Simulation and Validation of INSAT-3D Sounder Radiance at NCMRWF

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Outline

1 .Introduction

2. Simulation of INSAT-3D Sounder Brightness Temperature

a. Using Radiative Transfer Model (RTTOV-9)

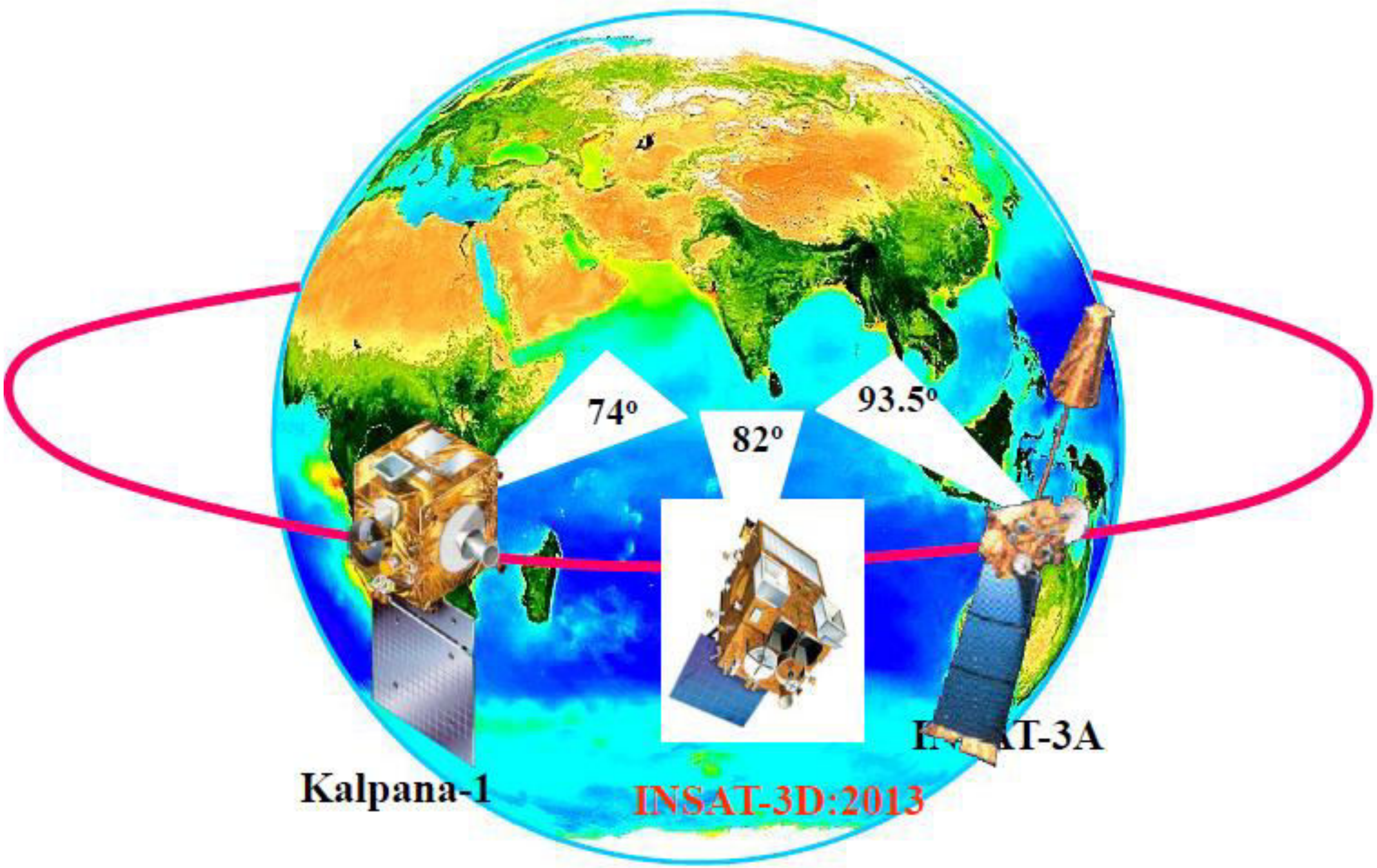
b. Using NWP Model (dbCRAS)

3. Validation of INSAT-3D Sounder Brightness Temperature

a. Against RT model simulated Brightness Temperature

b. Against NWP model simulated Brightness Temperature

Indian Geostationary Meteorological Satellites in Orbit



Introduction

India's advanced weather satellite, INSAT-3D, is the first geostationary sounder over India and surrounding oceanic regions, was launched on 26 July 2013.

Located at 82 °E, has 19 channel sounder and 6 channel Imager

Along with other polar satellite soundings, INSAT-3D provides fine resolution vertical profiles over India and surrounding region.

NCMRWF routinely receives near-real time soundings from polar orbiting satellites, and recently started receiving INSAT-3D sounder and imager data from India Meteorological Department (IMD).

Simulation, Validation, and assimilation of INSAT-3D sounder and imager data is in progress at NCMRWF.

Different Radiative Transfer models and Regional Atmospheric models are used to simulate the INSAT-3D Sounder and Imager brightness temperature.

INSAT-3D Sensors: Imager and Sounder

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 – 12.5

Resolution : 1 km VIS and SWIR

4 km MIR and TIR

8 km WV

19 channel Sounder

Spectral Bands (µm)

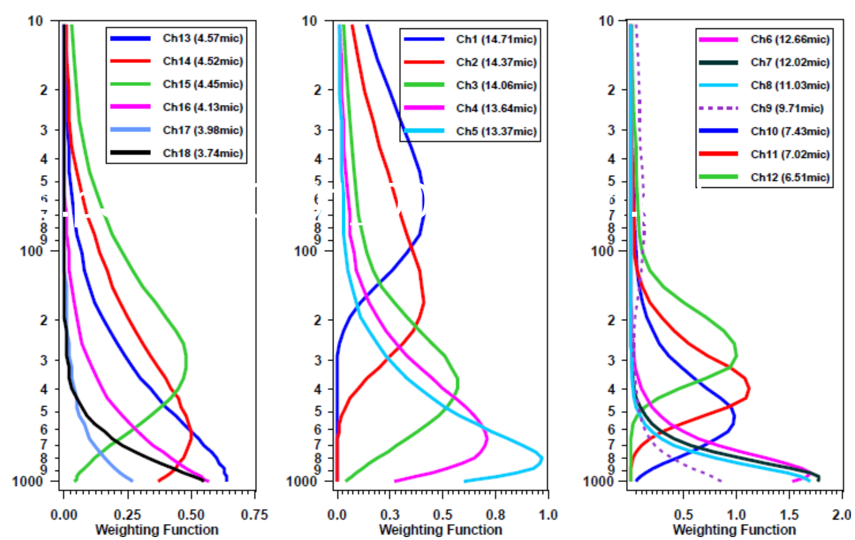
Short Wave Infra Red : 6 bands

Mid Wave Infra Red : 5 bands

Long Wave Infra Red : 7 bands

Visible : 1 band

INSAT-3D Weighting Function over Indian Region (July)



INSAT-3D Sounder Channels

Ch No	Central Wavelength (μm)	Principal absorber
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 Channel
9	9.71	Ozone
10	7.43	Water vapor
11	7.02	Water vapor
12	6.51	Water vapor
13	4.57	N_2O
14	4.52	N_2O
15	4.45	CO_2 - band
16	4.13	CO_2 - band
17	3.98	Window
18	3.74	Window
19	0.695	Visible

Period of Study

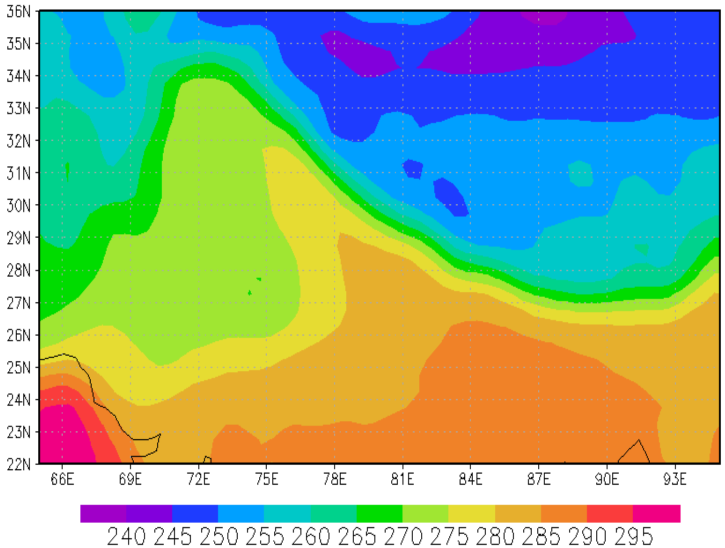
Simulation of INSAT-3D Sounder Radiance during 2013 North Indian Ocean Cyclone (NIOC) period

Four Cyclones during 2013 NIOC Period

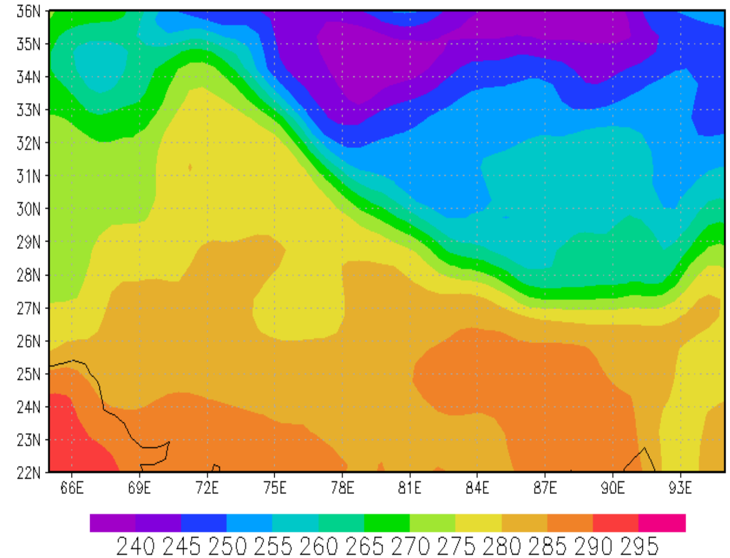
1. **PHAILIN (VSCS): 8 -14 October 2013**
2. **HELEN (SCS): 19 – 23 November 2013**
3. **LEHAR (VSCS): 23 -28 November 2013**
4. **MADI (VSCS): 6 -13 December 2013**

INSAT-3D: Observed and simulated BT (02 January 2014)

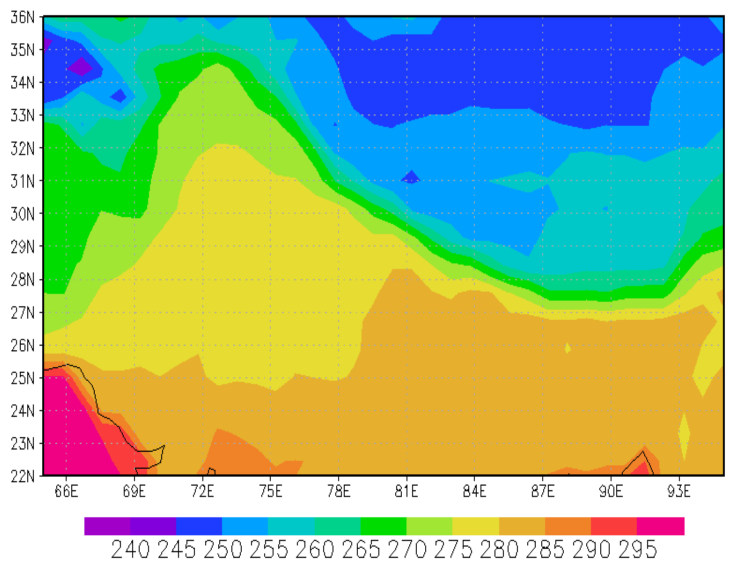
Observed BT : Channel 8 (11 µ)



RT Simulated BT : Channel 8 (11 µ)

