SPACEBORNE REMOTE SENSING TECHNIQUES FOR DISASTER MONITORING APPLICATIONS WITH EMPHASIS ON MICROWAVE SENSORS

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Themes of this workshop

In this Workshop, the suggested themes are:

1. Forest Fires
2. Earthquakes
3. ***Floods,*** Landslides
4. ***Tsunami, Dangerous sea conditions***
5. Pollution, and Dust Storms

This paper addresses the capability of only Microwave Sensors and restricts to 3 and 4

REMOTE SENSING MISSION REQUIREMENTS

Requirements of the RS missions are constrained by several factors and a few are highlighted below.

THEY NEED TO BE TRIED IN SMALLSATS

- Availability of suitable **Sensors – New sensors are expected to be tried for proof-of-concept on small satellite platform. No known pressure sensor for atmospheric pressure (GPS-ROS has shown some potentiality)**
- **No known sensor for sub-water sensing! Inferred only through surface features (Bathymetry)**
- Need to go for Missions with required **Optimal Sensor Combinations**

Examples: Sharing common hardware for Radiometer and Radar. Judicious choice of frequency is to be made due to FREQUENCY REGULATIONS (Example: SKYLAB's RADSCAT, ESA's AMI)

- **Temporal and Spatial Repetitivity: Ocean-atmospheric-related disasters are expected to be in 30-40 degree latitudes – Therefore Inclined orbits are desired**

TRMM was at 35 degrees, Megha-Tropiques at 20 degrees which gave up to 6 repetitive observations over the tropics.

Highlights of earlier Missions/Sensors

In context with Disaster Monitoring Applications, the following have significantly established capabilities

1. <u>Microwave Radiometers</u>

From SEASAT in 1975 to TRMM and Megha-Tropiques in 2011

Cyclone tracking, wind speed and rainfall estimates

2. <u>Scatterometers</u>

From SEASAT to Quick-scat and Oceansat 2

Ocean surface wind velocity (Cyclones)

3. <u>Altimeters:</u> Topex-Poseidon, Jasaon-1, -2, -3, SARAL)

Ocean surface level with an accuracy of a few cm - Tsunamis

4. <u>Synthetic-Aperture Radars:</u>

A large number of land and ocean applications (inclu. Earthquakes)

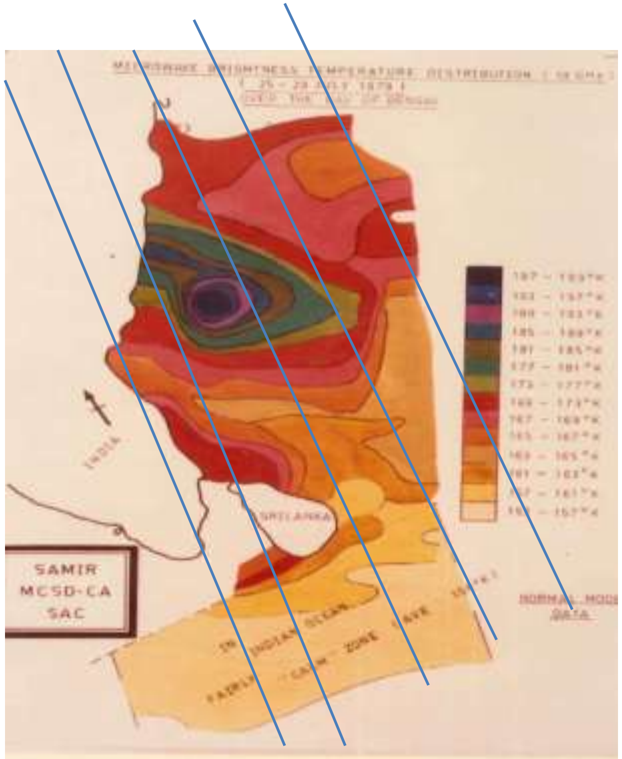
Constellation launched / proposed

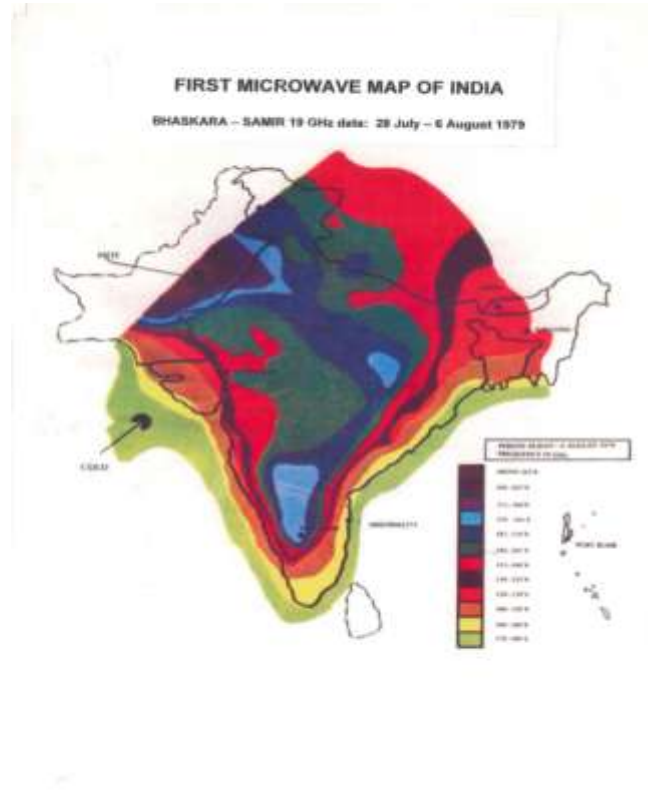
Mission: Disaster Monitoring Constellation (DMC) by SSTL (launched 34 satellites)					
		Mass	**Altitude**	**Major P/L; Specs**	**Applications**
1	Alsat-1		686 km	Multi-spectral imager 12 kg, 650 km swath; 1 GByte data 600 x 500 km	
2	UKDMC				
3	Nigeriasat-1				
4	Beijing-1				
5	Nigeriasat-2		700 km	Multi-spectral, PAN	
6	SSTL 100 v 3.0	100 kg	703 km	SWIR 1550-1750 nm Blue 450-515 nm Green 525-605 nm Red 630-690 nm NIR 774-900 nm	10 - 15 m VSNIR 20 - 30 m SWIR
8	NovaSAR-S (Planned 2014)	400 kg	580 km	Synthetic Aperture Radar 15 to 750 km; 6-30 m Resln.	Floods / disasters

1. Cyclonic events detected by microwave radiometers

Microwave Radiometers on Indian satellites

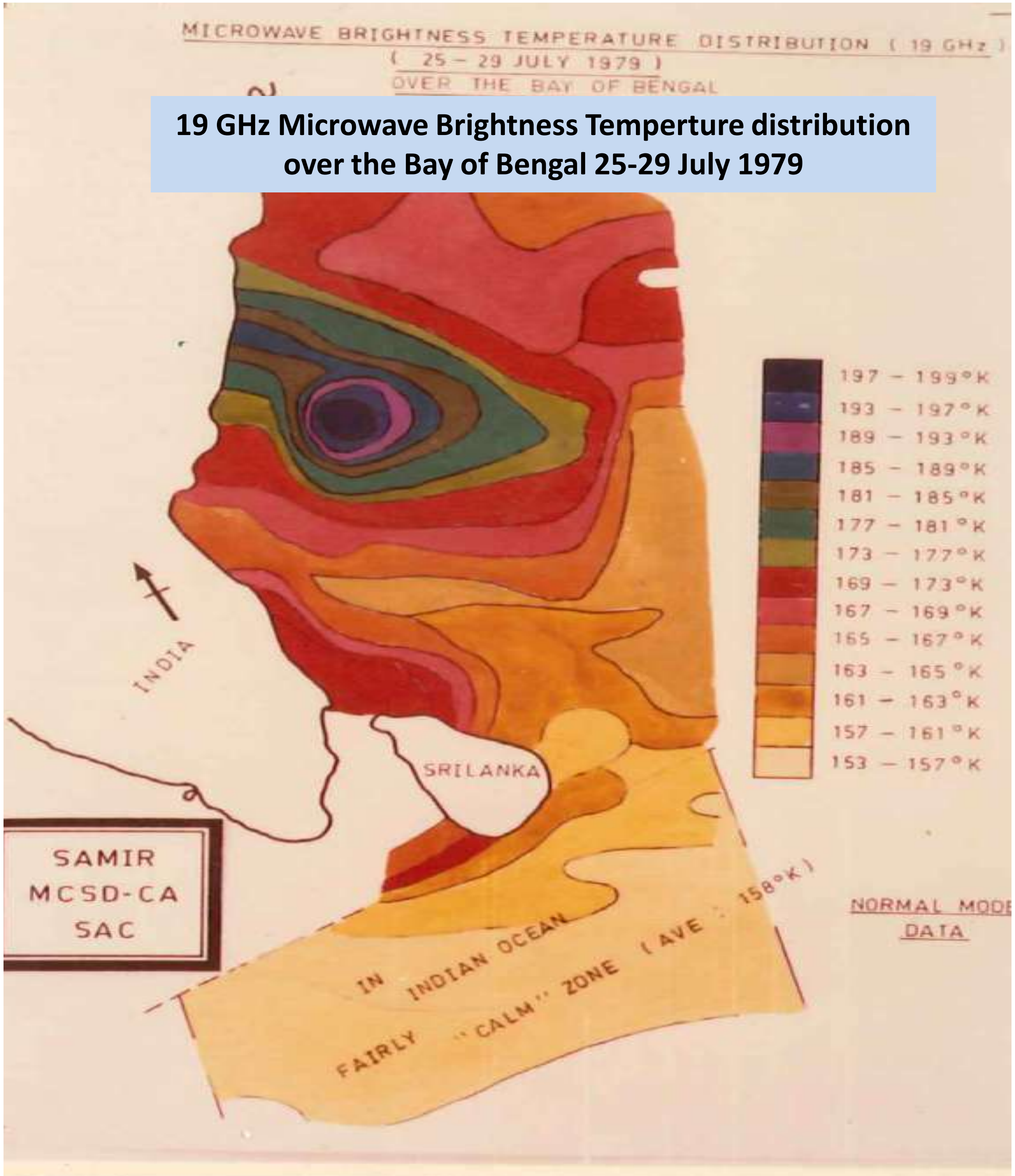
__1979, 81__: Satellite Microwave Radiometer (SAMIR) showed the possibility of **cyclone detection** in spite of operational limitations.





