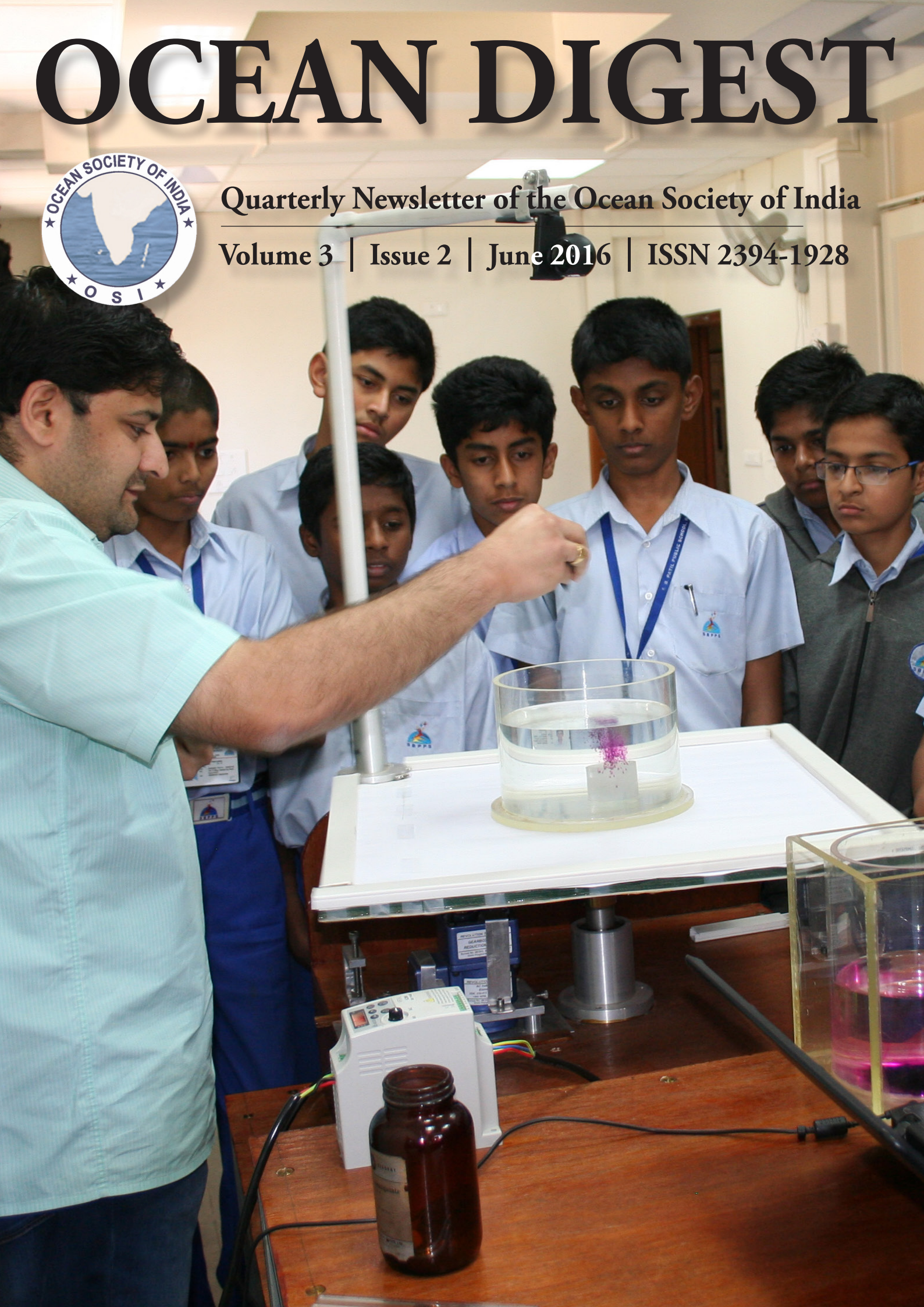
OCEAN DIGEST



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The El Niño

Invited Article

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Most of the school/undergraduate student-readers of this article must have read or heard about a big 'El Niño' that occurred from the spring of 2015 till April 2016, allegedly a major factor in the weaker-than-normal Indian summer monsoon during June-September last year, and for floods in Chennai last December, among other things. Let us check out what an El Niño is, and why it is important, in this short article.

Owing to the conservation of angular momentum of the earth, we have easterly winds in the equatorial region. These winds facilitate constant movement of surface water from the eastern portions of the equatorial Pacific to the western portions. This results in colder surface waters in the tropical eastern tropical Pacific by constantly 'upwelling' and bringing colder sub-surface waters up, along with various nutrients therein (See Fig.1) . This action is particularly prominent off the Peru coast. The colder and nutrient-rich water supports local abundance of fish. Now, the east-west temperature gradient results in higher sea level pressure in the east as compared to the west. Consequently, an east-west horizontal circulation with an upward motion along with lot of convection/rainfall in the western tropical Pacific happens, with subsidence in the east, where you get many foggy days. In association with the horizontal winds, you see that the thermocline, which is a boundary to the warmer surface waters and cooler sub-surface waters, is shallower in the tropical eastern pacific and deep in the west.

In the above processes, the atmospheric and oceanic processes act in tandem cooperatively, that is, positively feeding back into one another. This is known as Bjerknes feedback mechanism, named after the scientist who deciphered it in the 1960s.

The above are the normal, or 'mean' conditions in the tropical Pacific. However, nature is dynamic. It varies on different time scales. The slight fluctuations 'amplify', and manifest in various climate phenomenon that matters a lot to the mankind. The El Niño is one of these.

Now, in some years, one of the constituent atmospheric or ocean features that contribute to the normal tropical Pacific conditions changes. Let us say, as shown in Fig. 2a for example, that the easterly winds in the tropical western Pacific weaken, or are replaced by high frequency westerly wind bursts owing to some random phenomenon such as the Madden-Julian Oscillation(an intraseasonal variability). The anomalous westerlies result in propelling of the warmer surface waters to the east, associated with anomalous upwelling of colder sub-surface waters in the western tropical pacific. Once such a process is triggered under certain favourable conditions, the warm sea surface temperatures (SST) propagate eastward. Further, the atmospheric and oceanic anomalous conditions across the basin through which the signals travel are mutually amplified by air-sea coupling under the Bjerknes framework. After traveling east straddling the equator, the anomalously warm SSTs reach the eastern tropical pacific when the thermocline is deeper-than normal. These anomalous conditions peak typically during the boreal winter. The western tropical Pacific is anomalously cold and dry concurrently. This situation is known as El Niño (see Fig.2). The term is originally a local Spanish colloquial word meaning 'Christ child'. This was because of the peaking of these events in the Christmas season. We also have La Niña, which means 'Girl child'. In a linear sense, ocean-atmospheric structures, patterns, and impacts associated with the La Niña can be broadly visualized as opposite to those of the El Niños. As seen in Figure 2, the La Niñas are nothing but the amplified normal conditions, with cooler (warmer) than normal conditions in the eastern (western) equatorial Pacific, associated with the below (above) normal atmospheric signals. The atmospheric and oceanic conditions during the El Niños and La Niñas are so tightly coupled, scientists have introduced a word 'ENSO' (El Niño-Southern Oscillation) to describe them.

Incidentally, the east-west overturning atmospheric circulation in the tropics is known as a Walker cell. As discussed earlier, any changes in the tropical Pacific are reflected in changed atmospheric circulations. Thus, the Pacific Walker cells associated with a co-occurring ENSO act as a transmitter of their impacts to far-off regions by virtue of a changed strength or displacement of the rising and subsiding limbs. Normally, the ENSOs have a periodicity of 4-5 years, and

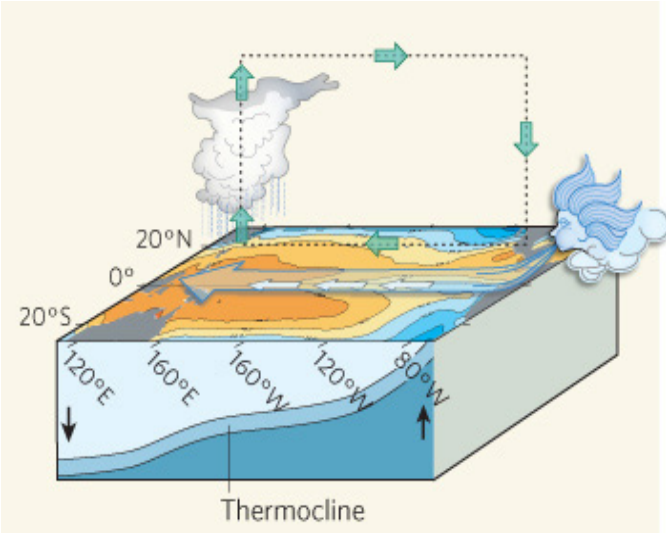

Fig. 1: From Ashok & Yamagata (Nature 2009, doi:10.1038/461481a) presents normal conditions in the tropical Pacific. Warm surface water and air are pushed to the west by prevailing easterlies. Consequently, colder water upwells in the tropical eastern Pacific, with a shallow thermocline (a subsurface boundary marking the sharp contrast between warmer upper waters and colder deeper waters). Opposite conditions prevail in the west, where the ocean waters are warmer, and the atmosphere wetter. The warmer (cooler) waters are shown in red (blue). From the figure, we can also visualize the observed east-west zonal atmospheric circulation above the tropical Pacific.