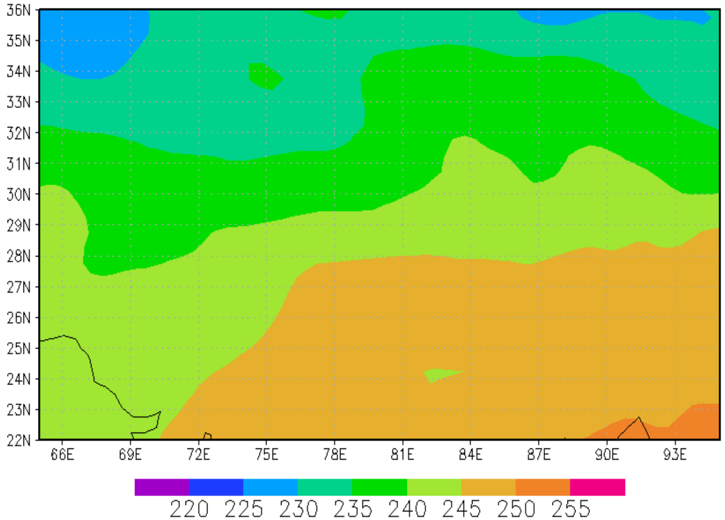


dbCRAS Simulated BT : Channel 8 (11 µ)

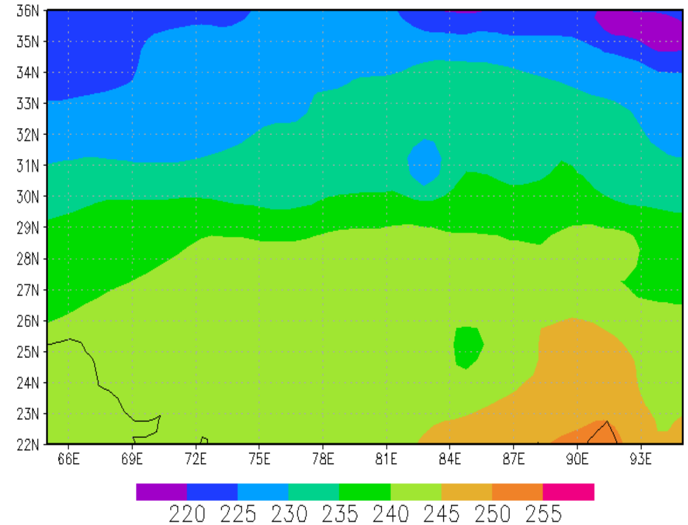


INSAT-3D: Observed and simulated BT (02 January 2014)

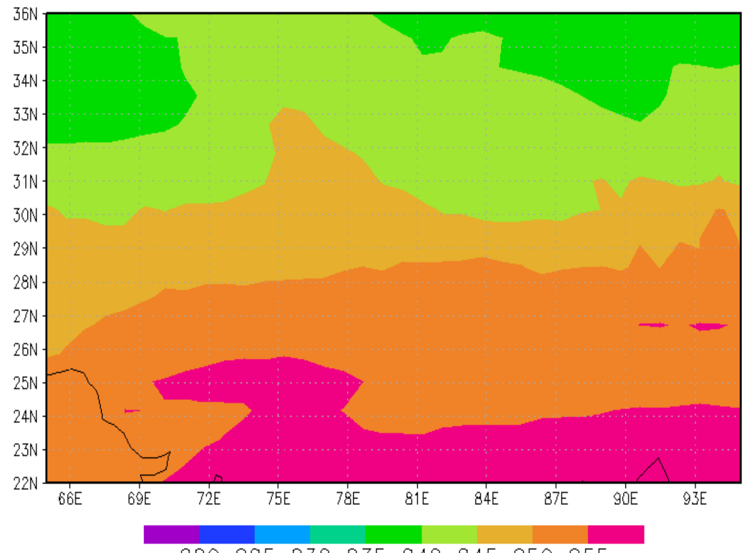
Observed BT : Channel 12 (6.5 µ)



RT Simulated BT : Channel 12 (6.5 µ)



dbCRAS Simulated BT : Channel 12 (6.5 µ)



Simulation: Using RTTOV (Version 9.2)

Single Level Surface Parameters: NCMRWF global model

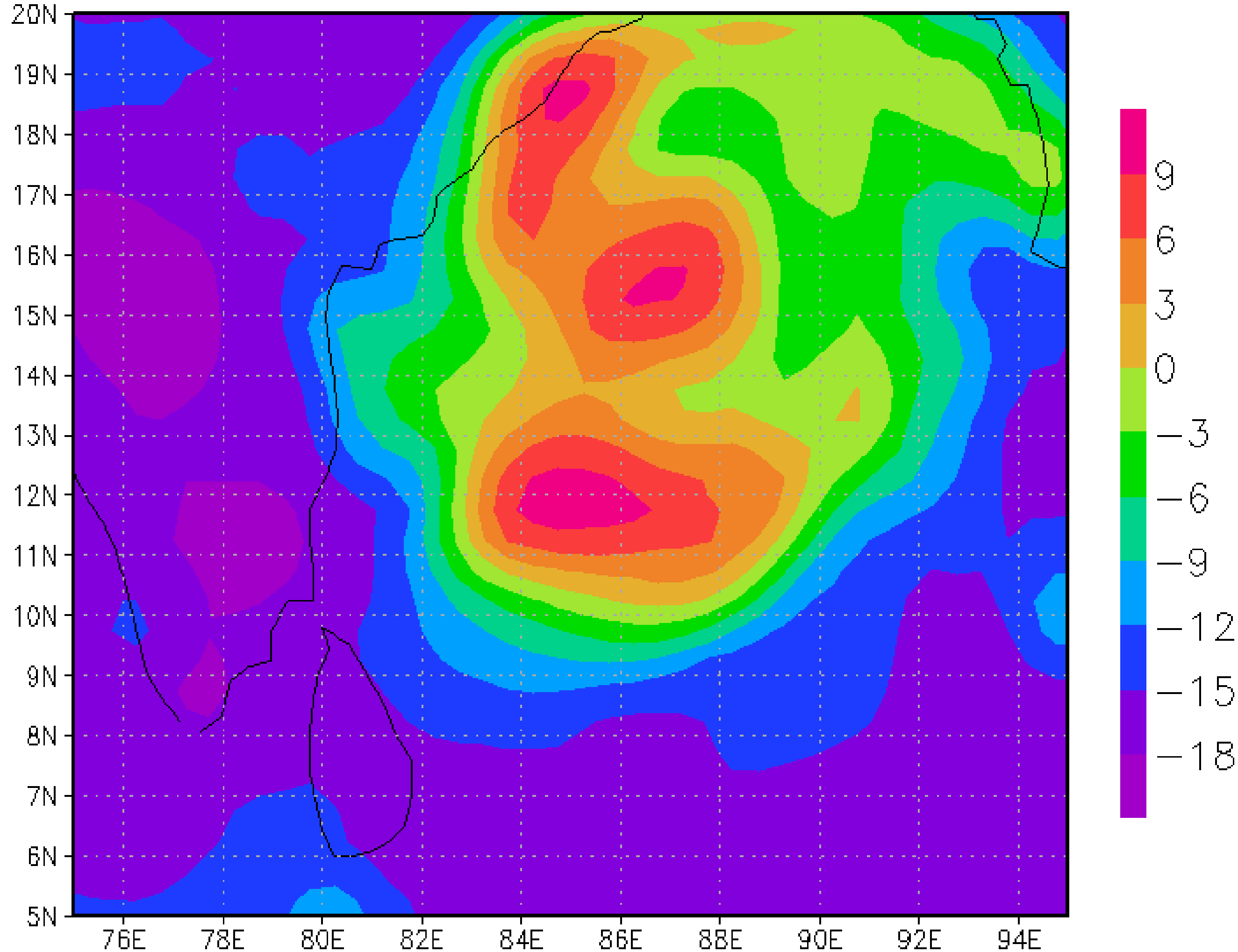
Temperature and Humidity profiles: NCMRWF global model

Ozone profile: Climatology

Cloud assumption: Clear sky

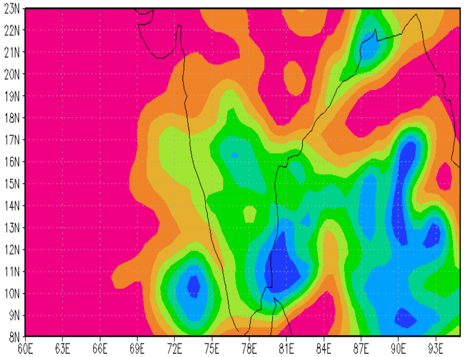
Phailin: Warm core

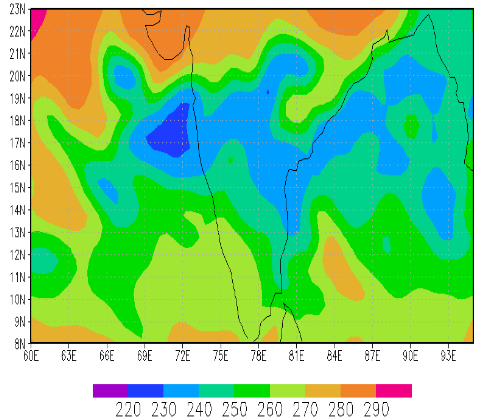
11 October 2013 Temperature difference (K) between warm core and environment



