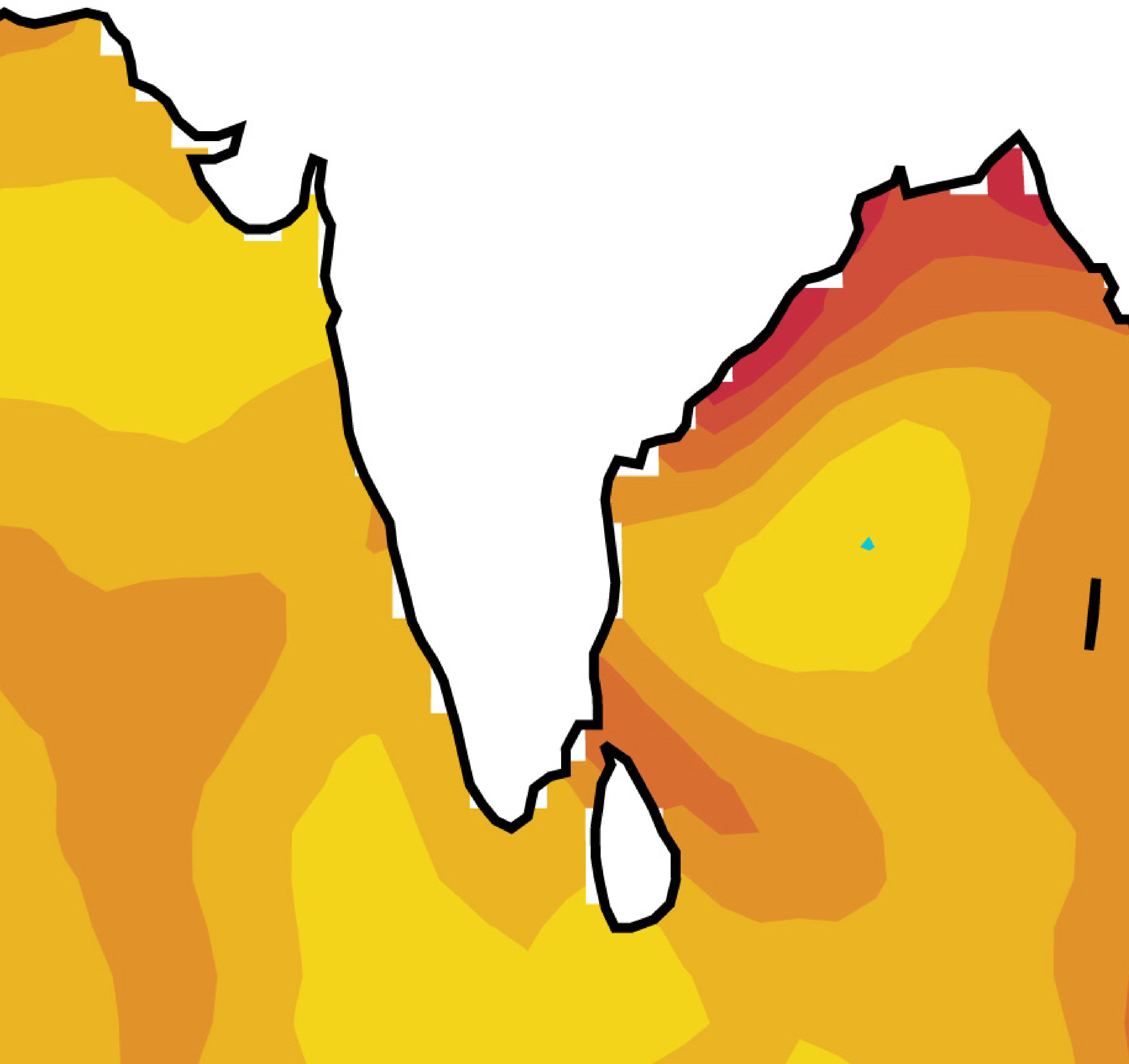

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Is sea-level rising?

Invited Article

Dr. A.S. Unnikrishnan

CSIR-National Institute of Oceanography, Goa

The common man and the policy makers are always concerned about the report of rising sea level both globally and regionally. The present article makes a brief survey of the scientific findings on this topic. There has been considerable research on sea-level rise caused by global warming. Thermal expansion in the ocean and melting of glaciers and ice sheets mainly contribute to sea-level rise. The various reports of the Intergovernmental Panel on Climate Change (IPCC) made assessments of observed sea level rise and future projections. Figure 1 shows the global mean sea level rise of 3.4 mm/yr (with a standard error of ±0.4 mm/yr) during the period from 1992 to 2016. These estimates have been made using data from satellite altimeters.

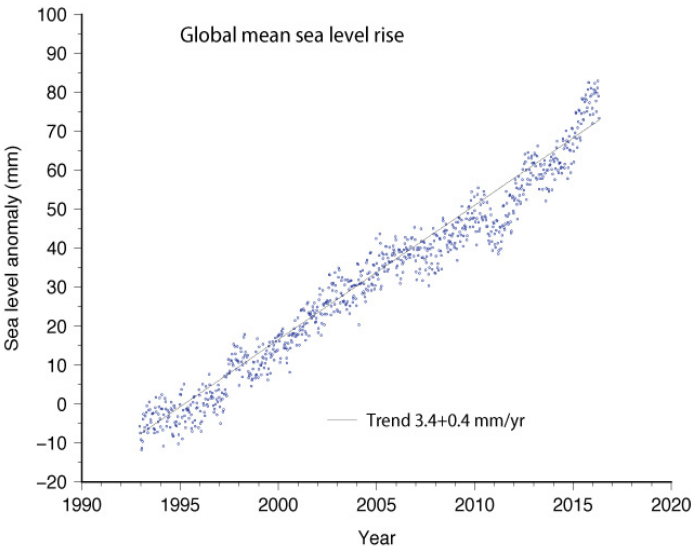

Fig. 1: Global mean sea-level time series. Dots indicate data from satellite altimeters (Topex/POSEIDON, Jason-1 and Jason-2), with seasonal signals removed. The straight line indicates the fitted trend. Data source: Mean Sea Level Group, University of Colorado

It is worth mentioning here that sea level change is influenced by changes in the hydrological cycle, melting of glaciers and ice sheets, ocean circulation, land subsidence, etc. [Figure 2]. The combination of these processes produces a complex pattern of total sea level change, which varies through time as the relative contribution of each process changes. Changes in any one of the components or processes shown in Figure 2 will result in a sea level change.

It is true that sea level has fluctuated in the past between glacial and interglacial periods. Geologists have studied these changes using proxies such as, sediment or ice

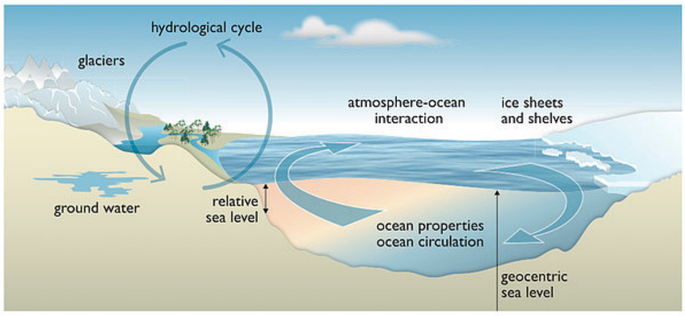

Figure 2: Climate-sensitive processes and components that can influence global and regional sea level [Source: Church et al. 2013, IPCC, Fifth Assessment Report]

cores. However, the rates of present-day sea-level rise (since the industrial period) have been considerably higher than those in the past.

It is interesting to note that a lot of research findings on sea-level rise since more than the past three decades came out based on analysis of data from instruments known as 'tide-gauges'. Tide gauges were originally installed in major ports to measure water surface elevations continuously. These instruments were earlier of 'mechanical type' and more recently of electronic type to measure and record water surface elevations at a point in the harbour area. Mechanical tide gauges use mechanical floats in a stilling well. As the water surface goes up or down, a pen attached to the float records on a chart which is fixed on a rotating drum. After a few days, the chart is removed and digitised to get instantaneous sea level. Electronic tide gauges are mainly of two types. (i) pressure gauge type and (ii) radar gauge type. The former uses a pressure sensor, which measures the hydrostatic pressure of the water column above it. The hydrostatic pressure can be converted into sea level height by using the hydrostatic equation. Radar gauge uses a radar sensor, kept at a height looking down the sea, sends out a pulse of radio waves and measures the travel time to be reflected off the surface and back to the sensor. By using the travel time and the speed of radio waves one can estimate the sea surface height.

The tide gauge data have been analysed and used to predict the time of 'high tide' and 'low tide', which are used by ships to decide the timing for entering and leaving harbours. Some of the oldest tide gauges in the world are found in Brest (France), Liverpool (U.K.) and Mumbai (India), which were operational since the late 19th century. In India, Survey of India (SOI) is responsible for maintenance of tide gauges and prediction of tides. The Indian Tide Tables, published by the SOI gives the tidal predictions at major ports along the Indian coasts and some neighbouring countries. The ports, where tide gauges are installed include those of Mumbai, Kochi, Visakhapatnam and Diamond Harbour (Kolkata).

