ISRO GPRC Report

Intersatellite Calibration of infrared sensors onboard Indian Geostationary Satellites using LEO Hyperspectral Observations

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Indian Meteorological Geostationary Satellites

INSAT-1D
VHRR

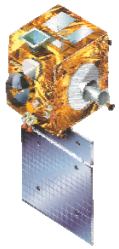
1990

INSAT-2A/2B
VHRR

1992/93

INSAT-2E
VHRR, CCD

1999



KALPANA-1
VHRR

2002

INSAT-3A
VHRR, CCD

2003

INSAT-3D
Imager/ Sounder

2013

INSAT-3DR
Imager/ Sounder

2015

GISAT
MX-LWIR/MX-VNIR/
Hys-VNIR/Hys-SWIR

2016

INSAT-3A & Kalpana-1

Launch Date & Location : Kalpana-1 - 74.0ºE (Sep 2002)
INSAT 3A - 93.5ºE (Apr 2003)

Payload : (i) VHRR & CCD 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
- **CCD Bands (µm)**

  Vis (0.62 – 0.68), NIR (0.77 – 0.86),
  SWIR (1.55 – 1.69)
  Resolution : 1 km

INSAT-3D

6 Channel IMAGER

Spectral Bands	(µm)	Resolution
Visible	: 0.55 - 0.75	1 km
Short Wave Infra Red	: 1.55 - 1.70	1 km
Mid Wave Infra Red	: 3.70 - 3.95	4 km
Water Vapour	: 6.50 - 7.10	8 km
Thermal Infra Red – 1	: 10.30 - 11.30	4 km
Thermal Infra Red – 2	: 11.30 - 12.50	4 km

19 Channel SOUNDER

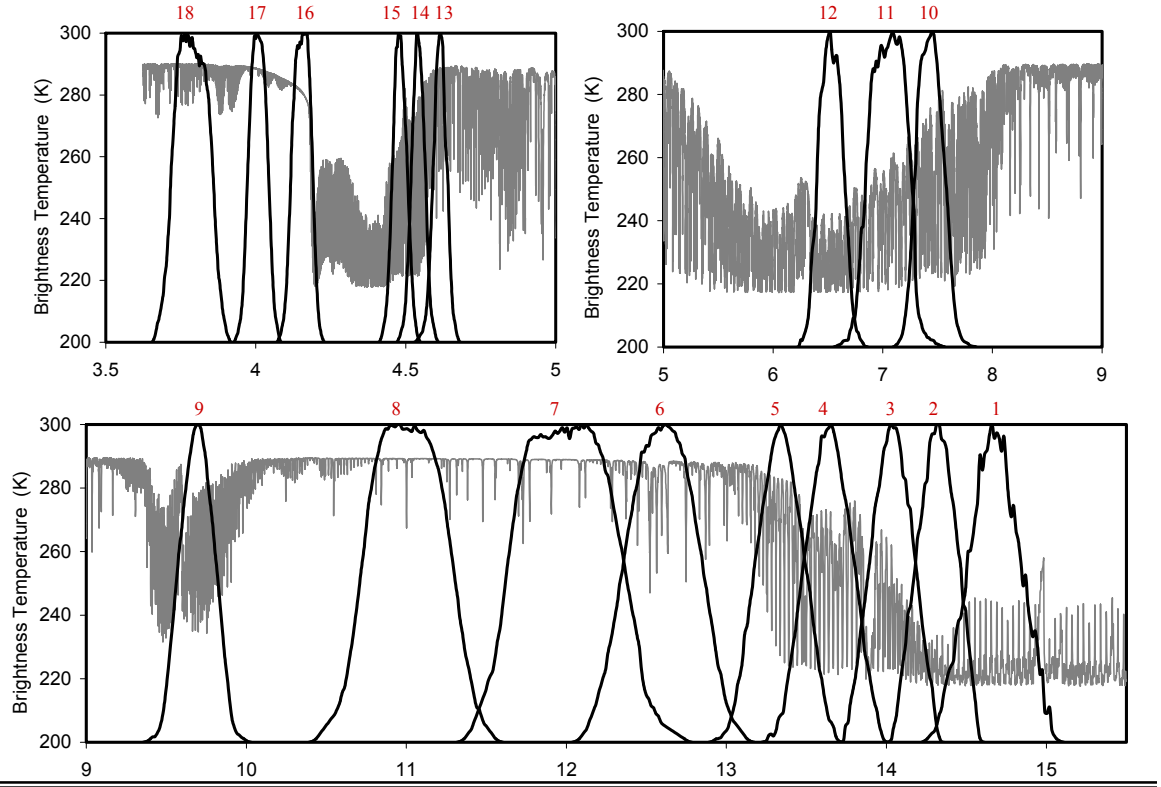
- **Spectral Bands (µm)**

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

- **Resolution : 10 km**

Launch Date: 26 Aug 2013

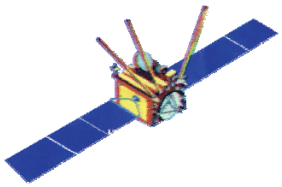
Location: 83E



Indian LEO Weather Satellites

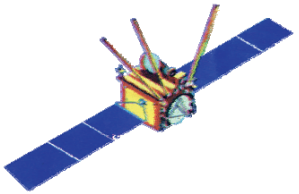
Current

OCEANSAT–1 (1999)



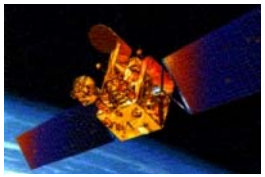
MSMR, OCM

OCEANSAT–2 (2009)



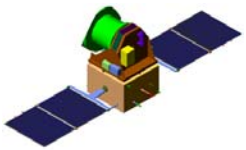
OSCAT, OCM, ROSA

SARAL (2011)



Altimeter

Megha-Tropiques (2011)



MADRAS, SAPHIR, ScaRaB, ROSA

Future

OCEANSAT–3 (2014)

OSCAT, OCM, ROSA

GCOM-W2

Scatterometer, AMSR-2

Satellite Sensors and Data Used

Indian Geostationary Satellites

www.mosdac.gov.in

Hyperspectral IR Sounders

IASI (Metop-A/B) 8461 IR-Channels (Morning/Evening Observations)

Data available through EUMETCAST

AIRS (Aqua) 2378 IR-Channel (Noon/mid-night Observations)