Observed BT

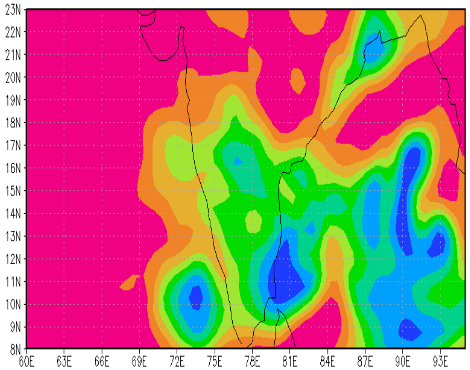
Simulated BT

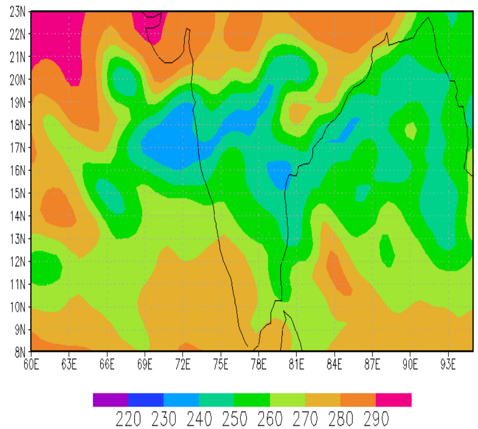


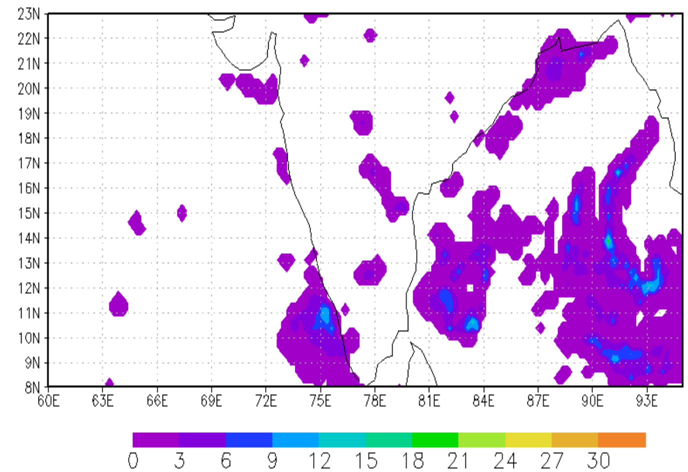


Channel 6: 12.66 µm

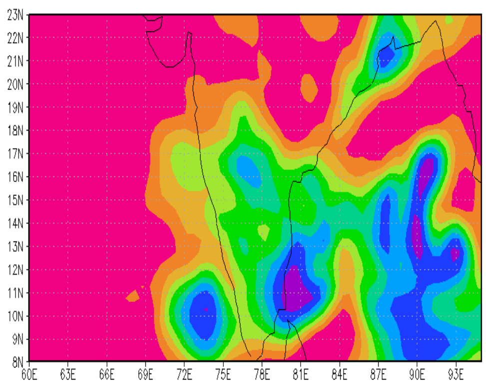
09-10-2013 (00 UTC)
PHAILIN

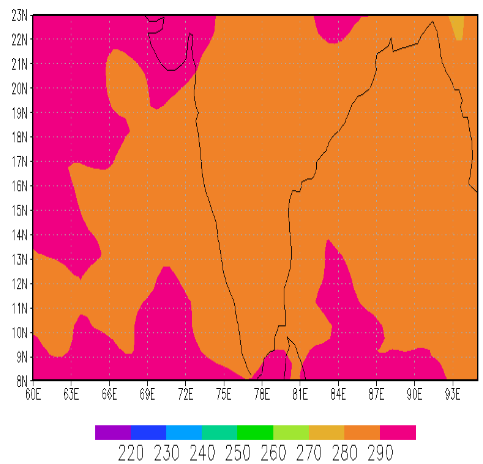






Channel 7: 12.02 µm



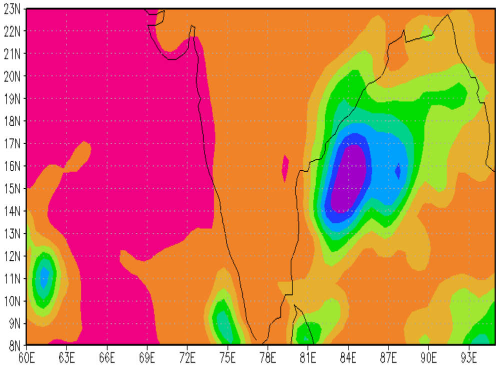


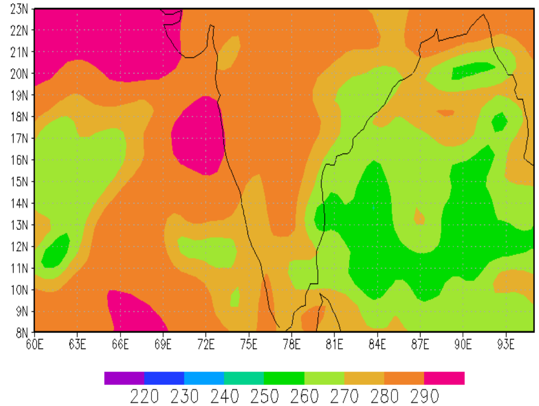
Channel 8: 11.03 µm

Observed BT

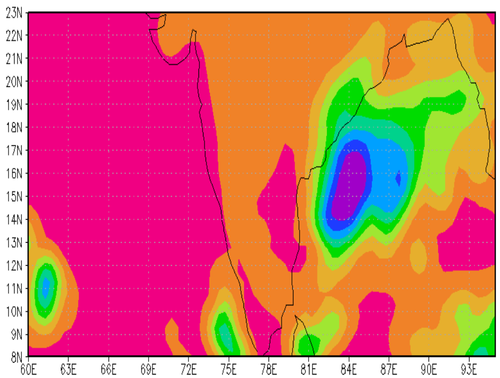
Simulated BT

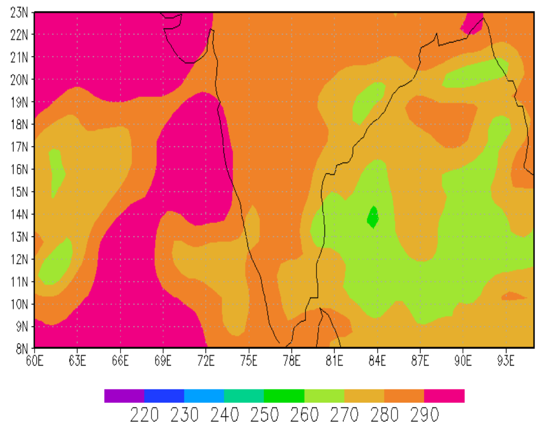
20-11-2013 (00 UTC)
HELEN



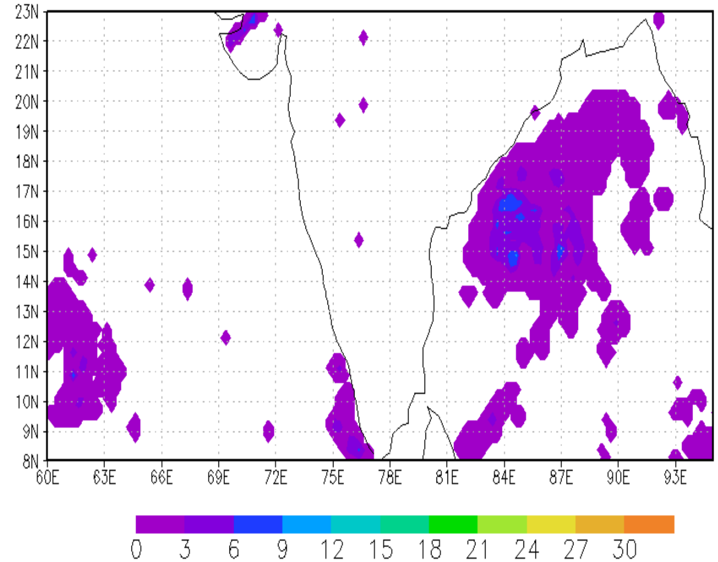


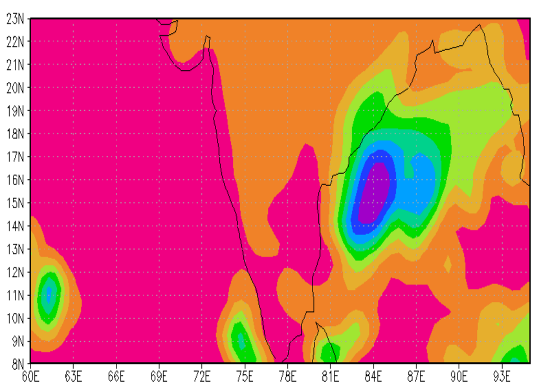
Channel 6: 12.66 µm

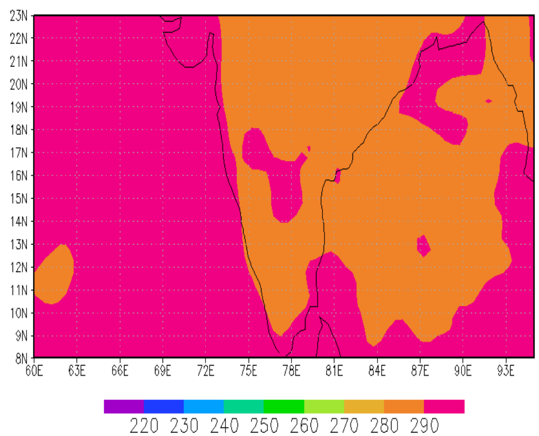




Channel 7: 12.02 µm



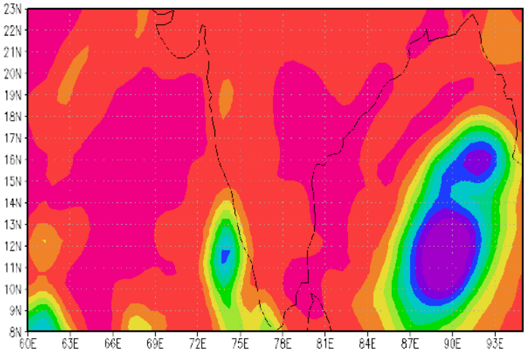


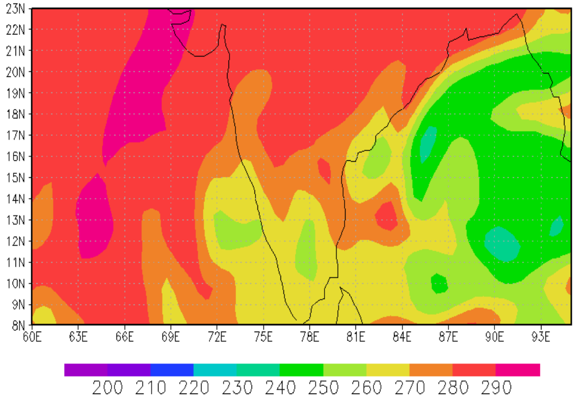


Channel 8: 11.03 µm

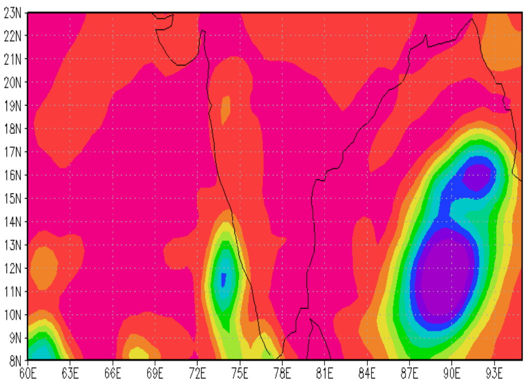
Observed BT **Simulated BT**

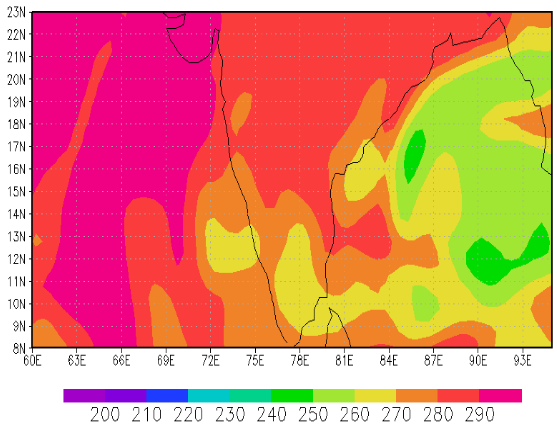
26-11-2013 (00 UTC)
LEHAR