Since 1980's, scientists started analysing these data more closely looking for long-term changes in sea level (sea-level rise). For this purpose, they started analysing the mean sea level (instantaneous water surface elevations or sea level measured by a tide gauge are averaged for a sufficiently long time such as a month or year to get monthly mean sea level or annual mean sea level. The surface waves and tides are filtered out before the averaging procedure). All the analyses using tide-gauge data showed a slow and gradual increase in mean sea level of the order of 1 to 2 mm/yr. However, there were some concerns, since the findings were based on data obtained from some selected (based on the quality of data) tide gauges over the globe. This issue got resolved with the availability of data on sea level measured from satellite altimeters.

Since 1992, altimeters onboard satellites starting with Topex/POSEIDON and later Jason-1 and Jason-2 started measuring sea level from space. An altimeter measures two-way travel time required for a radar pulse emitted by the antenna onboard the satellite and get it reflected from the ocean surface back to the antenna. These measurements provided sea level scientists the data having a near-global coverage (except regions pole ward of 66^o latitudes). These satellites repeat the track every 10 days. Various corrections need to be applied to the measured data, including the removal of tides, to obtain mean sea level data that are used for climate studies. The analysis of mean sea level data from satellites showed a good consistency with those obtained from tide gauges and the trends of the global mean sea-level rise obtained from satellite measurements, and tide gauges have been agreeing closely to each other strengthening the evidences on mean sea-level rise over the globe.

Along the west coast of India, there are two tide gauges, Mumbai and Kochi that have records of 113 and 56 years respectively. A typical record of Kochi is shown in Figure 3. The altimeter data is also superimposed on the figure. The net sea-level-rise trend for the entire period is about 1.81 mm/yr (1.45 mm/yr, as shown in Figure 3 and when corrections for glacial isostatic adjustment (GIA) of -0.36 mm/yr are subtracted becomes about 1.81 mm/yr), which is close to the global average trends (1.7 mm/yr), reported in the fifth assessment report of the IPCC. It may be noted that during the period of satellite altimeter, the trend is larger than that for the entire period including 20th century.

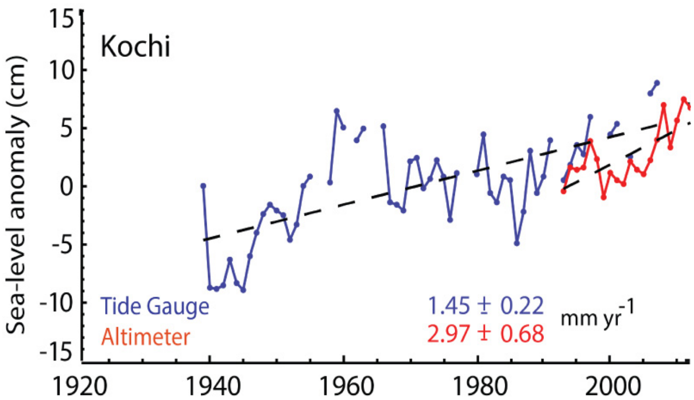

Figure 3: Tide-gauge (blue) and satellite altimeter (red) data at Kochi. The altimeter data is taken at offshore point. The figure is adapted from a published paper by Unnikrishnan et al., (2015) in Current Science. The dash indicates the fitted trend line.

Along the north east coast of India, for instance, the record at Diamond Harbour (Kolkata) shows a large trend of more than 5 mm/yr. This tide gauge is located in the deltaic region. Since the instrument is located on the land, any land movements could affect the readings. It is known that Indo-Gangetic delta is undergoing subsidence, which partly contributes to the large observed sea level rise from this tide-gauge record. Similar large trends have been reported for the records in Bangladesh as well. It may be noted that recent tide gauges also use GPS (global positioning system) measurements to determine vertical land movements. This is to account for a correction in the estimation of trends obtained for tide gauge records.

The altimeter data permits to prepare spatial maps of sea-level rise trends. We present a map prepared for the Indian Ocean (Figure 4) north of 10^{o}S , which shows a fairly uniform sea level rise of more than 3 mm/year for the north Indian Ocean. This estimate shows an increased sea-level-rise trend during the last 20 years compared to those obtained from tide gauge records for the past century. It is not fully understood whether this is an apparent acceleration in sea-level rise or not. This is due to a relatively short period of altimeter data (about 20 years). It may be noted that unusually large (greater than 5 mm/year) trends are found in some regions (towards the northern Bay of Bengal). We have reported this in our earlier study as uncertainties found in some regions, which are partly due to the presence of natural variability. In most of the regions, the sea-level rise is uniform and the rates are in accordance with global sea-level rise. Moreover, altimeter and tide gauge data have been complimentary to each other for the estimation of the present-day sea-level rise.

Climate models predict higher sea-level rise towards the end of the 21st century. Observations during the last two decades also show an enhanced sea-level rise. In any case, sea level will continue to rise for many hundreds of years, as already a lot of heat is absorbed in the ocean, which will continue to heat the ocean.

India has a long coastline of more than 7500 Km with several regions in the low-lying areas. Moreover, a large population in the country resides in the coastal areas. Sea-level rise and occurrence of extreme events, such as storm surges, will have a great impact in future. Long-term planning and necessary adaptation measures are needed particularly for vulnerable areas. Besides, deltaic regions, such as Sunderbans, are particularly vulnerable to sea-level rise. Subsidence, found in deltas adds to the effect of global warming induced sea level rise. Small-island nations like Maldives, which is only about 1.2 m above mean sea level, will face the consequences of

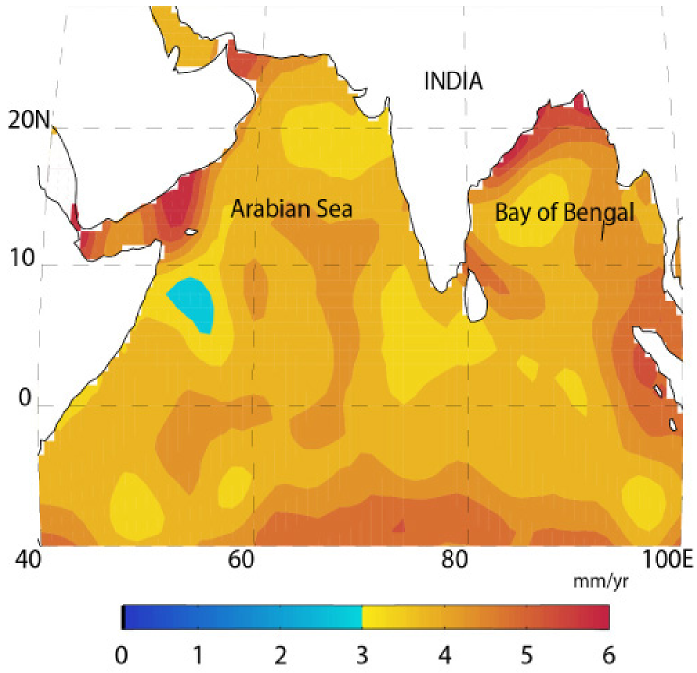

Fig.4: Spatial map of the sea-level rise trends during 1992 to 2015 in the Indian Ocean (north of 10^{o}S)

future sea level rise. Climate change will exacerbate already existing extreme events such as unusually large high tides in Mumbai as well as storm surges along the east coast of India.

Reference:
The present article has drawn information from research papers published by the author and report of the IPCC AR5 WG1 Chapter 13: Sea Level Changes, in which the author has served as a 'Lead Author'. Figure1 is prepared using data from the University of Colorado. Nerem, R. S., D. Chambers, C. Choe, and G. T. Mitchum. "Estimating Mean Sea Level Change from the TOPEX and Jason Altimeter Missions." Marine Geodesy 33, no. 1 supp 1 (2010): 435. Figure 2 is adapted from IPCC AR5 WG1 Chapter 13.

Data Assimilation in numerical ocean models: Indian perspective

Review Article

Neeraj Agarwal
Space Application Centre,
Ahmedabad

Measuring the properties of global oceans has been a challenge ever since the concept of measurements is introduced. The vastness, hostile conditions and the cost factor are some of the major reasons behind the data gaps in the oceans. Satellites sense the ocean surface, however they are unable to provide much information of the ocean beneath. Since last one decade, ARGO floats have been providing wealth of ocean information which has marginally improved our understanding, however, when it comes to knowing about the regional/basin/global scale synoptic conditions we look upon the numerical ocean models.

Numerical ocean models are a set of physical and mathematical equations which are solved in time to get the complete 4-D state of the ocean. Since 4-5 decades there has been a tremendous development in the field of numerical ocean modeling. The state of the art ocean models are quite complex and have components such as bio-geochemistry coupled to it.

Due to various approximations, numerical models are prone to generate errors and these errors grow with model integration time. It is therefore quite important to check these errors and apply mid-way correction to the models. With the availability of huge amount of surface observations of temperature, salinity and sea surface height from satellites, it is now possible to extensively generate error statistics at each model grid of moderate (0.5 x 0.5^{o}) to very high resolution (1km x 1km). This synergy of model output and observations to optimally provide an analysis state is known as data assimilation. There can be three major objectives of data assimilation:

- Generate accurate initial conditions from which the model can be initialized for an accurate forecast.
- Generate 4-D ocean state for several years for studying ocean processes
- Tune model parameters for improving the models.

Data assimilation techniques have evolved extensively (Malanotte-Rizzoli; 1996) since last 2-3 decades from simplest (nudging) to the most complicated ones (4-D variational method) and efforts are towards using an efficient approach to build an assimilation scheme for a chaotic system (like particle filter based method).

Due to high computational requirements it is quite impractical to use sophisticated assimilation schemes like the Ensemble Kalman filter or 4-D variational method in high resolution operational models such as those operationally being run at INCOIS or even the US navy. These operational agencies use the 3-D variational approach in their operational system.

