Indian Meteorological Satellite Missions: Current & Planned

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Space Applications Centre

Indian Space Research Organization

Ahmedabad, INDIA

23-24 Jan,2008:

New Orleans: GOES-R User Conference

Indian Meteorological Satellite Missions

PSLV

- Payload and Satellite: Design & Fabrication

  -Geostationary : Optical

  - Polar Orbiting: Thrust on Microwave

  (Passive/Active)

- Launch :

  » Polar : Operational

  » Geostationary : Operational

- Signal and Data Processing , Retrievals, Validation

- Applications with Users

  » Operational

  » R & D (National Institutions and Academia)

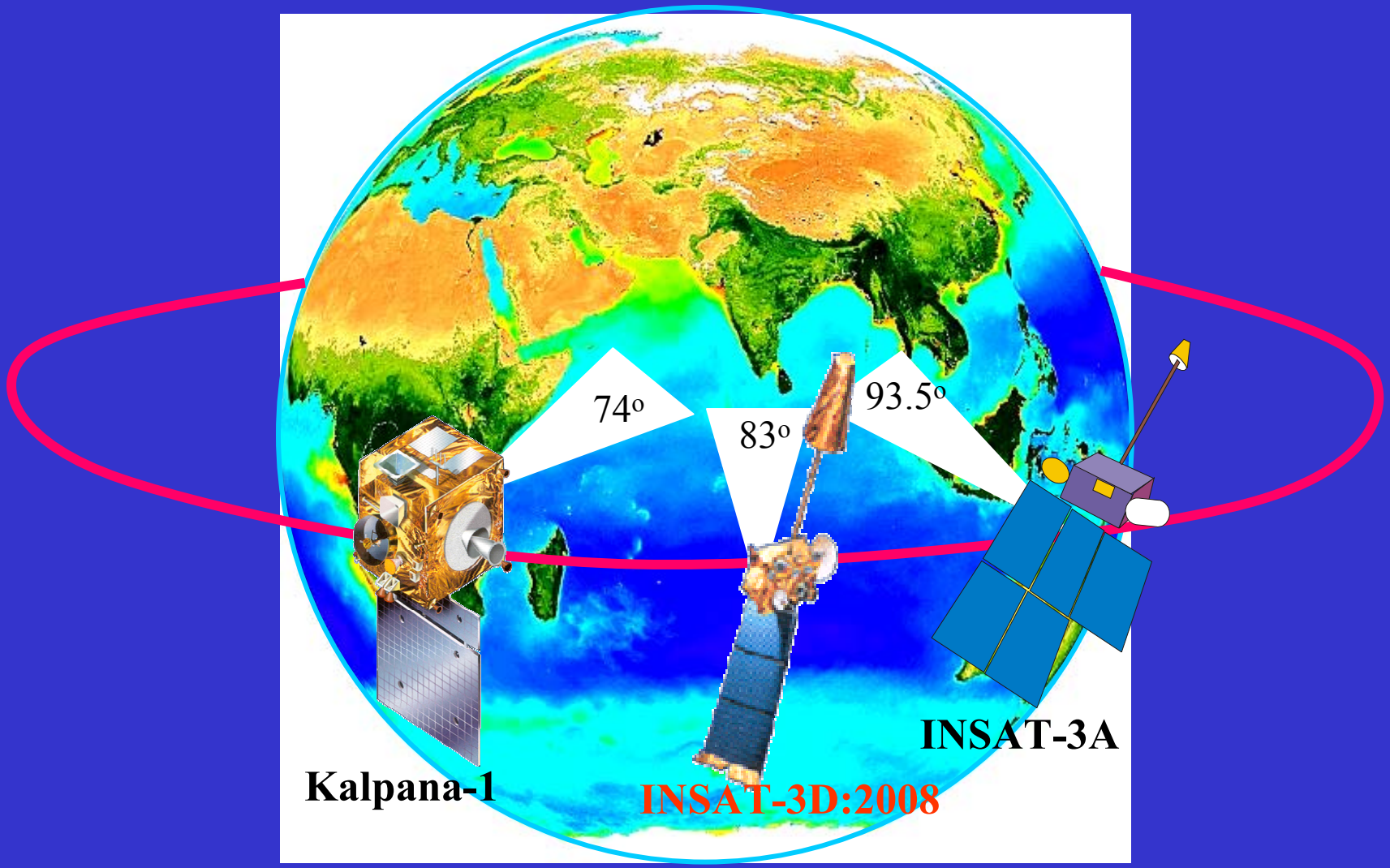
GSLV

INDIAN NATIONAL SATELLITE (INSAT) FOR METEOROLOGICAL APPLICATIONS

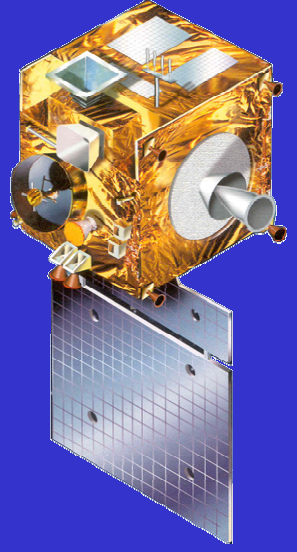
Satellite	Launch Date	Payload	Major Applications
INSAT - 1A	April 1982	Very High Resolutions Radiometer (VHRR) Visible : 0.55-0.75 µm (Res : 2.75 km) IR : 10.5 – 12.5 µm (Res : 11 Km)	Monitoring cyclones & monsoon CMV Winds OLR Rainfall Estimation Mesoscale features Flood/intense precipitation advisory Snow detection
INSAT - 1B	August 1983		
INSAT - 1C	July 1988		
INSAT – 1D	June 1990		
INSAT – 2A	July 1992	Visible : 0.55-0.75 µm (Res : 2 km) IR : 10.5 – 12.5 µm (Res : 8 Km	
INSAT – 2B	July 1993		
INSAT – 2E	April 1999	VHRR: As in 2B + WV Band: 5.7 -7.1 µm CCD: Band: 0.62 – 0.68 µm 0.77 – 0.86 µm 1.55 – 1.69 um	
KALPANA	September 2002	VHRR as in INSAT – 2E	
INSAT – 3A	April 2003	VHRR & CCD as in INSAT – 2E	

Total : 9 (Since 1982)

