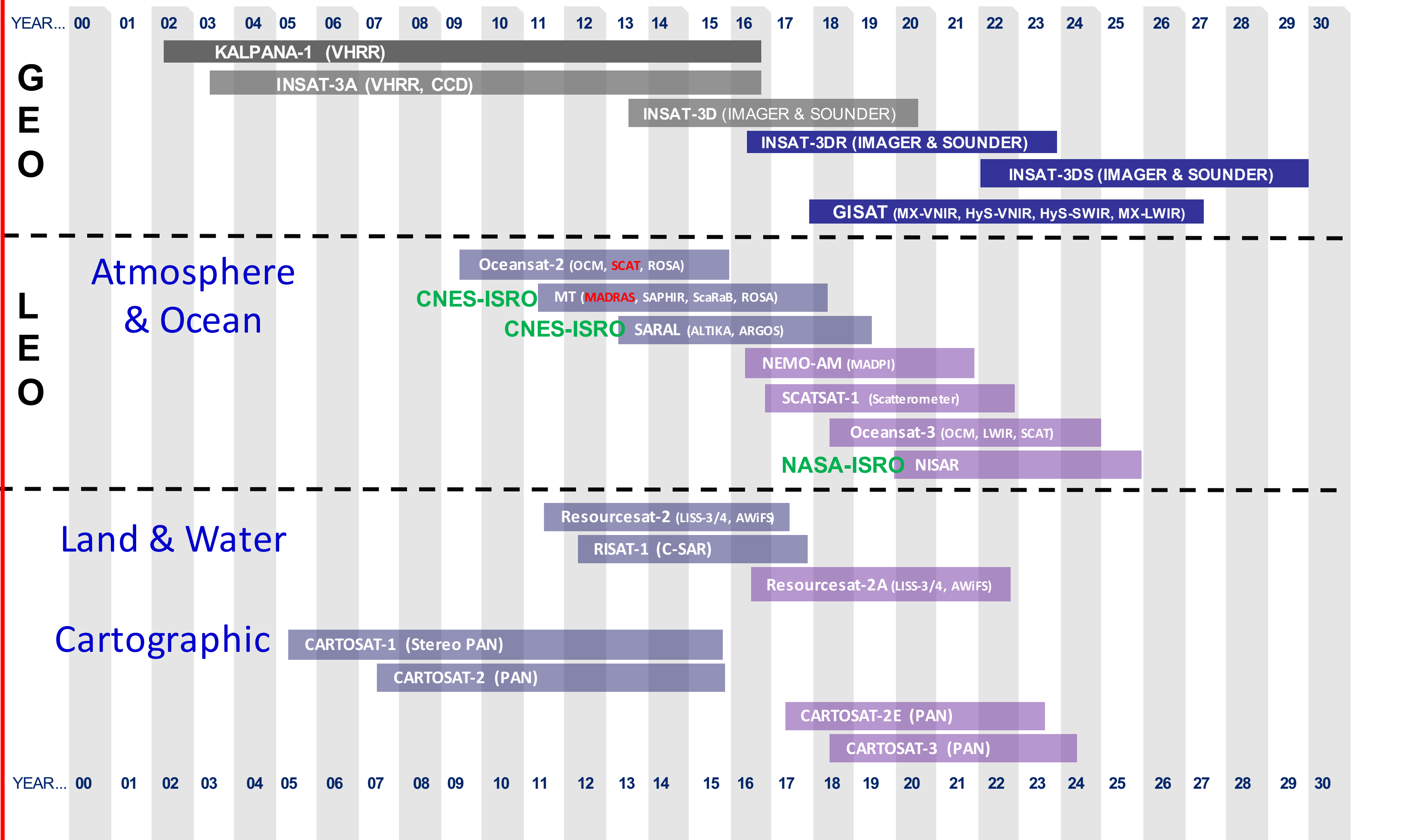
Atmospheric Motion Vectors from INSAT-3D: ISRO Status

Sanjib K Deb, D K Sankhala, C M Kishtawal

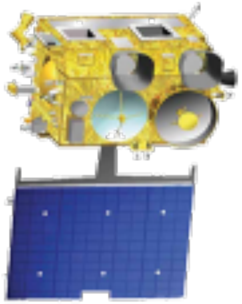
Atmospheric and Oceanic Sciences Group
Space Applications Centre
Indian Space Research Organization
Ahmedabad-380015, India
E-mail: sanjib_deb@sac.isro.gov.in

Contents:

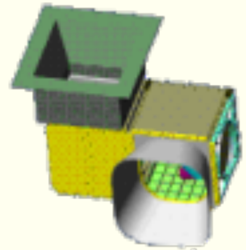
ISRO Current satellites for Earth Observations

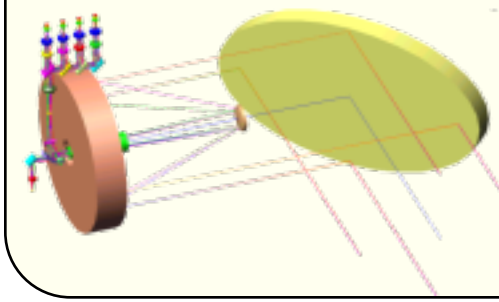


FUTURE GEO SATELLITES: INSAT - 3DR/3DS



LAUNCH: 2016/ 2022





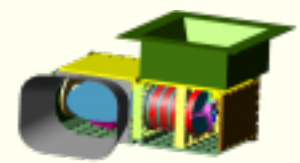
6 Channel IMAGER

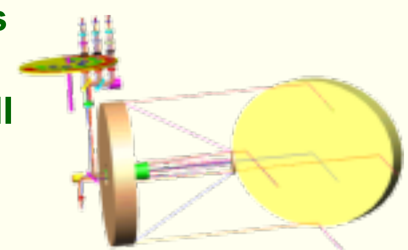
- Spectral Bands (µm)

Visible	: 0.55	-	0.75
Short Wave Infra Red	: 1.55	-	1.70
Mid Wave Infra Red	: 3.70	-	3.95
Water Vapour	: 6.50	-	7.10
Thermal Infra Red – 1	: 10.30	-	11.30
Thermal Infra Red – 2	: 11.30	-	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 : 4 sounding per band

FUTURE GEO SATELLITES: (GISAT)

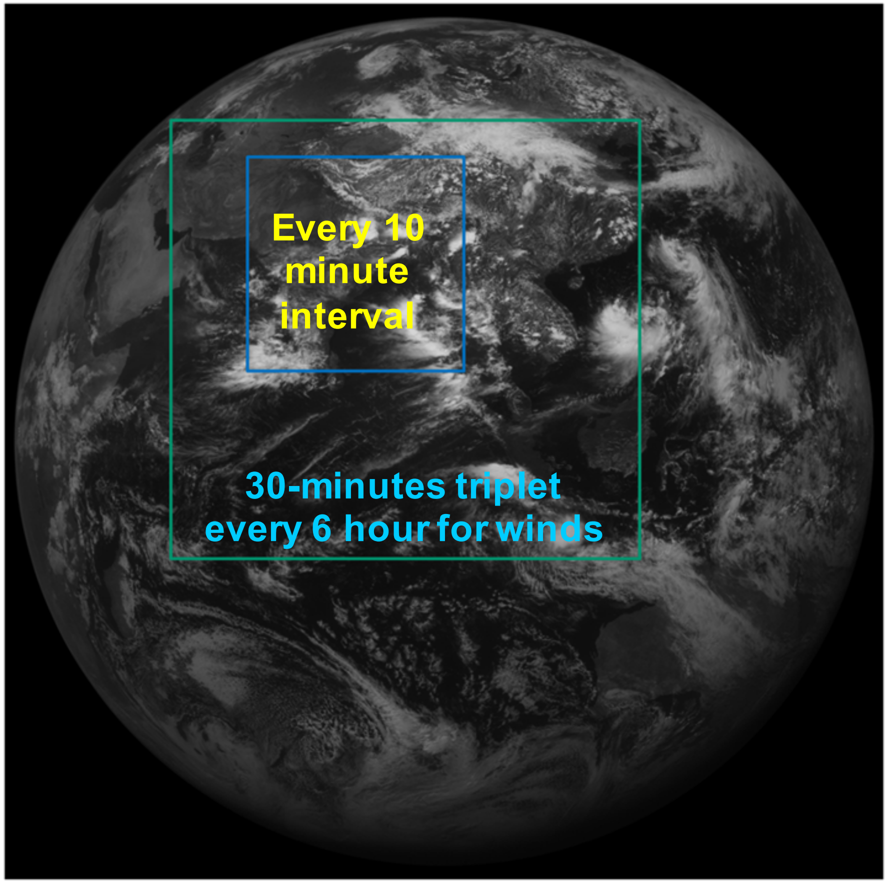
Launch Schedule: 2017, Geostationary orbit, 83E

MX-VNIR: Multispectral - Visible Near Infrared, HySI-VNIR: Hyperspectral Imager - Visible Near Infrared, HySI-SWIR: Hyperspectral Imager - Short Wave Infrared, MX-LWIR: Multispectral - Long Wave Infrared.

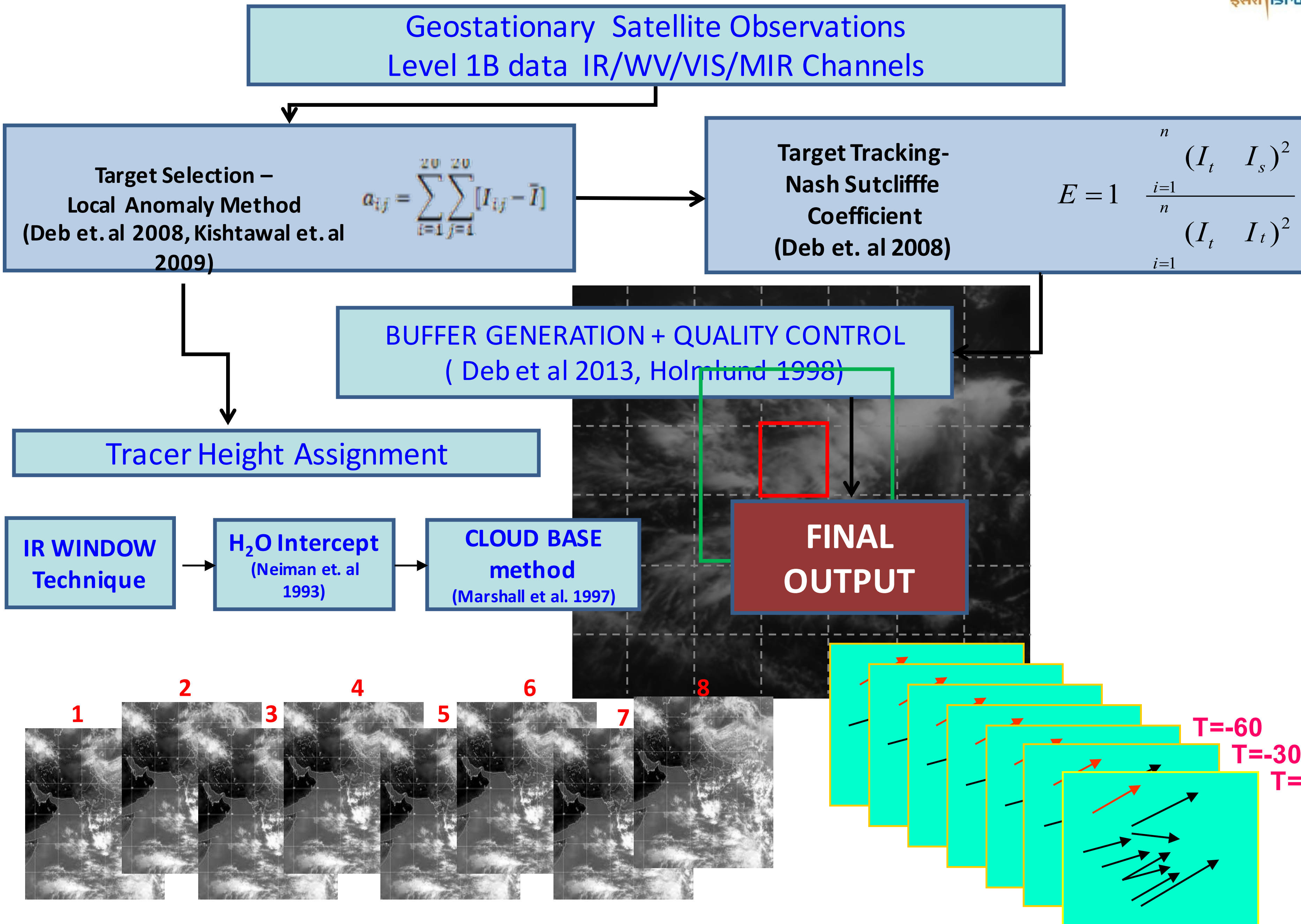
GISAT Scan scenario

Scan area for two scan scenario (5° & 10 °)

Band	Ch	SNR/ NEdT	IFOV (m)	Range (µm)	Channels (µm)
MX-VNIR	4	> 200	50	0.45 - 0.875	B1: 0.45-0.52 B2: 0.52-0.59 B3: 0.62-0.68 B4: 0.77-0.86 B5N: 0.71-0.74 B6N: 0.845-0.875
HyS-VNIR	60	> 400	500	0.375 - 1.0	$\Delta\lambda < 10$ nm
HyS-SWIR	150	> 400	500	0.9 - 2.5	$\Delta\lambda < 10$ nm
MX-LWIR	6	NEdT < 0.15K	1500	7.0 – 13.5	CH1: 7.1-7.6 CH2: 8.3-8.7 CH3: 9.4-9.8 CH4: 10.3-11.3 CH5: 11.5-12.5 CH6: 13.0-13.5



AMV ALGORITHM FLOWCHART



Major Modifications in Wind Retrieval Algorithm w. r. to earlier Kalpana-1 version

1. Use of first guess for search area optimization
2. Height assignment prior to tracking
3. Improved speed bias correction, varying with pressure level.
4. Improved quality check procedure.
5. Improved screening of erroneous winds.
6. Retrieval of AMVs using MIR (3.9 μm) channel during night time.

Height assignment

- Infrared window technique (WIN)/Histogram method (HIST).
- H_2O Intercept Method. (Nieman et al. 1993)
- Cloud Base Method (BASE). (LeMarshall et al. 1993)
- Few gross error checks. (Olander et al. 2001)

IR winds: - Infrared window technique.
- H_2O Intercept method.
- Cloud Base method.

WV winds: - WV Histogram method.
- H_2O Intercept method.

VIS winds: - Infrared window technique.
- Cloud Base method.
(Using collocated IR image)

MIR winds: - Infrared window technique.
- Cloud Base method.
(Using collocated IR image)

QUALITY CONTROL: QUALITY BASED SCREENING

(Holmlund -1998)

$$DCF = 1.0 \quad \tanh\left(\frac{}{A_1 \exp(\ \ S/B_1) + C_1}\right)^{D_1}$$

Direction Consistency Function

$$SCF = 1.0 \quad \tanh\left(\frac{S}{MAX(A_2 S, B_2) + C_2}\right)^{D_2}$$

Speed Consistency Function

$$VCF = 1.0 \quad \tanh\left(\frac{V}{MAX(A_3 S, B_3) + C_3}\right)^{D_3}$$

Vector Consistency Function

$$PCF = 1.0 \quad \tanh\left(\frac{V_m}{MAX(A_4 S, B_4) + C_2}\right)^{D_4}$$

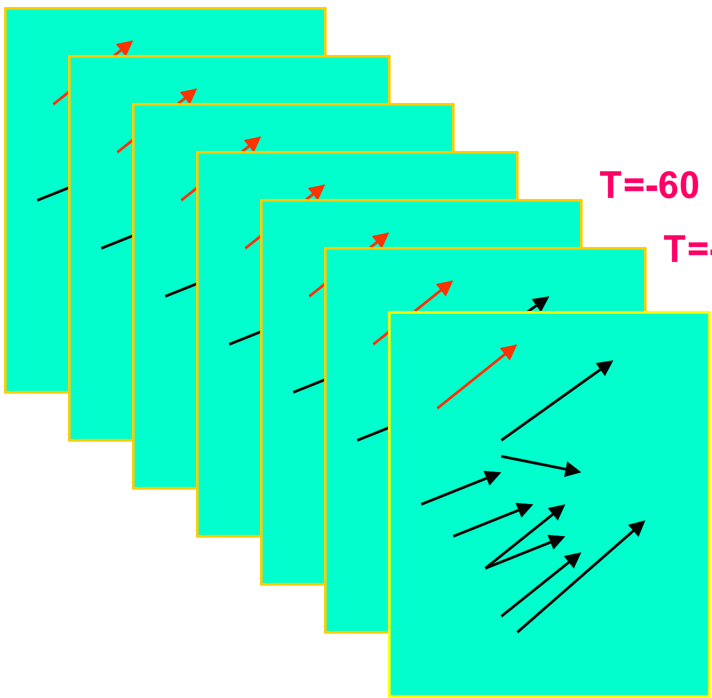
Spatial Consistency Function

$$QI = \frac{DCF + SCF + VCF + PCF}{4.0}$$

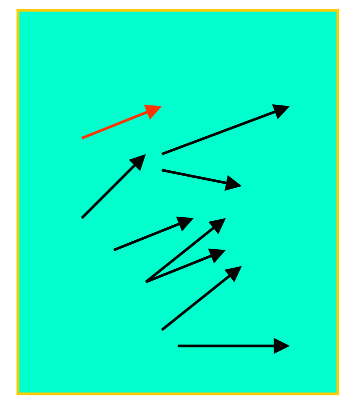
Use of above Quality Control procedure with little modification

Buffer generation for quality control

- Use of sector generated images (20-130E, 60S-60N) with improved registration and fixed lat/lon co-ordinate.
- Take advantage of using multiple 30-min images, rather than traditional 3 images.



