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ISRO's Geostationary data products archival & dissemination – Retrospect and prospect

PUSHPALATA B. SHAH and UTKARSH

Space Applications Centre, Indian Space Research Organisation, Ahmedabad, India

e mail : pushpa@sac.isro.gov.in

सार – इस भूमंडल पर प्रचंड प्राकृतिक मौसमी घटनाएं अनादि काल से जान-माल की अपार क्षति करती रही है। अभी अंतरिक्ष आधारित तकनीकों तथा उपकरणों का तात्कालिक प्रबंध किया गया है और इसका उपयोग पृथ्वी के प्रेक्षण आंकड़ों को तैयार करने तथा संग्रहित करने में किया जा रहा है। यद्यपि काफी मात्रा में किए गए शोध के माध्यम से मौसम की चरम घटनाओं के सार्थक/सही पूर्वानुमानों से जानमाल की क्षति को कम किया जा सका है फिर भी इस क्षेत्र में आगे और अध्ययन एवं अन्वेषण करने के लिए विश्लेषणात्मक पहल करने की आवश्यकता है। चूँकि पृथ्वी प्रेक्षण की प्रत्येक घटना का बहुकालिक क्षेत्रों में जिसकी तात्कालिक और भूतकालीन जलवायविक अध्ययनों में आवश्यकता होती है में महत्व होता है। इसे संगठनात्मक एवं समग्र रूप से संग्रहित करने और प्रसारित किए जाने की आवश्यकता है। इसको लंबे समय तक संचित रखने के लिए आधुनिक संरचना तथा कटिंग एज टेकलोलॉजी को अपनाने की अपवश्यकता है। उपग्रह संचार सुविधाओं का उपयोग करते हुए जी आई एस ए टी मिशन की भाँति जहाँ 200 मेगा बाईटस प्रति सेकेण्ड की गति से प्रति दिन काफी मात्रा में डेटा का आदान प्रदान होता है निकट समय के डेटा पब्लिक नेटवर्क पर प्रसारित करने के लिए बहुस्तरीय डेटा संग्रहण और तीव्रगति का बेण्डविडथ लगाया जाना चाहिए जिसका उपयोग अनुकूल प्रयोक्ताओं द्वारा किया जा सके। इस शोध पत्र में इसरों के समुद्री मौसम प्रेक्षणों के आंकड़ों के संग्रहरण और प्रसारण के लिए सामयिक इन्फ्रास्ट्रक्चर स्थापित किया गया है और तात्कालिक डेटा तथा मौसम चौकसी चेतावनी का प्रसारण भारतीय ब्रॉडकास्टिंग सिस्टम (आई एम ई टी सी ए एस टी) के द्वारा करने के लिए एक भावी योजना तैयार की गई है अब यह सुनिश्चित किया जाना है कि मौसमी घटनाओं के निकटतम वास्तविक समय की उपग्रह आंकड़ों का विश्लेषण अंतिम प्रयोक्ताओं तक समय पर उपलब्ध हो सके।

ABSTRACT. Natural extreme weather events have been causing excessive damage to life and property across the globe since time immemorial. Space based techniques and instruments have been improvised and utilised over the years to generate and collect earth observations data. Although a significant amount of research has led to meaningful forecasts of extreme weather events leading to minimising of the loss of life and property, the analytical approaches in this field need to be further studied and explored. Also, since every instance of earth observation is significant in multiple time domains (current as well as past which is required for climatology studies), it needs to be archived and disseminated in an organised and holistic manner. For long time preservation, modern infrastructure and underlying cutting edge technologies need to be adapted. With missions like GISAT, where the volume of data handled per day will be around 200 Mega bytes per second, multi level strategic approach for archival and high speed bandwidth for near real time data dissemination on public networks should be complemented with data broadcast to strategic users, using satellite communications. This paper describes the current infrastructure established for archival and dissemination and archival of ISRO's Met-Ocean data observations and the future road map in the area of instantaneous data and weather alerts dissemination through an Indian broadcasting system (IMETCAST). This is to ensure timely delivery of satellite data to end users to facilitate near real time analysis of weather events.

