Atmospheric Motion Vectors from Kalpana-1: An ISRO status

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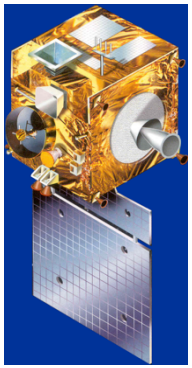
Contents:

- Current and future Indian Geostationary/LEO satellites.
- ISRO AMV retrieval algorithm.
- Improvement in Height assignment.
- Recent improvement in retrieval algorithm.
- Validation statistics with radiosonde.
- Spatial error analysis NCEP GFS.
- Conclusion
- Future directions.
- Few slides with latest status of OSCAT winds

ISRO missions and geophysical parameter retrieval & cal-val ongoing activities

GEO

Kalpana-1
2002



VHRR

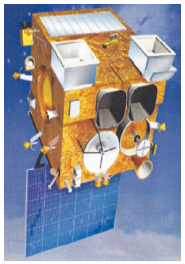
CMV, OLR,
Rainfall, AMV

INSAT-2E/3A
(1999/2003)

VHRR, CCD

AMV, OLR, Rainfall
Aerosol

INSAT-3D
(2012)



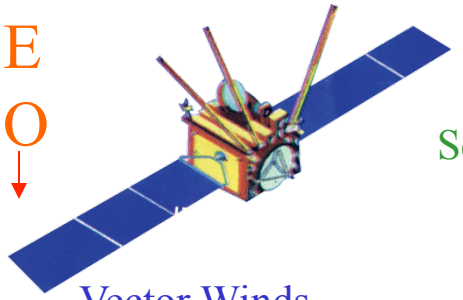
6-Ch VHRR
IR Sounder

SST, AMV, OLR, Rainfall,
T, h Profile

- INSAT-3D R
- Geo-HR(~2013)
- Follow-up (~2015)

LEO

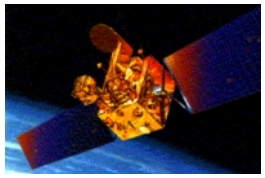
OCEANSAT–1/2
(1999/2009)



MSMR,
OCM,
Scatterometer
ROSA

Vector Winds
Aerosol, T & h Profille

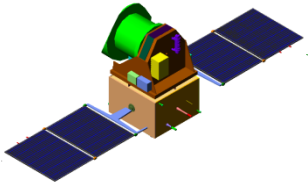
SARAL
(2012)



Altimeter

SSH, Waves, Winds

MEGHA-TROPIQUES
(2011)



MW Imager,
WV Sounder,
ScaRaB
GPS-RO

SS Wind, TWV, Rainfall
T, h Profile,
Radiation Budget

Current Indian Geostationary Meteorological Satellites

Satellites	INSAT-3A (2003)	KALPANA-1 (2002)
Location	93.5E	74E
Payloads	VHRR & CCD	VHRR
VHRR bands (μm):	Visible 0.55 - 0.75 (2 km x 2 km) WV 5.70 - 7.10 (8 km x 8 km) TIR 10.5 - 12.5 (8 km x 8 km)	Visible 0.55 - 0.75 (2 km x 2 km) WV 5.70 - 7.10 (8 km x 8 km) TIR 10.5 - 12.5 (8 km x 8 km)
CCD Camera (μm):	Visible 0.62 - 0.68 (1 km x 1 km) NIR 0.77 - 0.68 (1 km x 1 km) SIR 1.55 – 1.69 (1 km x 1 km)	

VHRR= Very High Resolution Radiometer
CCD = Charged Couple device (for agriculture related studies)

INSAT – 3D (Launch schedule: July/Aug-2012)

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 - 12.50

- 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 Bands	: Seven
Visible Band	: One

- Resolution (km) for all bands : 10 X 10
- No of simultaneous sounding per band : Four

INSAT Meteorological Data Processing System (IMDPS)

(Activities: Retrievals and Applications)

Ongoing:

(Using Kalpana-1 & INSAT-3A data)

- Rainfall
- *Atmospheric Motion Vectors (AMV).*
- Outgoing Long-wave Radiation (OLR)
- Upper Tropospheric Humidity (UTH)
- Sea Surface Temperature (SST).
- Cyclone –Track, Intensity
- Monsoon Monitoring
- Now-casting
- NWP impact through assimilation.
- Assimilation of WV radiances (NWP)

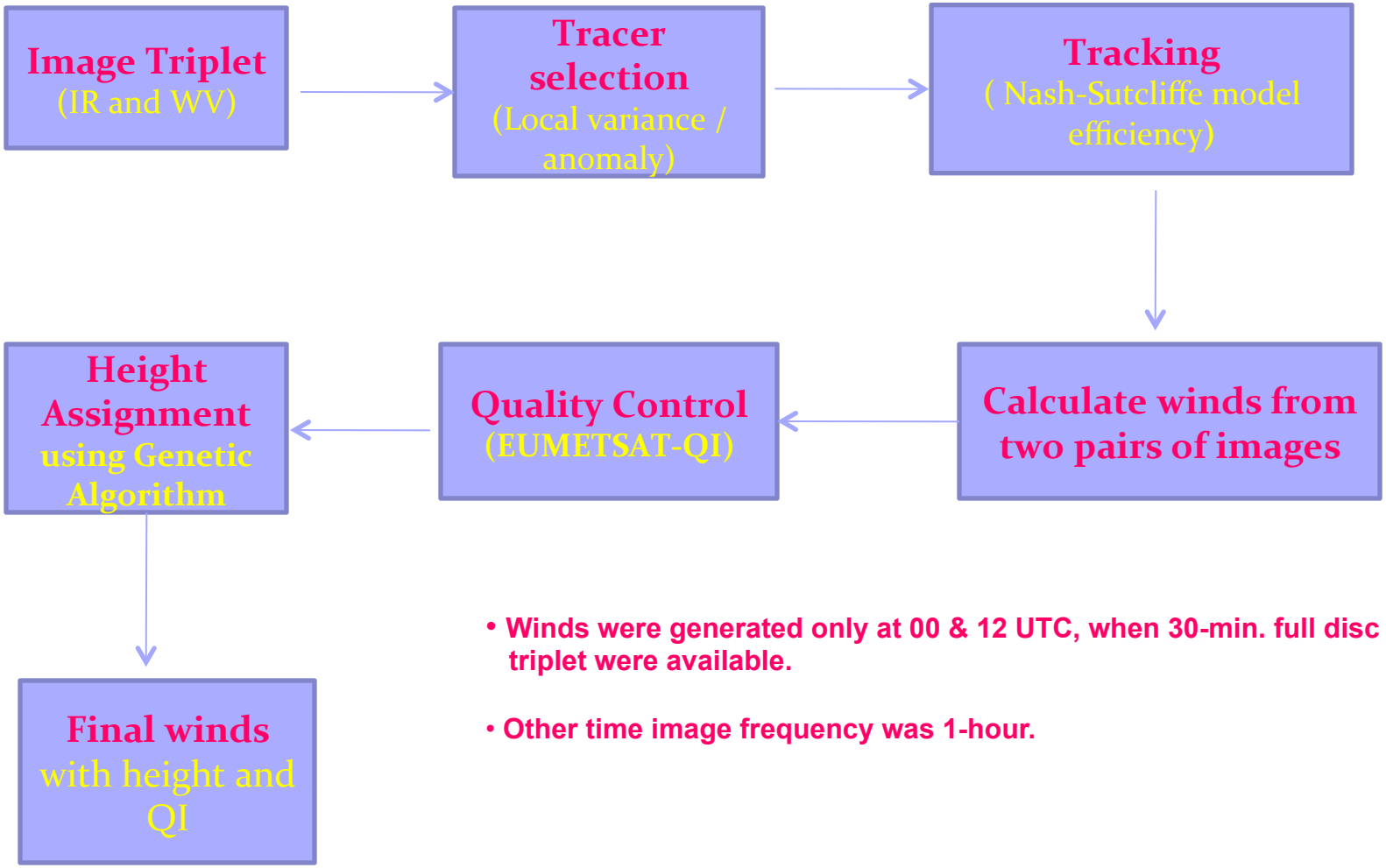
Future:

(Using INSAT – 3D data)

- Rainfall,
- SST, *AMV*, UTH, OLR
- Fire & Smoke,
- Fog,
- Aerosol Optical Depth,
- Snow
- Temp & Humidity profile,
- Total Ozone.
- Merged rainfall product (Polar & Geo)
- Cyclone track and intensity.
- Now-casting
- NWP impact through assimilation
- Assimilation of WV radiances

ISRO AMV winds retrieval activities

- Started in 2006/2007 time frame with the initiation of IMDPS project



- Winds were generated only at 00 & 12 UTC, when 30-min. full disc image triplet were available.
- Other time image frequency was 1-hour.

- References: 1. S. K. Deb, C. M. Kishtawal, P. K. Pal and P. C. Joshi, "A modified tracers selection and tracking procedure to derive winds using water vapor imagers", 2008, *Jour. Appl. Meteor. Clim*, 47 (12), 3252-3263.

2. C. M. Kishtawal, S. K. Deb, P. K. Pal and P. C. Joshi, "Estimation of atmospheric motion vectors from *Kalpana-1* imagers", 2009, *Jour. Appl. Meteor. Clim*. 48 (11) 2410-2421.

Height Assignment (Empirical Algorithm)

Randomly choose large number of Meteosat7 images and corresponding EUMETSAT winds

Training using GA

Generate an independent relationship for tracer height for MET7 images using BT of coldest, warmest pixels and latitude information

Calculate final optimized function for tracer height in Kalpana images

A mapping is defined between Meteosat7 and kalpana-1 using SRF

Verification in heights

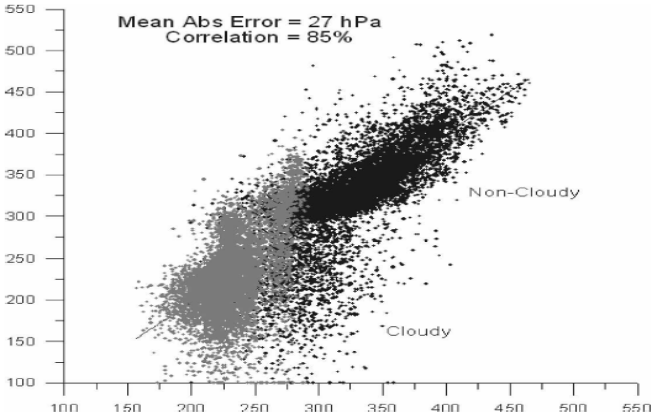


FIG. 6. Validation of derived WV tracer height [estimated pressure (hPa) on *x* axis] with corresponding EUMETSAT-derived height (*y* axis; hPa).

