Overview of Indian Satellite data Utilization for Preparing Extreme Precipitation Events

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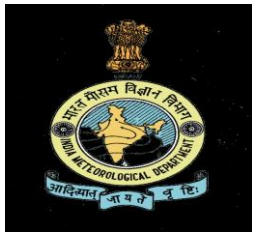
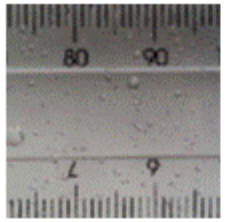


Outline

- What kind of satellite information can quad provide related to extreme precipitation events?
- How can users get information? Tools and website?
- Benefits of users in the Indo-Pacific region.
- Any opportunity for training?

Extreme Rainfall Events:2022

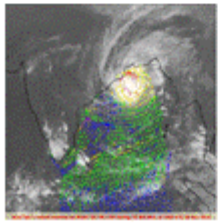


Monsoonal rain (S-W & N-E)

Heavy rainfall (floods & landslides)

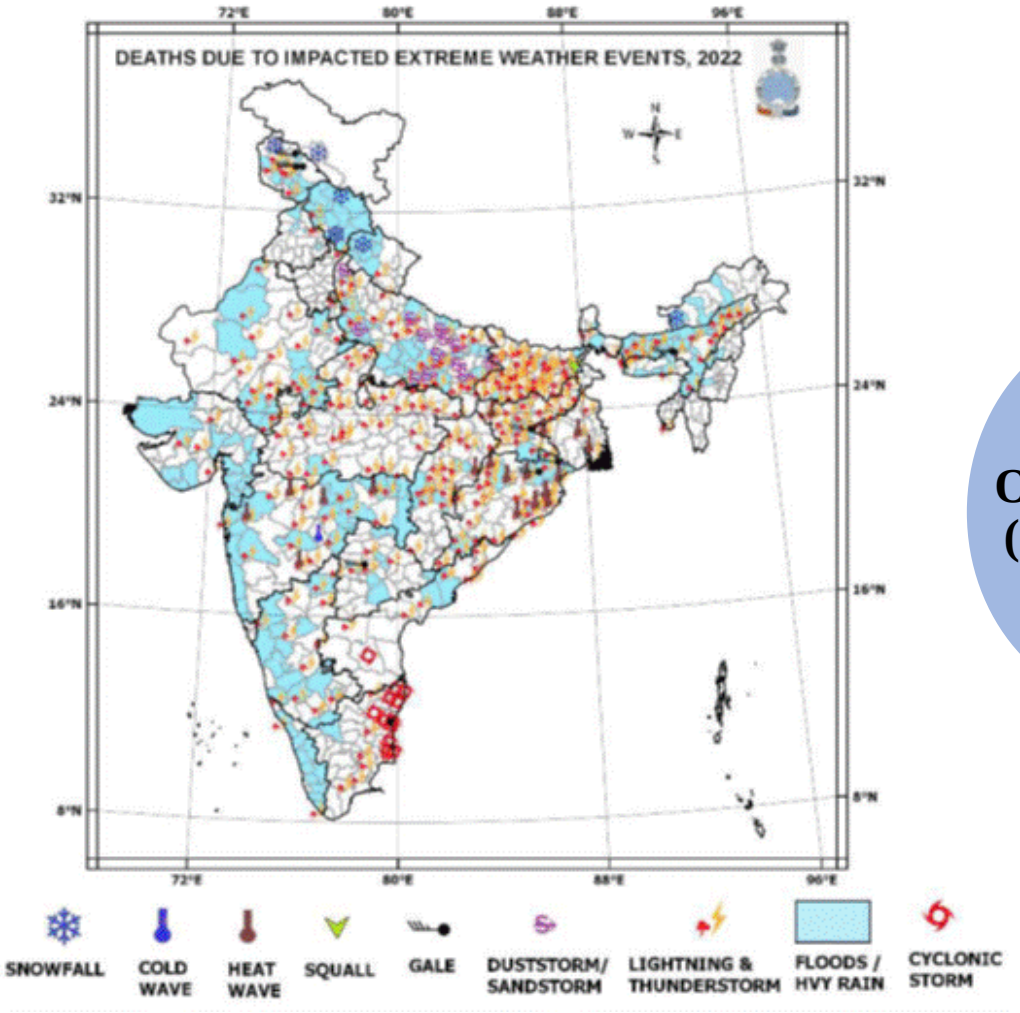
Thunderstorms and Lightning

Cloud Burst

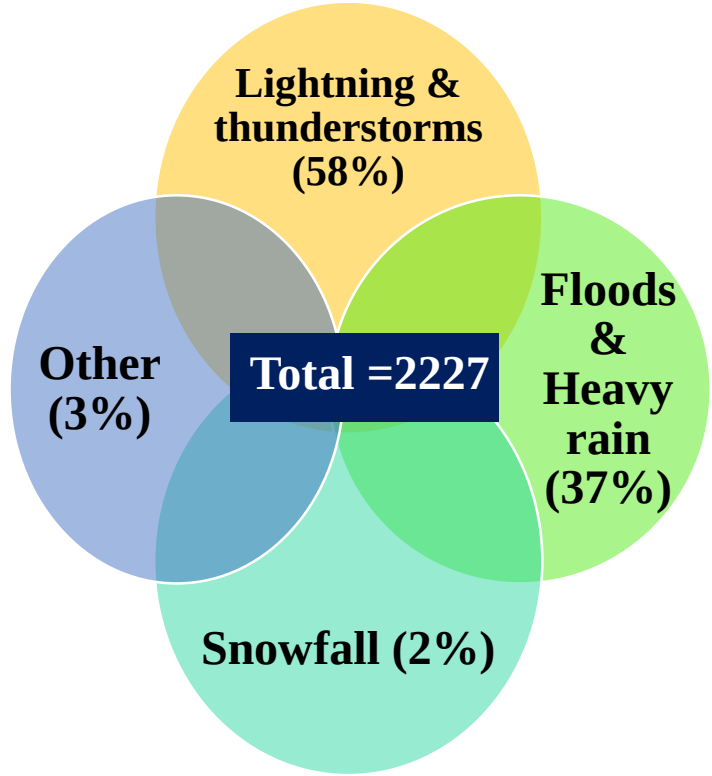


Tropical cyclones

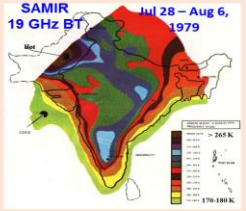
Significant Extreme Weather Events Occurred during 2022 (source , IMD)



Percentage of number of deaths during 2022 due to Extreme Weather Events (source , IMD)

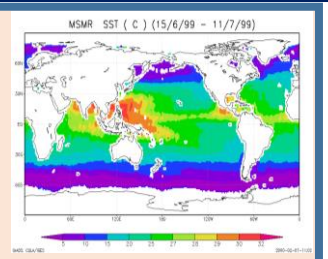


Satellite Information can Quad Provide Related to Extreme Precipitation Events



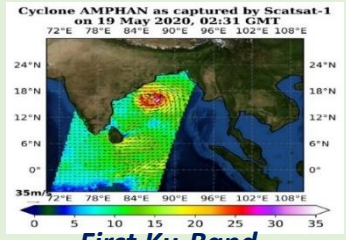
First MW Radiometer

Bhaskara-1/2
1979/1981
SAMIR, TV camera



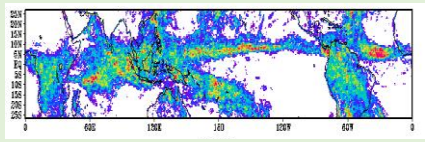
First Multi Frequency MW Radiometer (MSMR)

Oceansat-1
1999
OCM & MSMR



First Ku-Band Scatterometer

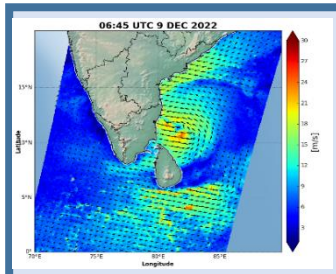
Oceansat-2,
2009
OCM, SCAT & ROSA

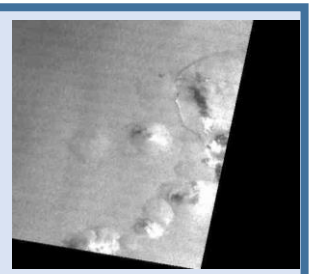


Joint Indo-French Mission
First MW Humidity Sounder, Radiation Budget Sensor

Megha-Tropiques,
2011
MADRAS, SAPHIR, ScaRab, ROSA

SARAL
2013
Ka-band Altimeter





SCATSAT-1
2016, SCAT

EOS-06
(Oceansat-3)
2022, OCM &SCAT

EOS-04
(RISAT-1A)
2022, SAR

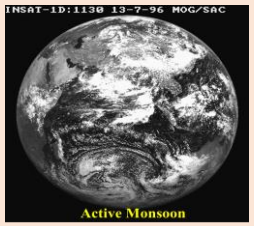
NISAR

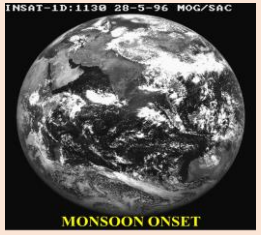
1980-2000 → **2000-2015** → **2016-2022** → **2023 +**

INSAT-1A/1B/1C/1D
1982/83/88/90
VHRR

INSAT-2A/2B
1992/93
VHRR

24-hr monitoring of Monsoon, Cyclone and other weather systems





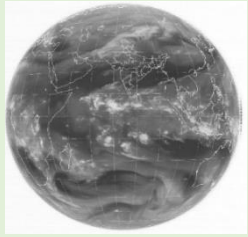
INSAT-2E/3A
1999/2003
VHRR, CCD

KALPANA-1
2002
VHRR

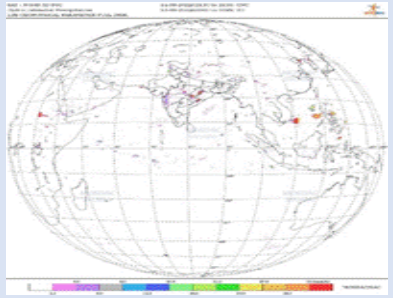
Kalpana-1 was first dedicated MetSat 30-min Imaging started with Kalpana-1

INSAT-3D
2013
Imager/ Sounder

INSAT-3D: First dedicated advanced MetSat with 6 Ch Imager with Split-Window and 18-Ch IR Sounder



INSAT-3DR (2016)
Imager/ Sounder



- **INSAT-3DS**
- **GISAT-2**
- **INSAT-4th Gen (Advanced Imager , Lightning Imager and Hyperspectral sounder..)**

Satellite Information can Quad Provide Related to Extreme Precipitation Events

INSAT-3D/3DR Operational Geophysical Products

Imager

S. No.	Geophysical Parameter	Code
1	Clear Sky Brightness Temperature	CSBT
2	Cloud Mask	CMK
3	Hydro Estimator	HEM
4	Improved IMSRA	IMC
5	Outgoing Longwave Radiation	OLR
6	Sea Surface Temperature	SST
7	Cloud Properties	CTP/CTT
8	Upper Tropospheric Humidity	UTH
9	Land Surface Temperature	LST
10	Total Precipitable Water	TPW
11	Fog	FOG
12	MIR Reflectance	REF
13	Snow	SNW
14	Insolation	INS
15	Land Surface Albedo	LSA
16	Net Effective Radiation	NER
17	Atmospheric Correction	TOA/BOA
18	Cloud Microphysics	CMP
19	Smoke	SMK
20	Forest Fire	FIR

S. No.	Geophysical Parameter	Code
21	Atmospheric Motion Vectors	IRW, WVW, MRW, VSW
22	Wind Derived Products (WDP)	WDP
23	Merged Wind Products	IRW_MERGED WVW_MERGED
24	High Resolution Winds	VSW_HR
25	Full Disc Winds	IRW_FD, WVW_FD
26	GOES Precipitation Index	GPI
27	Aerosol Optical Depth	AOD
28	Potential EvapoTranspiration	PET_DLY
29	Short Wave Radiation Over Ocean	SWR
30	5 day composite winds	5DCW
31	Actual EvapoTranspiration	AET
32	Land Surface Albedo (Daily/15-Day Composite)	LSA

http://www.mosdac.gov.in

Sounder

L1B Product

1. Clear Sky Brightness Temperature (CSBT)

Operational Geophysical Profiles

2. **Temperature Profiles**
3. **WV Profiles**
4. Surface Skin Temperature
5. Total Ozone

Derived products

6. Geo Potential Height (at 40 pressure levels)
7. **Total Precipitable Water**
8. **Layer-1 (1000-900 hPa) Precipitable Water**
9. **Layer-2 (900-700 hPa) Precipitable Water**
10. **Layer-3 (700-300 hPa) Precipitable Water**
11. **Lifted Index**
12. **Wind Index**
13. **Dry Microburst Index**
14. **Maximum Vertical Theta-e**

Cloud Properties

15. **Cloud Top Temperature**
16. **Cloud Top Pressure**
17. **Cloud effective Emissivity**

Rainfall Products: INSAT-3D/3DR

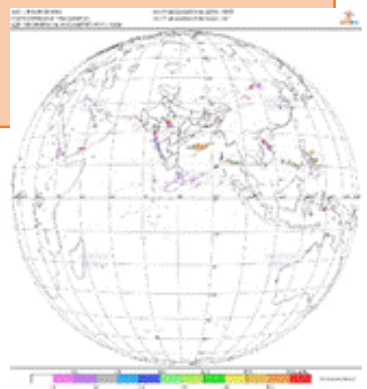
http://www.mosdac.gov.in

Hydro-Estimator (H-E)

Fine tuned for Indian region

- TIR observations are blended with model outputs.
- Rain rate relationship with Tb is dynamic.
- Correction procedures for orography and warm clouds.
- Rain at pixel levels of INSAT-3D/3DR over land and ocean.

