Cross Comparison of Meteorological Sensors

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Objective

- Inter-calibration of satellite measured radiances from diverse range of satellite instruments is important to make the observations consistent to produce globally homogenous products for environmental monitoring
- Proxy radiance generation (IR Imager/Sounder) for the verification of retrieval algorithm for future satellite sensors and system definition studies.

- **Presentation summarizes :**
  - **Inter-calibration of Indian geostationary satellites INSAT-3A, Kalpana and INSAT-3D Imager and Sounder channels with Hyperspectral sounder observations from IASI and AIRS.**
  - **Proxy radiance generation for INSAT-3D and verification with GOES-13.**

Indian Geostationary Met Satellites/Sensors

Kalpana : VHRR (WV and TIR channels)

INSAT-3A : VHRR (WV and TIR channels)

INSAT-3D (Launch - First quarter of 2013):

Imager (6 Channels – VIS, SWIR, MWIR, WV, TIR1, TIR2)

Sounder (18 IR + 1 Vis Channels)

GISAT (design stage): Hyperspectral Vis, NIR, SWIR

Multispectral IR (6 channels, 1.5 km spatial resolution)

Meteorological Products

http://www.mosdac.gov.in

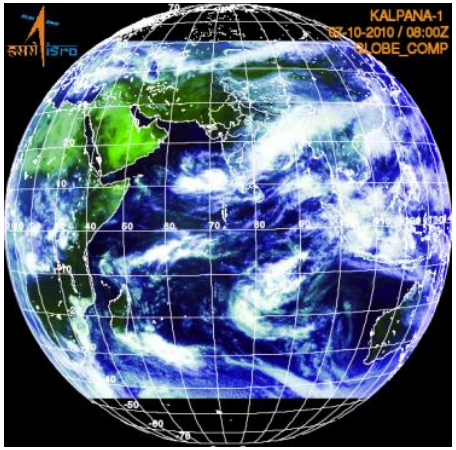
Kalpana /INSAT-3A

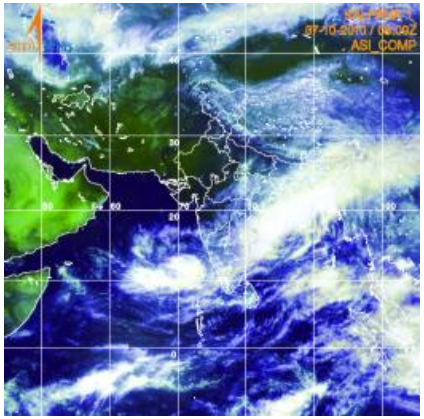
- Atmospheric Wind Vectors (AMV)
- Outgoing Longwave Radiation (OLR)
- Upper Tropospheric Humidity (UTH)

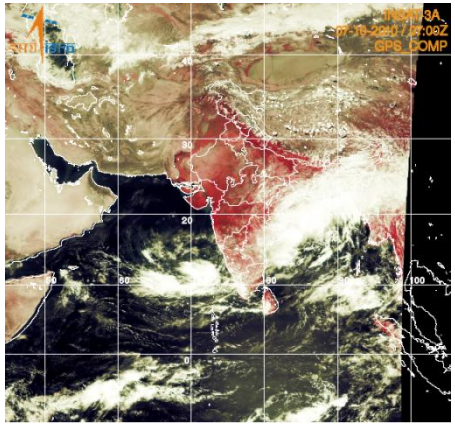
INSAT-3D Imager: AMV, OLR, UTH, SST

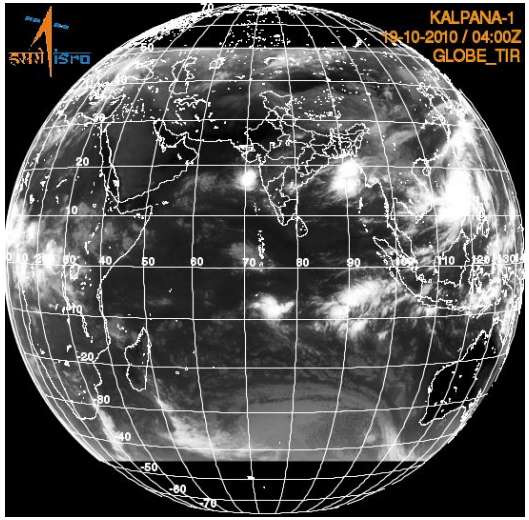
Sounder: T, q profiles, total column Ozone

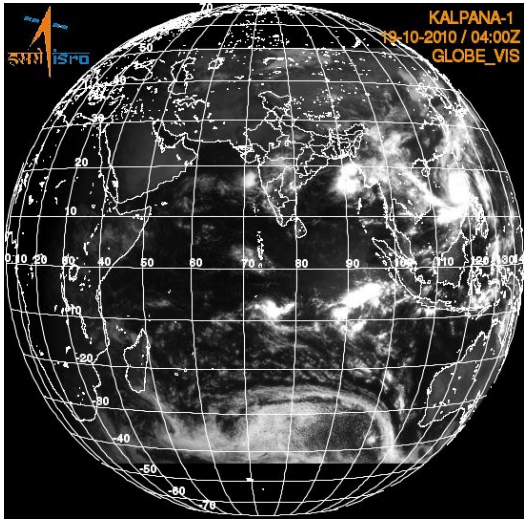
Sample Kalpana products (IMDPS) (30 minutes interval)