Data available through http://mirador.gsfc.nasa.gov/

Intercalibration of Kalpana

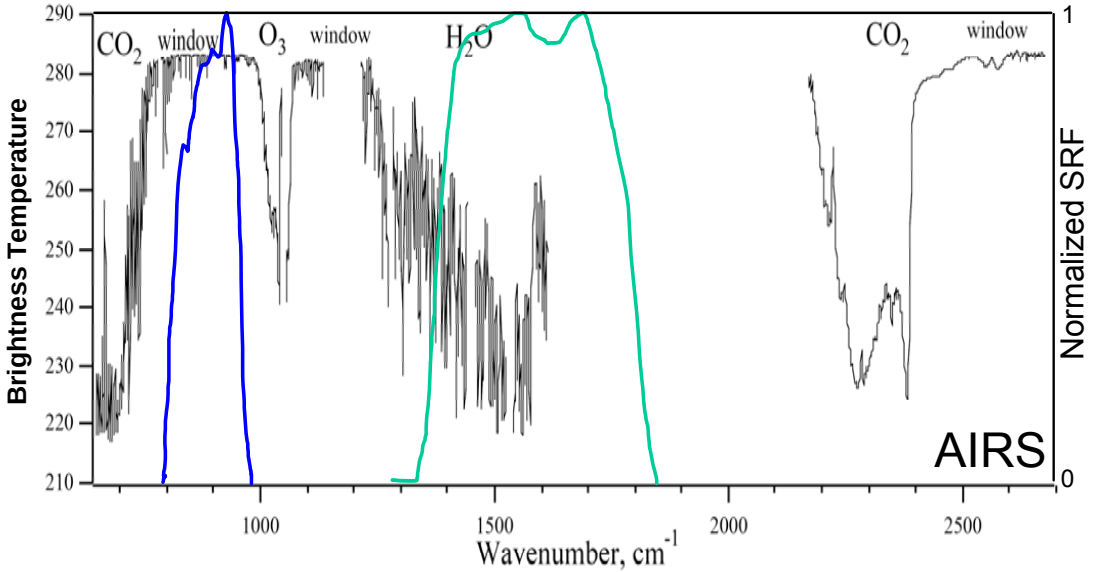
AIRS: Atmospheric InfraRed Sounder

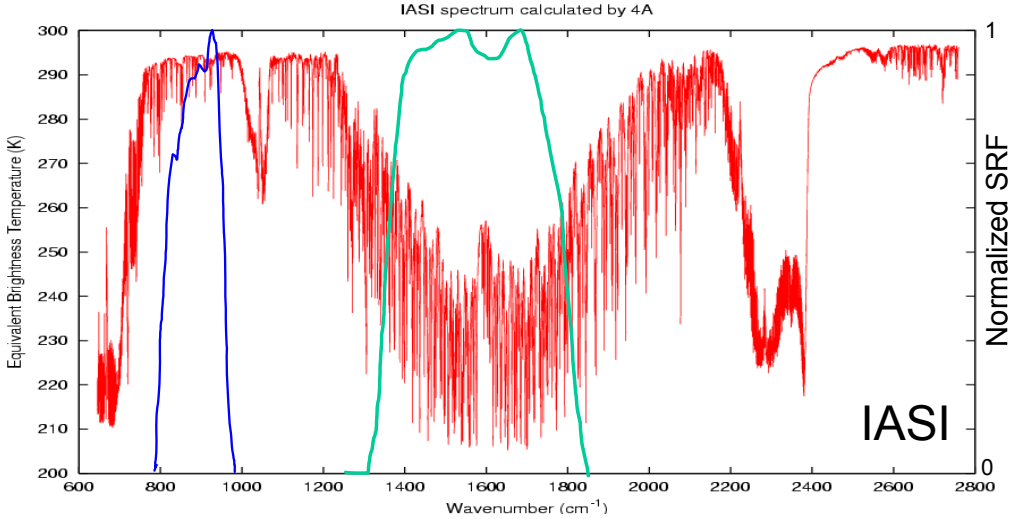
Polar Orbiting Aqua (2002)

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 (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

Kalpana / AIRS Intercalibration

Following steps are used:

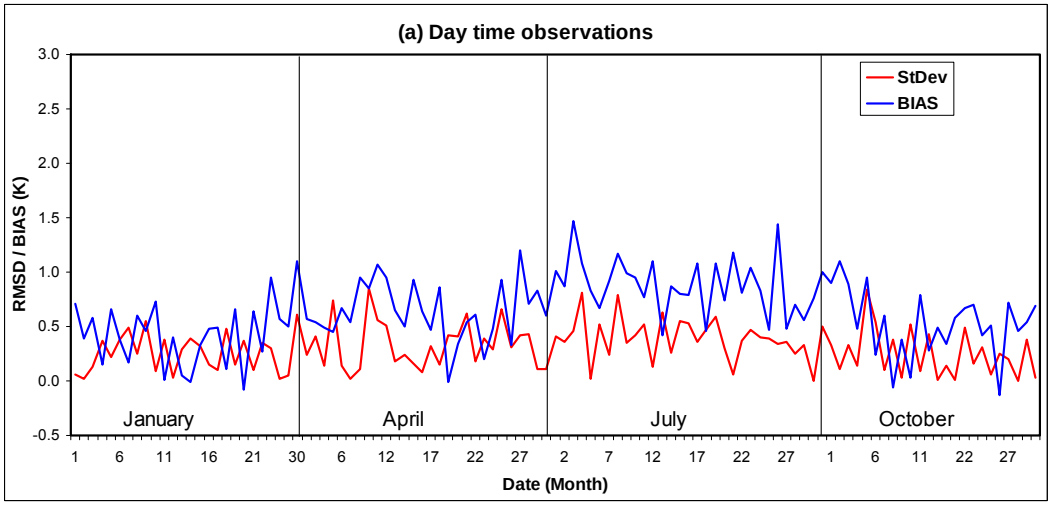
- **Missing or bad channels are interpolated from nearest 2 channels**
- **Convolution of Kalpana-TIR radiance from AIRS radiances**
- **environment uniformity test**:

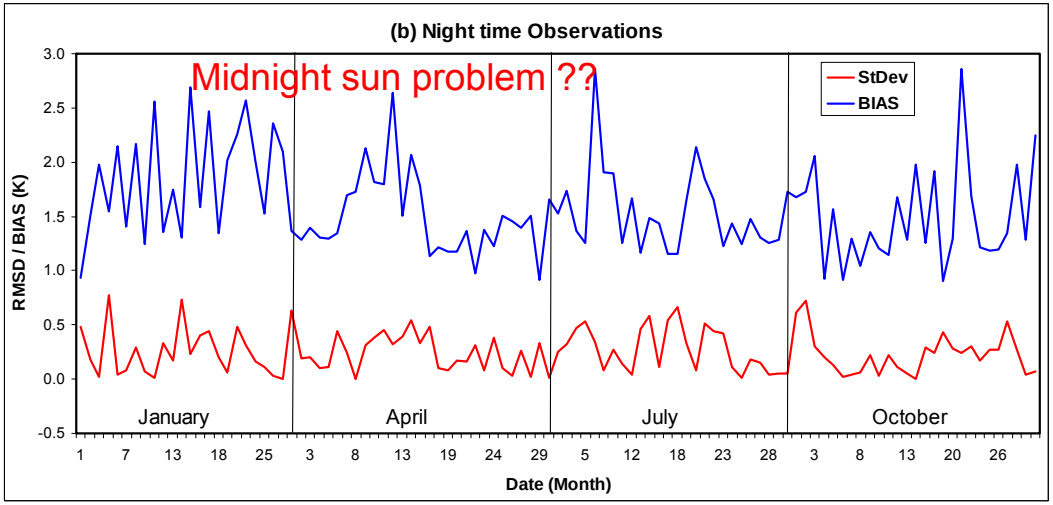
  SD of 3x3 AIRS and 5x5 Kalpana pixels < 2K
- **Land/Ocean flag:** use only ocean pixels
- **Clear scene:** Tb > 285K
- **Spatial Collocation:**

  < 0.2° (i.e. within one pixel resolution)
- **Temporal collocation:** $| t_{AIRS} - t_{Kalp} | < 15m$
- **Zenith angle collocation :**

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

  β_{AIRS} & $\beta_{Kalp} < 30°$





Month	Day-time				Night-time			
	RMSE	BIAS	SD	N	RMSE	BIAS	SD	N
Jan	0.57	0.43	0.37	4641	1.88	1.84	0.38	4027
Apr	0.76	0.64	0.40	8578	1.52	1.50	0.28	6482
Jul	0.99	0.88	0.44	3342	1.58	1.54	0.36	2291
Oct	0.64	0.52	0.37	3908	1.52	1.49	0.29	4106
Total	**0.75**	**0.63**	**0.41**	**20469**	**1.62**	**1.58**	**0.33**	**16906**

Kalpana / IASI Intercalibration

Data Source: IASI L1C through Eumetcast at SAC/ISRO in BUFR format

Methodology

- **Land/sea mask:** Use only ocean pixels
- **Temporal Collocation:** 5, 15, 30 Minutes
- **Spatial Collocation:**
  - Within IASI IFOV (2x2 pixels)
- **Zenith angle collocation:**

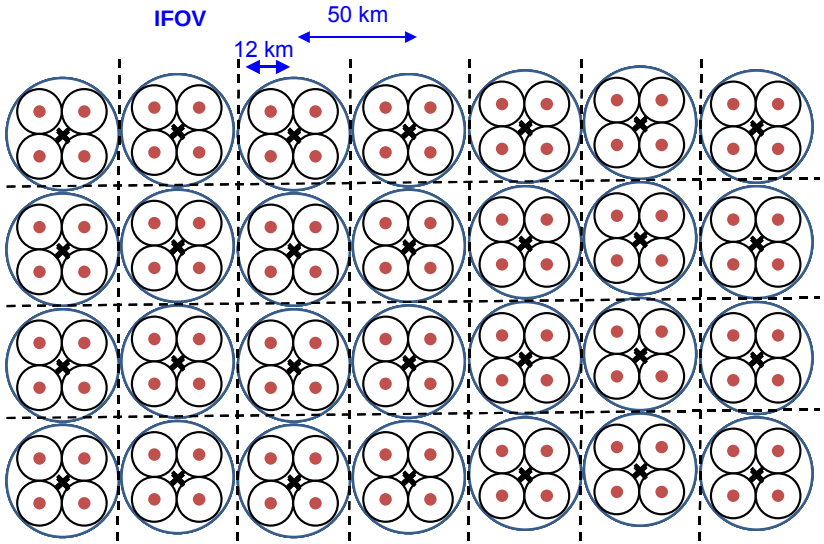
  $| \sec(\beta_{AIRS}) - \sec(\beta_{Kalp}) | < 0.01$, and