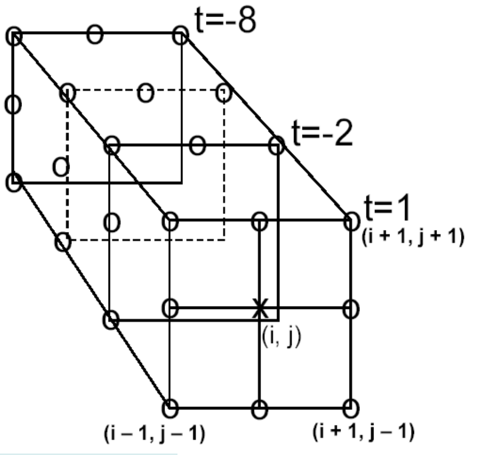
Only 1 set retrieved At a time



Vector-1

……….All the singular retrievals during past N-hours provide support

Vector Selection Criteria



- For every new vector under consideration, (from current image-pair), its vector difference from the buffer is computed as well as in 3 x 3 neighborhood, provided, the vectors are in same levels.

- Each vector difference is weighted according to distance and time difference from the current vector.
- The vector differences is arranged in ascending order, if the mean wind magnitude of first 10-vectors is less is 4 m/s, then the vector under consideration is accepted, otherwise rejected
- The final vector is computed by taking weighted mean of first 10 sorted vectors and current vector.
- The QI of the selected vector is calculated using EUMETSAT QI procedure.

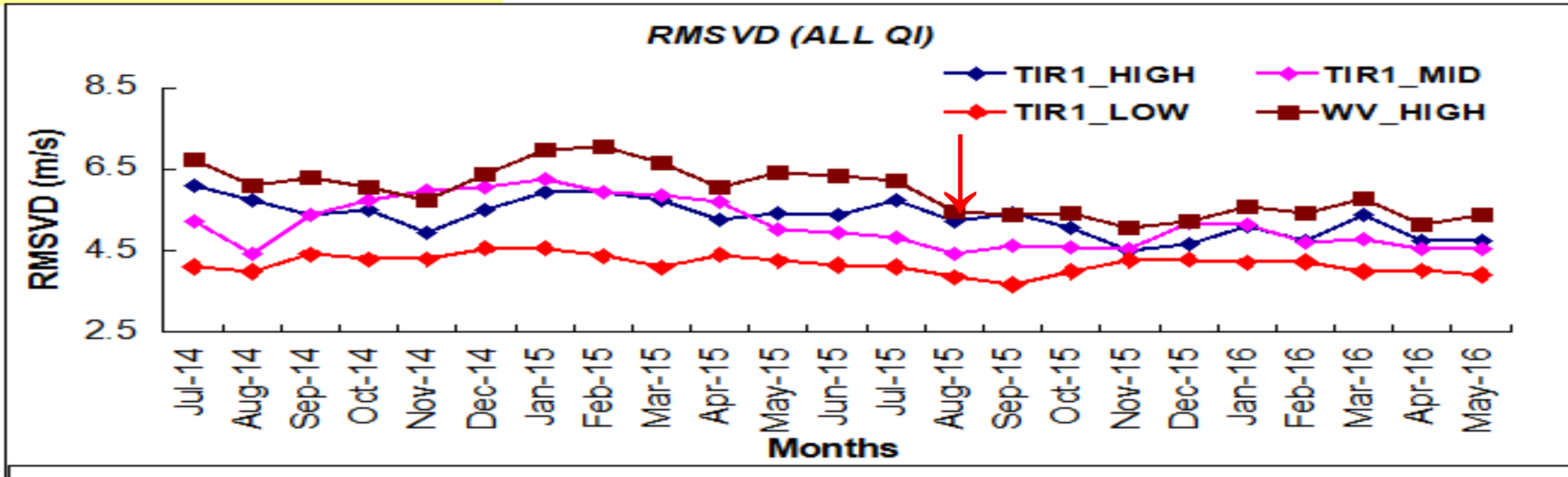
Salient Features of this modification

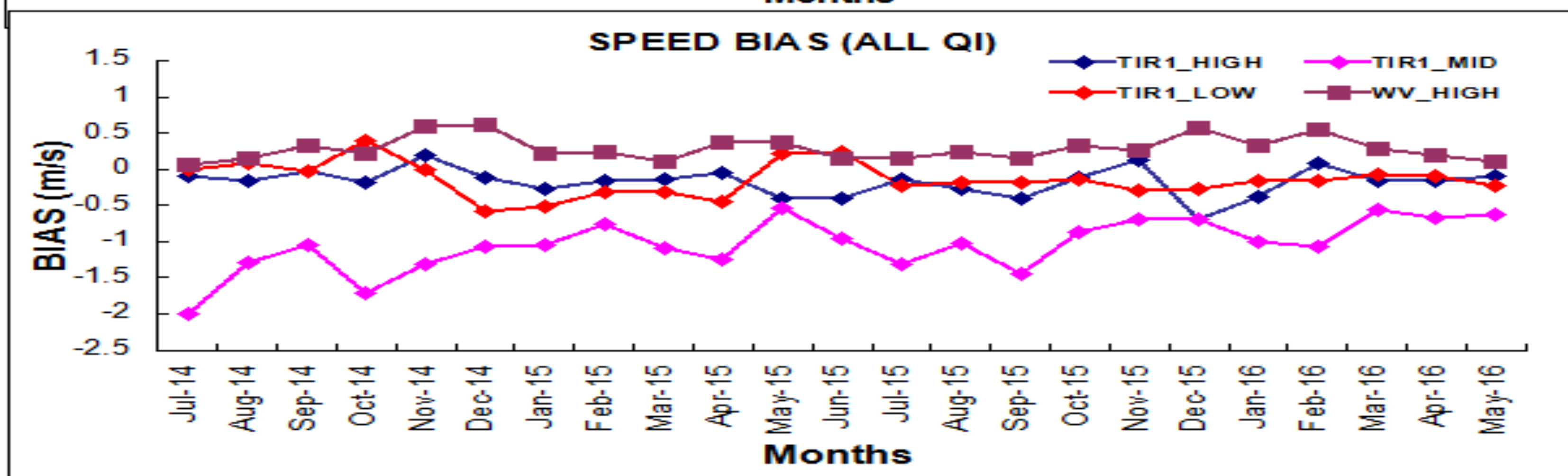
- Utilizes information buffer from past 4-hours for support.
- No thresholds assumed for land/cloud discrimination, making the algorithms more adaptable and dynamic in nature.

Validation results

1. Validation w. r. to Radiosonde: - July 2014 to May 2016
- Insat-3D TIR1 and WV AMVs

a. Temporal comparison



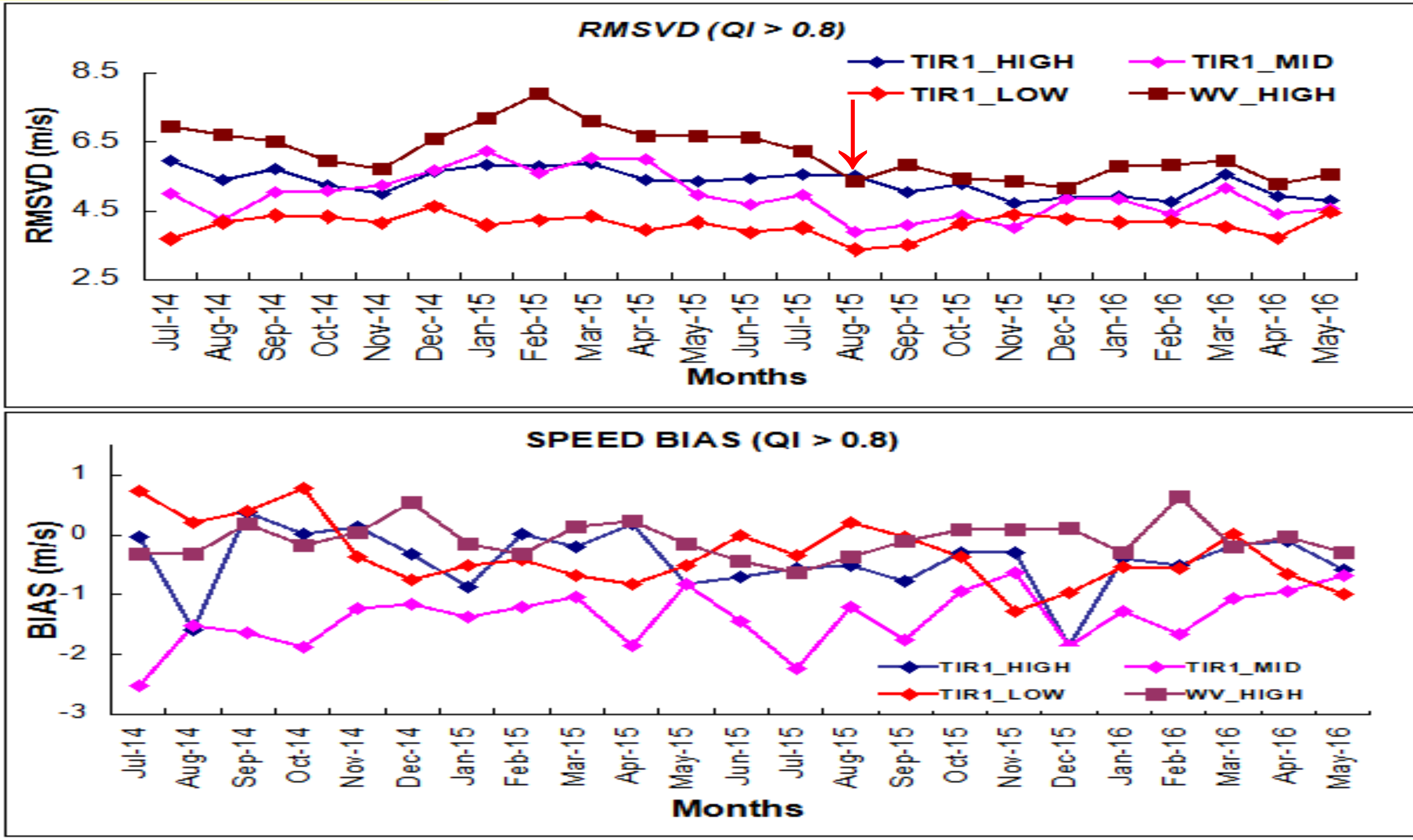


The time series of RMSVD and speed bias of INSAT-3D infrared AMVs for a) High, b) mid and c) Low levels and d) WV AMVs averaged over retrieval domain for from July 2014 to May 2016 two times a day (00 and 12 UTC) when validated with Radiosonde winds.

Validation results

Validation w. r. to Radiosonde: - July 2014 to May 2016
- Insat-3D TIR1 and WV AMVs

a. Temporal comparison



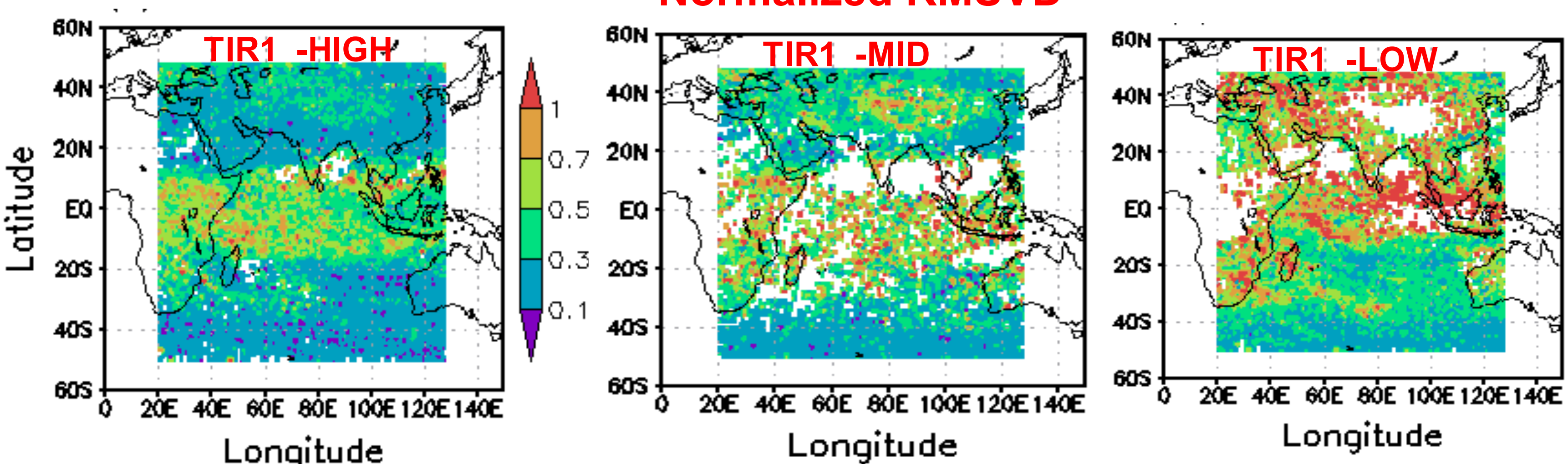
The time series of RMSVD and speed bias of INSAT-3D infrared AMVs for a) High, b) mid and c) Low levels and d) WV AMVs averaged over retrieval domain for from July 2014 to May 2016 two times a day (00 and 12 UTC) when validated with Radiosonde winds.