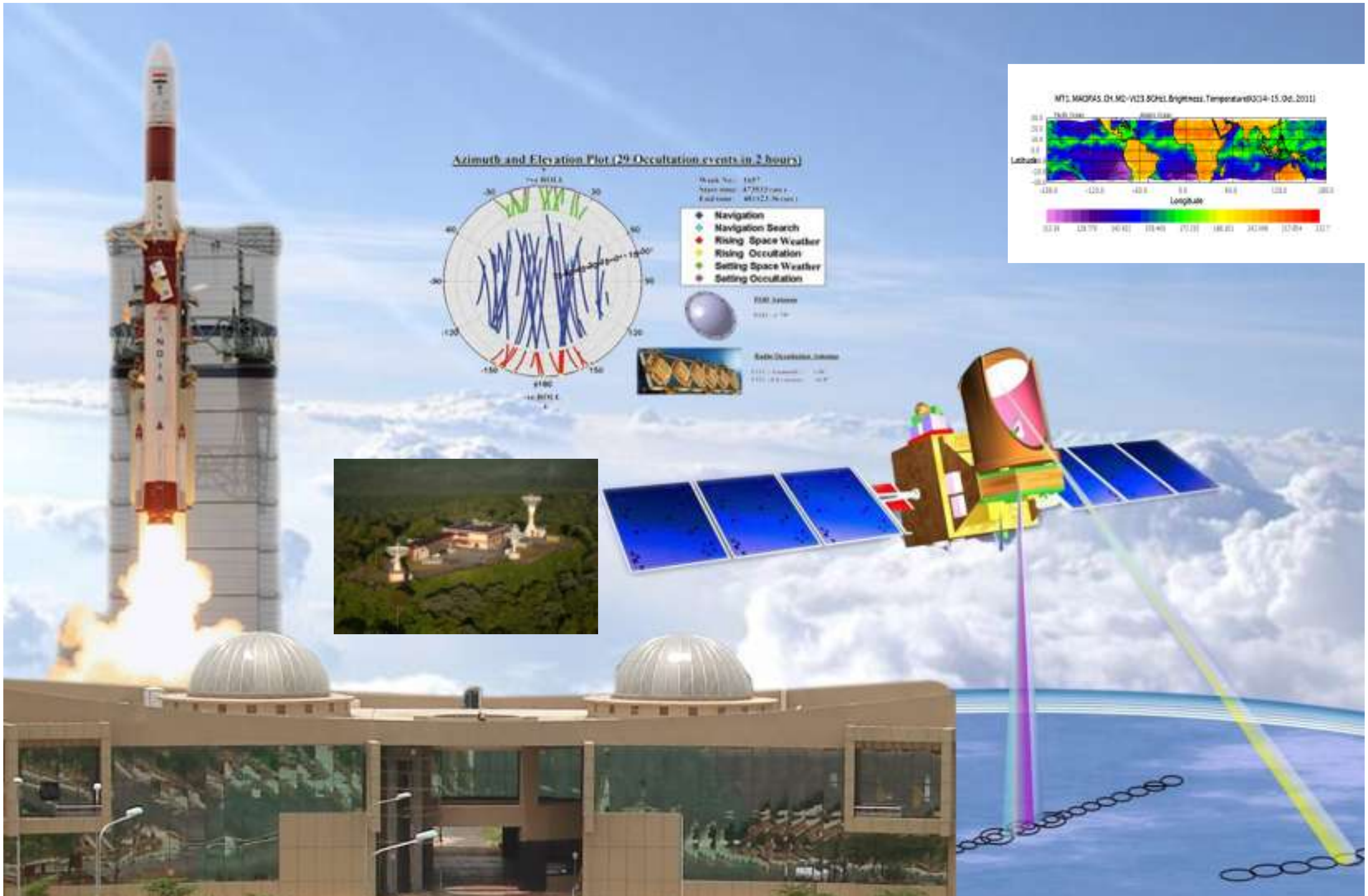
The Region of Bay of Bengal was covered in a few days but the gross cyclonic wind effects on ocean surface roughness could be observed

19 GHz Microwave Brightness Temperture distribution over the Bay of Bengal 25-29 July 1979

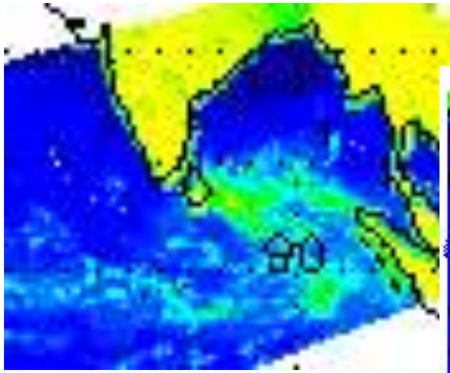


Megha-Tropiques

Payloads, Spacecraft, Launcher, Ground segment & Science



23 Dec



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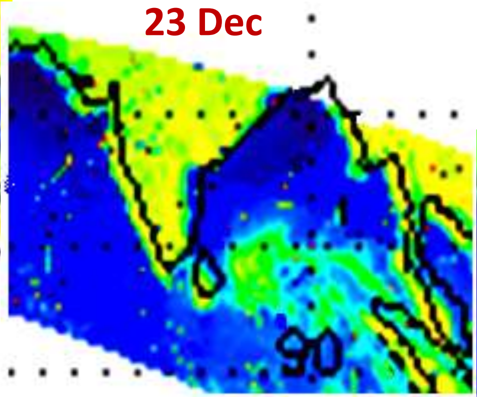
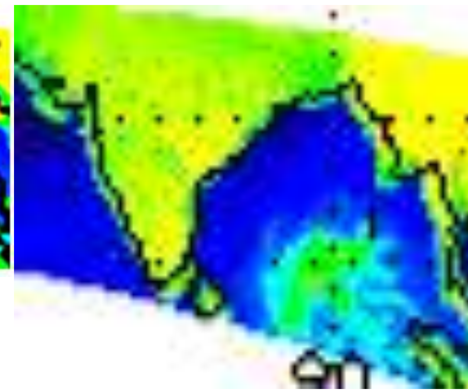
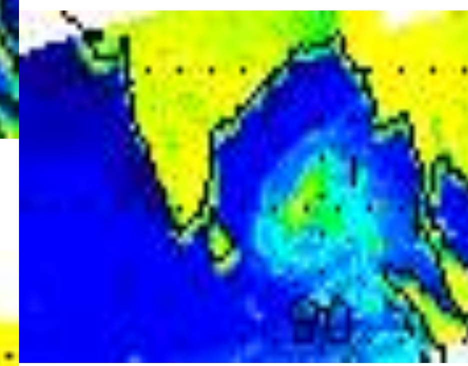


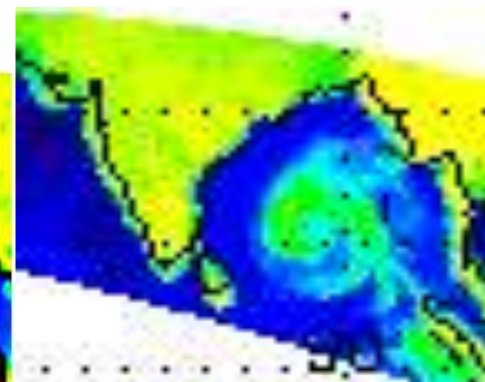
24 Dec



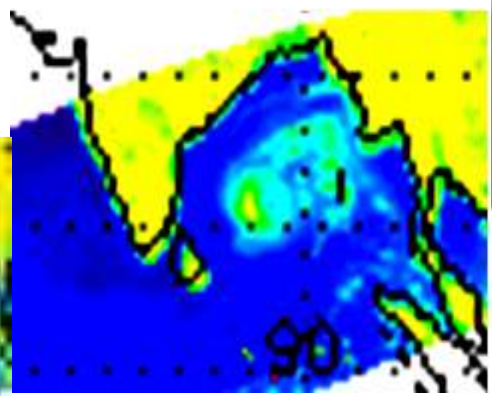
25 Dec



Tracking the Thane Cyclone using MADRAS 18.7 GHz Channel



26 Dec



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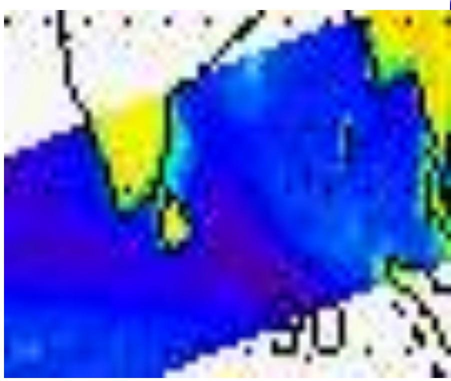
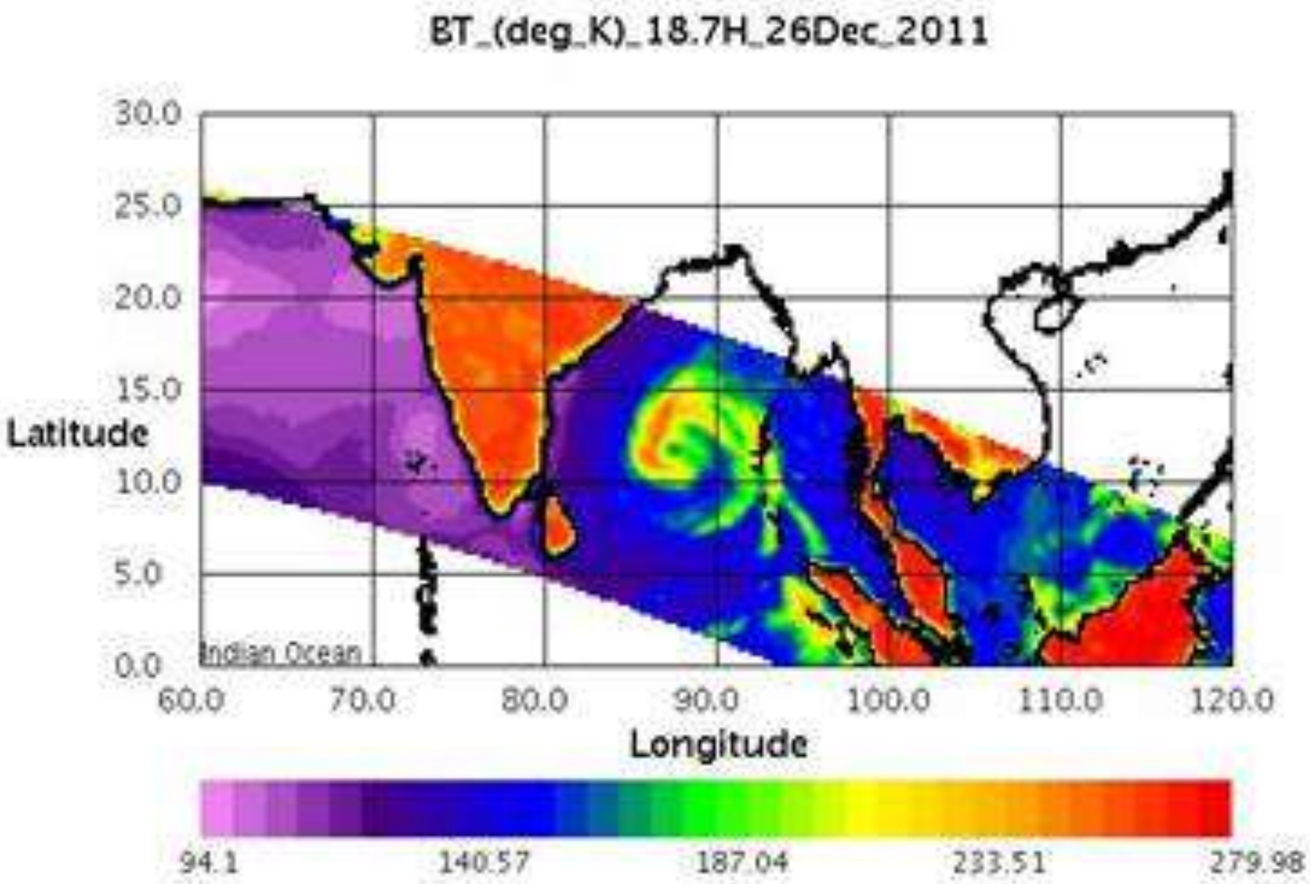
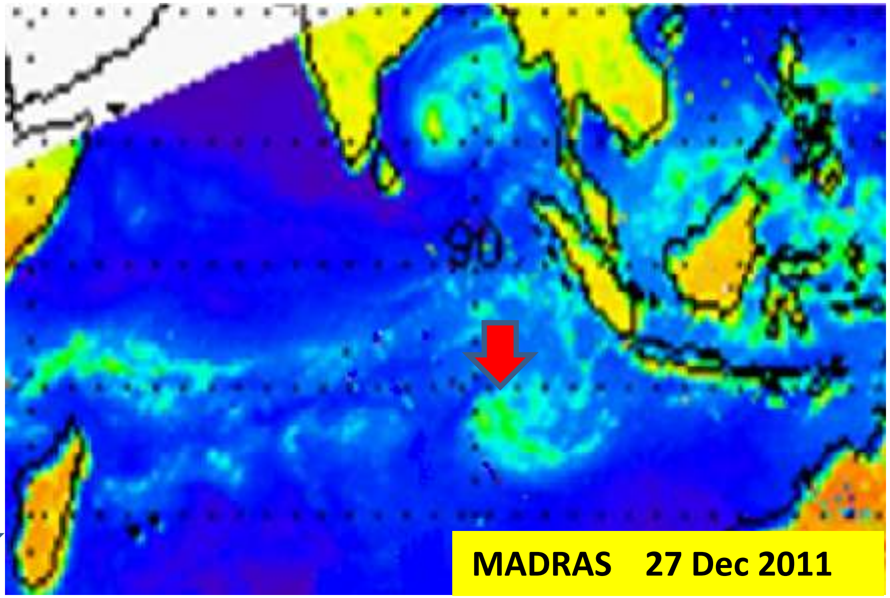
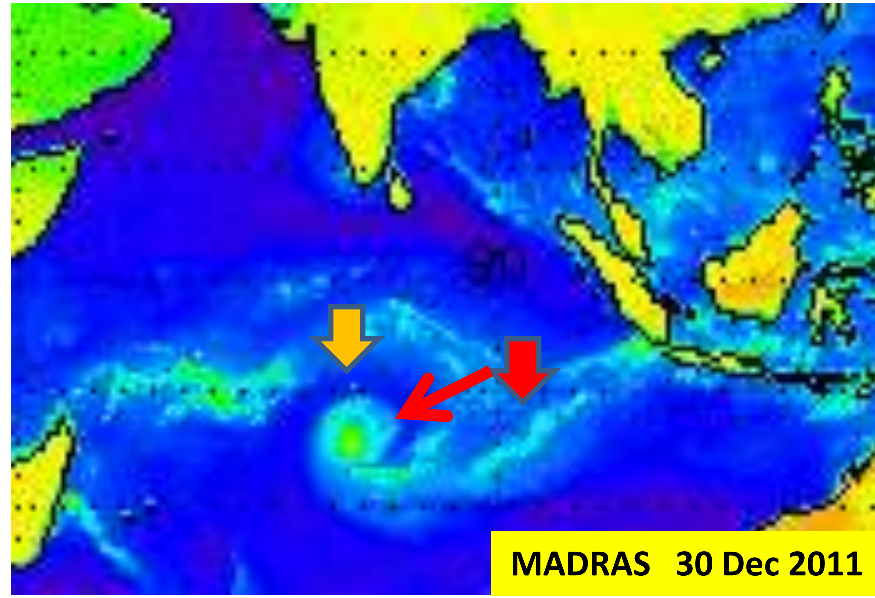


