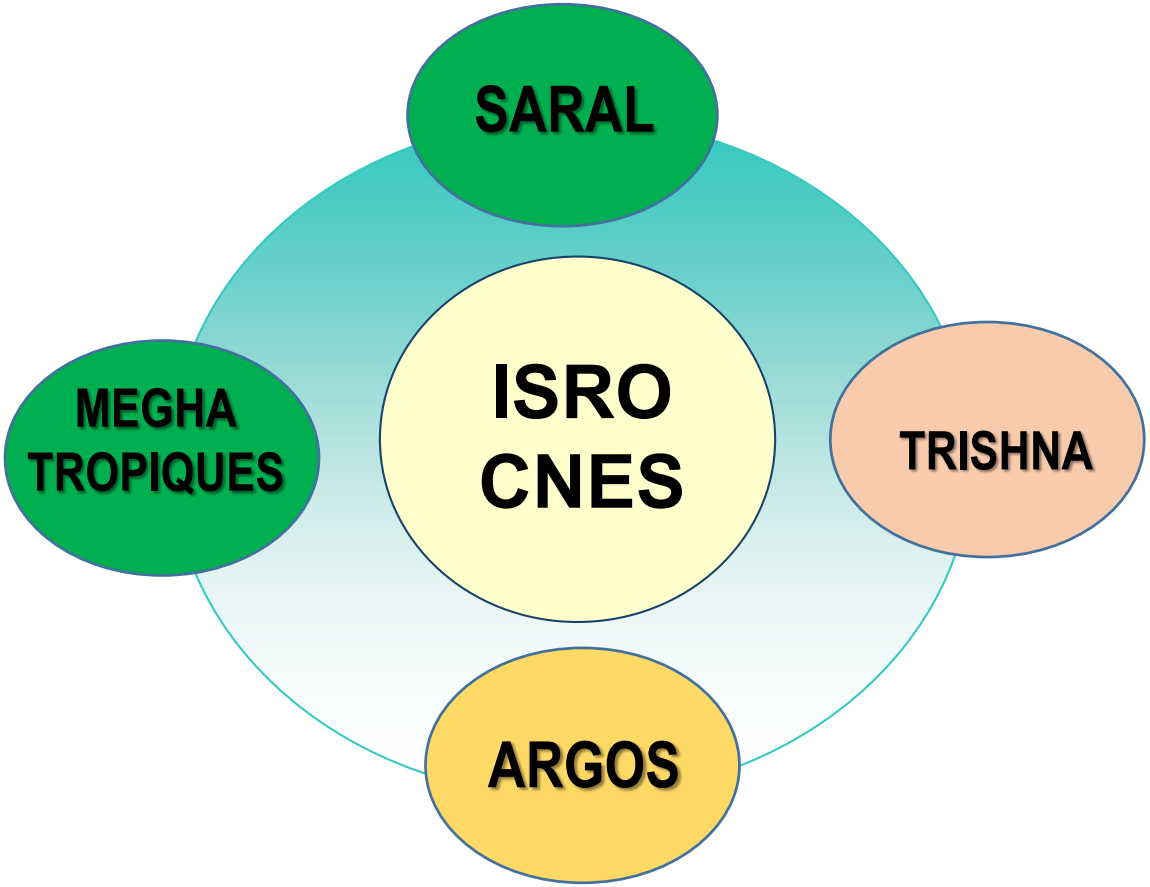
CNES-ISRO EO Collaboration
Products & Services from Indian Perspective



Shantanu Bhatawdekar
EDPO, ISRO HQ

ISPRS TC V Mid Term Symposium
November 20, 2018

Current Operational Remote Sensing Capabilities

Natural Resources Inventory & Disaster Management

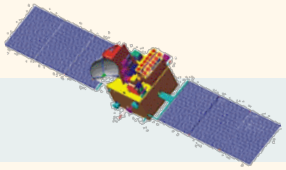
RESOURCESAT- 2 & 2A

- Three tier imaging : 56 m / 23 m / 5.8 m
- Revisit Capability : 03 / 11 / 03 days

Large Scale Mapping, Infrastru. Planning & Cartography

CARTOSAT-1, CARTOSAT-2 (3) & 2S (4)

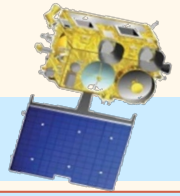
- 2.5 m Stereo imaging
- Sub-meter PAN and 1.5 m Multi-spectral



Oceanography

OCEANSAT-2 ; SARAL ; SCATSAT-1

- Ocean color 360 m with 2 days revisit
- PFZ, Ocean State Forecast
- Ocean Altimetry, Surface Wind Vector



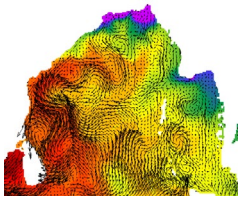
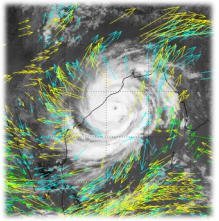
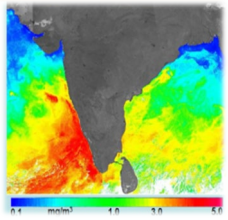
Weather & Climate

INSAT 3D & 3DR ; MEGHA-TROPIQUES

- 6 channel Imager – 48 images per day
- 19 Channel Sounder – Atm. Profiles
- Radio Occultation – humidity profiles

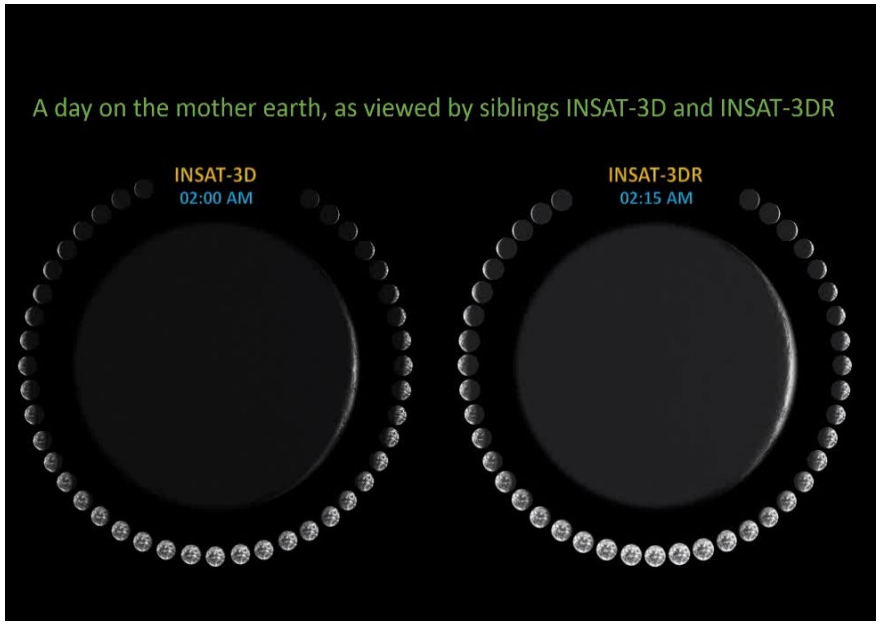




INSAT - 3D & 3DR

(July 2013 / Sep. 2016)



Observations at 15-minute interval : 48 images/ day

- Provide opportunity to capture short-lived cloud processes.
- More no. of AMVs (20-30%) & 10% improvement in accuracy.
- Structural changes within cyclone during rapid intensification stages are well captured
- Better estimation of cloud growth/decay and improvement in rainfall estimation

6 Channel IMAGER	
Bands (μm)	**Resolution**
VIS (0.55-0.75)	1km
SWIR (1.55-1.70)	1 km
MIR (3.8-4.0)	4km
WV (6.5-7.1)	8km
TIR-1 (10.2-11.3)	4km
TIR-2 (11.5-12.5)	

19 Channel SOUNDER

Central WL : 0.695 – 14.71 um

Visible : One Band

SWIR : Six bands

MWIR : Five Bands

LWIR : Seven Bands

Resolution (km): 10 X 10

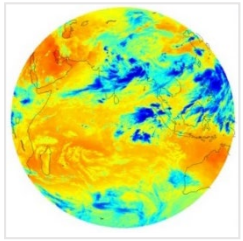
40 profiles of Temp. (surface to 70 km)

21 Profiles of Humid. (surface to 15 km)

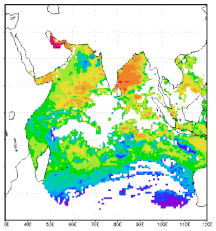
Integrated Ozone (Surface to ~ 12 km)

Imager Products

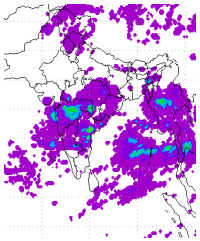
OLR



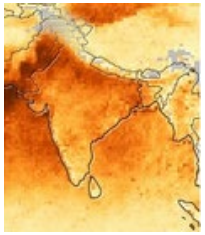
SST



QPE (RAIN)



AEROSOLS



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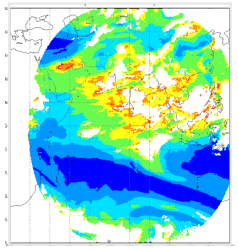
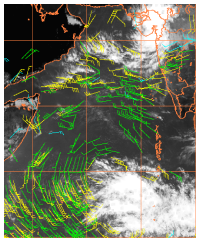
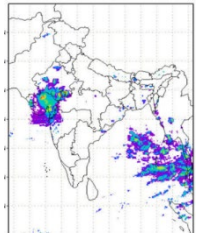


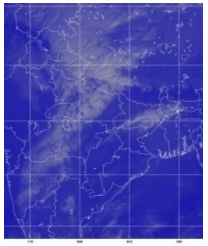
WV WINDS



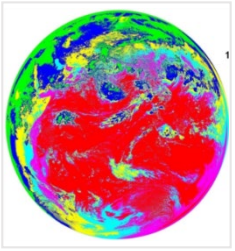
HE-RAIN



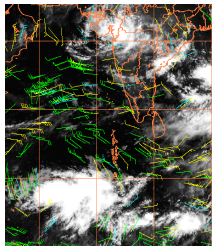
FOG



INSOLATION

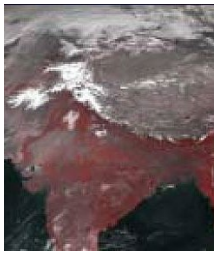


CLOUD WINDS

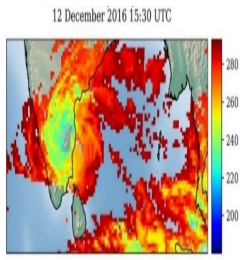


FIRE & SMOKE

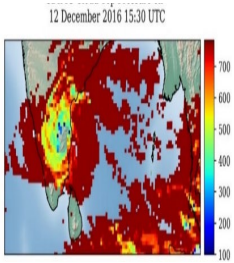
SNOW



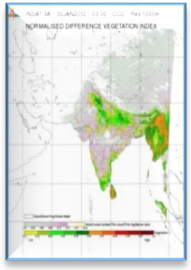
CLOUD TOP TEMP



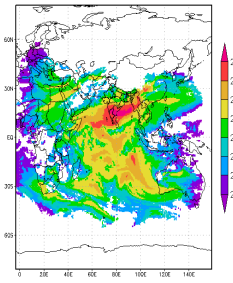
CLOUD TOP PRE.