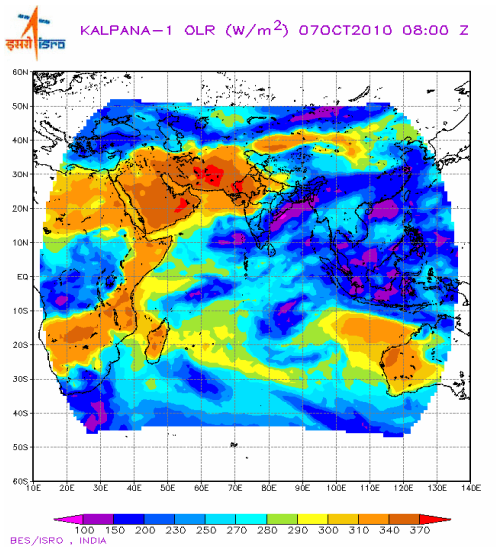


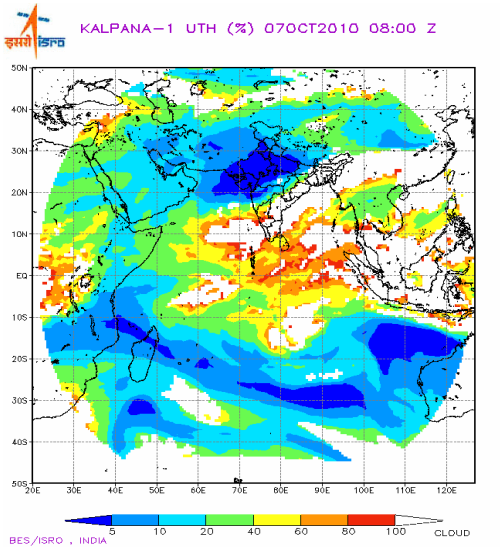


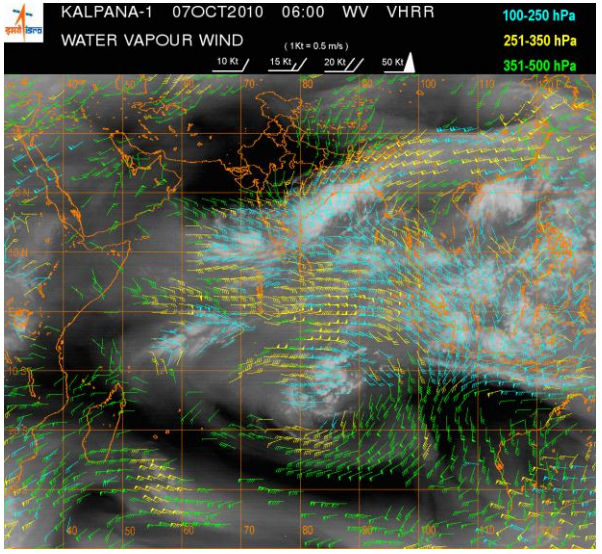


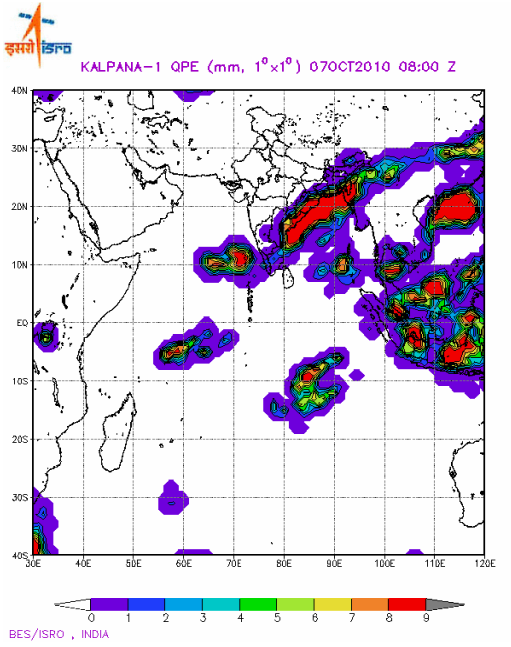


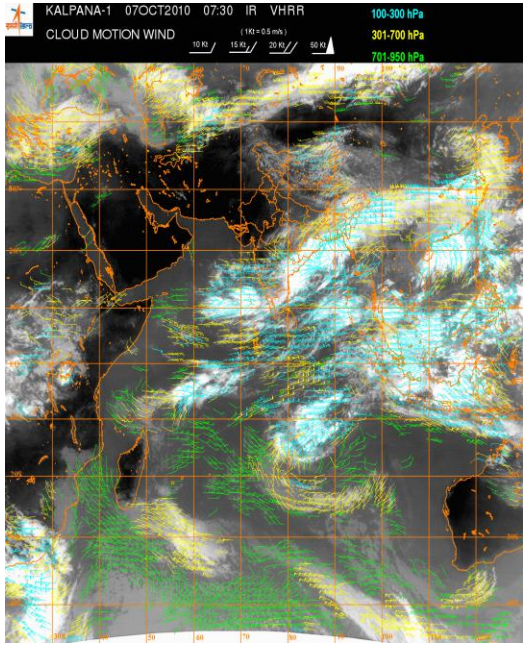


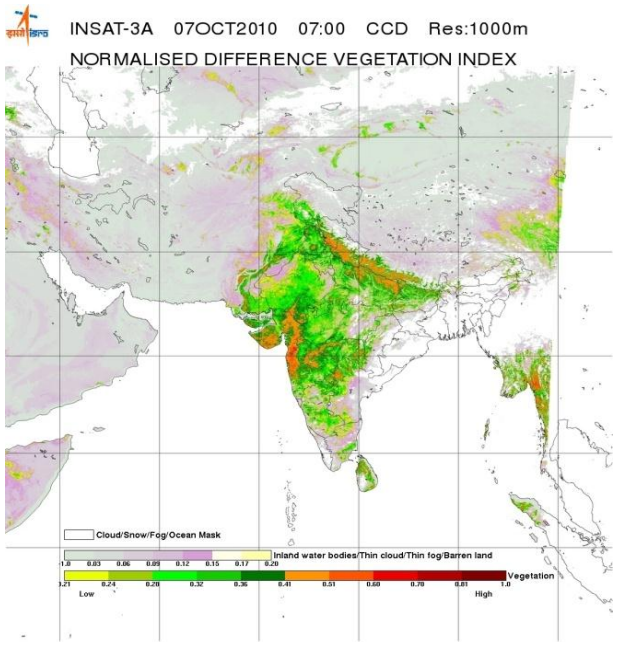

KALPANA-1 OLR (W/m2) 07OCT2010 08:00 Z
100 150 200 230 250 270 280 290 300 310 340 370
BES/ISRO , INDIA


KALPANA-1 UTH (%) 07OCT2010 08:00 Z
5 10 20 40 60 80 100
CLOUD
BES/ISRO , INDIA


KALPANA-1 07OCT2010 06:00 WV VHRR
WATER VAPOUR WIND
100-250 hPa
251-350 hPa
351-500 hPa

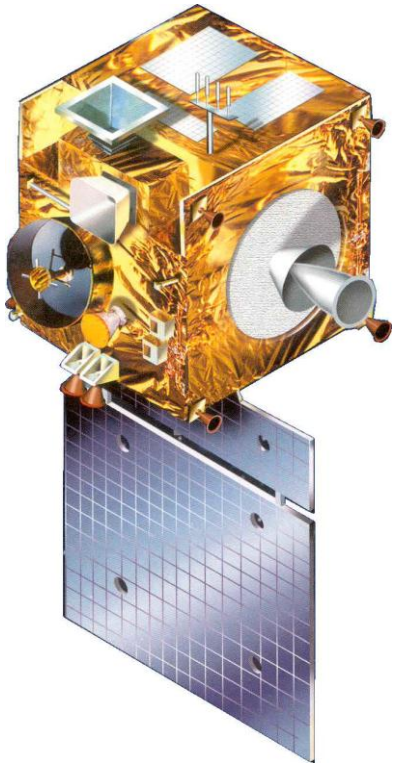

KALPANA-1 QPE (mm, 1°x1°) 07OCT2010 08:00 Z
0 1 2 3 4 5 6 7 8 9
BES/ISRO , INDIA


KALPANA-1 07OCT2010 07:30 IR VHRR
CLOUD MOTION WIND
100-300 hPa
301-700 hPa
701-950 hPa


INSAT-3A 07OCT2010 07:00 CCD Res:1000m
NORMALISED DIFFERENCE VEGETATION INDEX
Cloud/Snow/Fog/Ocean Mask
Inland water bodies/Thin cloud/Thin fog/Barren land
Vegetation
Low
High

Inter-calibration of Kalpana

- **Launched in Sep 2002**
- **Positioned at 74°E.**
- **Full disk every 30 minutes**
- **VHRR**
  - **VIS : 0.55-0.75 μm**
  - **WV : 5.7-7.1 μm**
  - **TIR : 10.5-12.5 μm**
- **Spatial resolution (at nadir) :**
  - **2 km for VIS**
  - **8 km for WV and TIR channels**



Aqua-AIRS and Metop-IASI spectral coverage with Kalpana SRFs for TIR and WV channels