2. Validation w. r. to model analysis:

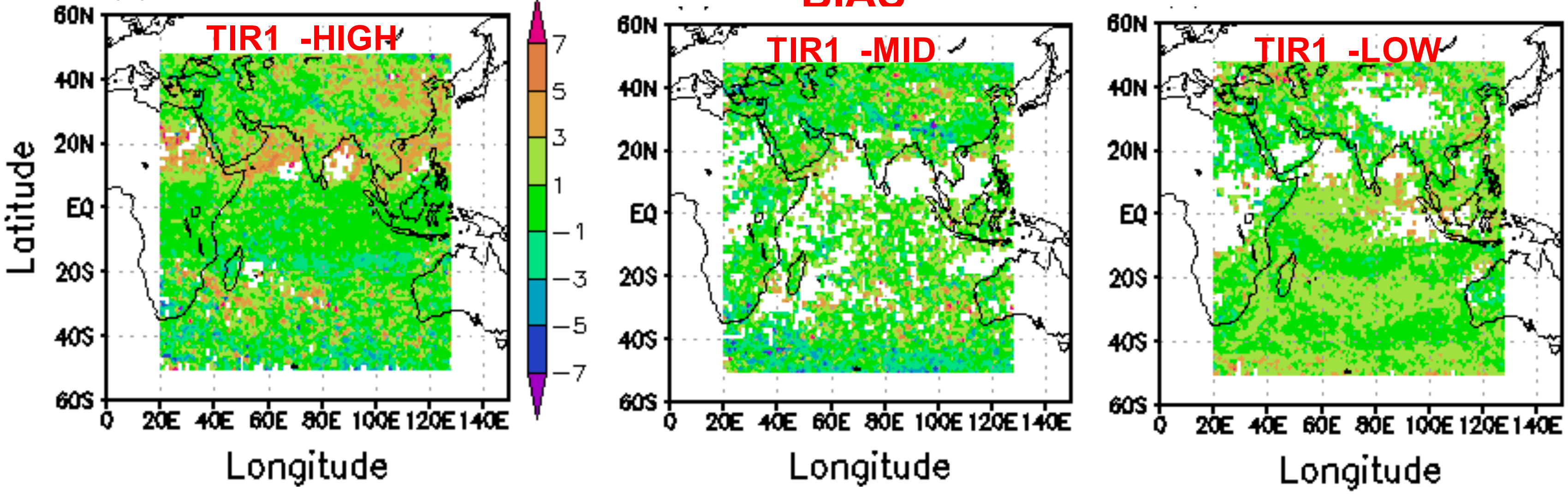
- APRIL 2016
- Insat-3D, TIR1 AMVs

a. Spatial variations

Normalized RMSVD



BIAS



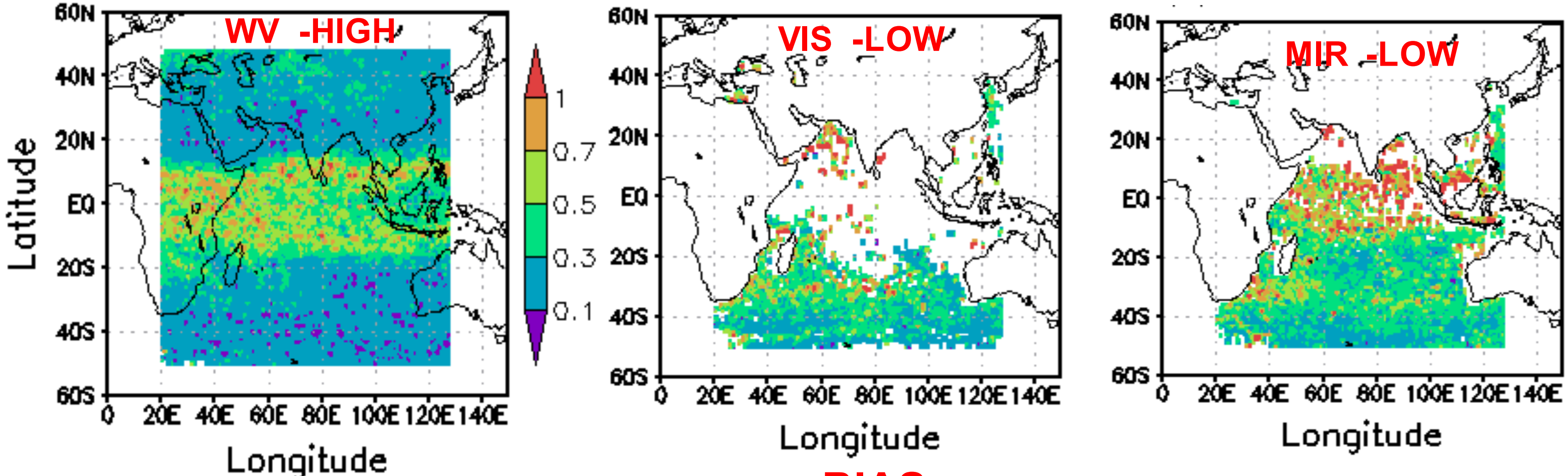
Spatial plots of normalized RMSVD (upper) and speed biases (lower) averaged for April 2016 when TIR1 AMVs from INSAT-3D are collocated with NCEP GFS analysis.

2. Validation w. r. to model analysis: - April 2016

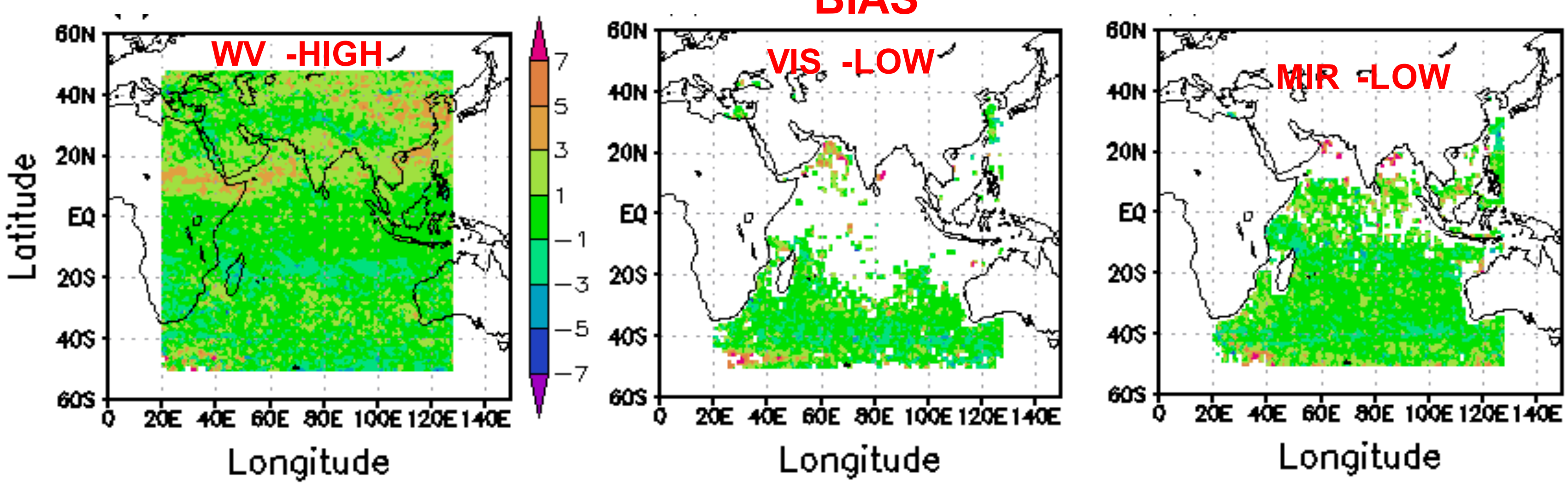
- Insat-3D, WV, VIS, MIR AMVs

a. Spatial variations

Normalized RMSVD



BIAS

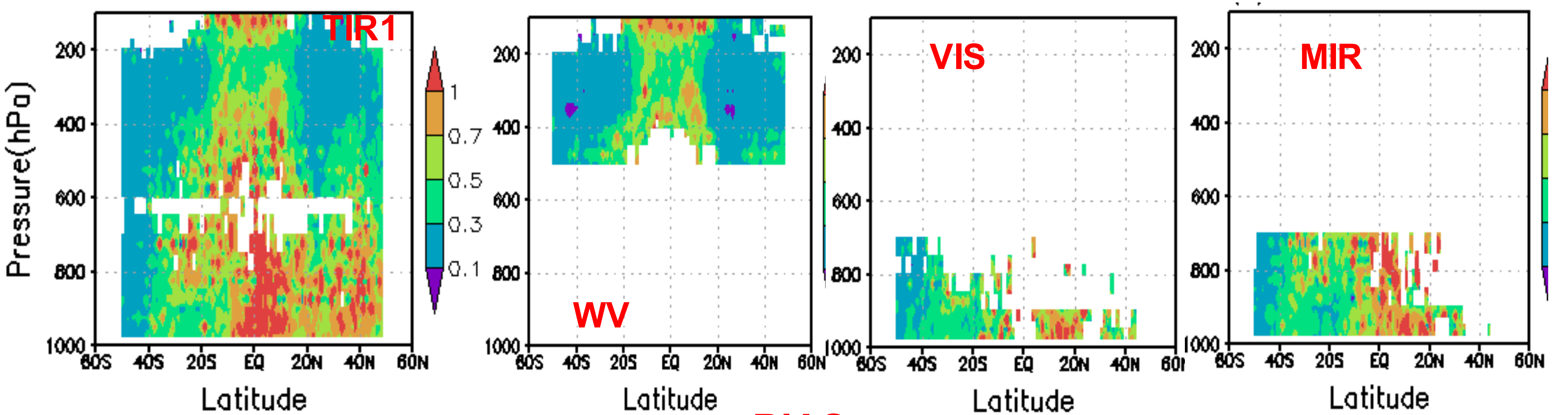


Spatial plots of normalized RMSVD (upper) and speed biases (lower) averaged for April 2016 when WV, VIS and MIR AMVs from INSAT-3D are collocated with NCEP GFS analysis.

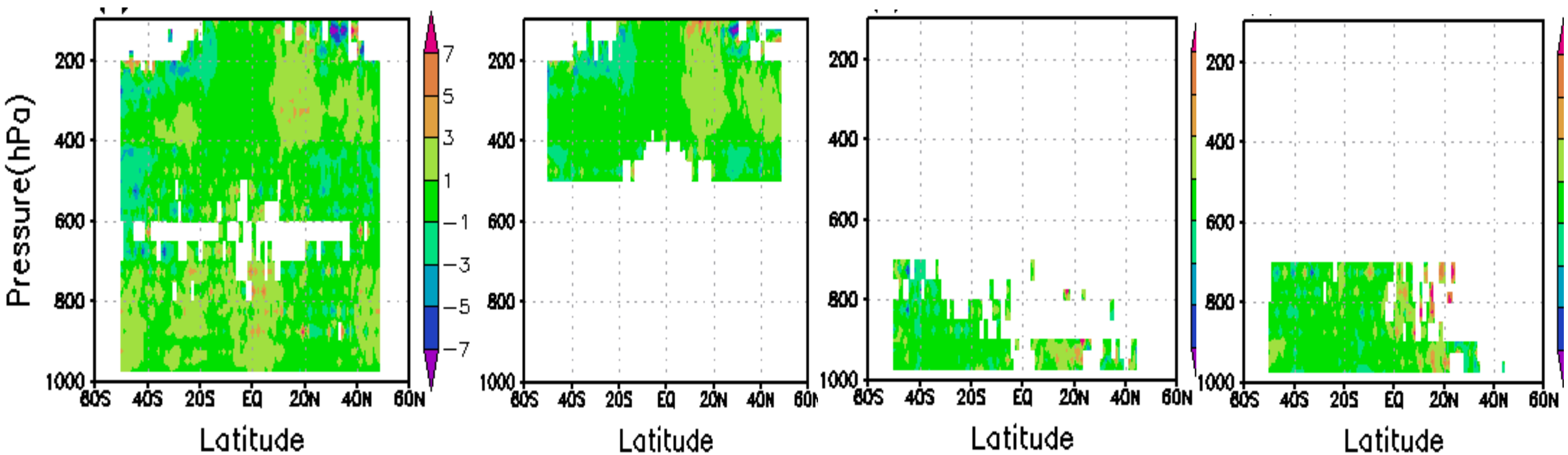
2. Validation w. r. to model analysis:

- April 2016
- Insat-3D, TIR1, WV, VIS, MIR AMVs

Normalized RMSVD



BIAS



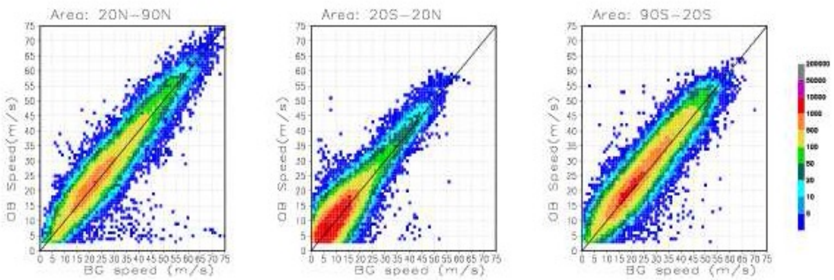
Vertical plots of normalized RMSVD (upper) and speed biases (lower) averaged for April 2016 when TIR!1, WV, VIS and MIR AMVs from INSAT-3D are collocated with NCEP GFS analysis.

INSAT-3D AMV VALIDATION w. r. to model analysis

NCMRWF

Infrared AMV: High Level

INSAT−3D IR(10.8), January 2016, High Level, Above 400 hPa



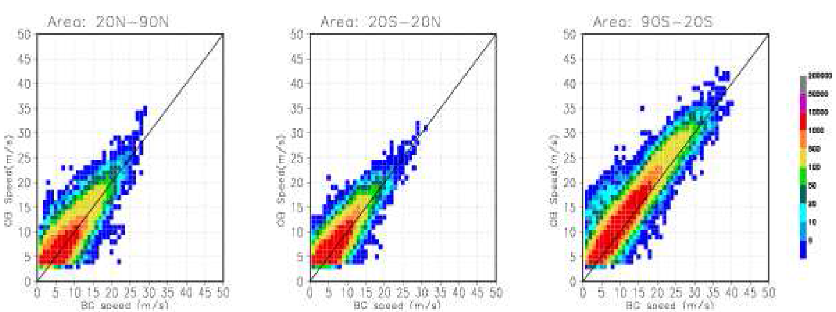
No.of OBS: 176945
Bias : .63
STD : 3.69

No. of OBS: 363000
Bias : .68
STD : 3.49

No. of OBS: 251680
Bias : 1.39
STD : 3.57

Infrared AMV: Low Level

INSAT−3D IR(10.8), January 2016, Low Level, Below 700 hPa



No.of OBS: 173832
Bias : .60
STD : 2.28

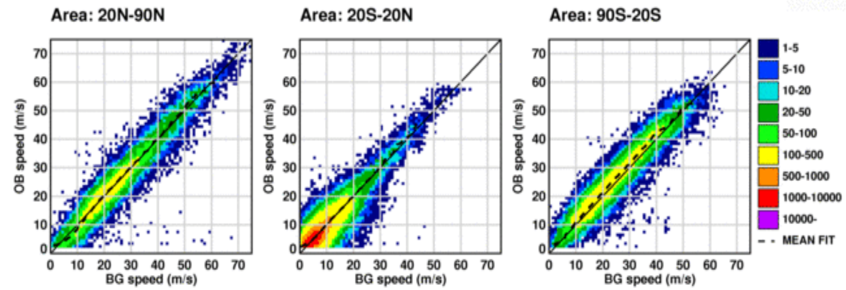
No. of OBS: 181734
Bias : .85
STD : 1.99

No. of OBS: 313829
Bias : 1.57
STD : 1.94

UKMO

Infrared AMV: High Level

INSAT-3d IR, January 2016, Above 400 hPa



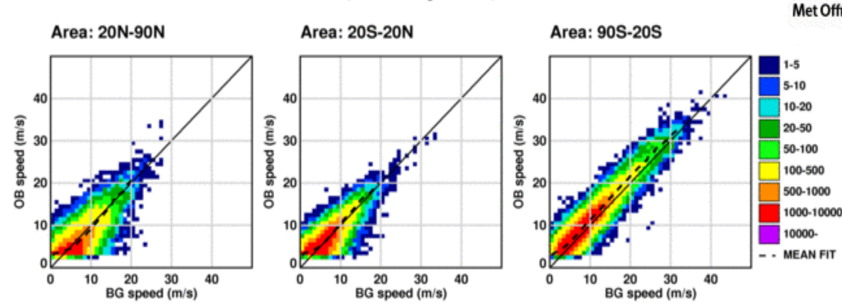
	Plotted	Used
Num:	45638	0 (0%)
Bias:	0.06	-
Stdv:	3.57	-
r:	0.96	