NDVI

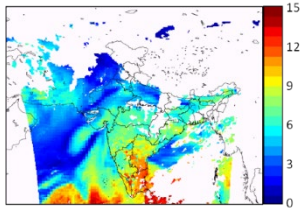


CLEAR SKY BT

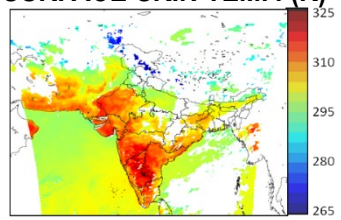


Sounder Products

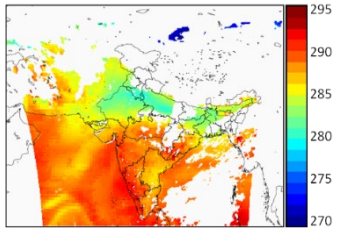
WV (G/KG) 850 HPA



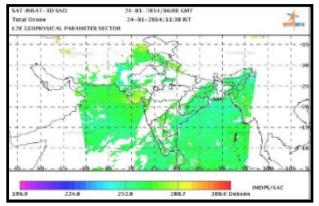
SURFACE SKIN TEMP. (K)



TEMP (K) 850 HPA



TOTAL COLUMN OZONE



IMDPS

INSAT Meteorological Data Processing System

- Fast Track System for Processing Kalapana-1 and INSAT-3A in 2006
- INSAT-3D processing system Operationalization at IMD (24 x 7) in 2014

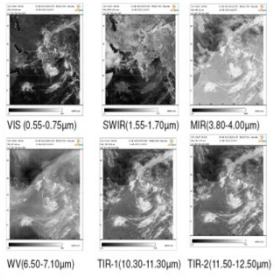
Major Sub-systems of IMDPS

Data Acquisition and Quick Look Display system(DAQLS)
- Base Band Reception H/W
- RT Data Acquisition and QLD S/W
- AWS Data Acquisition System (AWSAS)

Data Products System (DPS)
- Data Products Software, PMMS, PSS, OIDS
- Ancillary Data Processing Software (GTS, AWS)
- Data Dissemination Software (Internet, SIDS,HDF)
- Database Management Software (PSS DB, ADPS DB)

Geo-physical Parameter Retrieval (GPR) Software

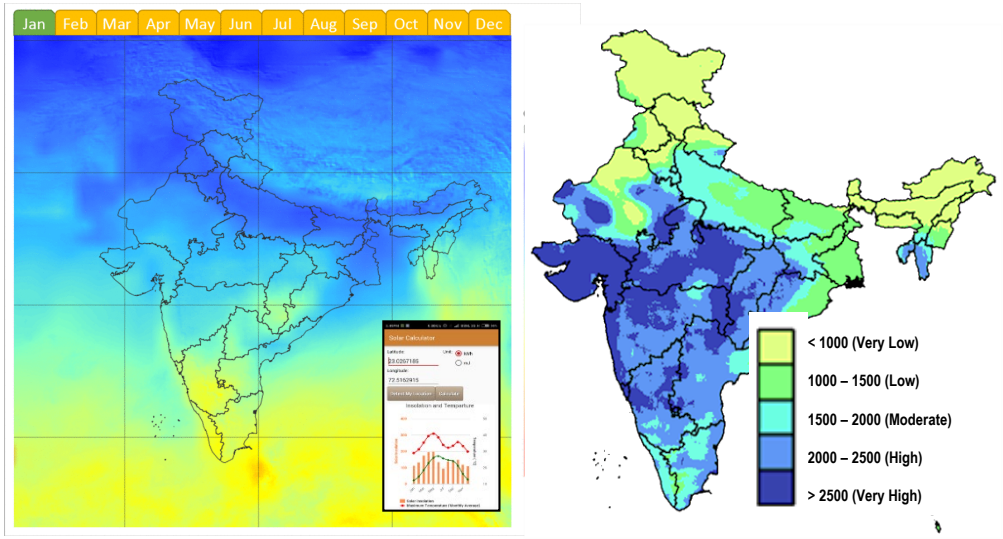
Meteorological Image Analysis Software (MIAS), McIDAS
METGIS Software (IGIS/IP Customized)
RAPID: Real time Analysis of Products and Information Dissemination
Satellite Imagery Display System (SIDS)



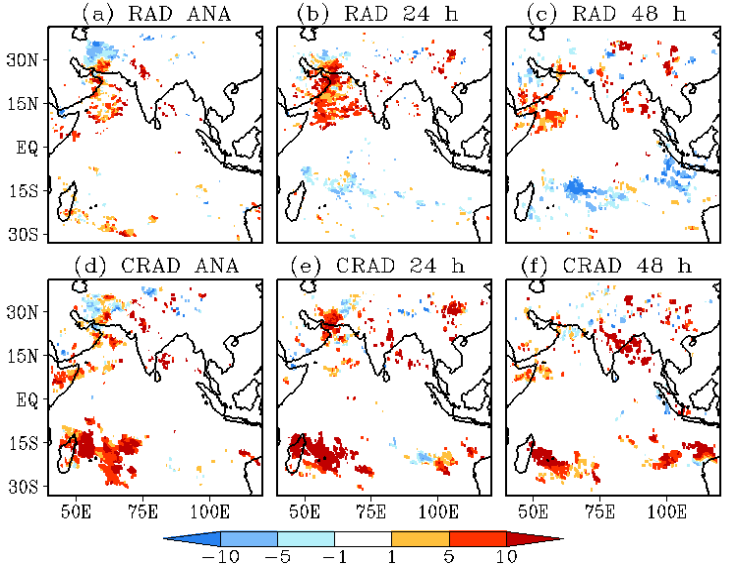
Real time Analysis of Products and Information Dissemination

RAPID

Solar energy potential & 48-Hour forecast

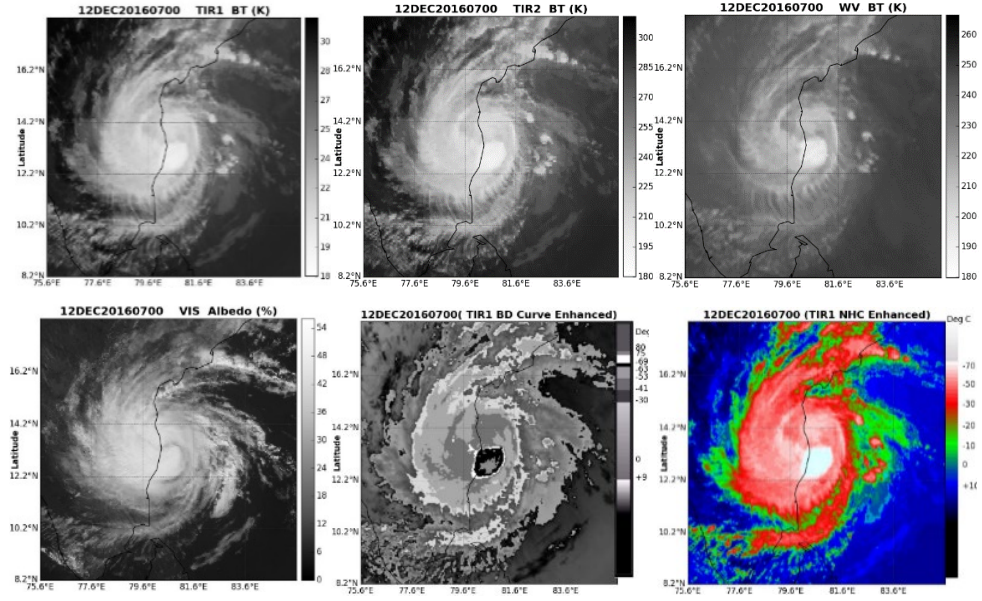


Assimilation of Clear-Sky Brightness Temperature

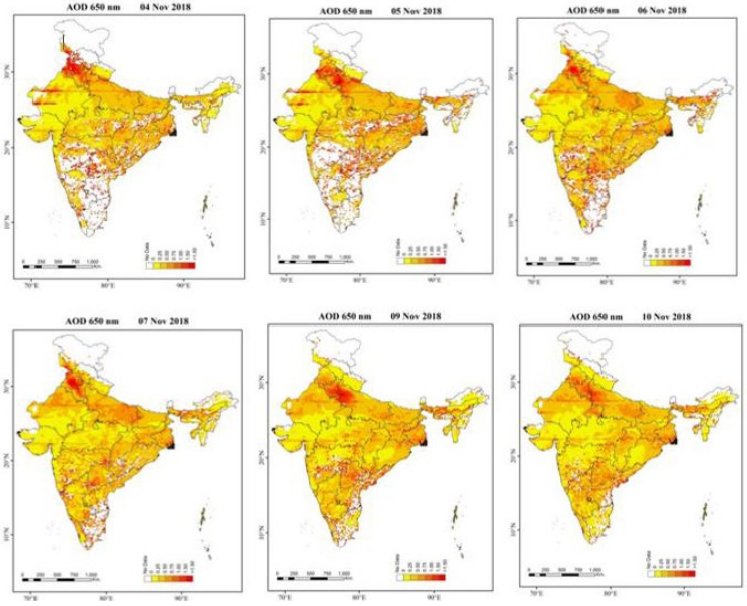


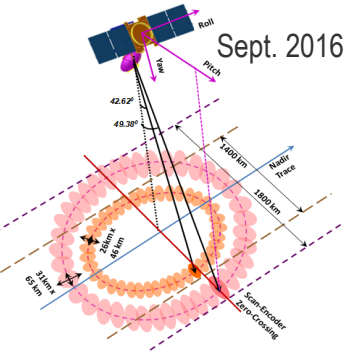
Improved Rainfall prediction

Continuous monitoring of Tropical Cyclones



Spatial distribution of INSAT-3D AOD





SCATSAT-1 ….*Continuity of data & services of OSCAT*

Payload : Ku band Scatterometer (13.515 GHz)