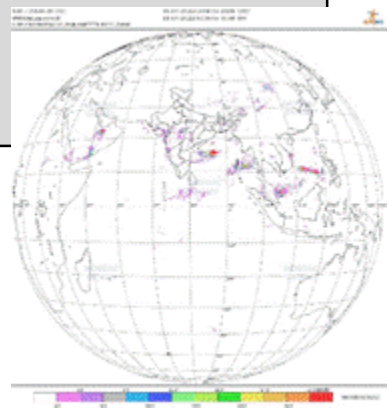
(Kuligowski et al. (2003), Varma & Gairola, 2015; Varma & Sharma , 2022)



INSAT Multi-Spectral Rainfall Algorithm (IMSRA)

- Calibrated TIR brightness temperature with TRMM-PR surface rainfall.
- Empirical regression relationship between brightness temperature and rainfall.
- Improved & corrected IMSRA (IMC)

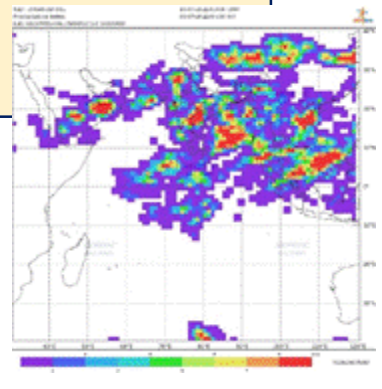
(Gairola and Varma, 2007; Gairola et al. 2016)



Quantitative Precipitation Estimation (QPE)

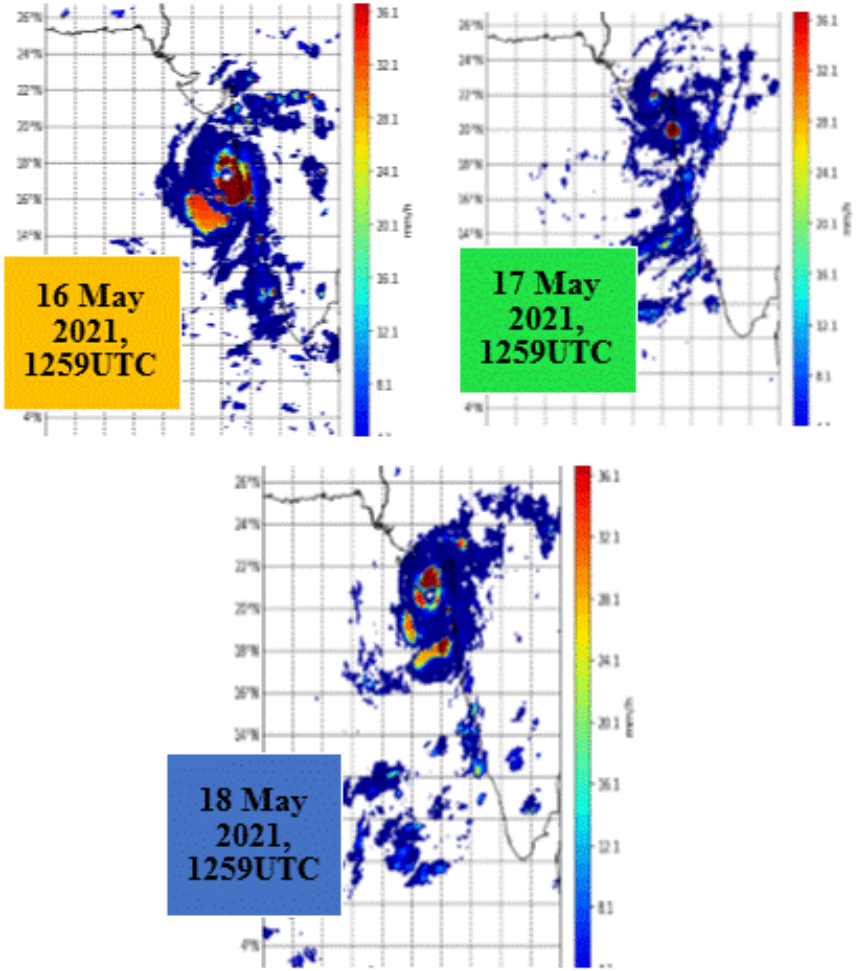
- Correlation between rain rate and fraction of area covered by satellite pixels colder than 235K (Arkin 1979).
- Works well for large spatial (1°x1°) and temporal (daily) scales.

(Arkin, 1979, Gairola and Varma, 2007)

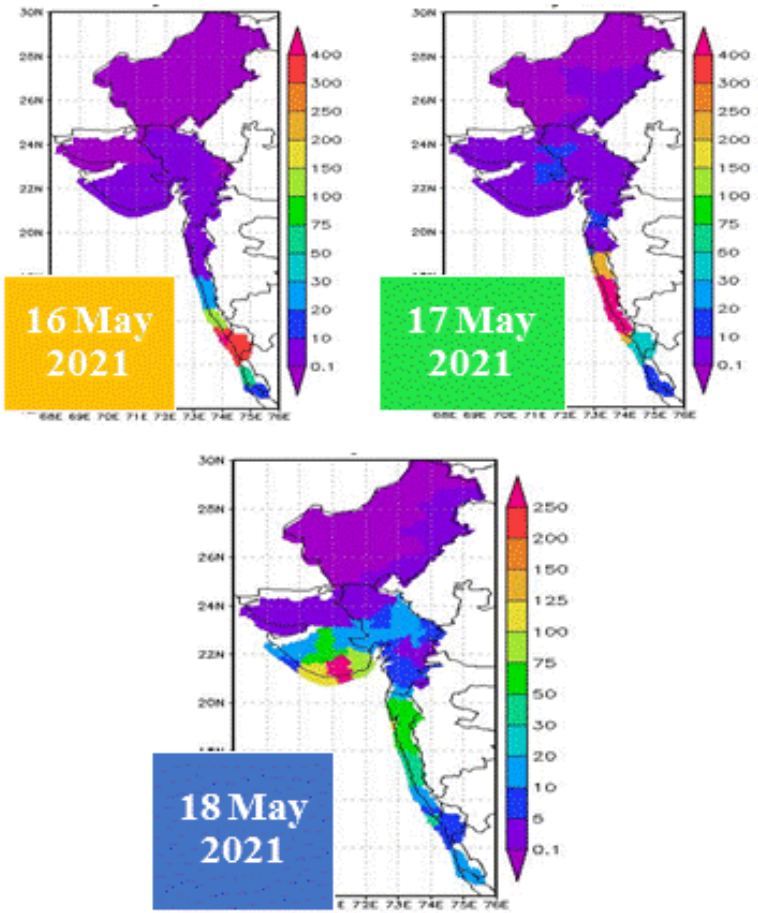


Benefit of Users in the Indo-Pacific region
H-E rain from INSAT-3DR (Tropical Cyclone Tauktae, May 2021)

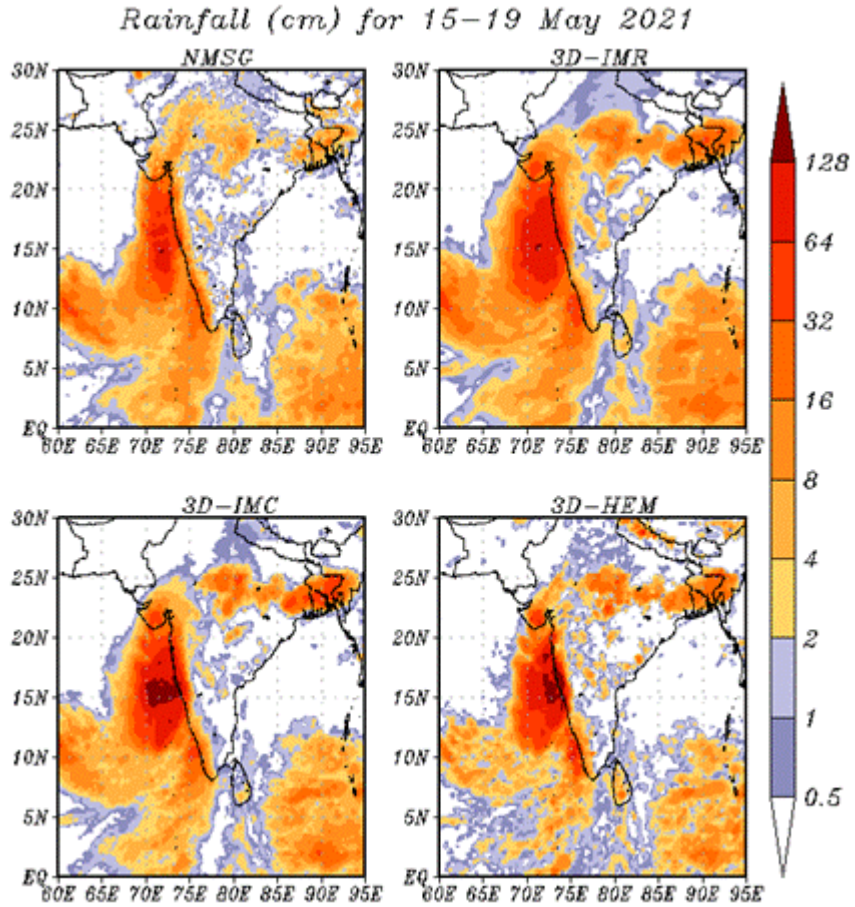
Spatial distribution of H-E rainfall



District wise distribution of H-E rainfall on daily scale



Validation with NMSG rainfall

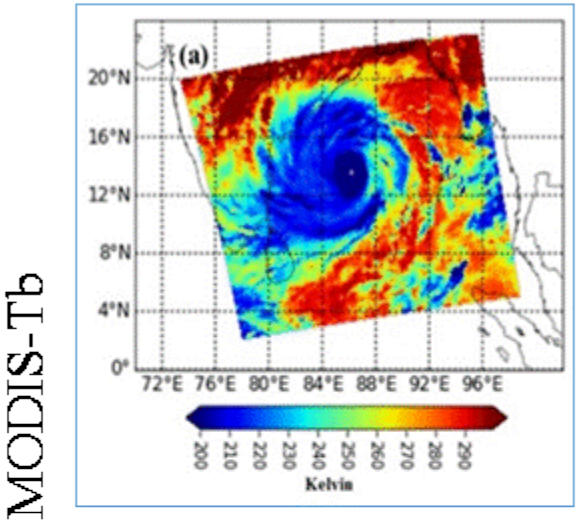


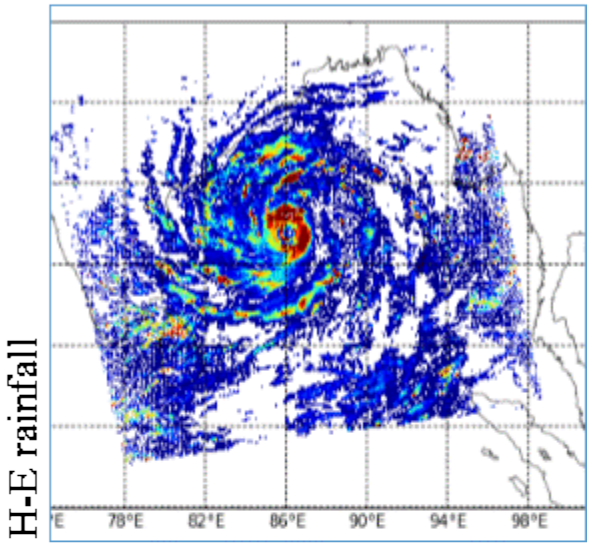
SAC/EPSA/SR-02/2021

Prakash & Bhan (2022) Nat. Haz.

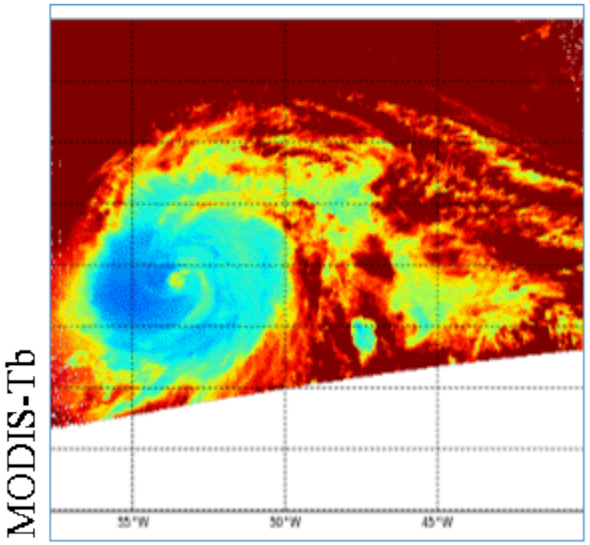
Benefit of Users in the Indo-Pacific Region

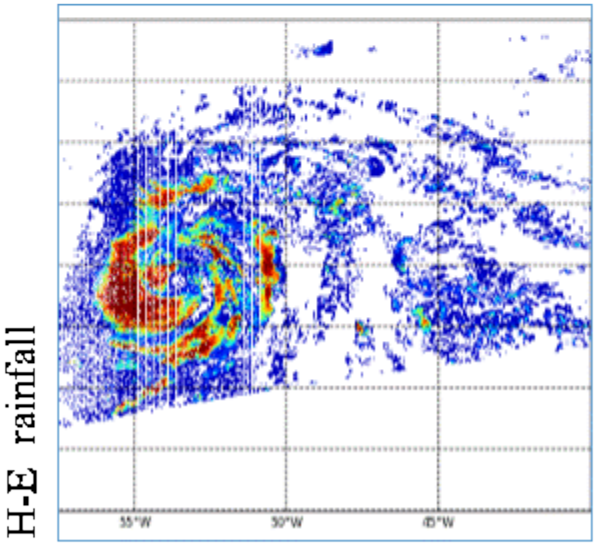
- **Rainfall structure**
- **Coastal regions**
- **Floods**





Tropical cyclone Amphan, over Bay of Bengal on 18 May 2020.