	Plotted	Used
Num:	114179	0 (0%)
Bias:	0.18	-
Stdv:	3.42	-
r:	0.87	

	Plotted	Used
Num:	55716	0 (0%)
Bias:	1.29	-
Stdv:	3.52	-
r:	0.95	

Infrared AMV: Low Level

INSAT-3d IR, January 2016, Below 700 hPa



	Plotted	Used
Num:	74154	0 (0%)
Bias:	-0.24	-
Stdv:	2.65	-
r:	0.73	

	Plotted	Used
Num:	91652	0 (0%)
Bias:	0.44	-
Stdv:	2.17	-
r:	0.76	

	Plotted	Used
Num:	131765	0 (0%)
Bias:	1.28	-
Stdv:	1.94	-
r:	0.93	

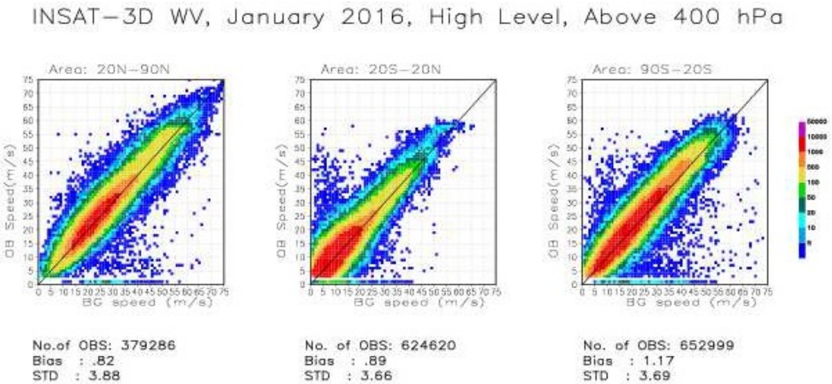
-Thanks to NCMRWF and UKMO

INSAT-3D AMV VALIDATION w. r. to model analysis

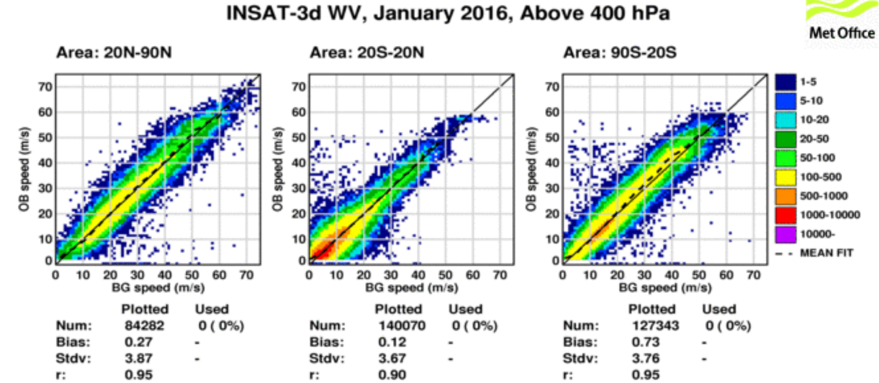
NCMRWF

UKMO

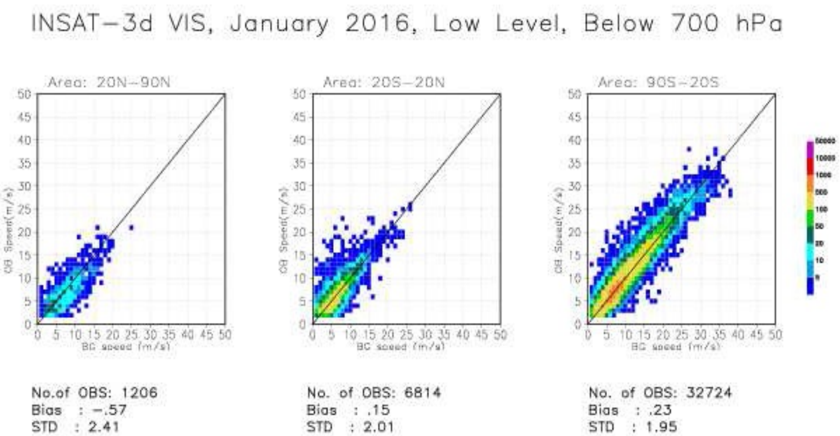
Water Vapor AMV: High Level



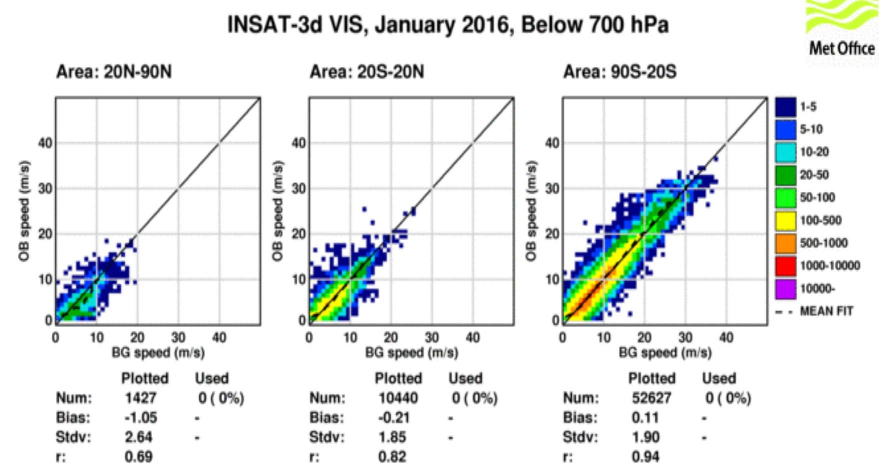
Water Vapor AMV: High Level



Visible AMV: Low Level

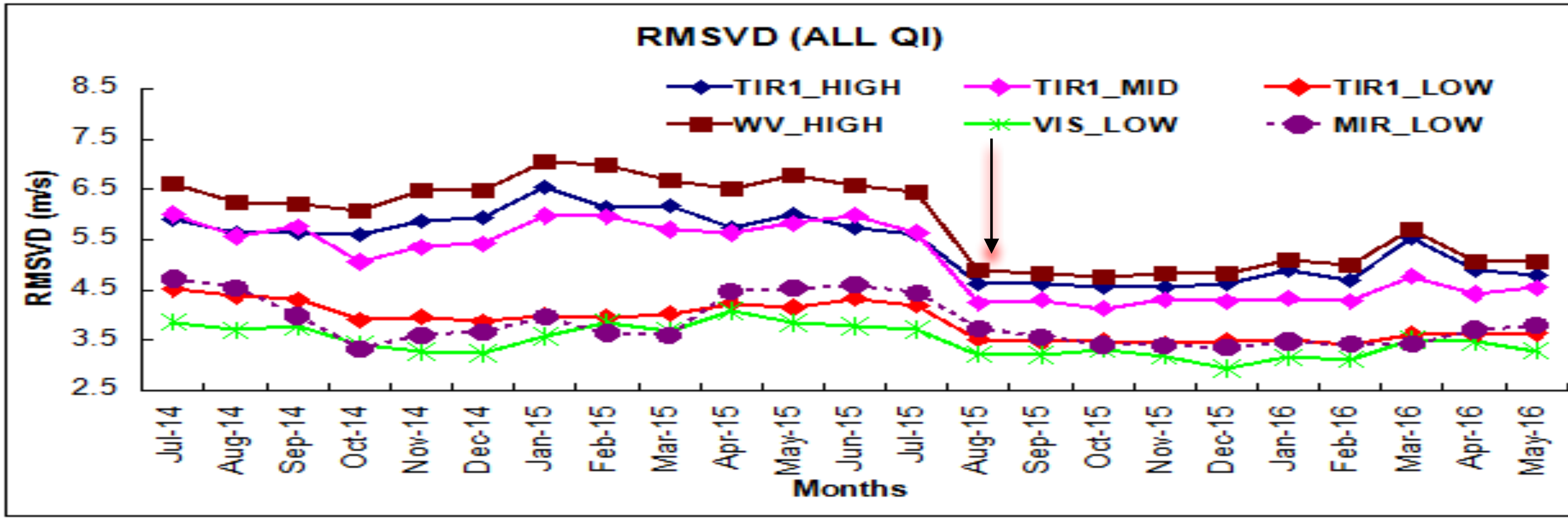


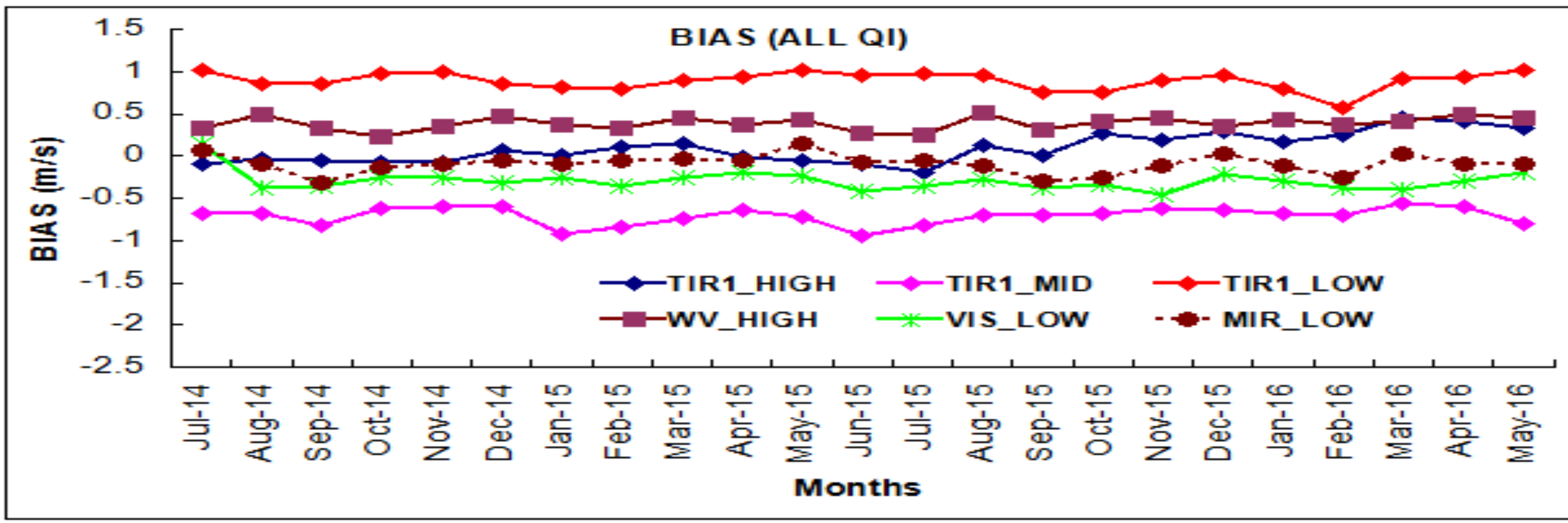
Visible AMV: Low Level



-Thanks to NCMRWF and UKMO

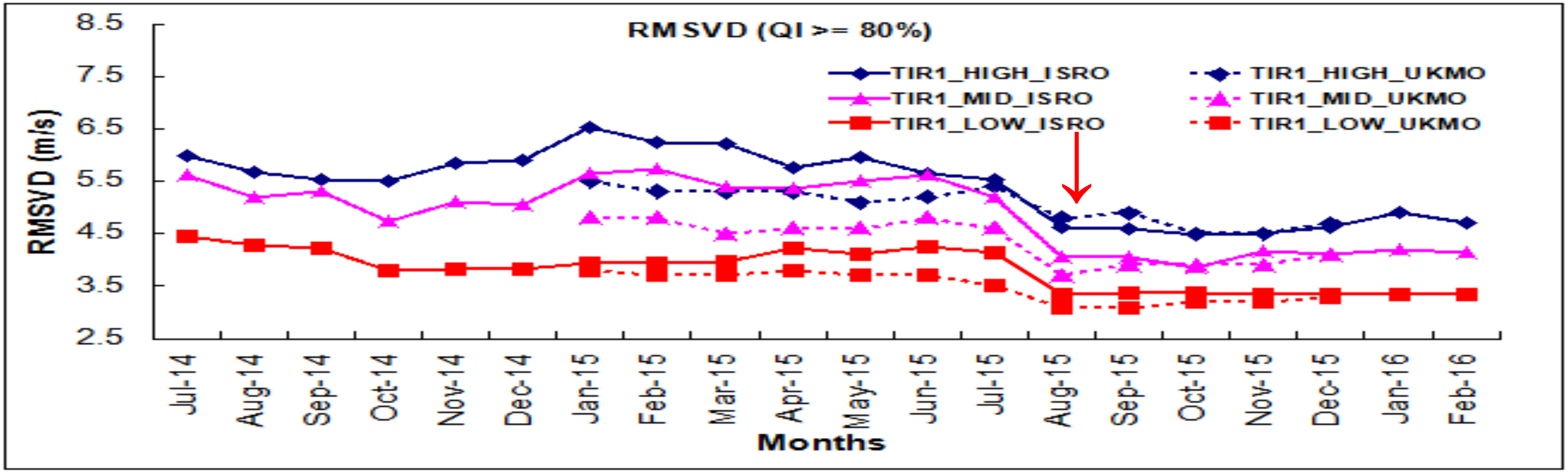
b. Temporal variations

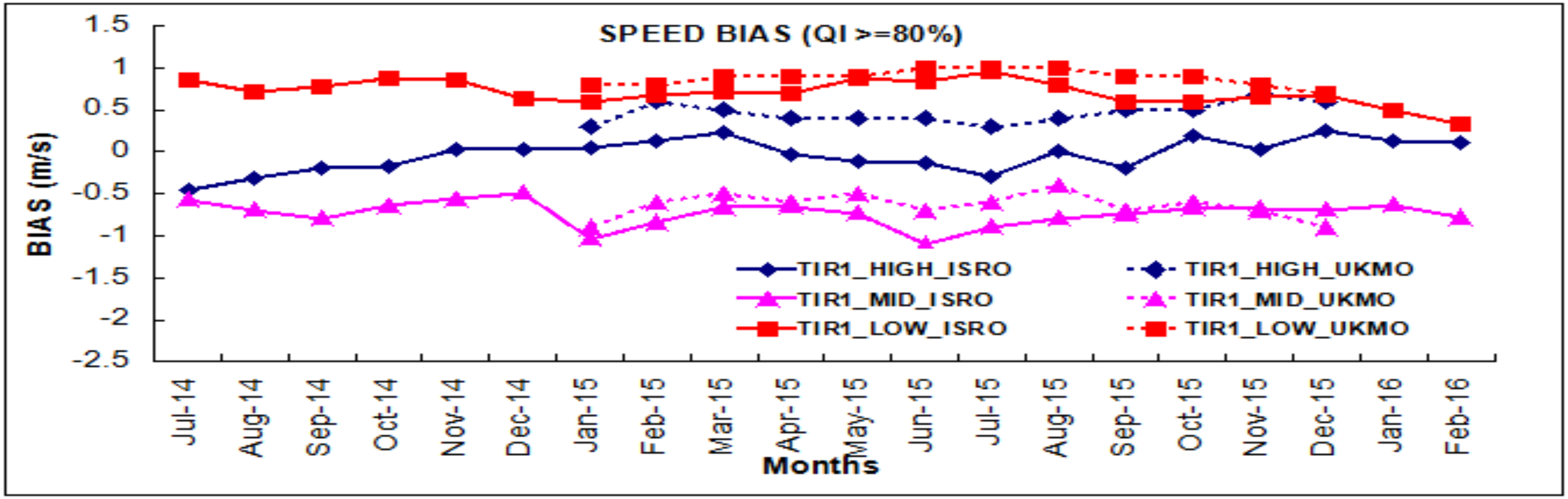




The time series of RMSVD and speed bias of INSAT-3D infrared AMVs for High, mid and Low levels, WV AMVs for High VIS and MIR AMVs for Low levels averaged over retrieval domain taking four times a day (00, 06, 12 and 18 UTC) when validated with NCEP GFS analysis.

