MULTIPLET BASED TECHNIQUE TO DERIVE ATMOSPHERIC WINDS FROM KALPANA-1

Sanjib K. Deb, C. M. Kishtawal, Inderpreet Kaur,
P. K. Pal and A. S. Kirankumar

Space Applications Centre
Indian Space Research Organization,
Ahmedabad, India
E-mail: sanjib_deb@sac.isro.gov.in

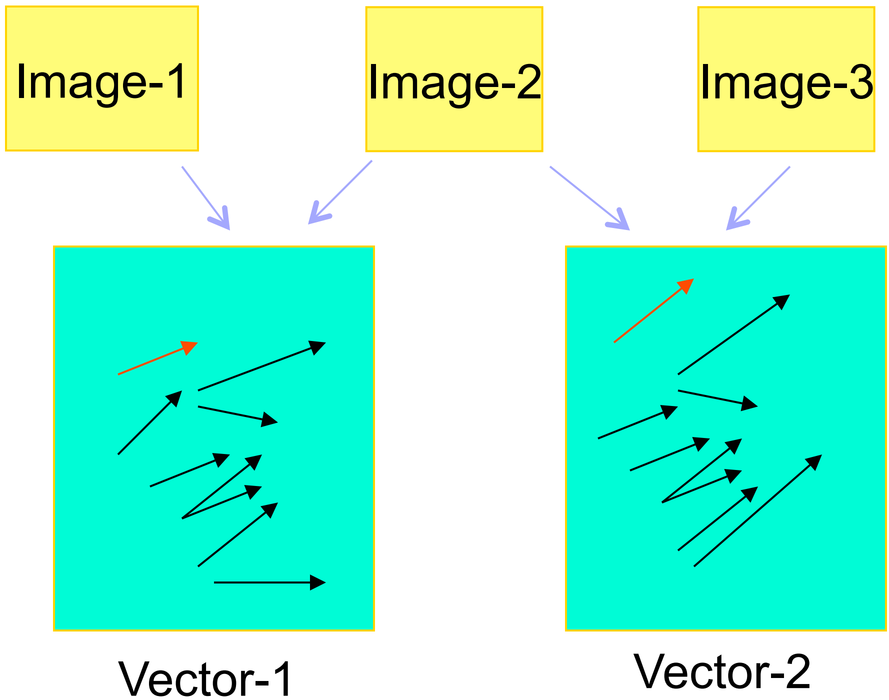
20-24 February 2012

11th International Winds Workshop,
Auckland, New Zealand

Contents:

- Limitations of Triplet algorithm.
- Temporal scale of AMV.
- Recent improvement in retrieval algorithm.
- Validation statistics with radiosonde.
- Spatial error analysis with NCEP GFS.
- Findings of this study.
- Future directions.

Conventional Triplet Method : Limitation



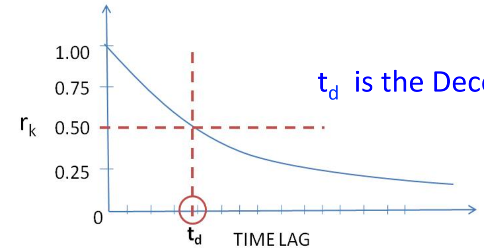
- **Conventional methodology requires that a vector is available in both sets, if not so, such vectors are rejected, because they don't get "support".**

- **Many "isolated" vectors thus get eliminated, even though they represent the real situation.**

AUTOCORRELATION & DECORRELATION TIME

- For a discrete time series $\{u_i : 1 \le i \le n\}$, for every member of the series some degree of dependence upon the preceding members can be deduced.

- For time lag ***k***, autocovariance :
$$c_k = \frac{1}{n-k-1}\sum_{i=k+1}^{n}\left(u_i-\bar{u}\right)\left(u_{i-k}-\bar{u}\right)$$



t_d is the Decorrelation time

- **Autocorrelation function :** $r_k = \dfrac{c_k}{c_0}$, c_o is the variance of the time series.