Current Indian Geostationary Meteorological Satellites



INSAT-3A & Kalpana-1

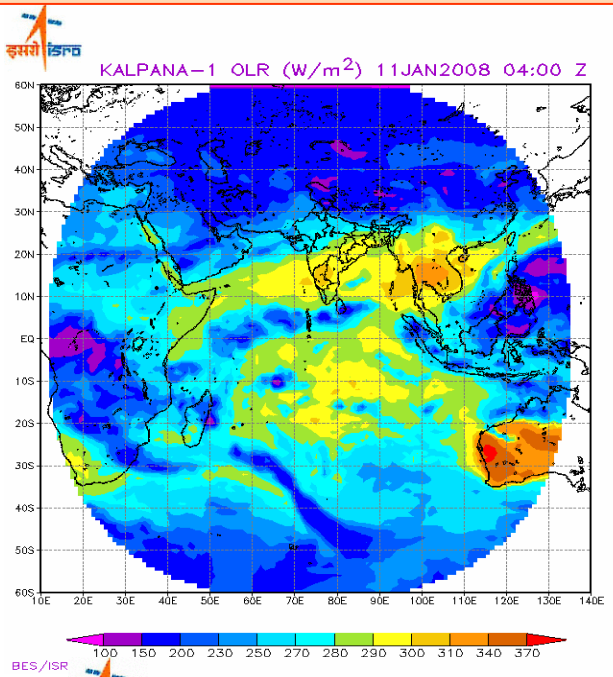


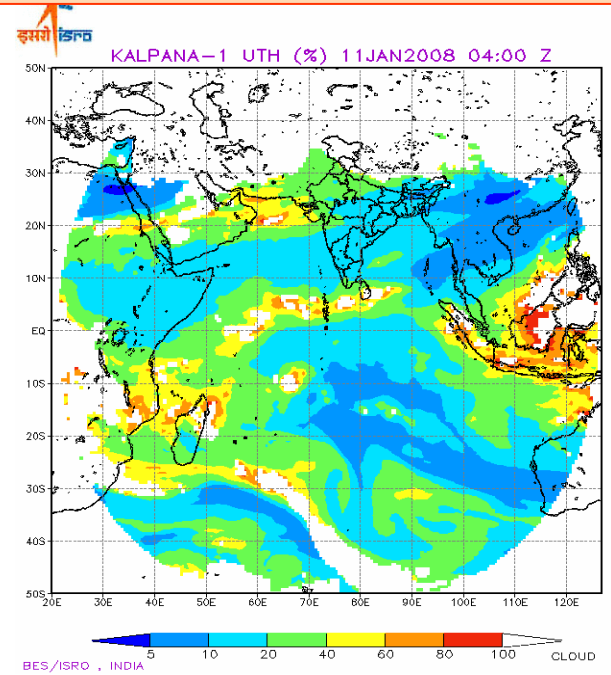
Location : INSAT 3A : 93.5ºE
Kalpana-1 : 74ºE

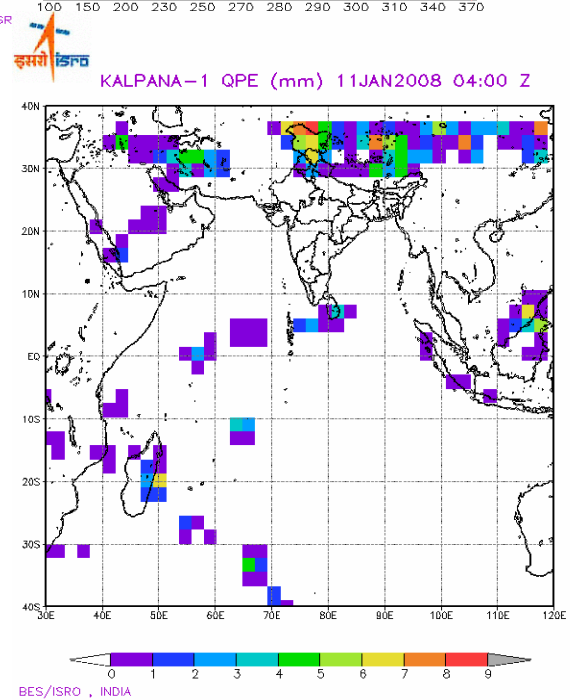
Payload : (i) VHRR & CCD camera in INSAT 3A
(ii) VHRR in Kalpana-1

- VHRR Bands (µm)
  - Visible : 0.55 – 0.75
  - Water vapour : 5.70 – 7.10
  - Thermal Infra Red : 10.5 – 12.5
- Resolution (km) : 2 X 2 for Visible
  8 X 8 for TIR and WV
- CCD Camera Bands (µm)
  - Visible : 0.62 – 0.68
  - Near Infra Red : 0.77 – 0.86
  - Short Wave Infra Red : 1.55 – 1.69
- Resolution (km) : 1 X 1 for all bands

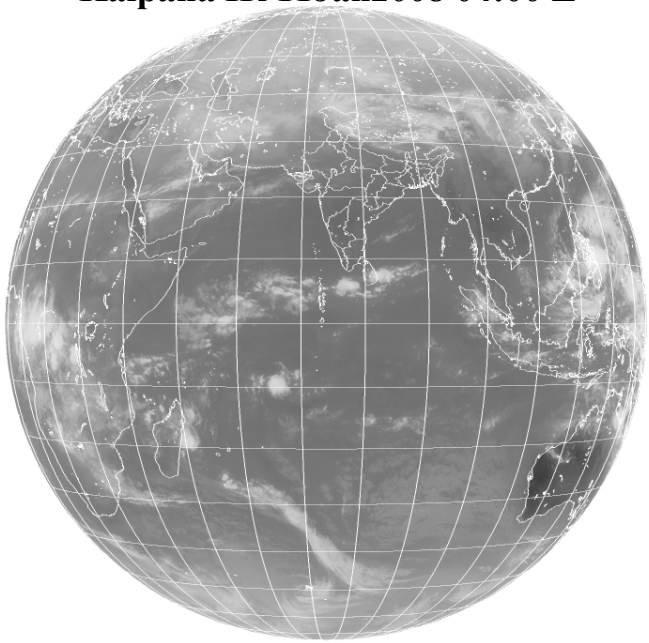
Operational Geophysical Parameters from KALPANA

