Retrieval and Applications of AMVs derived from Indian Geostationary Meteorological Satellites INSAT-3D/3DR: Present Status at ISRO

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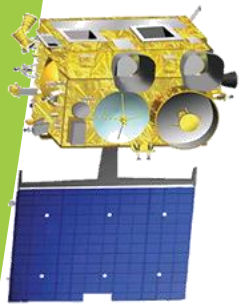
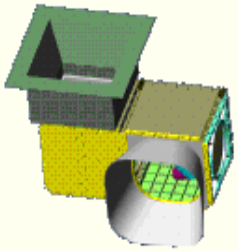
- Introduction
- Quality Assessment of AMVs
- Retrieval of HR-VIS AMVs and applications in NWP
- Retrieval of Rapid Scan AMVs and applications in NWP.
- Investigation of intra-seasonal variability for Indian Summer Monsoon (ISM) using AMVs
- Concluding remarks

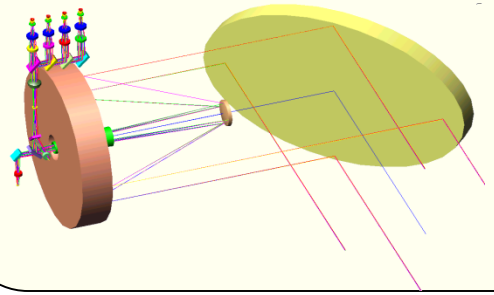
Meteorological GEO SATELLITES: INSAT – 3D/3DR/3DS



LAUNCH:
2013/2016
2022

6 Channel IMAGER



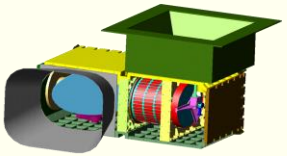


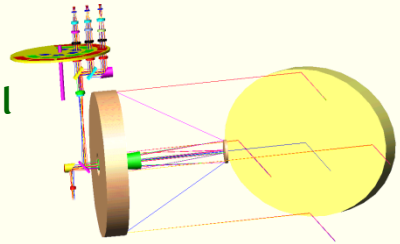
- Spectral Bands (μm)

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)

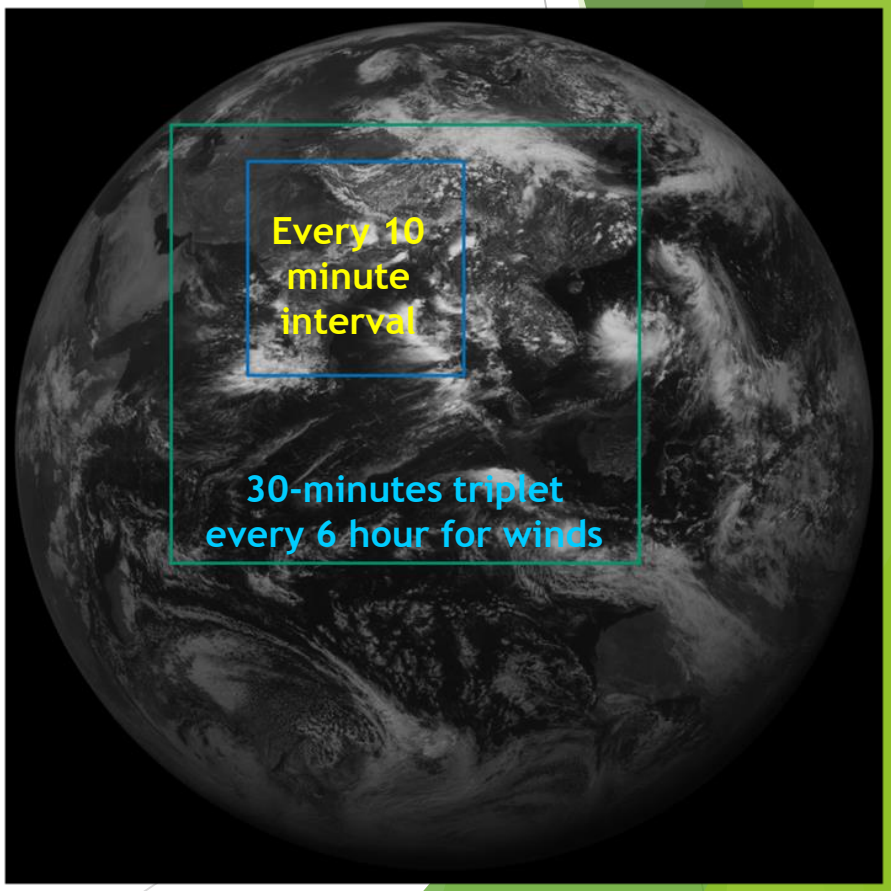
Launch Schedule: 2021, Geostationary orbit, 83E

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.

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

GISAT Scan scenario

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



Operational AMV products			
Satellites	Channel	frequency	Retrieval time
INSAT-3D	TIR1, WV, VIS [Day-time], MIR (3.9 µm) [Night time]	30 minute	0000, 0030, 0100, …
INSAT-3DR	TIR1, WV, VIS [Day-time], MIR (3.9 µm) [Night time]	30 minute	0015, 0045, 0115, …
INSAT-3D/3DR Staggering	TIR1, WV	15 minute	0000, 0015, 0030, 0045, …
INSAT-3DR	HR-VIS (1 Km)	30 minute	0015, 0045, 0115, …
Operational Wind derived products from AMVs			
INSAT-3D	Vorticity, Upper-level divergence, Lower-level convergence, Wind shear, 24-hour wind shear tendency	30 minute	0000, 0030, 0100, …
INSAT-3DR	Vorticity, Upper-level divergence, Lower-level convergence, Wind shear, 24-hour wind shear tendency	30 minute	0015, 0045, 0115, …

Quality Assessment of AMV

Radiosonde wind data

- The radiosonde wind measurements are obtained in real time from the National Oceanic and Atmospheric Administration (NOAA) as well as from the archival website http://www.esrl.noaa.gov/raobs/ for the region (0-150E, 60S-60N).

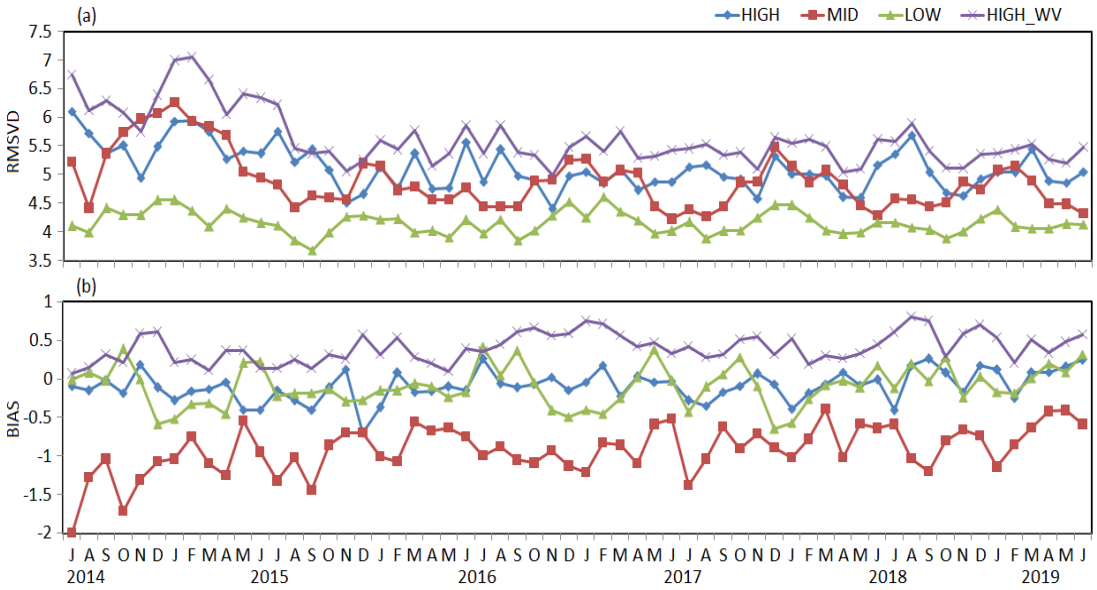
Wind from Wind Profiler

- L band radar, Lower Atmosphere Wind Profiler (LAWP) is installed at the National Atmospheric Research Laboratory (NARL), Gadanki near Tirupati, India.