Key words – Geostationary, Broadcast, Archival, Dissemination, Near real time, GISAT, Internet, IMETCAST, Infrastructure.

1. Introduction

The first weather satellite TIROS-1 launched by NASA set the pace for acquiring and archiving data from satellites and disseminating the same to the scientific community through Data Centers. NASA has adopted a strategy of mission specific data centers disseminating data though various web sites like National Climatic Data Center (NCDC-NOAA) [http://www.ncdc.noaa.gov/], National Space Science Data Center (Goddard Space Flight Center) [http://nssdc.gsfc.nasa.gov/], EarthExplorer (USGS) [http://earthexplorer.usgs.gov/], Earthdata center [https://earthdata.nasa.gov/], National Snow and Ice Data Center [http://nsidc.org/] and so on. The data center

TABLE 1

Current and future Geostationary and LEO Meteorological satellites

Long	Name	Launch	Instruments on board
Current geostationary meteorological satellites			
74 ° E	Kalpana-1	2002-09-12	DCS , VHRR
82 ° E	INSAT-3D	2013-07-25	DCS, IMAGER, SAS&R, SOUNDER
93.5 ° E	INSAT-3A	2003-04-10	CCD, DCS, SAS&R, VHRR
Current low earth orbiting satellites			
98.55°	SARAL	2013-02-25	A-DCS, AltiKa, DORIS, LRA (CNES)
20°	Megha-Tropiques	2011-10-12	MADRAS, ROSA, SAPHIR, ScaRaB
Future geostationary meteorological satellites			
74 ° E	INSAT-3DR	≥2015	DCS, IMAGER, SAS&R, SOUNDER
74 ° E	INSAT-3DS	≥2022	DCS, IMAGER, SAS&R, SOUNDER

consolidation initiative was highlighted in 2012 at the Symposium Uptime Institute [Petraska (2012)]. In 2014, NASA floated a request for Information (RFI) document for data center consolidation with a goal to achieve energy efficient data center [Petraska (2012)]. This establishes the need of consolidated data centers to provide satellite observation data at one place to increase availability and has been followed since inception of ISRO's Geostationary Data Products Archival & Dissemination Information System.

ISRO's first meteorological satellite METSAT (*i.e.*, KALPANA-1) was launched on 12 September, 2002 followed by INSAT-3A launched on 10 April, 2003 with an exclusive earth station for data reception at IMD Delhi. In order to cater to the growing requirements of data by the academia and research community in India, ISRO setup its own earth station and data reception centre at Bopal campus Ahmedabad around 2007-2008 time frame. Initially, data from International data providers was downloaded and archived and made available for use within ISRO by special interest groups working in meteorology and oceanography. This facility was called MOGWEB. With the regular inflow of data from the Bopal Earth Station, the need for expanding and up-scaling the infrastructure for met-ocean data archival and dissemination was the driving factor for establishing Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC). Also, seamless access to data was a prime requirement for the Indian Scientific community for the near real time analysis and alert warning mechanisms during extreme weather events such as cloud burst, cyclone etc. and reach to the society at large.

With a mission to conduct atmospheric, oceanic and environmental research using space technologies for societal benefits ISRO currently has three Geostationary Meteorological Satellites namely INSAT-3A, KALPANA1 and INSAT-3D and two low earth orbiting satellites namely MEGHA-TROPIQUES and SARAL-ALTIKA (Table 1). They contribute to the Integrated Global Observing System of the WMO, *i.e.*, WIGOS. The fact that observational data are unique and not reproducible lends to the conclusion that these should be preserved as part of the historical record of the dynamic behaviour of the Earth [National Research Council (1997)]. These data sets are used in conjunction with data from NASA and EUMETCAST for predicting extreme weather events such as cyclones, heavy rains and sea state.

