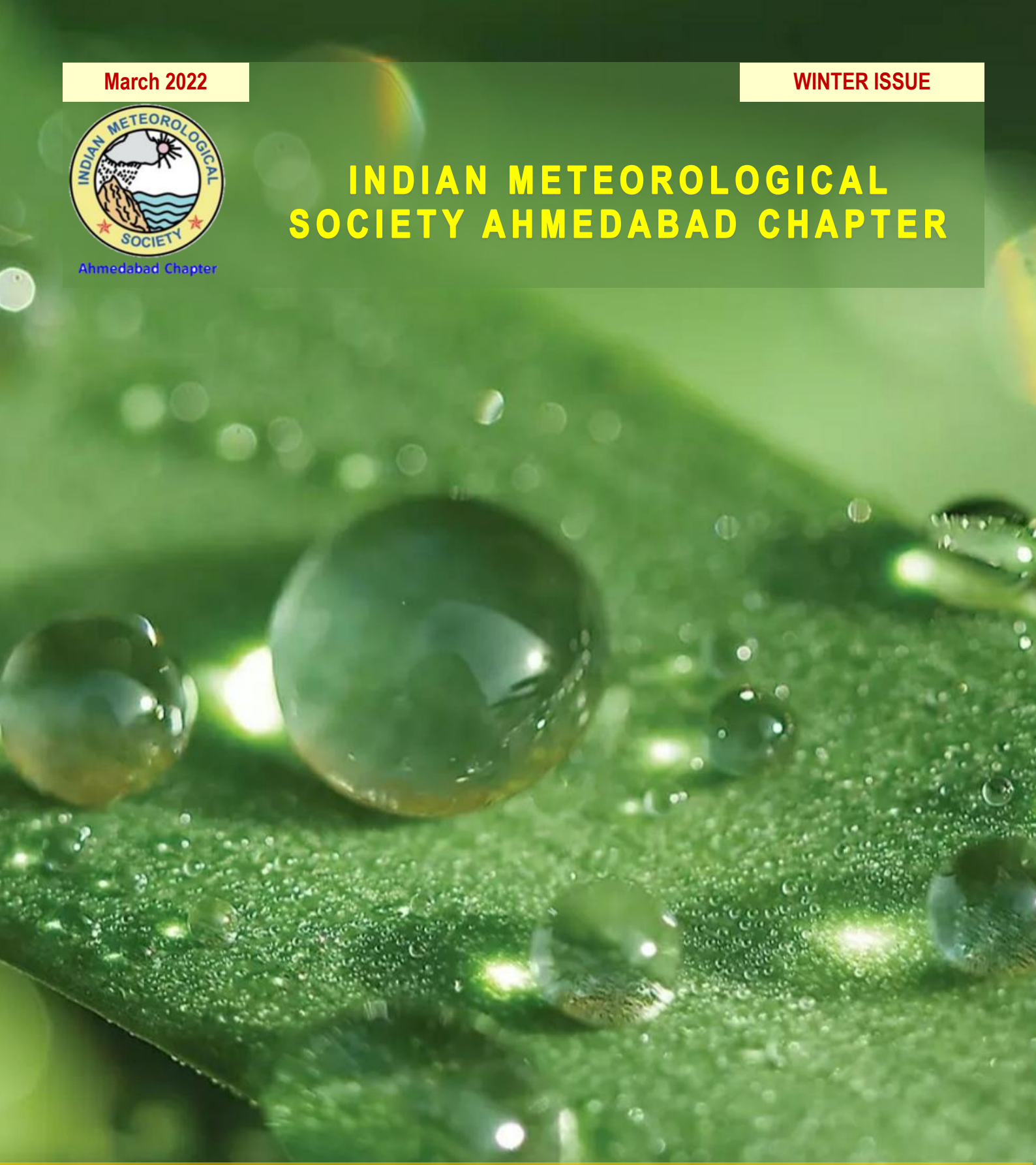
March 2022

WINTER ISSUE

Ahmedabad Chapter

INDIAN METEOROLOGICAL SOCIETY AHMEDABAD CHAPTER



E-MEGHA

From the Chairman's

Dr. Raj Kumar

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As I pen down the foreword to this winter issue of E-Megha, I heartily congratulate and welcome the newly formed IMSA Executive committee to carry the baton forward. At the same time I fondly reminisce the activities of IMSA for the past two years especially during Covid-era. Despite a completely new and adverse situation, IMSA as a society adapted and joined hands with other scientific societies for a collaborative framework of scientific celebration and learning. I am happy to note that apart from regular lectures and activities, we were able to organize interesting events like panel discussion, monsoon photography contest and involvement of student community through E-Megha. The science of meteorology is all-encompassing, from monitoring and forecasting in order to prepare ourselves better for future weather and climate, to tapping unconventional energy sources, it remains an integral and essential part of our life. The excitement of pursuing such a field is a joy in itself and I feel fortunate to be a part of this challenging yet fulfilling career.

I can fondly recall my entry to the field of satellite meteorology and oceanography, which was entirely new subject from the topics gone through in post graduation. My only acquaintance with Meteorology was India Meteorology Department, for which I was selected at approximate same time of my selection at ISRO, after my post graduation. I was unaware that this topic will not leave me, wherever I go. After joining in Meteorology Division at SAC, I was supposed to work on Active microwave remote sensing for Ocean and atmosphere, quite interesting field, which I still love and worked till my superannuation. Many of us may still remember the book of Ulaby, Fung and Moore on Microwave Remote sensing, which most of us at that time would have referred. Slowly and steadily with the superb guidance of our seniors and regular discussions with friends and colleagues, I could learn this challenging and interesting topic, Meteorology, a little bit.

My association with Indian Meteorological Society is also very interesting. Being an introvert , I was always trying to take back seat in putting forward my point of view during discussions. However, in one of such discussions, , there was a search for the post of Secretary IMSA and someone suggested my name.

With much hesitation , I agreed and I believe that it was a fantastic opportunity through which I learnt many lessons pertaining to both technical as well as social skills. Fortunately during that period only, idea of First Symposium TROPMET to be held in 1992, was mooted under the Chairmanship of Prof O P N Calla, if I remember correctly, who was incidentally the first Life member of Ahmedabad Chapter. The event was organized with great enthusiasm from all the IMSA members, it was a great success and the symposium was highly appreciated by all in IMS community as we started the TROPMET series. I can still recall the time when we were not having any funds for the symposium but had made very big plans for the organization. However the Chairman IMSA was always sure that somehow we will receive the required funds . Truly, to the great surprise of not only IMSA but whole IMS, we received more than expected and had a grand show. Many of the senior IMSA members may also recall the first weather calendar by IMSA of all weather events was also printed during that time and widely circulated. During that period, together with the involved office research , I was actively participating in the society activities after office hours. That was also the period, when I was busy in writing my Ph.D thesis. Truly speaking that time I could recognize my real potential by working in varied dimensions and with different personalities, and it also helped immensely in my thinking process, time management and shaping my professional career. Fortunately in 2016, I was entrusted with the responsibility of leading IMSA and was responsible for organising International TROPMET Symposium INTROMET-2017 and it gave me great satisfaction that TROPMET was initiated during my first association with IMSA as Secretary in 1992 and International TROPMET as Chairman of the Society. I really enjoyed my association with IMSA during all these years and presently during the present term of 2020-2022 by organising various events online even during the COVID-19 period with the active support of enthusiastic team of Executive Committee and members. In future also, I can assure that I will always be available to serve the society and promote the IMS activities.

I would also like to congratulate the E-Megha team for their outstanding efforts in bringing out this very contemporary Newsletter with an interesting medley of science, aesthetics and community information. I would also request the IMSA members to contribute more actively to E-Megha.

Wishing you all best of health, spirit and contentment!!

Secretary's Report

Dr. Abhisek Chakraborty

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Ahmedabad chapter is one of the active chapters of Indian Meteorological Society (IMS) dedicated in spreading awareness of meteorology and allied subjects in different parts of the society. Although the year 2022 started with the pandemic conditions due to the third wave of Covid-19, we could arrange few events.

In the last one year, we were successful in bringing out three issues (viz. summer, monsoon and winter) of our newsletter E-Megha. It was all because of the dedications by the E-Megha editorial team and the supportive roles of our members.

In collaboration with Space Education and Research Foundation (SERF) and R. K. University, Rajkot, we arranged a webinar on "Physics Nobel Prize – 2021: Complexity in Climate Science" by Prof. B.N. Goswami, FASc, FNA, FNASc, FTWAS on December 03, 2021, Rajkot. A good number of participants including researchers and students attended the webinar.

To celebrate the World Meteorological Day 2022, we also organized a panel discussion on "Role of ground water on agriculture and air pollution" on March 22, 2022. The selected panellists included Dr. V. M. Tiwari, Director – National Geophysical Research Institute, Hyderabad, Dr. Prakash Chauhan, Director – National Remote Sensing Centre, Hyderabad and Indian Institute of Remote Sensing, Dehradun, Prof. S. M. Tripathi, Indian Institute of Technology - Kanpur and Dr. Vinay Sehgal, Principal Scientist, Indian Agricultural Research Institute, New Delhi.

The results of the election for the Executive Council (EC) of IMSA for the term 2022-2024 is declared on March 11, 2022 by the Returning Officer Dr. S. P Vyas. The present EC plans to handover the charges to the incoming EC in the month of April 2022.

E-Megha Team

Dr. Indrani Choudhury Singh

Dr. Bipasha Paul Shukla

Dr. Suchandra Aich Bhowmick

Dr. Abhineet Shyam

Mr. Sambit Kumar Panda

IMSA Activity Log

IMSA Lecture on Physics Nobel Prize -2021

Complexity in Climate Science by
Prof. B. N. Goswami
FASc,FNA,FNASc,FTWAS

Online Discussion on World Meteorological Day (March 22, 2022) on "Role of groundwater on agriculture and air pollution''

Panellist

Dr. V.M. Tiwari, Director – NGRI

Dr. Prakash Chauhan, Director – NRSC & IIRS

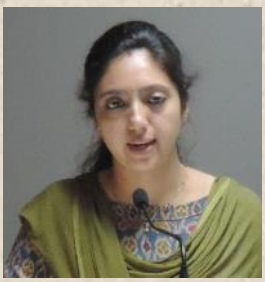
Prof. S N Tripathi - IIT Kanpur

Dr. V K Sehgal - Principal Scientist, IARI

Congratulations to our New Executive Committee Members

Dr. Rashmi Sharma (Chairperson)

Dr. Sanjib Kumar Deb (Secretary)



Dr. Rucha Dave

(Joint Secretary)

Dr. Surisetty V V Arun Kumar (Treasurer)

Dr. (Mrs.) Manorama Mohanty (Member)

Dr. Prashant Kumar (Member)

Shri Devang M Mankad (Member)

Dr. Som Kumar Sharma (Member)

Dr. Dhani Ram Rajak (Member)

Dr. Anurag Kandya (Member)

Dr. Abhisek Chakraborty (Member)

Editorial

A hot cup of coffee in a cold misty morning. The splash of first bloom welcoming new life after a long cold season. Well ! Winter and Spring both have always summoned the interests of poets and meteorologists alike, albeit for different reasons.

Also the month of March bears a solidarity with so many important occasions for celebrations; International Women's Day (IWD, 8th March), Pi Day, International Day of Action for Rivers (14th march), World Forestry Day (21st March), World Water Day (WWD, 22nd March) and World Meteorological Day (WMD, 23rd March).

Through this issue of E-Megha, we rejoice in the glory of these occasions through exploration, learning and interactions. The dual theme of IWD and Pi day is acknowledged by an article from our esteemed guest Prof. Nita Shah, HOD , Mathematics, Gujarat University, who delves on the topic of Visualizing Climate change as a dynamical system. We also commemorate WWD and WMD by noteworthy articles on advanced space sensors for ocean studies and new Cloud classification scheme respectively. Apart from these, the regular articles discuss about a wide range of interesting and thought provoking topics. We are very thankful to all our contributors , who despite of having a very involved schedule took time to nurture this endeavor.

Progressively, the student participation to E-Megha is increasing manifold. We are so amazed by the creative expressions of these ignited minds. I am sure in future also, the sparkling gems will continue to bedazzle with their innovative thoughts.

We also take this opportunity to welcome the new torch bearers for IMSA-AC. We aspire to work in close coordination to carry forward the aeon of scientific exploration further.

Hope you enjoy reading, pondering and munching over this issue of E-MEGHA.

E-Megha Team

INSIDE THIS ISSUE:

Guest Article on the occasion of

INTERNATIONAL WOMEN DAY

VISUALIZE CLIMATE CHANGE AS A DYNAMICAL SYSTEM

Nita Shah
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Prof. Nita Shah is the HOD of the Department of Mathematics at Gujarat University, India. Prof. Nita received her PhD in Statistics from Gujarat University in 1994 and was post-doctoral visiting research fellow of the University of New Brunswick, Canada. Prof. Nita's research interests include inventory modelling in the supply chain, robotic modelling, mathematical modelling of infectious diseases, image processing, dynamical systems and its applications, etc. Prof. Nita has published 24 books and 475+ peer-reviewed research papers. She has guided 33 PhD students and 15 MPhil students till now. She is a council member of Indian Mathematical Society.

The most debatable issue across the globe is climate change which is the result of human activities. It is characterized by an alarming rate of increase in the intensity of hazardous weather and climate events like Tsunami, Volcano bursts, disturbances in monsoon, etc. Mathematics acts as a very effective tool for solving the complex problems arising in various sciences and engineering disciplines. On the one hand, humans affect the environment, changing its properties; on the other hand, environmental conditions affect humans, in particular, their health and survival rate.

Current climate change is characterized by an unprecedented rate of increase in the global mean surface temperature (GMST). A report states that the GMST has increased by an average of 0.07^0 C per decade since 1880. That means the growth rate of GMST for the 21st century is 0.17^0 C per decade.

Mathematical techniques allow us to quantify and predict the effects of external natural and anthropogenic perturbance on the dynamics of climate change.

Mathematical models are used to study the impact of global warming on climate change. These models consider temperature, humidity, and precipitation as the climate variables. The climate models of varying degrees of complexity are formulated to predict climate change and variability on the geospatial scale. Climate changes are characterized by a high degree of uncertainty. This uncertainty is due to the influence of external perturbations both natural and man-made.

Mathematical techniques allow us to quantify and predict the effects of external natural and anthropogenic perturbance on the dynamics of climate change. Due to the numerous specific properties of climate change, the implementation of simulation in the laboratory looks misleading and time-consuming. Also, the time series of climate variables is not sufficient and contain data for only a few decades, which makes it difficult to analyze statistically significant estimates of the state of the climate. These drawbacks push us to build up mathematical models for projecting the evolution of the climate system under the natural and manmade perturbations.

The climate model as a dynamical system is a set of interrelated and interdependent variables. A system is treated as complex if it possesses properties such as emergent behavior, self-organization, a hierarchical structure, nonlinearity, etc. For example, the nonlinear space-time interaction between system components leads to the emergence of new dynamical properties, that cannot be observed by analyzing individual elements of the system. In this context, the earth's climate system (ECS) is a complex large-scale physical system that consists of five basic and interacting subsystems viz the atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere. Each of these subsystems is characterized by a finite set of distributed variables whose values at a given instant of time define the state of the subsystem. The models of the ECS should allow for reproducing the current climate, exploring its sensitivity to external factors, and predicting the state of the ECS for the years to come. The theory of dynamical systems can be applied to the study of the real climate system. It must be assigned with some abstract mathematical object that represents the idealization of ECS. It is assumed that such abstraction exists and observed dynamics of the ECS represent a realization of the trajectory that is generated by this model. The ECS model is assumed to be the deterministic semi-dynamical system that is dissipative, ergodic, and possesses a global attractor. A model of the ECS is a set of 3D nonlinear differential equations in a partial derivative that generate a deterministic finite-dimensional semi-dynamical system given by

$$\frac{dx}{dt} = F(x, \alpha, f),\ x \in \Re^n,\ x\big|_{t=0} = x_0,\ t \geq 0, \tag{1}$$

where x denotes the vector of state variables characterizing the system at a given time t, x_0 is a given initial state of a system, n is the dimension of the dynamical system, $\alpha \in \Re^m$ is the m-dimensional parameter vector, and f is an external force.