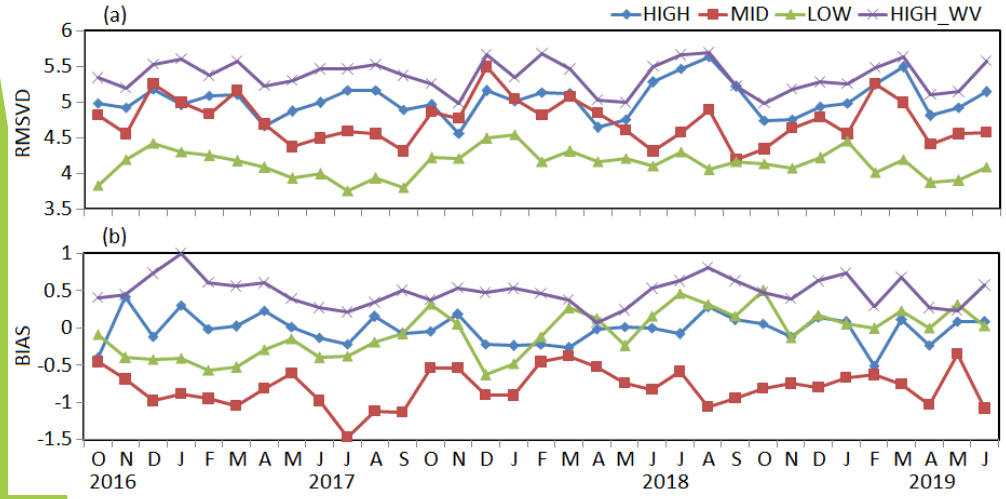
Numerical model data

Model	Parameters	Resolutions	Analysis/Forecast
NCEP	Temp, RH, U-wind, V-wind	0.5 × 0.5	Analysis + Forecast
NCMRWF	U-wind, V-wind	0.25 × 0.25	Analysis
ECMWF (ERA-INTERIM)	U-wind, V-wind	0.5 × 0.5	Analysis
ECMWF (ERA-5)	U-wind, V-wind	0.25 × 0.25	Analysis

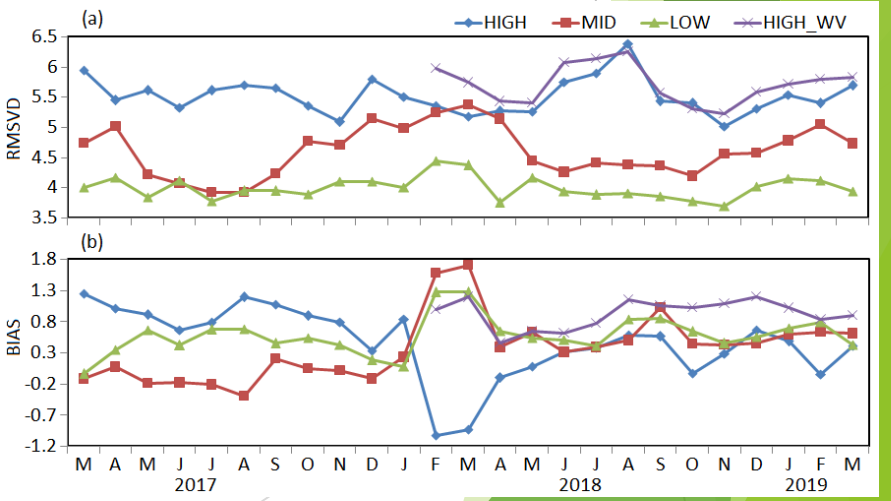
Validation with Radiosonde observations



Time series of monthly: a) RMSVD and b) bias of IR AMV for high, mid, low levels and WV AMV from INSAT-3D.