last through 3-4 seasons. The importance of the events lies on its ability to affect the global tropical climate, not just in the neighbouring regions. For example, as mentioned earlier, the ENSOs are known as the most prominent events affecting the Indian summer monsoon rainfall. A strong El Niño results in below normal summer monsoon rainfall, while a strong La Niña results in above-normal rainfall (Fig. 3a). On the other hand, the effects are opposite for the northeast monsoon due to changed seasonal circulation that is exacerbated by the El Niños, causing above normal rainfall in Tamil Nadu, etc., during December through February. Significant impacts of ENSOs have been documented throughout the tropics through modulation of the Walker Cells – the horizontal east-west circulation cells, and beyond tropics through some other responses. The impacts depend, in addition to the strength of the event, the seasonal circulation, and the distance of the region from the equatorial eastern pacific. Similarly, while Australia suffers a less-than-normal winter rainfall during June-July months with El Niño, Japan experiences above-normal summer monsoon rains. Understandably, the impacts are not just limited to the temperature and rainfall changes, but also the agricultural produce, fish catch, water management, etc. In fact, the El Niño was apparently coined by the Peruvian fishermen.

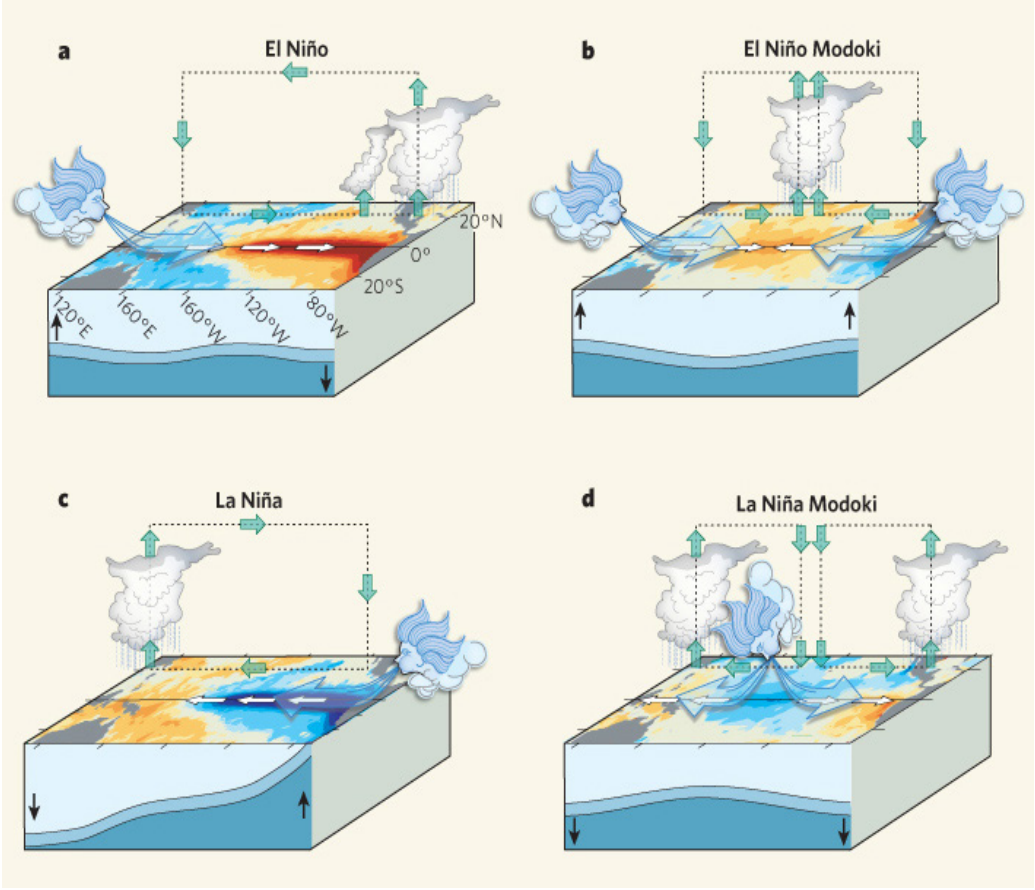

Figure 2: (a) An El Niño event occurs due to various factors, such as, say, weakening of the easterly winds in the west. This results in warmer than normal sea surface temperatures in the eastern tropical Pacific, associated with a deeper-than-normal thermocline and above normal rainfall, and opposite conditions in the west (b) anomalous conditions for an El Niño Modoki, with warmest surface conditions and above normal rainfall in the central tropical pacific, flanked by opposite conditions on both sides. (c) & (d) are the anomalous conditions for the La Niña and La Niña Modokis.

Recently, the ENSO characteristics have changed. Rather than the maximum anomalous warming being in the tropical eastern pacific with cooler than normal waters as seen in typical or 'canonical' El Niños, since late 1970s, we see a different type of events where the anomalous warming is constrained to the central tropical Pacific through 3-4 seasons, with cooler than normal SSTs flanking them on both sides. These are known now in scientific literature as the El Niño Modokis or central pacific El Niños. It is not yet clear whether the recent frequent occurrence of these events is associated with global warming or not. But the impacts of the Modokis are different in intensity and/or sign as compared to that of the canonical events. For example, the rainfall-reducing influence of an El Niño Modoki is apparently stronger over Indian summer monsoon as compared to that from a canonical El Niño (Fig. 3b), their impacts are opposite on the Japanese summer climate.

The ENSO research is at an interesting stage. In addition to getting a better understanding of the distinctions and similarities in the evolution of various flavours, predicting in advance the occurrence of these flavours correctly is important. In addition, stretching the lead ENSO prediction skills beyond the current lead times of 6-12 months is yet another topic. In fact, the lead prediction skills for ENSO are the best as compared to those for any other tropical climate phenomenon, be it monsoons, IOD, etc. And the dynamical ENSO prediction has been rather successful. However, the limited success in predicting the intensity and/or demise some of the recent cases have thrown excellent and exciting challenges at the science community. We also now realise that there are factors other than ENSO that modulate the climate. The relationship of ENSO with other such drivers is a topic of wide interest, as is the ongoing research to understand the future evolution and frequency of ENSOs in the background of an increasing global warming.

Interestingly, the seeds of understanding teleconnections of ENSOs to the far-off reasons were sown in India. In the background of the worst ever seen drought in 1877, prompted the authorities in India to set up an observatory. Sir Gilbert Walker, the then Director General of the India Meteorological Department during early 20th century, embarked to understand monsoon failures. He found out that the monsoon rainfall was strongly correlated with the two poles of what we know now as Southern Oscillation, a see-saw of surface pressure between Tahiti and Darwin, both in the tropical Pacific.

Mineral and Energy Resources along the off-shore region of West Coast of India with special reference to the Kerala Coast – A Review

History Article

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The West Coast of India is a rifted volcanic continental margin evolved after the break-up of Gondwana super continent during the mid-Cretaceous. The area experienced two major Precambrian magmatic events at about 678 Ma and 550 Ma ago. In the late Cretaceous period (85-90 Ma) the area experienced another magmatic event. Further, the Deccan basalt erupted from the Reunion hotspot (68.5-62 Ma) is found as continental flood basalts on the western India shield which extends through the entire western margin of India.

The western continental margins of India consist of a number of major sedimentary basins, which include the Kutch Basin, Surat Basin, Laxmi Basin, Bombay Basin and Kerala-Konkan Basin (Fig.1). Out of these, the Bombay Offshore basin is the major hydrocarbon containing basin in India. These basins were formed during the time of separation of Madagascar from India (85-90 Ma) and have several north-south trending grabens separated by basement highs which provide structure suitable for trapping of hydrocarbon.