C. SAC and UKMO validation comparison:

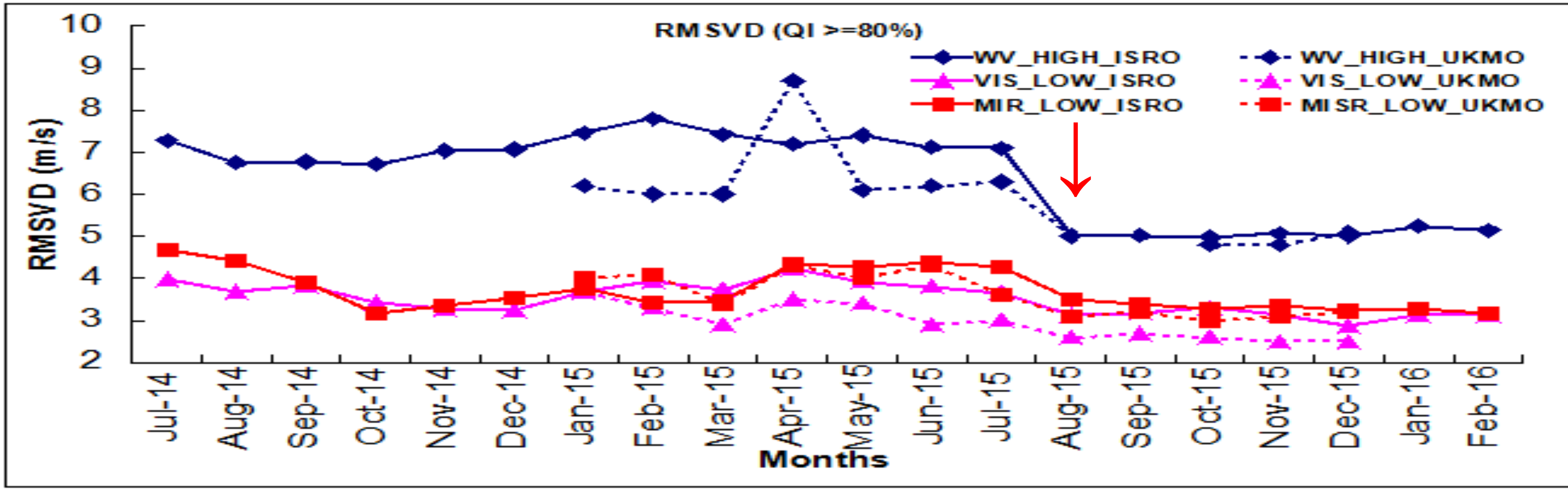


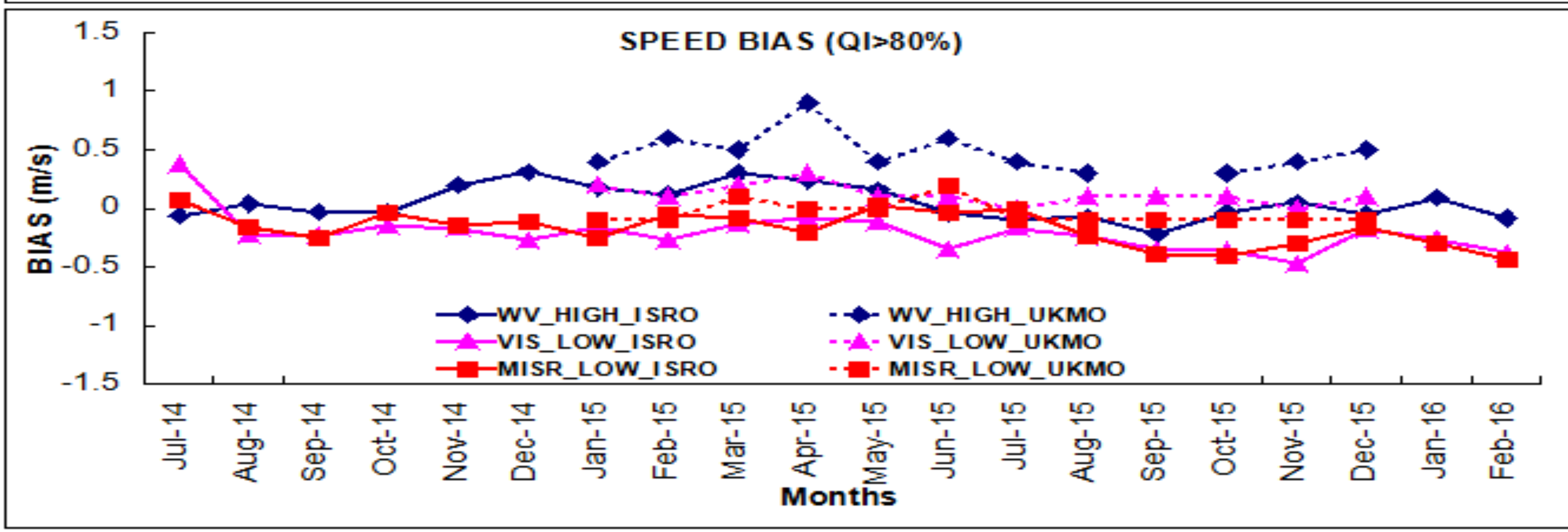


The time series of RMSVD and speed bias of INSAT-3D Infrared AMVs (High, Mid and Low) validated at SAC and UKMO: averaged over retrieval domain for July 2014 to December 2015 taking four times a day (00, 06, 12 and 18 UTC) when validated with model analysis.

-Thanks to UKMO

C. SAC and UKMO validation comparison:



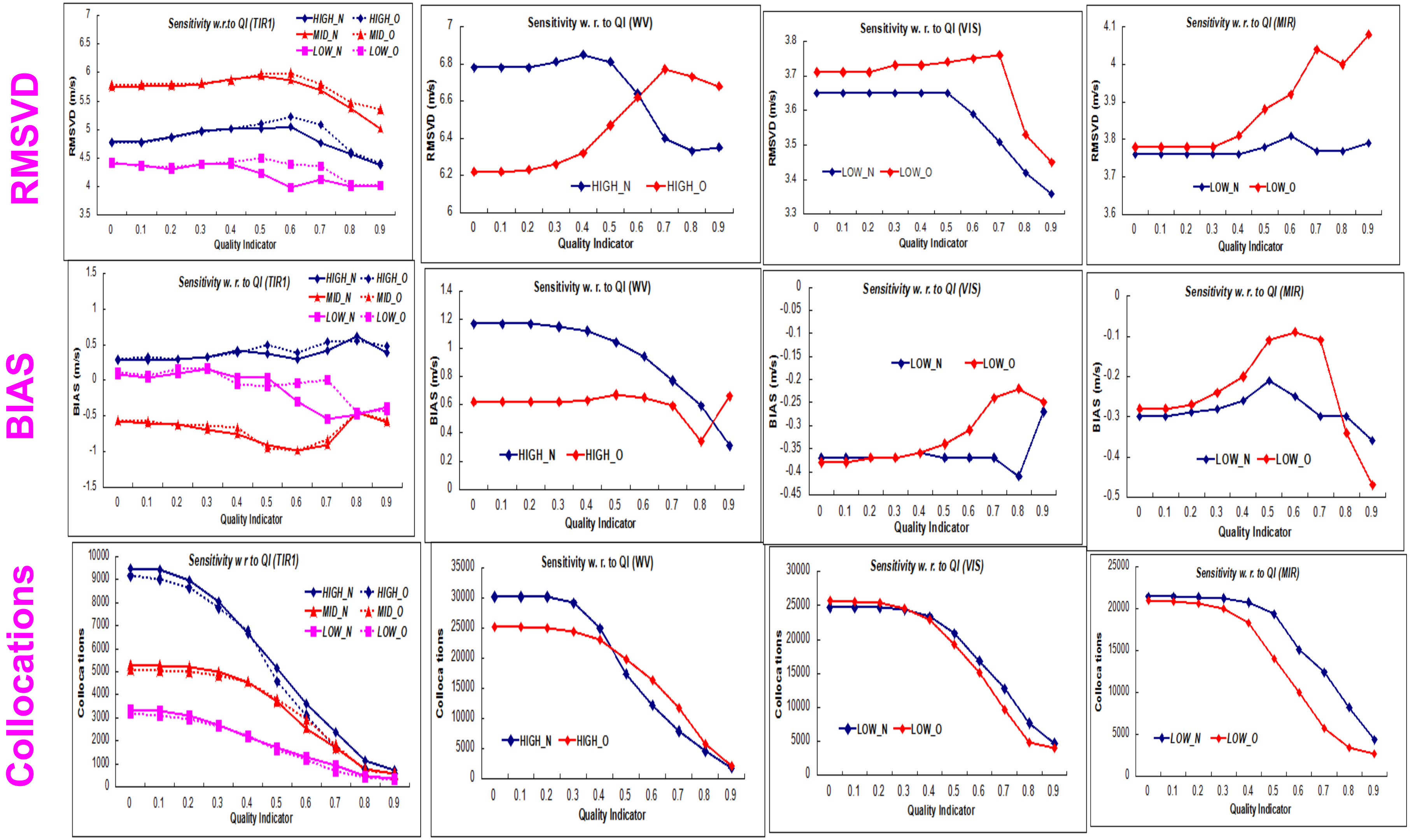


The time series of RMSVD and speed bias of INSAT-3D WV (High), VIS and MIR (Low-levels) AMVs validated at SAC and UKMO: averaged over retrieval domain for July 2014 to December 2015 taking four times a day (00, 06, 12 and 18 UTC) when validated with model analysis.

-Thanks to UKMO

Recent changes in Quality Indicator parameters

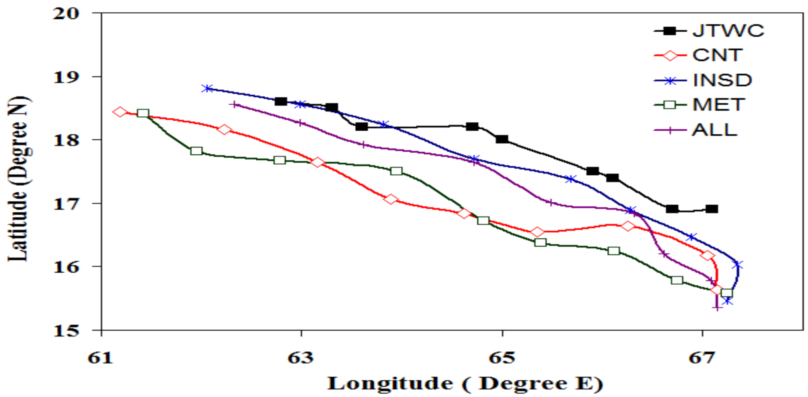
DATA Used: INSAT-3D TIR1, WV, VIS and MIR AMVs November 2015



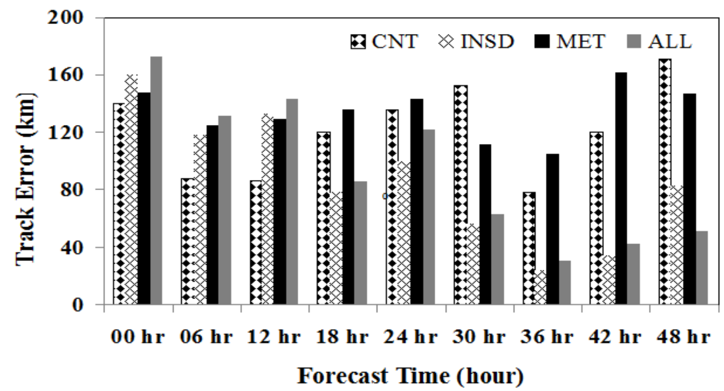
The RMSVD , speed bias and collocations of INSAT-3D TIR1 AMVs (High, Mid and Low levels) , WV (High), VIS (Low) and MIR (Low) against different Quality control values for the operational and new modified version averaged over retrieval domain for November 2015 taking two times a day (00 and 12 UTC) when validated with radiosonde winds.

NWP applications

a. Impact on track forecast of cyclonic storm NANAUK - Using WRF model



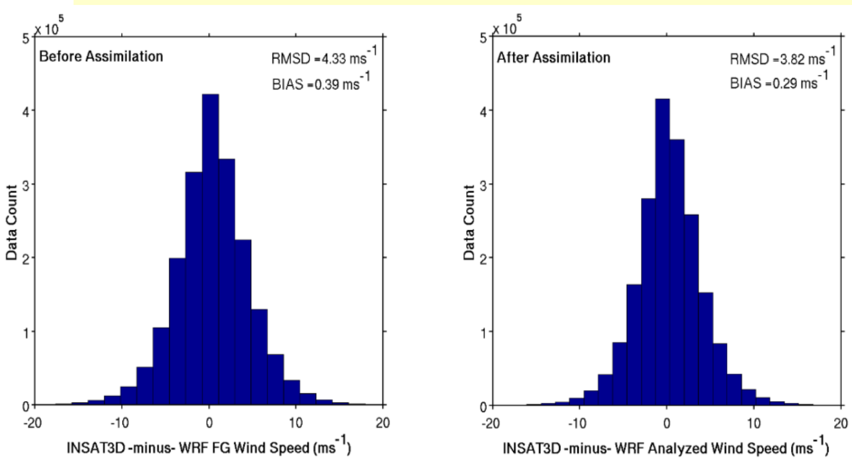
JTWC observed track along with forecasted track of cyclonic storm NANAUK from the control and different assimilation experiments.



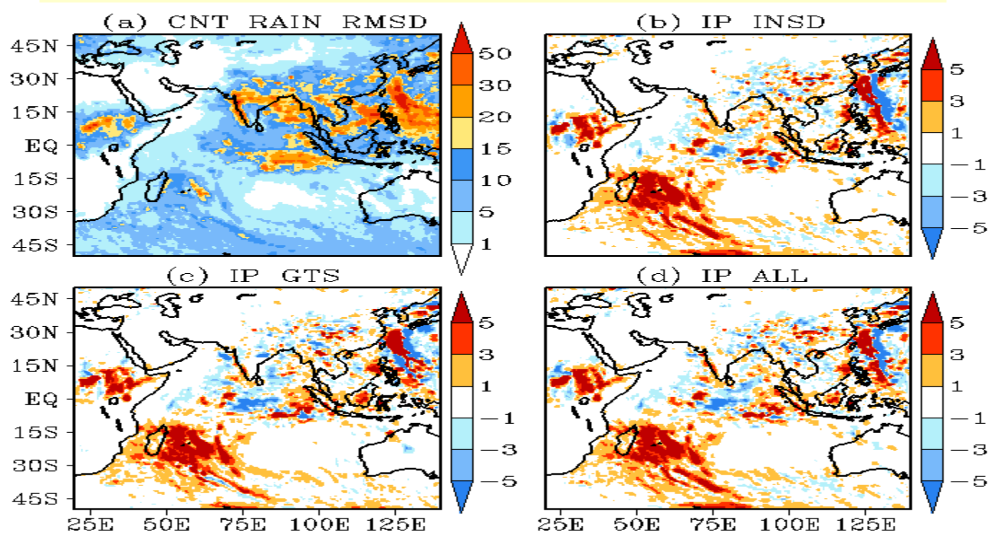
Track forecast errors in km for different forecast lengths From the control and assimilation experiments.

b. Impact of INSAT-3D AMV on WRF Model Prediction for summer monsoon July 2014

Histogram of First Guess and Analysis Departure during July 2014



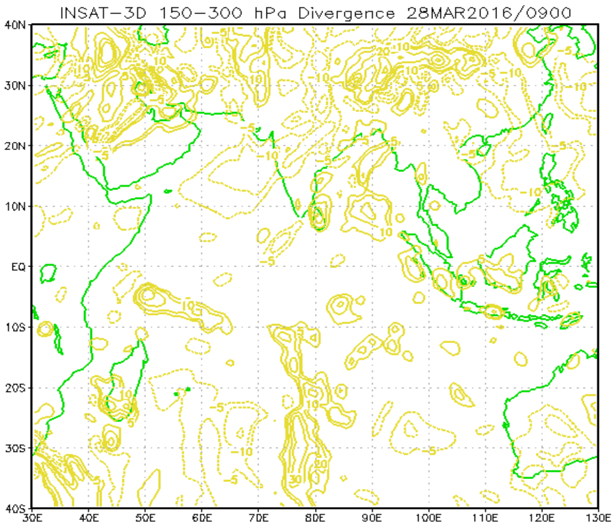
Impact of INSAT-3D AMVs on Rainfall Forecast

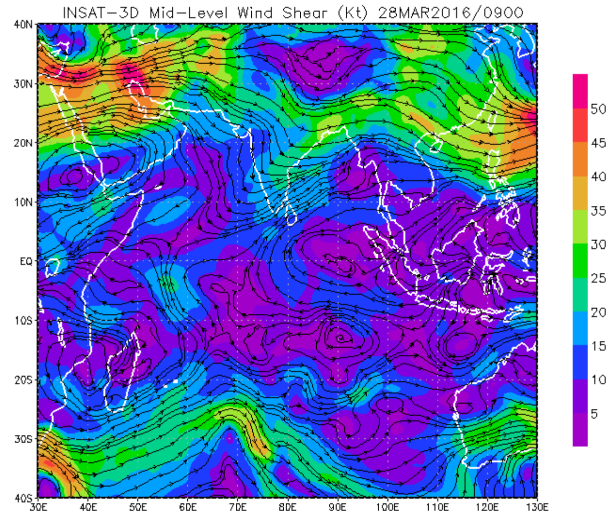


Derived products from INSAT-3D AMVs

28 March 2016 0900 UTC

Upper level divergence

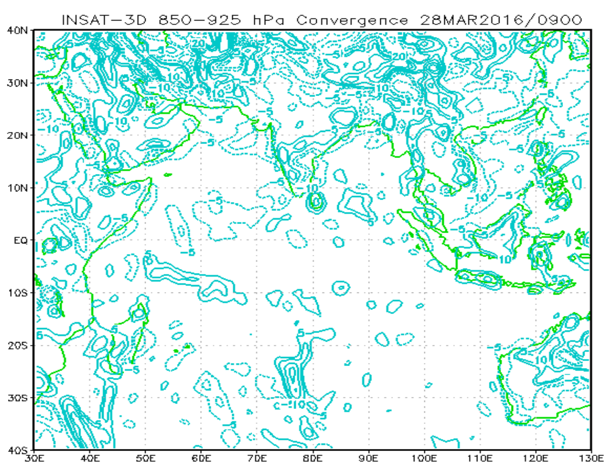


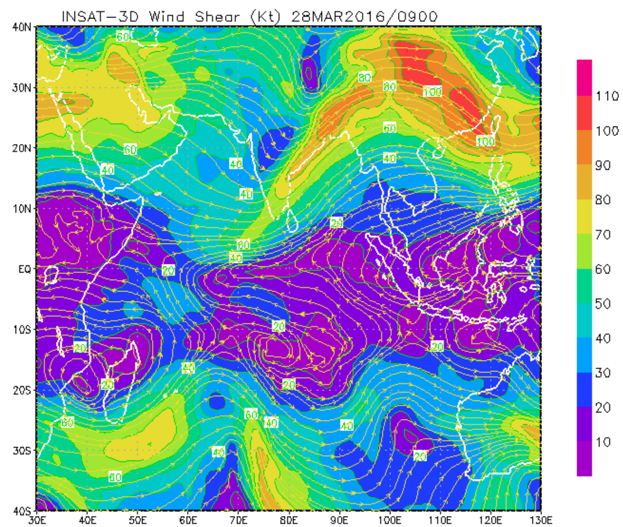


Mid-level Wind Shear:

Wind speed difference between mid (400-600hPa) and lower (700-925 hPa) levels (Shaded).