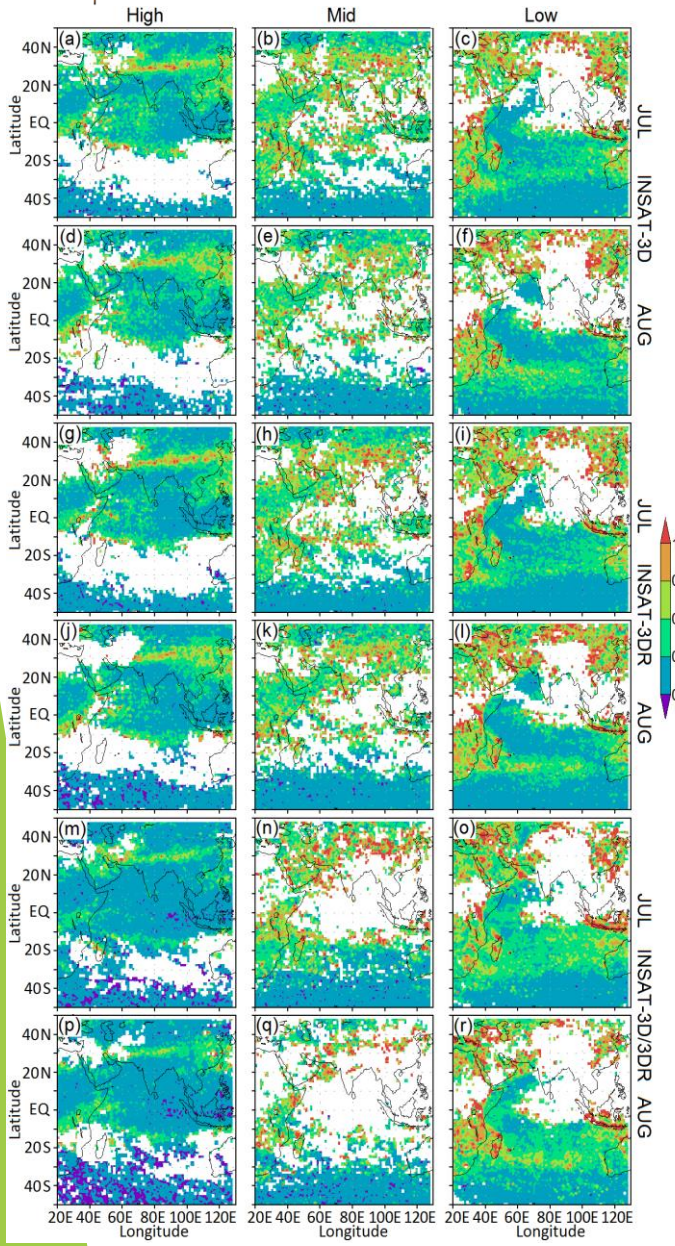


IR and WV AMV from INSAT-3DR

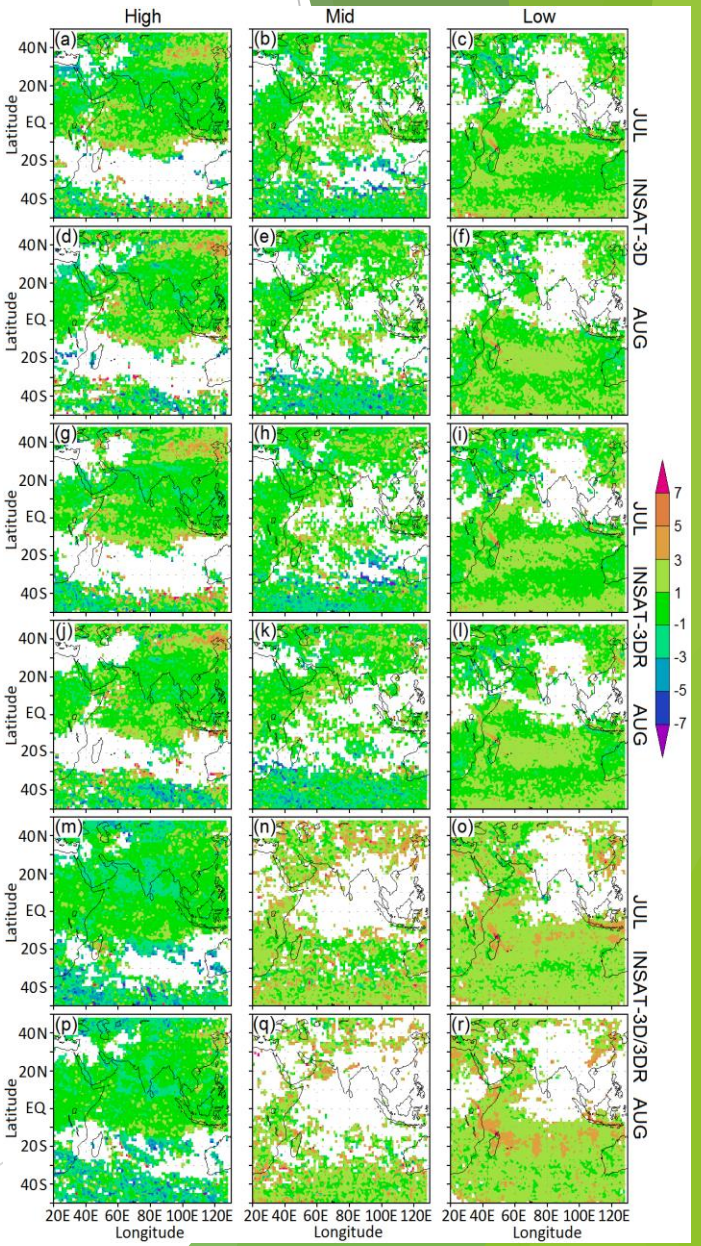


IR and WV AMV from staggering mode of INSAT-3D and -3DR

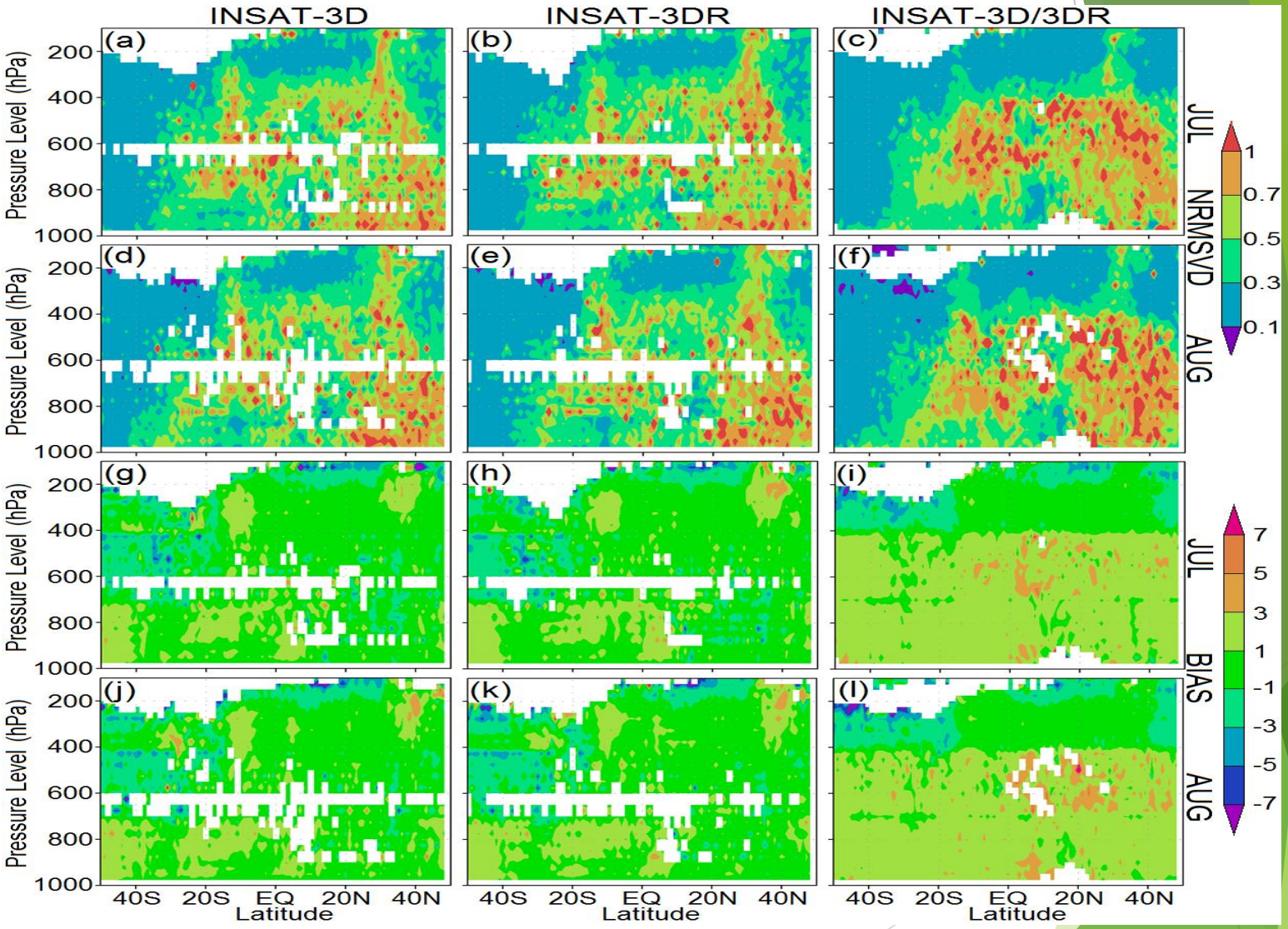
Validation with NCEP analysis wind



The spatial plots of normalized RMSVD and bias averaged for the month of July and August 2018 when IR AMVs from INSAT-3D (a-f), INSAT-3DR (g-l), and INSAT-3D/3DR (m-r) are collocated with NCEP GDAS wind analysis.

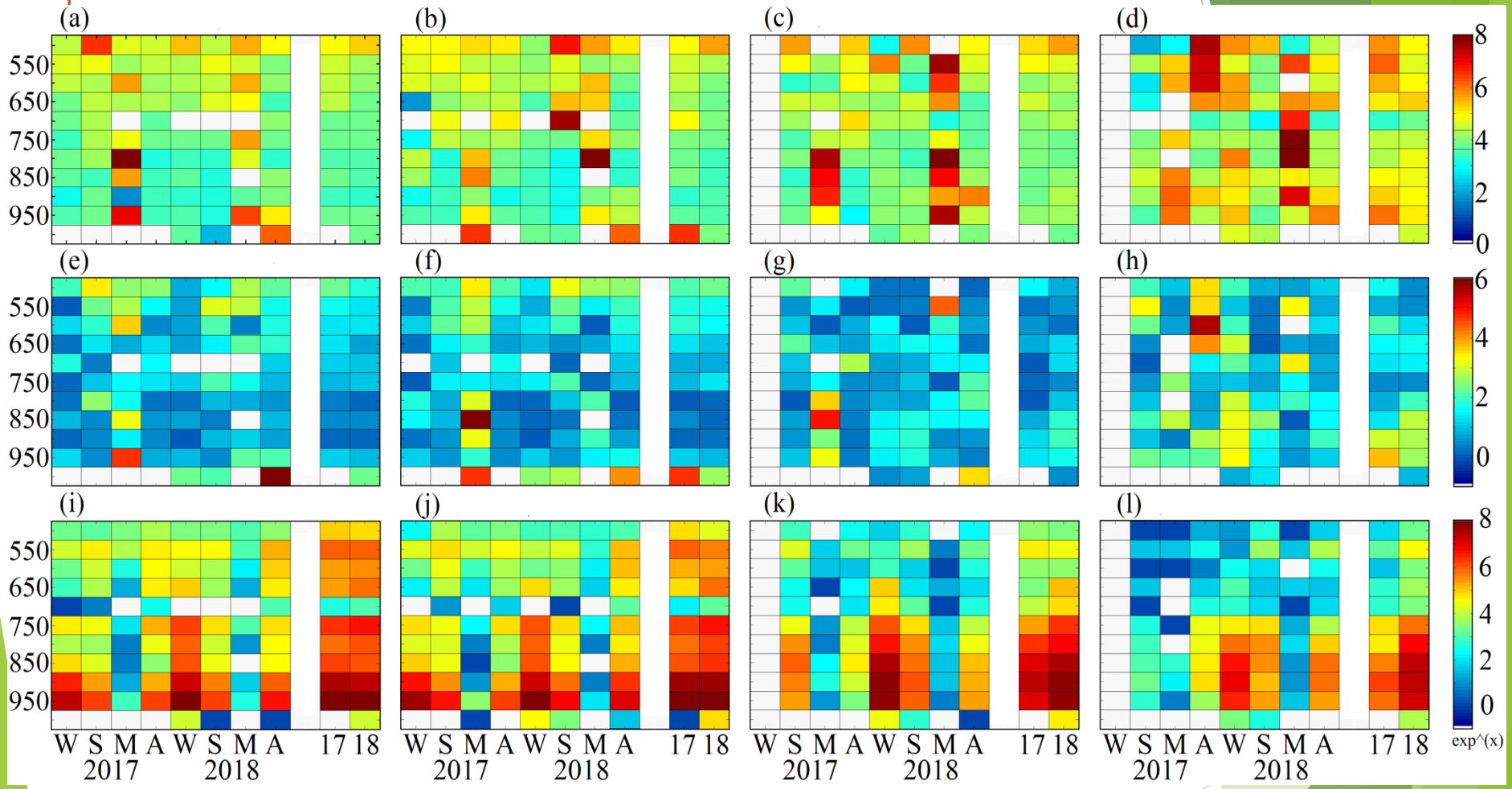


Validation with NCEP analysis wind



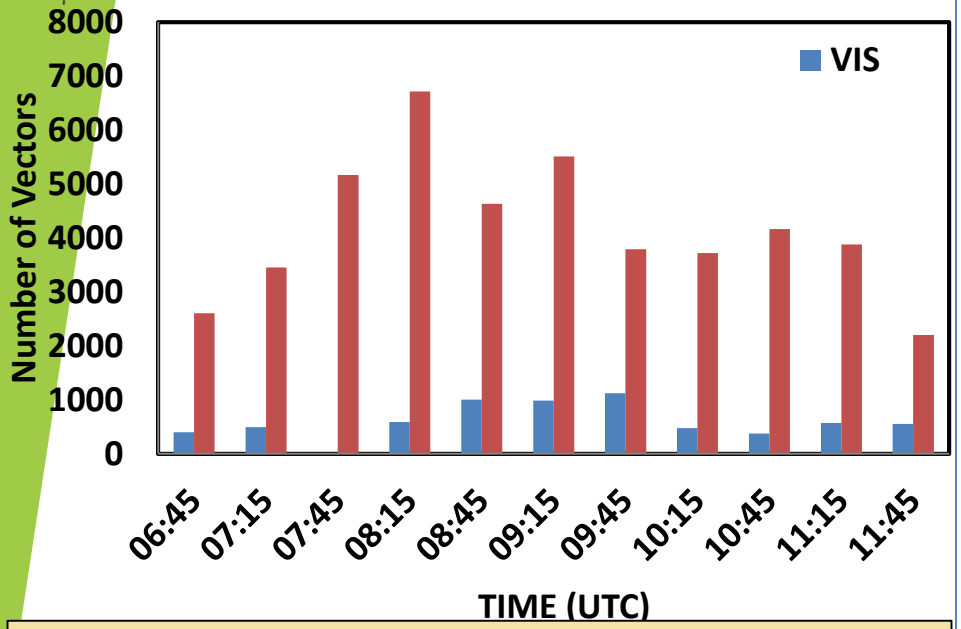
Hovmöller diagram showing the accuracy of IR AMVs against NCEP model analyzed winds. (a-f) NRMSVD for July and August 2018; (g-l) bias for July and August 2018.

