

practices, creating mass awareness programmes for the farmer community and having solutions that are holistic in nature.

The second plenary session included a debate on industry and agriculture since both depend on water; hence, there is a need to address the interdependencies and interlinkages between these two sectors. Many industries are interested, involved and investing to increase water use efficiencies in the agriculture sector, for providing benefits that go far beyond reduced water use. The second plenary session underlined linkages, challenges, opportunities, solutions and case studies based on smart agriculture and off-grid applications for water–energy nexus, which are initiated by corporates for the better management of water in the agriculture sector. One such case study discussed was showcased to have a water stewardship approach using sound practices on water efficiency and conservation in the private domain.

The forum also gave the opportunity to industry members to demonstrate responsible behaviour and proactive initiatives in the realm of water use efficiency through innovative technologies and so-

lutions through its third plenary session. The discussion was on initiatives that go beyond mere compliance to exploring and implementing innovations to stay ahead of the curve. The aim was to showcase initiatives by industry towards sustainable water use and reuse, and recycling of treated wastewater. The industrial sector showcased its work in the domain of reuse of treated wastewater for reducing water consumption, effluent treatment plant-based effluent network system, rainwater harvesting and practising zero waste water discharge.

The takeaway for the participants was to shift the focus from a scenario where there is inequitable allocation of water, skewed share of responsibilities for water augmentation, and disproportionate burden of pricing vis-à-vis water use, to a scenario where there is shared vision and responsibilities for water augmentation, greater accountability, an incentive framework for going beyond compliance, and a coordinated approach to water supply and management.

The forum reflected on the need to ensure that areas of Public–Private–Partnerships in water are executed as sustainable business models and in a time-bound

manner. It was further echoed that the government should propose a framework for recognizing water as a shared resource and for promoting integrated water resource management. The need for protecting the limited freshwater resources and their important role in preserving human and ecosystem health can only be achieved through collective wisdom to produce recommendations which offer practical, effective solutions to counter the catastrophic degradation of such resources.

1. *Manual of Aquifer Mapping*, Central Ground Water Board, Ministry of Water Resources, Government of India, 2012; <http://cgwb.gov.in/INTRA>
2. *Groundwater Management and Ownership*, Planning Commission, Government of India, 2007; [http://planningcommission.nic.in/reports/genrep/rep\\_grndwat.pdf](http://planningcommission.nic.in/reports/genrep/rep_grndwat.pdf)

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## MEETING REPORT

### Paleoceanography\*

The 12th International Conference on Paleoceanography (12 ICP) was attended by more than 700 participants, including scientists and students from 34 different countries. The theme of the five-day conference was ‘Paleoceanographic view of global climate change’.

The conference provided the participants an opportunity to update their knowledge about the newest discoveries, development of new proxies and current state of knowledge in palaeoceanography. The conference was structured around five themes: (1) timescale and rates of change; (2) development, calibration and application of new and existing paleo-proxies; (3) understanding

biogeochemical cycle, biota and evolution; (4) system dynamics and ocean–ice–continent interactions, and (5) reconstructing the future using paleoceanographic tools.

Appy Sluijs (Chair of 12 ICP) welcomed all the participants and gave an outline of the meetings and discussions to be carried out during the next few days. The conference had oral presentations in the morning sessions, and the afternoon sessions were for poster presentations. These were followed by perspective lectures in the evenings. Several companies dealing with palaeoceanographic instruments and analytical facilities, participated in an industrial exhibition.

A wealth of data was presented on accurate age constraints in palaeoceanography. New results of globally distributed benthic oxygen isotopic records

were employed to refine time series, called Prob-stack, using profile-hidden Markov model. New isotopic records clearly demonstrate that climatic variability on astronomical, orbital and millennial timescales can be documented from well-preserved benthic/planktic foraminiferal tests. It was shown, for example, that accurate orbital calibrations can be achieved from an integrative study of deep-sea benthic stable isotope and palaeomagnetic data. Discussions on the last interglacial (LIG) episode during the late Quaternary, presented an invaluable opportunity to investigate the response of polar warming in relation to different components of the Earth system. Extraction of this information from marine archives relies mostly on stratigraphic alignments to different reference chronologies in climatic archives, which have limitations and result in less accurate

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results. Thus it was demonstrated in a few studies that future climate-stratigraphic alignment should be based on multiple proxy reconstructions of time-scale based on marine sedimentary records integrating magnetic reversals, biostratigraphy, XRF-scanning, radiocarbon dates, susceptibility, benthic stacks and faunal abundance.