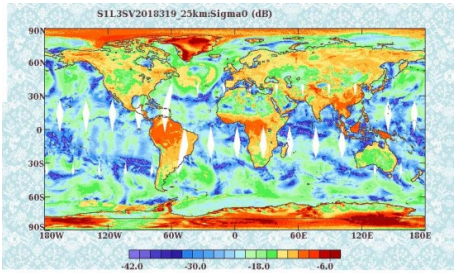
Orbits / day: 14 ½ ; ECT (DN): 08:45 AM LT; Repeat cycle: 2 days

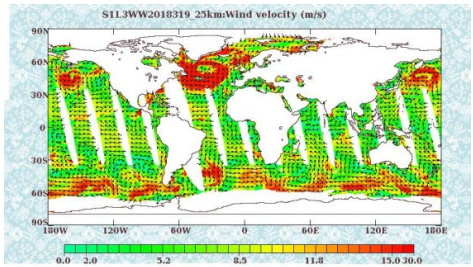
Operational Data Products

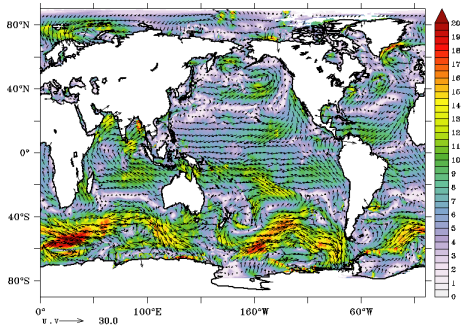
Param.	Sigma0	Wind	Sigma0	Wind
Swath	1800 km	1800 km	Global	Global
Cell size	50 km 25 km	50 km 25 km	0.5° , 0.25°	0.5° 0.25°

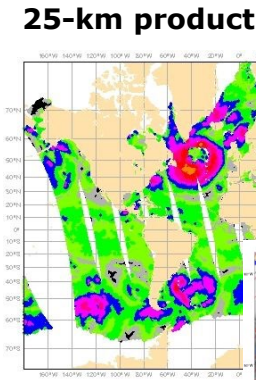
Value added Products

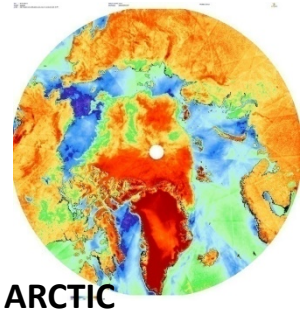
Param.	BT	Analyzed winds	Sigma0 Gama0	Sigma0 Gama0
Spatial Coverage	Global	Global	Global India	North Pole South Pole
Spatial Sampling	0.25°	0.25°	0.02°	0.02°



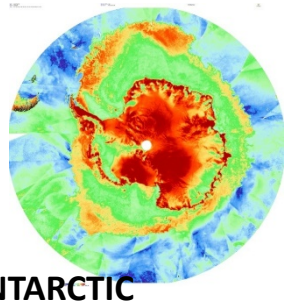




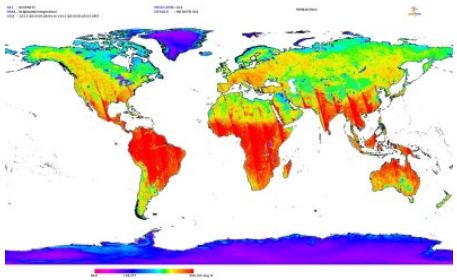


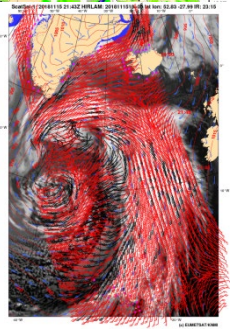


ARCTIC



ANTARCTIC



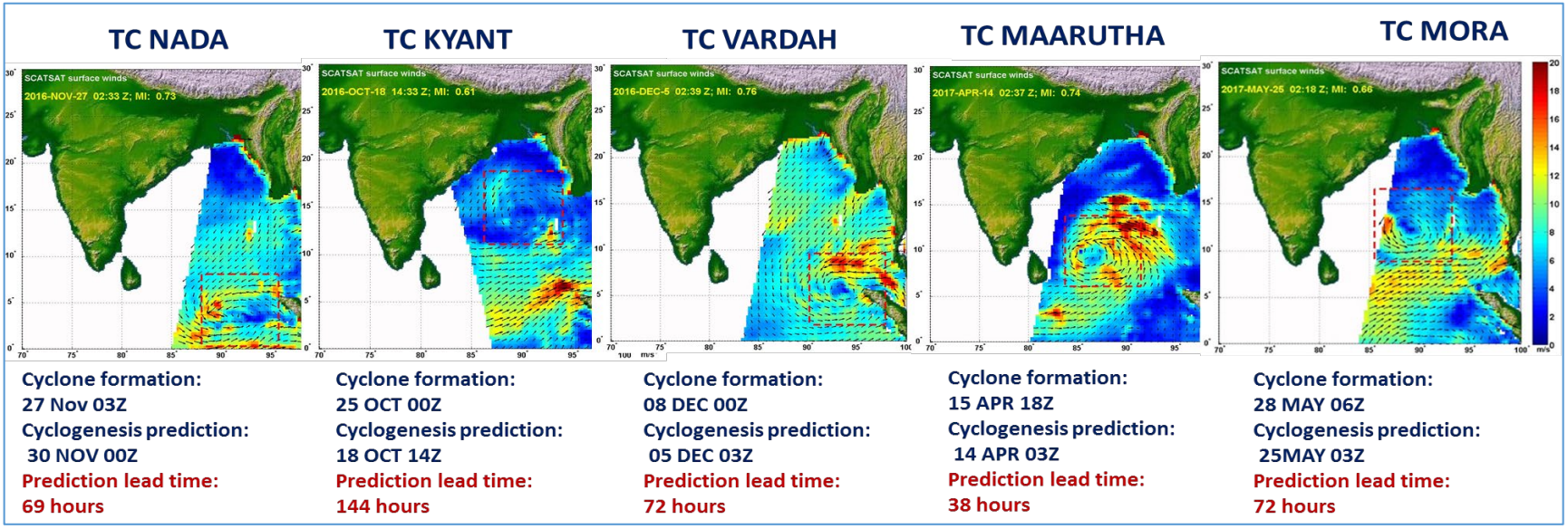


Data disseminated freely to NASA, NOAA, EUMETSAT, KNMI, ECMWF…..

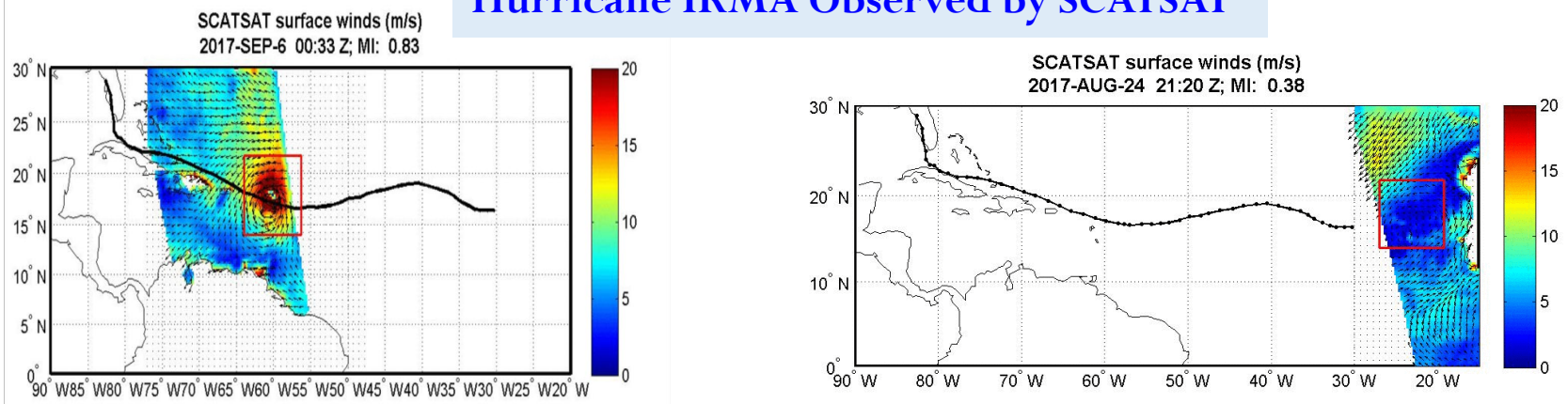
Tropical Cyclogenesis Prediction using SCATSAT-1

Scatsat-1 showing earliest detection of tropical cyclogenesis.