The Kerala and Konkan basins from the southern portion of the Western Continental Margin of India (WCMI) are shown in Figure 1. The Vengurla Arch, an approximately NE–SW trending basement high separates the Shelfal Horst-Graben complex of these two basins from that of the Bombay Offshore basin. The Konkan and Kerala basins were divided from each other by another basement high called the Tellicherry Arch. The basin covers mostly the southern and central parts of the Kerala coast between 8.5° and 10.5°N latitudes bounded by the Western Ghats in the east and the Arabian abyssal plain on the west. The major morphological features of the basin are (i) the shelf, (ii) shelf margin basin, (iii) Alleppey platform in the shelf-slope region, (iv) Pratap ridge, (v) Laccadive Ridge and (vi) the western Arabian basin. The margin is characterized by complex bathymetry and the presence of numerous topographic highs. The horst-graben complex in the shelf region divides the Kerala basin into Cochin depression and Cape Comorin depression. There is a marked variation in the trend of the shelf between Cochin

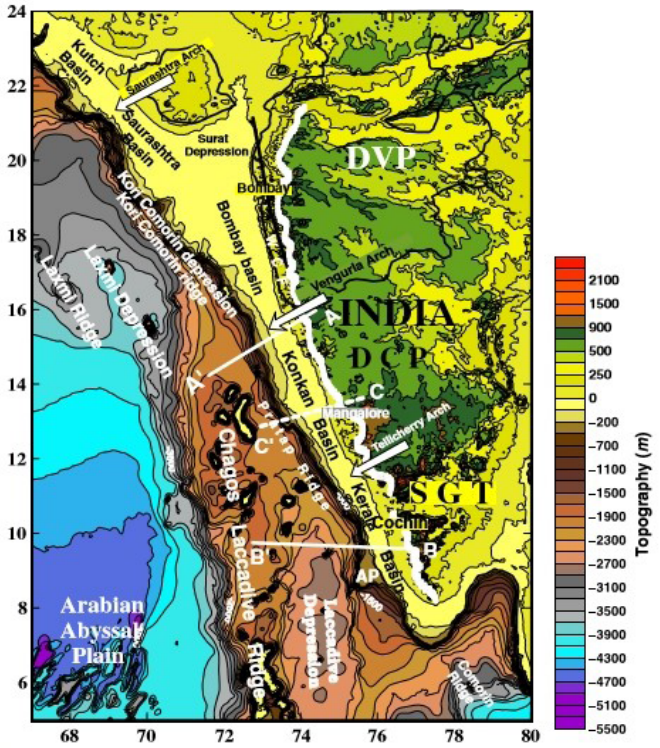

Fig.1. Morphological and Tectonic features along the Western continental margins of Indian Ocean and the adjoining Arabian Sea (after Sheena etal., 2012).

and Quilon. The shelf is wider in this region with a gentle seaward slope. This wider shelf is known as the Alleppey platform.

The Chagos–Laccadive ridge acts as a barrier and obstructs the sediment flow further west into the Arabian abyssal plain. The sediment deposition during the early rift phase started with continental environment which changed gradually to paralic and finally to pulsating marine conditions[1]. The lithological and stratigraphic information and sedimentation rates in this basin have been deduced from drilled wells (K-1, K-1-1, CH-1-1) and seismic data1-2.

The terrigenous sequence of the Kerala basin indicates the source as onshore denudation though minor fraction of sediment supply from the Laccadive ridge or the Mascarene plateau during the Paleocene[2]. The well data indicates that the Cochin shelf is accumulated with abundant supply of clastics particularly sand derived from granitic terrain. In contrast to

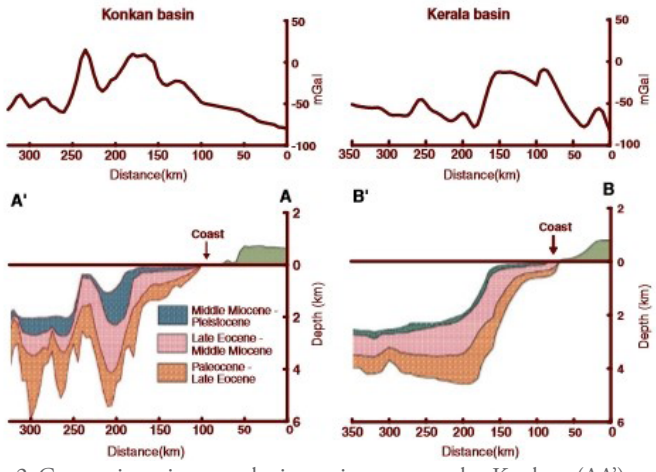

Fig.2 Composite seismo-geologic sections across the Konkan (AA') and Kerala (BB') basins are compiled and constructed from several sources[1,4,5]. Top panels show the gravity anomaly along these sections (after Sheena etal., 2012)

the basins in the north, the Kerala basin is characterized by the absence of thick Eocene–Oligocene carbonate platform. This change of facies during the Middle Cenozoic was attributed to the predominance of mechanical erosion in Kerala as opposed to geochemical erosion and deep weathering in the north during the Paleogene[2]. The rifting between Laccadive and the mainland India never reached the stage of sea-floor spreading as sediments in the offshore Kerala basin are almost exclusively terrigenous and paralic in nature[3]. There are five sedimentary sequences across the central part of the Kerala basin[4]. These five sequences into a three-layer sequence of which the first layer is of Paleocene-Eocene age, second Eocene-Miocene and the third Miocene-Pleistocene age similar to that adopted for the Konkan basin[5] (Fig.2).

A satellite derived gravity map of the region under discussion generated by the Director-General of Hydrocarbon (Fig.3), is a high resolution Bouguer anomaly map of the west coast of India based on satellite data and processed especially for oil exploration along the continental margin (Director General of Hydrocarbons, DGH, 2010). They tried to examine it for geodynamics and understand the nature of the continental margin. However the data is of very large wavelength and is too generalized to be of help in exploration.

From the geological and geophysical setting it is clear that there are many common features in the Kerala region that extend southwards from the Mumbai High that has proved oil resources. It therefore portrays the high potential region for oil and gas, Gas Hydrates, Phosphorites and submerged beach placers. The deeper part of the Indian Ocean may also be a source for manganese nodules and nodules rich in metals like Cu, Co, Ni similar to those found in the southern part of the Economic zone.

The importance of the region of Kerala and Konkan Basin was in one time limited to the shore line in the late Holocene and subsequent development of lagoonal terrain of central Kerala is a result of the slow transgression of the sea submerging the Kerala and Konkan basin. In such a complex geomorphic evolution of the coastal tract i.e. the course to visualize zone of local enrichment of heavy minerals including titanium and rare earth minerals, shell deposits and offshore beach placers. The data now emerging from satellite would indeed provide invalid data with regard to both the geological evolution and economical potential of the area. In this context few ongoing low altitude satellites are of particular relevance, these include the following, Seasat, Geosat GM, ERS-1/2 and TOPEX/POSEIDON altimeters data, GOCE, SWARM, and ADM-AEOLUS.

In the context of the blue economy, oceans are also the sources for renewable energy on the one hand and the sources of natural hazards like cyclones, seismicity and tsunamis. The new data as outlined above when generated would also constrain our strategy in evaluating these factors. Most of the present day investigations are based on large scale or large wavelength gravity and magnetic fields with few seismic profiles. It is suggested that much closer geophysical data will throw more realistic picture of the structural features for favorability of hydrocarbon and also delineating the heavy mineral resources, such as lime stone resources, ilmenite and other black sands, rare earth mineral accumulation etc., in western continental margin of India.

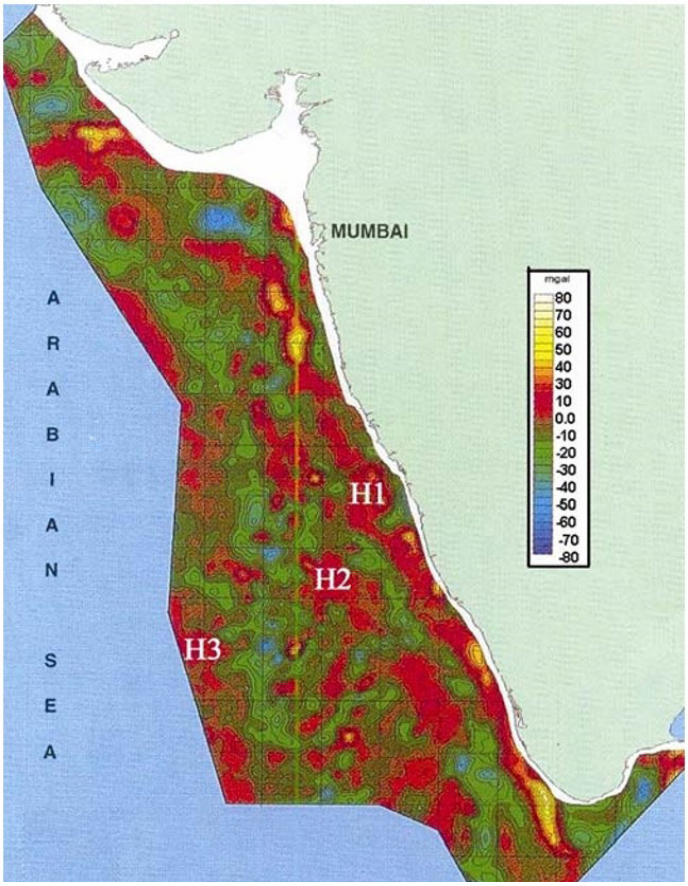

Fig.3. Satellite derived Bouguer anomaly map of the west coast of India, showing linear gravity high H1, H2 and H3 are related to magmatic intrusion (Deccan trap) associated with the formation of the rifted margin (after D. C. Mishra, 2011).