However, in non-operational scenario where we need to optimize model parameters or we need to prepare long term hindcast analysis, one can use advanced data assimilative procedures. For the Indian Ocean several studies have been performed using simple to intermediately complex data assimilation schemes. Agarwal et. al. (2008) used simple techniques of nudging and Cressman to assimilate ARGO temperature and salinity profiles into the OGCM. Though the techniques used were simple, there was a clear improvement in the thermocline and mixed layer depth in the assimilated runs.

Chakraborty et. al. (2014, 2015) used the method of singular evolutive ensemble Kalman (SEEK) filter to assimilate satellite derived sea surface temperature, sea surface salinity and sea surface height into the OGCM. It was found that the maximum impact of assimilation comes due to the assimilation of sea surface height data which can correct the model upto thermocline depth. Ratheesh et. al. (2014) used the method of ensemble optimal interpolation (EnOI) to assimilate satellite derived sea surface temperature and sea surface height data into the sigma coordinate Indian Ocean Model. The outputs of this data assimilative model are available on www.mosdac.gov.in in near real time on a regular basis.

Though data assimilation used by various operational agencies are able to do a fairly good job in arresting model drifts and produce accurate forecasts, there is a continuous need for doing assimilation in a regular manner. Once the assimilation stops, the model solution oscillates back to its equilibrium state and errors become large. So the challenge is to use data assimilation procedures not just to improve model's initial condition, but also to estimate model parameters. Optimal setting of parameters (Menemenlis et. al. 2005) used in various procedures will lead to model improvement and the requirement of assimilating the fields may not be continuous.

Another challenge is to assimilate high resolution data sets into the model. This is once again a practical difficulty where the state vector and the observation vector size become too large to be handled. Necessary efforts are required to address this issue. Assumption of normal distribution of state variables to be assimilated can also be done away with by using stochastic data assimilation techniques such as the particle filter method.(Ratheesh et al.,2016).

References

Chakraborty, A. et al. (2015). Improving ocean state by assimilating SARAL/AltiKa derived sea level and other satellite-derived data in MITGCM. Marine Geodesy, 38(sup1), 328-338.

Chakraborty, A. et al. (2014). A SEEK filter assimilation of sea surface salinity from Aquarius in an OGCM: Implication for surface dynamics and thermohaline structure. Journal of Geophysical Research: Oceans, 119(8), 4777-4796.

Cummings, James A. et al. Ocean data assimilation systems for GODAE. No. NRL/JA/7320-09-9126, 2009.

Malanotte-Rizzoli, Paola, ed. Modern approaches to data assimilation in ocean modeling. Vol. 61. Elsevier, 1996.

Menemenlis, Dimitris, et al. "Using Green's functions to calibrate an ocean general circulation model." Monthly weather review 133.5 (2005): 1224-1240.

N. Agarwal, et al., "Assimilation of sub-surface temperature profiles from Argo floats in the Indian Ocean in an ocean general circulation model," Current Sci., vol. 95, no. 4, pp. 495– 501, Aug. 2008

Ratheesh, S., et al. (2014). An EnOI assimilation of satellite data in an Indian Ocean circulation model. Geoscience and Remote Sensing, IEEE Transactions on, 52(7), 4106-4111.

Ravichandran, M., et al. (2013). Evaluation of the global ocean data assimilation system at INCOIS: The Tropical Indian Ocean. Ocean Modelling, 69, 123-135.

Smitha Ratheesh, et al. (2016) Assimilation of satellite chlorophyll measurements into a coupled biophysical model of the Indian Ocean with a guided particle filter, Remote Sensing Letters, 7:5, 446-455.

On the Errors in Simulated SST Associated with Tropical Cyclone Nargis

Student Article

Jyothi Lingala and Sudheer Joseph

Indian National Centre For Ocean Information Services,

Hyderabad

Introduction

Tropical Cyclone (TC) Nargis was unique in many aspects in the history of tropical cyclones. It resulted in extreme infrastructural, economic and human loss to Myanmar, where landfall occurred on 2nd May 2008 [1]. On 27th April, India Meteorological Department (IMD) reported the system as depression, and later on 28th April, IMD upgraded it to Cyclonic Storm Nargis when it was positioned at about 550 km east of Chennai coast. Further, on 29th April, IMD declared it as a very severe cyclonic storm. In the present work, we analyse the simulations of surface temperature from Hybrid coordinate model (HYCOM) to understand the ability of the model to mimic the thermal state of the upper ocean during the cyclone Nargis.

Observed vs simulated SST during Nargis

Figure 1 shows the SST snapshots of 27-Apr and 1-May when the storm passed closer to the RAMA buoy location. It is evident that the storm in NOGAPS is better compared with observation during its initial stage, but as it evolved, was overestimated by NOGAPS. We have plotted simulated SST from HYCOM sampled at the RAMA buoy location closer to the track of Nargis. The storm passed through 16ºN, and RAMA buoy location was at 15ºN. The difference plot (Figure 2C) shows two distinct maxima of errors. During the regular period, the errors of SST are in general < 0.5ºC, whereas, before and after the passage of cyclone, the errors increased to a maximum of 1.4ºC (Figure 2C).

In this short article, we made efforts to trace the origin of the amplification of errors in model SST. Time series presented in Figure 2C shows that, the errors were maximum between 29-April and 30-April and became minimum on 1-May and reached the second peak on 8-May. Thus, the simulated SST errors were not maximum when cyclone was close to RAMA buoy, but errors were maximum immediately before and after a week.

In Figs. 2A-C the wind speed, zonal and meridional components (U & V) of NOGAPS which are used to force HYCOM are plotted against that of QuikSCAT winds. It is evident from the comparison that the NOGAPS overestimates wind speeds from 27-April, and the deviation becomes maximum on 1-May, when the eye of the storm reached

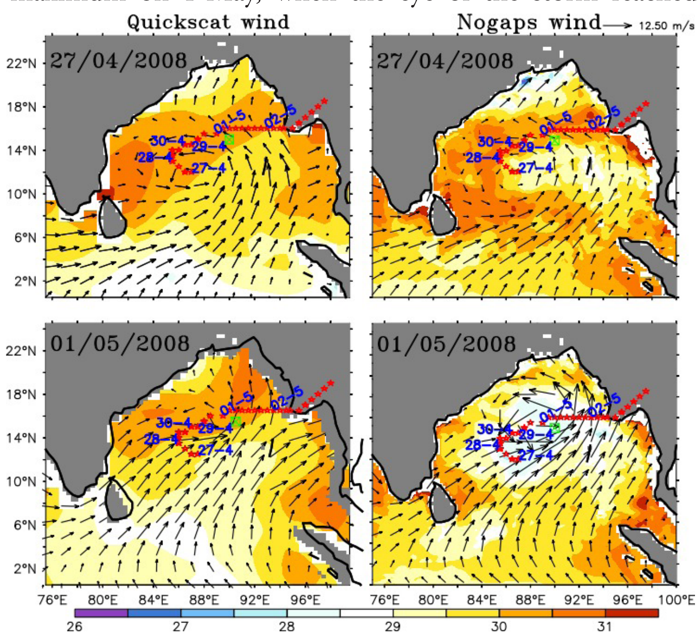

Figure 1: Track of Cyclone Nargis (red stars) plotted over wind vectors of QUIKSCAT(left) and over NOGAPS (right). Top panel shows SST and wind during the start date of NARGIS (ref:IMD) and bottom panel shows the stage on 1-May-2008 when the storm was at its closest location to RAMA buoy observations. Green rectangular mark indicates location of RAMA buoy in the close vicinity of the storm. Colored background represents Tropflux SST in column-1 and model simulated SST in column-2.

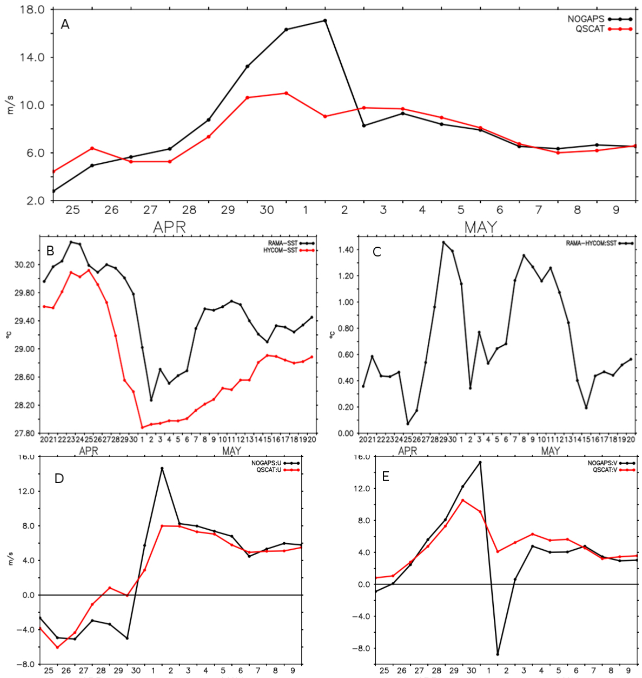

Figure 2: A)NOGAPS and QuikSCAT wind speeds.(B) Comparison of the simulated vs RAMA SST (C) and their difference.(D) Zonal (E) and their meridional components

closer to the RAMA buoy. U & V components at the early stage of the cyclone showed that the U wind of NOGAPS had a higher error compared to the V wind. On 1-May, the direction of U & V winds got corrected, but it overestimated the wind speed by about 6 m/s. On 2-May there were large amplitude and directional errors in the meridional component of simulated winds, ≈11 m/s compared to the QuikSCAT winds.