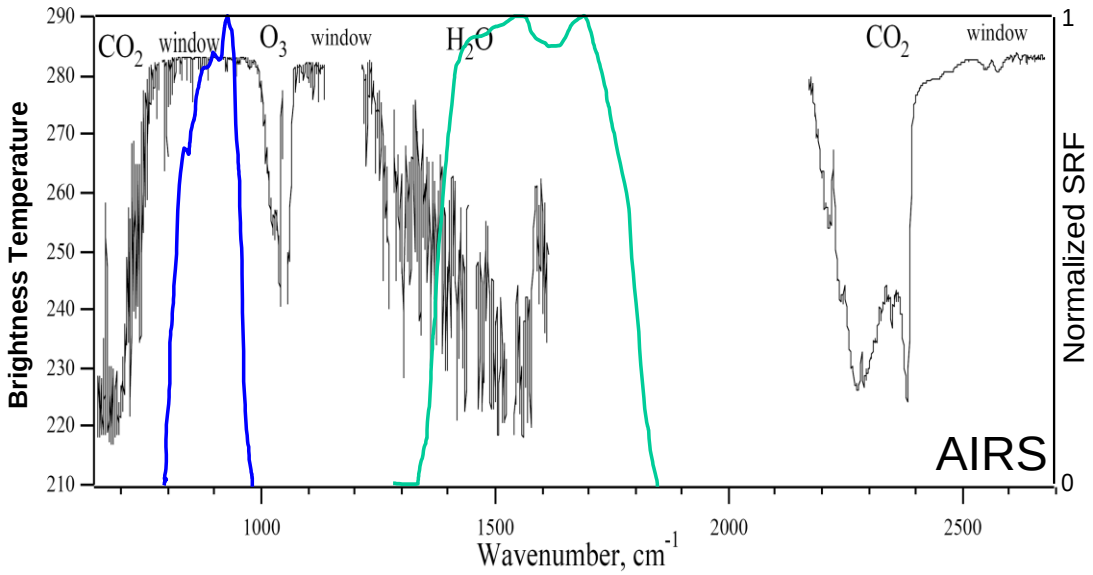
AIRS: Atmospheric InfraRed Sounder

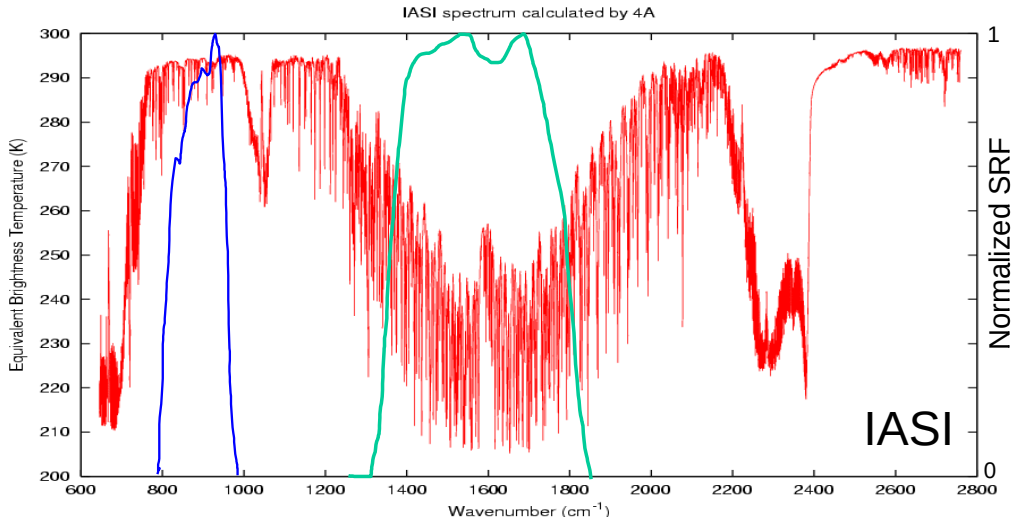
Polar Orbiting Aqua (2002)

Channels: 2378 (650 cm^{-1} to 2675 cm^{-1})
(3.74 µm - 15.4 µm)

Spectral resolution: $\nu/\Delta\nu \approx 1200$

Spatial Resolution: 13.5 Km at Nadir





IASI: Infrared Atmospheric Sounding Interferometer (Polar Orbiting Metop-A, 2007)

Channels: 8461 (645 cm^{-1} to 2760 cm^{-1})
(3.62 µm - 15.5 µm)

Spectral resolution: 0.35 cm^{-1} at SWIR
0.50 cm^{-1} at LWIR
(resampled at 0.25 cm^{-1})

Spatial Resolution: ~12 km at Nadir

Inter-calibration Procedure

- Convolved radiance of broadband sensor using hyperspectral sounders:

$$R_{conv} = [\sum_{i=1}^{n} R_{AIRS}^{i} S_{Kalp}^{i} \Delta\nu] / [\sum_{i=1}^{n} S_{Kalp}^{i} \Delta\nu]$$

- S_{Kalp} is Kalpana SRF at the central wavenumber of hyper-spectral channel,
- Missing or bad channels are interpolated from nearest 2 channels.
- **Conversion of radiances to brightness temperature by inverting the equivalent Planck's function:**

$$R_{conv} = \frac{2hc^2\nu^3}{\exp\{hc\nu / k(a_1 + a_2 T_b)\} - 1}$$

- a_1 (=1.052K) and a_2 (=0.996) are the band correction coefficients and ν (=885.602 cm^{-1}) is central wavenumber for Kalpana TIR channel

Inter-calibration Procedure…

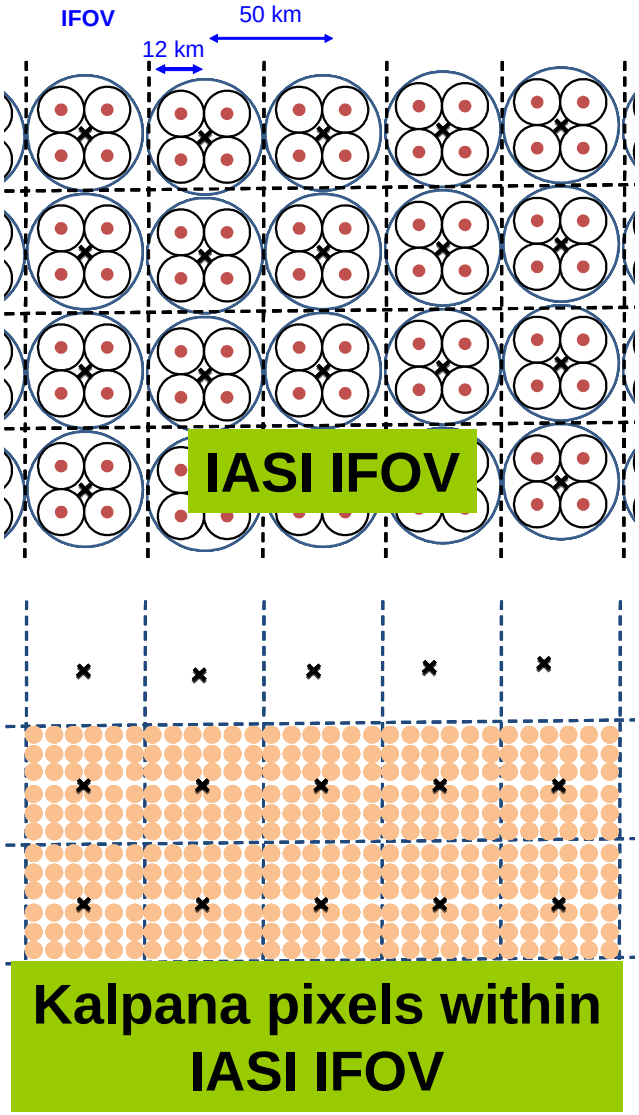
Data Source: Metop-IASI L1C (Eumetcast, BUFR format)

- **Land/sea mask: Use only ocean pixels**
- **Temporal Collocation: 15 Minutes**
- **Spatial Collocation: Within IASI IFOV (2x2 pixels)**
- **Zenith angle collocation:**