The complex nature of the system renders to get the analytic solution for the climate system. This suggests opting for numerical methods to solve eq. (1). Here, the original system of partial differential equations in (1) is replaced by discrete space-time approximations using the Galerkin approach, finite-difference method, finite-element method, etc. This changes climate models to discrete dynamical systems. The numerical solution of the discrete model needs the use of high-performance computers. Due to the discrete structure of the ECS model, a large number of physical processes and cycles cannot be explicitly represented on the model grid. This restricts realistically reproduction of the physical processes on the spatial scale of the order of two-fold resolution of the model grid. Such processes are parametrized as

$$x_k = M_{0,k}(x_0),\ k = 1, 2, \ldots, K, \tag{2}$$

where $M_{0,k}$ is a nonlinear model operator that propagates state variables from the initial time t_0 to time t_k and K is the number of time steps.

The ECS evolutions consider on the attractor assumes that the ECS is an ergodic dynamical system. This allows for computing the statistical characteristics of a system by averaging along a certain trajectory. The attractors of the dissipative dynamical system also known as strange attractors are characterized by a very complex fractal structure, To determine their fractal dimension, the Kalpan-Yorke conjecture is the widely used mathematical tool.

The deterministic climate models are very useful for exploring and projecting long-term climate change. The model

$$dx = F(x,t) + g(x,t)dW \tag{3}$$

Considers the study of natural climate variability against human-induced global warming. In eq. (3), $x \in \Re^n$ is the multidimensional random processes satisfying the initial condition $x\big|_{t=0} = x_0$ with probability 1, $W \in \Re^s$ is a vector of independent Winner processes, and $g(x,t)$ is a matrix that describes the dependence of the sub-grid noise on the state variables. This noise plays the role of fluctuations of solar isolation at the top of the atmosphere, sea surface temperature oscillations, weather processes, etc., and can be reduced by using wavelet transforms.

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ADVANCED SPACE-BORNE SYSTEMS FOR OCEAN STUDIES – FILLING THE GAPS IN OUR SCIENTIFIC UNDERSTANDING!

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A mere vastness, diversity and complexity of oceans have attracted scientists and researchers since time immemorial. Observations become key in this endeavour, and it is this aspect that has opened up greater vistas towards understanding this important component of the earth system. With the availability of enormous data from satellites (Le Traon et. al. 2015) along with Global Ocean Observing Systems (Moltman et. al. 2019), to observe the oceans using buoys and Argo floats, many large scale processes of the oceans have been understood and addressed. However, our understanding of the complex processes at spatial scales less than few kms and its interaction with large scales in terms of energy cascading is still preliminary.

"Ocean Decade" will witness new and emerging technologies, for sustainable ocean development to move from "Oceans that we have" to "Oceans that we want".

Different scales (spatial and temporal) of ocean dynamics as seen from Figure-1 (Adopted from Carr et. al. 2011), suggests large canvas of variabilities associated with various physical and biological processes. Though satellites have paved the way towards greater understanding of many of these aspects, yet there are many gaps in our understanding due to non-availability of space-based observations at finer scales. At mesoscales (scales of the order of few hundreds of kms and 2-3 days), satellite altimeter observations are the backbone of the observing system, but conventional nadir looking system misses many finer details (sub-mesoscale) across the swath. Forthcoming Surface water

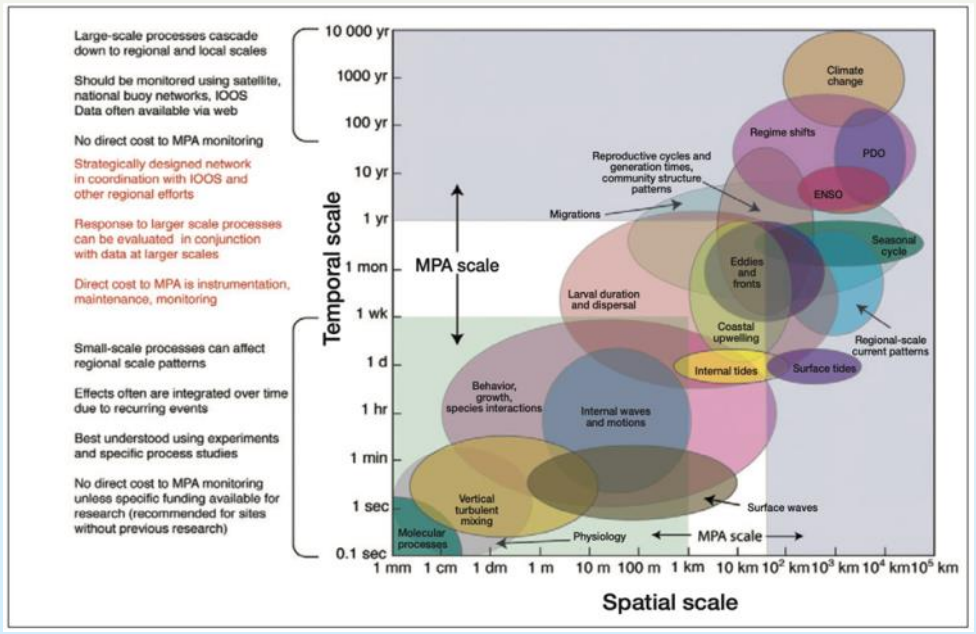

Figure 1 Spatial and temporal scales of oceanic processes. Adopted from Carr et. al. 2011

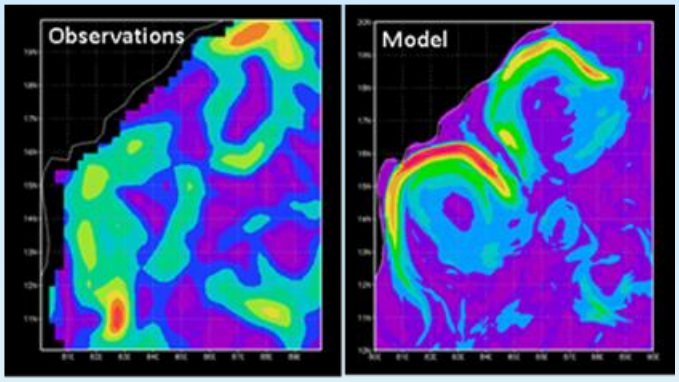

Figure 2 (Left Panel) State of the art altimeter observations as available today (Right panel) Simulated observations from SWOT kind of a mission

and Ocean Topography (SWOT) (Morrow et. al. 2019) is a step towards revolutionizing the ocean surface height measurements at a finer scale and enabling better understanding of scale interactions. From the ocean wave observation perspective, the missing point has been data on 2-dimensional spectra from space on a global and regular basis. CFOSAT, Chinese-French Oceanography Satellite, launched in the year 2018 (Hauser et. al. 2020), is providing valuable information on ocean surface winds and waves which is proving to be extremely useful for ocean weather studies towards safe navigation. From marine biology perspective, detecting, monitoring and predicting short term coupled bio-physical phenomena has always been a challenge. GOCI, the first Geostationary Ocean Color Imager, launched in the year 2010 paved the way for advanced biogeochemistry process understanding. These three satellite missions, SWOT, CFOSAT and GOCI/COMS are the new generation ocean satellites, which along with the conventional ones, form the backbone of satellite oceanographic studies.

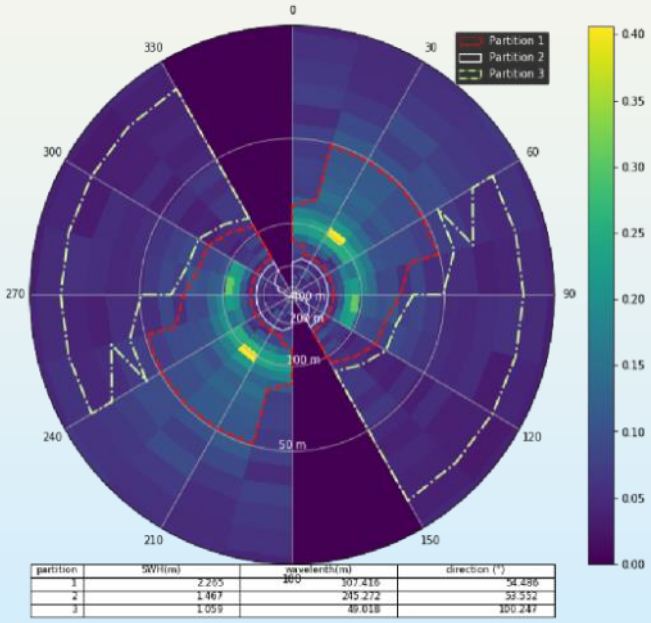

Figure 3 Snapshot of 2D wave spectra from CFOSAT for 29 July 2019 in the Bay of Bengal (89.5E; 14.3N)

The SWOT mission is a joint US-French mission, based on the interferometric SAR principle, will measure the fine-scale details of ocean surface topography and temporal changes in water level over inland water bodies. Interaction of sub-mesoscale with the mesoscale features in the ocean and how the energy cascading takes place is still not understood. What we observe from the conventional altimeter is shown in Figure-2 (scales larger than 200 km) and what researchers want to see in small scale features of ocean dynamics to understand their impact on marine ecosystems (Abdalla et al., 2021). This missing link of ocean dynamics (15 km -200 km), resolving the 2-d details therein, and to understand the ocean energy budget will be the primary goal of SWOT mission.

The CFOSAT mission is another unique mission, which is helping in ocean wave studies. It hosts two instruments, (i) Scatterometer, and (ii) Surface Waves Investigation and Monitoring Instrument (SWIM) which is multi-beam (6 beams) Ku-band rotating system (Hauser et. al. 2020). Simultaneous measurements of global ocean surface winds and large swath surface wave spectra information brings out different perspectives to study of marine meteorological forecasting towards safe navigation, ocean/atmosphere exchanges and impacts of climate change on ocean surface. These spectra when assimilated in to ocean wave model will result in improved wave prediction, especially under extreme weather conditions. An example of wave spectra from CFOSAT is shown in Figure-3.

Data acquisition, typically once in a day from a polar orbiting sun- synchronous ocean color sensor is not sufficient to resolve the tidal and diurnal variability in coastal waters where the in-water constituents and processes are modified due to tides, coastal currents, and waves. Further, frequency of usable data in coastal regions is limited due to clouds, glint, haze etc. (Ruddick et.al., 2014). On the other hand, a sensor placed in geostationary orbit offers data acquisition at the rate of one image per hour or 4-5 images in a day to resolve critical dynamic processes of coastal oceans. In addition, the advantage of acquiring data during clear skies or scattered clouds is greatly enhanced. The disadvantage compared to a sensor in polar orbit is the area of data acquisition which is limited to satellite visibility at the equatorial sub-satellite point. The challenges of resolving the short term variability in ocean bio-physical parameters, remained unanswered till GOCI, a multi-band ocean color instrument was launched in 2010 in a geostationary orbit by Korea Ocean Satellite Centre. High temporal datasets of sea surface temperature (SST) and ocean surface chlorophyll from this satellite helped in studying the diurnal changes in coupled bio-physical processes (Agarwal et. al. 2019), as shown in Fig 4. A sensor such as GOCI which acquires eight images per day offers opportunity to resolve new processes from space such as identification and propagation of

estuarine and coastal fronts, movement of near -shore algal blooms, pathways of dissolved, particulate organic matter pollutants and litter, dispersal of larvae of important commercial fish groups, movement of potential coastal fishing zones, pelagic –benthic coupling and long-term dynamics of coastal biogeochemical processes. ISRO's forthcoming EOS-6/Oceansat-3 mission will further add to our understanding of coupled biophysical phenomena, with the simultaneous observations of ocean surface wind, SST and ocean colour information.

The prospect of enhanced understanding of ocean science from space looks quite encouraging with the advanced instruments and processing algorithms for generating high-class ocean observables. Truly, this decade, which is proclaimed as "Ocean Decade" by the United Nations will witness new and emerging technologies, which will help scientists and researchers to undertake advanced scientific issues towards formulating robust plans for sustainable ocean development with a goal to move from "Oceans that we have" to "Oceans that we want".

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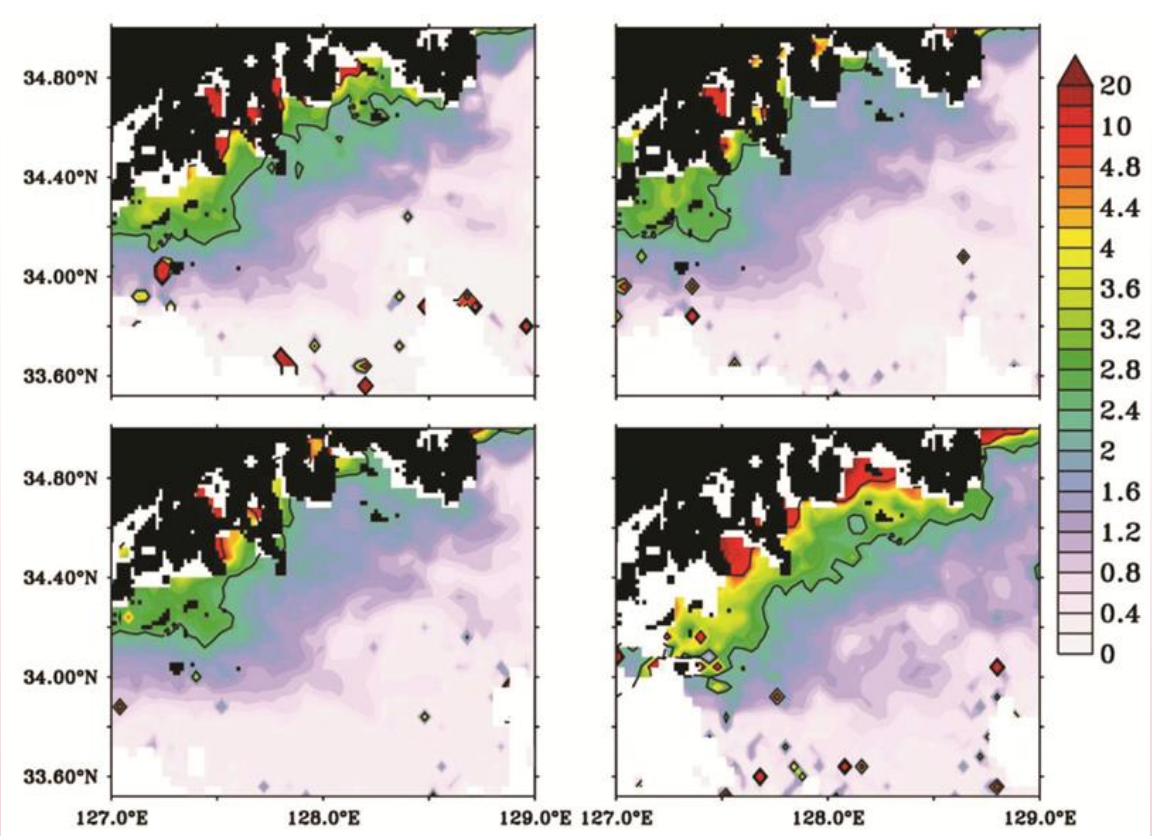

Figure 4 Variation of GOCI-derived chlorophyll a concentration (mg/m3) within a day. The images are for 1 January 2018, 00:27Z, 02:27Z, 04:27Z and 06:27Z. Taken from Agarwal et. al. 2019

FOG : MISSED YOU THIS YEAR!!

Sasmita Chaurasia
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No panic call from India Meteorological Department (IMD)!! No coverage of flight delay!! No accident reported due to fog in media this winter over the Indo-Gangetic plains!! What a relief.

Fog is a situation when the horizontal visibility, is reduced to less than 1000 m near the Earth's surface due to the presence of cloud droplets. The reduction of horizontal visibility due to fog has a huge influence on transport in air, over land as well as on open water. However, presence of fog may be very beneficial in cases when fog water can be collected to meet the water crisis of some semi-arid or desert regions. Even though fog is a regular phenomena every winter over the North Indian region and more specifically over the Indo-Gangetic (IG) plains, its duration as well as spatial extent varies year to year

According to a senior scientist at IMD, Delhi, the favourable combination of calm and light wind, constant higher moisture supply and stable boundary layer upto 1500m from the surface was missing this winter, which is the main reason for less number of fog days in December.

Over northern India, most of the fog formation is due to radiative cooling, however, advection fog is also observed. The main mechanism of fog formation is associated with temperature inversion. Radiation fog which is mainly observed during early winter is associated with low wind speed, high relative humidity, low surface temperature and thus a stable boundary layer. Due to prevailing temperature inversion in the boundary layer during entire winter in the north Indian plains, the high level of pollutants over the region during this period of the time gets trapped. These pollutants act as condensation nuclei that leads to fog formation under favourable meteorological condition. Apart from the factors mentioned above, the soil condition also plays an important role in fog formation in this region. Thus, the formation of fog is a complex phenomena and lack of any one of the conducive meteorological condition leads to a variation in the fog frequency both in temporal and spatial scale. Therefore, even though every winter is similar for a common man, it is completely different as far as fog is concerned.

