Volume 27, Issue 4
December 2020

SPECIAL ISSUE: CRYOSPHERE

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SIGNATURES

Inside this issue:

EDITORIAL COLUMN

Dear Readers,

Winter is just around the corner and we are very delighted to present the December edition of “Signatures”. This newest edition of Signatures is a special issue on the Science of Cryosphere. Experts in this field have lucidly written articles that all of us can understand : Himalayan Cryosphere, Antarctic Ice, Pro-Glacia lakes , the linkage between Climate change and Cryosphere and the 39th ISEA. In particular, two very interesting articles to watch out are from experts in the fields: Dr. A. V. Kulkarni (Divecha Centre for Climate change, IISc) and Dr. S. S. Randhawa (HP-State Centre on Climate change) . We encourage you to read them, talk about them in your circles and make it part of the conversations. It is only when science becomes part of the general talk that it earns its rightful place.

The main highlight of this issue is an interview with our beloved Director SAC, Shri. D. K. Das Sir, who is superannuating on 31st December 2020. We are very fortunate to have him share some pearls of wisdom from his vast experience. Especially our young readers will be encouraged to use technology for societal benefits. All of us, from Signatures wish him and his family a very happy and fulfilling post-retirement life.

To know more about the ISRS-AC happenings, we have the Secretary’s report detailing each activity that took place during Jul-Dec, 2020.

Continuing from our previous edition, the current issue also has pages on ‘Remote Sensing News’, that give useful information through the small notes / clips.

As part of the upcoming conferences, you will find detailed information on the forthcoming ISRSNS Symposium. You will also find information on other symposiums and conferences.

This issue of Signatures also has review of the book ‘Vikram A. Sarabhai – the Visionary Scientist’ which is written by ISRS-AC member Dr. Satyendra M. Bhandari, paying tribute to the father of Indian space program during his birth anniversary celebrations.

On 31st October, the scientific community lost a brilliant mind and a noble person, Dr. Pranav Desai. He worked tirelessly throughout his post-retirement life for the welfare of old pensioners and crusading for the newly joined scientists. May his soul rest in peace!

With this the editorial team hopes that in this period of loss and uncertainty, we find hope in knowledge and continue our pursuit of science.

Wishing you a very happy reading and warm greetings for the New year 2021

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CHAIRMAN'S ADDRESS

RAJEEV JYOTI

I feel honoured to present the foreword for the new edition of Signatures: The official Newsletter of the Indian Society of Remote Sensing - Ahmedabad Chapter. This is a special issue that spotlights the Cryosphere, which is of extreme importance in the light of Global climate change accentuating snow melt processes which eventually accelerate sea level rise.

As a proactive society, ISRS-AC has joined hands with other scientific communities to have a series of online lectures and activities to promote learning and thought sharing even during the COVID-19 period. The ISRS-National Symposium 2020 on Remote Sensing for Environment Monitoring and climate change assessment: Opportunities and Challenges is another stepping stone in bridging the gap between science and society.

Let us get equipped for the times to come: cooperation, societal contributions and effective dissemination of ideas and knowledge will be ISRS-AC's commitment for the future. I am extremely happy to record the pivotal role played by the Signatures team towards this goal.

Finally I would like to take this opportunity to wish you all a very positive, healthy , safe and joyful year ahead. Let 2021 usher in loads of positivism, sense of well being and strength which we all so much require at this moment.

(Rajeev Jyoti)

Chairman, ISRS-AC

SECRETARY'S REPORT

D. RAM RAJAK

On one hand humans are fighting with the Covid-19 pandemic and on other hand they are learning how to continue with their essential duties in this new normal. ISRS-AC has also been busy in organising multiple events and making people aware about various dimensions of the Remote Sensing science, technology and related applications. The chapter is dedicatedly making all preparations to organise the ISRS-ISG National Symposium 2020 (ISRSNS2020) and Annual Convention with Space Applications Centre, ISRO, Ahmedabad. It is the first time that this event is being organised in ONLINE mode; hence many new challenges are being encountered, faced and solved. The ISRSNS2020 is scheduled during December 18-19, 2020 and the theme of the symposium is "Remote Sensing for Environment Monitoring & Climate Change Assessment: Opportunities and Challenges". The chapter is also contributing in preparations of Silver Jubilee Celebration of IRS-1C Launch organised by ISRS. It is planned to be held on December 28, 2020.

The chapter has organised more than half a dozen activities since previous issue of the Signatures. A popular lecture on "Do Forests Attract Rain?" was delivered in online mode by Mr. Rohit Pradhan, Scientist in Space Applications Centre, ISRO, Ahmedabad on July 18, 2020. He discussed various hypothesis associated with growth of forest and rainfall occurrences. The lecture also dealt with how satellite data helps in knowing the isotopic composition of atmospheric water vapour for hydrological studies. The 34th Annual General Body Meeting of ISRS-AC was held on 2nd Aug 2020 with a webinar lecture on "New Approach for Improving Ocean Colour Retrieval" by Dr. D. R. M. Samudraiah, former Deputy Director, SEDA, Space Applications Centre, ISRO. On Independence Day 2020, one more popular lecture (to celebrate National Remote Sensing Day on August 12) was organised on "Environment Watch from Space: Exploring Impacts of COVID-19 Lockdown on Environment". The lecture was delivered by Dr. Mehul Pandya, a senior scientist in SAC-ISRO, Ahmedabad. The talk discussed how space-based observations enabled the probing of significant impacts of COVID-19 enforced lockdown on the Earth's environment. More than 100 people attended the webinar. It was followed by an online quiz for university graduate and post-graduate students. The event was co-organised with Indus University and Nirma University, Ahmedabad.

On the occasion of World Ozone Day 2020 (September 16), a lecture on

SECRETARY'S REPORT (CONTD.)

"Ozone layer and ozone pollution: Issues, challenges and future ahead" was organised. The lecture was delivered by Dr. Manish Naja, Chairman – Atmospheric Science Division, ARIES in virtual mode. A national webinar was co-organised with M G Science Institute, Ahmedabad on 19th September 2020. The theme of the webinar was "Remote Sensing & GIS For Plant & Environmental Studies" and three talks were delivered on this occasion by Dr. Prakash Chauhan (Director, IIRS, Dehradun), Dr. Shibendu S. Ray (Director, MNCFC, New Delhi) and Dr. C. P. Singh, a senior scientist in SAC-ISRO, Ahmedabad. ISRS-AC has started celebrating World Rivers Day (WRD) this year onwards. To celebrate WRD-2020, a popular webinar on "Search of the Vedic Saraswati River" was organised in virtual mode on 27th September 2020, which was attended by over 100 participants. The talk covered the importance of rivers and discussed the various research studies being carried out to explore the ancient Saraswati River. ISRS-AC has started celebrating Antarctica Day since this year. A popular lecture (India in Antarctica) to celebrate Antarctica Day 2020 was arranged on December 1st. The lecture was delivered by Dr. Rasik Ravidra, Former DDG, GSI and Former Director, NCPOR through a webinar, which was attended by around 100 participants from all over India.

Learning & moving ahead is human nature. Let us continue it in this new normal !

(D. Ram Rajak)

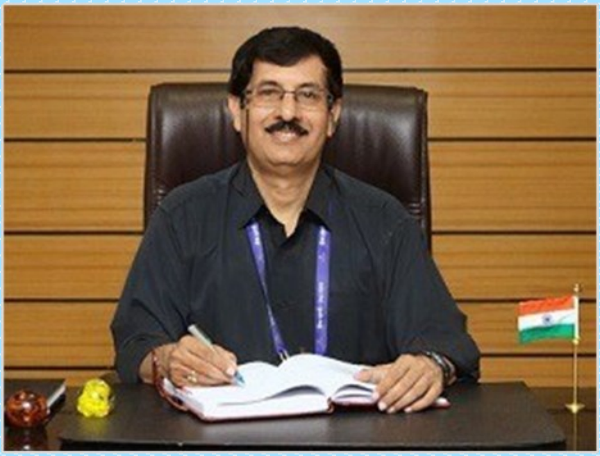
Secretary, ISRS-AC

Scientist, SAC-ISRO, Ahmedabad

AN EXCLUSIVE INTERVIEW WITH

SHRI D.K. DAS

DIRECTOR, SPACE APPLICATIONS CENTRE, ISRO



PERSON OF EMINENCE

Shri D. K. Das is a Distinguished Scientist and the Director of Space Applications Centre (SAC), Ahmedabad, a lead centre for design and development of space-borne instruments and applications for ISRO missions. He is a highly accomplished and renowned space Scientist and Engineer who has successfully led the development of over 30 communication and navigation payloads for ISRO.

Shri D. K. Das born in 1961 at Sualkuchi, Assam, is a graduate in Electronics Engineering from Indian Institute of Technology (IIT), Banaras Hindu University (BHU). He started his professional career at Space Applications Centre, ISRO in 1983 in the area of Communication & Navigation Satellite technology. Since July 2018, he is designated as Director, Space Applications Centre. He is a recipient of many prestigious awards : ISRO-ASI award (2010) , ISRO Merit Award (2010) and ISRO Performance Excellence Award (2015). He is elected as Corresponding Member of International Academy of Astronautics (IAA) in 2019. He is a member of Space Communications and Navigation Committee (SCAN) of International Astronautical Federation (IAF). He is also designated as Chair of 'Committee on Earth Observation Satellite' (CEOS) for the year 2020.

Signatures: Sir, you leave a rich legacy. How do you visualize the future of SAC in the next decade?

Das Sir : The recent revamping of Indian Space program and opening of space segment for private participation has oriented the scenario towards user demand approach to technological developments. SAC, which encompasses industry and institute collaborations for various space applications, positively finds its bearings on a strong foothold. However, the demand for space based applications and services is very high and is projected to curve exponentially in near future. So in this framework, the role of SAC is crucial as well as challenging. I personally visualize SAC to scale greater heights in the next decade, as it takes up new challenges, expands its horizons and assumes its role as major player in Indian space program.

Signatures : What according to you defines the basic fabric of ISRO culture ?

Das Sir : The basic fabric of ISRO is spun with yarns of hard work and innovative ideas. ISRO embodies an unparalleled team spirit, a driving passion to succeed and an unwavering commitment towards the country. That's the crux of ISRO culture.

AN EXCLUSIVE INTERVIEW WITH

SHRI D.K. DAS

DIRECTOR, SPACE APPLICATIONS CENTRE, ISRO

Signatures : As you know many youngsters have joined SAC in the recent past. What would be your advice to them in the interest of organization and in their career growth?

Das Sir : I heartily welcome our new generation who have joined ISRO recently. My advice for them is to have a zeal for learning and perseverance towards a project. It is rightly said by Kavi Guru Shri Rabindra Nath Tagore "You can't cross the sea merely by standing and staring at the water". ISRO is driven by its dedication towards cutting edge technology and societal applications and new generation ISROites should strive towards carrying the baton forward.

Signatures : Sir, what message you would like to convey to members of ISRS-AC and our readers?

Das Sir : Remote sensing is a confluence of science, art and technology. It is embedded intricately in all our lives. As members of this society, it is on us to explore and appreciate both the beauty and application of remote sensing. Young readers / Students may like to take up interesting projects in the field of remote sensing with their curiosity, discussion and participation.

Along with his professionally illustrious career, he is also a nature enthusiast and has a brilliant eye for photography. Even in his busy schedule, he manages to squeeze time to capture exquisite and breath taking shots , a few of which we share here with our readers.

Signatures team is grateful to Shri D. K. Das Sir for his valuable time and wishes him a very happy, heathy and fulfilling journey ahead.

ISRS-AC ACTIVITIES

JULY 2020—DECEMBER 2020

- ◊ A popular lecture on "*Do Forests Attract Rain*?" by Mr. Rohit Pradhan (Scientist in Space Applications Centre, ISRO, Ahmedabad) on 18th July 2020.

- ◊ The 34th Annual General Body Meeting of ISRS-AC on 2nd Aug 2020 with a webinar lecture on "*New Approach for Improving Ocean Colour Retrieval*" by Dr. D. R. M. Samudraiah, former Deputy Director, SEDA, Space Applications Centre, ISRO.

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- ◊ An online quiz for university graduate and post-graduate students, co-organised with Indus University and Nirma University, Ahmedabad.

- ◊ On World Ozone Day 2020 (16th September), a lecture on "*Ozone layer and ozone pollution: Issues, challenges and future ahead*" by Dr. Manish Naja, Chairman – Atmospheric Science Division, ARIES via GoToMeeting.