Main drawbacks

- An ad-hoc method.
- Tries to re-produce operational height assignment of Meteosat7, with its own limitations.
- Needs further training for other satellites, since the mapping is sensitive to satellite SRF.
- Don't use NWP forecast as background.
- **This is where ISRO-CIMSS collaboration has come up in 2010/2011.**

Improvement in Height assignment

-Collaboration with CIMSS/SSEC

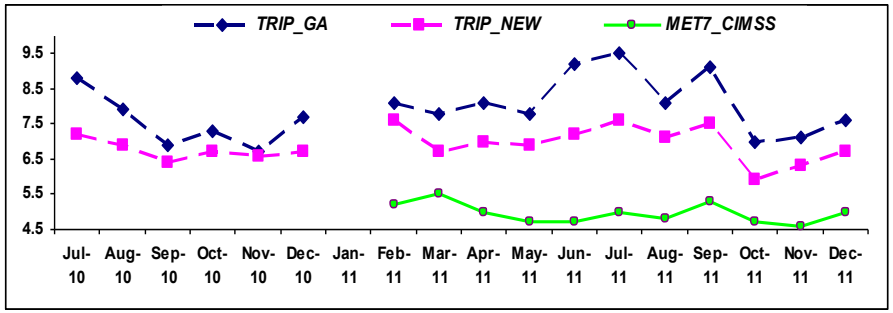
-(Chris Velden & his group)

Implemented following height assignment techniques in ISRO Algorithm

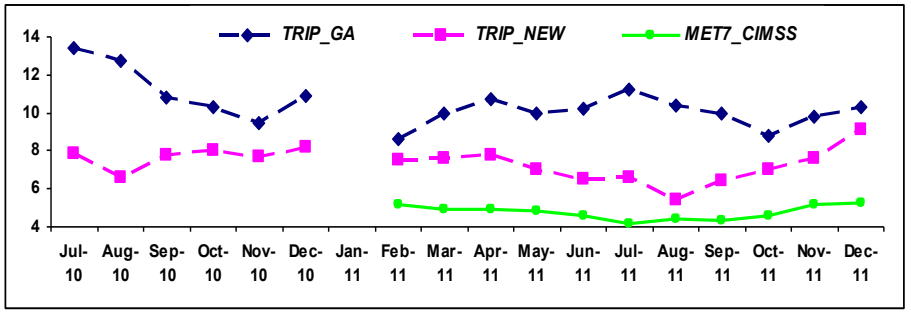
- Infrared window technique (WIN).
- H_2O Intercept Method. (Nieman et. al 1993)
- Cloud Base Method (BASE). (LeMarshall et. al 1993)
- Few gross error checks.

RMSVD

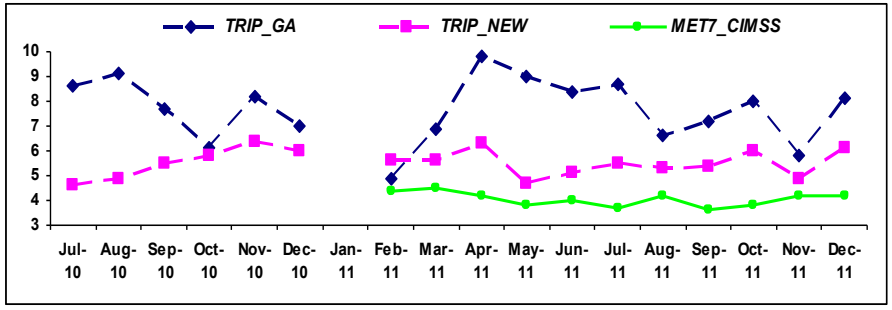
IR Winds **HIGH-Level**



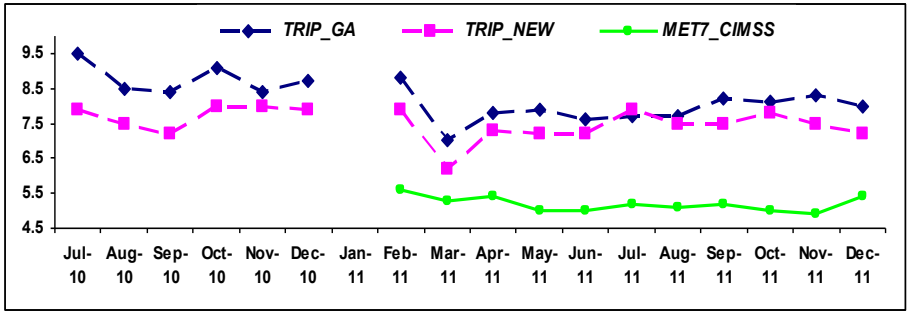
IR Winds **MID-Level**



IR Winds **LOW-Level**



WV Winds **HIGH-Level**



All the above validation is with radiosonde in region [30E -130E; 50S – 50N]

Reference: S. K. Deb, Steve Wanzong, C. S. Velden, Inderpreet Kaur, C. M. Kishtawal, P. K. Pal and W. P. Menzel, "Height Assignment improvement in Kalpana-1 Atmospheric Motion Vectors", 2011, submitted to *Remote Sensing Lett.*

Improvement in retrieval algorithm

- Use of full disc image is replaced with sector generated image with improved registration and fixed lat/lon co-ordinate.
- Take advantage of using multiple 30-min images, rather than traditional 3 images.
- The study (Kaur et al. 2011) for finding the temporal scales of satellite derived atmospheric winds over Asian Monsoon region has shown that Minimum Decorrelation time scale in AMV is ~ 4 hours.
- Based on the above study we take winds retrieved from previous 8-images (i.e. 7 sets of winds using 2-image at a time) as support for current time retrieval.

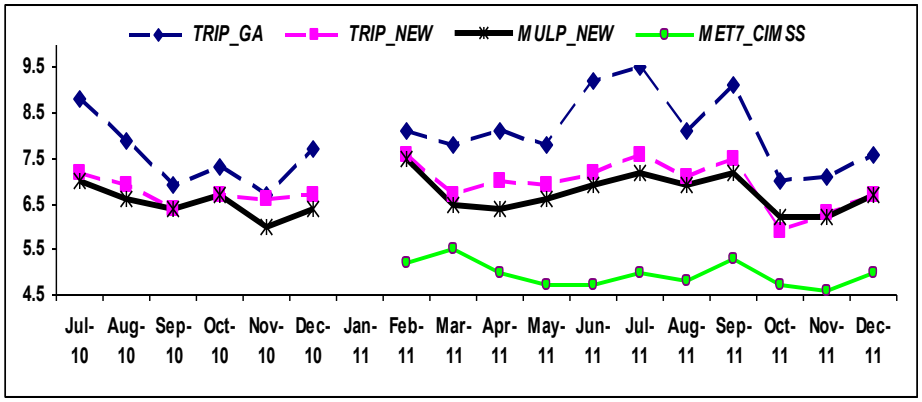
Details in the Session-2 presentation

References: Inderpreet Kaur, C. M. Kishtawal, S. K. Deb and Raj Kumar, "Temporal Scales of Satellite Derived Atmospheric Winds over the Asian Monsoon Region.", 2011, Published online 26 October 2011: DOI: 10.1109/LGRS.2011.2167494 *IEEE. Trans. Remote Sens. Letters*

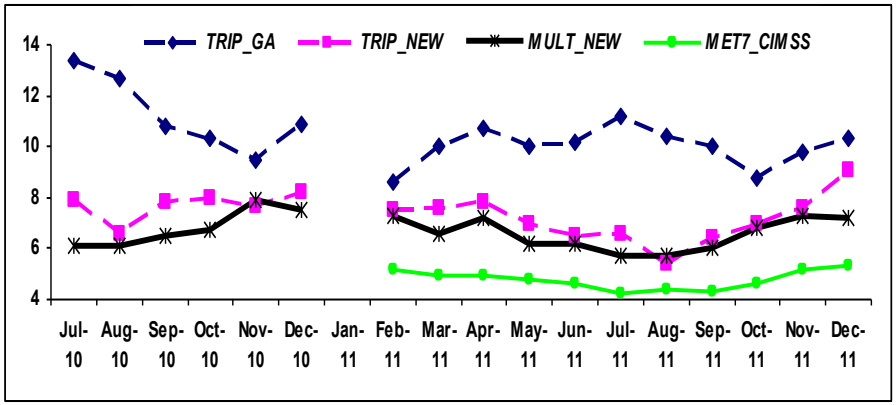
Validation statistics with radiosonde

RMSVD

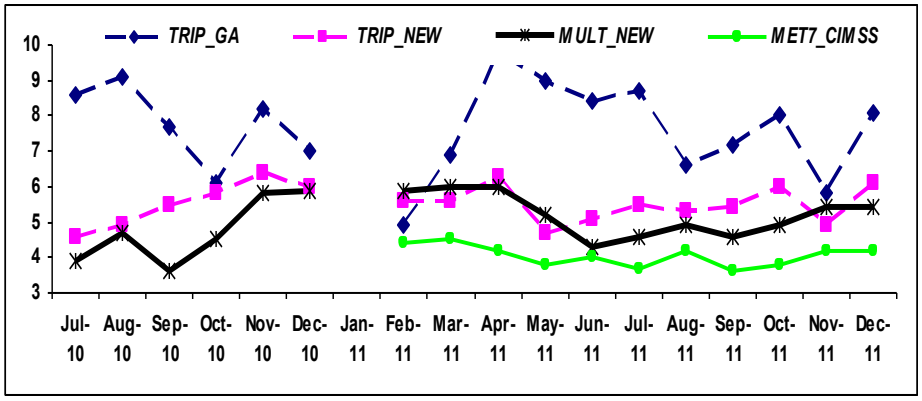
IR Winds HIGH-Level



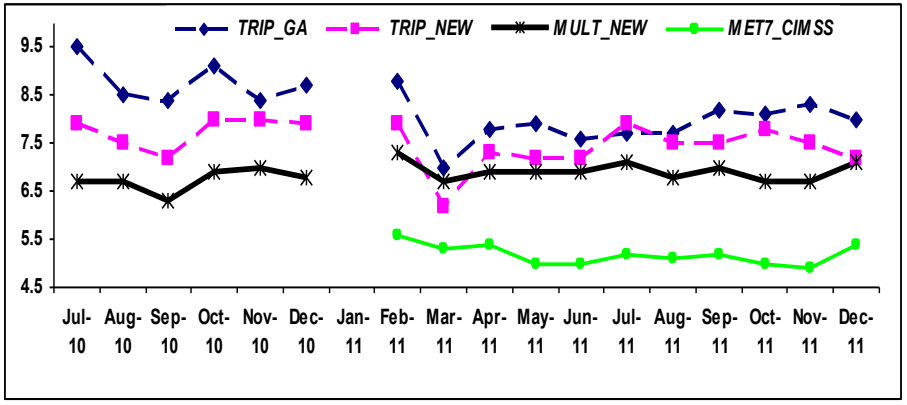
IR Winds MID-Level



IR Winds LOW-Level



WV Winds HIGH-Level



Note: Retrieval algorithm and resolution of Kalpana-1 & Meteosat7 are different.