Hurricane Teddy over Atlantic Ocean on 17 September 2020.

Sharma and Varma, 2023, accepted in JESS

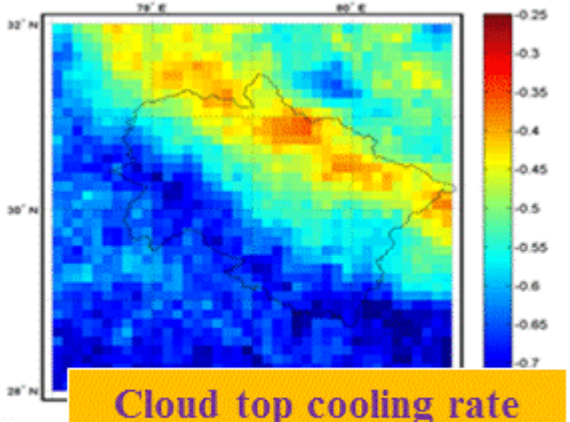
Cloudburst Potential and Heavy Rain Alerts using INSAT-3D/3DR

Nowcasting of extreme rainfall events over Western Himalayan region using Nowcasting of ExTreme orographic RAin events (NETRA) algorithm

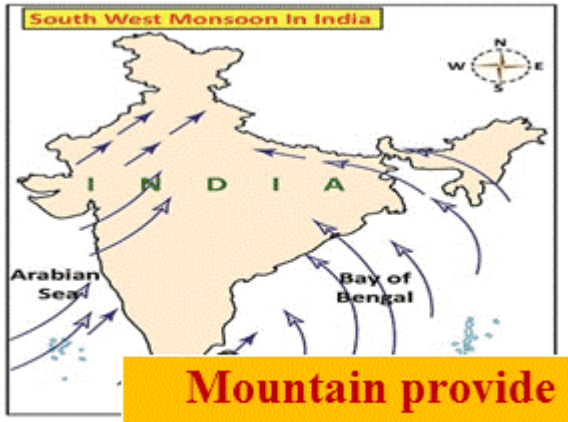
Cloudburst Potential alert is made available on real time over MOSDAC web portal using NETRA

INSAT-3D/3DR based heavy rain nowcasting

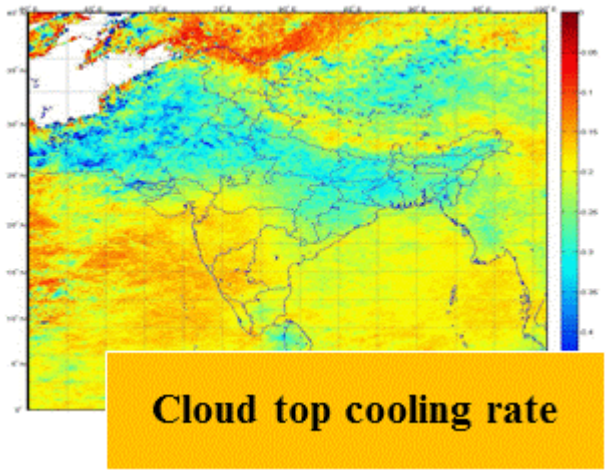
Location specific validation of Cloudburst Potential



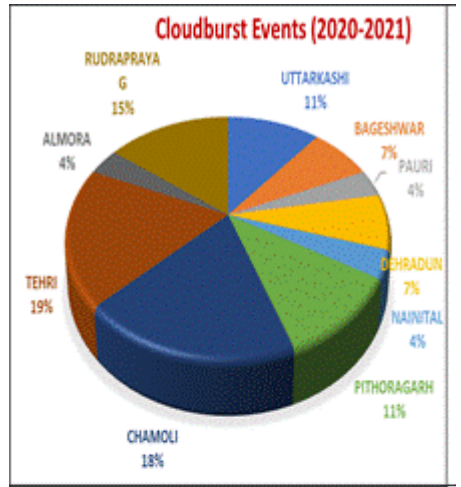
Cloud top cooling rate threshold

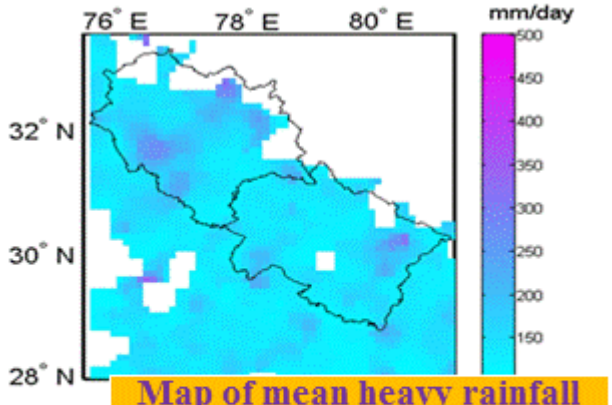


Mountain provide orographic lifting



Cloud top cooling rate

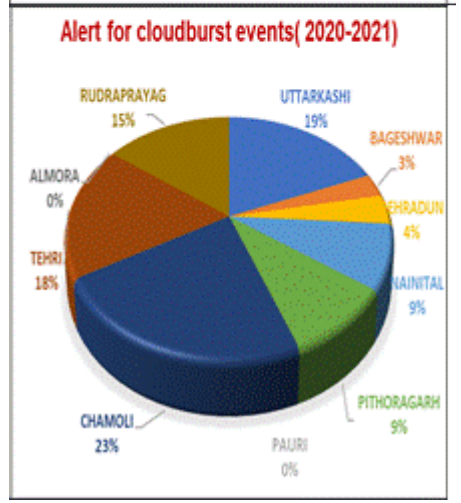




Map of mean heavy rainfall (Daily rainfall >100mm) over WH

Uttrakashi cloud burst (3rd May, 2021)

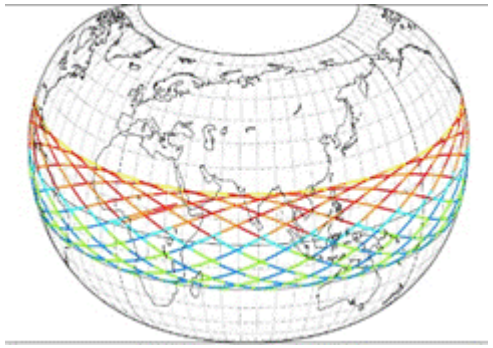
Real time alerts available over MOSDAC (ISRO)



Shukla et al., 2017, IEEE Journal of selected topics in applied earth observations and remote sensing

Rainfall Monitoring using Microwave Frequencies (Megha-Tropiques)

- **Launched: 12Oct 2011**
- **An Indo_French joint satellite mission**



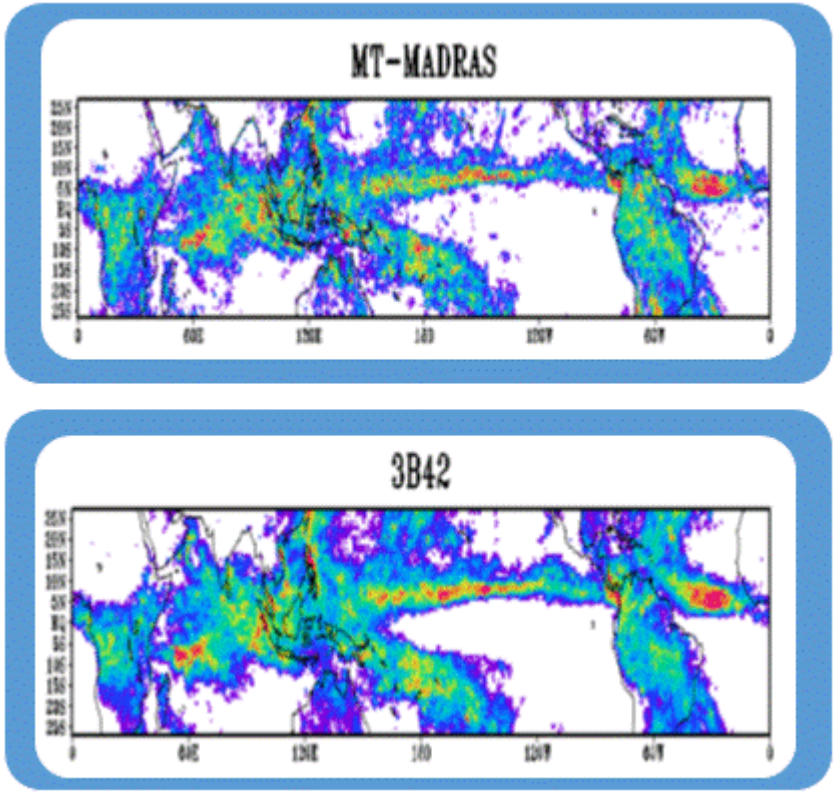
SAPHIR: *6 channel sounder near to 183 GHz sounding upto 12km height water vapor profiles*
Resolution:10km
Swath:2200km

ScaRaB: *Outgoing fluxes at TOA*
Resolution: 40km
Swath: 2200km

Microwave Analysis and Detection of Rain and Atmospheric Structure (MADRAS) : *Precipitation and cloud properties*
89 & 157 GHz: ice particles at cloud top
18 & 37GHz: cloud liquid water and precipitation
23GHz:Integrated water vapour.

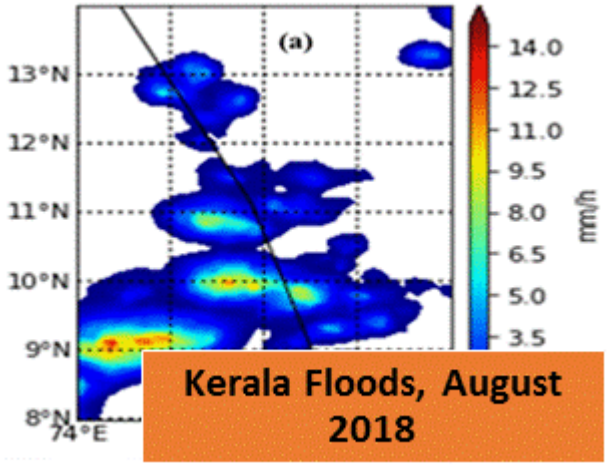
ROSA: *Temperature and humidity profiles.*

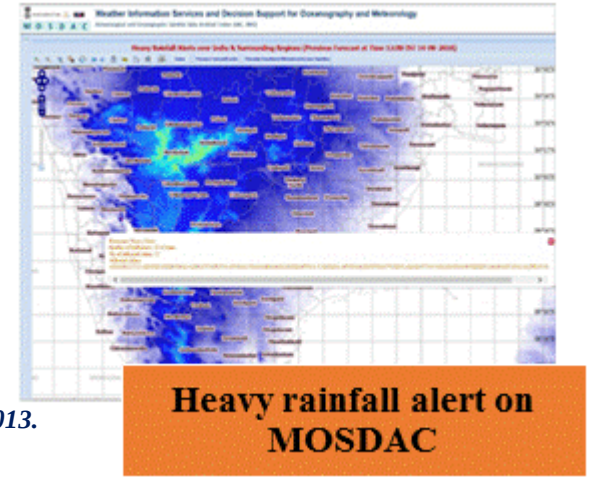
Global monthly averaged rain rates: Nov 2011
(a) MADRAS and (b) TRMM3B42



Gohil, B. S, R. M. Gairola, A. K. Varma, C. Mahesh, R. K. Gangwar and P. K.Pal, Q J R MetS, 2013.
Varma, A.K., D. N. Piyush, B. S.Gohil and P.K. Pal, Advances in Space Research, 2015.

Rainfall Monitoring from SAPHIR



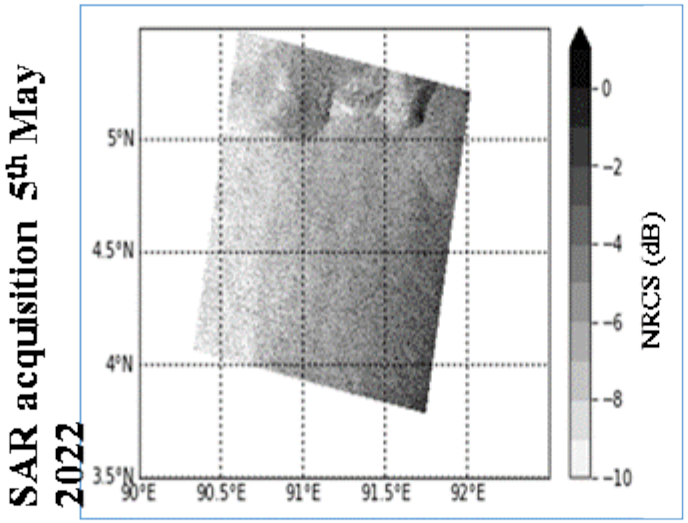


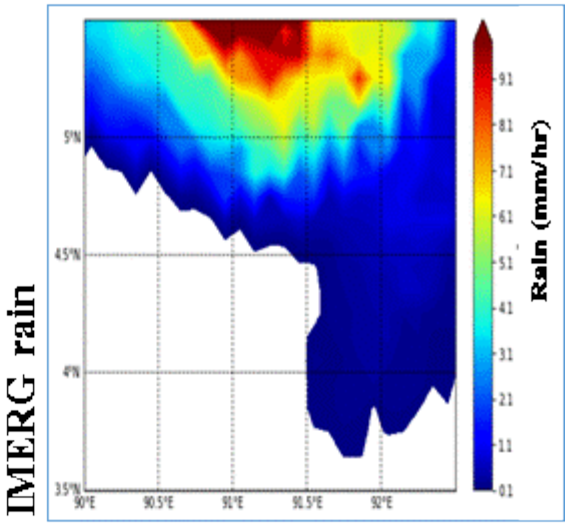
Varma, A.K., Piyush, D.N., Gohil, B.S., Pal, P.K., and Srinivasan, J., 2016.
Sharma, N. and Gopalan, K. AC/EPSA/AOSG/SR/21/2018.