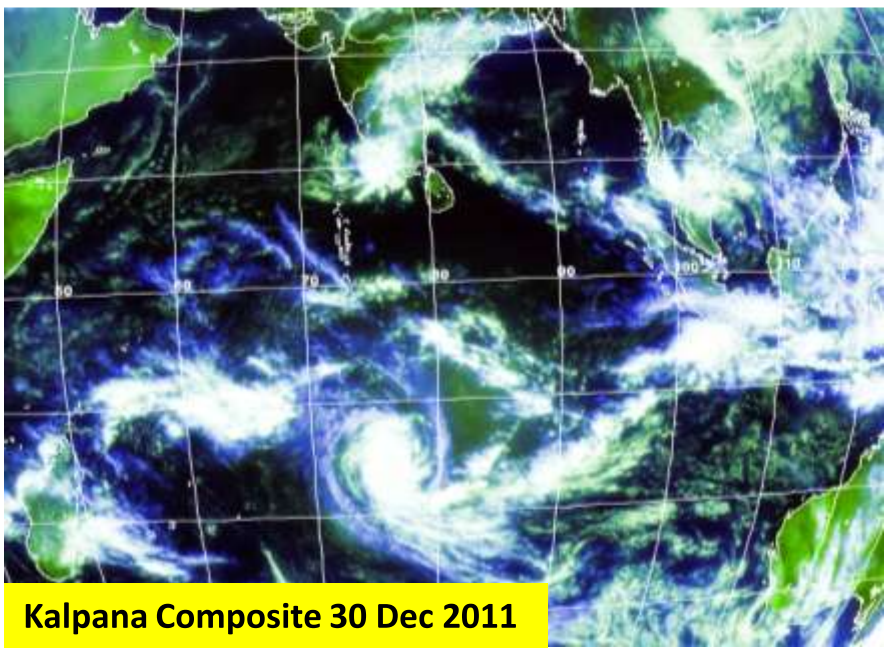
30 Dec

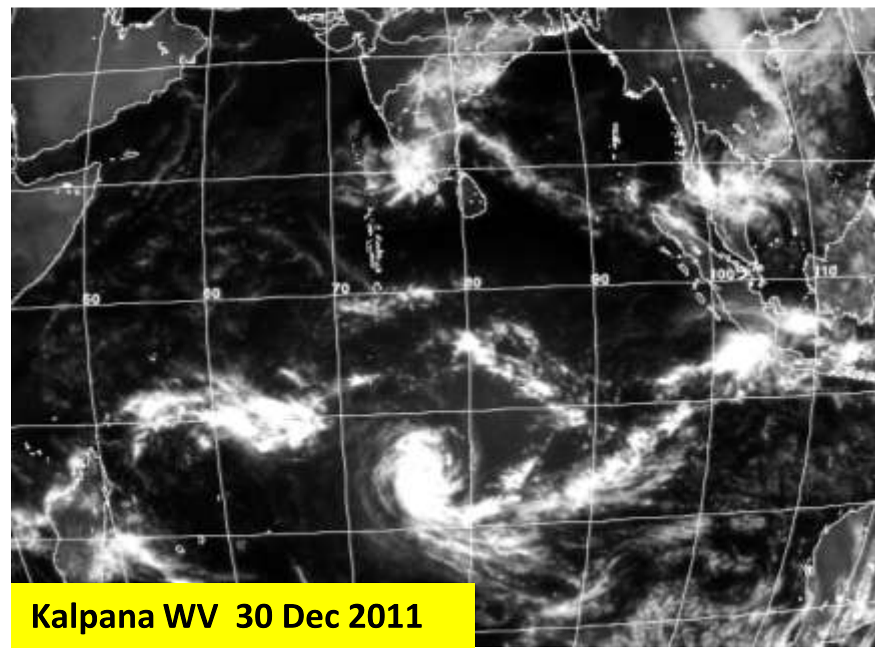

BT_(deg_K)_18.7H_26Dec_2011
Latitude
Longitude
30.0
25.0
20.0
15.0
10.0
5.0
0.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
Indian Ocean
94.1
140.57
187.04
233.51
279.98