The life span of the dataset is unlimited as the same forms an integral part of climate studies and also constitutes as primary data for researchers and modellers. At ISRO, the responsibility of archiving and disseminating this precious data is shouldered by Space Applications Centre (SAC) through MOSDAC (Meteorological and Oceanographic Satellite Data Archival Centre, www.mosdac.gov.in). The data centre processes, archives, documents, and distributes data from current Earth-observing satellites and field measurement programs in a consolidated manner and ensures the near real time delivery.

2. Early practices

Initially, access to science data (satellite observations) was limited to small group of users. In early

Fig. 1. Data ingestion, archival and dissemination

1980s science data were generally held by Principal Investigators (PIs) or held at specialised data systems. This limited the data access to only PIs or small team responsible for generating the data. Data policies for redistributing data were absent [Ramapriyan, *et al.*]. To cater to the needs of much larger scientific community and support the collaborative activities, more open data storage/archival systems evolved and were supported by establishment of Data Archival Systems.

3. Archival systems standards

A fundamental design requirement for major digital preservation and repository development efforts is the Open Archival Information System (OAIS) [Lavoie (2000)] as per the ISO 14721 standard. OAIS is an archive, consisting of an organization of people and systems that has accepted the responsibility to preserve information on a long term basis and make it available to the Designated Community. "Long term" is long enough to be concerned with the impacts of changing technologies, including support for new media and data formats, or with a changing user community. There is a particular focus on digital information, both as the primary form of information held and as supporting information for both digitally and physically archived materials. There are five functional entities in an OAIS and each of these have been established and implemented at MOSDAC.

Ingest : It involves reception of information from producers and packaging it for storage. It accepts and verifies a SIP (submission information package), creates an AIP (Archival Information Package) from the SIP and transfers the newly created AIP to archival storage. The Bopal Earth Station of SAC is setup for the tracking and reception of geo stationary satellite signals. Data is acquired at the master data reception system and the data products generation system generates the final products required for weather and ocean studies and analysis.

Archival storage : This calls for the storage, maintenance and retrieval of the AIPs. It accepts AIPs submitted from the Ingest function, assigns them to long term storage, migrates AIPs as needed, checks for errors, and provides requested AIPs to the Access function. Before the products are archived at MOSDAC, they are made available at various ftp sites for near real time access by scientific community and finally archived on NAS storage with supporting information (*i.e.*, metadata) stored in Oracle 10g database.

Data management : This system coordinates the Descriptive Information of the AIPs and the system information that supports the archive. It maintains the database that contains the archive's information by executing query requests and generating results; generates reports in support of other functions; and updates the database. At MOSDAC this activity is enabled with every data set acquired and the entire chain from data acquisition to archival is fully automated as shown in Fig. 1.

Administration : MOSDAC administrator manages the daily operations of the archive in-line with the functions defined by OAIS. MOSDAC Administrator attends to submission agreements from information producers, performs system engineering, audits SIPs to ensure compliance with submission agreements and develops policies and standards. He/She handles customer services and acts as the interface between Management and the Designated Community in the OAIS environment.

Access : This activity includes the user interface that allows users to retrieve information from the archive. It generates a Dissemination Information Package (DIP) from the relevant AIP and delivers it to the customer, who has requested the information. MOSDAC offers an on-line data search and retrieval mechanism supported by WMO compliant metadata and search filters across various elements such as satellite missions, parameters, resolution, time stamps, payloads etc. All data is served over user designated FTP locations.

Modes of data dissemination / distribution : Prediction and forecasting of extreme weather events need to be supported by near real time data services from various satellite missions. The forecasting models have improved significantly, thereby leading to effective preventive measures being taken by administrators to see that loss of life is minimised. In current times, data products and services are made available via direct dissemination / readout, Global Telecommunication Systems (GTS) and ftp over Internet.