- Defining **Vector wind** is a complex quantity **U = u+iv ,** where i is square root of -1

- Vector Autocorrelation Coefficient :
$$c_k = \frac{\frac{1}{n}\sum_{i=1}^{n-k}\left(X_i-\bar{X}\right)\left(Y_i-\bar{Y}\right)^*}{\left[\frac{1}{n}\sum_{i=1}^{n-k}\left|X_i-\bar{X}\right|^2\right]^{\frac{1}{2}}\left[\frac{1}{n}\sum_{i=1}^{n-k}\left|Y_i-\bar{Y}\right|^2\right]^{\frac{1}{2}}}$$
, where X and Y are two complex quantities.

- **DECORELATION TIME** is an Index to define the time at which the Autocorrelation coefficient drops to 0.5 .

- Assumed beyond this time the two variables cease to have any meaningful relationship.

REGION OF STUDY:

- **Indian Monsoon Region**

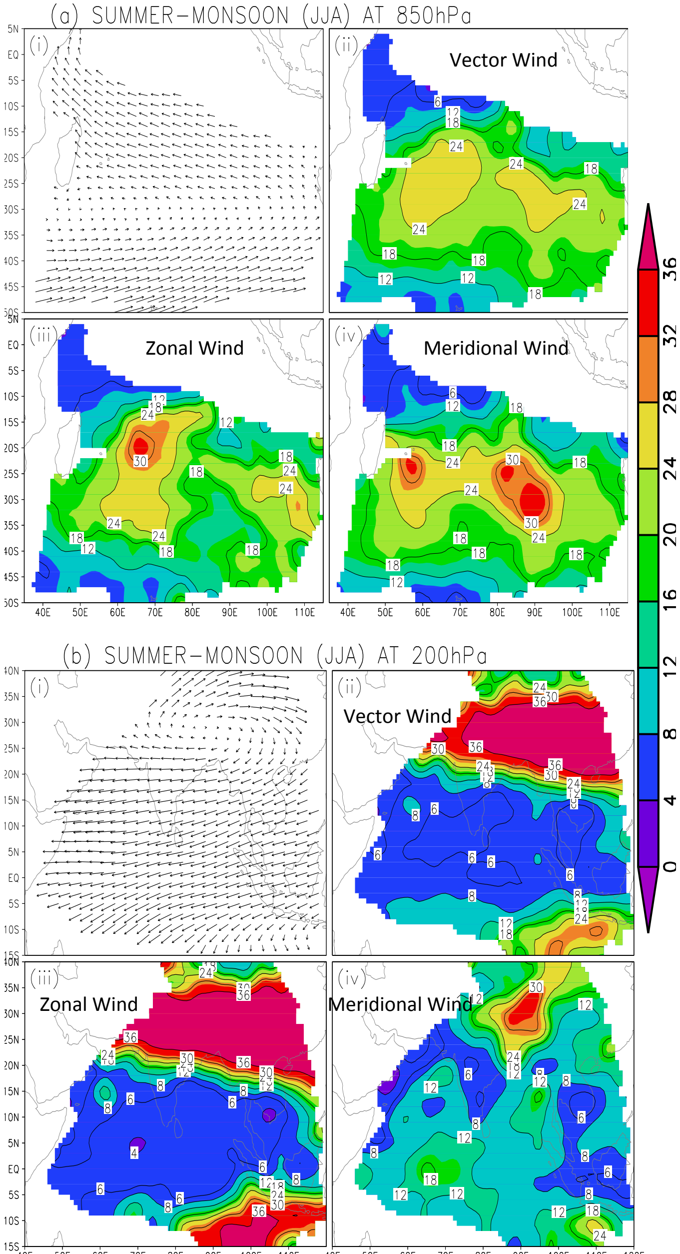
- To ensure availability of reasonable temporal observations those regions were selected where data gaps were less than a certain threshold.

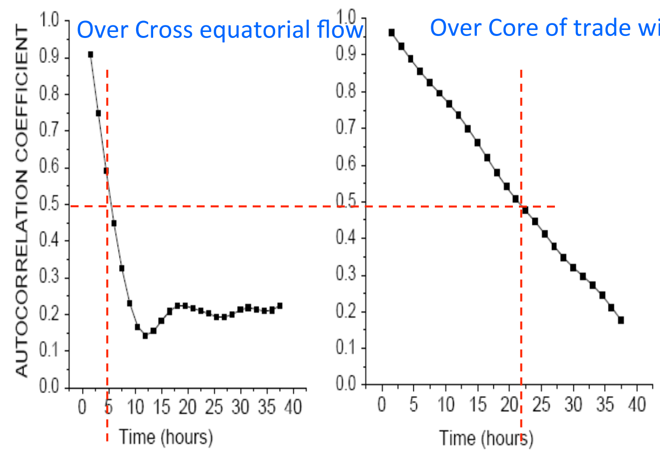
- Threshold for upper atmosphere was fixed at 50% of maximum available observations.