Tracking another Indian Ocean Cyclone using MADRAS 18.7 GHz Channel

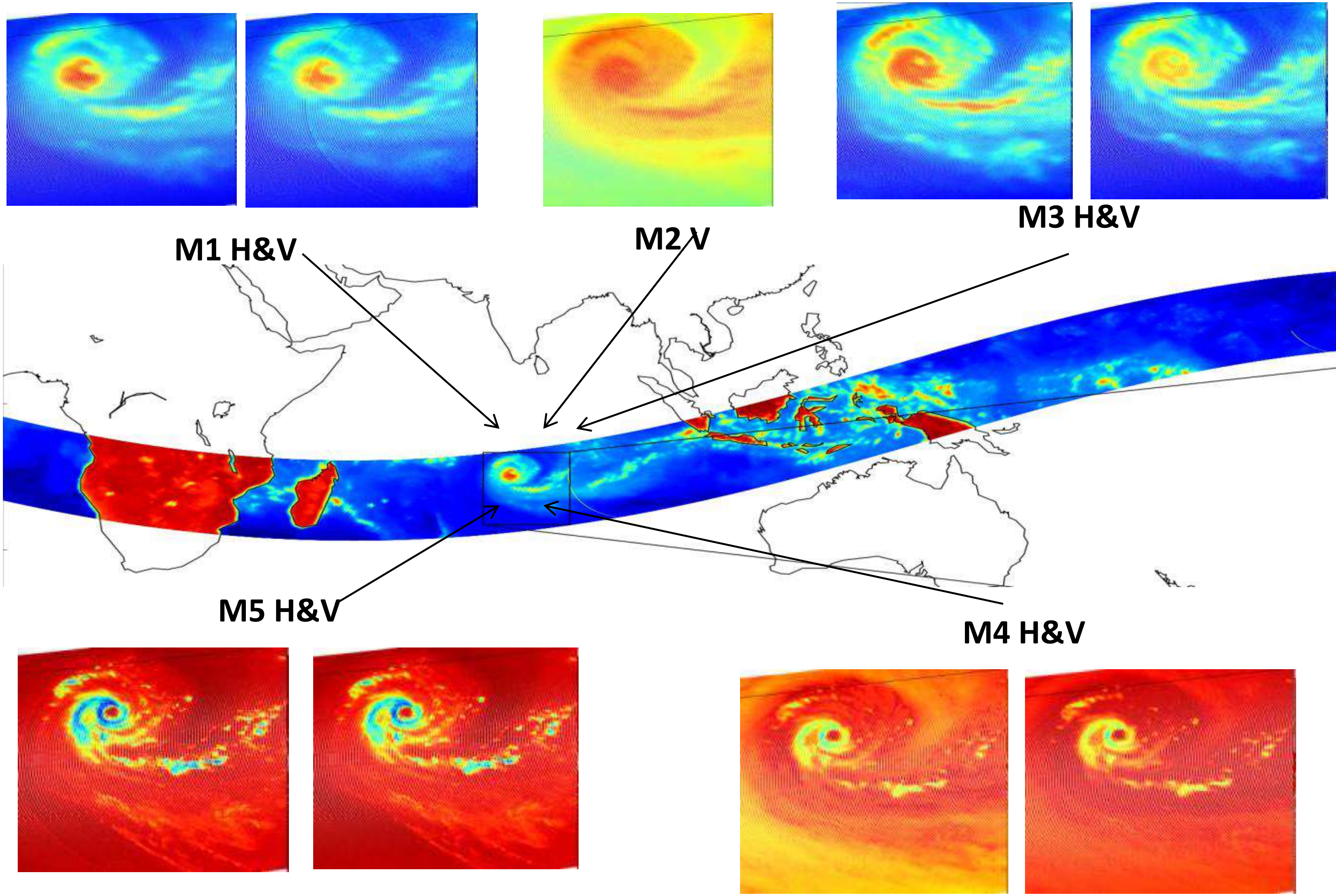




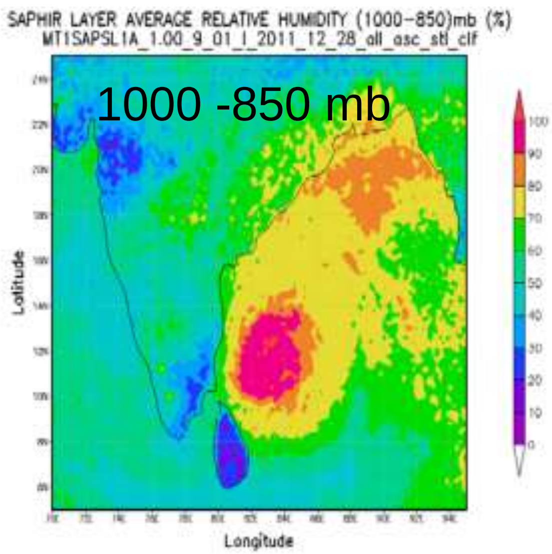


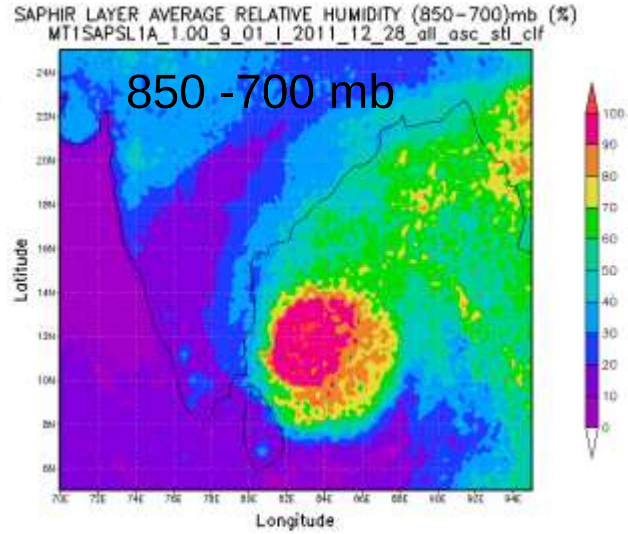


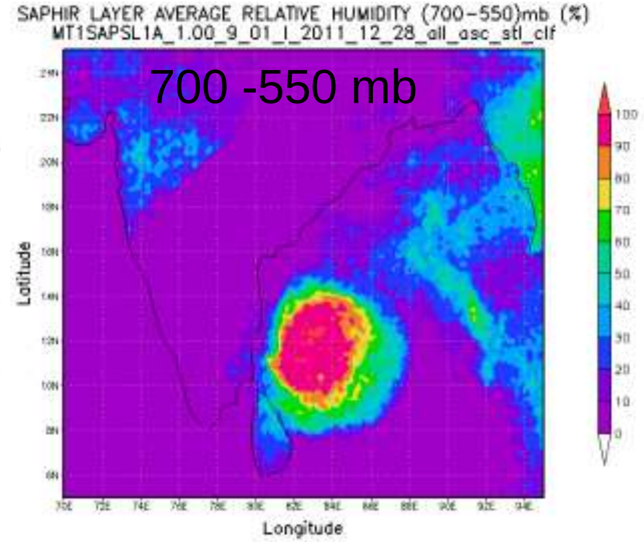
Source: CNES

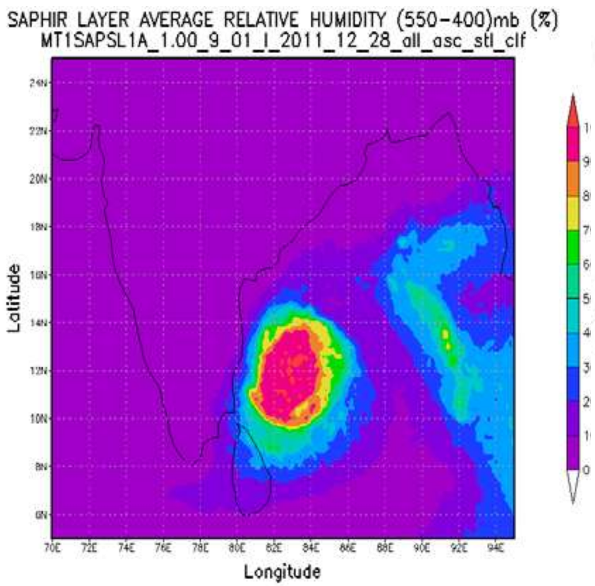


SAPHIR Derived Humidity over Thane Cyclone (Dec 28, 2011 all passes)
Humidity maps show cyclonic structure with high humidity in the central portion of the storm for all the six layers (PK Pal Indo-French Workshop Dec 2012)

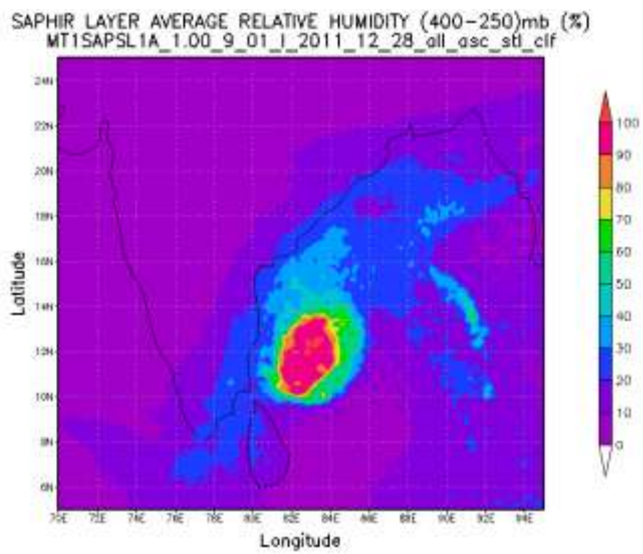




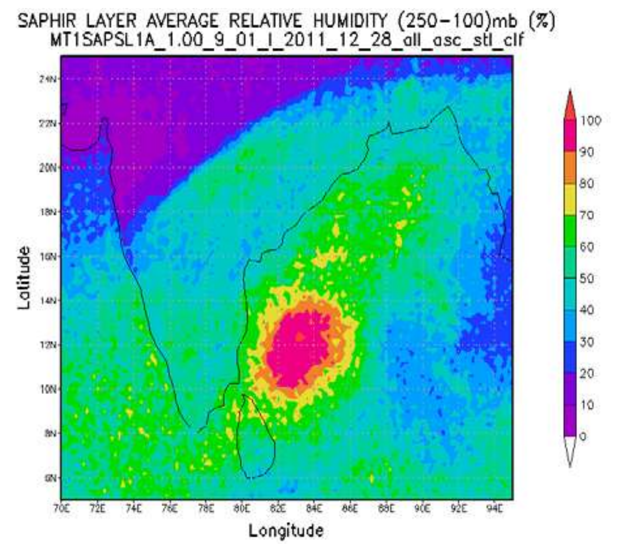




550 -400 mb

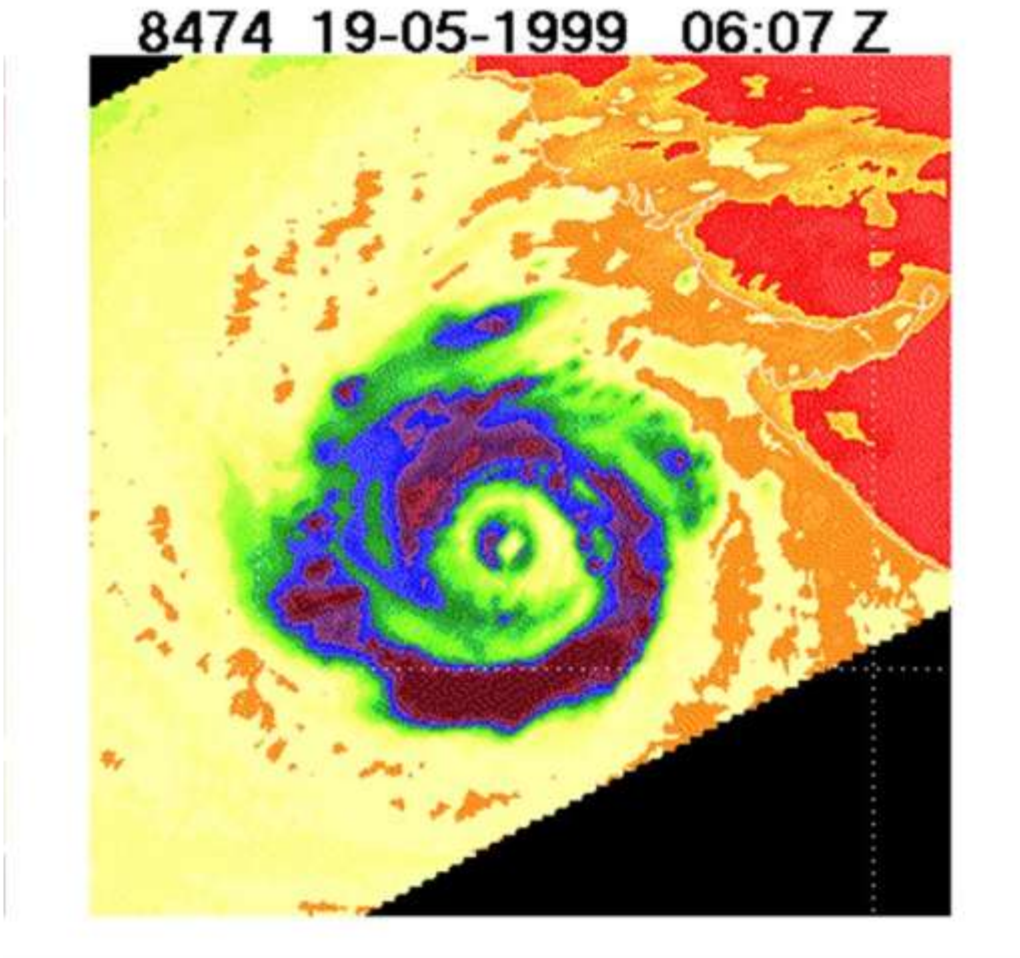


400 -250 mb



250 -100 mb

PK Pal et al



Source: SAC

TRMM Microwave Imager (TMI) 85 GHz brightness temperature pattern just before the landfall of the Orissa super-cyclone. The eye of the cyclone can be more accurately located in this channel and can therefore improve the accuracy of forecast of the track of tropical cyclones. (MADRAS has the 89 GHz channel)