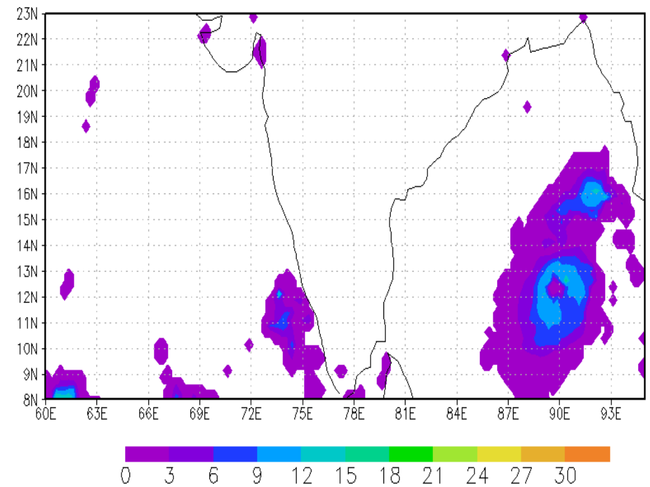




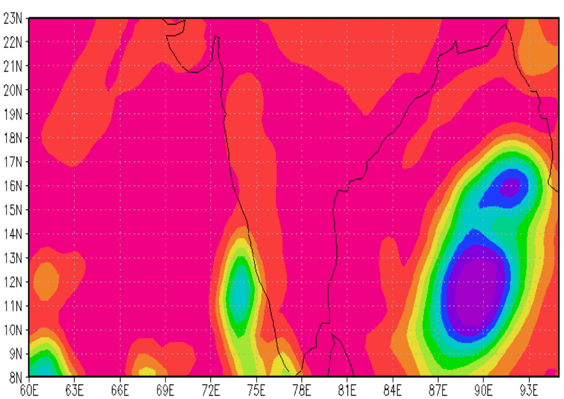
Channel 6: 12.66 µm

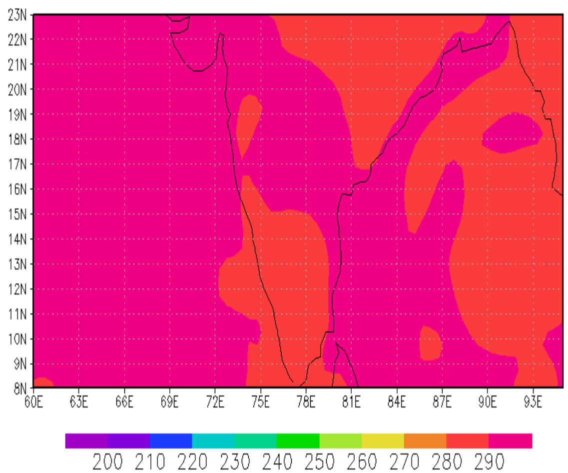






Channel 7: 12.02 µm



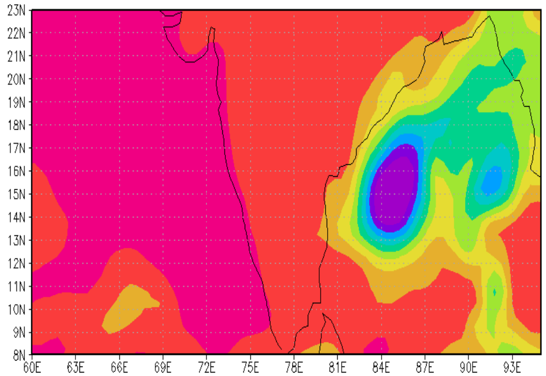


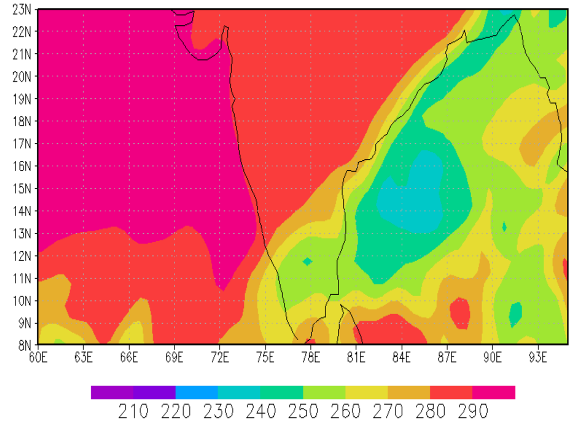
Channel 8: 11.03 µm

10-12-2013 (00 UTC)
MADI

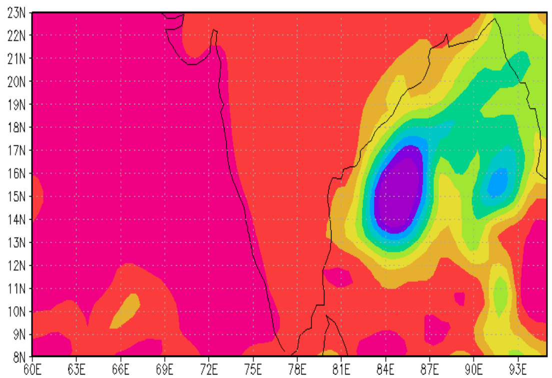
Observed BT

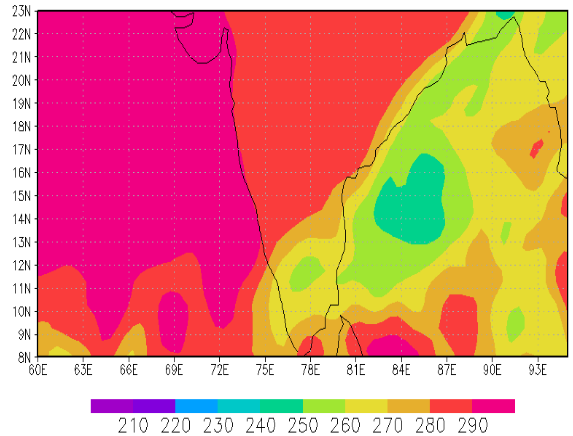
Simulated BT

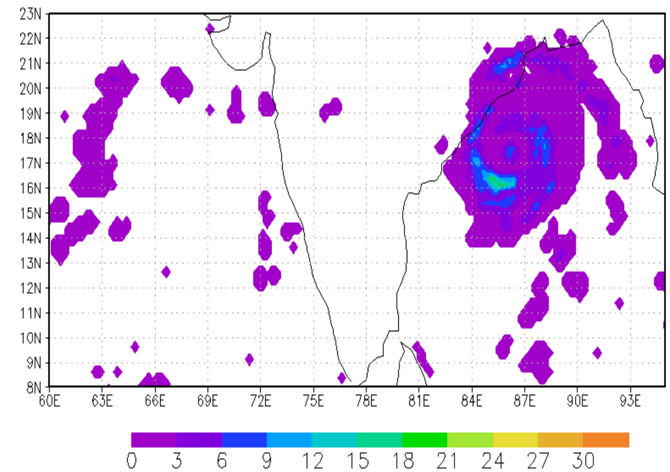




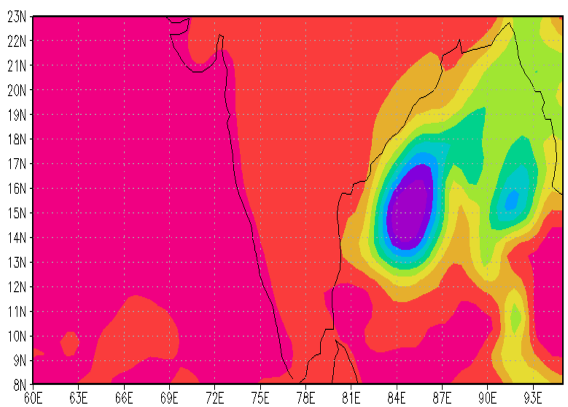
Channel 6: 12.66 µm

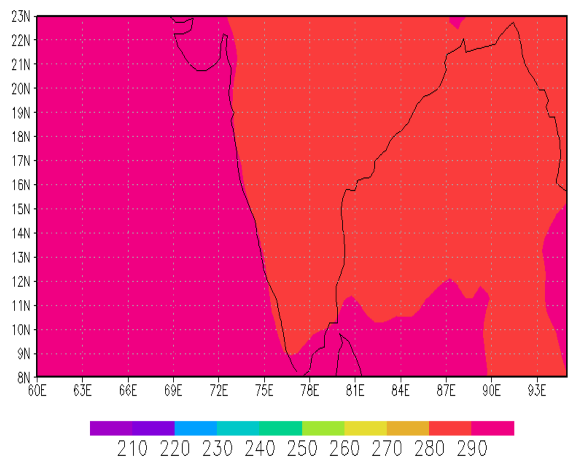






Channel 7: 12.02 µm

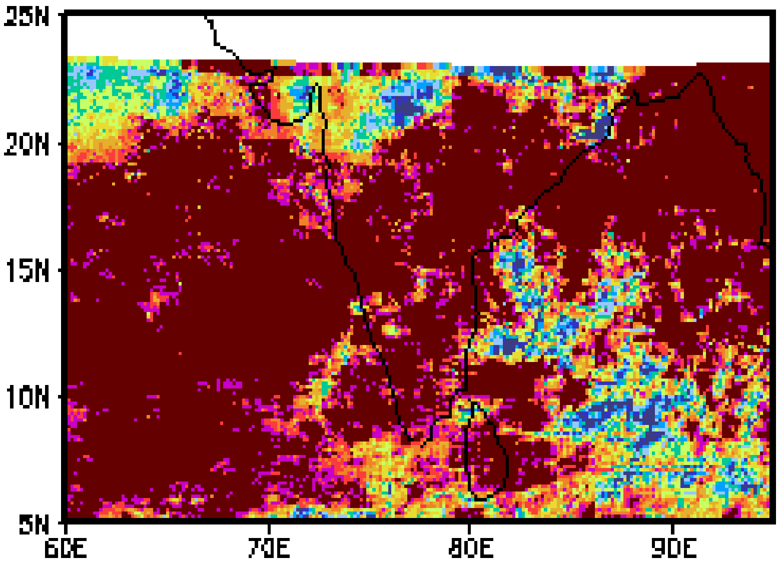




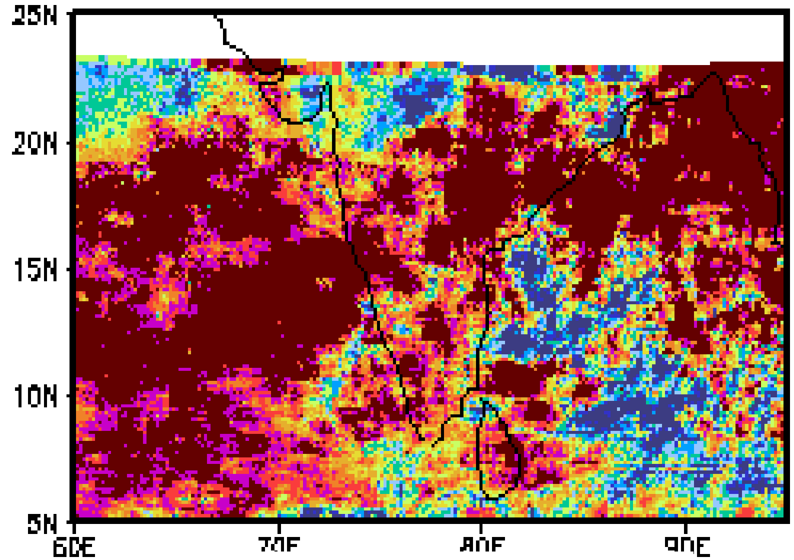
Channel 8: 11.03 µm

PHAILIN:08-14 October 2013

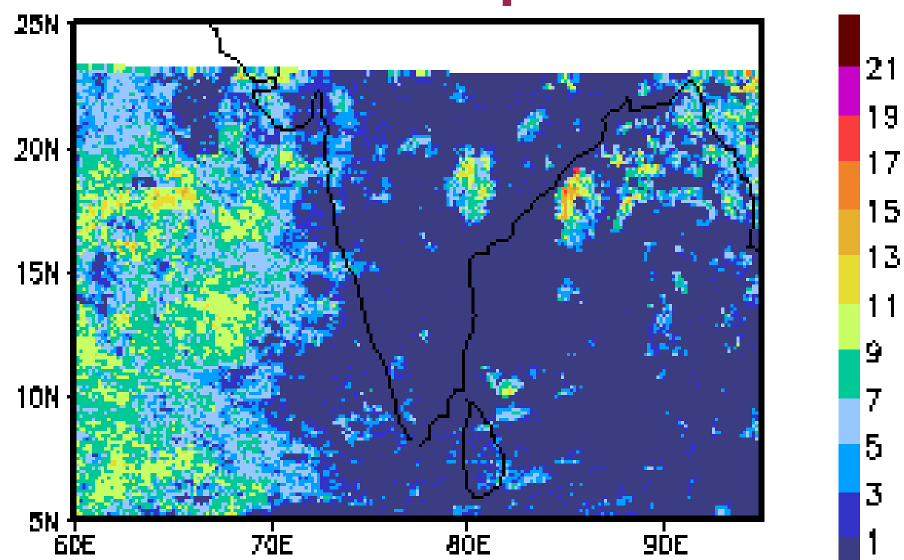
Channel-6: 12.66 µm



Channel-7: 12.02 µm



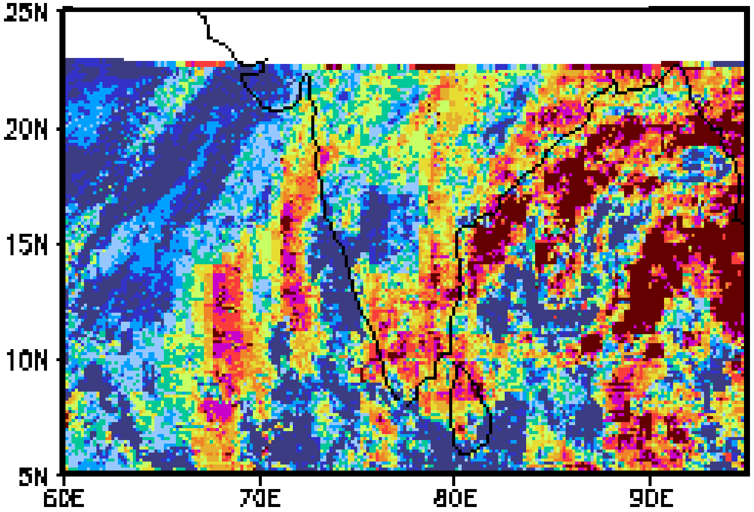
Channel-8: 11.03 µm



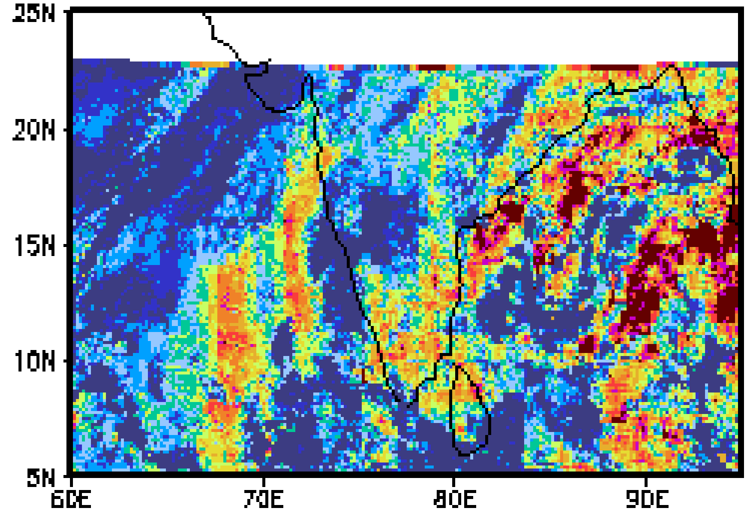
Mean difference in Observed and RT model simulated BT