And this year fog was largely missing!!. As reported by IMD, Delhi, ~285 fog hours that is observed this winter is almost half of the normal ~570 fog hours. This season dense fog condition (when the visibility is below 200 m), was seen for just 8 days (33 hours only) in comparison to normal 19 days (and 110 hours). According to the climatology of fog over Northern India, it starts around mid-December and continues till mid-February with a peak in January. However, this year December was mostly clear with only few small patches of fog. According to a senior scientist at IMD, Delhi, the favourable combination of calm and light wind, constant higher moisture supply and stable boundary layer upto 1500m from the surface was missing this winter, which is the main reason for less number of fog days in December. A western disturbance (W.D.) crossed the IG plain between 28-31 December 2021, which added the required moisture. Before that the moisture from the irrigated crop fields as well as the moisture from the river network, was not able to provide the required amount of moisture that is essential for

Fig 1: A photograph showing the low visibility condition of 21 Jan 2022 morning over Shiv Nadar University, Greater Noida, UP. Photo Courtesy: Ms Ananya Chaurasia

the formation of fog. In January the IG plains received rain due to western disturbance.

Even though it added the required amount of moisture, the pollutants that act as condensation nuclei are washed out. After 26 January 2022, the strong wind at the lower level disturbed the stable boundary layer. Figure 1 shows a photograph showing the low visibility condition over a location in the IG Plains on 21 January 2022, corresponding to a dense fog event.

On 21 January 2022, a widespread fog was observed over the IG plains by INSAT-3DR imager data, which is shown in figure 2. From the figure it is observed that on 21 January 2022, widespread fog engulfed not only the IG plains of India, but some part of Gujarat also witnessed fog. Similar widespread fog was also observed on 01 February 2022 over IG plains of India and some parts of Gujarat as shown in figure 3. This type of fog is due to the advection of moisture laden warm air from the ocean (here the Arabian Sea) over a cold surface of land.

This year very unusual fog was observed during early morning hours over Gujarat many a times, out of which the severity was maximum on 01 Feb 2022. On this day Ahmadabad and its outskirt woke up to witness a very dense fog condition with visibility ~50m even at 9 AM. However, many a times these events were not captured by METAR ((MEteorological Terminal Aviation Routine Weather Report) observations (point observations). In contrary, the complete lifecycle of fog over any location is being monitored by the geostationary satellites (INSAT series) successfully. The geostationary satellites are thus becoming helpful for short-range forecasting/nowcasting of severe weather events.

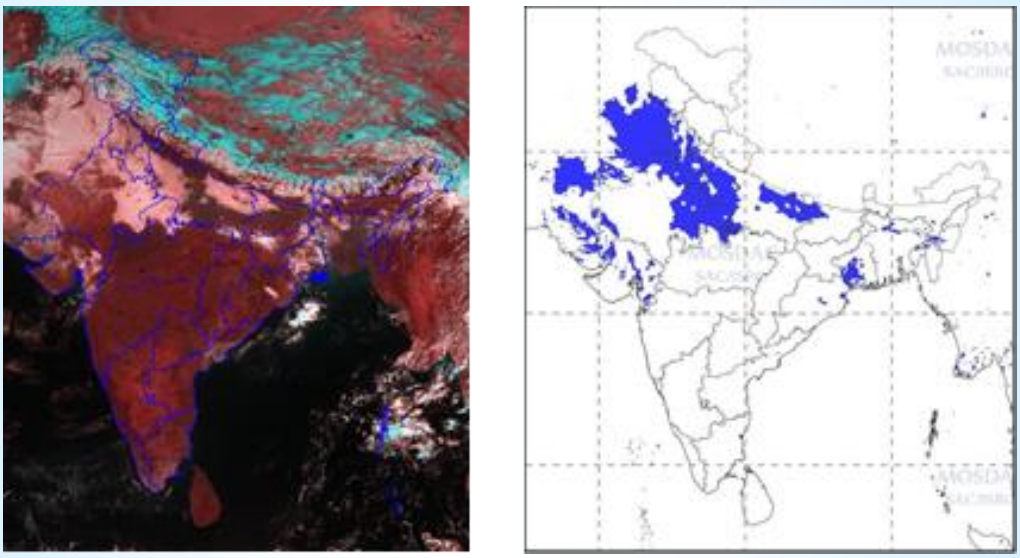

Fig 2: Fog observed by INSAT-3DR imager (left panel RGB image and right panel fog product) on 21 January 2022 at 1045 AM.

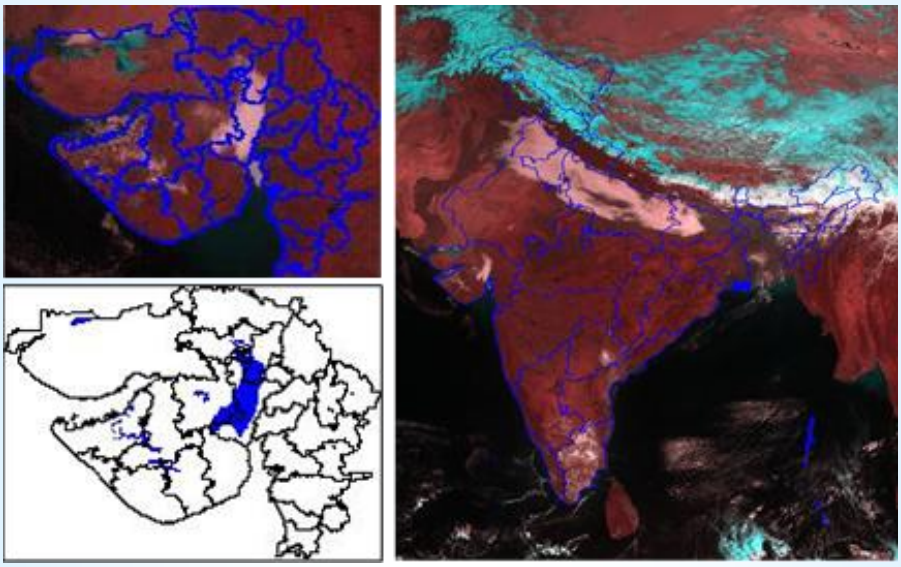

Fig 3: Fog observed by INSAT-3DR imager on 01 Feb 2022 at 10.45AM. (Right panel shows the RGB image of India, Left top panel shows the RGB over Gujarat and Left bottom panel shows the fog product)

NEW NOMENCLATURE FOR CLOUDS

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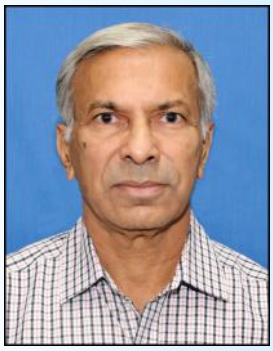


If one looks at the history or evolution of cloud nomenclature, the names were mostly derived from latin words and they are a bit difficult to remember by common man. Here is an attempt to rename the clouds which may be more acceptable to common people in India.

First let us look at the familiar names which are described in any meteorology text book. The person frequently identified as the father of modern meteorology was an English pharmacist named Luke Howard, who came to prominence at the beginning of 19th century. In fact, meteorology did not really get going as science until shortly before the beginning of 19th century, though the term meteorology had been coined by T. Granger in a book of logic in 1626. Howard is mainly remembered now for giving cloud types their names in 1803.

Four main types of Clouds

Howard initially divided clouds into three categories; Cirrus, Cumulus and Stratus. Here we propose equivalent new names for these categories.

Meghkesha (Cirro-form)

The Latin word 'cirro' means curl of hair. Composed of ice crystals, meghkesha clouds are whitish and hair-like. There are the high, wispy clouds to first appear in advance of a low-pressure area such as a mid-latitude storm system or a tropical system such as a hurricane.

Meghmala (Cumulo-form)

Meghmala is generally detached clouds and they look like white fluffy cotton balls. They show vertical motion or thermal uplift of air taking place in the atmosphere. They are usually dense in appearance with sharp outlines. The base of meghmala clouds are generally flat and occurs at the altitude where the moisture in rising air condenses.

Meghdut (Strato-form)

From the Latin word for 'layer' these clouds are usually broad and fairly wide spread appearing like a blanket. They result from non-convective rising air and tend to occur along and to the north of warm fronts. The edges of meghdut clouds are diffuse.

To these three forms Howard subsequently added a fourth form

Meghraj (Nimbo-form)

He designated a special rainy cloud category which combined the three forms Cumulo + Cirro + Stratus. He called this cloud, 'Nimbus', the Latin word for rain. Let us call it as Meghraj. The vast majority of precipitation occurs from meghraj clouds and therefore these clouds have the greatest vertical height.

The beauty of Howard's classification system is that the basic components can be freely recombined to describe every shape and size of clouds like stratocumulus, cirrostratus, cumulonimbus etc. Based on his observations, Howard suggested that there can be modifications (or combinations) of the core four clouds categories. According to his observations, clouds can often have features of two or more categories; meghkesha + meghdut, meghmala + meghdut, etc. His research served as the starting point for the ten basic types of clouds we observe.

Ten Basic Types of Clouds

From the World Meteorological Organization's (WMO) International Cloud Atlas, the official worldwide standard for clouds, the following are names of the ten basic cloud types. It is proposed here new names for these basic clouds.

Meghmala (Cumulus)

Meghdut (Stratus)

Meghmadhu (Stratocumulus)

Meghadri (Altocumulus)

Meghrajdut (Nimbostratus)

Meghneel (Altostratus)

Meghkesha (Cirrus)

Meghmoni (Cirrocumulus)

Meghnath (Cumulonimbus)

Meghdutkesha (Cirrostratus)

According to the height of the clouds, these are divided in following three groups

High-Level Clouds

Meghkesha (Cirrus) , Meghmoni (Cirrocumulus), and Meghdutkesha (Cirrostratus) are high level clouds. They are typically thin and white in appearance, but can appear in a magnificent array of colors when the sun is low on the horizon.

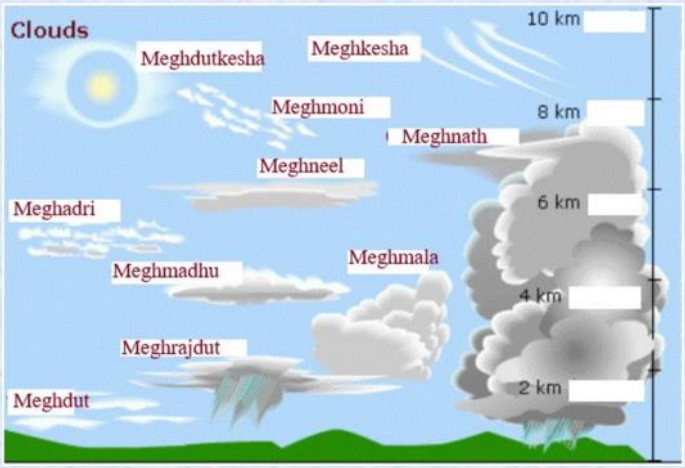
Mid-Level Clouds

Meghadri (Altocumulus), Meghneel (Altostratus), and Meghrajdut (Nimbostratus) are mid-level clouds They are composed primarily of water droplets. However, they can also be composed of ice crystals when temperatures are low enough.

Low-Level Clouds

Meghmala (Cumulus), Meghmadhu (Stratocumulus), Meghnath (Cumulonimbus) and Meghdut (Stratus) are low clouds composed of water droplets. Meghnath, with its strong vertical updraft, extends well into the the high level of clouds.

The shapes and heights of these clouds can be visually represented by the following figure.



Let us briefly describe each type of clouds and when they can be seen in the sky.

Meghmala (Cumulus)

Meghmala clouds are the clouds one learns to draw in childhood and they serve as the symbol of all clouds. Their tops are rounded, puffy, and bright white when sunlit, while their bottoms are flat and relatively dark. Meghmala clouds develop on clear, sunny days when the sun heats the ground directly below. That is why they get also the name of "fair weather" clouds. They appear in the late morning, grow, and then disappear toward evening.

Meghdut (Stratus)

Meghdut clouds hang low in the sky as a flat, featureless, uniform layer of grayish cloud. They resemble fog that hugs the horizon instead of the ground. They are so broad and widespread that as if they can carry any message to far away distance. That is why they get their name as meghdut or messenger. Meghdut clouds are seen on dreary, overcast days and are associated with light mist or drizzle.

Meghmadhu (Stratocumulus)

Meghmadhu are low, puffy, grayish or whitish clouds that occur in patches with blue sky visible in between. When viewed from ground, meghmadhu have a dark, honeycomb appearance. One can see meghmadhu clouds on mostly cloudy days. They form when there is weak convection in the atmosphere.

Meghadri (Altocumulus)

Meghadri and meghmadhu are often mistaken. Besides meghadri being higher up in the sky, another way to distinguish them apart is by the size of their individual cloud mounds. If one places one's hand up to the sky and in the direction of the cloud; if the mound is the size of one's thumb, it is altocumulus. If it is closer to fist-size, it is probably stratocumulus. Meghadri clouds are often spotted on warm and humid mornings, especially during summer. They can signal thunderstorms to come later in the day.

Meghrajdut (Nimbostratus)

Meghrajdut clouds cover the sky in a dark gray layer. They can extend from the low and middle layers of the atmosphere and are thick enough to blot out the sun. Meghrajdut are the quintessential rain cloud. You'll see them whenever steady rain or snow is falling over a widespread area.

Meghneel (Altostratus)

Meghneel appear as gray or bluish-gray sheets of cloud that partially or totally cover the sky at mid-levels. Even though they cover the sky, you can typically still see the sun as a dimly lit disk behind them, but not enough light shines through to cast shadows on the ground. Meghneel tend to form ahead of a warm or occluded front. They can also occur together with cumulus at a cold front.

Meghkesha (Cirrus)

Like their name suggests (which is Latin for "curl of hair"), meghkesha clouds are thin, white, wispy strands of clouds that streak across the sky. Because cirrus clouds appear above 6 Km, an altitude where low temperatures and low water vapour exist, they are made up of tiny ice crystals rather than water droplets. Meghkesha typically occur in fair weather. They can also form out ahead of warm fronts and large-scale storms like tropical cyclones, so seeing them can also indicate storms may be coming.

Meghmoni (Cirrocumulus)

Meghmoni clouds are small, white patches of clouds often arranged in rows that live at high altitudes and are made of ice crystals. Called "cloudlets," the individual cloud mounds of meghmoni are much smaller than that of meghadri and meghmadhu and often look like grains or pearls. Meghmoni clouds are rare and relatively short-lived, but you'll see them in winter or when it is cold but fair.