The new data emerging from the above said satellites, integrated with more ground and ship-borne data would greatly enhance our capabilities for developing a sustainable blue economy in addressing the discovery and management of mineral resources. It would also be of considerable societal interest in monitoring and mitigating natural hazards and climate change and generating renewable energy sources. There is a need for building up larger organizational capabilities that will facilitate speedier access to the satellite data and enhancing inputs into ground geophysics.

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Thinking Differently About Climate Change

Contributed Article

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It seems every week global media races to deliver more bad climate news. Such dire warnings should goad governments into action, but how will that translate to farmers in Indian villages or a mother in Flint, Michigan, struggling to find clean drinking water?

Since the inception of the Industrial Revolution, humans have added more greenhouse gases to the atmosphere than nature could remove, and we know with 100 percent certainty that this is keeping more of the sun's energy trapped by the Earth's atmosphere. We can say with the same high certainty that the planet is not losing more energy to space, so it must be hiding this extra energy somewhere — some appears as an increase in global temperature, some goes into the seas, and some is being spent on melting glaciers, among other "heat sinks".

But to translate those scientific certainties into region-specific climate impacts is not an easy task. Scientists don't yet have Earth-system models capable of offering such predictions and projections at the fine scales needed for communities to make all of the necessary decisions on resource management or energy and food production. It's even harder to advise for the next few years or decades.

The Paris "COP21" meeting under the United Nations Framework on Climate Change led to historical agreement, which was signed into action on this year's Earth Day, with nearly all countries putting down their Intended Nationally Determined Contributions (INDC) to reduce their carbon emissions. The coming years will be crucial in monitoring the progress of this impressive bottom-up agreement reached by nearly every nation on Earth. [A Tale of 2 Worlds: Nations Collide on Climate Change (Op-Ed)]

But the planet's biggest obstacle may be the human mind. We humans are notoriously bad at managing too many crises at one time. All our good intentions tend to focus on one action while quietly letting slide many other issues (http://www.livescience.com/41578-climate-change-needs-communicators.html). Let me cite a few examples.

Obama staked his personal reputation on getting countries like China and India to commit big on their INDCs while also upping the ante for the United States in terms of its own commitments to climate action. But Obama's overall record on climate is not as rosy. Consider expanded Arctic drilling and coal exports, for example. Countries like China and India also may shave to play their own tricks by expanding on coal-fired power plants or even underreporting their coal use as China did while struggling to live up to their INDCs (http://www.eia.gov/todayinenergy/detail.cfm?id=22952).

This two-steps forward and one-step back approach to climate action also occurs with corporations. While the number of corporations committed to being greener and more sustainable is quite long, stories such as Volkswagen cheating on emissions tests is an example of a step backward, driven by profit. Natural disasters also leads to such backtracking, as seen with Japan abandoning its commitment to the Kyoto protocol following the Fukushima nuclear disaster. While earthquakes are unrelated to climate change and tsunamis are a natural consequence of some earthquakes with an epicenter in the oceans, the damage to the Fukushima nuclear plant by the tsunami had unintended consequences. The loss of life due to the radiation leak from the nuclear plant have forced Japan to rethink its strategy of relying extensively on nuclear power with the abandonment of its commitment to the Kyoto protocol being the first casualty albeit not unexpected (http://www.climatechangedispatch.com/japan-to-build-40-new-coal-power-plants.html). Fortunately, Japan submitted an INDC of 25% by 2030 with respect to its emission in 2005.

Many of us are guilty of the same fancy footwork — buying a hybrid car but not tracking meat consumption; a Prius owner with a heavily meat-based diet can have the same or even a larger carbon footprint as a vegetarian SUV driver! Food production is just as resource intensive in terms of its carbon footprint as energy consumption which makes our diet as important global warming as the car we drive (http://journals.ametsoc.org/doi/pdf/10.1175/EI167.1). Single action bias is a natural consequence of the human brain's limitation of being able to manage only a finite pool of worry. Climate change tends to take the backseat when other pressing issues bubble up to the top, making it even more important to avoid scary messages about climate change (http://onlinelibrary.wiley.com/doi/10.1002/wcc.41/abstract).

While climate change is already here, and the impacts will continue to get worse barring any action, our ultimate salvation will not come from increasingly alarming messages or an approach based purely on expectations that we will wean ourselves off the carbon-diet we have been on since the Industrial Revolution. The rational half of the human brain has already realized that climate change is a concern and we are responsible for it. But human decisions are not always rational. In fact, we mostly practice rational ignorance when the benefits to ourselves are not obvious. It is the emotional half of the brain that also needs to be convinced if decisions require attitude or behavioral change.

To break through, we need to influence minds when they are still evolving. Teach students about climate change and its potential harmful consequences but along with the way they themselves make decisions when dealing with issues that may not directly affect them at that time or benefit them immediately. For ex., a majority of students feel that most of the things they are being taught are of no use in real life. But the parents have the hindsight to know that life is lived

forward and understood backward, so what may not appear useful in college may turn out to be a lifesaver later in life. Making the hard topics palatable is difficult enough but to teaching a course to make them think carefully about the environmental impact of all their actions for the rest of their lives is a monumental challenge.

At UMD, I created a course that looks at Earth, life and sustainability as a nexus. Life as we know it is carbon-based, the waste produced by life is also carbon-based and the energy we use is all carbon-based. Climate change is just a natural consequence of our own evolution and the evolution of our way of life.

But there is no reason to believe that a planet that is too warm for our own good is inevitable, or to think that we are not capable of evolving towards sustainability as the next natural step. We learned our lessons and now we all just need to get on the same page about dealing with the energy-intense life we enjoy, but do so without destroying our own habitat.

As a way to get the students to think differently, I ask them to defend their position in class and to write articles for a general audience that address climate in the context of human nature. I am not sure how this approach will affect future generations, but some of the articles by my students make me think that they can be trained to be more deliberate about the intrinsic human potential to deal with climate change despite our own evolutionary baggage of a rational and emotional brain.

In an encouraging sign, students did think broadly by focusing on the role of religion in combating climate change (http://www.dbknews.com/2016/03/29/climate-change-faith-religion-leaders/) or suggesting that human altruism can be an effective tool to deal with this potential global tragedy of the commons (http://www.dbknews.com/2016/03/28/an-altruistic-brain-will-help-solve-climate-change/). One student abandoned the meat diet and followed it up with a bit of investigative reporting on a foodchain not walking the talk on its sustainability (http://www.dbknews.com/2016/03/29/words-nobody-wants-to-hear-chipotle-isnt-that-great/). Even an ambitious computer science student stood his position to argue that capitalism does not have to be harmful to the environment as illustrated by the success of the organic food revolution (http://uncubed.com/blog/23453/). A more challenging position is being argued by the philosophy freshman in class that a moral and ethical case has not been made for climate action! I eagerly await her article.

Quite heartening considering that these are young undergraduates from various majors from Biology to Geology to Philosophy and Chinese. A small cross-section of students from various majors have sown that it is indeed possible to give them not only the scientific knowledge but also the human dimension so that they can approach climate action from an honest perspective based on our own strengths and limitations. Maybe this is one additional tool to equip posterity to do the global warming cha-cha-cha without going two-steps forward and one-step back. I never remember my steps in a dance anyway but the future generations will need to master the art to avoid the worst consequences of our way of life.

Mimicking Fluid Dynamics of Oceans and Atmosphere in Laboratory

Review Article

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Oceans occupy almost 70 percent of the surface of the Earth and house wealth of life forms and present themselves as a huge reservoir of energy[1]. Processes and phenomena in the atmosphere are important to humans who live on the land which occupies the remaining 30 percent of the surface of the Earth. However the credit for genesis of most of the atmospheric phenomena of interest to humans (cyclones, monsoons and so on) goes to the continuous and intimate talk between the atmosphere and the oceans in terms of exchange of energy, water vapor, carbon dioxide etc.[1,2]. This ocean-atmosphere coupling holds the key to many interesting phenomena such as El Niño Southern Oscillation (ENSO) that have deep impacts on the society, economies and civilizations [3,4].