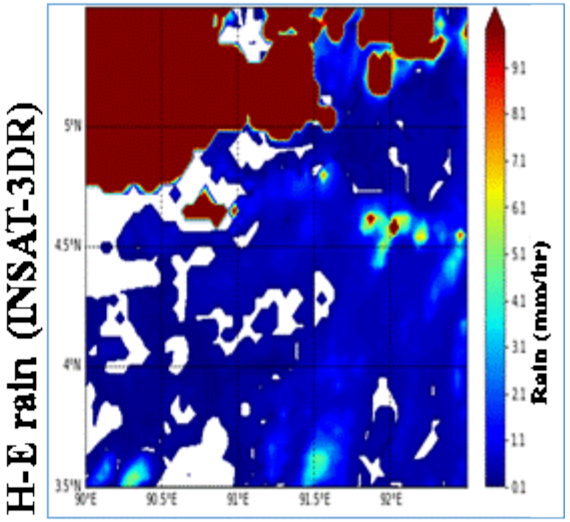
EOS-04 (RISAT-1A): Convective rain cell imprints in C-band SAR over ocean

Launched: 14Feb 2022

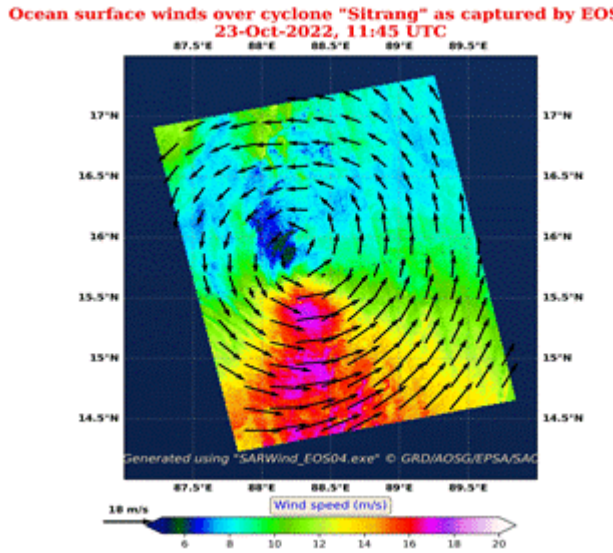
Frequency	**C-band (5.35 GHz)**
Polarization	**Single, Dual , & Circular (Hybrid)**
Swath	**10 km to 240 km**
Incidence Angles	**20° – 49°**
Spatial Resolution	**3 to 8, 25, 50 m**
Repetivity	**25 days for 240 km swath – systematic**
Modes	**Stripmap, CRS, MRS, Spotlight**







High resolution (~ 1km) ocean surface wind speed



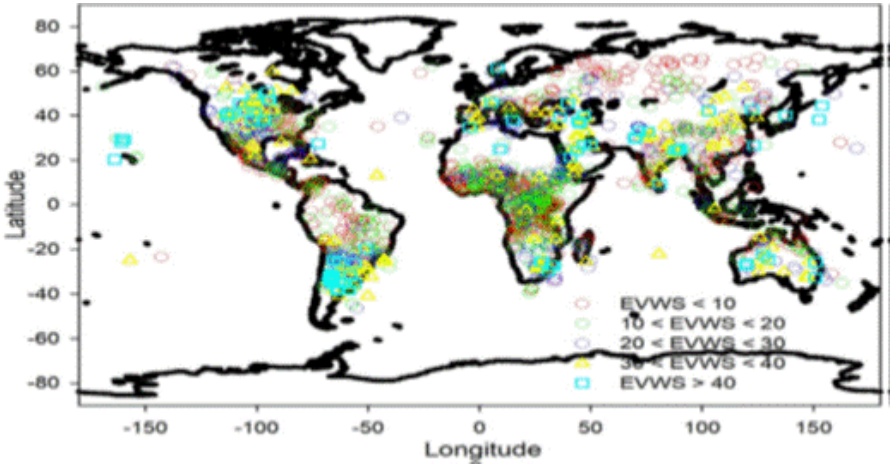
****NISAR****

Rain cell identification and analysis using multi-frequency (L & S) and multi-polarization imageries.

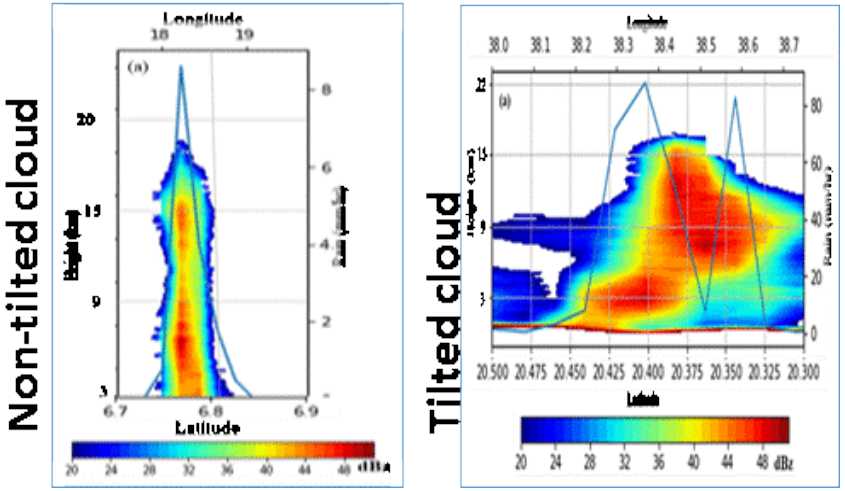
Sharma, N & Shukla, B.P., SAC/EPSA/AOSG/06/2022

Rainfall and Vertical Structure of Cloud

Global distribution of deep convective clouds (DPR, 2018)

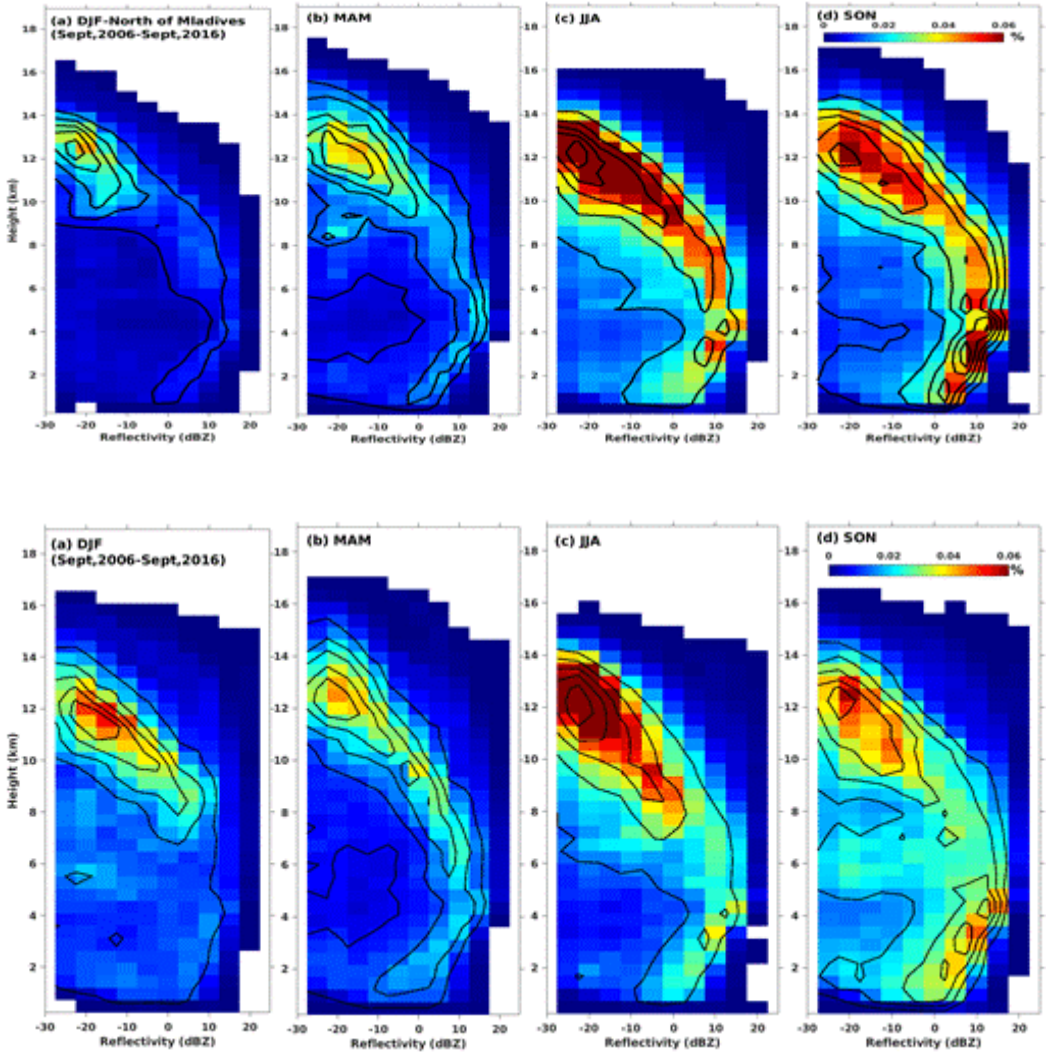


Vertical structure of clouds (DPR, 2018)



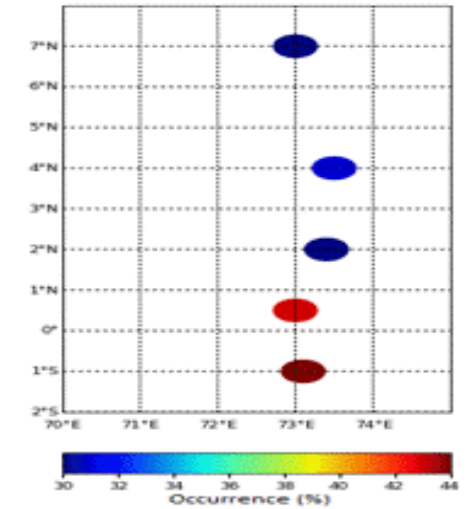
Sharma et al. ASR, 2022

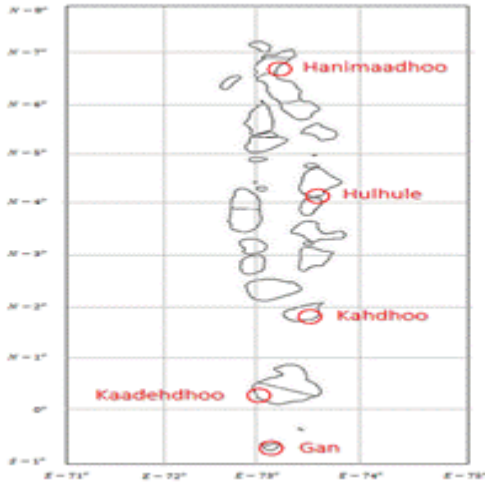
Vertical structure of precipitating cloud characteristics over the Maldives using CloudSat observations (2006-2016)



Source: Dr. Subrahmanyam @ NRSC, ISRO

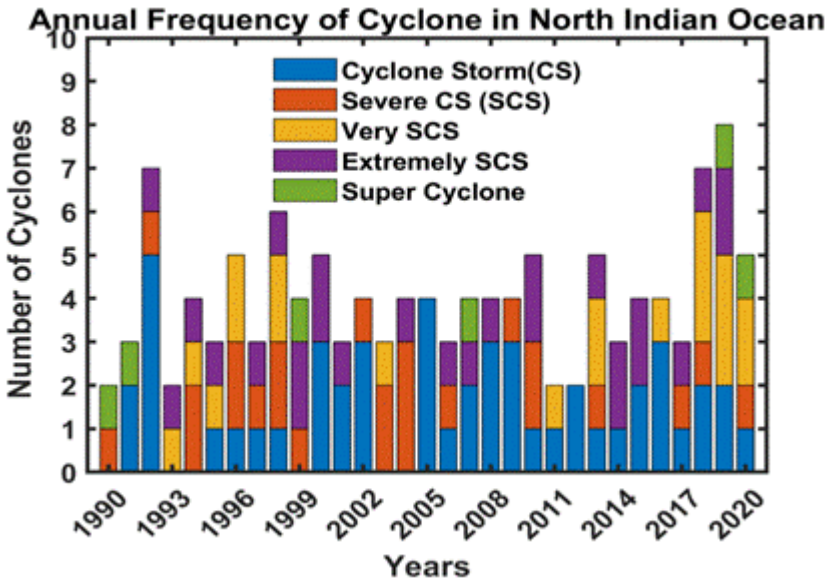
% Occurrence of stratiform rain during 2019 using GPM-DPR data