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

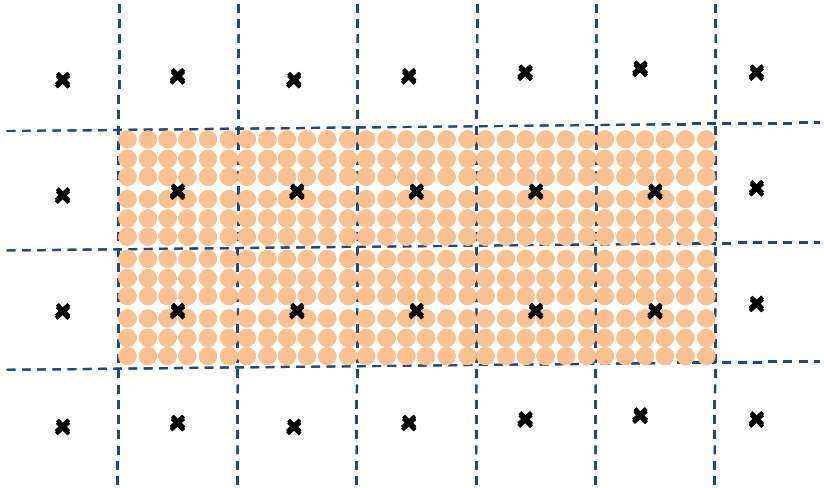
  Wang et al., JAOT 2009, vol.26,1843-1855

  (SD of Kalpana Tb within one IASI IFOV) / (mean Tb of IASI FOR) < 0.01

ISAI Observation geometry

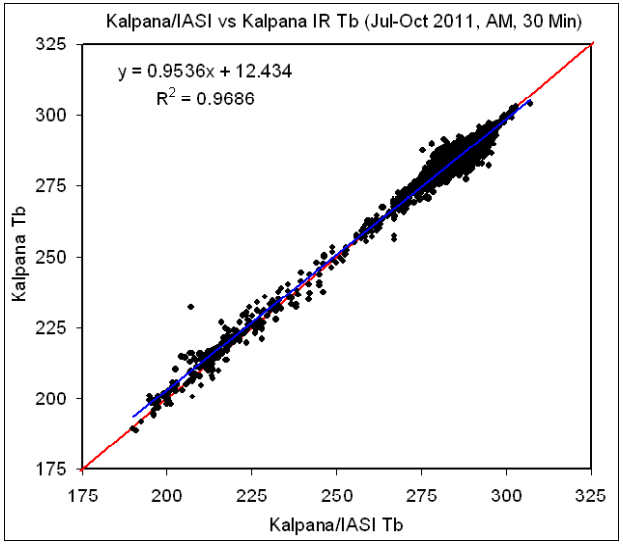


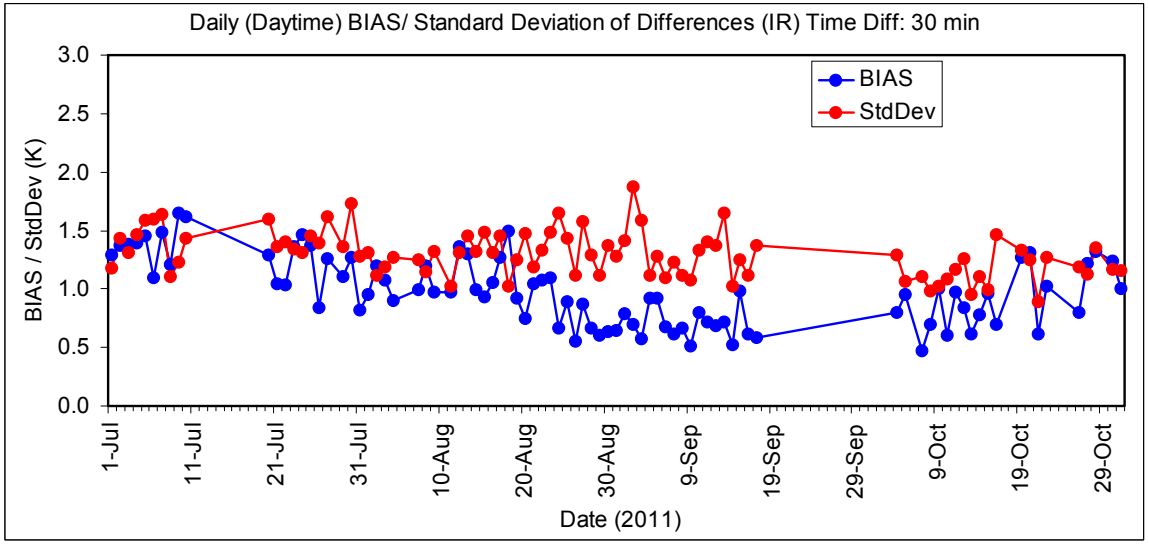
Kalpana IR/WV pixels within ISAI IFOV



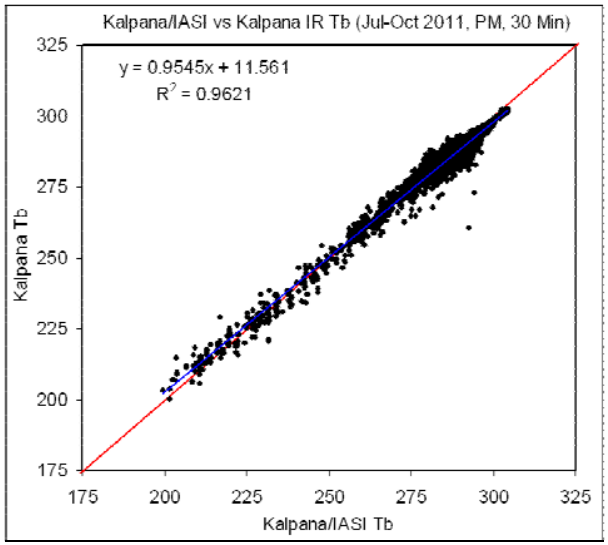
TIR Channel Kalpana/IASI (Jul-Oct, 2011)