Validation with Wind Profiler data



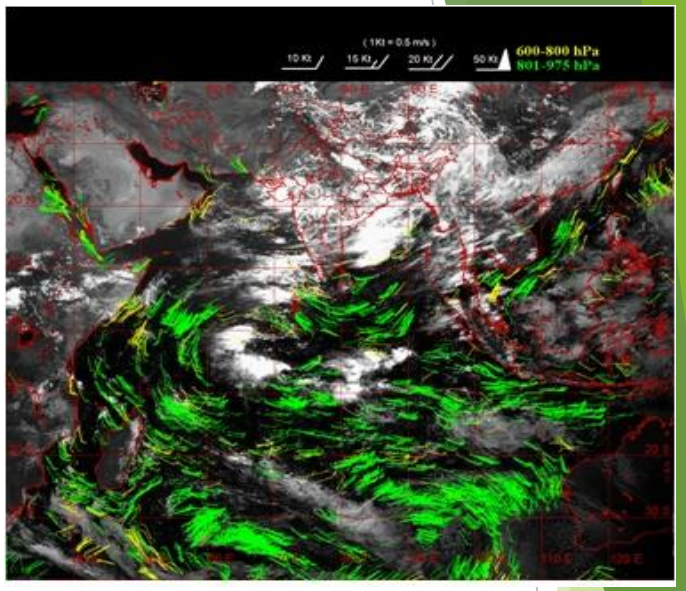
The vertical profiles of (a-d) RMSVD, (e-h) bias and (i-l) number of collocation (NC), when INSAT-3D, INSAT-3DR, STG-3D and STG-3DR AMVs are collocated with profiler winds

Retrieval of HR-VIS AMVs and applications



Number of wind vector retrieved at particular time on 06 July 2017.

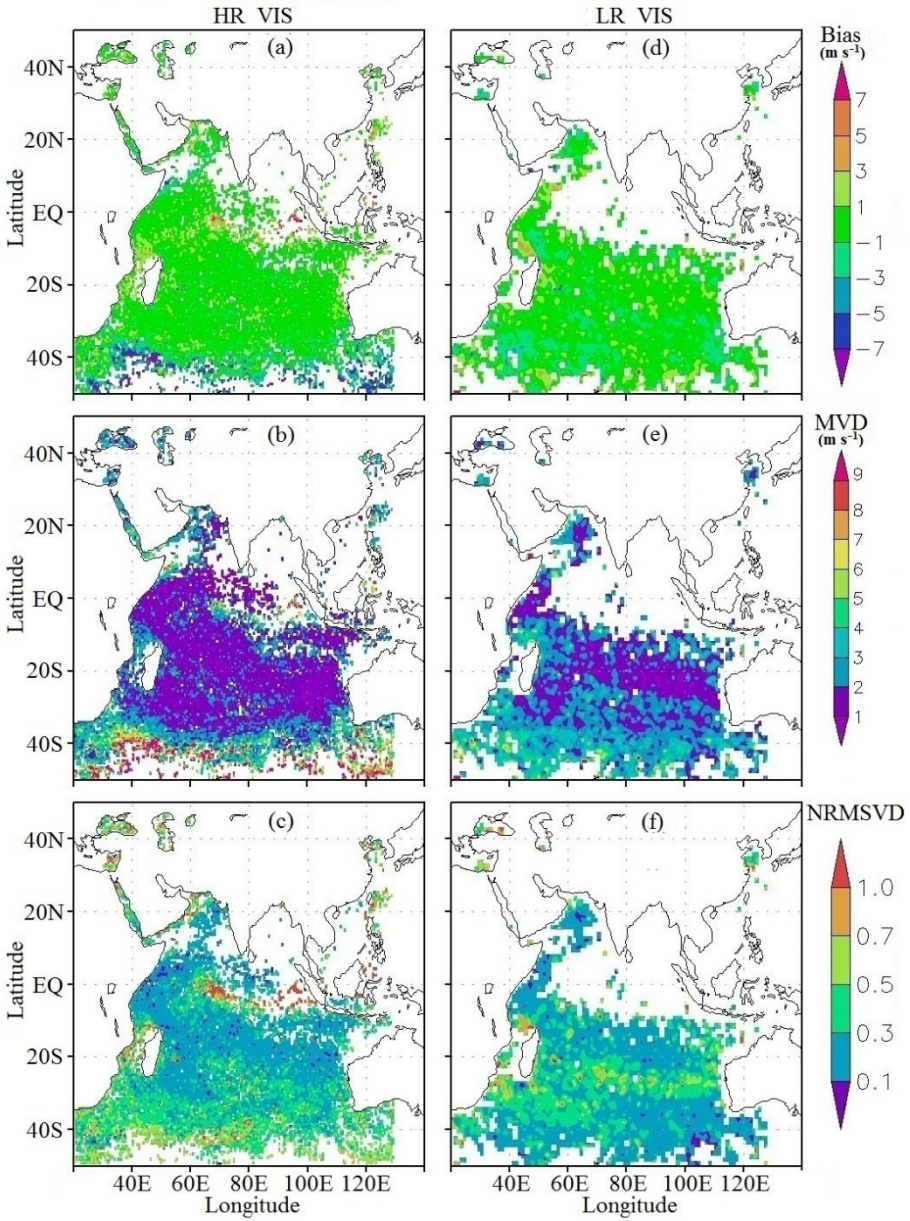
01 July 2017 08:15 UTC



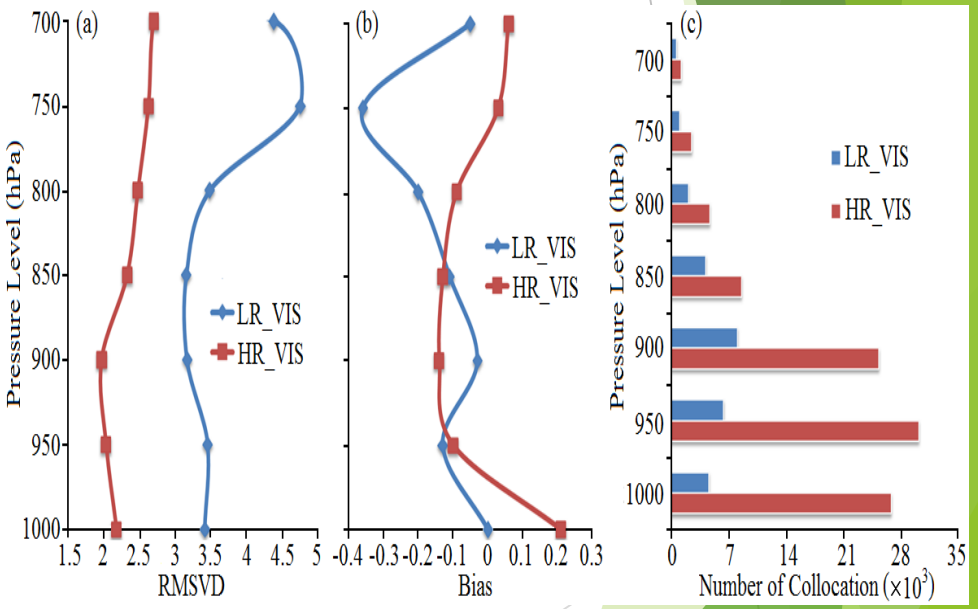
Validation w.r.to NCMRWF wind data

Validation of INSAT-3DR derived high resolution (HR) VIS AMVs, coarser resolution (LR) VIS AMVs with NCMRWF winds. Normalized RMSVD is dimensionless.

	1 – file (01 July 2017) 08:45 UTC			32 – files (01 – 15 July 2017)	
	VIS	**HRVIS**		**VIS**	**HRVIS**
NC	408	4417		24657	115618
RMSVD	**3.08**	**2.30**		**3.02**	**2.89**
BIAS	-0.14	-0.20		-0.18	-0.32



Spatial plots for INSAT-3DR high resolution VIS AMVs and coarser resolution VIS AMVs *vs.* NCMRWF analysis winds and for July 2017. (**a, d**) Bias, (**b, e**) MVD and (**c, f**) normalized RMS *vs.* vector difference.