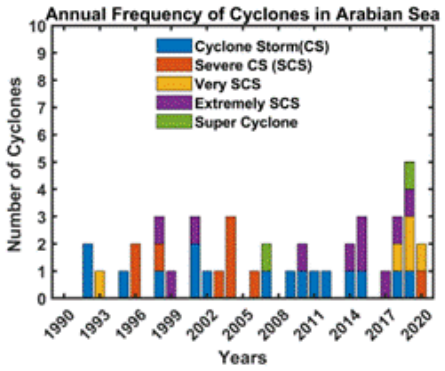


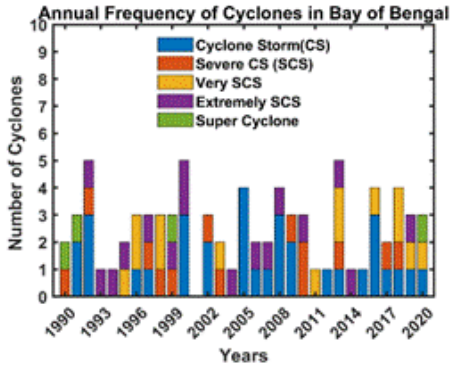


Rainfall in Tropical Cyclones

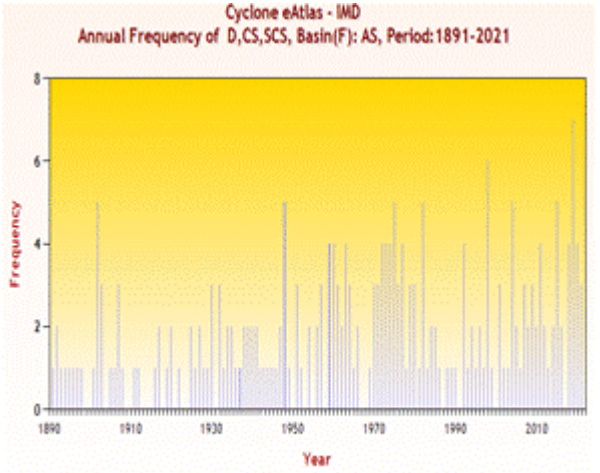
Statistics of TCs in the North Indian Ocean: In the last 31 years (1990-2020) based on the TC best track data created by RSMC New Delhi

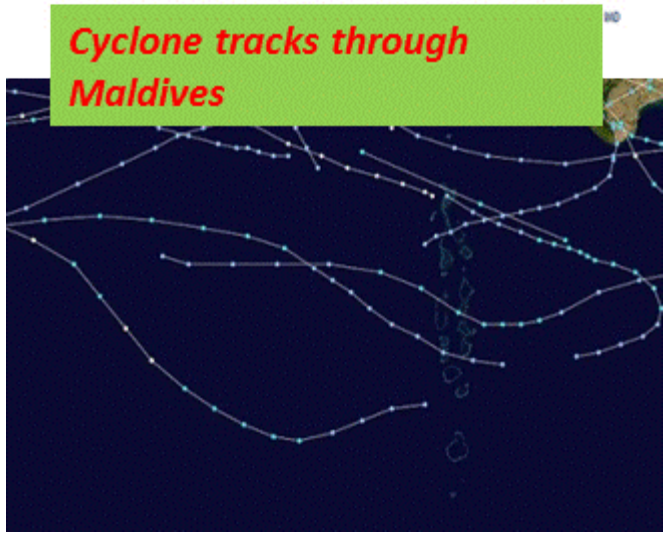




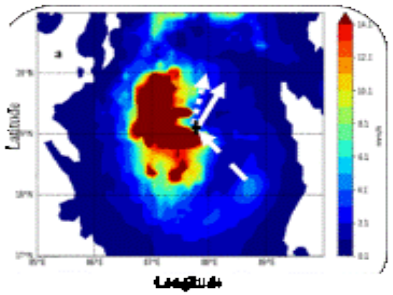


Severe Cyclonic Storms - Maldives

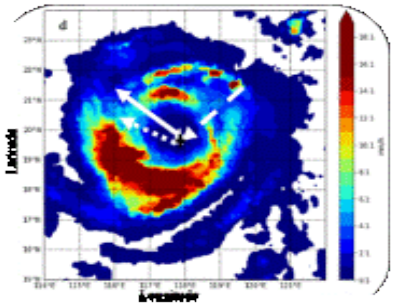




Rainfall asymmetry in tropical cyclones



IMERG rainfall during TC- BULBUL on 8 November 2019



IMERG rainfall during TC HAIMA on 20th October 2016

Highlights:

- **Cyclone intensity= 36.1m/s and wind shear=7.5m/s.**
- **Weakly tilted structure.**
- **Rainfall is distributed around the eye of TC.**

Highlights:

- **Cyclone intensity= 36.1m/s and wind shear=7.5m/s.**
- **Weakly tilted structure.**
- **Rainfall is distributed around the eye of TC.**
- **Maximum rainfall in south-west direction.**

Source: Dr. Subrahmanyam @ NRSC, ISRO

Sharma, N., and Varma, A.K., Natural Hazards, 2022

Long-Term High-Resolution Gauge Adjusted Satellite Rainfall Product over India

Background

The existing merged rainfall products over India are at coarser spatial (0.25° × 0.25°) or temporal (24-hour) resolution (e.g. IMSRA adjusted by IMD Gauges, NMSG rain, etc.)

Methodology

The Maximum Likelihood Estimation (MLE) based merge-rainfall provides an Optimal Solution as compared to objective analysis method.

Results

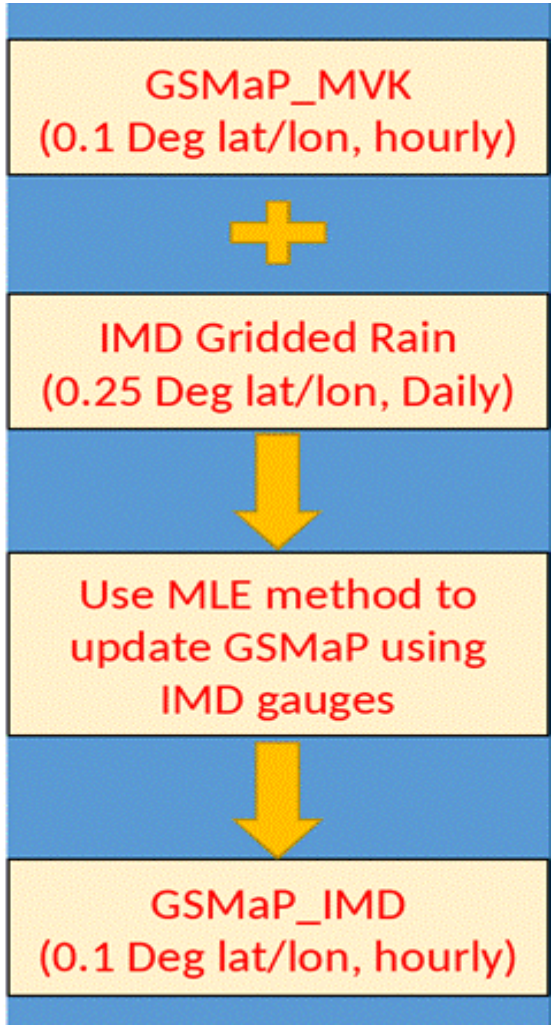
In general lesser RMSE and higher correlation as compared to standard GSMaP rainfall (GSMaP_Gauge), IMERG Final, etc.

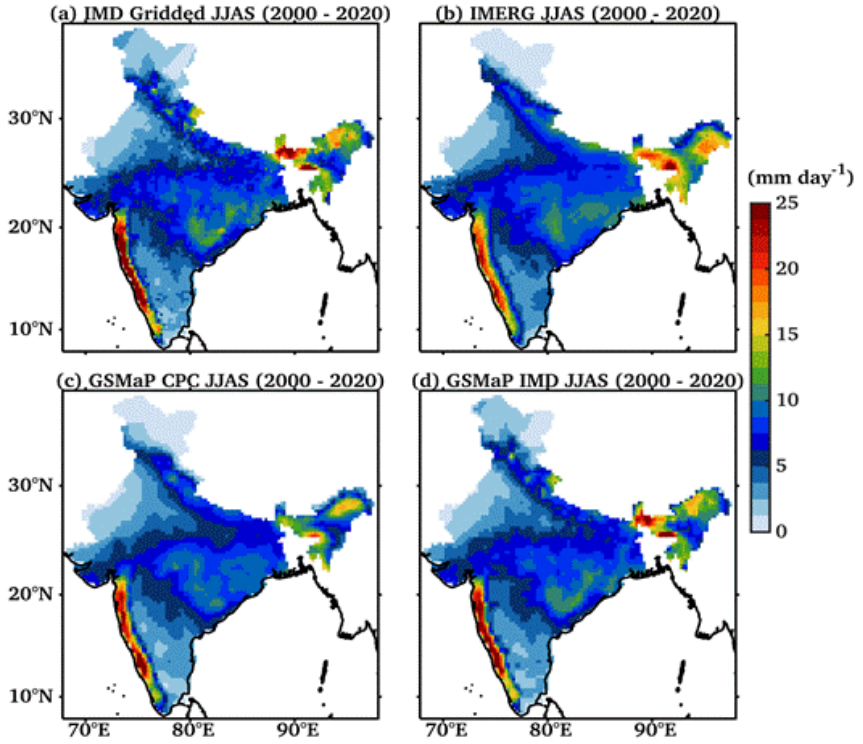
These improvements are very significant over the high rainfall regions mainly Western Ghats and NE India.

Developed Rainfall Data

Develop GSMaP_IMD, a long-term (22 years) high spatio-temporal resolution rainfall product adjusted by IMD Gridded rainfall.

A targeted resolution is hourly in the temporal direction and 0.1° in the spatial direction.





Spatial distribution of mean daily rainfall during summer monsoon (June to September) from (a) IMD gridded rain, (b) IMERG Final-run, (c) GSMaP_Gauge (here GSMaP_CPC), and (d) GSMaP_IMD rainfall for years 2000-2020.

Kumar et al. 2021, AGU ESS

Under ISRO-JAXA collaboration

Tools and Websites

MOSDAC इसरो ISRO

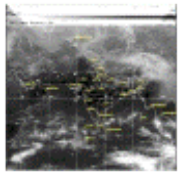
Govt. of India

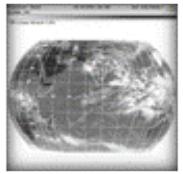
Meteorological and Oceanographic Satellite Data Archival Centre

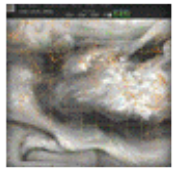
Application of Space Technology for the benefit of the common man

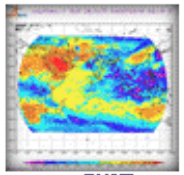
Weather and Sea state forecasting, alerts, cyclone prediction and continuous weather and ocean data availability