Statistics: Average of all 17 months

	IR- HIGH			
	TRIP_GA	TRIP_NEW	MULT_NEW	CIMSS
MVD	7.6	6.7	6.4	4.7
RMSVD	7.9	6.8	6.6	4.9
SD	1.8	1.3	1.6	1.2
BIAS	-0.8	-0.7	-1.4	-0.9
SP	15.2	16	17.7	16.3
NC	4043	4671	4609	4175
	IR-MID			
MVD	9.9	7	6.2	4.4
RMSVD	10.4	7.3	6.6	4.7
SD	2.9	1.6	2.1	1.2
BIAS	-5.0	-1.8	-0.7	-1.2
SP	11.3	13.2	14.6	13.7
NC	883	857	842	848
	IR-LOW			
MVD	7.3	5.4	4.8	3.9
RMSVD	7.6	5.5	5	4.0
SD	0.9	0.4	0.9	0.4
BIAS	-3.1	-2.4	-1.0	-0.8
SP	7.8	7.8	8.5	8.8
NC	93	86	175	160
	WV-HIGH			
MVD	7.6	7.1	6.4	4.9
RMSVD	8.2	7.5	6.7	5.1
SD	2.8	2.15	1.8	1.6
BIAS	-1.2	-0.4	-0.4	-0.3
SP	18.3	18.4	17.9	17.2
NC	2873	2985	4766	3706

Filters:

Hor. Dist. < 110 Km
Vert. Dist. < 25 hPa
Speed Diff. < 30 m/s
Dir Diff. < 60 deg
AMV Speed > 2.5 m/s

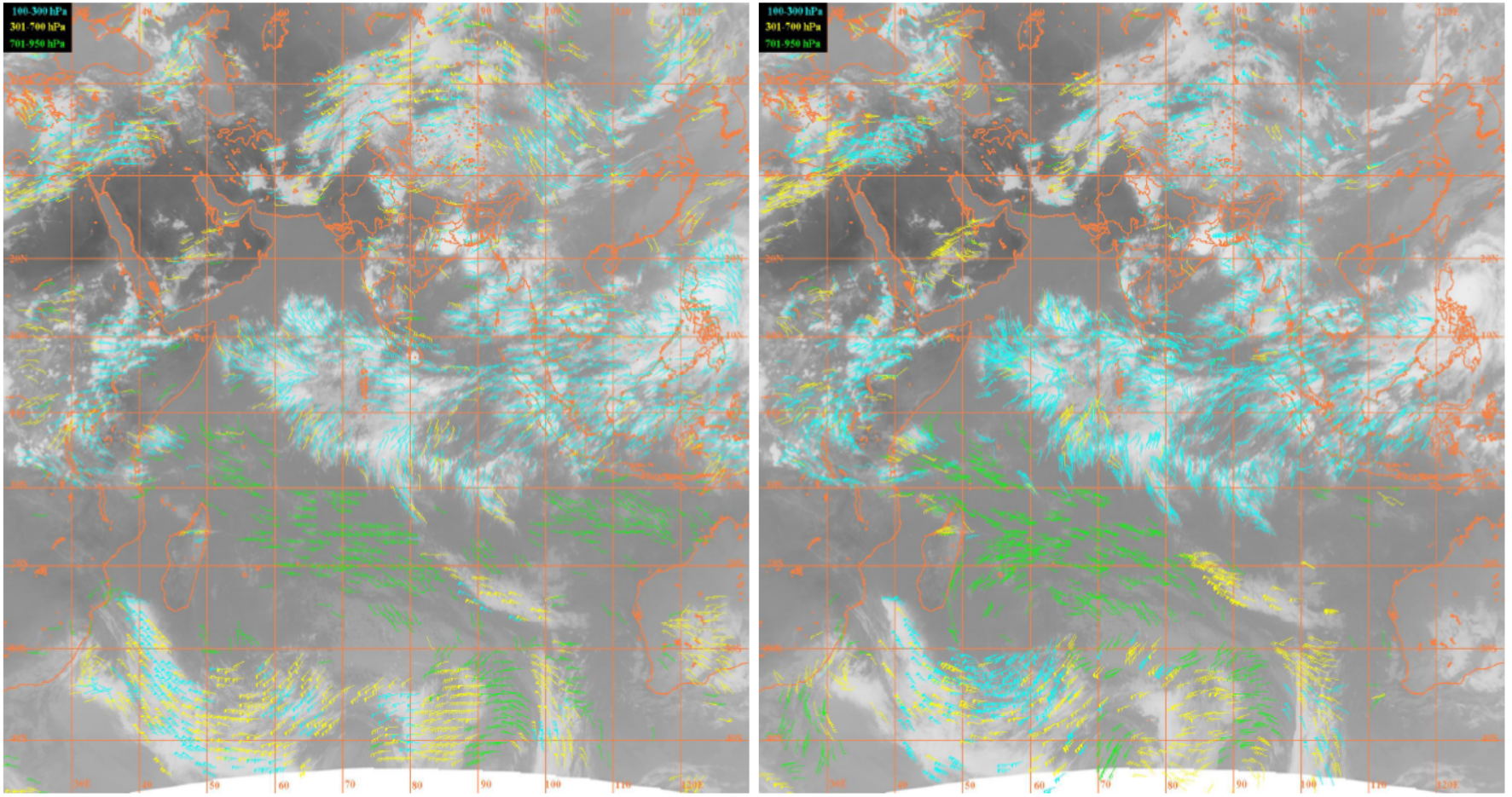
Approx. 7-9% of total collocations are affected due to these filters.

Examples

Kalpana-1/ISRO

Infrared winds valid at 26 May 2011 12 UTC

Meteosat-7/CIMSS



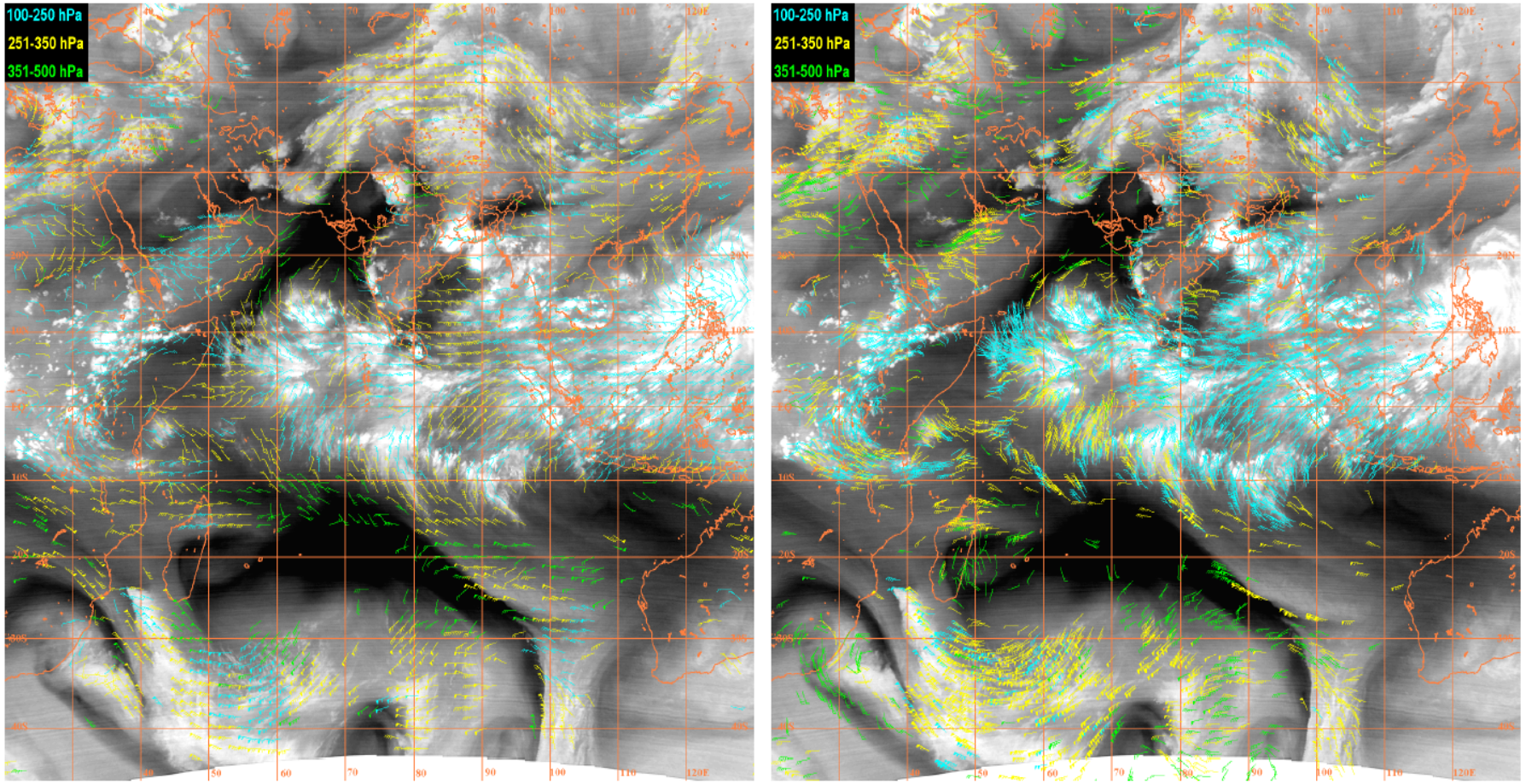
a) b)

Figure 4: A typical example of CMV winds derived over Indian Ocean region (20E-130E, 50S-50N) for 26 May 2011 valid at 1200 UTC using: a) Kalpana-1 VHRR with the present algorithm and b) Meteosat-7 VHRR derived at CIMSS USA.

- Thanks to CIMSS for Met7 winds

Water vapor winds valid at 26 May 2011 12 UTC

Kalpana-1/ISRO **Meteosat-7/CIMSS**



a) b)

Figure 5: A typical example of WV winds derived over Indian Ocean region (20E-130E, 50S-50N) for 26 May 2011 valid at 1200 UTC using: a) Kalpana-1 VHRR with the present algorithm and b) Meteosat-7 VHRR derived at CIMSS USA.