2. Ice-snow extent detected by microwave radiometers

OCEANSAT-1 (1999) RADIOMETERS OBSERVE THE SEASONAL CHANGES OF ANTARCTIC ICE COVER

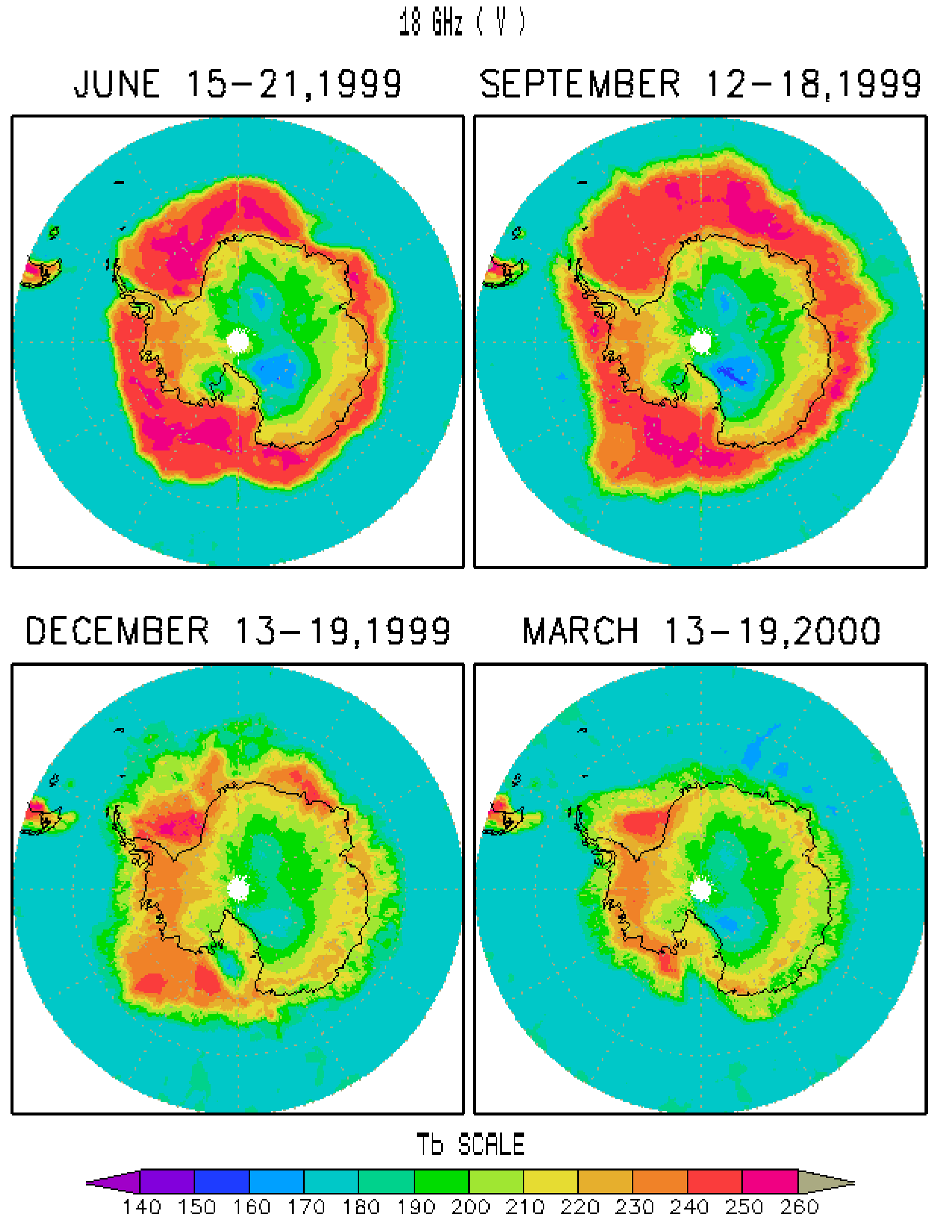
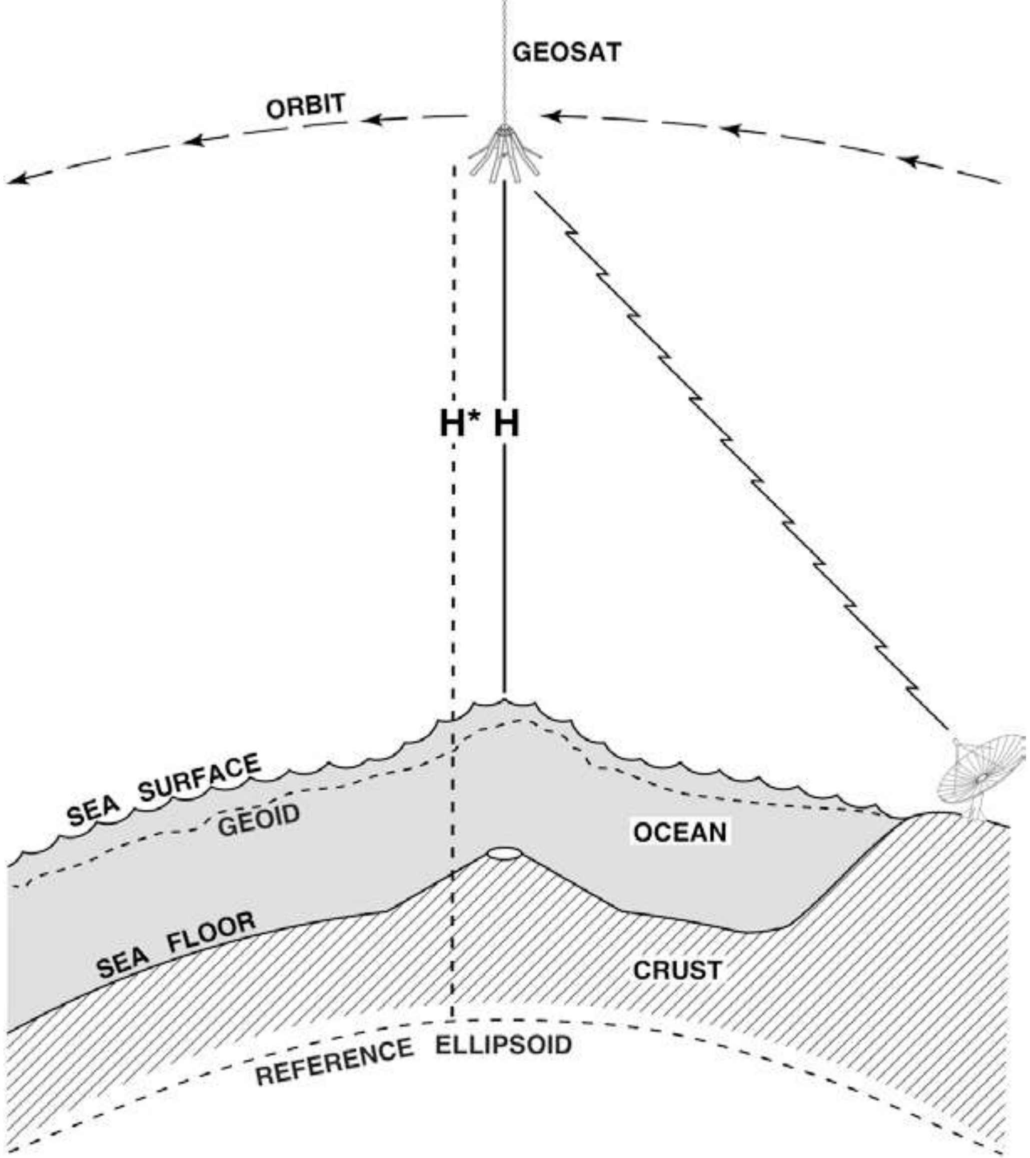


FIG. 1. Weekly Average 18GHz. (V) Brightness Temperature Images over Antarctic Region from MSMR for Four Different Seasons

3. Tsunami conditions – manifested by Sea-surface height detectable by ALTIMETERS

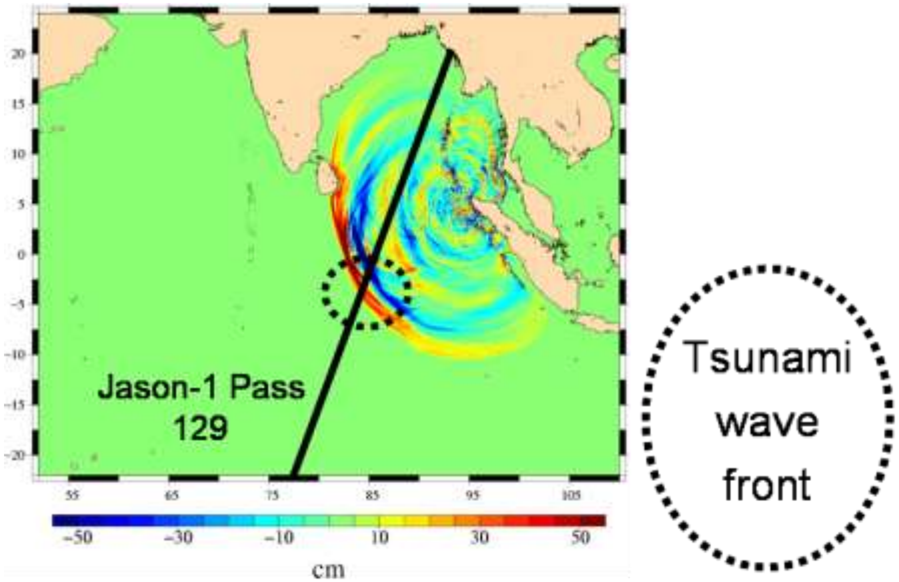


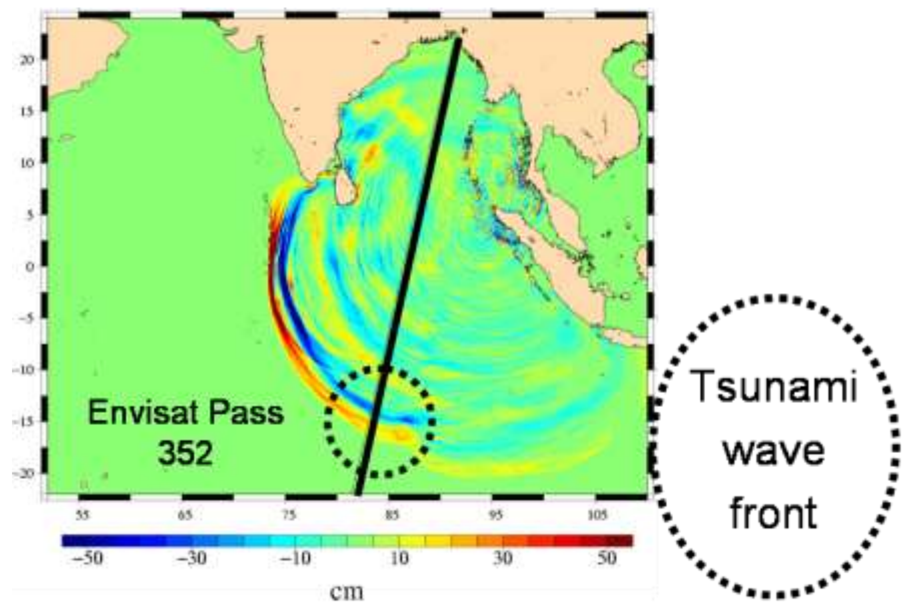
***<u>Principle of an altimeter</u>*: Time taken for a two-way transit of electromagnetic waves (pulse) is measured to get height H**

Detection of Tsunamis by altimeters

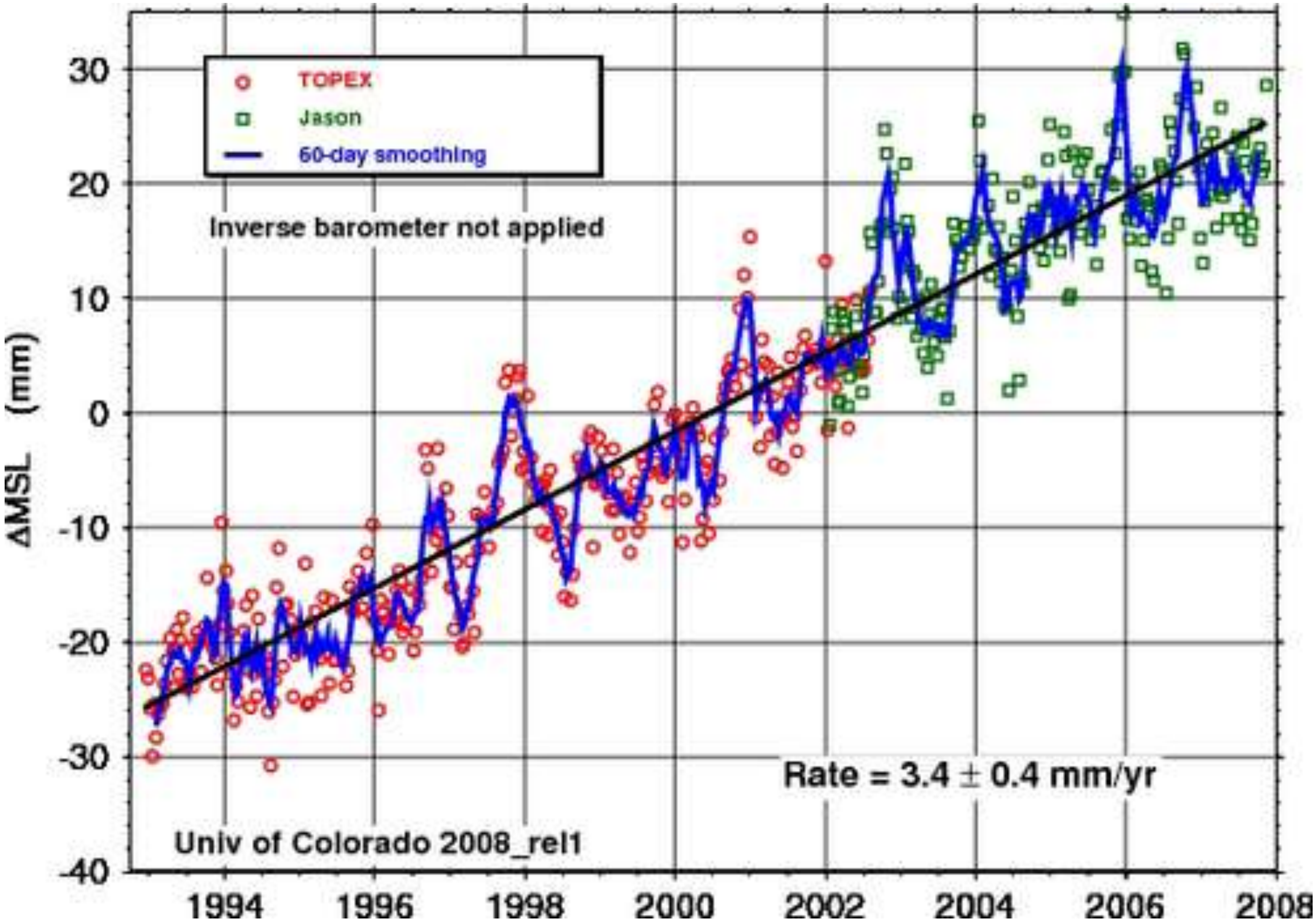
- Tsunamis are waves triggered by the vertical deformation of the ocean bottom, caused by sub-marine earthquakes or landslides.
- They lead to waves crossing the oceans at high speed (around 800 km/h), and a potentially enormous quantity of water flooding the coasts when these waves come to shore.
- Theoretically, sea level anomalies observed by altimetry should reflect these waves.
- However, observation is difficult, since the additional height is one of the signals of ocean variability.
- Studying the differences between the few altimetric observations and the tsunami propagation models should enable the scientific community to enhance their understanding of such phenomenon and to fine-tune the models.
- Only a multidisciplinary, multi-technique study can grasp all the forces at work here (geophysical, hydrodynamic, energetic etc.).

