmental plans and goals.

Impact of COVID-19 induced lockdown and Unlock periods on the Air quality of Guwahati city, India

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The novel corona virus also known as (SARS-CoV-2) was first identified in Wuhan, China in late December 2019. COVID-19 is a highly contagious and mutable disease which has become a pandemic. It has been reported in more than 216 countries around the world. There is no cure widely available till date which has resulted in panic and despair across the globe. The majority of nations had opted for partial to total lockdown restrictions as a measure to contain the spread of COVID-19. India announced 68-day nationwide lockdown on March 25, 2020 which was subsequently extended and succeeded by different phases (with relaxation in restriction rules) till May 31, 2020. The lockdown has dramatically impacted the economy of the country. However, it has come as the breathing space for the environment as its anthropogenic exploitation came to standstill. Drastic reduction in pollution level and increment in environment friendly variables have been observed around the world. The aim of the present study was to assess the trends of Particulate Matter (PM_{10}), Sulphur Dioxide (SO_2) and the Oxides of Nitrogen (NO_x) during the Pre-lockdown, lockdown and Post-lockdown periods and similar period of 2019 in Guwahati city. The meta-analysis of continuous data was performed using descriptive statistics. Air pollutant data was acquired from the Central Pollution Control Board (CPCB) and Assam Pollution Control Board (APCB). The result revealed that as much as 63.02%, 80.28% and 84.25% reduction in the mean concentration of PM_{10}, SO_2, and NO_x pollutants respectively and the fluctuation from the mean values was also drastically reduced by (93%) PM_{10}, (96.11%) SO_2 and (89.47%) NO_x in comparison to similar period of 2019. The significance of the study is to show how the different sets of restrictions (in phases) imposed upon a city can heavily reduced pollutant concentrations. The study suggests that after modifications (to minimize the economic damages) the lockdown can also be one of the important measure to arrest high pollution levels in the urban areas.

COVID-19 and weather parameters: A case study of Maharashtra, India

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One of the most discussed topic of 2020 is COVID-19, which is declared as epidemic by World Health Organization. Virus named as novel corona virus is responsible for COVID-19 is first time observed in the Chinese city named Wuhan. Many studies have been conducted to understand different perspectives of COVID-19 in diverse areas. Out of these, one of the important perspectives is to understand the relationship of meteorological parameters with Corona virus in different scenarios. Considering this view, in the present study, efforts has been done to put a light on the relationship between the COVID-19 cases with respect to change in the weather parameter. For this case study, state of Maharashtra is studied which one of India's leading commercial and industrial centers. Meteorological and COVID-19 related data is collected from authentic websites for a period from 09th March to 31st July 2020. Statistical package for Social Sciences (SPSS) is used for different statistical tests. Strength of the relation between different weather parameters with COVID-19 is calculated by using Spearman correlation. To find the trend, linear regression technique is used, which show that with the increase in 1 ^{O}F temperature, number of daily cases of COVID19 increase by 279 in number. Positive trend observed between COVID-19 and Weather parameters is not significant, moreover rigorous and sophisticated lab studies are required to support the results along with field study. This may be co incidental that with time both COVID-19 cases and temperature are increasing. So at least one complete cycle of COVID-19 is required to find the threshold value of temperature in upper and lower range at which the corona shows some significant changes.

An overview of the impacts of Covid-19 on marine sector in India and their implications for achieving sustainable development of marine resources

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The outbreak of the coronavirus disease (Covid-19) since December, 2019 and the resultant lockdown has impacted terrestrial as well as marine environment both positively and negatively, which is currently being investigated worldwide. In the case of the marine environment, while the absence of large-scale fishing operations has been prominent, slowdown of various anthropogenic impacts on the sea i.e., marine transportation, mining etc. during the lockdown phase has also been evident. In the present study, the positive as well as the negative impacts associated with the anthropogenic developments of the Covid-19 scenario, have been explored with an emphasis on the changes in the climatic variables for the marine environment . From the perspective of natural responses to the scenario, an interesting example is the reduction of the mean sea surface temperature (SST) by 0.5°C in the North India Ocean, which had been reported during the lockdown phase due to the reduction in the carbon dioxide (CO_2) emissions. On the other hand, the community dependent on the ocean i.e., marine fishers have also experienced a huge economical loss during lockdown from 25th March, 2020 in India followed by the annual fishing ban period during mid-April to mid-June, imposed by Government of India. Therefore, marine fishers were forced away from not venturing into the sea for about 90 days instead of the usual 60 days of the scheduled ban period. These developments are expected to impact the regional climatology as well as the sustainability of the marine environment (as per the Sustainable Development Goal 14; SDG 14) itself in two important ways as follows. One, the resumption of fishing activities could likely result in overfishing, illegal or unreported fishing activities etc. to overcome the economic loss during the lockdown phase leading towards unsustainable fishing. Secondly, the increase in fuel consumption of fishing boats and a corresponding increase in the emission factors of gases such as carbon monoxide, particulate matter and nitrogen oxide are possible futuristic scenarios which negatively impact the control of emissions. These can become the causative factors for climatic changes on a regional-scale and require rapid attention. From the perspective of conservation, the slow restoration of the demand-supply chain related to the marine trade of seafood could open a window for sustainable resource management, if supported by suitable policy frameworks. Therefore, the difficult circumstances of the Covid-19 pandemic may be able to provide an uncommon opportunity to study and assess the impacts as well as to plan for restoration of the ocean 'health' .