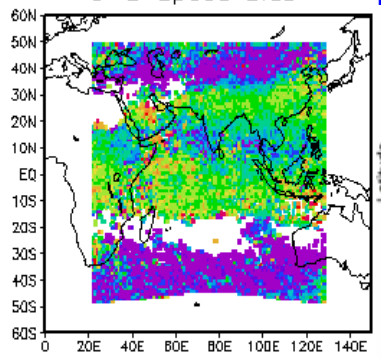
- Thanks to CIMSS for Met7 winds

Spatial error analysis with NCEP GFS analysis

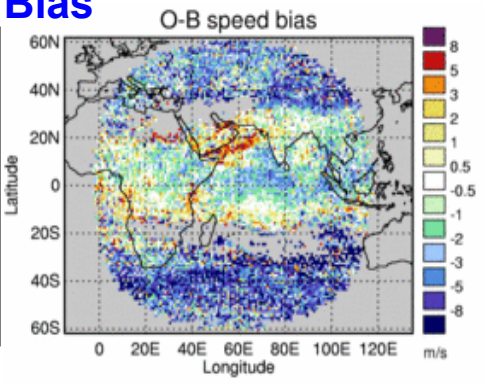
HIGH Level IR winds comparisons Period: September 2011

Bias

Kalpana-1

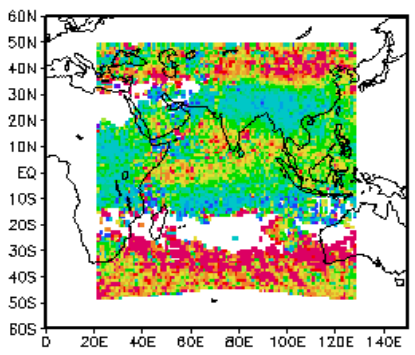


Meteosat-7

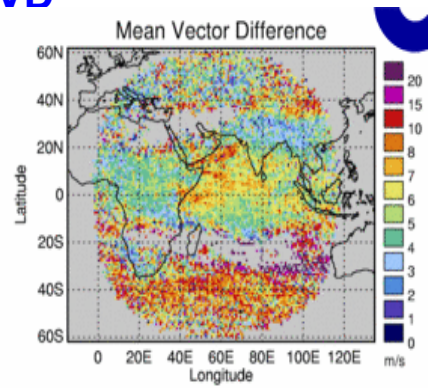


MVD

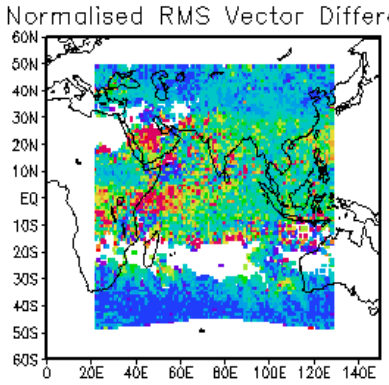
Kalpana-1

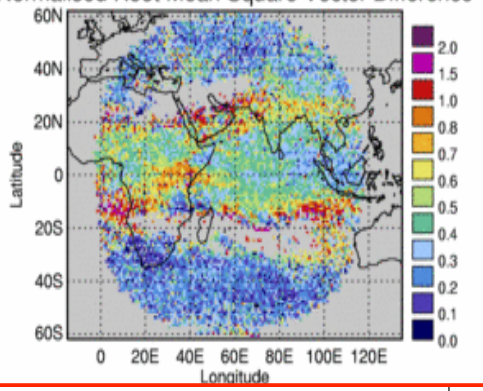


Meteosat-7

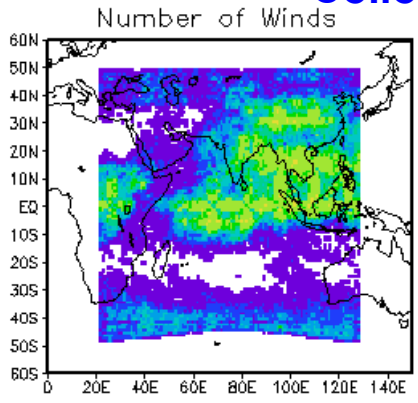


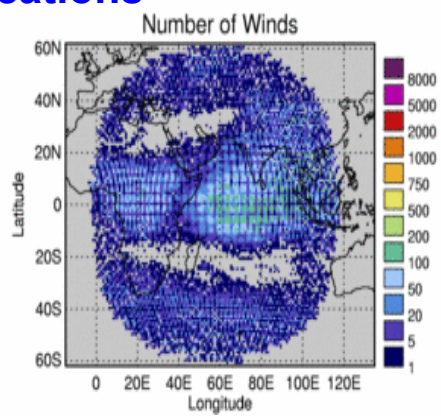
RMSVD (Normalized)

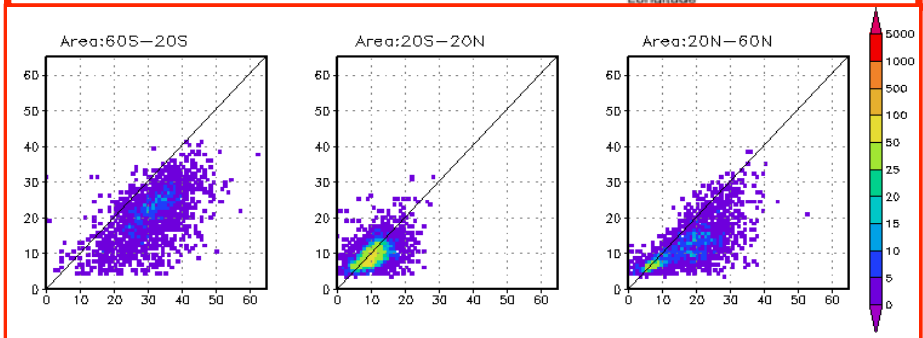


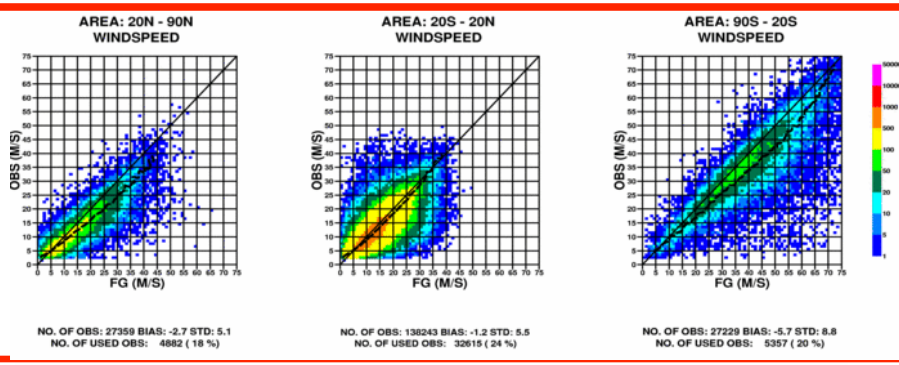


Collocations







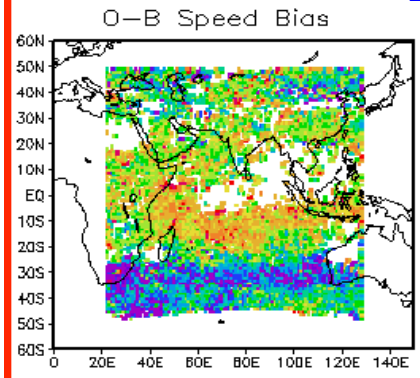


- Thanks to UKMO website

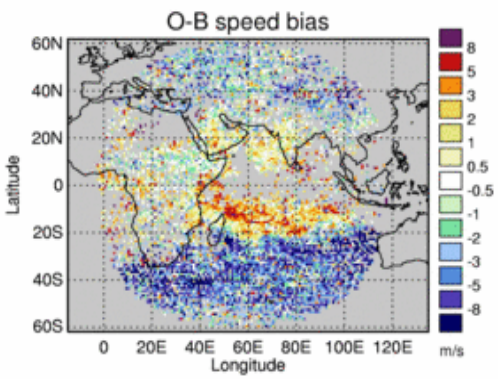
MID Level IR winds comparisons Period: SEPT2011

Bias

Kalpana-1

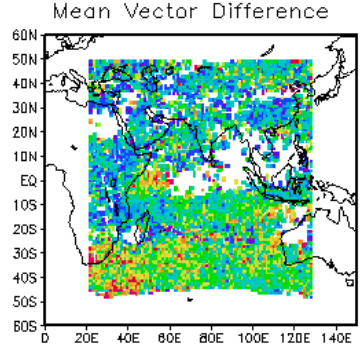


Meteosat-7

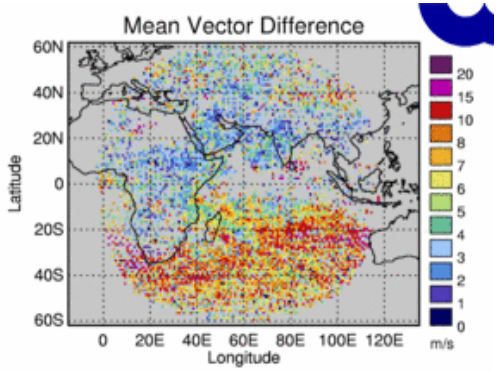


MVD

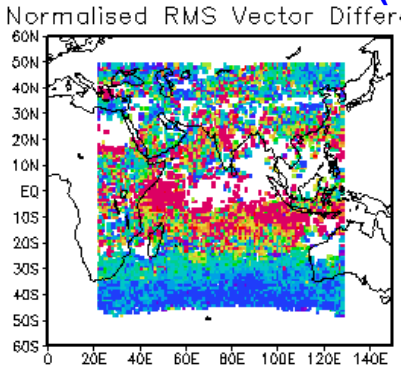
Kalpana-1

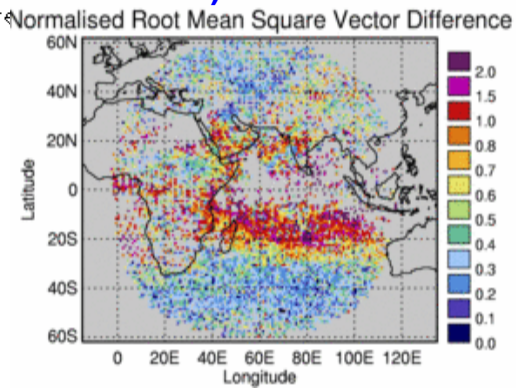


Meteosat-7

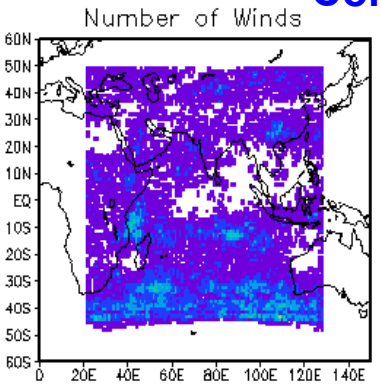


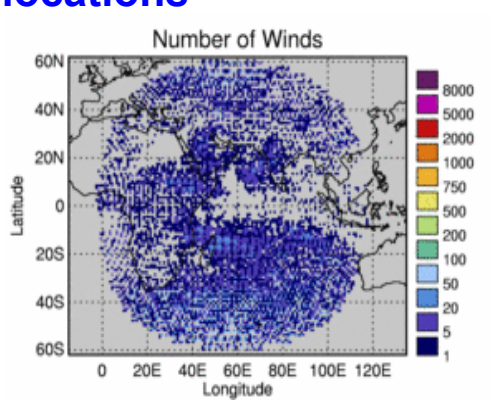
RMSVD (Normalized)