Jason Altimeter data





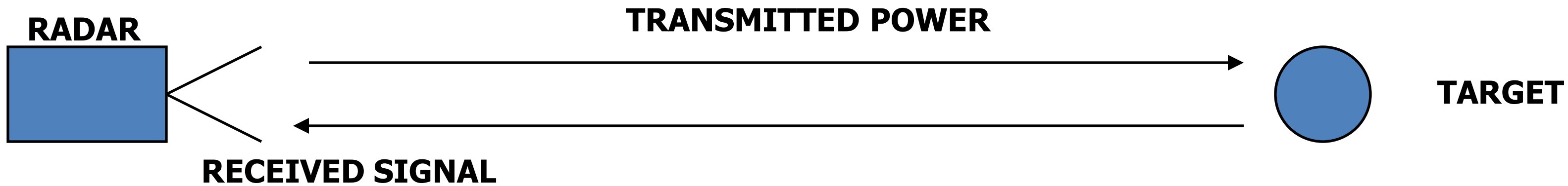
Sea-level rise due to long-term effects using altimeter


TOPEX
Jason
60-day smoothing
Inverse barometer not applied
Rate = 3.4 ± 0.4 mm/yr
Univ of Colorado 2008_rel1
ΔMSL (mm)
30
20
10
0
-10
-20
-30
-40
1994
1996
1998
2000
2002
2004
2006
2008

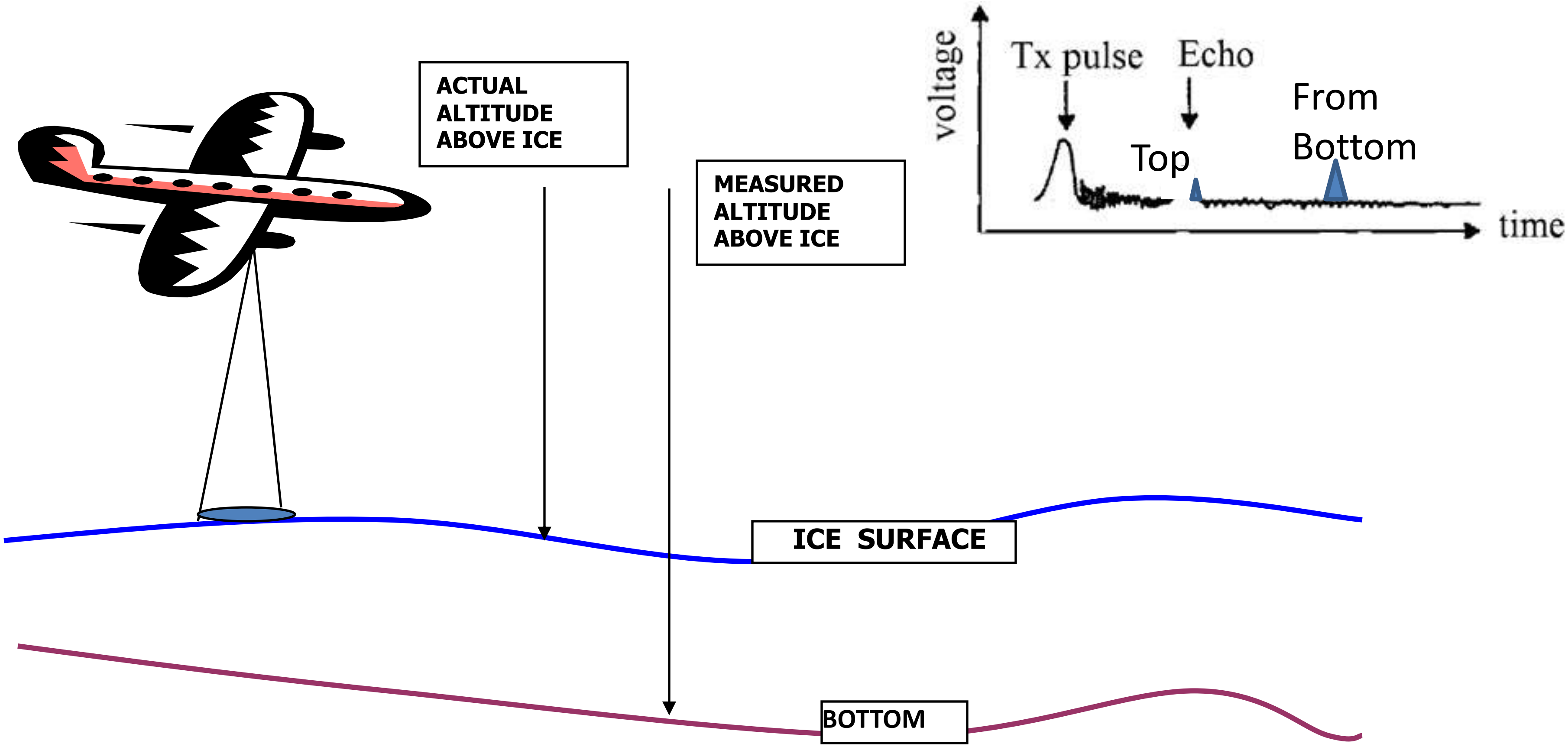
4. Ice-snow depth measured by unfocused airborne synthetic-aperture radar at 150 MHz

RADAR FOR ICE THICKNESS MEASUREMENTS

- RADAR MEASURES RANGE (DISTANCE)
- A SHORT ELECTROMAGNETIC WAVE – PULSE SENT FROM A RADAR (TRANSMITTER) HITS THE TARGET AND RETURNS TO THE RADAR (RECEIVER) AFTER TRAVERSING TWO TIMES THE DISTANCE (D)
- THE TIME DELAY (T) GIVES THE TWO-WAY DISTANCE (2D)
- HENCE THE ACTUAL DISTANCE IS
- $D = cT/2$
- WHERE c IS THE VELOCITY OF LIGHT (EM WAVES)



HISTORICAL BACKGROUND



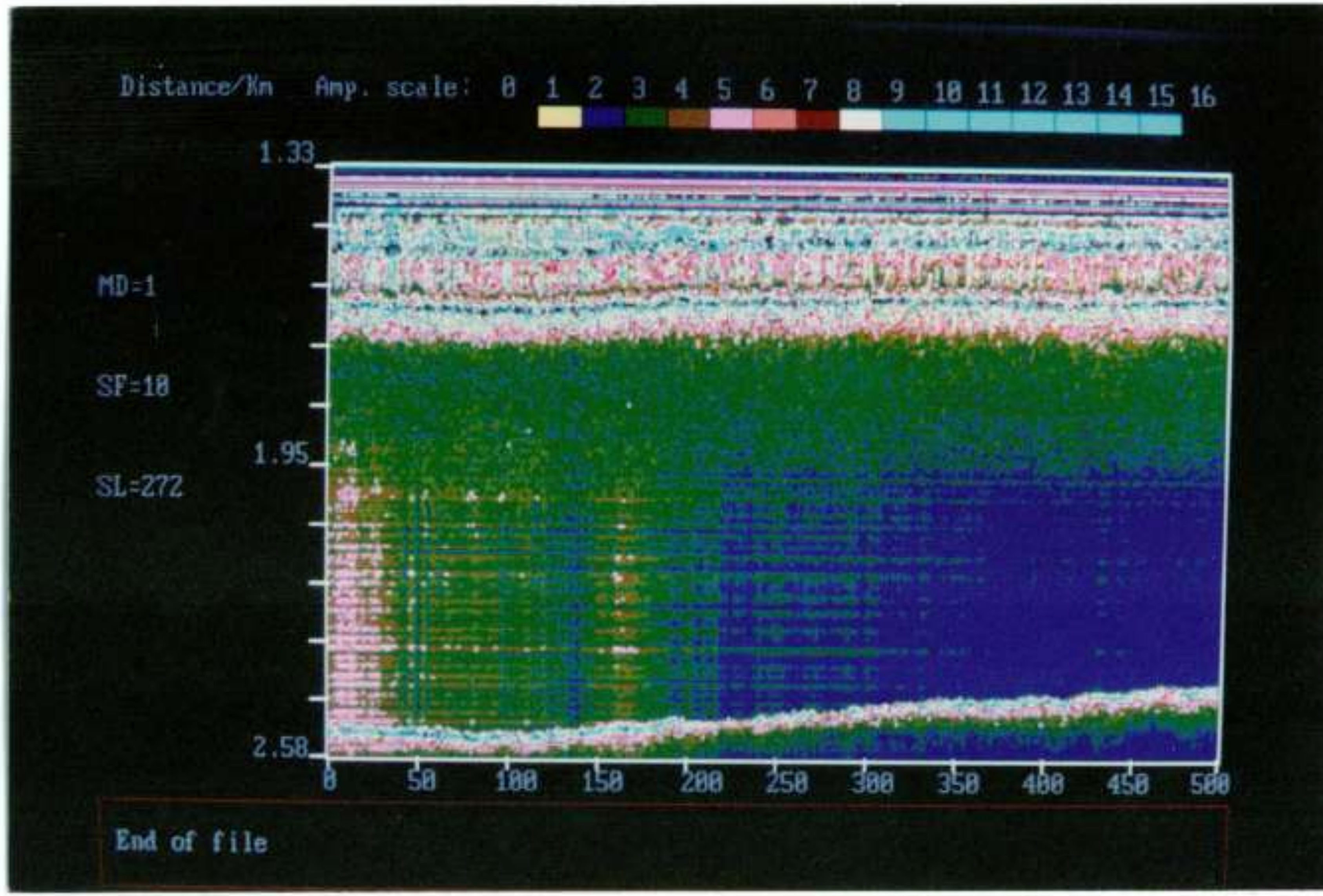
AN AIRBORNE RADAR USED AS AN "ALTIMETER" IN GREENLAND (WAITE,1959) SHOWED A LARGER ALTITUDE THAN THE ACTUAL CLEAR ALTITUDE AND HENCE CRASHED BY TOUCHING THE ICE SURFACE (OVER-ESTIMATED ALTITUDE)