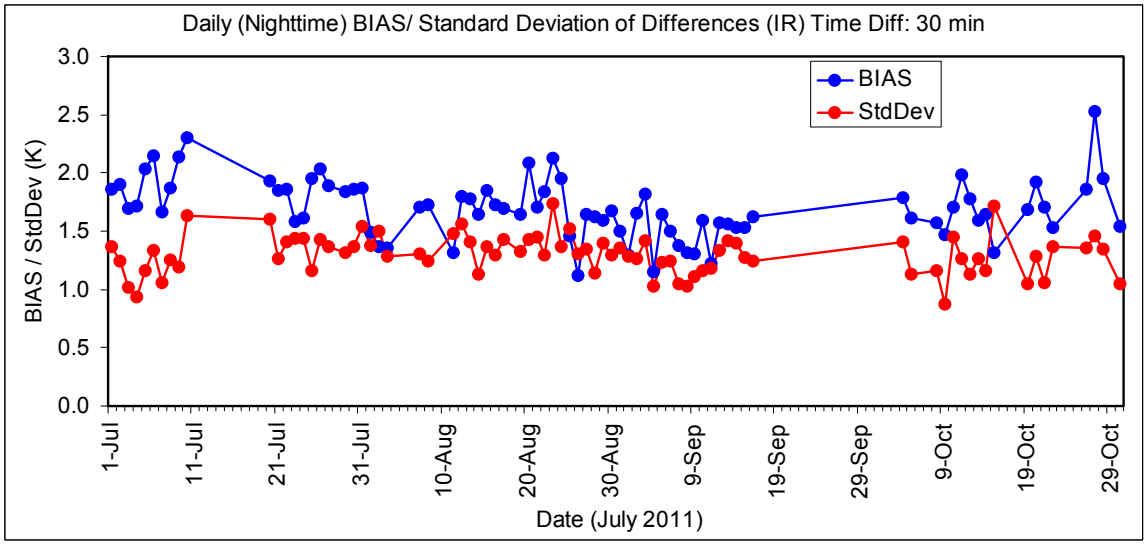
(Morning) Mean StDev = 1.3 K





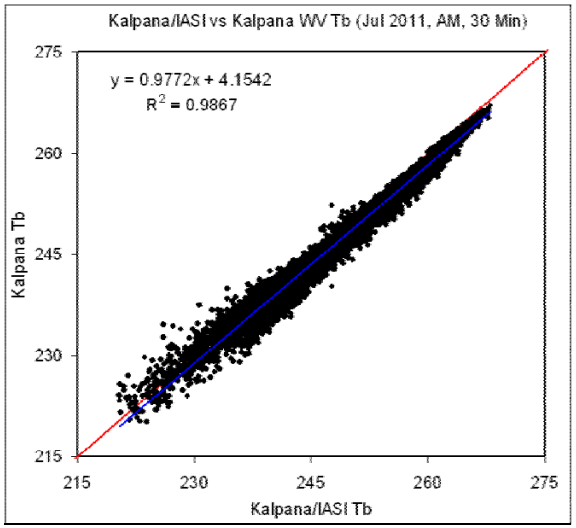
(Evening) Mean StDev = 1.3 K

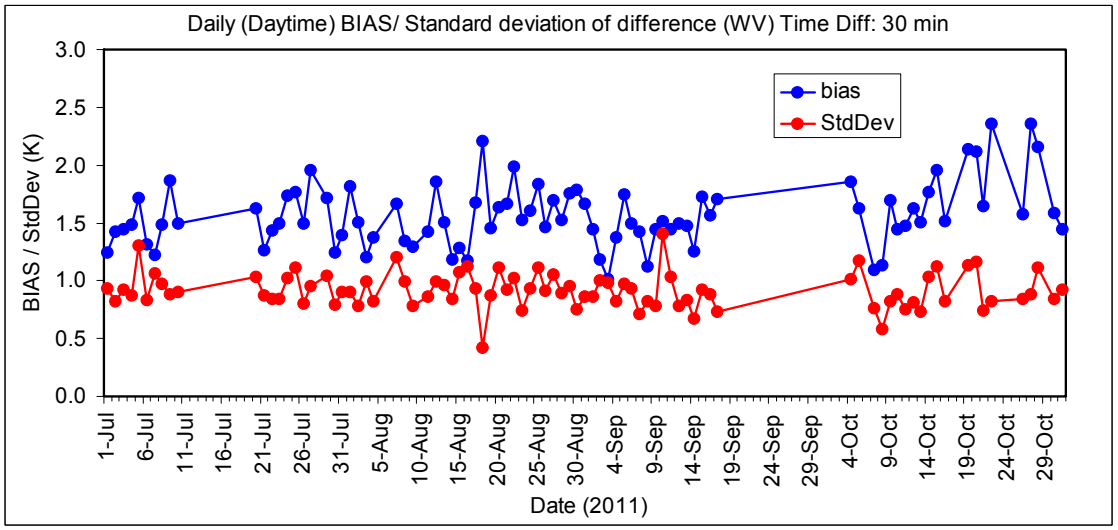




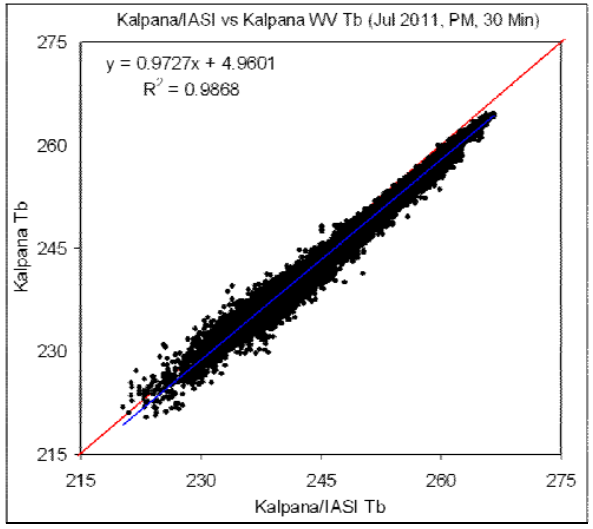
WV Channel Kalpana/IASI (Jul-Oct, 2011)

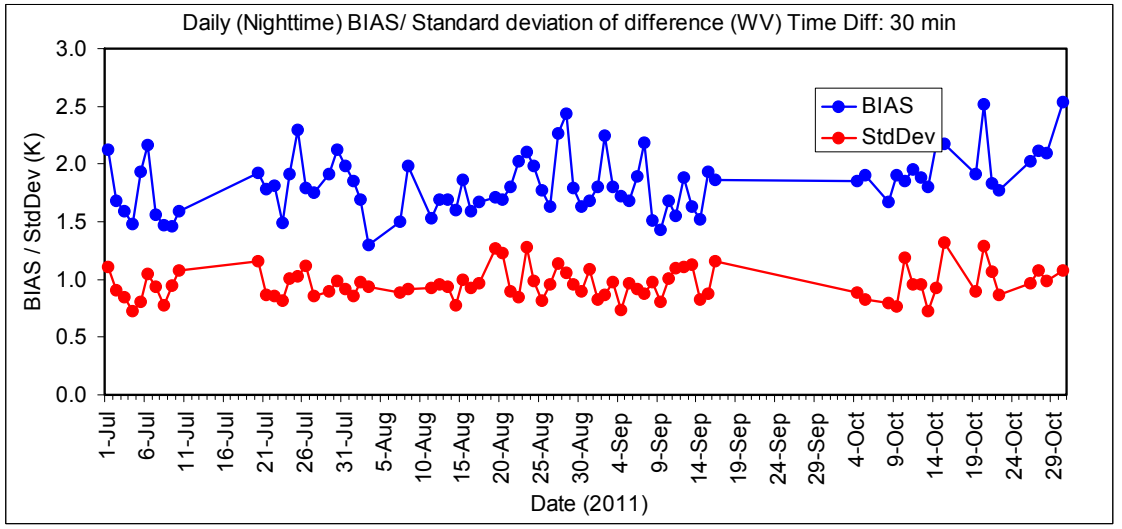
(Morning) Mean StDev = 0.9K





(Evening) Mean StDev = 1.0 K

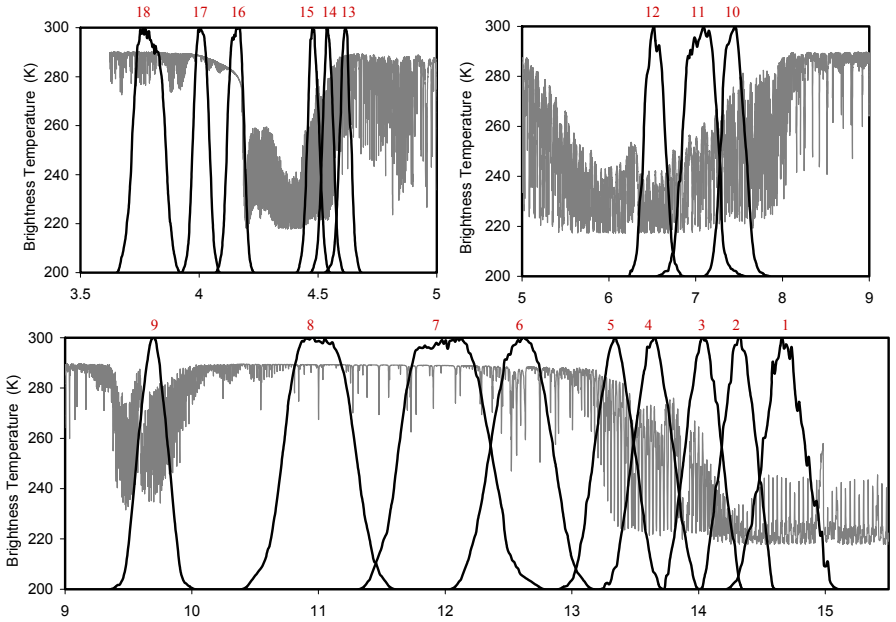




Summary of Kalpana Intercalibration

- Kalpana TIR Channel intercalibrated with AIRS radiances for 2011 (clear sky conditions)
  - Std. Dev. of differences very small 0.3-0.4K
  - Bias smaller during daytime with seasonal variations
  - Bias higher during nightime
- Kalpana TIR and WV channel intercalibration with IASI radiances (all-sky conditions)
  - Std. Dev. of differences high (1.3K TIR and 0.9K WV)
  - TIR: bias smaller during daytime with seasonal variations during
  - TIR: higher bias during nighttime
  - WV: lower bias during daytime and higher bias during nighttime