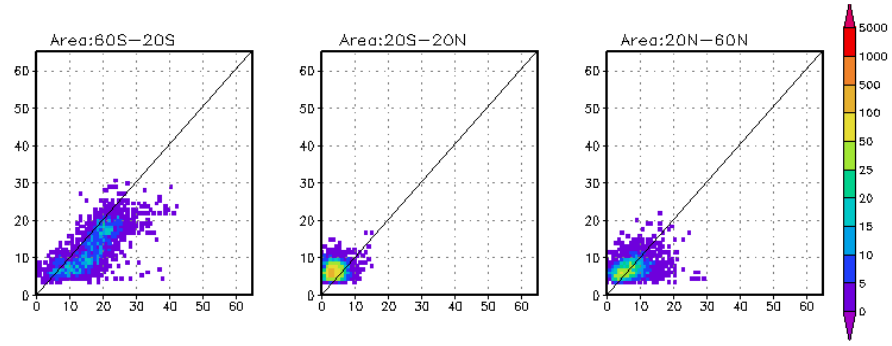




Collocations





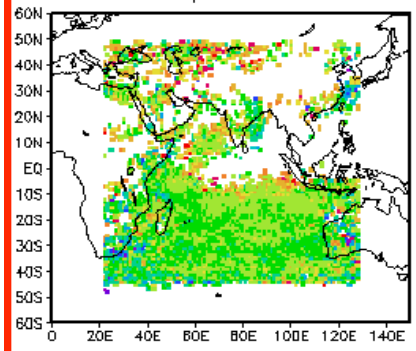


- Thanks to UKMO website

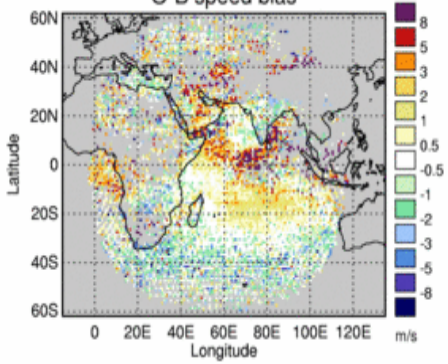
LOW Level IR winds comparisons Period: SEP2011

Bias

Kalpana-1

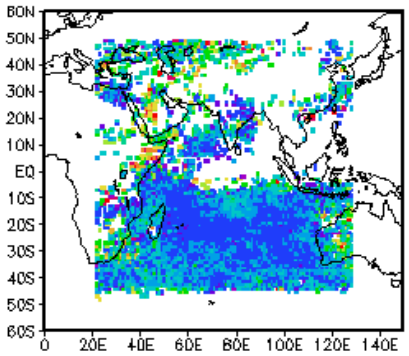


Meteosat-7



MVD

Kalpana-1



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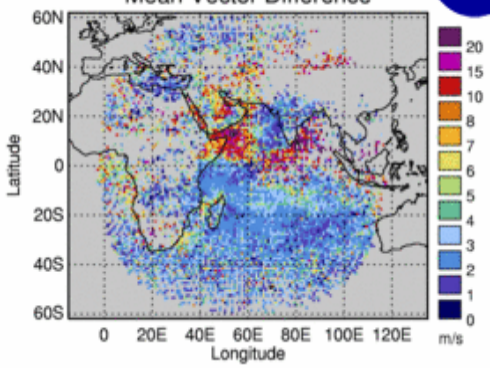
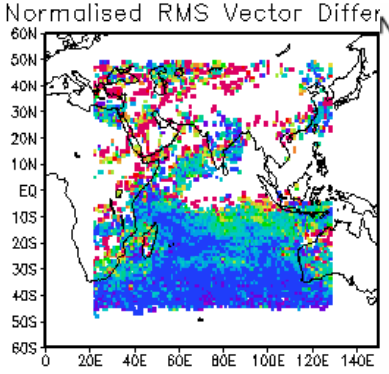
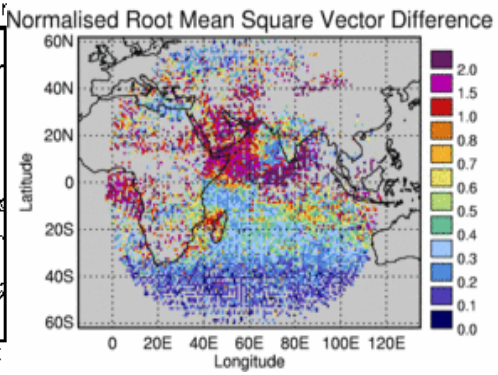
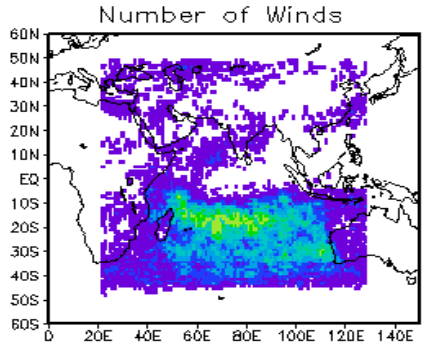


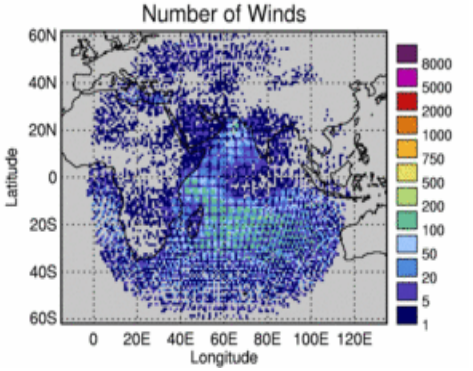
RMSVD (Normalized)

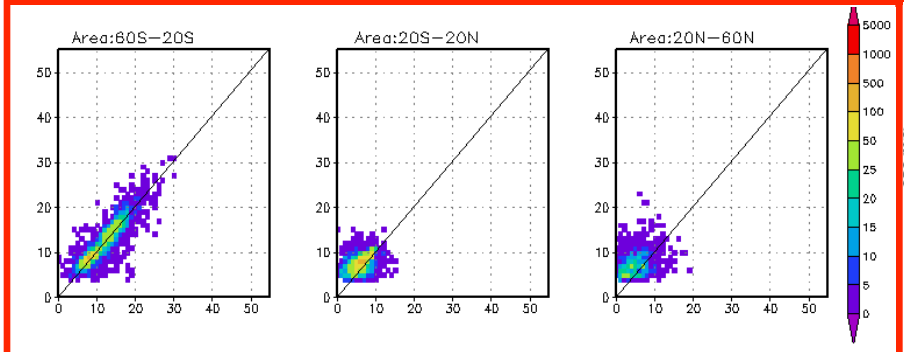


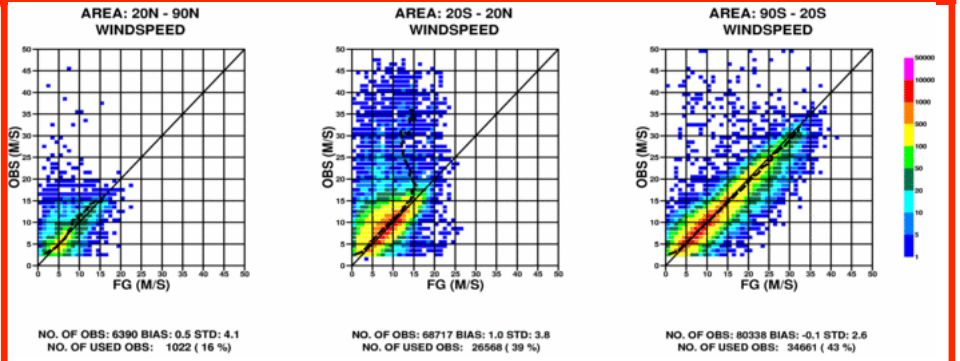


Collocations







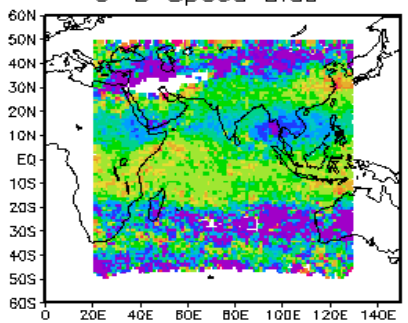


– Thanks to UKMO website

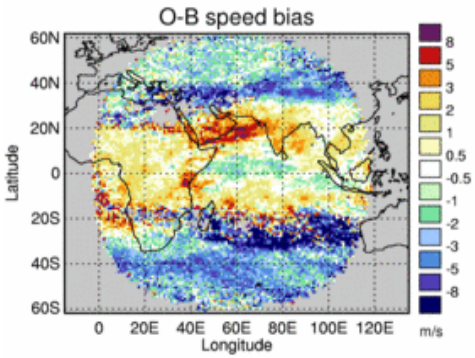
HIGH Level WV winds comparisons Period: SEPT2011

Bias

Kalpana-1

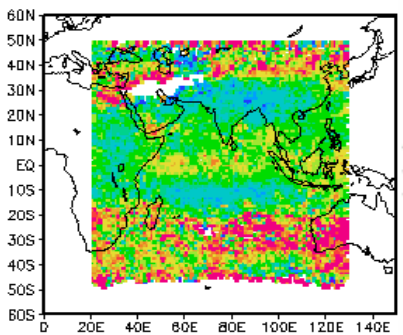


Meteosat-7



MVD

Kalpana-1



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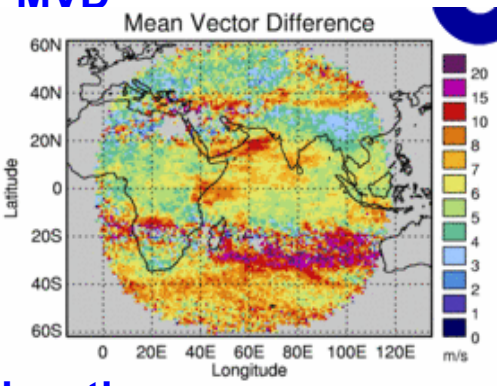
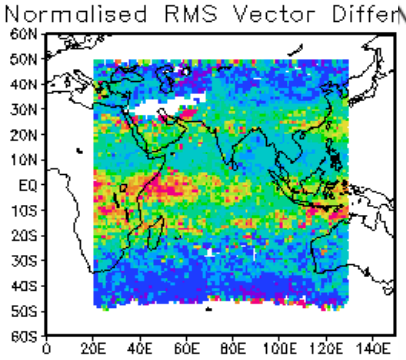
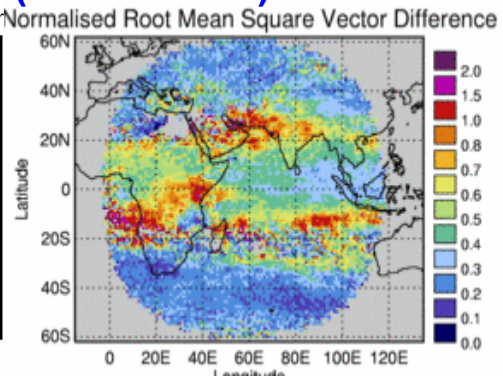
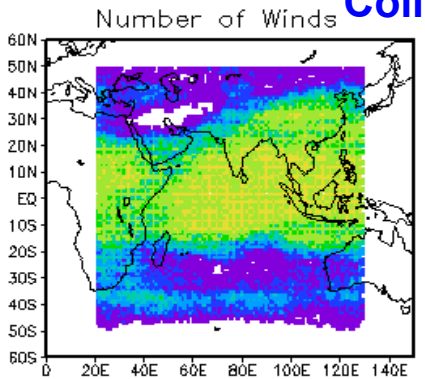