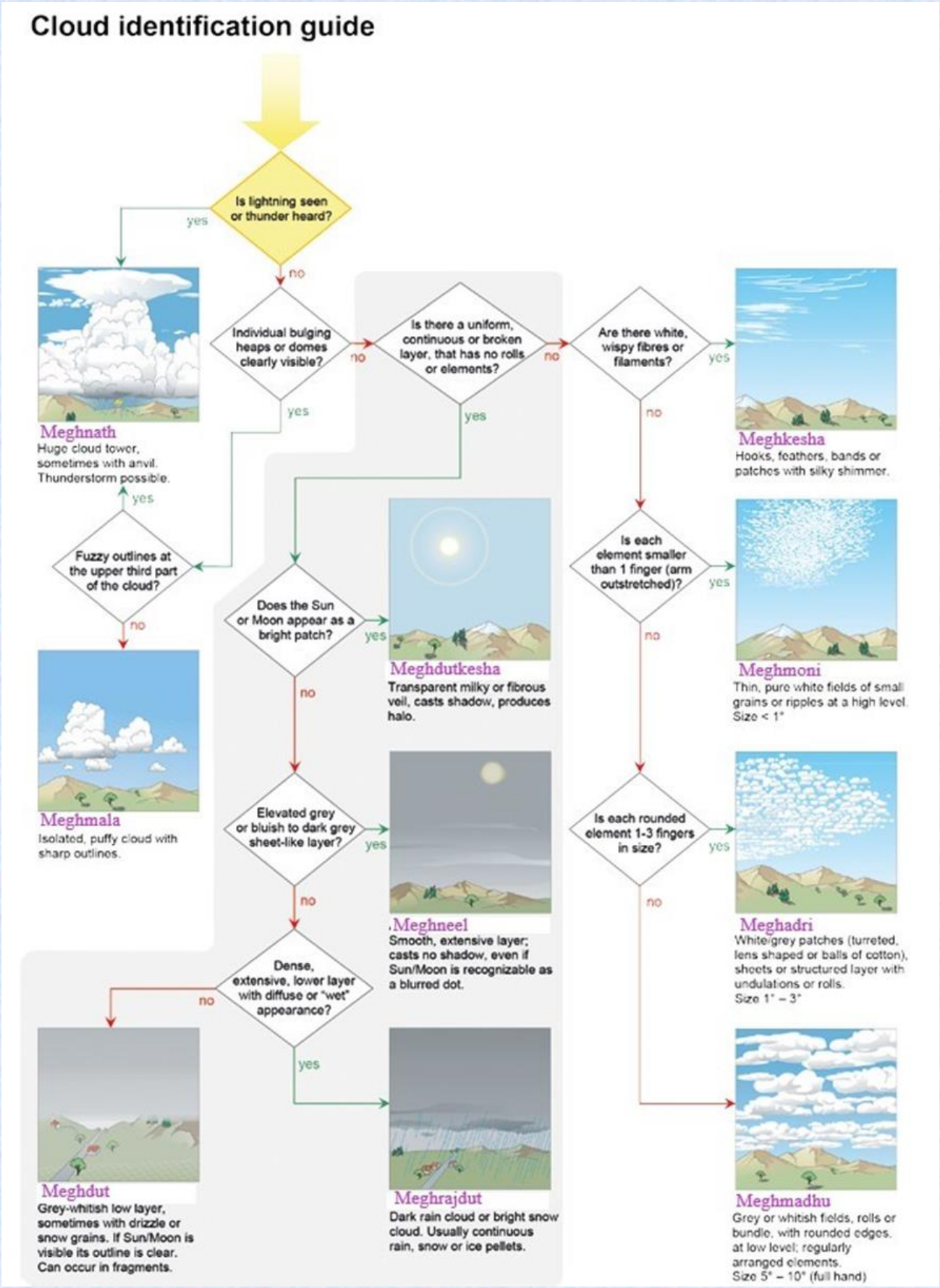
Meghnath (Cumulonimbus)

Meghnath clouds are one of the few clouds that span the low, middle, and high layers. They resemble the meghmala clouds from which they grow, except they rise into towers with bulging upper portions that look like cauliflower. Meghnath cloud tops are usually always flattened in the shape of an anvil or plume. Their bottoms are often hazy and dark. Meghnath clouds are thunderstorm clouds, so if one sees it one can be sure there is a nearby threat of severe weather (short but heavy periods of rainfall, hail, and possibly even tornadoes). As meghnath is listed in number nine of the ten basic clouds and it's tops are so high that it became the source for the proverb "on cloud nine", meaning on top of a great height.

Meghdutkesha (Cirrostratus)

Meghdutkesha clouds are transparent, whitish clouds that veil or cover nearly the entire sky. To distinguish meghdutkesha one has to look for a "halo" (a ring or circle of light) around the sun or moon. The halo is formed by the refraction of the light on the ice crystals in the meghdutkesha clouds. Meghdutkesha indicate that a large amount of moisture is present in the upper atmosphere. They are also generally associated with approaching warm fronts.

These clouds can be identified as per the guide given in the International Cloud Atlas of WMO, 2017 edition, which is available online. Here the scheme is modified with new names.



GLACIER MONITORING OF HIMALAYA-KARAKORAM REGION USING SPACEBASED OBSERVATIONS

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Fresh water resources from glaciers are one of the most important natural resource on the earth, however, sustainability of these resources has been questioned in various research studies in purview of global warming and climatic variations. IPCC report has mentioned a general decline in low-elevation snow cover, glaciers and permafrost which amounted to vary the seasonality of runoff in snow-dominated and glacier-fed river basins having local impacts on water resources and agriculture. Himalayan-Karakoram (H-K) mountain ranges in the North of Indian continent with arcuate strike of NW–SE for about 2400 km, a part of High Mountain Asia (HMA), holds one of the largest concentration of glaciers outside the polar regions in its high-altitude regions. These masses are the perennial source of water to tributaries and drainages of Indus, Ganga and Brahmaputra river systems. Glaciers of the Himalayan region are also in a general state of retreat following the global pattern. The retreat is attributed to the global rise in temperatures, especially in the Himalayan region, which has been reported higher than the global average. A series of studies of retreat of glaciers by using loss in the area as a parameter for glaciers of Baspa sub-basin; Parbati glacier; Samudra Tapu glacier; Gangotri glacier; 466 glaciers of Chenab basin; 2630 glaciers from different sub-basins in Himalaya have been carried out over a period of times. These studies were based on two different type of datasets i.e topographical maps and IRS LISS III/Landsat images. In continuation, a more exhaustive study has been carried out for 5234 glaciers (out of which 3435 are debris-free) of H-K region, mapped at a scale of 1: 25,000 using primarily IRS LISS III data and partially Landsat data across the H-K region spanning from Kashmir in West to Sikkim in East, between the years 2001 and 2016/2017/2018. It includes glaciers of Jammu and Kashmir, Ladakh, Himachal Pradesh, Uttarakhand, and Sikkim in India and a few glaciers of Nepal and the adjoining Tibetan region north of Nepal.

The results again prove that debris free glaciers are more vulnerable to global warming than the debris covered glaciers.

Figure 2 shows map of the outline of the glaciers, which is highlighted in image through False Color Composite (RGB:SWIR-NIR-GREEN) based on reflectance properties of target, and along with rectification for the ridge line and snout position/outcrops using DEM (SRTM/ASTER) data and multi-temporal spectral images. The changes in glacier extent have been computed while maintaining the consistency of the data from same sensor with half-pixel registration error between 2001 & later images. Uncertainty estimates in mapping error was also performed using contribution of number of peripheral pixels and spatial resolution of sensor.

The results of area changes of glaciers are being presented according to geographical spans of sub-basins in H-K region. The glaciers covered are located in states of Bharat, parts of Nepal and a few in Tibetan Plateau. The entire glaciated regions region has been divided into six parts as mentioned below;

i. N-W Himalaya or Karakoram region north of Indus river

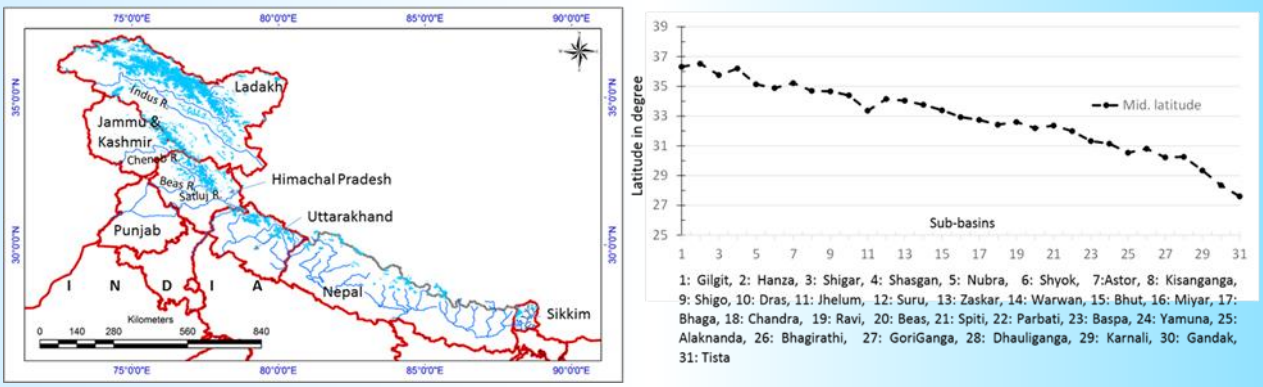

Figure 1: Spatial distribution (left panel) of the monitored glaciers in Jammu and Kashmir, Ladakh, Himachal Pradesh, Uttarakhand, Sikkim (States of India) and parts of Nepal and Tibetan Autonomous Region (N-TAR). Right panel shows the Latitudinal distribution of sub-basins across H-K region

ii. N-W Himalaya south of Indus river

iii. Western Himalaya covering Satluj and Chenab basins within Himachal Pradesh

iv. West Central Himalaya covering glaciated regions of Uttarakhand

v. Central Himalaya covering glaciated parts of Nepal and adjoining regions

vi. Eastern Himalaya covering glaciated parts of Sikkim

The mapping results have been analysed in different sectors of H-K region. Monitoring of glaciers based on sample of 5234 glaciers in Himalayan and Karakoram region using IRS LISS III images between 2001 and 2016/2017/2018 has shown loss of 1.44 % and net gain of 0.026 % in area of glaciers respectively (Figure 3-left panel). The mapping uncertainty is less than 0.01 %. A clear distinction between glacial changes in sub-basins in the right bank of Indus river (Karakoram region /J & K and Ladakh) and the Himalayan region has emerged. In the Karakoram region, 2143 glaciers with an area coverage of 18343.88 Km2 show a gain of 0.026%, whereas in Himalayan region 3091 glaciers covering an area of 11451.53 km^2 show loss of 1.44% over a period of mean 17 years. Loss in glacier area in Himalayan region varies from 0.76 % in sub-basins South of the Indus river (N-W Himalaya/ J & K and Ladakh) , 2.2 % in Chenab and Sutlej basins (Western Himalaya/Himachal Pradesh), 0.84 % in Ganga basin (West-Central Himalaya/Uttarakhand), 2.16 % in Ganga basin (Central Himalaya/Nepal and a few glaciers of Tibetan region) and 2.15 % in Tista sub-basin (Eastern Himalaya/Sikkim). Among debris free glaciers of the total glaciers monitored, the area loss varies from 0.04 % in Karakorum, 0.42 % in N-W Himalaya, 3.33 % in Western Himalaya , 2.95 % in West-Central Himalaya, 3.82 % in parts of Central Himalaya and 4.19 % in Eastern Himalaya. The results again prove that debris free glaciers are more vulnerable to global warming than the debris covered glaciers. The data also indicates clearly the effect of latitudinal variations from higher to lower latitudes on the gain or loss in the area of glaciers in addition to microclimatic and geomorphological reasons (Figure 3-right panel).

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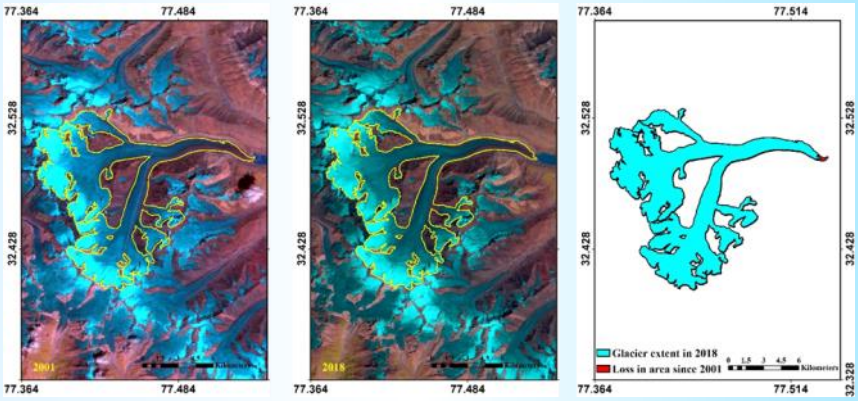

Figure 2: A panel showing two images (2001 and 2018) used for mapping the changes (Right part of the panel) in the area of a partial debris-covered valley glacier Chandra sub-basin (Samudra Tapu glacier) in Himachal Pradesh.

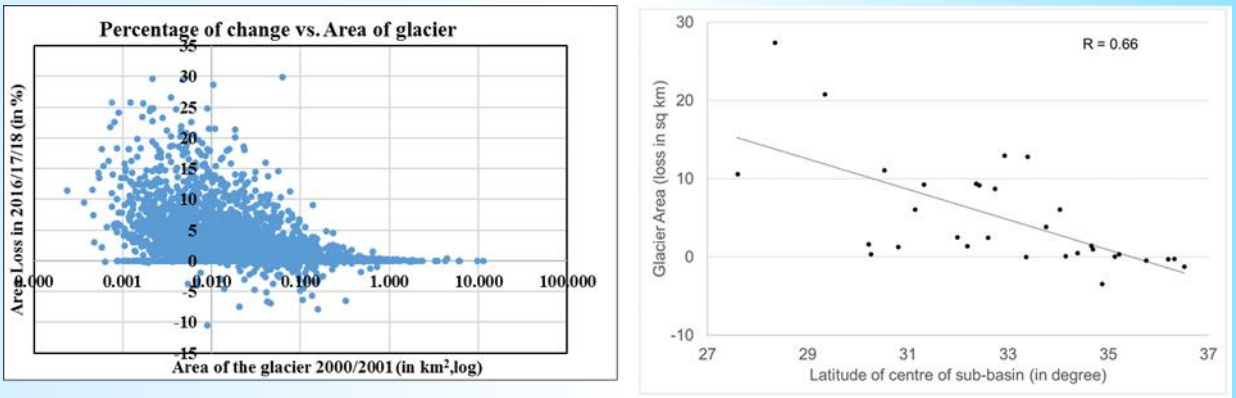

Figure 3: A scatter plot (left panel) showing the area of glaciers (X-axis) monitored (2000/2001) and the percent loss (Y-axis) (2016/17/18) based on the data of 5234 glaciers. The figure shows that loss of area is more in smaller glaciers than large glaciers; that most of the glaciers in our study are less than 200 km^2; and that an almost equal number of glaciers show virtually no change in the area. The advance and surge are represented in negative percentage change, especially in the Karakoram region. Latitudinal variations (right panel) of the loss in glaciated areas undertaken in the H-K region.

INDIAN OCEAN WARMING: WHAT SATELLITE SST REVEALS?

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Sixth assessment report of IPCC (Inter-governmental Panel for Climate Change), released on August 2021, has revealed an unprecedented change in Earth's climate due to human altered radiation budget. One of such prominent impact pointed out in the report is the basin-wide warming of global ocean. Global average Sea Surface Temperature (SST) warmed about 0.7° C (0.11° C/decade) and the average warming of Indian Ocean waters are about 1° C (0.15° C/decade) during 1951 to 2015 period. It is a striking reality that Indian ocean waters are warming at a rate faster than global average value. Many studies have pointed out the warming of Indian Ocean waters and its consequences are far-reaching, particularly on marine ecosystem. The increasing SST adversely affects the habitat of marine life; some such impacts include shifting of fish schools towards other regimes, decline of coral reefs, etc. Other significant impact of ocean warming includes decrease in primary productivity, decline in oxygen content, increase in upper ocean heat content, increase in the frequency and area of marine heat wave, sea level rise, etc.

Studies have shown the decrease in primary productivity associated with near surface warming of ocean waters and is primarily owing to the increasing stratification due to warming.

A large percentage of global population lives around Indian Ocean and depends on it for their socio-economic benefits. They are largely vulnerable to the adverse impact of Indian ocean warming. Satellite observations of SST has revealed the signatures of Indian Ocean warming and has been used to understand the warming trend in the Indian Ocean. The daily SST fields of 25 km resolution are obtained from www.ncei.noaa.gov/data/sea-surface-temperature-optimuminterpolation/acess/avhrr-only, which is a blended product of in situ and satellite observations

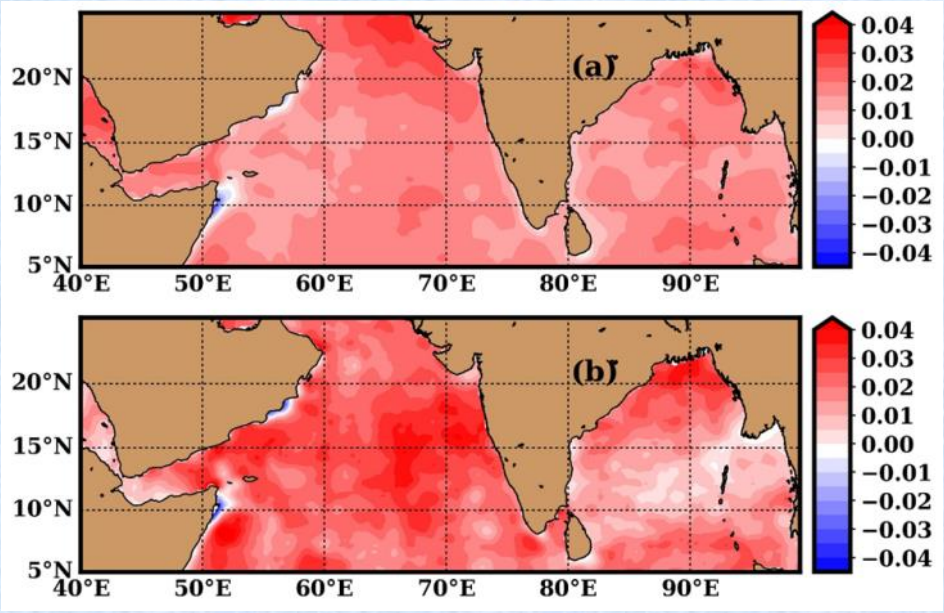

Figure 1: Observed trend in SST (oC/yr) for the northern Indian Ocean during 1983 to 2016. (a) annual trend and (b) summer monsoon trend (JJAS)

(mainly SST from Advanced Very High Resolution Radiometer(AVHRR)) using the optimum interpolation method.