Eddies in the atmosphere, movements of air masses, effects of rotation of the Earth on flows in the atmosphere and oceans, effects of the differential heating between the poles and the equator (due to the spherical shape of the Earth as well as the inclination of its axis with respect to the plane of revolution around the Sun), effects of atmospheric flows over the oceans in terms of bringing cold and nutrient-rich waters from deep oceans to the surface and so on, are examples of flows that grossly determine the weather patterns across the globe.

Although extremely complex interactions result in most of the spectacular weather/oceanic phenomena we observe, it is often possible to isolate, from all these interactions, those that are essential to the phenomenon under consideration. With this, a possibility opens up for appreciating the underlying essential physics of the phenomenon and bringing it out vividly to the students, research scholars as well as the general public. To this end, we shall see that many flow features of atmospheric and oceanic flows have been mimicked in the laboratory with simple rotating tank experiments.

A good example of such experimental setup is the "Weather in a Tank" experiment designed at Massachusetts

Fig 1. Left panel shows weather circulation patterns from a satellite image as marked by the clouds (at the center is the North pole and Arctic ice). Right panel shows the rotating tank equivalent visualized by food colors (at the center is an ice can mimicking the equator-to-pole temperature gradient). Figure is taken from Illari et al. (2009).

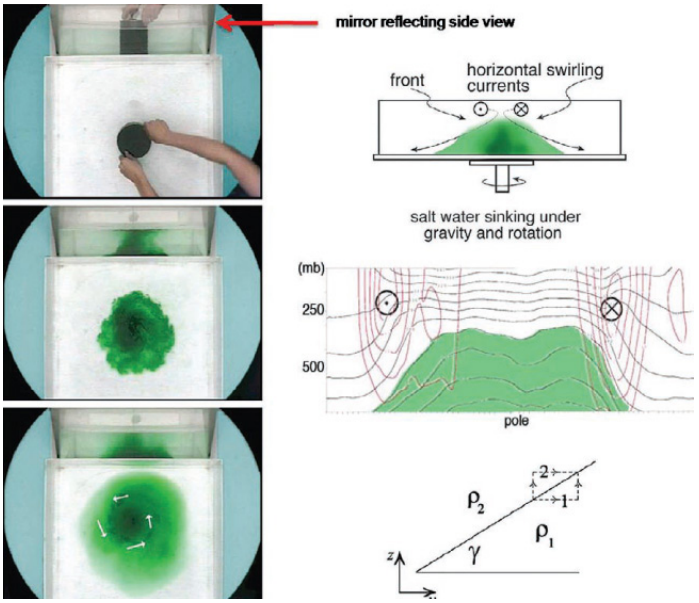

Fig 2. Visualization of fronts. Figure is taken from (Illari et al. 2009).

Institute of Technology (MIT); Spinlab at University of California at Los Angeles (UCLA) is another such initiative. A simple rotating table equipped with a camera mounted on the table serves to mimic the viewpoint of humans stuck to the surface of the Earth (due to gravitation). The flows in the tank as observed by this camera attached to the rotating table would then be very similar to the flows observed by us – this is how Earth's rotation is mimicked. The equator-to-pole temperature gradient is usually mimicked by putting ice in a tin can at the center of the rotating tank. Flows are visualized with the help of simple food colors or non-hazardous coloring agents such as potassium permanganate.

Figure 1 shows an interesting visual comparison of atmospheric weather patterns at mid- and high-latitudes as observed by a satellite (left panel) and the corresponding eddies simulated in the laboratory setup (right panel). The main effects that are essential to these flow patterns are the equator-to-pole temperature gradient and rotation of the Earth. Similarly figure 2 shows how fronts can be simulated. The key aspect here is that the cold descending air column over, say the North pole, is laterally supported, to some extent by the rotation of the Earth. This forms sloping ridges that often come to the higher-/mid-latitudes as cold fronts. These are characterized by very sharp changes in temperature across the ridge.

Figure 3 shows the demonstration, at IITM, Pune, of the Ekman flow that occurs in the presence of friction and rotation. Such situations are common in the top 50 meters or so of the oceans[1]. Here the tub, filled with water, is rotated

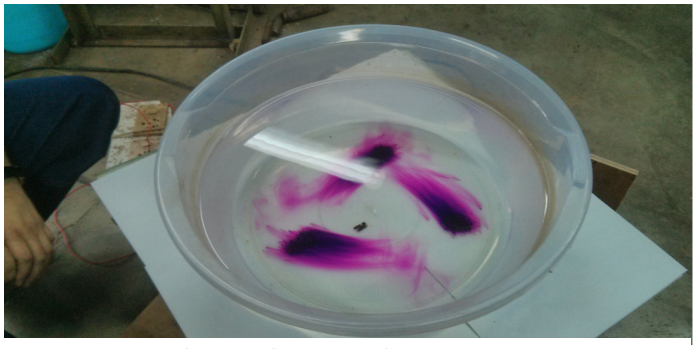

Fig 3. Formation of Ekman flow due to friction and rotation in a setup at IITM, Pune. Potassium permanganate is used to visualize the flow near the bottom of the tank.

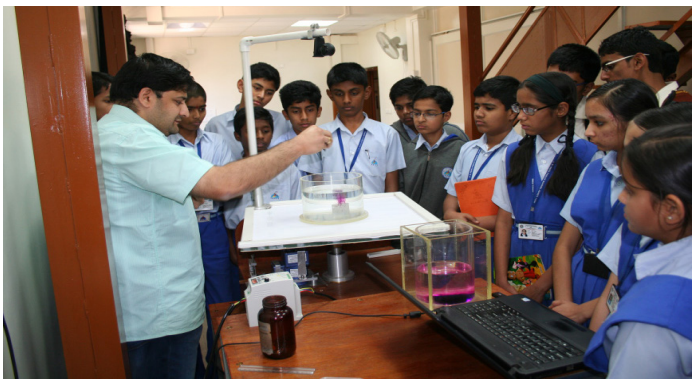

Fig 4. National Science Day 2015 - Demonstration of Taylor Columns in the rotating tank setup at IITM, Pune. Potassium permanganate is used to visualize Taylor Columns. Taylor Columns represents the behavior of the fluid as if it is formed of columns that are oriented parallel to the rotation vector of the bulk of the fluid.

at constant speed till all the water starts rotating with the tub (solid body rotation). Potassium permanganate crystals are introduced to observe the flow patterns near the bottom of the tub. The speed of the tub is then reduced while the water inside continues to rotate faster. This introduces friction between the bottom wall of the tub and water due to relative motion between them. The fluid next to the bottom of the tub then starts curling inwards instead of going around along circular lines. This is the Ekman drift that occurs in the lower atmosphere and upper oceans.

Figure 4 shows the experiment of Taylor columns being demonstrated to students on the occasion of National Science Day 2015 celebrations at IITM, Pune. Rapidly rotating fluids exhibit rigidity in the direction parallel to the rotation axis. In such cases the fluid behaves like a column (Taylor Column) with its length parallel to the axis of rotation, in accordance with the so-called Taylor-Proudman Theorem. Such rigidity makes the fluid mixing difficult and such situations occur frequently in the mid- and higher-latitudes.

To summarize, laboratory experiments such as those described above can provide insights into the factors that are most essential to the occurrence of the phenomenon under consideration and this is of importance from the viewpoint of appreciating the underlying physics. This is beneficial for students as well as researchers. Apart from serving as an excellent tool to interest students and enhance their understanding of the basic ideas of Geophysical Fluid Dynamics, the rotating tank experiments also hold a somewhat unexplored yet promising potential of addressing certain important research problems related to convection and mixing in stratified and rotating fluid.

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Decadal Variability of Winds over Tropical Indian Ocean

Student Article

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Abstract

To understand the decadal weakening of the Indian summer monsoon rainfall (ISMR), we explore the low level circulation over the tropical pacific using various Observational and Reanalysis datasets for the period 1951 to 2008. We found that the interannual correlations between the ENSO and ISMR have continued to weaken since 1950s, irrespective of the choice of an index. Our analysis shows that, in the post-1977 period, the circulation over Tropical Pacific and Tropical Indian Ocean are disconnected.

Introduction

Indian summer monsoon rainfall (ISMR) has a huge impact on the socio-economic conditions of India. ISMR has intra-annual and inter-annual variability. Various factors have been attributed for the variability like the El Niño Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), Eurasian snow-depth, Atlantic circulations etc. ENSO is a prominent driver of the Indian summer monsoon. ENSO teleconnections to ISMR have been extensively studied. Pacific Sea Surface Temperature (SST) indices like NINO3, NINO4 were used. Recently, NINO3.4 was found to be better correlated with ISMR. However, these relationships have been weakening [Kumar, 1999]. The Warm Water Volume of equatorial Pacific (WWVEP) had the advantange of pre-monsoon lead prediction skill [Rajeevan and Mcphaden, 2004]. The interannual manifestations of the tropical Pacific (TP) variability are also undergoing changes, such as the frequent occurrence of El Niño Modokis since late 1970s, while that of the canonical El Niño events has reduced.