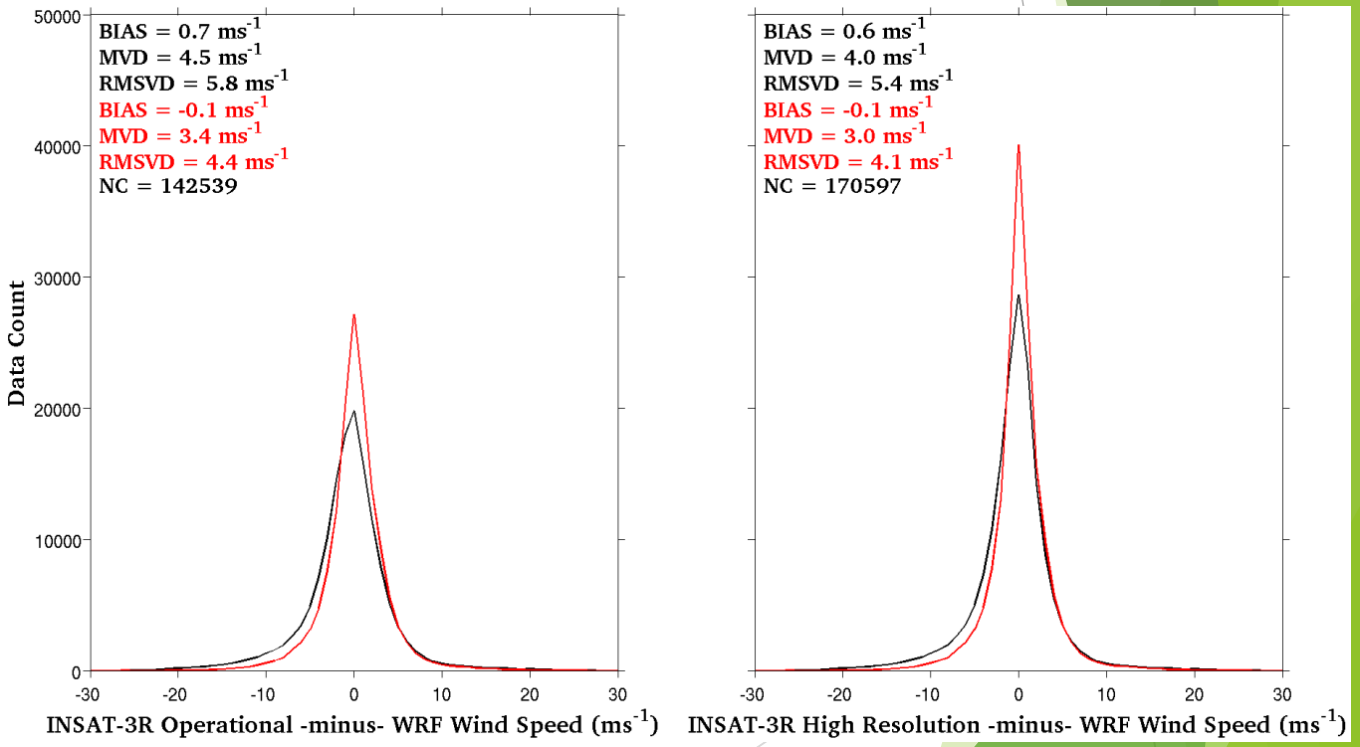


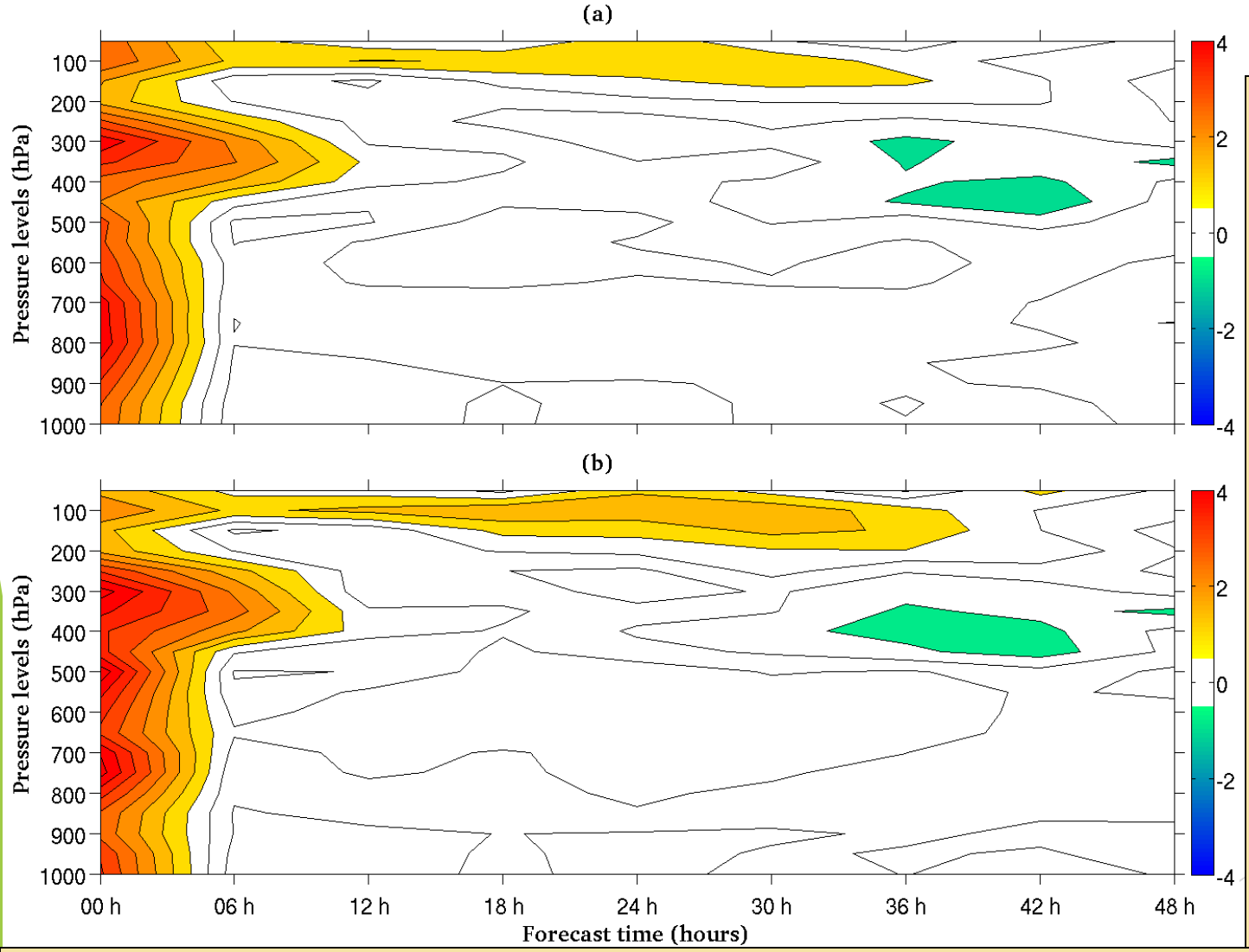
The vertical profiles of (a) RMSVD, (b) Bias, and (c) Number of Collocation, when wind from LR VIS and HR VIS are collocated with NCMRWF analysis wind data.

Application of HR-VIS in WRF simulation

- All experiments are conducted in a single domain consisting of 400×400 (30.1°E – 119.9°E, 31.1°S – 49.4°N) grids with 25 km horizontal grid resolution. The model has 36 pressure levels with top of the atmosphere at 10 hPa.

Histogram of INSAT-3DR coarser resolution VIS AMVs minus WRF wind speed (ms^{-1}) (Left panel) and INSAT-3DR High Resolution VIS AMVs minus WRF wind speed (ms^{-1}) (Right panel) during July 1-15, 2017.



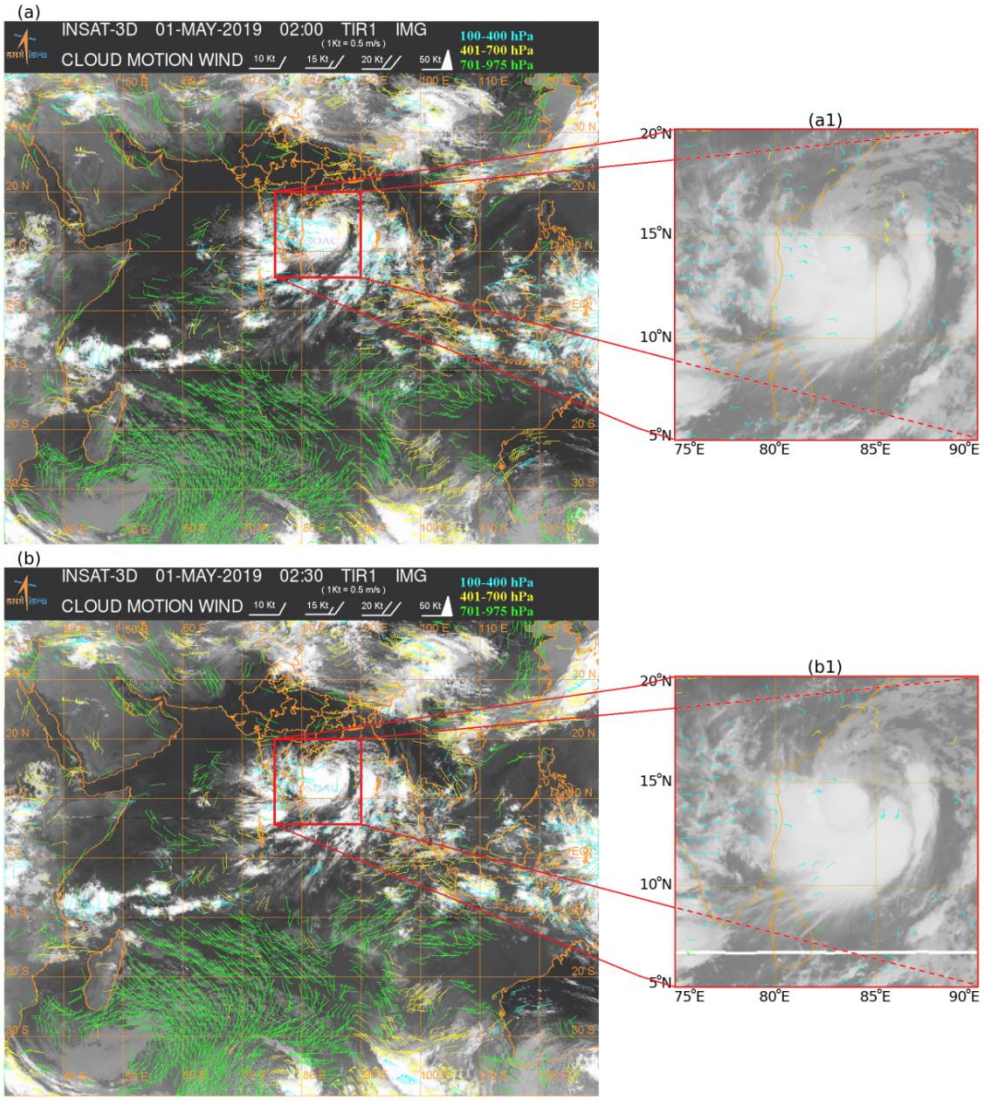


During July, the Low Level Jet is very strong and associated with this a high level anticyclone develops known as the Tibetan high and the reverse wind flow in the high level known as the Tropical Easterly Jet (TEJ). May be the assimilation of Visible AMVs produces stronger LLJ and hence high impact in the upper levels. Moreover the initial condition from the global model also contains the LLJ and TEJ information.