- ◊ A national webinar with M G Science Institute, Ahmedabad on "*Remote Sensing & GIS For Plant & Environmental Studies*" on 19th September 2020. Talks by Dr. Prakash Chauhan (Director, IIRS, Dehradun), Dr. Shibendu S. Ray (Director, MNCFC, New Delhi) and Dr. C. P. Singh, a senior scientist in SAC-ISRO, Ahmedabad.

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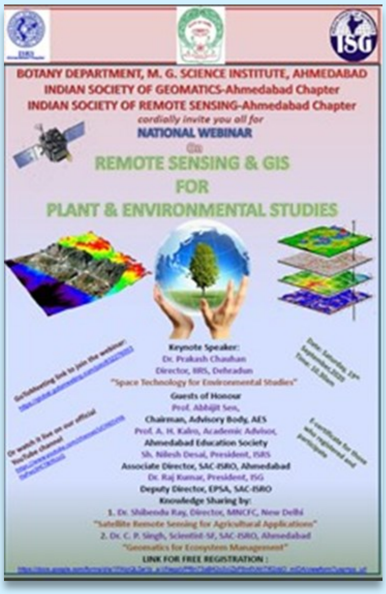
- ◊ ISRS-AC also started celebrating Antarctica Day since this year. A popular lecture (*India in Antarctica*) by Dr. Rasik Ravindra, Former DDG, GSI and Former Director, NCPOR on 1st December.

- ◊ ISRS-ISG National Symposium 2020 (ISRSNS2020) and Annual Convention in ONLINE mode during 18-19th December 2020 with the symposium theme as ***Remote Sensing for Environment Monitoring & Climate Change Assessment: Opportunities and Challenges***.

ISRS-AC ACTIVITIES

JULY 2020—DECEMBER 2020



HIMALAYAN GLACIERS AND CLIMATE CHANGE

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The Himalayan mountain range is one of the significant Water Tower of Asia and stores a large concentration of snow and glaciers. Glaciers are generally described as a mass of ice slowly moving from higher to lower altitudes. The Himalayan region generates more runoff due to high orographic precipitation and delay release due to storage as snow and Ice. The region experiences precipitation during winter in the form of snow and melts during summer. Therefore, water is supplied during the hot and dry season, making many rivers like Indus, Ganga and Brahmaputra perennial. It has helped to sustained Indian civilisation along the banks of these rivers. However, the availability of water from this source can significantly influence in future due to climate change. The Himalayan range is experiencing a higher rise in temperature than the global mean and also higher than Indian subcontinent (Sabin et al., 2020). Besides, no trend in precipitation observed, but snow precipitation reduced. It is influencing the distribution of Himalayan glaciers and seasonal snow cover. It can have a profound effect of availability of water in numerous mountain communities and on people living on Indo-Gangetic plains.

However, the distribution of glaciers is not uniform throughout the Himalayan basins. Indus basin has the largest concentration of glaciers, and it has approximately 26000 sq km area. The average glaciated areas in Ganga and Brahmaputra basins are 11,621 and 15,606 km^2, respectively. The contribution of snow and glacier melt in total discharge is 62% in Indus, 20% in Ganga and 25 % in Brahmaputra basins (Lutz et al., 2014). The contribution is relatively less in Ganga and Brahmaputra basins due to heavy monsoonal precipitation. Therefore, Indus River considered more vulnerable under future climate change scenarios due to enormous contribution from snow/glacier melt, large population, high water stress and geopolitical conditions (Immerzeel et al., 2020).

The Himalaya glaciers are retreating due to increase in temperature and decrease in snowfall. The rates of retreat have probably accelerated in the past few decades. However, the observed tendencies are not regionally uniform. They vary across the entire Himalaya from glacier to glacier, ranging from a few meters to as high as 61 m/a. The mean rate of retreat is -14.2m/a. The large variability in retreat linked with topography, glacier extent, debris cover and climate.

In Himalaya, investigations of 39,500 km^2 glacier area indicate a rate of loss as -4.3±2.4 % per decade. In Indus basin, the area loss rate observed to be -2.5±2.5% per decade whereas Ganga and Brahmaputra basins are losing glacier area at the rate of -2.7±2.4 %/decade and -7.7±9.4 % per decade, respectively. The loss in glacier area is possibly due to changes in mass loss, and mass loss almost doubled from the 1970s (Maurer et al., 2019). In future, due to global warming rise in temperature will be much higher and this will reduce glacier area substantially, creating new hazards for the mountain communities.

One of such hazards is the formation of new glacier lakes and Glacier Lake Outburst Flood (GLOF). Therefore, numerous investigations carried out to map potential lake sites and also a possible expansion of existing glacier lakes. To identify potential lake sites, initially, Laminar flow

HIMALAYAN GLACIERS AND CLIMATE CHANGE (CONTD.)

method was used to estimate the spatial distribution of glacier depth. In this method, depth estimated using surface velocity and glacier slope (Prateek et al., 2013). The Spatial distribution of glacier depth and surface DEM used to estimate bottom topography and over deepening (Remya et al., 2019). This technique can provide a volume of potential lakes and also further expansion of existing lakes. It will help in minimising the potential risk from glacier lake outburst flood to the mountain communities in the Himalaya.

The climate change will influence not only glaciers but also the distribution of seasonal snow cover. The seasonal snow is likely to melt early, potentially changing existing seasonal pattern of stream runoff. It will also lead to early drying of seasonal mountain streams and springs, creating a necessity of new adaptation strategies for the mountain communities. The recent innovation of Ice Stupa in Ladakh is one such example and additional scientific investigations needed for further extension to other parts of the Himalaya. Changing cryosphere and climate is likely to challenge all societal activities in the Himalaya, creating a need for a knowledge-based approach to meet the livelihood challenges of mountain communities.

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APPLICATIONS OF REMOTE SENSING TECHNIQUES IN THE ESTIMATION OF SEASONAL SNOW COVER OVER INDIAN HIMALAYAN REGION (IHR)

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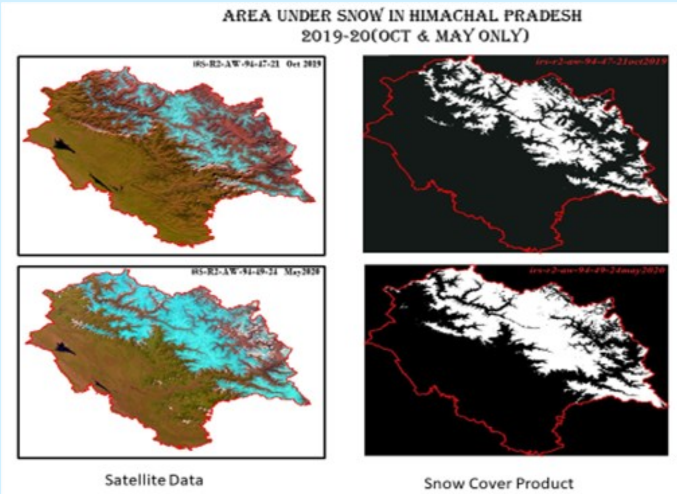
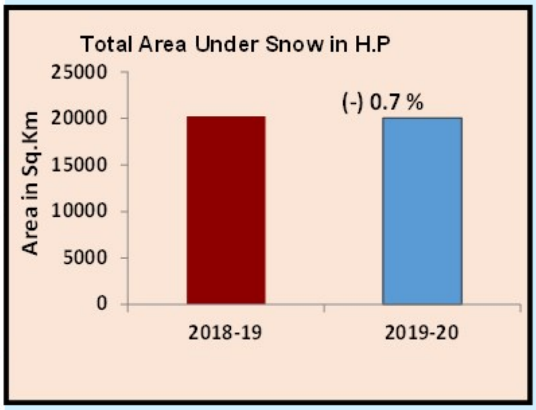
The Indian Himalayan Region more popularly known as IHR extends through 11 Indian States and Union Territories and comprises of five biogeographic provinces i.e., Trans, North West, West, Central and East Himalaya and covers approximately an area of 591 thousand km^2 (Rodgers & Pan war, 1988). It has a large altitudinal range (300-8000m, amsl) and supports a unique flora and fauna. The IHR region has vast areas with about 17 per cent of the region being under the permanent snow cover and glaciers, and about 39-40 percent under seasonal snow cover forming an unique water reservoir. This feeds important perennial rivers that provide water for drinking, irrigation , and hydropower. Every year , about 1,2000,000 million m^3 of water flows from Himalayan Rivers. The IHR is home to nearly 4 percent of the country's population , and provides directly or indirectely for their livelihoods. However, the Himalayan ecosytem is highly vulnerable due to geological reasons, increasing population pressure, exploitation of natural resources and other related challenges. These effects are likely to be exacerbated due to the impact of climate change, which may adversely impact the Himalayan ecosystem through increased temperature, changing precipitation patterns, episodes of drought and biotic influences.

Snow is an essential and a key freshwater resource present in the cryosphere of Indian Himalayan Region (IHR) . Large areas in IHR are covered with seasonal snow cover during winter and snow cover changes significantly due to melting in summer and therefore its monitoring over a period of time is important for hydrological and climatological purposes, as most of the perennial rivers originating from the Himalayas depends upon the snow cover for their discharge dependability. Besides this, the snow cover has the implications on various socio-economic indicators of development like livelihoods, tourism, transport, environment, land management, water and many other developmental activities and the other environmental issues. The snow cover distribution and its patterns are also useful for undertaking various snowmelts run off models studies in order to understand the hydro power potential of different river basins in the IHR (Rango and Martinec 1995; Rango 1996; Singh et al 2000; Kulkarni et al 2002a); therefore monitoring and evaluation of seasonal snow cover is essential and requires a continuous surveillance. The mapping and monitoring of snow cover in the mountainous terrains for planning the developmental activities using ground-based conventional techniques has various limitations such as spatial coverage, time consuming and accessibility and therefore, the applications of remote sensing data by virtue of its synoptic coverage has proven to be very useful technological tool for carrying such studies over the Himalayan region in the real-time manner.

Globally, satellite remote sensing has been extensively used for snow cover monitoring (Dozier et al. 1981; Dozier 1984, 1989; Hall et al. 1995, 1998, 2001, 2002; Negi et al. 2008). The medium spatial resolution (10–90 m) satellite sensors, e.g., Landsat MSS (80 m) and TM (30 m), (15–90 m) and Indian Remote Sensing (IRS) LISS-III (23.5 m), WiFS (188 m), AWiFS (56 m) have been used for the measurement of snow cover of region/basin specific (Kulkarni et al. 2002b, 2003; Kulkarni and Rathore 2006; Gupta et al. 2005; Negi et al. 2005a, 2009). The Moderate Resolution Imaging Spectroradiometer (MODIS) snow cover

APPLICATIONS OF REMOTE SENSING TECHNIQUES IN THE ESTIMATION OF SEASONAL SNOW COVER OVER INDIAN HIMALAYAN REGION (IHR) (CONTD.)





Basin wise Snow Cover in H.P using AWiFS sensor			
Basin	Year 2018-19	Year 2019-20	% Change
Chenab	7644.12	7154.11	(-)6.41
Beas	2418.08	2457.68	(+)1.63
Ravi	2253.49	2108.13	(-)6.45
Satluj	7894.54	8344.08	(+)5.69
Total	20210.23	20064.00	(-)0.72

data are also being used for snow cover mapping which is based on Normalized Difference Snow Index (NDSI).

There are numerous studies with reference to the snow cover mapping have been carried out over the IHR as well as in the Hindu Kush –Himalayan (HKH) Region. As per the study carried out by (Gurang et al. 2011) using MODIS data during the period 2000 to 2010 over HKH reveals that the average snow covered area mapped during this period is 0.76 million km^2 which is 18.23% of the total geographical area of the region indicating the linear trend in annual snow cover from 2000 to 2010 is −1.25±1.13%., which is in consistent with earlier reported decline of the decade from 1990 to 2001. A similar trend for western, central

and eastern HKH region is 8.55±1.70%, +1.66% ±2.26% and 0.82±2.50%, respectively was also observed.