(*i*) *Broadcast of data* - Broadcast of data received from both geostationary and polar orbiting satellites provides suitably equipped users with real-time access independent of any telecommunications infrastructure except the data receiving station. Users within the satellite's field-of-view can receive such data via dedicated user reception systems employing a fixed antenna. The latest generation of geostationary satellites can broadcast data to users having High Rate User Stations (HRUS) and Low Rate User Stations (LRUS), making use of the High Rate Information Transmission (HRIT) or Low Rate Information Transmission (LRIT) standards, respectively. For polar orbiting satellites, instrument data at level 0 may be received via dedicated user reception systems employing a tracking antenna, whenever a satellite is within reception range (*i.e.*, when the elevation of the over passing satellite at the reception site is greater than around 5°). The latest generation of polar orbiting satellites can also broadcast data to users having High Resolution Picture Transmission (HRPT) reception systems and Low Resolution Picture Transmission (LRPT) reception systems making use of the HRPT or LRPT standards respectively.

(*ii*) *Global telecommunication system (GTS)* - Many satellite products, especially those processed to level 2 (by and large geo physical parameters) or above are distributed to WMO member states via the GTS. Typically they are injected onto the GTS via links to regional GTS hubs and transmitted in one of the approved WMO binary data exchange formats such as BUFR (the Binary Universal Form for the representation of meteorological data) and GRIB (WMO General Regularly distributed Information in Binary form).

(*iii*) *Commercial telecommunication satellites* - In recent years emphasis has been on the use of commercially available telecommunications satellites for the purpose of distributing meteorological satellite data and products. Data distribution can be optimized from a pure telecommunications point of view and evolve with time in order to meet new requirements and benefit from the most cost-efficient technology. The most widespread approach involves file transmission with Internet Protocol (IP) using Digital Video Broadcast by Satellite (DVB-S) as available from various telecommunications operators around the world. This allows data rates of tens of Mbps to be received with standard low-cost equipment. Dissemination is performed in Ku-Band or in C-band. C-band offers more robust signal strength in inter tropical regions because of its lower attenuation by water vapour and liquid water. It is however more sensitive to local interference with radars.

These services can offer unified access to various sources of data including different satellites, geostationary or LEO, as well as multi-satellite composite products, R&D products, high-level products and non-satellite information. Satellite data dissemination *via* such systems is not specific to the satellite user community and is a component of the WMO Information System (WIS). The most developed system of this type is the EUMETCast service, which is EUMETSAT's Broadcast System for Environmental Data. Using EUMETCast as a backbone, a global dissemination system is being established through the Integrated Global Data Dissemination System (IGDDS) project.

(*iv*) *Internet* - Satellite data are widely available on the Internet, both for public consumption and also as a means to disseminate data to a limited set of users. Satellite data and derived products are transferred using both http and ftp Internet protocols by satellite operators and data processing centres using both 'push' and 'pull' methods. The nature of the Internet combined with the typical data volumes is such that this method is usually not appropriate for critical near-real-time data sets but, with ever increasing bandwidth and improving performance and resilience, there is a trend towards increased use of Internet as a means to disseminate satellite data.

TABLE 2

Data Utilisation for Near Real Time Phailin analysis for period 8-13 October, 2013

Mission	Product count
KALPANA	10775
INSAT3A	19
MEGHATROPIQUES	330
SARAL	146

Distribution of ISRO satellites based met-ocean data over GTS is done by IMD, which is the Regional Telecommunication Hub (RTH) for the GTS. It collects and disseminates the data and products within its area of responsibility and also facilitates exchange of such data with other RTHs [Meteorological Telecommunication].

4. Mosdac data services

Currently, MOSDAC provides near real time data services on the National Knowledge Network (NKN) at 50 Mbps bandwidth, to operational agencies like NASA (SAPHIR data of Megha- Tropiques), National Centre for Medium Range Weather Forecasting (NCMRWF) (EUMETCAST data) and IMD, Delhi (KALPANA-1 data).