INSAT-3D / IASI Intercalibration



Data Source: IASI L1C (Eumetcast)

Temporal Collocation: < 15 Minutes

Spatial Collocation: within IASI pixel (12 km)

Zenith angle collocation: $\left|\frac{\cos(geo\_zen)}{\cos(leo\_zen)} - 1\right| < \max\_zen$

maxzen = 0.1-0.4 depending upon the absorption

Spatial homogeneity test:

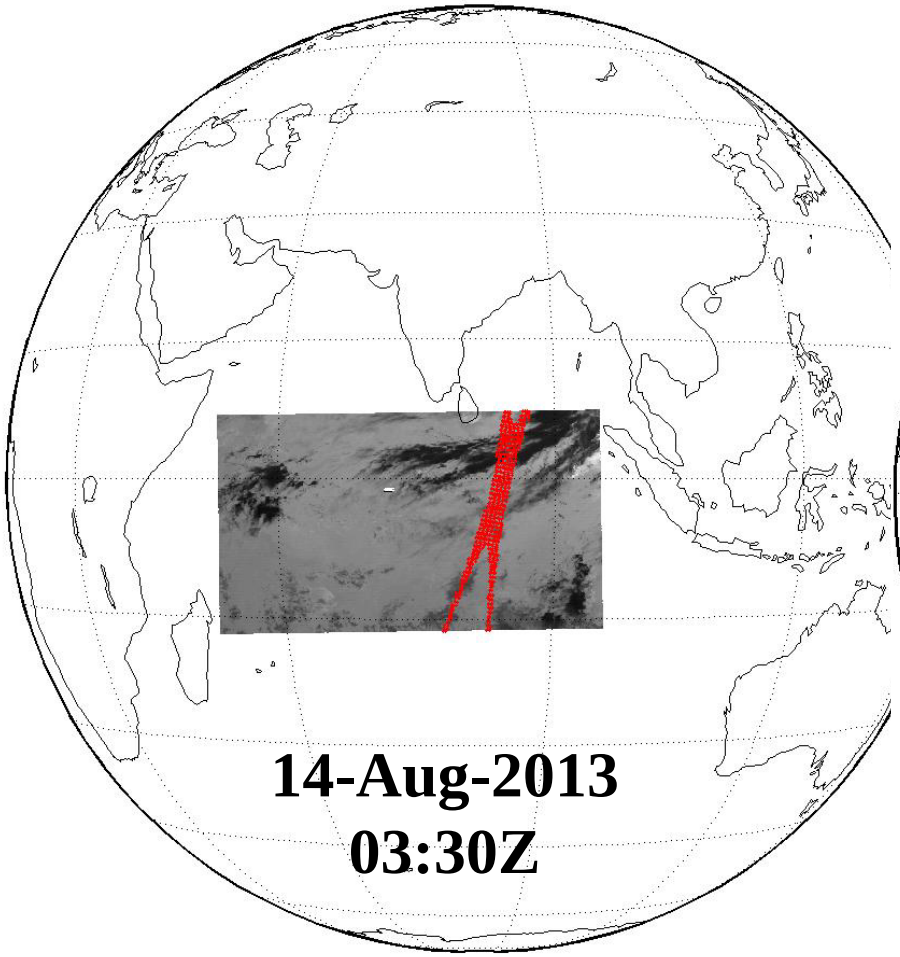
Std. Dev. of INSAT-3D (7x7 pixel) and IASI (5x5) radiances within environment surrounding the target pixel

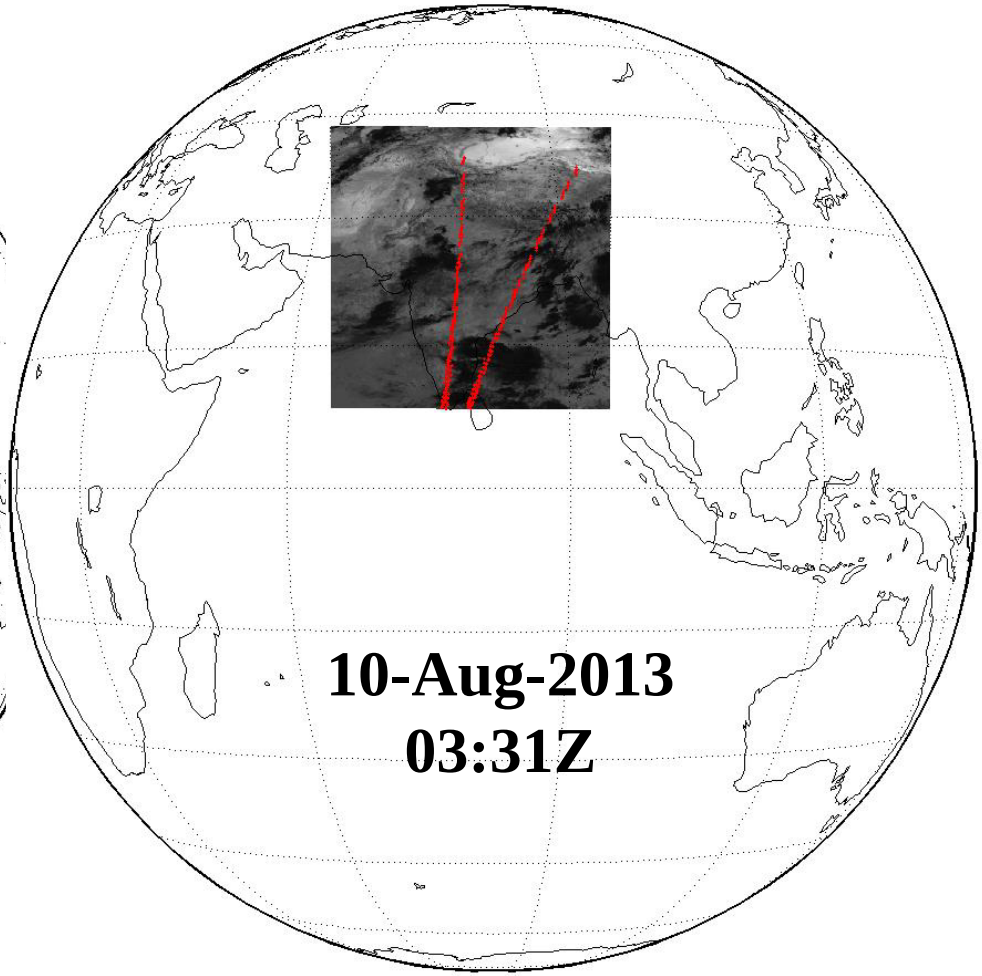
- Convolved radiance of broadband sensor using '*n*' number of hyperspectral sounders channels may be computed using:

$$R_{conv} = [\sum_{i=1}^{n} R_{IASI}^{i} S_{INSAT}^{i} \Delta v] / [\sum_{i=1}^{n} S_{INSAT}^{i} \Delta v]$$