In another study carried out over IHR in the Western and West-Central Himalayan Region during the period 2004-2014 (Rathore et al. 2018) using AWiFS satellite data products confining to the areas within the catchments of Indus, Chenab, Satluj and Ganga basins reveals high variability during accumulation than in ablation period in the snow cover along with a subtle increase in snow cover during 2004–2014. Based on the variability in the area – altitude distribution of the basins, the analysis reveals that the Ganga basin has gentle slope of accumulation and ablation pattern during this period in comparison to the Chenab and Satluj basins reflecting variation in the snow cover form one basin to another. This is further corroborated by the fact that the Ganga basin being at lower altitude receives less solid precipitation in the form of snow during winters in comparison to the Indus (South) and Chenab basin

APPLICATIONS OF REMOTE SENSING TECHNIQUES IN THE ESTIMATION OF SEASONAL SNOW COVER OVER INDIAN HIMALAYAN REGION (IHR) (CONTD.)

which is at middle altitude and the Indus (North) and the Saltuj being at higher altitudes. Further the snow cover area in Ganga basin in comparison to the Western and West-Central basins is comparatively less as about 60% of the total area of Ganga basin lies below 4000m amsl, whereas the snow cover in the western basins is almost same indicating similar accumulation and ablation pattern during this period. The findings of two studies carried out in the HKH and IHR regions seem to be consistent to each other.

The State of Himachal Pradesh that forms a part of the NW Himalayan region receives winter precipitation in the form of snow at the higher altitudes during winter season. About 1/3rd of the total geographical area remains under thick snow cover during the winter season. Most of the major rivers and the perennial streams originating from the Himalayas depend upon the seasonal snow cover for their discharge dependability. Considering the importance of seasonal snow cover as a major input in controlling the hydrology of the river basins, seasonal snow cover assessment in its spatial distribution was carried out in different river basins (Satluj, Beas, Ravi and Chenab) in Himachal Pradesh during the winter season from October to May (2019-20) and it temporal analysis was done with respect to 2018-19 snow cover. Based on the analysis carried out from snow cover mapping in Himachal Pradesh during 2019-20 (October to May) a marginal decrease of the order of about 0.72% in the area under snow has been observed in Himachal Pradesh in comparison to the total area during 2018-19 i.e. total average area under snow in 2018-19 (20210.23 Km^2) has reduced to 20064.00Km^2 in 2019-20. Further during peak winter months, the snow cover area has reduced gradually from February onwards which may affect the runoff patterns during the summer months. Based on the data analyzed, more snow cover has been observed in Satluj basin during winter months (November to January) than the Beas and Ravi basins, whereas Chenab basin has not shown much change in the area under snow during this period. Based on summer month analysis, in Chenab basin (65% of the total basin area) and Satluj basin (50% of the total basin area) will contribute as snow melt in the river system after May onwards in comparison to Beas basin (45%) and the Ravi basin (26%) of the total basin area in 2020.

To summarize, the snow cover is an important parameter in understanding the hydrology of the river basins that sustains the livelihoods of the people living not only in the mountains but also downstream in the plains. The changing snow fall pattern may affect the runoff patterns of the Himalayan rivers affecting the hydro power development and the water requirements of the mountain regions and the remote sensing has a significant role in its mapping and monitoring, which is not possible by the any other conventional method by virtue of the topographical constraints.

WHY WE WENT TO THE WHITE CONTINENT? THE STORY OF 39TH ISEA

C. P. Singh[1], Vivan Prakash[2], Naveen Tripathi[3], Saurabh Tripathi[4]
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Background

Over 170 million years ago, Antarctica and India were a part of the Gondwana and further a part of the super-continent Pangea. Due to plate tectonics, the continents split and moved to form new continents. Antarctica was thus formed and reached its present position about 25 million years ago. Just to put things into perspective, evolution of humans happened later only between 5 – 7 million years ago and still this is the only continent which is uninhabited permanently by humans. Until 17th century, Antarctica, "the white continent" was longing to see a human, the famous explorer Captain James Cook took the lead & circumnavigated this continent during 1772 to 75. Inspired by him, many explorers later attempted to reach there, but could not succeed. Nearly after 150 years (in 1911), a Norwegian explorer Ronald Amundsen finally made it to the South Pole. Only 3 weeks later, a British explorer Robert F. Scott also reached there but it costed his life while returning. Antarctic is surrounded by Southern Ocean and James cook discovered Antarctica while he was crossing the Antarctic Circle. It is the fifth largest continent in the world with its unique wildlife, extreme coldness (winter temperature range is -80ºC to -90ºC), dryness (average precipitation is 10 cm/year), windiness (wind speed can go up to 327 km/h) and unexplored territories. The word Antarctica is derived from the Greek word antarktike, which means "opposite to north" i.e., opposite to the Arctic. The world's largest ocean current, the Antarctic circumpolar current circumvents the Antarctic continent. Of the 14 million-sq.km area, 98% is covered with thick ice sheets that formed about 25 million years ago holding 75% of the earth's fresh water. The average thickness of the ice sheet is about 1.9 km with the highest being 3.6 km near the pole. The remaining 2% ice-free areas of Antarctica houses around 69 major research stations constructed by almost 42 countries, which are spread over the entire continent. There are many summer and logistic stations as well. The largest research station in Antarctica is McMurdo constructed by USA. All these stations are governed by Antarctica treaty, which was first signed by 12 countries in 1959. Currently, with 54 countries, which are party to the treaty, prohibits all kind of detrimental activities (e.g. military activities, nuclear explosions, oil & mineral exploration and waste disposal) and supports only scientific research.

It is going to be four decades from the time the Indian scientists took interest on the frozen continent of Antarctica way back in 1981. India has certainly come a long way since then, both in terms of our scientific accomplishments as well as on the logistics front. India has two functional research stations known as Maitri and Bharati. Maitri was established in the year 1988 on an ice free, rocky area on the Schirmacher oasis (70°45'52" S & 11°44'03" E). Maitri erected over stilts of steel, has shown its durability in 3 decades. It is an inland station about 100 km from the shore at an elevation of about 50 meters above sea level. It can support 25 persons in the main building during summers as well as winters and about 40 in summer facility comprising of containerized living modules. The station consists of one main building, fuel farm, fuel station, lake water pump house, a summer camp and a number of smaller containerized modules. The main building offers regulated power supply, automated heating with hot and cold running water, incinerator toilets, cold storage, living, dining, lounge and containerized laboratory space. The Bharati station established in 2012, about 3000 km east of Maitri, located

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between Thala Fjord & Quilty bay, east of Stornes Peninsula at 69° 24.41' S, 76° 11.72' E at 35 m above sea level is the state-of-the art scientific research station. It can support 47 personnel on twin sharing basis in the main building during summer as well as winters with additional 25 in emergency shelters / summer camps during summers and thus making the total capacity as 72. The station consists of one main building, fuel farm, fuel station, sea water pump house, a summer camp and a number of smaller containerized modules. The main building offers regulated power supply, automated heating and air conditioning with hot and cold running water, flush toilets, sauna, cold storage, aesthetically designed living, dining, lounge and laboratory space. The communication at both stations is through dedicated satellite channels providing connectivity for voice, video and data with India mainland. In order to reach the stations, aircrafts are used from Cape Town, but the voyage from Cape Town, S.A. is most interesting mode of travel. The voyage is performed through a hired ice-class ship. Few scientific works are carried out on board. The ship also keep a smaller boat which can be used for survey and sampling. The ship has a Heli-hangar which accommodates one small helicopter (4/5 seater squirrel) and a Kamov (Russian make) copter. The former is used for conveyance in field in Antarctica while the latter is primarily used to move heavy cargo from ship to the stations.

Over the years, several institute and universities from all over the country have been actively participating in the Indian Scientific Expedition to Antarctica (ISEA), including Space Applications Centre (SAC), Ahmedabad. A wide gamut of research fields have been attempted and executed successfully over the years and the same have been contributing to the world of science in a very significant way. Antarctic region provides an excellent opportunity for conducting scientific research as its one of the most pristine laboratories, of significance to world. Antarctic Regions hold an important place while answering the key questions about the global climate change. Attempts to address some of these issues has helped mitigating on some important problems concerning human life and well-being. Antarctica is a place where ozone hole was discovered. The recent elevated carbon emissions along with greenhouse gases has been a concern as this may lead to rapid melting of ice. If the ice in Antarctic were to melt, the sea level would rise to approximately 63 m, which will affect all the coastal cities by inundating them. Diversity of flora is very low in Antarctica because of its extremely low temperature, moisture, low precipitation, etc., which hinders any plant growth. However, some species of lichens, algae, mosses and liverworts can be found in Antarctica, which can survive extreme cold conditions. Lichens are best adapted to survive at lower temperatures, & with less light & water. Penguins, Skua, Snow petrels, Albatross are the birds which habitat Antarctica which can survive extreme coldness. The marine life consists of whales, fish, cephalopods, seals and krill. Krill has an important role in the food chain as it is the main food source of the Antarctic marine organisms. These Antarctic organisms have different features for surviving the extreme coldness of the continent.

Keeping all these in mind a comprehensive program encompassing the Atmospheric Sciences (climate dynamics, atmosphere-cryosphere

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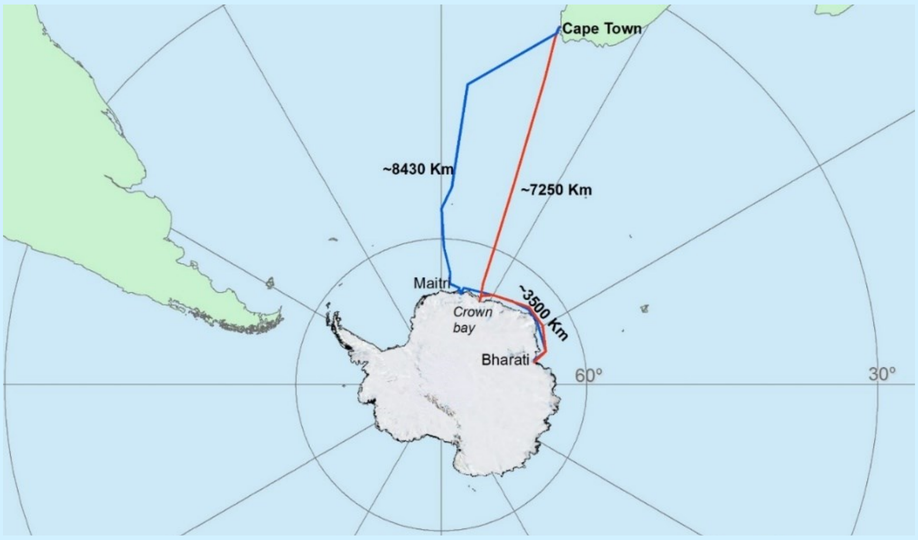

Figure 1: Voyage track map (Red line – Onward voyage route, Blue line – Return voyage route)

interactions, space weather), Biological & Environmental Sciences (molecular ecology, adaptation strategies, sea-ice ecosystems, terrestrial flora and fauna: physiology and population dynamics, food-web dynamics, search for novel bioactive molecules and processes, genomics, human physiology and medicine) and Earth Sciences & Glaciological Sciences (paleoclimate, coastal deposits and soils, sea-ice biogeochemistry, lake biology & biogeochemistry, deglaciation history, Gondwana-India-Antarctica, rift zones studies, meteorite search, geology and geophysics, cryosphere studies) is chalked out by NCPOR, Goa. Most of the projects are for long-term while few are for a short period of 2-4 years. Space Applications Centre started its journey to the white continent in a more organised manner since 28th ISEA (2008-09) with objectives pertaining to remote sensing viz. hyperspectral observation, meteorological observation, laser profilometer measurements, GPR and aerial survey, DGPS measurement, snow fork and spectroradiometer observations, Corner Reflector (CR) / Active Radar Calibrator (ARC) deployment, GNSS reflectometry experiments. During 39th ISEA (2019-2020) two more scientific components were added i.e. Lichen spectroscopy and energy-balance measurements.