THUS AN APPLICATION WAS FOUND -
RADAR FOR ICE THICKNESS MEASUREMENTS

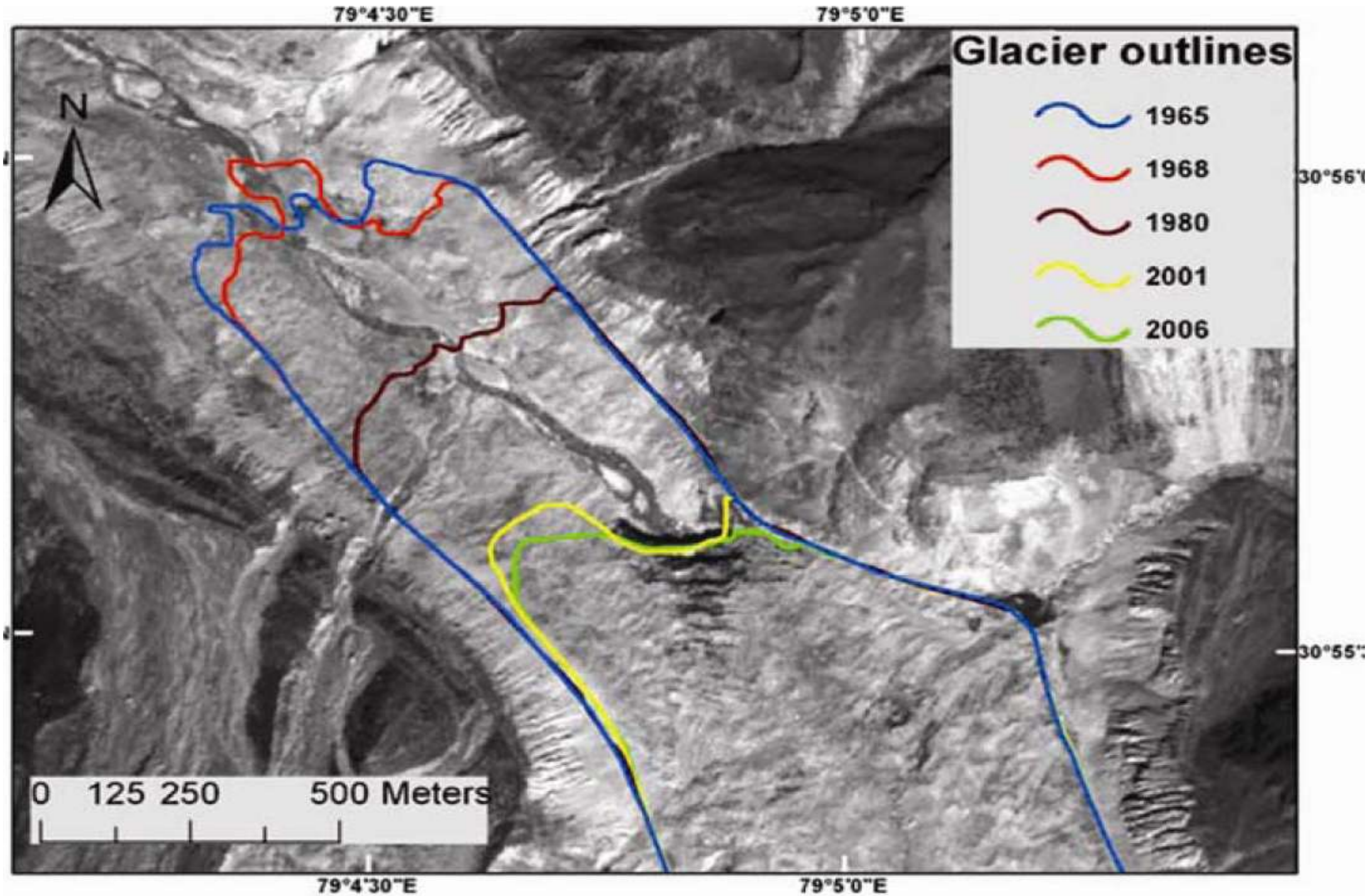
- ELECTROMAGNETIC WAVES CAN PASS THROUGH ICE, SNOW, SMOKE, CLOUDS, DUST, ETC. HENCE A RADAR WORKS IN VARIOUS ATMOSPHERIC CONDITIONS
- IT ALSO WORKS IN DAY AS WELL AS NIGHT
- IN AN ICE MEDIUM THERE WILL BE TWO RADAR RETURN (ECHO) PULSES
  - ONE REFLECTED FROM THE TOP SURFACE (ICE)
  - THE SECOND ONE FROM THE BOTTOM SURFACE (ROCKY, SOIL)
- THE DIFFERENCE IN TIME DELAY WILL GIVE THE THICKNESS, D
- WAVE PROPAGATES SLOWER BY 1/SQRT OF THE DIELECTRIC CONSTANT (ABOUT 3.1 FOR SNOW/ICE)
- THE ACTUAL THICKNESS IS D/(SQRT(3.1))

RADAR ON HUT PULLED BY A "TUCKER" ON A FAST-MOVING GLACIER – "DOWNSTREAM-B" IN ANTARCTICA

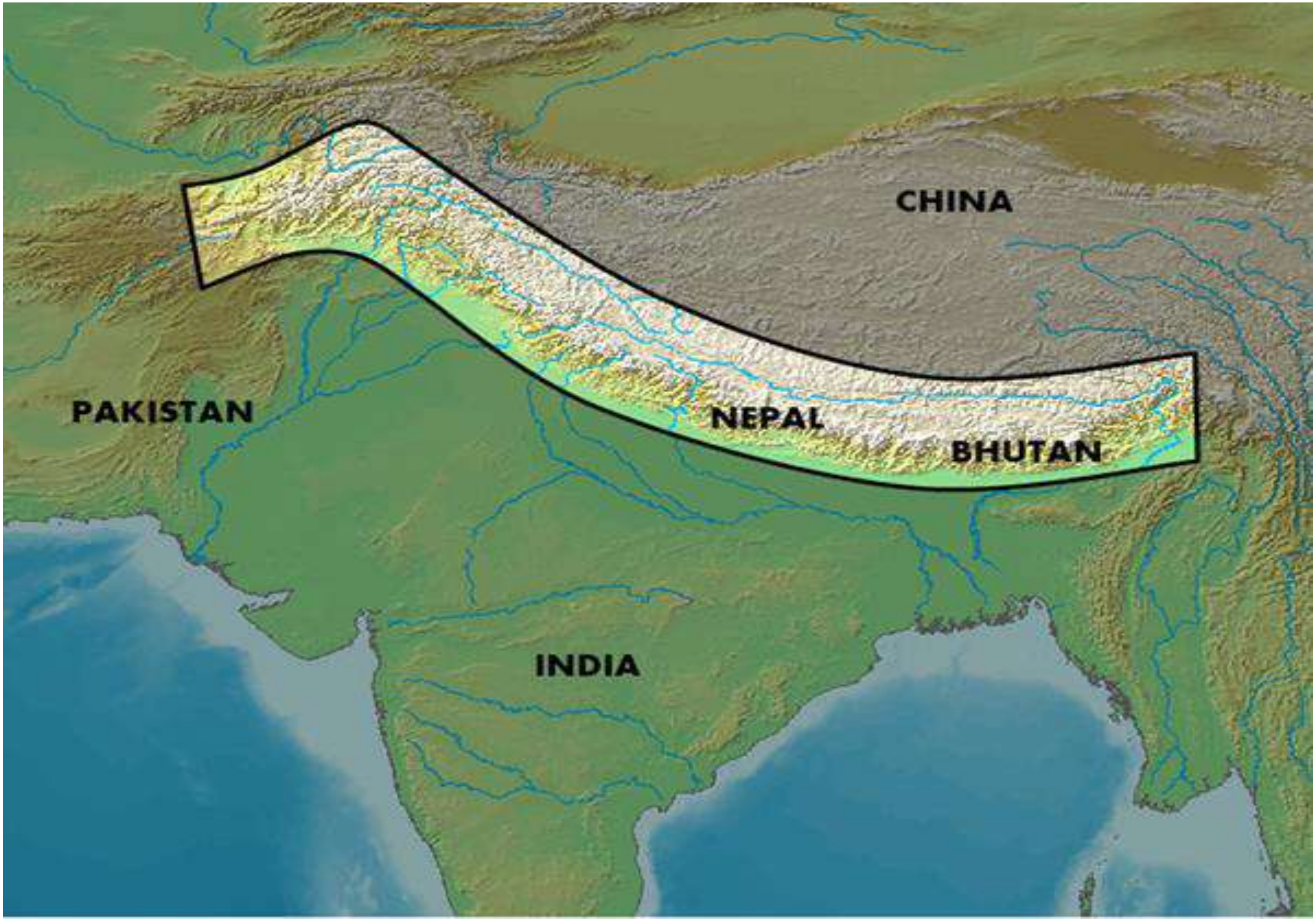
Depth in Ice, > 1.2 km



Vertical profile in ice

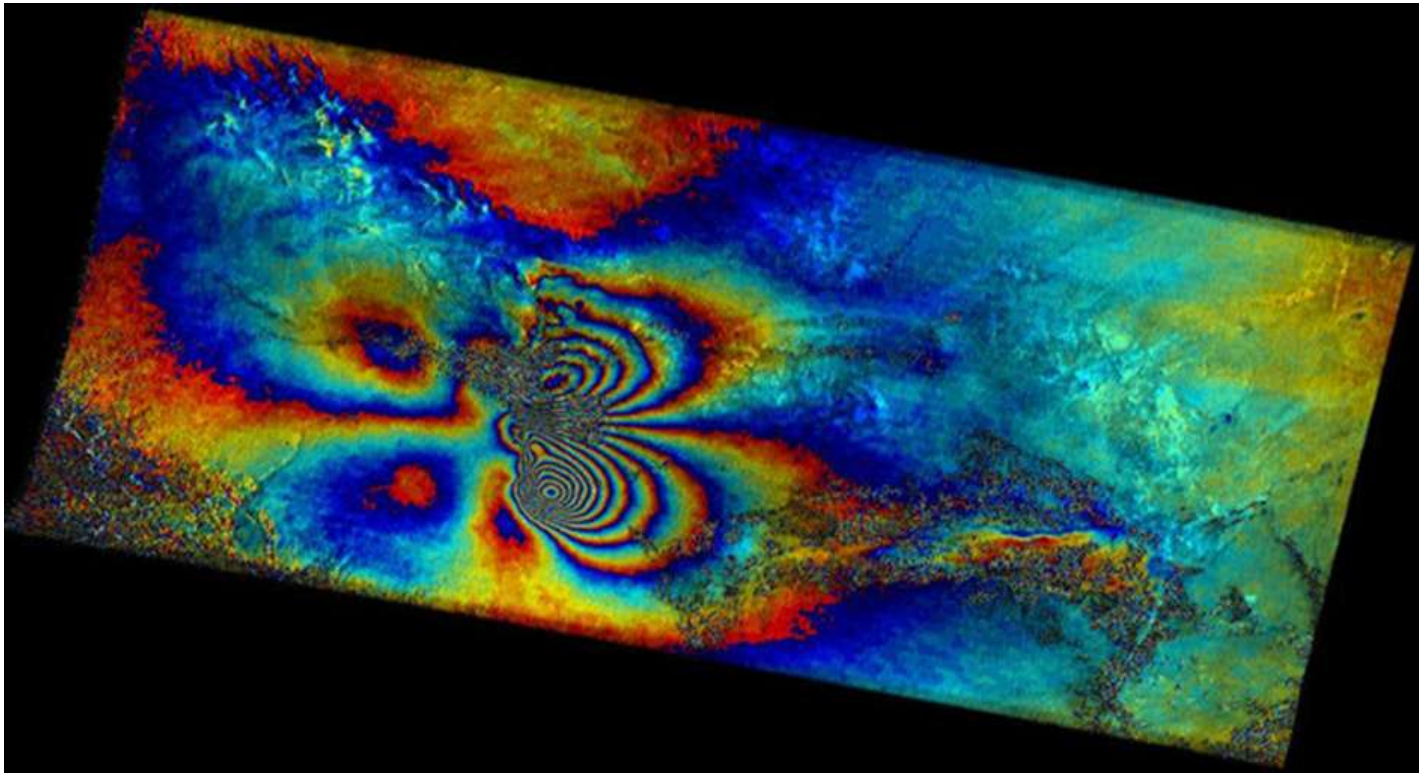


Gangotri Glacier retreated 26.5 meters per year form 1968-2006



Shows Glacier Region

Earthquakes



Envisat WSM/IM InSAR image of Bam, Iran. Interferogram shows ground motion associated with the 26 December 2003 earthquake

http://www.esa.int/spaceinimages/Images/2004/07/Envisat_WSM_IM_InSAR_image_of_Bam