Results

In agreement with Rajeevan and Mcphaden [2004], we find that interannual correlations of the ISMR with ENSO SST indices such as the NINO3 index (Fig. 1), NINO4 index (Figure not shown), etc., continue to weaken. The simultaneous correlation of the WWVEP with the ISMR has also weakened to the threshold of statistical significance.

Why the continuous weakening of the TP impact on the ISMR? Decadal changes in the atmospheric circulation provide a hint. For the 1958-2008 period, the correlations of the low-level winds with the ISMR resemble strengthened easterlies in the TP, akin to anomalous winds during a La Niña. These correlation vectors in the TP are "seamlessly" connected with a strong ISM type of circulation in the tropical Indian Ocean. We also see a cyclonic (anticyclonic) correlation vectors south of Japan (Bay of Bengal) (Figure 2). However, the corresponding correlations for the 1977-2008 indicate a 'disconnect' in correlation vectors between the TP and tropical Indian Ocean. We believe that this is mainly due to a decadal change in the mean circulation. Indeed, a difference plot between the low level circulation between the

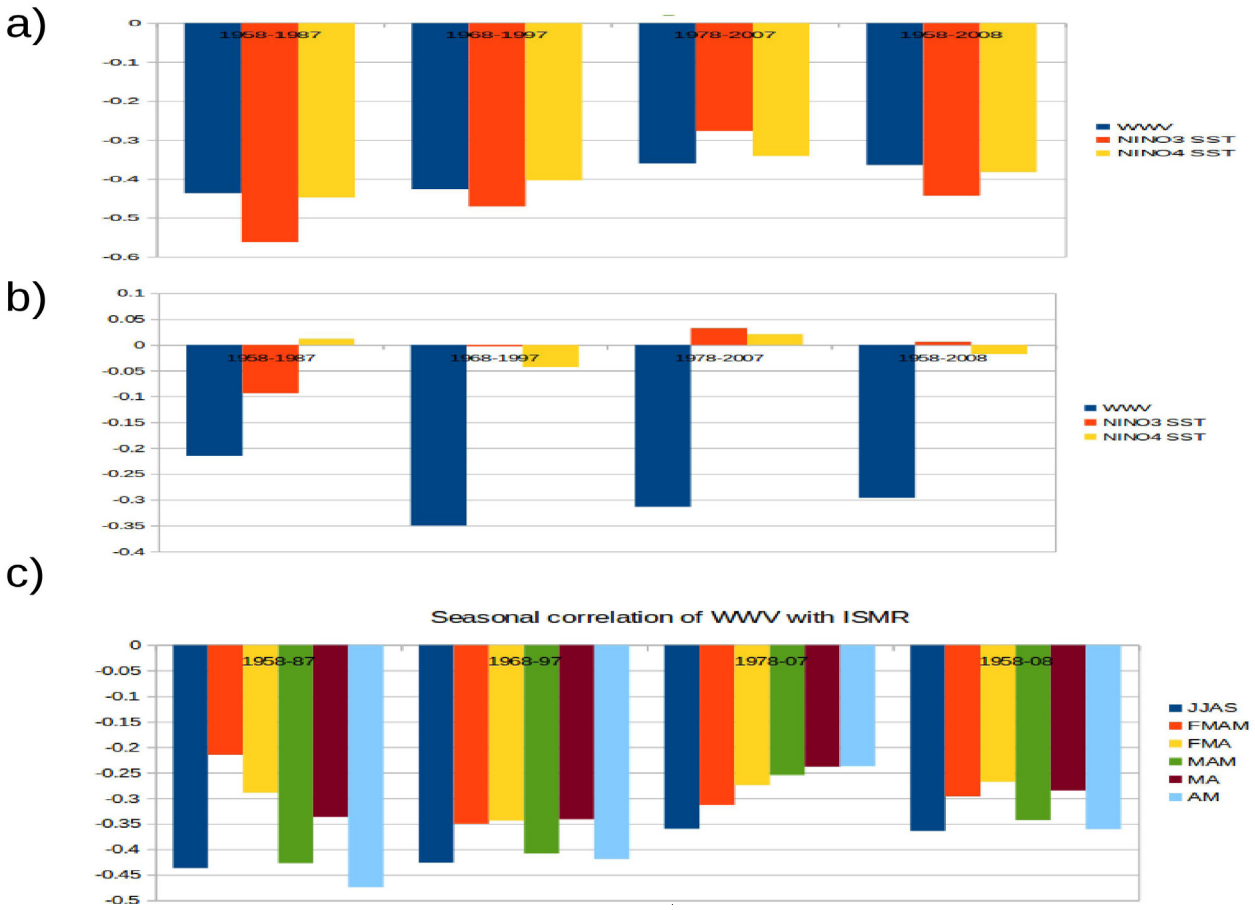

Fig.1. Correlations of Pacific indices with ISMR during a) JJAS, b) FMAM. c) Seasonal correlation of WWV with ISMR.

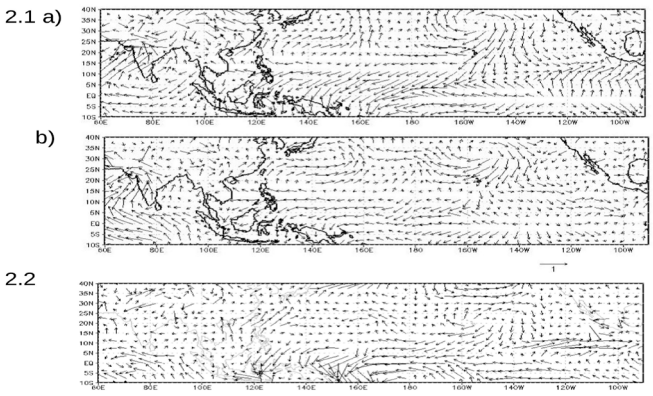

Fig. 2.1. a) Simultaneous Spatial Correlations of Winds during JJAS and ISMR for the period 1958-2008. b) Simultaneous Spatial Correlations of Winds during JJAS and ISMR for the period 1977-2008. 2.2. The shift of the mean state in the recent period. The earlier period 1958-1978 removed from the mean of total period 1958-2008.

1958-2008 and 1977-2008 indicates an eastward shift of the subtropical high in the recent period. This has resulted in the ' anticyclonic' (cyclonic) correlation vectors south of Japan (Bay of Bengal) in the recent period. These vectors are opposite in direction to the canonical ENSO connection patterns [see Figures 7c and 8a of Lau and Nath, 2001]. Such a background shift results in current weakening of the ENSO connections.

We are also examining the potential relevance of strong signals from the southern Indian Ocean in the recent period (Fig. 2.1 b), and attempting to understand the shift in the WWVEP leading to February-March (Figure 1).

Data

For our analysis, we used surface winds from NCEP Reanalysis, subsurface temperature from SODA reanalysis and ISMR data from IITM.

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Acknowledgements

We are grateful to Prof. Raghu Murtugudde for his valuable suggestions.

Note

This work has been submitted in the CLIVAR-ICTP International Workshop on Decadal Climate Variability and Predictability, and International Symposium on the Indian Ocean- IO50. A paper related to this work will be submitted for publication soon.

Wonderful World of Internet

Contributed Article

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Computer technology dates from an era just before the World War II i.e. from the late 1930s to the early 1940s. The second half of the 20th century may well be called the beginning of the age of computers. American scientists Robert Elliot Bob Kahn, and Vinton Grey Cerf developed internet in 1969. Internet came to India in 1980s. The internet is the global system of interconnected computer networks that use internet protocol suite (TCP/IP) to link billions of devices. TCP/IP is a seven layered stack. TCP/IP is an acronym for Transmission Control Protocol / Internet Protocol. TCP/IP is the basic communication language or protocol of the internet. It can also be used as a communication protocol in a private network like intranet and extranet. Today people in almost every field of endeavor such as Engineering, Physical Sciences, Economics, Psychology, Education, Social Sciences, Medical Sciences, Law, Research and Business have some contact with computers and internet. In 1989, British computer scientist Tim Berners-Lee developed World Wide Web (also popularly known as Web). In 2004, the Queen of England honored Tim Berners-Lee with knighthood (title of 'Sir'). Web is the gateway to internet. Software through which we browse through the internet is called Web Browser. At present some of the commonly used web browsers are Google Chrome, Microsoft's Internet Explorer, Opera, Mozilla Firefox and Apple's Safari. Web browser software works as a search engine and its design is based on highly sophisticated and intricately designed data bases. Most people use the terms internet and World Wide Web or just Web, interchangeably but the two terms are not synonyms. World Wide Web is the primary application that billions of people use on the internet and it has changed their lives immeasurably. However, the internet provides many other services too. Web is a global set of documents, images and other resources. Internet is the synergy and churning of multiple disciplines. World's first website is still online. Like any other technology, internet also has its own vocabulary and dictionary of terms. Some of the commonly used internet terms are – Blogging, E-mail, Bandwidth, Download, Search Engine, Twitter, E-learning,