Mean Prediction Lead Time: 79 hours (~3 days in advance)

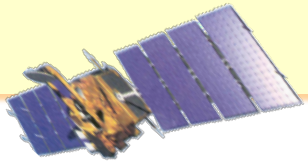


Hurricane IRMA Observed by SCATSAT



Life cycle of winds captured by SCATSAT during Aug 24 to Sept. 11, 2017

MEGHA TROPIQUES (Joint Indo-French mission)

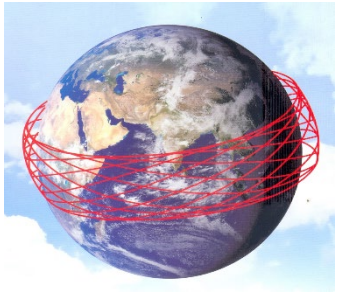


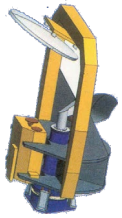
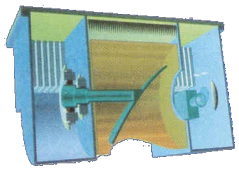
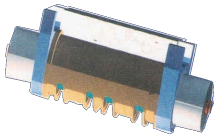
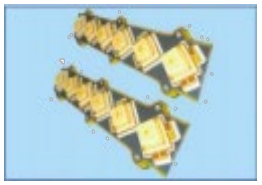
(Oct. 12, 2011)
PSLV (C-18)

for studying water cycle & energy exchanges of tropical convective system

Successful 7th Year of operations in progress

Altitude	: 865 Km near circular
Inclination	: 20 degrees
Swath	: 1700 to 2200 km
Repeativity	: up to 6 times a day

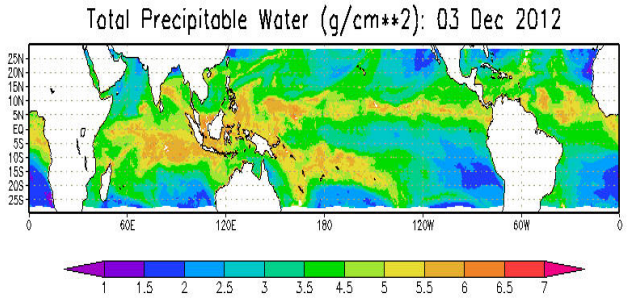


MADRAS	SAPHIR	SCARAB	ROSA
			
Microwave radiometer 18, 23, 36, 89 & 157 GHz; Wind speed, total water vapour, cloud liquid water, rainfall, cloud ice	Six-channels at 183 GHz Humidity Profiling at 6 altitudes	4 Channels at 0.5 - 0.7, 0.2 - 4 10.5-12.5 & 0.2-200 mm Long-wave radiation fluxes	GPS receivers at L1 & L2 channels Temperature & humidity profiles

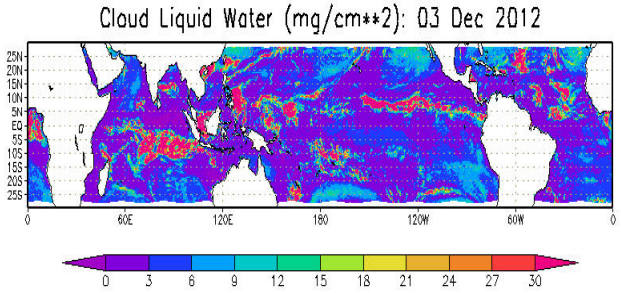
Extension of MoU was signed by ISRO & CNES in Oct. 2016 for 4 more years.

MADRAS GEO-PHYSICAL PRODUCTS

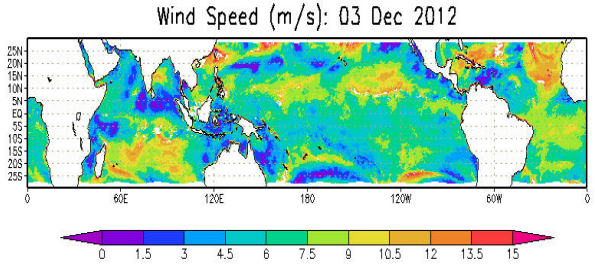
TOTAL PRECIPITABLE WATER (TPW)
0.34 g/cm2 (for clw < 50 mg/cm2)



CLOUD LIQUID WATER (CLW)
3.72 mg/cm2 for CLW < 30 mg/cm2

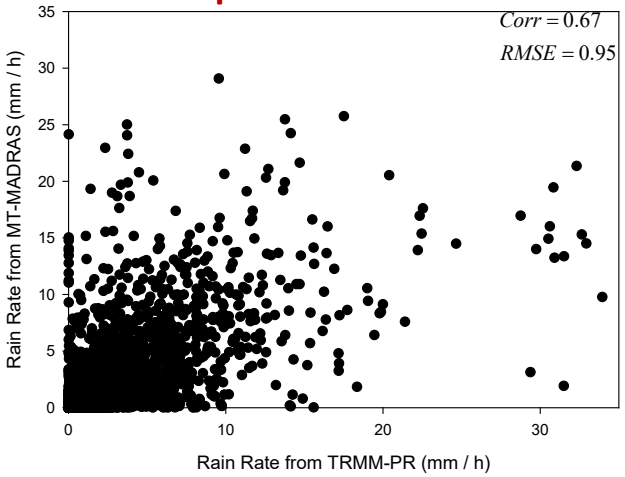


OCEAN SURFACE WIND SPEED
1.4 m/s (for clw < 18 mg /cm 2

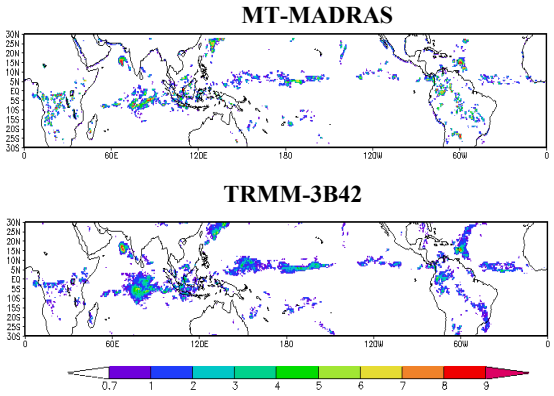


- **Assimilation of WS & TPW improved the near-surface model analyses as well as subsequent model forecasts.**
- **Improvement parameter shows > 10 % improvement in 24 h rainfall forecasts over Indian Ocean.**
- **Assimilation of radiances showed improvements in forecast of moisture, temperature, winds & precipitation forecast skill.**

Comparison of Rain Rate

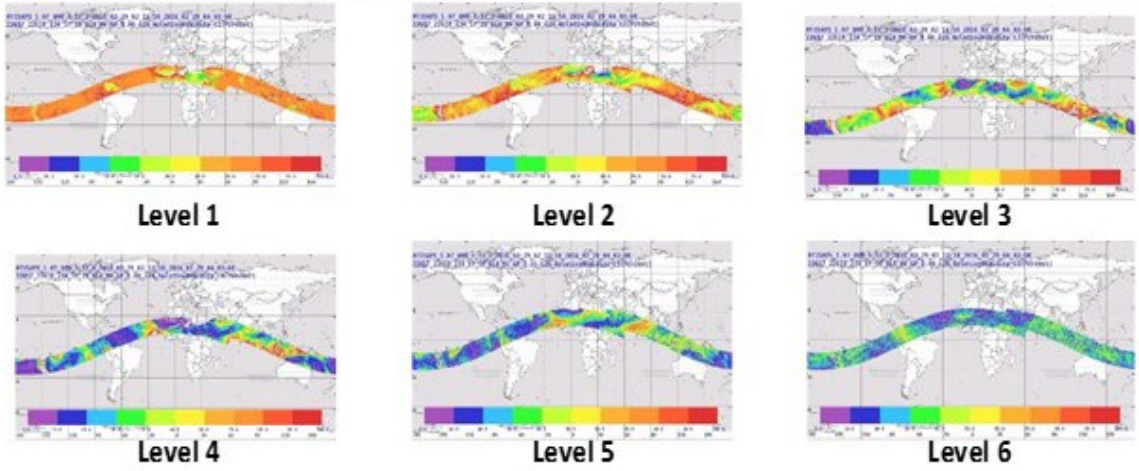


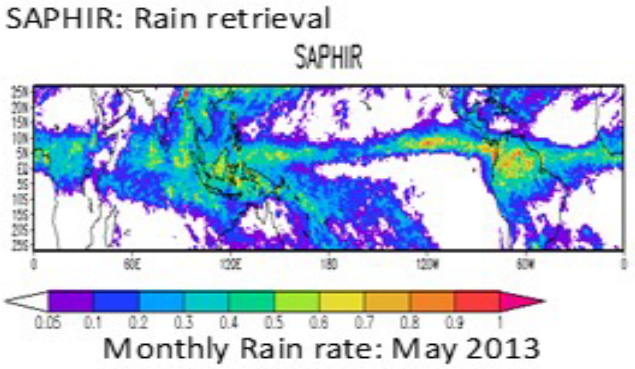
Daily Average Rain Rate (mm/hr)

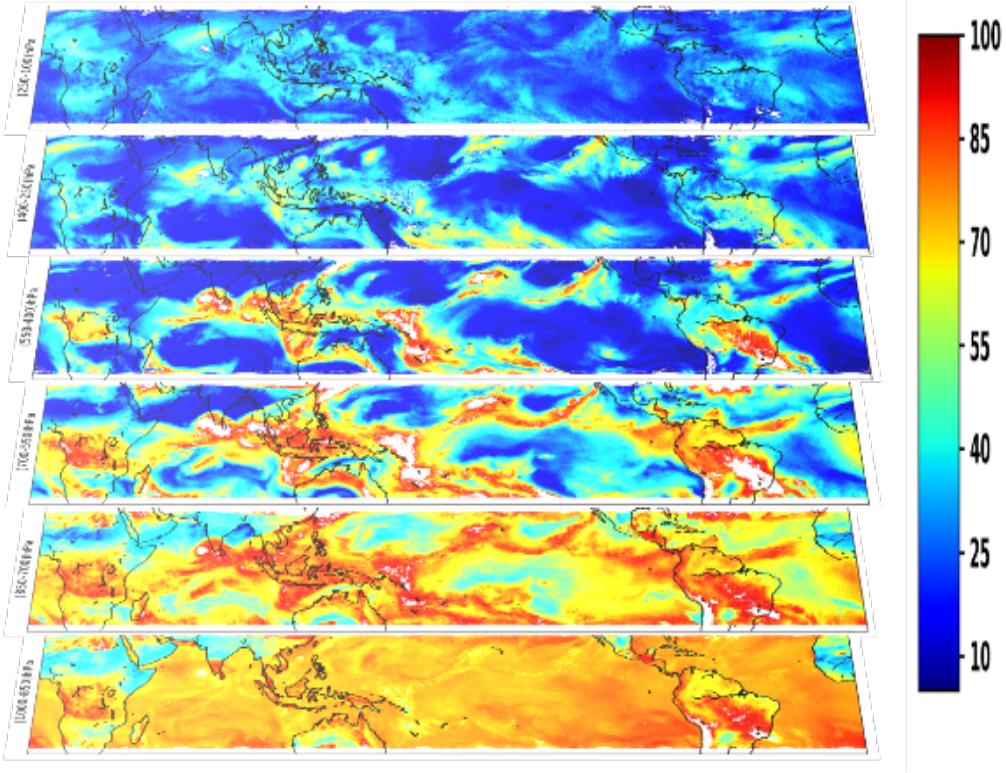


Surface	Corr. (R)	RMSE mm/h)	No of Points
Land	0.48	0.96	12215
Ocean	0.73	0.95	46952
Land + Ocean	0.67	0.95	59167