The Journey

The 39th ISEA on-board M/V Vasiliy Golovnin spanned 108 days at sea, cruising from Cape Town (December 24, 2019) to Antarctica (January 12, 2020) and back to Cape Town (April 10, 2020) amid the worldwide COVID-19 pandemic situation. The voyage route comprised of four sections *viz.* Cape Town to Crown Bay (January 5, 2020), Crown Bay (January 6, 2020) to Quilty bay, Larsemann hills (January 12, 2020); Larsemann hills (February 19, 2020) to India Bay, Princess Astrid Coast (February 28, 2020); and India Bay (March 24, 2020) to Cape Town (April 10, 2020). To avoid the rough weather a detour was taken during the return journey (fig.1). The voyage covered a latitudinal stretch of southern Indian Ocean from 34° S to 70° S and longitudinal stretch from 0° E to 80° E. In total ~

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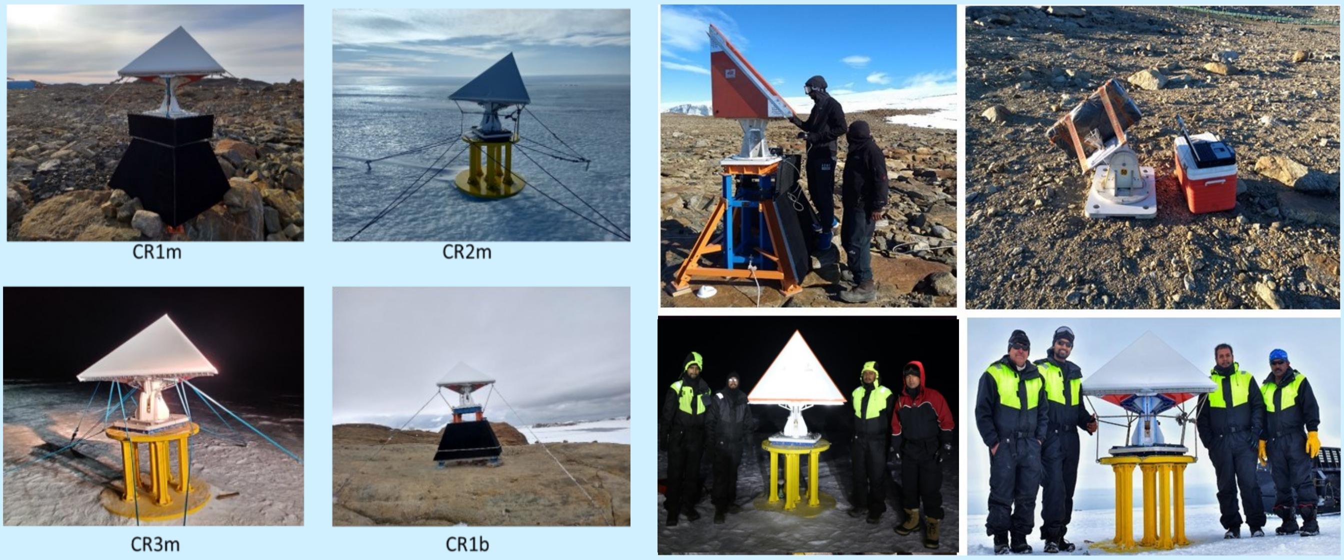

Figure 2: All four permanently deployed triangular trihedral corner reflectors near Maitri and Bharati Research Station, Antarctica during 38 and 39 ISEA *(CR1m-Near Maitri Station (Ascending), CR2m -Ice sheet, Maitri (Ascending), CR3m-Ice sheet, Maitri (Descending), CR1b-Near Bharati Station (Descending) and few field photographs of the CR installations and ARC deployment*

22,000 km, enduring rough seas and bad weather days. During the expedition, science and logistic works were carried out in tandem. The scientific observations for voyage team began as soon as we crossed the Exclusive Economic Zone (EEZ) at -36^{o} S latitude. However, studies planned by SAC having four main elements, *viz*., CR & ARC deployment, polar ice studies, GNSS reflectometry and lichen spectroscopy were taken up as soon as SAC teams reached respective sites in Antarctica. The first team of SAC (Vivan and Saurabh), reached Maitri on December 11, 2019 itself by flight and started the work subsequently. The voyage team (C.P. Singh and Naveen) started the work after reaching Crown Bay on January 5, 2020. Both the teams returned by voyage to Cape Town, South Africa on April 10, 2020. Due to global lockdown all summer expedition members were halted in a hotel for 40 days before they could be repatriated to India (on May 22, 2020), and to further undergo 14 days of institutional / home quarantine. However, with many and varied experiences the objectives were met and further discussed in subsequent section.

Scientific studies of SAC

The scientific studies of SAC in Antarctica are mainly oriented towards the monitoring and assessment of ice dynamics in the parts of East and West Antarctica, covering Indian Antarctic Stations, “Bharati” and “Maitri”. The analysis from synergetic use of *in-situ* and space borne observations from various satellite missions of ISRO, namely RISAT, SARAL, SCATSAT-1, Resourcesat-3 and data from Cartosat series are

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Figure 3: Field Photographs of GNSS reflectometry experiments

major thrust to monitor these changes. CAL/VAL network establishment in Antarctica is another important element for ensuring

the calibration of data from ISRO's SAR missions. GNSS reflectometry for snow depth estimation and wind sensing over waterbody has been a new area of work. Lichen spectroscopy is another added research element towards understanding impact of climate change in Antarctica.

Establishment of Indian Cal-Val Network for Synthetic Aperture Radar (SAR) calibration

Corner Reflector is generally used in calibration of Synthetic Aperture Radar (SAR) satellite sensors as their expected position in a focused SAR image and their expected Radar Cross Section (RCS) is well-defined. It was proposed to establish CR network near Maitri and Bharati station in Antarctica for calibration of future SAR missions e.g. RISAT-1A and NISAR which requires large homogeneous area to cover its full swath of 250 km. Precise locations for all permanently deployed CRs near Maitri and Bharati Research Station will be useful in geometric calibration. Any relative shift observed in ice sheet CRs and near station CR will also provide useful information in computation and validation of ice velocity. Towards achieving these goals, permanent SAR calibration sites were established during 38 ISEA by deploying two CRs, one each at proximity to Maitri and Bharati Research Stations. Site and CR response has also been analysed over various ice sheet locations by deploying CR and Active Radar Calibrator (ARC) synchronous to Sentinel-1 pass. During the 39 ISEA, two Corner Reflectors were permanently deployed on ice sheet near Maitri Research Station in mid-range locations for NISAR simulated footprints (one each for ascending and descending pass). These CRs will also be useful for calibration of RISAT-1A. Cover for previously deployed CR near Maitri Research Station was also changed and one CR was shifted and deployed permanently to a new location near Bharati Research Station. Before permanent deployment, point targets (CR and ARC) were deployed at various ice sheet location for site suitability, impulse response analysis and radome loss experiments synchronous to Sentinel-1 pass. Active Radar Calibrator (ARC) impulse response was tested at various gain levels in different background clutter environment and different

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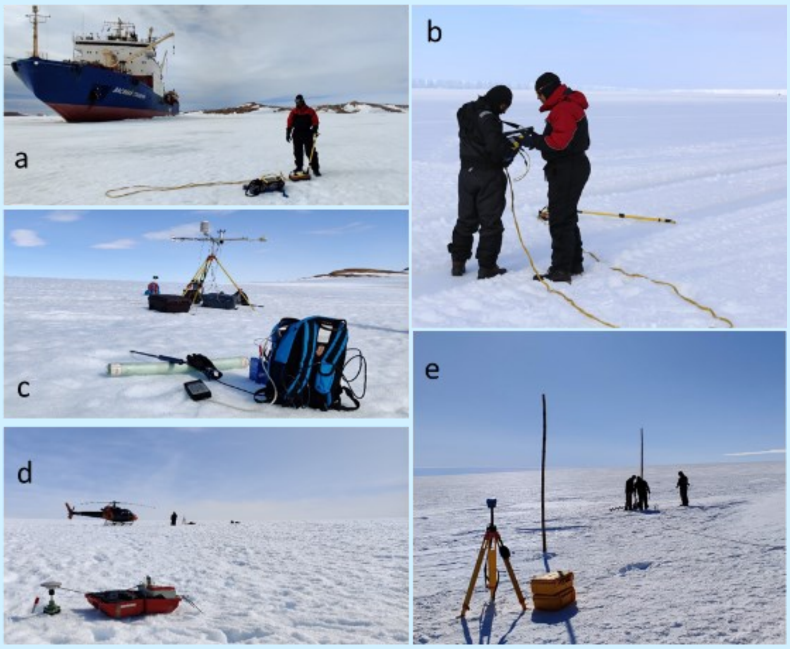

Figure 4: (a) & (b) GPR Observation over Fast ice near Bharti and King Baudouin Ice Shelf, Dronning Maud Land, East Antarctica (c) snow fork and energy balance observations on ice sheet near PB Point, Bharti (d) DGPS observations at Dalk Glacier (e) Stakes Installation and DGPS observations at Polar record Glacier

polarisation. Positive response has been observed for both high resolution (IW mode) and low resolution (EW mode) Sentinel-1 data. ARC will be useful for SAR radiometric and polarimetric calibration due to its handy nature, tuneable RCS and tuneable polarisation nature. The major challenge while working in field used to be the wind-chill induced temperature drops (-35^{O}C), transportation of all required materials to deployment location and securing permanently deployed CRs properly with cover and rope support on same day to avoid any instability due to wind.

GNSS Reflectometry for snow depth estimation & wind speed sensing (in-situ data collection and analysis).

GNSS reflectometry was used for estimation of ice layers depth by measuring reflections in different delays from different layers and monitoring of ice/snow surface properties using interference pattern captured by direct looking antenna for rising/setting GPS satellites. Antarctica being the windiest continent, we were getting wind speed varying from 0 to 30 m/s over the lake surface, which is very rare in the main land. Reflections were taken from the lake surfaces on low and high wind days, which will be used to validate the model with IMD's HSWR (High Speed Wind Recorder) data.

Surface Melting, Ice Dynamics, Elevation Change and Mass Balance Studies:

The scientific measurements for polar ice studies started with GPR (1 GHz) survey over the fast ice (Sea Ice) for snow/ice depth and snow properties measurements (density, wetness and dielectric constant) using snow fork instrument. Surface

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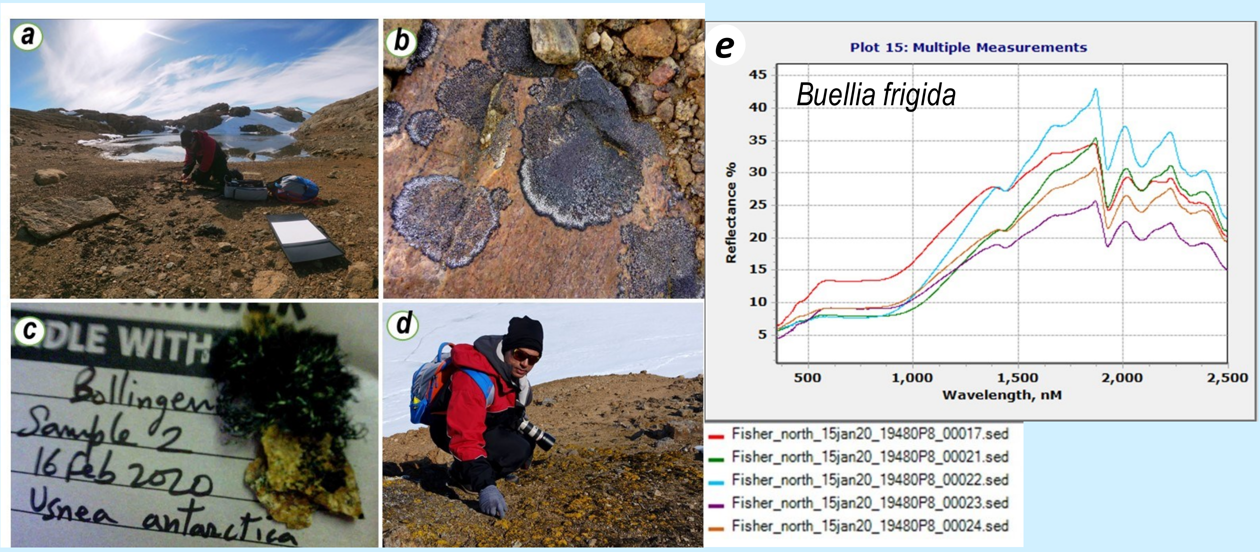

Figure 5: Glimpses of field work during Lichen spectroscopy and sampling at a. Fisher island, b. Buelia frigida at Amrey, c. Bollingen island sample, d. Osmar island and e. Reflectance spectra of B. frigida taken in Fisher island

melting studies, energy balance and snow properties measurements were taken over ice sheet in Bharati and Maitri for about 20 days. These measurements needed to be used for technique development and validation of surface melt products derived using backscatter responses from Indian microwave Scatterometer, SCATSAT-1. It was quite an experience to visit on ice sheet near Bharati where we installed the energy balance instrument. Crossing a wooden bridge and melting ice sheet with sound of channels beneath, is an unforgettable memory. DGPS surveys were conducted for the validation of elevation and velocity observations on ice sheet and glaciers around Schirmacher Oasis and Larsemann hills including Dalk glacier, Polar Record glacier, Potsdam glacier, Dog's neck barrier on the coast of Prince Elizabeth station and on the Amery Ice Shelf between Gallock Island and Reinbolt hills. Furthermore, for ice velocity measurements, new stakes were installed at two very hostile locations on Polar Record Glacier and their DGPS measurements were taken. DGPS survey, for the purpose of surface elevation measurement, was done for about 20 kms of track on marginal ice sheet in the region from

Maitri/Dozer Point to Novo Airport, Sankalp Point and up to 6 kms South of Novo runway. Crevasses in this area is real working challenge which we faced apart from two failed attempts to land in this area due to flat-light conditions and approaching blizzards.