Lower level convergence





Wind Shear:

Wind speed difference between upper (100-300hPa) and lower (700-925 hPa) levels (Shaded).

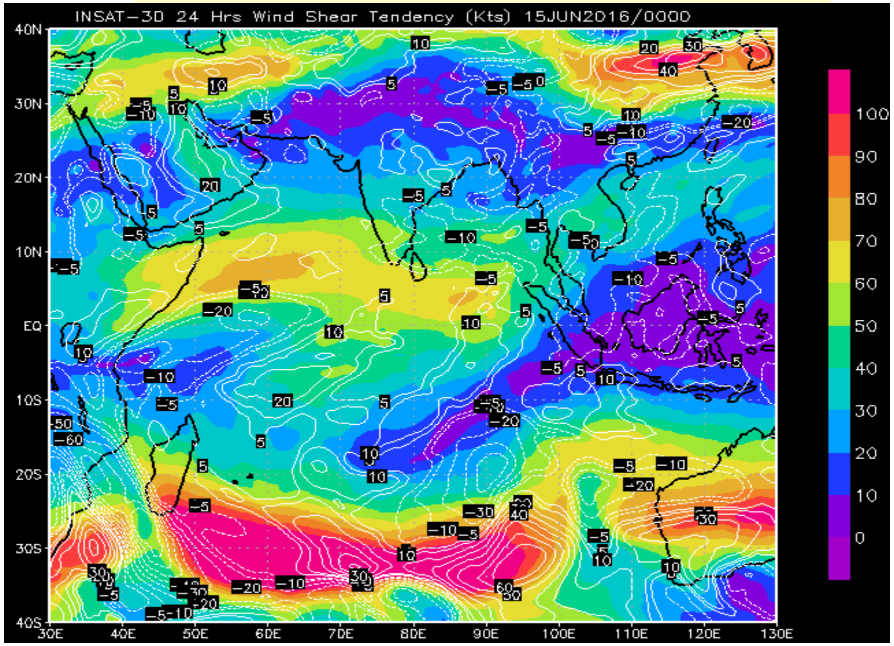
24 Hr Atmospheric shear tendency

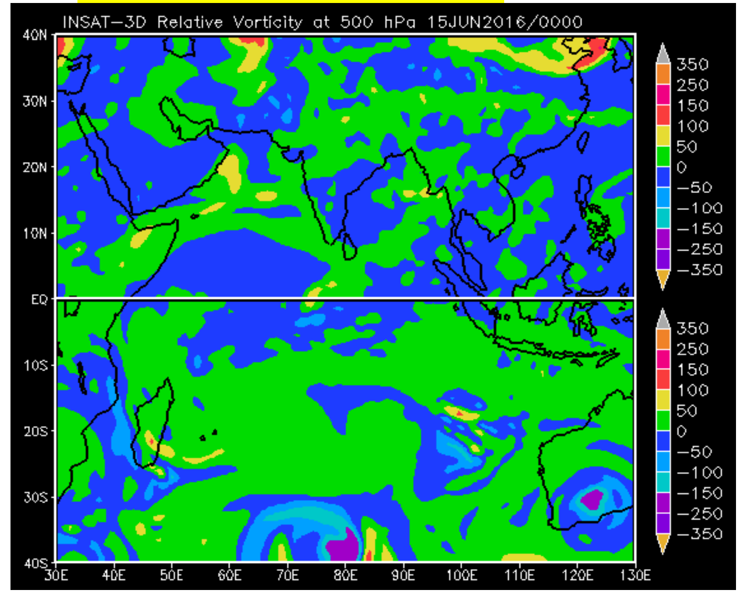
The change in deep-layer wind shear over 24 four hours is plotted with the line contours

15 June 2016 0000 UTC

Relative vorticity

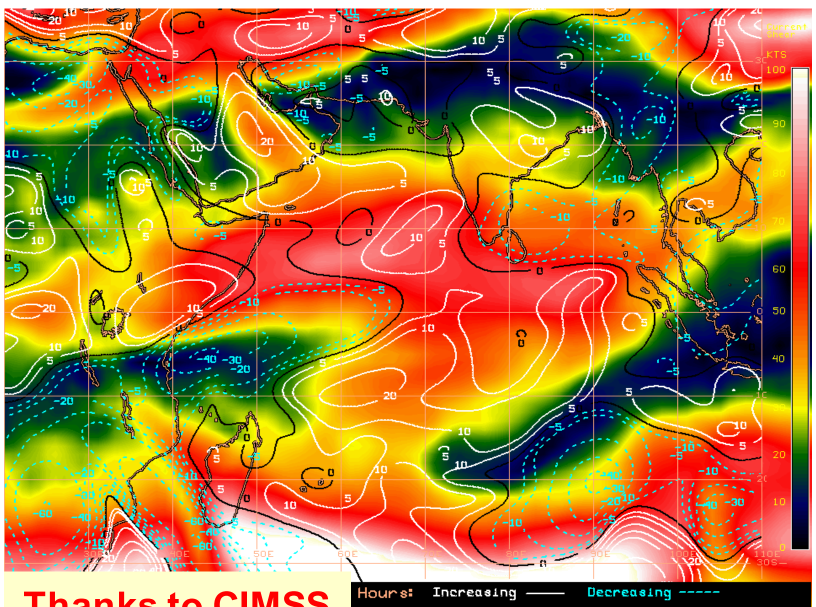
INSAT 3D



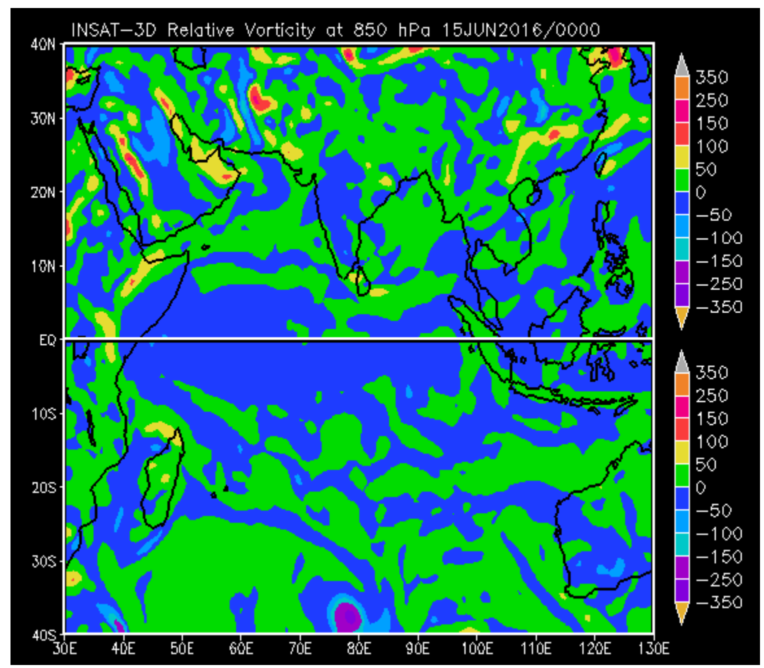


500 hPa

Meteosat 7



Thanks to CIMSS



850 hPa

Algorithm development for synergistic use of INSAT-3D and INSAT-3DR data in staggering mode

Proto-type algorithm: INSAT-3D TIR1 and KALPANA-1 Infrared images
NOVEMBER 2015

INSAT-3D: AMV at 1200 UTC

0800, 0830, 0900, 0930
1000, 1030, 1100, 1130
1200

4 Km images are re-sampled to 8 KM

KALPANA-1: AMV at 1215 UTC

0815, 0845, 0915, 0945
1015, 1045, 1115, 1145
1215

Original 8 Km resolution image

In staggering mode: AMV at 1215 UTC

1015, 1030, 1045, 1100
1115, 1130, 1145, 1200
1215

Both K1 and 3D images are in 8 Km

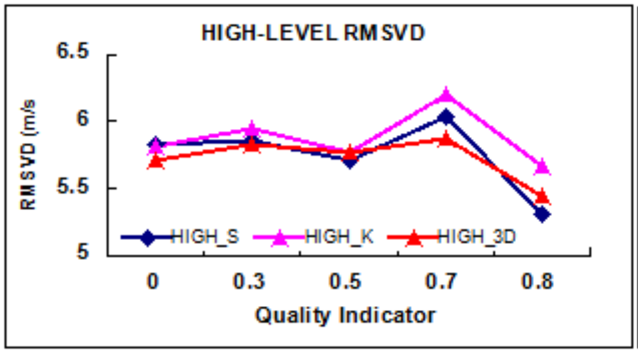
In staggering mode: **1. Before tracer selection and tracking Kalpana-1 images are calibrated using INSAT-3D**

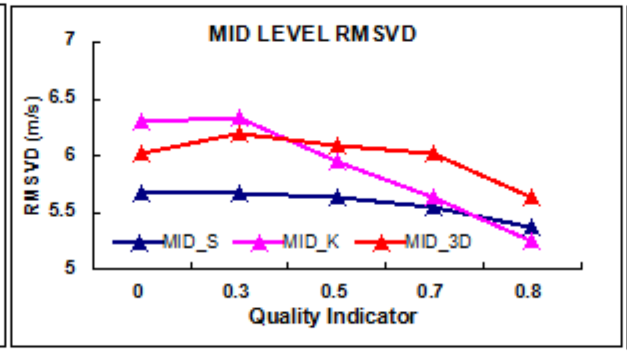
2. Height Assignment is done using INSAT-3D images

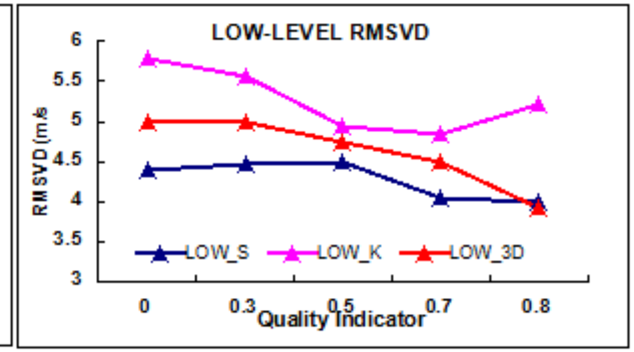
Offline AMVs retrieved: 0000 & 1200 UTC for INSAT-3D
(Total 53 Files) 0015 & 1215 UTC for Kalpana-1
0015 & 1215 UTC for staggering mode

Validation with RS Winds : 0000 & 1200 UTC

Root mean square vector differences (RMSVD)