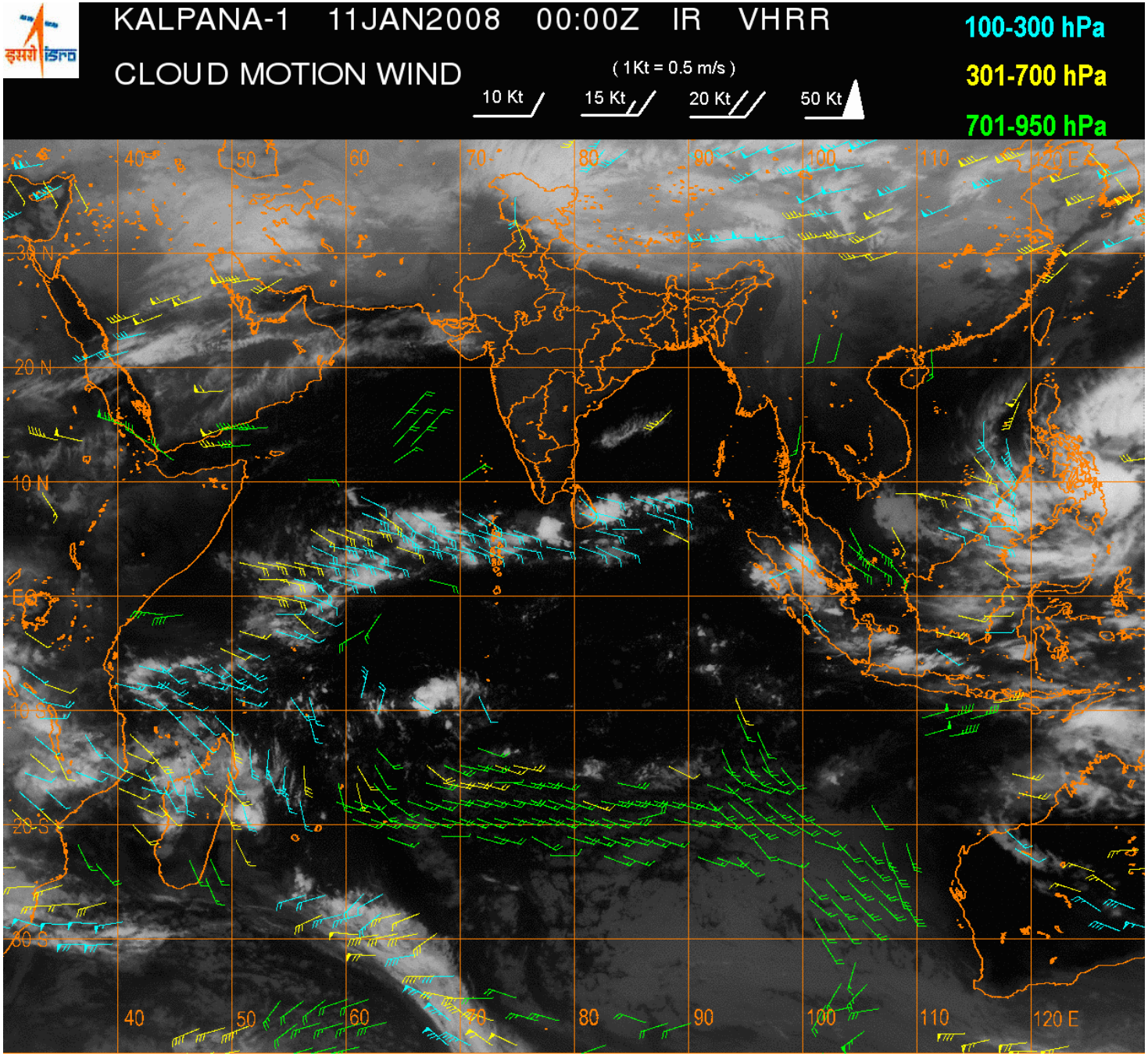


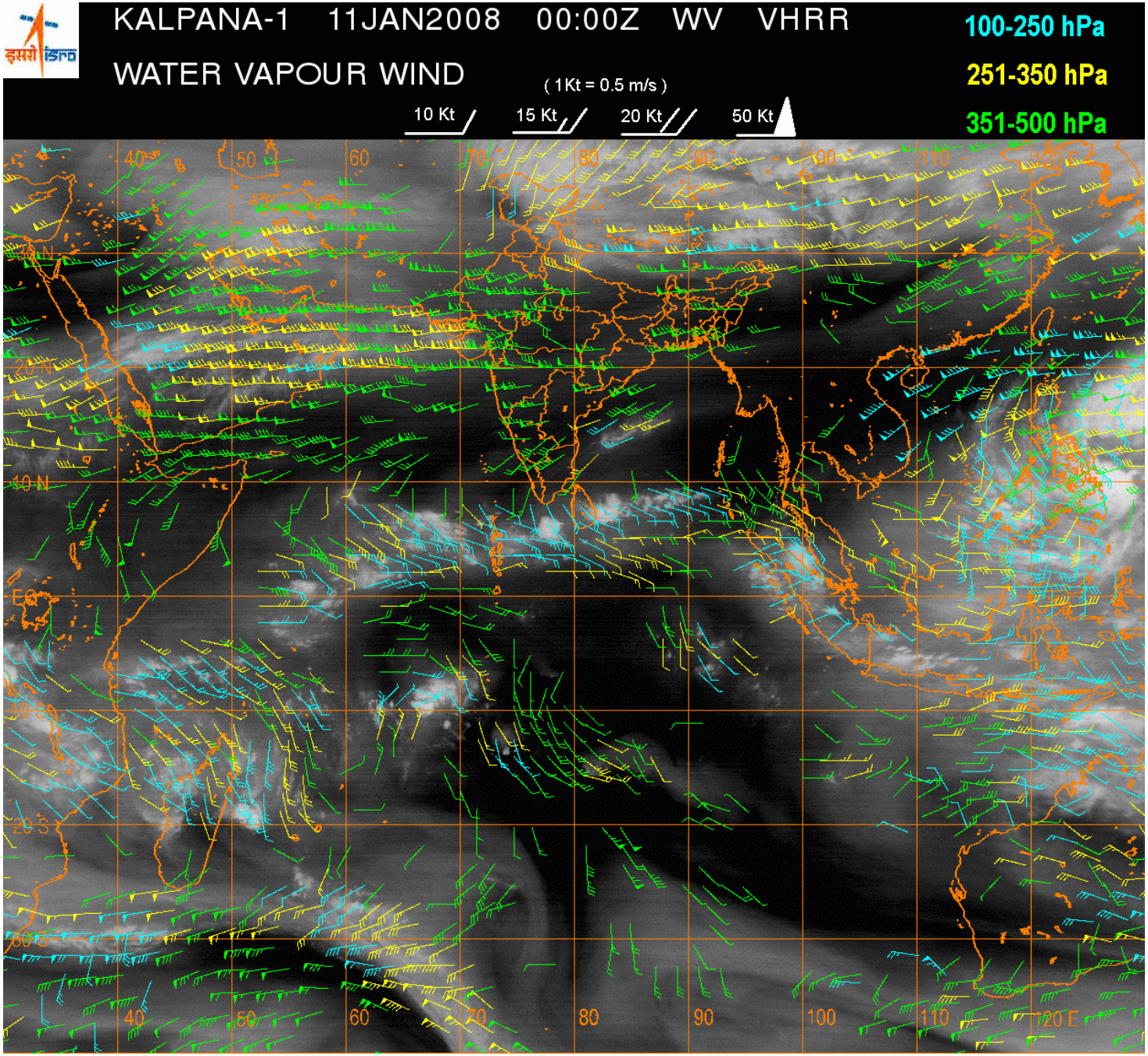




Kalpana IR 11Jan2008 04:00 Z




KALPANA-1 11JAN2008 00:00Z IR VHRR
CLOUD MOTION WIND
(1Kt = 0.5 m/s)
10 Kt
15 Kt
20 Kt
50 Kt
100-300 hPa
301-700 hPa
701-950 hPa
40
50
60
70
80
90
100
110
120 E
30 N
20 N
10 N
EQ
10 S
20 S
30 S


KALPANA-1 11JAN2008 00:00Z WV VHRR
WATER VAPOUR WIND
(1Kt = 0.5 m/s)
10 Kt
15 Kt
20 Kt
50 Kt
100-250 hPa
251-350 hPa
351-500 hPa
40
50
60
70
80
90
100
110
120 E
30 N
20 N
10 N
EQ
10 S
20 S
30 S

Validation of CMV

Validation with Radiosonde: [30E -130E; 50S – 50N]

Meteosat7 VS Radiosonde

Sep 07

Parameters	HIGH 100-399 hPa	MID 400-699 hPa	LOW 700-950 hPa
MVD	8.35	7.82	4.57
RMSE	9.47	8.73	4.87
MSD	6.32	6.05	4.29
MDD	20.28	32.64	36.84
BIAS	-3.57	-3.27	-2.38
NC	214	104	39