Assessment of lichen distribution in Antarctica using Remote Sensing

With deglaciation exposing new substrates for growth of lichens as they are first coloniser at exposed areas, a reliable wide-scale mapping method for lichens is relevant proposition to study the impact of climate change in Antarctica. Even

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though the overall diversity of the Antarctic flora is somewhat known, most studies have confined to few locations and complete spatial distribution map is not available. In order to assess the remote sensing based lichen distribution in Antarctica, geocoded occurrence records with *in-situ* end-member spectra at 16 sites (islands, nunataks and mountains) were taken. Mainly, Larsemann hills, Schirmacher oasis, Reinbolt hills (Amery) and Bollingen island for data (spectra, samples, presence record – geocoded photographs) were covered. Total 100 *in-situ* end-member spectral signatures of lichen species have been recorded using a field hyperspectral spectroradiometer. Moreover, little more than 100 samples have been collected for further identification and analysis. Some of the islands and mountains visited for lichen sampling were the first by any Indian scientist. The preliminary observations of lichen spectra suggest that the maximum variability between lichen species remains at around 950 nm. Most of the lichens showed a more gradual increase through 400 -1300 nm with a max inflection point at about 680 nm (red edge). Spectra of common lichens are somewhat similar in shape beyond 700 nm, but the magnitude of reflectance varies. More analysis will be required to understand the patterns and the differences. It is expected that, in the absence of satellite based hyperspectral data, the multispectral data from Sentinel, Landsat and Resourcesat satellites can be utilised synergistically to assess the lichen abundance in Antarctica. Witnessing the serene environment, icebergs and wildlife around was amazing experience.

Acknowledgements

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MONITORING OF PRO-GLACIAL LAKES FROM SPACE

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A lake is a body of water surrounded by land, which do not flow but may have flowing water like rivers into and out of them. Most of the lakes on the Earth surface are fresh water lakes, and lies in the Northern hemisphere. Canada has almost 60% of lakes of the World, whereas Finland is known as *The Land of the Thousand Lakes* (approx. 187,888 in number). Many lakes are man-made reservoirs built to produce electricity, for recreation, or to use the water for irrigation or industry, or in houses. However, Natural lakes are generally found in mountainous areas, rift zones, and areas with ongoing glaciation. All lakes are temporary over geologic time scales, as they will slowly shade away in sediments or spill out of the basin containing them. There are 11 major lake types, which are further subdivided into 76 subtypes.

Himalaya possess largest concentration of snow and ice, outside of polar region, and place of origin of lakes in past and present geological time scale. A proglacial lake abuts and extends beyond the glacier terminus. Proglacial lakes are formed primarily due to the isostatic depression near to ice body, or obstacle created by end moraine of a glacier to form a moraine-dammed lake. Large proglacial moraine dam lakes can only form where debris supply at the glacier margin is greater than the capacity of melt stream to transport sediment away and affects glacier mass balance and hydrology. Among various types of glacial lakes, some are formed at the terminus of the glacier due to damming by the moraine brought down by glacier movement across the channel of glacier melt water, if there is a steady rise in the ablation rates of glaciers. Adjoining water bodies in the form of moraine-dammed lake (MDL) considerably accelerates the rate of ablation near the glacier terminus in comparison to ice beneath debris cover. Any catastrophic nature over such high altitude lake poses a serious threat to downstream society and requires a regular spatial and temporal monitoring, made possible by remote sensing based observations from different parts of Electromagnetic spectrum.

Monitoring of Katkar in Zaskar and Gepang-gath glaciers, located in Chandra sub-basins, is discussed as a case study using the using Landsat and IRS images of the year 1976, 1989, 2001, 2006/07, 2012, 2016 & 2019. Both of the glaciers are situated at opposite side of a ridgeline of Indus and Chenab basins. Katkar glacier is debris free glacier with an area of 24.4 sq km and having a slope less than 3^{o} near snout with reference to SOI of 1962. Gepang-gath glacier is debris covered glacier with an area of 13.1 sq km and having a slope less than 2^{o} near snout with reference to SOI of 1962. LISS III, Landsat & SRTM DEM is used for this study.

Figure 1 shows the various features of Katkar glacier, almost a textbook example to discuss various glacier feature. MDL of Katkar glacier was not there during 1962 as per the SOI topographical map. The lake was observed on the corona satellite image of 1965, which was released to global community by US. This shows that this lake was formed between 1962 and 1965. However, supra-glacial lakes, smaller than this are shown on the map. This confirms that the lake is not a matter of omission. Glacial lakes are formed, where the inclination of glacier surface is less than 2°. Slope near snout of this glacier was found to be less than 3^{o} which provide suitable terrain condition to form MDL. Gepang-gath glacier is debris covered glaciers and located in Chandra sub-basin. Approximately

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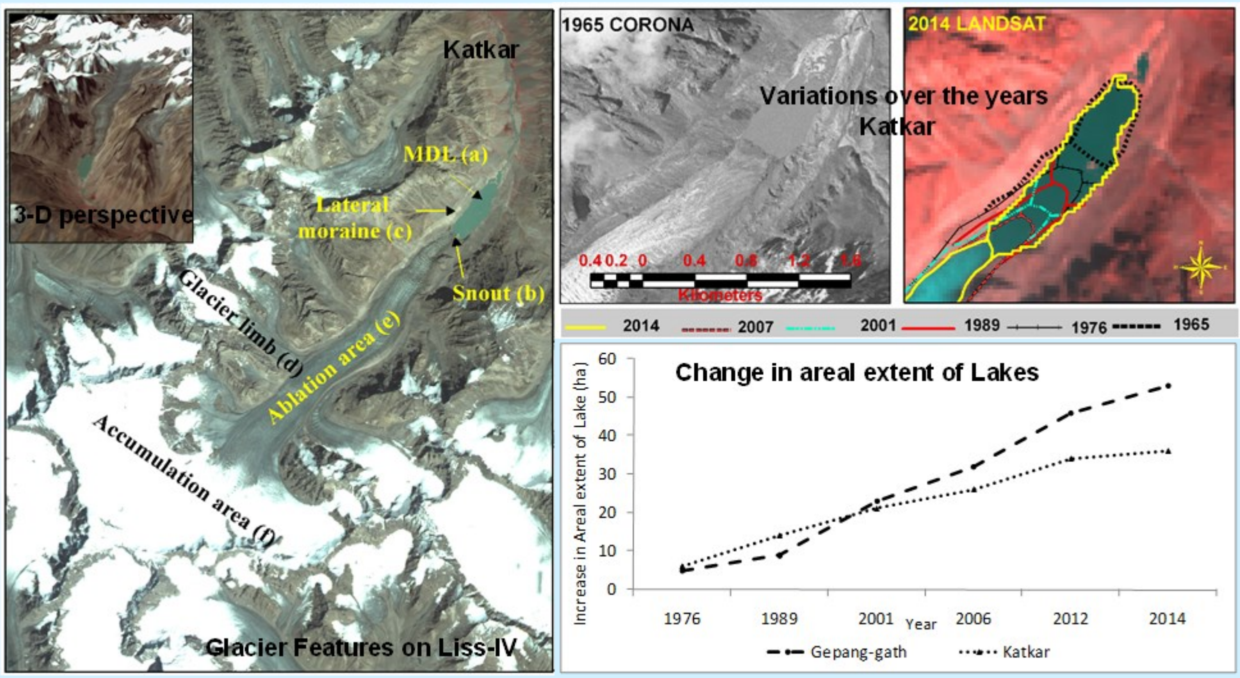

Figure 1: Glacier features along with variations in lake extent over the years and change in areal extent of MDLs.

29% area of glacier is covered by debris. Another important aspect is how much water is stored at such high-altitude lake, and what could be the potential in worst case of outburst. Empirical relation to estimate the peak discharge and probability of lake burst was used which were developed for terrain outside of Himalayan region.

McKillop and Clague (2009) developed the moraine -dammed lake outburst probability model by considering the utility of remote sensing in gathering information and also based on the inventory of 189 moraine-dammed lakes in British Columbia. Parameters considered for this approach are- moraine height-to-width ratio, moraine – ice free or ice core), lake area and geology of moraine constituents s. a. sedimentary, metamorphic rocks.

Peak discharge was found to vary from 196 to 726 m^3/sec and 287 to 1012 m^3/sec for Katkar and Gepang-gath glacier MDLs. The McKillop and Clague probability model yields a very low outburst probability of less than 1% for both the lakes. Outburst probability is very low that indicates, if the lake increases its extent in due course of time, it may not cause an outburst flood. As all the MDLs of Himalayan regions are continuously dewatering by its outlet channels, lakes will not outburst by its own, however natural calamity like earthquake, cloudburst or avalanches may trigger the outburst of these lakes such as happened in the case of Kedarnath flood.

However, it may be difficult to detect the lake during the accumulation month due to presence of

MONITORING OF PRO-GLACIAL LAKES FROM SPACE (CONTD.)

snow and lake may be buried under snow. SAR sensor plays an important role to detect the lake as microwave signal penetrates through snow and interact with buried target primarily due to material properties such as surface roughness and dielectric constant. RISAT-1 images were used to detect MDL of Samudra tapu glacier buried under ~2m thick snowpack conditions during the winter period.

A programme for monitoring and mapping of high altitude lakes is also in progress under Wetland mapping of India at Space Applications Centre ISRO, Ahmedabad. This will help to generate a complete database for all hilly states and also to identify the occurrence and disappearance of such high altitude lakes. A comparative analysis will further be carried out using previous database of year 2005-2006 and present database to be generated using year 2017-2018 images for high altitude lakes above 3000 masl.

The formation of lakes, stored water and probability of bursting out of such lakes can cause flash floods in the downstream areas resulting in damage to life and property. Remote sensing paves a way to map, monitor and assess the possible hazards, and help in taking preventive measures with installing alert system for any disaster mitigation initiatives.

HIMALAYAN GLACIER'S MONITORING FROM SPACE; WHY AND HOW?

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One prominent part of the global cryosphere lies in the Northern part of Indian sub-continent which is physiographically characterized by a mountain system extending from North-West to North-East in an arcuate shape called as Himalayan Mountain system. The system has many ranges and itself is associated with other ranges of Central Asia such as Hindukush, Karakoram, Kunlun Shan, Tien Shan etc. originating from Pamir Knot, and collectively termed as High Mountain Asia (HMA). The high altitudes, moderate latitudes and availability of perceptible atmospheric water over the regions of HMA, make these mountainous regions to hold largest concentration of snow and ice outside of the Polar Regions. The meltwater from snowfall and ice together becomes the source of water to all the river systems originating from these mountain chains in addition to the rainfall. Thus, Indus, Ganges and Brahmaputra river systems, which drain from Himalayan-Karakorum (H-K) mountains to merge into Indian Ocean, are the lifelines for water resources and economic development of Indian subcontinent since the ancient times. Today, more than hundred million people's livelihood depends on the snow and glacier melt runoff from HMA. Therefore, a substantial research through a large number of studies have been carried out to estimate the freshwater reserves of HMA and the changes in the reserves as a result of climatic variations. The snow and glacier reserves of HMA are likely to reduce in future if global warming and associated climate changes continues (Hock et al., 2019). It will have a great impact on water resources of Northern India in future. Few authors have predicted that by 2100, approximately 2/3rd of glaciers of Himalayas will lose their existence (Tawde et al, 2019). In addition to water resources, glaciers contribute to oceans and govern the weather and climate through the exchange of heat between glaciers and atmosphere.