The errors in wind direction have implication to the SST simulated by HYCOM. The significant errors in SST, where model made substantial underestimation compared to the observed SST is seen on 29-April (Figure 2B) is associated with the directional error in U. If the direction of NOGAPS wind were of same as that of QuikSCAT, it would have advected warm waters to the sampling location. However, the SST errors are seen after the passage of the cyclone from 7-May to 13-May over the sampling site apparently, have a different source other than directional errors in NOGAPS winds as it matches well with QuikSCAT winds for both direction and speed. We do not have clear reasons for the post-cyclone SST errors at the vicinity of RAMA buoy which need further analysis. However, from the examination of surface thermal structure of both model and RAMA buoy, we believe the increase of errors after the cyclone is due to the deficiencies/delay in thermocline adjustment back to the normal wind conditions after the passage of the cyclonic storm.

To summarise, the present case study showed that directional errors in NWP winds play a significant role in shaping errors of simulated SST during storms compared to the errors in wind speed.

References

McPhaden et al., Ocean-atmosphere interactions during cyclone nargis. EOS, Transactions American Geophysical Union, 90(7):53–54, 2009.

The Mediterranean Sea: General Circulation and Eddies

Contributed Article

Mahesh Shinde
Indian Institute of Tropical Meteorology, Pune

The Mediterranean Sea is a sub scale ocean which is connected to the Atlantic Ocean to the west and enclosed by land, thus also known as semi-enclosed basin. Geographically, on the northern side it is surrounded by European land mass, on the south by North Africa and at the Eastern by the Asia. The Mediterranean sea covers the area of about 2.5 million square km and has average depth of 1500 meter with most deepest about 5267 meter in the Ionian sea (known as the Calypso Deep point). It is connected to the Atlantic Ocean by a narrow strait of Gibraltar. The Mediterranean Sea is mainly divided into two basins namely, the western and eastern Mediterranean having different topographic and oceanographic characteristics which is connected by small passage of the Sicily strait. The straits in the Mediterranean are very important and acts as a Hydraulic control in exchanging the water masses from one basin to another. The small sea

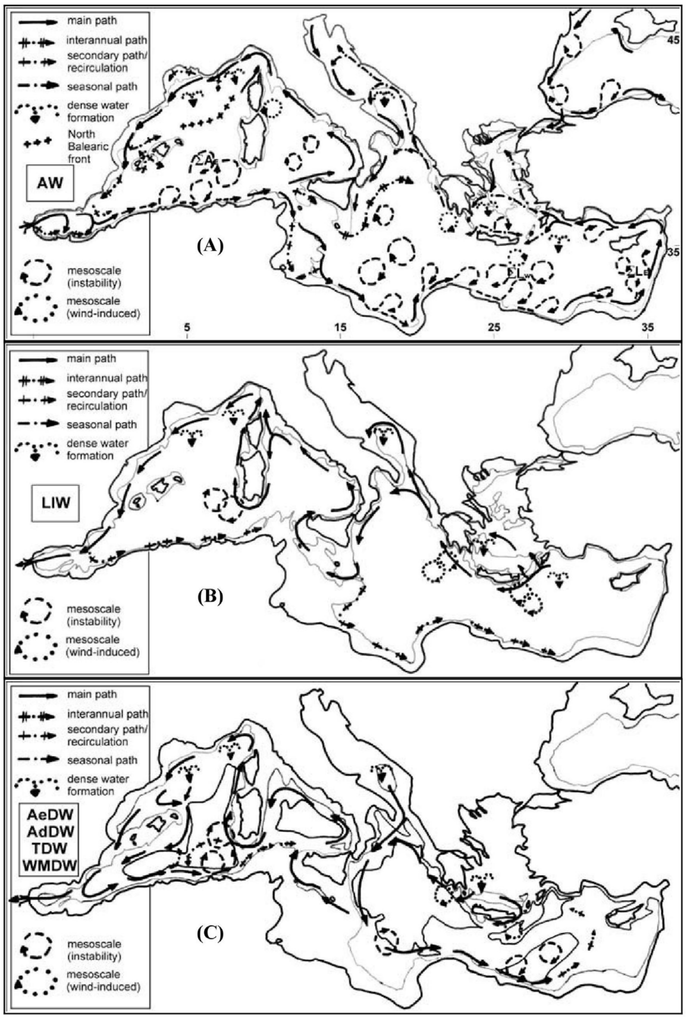

Figure 1: General Circulation in the Mediterranean Sea. (A) Circulation of incoming Atlantic Water (AW) at the surface layer. (B) Circulation of the Levantine intermediate Water (LIW). (C) Circulation of Deep Waters (DW) (Millot and Taupier-Letage, 2005).

like Alboran, Algerian, Tyrrhenian, Ligurian and Catalan are the characteristics sub basin of western Mediterranean. The eastern Mediterranean composed of sub basins like Adriatic Sea, Ionian basin, Levantine basin and Aegean- Crete basins. These small scale seas and basins have their own water mass variability and exchange the water properties between the basins. The role of channels and passages in the Mediterranean Sea are very important as they act as main controlling gate for the water mass exchange among the various sub basins and also interacting point with the global ocean (Lafuente 2008). The Mediterranean Sea connects with the global ocean through the strait of Gibraltar, which is a narrow passage of 14 km wide and with sill depth of 300 km. Another important strait in the Mediterranean Sea is the strait of Sicily with relatively complex topographic features and splits the sea into two sub basin, the western and eastern Mediterranean. The main topographic and oceanographic features of the various straits and channels are elucidated (Lafuente 2008). The straits with sill depths impose topographic constraints in exchanging the deep and intermediate water masses in the basin. Mixing and general circulation of the Mediterranean Sea is controlled by these straits which are considered as the hydraulic control (Bryden 1991). For example, the seasonal variability of transport through main straits such as, the strait of Gibraltar, the strait of Sicily and Corsica using high resolution modelling has carried out using OPA model with 1/16° grid configuration and forced with daily air-sea interaction fluxes from ECMWF database (Beranger 2005). Thus the straits in the Mediterranean Sea are considered as the key points in controlling the water mass exchange in the basin.

The general circulation in the Mediterranean Sea is composed by basin scale gyres and intense coastal currents (Millot 1991, Robinson et al 1991). The fresh Atlantic water flows into the Mediterranean basin through the strait of Gibraltar replacing the denser and saltier Mediterranean water that flow out into the Atlantic Ocean. The incoming Atlantic water then interacts with air-sea fluxes and becomes warmer and saltier and later mixed with surface Mediterranean water (Modified Atlantic Water), which is saltier in nature. The incoming Atlantic water (AW) forms the Alboran Gyres (western and eastern Alboran gyres) in the Alboran Sea (Gascard and Richez 1985). Later the Atlantic water propagates eastwards to form the Algerian current which is characterized by well marked meanders created due to the instabilities and uneven topographic features (Beranger 2005). The mesoscale eddies thus formed in the Algerian basin where circulation and recirculation of the Algerian eddies are observed (Millot 1999). Then the Algerian current travels further through the strait of Sardinia and bifurcates into two branches at the Sicily Strait. One branch enters in the Tyrrhenian Sea and other enters in the eastern Mediterranean basin (Millot 1987). The AW then flows northwards through the strait of Corsica and mixes with the Western Sardinian Current to form the North Current (Robinson et al 1999). The AW then enters the eastern Mediterranean basin at the strait of Sicily and bifurcates into two distinct streams such as northern stream also known as Atlantic Ionian Stream and the southern stream is known as the Atlantic Tunisian Current (Korres et al 2000). These streams have their important properties and variations and later merge at the African coasts to form coastal currents (Beranger 2005, Hamad 2005). These southern coastal currents then flow eastward along with the African coast towards the southern part of the Levantine basin. There

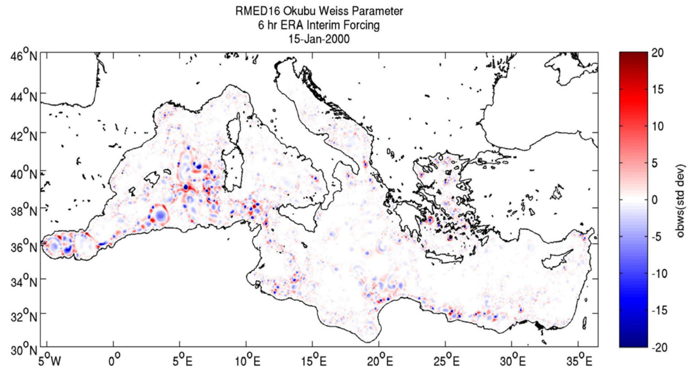

Figure 2: Spatial map of Okubu-Weiss parameter from model for 15 January 2000.