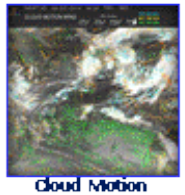
MET & OCEAN DATA PRODUCTS

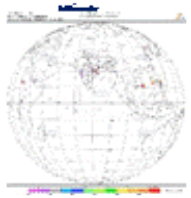

Visible Asian Sector

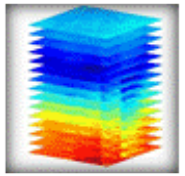

Thermal IR

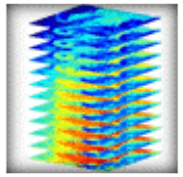

Water Vapour

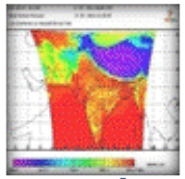

OLWR

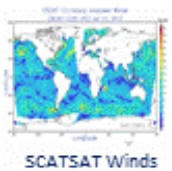

Cloud Motion Vector

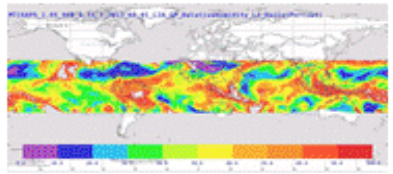

H-E rainfall

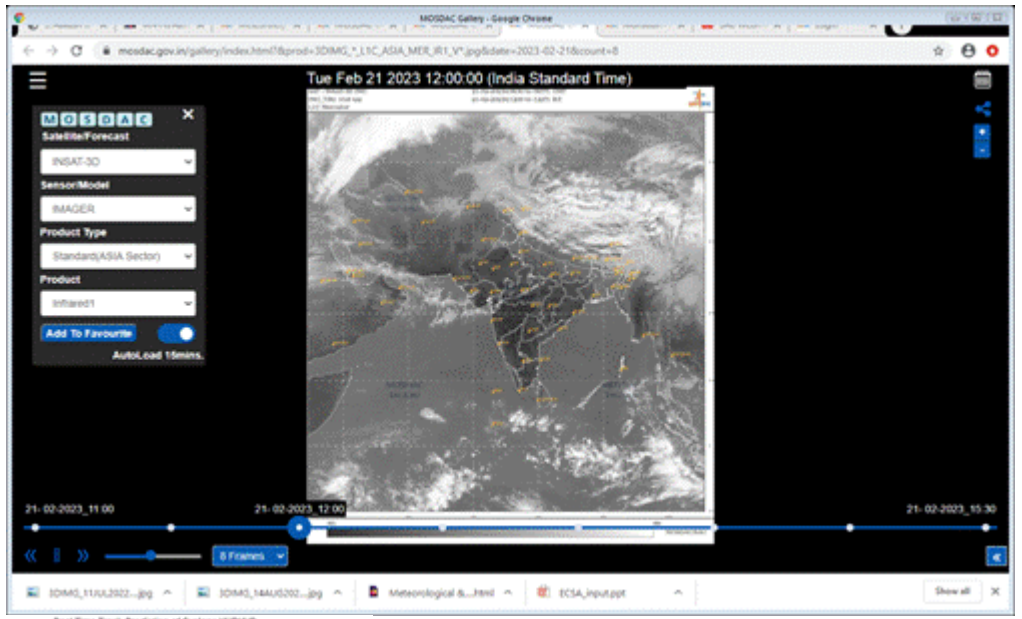

Temperature Profile

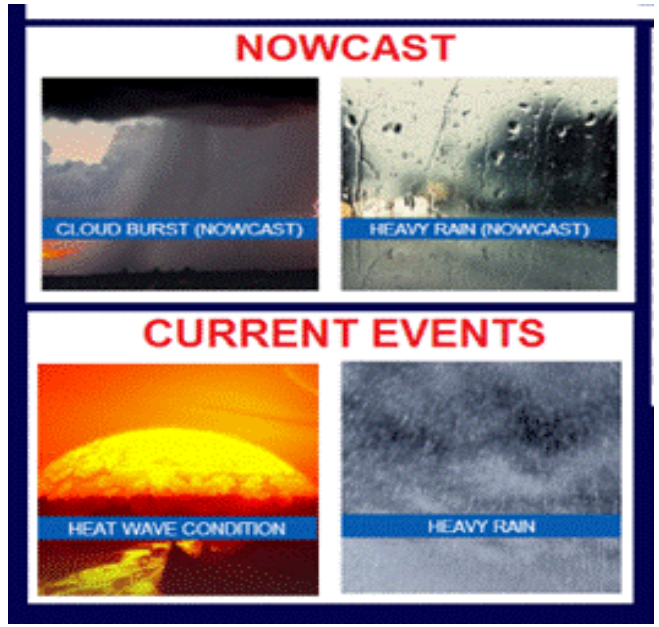

Humidity Profile

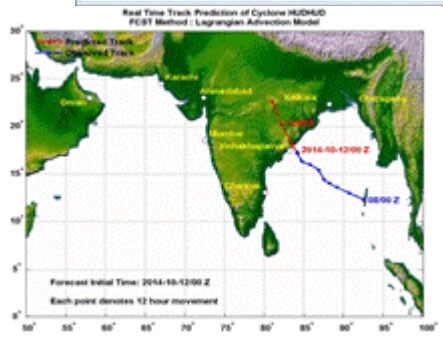

Mean Surface Pressure

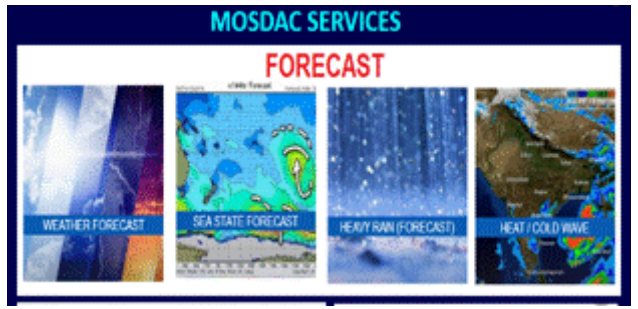

SCATSAT Winds


Daily Relative Humidity





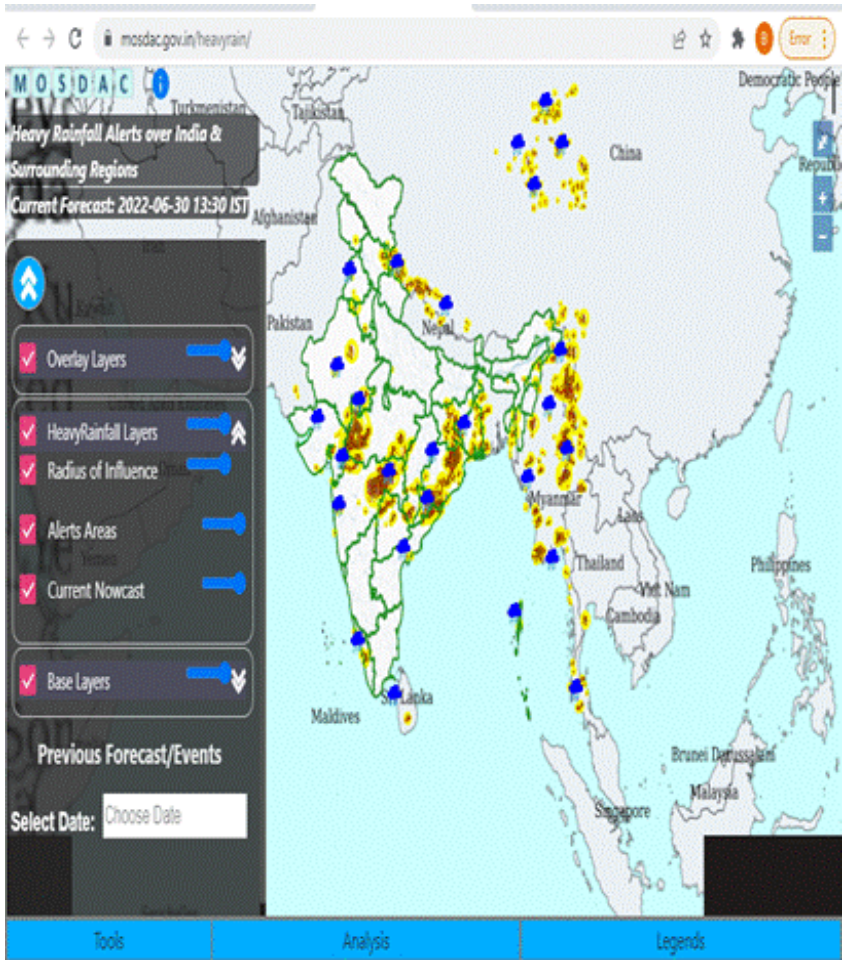




http://www.mosdac.gov.in

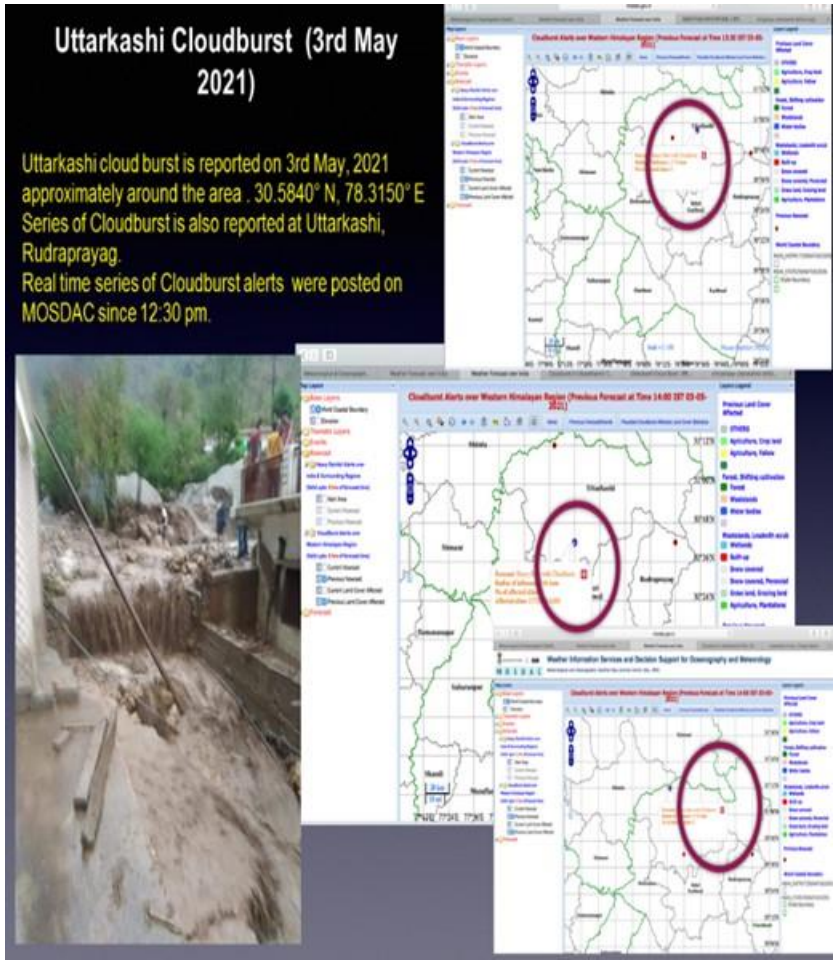
Tools and Websites

Heavy rainfall alerts



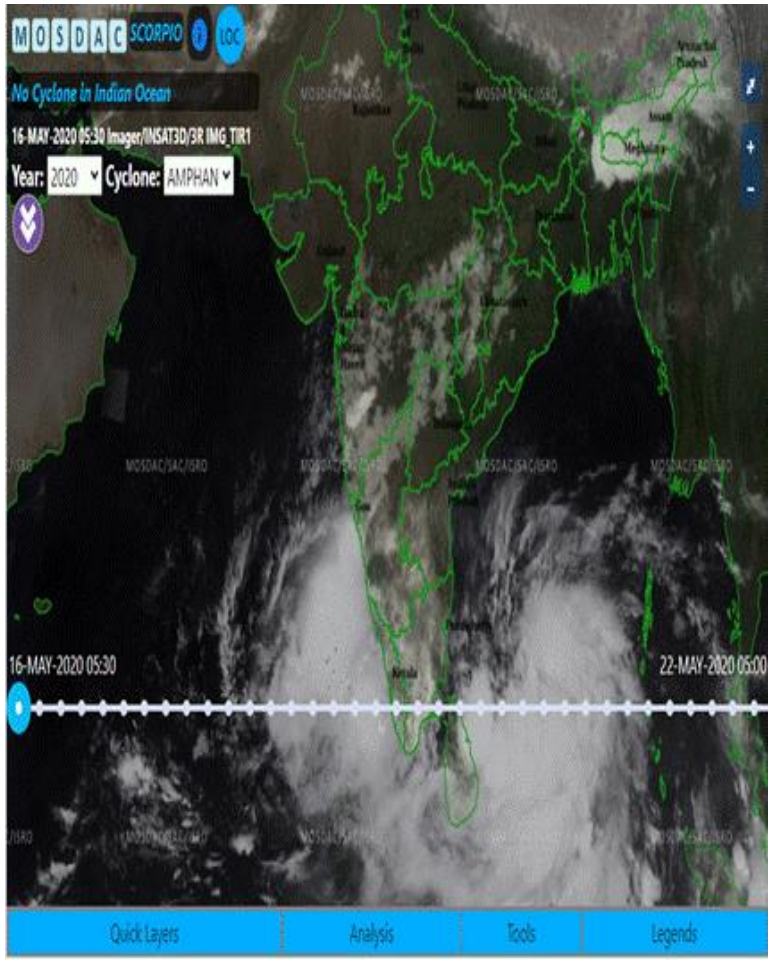
https://mosdac.gov.in/heavyrain/

Cloudburst alerts



https://mosdac.gov.in/cloudburst/

Satellite based Tropical Cyclone Monitoring & Prediction



https://mosdac.gov.in/scorpio/

Tools and Websites

RAPID at IMD

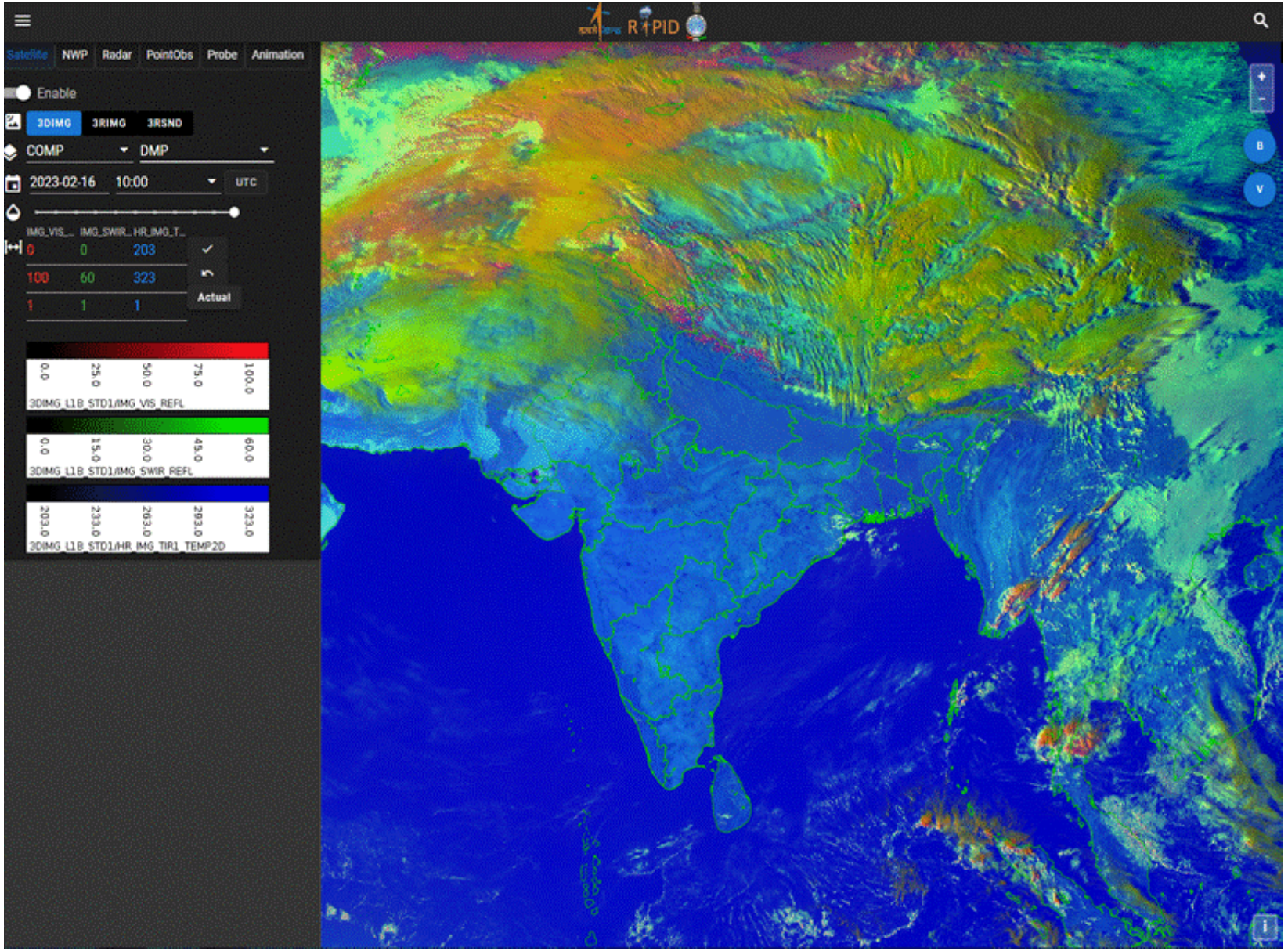
Real-time Analysis of Products & Information Dissemination (RAPID) is an interactive web-based tool to visualize and analyze the INSAT-3D/3DR satellite data (also radar, ground observations and NWP model outputs) in real-time.