Figure 1 shows the observed annual and summer monsoon trend of SST for the northern Indian Ocean during the period 1983 to 2016. An alarming trend of basin-scale warming is evident from the figure and is more prominent during summer monsoon. For summer monsoon analysis SST for the months of June, July, August and September (JJAS) are extracted from the data. One salient feature is the warming trend of Arabian Sea (~0.04° C/yr) during summer monsoon as compared to Bay of Bengal. Arabian Sea is one of biologically productive region during summer monsoon owing to the vertical transport of nutrients from sub surface to surface due to coastal upwelling. It has a great significance for fishery industry. Studies have shown the decrease in primary productivity associated with near surface warming of ocean waters and is primarily owing to the increasing stratification due to warming. The increasing trend of SST on Indian coastal waters during summer monsoon has been reported by Shailee et al., 2019. Study by Roxy et al., 2014 has revealed that the warming rate of western tropical Indian Ocean is faster than any other region of the tropical oceans. However, two strong coastal upwelling regions in the western Arabian Sea, Somali and Oman region, shows negative trend of SST, although it is very confined to coast (Figure 1). This suggest that warming rates are depressed along the coastal regions of strong upwelling. Though this kind of findings has been reported for other strong upwelling regions, a detailed analysis is needed to reveal the underlying mechanism. This is very important as knowledge of future changes in upwelling regions is a crucial factor in the socio-economic system.

Long term series of SST (Figure 2) also supports the increasing warming trend of surface waters at northern Indian Ocean. A positive trend of 0.02° C/yr is observed for both summer monsoon and annual mean SST for the northern Indian Ocean. Further analysis has shown larger rate of warming in the Arabian Sea after 2016 (Figure not shown). Major contributor to this observed warming of Indian Ocean might be anthropogenic induced direct radiative forcing. Apart from this direct radiative forcing, many pioneer studies have shown the impact of various key factors such as Indian Ocean warm pool, anomalous warming induced by ElNino events, etc on this observed warming trend in the western Indian Ocean. Indian Ocean warming is a major contributor in the global mean SST trend and a more detailed analysis is essential to address various key factors in the warming trend of Indian Ocean waters.

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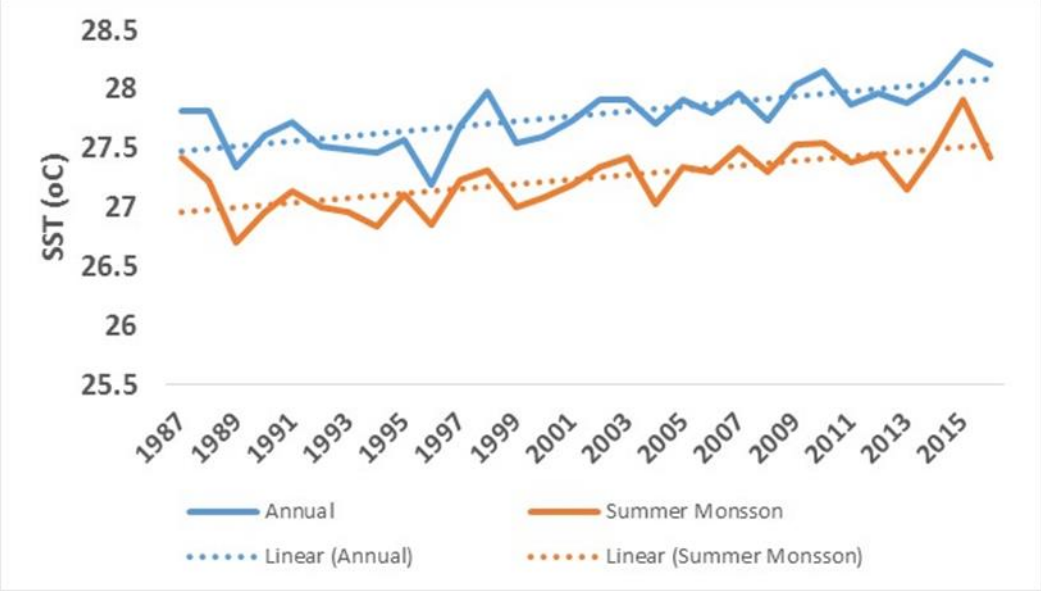

Figure 2: Time series of domain averaged summer monsoon and annual SST (oC) over northern Indian Ocean.

DESERTS IN THE OCEAN

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As a matter of fact, life originated in the Ocean somewhere around 3.5 billion years ago, and there is no denial that Oceans cover about 50% of the global net primary productivity (Field et al. 1998). Oceans play a significant role in Earth's system by absorbing solar radiation, acting as a huge heat sink, as Carbon reservoirs, and of course as huge resources for food and pharmaceutical industries. But, sadly, oceans are suffering, and so would we. By the year 2100, more than half of the world's marine species will be endangered (www.unesco.org); between 20 and 35% of mangrove area has been lost since the last 40 years (FAO 2003, FAO 2007), about 13% of global fisheries have collapsed due to overfishing, and there are about 400 dead zones worldwide (Diaz and Rosenberg 2008).

As the marine ecosystems are not restricted to a single nation, the responsibility of keeping them healthy also lies on all the neighboring countries and through international cooperation.

Whereas productivity flourishes in oceans, yet there are regions which contain low phytoplankton biomass and thus low primary productivity. Such regions are called ocean deserts. Here, most marine life cannot survive. Major ecological impacts of such regions include reduced biodiversity, change in community structure and sustenance (e.g. Diaz and Rosenberg 1995). They also affect the financial wellbeing of the society.

Ocean's biological productivity can be low due to two reasons: due to natural course involving ocean circulation regime and changes (Gilbert et al. 2005), and due to human interference (Rabalais et al. 2002, Kemp et al. 2005) or in other words due to over nutrition or under nutrition. Under nutrition is usually a case with Deep Ocean, having poor proximity to land and hence to nutrients. Such biologically low productive zones are 'natural deserts'. On the other hand, over-nutrition is a cause of concern and human beings play the role of catalyst in such cases. In their natural course, rivers wash away sediments from the land and deposit them in

Ocean Biological Deserts

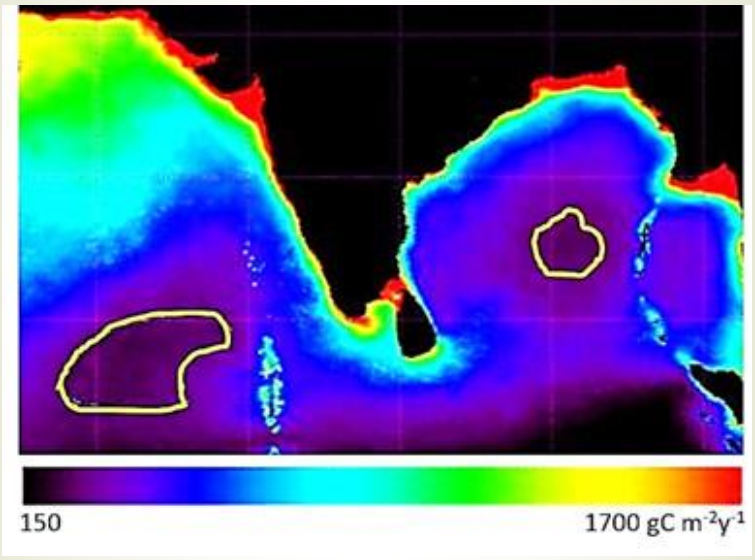

Fig. 1: Decadal primary production in Northern Indian Ocean (1998-2007). Regions with low value of decadal NPP, in both Arabian Sea and Bay of Bengal, are the ocean biological deserts (shown by yellow coloured boundary)

the ocean waters, thereby making such areas fertile. However, unsustainable land use practices such as excessive agricultural runoff, industrial and domestic waste discharge into the oceans cause excessive nutrient load. The industrial effluents contain organic and inorganic chemicals, which are detrimental to marine life.

Large amount of nutrients causes unrestricted Phytoplankton growth, called 'algal bloom' through the process called 'eutrophication'. Bloom itself is nontoxic (exception is 'red tide'), but they prevent sunlight from reaching the bottom layers. Also, when the Phytoplanktons complete their life cycle, huge colonies of microbes decompose them and in this process, they suck up all the dissolved oxygen causing suffocation of other life forms due to depletion in oxygen, and finally causing death. Thus, the region becomes a 'dead zone'. In recent decades, their numbers have soared. Ocean dead zones with zero oxygen have quadrupled in size since 1950. Between 1998 and 2006, the total area lost to ocean deserts added up to 6.6 million square km, representing about a 15% expansion. In India, UNEP has declared some part of western Indian shelf as dead zone (UNEP 2006).

The Spread

Sometimes the dead zones are temporary which last for hours or days and sometimes they are permanent. In natural dead zones, there is a chance for the organisms to adapt, but, not in the other case. The coastal areas of the Baltic Sea, northern Gulf of Mexico (second and third largest), and northwestern shelf of the Black Sea (by far the largest), Chesapeake Bay, Neuse River estuary are some of the hypoxic (low oxygen) zones. A temporary massive dead zone is routinely formed in Arabian sea due to the strong monsoonal wind forcing causing ocean upwelling, thereby, increasing primary productivity to the extent that it creates oxygen depletion.

Before 1960s, the NW region of the black sea was highly productive. But, between 1960s and 1980s, nitrogen and phosphorous compounds were flushed out from the land by the river Danube, from 11 countries, leading to eutrophication (Mee 2006). The main sources of nutrients were agricultural runoff consisting of fertilizers and pesticides, waste water from urban and industrial use and burning of fossil fuels. However, in 1990s, the local economy of the area saw a downward shift, and so the nutrient discharged to the black sea reduced which resulted in the reduction in hypoxia and restoration of ecosystem. By 1999, the hypoxic area had gone down to <1000 km2. Another example is Gulf of Mexico which observes 22,000 square km of dead zone every summer since 1970s (Rabalais et al. 2007). This is because of the large amounts of fertilizers used on land in Soy and Corn fields in the United States which contaminate the ground water which reaches the Mississippi-Missouri river system, emptying in the Gulf. The third example is from the Baltic Sea which holds the world's largest oxygen depleted dead zone caused by anthropogenic factors (Conley, 2012).

What lies ahead?

As the marine ecosystems are not restricted to a single nation, the responsibility of keeping them healthy also lies on all the neighboring countries and through international cooperation. In view of this, the United Nations has set up an international program to support ecosystem based management of the coastal and marine resources in the Large Marine Ecosystems (LMEs) in order to improve the understanding of the ecosystems along with the anthropogenic influence.

Some of the countries have successfully reverted dead zones e.g. Lake Geneva in Switzerland and Lake Erie in the United States. Remote sensing can play an important role in identifying and monitoring of ocean biological deserts. Raman et al. (2016) have used Sea Surface Temperature (SST) and chlorophyll a data from space borne missions to identify the ocean deserts in the Arabian Sea and Bay of Bengal (Fig 1).

With a little more care, together we can revert and prevent ocean biological deserts.

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OCEAN WIND INTERACTION: A KEY DRIVER OF OCEANIC FOOD CHAIN

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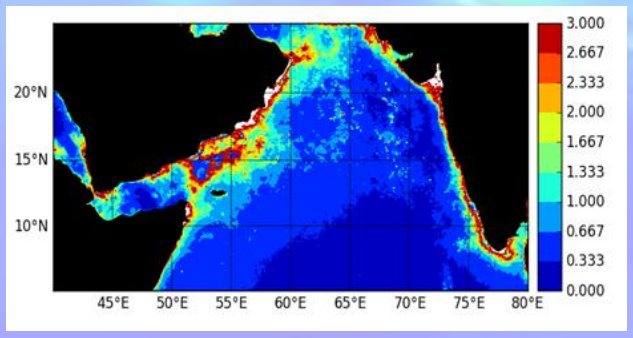
In a global warming scenario the land sea temperature gradients will increase. This would result in increased upwelling favourable winds.

Ocean temperature and motion fields can be separated into three distinct layers: mixed (surface) layer, upper ocean (above the thermocline), and deep ocean. The surface and upper ocean, which supports 90% of marine life is constantly evolving under the action of winds, sea surface currents, and air sea interactions. The oceanic mixed layer is the layer in which active turbulence has homogenized some range of depths. This depth is characterized by near uniform temperature and salinity. This mixed layer is followed by thermocline which separates the mixed layer from the deep ocean and characterized by rapidly changing temperature. Phytoplankton, the photosynthesizing microscopic organisms that inhabit the upper sunlit layer (euphotic zone) of ocean are the foundation of marine food web. They are the primary producers which support a large number of zooplanktons (aquatic microorganisms) and marine life. Apart from sunlight, the phytoplankton need nutrients in the form of nitrates, phosphates, silicates etc. for their growth. Under normal circumstances the surface layer of ocean is nutrient limited and thus the ocean waters are mostly oligotrophic (low phytoplankton biomass). Most of the nutrients are found below the euphotic zone where phytoplankton growth is inhibited by light unavailability. Ocean circulation and mixing uplifts nutrients from the deeper layers into the euphotic zone where phytoplankton can grow and support a wide range of marine life, fishes etc. Oceanic circulation can be wind driven circulation or thermohaline circulation driven by density gradients due to exchange of ocean heat and water with atmosphere. The wind driven circulation is the more vigorous of the two and the thermohaline circulation is weaker.

Wind stress is an important forcing of sea surface perturbations either as waves or sea surface currents (Wang et al 2011). Surface ocean currents are primarily affected by wind patterns. Trade winds or easterlies which are east-to-west prevailing winds that flow in the Earth's equatorial region can push water along the top of the ocean and aid in the formation of surface currents. Large wind movements over long distances combined with Coriolis effect results in the formation of ocean gyres which are large circulating ocean currents. Whenever ocean water is pushed by the action of winds, water from below is uplifted to replace the transported water. The phenomenon in which cooler and nutrient rich waters are uplifted to the surface is called as upwelling. The component of wind driven ocean current referred to as Ekman transport is the net motion of fluid as a result of a balance between Coriolis force and drag force. Trade winds can result in equatorial upwelling by Ekman transport and water mass divergence. This is because the Coriolis force acts in opposite direction on both sides of the equator resulting in



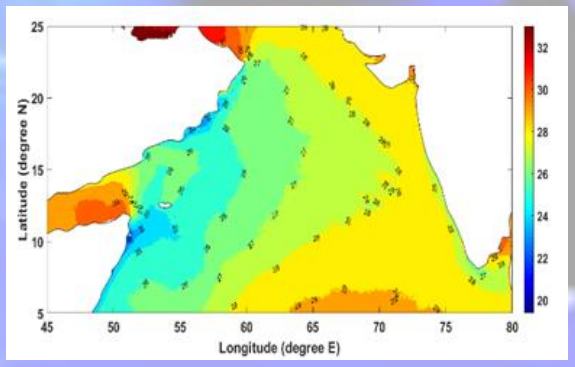


Figure 1: Seasonal climatology (June-September) of chlorophyll concentration (mg/m3) and SST (0C) for Arabian Sea

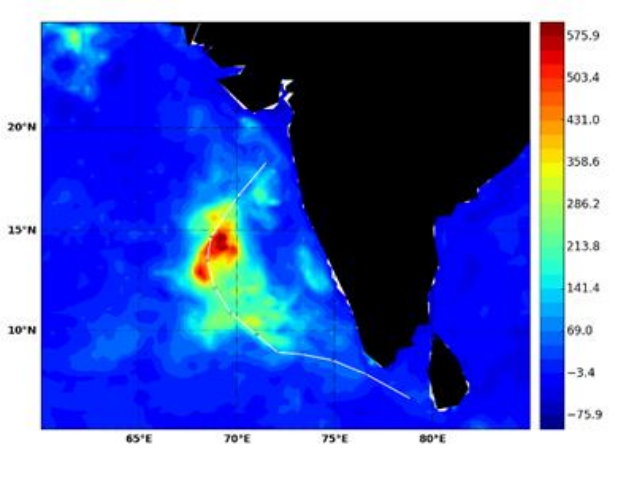


Figure 2: Normalized chlorophyll anomaly (in percentage change from climatological mean) for the month of December 2017 (cyclone Ockhi). Citation: Ganguly et al. 2020.