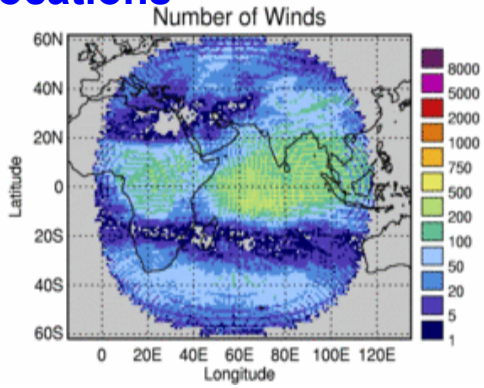
RMSVD (Normalized)

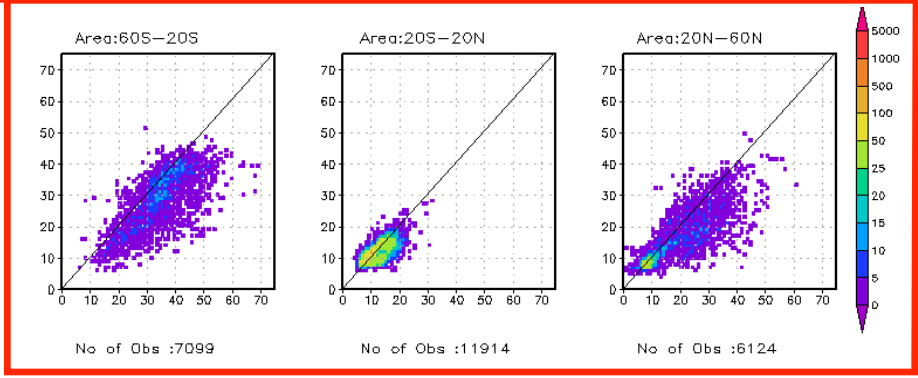


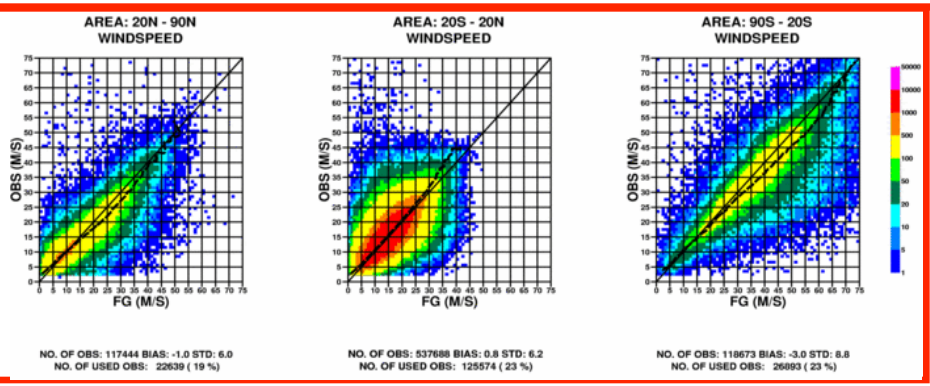


Collocations









– Thanks to UKMO website

Conclusions:

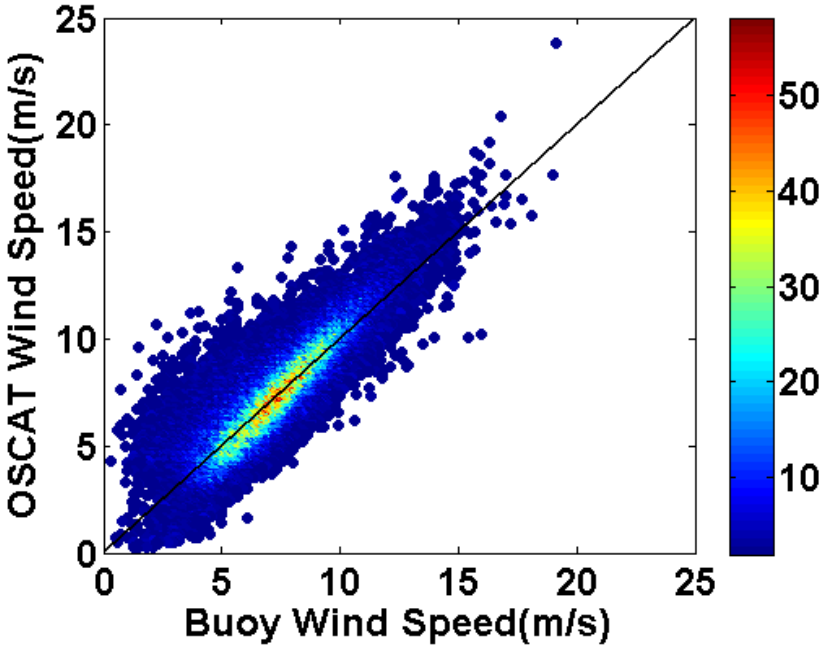
- Statistical analysis shows significant improvement after implementation of new height assignment and some positive impact for new retrieval algorithm.
- However more improvement is required to match with accuracies of other operational agencies.
- Spatial error analysis resembles well with UKMO error analysis for Met7.

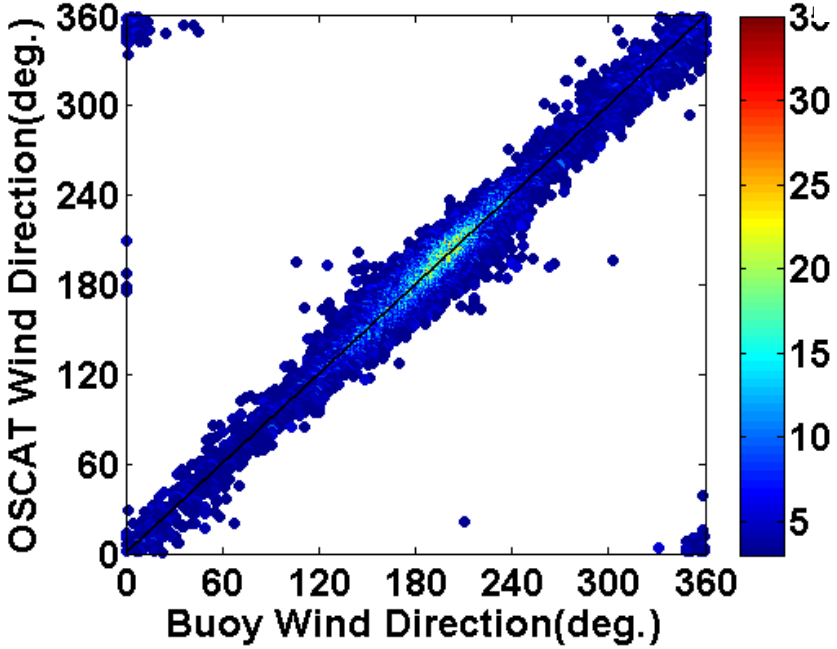
Future directions:

- Expect some more improvement with incorporation of auto editor.
- Optimization in tracer selection.
- To retrieve winds from visible and 3.9 μm channel.
- Wish to collaborate with other operational agency for further improvement.

OSCAT: ISRO Status

OSCAT Validation: Latest version released on 15th December 2011





Statistics of OSCAT comparison with Buoys, Model and ASCAT for 4-24 m/s

OSCAT with	Temporal Difference	No. of collocated data	Wind speed		Wind direction	
			Bias	RMSE	Bias	RMSE
Buoy	30 min	51039	0.091	1.393	-0.447	21.261
ASCAT	3 hr	9,78,455	0.19	1.14	0.49	18.39
ECMWF	6 hr	29290996	0.018	1.439	-0.69	17.16
NCEP	6 hr	33951459	-0.076	1.754	-0.46	18.83

Source: OSCAT ISRO validation team

Analysed Wind Products

-Source: Rajkumar & Abhishek Chakraborty (rksharma@sac.isro.gov.in)

Daily 3 Products: 50 Km resolution

2 Products of 12 Hourly Analysed Winds for 0-12 and 12-24 UTC

1 Product of Daily Analysed Winds

Parameters

1. Wind Speed Magnitude (m/s)
2. U-component of Wind (m/s)
3. V-component of Wind (m/s)
4. Wind stress (Pa)
5. Zonal wind stress (Pa)
6. Meridional wind stress (Pa)
7. Wind Divergence (s^-1)
8. Curl of wind stress (Pa/m)