Impact of lockdown on air quality in megacities of India during COVID-19 pandemic

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In the month of March 2020, the World Health Organization (WHO) declared COVID-19 as a pandemic. Amid the COVID-19 pandemic, Government of India has also initiated preventive measures by imposing nationwide lockdown initially for three weeks from 24th March 2020 to 14th April 2020 and extended up to 3rd May 2020. The aim of this study is to assess the impacts on air quality ($PM_{2.5}$, PM_{10}, NO_2, NH_3, SO_2, CO and O_2) during different phases of lockdown in different cities (Delhi, Mumbai, Bengaluru and Nagpur) of India. As a result, significant reduction in aerosol concentrations were observed; 40%, 53%, 45% and 34% in $PM_{2.5}$ and 37%, 53%, 35% and 20% in PM_{10} at Delhi, Mumbai, Bengaluru and Nagpur respectively. Other air quality parameters such as NO_2, NH_3, SO_2 and CO showed declining trends whereas increasing trend for O_2 was observed. The present air quality data were also compared with previous year (2019) data and found significant reduction in the current year (2020). The overall results demonstrate that air quality is significantly improved due to nationwide lockdown.

Review of Lockdown Consequences on the Aerosol Heterogeneity over Indian Subcontinent

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The covid-19 is pandemic for humans but at the same time it's recharging the natural resources which were becoming worse due to human activity. This pandemic forced us to concise our activity and at several places the governments also imposed the lockdown to reduce the impact of this pandemic. The restricted human activities in all the dimensions which contributed for the degradation of the natural resource became boon for the nature and a clear impact were seen in the air quality as well. Aerosols are one of the contributors which worsen the air quality and in the present work we have focused on the aerosols.

In the present work we have explored the changes in heterogeneity of aerosol distribution occurred during the lockdown period. We have used the MODIS aerosol optical depth (AOD) data to visualize the changes occurred in AOD over Indian subcontinent owing to shutdown of the industries and other major aerosol emitting sources. We know that over any part along with the generation of aerosols, several other factors also contribute to the total concentration of aerosols/pollutants. Meteorology, topography, terrain and redistribution of aerosols are major factors which also governs the concentration of the aerosol over a location along with the generation of the aerosols.

As during the lockdown period major industries were shutdown thus this provided us the golden opportunity to explore more about the background aerosol concentration along with its other potential contributors. This process enabled us to quantify the background concentration of aerosols over the Indian subcontinent. To explore in more detail we also utilized the ground based observations from AERONET over several observational sites in India. The time span selected for this work is from Jan 2019 to Aug 2020. But there was limitation with AERONET data quality for year 2020. AERONET provides data with three quality levels: Level 1.0, Level 1.5 and Level 2.0. The data at level 1.0 and 1.5 are provided in nearly real time while level 2.0 takes longer time to ensure the highest quality data. Thus due to limitation of availability of level 2.0 data we have used level 1.5 data for the study of aerosol properties. With the help of the AERONET data we could visualize the effect of lockdown in more details over sites falling over various terrain regions. This study also provided us the information about the dominant aerosol type and information regarding the other physical properties of the aerosols. We have analysed the last year information regarding the aerosols so that we could visualise the actual changes occurred due to lockdown. This study provided us the proper view about the heterogeneity in aerosol before and after lockdown over Indian domain along with changes that occurred with the resume of human activities. The results showed that with restriction in human activities for months aerosols concentration reduced but not fully removed from the atmosphere. We could notice substantial presence of the aerosols in the period of lockdown also which gave information about the background aerosols. This study also provided us with other physical properties regarding the background aerosols.

Rethinking Waste Management during Covid-19 – Assessment and Strategies to Manage Household Biohazard Personal Protection Equipment

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"SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2)" formally known as "COVID-19" outbreaks in India at end of march 2020 causing a wide spread havoc not only in India but across the globe. Protective measured used for prevention of infections includes used of masks, hand gloves, sanitizer, face shields etc. The waste generated due to these products were initially not part of environment but now is found in every household. This has become a new normal for people leading to generation of new kind of waste stream which can be referred as COVID waste.