it is characterized by large meanders and anticyclonic eddies (Figure 1(A)). The intermediate water mass formation and deep water circulations are taking place in wintertime which is triggered by convection (Robinson 1991). The Levantine Intermediate Water (hereafter LIW) can be observed at the depth of 200 to 500 meter in the northern Levantine Basin and also in the vicinity of the Rhodes islands (Beranger 2005). The LIW then bifurcates into two branches. One branch of it goes into the Adriatic Sea and plays the role in convection processes there. The another branch of LIW propagates towards the Ionian basin and then flows through the strait of Sicily as Eastern Overflow Water which can be traced at upper layers. The signature of LIW can be identified in the region of the Strait of Sicily at 300 to 350 meter depth (potential temperature of 13.73 to 13.82°C and salinity of 38.73 to 38.78 psu) (Astarldi 2002). Before entering to the Western Mediterranean through the strait of Sardinia, it re-circulates cyclonically in the Tyrrhenian Sea (Millot 1987). Then LIW flows northwards in the Gulf of Lions and contributes in the deep convection there (Millot 1987). Finally, the LIW flows out in the western Mediterranean through the Gibraltar Strait into the Atlantic Ocean in the upper layer of the Mediterranean Outflow Water (Millot 2005) as seen in Figure 1(B). Another important deep water namely, the Western Mediterranean Deep Water is formed in the Gulf of Lions in the winter season under the influence of strong northerly winds (mistrals) (Send 1999). In addition to this, the Cretean Intermediate Water is formed in the Aegean Sea which is found between 500m and 1200m deep. All these water masses are formed during the wintertime conditions characterized by strong surface cooling and evaporation. Some part of the western Mediterranean Deep water flows out from the western Mediterranean as the lower layer of the Mediterranean Outflow Water. Remaining part enters in to the Tyrrhenian Sea via the strait of Sardinia (Figure 1(C)). Besides these important intermediate and deep waters, there are also other currents exist in the Mediterranean. Their description and basin wide similarities and dynamical characteristics are described in Millot (2005). The general circulation in the Mediterranean Sea is relatively complex and mainly forced by strong ocean-atmosphere fluxes, the water deficiency, the Coriolis force and mesoscale variability imposed by topography or wind.

The marine eddies are the important structure in transferring the energy from one place to another and plays key role in upper ocean mixing. The detection of such eddies and their characteristics from satellite imagery provide valuable information about their dynamics (Isern-Fontanet et al., 2006). The mesoscale eddies can be detected using conventional and robust method such as vorticity maps and Okubo-Weiss parameter (W). The Okubu-Weiss parameter is defined as W = (Normal Strain)2 + (Shear Strain)2 - (Vorticity)2. The eddies in the Mediterranean basin are generated by instabilities caused as effect of strong mixing and uneven topography, especially in the Algerian basin where it redistributes the properties of surface water (Isern-Fontanet et al., 2006, 2003). Here, detection of eddies simulated by model (more details of model configuration is available in Shinde (2016)) have been analyzed by using Okubo-Weiss parameter (Figure 2). Such eddies are observed in the Algerian basin as a result of an instabilities produced by a slope along the Algerian coast. The life time of these eddies is of the order of few months to years (up to 3 years) (Millot et al., 1997). The large scale eddies present in the Algerian basin has an impact on the surface as well as on the intermediate level circulation in the western basin of the Mediterranean. Sometimes these eddies mixed with other eddies present in the Algerian basin and contributes in the redistribution of the upper layers. The application of Okubu-Weiss parameter to eddy gives information about spatial distribution of an eddy which is dominated by vorticity, eddy core and background region which is dominated by deformation.

References

Mahesh Shinde, 2016, Implementation of A High Resolution Regional Ocean Model For Investigating Air-Sea Interaction In The Mediterranean Area. PhD Thesis, University of Barcelona, Spain. 1-192.

Status of Bay of Bengal upper ocean mean state in different Reanalysis Products

Student Article

Ananya Karmakar[1,2], Anant Parekh[1] and C. Gnanaseelan[1]

[1]Indian Institute of Tropical Meteorology (IITM), Pune 411008, India

[2]Department of Atmospheric and Space Sciences, Savitribai Phule Pune University, Pune 411007, India

Abstract

This study compares long term mean physical features of the Bay of Bengal (BoB) in different ocean reanalysis, Global Ocean Data Assimilation System (GODAS), Geophysical Fluid Dynamics Laboratory (GFDL), Ocean Reanalysis System 4 (ORAS4), and Simple Ocean Data Assimilation (SODA) respectively with observations. These reanalysis data are widely used for various diagnoses studies. Study also analyzed the monthly evolution of errors and the consistency of these reanalysis compared to observations (World Ocean Atlas-2013 (WOA-2013)) and ocean surface current analysis real time). Analysis revealed that SST and SSS are better represented by all the reanalysis fields, however mixed layer depth (MLD) is better represented by SODA, followed by GFDL, ORA and GODAS. In case of circulation ORA perform best among all, GODAS displays large error compared to others. Better zonal circulation in ORA than others is attributed to the assimilation of along track altimeter data, which is not the case for the other reanalysis. Further analysis reveals that the upper ocean salinity bias is largely contributing to the density biases and upper ocean stability leading to larger error in MLD, accurate salinity profiles assimilation can reduce MLD error to a greater extend.

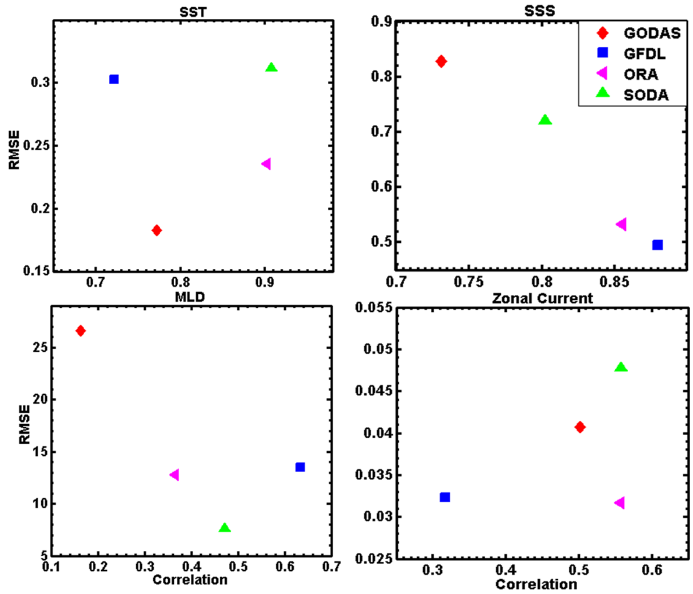

Figure 1: Scatter plot of Correlation and RMSE for the SST (°C), SSS (psu), MLD (m), and zonal current (m/s), for all the reanalysis products.

1. Introduction

The Bay of Bengal (BoB) is a unique semi-enclosed tropical basin that experiences a dominant seasonal reversal in the surface wind field associated with summer (May-September) and winter (November–February) monsoons. BoB receives high fresh water flux via precipitation and runoff of the many rivers; in contrast to the relatively lesser annual evaporation. As such BoB surface water is warmer and fresher compared to rest of the tropical and subtropical global oceans. Simulation of the BoB upper ocean characteristic is one of the challenging tasks for the ocean models. In general ocean models and reanalysis products are the diagnosis tools to study the role of various physical processes for the oceanic variability; however comprehensive evaluation of different reanalysis products with the observations for the BoB is missing.

Different agencies such as National Centers for Environmental Prediction (NCEP), European Centre for Medium Range Prediction (ECMWF), GFDL, and The University of Maryland developed ocean reanalysis system. Here we took four reanalysis products such as GODAS, GFDL, ORAS4, and SODA. These analyses employ different type of ocean general circulation models (OGCMs) Modular Ocean Model i.e., (MOM) 3, MOM4, Nucleus for European Modelling of the Ocean (NEMO) and Parallel Ocean Program numeric (POP) and different data assimilation schemes 3DVAR data assimilation scheme (Derber and Rosati, 1989), optimal interpolation (Gandin, 1965) and (4D-Var) algorithms (Courtier et al., 1994) NEMOVAR (Mogensen et al., 2012) to combine number of networks of available ocean observations in order to get a dynamically best ocean state. The nature of the OGCM, data assimilation schemes and observations used varies reanalysis to reanalysis; hence these reanalysis data differs with each other. These reanalysis are the only source of almost real time three dimensional states of oceanic parameters, which are used to study for oceanic variability of different temporal and spatial scale. The present study analyzes the long term mean vertical structure of temperature, salinity and currents in different reanalysis products and are compared to observations WOA-2013 and ocean surface current analysis real time (OSCAR) over BoB.

2. Methods

As discussed in the previous section four mostly used ocean reanalysis are considered in this study for the inter-comparison with observations over BoB (77°E-100°E,5°N-22°N). For this long term (30 years) mean temperature, salinity and current profile data from the above reanalysis are used. To explore the role of various processes to surface and mixed layer biases, Brant Vaisala Frequency and current shear are calculated using temperature, salinity and current profiles.

2.1. Quantification of errors and skill

It is very important to quantify the error and skill of the reanalysis products with the observation. Figure 1 shows the RMSE vs. correlation scatter plot for the SST, SSS, MLD and zonal current for GODAS, GFDL, ORA and SODA reanalysis. This error and correlations are computed based on the WOA-2013 (OSCAR) climatology data. All the reanalyses display poor spatial correlation greater than 0.7 for SST and RMSE is between 0.15 to 0.3 °C reported by ORA, GODAS SODA, and GFDL. In case of SSS, correlation is greater than 0.70 and RMSE is 0.48 psu, 0.52 psu, 0.72 psu and 0.82 psu by GFDL, ORA, SODA and GODAS respectively. In case of MLD, SODA, GFDL and ORA display correlation greater than 0.3 but GODAS has considerably poor correlation 0.1. RMSE is less than 15m in SODA, GFDL and ORA however it is 28m in GODAS. This could be partially due to the assimilation of synthetic salinity profiles instead of actual salinity profiles, however rest of the reanalysis are assimilating actual salinity profiles. In general zonal currents are stronger than meridional current in the BoB. In case of zonal current except GFDL all reanalysis products have greater than 0.5 correlations, ORA displays lowest error followed by GFDL, GODAS and SODA.