Oct 07

Parameters	HIGH 100-399 hPa	MID 400-699 hPa	LOW 700-950 hPa
MVD	8.68	6.56	5.09
RMSE	10.28	8.01	5.39
MSD	6.48	5.06	3.80
MDD	23.25	27.99	34.03
BIAS	-4.1	-2.5	-0.75
NC	197	144	45

Nov 07

Parameters	HIGH 100-399 hPa	MID 400-699 hPa	LOW 700-950 hPa
MVD	9.09	8.99	5.51
RMSE	10.84	10.22	5.72
MSD	6.49	7.41	4.76
MDD	21.19	24.20	31.69
BIAS	-4.54	-4.75	-2.09
NC	188	177	36

Kalpana VS Radiosonde

Parameters	HIGH 100-399 hPa	MID 400-699 hPa	LOW 700-950 hPa
MVD	9.14	7.81	7.17
RMSE	10.35	8.43	7.31
MSD	6.71	5.56	4.9
MDD	19.53	23.04	28.3
BIAS	-3.97	1.69	4.34
NC	551	100	20

Parameters	HIGH 100-399 hPa	MID 400-699 hPa	LOW 700-950 hPa
MVD	8.17	8.17	9.68
RMSE	9.81	8.6	9.89
MSD	5.95	6.27	6.91
MDD	20.18	21.67	40.97
BIAS	-3.64	-0.43	5.14
NC	389	81	22

Parameters	HIGH 100-399 hPa	MID 400-699 hPa	LOW 700-950 hPa
MVD	9.79	9.8	6.15
RMSE	11.45	10.56	6.2
MSD	6.99	7.01	4.76
MDD	19.88	23.17	17.92
BIAS	-3.73	-2.30	3.84
NC	376	114	17

Validation of WVWV

Validation with Radiosonde: [30E -130E; 50S – 50N]

September 2007

Parameters	EUMETSAT	KALPANA
MVD	8.94	8.78
MSD	5.62	5.30
MDD	28.84	27.58
BIAS	0.87	1.44
NC	296	360

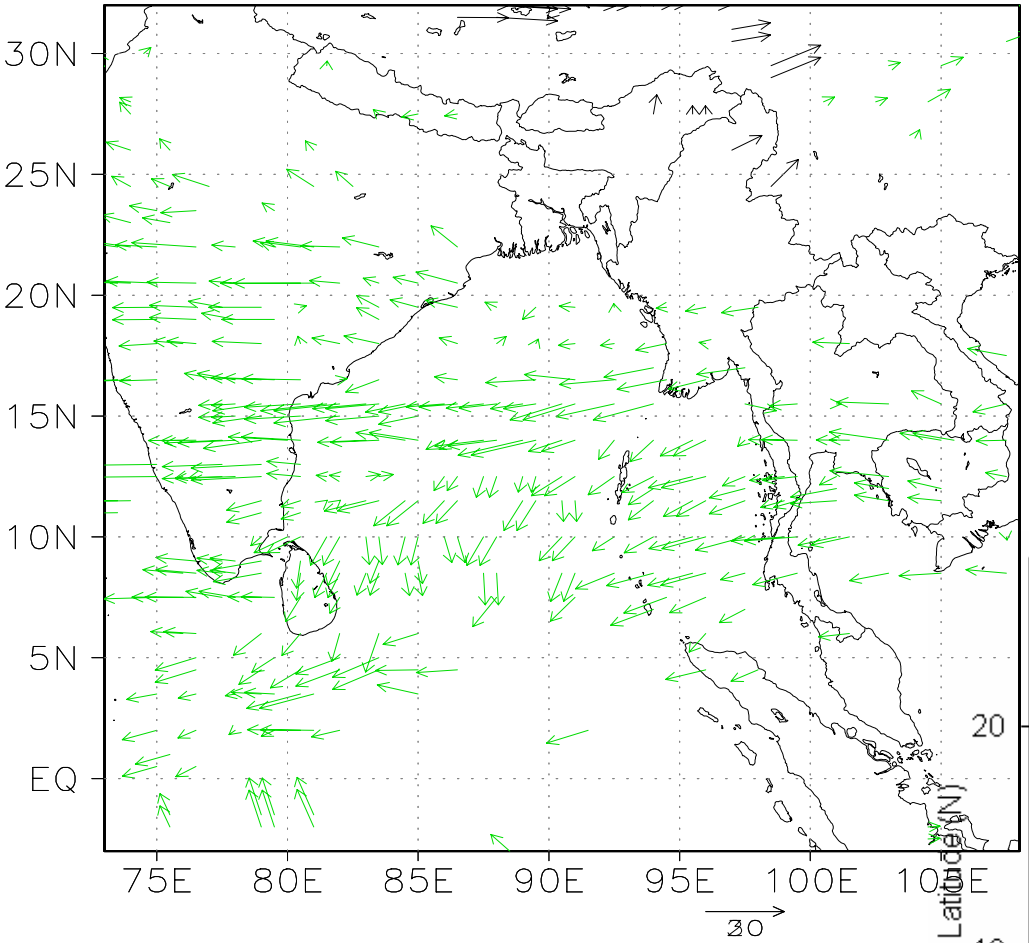
October 2007

Parameters	EUMETSAT	KALPANA
MVD	7.88	8.27
MSD	5.25	5.98
MDD	25.35	20.00
BIAS	1.98	3.60
NC	319	355

November 2007

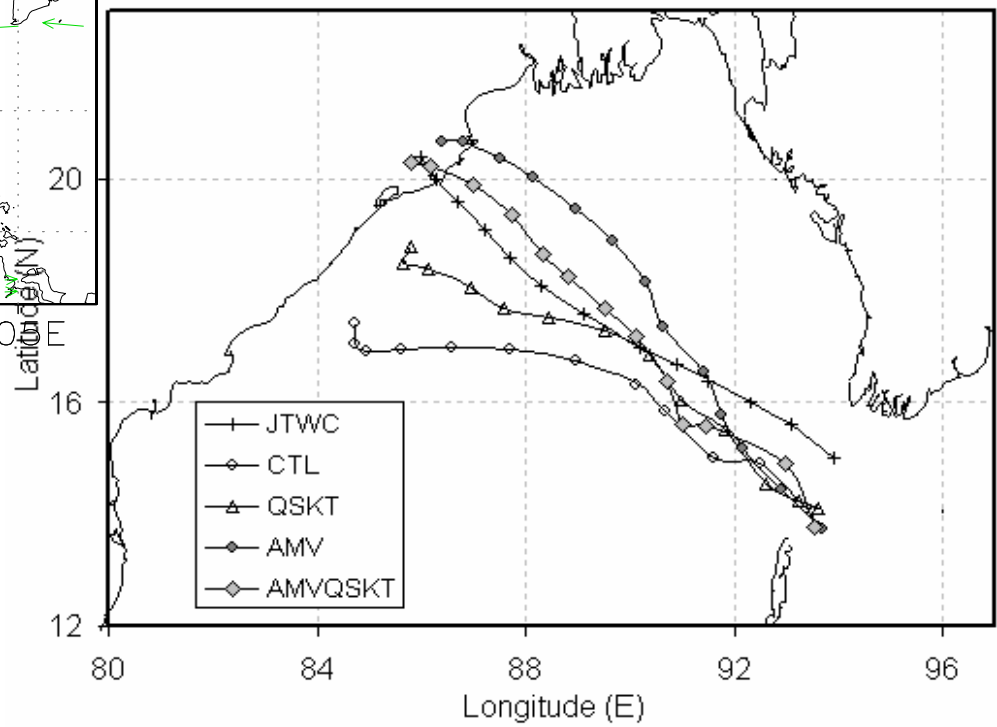
Parameters	EUMETSAT	KALPANA
MVD	8.55	9.4
MSD	6.09	7.11
MDD	20.55	19.9
BIAS	3.77	4.95
NC	339	459