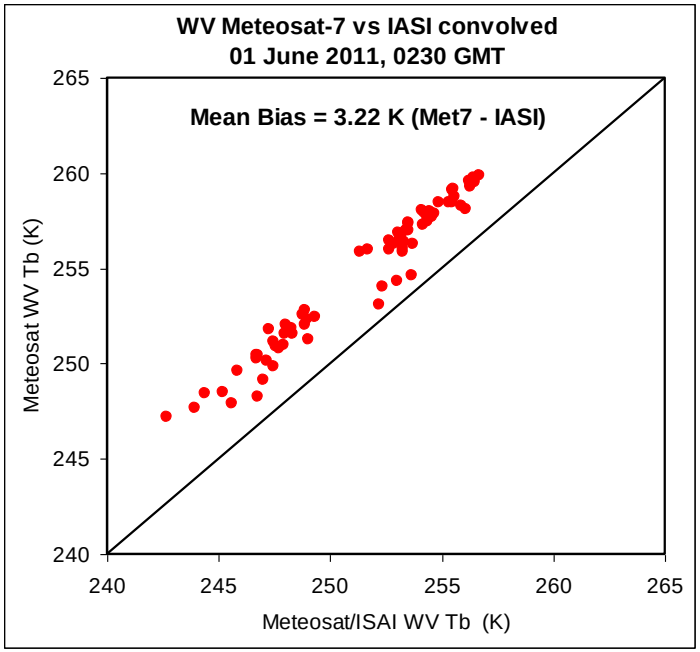
  $| \sec(\beta_{IASI}) - \sec(\beta_{Kalp}) | < 0.01$

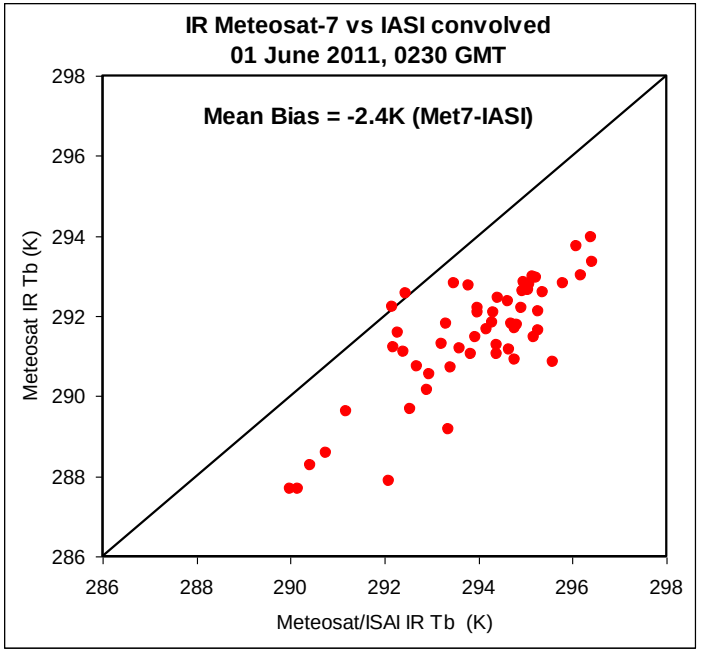
  β_{IASI} & $\beta_{Kalpana}$ < 10°
- **Spatial homogeneity test:**

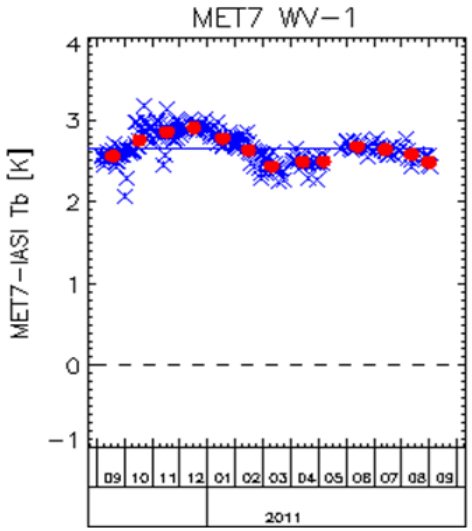
  (Std. Dev. of Kalpana Tb within one IASI IFOV) / (mean Tb of Kalpana within one IASI IFOV) < 0.01

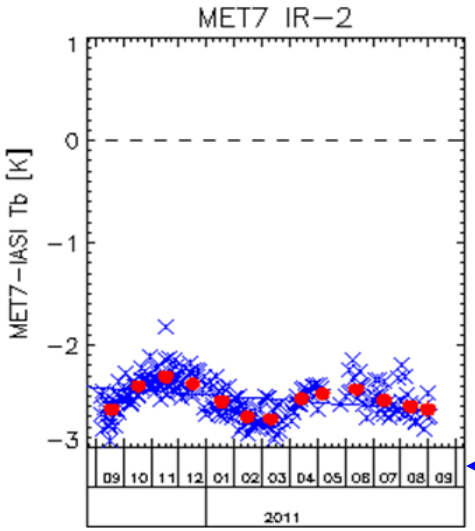


Procedure testing with Meteosat-7







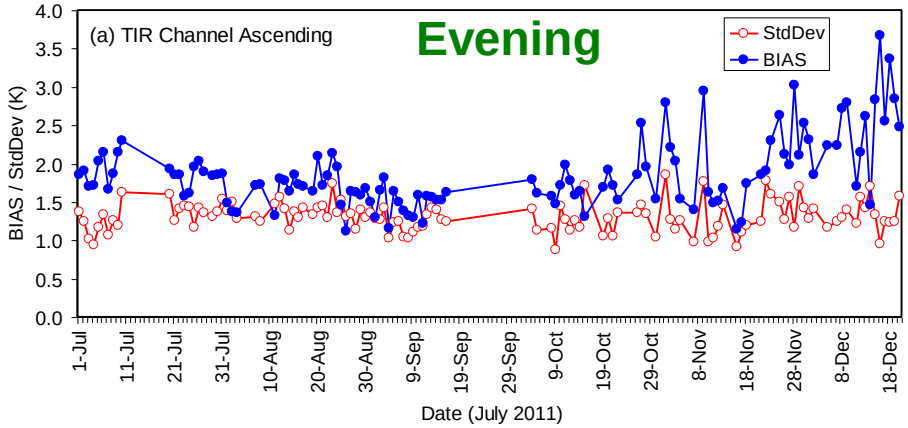


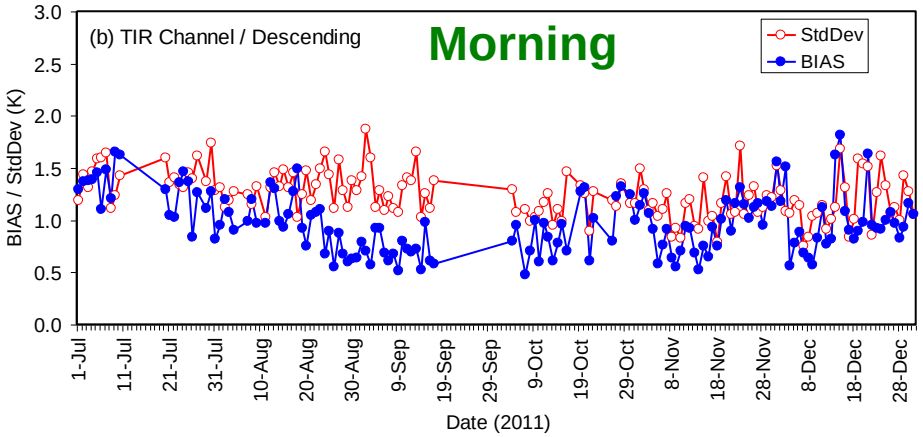
Meteosat-7 vs IASI convolved
01 June 2011, 0230 GMT