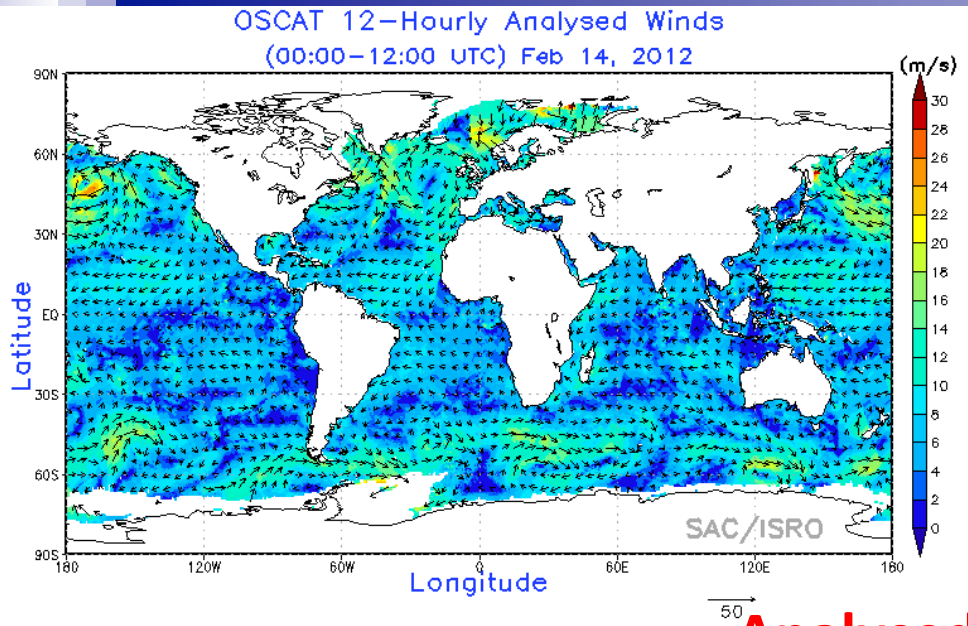
Total 3 Files for each Product

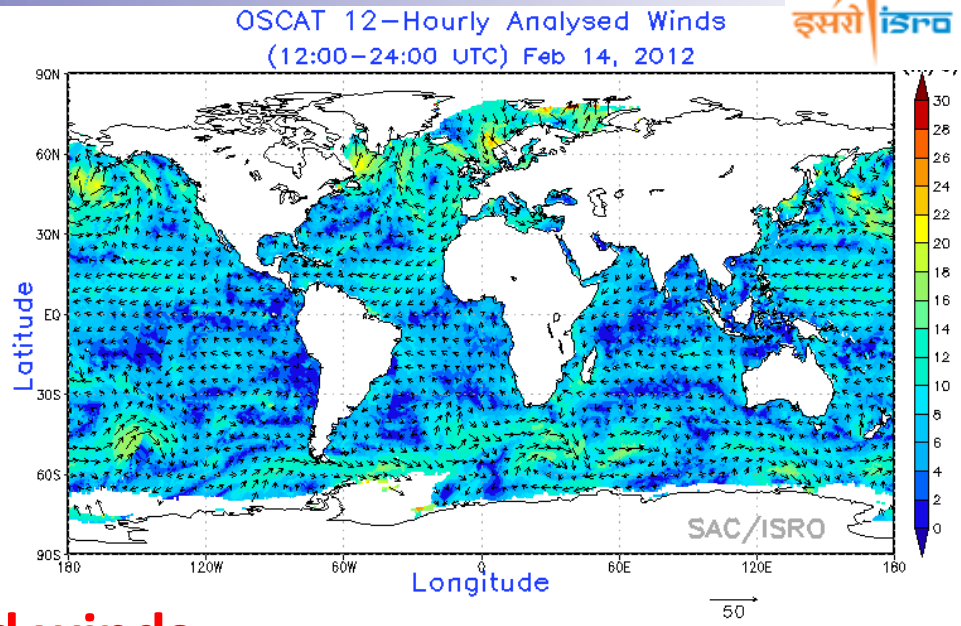
1) Binary File O2SCT_25MAY2011_DAILY_L04_AWV50.grd (~8MB) for Daily
2) Log File O2SCT_25MAY2011_DAILY_L04_AWV50.Log (~1KB)
3) Wind GIF File O2SCT_25MAY2011_DAILY_L04_AWV50.gif (~39KB)

For 12 Hourly

O2SCT_25MAY2011_0600_L04_AWV50.grd for 00-12 UTC

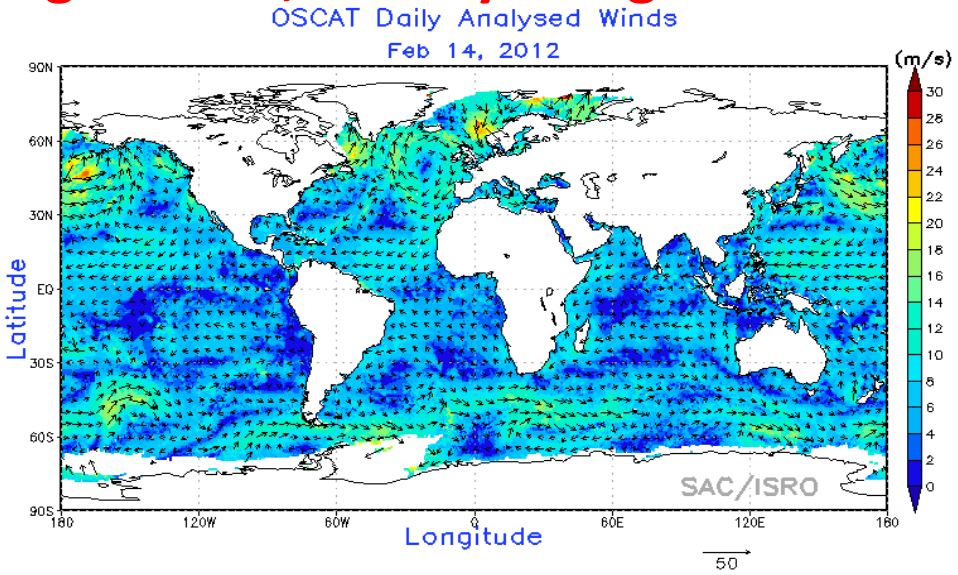
and O2SCT_25MAY2011_1800_L04_AWV50.grd for 12-24 UTC

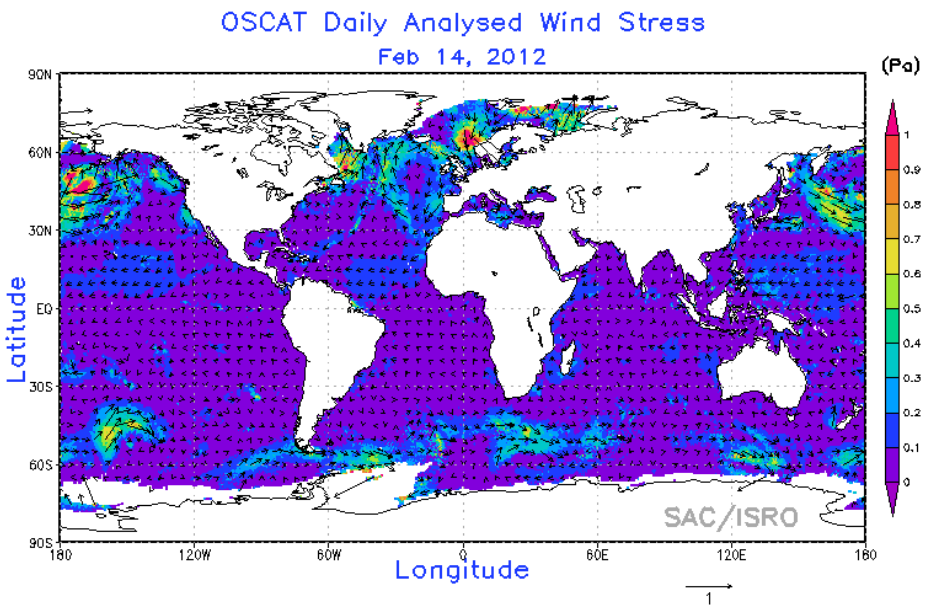


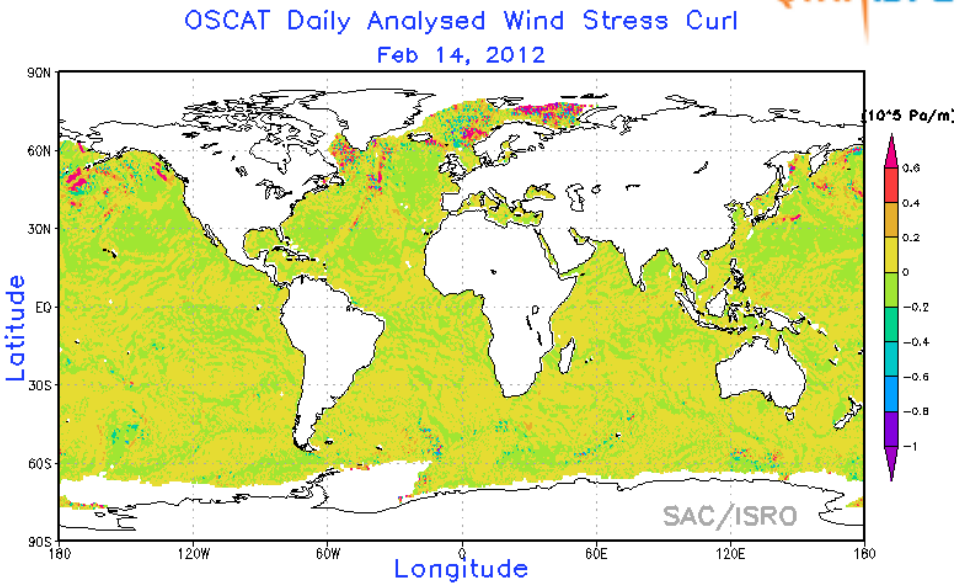


Analysed winds

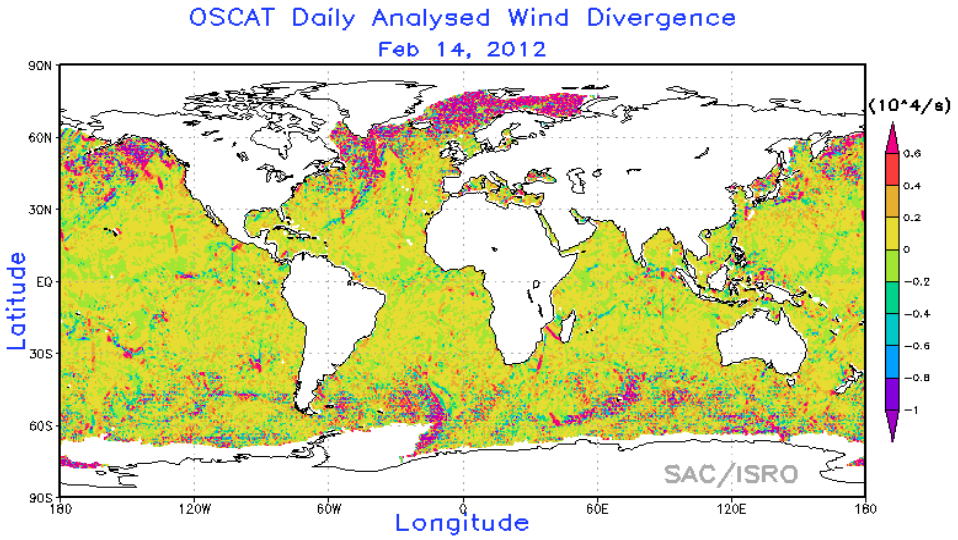
Daily using OSCAT ; 12 Hrly using OSCAT & ASCAT