- At lower level it was taken to be 20- 25 % of maximum available observations.

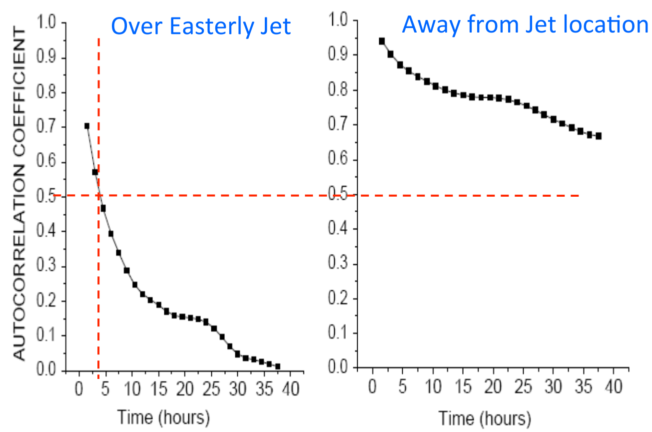
Reference: Inderpreet Kaur, C. M. Kishtawal, S. K. Deb and Raj Kumar, "Temporal Scales of Satellite Derived Atmospheric Winds over the Asian Monsoon Region.", 2011, Published online 26 October 2011: DOI: 10.1109/LGRS.2011.2167494 *IEEE. Trans. Remote Sens. Letters*

Decorrelation Time scales for Summer Monsoon (JJA)