EUMETSAT - GSICS webpage for Meteosat-7 vs IASI intercalibration

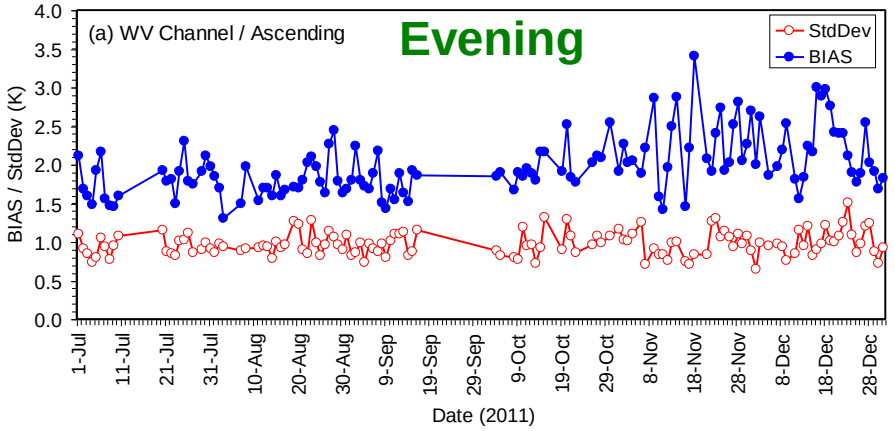
Intercalibration of Kalpana with IASI

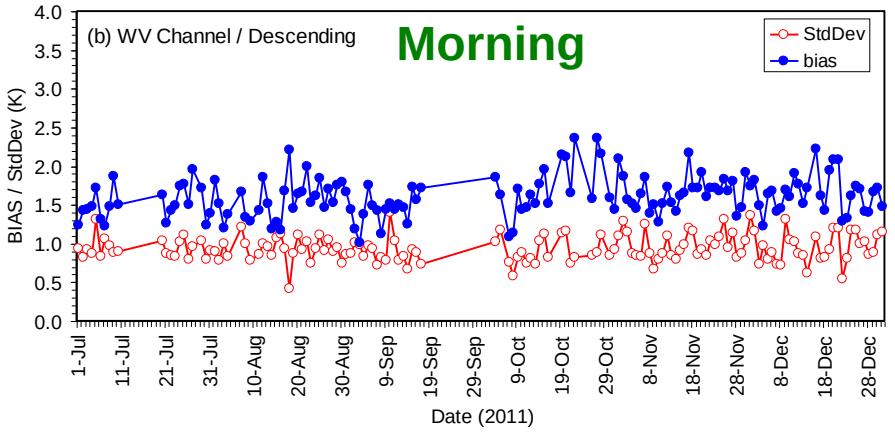
Kalpana TIR Channel vs Metop-IASI Convolved

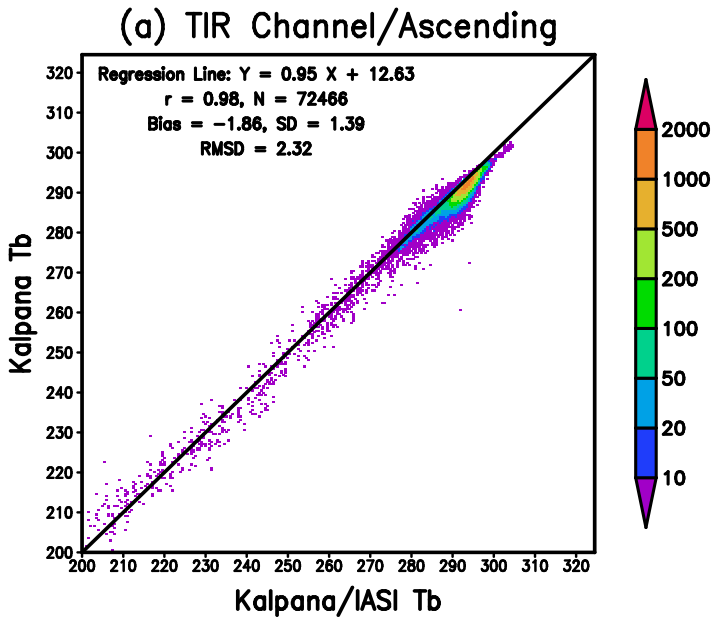


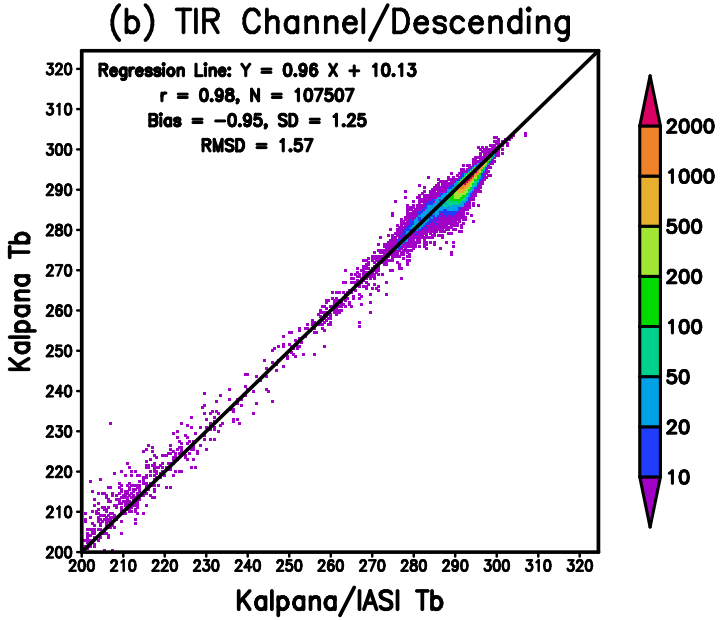


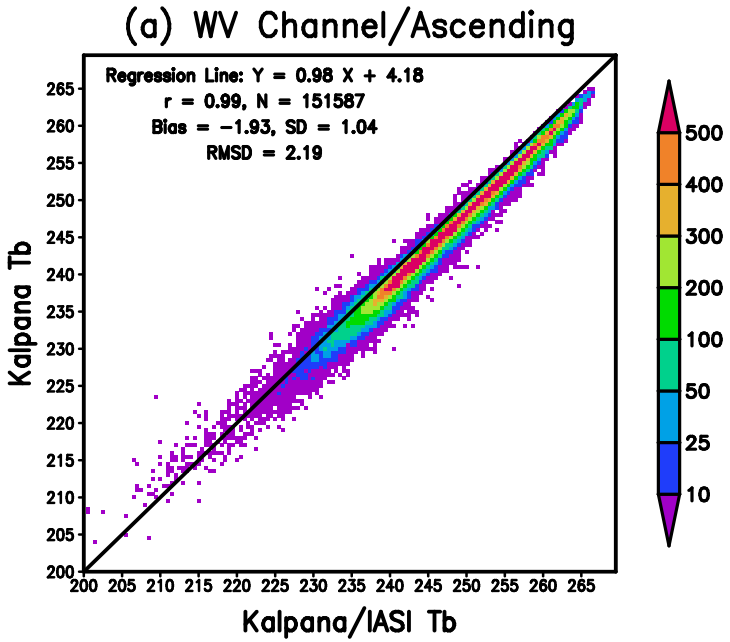
Kalpana WV Channel vs Metop-IASI Convolved