Home Page, Dial-up Connection, Video Conferencing, Attachment, Facebook, Browse, YouTube and Surfing. Internet is also described through photographs. Internet is an online phenomenon which is increasingly ruling and shaping our lives. In internet vocabulary, user of internet is called 'Netizen' just as the native of a country is called citizen. E-mail is perhaps one of the most widely used technologies of internet. E-mail began as an experiment by the military to be able to send mails to and from the battlefield. Internet's E-mail facility has lowered the importance and usefulness of postman and post office. The first E-mail was sent in 1972 by using two machines by an engineer named Ray Tomlinson. Over the years E-mail has evolved with many different programs put with it and many people working to improve the E-mail system of the internet. Internet is also described as a world changing online phenomenon. Internet has transformed the world into an online global society. Of the seven billion people on the planet, more than 2.4 billion use the internet. Asia accounts for 1.1 billion, including 200 million Indians. There are at present around 1 billion websites, up from 74 million in 2005 and 555 million as late as 2011. Internet enabled technologies are poised to play key and crucial roles in the online delivery of higher education in the near future and shall there by herald migration from traditional Gurukul to online e-Gurukul and from traditional campus to digital campus. Internet technologies shall bring nomenclature like e-author, e-faculty and e-scientist in the emerging internet domains of e-education and e-research. "Internet for Me and Me for Internet" has become the unspoken slogan of today's young generation. Internet has become an indispensable integral part of our daily lives. Today's young generation may not have reasonable adequate knowledge of Hindu mythological eras "Sat Yug (Era)", "Dwapar Yug (Era)", "Treta Yug (Era)" and "Kal Yug (Era)" but have reasonable adequate knowledge of "Internet Yug (Era)". Today internet's vocabulary is being used in literature and in the lyrics of both film and devotional songs. Internet is also described as 'Network of Networks'. Internet is an incredible invention of science and technology which has given wings to the flights of imaginations of internet users. Internet has brought unparalleled revolutionary changes in communications. No other technology could influence human lives as significantly as internet could. Today's young generation treats internet surfing as internet pilgrimage. Internet has brought the entire world on our fingers.

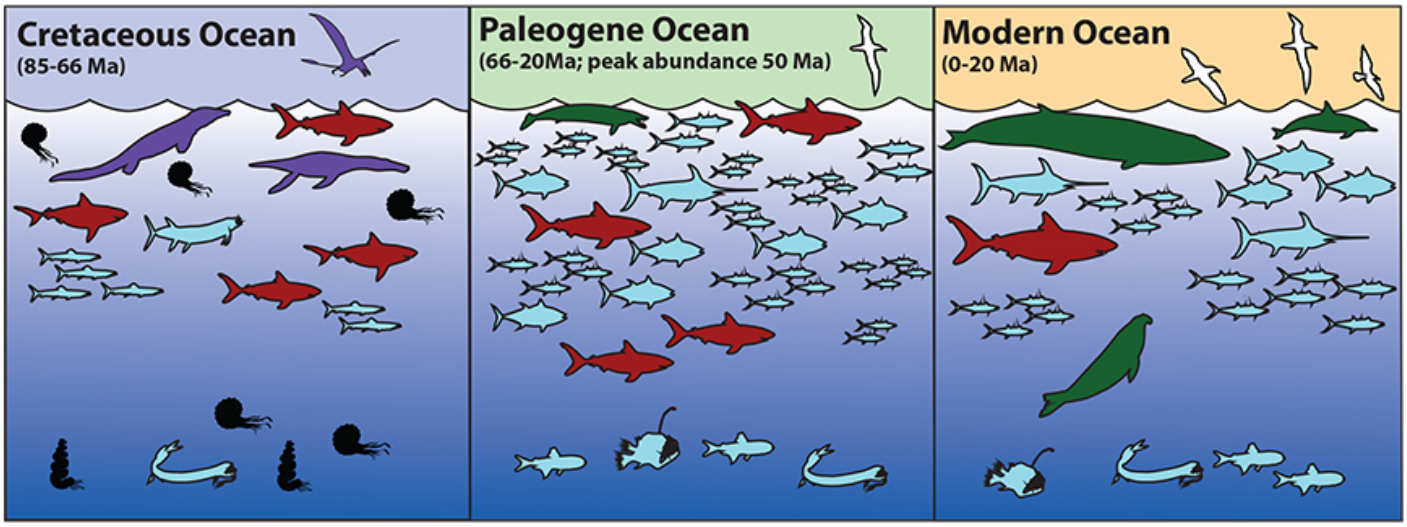
Besides E-mail, YouTube is another most widely used facet of internet. The most popular YouTube video ever is "Gangnam Style" with over 2 billion views. YouTube was cofounded on 23rd April'2005 by Jawed Karim (Native of Germany), Steve Chen (Native of Taipei) and Chad Hurtley (Native of United States). Eleven years after its inception, YouTube website is visited by around one billion users every month, watching around six billion hours of video. Hundred hours of film is uploaded every mnute. In India alone, YouTube gets more than sixty million unique users every month and watch time has been growing at 80% on year to year basis. With over four hundred million internet users in India and six million new mobile internet users being added every month, India is seeing a phenomenal growth in online video consumption through internet. The Indian government has also turned to YouTube. Some of India's union ministers today have a YouTube channel, including Prime Minister Modi, who also has an official channel, PMO India that documents his travels, meetings and speeches, among other things. YouTube has thousands of free tutorials uploaded by helpful amateurs that show users how to do almost everything. YouTube is a visual record of what's happening in the world and it is accessible to every internet user (Netizen). From gentle videos of domestic life to a rescue video of a Siachen soldier trapped under 10 meters of snow after an avalanche, YouTube shows us far more of the planet than documentaries and magazine supplements ever could. Scientists have even shared their discoveries on YouTube. YouTube is improving our memories. YouTube has certainly changed the world and is continuously doing so in its own way. YouTube is currently world's most popular video sharing website headquartered in San Bruno, California, United States.

Wikipedia is another very popular and widely used component of internet. Wikipedia is free access and free content encyclopedia of the internet. Wikipedia is ranked among the ten most popular websites. Wikipedia constitutes the internet's largest and most popular general reference work. The English Wikipedia is one of the 291 Wikipedia editions and is the largest with 5,137,005 articles. It has 38 million articles in over 250 different languages. It has around 500 million unique visitors every month. Wikipedia is internet's free online global library with no copyrights and intellectual rights related restrictions on the use of its contents by the internet users. Wikipedia is owned by a non-profit American organization "Wikimedia Foundation" which is in San Francisco, California, United States. Wikipedia was started on 10th January 2001 by Jimmy Wales and Larry Sanger as part of an earlier internet encyclopedia named "Nupedia". On 15th January 2001, Wikipedia became a separate website of its own. Any internet user, who wishes to can change the pages of Wikipedia or even make new pages. Wikipedia has a standard page layout for all its pages in the Wikipedia. Wikipedia has more than 1.75 billion words across all editions of Wikipedia. The English Wikipedia is the biggest among all its editions. Name Wikipedia is a combination of two words viz. "Wiki" which is a Hawaiian word for quick and "Encyclopedia". Wikipedia is also described as 'Dictionary of Dictionaries'. We should not be surprised if internet becomes a part of school, college and university syllabus in the near future. Although the internet has been widely used by the academia since the 1990s, the commercialization incorporated its services and technologies into virtually every aspect of modern life. Internet use grew rapidly in the west from the mid 1990s and from the late 1990s in the developing world. In 20 years since 1990, internet use has grown 100-times. Today internet knowledge is considered as a symbol of competence and modernity. Internet has widened the gap between rich and poor as this gap now also includes the gap between information-rich and information-poor. Internet is a global network comprising many voluntarily interconnected autonomous networks. Internet operates without a central governing body.

News and Views

Recent Updates

Will more snow over Antarctica offset rising seas?
Eric Steig, a UW professor of Earth and space sciences makes it clear that we cannot have confidence in projections of future snowfall over Antarctica under global warming. The 31,000 year snowfall record helps to understand how winds affect



The Structure of Ocean Ecosystems Has Been Stable for Tens of Millions of Years, with Punctuated Changes

Antarctic weather, and how atmospheric connections with the tropics influence the amount of relatively warm ocean water that laps at the frozen continent's edge. [Read More: T.J. Fudge et al. Variable relationship between accumulation and temperature in West Antarctica for the past 31,000 years. Geophysical Research Letters, May 2016].