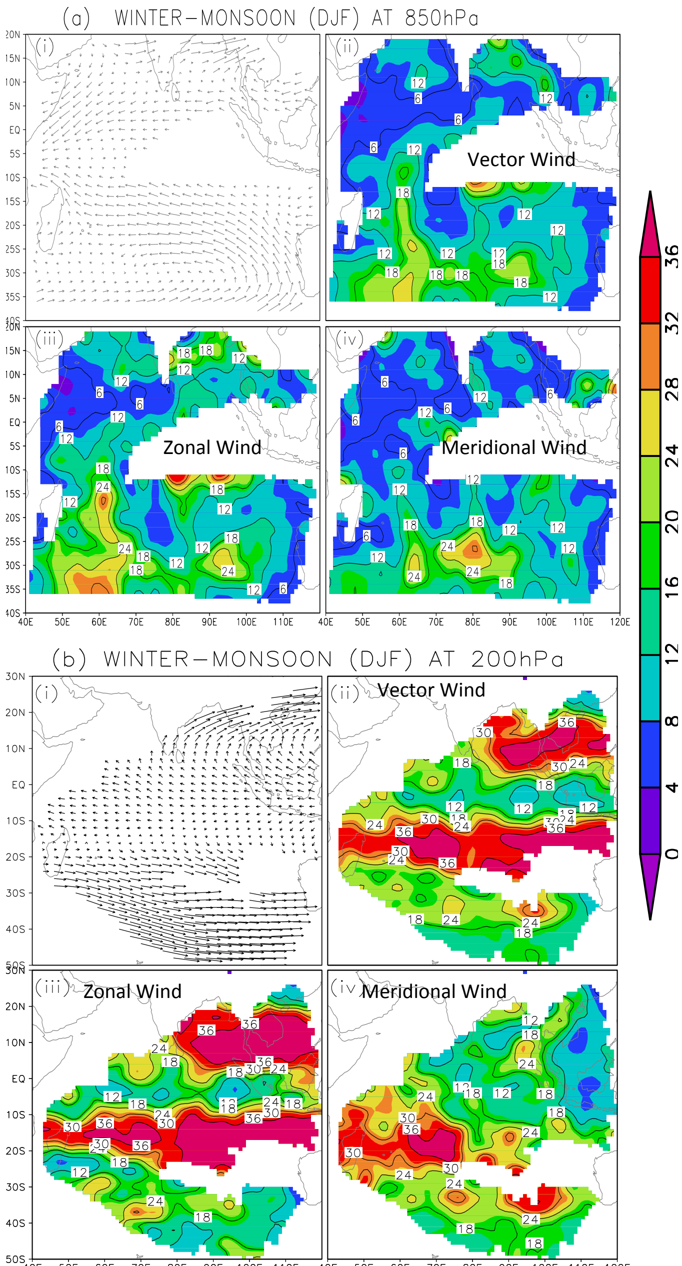


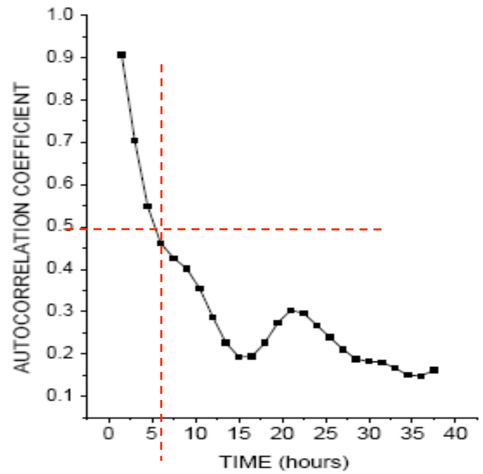
- **Most stable winds occur in core of the trades for 850hPa winds.**
- **This persistence of winds is evident in in t_d ~ 18-24 hours.**
- **Weakest winds occur in region over northern tip of Madagascar.**
- **In this region t_d ~ 6 hours.**



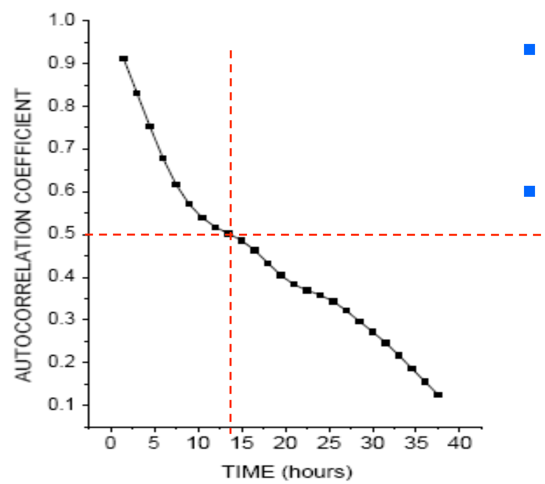
- **Winds over Northern IO and peninsular India have low t_d ~ 4-8 hours.**
- **Strong lateral and vertical wind shears in the Easterly jet (~14N) might be responsible for low stability.**
- **Highly stable zonal and meridional flow over the mid-latitudes, t_d ~ 24-36 hours.**

Decorrelation Time scales for Winter Monsoon (DJF)





- Cloud free conditions lead to less data over the subcontinent.
- Persistence levels of the order of 6-12 hours were observed in all the three cases.



- Westerlies towards the Australian Region are stable and strong winds.
- Very high decorrelation time scales ~36 hours were observed

Findings from temporal scale satellite winds study

❖ Dominant Seasonal Forcing cause the winds to be highly persistent.

❖ Minimum Decorrelation time scale is observed ~ 4 hours.