SAPHIR-6 LEVEL HUMIDITY



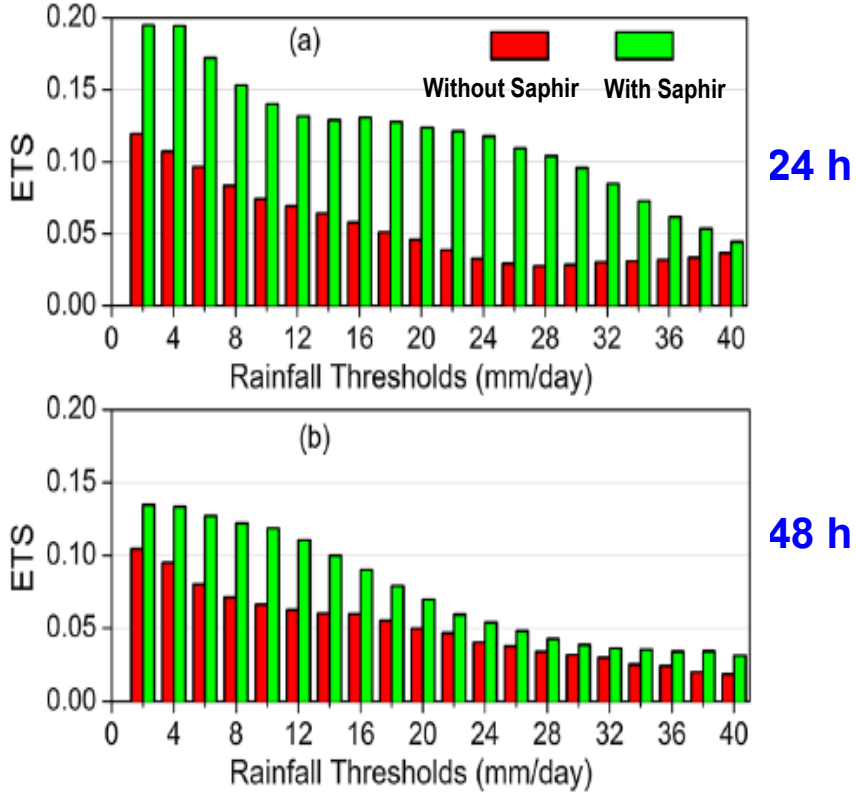


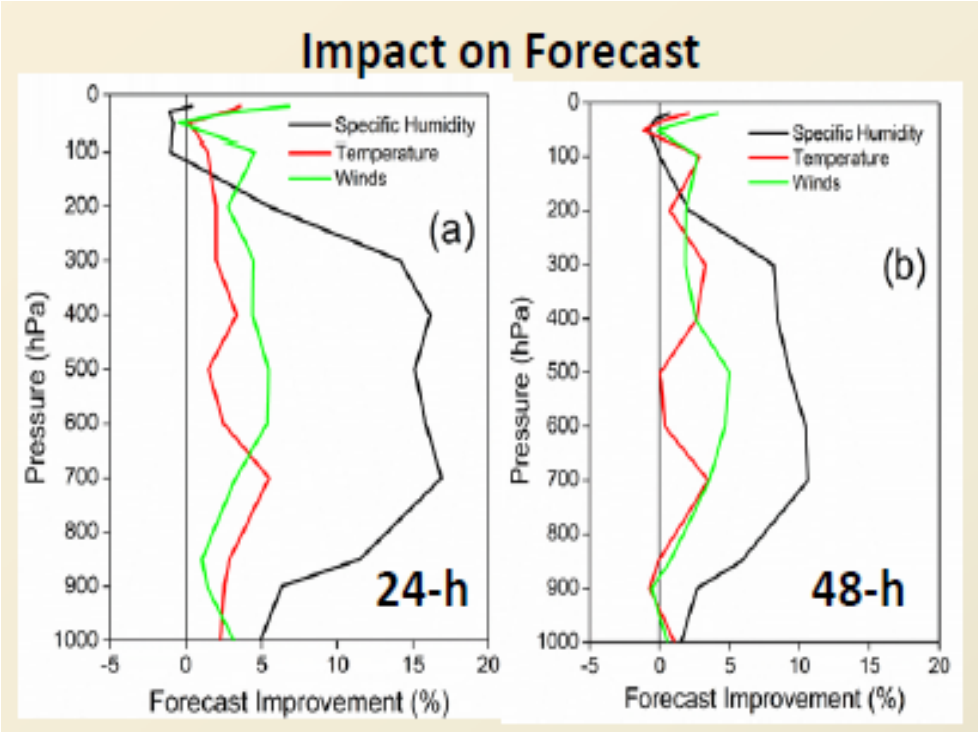


- After MADRAS failure, SAPHIR was successfully exploited for precipitation retrieval.
- SAPHIR swath rain product is operationally available since July 2015 from MOSDAC.
- SAPHIR radiances are routinely assimilated in NCMRWF NWP model for operational forecast.
- SAPHIR brightness temperatures on real time are being pulled by GPM.

Impact of Assimilating Megha-Tropiques SAPHIR Radiances

SAPHIR clear-sky radiances are assimilated in various operational NWP centers including NCMRWF, India.





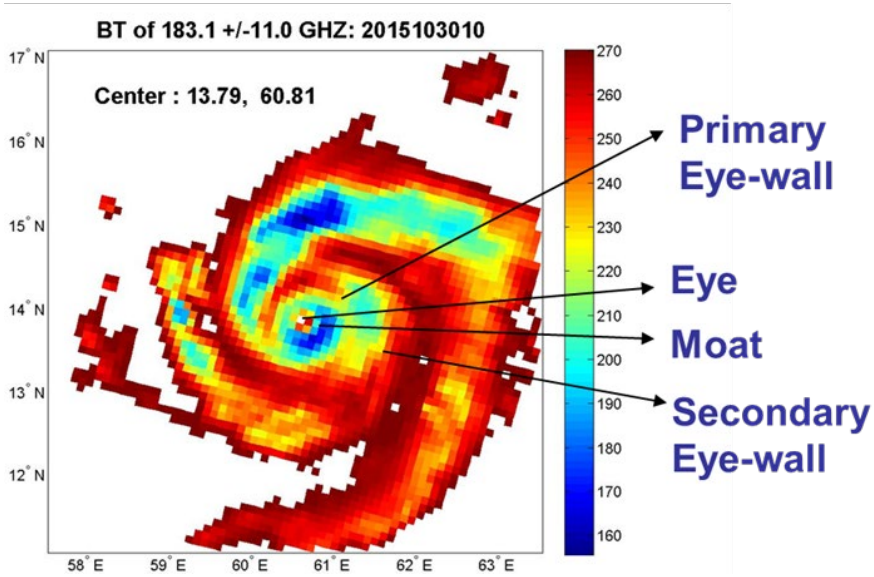
- Assimilation of SAPHIR Radiances in the Weather Model improved temperature, moisture, winds as well as rainfall forecasts.
- Larger than 10 % improvements are found in moisture prediction.

Observational Analysis of TC structure by SAPHIR

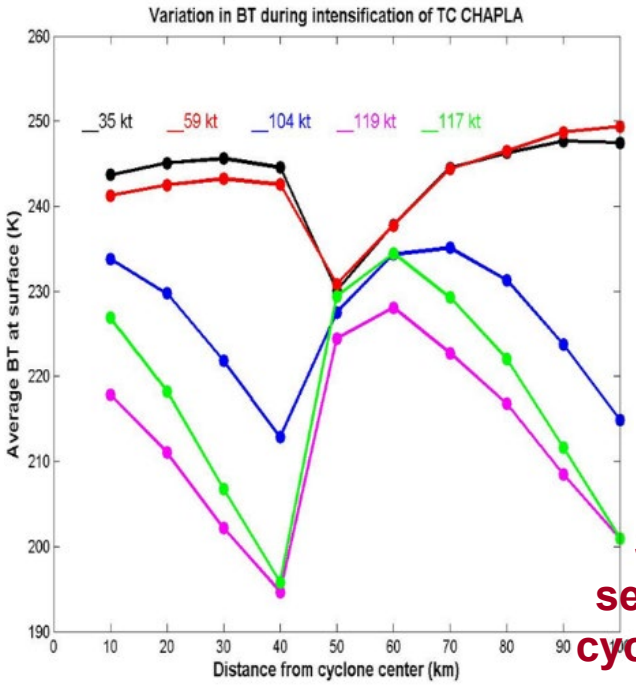
Center Estimation

- In SAPHIR observed brightness temperature distribution, the eye of TC can be estimated by identifying a local brightness temperature maximum circled within the extreme low brightness temperature present in the eyewall.
- The center estimation by identifying the warmest pixel is limited to strong cyclone cases only.