Overall analysis concludes that ORA performed

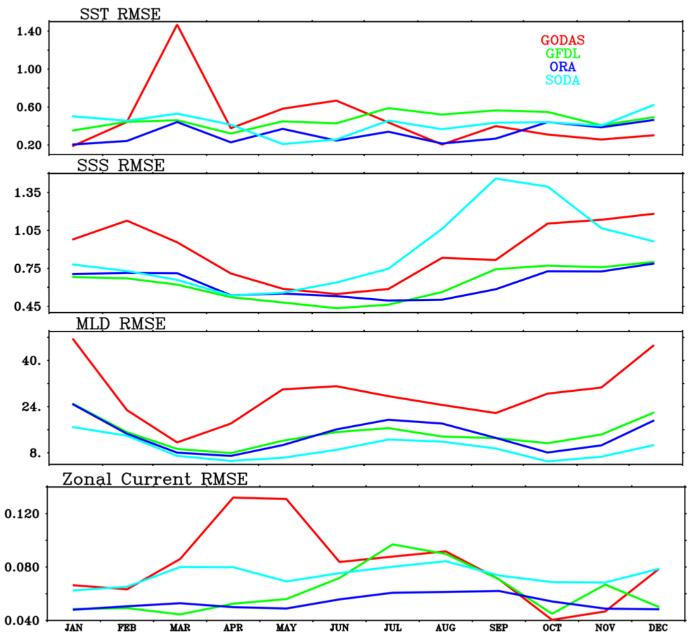

Figure 2: Monthly evolution of RMSE of (a) SST (°C), (b) SSS (psu), (c) MLD (m) and (d) zonal currents (m/s) for the TIO, EIO, AS and BoB.

better followed by the SODA, GFDL and GODAS. Since Bay of Bengal have strong seasonality and so these reanalysis products are used for the seasonal forecast apart from annual mean error analysis as it will be equally important to study month wise evolution of errors in all the physical variables. This enforced us to study error evolution month wise.

2.2. Temporal evolution of error

Figure 2 shows the temporal evolution of error in SST, SSS, MLD and zonal currents for BoB in different reanalysis products. Month wise error evolution of SST does not show any specific dependency on time in ORA, GFDL and SODA; however GODAS shows higher error during March compared to rest of the year (Figure 2a). Figure 2(b) shows error in SSS, in BoB GODAS displays higher error in fall and winter and SODA displays higher error in summer and fall. MLD error evolution (Figure 2c) in ORA, SODA and GFDL are more consistent with each other, however GODAS displays inconsistency in temporal evolution as well as error magnitude compared to other reanalysis products. In case of current (Figure 2d) except GODAS rest of the analysis display higher error in summer however GODAS displays maximum error in spring. Analysis of Brunt Vaisala Frequency and vertical current shear (Figures are not shown here) in these reanalysis products support that stability in all reanalysis products is weaker and vertical shear of currents is overestimated. Overall ORA shows least error in most of the variables and remains almost constant throughout the year.

3. Summary and Conclusion

This study advocates that to improve the upper ocean stability as well as to reduce the positive bias in MLD over the BoB, error in vertical structure of salinity as well as current needs to be reduced. Secondly, it is very important to reduce the strong vertical shear bias of the horizontal zonal currents. Thirdly, to improve horizontal circulations it is important to assimilate the altimeter observations. Temporal evolution of errors reveals that errors do evolve with time and SST and MLD errors are higher during spring and summer. Ocean states of BoB during summer months play significant role in the seasonal and extended range prediction of Indian summer monsoon rainfall. Overall surface temperature, salinity and horizontal circulation are better simulated by the ORA whereas MLD is better simulated by the SODA. This may be useful information for the research community.

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References

Courtier P, Thépaut J-N,Hollingsworth A. 1994. A strategy for operational implementation of 4D-Var, using an incremental approach. Q. J. R. Meteorol. Soc. 120: 1367–1388.

Derber, J. and Rosati, A. 1989 A global oceanic data assimilation system. J. Phys. Oceanogr., 19,1333–1347.

Gandin, L. S., 1965: Objective analysis of meteorological fields. Israel Program for Scientific Translation, 242 pp.

Mogensen K, Balmaseda MA, Weaver A (2012) The NEMOVAR ocean data assimilation system as implemented in the ECMWF ocean analysis for system 4. ECMWF Tech Memo (668).

Weaving World Wide Web

Contributed Article

Manoj Kumar Tandon
Visiting Faculty, Savitribai Phule Pune University (SPPU), Pune.
Symbiosis International University (SIU), Pune.
Centre for Advanced Training in Earth System Sciences and Climate, Pune

Tim Berners-Lee, British computer scientist, invented World Wide Web in 1989. He was born on June 8, 1955 in London, United Kingdom. He was knighted in 2004 by the Queen Elizabeth II of England for his services to the global development of Internet. World Wide Web (WWW in brief) is an information space where documents and other web resources are identified by URLs, interlinked by hypertext links, and can be accessed via internet. In 2009, Sir Tim Berners-Lee established World Wide Web Foundation in 2009. The Web Foundation is advancing the Open Web as a means to build an internet savvy online global society by connecting everyone, raising voices and enhancing participation. World Wide Web has become known simply as the Web. When used attributably, as in web page, web browser, website, web server, web traffic, web search, web user and web technology, it is invariably written in lower case. Otherwise, the initial capital is often retained (the Web), but lower case is becoming increasingly popular. Web pages are primarily text documents formatted and annotated with Hyper Text Markup Language (HTML). Hyper Text Markup Language is the formatting language of the Web. World Wide Web was central to the development of the 'Information Age' and is the primary tool billions of people use to interact on the internet. In addition to the formatted text, web pages may contain images, videos and software components that are rendered in the user's web browser as coherent pages of multimedia content. Embedded hyperlinks permit users to navigate between web pages. World Wide Web is basically a system of internet services that support specially formatted documents. According to WorldWideWeb.com the indexed web contains at least 4.02 billion pages as on June'2016.

Many people use the terms Internet and World Wide Web (aka Web) interchangeably but in fact the two terms are not synonymous. The internet and the Web are two separate but related things. The internet is a massive network of networks, a networking infrastructure; whereas World Wide Web is a way of accessing information over the medium of the internet. World Wide Web is an information servicing model that is built on top of the internet. The Web is a portion of the internet. Web is just one of the ways in which information can be disseminated over the internet. World Wide Web is one set of software services running on the internet. The Internet is one of the most fundamental and important tools of our time. Never before have we seen such opportunities for human empowerment, social development, technical innovation and economic growth – opportunities that span the globe and touch everyone in its reach. Following table gives brief comparison between the internet and the World Wide Web.

Feature	Internet	World Wide Web
Estimated Year of origin.	1969, Though the opening of the network to commercial interests began only in 1988.	1993
First version.	ARPANET	NSFnet
Comprises	Network of computers.	Files, folders and documents stored in different computers.
Governed by	Internet Protocol.	Hyper Text Transfer Protocol.
Dependency	This is the base, independent of World Wide Web.	It depends on internet to work.
Nature	Hardware	Software

Sir Tim Berners-Lee founded World Wide Web Consortium (WWWC or simply W3C) on 1st October, 1994. WWWC is the main international standards organization for the World Wide Web. World Wide Web is also described as a system of internet servers that support specially formatted documents. These documents are formatted in HTML. There are several applications called web browsers that make it easy to access and browse through the World Wide Web. Two such browsers are Firefox and Microsoft's Internet Explorer. Some other notable web browsers are Opera, Safari, Chrome, Mozilla, Omniweb, iCab, Konqueroer, Epiphany and K-Meleon. 'WorldWideWeb' was the first browser and editor written by Tim Berners-Lee in December 1990. Sir Tim Berners-Lee wrote the first World Wide Web server "httpd". The World Wide Web is international multimedia system of sound, pictures and video for finding information on the Internet.