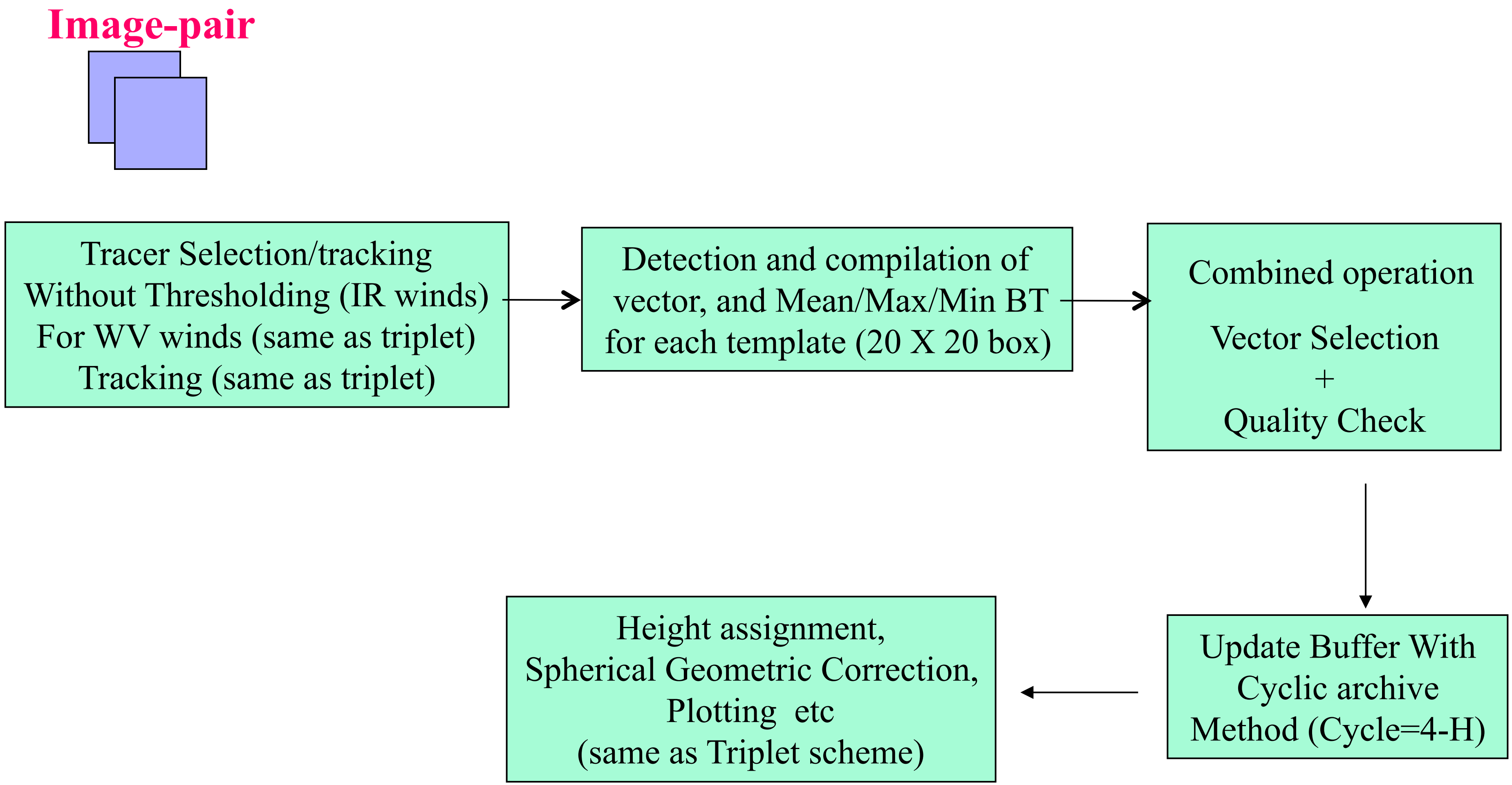
❖ Each AMV represents 160km x 160km area and loses out on the fine scale features of winds.

❖ AMVs themselves have inherent errors ~ 8m/s and 4m/s in mean vector difference for the upper and lower atmospheric levels (Borde et al , 2010) which may affect the accuracy of the decorrelation time scales.