surface water divergence and upwelling of cold, nutrient rich waters. The equatorial upwelling induced by easterly winds creates cold sea surface temperatures in the eastern equatorial Pacific and Atlantic Oceans where the thermocline is shallow. This divergence zone near the equator is also a region of high biological productivity. Apart from equatorial upwelling the trade winds are also responsible for some of the most prominent coastal upwelling regimes. These coastal upwelling regions are coastal hotspots for increased primary and secondary productivity and important potential fishing zones. The Peru-Chile upwelling also called the Humboldt current system is one of the most important coastal upwelling system in which alongshore trade winds sustain upwelling activity almost all round the year. This coastal upwelling system has high primary productivity which in turn supports diverse and abundant fisheries, particularly the Peruvian anchovy (Chavez et al. 2008). The Benguela upwelling is another prominent eastern boundary upwelling system along the west coast of Africa in which trade winds sustain upwelling activity. The upwelling along these coastal regions manifest in the form of increased phytoplankton biomass which are conspicuous in ocean colour sensors in the form of increased chlorophyll concentrations. The cold band of upwelled water is also visible in SST imagery. Some other well known coastal upwelling systems are the Baja-California upwelling system, Oman-Somalia upwelling system. Coastal upwelling is observed along the coasts of Oman-Somalia and south west coast of India during the south west monsoon season (June-September). During this season strong south westerly monsoon winds blow along the coasts of Oman and Somalia bringing nutrient rich cold waters and promoting new productivity. Upwelling generates some of the world's most fertile ecosystems. Even though coastal upwelling regions only cover 1 percent of the total area of the world's oceans, they provide about 50 percent of the fish harvest brought back to shore by the world's fisheries. Chlorophyll concentration and sea surface temperature (SST) during south west monsoon upwelling season for Arabian Sea is shown in Figure 1. Phytoplankton bloom like concentrations and cooler SST are observed near Oman coast and west coast of India. Cyclonic storms also promote new productivity in oceans by turbulent mixing and upwelling. Tropical cyclones are extreme weather events that can profoundly influence the marine ecosystem. The strong forcing of tropical cyclone produces two kinds of dynamic responses in the upper ocean, namely turbulent mixing and upwelling.

Cooling of sea surface after the passage of cyclone is a well-documented phenomenon. The strong, intense rotating nature of near surface winds cause upwelling by a mechanism called Ekman suction. The nutrient deficient surface waters are replaced with cold, nutrient rich waters that are conducive for phytoplankton growth. Cyclones are associated with heavy cloud cover and rainfall. After the passage of the cyclonic storm, the presence of ample sunlight and nutrients promote phytoplankton growth. These regions with high primary productivity attract a lot of oceanic biodiversity ranging from zooplankton to fish to predatory birds and are thus vital for the marine ecosystem.

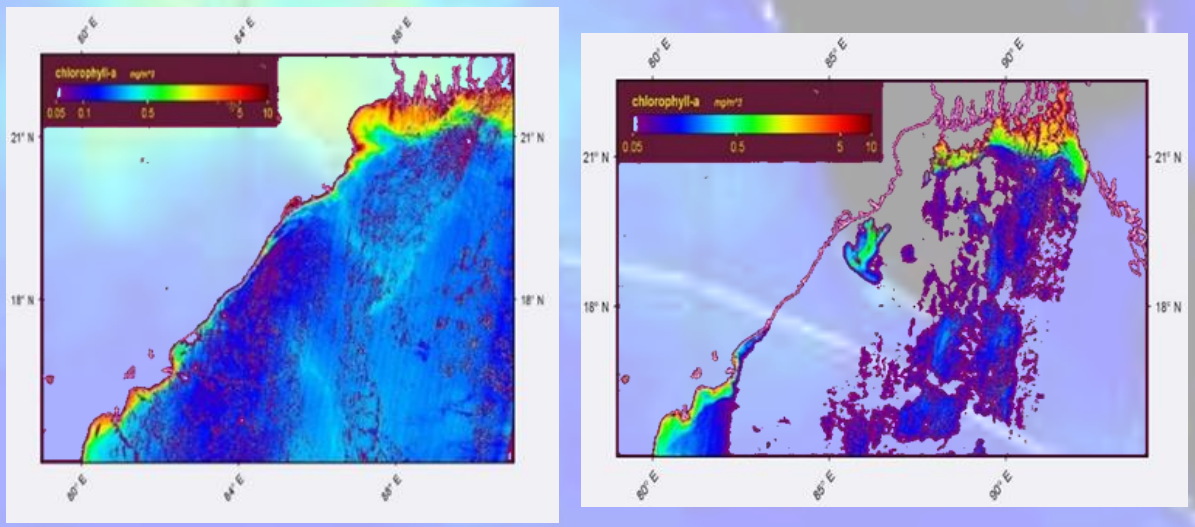


Figure 3: Oceansat-2 OCM derived chlorophyll for (a) May 17, 2021 (before Yaas cyclone), and (b) May 29, 2021 (after Yaas cyclone)

The Arabian Sea and Bay of Bengal experience cyclonic storms every year. The Bay of Bengal which is warmer compared to Arabian Sea generally experiences more frequent cyclones. There are usually two distinct seasons for occurrence of cyclones during April/May and during October/November. The extent of tropical cyclone induced cooling and phytoplankton growth is controlled by the combined effect of cyclone intensity and translation speed. The vertical distribution of temperature and salinity and presence of oceanic eddies also plays a vital role in determining the upper ocean response to cyclone. Eddies are circular current of water which inject nutrients from deeper layers into the surface layers. They are classified as cyclonic and anticyclonic depending on their rotation (clockwise/anticlockwise) and hemisphere (north/south). Cyclonic eddies are normally characterized by colder temperatures near their core and thinner mixed layer depth, while anticyclonic eddies are characterized by warmer core temperatures and thicker mixed layer depth. Eddy formation after the passage of a cyclone is a frequently observed phenomenon. Often, the bloom like phytoplankton concentration appears near the core of the eddy. Phytoplankton bloom like chlorophyll concentrations in Bay of Bengal and Arabian Sea has been observed after the passage of cyclones like Phailin, Vardah, Hudhud, Ockhi, Yaas etc. based on remote sensing observations. Figure 2 shows the normalized chlorophyll anomaly for the month of December 2017 after the passage of cyclone Ockhi. Chlorophyll concentrations are found to be 3-6 times the climatological mean after the passage of Ockhi. Figure 3 shows the chlorophyll images before and after cyclone Yaas.

It is hypothesized that in a global warming scenario the land sea temperature gradients will increase. This would result in increased upwelling favorable winds. Studies of coastal upwelling along west coasts of North and South America and west coast of Africa have shown intensification of coastal winds. This can have direct implications on the coastal primary and secondary productivity. Since coastal upwelling sustains some of the most prominent fishing grounds any change in upwelling can impact marine fisheries. Also, increase in frequency of cyclonic storms in a global warming scenario can adversely impact the biodiversity of coastal ecosystems.

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SPACE AID TO UNDERSTAND THE ROLE OF POLAR CRYOSPHERE IN CLIMATE CHANGE

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The polar ice regime consists of ocean, ice sheet, sea ice, ice shelf, atmosphere, and polynyas. Because of the complex feedback mechanism amongst these components, improved knowledge of the physical processes is required for better understanding of the potential changes in ice mass balance. In this article, the polar sea ice and icesheet has been discussed in two sub-sections for providing a better clarity to the readers.

Polar sea ice, a seasonally fluctuating element, has an important climate regulating impact by limiting exchanges of momentum, heat and moisture between the ocean and atmosphere. It modulates the normal exchange of heat and mass between the atmosphere and ocean by isolating sea surface from atmosphere. It also affects the atmosphere through strong ice albedo-feedback mechanism and ocean through the release of brine/fresh water during its growth/melt cycle. Since the total time duration of the growth and the melting is of the order of one year, the ice cover effectively integrates the climate signal over this short period and acts as an indicator of climate change. Sea ice floats on less dense oceanic water, however, its density is usually higher than fresh water ice due to brine content. As the top layer of seawater cools during winter, the density increases so the surface water sinks. This sinking water is replaced by warmer water from below. It creates a pattern of convection through which the whole water mass gradually cools. When the temperature reaches near freezing point (depends on water salinity), the water layer reaches its maximum density. Further cooling below freezing temperature (approximately -2° C) results in the colder water forming ice crystals. These crystals stay at the surface and force no more convection to take place from top layer. The resulting sea ice that forms depends on kind of prevailing weather at the time of its formation (Fig. 1).

Earth's sea level fluctuations are predominantly driven by the amount of ice contained in the Greenland and Antarctic ice sheets (GrIS and AIS, respectively).

Passive microwave sensors have been used to provide a long-term climate record due to their ability to see through clouds and darkness. The particular sensors include the Nimbus 7 Scanning Multichannel Microwave Radiometer (1978-1987), the series of DMSP Special Sensor Microwave Imagers (1987-present), and the more recent Aqua Advanced Microwave Scanning Radiometer for EOS (2002-present). Active sensors operating at visible wavelengths include the ICESat Geoscience Laser Altimeter System that provides information on sea ice thickness, whereas RADARSAT, an active microwave sensor, provides sea ice information at higher spatial resolutions (~100 meters) than the passive microwave systems. While sea ice extent/area and concentration are being monitored using remote sensing data for past many decades, estimation of its thickness was a relatively challenging task. Sea ice extent/area and concentration are being estimated using data acquired from various RS sensors including microwave radiometers, Scatterometers, Synthetic Aperture Radar (SAR), optical & near infrared camera etc. Space Applications Centre (SAC), Ahmedabad is monitoring sea ice in the Arctic and the Antarctic and daily sea ice images at 2.25 km (Fig 2). Currently the best spatial resolution sea ice images in the world are available at ISRO portal VEDAS (https://vedas.sac.gov.in/vedas_new/view/south pole.jsp).

Fig 1: Views of sea ice: Pancake formation a stage of sea ice formation (Left most); Floes of various sizes are visible in the photograph (middle). (660 16' 03'' S, 750 40' 09'' E; 22 December 2013; 33 ISEA). A satellite view covering large floes and polynyas (rightmost). (Resourcesat-2; LISS IV; FCC 432; 10 January 2016).

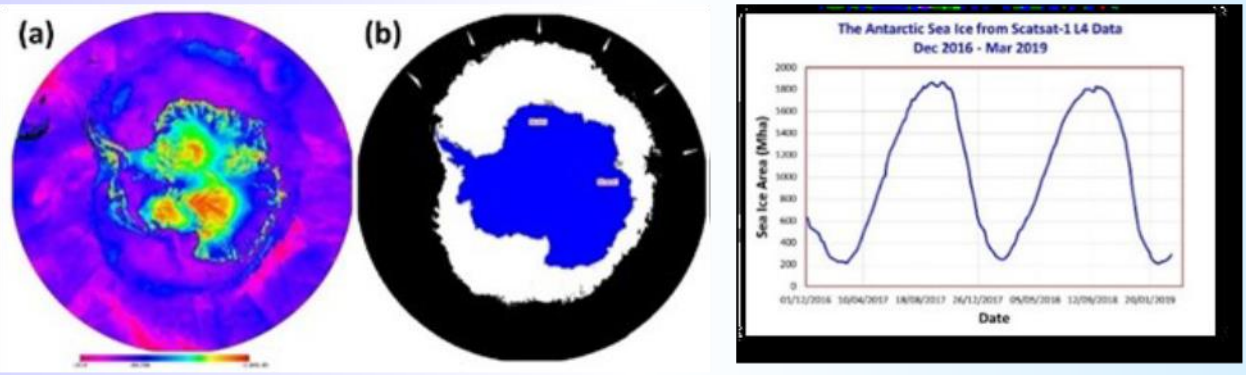

Fig 2 : An example of (a) False Color Image of Scatsat-1 Scatterometer data over the Antarctic for September 25, 2020, (b) corresponding sea ice image (sea ice is while, Antarctica is masked out and (c) The Antarctic Sea Ice Derived using Scatsat-1 Data (L4 Product at 2.25km).

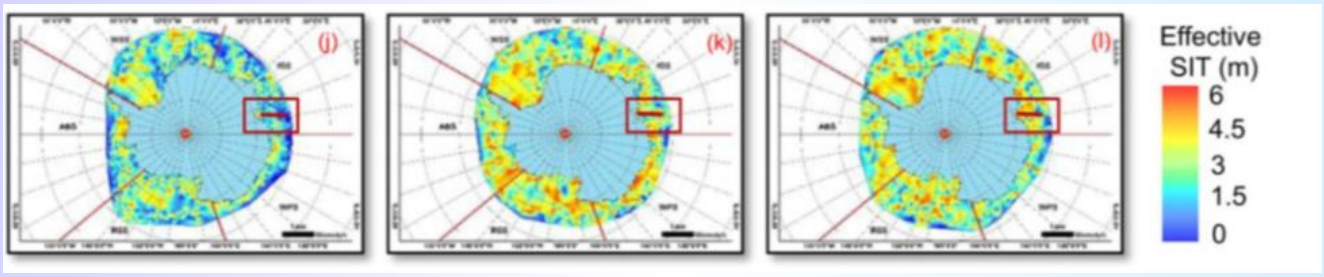

Figure 3: Sea ice thickness in the years 2016, 2017 and 2018 are shown in three maps respectively (left to right) at spatial resolution of 10 km. Transect drawn inside the red square box shows effective sea ice thickness trend.

Currently, satellite altimetry (both laser and radar) potentially offers the only practical means of measuring and monitoring the Antarctic sea ice thickness over large scales. Several earlier satellite missions (e.g., ICESat, ERS, CryoSat-2 and EnviSat) have demonstrated that altimetry offers great potential in monitoring sea ice thickness but also showed considerable uncertainties. These measure the elevation of the snow or ice surface, which can be used to estimate the sea ice thickness using an isostatic relationship between the above and below sea level portions of the ice cover. So, for all radar altimeters have used Ku band (ERS-1/2, CryoSat-2, EnviSat, GFO, Jason-1/2), SARAL mission is the first mission in Indo- French collaboration which has used Ka band. Studies in SAC have demonstrated the use of SARAL/AltiKa mission to retrieve effective sea ice thickness in the Antarctic region using radar waveforms (Fig 3). Currently sea ice thickness products are available at ISRO portal VEDAS.

(https://vedas.sac.gov.in/vstatic/SouthPloe_SIT/index.html).

According to scientific measurements, both the thickness and extent of summer sea ice in the Arctic have shown a dramatic decline over the past thirty years. This is consistent with observations of a warming Arctic. The loss of sea ice also has the potential to accelerate global warming trends and to change climate patterns.