Tropical structure cyclone observed by SAPHIR



Curtsey: Dr. Neeru, ASD/AOSG/EPSA

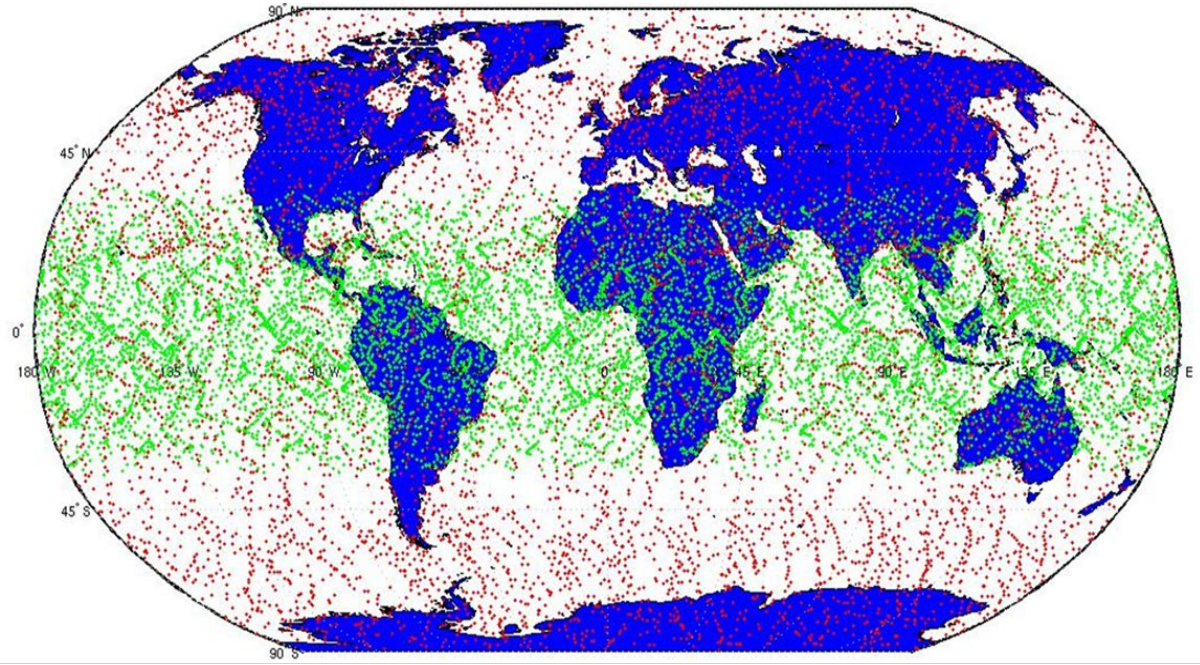


SAPHIR BT sensitivity with cyclone intensity

More frequent high resolution microwave observations are helpful for understanding internal dynamics & rapid intensification processes within TCs.

MT-ROSA Products

One Month Distribution of RO events:



MT-ROSA OCEANSAT-2 ROSA

MT-ROSA	O2-ROSA
-40 to +40 deg. Range (Global)	Global, but more coverage over high latitude
Rising & Setting Occultation	Only Rising Occultation
200+ products / day	100+ products /day
Instrument – TAS-I (Italy)	
Identical Algorithm is used	

MT-ROSA is operationalised since April 2016 through MOSDAC.

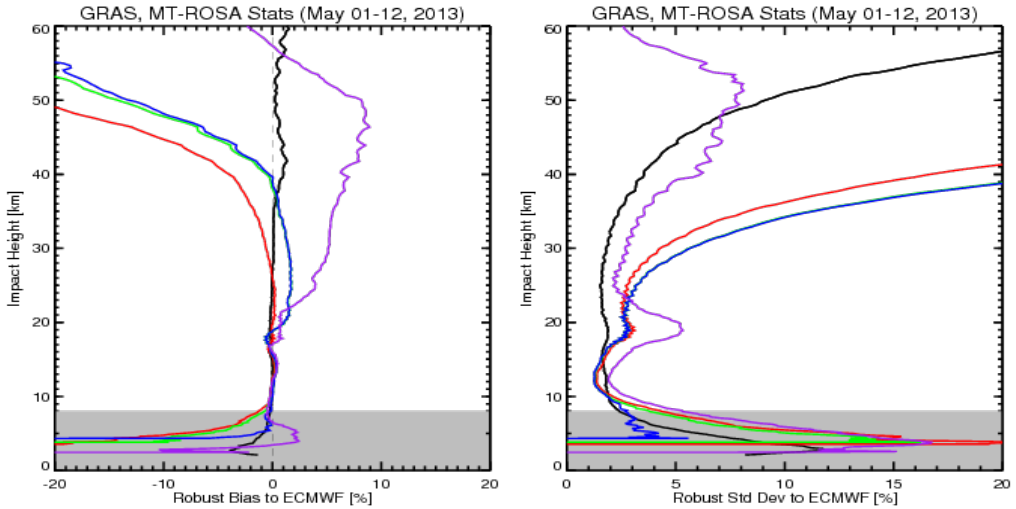
- ❖ Disseminated to major national & international weather forecast agencies, such as IMD, NCMRWF, ECMWF.
- ❖ MT-ROSA products (NetCDF) disseminated directly from ISSDC to NCRMWF for NWP model assimilation and weather forecasting.
- ❖ MT-ROSA (Level-1 & Level-2) products are generated for NRT dissemination to global weather agencies viz. ECMWF, DMI, including for IMD (Delhi).

Operational products

- Temperature profile
- Pressure profile
- WV partial pressure profile
- Dry Temperature profile
- Dry Pressure profile
- Refractivity profile
- Bending Angle profile
- Impact parameter profile

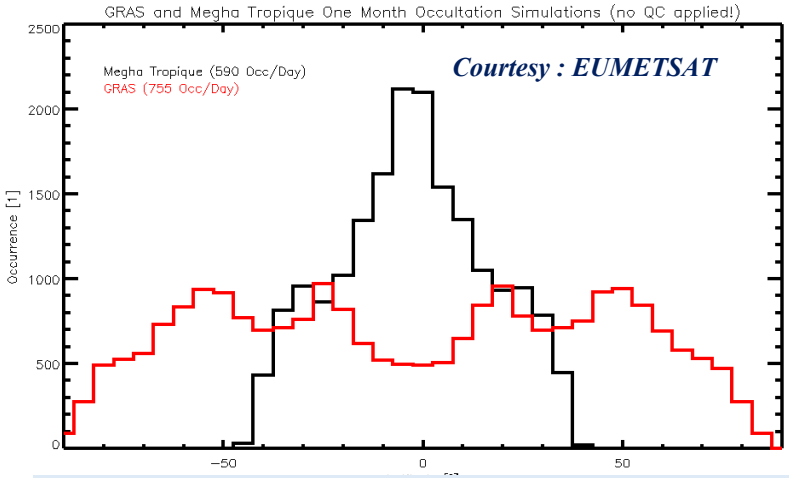
Significance and Gap area of MT-ROSA

EUMETSAT assessment on MT ROSA Data:



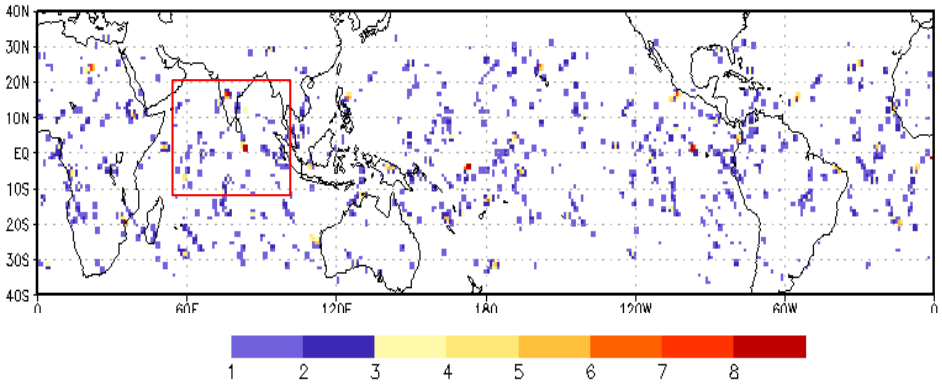
- Data quality has improved, both in terms of relative bias (< 0.5%) and std. dev. (< 3.0%) (8-25 km) (*left*)
- Std. dev. slightly lower for altitudes > 22km (*middle*)
- Standard deviations larger in lower troposphere (*middle*)

No of occultation per latitude band from GRAS & ROSA

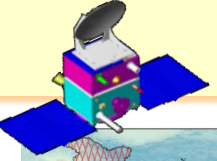


MT-ROSA significantly complements polar missions by augmenting tropical data density (one-day event distribution plot of MT-ROSA (black) & GRAS (red)

Accumulated ROSA events in 1° x 1° grid over 12 days

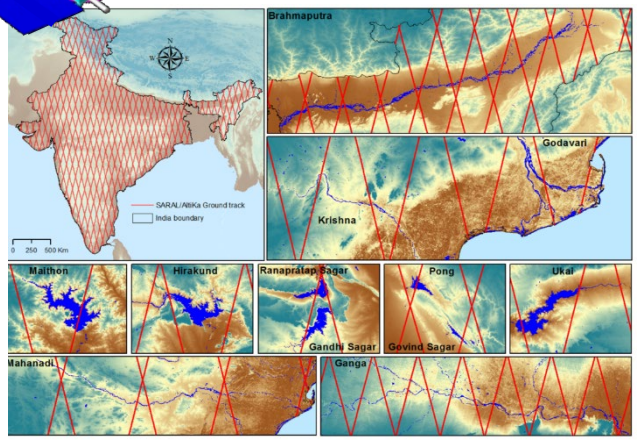


Data density scanty even in the Indian region shown by red box even after 12 days accumulation. Can be improved by putting ROSA type receivers in constellation formation.