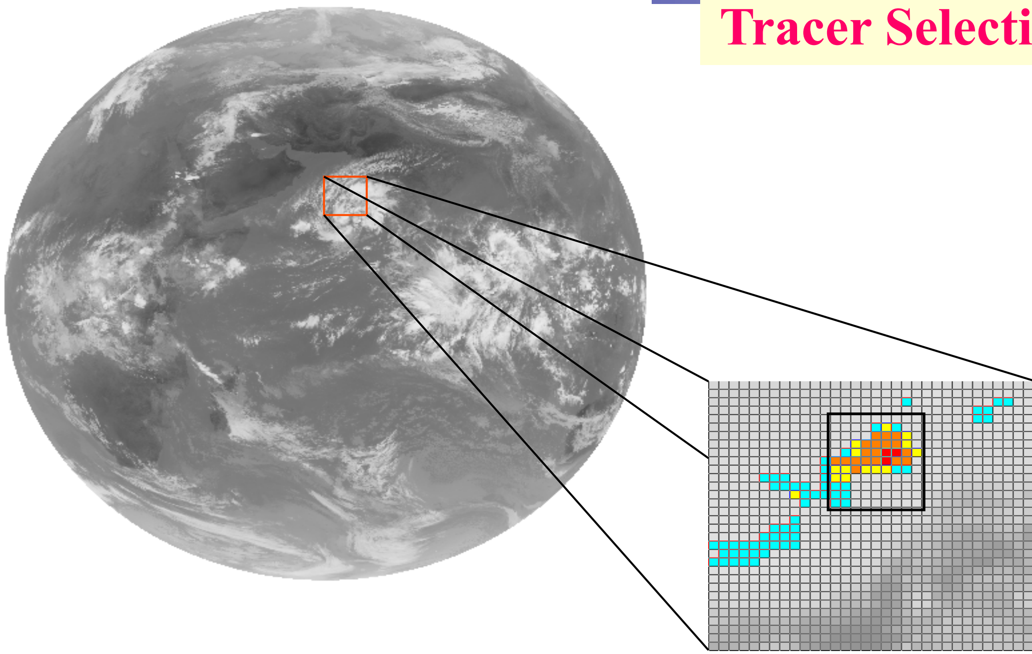
❖ This information can be potentially useful in the optimization issues eg. in assimilation , validation and retrieval.

❖ Can be used for the Short term empirical prediction.

Recent modification in retrieval algorithm



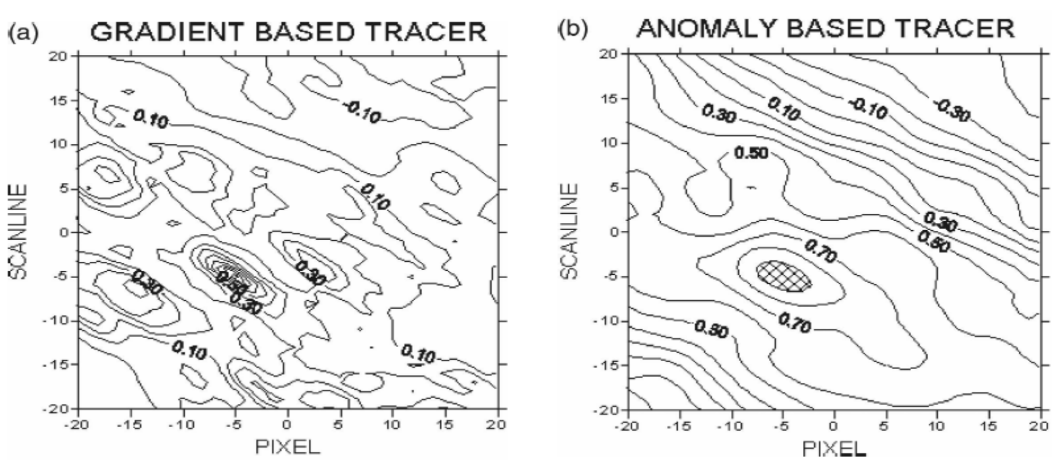
Tracer Selection method



•The tracer selection method based on local image anomaly. This method results in smooth tracer fields compared to standard "bi-directional gradient" method, particularly in WV images. This can reduce tracking errors.