HELEN:19-23 November 2013

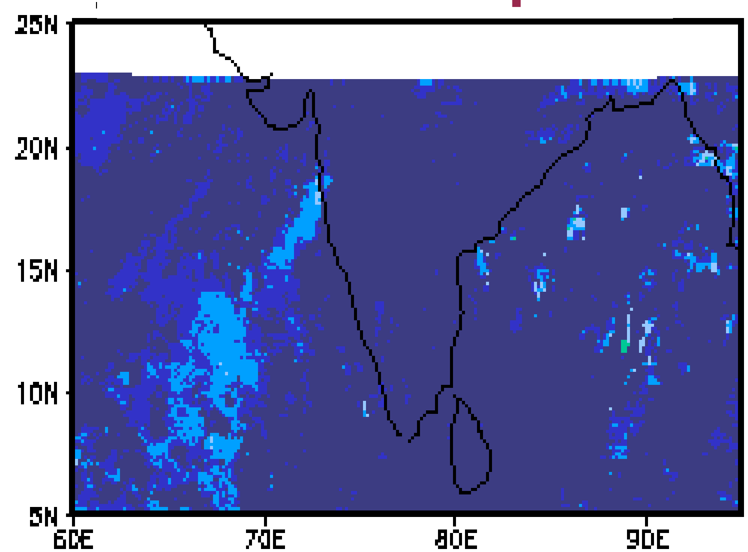
Channel-6: 12.66 µm

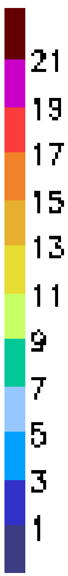


Channel-7: 12.02 µm



Channel-8: 11.03 µm

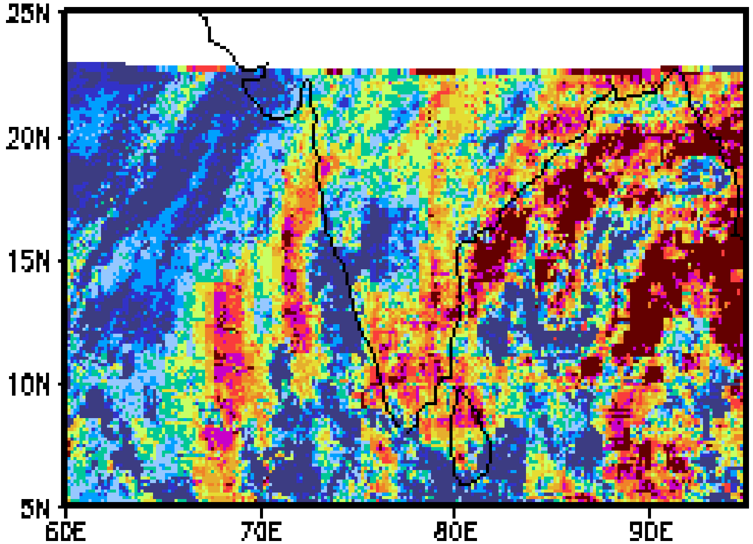




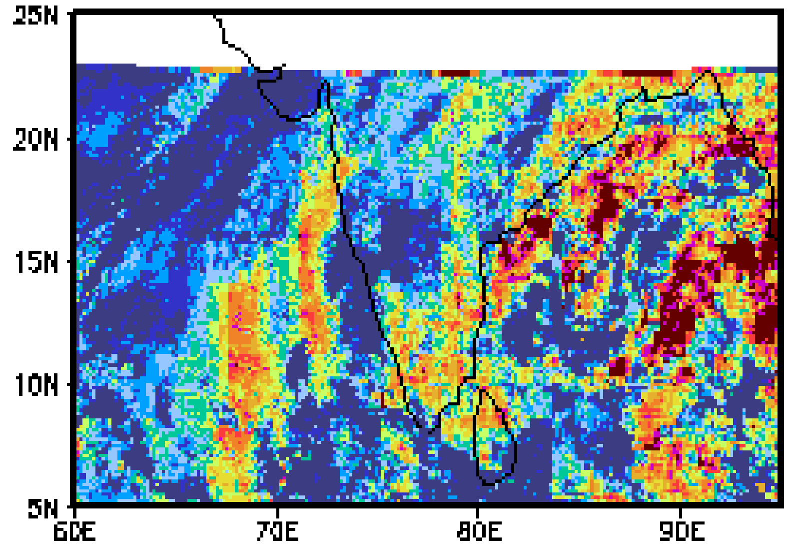
Mean difference in Observed and RT model simulated BT

HELEN:23 - 28 November 2013

Channel-6: 12.66 µm

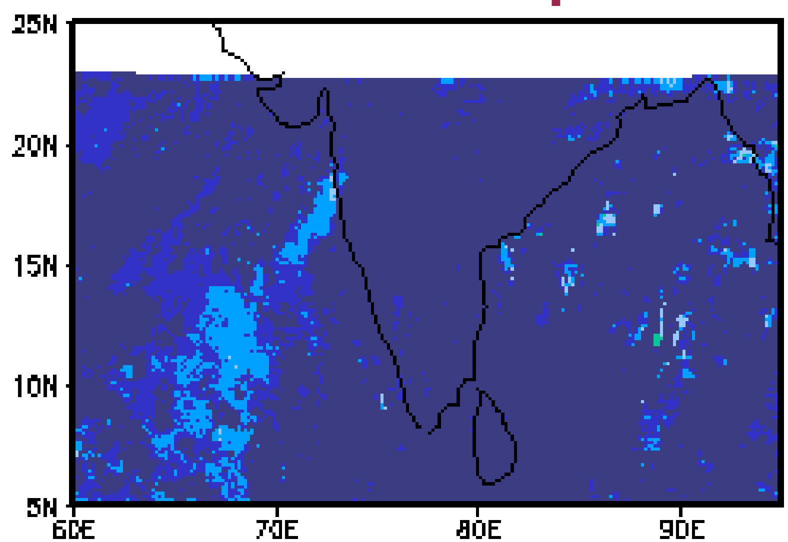


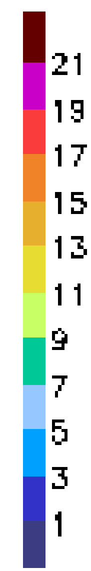
Channel-7: 12.02 µm



Mean difference in Observed and RT model simulated BT

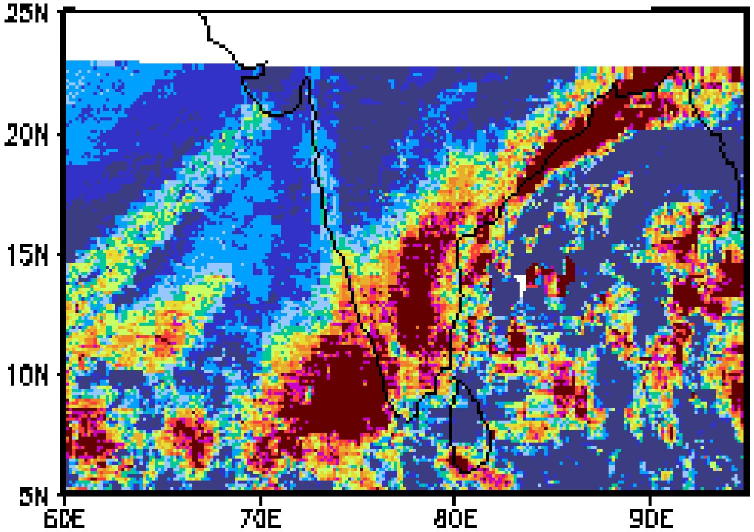
Channel-8: 11.03 µm



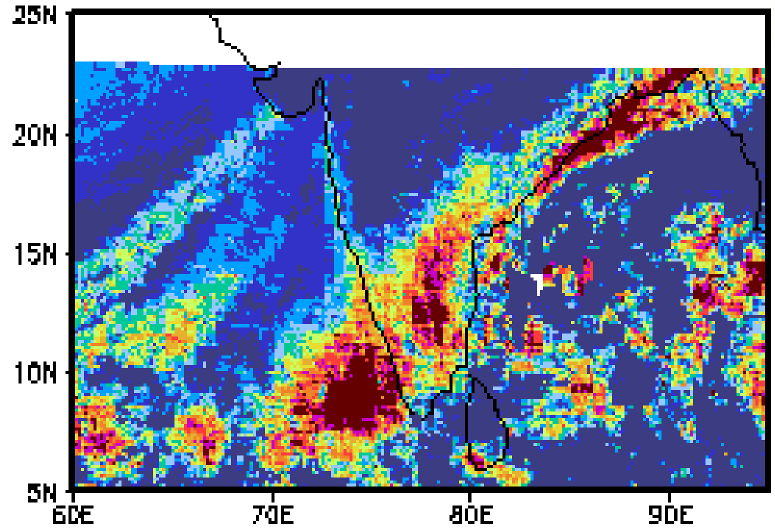


MADI:06 - 13 December 2013

Channel-6: 12.66 µm

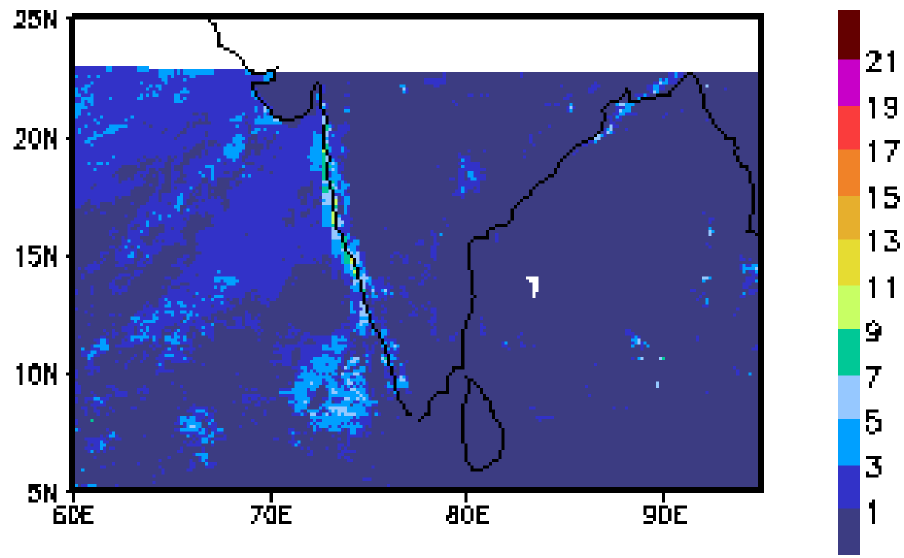


Channel-7: 12.02 µm



Mean difference in Observed and RT model simulated BT

Channel-8: 11.03 µm



Simulation: Using NWP model (dbCRAS)