25.Feb. 2013

SARAL - (Joint Indo-French mission)



- ALTIKA - A Ka-band (35.75 GHz, BW 500 MHz) radar altimeter
- ARGOS - Data Collection Platform
- A dual-frequency MW radiometer (23.8 & 37 GHz)
- DORIS: For achieving adequate orbitography performances
- LRA: For Orbitography & system calibration

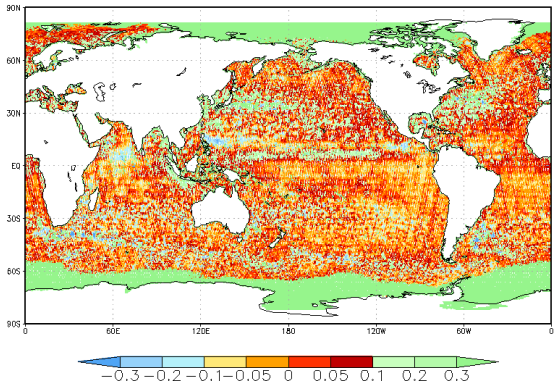
Ocean circulation, sea surface elevation, Marine meteorology & sea state forecasting

Parameter	Specification
Apogee / Perigee Altitude	800 kms / 786 kms
Repeat period	35 days
No. of orbits in a cycle	501
Local time of ascending node	06:00
No of Orbits/day	14 +11/345
Path to path distance	75 km
Consecutive track	2800 km
Pointing Accuracy	0.1 Deg

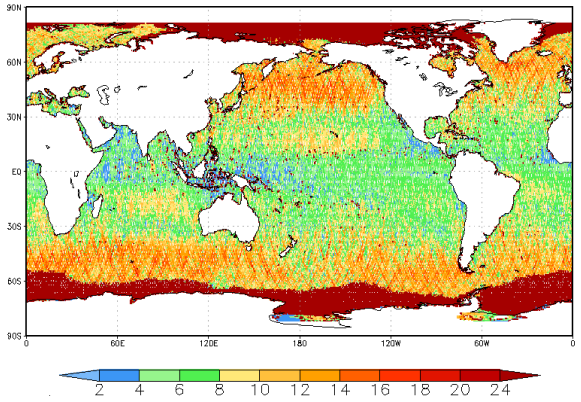
- From 4 July 2016, SARAL entered a new phase called SARAL-DP (Drifting Phase).
- Its altitude of 800 km is increased by 1 km and no more maneuvers are performed on the satellite, except for collision avoidance.

Operational products from SARAL - AltiKa

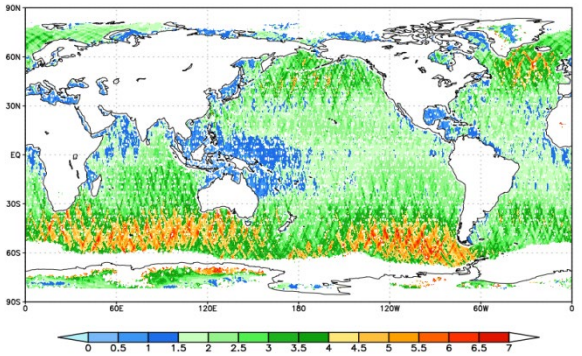
Sea Surface Height Anomaly (cm)
1-Cycle Plot (35 days)



Ocean Surface Wind Speed (m/s)
1-CyclePlot (35 days)



Significant Wave Height (m)
1-Cycle Plot (35 days)



Sea Surface Height = ~4 cm

Significant Wave Height = ~30 cm

Surface Wind Speed =~1.7 m/s

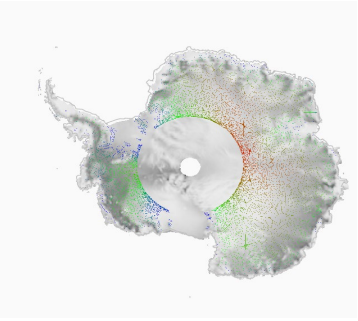
AltiKa Repeat Cycle = 35 days

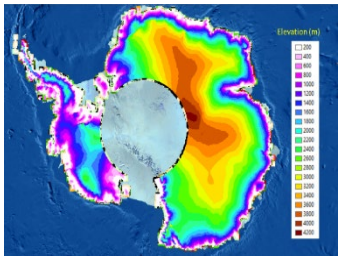
Along-track res. for 1-Hz data = 6 km

Along-track res. for 40-Hz data = 175 m

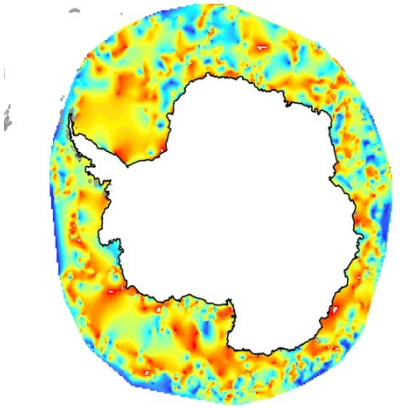
Ice sheet Surface Elevation &Sea ice thickness distribution

Ice sheet surface elevation derived using re-tracker data





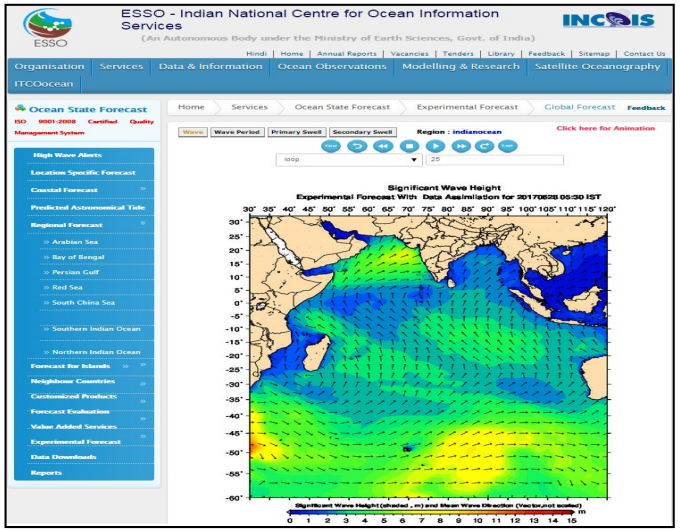
Sea ice thickness distribution - using waveform data

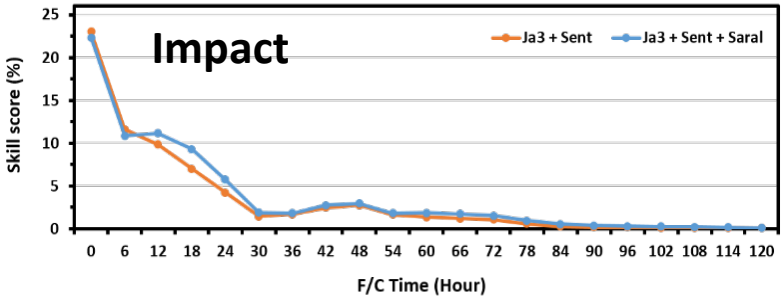


Coastal Products (Sea level, Significant Wave Height &Wind speed) hosted on MOSDAC

Operational Wave Forecasting (INCOIS)

AltiKa data is being assimilated along with Jason & Sentinel altimeters in operational wave model set up.

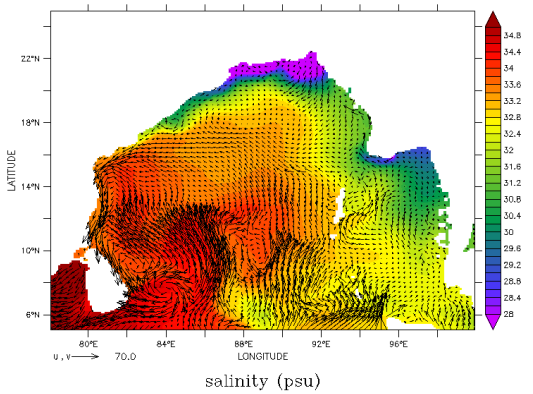




Adding SARAL/AltiKa improves the skill of predicted wave height for 12-24 hr lead forecast.

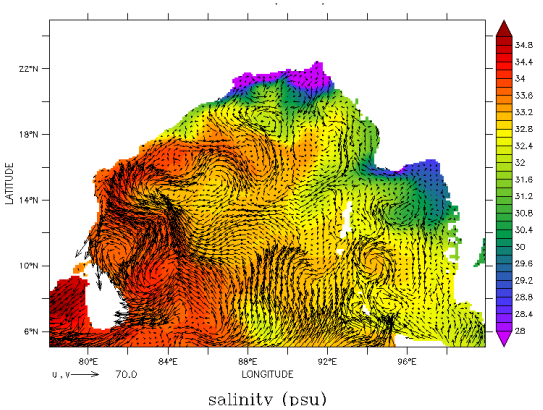
Assimilation in Ocean Circulation Model

Ocean Surface Salinity overlaid with surface current (simulated by model without AltiKa data)



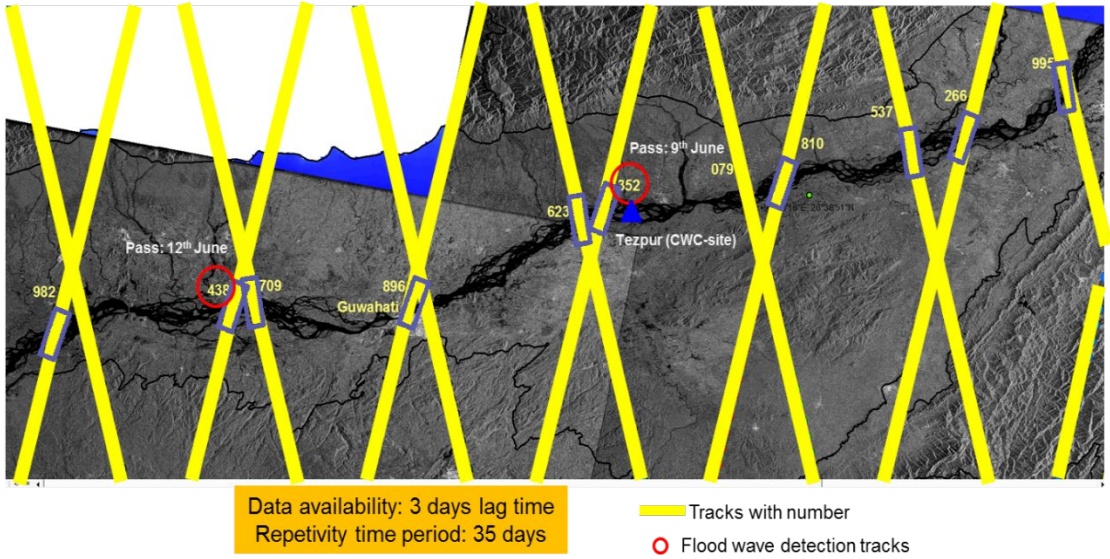
- Assimilation of SLA improved overall performance of model around 10-15%.
- Small Scale features of ocean circulation are well resolved a