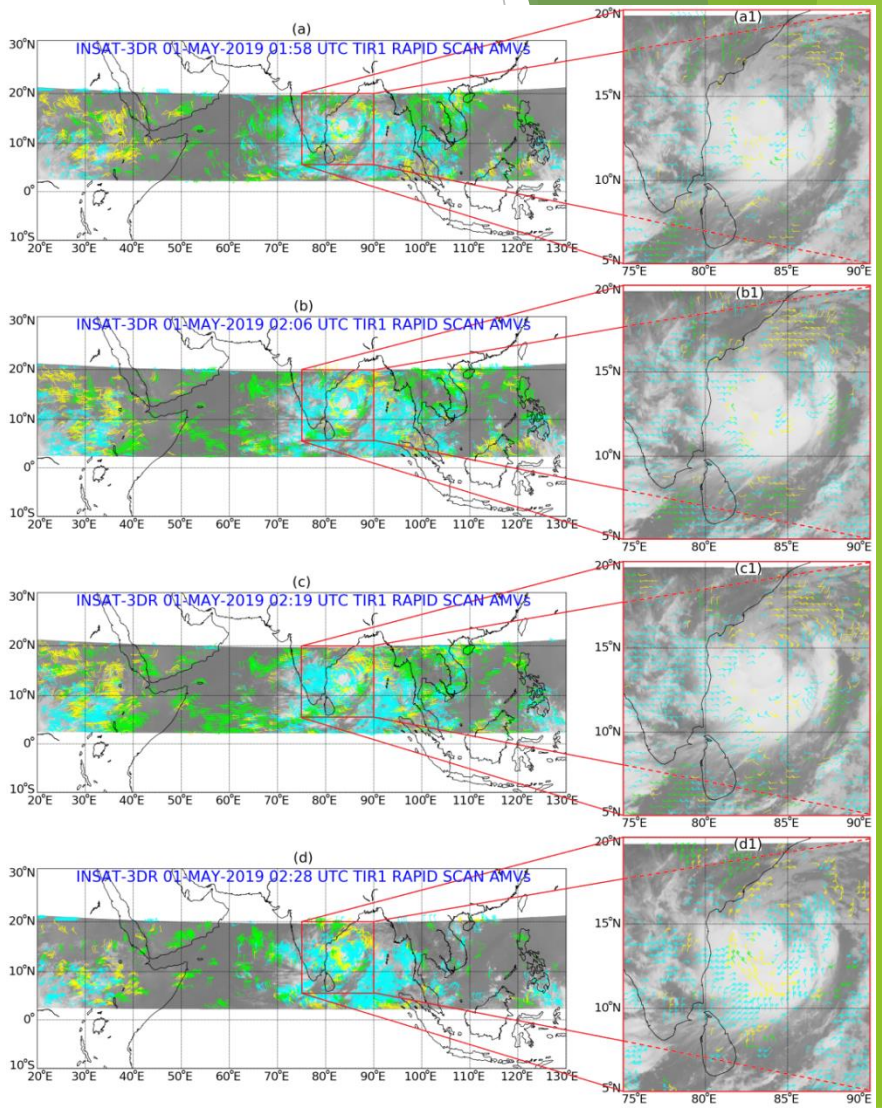
Forecast of wind speed in terms of percentage (a) LR VIS AMVs and (b) HR VIS AMVs.

Retrieval of Rapid Scan AMVs using TIR1 channel of INSAT-3DR satellite

AMVs from INSAT-3D infrared channel valid at May 1, 2019.

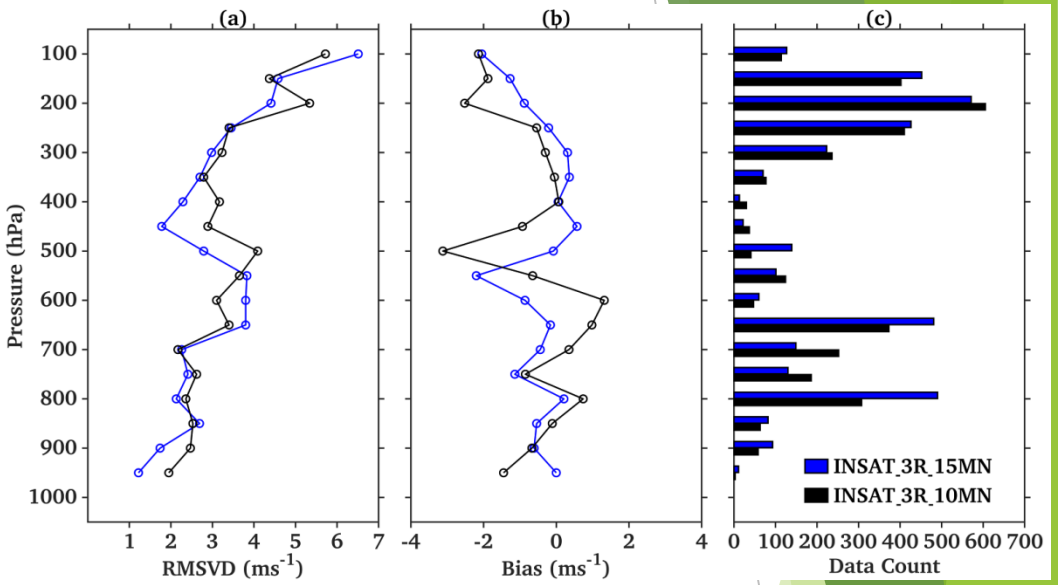


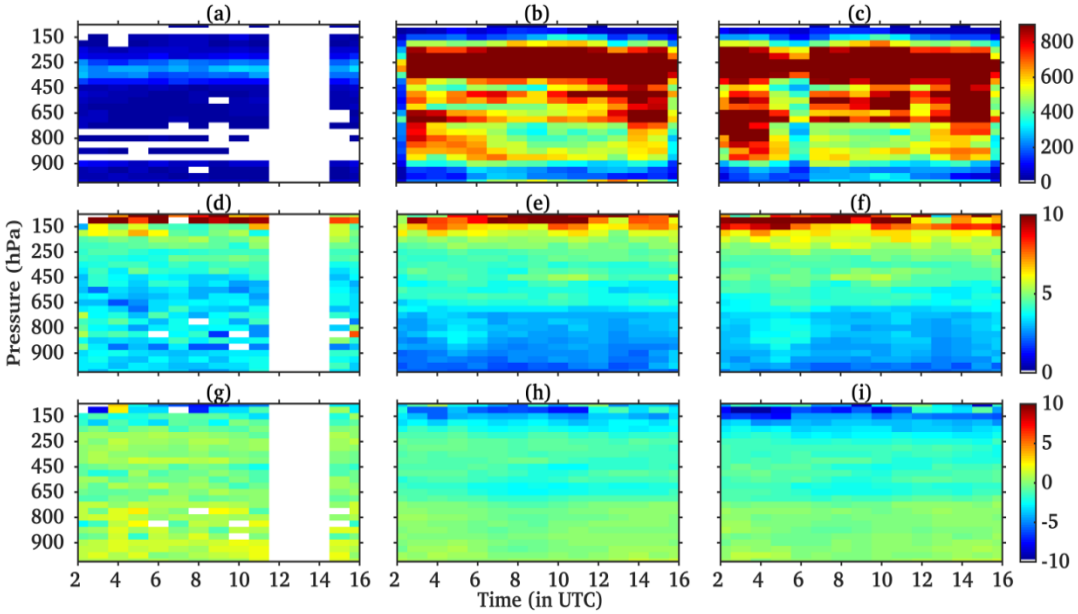
RS-AMVs over the study region valid at May 1, 2019 with a 16 × 16 pixel tracer size.