Direct Broadcast CIMSS Regional Assimilation System

Ancillary Data required

- Global NOAA 24km daily snow cover file
- **Global Surface Observations:**
- NCEP daily 0.5 degree Sea Surface temperature
- MODIS sounder data: Cloud top pressure, Effective cloud Amount (ECA) and total precipitable water
- **NCEP/NCMRWF Global Forecast System (GFS) half-degree forecast files**
  - **For Spin up: Three hourly GFS files 00 through 12 hour forecast**
  - **For Forecast: Six hourly GFS files 06 through 72 hours**

Domain Centre	**28° N, 77°E (Delhi, India)**
Horizontal Resolution	**48 km (210 x150 grids)**
Vertical Sigma levels	**38**
Topography	**2 minute USGS Global dataset**
Boundary Condition	**NCEP GFS forecast at 6- hourly interval**
Analysis	**12 hour spin-up forecast with MODIS cloud parameters and precipitable water**
Cloud assimilation	**Bayler et al., 2000**
Initialization	**Vertical normal mode (Bourke and McGregor, 1983)**
Model dynamics	**Semi-implicit time scheme (McGregor et al., 1978)** **Third order time filter (Raymond, 1991)** **Advective form of equations of motion (Leslie et al., 1985)** **Pseudo-non-hydrostatic and parameterized rain drag (Raymond and Aune, 1998)** **6^{th} order tangent filter replaces the horizontal diffusion (Raymond, 1988)**
Model physics **Convective Parameterization** **Cloud microphysics**	 **Modified Kuo type (Raymond and Aune, 2003)** **Explicit cloud and precipitation microphysics (Raymond, 1995) with diagnosed liquid/ice phase (Dudhia, 1989)** **Water/ice cloud sedimentation (Lee, 1992)**
Shortwave and Long wave Radiation	**Ackerman and Stephens, 1987**
Land-surface processes	**Vertical turbulent exchange (Raymond, 1999)** **5-layer soil model (Kondo et al., 1990 and Lee and Pielke, 1992)**
Model products	**Different meteorological parameters** **11 µ Infra-Red and 6.7µ Water Vapor synthetic satellite images**

Cloud Assimilation

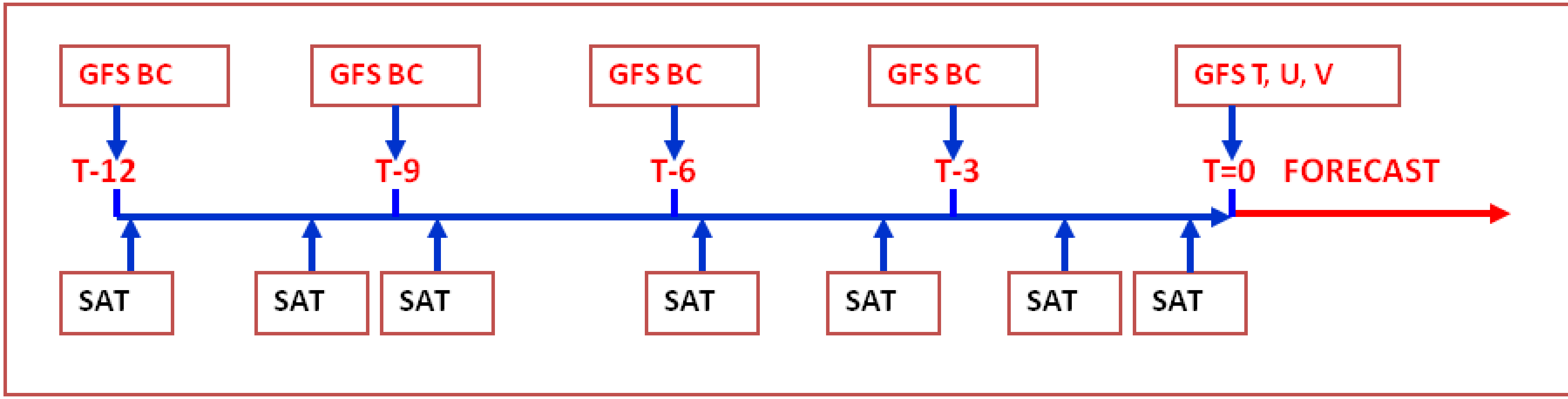
- Cloud-Top Pressure (CTP) and Effective Cloud Amount (ECA) are first binned to the model grid.
- The distribution of CTP is examined to identify high and low cloud types. High and/or low clouds are constructed using the DBCRAS cloud physics as an upper constraint.
- ECA is used to determine the cloud mass to be added to the model grid. Model background clouds remain untouched when the averaged CTP matches the background.
- For clear fields of view model clouds are cleared and the column humidity is checked and adjusted to insure that clouds will not instantly reappear on the next model time step.

Water vapor assimilation

- Variational moisture adjustments using single column PW retrievals from MODIS.
- Fit a power law function to the model background mixing ratio profile. This represents the background mean mixing ratio profile.
- Subtract the mean profile fom the actual model background profile and save the increments. These represent the fluctuations from the mean.
- compute the layer PW from the mean mixing ratio profile.
- Iteratively adjust the mean profile power fit coefficients so that the "new" mean profile, plus the fluctuations, equals the observed.
- During the iteration RH is checked and does not allow it to exceed 95% since the observations are made in clear fields-of-view.

DBCRAS Spin-up Forecast :(12 hour spin-up creates the Analysis)

A 12-hour DBCRAS spin-up forecast is modified to handle the varying polar orbits of the Aqua and Terra satellites.

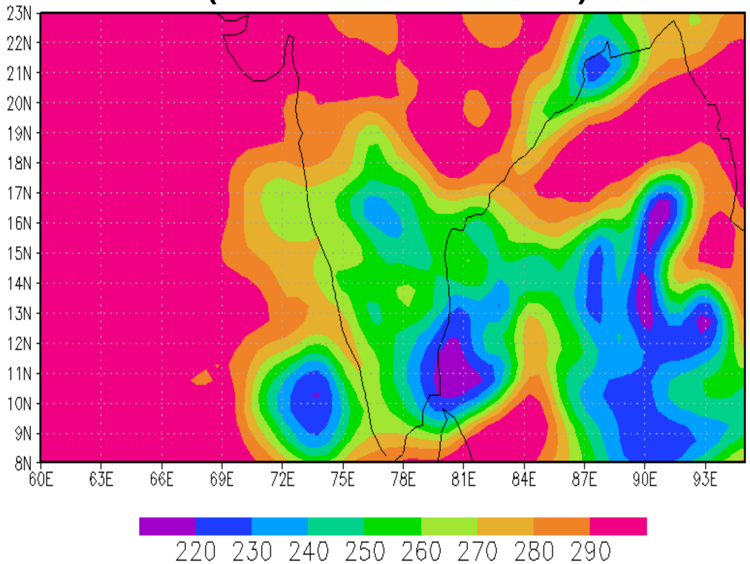


Analysis

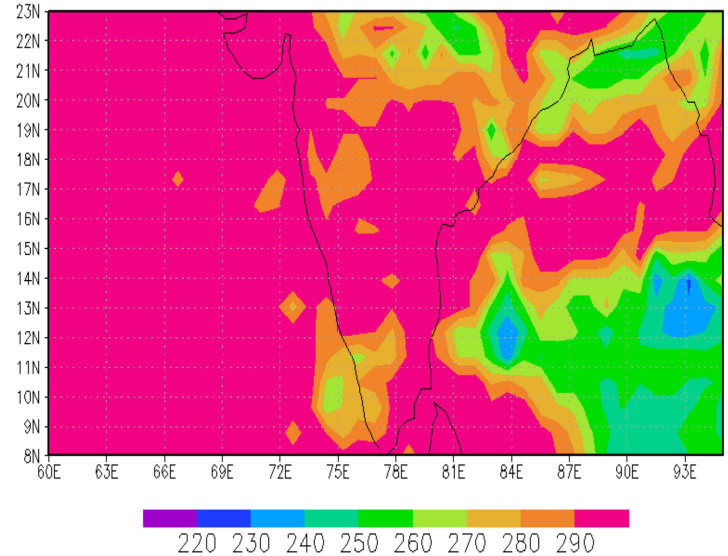
A 12-hour spin-up forecast is used to adjust water vapor and clouds. Satellite information is inserted at the mid-time of each individual satellite scan. Water vapor, cloud and precipitation mixing ratio from the 12-hour spin-up are merged with 6-hour forecast GFS winds and temperatures from the previous GFS run. The merge is conducted on 25 pressure levels from surface to 10 hPa.

PHAILIN:08 – 14 October 2013

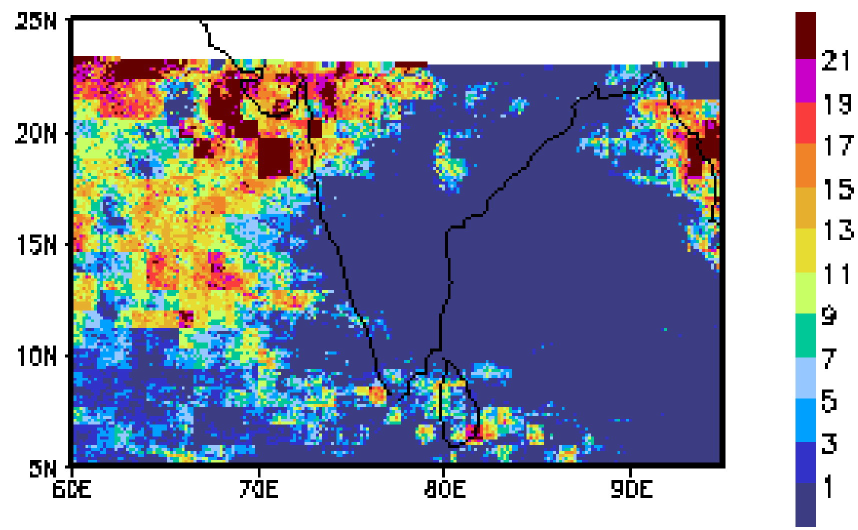
**INSAT-3D Sounder BT: Channel-8 (11.03 μ)
(09-10-2013 0023UTC)**



**dbCRAS simulated 11 μ BT
(valid for 09-10-2013 00 UTC)**

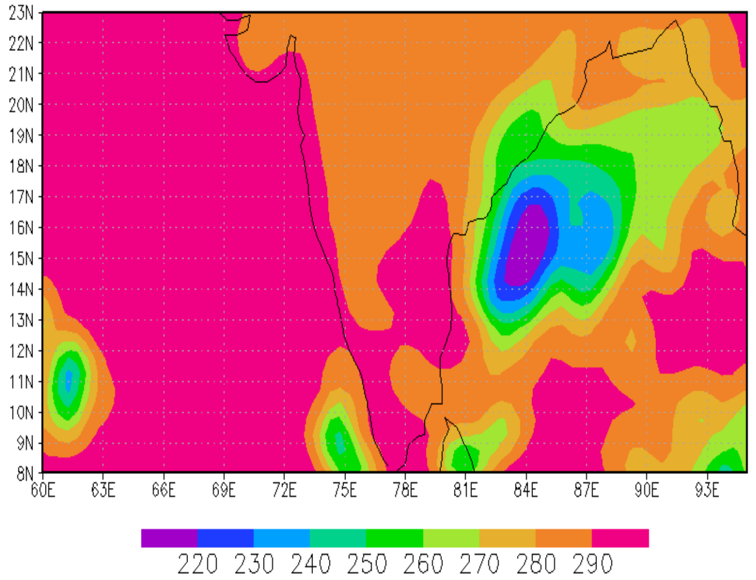


Mean difference in observed and dbCRAS simulated BT during PHAILIN (valid for 00 UTC)