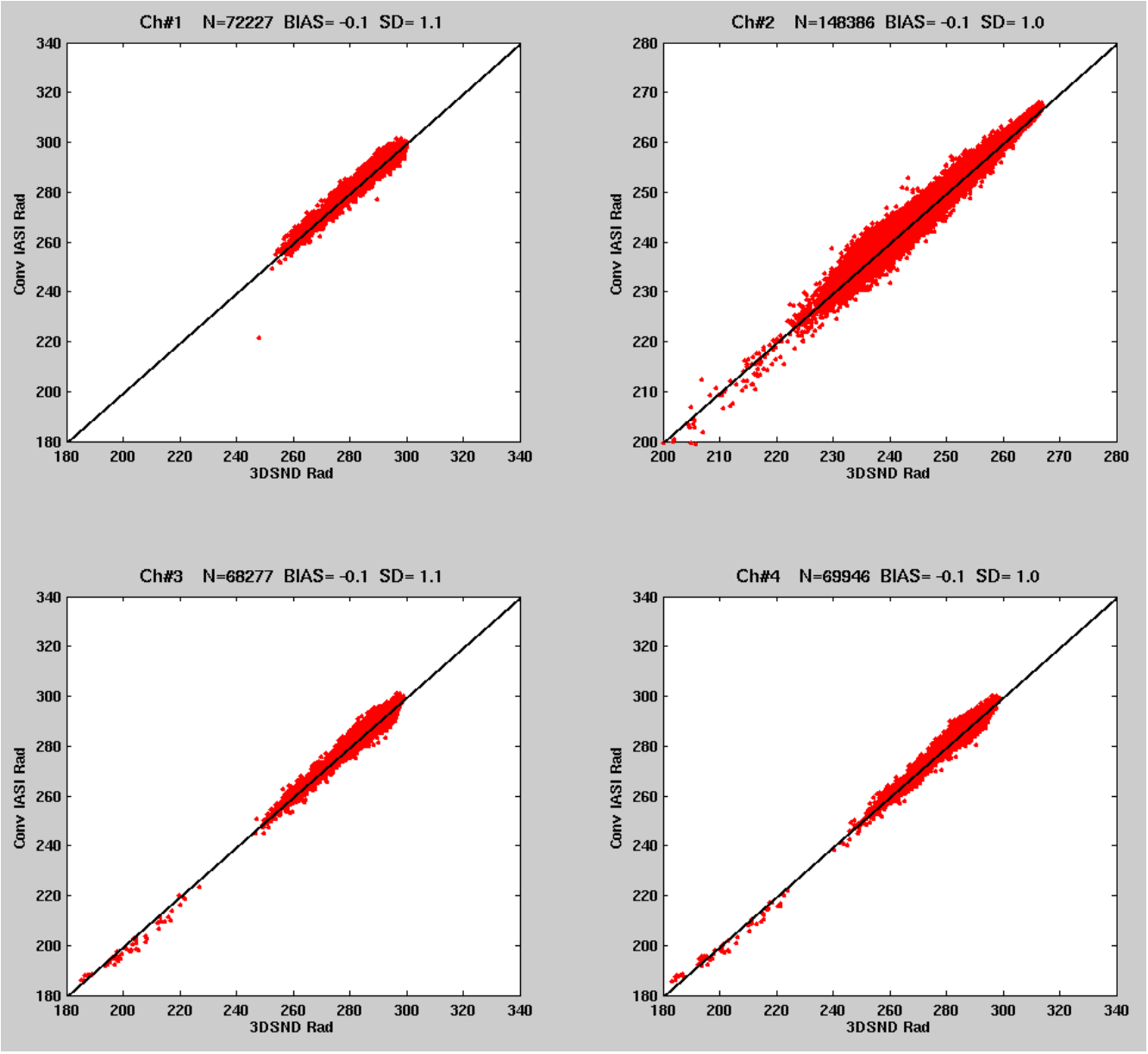
- R_{conv} is convolved broadband radiance, R_{IASI} is radiance of hyper-spectral sounder, superscript '*i*' is hyper-spectral channel index, S_{INSAT} is the sensor response function of INSAT-3D channels at the central wavenumber of hyper-spectral channel '*i*', and *'n'* is the total number of hyper-spectral channels in broadband sensor's SRF range.

INSAT-3D Sounder / IASI Collocation map for GSICS





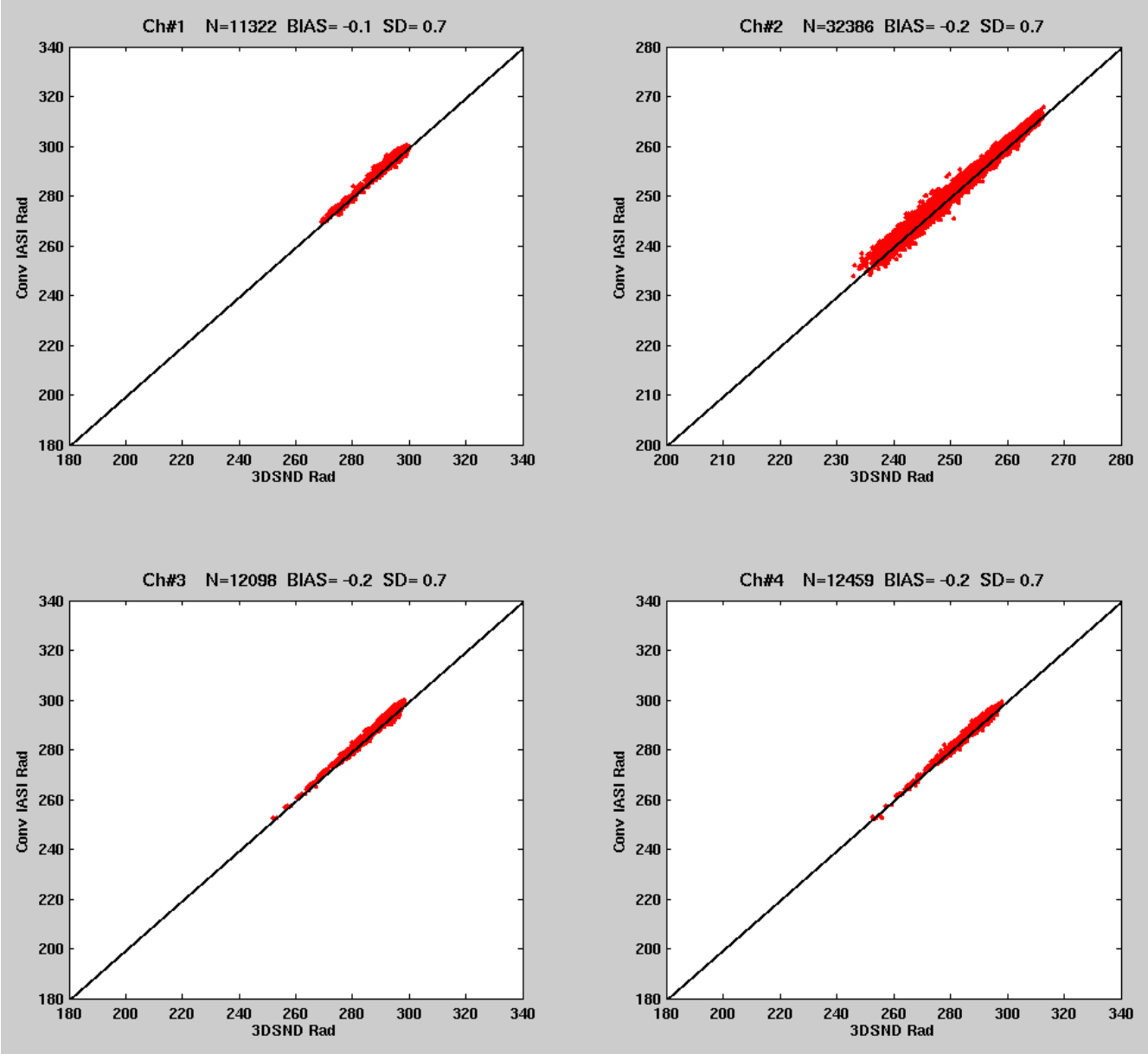
Night (13-16Z), Temporal Collocation : 15 Min,
Spatial homogeneity: ENV_TB_SD = 2K