The structure of ocean ecosystems has been stable for tens of millions of years, with punctuated changes

Researchers identify three periods of open ocean community structure driven by competition from other organisms, but not climate change. Distinct shifts between three stable states (Cretaceous, Paleogene, Modern Ocean) occurred rapidly, independent of climate shifts. The transition from "Cretaceous" oceans to "Paleogene" oceans 66 million years ago saw the disappearance of highly abundant invertebrate organisms called ammonites. Their mass extinction released fishes from predation and allowed them to explode in abundance in the warm greenhouse world of the Paleogene. Later, in the Modern ocean system, the evolutionary diversification of marine mammals, seabirds and large pelagic fish that compete with sharks, alongside the dramatic increase in variability of fish production, may have driven shark abundance down in the open ocean. [Read More: Eighty-five million years of Pacific Ocean Gyre ecosystem structure: long-term stability marked by punctuated change," appears in the May 18 edition of the journal Proceedings of the Royal Society B].

All in the NAAMES of ocean ecosystems and climate

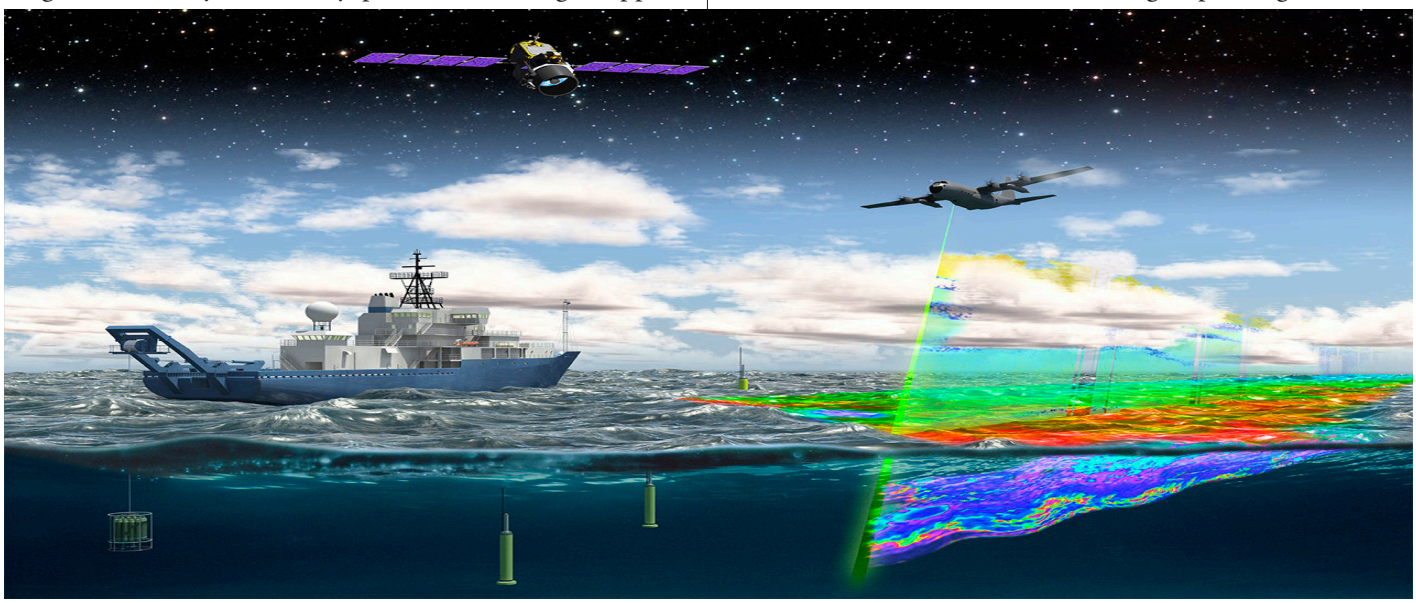
NAAMES, or the North Atlantic Aerosols and Marine Ecosystems Study, is a five-year NASA-funded study that aims to define that relationship better. During the field campaign, NASA satellites provide a larger view of ocean processes. This Satellite data can be used to calculate the total photosynthesis that goes on in the ocean every year," said Mike Behrenfeld, NAAMES principal investigator. "It's essentially equivalent to the total photosynthesis that's happening on land.". [Read More]

Ocean currents disturb methane-eating bacteria

Environmental change can cause warming of bottom waters in the Arctic Ocean, as a consequence of which more methane gas is released in the water column. This greenhouse gas concentration can potentially be controlled from entering the atmospheer by bacteria that feed on it. But ocean currents can easily disturb sweep over the methane seeping sites, and carries the bacteria communities away, thus disturbing methane filtration processes. [Read More]

Tiny ocean organism has big role in climate regulation

One of the most abundant bacterial group Pelagibacterales,



North Atlantic Aerosols and Marine Ecosystem Study (NAAMES)

plays an important role in the stabilisation of the Earth's atmosphere. Sunlight increases the abundance of certain phytoplankton, which in turn produce more dimethylsulfoniopropionate (DMSP). DMSP is broken down to DMS by this microbial community. DMS is known to increase cloud droplets through a series of chemical processes which affects the amount of sunlight hitting the ocean surface. [Read More]

How Cyclone Roanu governed Indian weather before the onset of Monsoon 2016

Cyclone Roanu was the first tropical storm of the season to develop in Bay of Bengal. The immensely strong low pressure system caused torrential rains along the entire eastern coast of India - Tamil nadu, Andhra Pradesh, Odisha and West Bengal. [Read More]

Pollutants can impact ocean life thousands of miles away

Recently, scientists have reported that iron and nitrogen produced as a result of pollution can circulate across the ocean and affect ecosystems thousands of kilometers away, contrary to that long old belief that the impact of air pollution is felt in the vicinity of where it deposits. Model studies showed that dust gets carried by ocean currents from North Pacific toward North America, down the coast and then back west along the equator. [Read More]

Deep-ocean buoys for tsunami detection

Deep-ocean tsunami detection buoys are one of two types of instrument used by the Asustralian Bureau of Meteorology to confirm the existence of tsunami waves generated by undersea earthquakes. These buoys observe and record changes in sea level out in the deep ocean. This enhances the capability for early detection and real-time reporting of tsunamis before they reach land. [Read More]

Conferences

Upcoming Events

- "What do we know about multicentennial, multimillenial variability?" Hamburg, Germany, 28-30 November 2016. [See More]
- ICTP Workshop on Advanced School on Earth System Modelling & Workshop on Climate Change and Regional Impacts over South Asia at IITM, Pune, 18-29 Jul 2016. [See More]
- ICTP Workshop on Climate Impacts on Health in Asia in New Delhi, India, 5-16 Dec 2016. [See More]

Send your correspondence and contributions to:

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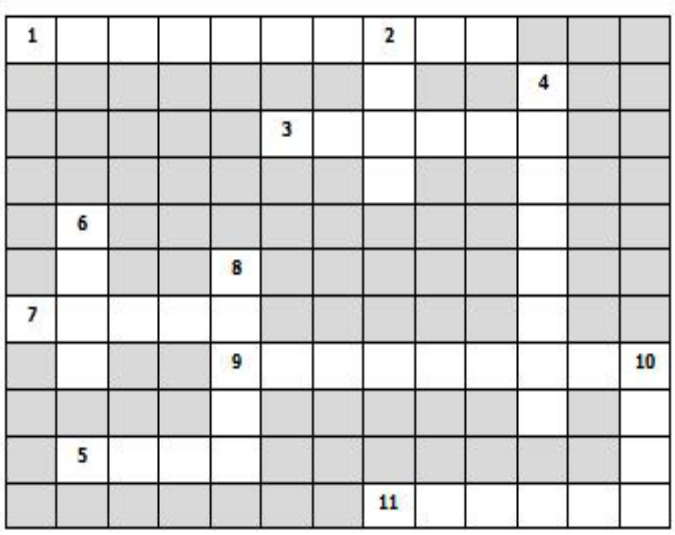
seelan@tropmet.res.in

www.oceansociety.in/oceandigest/

Crossword

The clues for the Earth Science Crossword can be traced to the present and previous issues of Ocean Digest. Enjoy.



ACROSS

1. A device that uses a laser or other light source to measure the height of the base of clouds
3. An ionized gas containing ions and electrons
5. A near periodic, sinusoidal geological structure formed under compression of the continental crust
7. The SI unit of energy is
9. It is the measure of the tilt of a planet's rotation axis
11. A physical quantity that has only magnitude but no direction

DOWN

2. This desert is also known as the Great Indian Desert
4. A circulation found in the near-surface layer of lakes and oceans under windy conditions
6. A nautical mile per hour is commonly known as
8. A reference equipotential surface around a planet where the gravitational potential energy is defined to be zero
10. Unit of time equal to one revolution of the Earth about the Sun

Compiled by Bhupendra B. Singh, IITM