Possible satellite configuration/s

1. Spacecraft with a single sensor
2. Composite sensors sharing common hardware
3. Satellites in constellation

PROPOSED SPACEBORNE INSTRUMENTS

Instrument	Specifications, nominal		Applications
Radiometer	18, 36 GHz	0.5 -1 K Sensitivity 1000 km swath	**Cyclone**-tracking, wind-speed
Radiometer	90 GHz	0.5 -1 K Sensitivity 1000 km swath	Ice-melt monitoring, **floods**
Altimeter	13 GHz	A few km Foot Print, 5 cm Accuracy	Sea level, **Tsunami**
Unfocused SAR	UHF /L-Band	Better than 2 m	Ice/glacier depth, **floods**
GPS Sounder	L1, L2; L5?	2 K accuracy	Atmos. temp and humidity

Notes:

1. The above are in order of technical ease and cost.
2. Airborne versions are strongly suggested before spaceborne version
3. Combination of the sensors will be based on a specific mission and sharing of common hardware

Preliminary Functional Block Diagram

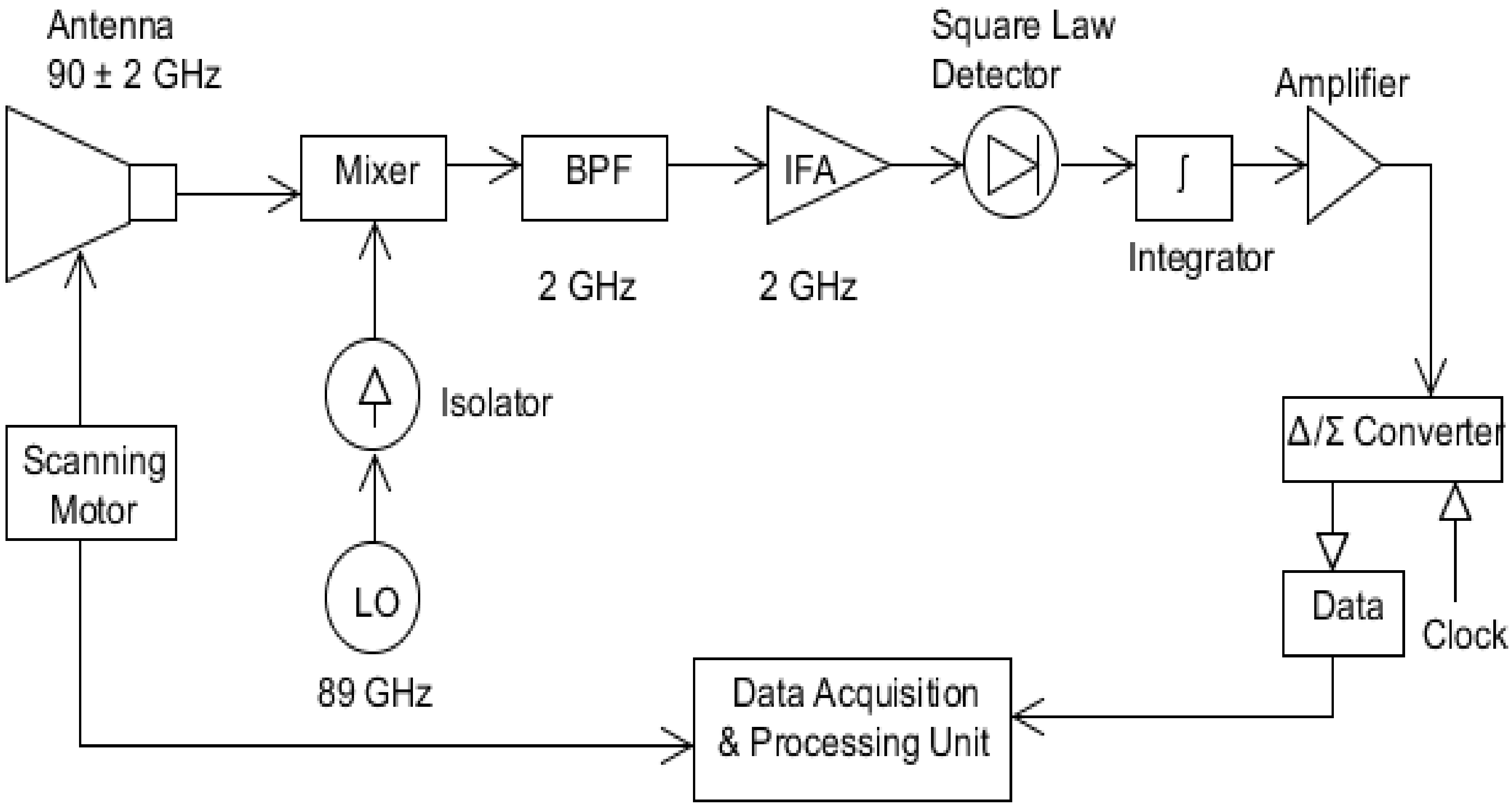
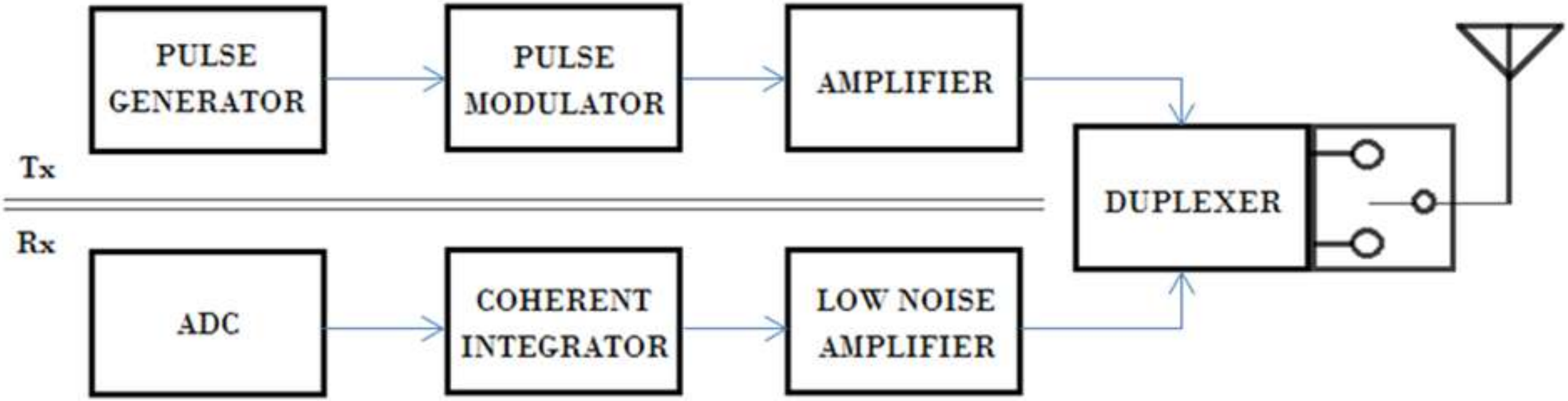
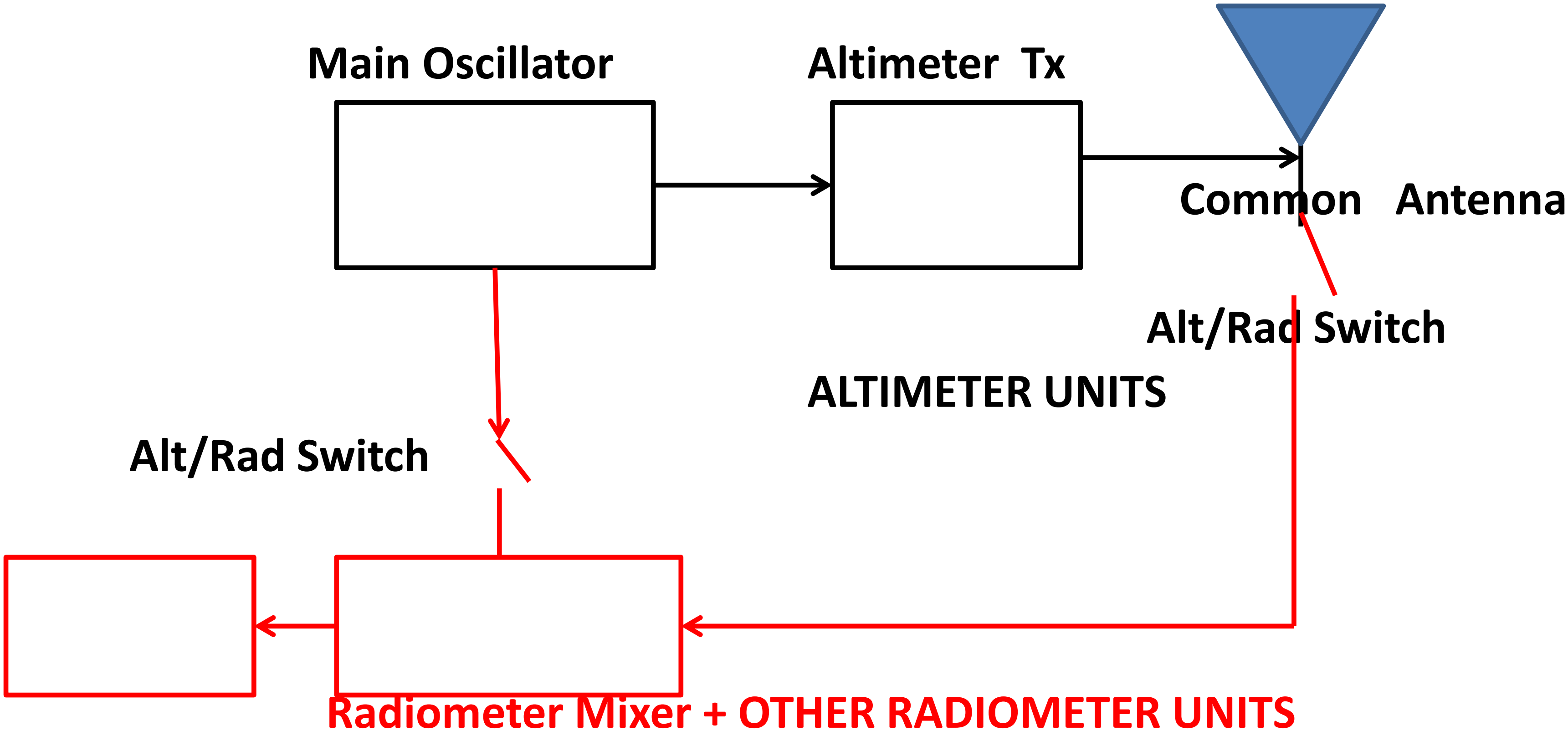


Fig:1 - 90 GHz Radiometer Preliminary Block Diagram

Un-focused Synthetic-aperture Radar



Radiometer – Altimeter combination



Notes:
1. Frequency of Alt is as per allocation (Ku or Ka)
2. Radiometer may be designed at the same frequency / or multiplied
3. Common antenna, common Local Oscillator save power and space
4. Selective or simultaneous (inter-pulse) operation (less interference)

PROPOSED CONSTELLATION

- MICROWAVE RADIOMETERS 18 & 36, AND 90 GHZ
- SYNTHETIC-APERTURE RADAR AND ALTIMETER
- CONSTELLATION OF **THREE - FOUR** SATELLITES
- INCLINED ORBIT OF 30 – 40 DEGREES FOR HIGH TEMPORAL MEASUREMENTS
- COVERAGE OF THE DYNAMIC OCEAN AND ATMOSPHERIC ACTIVITIES OF THE GLOBE
- MULTIPLE AND / OR STAND-ALONE SENSORS BASED ON SEASONAL ACTIVITIES (POWER CONSTRAINTS).
- RADAR AT LOWER ALTITUDE (400 KM) OTHERS AT 600 KM

THANKS