Assimilation of AMV for Cyclone Track Prediction

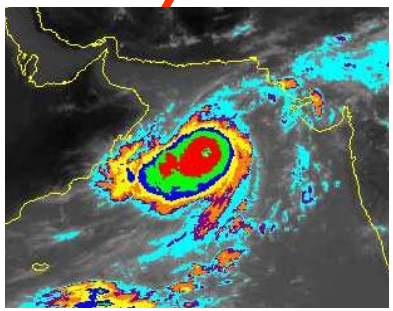


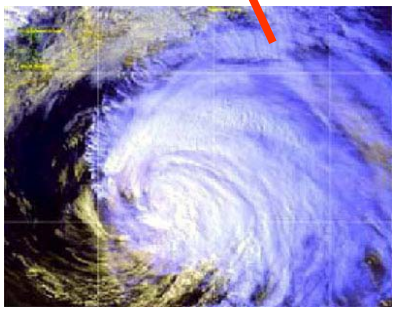
AMV's ; 12UTC 26th Oct, 1999

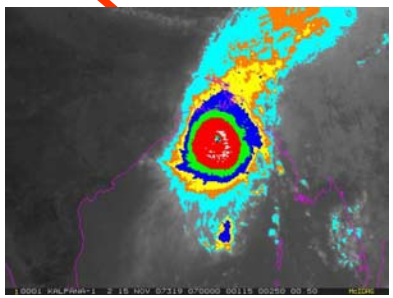
Cyclone Track using WRF



3 Super Cyclones over the Indian Ocean during the past decade







GONU

June 03-07, 2007

Max Wind 252 km/h

Orissa Super Cyclone

Oct 26-29, 1999

Max Wind 252 km/h

SIDR

Nov 09-16, 2007

Max Wind 250 km/h

Surface Parameters from INSAT

Land :

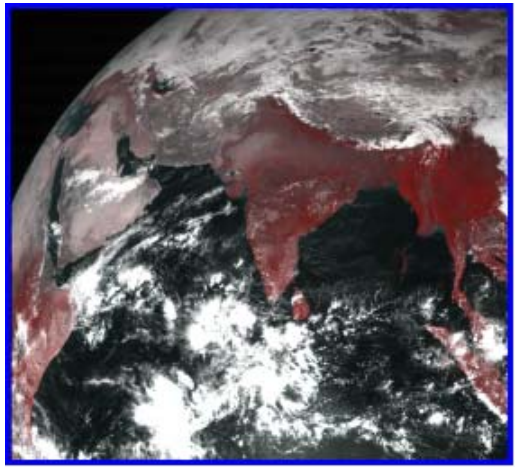
Basic (Daily & 10-day)	Sensors/bands	Derived (Daily & 10-day)
1. NDVI	CCD Red, NIR	Land cover, Frac. veg.
2. Insolation	VHRR VIS, TIR & WV	Shortwave / PAR
3. LST	VHRR TIR & WV	Net radiation
4. Surface albedo	VHRR VIS	Net radiation

Ocean:

1. SST	VHRR IR	Daily composite
2. Insolation	VHRR IR	Daily composite

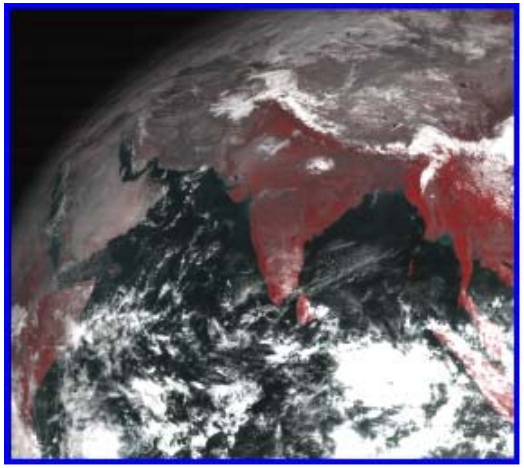
NDVI profile from INSAT 3A CCD (1km)

3A CCD FCC



28 Nov.' 06(0500 GMT)

3A CCD FCC

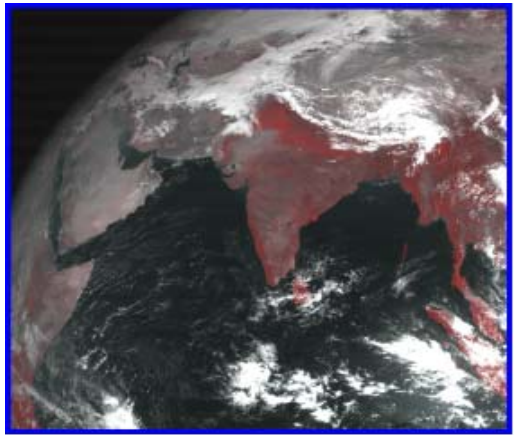


27 Dec.' 06 (0500 GMT)

3A CCD FCC

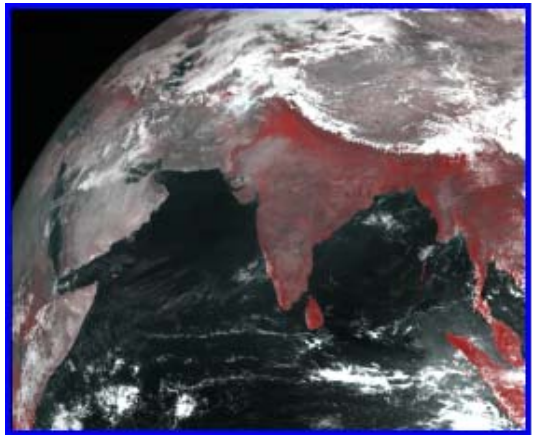
28 Jan.'07 (0500 GMT)

3A CCD FCC



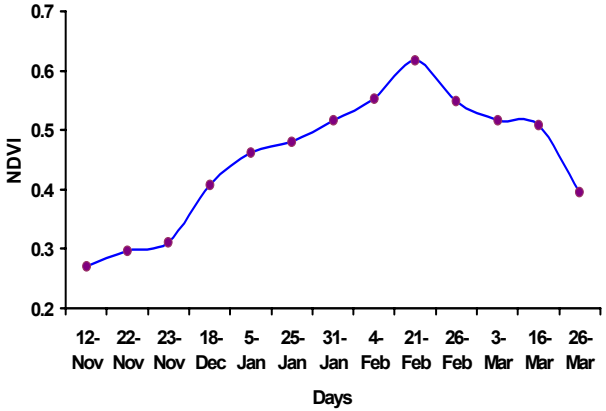
26 Feb.' 07 (0500 GMT)