Biogeochemical cycle responses and impacts due to climate change in geological past and Anthropocene were addressed, and various key questions were raised: Were ocean productivity and nutrient contents (C, N, P) remained the same during geological past (Holocene, LGM, LIG, Cenozoic, Mesozoic and Palaeozoic)? How were the biogeochemical cycles affected during rapid climate change events and transitions? What are the results of changes in biogeochemical cycles on biota in marine environments? Various researchers presented their work addressing these questions. Use of biomarkers as palaeoceanographic proxies was seen as a growing research field for reconstructing past sea-surface temperature changes as well as biological production, and also sea ice extent. New data from Indian and Atlantic section of the Southern Ocean, provide estimates of CO<sub>2</sub> during glacial/interglacial episodes. Organic-geochemical investigations have been conducted to assess anoxic condition during Paleocene-Eocene Thermal Maximum (PETM). Along with these experimental studies, numerical modelling approaches also have to be developed simultaneously.

Major climatic and biogeochemical oscillations impact the biodiversity of oceans. Geological evidence suggests that climate change results in the extinction or evolution of new species. Several researchers presented their work on foraminifera and climate change. For example, population of planktic foraminifera changed from dormant dextral to sinistral during Early Eocene Climate Optimum. In an interesting presentation, it was shown that planktic foraminifera, besides their palaeoceanographic importance, are valuable archives of ocean geochemistry and stable isotopes. Various questions were raised during this session regarding evolutionary history of species? Do populations move, adapt or die during biogeochemical oscillations?

The palaeo marine proxies are the backbone of palaeoclimatic and paleoceanographic research. However, numerous questions remain open in this field; the most frequently asked question is about the reliability of existing proxies. Need for newly developed proxies that can investigate the primary mechanism and environmental controls on existing marine proxies was emphasized. Impact of diagenesis on stable isotopic and trace element geochemistry in calcite of foraminifera was underscored. Use of foraminifera Mg/Ca palaeothermometry was discussed. Several participants presented their work employing various proxies to solve scientific problems related to palaeoceanography. Using multiple proxies on cores from the western tropical Pacific Ocean, it appears now that El-Niño-Southern Oscillation (ENSO) behaviour, on both glacial and interglacial periods, can be tested. El-Niño events in the equatorial Pacific occur during most of glacial or deglacial conditions, with proxy data pointing to the former. In addition, Ba, Sr and Os isotopes as well as <sup>18</sup>O are employed routinely in foraminifera; these would further improve palaeo-reconstructions.

Several oral presentations were made during the conference. Stephen Barker (Cardiff University, UK) delivered the first plenary lecture, in which he discussed the wealth of records available for the Quaternary to understand climatic fluctuations and get better insight into the intricacies of the Earth's climate system. He discussed some of the mechanisms that are considered to be responsible for Dansgaard-Oeschger (D-O) events and their global manifestation. He also discussed briefly the continuous marine record spanning the last 1.7 Myr from his ongoing work, highlighting the pervasive nature of abrupt climate change signatures during the late Pleistocene. Junichiro Kuroda (JAMTEC, Japan) highlighted his work on decoding the history of Earth's sea surface using osmium isotope (<sup>187</sup>Os/<sup>188</sup>Os) records of marine sediments. Clara Bolton (CEREGE, France) discussed how ocean acidification might influence coccolithophore calcification and its relation to oceanic CO<sub>2</sub> level. Jacky Autermann (Harvard University, USA) highlighted her findings on the role of mantle convection in un-

derstanding sea level and cryospheric changes during the past warm periods. Bas de Boer (University of Leeds, UK) described the importance of understanding past warm worlds having the same CO<sub>2</sub> concentration as of today, which can be used as an analogue for the present atmospheric greenhouse gas modelling as well as a response of ice volume to climate change. R. Lawrence Edwards (University of Minnesota, USA) discussed the Asian monsoon history over the past 640,000 years, implications for orbital- and millennial-scale climate change around world. Martin Frank (GEOMAR, Germany) discussed the importance of neodymium isotopes for reconstructing the past ocean circulation and water mass mixing. Sandy Kirtland Turner (UC Riverside, USA) highlighted an Earth system model approach in tracing the PETM carbon and temperature anomaly through the oceans and into the sedimentary record. Pincelli Hull (Yale University, USA) spoke about the evolutionary patterns of planktic foraminifera and their importance in Cenozoic palaeoceanography. Julianne Muller (AWI, Germany) discussed the molecular approach for understanding palaeo sea ice and climate dynamics.

The presentations made during the conference covered various aspects of palaeoceanography, including development of new proxies for deciphering past climate, calibration of developed proxies, climate model prediction and sea-ice-continent interactions on millennial and millions of years' timescale. It was inferred that for getting an insight into past climate, well-calibrated proxies are the key. It is the need of the hour to use interdisciplinary approach to understand past warm interglacial periods for better understanding of the present climate change and predictions for future. Marine records need to be studied in detail, because they have the advantage of being the best storehouse of the past climate records and are regulators of the modern climate variations.

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