This study carried out is focused on household waste generation and change in its trend due to COVID pandemic. The key finding which results into overall increase in trend of household waste is caused due to extensive use of precautionary products by individuals, increase in plastic packaging due to online mode of shopping and behavioural pattern caused by lockdown imposed like of stockpiling products and irregular cooking habitat has major cause of rise in household waste across the India. Data from a dipstick Pan-India online survey indicated 58% and 38% usage of reusable cotton, and disposable mask respectively. Approximately 25% of the mask users disposed up to 20, while 75% of users disposed up to 8 masks per week. Initial estimates suggest mask waste equivalent to 0.6% by weight of the household waste. However mixing and indiscriminate disposal of biohazardous mask waste presents unknown challenge and cross contamination of biodegradable and non-biodegradable waste. This presents both short term and long term challenge to the environment. The current pandemic has resulted waste demanding an urgent need for a proper system approach for waste management to reduce its impact on humans and environment.

This study evaluates the current situation in the light of Solid Waste Management 2016, Swachh Bharat Mission and Provision of Biomedical Waste Management. The study also reviews the guidelines issued by the WHO and Central Pollution Control Board. It would also analyse the PIL filed in Supreme Court and High Courts of Punjab and Haryana and High Court of Madras.

Is the climate and water related vulnerability gender neutral? Case study of slums in capital city of India

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Climate change is transforming countries the world over. Gendered divisions of household responsibilities across developing countries disproportionately enhance the vulnerability of women to climate change. Water crises have been enlisted as among the top five global risks, climate change being one of the main drivers. As a result of this, women are impacted the most since water is one of the most important Practical Gender Needs (PGNs) of women and is crucial to meet their Strategic Gender Needs (SGNs).

Urbanization is a reality to which India is no exception. Trends suggest that urban population in India is likely to increase from 410 million in 2014 to 814 million in 2050. A major chunk of this population will be living in slums and related settlements with inadequate access to basic water and sanitation facilities. There is a growing concern for increased vulnerability of slum dwellers to climate change. Thus, climatic changes coupled with non-climatic drivers affecting the quantity of water availability as well as its quality will further confound the scenario. All these factors will make the slum population, especially women and children highly vulnerable to climatic stresses.

The present study has been conducted to assess the vulnerability of poor slum women to climate linked water stresses on a statistically defined sample of 300 slum families living across five regions in Delhi, the Capital city India. A combination of quantitative and qualitative tools were used for the study. An index 'Climate Vulnerability Index for water at the household level' (CVI-WH) was used to quantify the vulnerability of slum women. The index is based on earlier developed indices such as WPI and CVI developed by group of hydrologists and social scientists (Lawrence et al., 2002 and Sullivan et al., 2005). The quantitative data was gathered by an interview schedule, whereas the qualitative aspects of vulnerability have been captured by using several Participatory Learning and Action tools.

The quantitative and qualitative assessments have shown that the slum women were highly vulnerable to climate mediated water stresses as evident by high CVI-WH values ranging between 0.62 and 0.67 across slums in the five regions of Delhi with an average vulnerability index of 0.63. By comparison, the city of Delhi as a whole faced much lower level of vulnerability with its CVI-WH value at 0.36. This was due to poor access to water resources, limited human capacity in terms of low levels of income and education, coupled with a dismal state of environment.

The study has shown that it is important to pay special attention to the slum areas and enhance the overall capacity of slum dwellers for accession and management of water resources. Thus, if the vulnerability of slum population especially women to climate change has to reduced it is not only important to invest in water related infrastructure but also to equip the poor women with skills and knowledge to enhance their adaptive capacity to face climatic variability and extremes. This will enable them to lead climate resilient lives.

Trend analysis of snowfall in Satluj basin Western Himalaya, India

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Trend analysis of snowfall is very crucial for hydrological studies to study the impact of climate change. In this study, trend analysis of snowfall data over a period of 33 years from 1976-2008 has been carried out using Simple linear regression, Mann–Kendall test and Sen's slope estimator in parts of Satluj basin Western Himalaya, India. In the Indian part of the Satluj basin, the Bhakra Beas Management Board (BBMB) maintains 21 snow gauges for the estimation of daily snowfall. Most of the snowfall in this area is produced by the westerly weather disturbances (WWDs) during the months of winter season that contributes significantly to the annual runoff during summer season downstream of the Satluj River. Overall, the results indicated that the snowfall has decreased over the studied period of 33 years with the mean snowfall showing decreasing trends annually, seasonally, monthly as well as elevation wise. Out of the total data of 21 stations, 14 stations revealed negative trends with significant trends at 8 stations. Highest number of stations with negative trends occurred during post-monsoon season. The trend analysis of snowfall was also carried over six elevation zones from less than 1500 to more than 4000 m amsl. The results indicated that the snowfall changes are significant below an elevation of 4000 m amsl in the area. However, over the elevation zones of 3000–3500 and 4000–4500 m amsl, the snowfall showed insignificant increasing trends probably due to its higher precipitation at higher elevations. Although the trends in snowfall were statistically insignificant most of the time but if such decreasing trends in snowfall continue, it may result in significant changes in future. The changes in the snowfall may be detrimental for the health of the glaciers/ice and other related resources of water in the area.

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