No specific OS / software / library /compiler required on the desktop/mobile phones. Access through browser.

RAPID follows Open Geospatial Consortium's (OGC) open standards.

Provides features of interest to scientific community.

https://rapid.imd.gov.in/r2v/



Tools and Websites

MMDRPS at IMD

The Multi-mission Meteorological Data Receiving & Processing System (MMDRPS) at IMD enables acquisition, processing, archival, and dissemination of complete meteorological data from the imager, sounder and DRT payloads of the INSAT-3D, INSAT-3DR and upcoming INSAT-3DS satellites in real-time.

MMDRPS

IMAGER

S. No.	Geophysical Parameter	Code
1	Clear Sky Brightness Temperature	CSBT
2	Cloud Mask	CMK
3	Hydro Estimator	HEM
4	Improved IMSRA	IMC
5	Outgoing Longwave Radiation	OLR
6	Sea Surface Temperature	SST
7	Cloud Properties	CTP/CTT
8	Upper Tropospheric Humidity	UTH
9	Land Surface Temperature	LST
10	Total Precipitable Water	TPW
11	Fog	FOG
12	MIR Reflectance	REF
13	Snow	SNW
14	Insolation	INS
15	Land Surface Albedo	LSA
16	Net Effective Radiation	NER
17	Atmospheric Correction	TOA/BOA
18	Cloud Microphysics	CMP
19	Smoke	SMK
20	Forest Fire	FIR
21	Atmospheric Motion Vectors	IRW, WVW, MRW, VSW
22	Wind Derived Products (WDP)	WDP
23	Merged Wind Products	IRW_MERGED WVW_MERGED
24	High Resolution Winds	VSW_HR
25	Full Disc Winds	IRW_FD, WVW_FD
26	GOES Precipitation Index	GPI

S. No.	Geophysical Parameter	Code
26	GOES Precipitation Index	GPI
27	Aerosol Optical Depth	AOD
28	Potential EvapoTranspiration	PET_DLY
29	Short Wave Radiation Over Ocean	SWR
30	5 day composite winds	5DCW
31	Actual EvapoTranspiration	AET
32	Land Surface Albedo (Daily/15-Day Composite)	LSA

SOUNDER

L1B Product

1. Clear Sky Brightness Temperature (CSBT)

Operational Geophysical Profiles

2. Temperature Profiles
3. WV Profiles
4. Surface Skin Temperature
5. Total Ozone

Derived products

6. Geo Potential Height (at 40 pressure levels)
7. Total Precipitable Water
8. Layer-1 (1000-900 hPa) Precipitable Water
9. Layer-2 (900-700 hPa) Precipitable Water
10. Layer-3 (700-300 hPa) Precipitable Water
11. Lifted Index
12. Wind Index
13. Dry Microburst Index
14. Maximum Vertical Theta-e

Cloud Properties

15. Cloud Top Temperature
16. Cloud Top Pressure
17. Cloud effective Emissivity

Tools and Websites

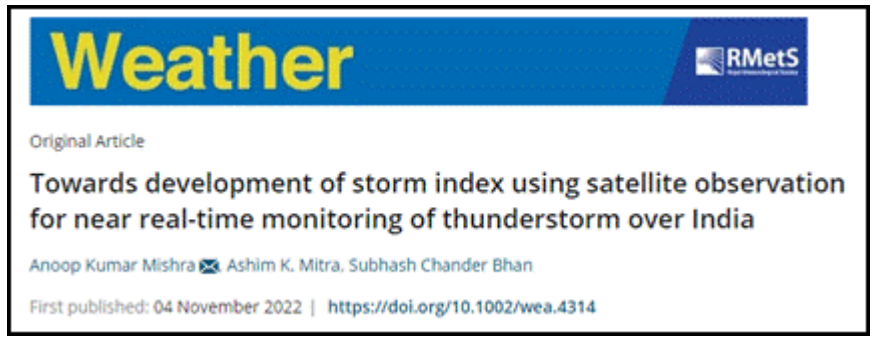
INSAT-based tool for thunderstorm monitoring at IMD

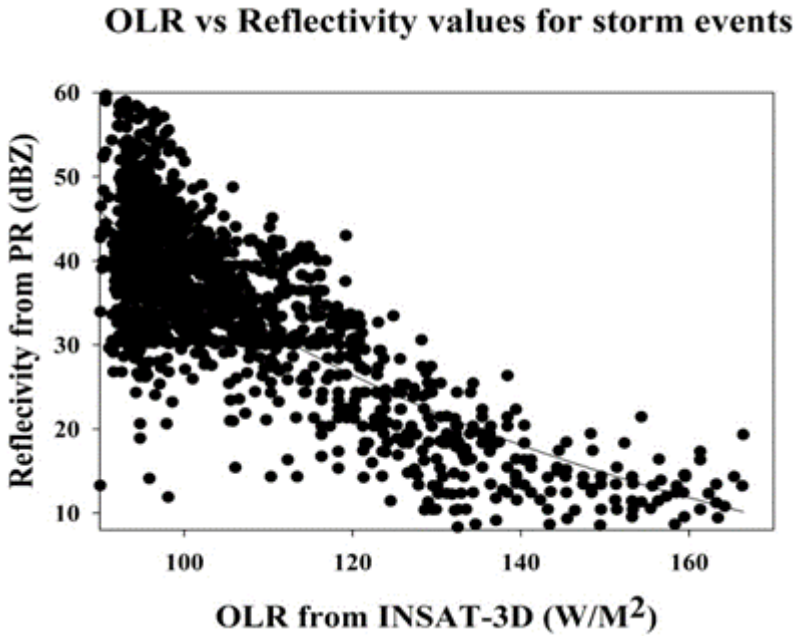
A storm index is experimentally derived using integrated observations from space-borne radar and satellite observations from INSAT-3D/3DR for near real-time monitoring of storms over India.

It is derived at every 15 minutes at spatial resolution of 8 km by integrating Outgoing Longwave Radiation (OLR) from INSAT-3D and reflectivity from Precipitation Radar (PR) onboard TRMM.

Storm signature represented by low OLR values were compared against high reflectivity from PR for a large datasets to establish a linkage between reflectivity and OLR which was used for the derivation of storm index.

OLR threshold for shallow and convective storms were identified by reflectivity thresholds and Storm index was derived as OLR threshold divided by actual OLR values. Severity of the storms were detected by the depression below OLR threshold.





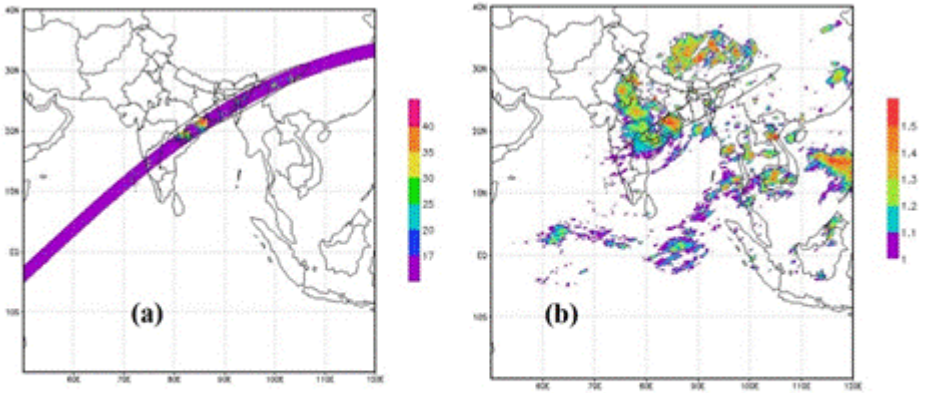
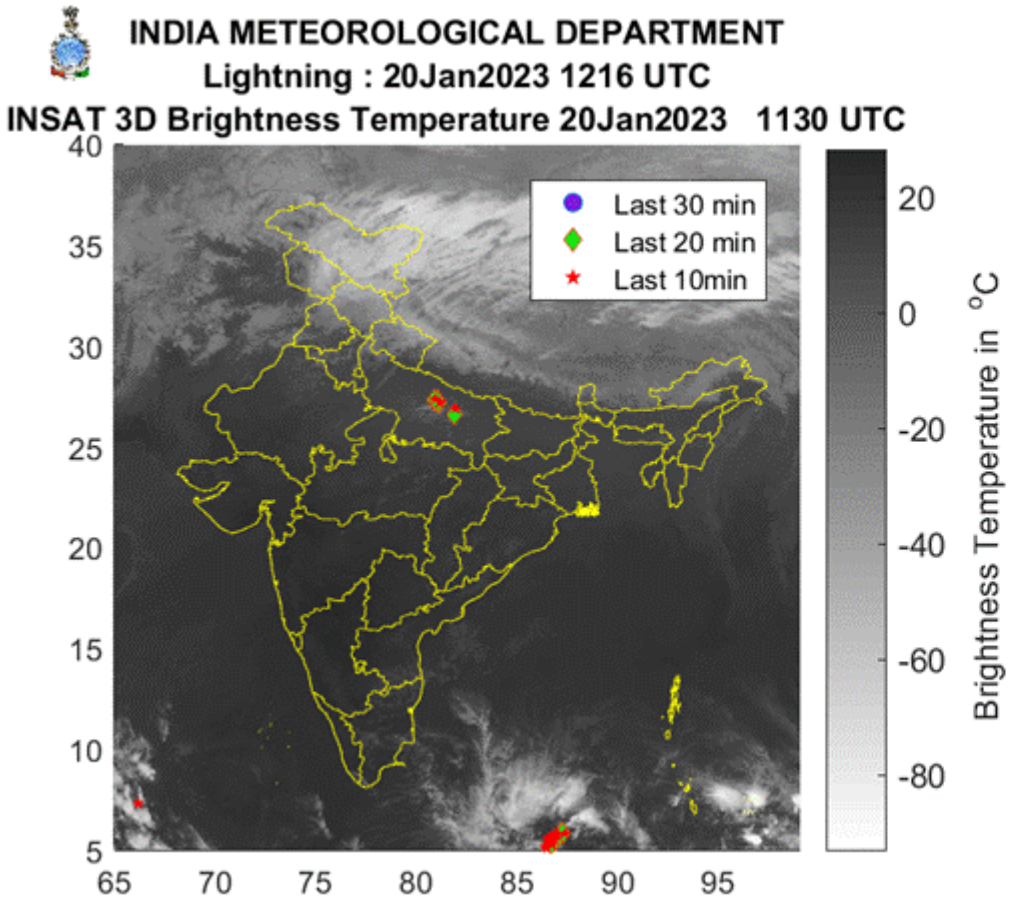