Around 2TB of data is downloaded by users from MOSDAC on a monthly basis. Typical applications of the MOSDAC data are related to cyclone prediction, weather forecasting, heavy rain forecasting, heavy rain reporting and nowcasting of cloud burst in Western Himalayan region. Typical utilisation of Satellite data for the real time analysis of cyclone Phailin [SAC Internal report (2014)] for the period 8-13 October, 2013 is given in Table 2.

According to Mr. Mritunjay Mohapatra of the disaster warning division of IMD, Delhi, "The images from INSAT-3D give better resolution and allow more precise forecast". Data from the Indian satellites KALPANA, INSAT-3D, OCEANSAT and MEGHATROPIQUES are used for data assimilation in weather prediction models by NCMRWF [Progress in Weather and Climate Prediction].

5. Infrastructure

With the launch of new geostationary satellites, the data volume at MOSDAC being moved and stored across the network has increased exponentially. Hence, multilevel strategic approach is put in place with various components and supporting systems. Each component and its supporting system is implemented to work together flawlessly in order to secure, store and exchange data.

Infrastructure for ensuring long-term data access requires modernizing data archives and addressing requirements of long-term data preservation, search & retrieval accessibility, and security requirements. The long term preservation and management of satellite data must meet two basic prerequisites [NEC Corporation of America (2009)] *viz*., Archival and storage. It involves:

Archive : Archiving of satellite data, preparing metadata to provide representation information, packaging information, content information and other descriptive information, efficient search capabilities and separate content storage from applications to facilitate physical and logical migration support at the data layer.

Storage : Massive scalability, greater operational predictability, resiliency and minimum downtime.

Out of various functional and vulnerable elements of archival system, Storage is most critical. Traditional, Direct-Attach Storage (DAS) preference has lowered with the complexity of applications. Network Attached Storage (NAS) or Storage Area Networks (SAN) provide faster data speeds such as 10GbE – 40GbE – 100GbE (Gigabit Ethernet) and 2GFC - 4GFC - 8GFC and future 16GFC (Gigabit Fibre Channel) and can be front-runners in reducing complexity of design and implementation. To achieve better performances of backup and restore operations [Chervenak, *et al*. (1998)] more advanced storage system can be considered like Venti [Quinlan and Dorward (2009)] that identifies data blocks by a hash of their contents.

Trends in Infrastructure development for data archiving are towards satisfying standout characteristics of scalability, low cost of backup & recovery, easy migrations and environmental factors. These include supporting User-Centric Computing where users use personal devices for work, software-defined everything and reducing carbon-footprints. Software-defined everything defines Software Defined Data Centers (SDCC), Software Defined Networking (SDN) and Software Defined Storage (SDS) [Barroso and Hölzle, 2009]. It is also crucial for Cloud based archival, dissemination services and enables delivery of true infrastructure-as-service and platform-as-a-service with requisite performance, availability and security requirements.

6. Future perspective

ISRO has made its mark among space faring agencies with a progressive space program and

Fig. 2. Scope of environmental data

international collaborations in launching of satellites and exchange as well as sharing of data. Globally, climate and weather are major research areas, especially with the current understanding of global warming and its manifestations. This research needs to be supported with large volumes of meteorological data. The current concept of collaboration emphasizes on complementary roles – payload developed by one country is launched by another country and the data is shared globally for near real time applications and studies. Such synergy calls for international standards being adopted at all stages of the ground segment with fault tolerant mechanisms in place.