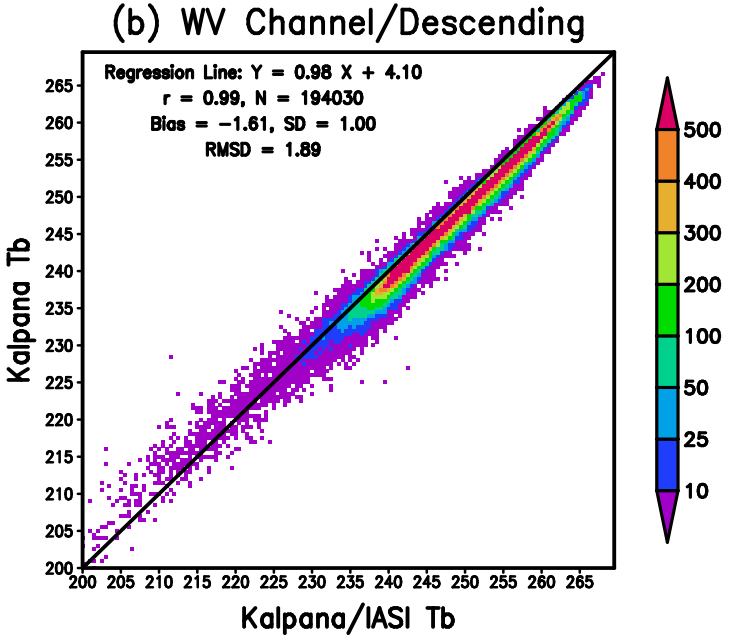




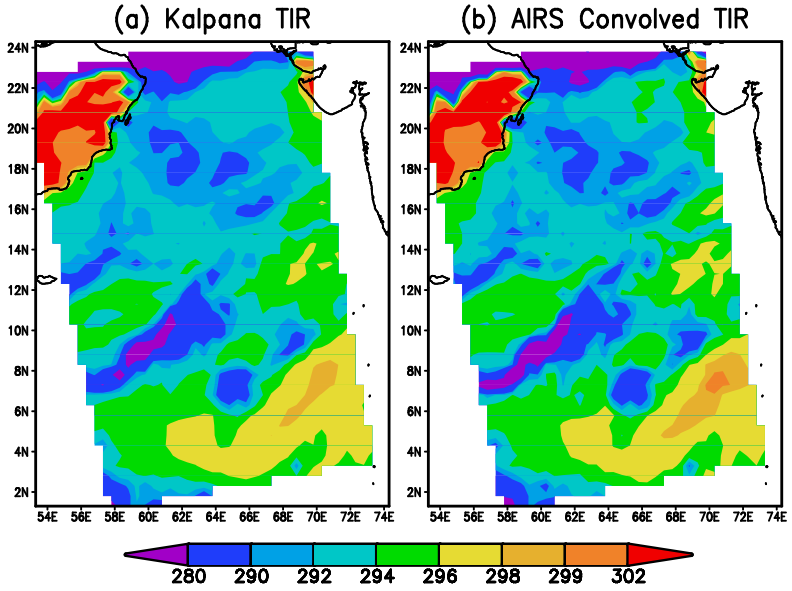

(a) TIR Channel/Ascending
Regression Line: Y = 0.95 X + 12.63
r = 0.98, N = 72466
Bias = −1.86, SD = 1.39
RMSD = 2.32
Kalpana Tb
Kalpana/IASI Tb
2000
1000
500
200
100
50
20
10

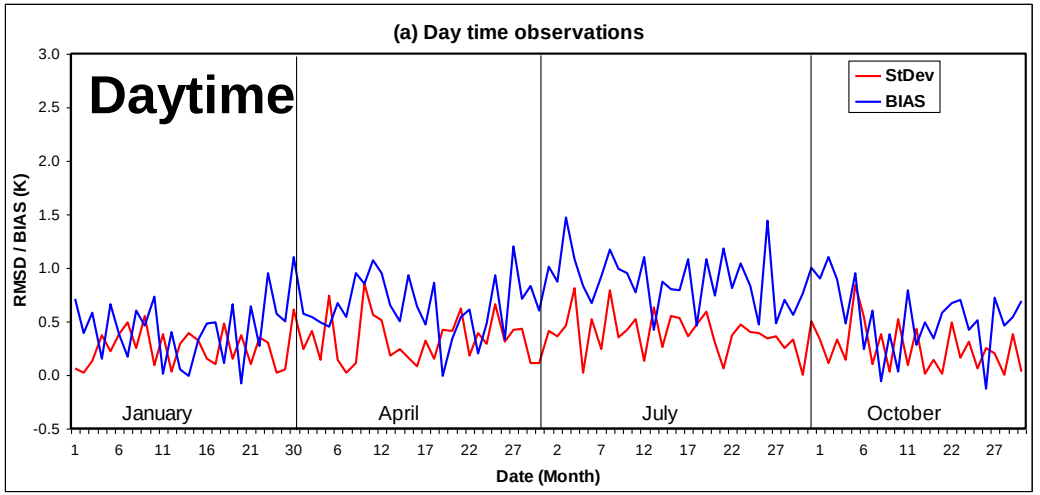

(b) TIR Channel/Descending
Regression Line: Y = 0.96 X + 10.13
r = 0.98, N = 107507
Bias = −0.95, SD = 1.25
RMSD = 1.57
Kalpana Tb
Kalpana/IASI Tb
2000
1000
500
200
100
50
20
10

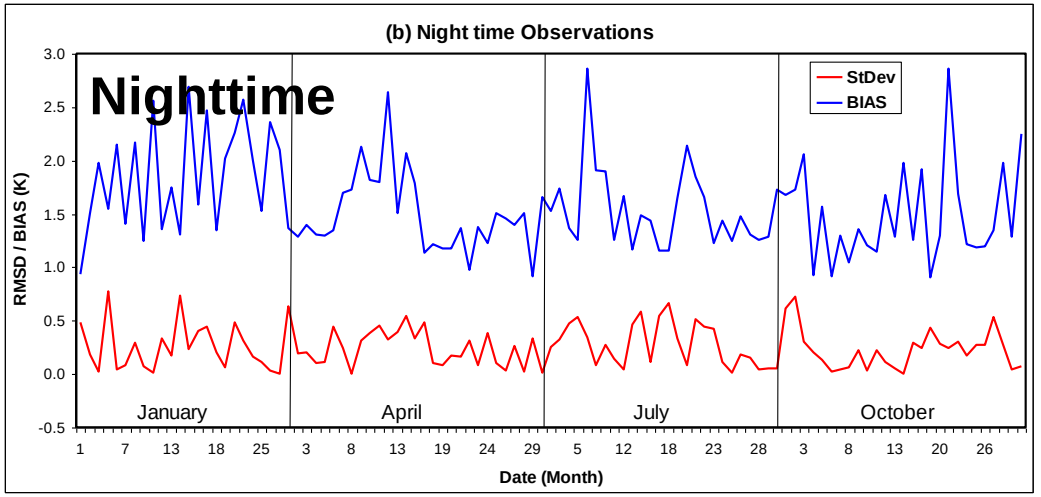

(a) WV Channel/Ascending
Regression Line: Y = 0.98 X + 4.18
r = 0.99, N = 151587
Bias = −1.93, SD = 1.04
RMSD = 2.19
Kalpana Tb
Kalpana/IASI Tb
500
400
300
200
100
50
25
10


(b) WV Channel/Descending
Regression Line: Y = 0.98 X + 4.10
r = 0.99, N = 194030
Bias = −1.61, SD = 1.00
RMSD = 1.89
Kalpana Tb
Kalpana/IASI Tb
500
400
300
200
100
50
25
10