Therefore, monitoring the changes in snow and glaciers is a pre-requisite to keep ourselves prepared for any water crisis likely to happen in future along with increasing demand of water resources due to rise in population and economic development. Conventional methods of monitoring glaciers under harsh climate and inaccessible terrain conditions are quite difficult, economically not viable and limited in numbers for frequent observations. Satellite based remote sensing techniques provide a unique synoptic way to monitor these natural resources which is systematic and unbiased record of scientific observations. Realizing the need of exploring and utilizing the Earth Observation data from its own sensors Space Applications Centre ISRO started projects of cryosphere mapping, monitoring and analysis focusing on North Indian Mountain System (NIMS) consisting of Himalaya, Karakoram and Hindukush (HKH) ranges about three decades ago. Space Applications Centre ISRO has utilized a fleet of active and passive sensors such as LISS-III/LISS-IV/AWiFS series, PAN/Cartosat-1 stereo images, RISAT-1, Landsat series, CORONA, ASTER etc. along with a wide range of ground instruments for developing and validating the retrieved parameters.

Glaciers are natural bodies of snow, ice, water and sediments which move down the slope, annually replenished by snow and melted by heat. In an ideal condition, the mass of glacier every year

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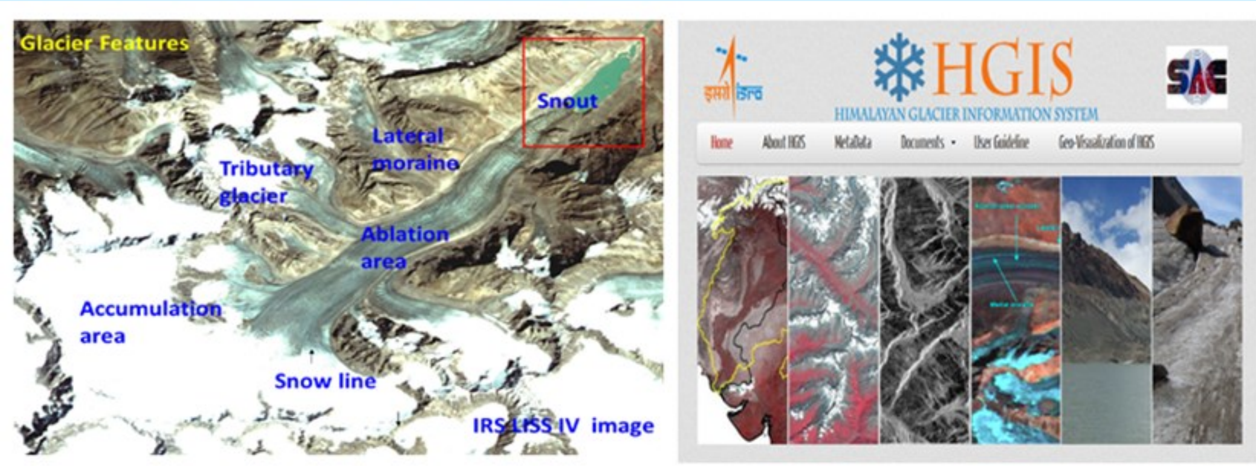

Figure 1. Glacier features shown on a LISS-IV image (left) and Interface of Himalayan Glacier Information System (right).

should remain unchanged, however in nature it is not always true. It remains either positive or negative and sometimes unchanged. But the worry of world is that there is a gradual negative trend of mass balance of glaciers due to global warming. There are a few questions which arise from this point. What is rate of volume change of glaciers on a global average and individually for all glaciers with respect to rise in global temperature at macro and micro level?

In Himalayas, glaciers normally occur above an altitude of 4000m. But this varies from west to east depending upon climate and terrain parameters. The part of glacier at lowest altitude is called as terminus or snout of the glacier. This is the point from where stream originates. There are always two major zones which are identified on any glacier; accumulation and ablation zone. The two zones are based on the definition of mass balance of glaciers. The dividing line of two zones is called Equilibrium Line (EL). The zone above this line is accumulation and below this line is ablation zone. The EL is defined as where mass change of glacier remains zero. The accumulation zone is the zone where mass change remains positive always and on ablation zone mass change remains negative. On the surface, the two zones can be identified by presence of snow and presence of exposed ice or debris covered ice. This line fluctuates each year depending upon mass balance. In winters, the entire surface of glacier remains covered with snow. So one can't identify the glacier outline. As the summer approaches the line goes up and becomes stationary at a specific altitude. For Himalayan region, this time approximates corresponds to months of July, August and September. Only during these months expeditions are carried out. In rest of the months normally glaciers remain covered with snow. As far area of glaciers is concerned there are glaciers which are even smaller than 1 sq km and some are larger than even 700 sq km (example Siachen glacier in East Karakoram region.). Thickness of glaciers can be from few meters to hundreds of meters. In study and monitoring of Himalayan glaciers, scientists face a major difficulty. It is the debris

HIMALAYAN GLACIER'S MONITORING FROM SPACE; WHY AND HOW? (CONTD.)

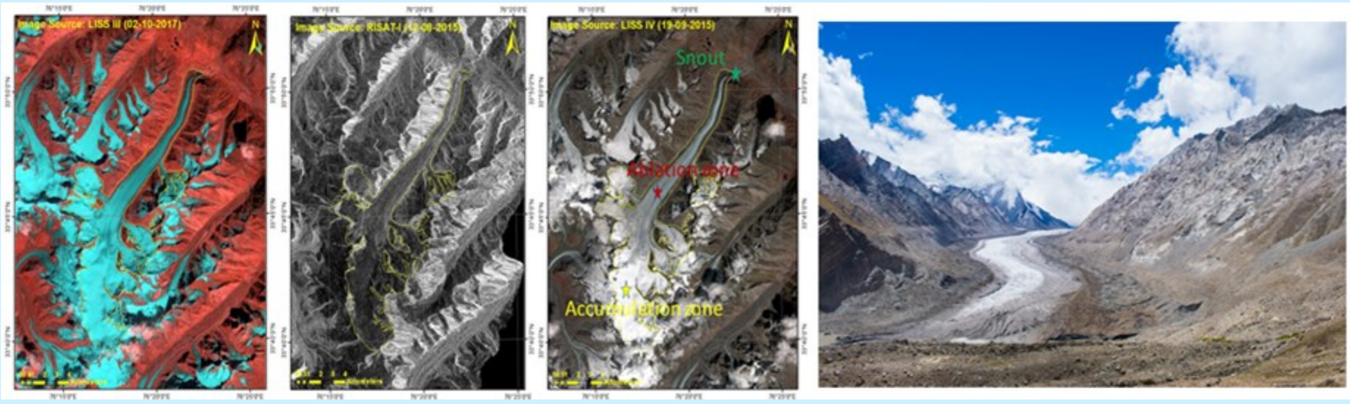

Figure 2. A view of Drung-Drang glacier in Ladakh using AWiFS , RISAT MRS, LISS IV images along with a ground photograph

cover on the ablation zones of glaciers. Debris cover is the accumulation of rock fragments which fall from adjoining mountains on the glacier surface. The size and thickness of rock fragments play a major role in energy exchange between ice and atmosphere. Majority of large and gently sloping ablation zones of glaciers are sometime totally debris free, partially debris covered, or fully debris covered. Therefore, debris cover poses a serious problem in interpretation of fluctuations of underlying ice using remote sensing data. Therefore, the studies of monitoring of glaciers have to take extra care for debris covered glaciers.

There are many dimensions of glacier monitoring. First and foremost is mapping of glaciers which is called as Glacier inventory. It includes mapping and characterizing its attributes of each glacier (Figure 1). There is an inventory called as RGI inventory which includes glaciers of entire world. Similarly, Space Applications Centre has also carried out many inventories of glaciers for different basins of Himalayas in different time frames. Based on this experience, an inventory of glaciers of Indus, Ganga and Brahmaputra basins over H-K region was carried out by SAC using AWiFS and LISS III data of 2003 to 2007. This covers all glaciers of H-K region. Based on this inventory, a system for viewing and retrieving parameters of glaciers was developed called as HGIS (https://vedas.sac.gov.in/SAC_HGIS/). This inventory is now under revision using recent satellite data. Then there are two major approaches to monitor glaciers using satellite images. The first one is based on monitoring area changes, which can be measured directly using medium to high-resolution satellite images. The second approach estimates the annual mass changes of glaciers. This deals with the study of total accumulation of snow on the glacier and total ablation of snow and ice from the glacier in a year. Two popular methods which are employed include a) finding Equilibrium Line Altitude (ELA) or equivalent Accumulation Area Ratio (AAR) by measuring snowline at the end of ablation season using satellite images and relating it empirically with annual mass balance; b) geodetic methods which are based on finding elevation change of glaciers over a period of time using DEMs and converting these changes to volume and mass changes. In geodetic approach, conversion of elevation changes to volume and mass requires

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knowledge of density of snow and ice at the time of image acquisition. There are many other challenges in DEM differencing (see Box). Nonetheless, DEM differencing is a very useful technique for estimating the changes in thickness of glaciers and consequently the mass balance. The third approach is based on energy balance approach and fourth is by hydrological methods. Today, There are many research teams world over which are working on Himalayan glaciers but three decades ago, the seeds of glacier monitoring in Himalaya were sown at Space applications centre. SAC has pioneered in all the approaches in monitoring of glaciers for the last two decades. Recently another dimensions are added by i) retrieving and analysing ice velocity of major glaciers of H-K region and ii) by using RISAT MRS SAR data for generation of glacier surface facies. Recently SAC completed monitoring of 5234 glaciers of H-K region for about one and a half decade. Many expeditions have been carried out to confirm the findings on the ground.

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Why can't we directly perform DEM 1 – DEM 2 to find the change in ice thickness of glaciers?

DEM generation depends on several parameters such as (i) System parameters (photogrammetry, inteferometry , LIDAR, or DGPS etc) which include spatial resolution, orbital parameters, data acquisition methods (along or across track pairs), B/H ratio of stereo pairs, temporal coherence, base line etc, (ii) Technique parameters which include algorithms used for GCP model errors, image matching and interpolation, (iii) Terrain parameters which include type and slope of the surfaces as in snow and glaciated terrain. Ideally, the difference between two DEMs should be zero on non-changing or stable terrain before finding the difference over unstable terrains like glaciers. However, this is rarely the case due to differences in the above mentioned parameters of the two DEMs. Hence, it becomes crucial to first quantify the bias present between the two DEMs before finding the change in elevations of the glaciers.

SEA ICE: OBSERVATIONS FROM SPACE

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Sea ice is one of the most important element of global cryosphere. It is formed when ocean water gets cooled below its freezing temperature of approximately -2°C or 29°F (Source: NSIDC). Such ice extends on a seasonal basis over great areas of the ocean. Sea ice covers about 7% of the Earth's surface and about 12% of the world's oceans (Source: NSIDC). Sea ice is important to the study of oceans because it affects oceanic chemical and physical properties, density structure, oceanic dynamics, and heat exchanges between the ocean and the atmosphere. It covers over 20 million km^2 of the ocean at any given time, greatly limiting the exchange of heat, moisture, and momentum between the atmosphere and ocean and reflecting most of the solar radiation incident upon it. Sea ice provides insulating effect between ocean and atmosphere. But heat can escape rather efficiently from areas of thin ice and especially from leads and polynyas (small openings in the ice cover). Roughly half of the total exchange of heat between the ocean and the atmosphere occurs through openings in the ice.

Much of the world's sea ice is enclosed within the polar ice packs in the Earth's Polar Regions: the Arctic ice pack of the Arctic Ocean and the Antarctic ice pack of the Southern Ocean. Due to the action of winds, currents and temperature fluctuations, sea ice is very dynamic, leading to a wide variety of ice types and features. Depending on location, sea ice expanses may also incorporate icebergs.