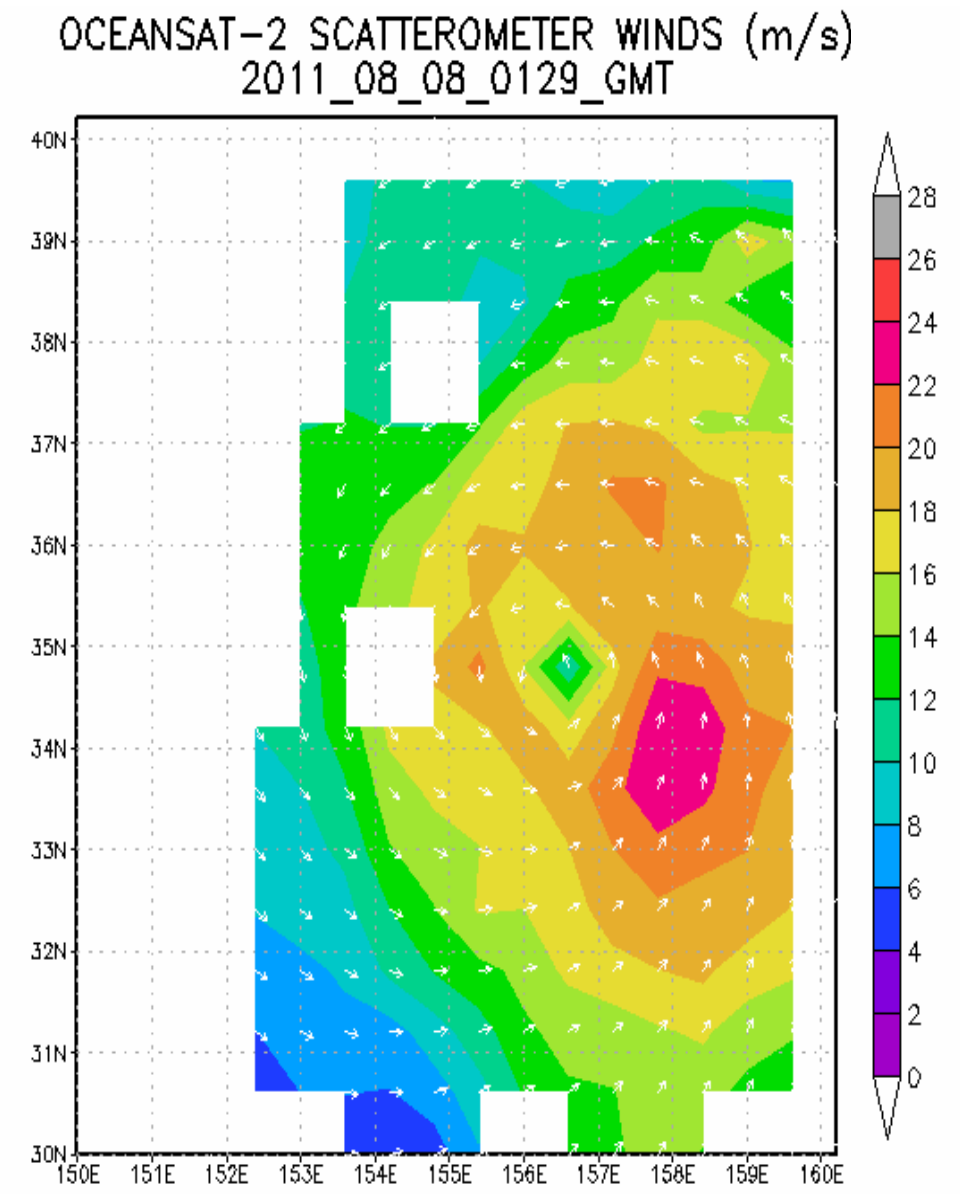


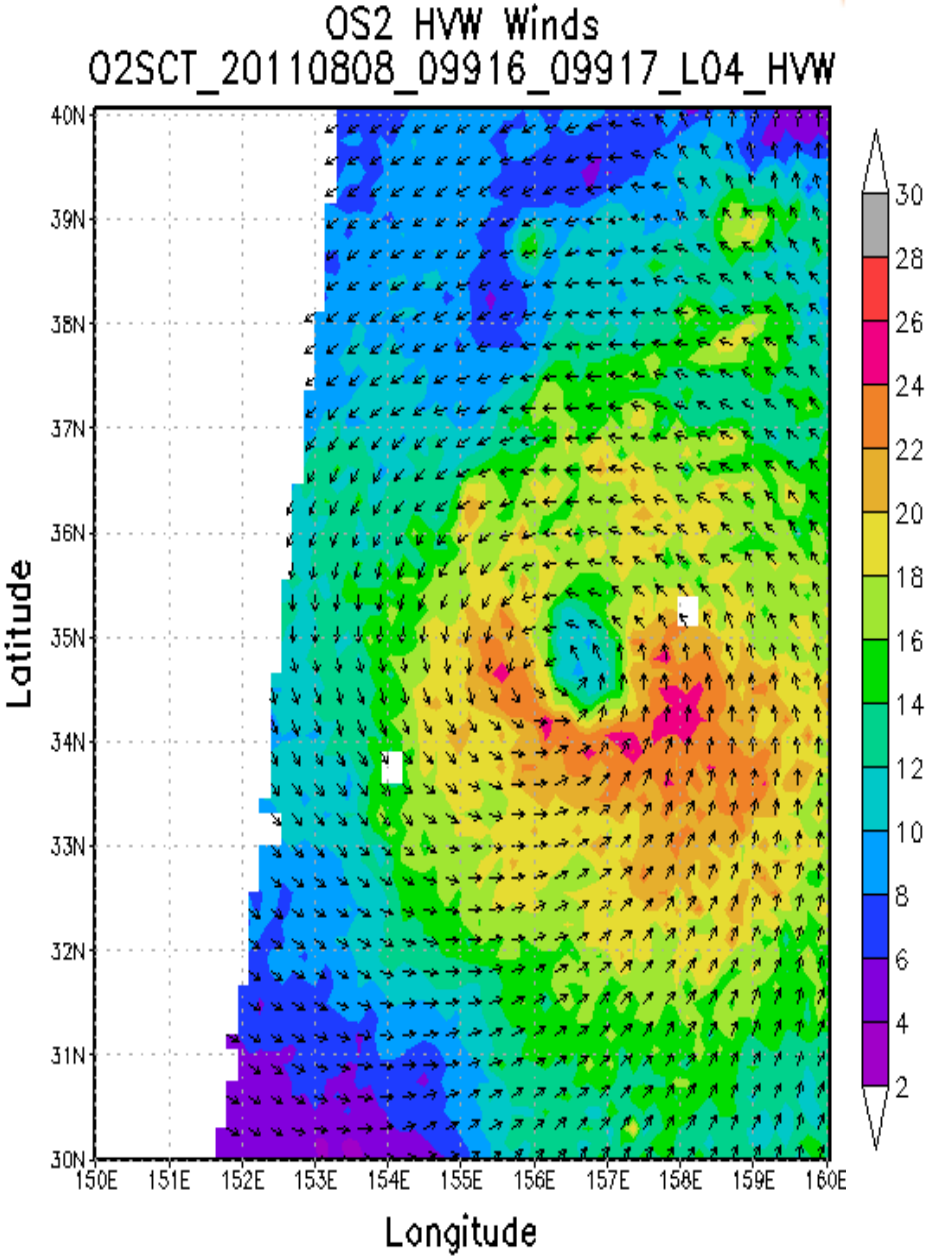
Daily Analysed wind Products using OSCAT (Stress, Curl, Div.)

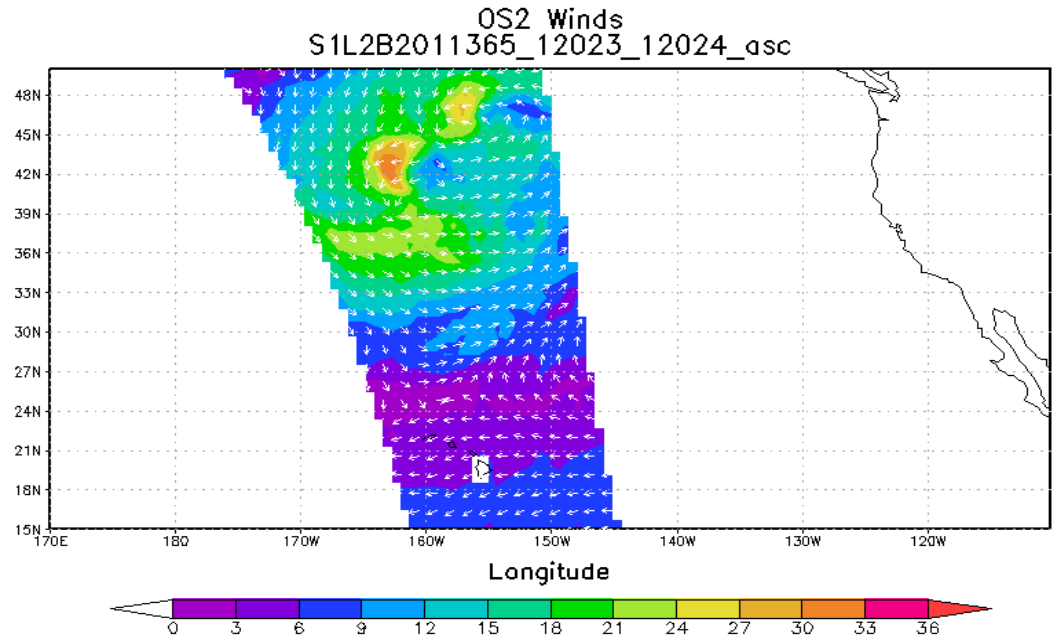


Fine features resolved by High Resolution OSCAT winds during Cyclone "MERBOK"

- Source: B. S. Gohil & Rajesh Sikhakolli (bsgohil@yahoo.com)

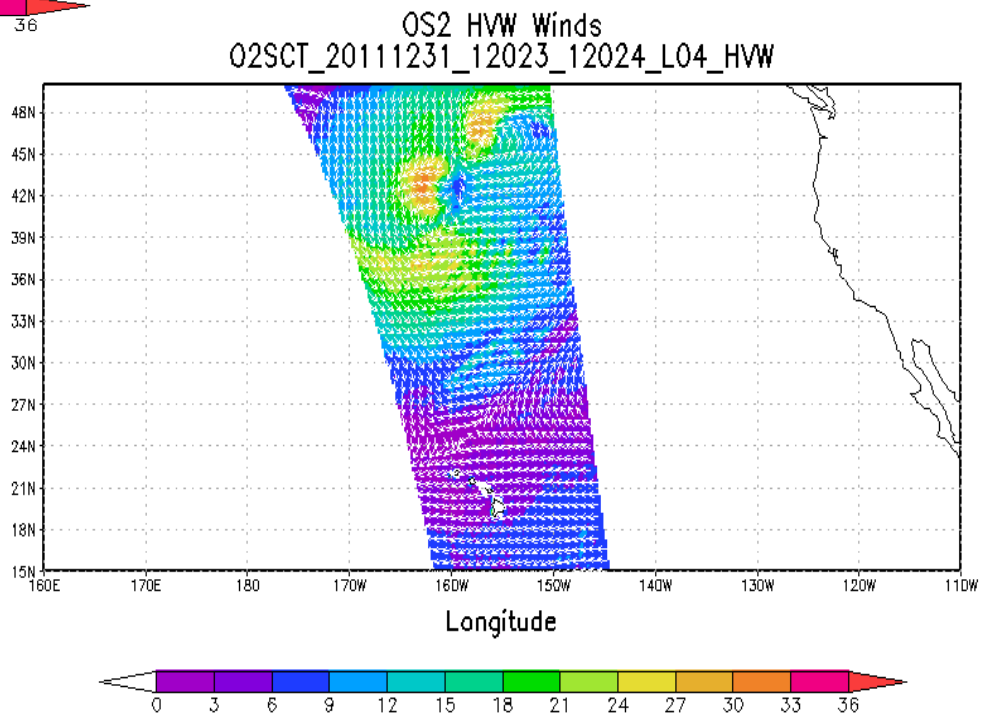






L2B Winds

High Res winds



Acknowledgement

- EUMETSAT for financial support for attending 11IWW
- SSEC/CIMSS for scientific collaboration.
- 11IWW organizing committee for all support.
- Director and Associate Director SAC/ISRO for all support.
- EUMETSAT/CIMSS/UKMO for using their AMV products and analysis report.

THANK YOU