Intercalibration of Kalpana with Aqua-AIRS for 2009



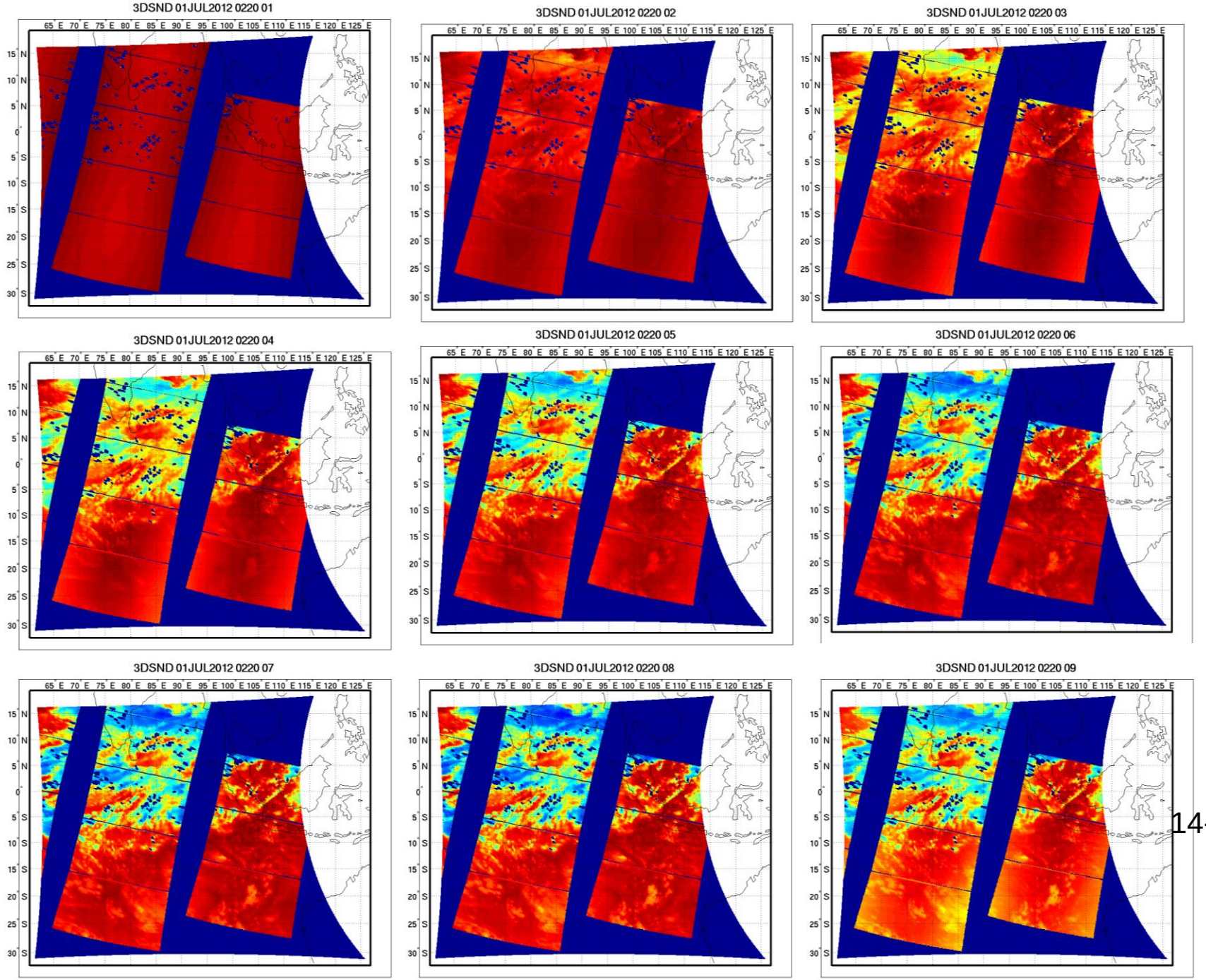


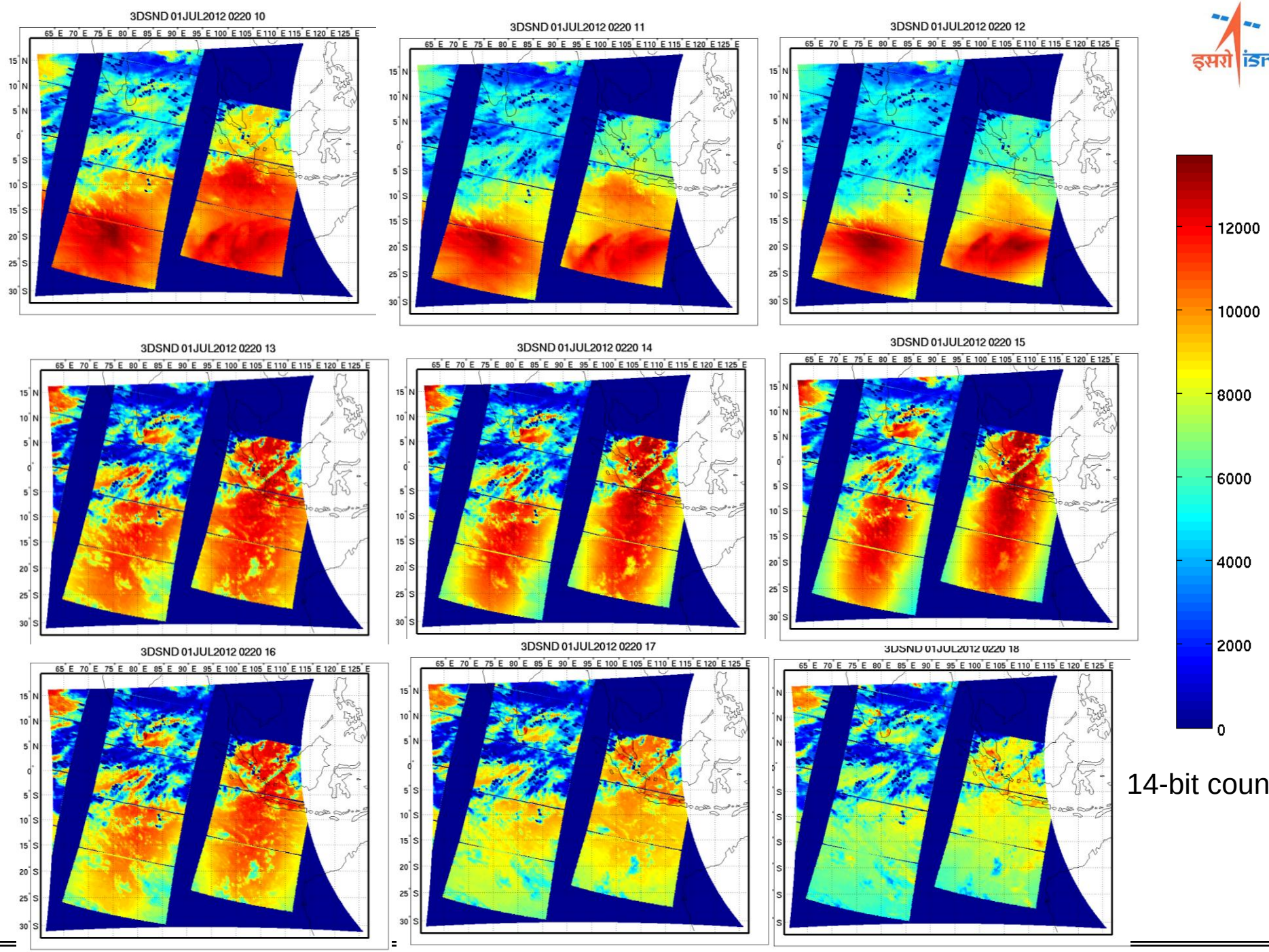


- Only for clear sky (Tb > 280K)
- Small Std. Dev.: 0.3-0.4 K
- Bias smaller during daytime with seasonal variations
- Bias higher during nighttime