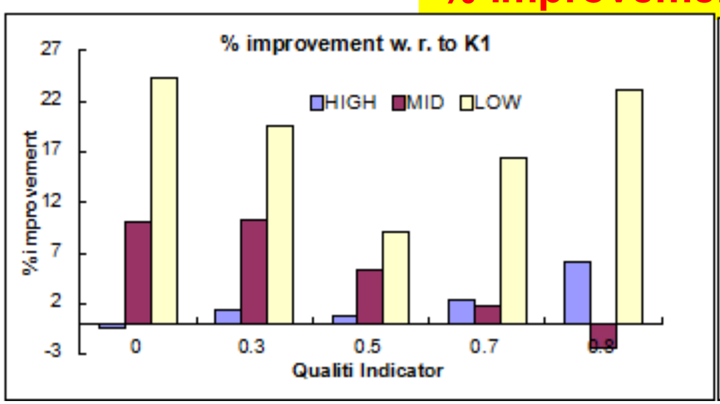


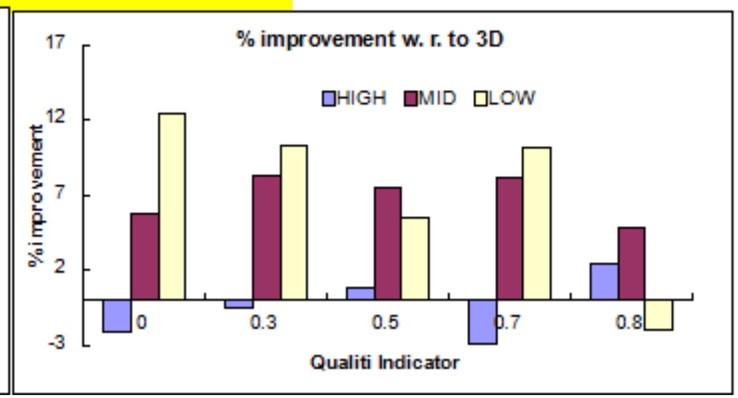


HIGH: 100 - 400 hPa **MID: 401-700 hPa** **LOW: 701 - 950 hPa**

% improvement in RMSVD

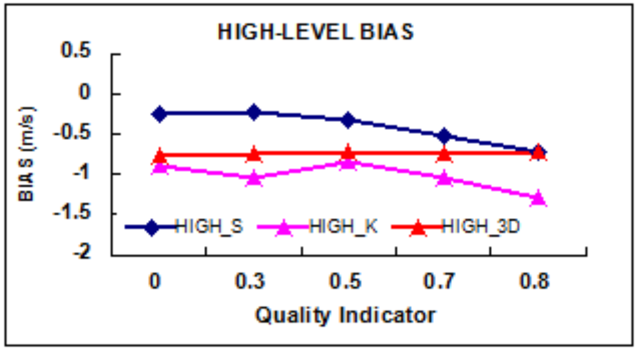
With r. to K1 together: 8.5%

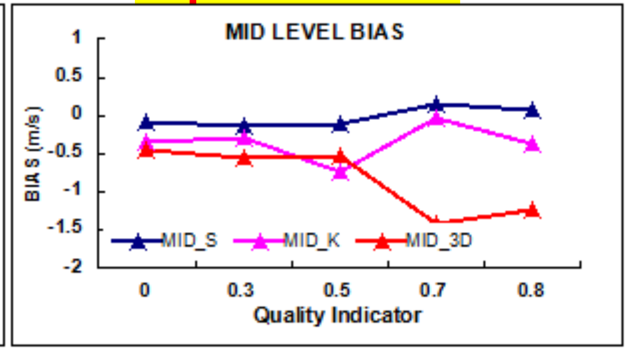


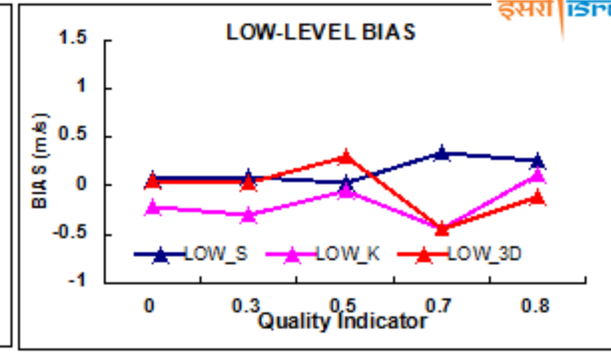


With r. to 3D together: 4.6%

Speed BIAS





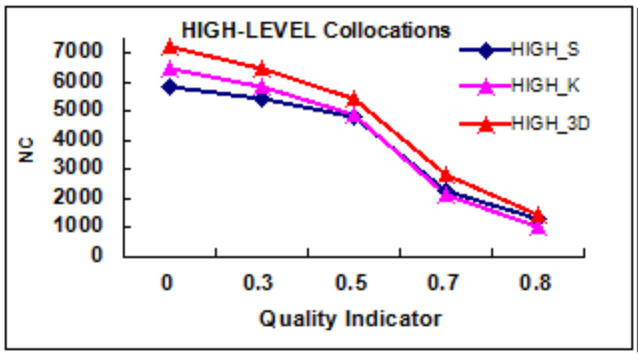


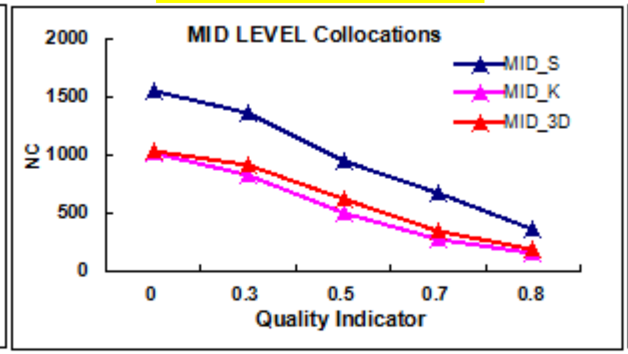
HIGH: 100 - 400 hPa

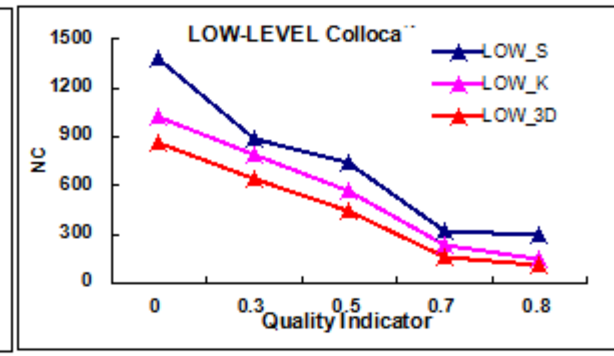
MID: 401-700 hPa

LOW: 701 - 950 hPa

Collocations





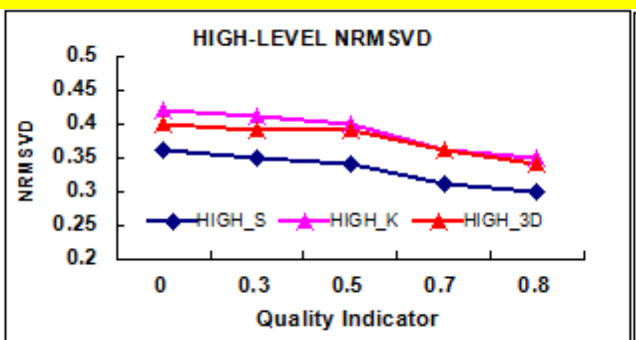


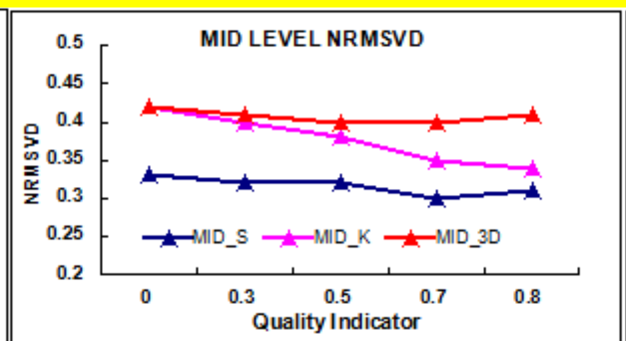
HIGH: 100 - 400 hPa

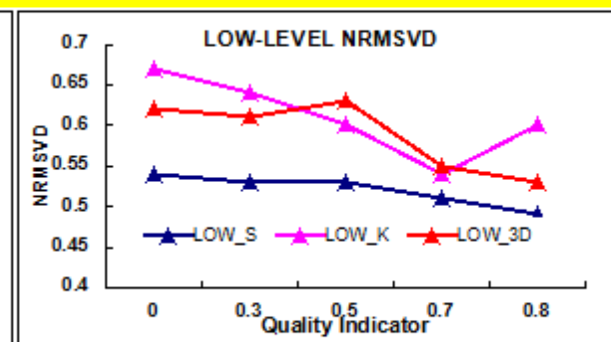
MID: 401-700 hPa

LOW: 701 - 950 hPa

Normalized Root mean square vector differences (NRMSVD): with mean RS winds







HIGH: 100 - 400 hPa

MID: 401-700 hPa

LOW: 701 - 950 hPa

HIGHLIGHTS

- *INSAT-3D AMVs are now assimilated in IMD's global and regional operational models.*
- *Daily monitoring and assimilation of INSAT-3D AMVs are being started in NCMRWF operational models since September 2014.*
- *Regular operational monitoring of INSAT-3D AMVs are being started at UKMO from January 2015.*
- *Algorithm for AMV derived products is operational at IMD Delhi. It will further enhance the monitoring of tropical cyclones over Indian ocean.*
- *Recently, slight improvement in accuracies is achieved due to fine tuning of quality indicator (QI) parameters in the algorithm.*

EUMETSAT/UKMO Requirement

1. Separation of clear sky and cloudy winds in Water Vapour AMVs
2. Retrieval of AMVs using full-disc images.

Concluding remarks

1. **The accuracy of INSAT 3D AMVs are stable for the last two year.**

2. **As the operational lifespan of either Kalpana-1 or Meteosat 7 is going to end any time soon, the newly derived AMVs from *INSAT 3D* can be used as suitable substitutes for the presently available AMVs derived using the data from the older satellites**.

3. **The availability MIR channel in *INSAT 3D* has also enhanced the quality of night-time low-level AMVs, which is not possible with other available satellites Kalpana 1 or Meteosat 7 over this region.**

4. **With limited impact studies, it is observed that assimilation of *INSAT 3D* AMVs has improved the cyclone track forecast for different forecast lengths and also have some positive impact for July 2014 monsoon experiments.**

5. **As the operational derivational procedure of *INSAT 3D* AMVs evolves over time, assessing the impact of these winds will require continuous evaluation.**

6. **With proposed launch of INSAT 3DR in 2016, the synergistic use of 3D and 3DR data will further enhance the quality of AMVs over Indian Ocean.**

7. **Launch of GISAT-1 in 2017/2018 will also improve the quality of AMVs over IO.**

References:

1. S. K. Deb, C. M. Kishtawal, Prashant Kumar, A. S. Kiran Kumar, P. K. Pal, Nitesh Kaushik and Ghansham Sangar, "Atmospheric Motion Vectors from *INSAT-3D*: Initial Quality Assessment and its impact on track forecast of cyclonic storm NANAUK", 2016, ***Atmos. Research***. 169:1-16

2. Prashant Kumar, S. K. Deb, C. M. Kishtawal and P. K. Pal, "Impact of INSAT-3D Retrieved Atmospheric Motion Vectors on Weather Research and Forecasting Model Predictions over the South Asia Regions.',2016, ***Theor. Appl. Clim***. Published online 13 January 2016

Acknowledgement:

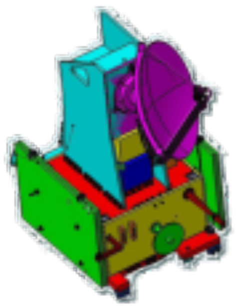
- **IWWG and WMO for financial support for attending 13th IWW**
- **13th IWW organizing committee for all support.**
- **Director SAC/ISRO and Chairman ISRO for all support.**
- **EUMETSAT/CIMSS/UKMO for using their AMV products and analysis report.**

???

THANKS

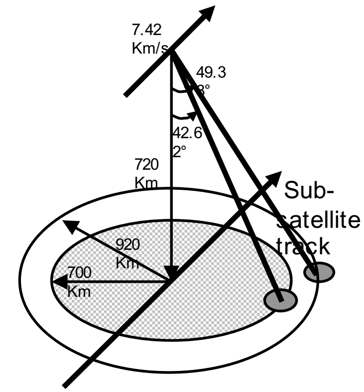
FUTURE LEO SATELLITES: (SCATSAT-1)

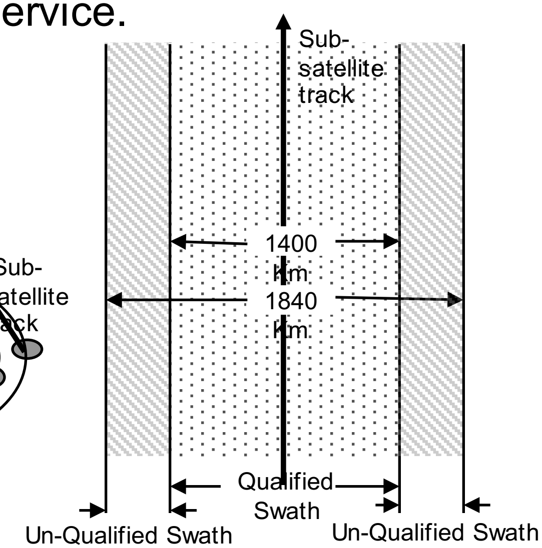
SCATSAT-1 is planned as an in-orbit replacement for the Scatterometer carried onboard Oceansat-2, which is non-functional after 4 ½ years of service.



Orbit : 720 km in sun-synchronous

LAUNCH: End 2016





- IMS-2 Bus
- Ku-Band (13.515 GHz) Pencil beam Scatterometer
- Ground resolution: 50 km x 50 km
- Swath: 1440 Km
- Polarization: HH and VV
- Wind Direction: O to 360 deg with accuracy of 20 deg
- Wind Speed: 4 to 24 m/s with accuracy of 10% or 2m/s

Objectives:

- To provide global wind vector data for national and international user Community.
- To provide continuity of weather forecasting services to the user communities.
- To generate wind vector products for weather forecasting, cyclone detection and tracking.

Some upgradation in L1B data product software (Aug-2015)
- to improve the data quality

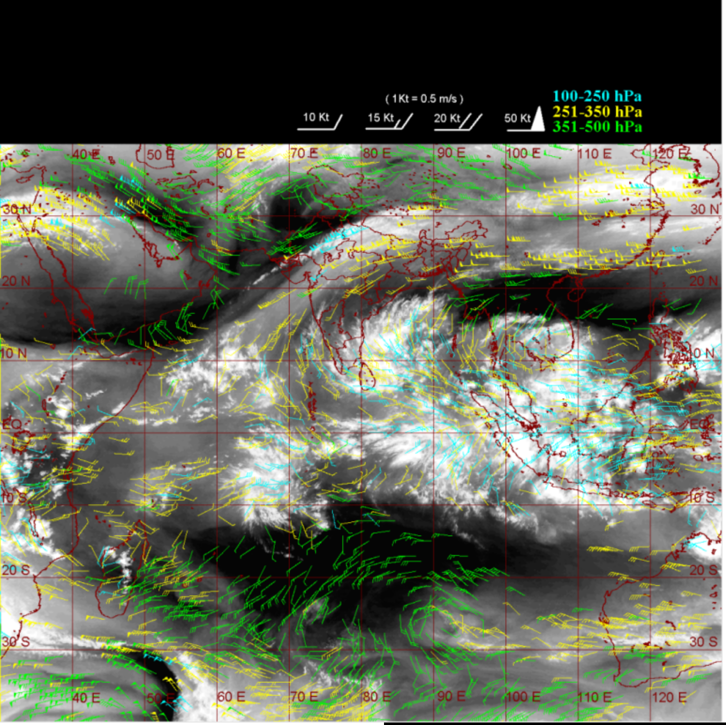
- Increasing the number of GCPs and automatic template based registration for better accuracy.
- To achieve sub-pixel shift measurement, phase correction and gradient based methodologies were used.
- Operationalization of GSICS calibrated radiances.

Identification of clear-sky winds from Water Vapour AMVs

November 2015

	Cloudy WV	Clear-sky WV	Mixed WV
RMSVD	6.56	4.93	6.43
BIAS	-0.40	-0.46	-0.41
NC	18413	2219	20632

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
RMSVD	6.43	6.43	6.43	6.48	6.55	6.48	6.21	6.10	6.05
BIAS	-0.41	-0.41	-0.41	-0.44	-0.45	-0.42	-0.48	-0.65	-0.85
NC	20632	20632	20621	19711	16512	11417	8047	5282	3143