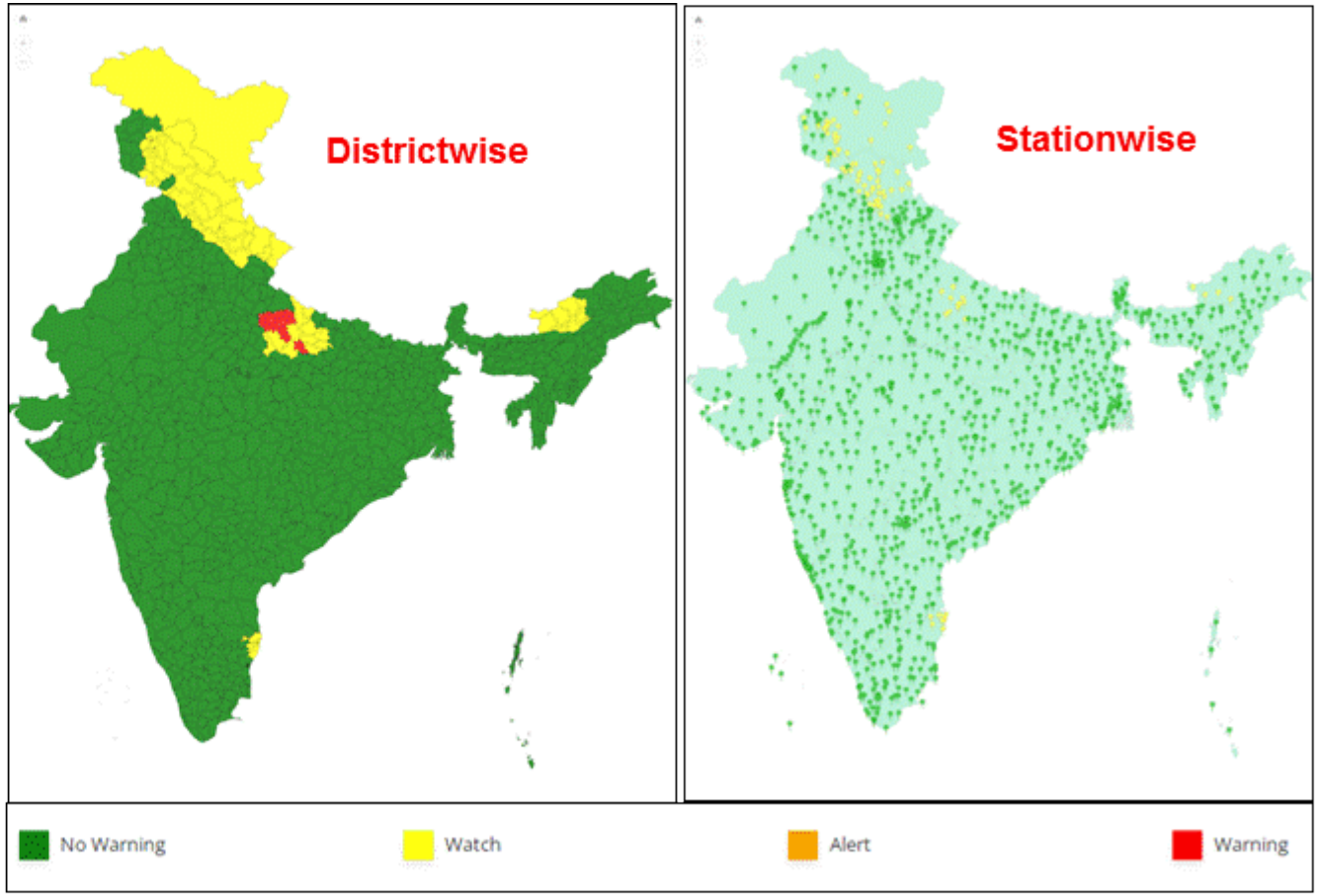
Figure : Storm clusters on August 04, 2014 at 1500 UTC indicated by (a) reflectivity from PR (b) Storm Index from INSAT 3D

Tools and Websites

Tools for operational Nowcasting of Lightning at IMD



Last 10-, 20- and 30-minutes lightning observations (*in-situ*) superimposed with INSAT-3D (*satellite*) images for near real-time monitoring



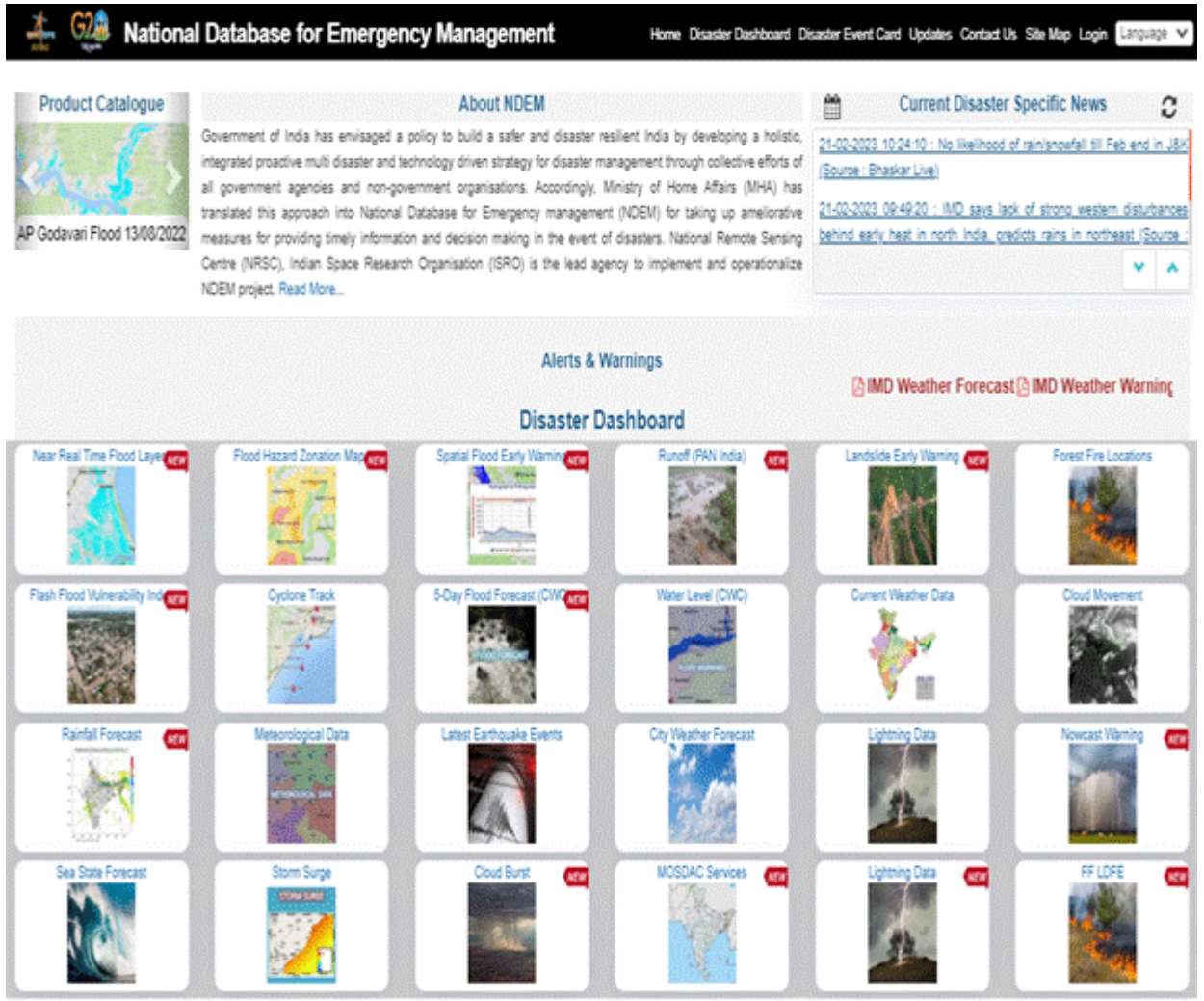
Regular dissemination of 3-hourly nowcast for all 732 districts of India and at station scale for 1089 stations by the IMD.

Primarily for two phenomena: (a) Thunderstorms & associated weather, (b) Intensity of rainfall occurrence

Tools and Websites

https://bhuvan.nrsc.gov.in (for various applications)

https://ndem.nrsc.gov.in/login.php (National Database for Emergency Management)



Tools and Websites

Archive of Remote Sensing data including Indian and Foreign Remote Sensing sensors acquired since 1986

Visualisation portal for full resolution multi-mission data

https://bhoonidhi.nrsc.gov.in/vista

For climate products

https://bhuvan-app3.nrsc.gov.in/data/download/index.php?c=p&s=NI&g=all

Training Opportunities

Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP)
(Affiliated to the United Nations, OOSA)

- 9 Months PG Diploma Course: Satellite Meteorology and Global Climate (SATMET). Every alternate year. 12 PG Diploma courses are conducted at SAC since 1998 (177).
- 2-weeks short courses: Weather Forecasting using NWP models. 4 courses are conducted (198).
- During Covid time, 2 weeks short courses on “Use of Space Technology for weather and climate studies” are conducted in online mode. So far 2 such courses were conducted at SAC (115).

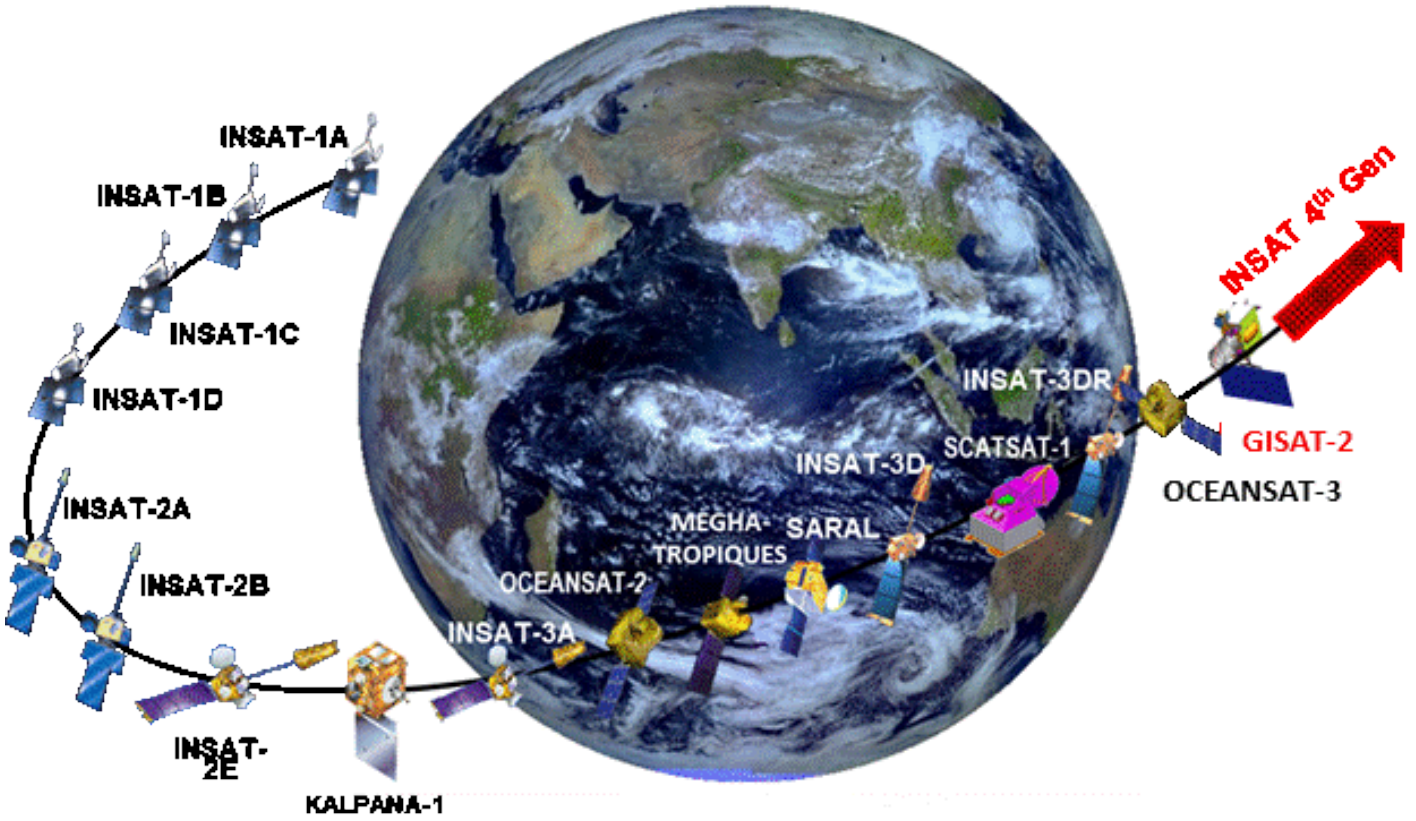
Training Opportunities

IMD

- **IMD is conducting training programs since 1943.**
- **Training activities at MTI, Pune and ICITC, New Delhi of IMD got the WMO recognition as components of Regional Training Centres in 1986.**
- **Meteorological training programs, catering different categories of meteorological personnel from India and Asia-Pacific region.**
- **In addition, to upgrade the knowledge & skill of the meteorological personnel, a number of short-term tailor-made training courses are organized.**

FOREIGN TRAINEES TRAINED IN GENERAL METEOROLOGY TILL DECEMBER 2022 = 318

AFGHANISTAN	21	GHANA	01	LESOTHO	10	NEPAL	07	SRI LANKA	29	UAE	02
BANGLADESH	21	IRAN	02	MALDIVES	35	NEW GUINEA	02	SUDAN	05	UGANDA	01
BHUTAN	20	INDONESIA	02	MAURITIUS	23	NIGERIA	12	SYRIA	09	VANUATU	01
DOHA QATAR	02	KENYA	01	MALAYSIA	11	OMAN	03	TANZANIA	02	VIETNAM	06
EAST AFRICA	03	KOREA	03	MONGOLIA	02	PHILIPPINES	04	THAILAND	03	YEMEN	14
ETHIOPIA	35	LAOS	04	MYANMAR	02	SEYCHELLES	01	TRINIDAD & TOBAGO	01	ZAMBIA	01
CAMEROON	12									FIJI	05


INSAT-1A
INSAT-1B
INSAT-1C
INSAT-1D
INSAT-2A
INSAT-2B
INSAT-2E
KALPANA-1
INSAT-3A
OCEANSAT-2
MEGHA-TROPIQUES
SARAL
INSAT-3D
SCATSAT-1
INSAT-3DR
OCEANSAT-3
GISAT-2
INSAT 4th Gen

Thank You