In the Arctic region, sea ice starts its growth in September/October and reaches its maximum in March when it covers the entire Arctic basin. This trend is reversed during the summer, and the ice extent reaches its minimum in September. In the Antarctic, the annual fluctuations range between a minimum in February to a maximum in September when ice extends to latitudes between 55° and 65° S. Sea ice area for the year 2020 derived using ISRO's SCATSAT-1 Scatterometer data in the Arctic (within the coverage of SCATSAT-1) shows minima of about 3.3 million km^2 in September to a maximum of about 11.5 million km^2 (almost equal to double the area of Australia) in March (Source: https://vedas.sac.gov.in/vedas_new/view/north_pole.jsp). The corresponding areas for the Antarctic are 2.6 million km^2 and 19.7 million km^2 in February and September respectively (Source:

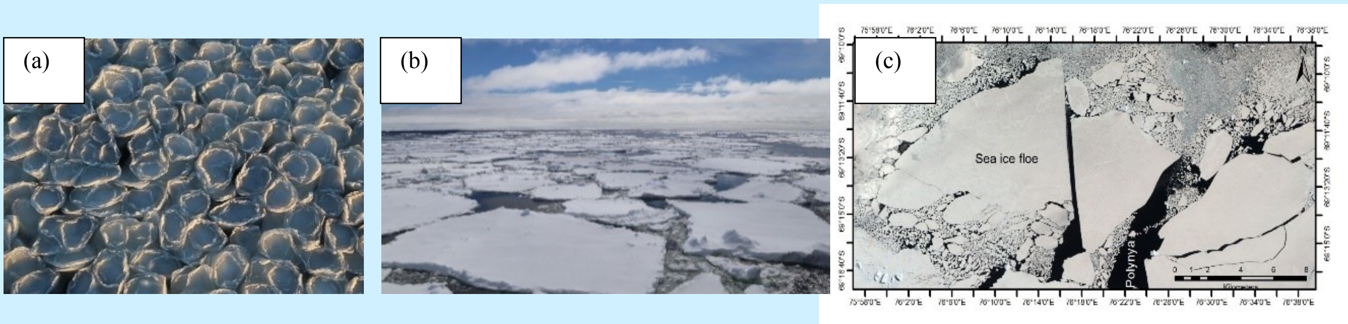


Figure 1: Views of sea ice: (a) Pancake formation-a stage of sea ice formation; (b) Floes of various sizes are visible in the photograph. (66^0 16' 03'' S, 75^0 40' 09'' E; 22 December 2013; 33 ISEA). (c) A satellite view covering large floes and polynyas. (Resourcesat-2; LISS IV; FCC432; 10 January 2016).

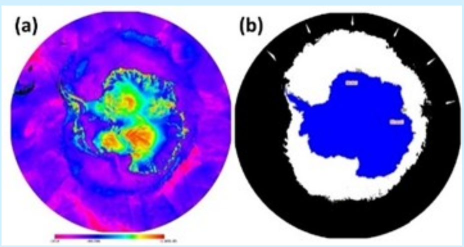
SEA ICE: OBSERVATIONS FROM SPACE (CONTD.)

https://vedas.sac.gov.in/vedas_new/view/south_pole.jsp). Sea ice influences the global ocean and atmosphere in a profound manner. Its continuous interaction with the underlying oceans and the overlaying atmosphere leaves major impacts on weather, climate, and ocean current systems.

It is difficult to study sea ice directly because it forms in remote regions and harsh weather conditions. Ships and submarines have been used to gather data for sea ice, and scientists have established field camps and deployed ocean buoys in the Arctic to study the movement of sea ice. Sea ice is measured from space using both active and passive sensors operating at a variety of wavelengths from visible to infrared to microwave. The passive sensors operating at visible wavelengths such as Landsat ETM+ and Terra and Aqua MODIS provide the highest spatial resolution, typically from 15 meters to 1 kilometer. Active sensors, like radars and lasers, send a signal out and receive it back, whereas passive sensors passively receive radiation coming to the instrument from elsewhere.

Microwave sensors have the advantages that they can "see" in darkness as well as light and that, at particular microwave wavelengths, they are also able to see through clouds. Passive microwave sensors have resolutions ranging from about 5 kilometers to 50 kilometers depending on the particular microwave wavelength used. Because of their ability to see through clouds and darkness, passive microwave sensors have been used to provide a long-term climate record. 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



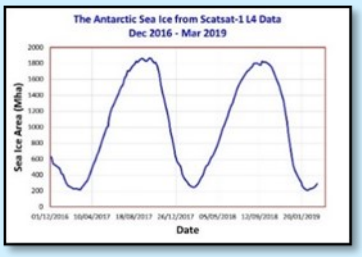


Figure 2 : An example of (a) False Color Image of Scatsat-1 Scatterometer data over the Antarctic for September 25, 2020, (b) corresponding sea ice image (sea ice is while, Antarctica is masked out and (c) The Antarctic Sea Ice Derived using Scatsat-1 Data (L4 Product at 2.25km).

SEA ICE: OBSERVATIONS FROM SPACE (CONTD.)

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 2.25km.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).

An example of sea ice images derived from India's Scatsat-1 scatterometer data is shown in Figure 2 along-with its corresponding False Color image for September 25, 2020.

Techniques are being developed for estimating thickness of sea ice from surface characteristics. 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 (Figure 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.

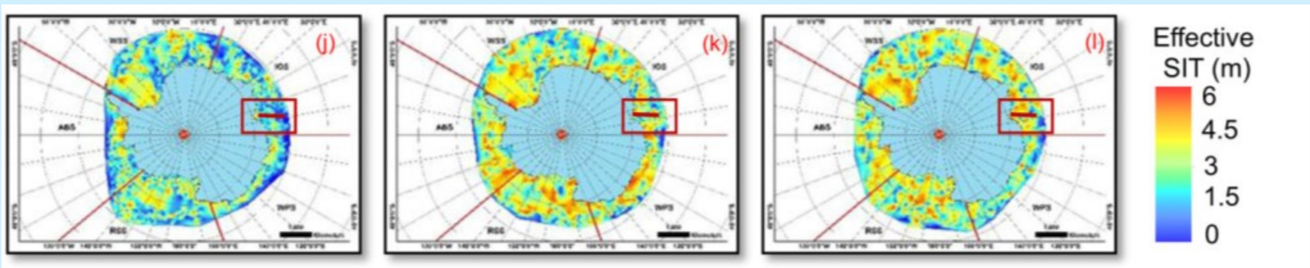


Figure 3: Sea ice thickness in the years 2016, 2017 and 2018 are shown in three maps respectively (left to right) at spatial resolution of 10 km. Transect drawn inside the red square box shows effective sea ice thickness trend.

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Since 34th Indian Scientific Expedition(ISEA), SAC, ISRO provides sea ice advisories to the voyage and NCPOR for safer ship navigation using sea ice concentration, ice thickness and extent and inferences drawn by visualizing the RISAT, AWiFS, LISS3, LISS4 and MODIS data. Based on the experience gained and feed-back received from these expeditions, a Graphical User Interface (GUI) based Web-GIS application to automatize the procedure using sea ice concentration (SIC), AltiKa derived sea ice thickness (SIT) and SCATSAT-1 derived sea ice extent (SIE) products for generation of Near real time sea ice advisory is available on VEDAS has been developed:

https://vedas.sac.gov.in/vstatic/ship_nav/index.html

ELECTROMAGNETIC FOOTPRINT FROM SPACE AS AN ANALYST OF POLAR ICE SHEETS

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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 volume is done by estimating the mass balance of the GrIS and AIS. 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 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 km2), 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 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. Suryawanshi et al. (2019) utilized the SARAL/AltiKa altimeter data for the assessment of change in surface elevations over Antarctic ice sheet (Figure.1). 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

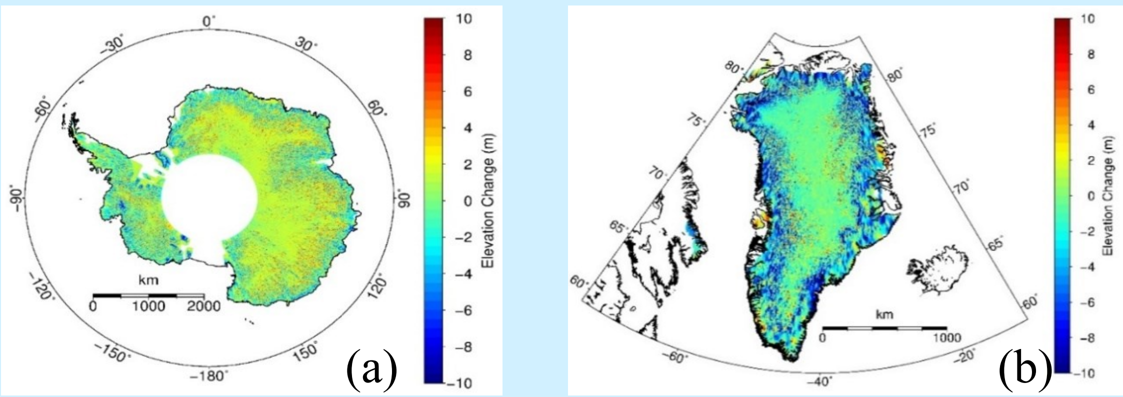

Figure 1: Difference map of AltiKa35 (March 2013 - July 2016) elevations and ICESat DEM (February 2003-June 2005) elevations over the (a) Antarctic ice sheet and (b) Greenland ice sheet.

ELECTROMAGNETIC FOOTPRINT FROM SPACE AS AN ANALYST OF POLAR ICE SHEETS (CONTD.)

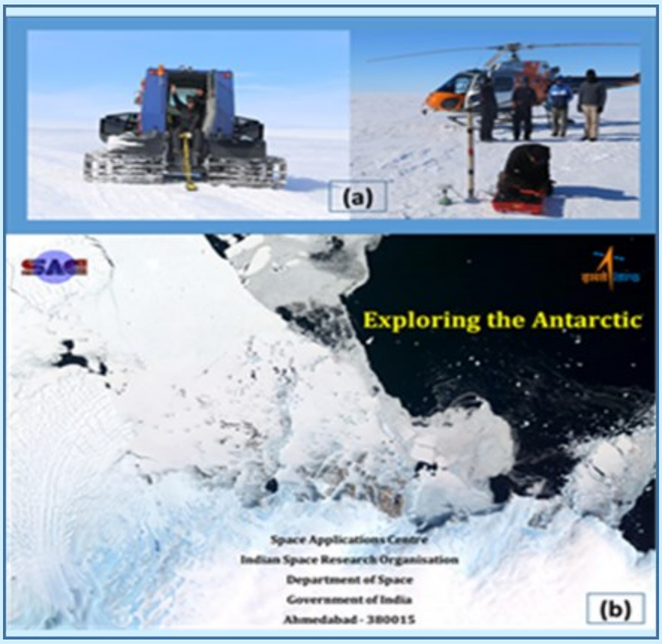

Figure 2: (a) Sample photograph of in-situ data collection by SAC participants (b) cover page of the book 'Exploring the Antarctic'

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.

Antarctica, being largest contributor to snowy and icy regions, carries special importance in energy balance studies. Net energy fluxes at the surface are mainly determined by radiative and turbulent fluxes. The sensible heat flux and the latent heat flux are the main heat source and main heat sink, respectively, in all seasons (Gusain, Mishra and Arora, 2014). Energy fluxes are sensitive to local and regional weather and surface (snow covered or rocky) conditions, and fluctuate drastically from flat interior to steep coast of the Antarctic ice sheet. Moreover, heat loss is compensated by convection, at the flat interior plateau, whereas sublimation plays a vital role at ice sheet margin/coastal region during short Antarctic summer (Van den Broeke et al., 2005). 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 (Oza et al., 2011; Oza 2015; Oza et al., 2019). Studies confirmed that ice shelves in East Antarctica are not immune from warming effects and demand constant monitoring. Meltwater induced by atmospheric warming percolates from the surface into hydrofractures 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 (Oza 2015). SAC has carried out several studies for the assessment of rifts, crevasses and ice calving using optical and SAR data (Darji et al., 2018; Jayaprasad

ELECTROMAGNETIC FOOTPRINT FROM SPACE AS AN ANALYST OF POLAR ICE SHEETS (CONTD.)

et al., 2014). Studies emphasized that that Antarctic Ice shelves are sensitive indicators of climate change due to the direct interface with the warm atmosphere and ocean, which demands for continuous monitoring.

Due to several scientific reasons, Antarctica holds interests from countries across the globe and India is also one of them to have its own science program for Antarctica. India got involved in the Antarctic science expeditions during 1980s. National Centre for Polar and Ocean Research (NCPOR), Goa, is the nodal agency for execution and coordination of expeditions. Participation of SAC, ISRO in the Antarctic Expedition for the exploration of remote sensing technology to understand the polar cryosphere processes started with the 28th Indian Scientific expedition to Antarctic in 2008-09. Since 28th expedition, SAC has participated for several times for the collection of valuable in-situ data (Figure 2a) for the calibration and validation of satellite derived cryosphere products. A book " Exploring the Antarctica" has been published (SAC, 2020) containing the highlights of various scientific studies in the Antarctic region undertaken by Space Applications Centre (Figure 2b).