Oct-Nov 2013

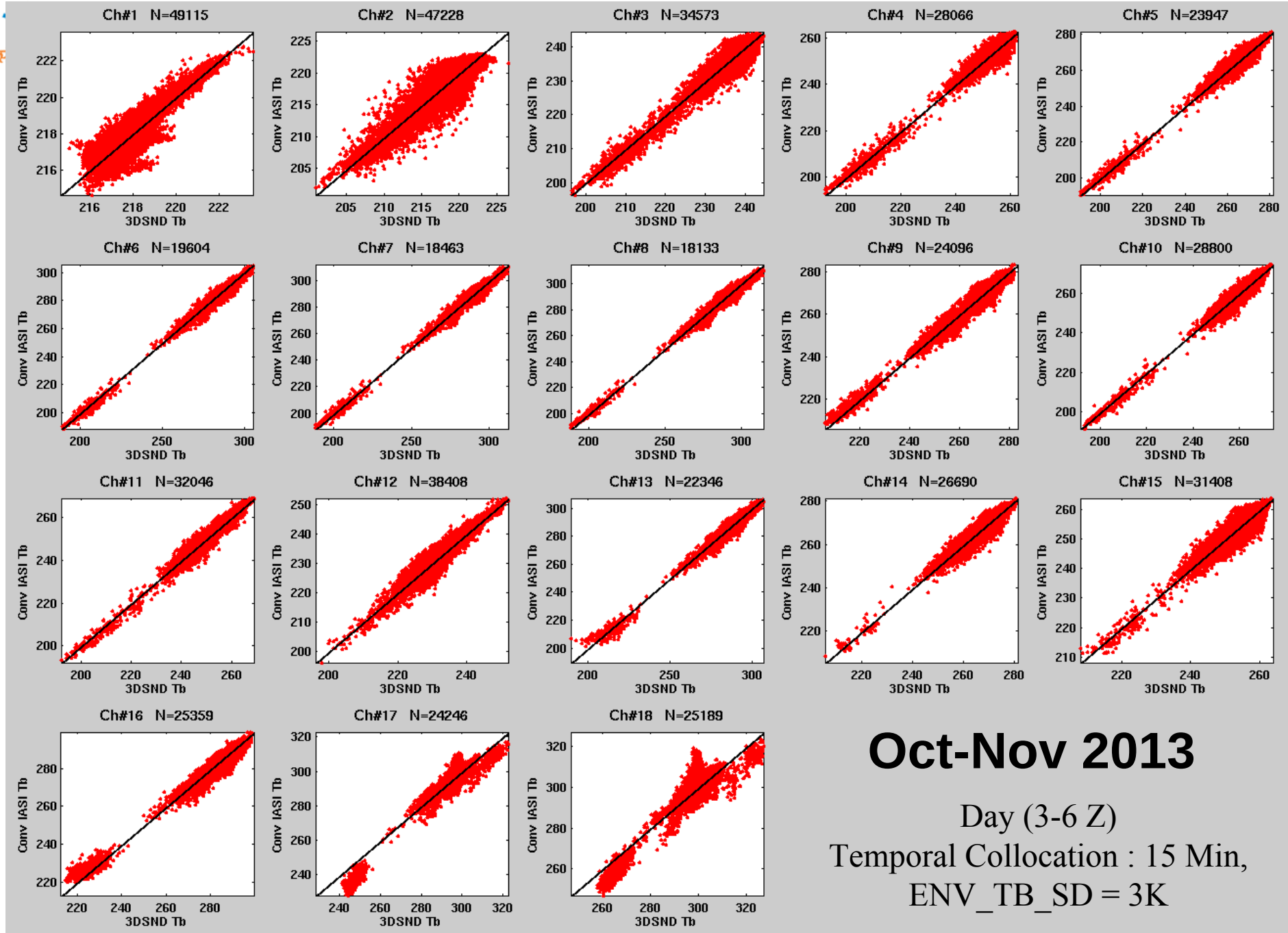
Ch#	BIAS (K)	SD (K)
MIR	-0.1	1.1
WV	-0.1	1.0
TIR1	-0.1	1.1
TIR2	-0.1	1.0

Night (13-15Z), Temporal Collocation : 5 Min,
Spatial homogeneity: ENV_TB_SD = 1K