Polar icesheet is another important component of polar Cryosphere region. Earth's sea level fluctuations are predominantly driven by the amount of ice contained in the Greenland and Antarctic ice sheets (GrIS and AIS, respectively). Variation in that amount of ice is a critical unknown, which hinders accurate sea level prediction. Monitoring the variability in ice surface elevation/volume is done by estimating the mass balance of the GrIS and AIS (Fig. 4). Therefore, measuring the present and past snow accumulation, ice melting and ice calving over the Earth's ice sheets are essential for understanding the current and previous contributions of the ice sheets to sea level changes. The mass balance of an ice sheet is defined as the result of all

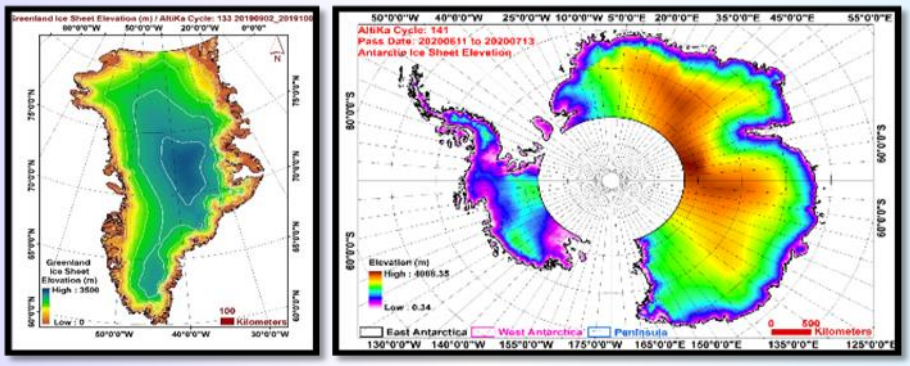

Fig 4: Ice sheet surface elevations maps of Antarctic ice sheet (Left) and Greenland ice sheet (right) using SARAL/AltiKa altimeter.

mass gain (termed accumulation) minus all mass loss (termed ablation and calving). Both of them originate on land and discharges into the ocean. Although AIS (12.3 M km^2) is seven times the size of GrIS (1.7 M km^2), Intergovernmental Panel on Climate Change (IPCC AR5) concluded that GrIS mass balance is the largest exclusive source for present sea level rise and will remain so for decades (Van den Broeke et al., 2017). For the central regions

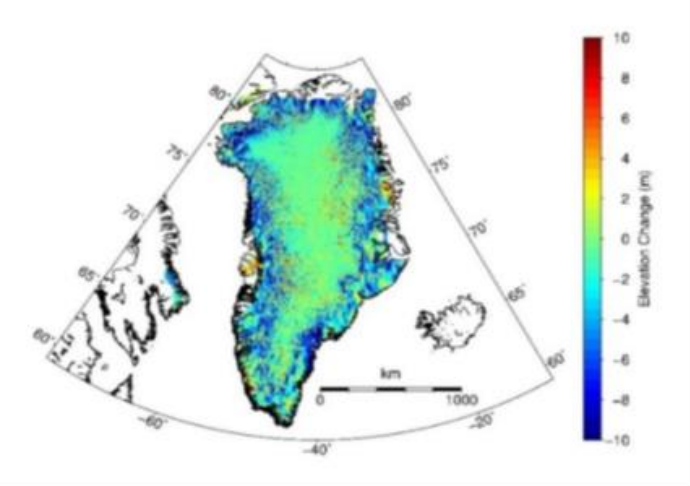

Fig 5: Difference map of AltiKa35 (March 2013 - July 2016) elevations and ICESat DEM (February 2003- June 2005) elevations

of Antarctica and Greenland radar/laser altimetry or airborne laser, profiling can be used. In addition to satellite altimetry, sensors measuring changes in Earth's gravity are also in use to measure the changes in ice sheet mass balance.

Loss of ice mass alters the gravity, which becomes the basis for the assessment of ice sheet mass balance using GRACE satellites. Elevations data at 500m gridded products are regularly being generated and available at ISRO portal VEDAS (https://vedas.sac.gov.in/vedas_new/view/south_pole.jsp).Changes in the surface elevations of polar ice sheets are the result of changes in ice dynamics and surface mass balance. SARAL/AltiKa altimeter data for the assessment of change in surface elevations over Antarctic ice sheet (Fig 5). Decadal mass balance estimation indicates ice mass gain of 496 Gt/year for AIS and loss of 226 Gt/year for GrIS. Annual mass balance indicates loss of 293 Gt and gain of 150 Gt during 2013-14 and 2014-15 respectively, for AIS. While over GrIS, ice mass loss of 187 Gt and 210 Gt is estimated during 2014-15 and 2015-16, respectively.

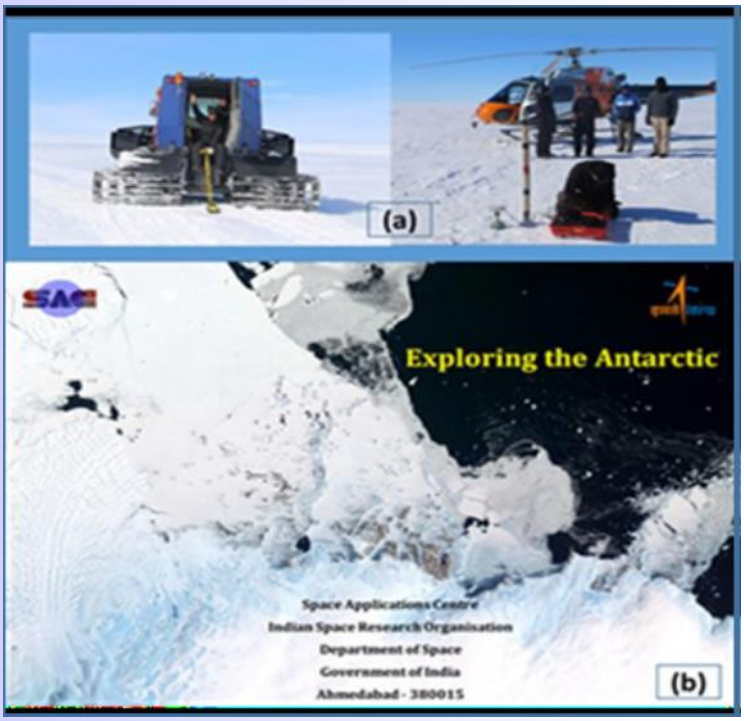

Fig 6: (a) Sample photograph of in-situ data collection by SAC participants (b) cover page of the book 'Exploring the Antarctic'

Long-term variations observed in energy fluxes over the Indian Antarctic stations Maitri and Bharati were studied at SAC using parameters from European Centre for medium range weather forecasts (ECMWRF) Reanalysis-Interim (ERAI) dataset. Warming induced melt water alters the dielectric properties of the upper layers of ice shelf, which becomes the basis for the assessment of surface melting using microwave radiometers and scatterometers. Several studies were carried out at SAC for the assessment of surface melting over Antarctic ice shelves using QuikSCAT, OSCAT and SCATSAT-1 scatterometers. Studies confirmed that ice shelves in East Antarctica are not immune from warming effects and demand constant monitoring. Melt water induced by atmospheric warming percolates from the surface into hydro fractures and affects shelf stability. Higher correlations were obtained between the surface Melt Index (MI) and rift propagation for narrow rifts over the Amery ice shelf, East Antarctica. The tropical linkage of MI with ENSO anomalies was also investigated. SAC has carried out several studies for the assessment of rifts, crevasses and ice calving using optical and SAR data. National Centre for Polar and Ocean Research (NCPOR), Goa, is the nodal agency for execution and coordination of expeditions. SAC ISRO has participated in number of expeditions in developing and validating retrieval and analysis of remote sensing derived parameters to understand the polar cryospheric processes (Fig 6a). A book "Exploring the Antarctica" has been published containing the highlights of various scientific studies in the Antarctic region undertaken by Space Applications Centre (Fig 6b).

Reference:

SAC, 2020, Exploring the Antarctic. Space Applications Centre, ISRO, Ahmedabad, India, ISBN :978-93-82760-37-5, p 143.

BIO OPTICAL CHARACTERIZATION FROM SPACE CUM AIRBORNE WITH REDUCED UNCERTAINTY

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Way back in 1978, the first satellite Nimbus-7 carrying coastal zone colour scanner (CZCS) as a proof of concept, laid the foundations of the subsequent ocean colour satellites to address the scientific problem for biological oceanography and

No measurement is complete without error !

oceanic food chains. After its launch, global scientists started realizing in terms of multi directional improvement like number of specific bands selection for oceanic applications and environmental studies. However, the sensor designing among all considerations related to ocean applications i.e. sensitivity of a sensor is to detect the minimum change in radiance over ocean surface. The signal to noise (S/N) ratio of the ocean colour sensor should be high or optimum depending upon minimum change detection of a geophysical product i.e. change in chlorophyll chl-a) with minimum pixelization noise in spatial domain. Since water leaving radiance from ocean surface, contributes 10% of the top of the atmosphere (TOA) radiance at the sensor level at blue channel in open ocean while in coastal region, coloured dissolved organic matter (CDOM) dominating water contributes <1% to the sensor level at blue channel. That leads a global challenge to derive the oceanic products with a better accuracy. The uncertainty is a measure of error distribution and probability unlike to the error simply, i.e. measurement of the deviation from the hypothetical 'truth'. That makes sense not only for application scientists but also for engineers too to design and manufacture such a highly sensitive ocean colour sensor to cater the global needs. The other parameters cannot be avoided based on their importance and those are spectral resolution, saturation radiance and quantization bits particularly. Apart from sensor parameters, algorithm uncertainties also take place in the derived products from space. Those algorithms are radiative transfer model and bio optical model dealing with the light propagation through the atmospheric column until reaches the ocean surface and penetrates the water column. So, based on Guide to the expression of Uncertainty in Measurement (GUM, 2008), the error propagation theory may help to examine the quantitative uncertainty associated with the marine optical products like Chl-a (mg/m^3), light absorption due to coloured dissolved organic matter (1/m) and back scattering due to total suspended matter (TSM) in coastal region and open ocean on pixel to pixel basis in satellite imagery.

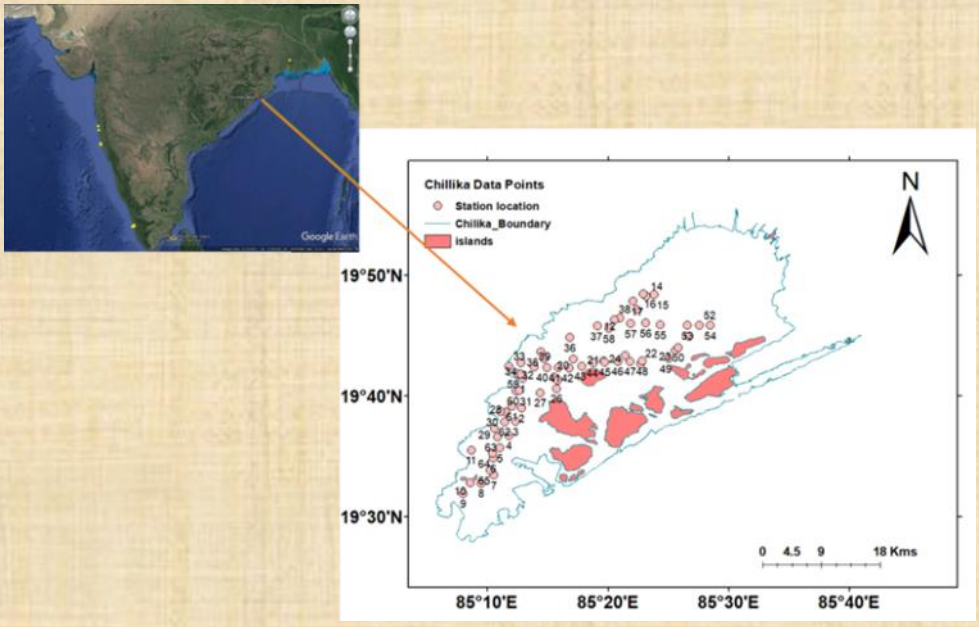

Figure 1: Seasonal climatology (June-September) of chlorophyll concentration (mg/m^3) and SST (° C) for Arabian Sea

Global Outlooks

The oceanographic community is looking to develop biogeochemical climate data records from satellite measurements. The continuous global monitoring exceeds 20 years from ocean colour satellites including SeaWiFS;(1997–2010), MODIS Terra, (1999-present) and Aqua (2002-present), Medium Resolution Imaging Spectrometer (MERIS; 2002–2012), the Visible Infrared Imaging Radiometer Suite VIIRS, onboard Suomi NPP (2012-present) and onboard JPSS-1 (2018-present), the ESA Ocean and Land Colour Instrument OLCI, onboard Sentinel-3A (2016-present) and onboard Sentinel-3B (2018-present), JAXA Second generation Global Imager SGLI, (2017-present), Ocean colour monitor OCM on board Oceansat-2 (2009-present).

In last two decades, the role of global oceanic sensors increased in order to address the ocean monitoring and the climate change. Way back in 1965, the intel co-founder Gordon E. Moore made a prediction about the semiconductor industry that the number of transistors doubles in every two years on the integrated circuits and after whom it is named as Moore's principle. Since 1965, the enormous growth in computing power was acknowledged to address the global problem like climate change, marine ecosystem and many more. The intergovernmental panel on the climate change (IPCC) 2021 says that the rise in the global surface temperature is 1.5° C relative to 1850-1900. If it continues with the same compounding rate then by the end of this century, the expected rise in temperature may exceed 4.4° C. By the time, our planet 'Earth' might be no longer habitable. So the importance of the satellite imageries plays a substantial role not only for the climate related issues but also for the policy makers too to make intelligent decisions for sustainable growth to the ecosystem time to time for the mankind and society.

Utilization of ISRO-NASA Joint mission (AVIRIS-NG)

In last few decades, the empirical approaches for different ocean color sensors having multispectral bands, were supported in open ocean waters using large database of in situ measured values to derive the concentrations of chlorophyll-a (mg/m^3). Further advancement involved the use of semi-analytical models such as Garver–Seigel–Maritorena (GSM) and quasi-analytical (Lee–Morel), which showed marginal improvements over the empirical approaches in deriving chl-a concentrations for optically complex Case-2 waters. A major disadvantage in these bio-optical models (GSM and Lee–Morel) was the selection of either constant or partially constant parameterizations, not able to deal with modulation of light field within the water column. While in practice, all the parameters are variable in nature.

Utilization of ISRO-NASA Joint mission Airborne Visible Infrared Imaging Spectrometer-Next Generation (AVIRIS-NG) was carried out in Chilika lagoon with some inferences that the variabilities in bio-optically active constituents in the water column were explained with marginal improvement in accuracy using recently developed semi-analytical bio-optical model (Anurag et al, 2021). Since the lagoon water is highly turbid and optically complex brackish water, so it is difficult to invert water-leaving radiance to derive concentrations of the bio-optical constituents with a better accuracy. The analyses show that by modeling the variability in the coloured dissolved organic matter (acdm) slope, the large errors associated with chlorophyll estimation in optically complex waters was reduced significantly. The model was tested on a data set collected from an optically complex Chilika lagoon situated in the northeastern region of India. The estimations of Chlorophyll-a using GSM, Lee Morel and model with improved parameterization for optically complex waters of Chilika lagoon, Odisha, have been shown in figure 2. The analyses indicate a substantial change in the estimation of chl-a (mg/m^3) with a mean absolute percentage difference (MAPD) of 58% as compared to GSM (175%) and Lee–Morel (189%) bio-optical model when compared with the in situ measurements. This study reveals that the bio-optical models developed for global oceans needs to be regionally parametrized for optical constituents in complex water bodies to estimate chlorophyll concentration with reduced uncertainty.

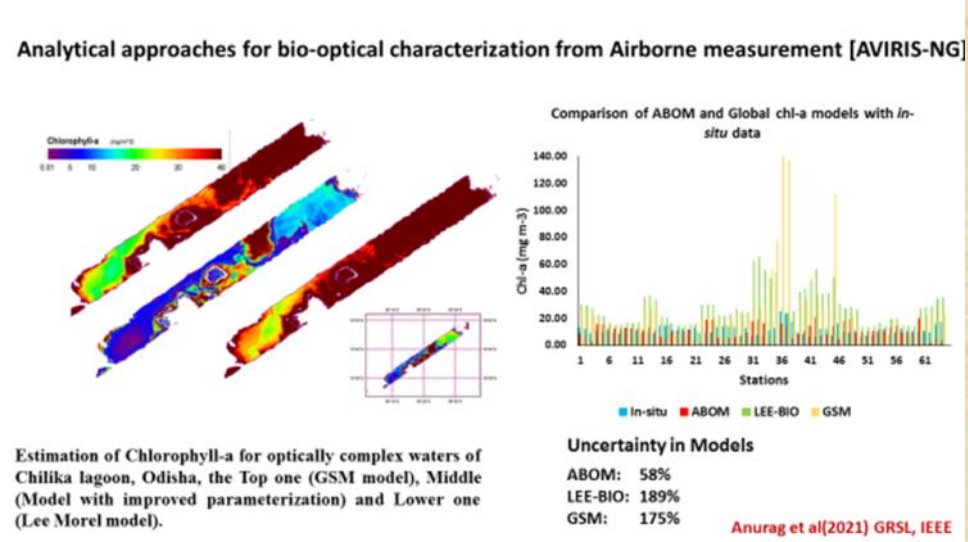

Figure 2: Normalized chlorophyll anomaly (in percentage change from climatological mean) for the month of December 2017 (cyclone Ockhi). Citation: Ganguly et al. 2020.

Early Warning Systems must protect everyone on Earth by 2027, UN announcement: To mark World Meteorological Day (WMD) 2022 (March 23), United Nations secretary-general António Guterres has announced a major new initiative: everyone on Earth should be protected by early warning systems against extreme weather and climate change within the next five years. Guterres tasked the World Meteorological Organization (WMO) with leading the effort by presenting an action plan at the next UN Climate Conference, COP 27, in Egypt, from November 7-18, 2022. The theme of this year's WMD is 'Early Warning and Early Action – Hydrometeorological and Climate Information for Disaster Risk Reduction' and is intended to highlight the vital importance of hydrometeorological and climate information for disaster risk reduction.