Ocean Surface Salinity overlaid with surface current (simulated by model after assimilating AltiKa data)

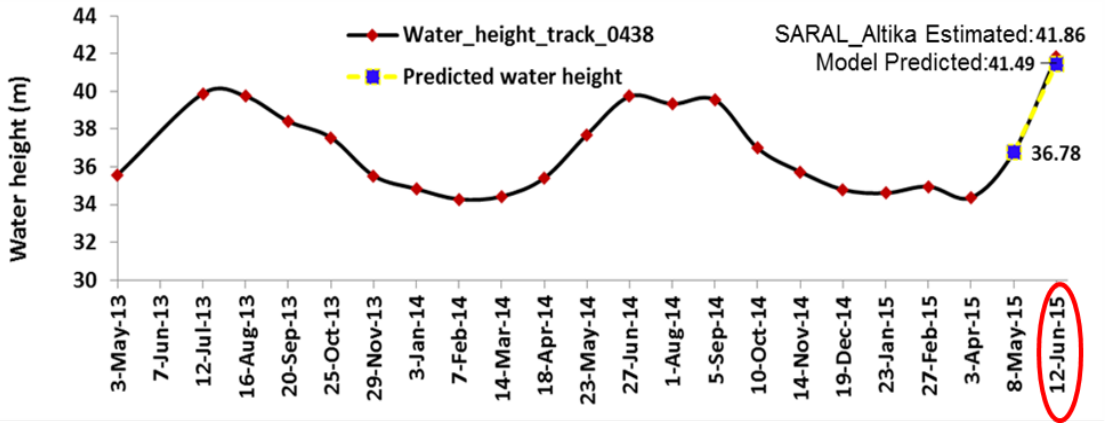


Altika Data for Inland Hydrology

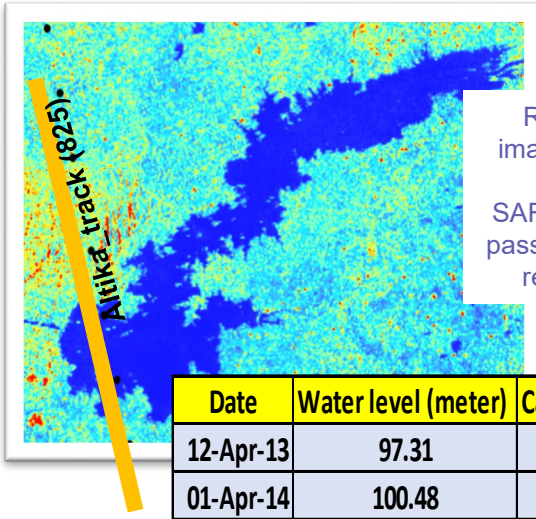
Indian region of the Brahmaputra river along with SARAL-Altika tracks overlaid on RISAT-1 radar image.



Brahmaputra river water (during April 2013 to June 2015) including model predicted water levels for 12th June 2015.



Assessment of water levels for Ukai



RISAT-1 image, along with SARAL/AltiKa pass over Ukai reservoir

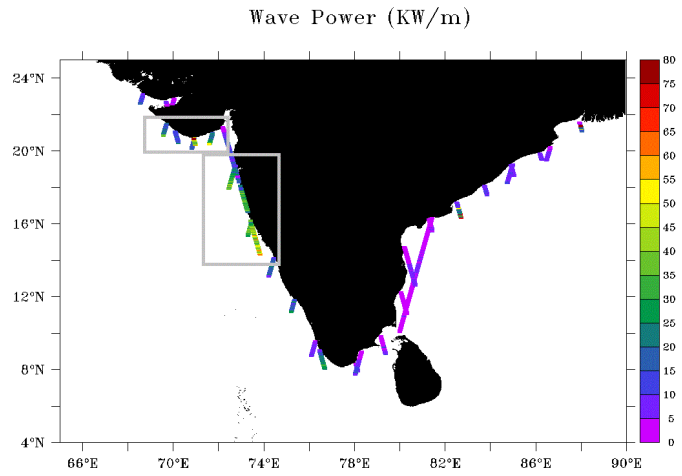
Date	Water level (meter)	Capacity (MCM)
12-Apr-13	97.31	3347.75
01-Apr-14	100.48	4570.81
01-Apr-15	95.89	2905.15
01-Apr-16	94.12	2424.73
01-Apr-17	98.5	3819.261

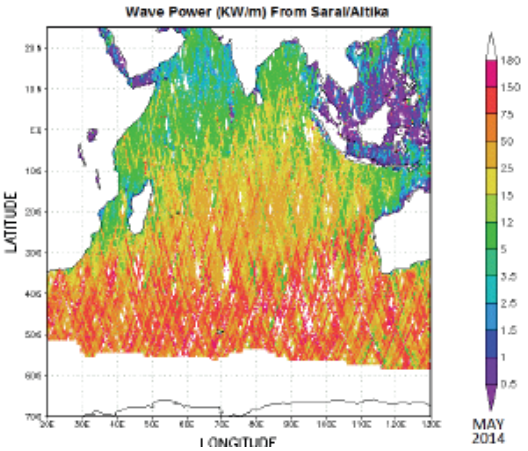
- Water level over the inland water bodies is retrieved using altimeter waveforms data.
- Range is corrected for tropospheric, ionospheric and tidal correction.
- Re-tracking algorithms are developed & operationalised.

Using the coastal Altimeter data: SARAL/AltiKa

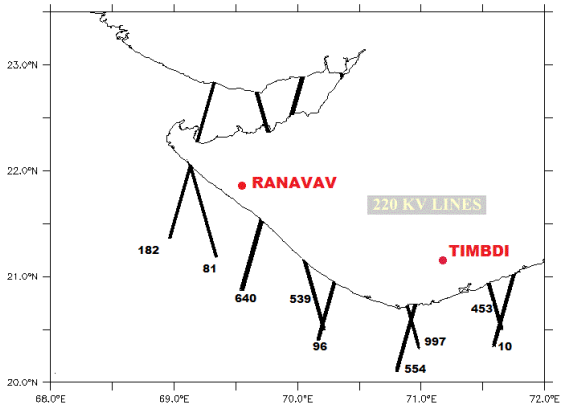
(Wave Energy: A prototype for Gujarat Coast)

Wave power potential for the coastal regions of India

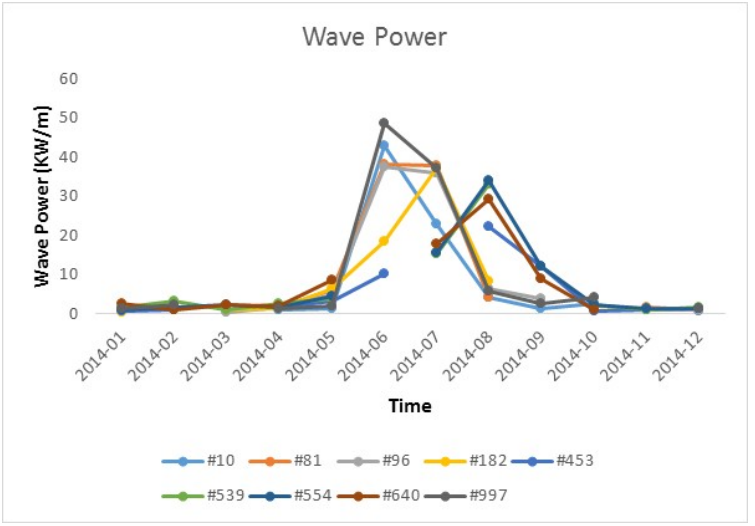




AltiKa Tracks in the Gujarat Coastal waters



Seasonal variability in the wave power potential near Gujarat coast



- Wave energy potential estimated using wave model
- Technique developed for 10-km resolution wave energy forecast.
- Strong Seasonality in the wave power potential
- Geospatial Energy Portal of India for NITI Aayog

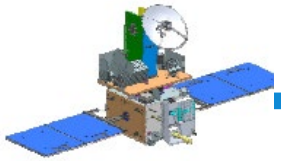
TRISHNA - Joint TIR & VNIR Mission

- Two main objectives driven by scientific requirements:
  - Ecosystem stress and water use monitoring
  - Coastal zone monitoring and management

Payloads – 50 m ; 932 km swath	
TIR (CNES)	4 bands (8.6 to 11.5 μm)
VNIR (ISRO)	6 bands (485 to 1610 nm)

Bus System (ISRO)	
Bus	IMS-3 (Modified)
Payload Mass	<200 kg
Data rate	~700 mbps
Launch	PSLV
Orbit	761 Km ; 8 days revisit SSPO, 1 PM

- **Mission Definition Review (Dec 2017)**
- **Cleared feasibility for Phase-2 (Feb 2018)**
  - Mission life: Revised from 3 to 5 years.
  - TIR , VNIR, SWIR Bands finalized with inclusion of Cirrus Band for cloud detection (1.38 μm).
  - Ground Station requirements identified.
  - CNES confirmed support of X band polar station for every orbit data.
- **Joint science working groups being formed to initiate the pre-launch science activities.**



Hosting Argos-4 on Oceansat-3

- ARGOS offers worldwide transmitter tracking service
- Provides in-situ environmental data collection from platform located in different continents and oceans in UHF frequency.
- Continuing collaboration in ARGOS mission with hosting Argos-4 payload on Oceansat-3.
- Collecte Localisation Satellites (CLS) proposed:
  - Upgradation of existing L Band Ground Station at INCOIS for collection of Argos data.
  - Data acquisition system and software to tap ARGOS data
  - Enabling Indian manufacturer(s) for production of Argos beacons in India
- Argos-4 delivery expected in Q1- 2019
- Oceansat-3 Launch expected in Q4 - 2019.

India-France Vision for Space Cooperation in Earth Observation

Bringing societal benefits of space technology

- Joint development of advanced instruments to study weather & climate
- Sharing of data & direct reception of EO missions (Met & Ocean)
- Sharing of expertise in data analysis, algorithms and modelling

Imaging Earth in high resolution

- Joint EO mission in optical and microwave domains

Addressing the Global Challenges including climate change

- Pursue cooperation for climate monitoring on the joint missions Megha-Tropiques and Saral-Altika, ongoing studies of Trishna satellite and Oceansat3-Argos mission

THANKS...