The current global scenario for data sharing has been examined by us. Current operators in this field are FENGYUNCAST (covering Asia-Pacific region), GEONETCast-Americas operated by NOAA covering North and South America and EUMETCast operated by EUMETSAT covering Europe, MiddleEast, Africa and the Americas. On similar lines, India can play a major role in the SAARC (South Asian Association for Regional Cooperation) nations by setting up an Indian Met data broadcasting (IMETCAST) and dissemination system that can distribute products, in situ data, environmental data as well as weather alerts. A huge variety of data can easily flow into the system by virtue of the products from various satellites like INSAT3A, KALPANA1, MEGHATROPIQUES, OCEANSAT Ocean Colour Products, OCEANSAT-SCAT PRODUCTS, INSAT3D Imager and Sounder and SARAL ALTIKA as well as all other proposed follow on missions.

The next promising geo stationary satellite from ISRO is GISAT, a Geostationary Imaging Satellite, which has Multi spectral bands VNIR and LWIR at ~50 m resolution and Hyper spectral bands HyS-VNIR/SWIR at ~500 m resolution and MX-LWIR band at 1.5 km resolution covering a spectral range of 0.4 microns (visible) to 13 microns (thermal) [SAC-ISRO Internal Document].

The various scan modes planned with reference to meteorological and agricultural applications of GISAT are

(*i*) Full globe (18° * 18°) scan of 74 minutes in MX-LWIR and MX channel for 390 minutes.

(*ii*) Indian sub-continent and surrounding ocean (10° * 10°) scan of 25 minutes in MX-LWIR and MX channel for 130 minutes.

(*iii*) Indian land mass (5° * 5°) scan of 6.5 minutes in MX-LWIR, 36 minutes in MX channel, 231 minutes in MX + HyS channel and for 177 minutes in HyS channel. Indian peninsula and coastline (3000*3000 km) scan of 3.2 minutes in MX-LWIR, 18 minutes in MX channel, 104 minutes in MX + HyS channel and for 71 minutes in HyS channel.

(*iv*) User defined area (1000*1000 km) scan of 1.1 minutes in MX-LWIR, 7 minutes in MX channel, 37 minutes in MX + HyS channel and for 19 minutes in HyS channel.

This will result in large volumes of data available in a timely manner to support meteorology, weather applications, disaster monitoring, oceanography, forestry and agriculture monitoring and management.

The IMETCast may also have a separate channel to broadcast environmental alerts like cyclones, forest fires, heavy rains, fog, smoke etc. This will be further supported by on-line analysis tools and modules for the new generation of weather researchers and oceanographers.

The scope of environmental data is best depicted in Fig. 2. The data management challenges go beyond just volume of data. The challenges are in terms of data discovery and integration, data stewardship and information, what to archive and where and how to archive. Procedures for making archive decisions and how it fits in the end-to-end environmental data management life-cycle will be evolved. The Environmental data will be made visible, accessible and independently understandable to users, except where limited by law, regulation, policy or security requirements. Other major requirements are:

(*i*) Developing and maintaining metadata throughout the environmental data lifecycle that comply with standards.

(*ii*) Enabling integration and/or interoperability with other information and products.

7. Conclusions

Space-based and space-age instrumentation have played a major role in observing the earth’s atmosphere, oceans and land surface, other planetary atmospheres, and astrophysical phenomena will continue to evolve and expand. In the perspective of the futuristic trends it is assured that all geostationary satellite data will be preserved and distributed in a manner commensurate to :

- Lead and conduct research programs that advance our understanding of atmospheric, oceanic, environmental and astronomical science.
- Facilitate the transfer of knowledge to operational observing and forecast systems.
- Support research initiatives with technical and management expertise.
- Support undergraduate and graduate students in the research process.

The data archival and dissemination setup is being upgraded to cater to forthcoming missions like GISAT. This mission will help in generating alerts related to natural disasters, floods and forest fires within five minutes (approx.) of the event. Currently, all weather products from Indian satellite Missions are generated indigenously on an operational basis. Data is made available in near real time. Weather alerts and warnings are disseminated through on-line decision support based web applications hosted from MOSDAC.

In this paper we have brought out the current infrastructure at ISRO for dissemination and archival of Met data observations and the future plan towards IMETCAST.

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