3A CCD FCC

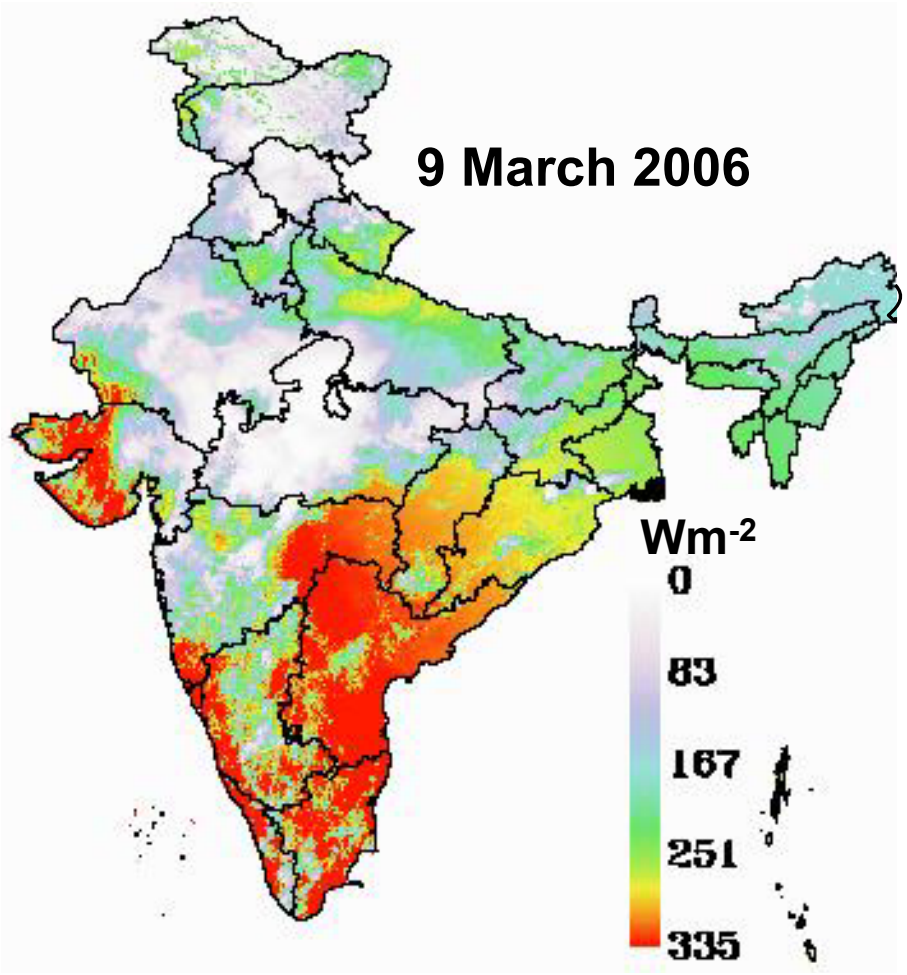


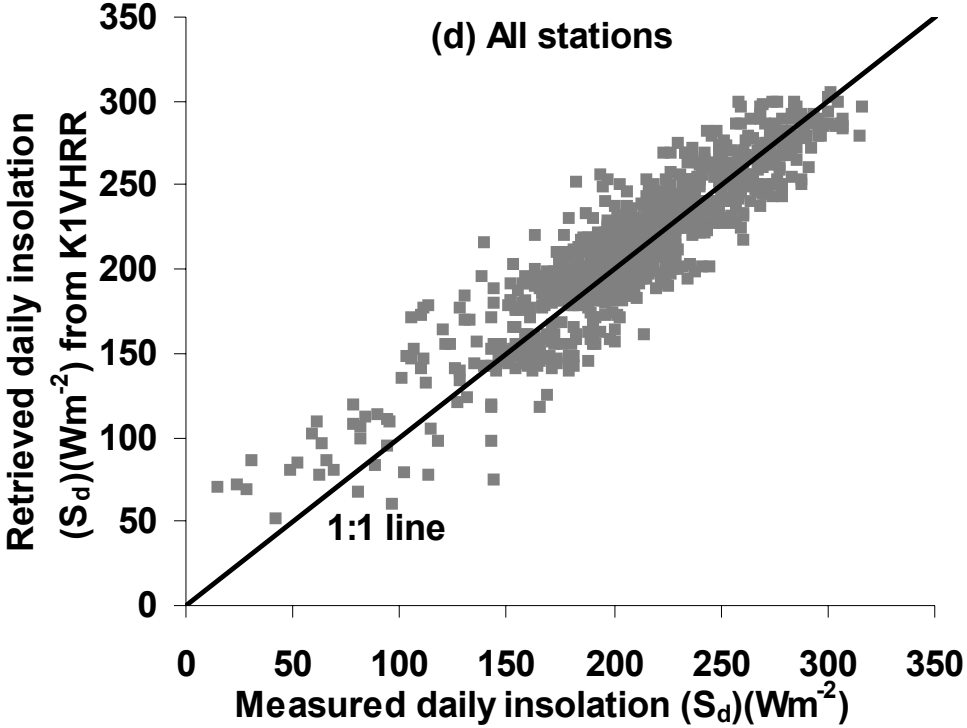
26 Mar.' 07 (0500 GMT)

Wheat NDVI profile



Daily insolation from VHRR and validation with pyranometer measurements





INSAT - 3D

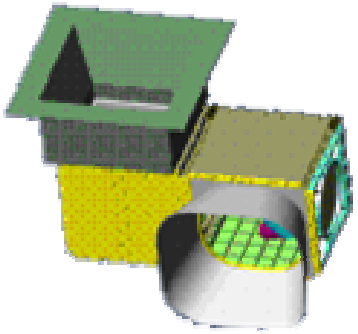
Improved Understanding of Mesoscale Systems

6 Channel IMAGER

- Spectral Bands (µm)

Visible	: 0.55 - 0.75
Short Wave Infra Red	: 1.55 - 1.70
Mid Wave Infra Red	: 3.80 – 4.00
Water Vapour	: 6.50 - 7.10
Thermal Infra Red – 1	: 10.30 - 11.30
Thermal Infra Red – 2	: 11.50 - 12.50

- Resolution : 1 km for VIS, SWIR
  4 km for MIR, TIR
  8 km for WV



19 Channel SOUNDER

- Spectral Bands (µm)

Short Wave Infra Red	: Six bands
Mid Wave Infra Red	: Five Bands
Long Wave Infra Red	: Seven Bands
Visible	: One Band

- Resolution (km) : 10 X 10 for all bands
- No of simultaneous sounding per band : Four