World Wide Web's explosion onto the global scene is one of the most dramatic arrivals of technology in history. Consequently, myths and misconceptions about the origin and future of the technology have run wild. One of the most significant changes in the last 20 years has been the development and awe-inspiring acceptance of World Wide Web. Time magazine has named the creator of World Wide Web, Tim Berners-Lee, as one of the hundred greatest minds of the 20th century. He is responsible for one of the 20th century's most important advancement viz. World Wide Web. Three fundamental technologies that remain the foundation of today's Web are (i) HTML: Hyper Text Markup Language. HTML is the formatting language for the Web, (ii) URI: Uniform Resource Identifier. URI is a kind of address that is unique and used to identify each resource on the Web; it is also called as URL (Uniform Resource Locator) and (iii) Hyper Text Transfer Protocol (HTTP), it allows for the retrieval of linked resources from across the Web. The Web was originally conceived and developed to meet the demand for automatic information sharing between scientists in universities and institutes around the world. World Wide Web is one of several utilities that form the Internet. The Web is a wonderful place. It connects people from across the globe, keeps us updated and creates revolutions never before seen in our lifetime. It has certainly come a long way since its humble beginnings back in the early 1980s. The Web does not and will not stay in its current format. The Web is constantly changing, web does not stand still. Like any other science, World Wide Web is constantly evolving. We were so used to receiving the web through desktops that we didn't anticipate mobile, tablets and apps each of which take the information provided from the web and display it in their own unique way and format. Tim Berners-Lee created the web as open source and allowed the world to access it for free. He didn't patent the web (from which he could have made billions) and allowed it to be extended by anyone in the world. World Wide Web is an internet based computer network that allows user on one computer to access information stored on another computer through a series of interconnected networks. Despite its increasing role in communications, the World Wide Web remains uncontrolled: any individual or institution can create a website with any number of documents and links (URLs). This unregulated growth of World Wide Web leads to a huge and complex web, which becomes a large directed graph whose vertices are the documents and whose edges are the links (URLs) that point from one document (vertex) to another document (vertex). The topology of this directed graph determines the web's connectivity and consequently how we can locate information on it. Size of web is also called the 'Diameter of the World Wide Web' and it is currently estimated to be around 8 x 108 documents. The continual changing of web documents and links make it impossible to catalogue all the vertices and edges of the web directed graph. With the web constantly expanding, the researchers have proposed and demonstrated the feasibility of using quantum computers to run Google's page ranking algorithm faster. Quantum computers could help web search engines keep up with the internet's continual growth. Use of World Wide Web as an instructional tool is gaining momentum as more teachers, instructors and trainers incorporate World Wide Web into their repertoire. Grouped together, any instruction that makes use of a computer is called Computer Based Training and those strategies that employ the web as repository for instructional information are known as Web Based Instruction. Web Based Instruction can be employed in a distance education model or as an adjunct to teacher led classrooms. An added bonus of Web Based Instruction is the fact that it can offer students a "Virtual Teacher" because the students can access the instructional material anytime, anywhere. The web is just the tip of an iceberg and is only scratching the surface of what can really be achieved and it is for the designers and developers to understand web's fundamental aim. Online global society is thinking whether the World Wide Web is becoming our external memory drive.

INDO-MARECLIM: Scientific network involving European and Indian Institutions

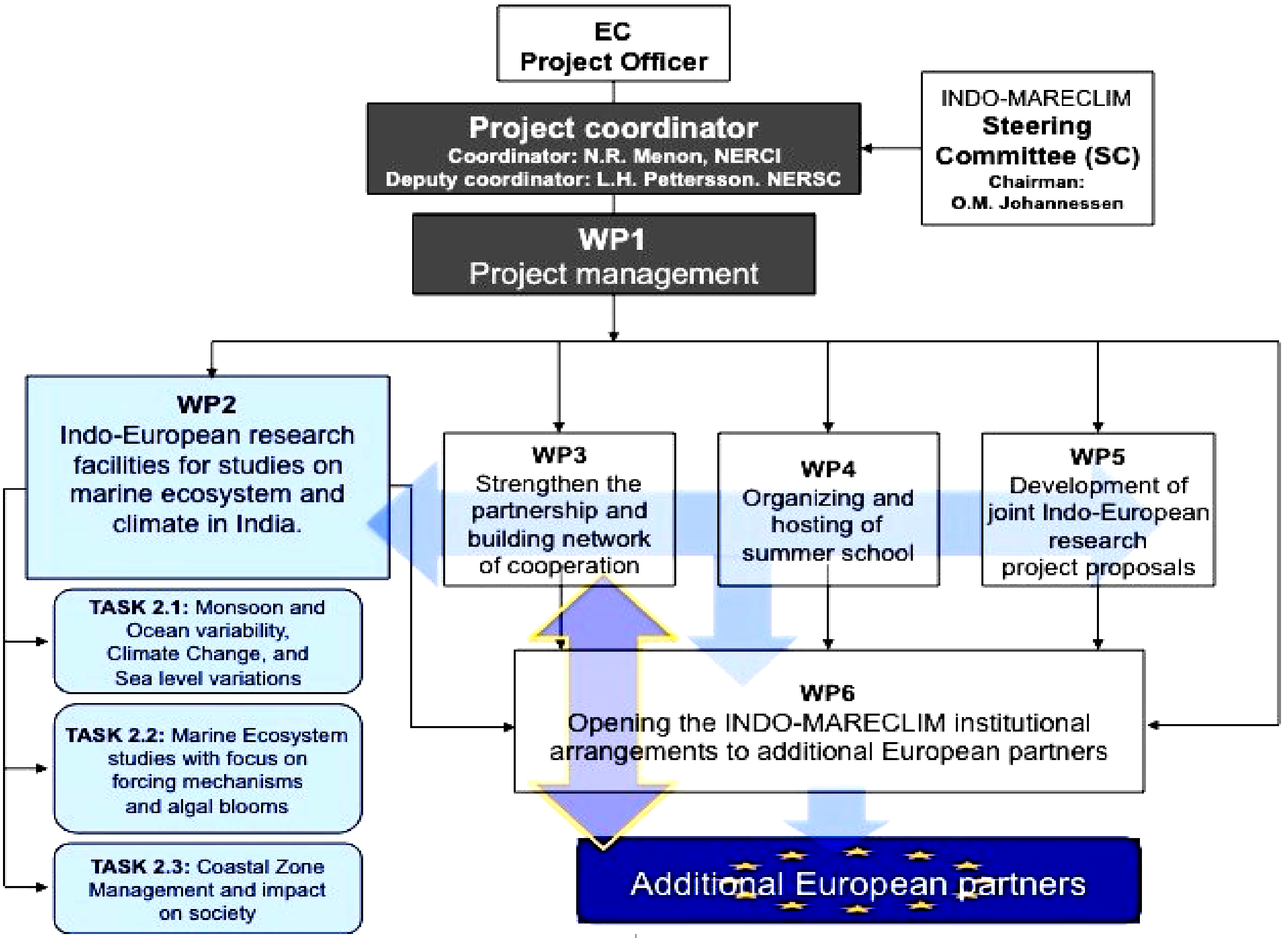
Contributed Report

Bindu. G.[1], Nandini Menon. N[1], Ajith J. K.[1], N. R. Menon[1], Lasse Pettersson[2], Shubha Sathyendranath[3], Trevor Platt[3] and Ola M Johannessen[2]

[1] Nansen Environmental Research Centre (India), 6A, Oxford Business Centre, Sreekandath Road,Cochin-682016, India
[2] Nansen Environmental and Remote Sensing Centre, Thormohlens gate 47, N-5006, Bergen, Norway
[3] Plymouth Marine Laboratory, Prospect Pl, Plymouth PL1 3DH, United Kingdom

Nansen Environmental Research Centre, India (NERCI) in Cochin co-ordinated a EU-FP7 seventh framework programme under the INCO-LAB (Strengthening European research facilities in third countries) scheme during 2012-2015 with the intention to capitalize and exploit the bilateral Indo- Norwegian cooperation built up by NERCI since 1998 with additional support from other collaborators in India and Europe. EU research institutions working on the same area of interest as that of NERCI joined as partners and the similar scientific interests helped in building strategic R&D partnerships between EU and Indian institutions. Major goal of the project entitled "INDO-European Research Facilities for Studies on MARine Ecosystem and CLIMate in India (INDO-MARECLIM)" was to address some of the challenges of the Indian Ocean and the Indian sub-continent (such as monsoon variability, sea level rise, coastal erosion, changes in primary production, fisheries and biodiversity) under past, current and future global change. Research on Indian marine ecosystem helped in formulating a consortium involving leading marine institutions in India (Indian National Centre for Ocean and Information Services (INCOIS), Anna University, Toc H Institute of Science and Technology) and EU (Nansen Environmental and Remote Sensing Center (NERSC), Norway; Plymouth Marine Laboratory (PML), UK; Centro Euromediterraneo per i Cambiamenti Climatici (CMCC), Italy; Institut Francais Recherche Pour L´Exploitation de la Mer (IFREMER), France; and Stichting Dienst Landbouwkundig Onderzoek (Alterra), The Netherlands) through a network developed by NERCI.

The overriding context for the work carried out under INDO-MARECLIM was on the marine system encompassing the Indian sub-continent, on which a large population relies for its livelihood, which is impacted to an unknown degree by the effects of climate change, and in which there are competing interests to reconcile, such as those of fishing and tourism. Indian scenario is very complex, with some states like Kerala having literacy and life expectancy comparable with those in developed countries although the gross domestic product is very much lower (Amartya Sen, 2005); and some maritime states having well advanced oceanographic education and research facilities,



which are at par with world's leading institutes. Despite these advancements, aspects of its economy and of the related social fabric are vulnerable to the impacts of climate change now underway. INDO- MARECLIM contributed to build strategic R&D partnerships between institutions in Europe and India, wherein the infrastructure of NERCI developed through this programme provided a platform for EU partners to share, learn and gain knowledge on the potential negative impacts of climate change on marine ecosystem, particularly fisheries and its repercussions on the socio-economic scenario.

Specific contexts

At the outset, a number of specific issues were identified as requiring particular emphasis. Within the overall objective of INDO-MARECLIM project three scientific areas of research were initially selected for development of scientific cooperation;1) Monsoon and ocean variability, Climate change and Sea level variations, 2) Marine Ecosystem studies, including algal blooms and 3) Coastal Zone Management and impact on society

First and foremost among these was the variability of the monsoon system, on which the terrestrial and marine ecosystems of India are so strongly dependent. The monsoon is a variable phenomenon between years, principally as a response to inter-annual modulation in physical forcing. It was considered vitally important to assess what further modifications might be expected as a consequence of global warming and climate change. A related issue was that of sea-level rise, which was clearly evident in the state of Kerala with a low-lying coastal fringe. Hand in hand with sea-level rise, we can expect increased coastal erosion, antagonistic to both artisanal fisheries in the coastal fringe and to development of tourism. Recognition of the high significance of both monsoon variability and sea-level rise led to the requirement for research in physical oceanography as a priority in INDO-MARECLIM.