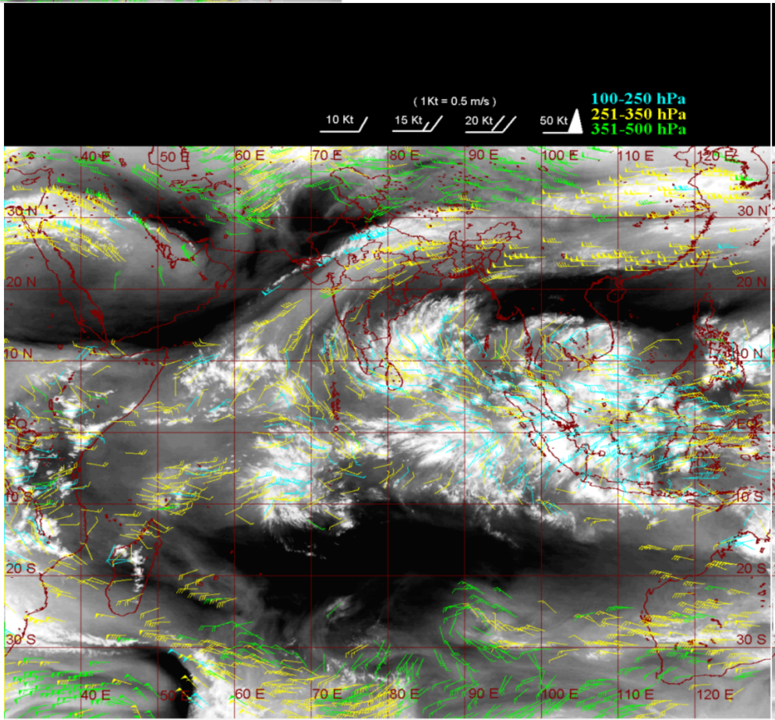


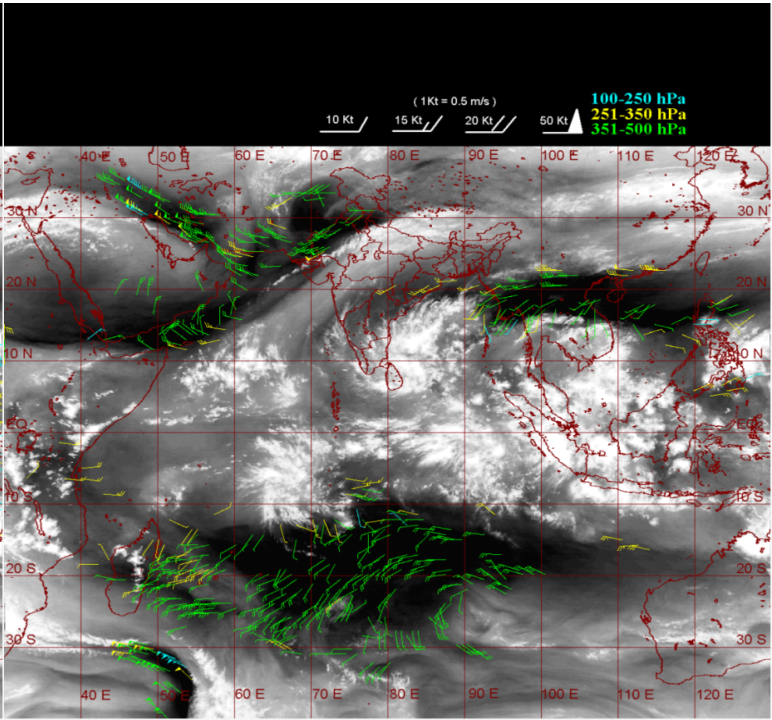
28NOV2015_1200

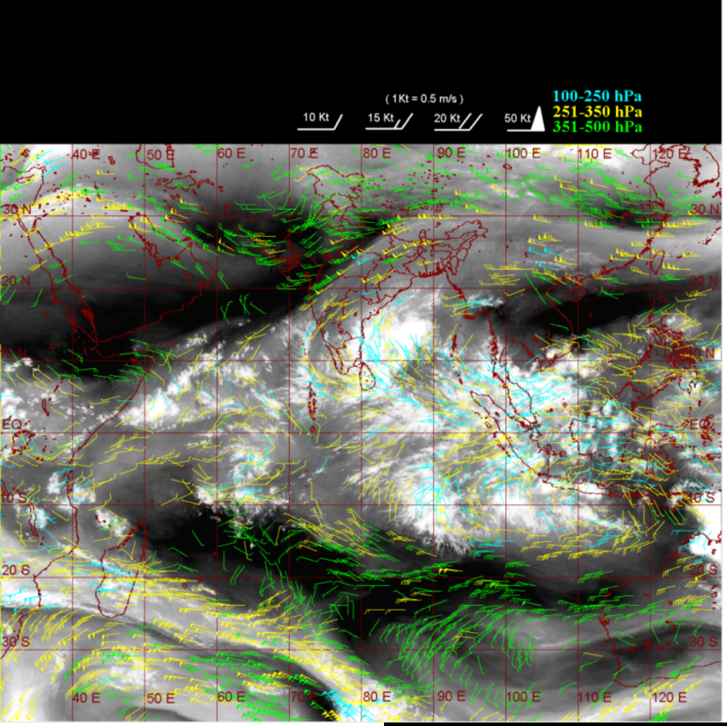
NC - 7289

CL - 6028

CS - 1261





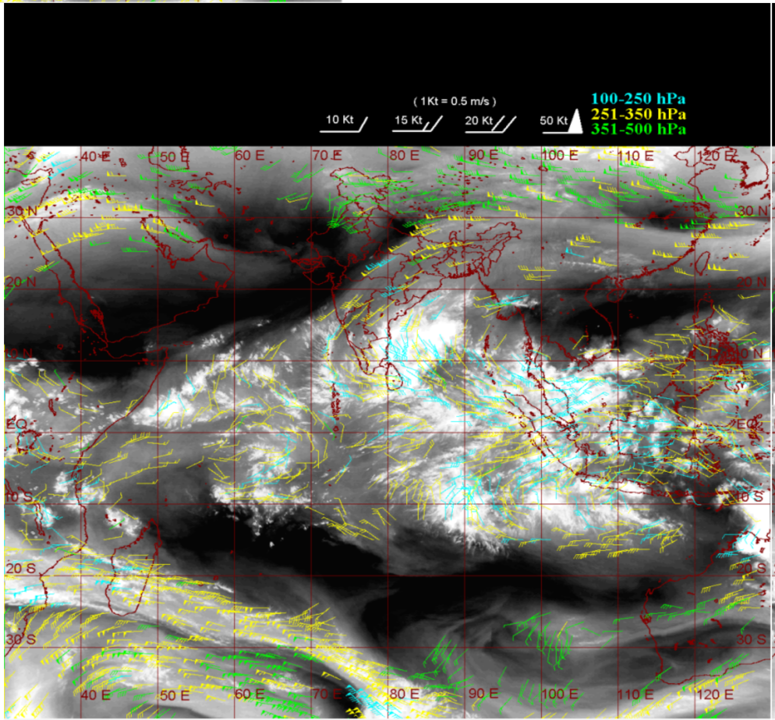


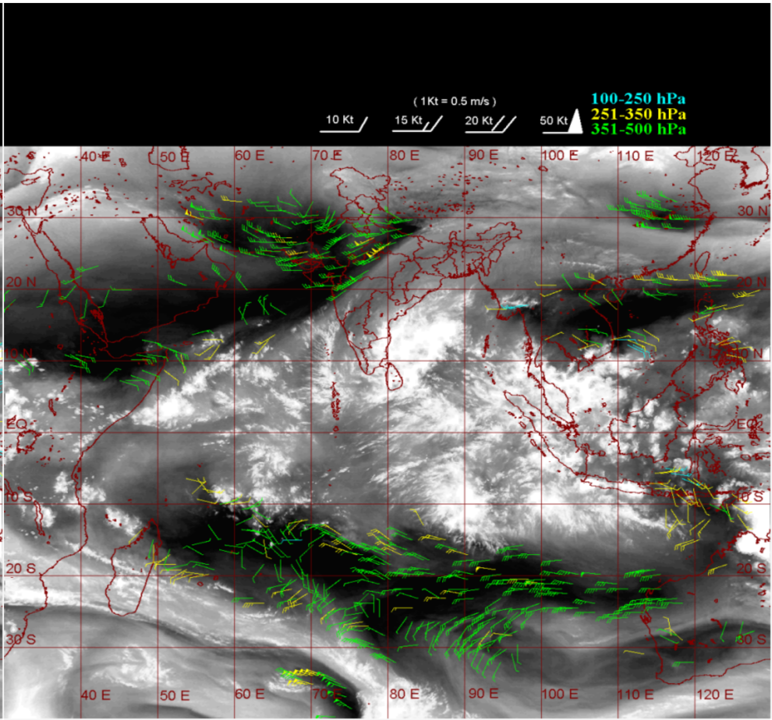
30NOV2015_1200

NC - 7525

CL - 5946

CS - 1576





INSAT-3D AMV Quality

Full Disc data
vs
Sector generated data

Period: December 1-15th 2014
Evaluated by NCMRWF

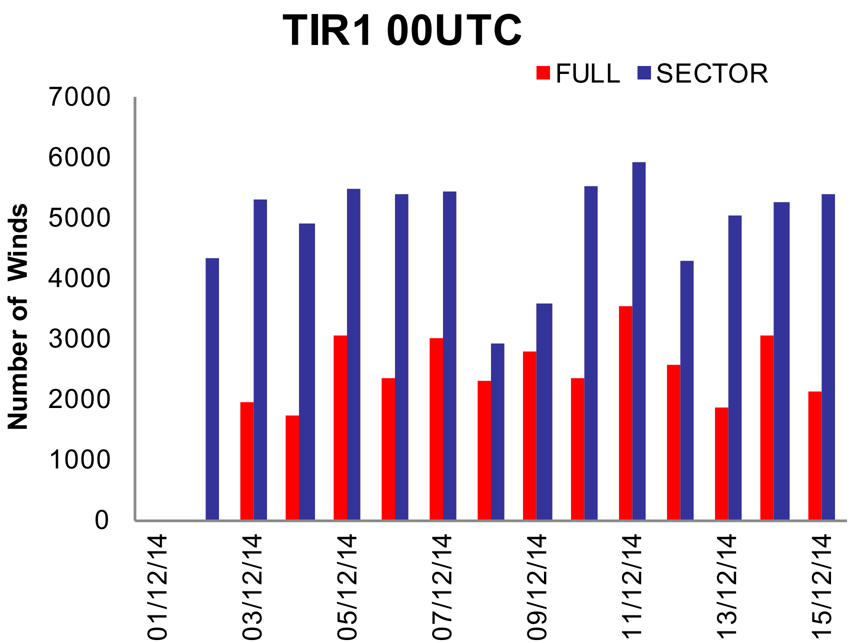
Validation against NCMRWF First guess & RSRW Winds

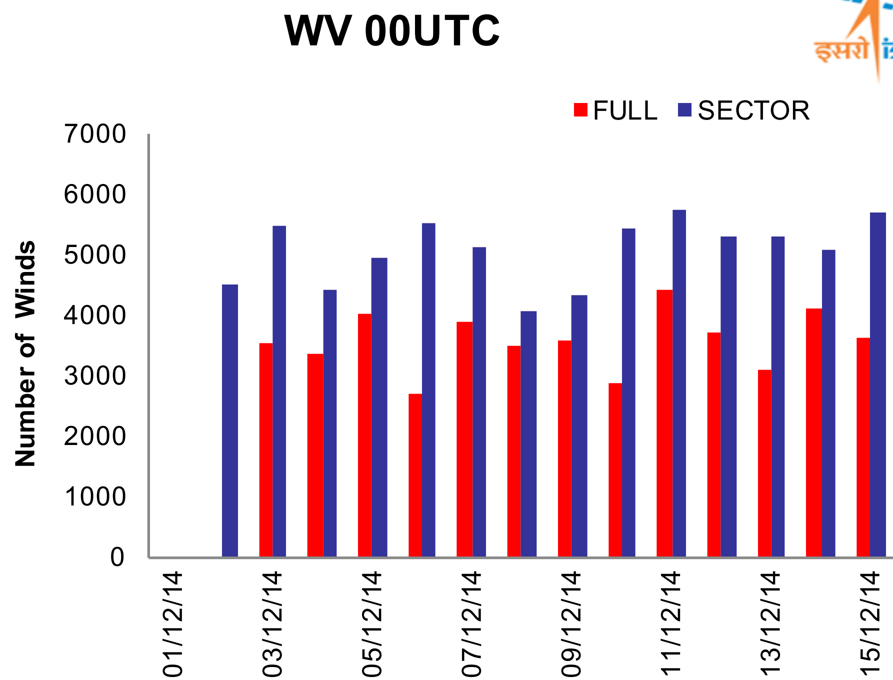
- Validation for TIR1 and WV Winds (00, 06, 12 and 18 UTC)

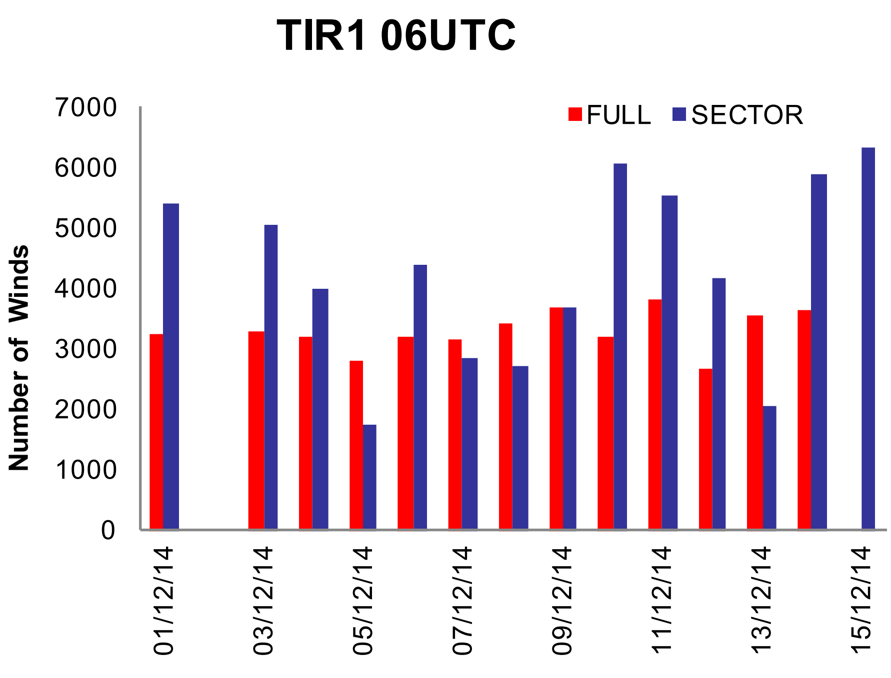
  1) All winds (irrespective of Quality Indicator)

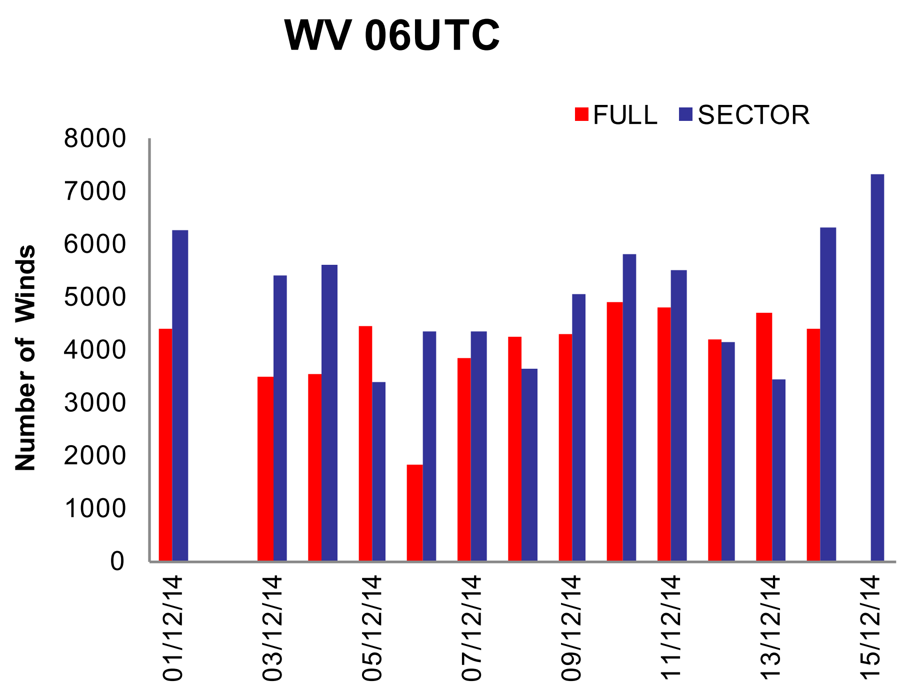
  2) Winds with Quality Indicator > 0.8

- Data: 1 to 15 December 2014


TIR1 00UTC
FULL
SECTOR
Number of Winds
0
1000
2000
3000
4000
5000
6000
7000
01/12/14
03/12/14
05/12/14
07/12/14
09/12/14
11/12/14
13/12/14
15/12/14


WV 00UTC
FULL
SECTOR
Number of Winds
0
1000
2000
3000
4000
5000
6000
7000
01/12/14
03/12/14
05/12/14
07/12/14
09/12/14
11/12/14
13/12/14
15/12/14


TIR1 06UTC
FULL
SECTOR
Number of Winds
0
1000
2000
3000
4000
5000
6000
7000
01/12/14
03/12/14
05/12/14
07/12/14
09/12/14
11/12/14
13/12/14
15/12/14


WV 06UTC
FULL
SECTOR
Number of Winds
0
1000
2000
3000
4000
5000
6000
7000
8000
01/12/14
03/12/14
05/12/14
07/12/14
09/12/14
11/12/14
13/12/14
15/12/14

Validation against co-located RSRW winds

Root Mean Square Vector Difference (RMSVD) : ALL WINDS			
	Northern Hemisphere	Tropics	Southern Hemisphere
Low Level(1000hPa – 700hPa)			
TIR –Full-Disc	5.54(131)	3.86(30)	4.32(22)
TIR –Sector	5.19(742)	3.24(88)	4.99(42)
Middle Level(700hPa – 400hPa)			
TIR –Full-Disc	6.10(184)	5.26(26)	5.92(10)
TIR –Sector	8.10(395)	4.56(42)	5.51(20)
High Level(400hPa – 100hPa)			
TIR –Full-Disc	8.29(120)	4.97(408)	5.59(25)
TIR –Sector	8.29(430)	5.56(560)	8.85(45)
WV –Full-Disc	8.48(546)	6.74(821)	5.10(172)
WV –Sector	8.10(1349)	5.82(1039)	6.22(222)

Root Mean Square Vector Difference (RMSVD) : (QI >0.8)			
	Northern Hemisphere	Tropics	Southern Hemisphere
Low Level(1000hPa – 700hPa)			
TIR –Full-Disc	4.85(16)	3.88(7)	4.34(7)
TIR –Sector	4.29(182)	3.77(19)	7.33(3)
Middle Level(700hPa – 400hPa)			
TIR –Full-Disc	5.81(37)	3.12(9)	-
TIR –Sector	7.18(87)	3.47(5)	6.07(6)
High Level(400hPa – 100hPa)			
TIR –Full-Disc	5.58(11)	5.24(30)	8.09(3)
TIR –Sector	6.96(47)	4.56(32)	8.44(2)
WV –Full-Disc	8.81(75)	5.39(47)	3.72(19)
WV –Sector	7.34(167)	5.03(69)	6.53(21)

- Need further investigation to make it operational