NINETEEN CHANNEL ATMOSPHERIC SOUNDER

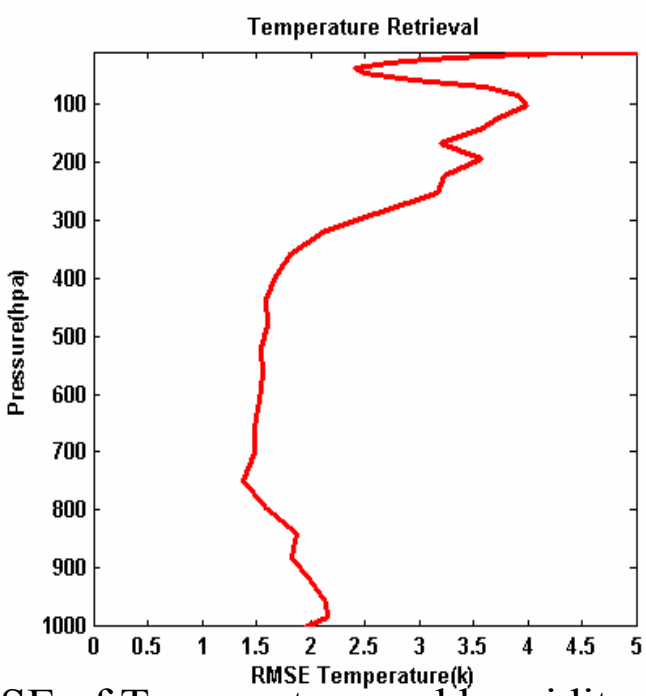
A-19 channels atmospheric sounder for derivation of vertical temperature and moisture profiles with a resolution of 10 km at Sub-Satellite

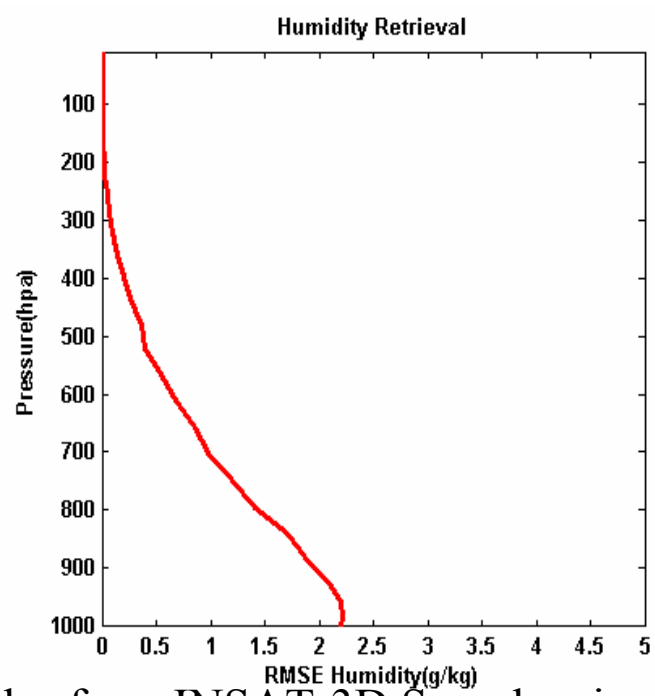
Channel No.	Central Wavelength in um	Principal absorbing constituents
1	14.71	CO-2 band
2	14.37	CO-2 band
3	14.06	CO-2 band
4	13.96	CO-2 band
5	13.37	CO-2 band
6	12.66	water vapor
7	12.02	water vapor
8	11.03	window
9	9.71	ozone
10	7.43	water vapor
11	7.02	water vapor
12	6.51	water vapor
13	4.57	N-2 0
14	4.52	N-2 0
15	4.45	CO-2
16	4.13	CO-2
17	3.98	window
18	3.74	window
19	0.69	vis

Only Sounder in Geostationary orbit, after GOES

INSAT-3D Sounder Simulation Studies

- Tropical regions have high water vapour content
- Effective Channels Simulated for tropical atmosphere
- Regression Retrieval for temperature and humidity profile
  - Training dataset : SeeBor (SSEC/UW)
  - RT Model : PLOD Fast RT model





RMSE of Temperature and humidity profiles from INSAT-3D Sounder simulated radiances using non-linear regression (for Indian region)

Future Geostationary Satellites

- **INSAT 3D Repeat (~ 2012)**
- **Follow-up of INSAT-3D**
  - **Defining Stage**
  - **Very High resolution Radiometer**
  - **Sounder – more channels**
    - Different channel simulations using hyperspectral Sounder observation (Metop-IASI/ Aqua-AIRS)
    - Sensitivity study with different central wavenumber and bandwidth to arrive at suitable number of sounder channels for profile retrieval over Indian region.

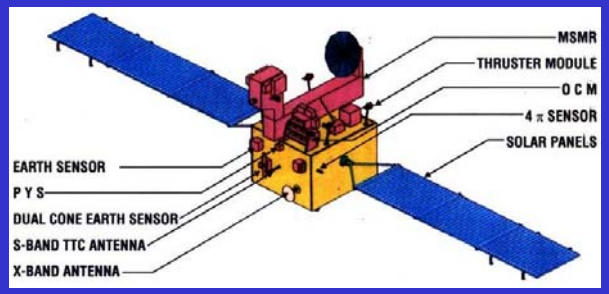
… contd

Future Geostationary Satellites

- Geo – HR (~2012) [name yet to be frozen]
- Visible – 50 m
- 3 Channel IR – 1.5 Km
- Visible and SWIR Hyper-spectral – 500 m
  - ❑ 50 – 60 channels in VIS
  - ❑ 50 – 60 channels in SWIR
- For general remote sensing and can also be used for meteorological purpose

IRS-P4

Oceansat-1



Specifications

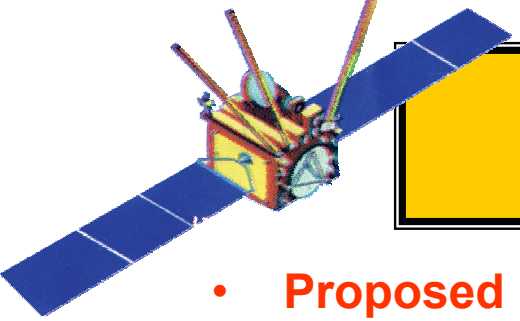
Altitude	720 Km
Swath	1360 Km
Repetivity	2 days
Orbit inclination	98
Launch	May 26, 1999
Sensors	MSMR & OCM

MSMR

Weight	65 Kg
Frequency	6.6, 10.6, 18 and 21 GHz
Polarization	V & H
Spatial Resolution	40 to 120 Km
Temperature Resolution	1 K
Parameters	: WS,WV,SST,CLW,Rain

OCM

Sensor	OCM - 1
Resolution (km)	0.360
Swath(km)	1420
Repeativity(days)	2
Equatorial crossing (hrs)	12:00
Spectral bands (nm)	412±10 443±10 490±10 510±10 555±10 670±10 765±20 865±20
Radiometric quantisation	12
SNR	~350



Oceansat -II

- **Proposed Instruments:**
  - Scatterometer Ku band
  - Ocean Colour Monitor
    - Instead of 660-680 nm in OS-I it has 610-630 nm
  - Radio Occultation (ROSA)