Quantitative assessment

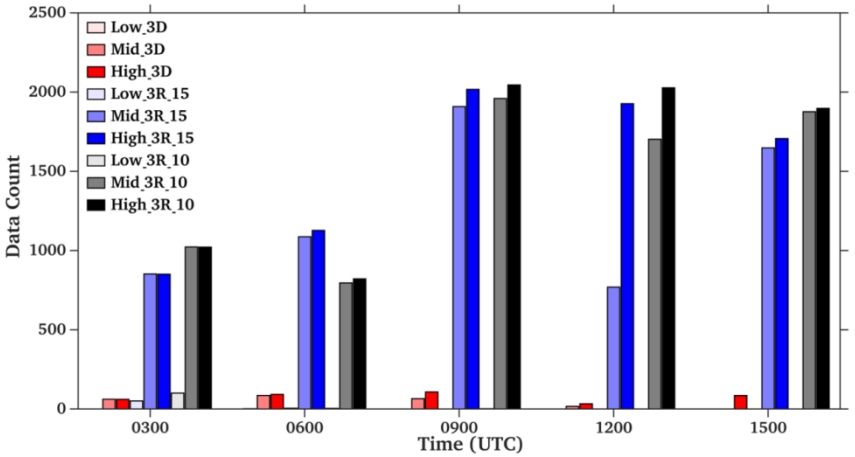
Comparison of INSAT-3DR 10 minute and 15 minute RS-AMVs with respect to radiosonde observations. (a) RMSVD, (b) Bias and (c) Data Count



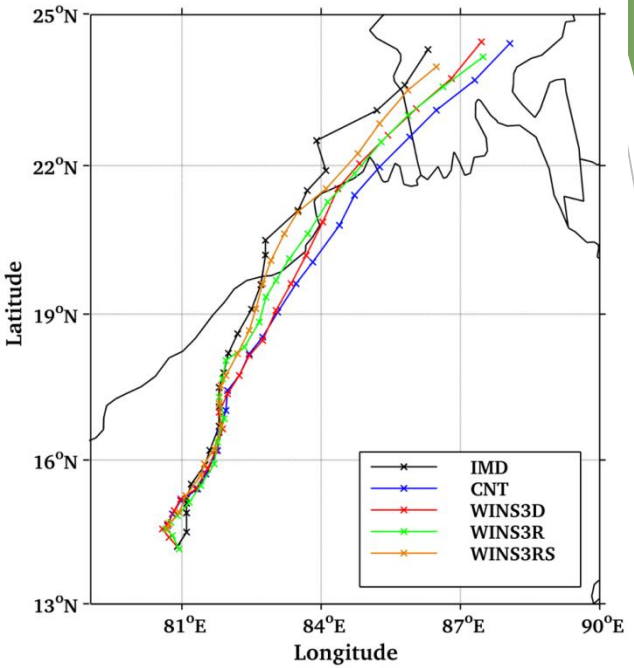


Vertical plots showing (a, b, c) Number of Collocations, (d, e, f) RMSVD, and (g, h, i) bias for INSAT-3D AMVs, INSAT-3DR 10 minute and 15-minute RS-AMVs against ERA-5 model reanalyzed winds.

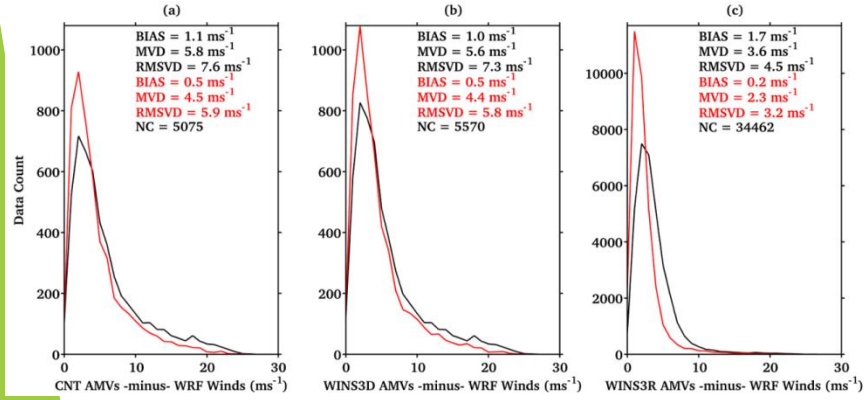
Application of RS-AMVs in WRF model simulation



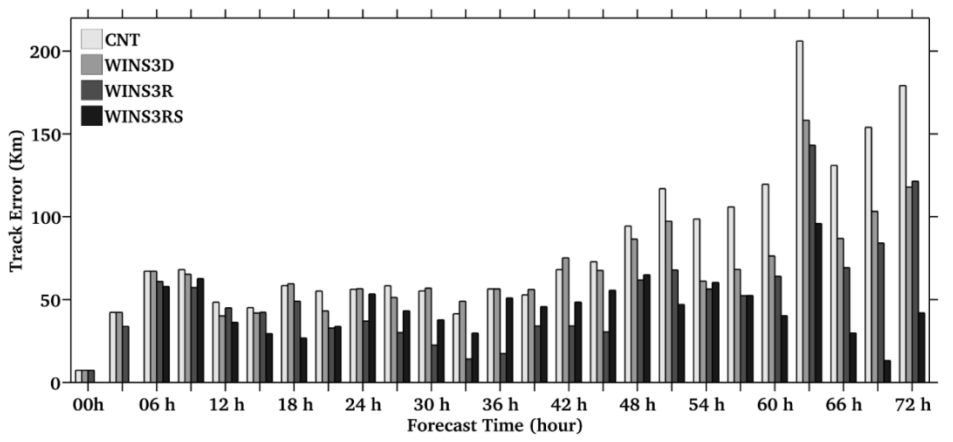
The number of available wind vectors near to TC centre with a radius of 500 km at different vertical levels and times when AMVs are retrieved using 10 and 15 minute INSAT-3DR RS data and operationally available 30 minute INSAT-3D data.



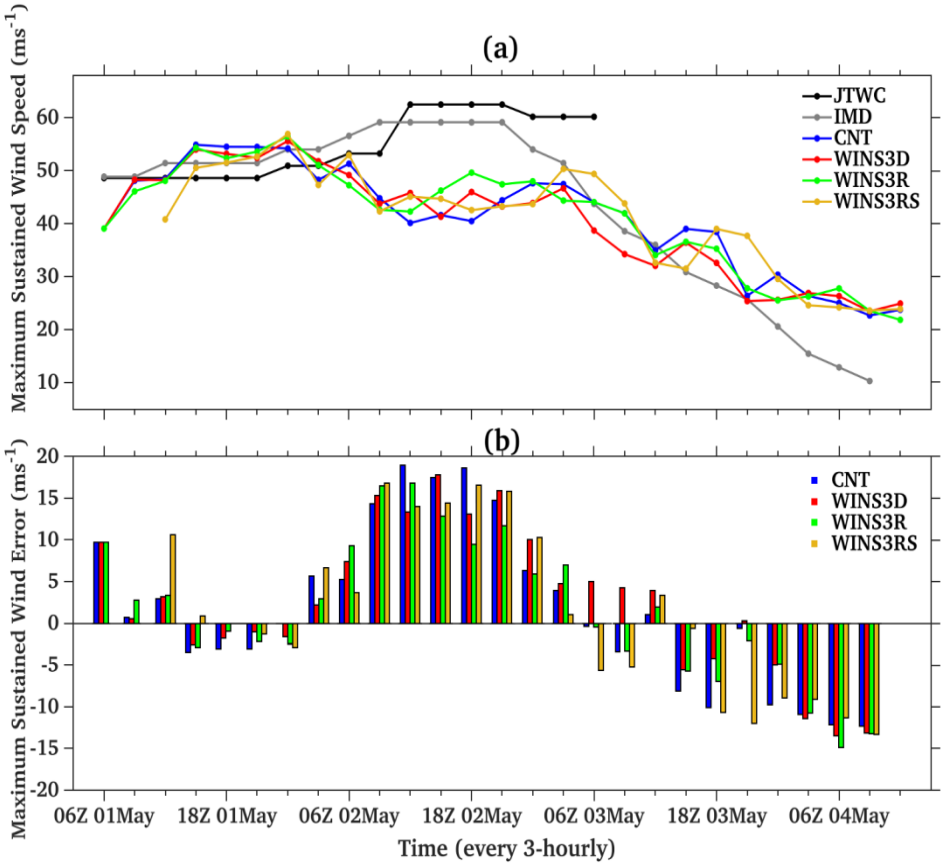
The CNT, WINS3D, WINS3R, and WINS3RS simulated track along with IMD observed track for TC FANI initialized from 0600 UTC of May 1, 2019.



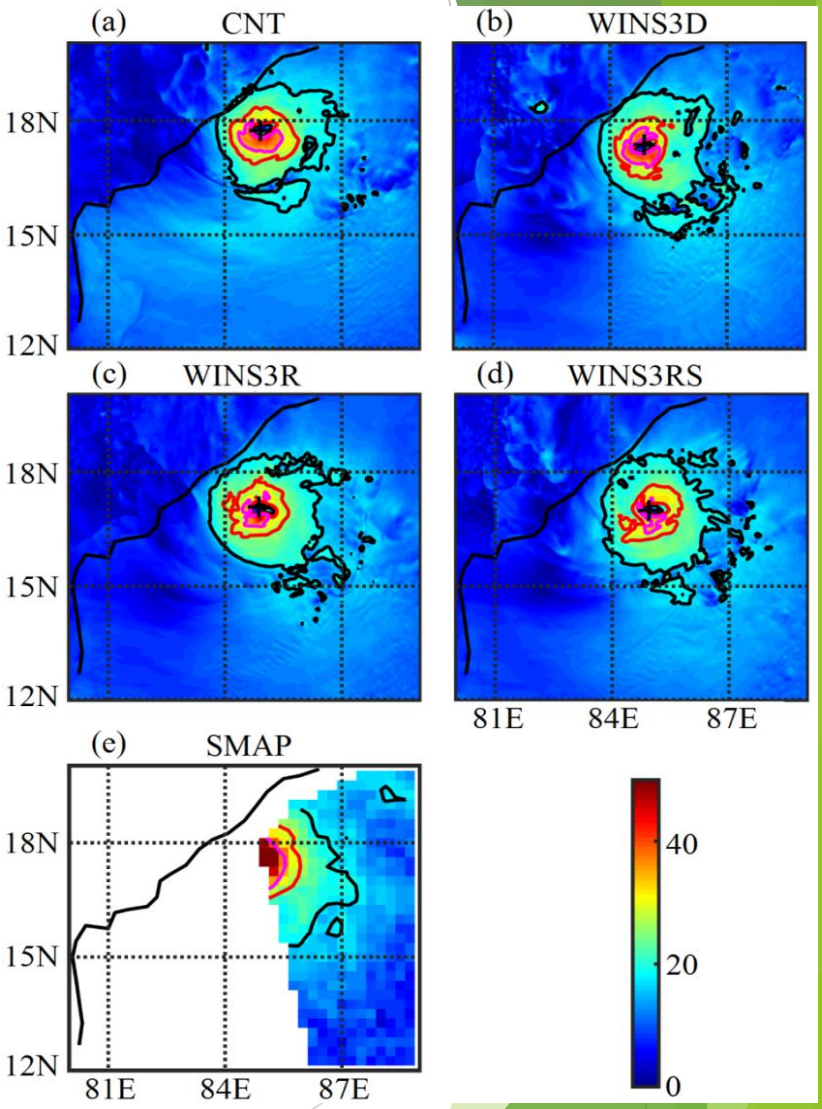
Distribution of background departure and analysis departure for AMVs used in (a) CNT, (b) WINS3D, and (c) WIND3R experiments.