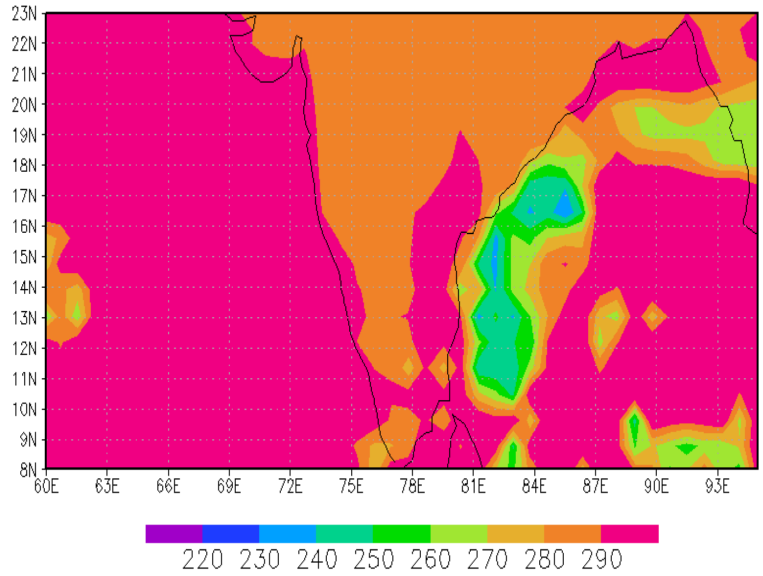


HELEN:19 -23 November 2013

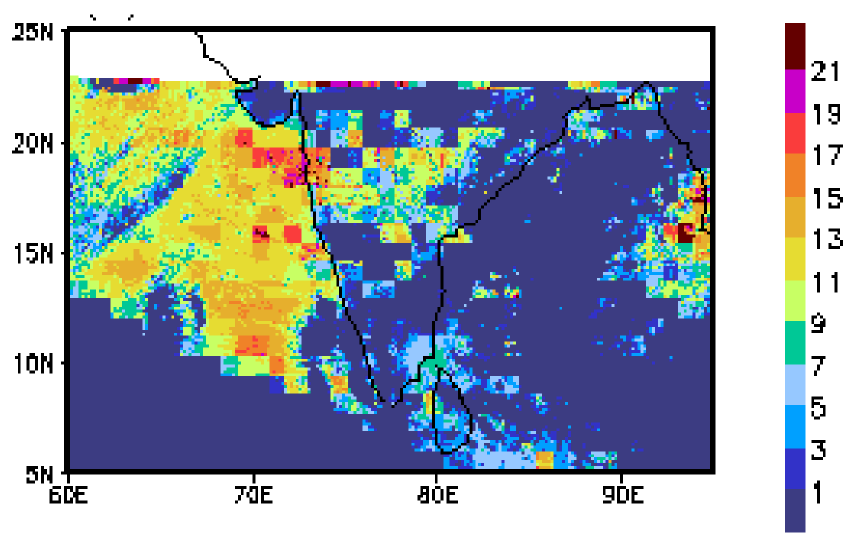
INSAT-3D Sounder BT: Channel-8 (11.03 µ)
(20-11-2013 0023UTC)



dbCRAS simulated 11 µ BT
(valid for 20-11-2013 00 UTC)

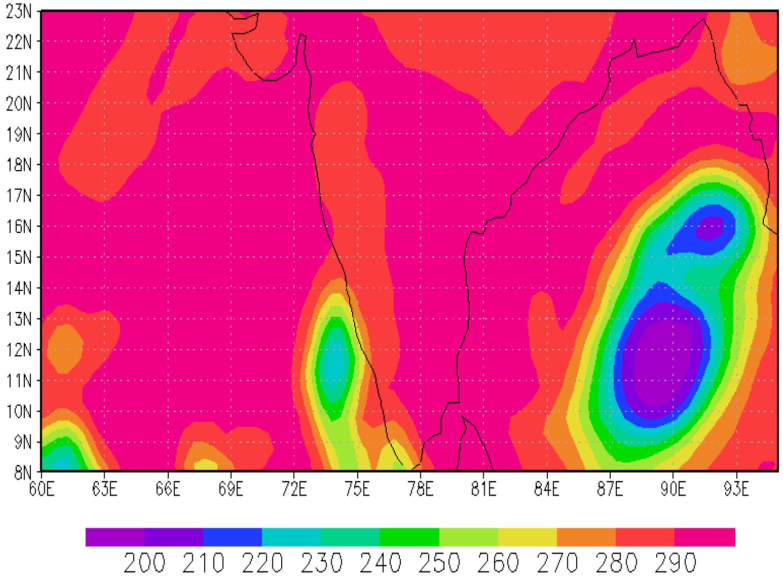


Mean difference in observed and dbCRAS simulated BT during HELEN (valid for 00 UTC)

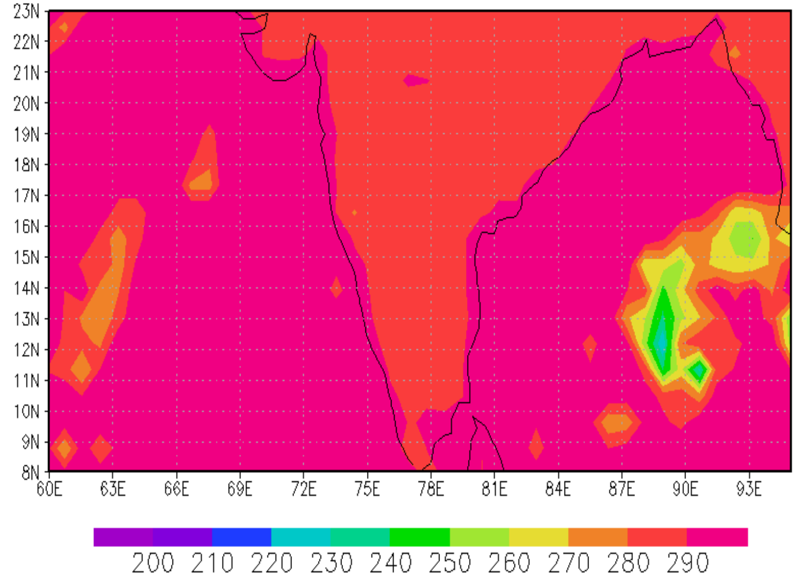


LEHAR: 23 - 28 November 2013

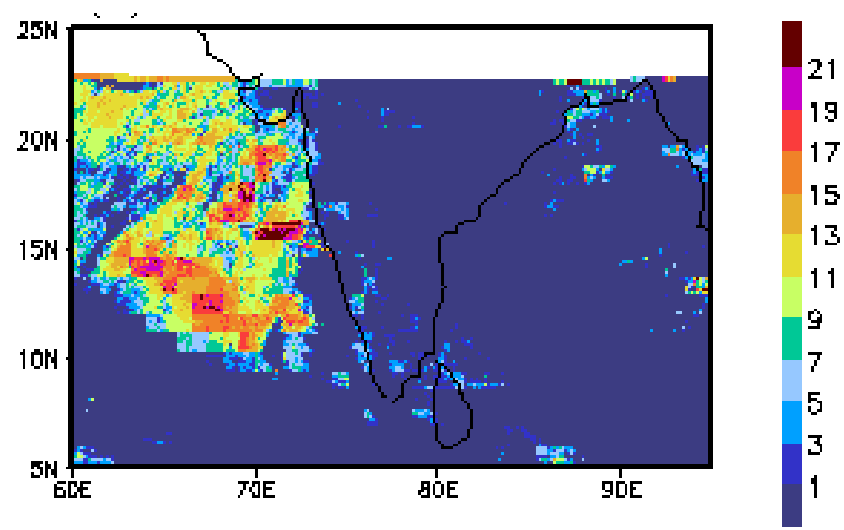
INSAT-3D Sounder BT: Channel-8 (11.03 µ)
(26-11-2013 0023UTC)



dbCRAS simulated 11 µ BT
(valid for 26-11-2013 00 UTC)

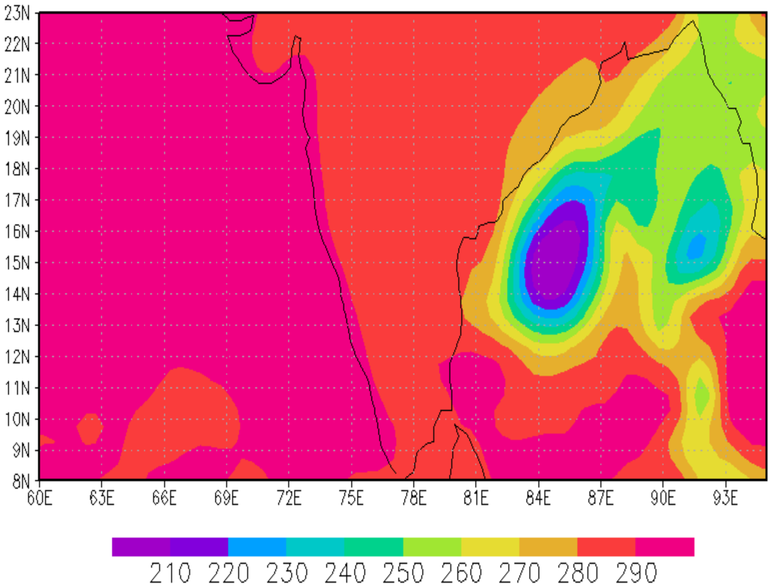


Mean difference in observed and dbCRAS simulated BT during LEHAR (valid for 00 UTC)

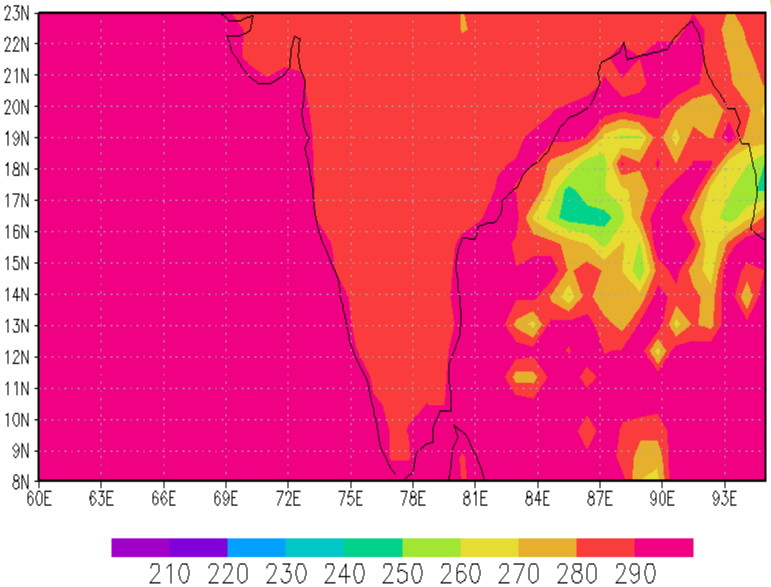


MADI: 06 - 13 December 2013

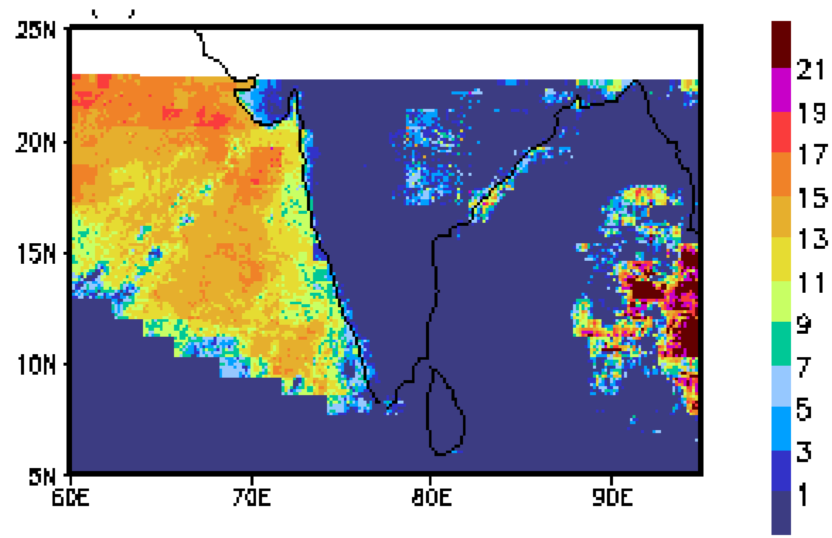
INSAT-3D Sounder BT: Channel-8 (11.03 µ)
(10-12-2013 0023UTC)



dbCRAS simulated 11 µ BT
(valid for 10-12-2013 00 UTC)