Global Warming shrinking Marine Cold Spells:

As the atmosphere and oceans warm, marine cold spells are becoming less intense and less frequent overall, according to a new study carried out by Yuxin Wang, lead author and ocean and climate scientist at the University of Tasmania.

According to him, "predicting cold spells could be important for fisheries' long-term planning and for ensuring catch limits are sustainable." Marine cold spells are natural, but their rates are changing around the world. Over the past decade, cold spells have occurred roughly 10 days per year globally, a notable drop from about 40 days per year in 1985. The study, thought to be the first to quantify and compare the changing nature of marine heat waves and cold spells over several recent decades on an ocean-wide, global scale, found that the oceans are warming, corresponding to global warming trends, and sea surface temperatures are becoming variable over time. That variability leads marine heat wave and cold spell intensities to change at different rates, complicating scientists' attempts to predict each. The study is published in AGU's Geophysical Research Letters.

40 years review of Tropical Cyclone Programme by WMO:

Ahead of World Meteorological Day on 23 March 23, 2022, which this year celebrates on the theme of Early Warning and Early Action, the World Meteorological Organization (WMO) has published a review of its Tropical Cyclone Programme (TCP), established in 1980. There is an average of 84 named tropical cyclones every year, resulting in an average of 43 deaths and US$78m in economic losses every day. They have also been responsible for one third of both deaths and economic losses from weather-, climate-

and water-related disasters, according to WMO statistics ranging from 1970-2019. But the death toll has fallen dramatically thanks to improvements in forecasting, warning and disaster risk reduction which lie at the heart of the TCP. The TCP was established in response to disasters such as Tropical Cyclone Bhola in 1970 which killed an estimated 500,000 people in Bangladesh and prompted international calls at the United Nations General Assembly

to find ways and means to mitigate the harmful effects of tropical cyclones. The TCP includes two components: a global component and a regional component, of which each has four program areas – meteorology, hydrology, disaster risk reduction and capacity development via research and training. The global component identifies and coordinates areas requiring cross-region coordination, and common issues requiring global effort to cope with tropical cyclones. The regional component focuses on strengthening regional coordination frameworks, including observation, forecasting coordination, data sharing, and contingency plans.

A new satellite reference for all sea level measurements:

US space agency NASA has announced that the ocean-monitoring satellite Sentinel-6 Michael Freilich has become the new reference satellite for all sea level measurements. The latest in a long line of US/European sea level satellites, Sentinel-6 Michael Freilich became the official reference satellite for global sea level measurements on March 22, 2022, meaning that all future sea surface height data collected by other satellites will be compared with information produced by Sentinel-6 to ensure accuracy. Launched in November 2020, the satellite is continuing a nearly 30-year legacy started by the TOPEX/Poseidon satellite, which began its mission to measure sea surface height in the early 1990s. A series of successor satellites have carried on the effort since then, with Sentinel-6 Michael Freilich being the most recent. Its twin, Sentinel-6B, is slated to launch in 2025. Sentinel-6 was jointly developed by ESA (European Space Agency), EUMETSAT, NASA and NOAA, with funding support from the European Commission and technical support on performance from CNES.

Bespoke kite-balloon aerostat unravel cloud composition:

Understanding the formation of cloud droplets requires gentle, microscopic study with the clouds being undisturbed by rotor wash or movement of the instruments within the cloud. This is impossible with

manned aircraft, UAVs, free floating balloons or parachute-sondes because they cause too much disturbance moving rapidly sideways or vertically through the clouds. Also, as the laser droplet measuring devices are exceptionally expensive and rare, they need to be attached to a reliable device that will not fail or go missing. The €3m EUREC4A science project, that sent a fleet of vessels and aircraft across the Atlantic and back, to understand the internal workings of maritime clouds and the couplings between clouds, circulation and convection, uses a 70Kg laser cloud droplet monitor on a 250 m3 Desert Star Helikite which is developed by the UK-based kite-balloon manufacturer Allsopp Helikites. Desert Star Helikite uses both wind and helium to provide lift, it is both exceedingly stable and reliable in high winds, while also being lighter than air thus enabling it to fly when there is no wind. According to Allsopp Helikite, no other tethered aerostats are as easy to fly from ships as Helikites and none of similar size can reach the high altitudes required. In 2019, the Desert Star Helikite was put into action, flying high into the clouds for several weeks, gathering ground-breaking droplet formation data as the EUREC4A fleet traveled from Portugal to Barbados. In 2020, the feat was repeated by the same Helikite, but this time going from Rio to Portugal.

Compiled by Abhineet Shyam
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JAMBUGHODA : A NATURE'S TRAIL

SHAURYAA SINGH
Class: 7
DPS-Bopal , Ahmedabad

Nature makes everything so beautiful and magnificent. And one such beautiful and magnificent place is Jambughoda. You might have not heard the name, but this place lies beautifully in a place in Gujarat. It is unknown to many but the ones who have seen it have seen another miracle of nature. And I had the opportunity to visit this blissful place. My parents had decided that we would go to statue of unity. Yes, we had not visited it. But the temperature was so damn hot, that

we dropped the idea. My parents again started their research, because a four day holiday cannot go to waste! Soon they found this Jambughoda place. They found the pictures to be interesting. The pictures were full of greenery. And honestly, my parents love greenery. So they had fixed that we would go to this natural place Jambughoda. Weird name, isn't it? When the day came we started our four hour trip. The two hours on the way were simple like any other new trip. And so was the next hour. But suddenly we started to enter a green patch. We could see mountains which were far away. Which was surprising. Ahmadabad and the near regions are way too dry. And all of us were shocked in a good manner to see the fresh GREEN greenery. Soon it started to get thicker and brighter. Before I could realize, we were on a road made on a forest. It was difficult to think that there would be a resort in there. We went deeper and deeper and on taking many turns we were on an entrance on which it was written, Vananchal. It was so lovely to see such a place. The resort was big, marvelous and green! As we entered a bridge like structure was made. We walked under the canopy made by green tall old trees. The reception wasn't much like expected. But it was way more beautiful. It was made under a canopy. The bright sunlight partially penetrated through the canopies.

We did the check in and all. And when we entered the resort's main portion, we all gasped. The beauty of the nature was brushed to finesse. The birds were chirping and singing the most lovely song. It was like the whole nature welcomed us. I forgot myself for a moment, because what I just saw was a miracle. It was what we call magic. Never in my dreams could I think that Gujarat could portray nature so beautifully. The man ahead of us just led us to our rooms. He unlocked the room and kept our luggage inside. Most of the people love to see their room. But I loved to see that place! Birds were singing songs, squirrels were playing hide and seek, butterflies were kissing the flowers, a horse was running gracefully and proudly in the green (tree filled) garden and I....I was looking at everything with my mouth opened. There was a swimming pool in front of our room and there was a thick dense forest just behind our room.

I smiled brightly. I was so happy mom and dad chose this place. But when I entered our room, it was another lovely surprise. It was made in a lovely traditional way. With beautiful paintings and carvings, it gave the room a very amazing traditional look. Outside there was a sitting area

which was so perfect. We could look at the swimming pool and the nature's beauty properly from there. We were so tired that we had the most tasty paneer do pyaza, mix veg and tandoori roti. My gosh, it was heavenly. The next day we decided to enjoy the resorts delight. Resorts delight, what so? Believe me, the resort was huge and awesome! It had so many activities and a zoo. Yes a zoo! Well there weren't tigers and lions, but there were rabbits, ducks, horses and tons of other animals. And I don't want tigers and lions in the same place I am. So we headed for the activities. There were so many games! They had horse riding, the zoo thing I was talking about, zip line, machan, swimming pool and monster car. And all those activities were inside that lovely green place. So we started with the zoo. Well we didn't start, but the man who took care of ducks opened the duck cage and there were many of the white ducks. Walking and running through the green gardens these ducks shone in the sunlight. As they showed, the area turned into paradise. Then we saw the rabbits. There were white, black, grey, brown and mustard colored rabbit. Some of them were so young that they looked damn cute. They looked at us pretty astonished. Then we headed through the bushes and gardens to see the dogs. Variety of dogs. There were Dalmatians, Indian pariah dog (obviously), dachshund and pups of German shepherd. This time I was the one astonished.

The owner also had a white friendly Labrador. Then we went near machan. The machan was big and adventurous. It ran though tall and bushy trees. And then I climbed it. I was really scared, but excited. I made it to the end and had to come back. During my way back I started to feel the pitter patter of rain drops on my head. Of course there was rain in such a green area. The droplets of rain appeared like pearls, because there was no pollution so the drops were clean and shiny. I got down. It wasn't raining much, just drizzling so we enjoyed it. Like a movie actress, I spread my arms and did turns, looking above and closing my eyes. Very dramatic. Then dad went for monster drive in the monster car. This thing was bold and red colored, it had huge wheels. It went outside the resort near the forests. The forests were scary and thick green. After he came back, we had breakfast and mom and dad had tea. We then saw many more things and then came back to our room. The next day I had my math test. So I would sit in the verandah, near the green lovely patch. So I attended and did my test. It was raining heavily. It was so spectacular to look at the heavy rain landing directly on the leaves of the trees. Well I did my test in the most interesting manner, between the arms of nature. We later went to an animal wildlife sanctuary – Jambughoda wildlife sanctuary. It was paradise. We were slowly driving in the middle of the forest looking for animals to spot. We could hear the chirps of birds and many forest noises. The experience was beautiful! Suddenly I saw a rock like structure and when I saw it with my binoculars, it was a porcupine! Then I saw a fox an many more animals. I was so happy. Then we went to Kada dam. And it's a must visit. Because it is heaven. The images we see on our wallpapers, it matches the same. The dam was filled with water and thick green mountains were seen. I have literally no words to describe it. Or maybe infinite words to describe it. It was amazingly amazingly amazingly extravagant. This trip made the biggest impression of nature in my mind.

Student's Corner: The World as we see it

Mountain stream

By

SAMAR SINGH

Class: SR. KG

DPS Ahmedabad

Freezing full moon

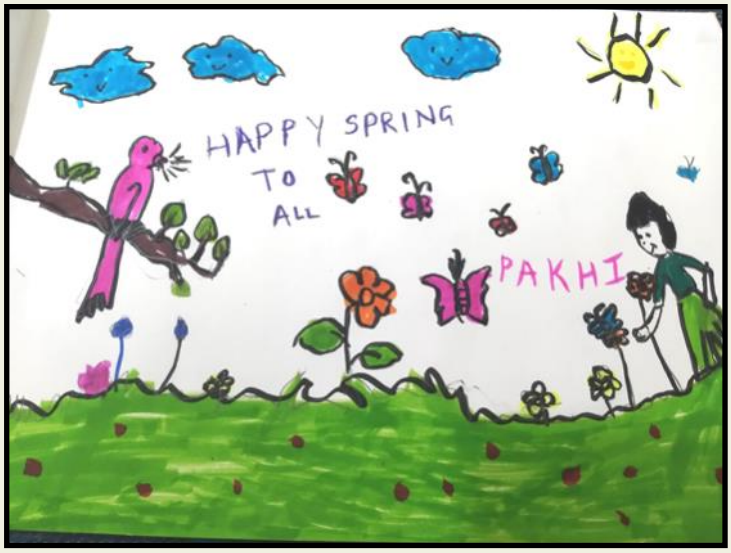
By

SIDHIKSHA DEB

Class: 7

UDGAM SCHOOL FOR CHILDREN,

Ahmedabad



Joy of spring

PAKHI VISHWAKARMA

Class: 2

DAV INTERNATIONAL,

Ahmedabad

THE DISAPPEARING WOODS: SOMEDAY SOMEHOW

Ananya Chaurasia
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I walk in through that door
My mind is marching in
But nothing quite explains,
Why you....I'm falling out of
View...
And do you feel the pain?
This pain I felt in you.
As if I always knew, the words I'd never say to you.
Somehow. These words that would mean nothing.
It's alright.
It's alright.
We're running out of things to say
We've got the answer.
It's alright.
It's alright.
Oh, please don't say you're sorry
I know.
And it will all be fine. Someday.
I'll gladly take the blame for all we've ever had.
I'll take these broken things and I'll try to mend the Cracks.
And everything I do I did it all for you.
But it's all over Yes, It's all over.
It's alright.
It's alright.
We're running out of things to say
We've got the answer.
It's alright.
It's alright.
Oh. Please don't say I'm sorry.
I know.
And it will all be fine. Somehow.

SPRING

ANIKA SHUKLA
Class: 7
UDGAM SCHOOL FOR CHILDREN, Ahmedabad

I love the spring, just every day,

There's something new that's come to stay.

Another bud,

another bird,

Beautiful butterflies , being lured,

With the bloom of every flower.

Not every sunrise can be the same.

Each one beautiful in its own way,

Is it anyhow possible that we can repay?

The care of nature,

And it's magic.

Every new season,

every new time,

Leaving behind a beautiful chime....

E-Megha appreciates the students contributors for the year 2021

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DAV International School

Nischhal Shukla ,
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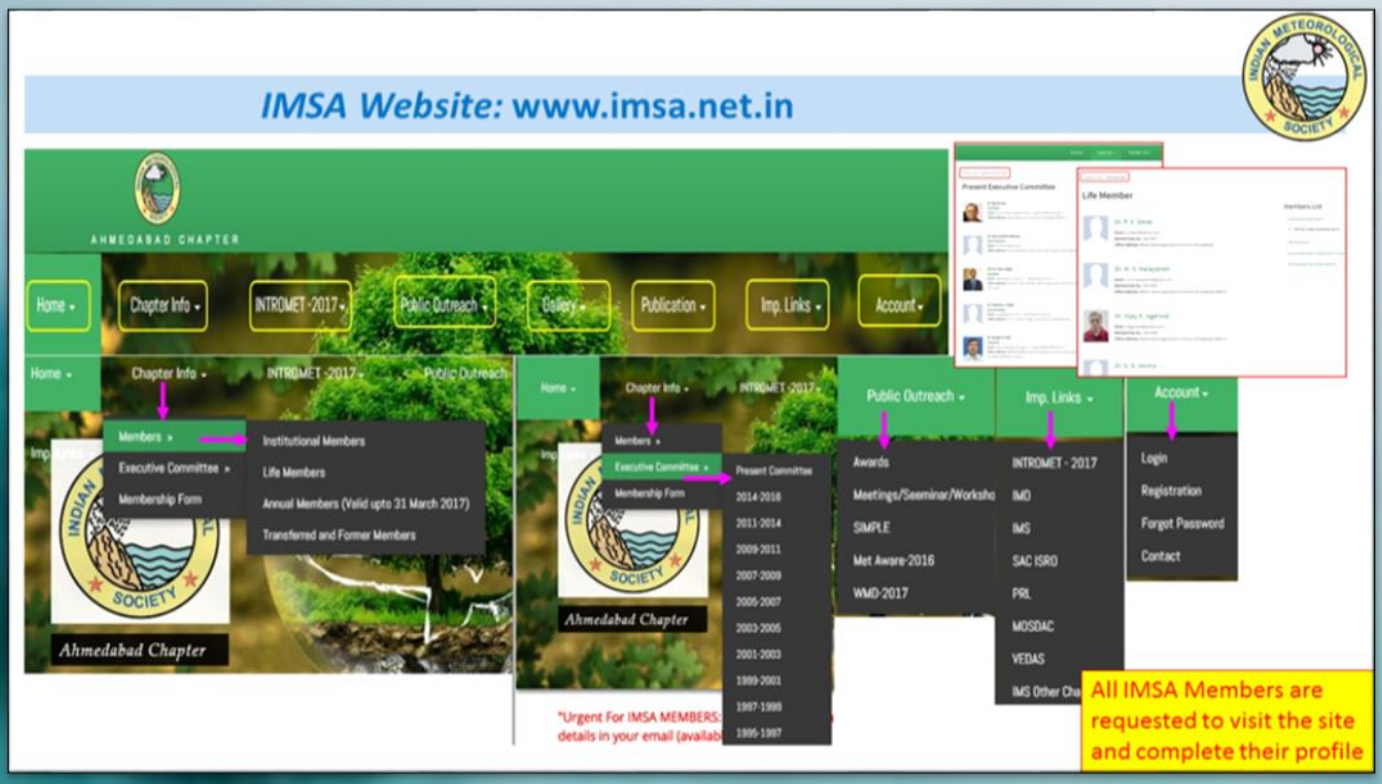

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