Track error in CNT, WINS3D, WINS3R, and WINS3RS runs against IMD best track for different forecast hours.



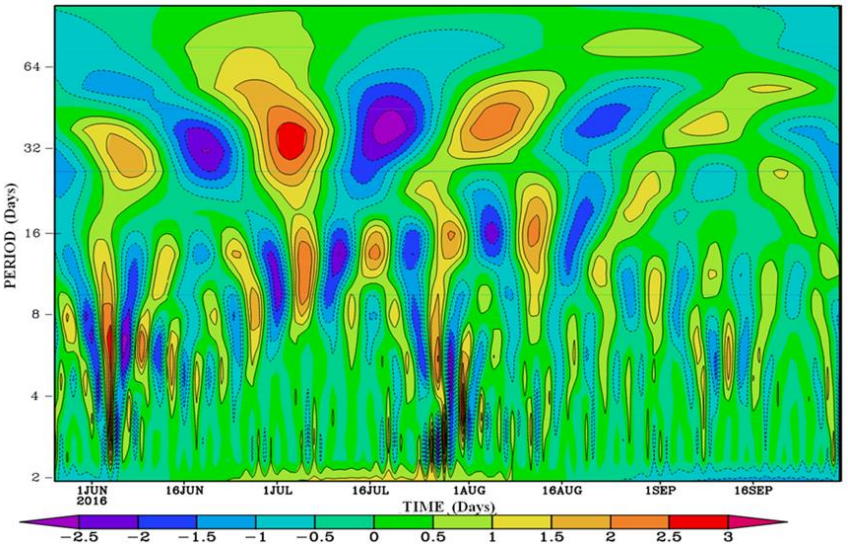
(a) Maximum sustained wind speed forecast and (b) forecast error against IMD best track intensity estimates.

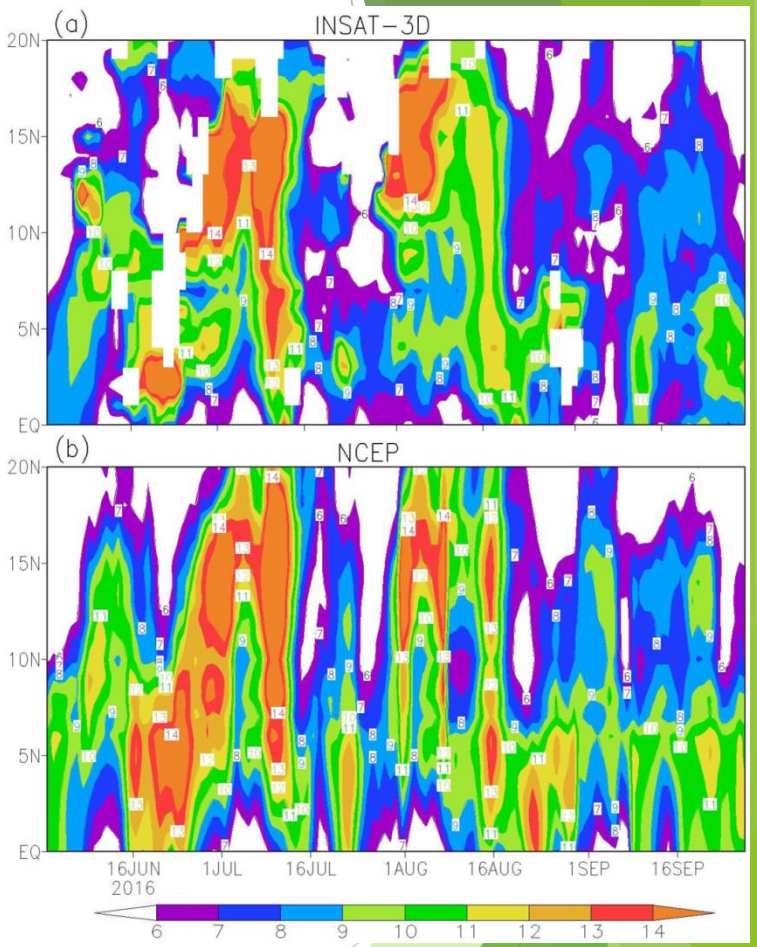


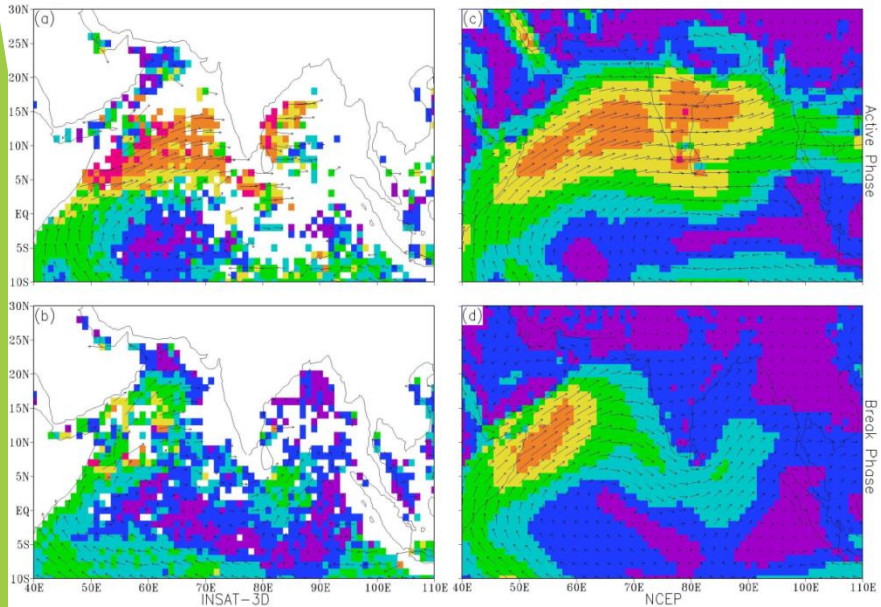
Comparison of TC FANI surface wind structure forecast against SMAP satellite wind product at 1200 UTC May 2, 2019. (a) CNT, (b) WINS3D, (c) WINS3R, (d) WINS3RS and (e) SMAP

Investigation of intra-seasonal variability for ISM

Morlet wavelet analysis of the INSAT-3D low-levels winds (m/s) averaged over the Bay of Bengal box (10◦N-20◦N; 80◦E-95◦E) during the monsoon season of 2016.







Average INSAT-3D low-levels wind speed and wind vectors during (a) active (July 8-12, 2016) and (b) lull (July 24-29, 2016) phases during the 2016 monsoon season.

Hovmoller (time-latitude) plot of (a) INSAT-3D low-levels wind speed (m/s) and (b) NCEP low-levels wind speed (m/s) averaged between 80◦E and 95◦E longitude during the summer monsoon season of 2016.

Concluding remarks

- **The quantitative assessment of AMVs from INSAT-3D and INSAT-3DR are carried out with winds from other sources, viz. radiosonde, model analysis winds and winds from the profiler.**

- **The retrieval and impact of HR VIS winds are demonstrated for the Indian summer monsoon month July 2017, however in future, the impact of HR VIS AMVs will be assessed by considering various extreme weather events. This algorithm is presently operational at IMD Delhi.**

- **The retrieval of rapid-scan (RS) AMVs from INSAT-3DR satellite is attempted and the impact of RS-AMVs on the track and intensity prediction of the Bay of Bengal tropical cyclone FANI is demonstrated.**

- **Low-level AMVs are quite successful in capturing all the observed features of the ISM. When a complex Morlet wavelet transform is used to wind time-series, it shows two prominent modes of variability one with 32-64 days periodicity and the other with 8-16 days periodicity in INSAT-3D low-level AMVs.**

References

- Dineshkumar K Sankhala, Prashant Kumar, Sanjib K Deb, Neeru Jaiswal, C. M. Kishtawal and R. M. Gairola, "Retrieval and Application of Rapid Scan Atmospheric Motion Vectors using Infrared channel of INSAT-3DR Satellite", 2021 Accepted to *Pure. App. Geo. Phys.* DOI:10.1007/s00024-021-02687-1

- Dineshkumar K. Sankhala, Sanjib K Deb, Prashant Kumar and C M Kishtawal, "Retrieval and application of high resolution low-level visible winds from INSAT-3DR Imager", 2020, *International J. of Remote Sensing.* 41(12): 4724–4739

- Dineshkumar K. Sankhala, S. K. Deb, and V Sathiyamoorthy, "Intra-seasonal variability as captured by INSAT-3D low-level atmospheric motion vectors over the Indian summer monsoon region in 2016", 2019, *J. Earth Syst. Sci.*, 128:31

Thanks