Second priority was given to the effects of climate change on the marine ecosystem. Here, the principal focus was on primary production, on which the entire ecosystem depends. Advantage was taken of the rapidly-developing use of visible spectral radiometry (ocean colour) and remote sensing to study regional, seasonal and inter-annual variations in primary production as a starting point for ecosystem analysis, in particular the effects on biodiversity, especially fisheries.

These oceanographic and ecosystem analyses were conducted with an eye on the potential social relevance. The focus of the coastal zone related research was to assess the impact of monsoon and climate variability on coastal livelihood. The impact of coastal upwelling on the fishery resources and sustainability of stock in the coastal sector in selected fishermen villages and landing centres was investigated by reviewing census data and conducting interviews and questionnaire surveys. The impact of seasonal variability on the economic status of fisher folk was also studied.

Specific objectives

Research goals were established to address outstanding issues related to monsoon and climate change. To fit the above mentioned issues into a clear functional mode, the project was divided into 6 work packages involving close interaction and team work between the consortium partners (Figure 1). The main objectives focussed in the area of monsoon and ocean variability, climate change and sea level variations included: i) ISM in relation to ENSO and IOD (Cherchi and Navarra, 2013), ii) Climate Change in Jet streams (Abish et al.,2013, Abish et al., 2015), iii) Moisture Trend over the Arabian Sea (Ratna et al., 2015) iv)Cold Pool of the Bay of Bengal (George,2015) v) Barrier Layer and Upwelling in the Arabian Sea (de Boyer et al. 2014) vi) Sea level rise (Johannessen,2015) vii) Monsoon Onset over India (Alessandri et al.,2015) viii) Statistical Downscaling for precipitation forecasting, ix) Aerosols and monsoon, x) Teleconnection between monsoon and the Mediterranean (Cherchi et al., 2014,2015) xi) Indian Ocean Warming and xii) Indian Ocean Dipole.

Marine ecosystem studies, including algae blooms focused on the following aspects to gather a glimpse of the events happening in Indian waters: (i) performing satellite Earth Observation data validation and application studies (Salim et al., 2015), (ii) making a primary production atlas for the Indian waters (Salim et al., 2015) (iii) Synergistic utilisation of ocean colour and other EO data to study eddy-induced algal blooms (Menon et al.,2014) (iv) impact of climate change on primary production, and (v) implementation of a marine ecosystem model for the Indian Ocean (Sankar et al., 2014).

The focus of the coastal zone related INDO-MARECLIM research was to assess the impact of monsoon and climate variability on coastal livelihood (Ambilikumar and Raju, 2015). The impact of coastal upwelling on the fishery resources (Dijk et al.,2013)and sustainability of stock in the coastal sector in selected fishermen villages and landing centres was investigated by reviewing census data and analysing different interviews and questionnaires (Pavithran et al., 2014; Riel, 2013). In addition the impact of seasonal variability on the economic status of fisher folk was studied (Ambilikumar and Raju, 2015).

As part of network building during the course of INDO-MARECLIM, a bio-optical research laboratory was established at NERCI; a total number of 138 scientists from approximately 60 Indian and 33 European research institutions got involved in knowledge dissemination events and exchange visits of scientific personnel. Additionally 450 young scientists and students participated in scientific networking activities like workshops and winter school. These Indo-European events of research cooperation have founded the basis for future scientific cooperation between both established and emerging scientists in Europe and India.

The networking among Indian and EU scientists was a mutually beneficial experience. For e.g., the atmospheric, oceanic, primary production and ecosystem models developed by the EU consortium partners were put to test in the Indian context. Working on Indian conditions helped in the fine tuning as well as calibration of the models. Furthermore, the EU scientists benefitted from the expert knowledge of the Indian scientists in the regional and local context, for e.g., monsoon variability and dynamics and the socio- economics of the fishing community of Kerala.

INDO-MARECLIM team has worked strenuously to spread excellence and dissemination of knowledge acquired during the project. The dissemination activities were designed to reach as large an audience as possible, covering all the Marine Research Institutions in India and maximum number of institutions in EU and Associated Countries. The dissemination activities aimed to provide the target beneficiaries with information on Research and Technology Development that is relevant to their specific interests. The potential impacts of INDO-MARECLIM includes: scientific co-operation, validation of EU technologies, scientific network involving European and Indian institutions and forming of new consortia and practical solutions to enhance scientific research monitoring which would pave the way for more cooperation with scientists from EU and Indian institutions in the field of Climate change and marine ecosystem studies in the future.

Read More: INDO-MARECLIM Bibilography

News and Views

Recent Updates

Freshening of the Southern Ocean

The northward drift of sea-ice surrounding the Antarctic subcontinent has strengthened. This has lead to an increased extent of sea ice in the Southern Ocean. The northernmost edge of the sea ice is located roughly at 60 degrees south. During spring, the ice starts melting, releasing freshwater into the ocean. This freshening of the Southern ocean can have a major influence on the planet's surface heat balance and the atmospheric carbon dioxide levels. [Read More]

Nutrient pollution is changing sounds in the sea

Marine ecosystems are degraded by 'eutrophication', caused due to excessive nutrients washing into the sea from adjacent land. This leads to change in sounds made by marine life, which potentially upsets the navigational cues for fish and other sea creatures. [Read More]

Increased ocean acidification is due to human activities

North-east Pacific has absorbed an increasing amount of anthropogenic carbon dioxide over the last decade. Most of the carbon dioxide lingers on the upper layers of the ocean thereby affecting the chemistry of the ocean. The region's pH had dropped by 0.002pH, resulting in more acidic waters. [Read More]

Latest ocean warming reviews reveal extent of impacts on nature and humans
Warming of ocean is one of today's prime concerns. Humans are affected in direct ways and the impacts are already being felt. Ocean warming is causing increased disease in plant and animal populations, and impacting human health as pathogens spread more easily in warmer waters. Damaged fish habitats will lead to reduced catches in tropical regions. The number of severe hurricanes has increased. Ocean warming has led to increased rainfall in mid-latitudes and monsoon areas, and less rain in various sub-tropical regions. These changes are likely to have impacts on crop yields in North America and India. [Read More]

Conversion of forest land the reason behind weakening of monsoon
A recent study by scientists revealed that weakening of monsoon over north-central and north-east India is due to large scale conversion of forest land to crop land. Changes in land-use land cover have an influence on large-scale atmospheric and oceanic circulation, which drives Indian monsoon. [Read More]

A strange thing happened in the stratosphere
The quasi-biennial oscillation is the stratosphere has never changed until late 2015. Scientists are studying their potential causes and implications. A strong El Niño in 2015-16 or the long-term trend of rising global temperatures could have triggered this change. [Read More]

Conferences

Upcoming Events

- OSICON 2017, the 5th National Conference of the Ocean Society of India, will be held at ESSO-NCESS, Thiruvananthapuram, during 17-19 May 2017. Watch www.oceansociety.in for updates and registration.
- India Conference on Radar Meteorology is scheduled to be held at IIT, Kharagpur. 8-11 January 2017 [See More]

Opportunities

Fellowships/Awards

- Dev Raj Sikka Best Paper Award for Monsoon Meteorology. Last date to apply: 31 January 2017 [See More]

Send your correspondence and contributions to:
OSI Pune, Indian Institute of Tropical Meteorology, Pashan, Pune 411008, India.
oceandigest@tropmet.res.in
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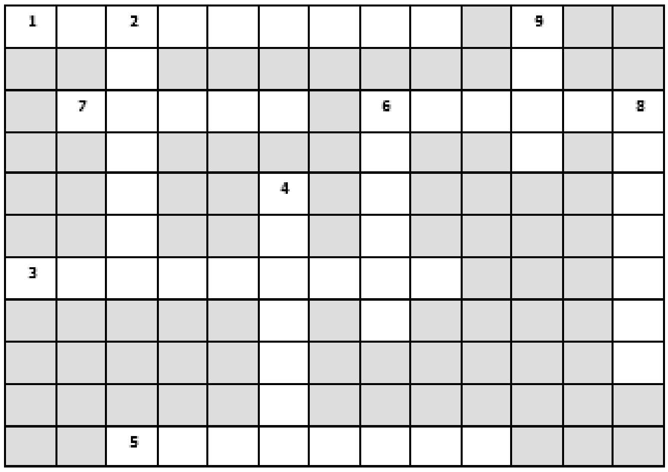
Crossword

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



ACROSS

1. It is the point on the Earth's surface that is directly above the focus of an earthquake
3. The wind that carries high density air from a higher elevation down a slope under the force of gravity is named as
5. This is the most abundant gas in the atmosphere by volume
6. A tide just after a new or full moon, when there is the greatest difference between high and low water
7. The Great Barrier Reef is located in this sea

DOWN

2. A line on a map connecting points having the same amount of rainfall in a given period is termed as
4. The persistent body of dense ice that is constantly moving under its own weight
6. A narrow passage of water connecting two seas or two other large areas of water is better known as
8. This state has the longest coastline of all Indian states
9. This type of regions are too dry or barren to support vegetation

Compiled by Bhupendra B. Singh