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REMOTE SENSING NEWS

LAUNCH OF SENTINEL-6 TO MONITOR GLOBAL OCEAN

Sentinel-6, a joint U.S.-European satellite built to monitor global sea levels was launched on November 21, 2020. Sentinel-6 is named after Michael Freilich, the former director of NASA's Earth Science Division, who was a leading figure in advancing ocean observations from space. The mission will extend a nearly 30-year continuous dataset on sea level while enhancing weather forecasts and providing detailed information on large-scale ocean currents to support ship navigation near coastlines. Sentinel-6 will also make atmospheric measurements that can be used to complement climate models and help meteorologists make better weather forecasts.

UN REPORT COMMENDS ISRO'S EFFORTS IN HELPING THE COUNTRY TO FIGHT THE PANDEMIC

The UN report titled, 'Geospatial Practices for Sustainable Development in Asia and the Pacific 2020' has cited efforts made by ISRO in assisting the Indian government towards containing the Covid-19 pandemic. The report specifically cites the role of 'Bhuvan'. 'Bhuvan' played an important role in tracking, identifying hotspots, vegetable markets, food needed, home isolation and pollution. ISRO customized the portal as 'Bhuvan Covid-19'. This platform enabled the country to track the pandemic and keep the public updated on the current situation.

INDIA DRAFTS A NEW REMOTE SENSING POLICY

Department of Space (DoS) has drafted a new 'Space Remote Sensing Policy – 2020' (SpaceRS Policy – 2020). The policy aims at encouraging various stakeholders in the country to actively participate in space based remote sensing activities to enhance commercialization of space technology. It shall come into effect upon approval of the Cabinet.

REMOTE SENSING NEWS

REMOTE SENSING SATELLITE TECH WITH AI FOR MONITORING AIR POLLUTION

In recent research conducted by the London School of Hygiene & Tropical Medicine (LSHTM) and published in Remote Sensing, a fusion of artificial intelligence with remote sensing satellite technologies is done to enable an accurate coverage of air pollution in Britain.

NEW METHOD TO STUDY OLIVINE

Planetary scientists from Brown University have developed a new remote sensing method for studying olivine, a mineral that could help scientists understand the early evolution of the Moon, Mars and other planetary bodies. Scientists have found that a band between 4 and 8 microns, could predict the amount of magnesium or iron in an olivine sample to within about 10% of the actual content. The researchers hope that this study, which is published in Geophysical Research Letters, might provide the impetus to build and fly a spectrometer that captures these previously overlooked wavelengths. Such an instrument could pay immediate dividends in understanding the nature of olivine deposits on the Moon's surface.

FOR THE BOOKWORMS, CHECKOUT THE FOLLOWING COLLECTION:

The Martian by Andy Weir | *The Hitchhiker's Guide to the Galaxy by Douglas Adams*

The Abyss Beyond Dreams by Peter F. Hamilton | ***Out of Orbit by Chris Jones***

2001: a Space Odyssey by Arthur C. Clarke | *Rocket Men: The Daring Odyssey of Apollo 8 and the Astronauts Who Made Man's First Journey to the Moon by Robert Kurson*

An Astronaut's Guide to Life on Earth: What Going to Space Taught Me About Ingenuity, Determination, and Being Prepared for Anything by Chris Hadfield

UPCOMING CONFERENCES

(2020-2021)

Indian Society of Remote Sensing (ISRS) and Indian Society of Geomatics (ISG) is jointly organizing a national symposium on **"Environment Monitoring & Climate Change Assessment: Opportunities and Challenges"** on December 18 -19, 2020**.** This symposium will mainly focus on the emerging climate change issues and will highlight some of the needs to monitor the environment through remote sensing. Some of the major sub-themes are as follows:

- *Space Based Observations for Environment Monitoring*
- *Monitoring Environmental Changes due to COVID-19 Pandemic*
- *Extreme Environmental Conditions and Climate Change*
- *Atmospheric Trace gases and Aerosols*
- *Climate Change Indicators, Impact and Assessment*
- *Current and Future Satellite Missions for Environment Watch*
- *Early Signals of Climate Change and Mitigation Measures*
- *Cryosphere Processes and Climate Change*
- *Desertification, Land degradation and Droughts*
- *Disaster Management and Weather Forecasting*
- *Land-Ocean-Atmosphere Interactions: Science & Applications*
- *Sensor Technologies and Data Processing (UAV, LiDAR, SAR, Hyper-spectral etc.)*
- *Big Data Analytics, Data Mining and Advanced Algorithms*
- *Agriculture, Water and Other Natural Resource Management*
- *Forestry, Environment and Ecosystem Management*
- *Entrepreneurship development in the Field of Earth Observations: Technology & Applications*
- *Astronomical and Planetary Remote Sensing*
- *GNSS systems and applications*

UPCOMING CONFERENCES

(2020-2021)

- ISRS National Symposium on Remote Sensing for Environmental Monitoring and Climate Change Assessment: Opportunities and Challenges, Ahmedabad, December 18-19, 2020.
- 5th World Conference on Disaster Management 2021, New Delhi, November 24-27, 2021.
- ICSIPGISM 2021: Satellite Image Processing and GIS Mapping Conference, New York, January 28-29, 2021.
- ICRSLMM 2021: Remote Sensing for Landslide Monitoring and Mapping Conference, Istanbul, May 06-07, 2021.
- IGARSS 2021: IEEE International Geoscience and Remote Sensing Symposium, Belgium, July 11-16, 2021.
- XXIV ISPRS Congress, The International Society for Photogrammetry and Remote Sensing. France, July 4-10, 2021

MEMBERS' PAGE: RECOGNITION AND AWARDS

DR. ABHA CHHABRA (L-1920)

'Global Land Fellow' for Life

The honorary title of 'Global Land Fellow for Life' is a recognition to Dr. Abha Chhabra's contribution having served as 'Member' of the First Scientific Steering Committee of Global Land Programme (GLP), a global research project of 'FUTURE EARTH'.

Visit https://glp.earth/users/abha-chhabra

PROF. DR. JATINDERKUMAR R. SAINI (L-5042)

* ***DAAD Fellowship*** *by Deutscher Akademischer Austauschdienst (DAAD) (The German Academic Exchange Service), Germany (November 2019)*
* ***'Top Peer Reviewer-2019'*** *by Web of Science (September 2019), Included in top 1% Computer Science reviewers in world.*

ANKUSH KUMAR (L-4449)

ISRO Young Scientist Merit Award

In recognition to the significant contribution in system design, and development of electro-optical payloads for HYSIS, GISAT-1 and Chandrayaan-2-orbiter by Indian Space Research Organization (ISRO) on 13th March 2019.

DESAI DEVANSH PARAG (L-5125)

Young Researcher Award 2020 *by Institute of scholars (InSc), Bangalore on October 2020.*

This award is for the publicationDesai D., Mandowara A., Nigam R (2020). Modeling of rice crop bass using Sentinel-1 backscatter coefficients: A case study over Nawagam, Gujarat, Journal of Agrometeorology, pp. 67-70.

HIREN ARVIND RAMBHIA (L-4998)

ISRO Awards-2018, Category: Young Scientist Merit Award

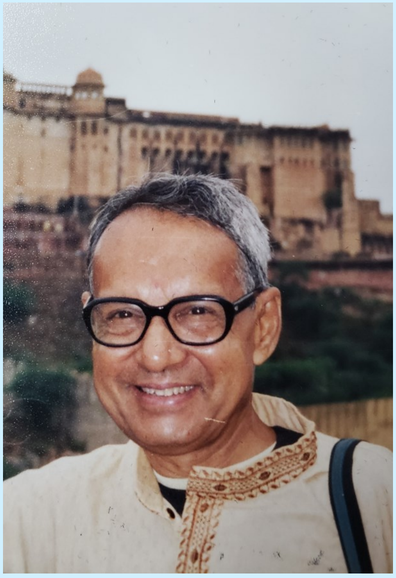
In recognition of innovative contributions to the Indian Space Programme by Indian Space Research Organization (ISRO) on 1st January 2020.

VITHLANI NIPA SUNILBHAI (1357/73-74)

Post Graduate Researcher Award *, by Biotic Science Congress (BioSCon), 2019 held at SCAS, Salem, Tamilnadu*

OBITUARY

DR PRANAV S DESAI (1944-2020)

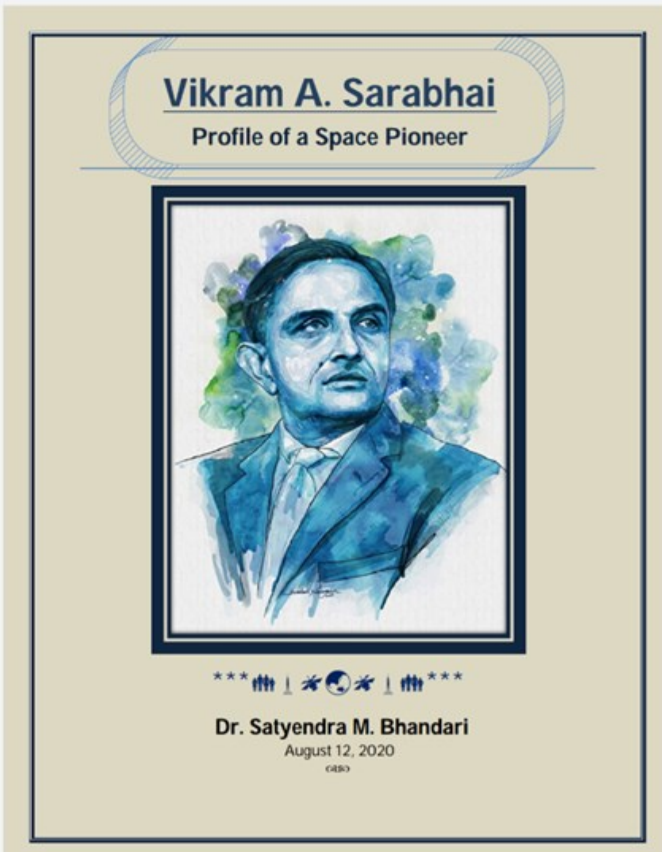


We, the members of Indian Society of Remote Sensing, Ahmedabad Chapter, are deeply saddened with the demise of **Dr Pranav S Desai,** one of brightest scientists and a great human being. He joined Meteorology Division at Space Applications Centre (SAC), Ahmedabad in the year 1977. During his tenure at Space Applications Centre (SAC), he guided his team members and inspired with his immense knowledge of radiative transfer modelling, satellite parameter retrieval and modelling the oceans and atmosphere. He superannuated from SAC in the year 2004. His passing away has left a huge void in the scientific community. He will be remembered for his brilliance and person with a very soft heart!

‘VIKRAM A. SARABHAI – THE VISIONARY SCIENTIST’

BY DR. SATYENDRA M. BHANDARI

BOOK REVIEW: RIMJHIM BHATNAGAR SINGH



“…His soul ventured into the exclusive arena
Reserved only for the chosen one
For he always believed in being Second to None…”

These lines from the poetic accolade ‘Vikram A. Sarabhai – the Visionary Scientist’ by Dr. Satyendra M. Bhandari, presented at the opening of the book, summarizes the whole life of the prophet scientist, encouraging the readers to dive deeper into the book. In a crisp and elucidate language, the author has brought forward the entire life of Dr. Vikram Sarabhai, the Father of Indian Space Science, Technology, Applications & Research (STAR). The short and concise book of just Forty four pages is a must read for all people of all ages to get insight to the inspiring life of Dr. Sarabhai right from his childhood, education, the enthusiasm for research, philanthropy, love for art and culture, magnificent standout on the worlds’ stage and inspiring generations through his legacy of science and culture.

The words from the mouth of Dr. Sarabhai placed under ‘Quotes’ are propitious, which can revive the ingenuity of minds. The book takes the readers through the life’s journey of Dr. Sarabhai through the lucid collection of photographs, systematically arranged to showcase his innocent childhood to the ravishing youth and then to becoming a paragon!

The book is a gift to all the science and space science enthusiasts and has come at the right time when ISRO is celebrating Sarabhai Birth Centenary in a big way!

ISRS-AC EXECUTIVE COUNCIL

2020-2022

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