Proxy radiance generation for INSAT-3D Sounder Algorithm testing

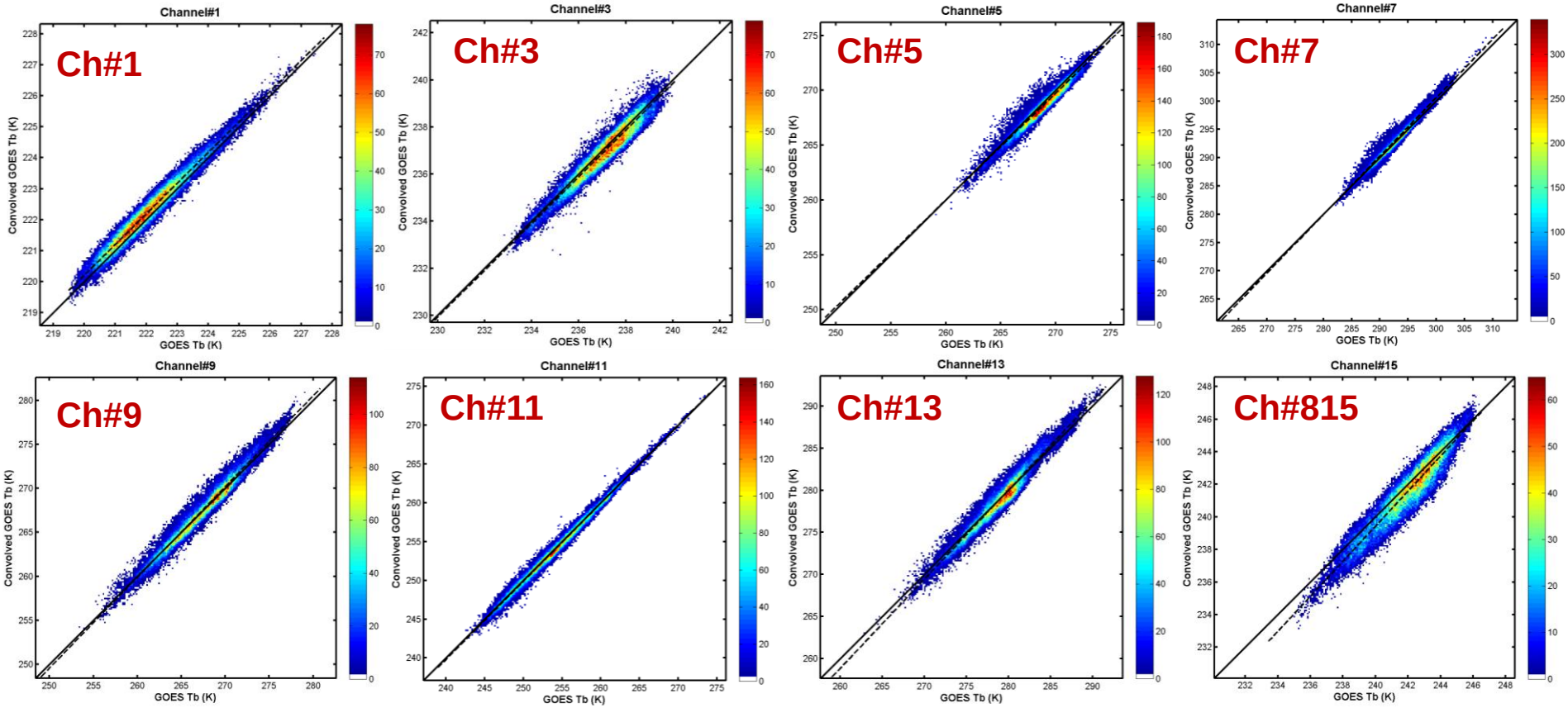
- Extend the Intercalibration methodology to generate proxy radiances for future satellite Imager/Sounder
- Testing the procedure with existing satellites (GOES)
- Bias correction (slope/offset) using data from similar existing satellite sensors or line-by-line radiative transfer model


3DSND 01JUL2012 0220 01
3DSND 01JUL2012 0220 02
3DSND 01JUL2012 0220 03
3DSND 01JUL2012 0220 04
3DSND 01JUL2012 0220 05
3DSND 01JUL2012 0220 06
3DSND 01JUL2012 0220 07
3DSND 01JUL2012 0220 08
3DSND 01JUL2012 0220 09
12000
10000
8000
6000
4000
2000
0
14-bit count

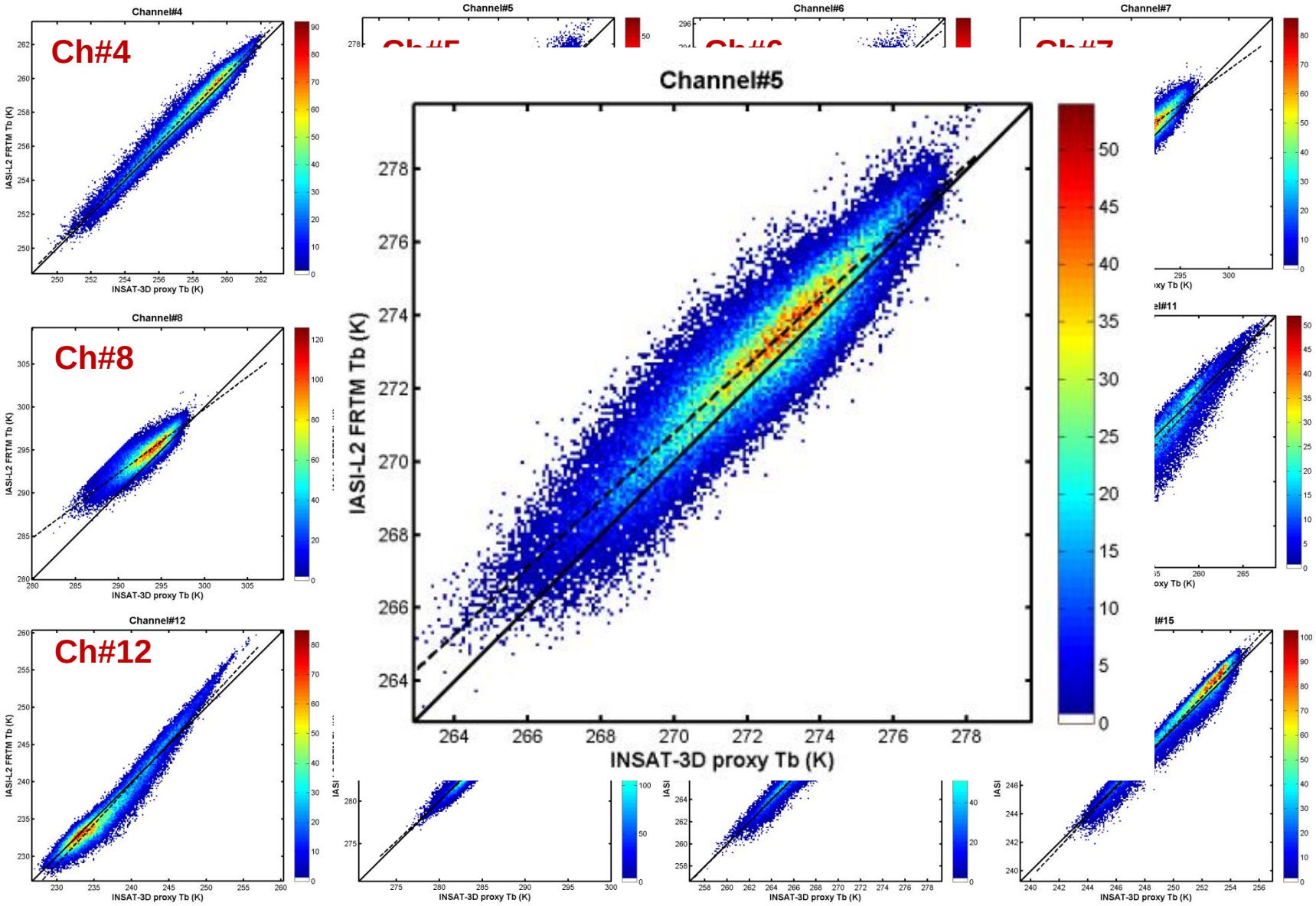

3DSND 01JUL2012 0220 10
3DSND 01JUL2012 0220 11
3DSND 01JUL2012 0220 12
3DSND 01JUL2012 0220 13
3DSND 01JUL2012 0220 14
3DSND 01JUL2012 0220 15
3DSND 01JUL2012 0220 16
3DSND 01JUL2012 0220 17
3DSND 01JUL2012 0220 18
12000
10000
8000
6000
4000
2000
0
14-bit count

Proxy Radiance for INSAT-3D using IASI

(Test with GOES-13)



Radiance bias correction for INSAT-3D



Future plans

- Intercalibration of Kalpana/INSAT-3A TIR and WV channels for entire period with Aqua-AIRS and Metop-IASI.
- Website (MOSDAC) to provide time series of the bias and Std. Dev. alongwith the GSICS correction coefficients.
- Application of proxy radiances for testing the algorithms for future satellites and system definition studies for new sensors.

Thank You