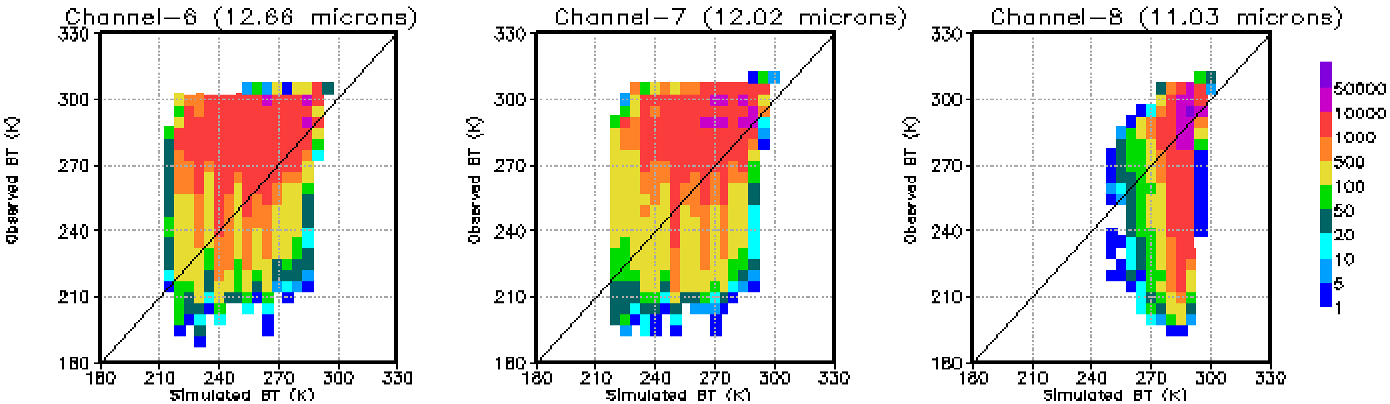
Mean difference in observed and dbCRAS simulated BT during MADI (valid for 00 UTC)



Validation

Against RT Model Simulated Brightness Temperature

PHAILIN
8-14 Oct. 2013

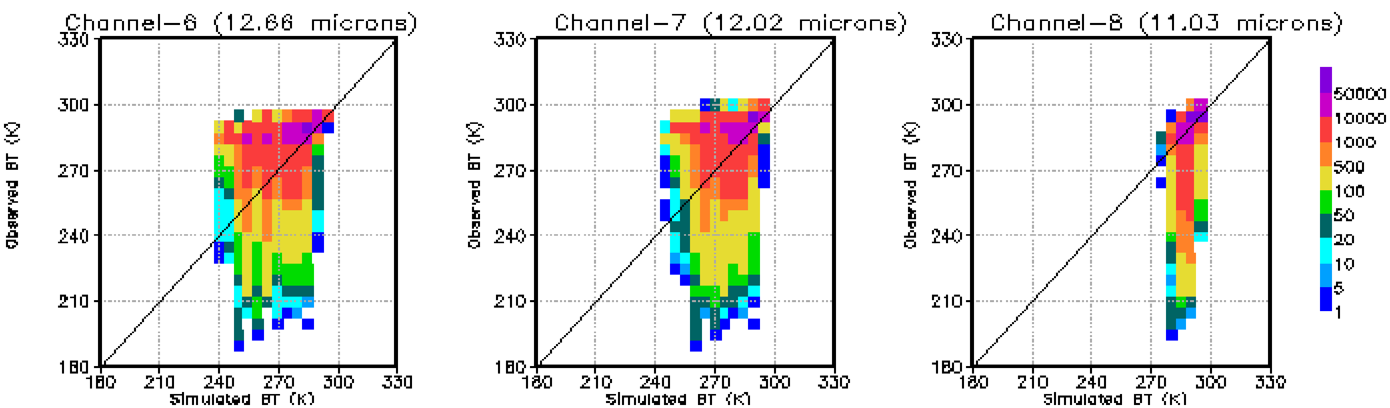


No.of OBS: 466720
Bias : 4.41
STD : 4.11

No. of OBS: 466720
Bias : 3.53
STD : 4.06

No. of OBS: 466720
Bias : -.33
STD : 3.64

HELEN
19-23 Nov. 201

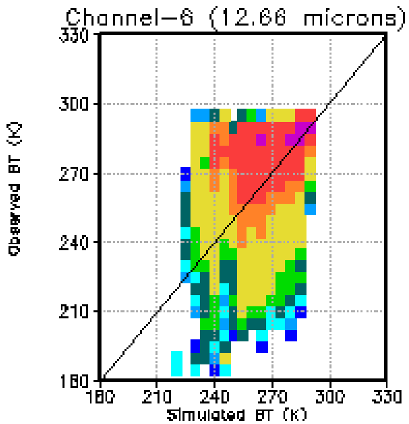


No.of OBS: 344488
Bias : 1.44
STD : 2.71

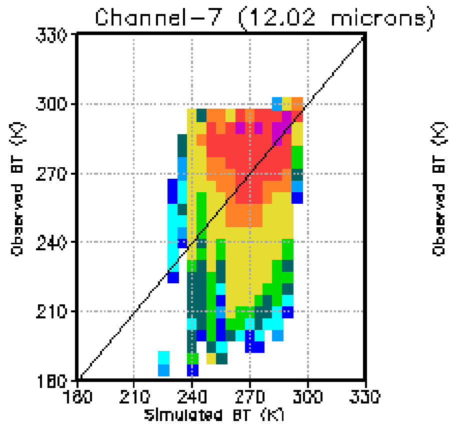
No. of OBS: 344488
Bias : .94
STD : 2.66

No. of OBS: 344488
Bias : -.43
STD : 2.32

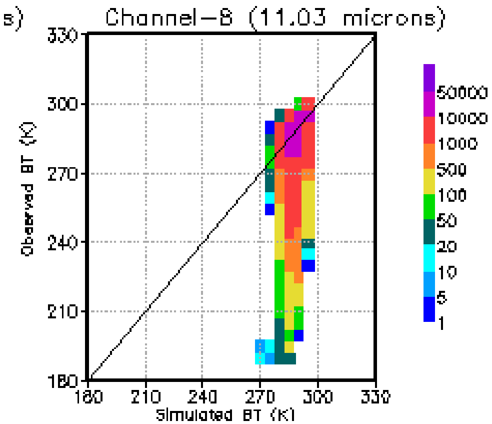
LEHAR
23-28 Nov. 2013



No.of OBS: 276999
Bias : 1.76
STD : 3.20

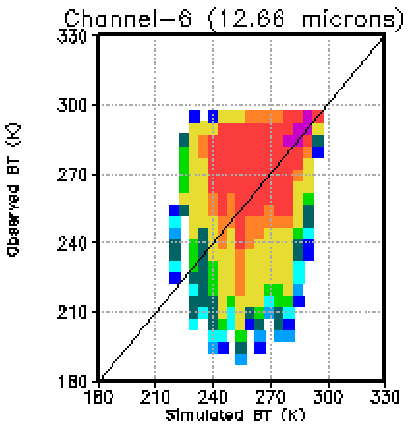


No. of OBS: 276999
Bias : 1.13
STD : 3.14

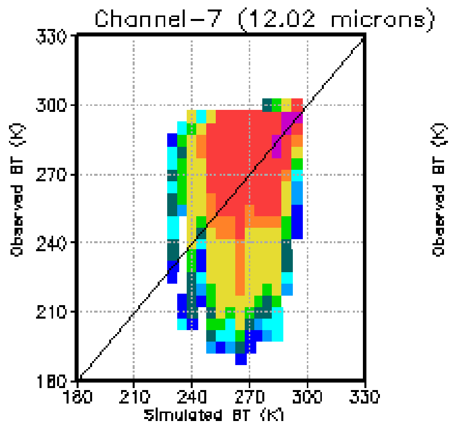


No. of OBS: 276999
Bias : –1.05
STD : 2.79

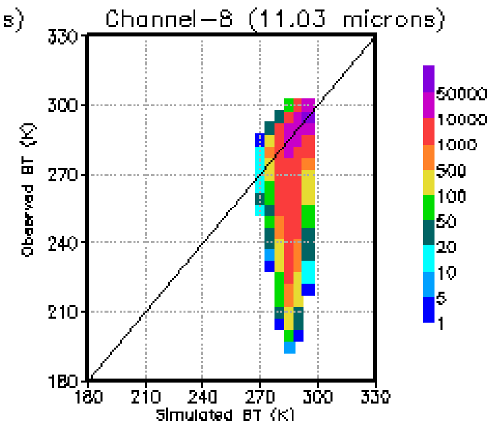
MADI
6-13 Dec. 2013



No.of OBS: 329445
Bias : 1.36
STD : 3.41



No. of OBS: 329445
Bias : .69
STD : 3.33

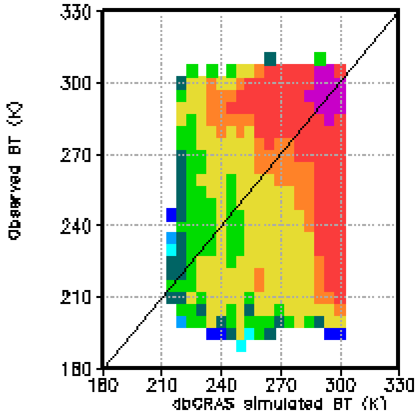


No. of OBS: 329445
Bias : –1.38
STD : 2.94

Validation

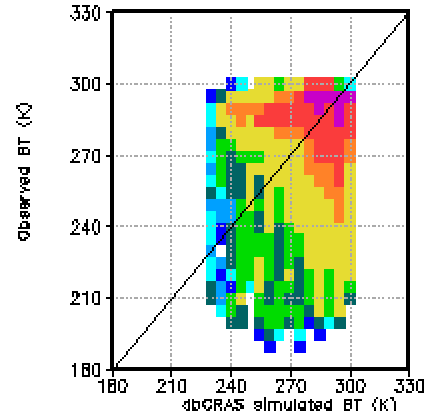
Against dbCRAS Simulated Brightness Temperature

PHAILIN



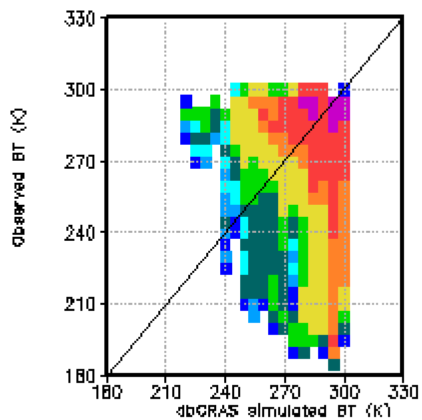
No.of OBS: 516096
Bias : -.69
STD : 5.52

HELEN



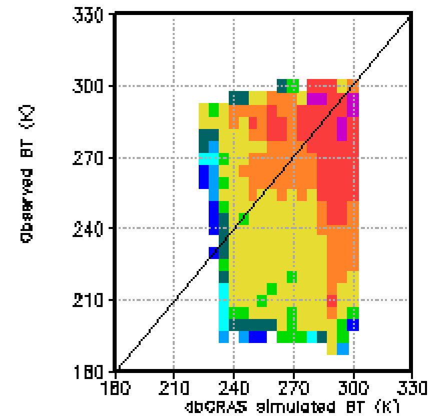
No.of OBS: 294912
Bias : -.24
STD : 3.71

LEHAR



No.of OBS: 294912
Bias : -1.58
STD : 4.63

MADI



No.of OBS: 368640
Bias : -1.27
STD : 4.85

Conclusions

Simulated INSAT-3D sounder BT using RT Model and NWP Model during 2013 NIOC period.

INSAT-3D clearly shows the warm core during cyclone.

RT model under predicted the 12 micron BT (Positive bias), while over predicted the 11 micron BT (Negative bias) with standard deviation less than 5K with respect to the observed BT.

dbCRAS simulated 11 micron BT matches well with the corresponding INSAT-3D BT in four cyclone cases in predicting the features. Negative bias and standard deviation less than 5K with respect to the observed BT.

Post launch update of RT coefficients has been done by ISRO. Making use of updated RT coefficients and the real-time SST value will reduce the bias and standard deviation in simulated BT.

Acknowledgements

India Meteorological Department (IMD) and Indian Space Research Organization (ISRO) for providing INSAT-3D data.

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THANKS
NCMRWF