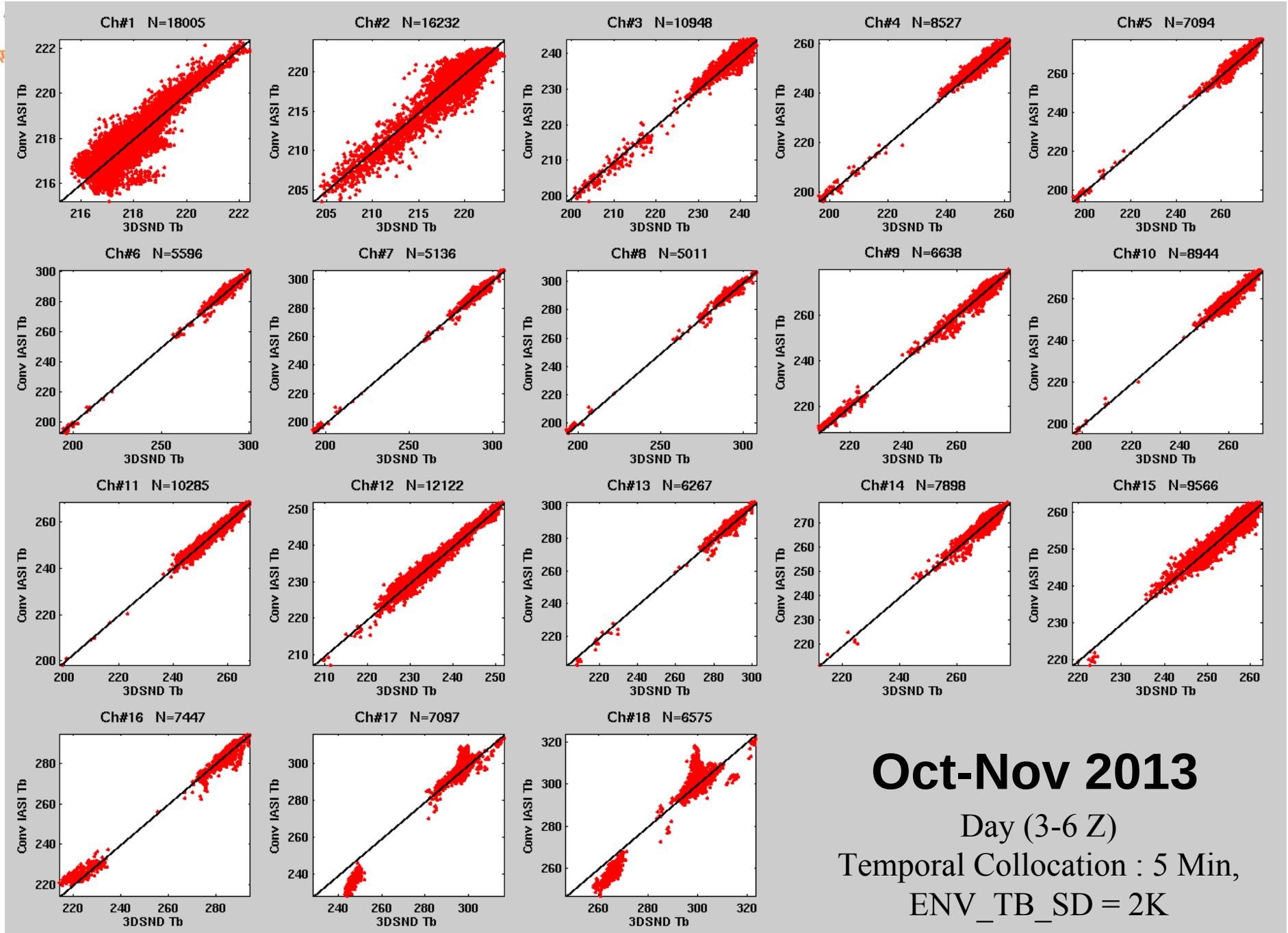
Oct-Nov 2013

Ch#	BIAS (K)	SD (K)
MIR	-0.1	0.7
WV	-0.2	0.7
TIR1	-0.2	0.7
TIR2	-0.2	0.7



Oct-Nov 2013

Day (3-6 Z)
Temporal Collocation : 15 Min,
ENV_TB_SD = 3K

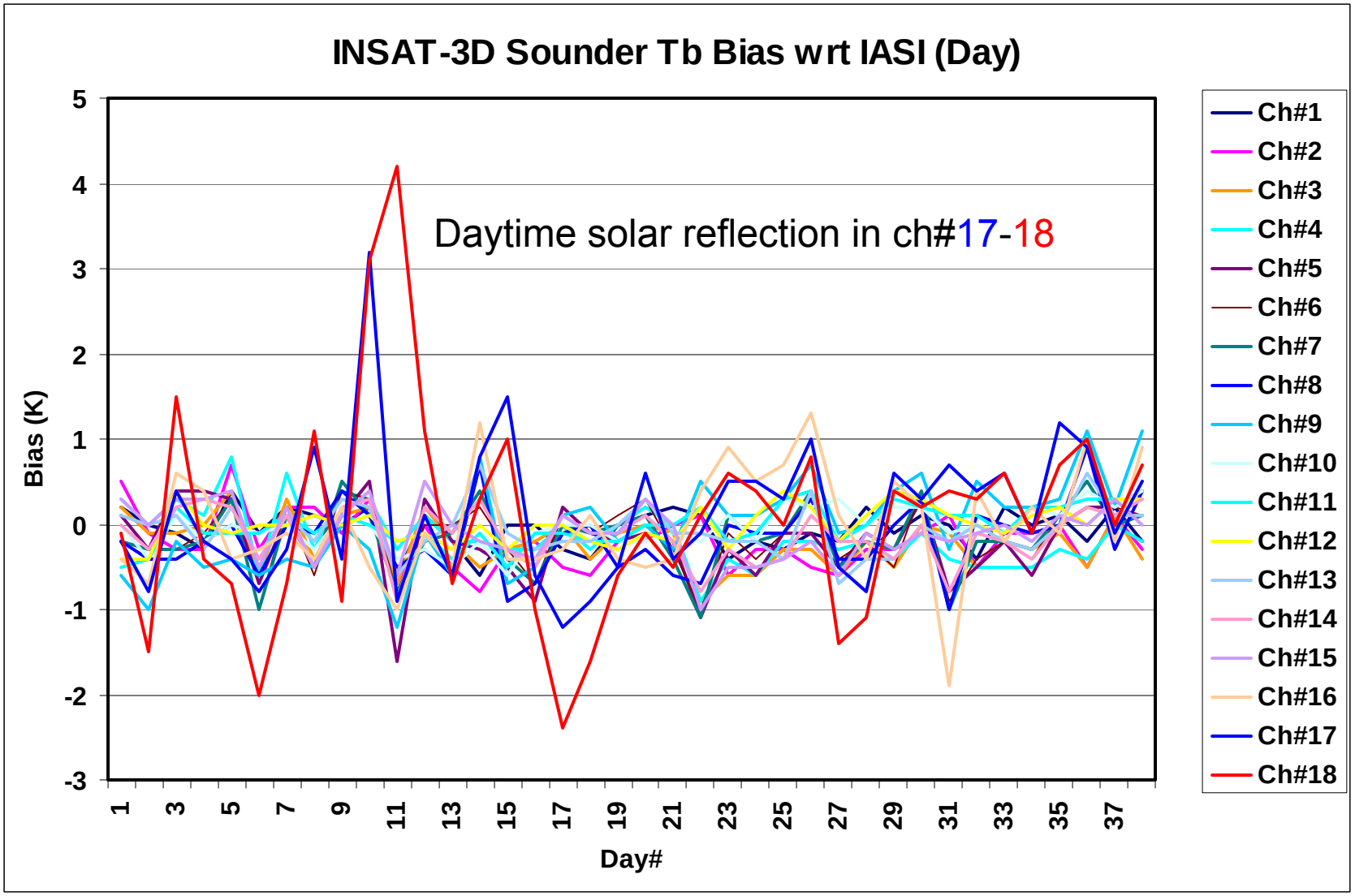


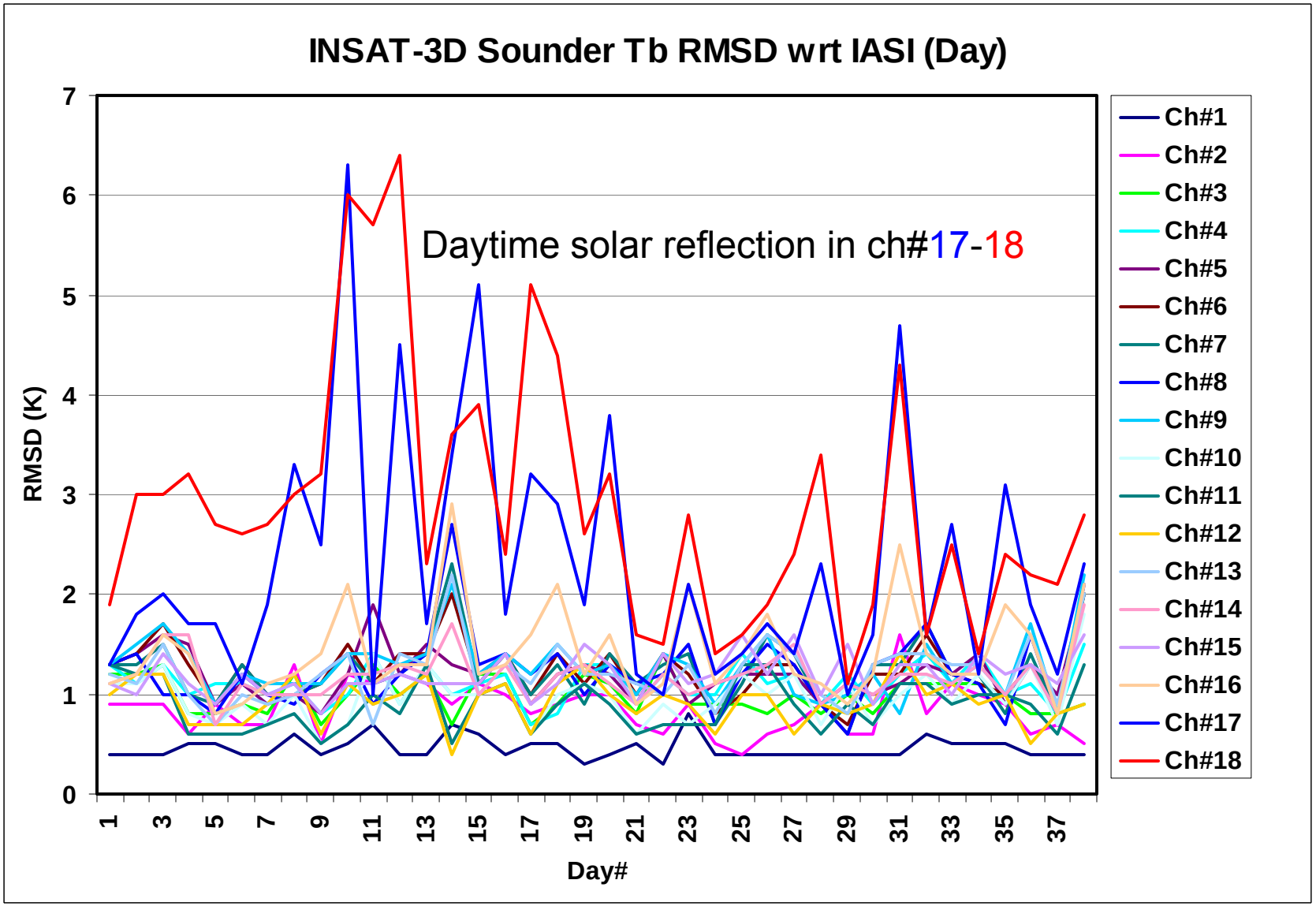
Oct-Nov 2013

Day (3-6 Z)

Temporal Collocation : 5 Min,

ENV_TB_SD = 2K


INSAT-3D Sounder Tb Bias wrt IASI (Day)
Daytime solar reflection in ch#17-18
Bias (K)
Day#
5
4
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
Ch#1
Ch#2
Ch#3
Ch#4
Ch#5
Ch#6
Ch#7
Ch#8
Ch#9
Ch#10
Ch#11
Ch#12
Ch#13
Ch#14
Ch#15
Ch#16
Ch#17
Ch#18


INSAT-3D Sounder Tb RMSD wrt IASI (Day)
Daytime solar reflection in ch#17-18
RMSD (K)
Day#
0
1
2
3
4
5
6
7
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
Ch#1
Ch#2
Ch#3
Ch#4
Ch#5
Ch#6
Ch#7
Ch#8
Ch#9
Ch#10
Ch#11
Ch#12
Ch#13
Ch#14
Ch#15
Ch#16
Ch#17
Ch#18

Status

- Draft GSICS intercalibration ATBD is ready
- A test run is being conducted offline for near real-time GSICS intercalibration of INSAT-3D Imager/Sounder since March 2014.
- GSICS correction coefficients based on GSICS guidelines are being generated
- Past data of Kalpana is being processed
- Website for GSICS will be launched shortly
- Intercalibration of solar channel to be taken in near future