- **Proposed Launch**
  - Mid 2008

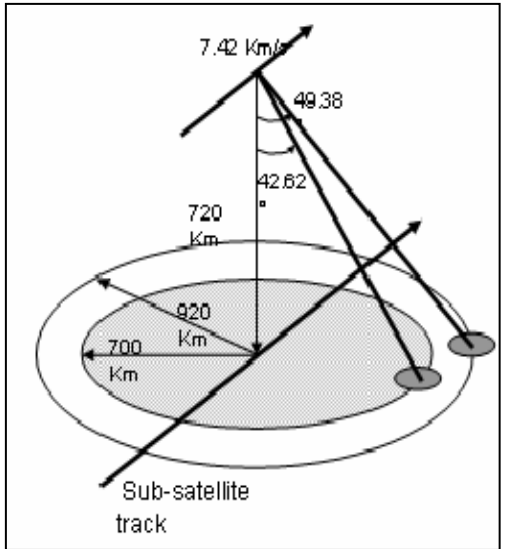
- **Announcement of Opportunity**
  - Last Date : March 31, 2008
  - Available in www.isro.gov.in

- **Applications:**
  - Sea State Forecast: Waves, Circulation and MLD
  - Monsoon and Cyclone Forecast – Medium and Extended Range
  - Antarctic Sea Ice
  - Fisheries and Primary productivity estimation
  - Detection and monitoring of Phytoplankton blooms
  - Sediment dynamics

Scatterometer Specifications

Parameter	Inner Beam	Outer Beam
Attitude	720 km	
Frequency	13.515 GH,	
PRF	200 H,	
Wind speed range	4 to 24 m / sec.	
Wind speed accuracy	Better than 20 % (rms)	
Wind direction accuracy	20° (rms)	
Polarization	H H	V V
Swath	1400 km	1840 km
Elevation angle	42.62°	49.38°
Incidence angle	48.90°	57.60°
Footprint	26 X 46 km	31 X 65 km
Scanning rate	20.5 rpm	

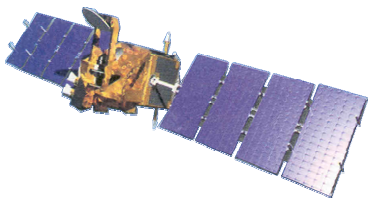
Scatterometer Observational Geometry



Megha Tropiques

(ISRO-CNES)

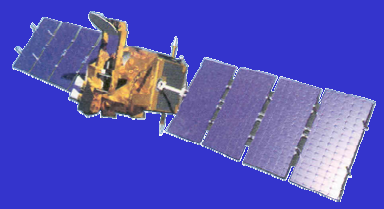
Launch Vehicle	PSLV
Bus	IRS
Year of Launch	~2009
Satellite Weight	500 kg
Satellite Altitude	~800 km
Inclination	~20°



Payloads

MADRAS	Pasive MW Radiometer
	18-85 GHz, 157 GHz
SAPHIR	183 GHz WV Sounder
ScaRaB	Visible-IR Radiometer
IGOR	GPS

Megha Tropiques

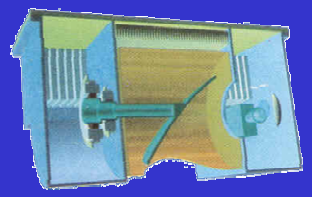


For studying water cycle and energy exchanges in the tropical belt

Low inclination (20º) for frequent simultaneous observations of tropics

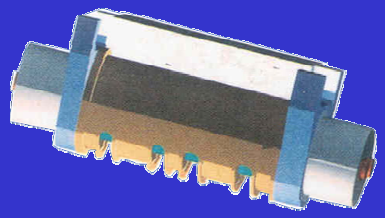
- Water vapour
- Clouds
- Cloud condensed water
- Precipitation
- evaporation
- Water vapour Profile

SAPHIR



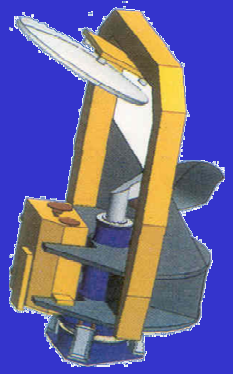
- Water vapour profile
- Six atmospheric layers upto 12 km height
- 10 km Horizontal Resolution

SCARAB



- Outgoing fluxes at TOA
- 40 km Horizontal Resolution

MADRAS



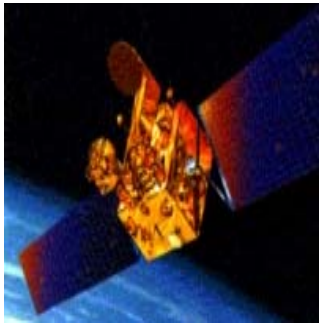
- Precipitation and cloud properties
- 89 &157 GHz : ice particles in cloud tops
- 18 & 37 GHz: cloud liquid water and precipitation
- 23 GHz : Integrated water vapour

IGOR

- Temperature and Humidity Profile

SARAL

AltiKa (Ka-band Altimeter): A collaborative ISRO-CNES Program



- **Central Objective: Need for high-resolution Altimetry**
- Launch is planned by the end of 2009.
- A complement to JASON-1 and gap-filler for Envisat altimetry.
- Requirement of a minimum of two altimeters in orbit.

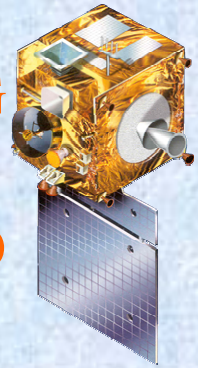
Satellite Description :

- Sun-synchronous, polar orbiting, inclination: 98.38 Deg.
- Altitude: ~800 km, Repeat cycle: 35 days
- Ka-band Altimeter (~35.5GHz)
- Dual frequency radiometer (23.8/36.8 GHz)

Indian Missions for Weather & Climate Studies : Current & Future

GEO

Kalpana-1
2002



VHRR

CMV, OLR, Rainfall

INSAT-2E/3A
(1999/2003)

VHRR, CCD

CMV, OLR, Rainfall
Aerosol

INSAT-3D
(2008)

6-Ch VHRR
IR Sounder

SST, CMV, OLR,
Rainfall,
T, h Profile

- **INSAT-3D R**
- **Geo-HR**
(~2012)

- **Follow-up**
(~2015)

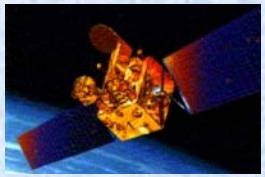
LEO

OCEANSAT–1/2
(1999/2008)

MSMR,
OCM,
Scatterometer
ROSA

Vector Winds
Aerosol, TWV

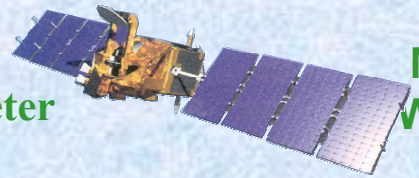
SARAL
(2009)



Altimeter

SSH,Waves, Winds

MEGHA-TROPIQUES
(2009)



MW Imager,
WV Sounder
ScaRaB
IGOR(GPS)

SS Wind, TWV, Rainfall
T, h Profile,
Radiation Budget

Thanks