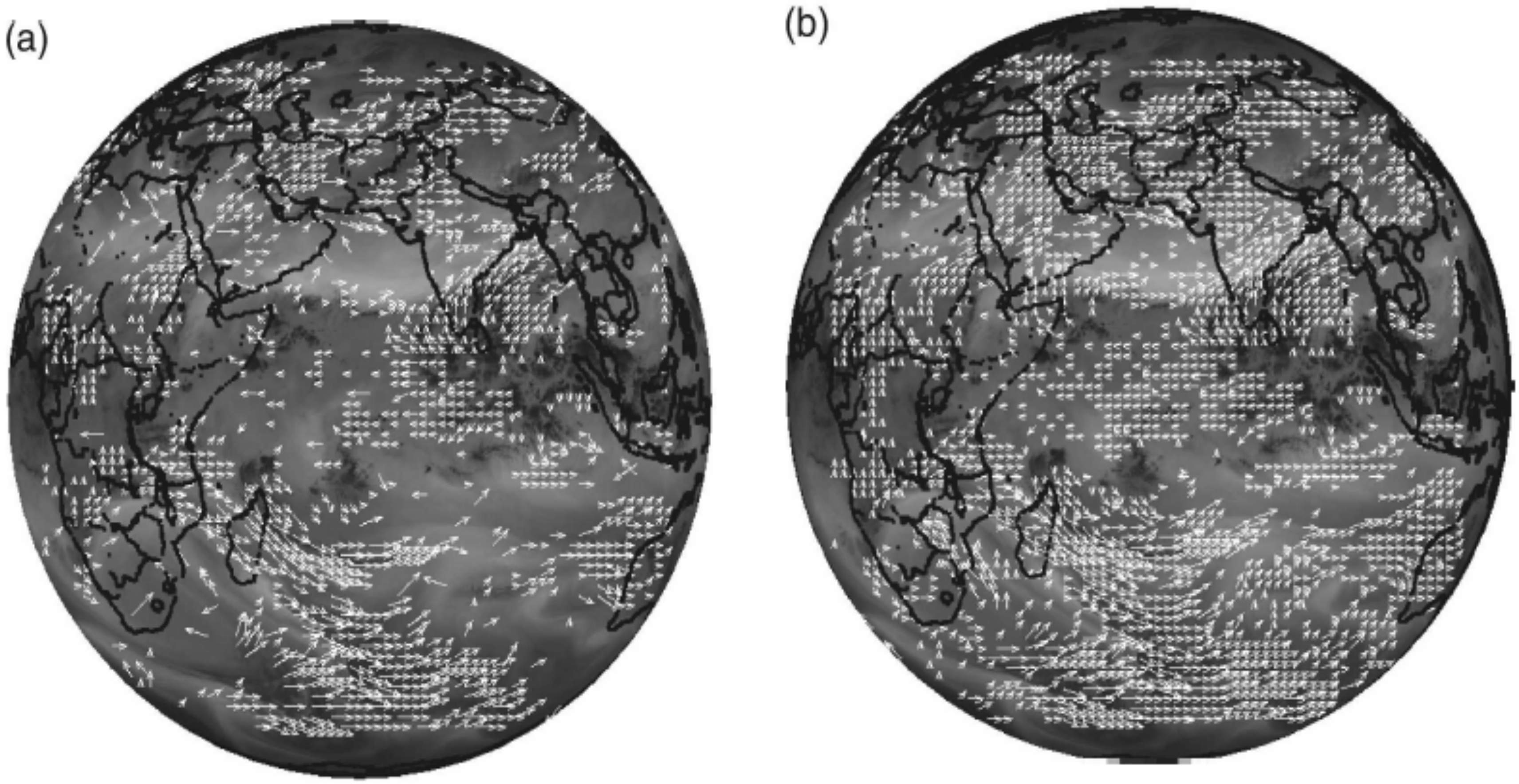
Tracer are selected in 20 x 20 template window

Local image anomaly $= \sum_i \sum_j [I(i,j) - \bar{I}],$



Maximum correlation of WV tracers calculated (from a sample template from 01 Oct 2006 00UTC) a) Bidirectional gradient based and b) anomaly based technique

- Source: Deb et. al 2008

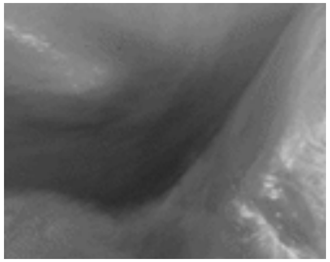


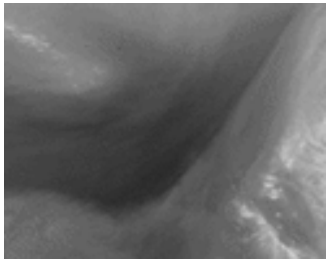
Gradient based tracer **Anomaly based tracer**

A sample figure showing the difference of the density of quality-controlled vectors (using identical quality-control criteria) produced by two tracer selection method

Modified Index for Tracking

Maximum match among tracers is determined by using Nash-Sutcliffe model efficiency instead of standard Max Cross Correlation (MCC).





Identical Image Pair

One image gradually added with noise

N.S. Fitness index has significantly higher sensitivity to noise compared to MCC thus reducing the chance of picking false target match points.

Nash-Sutcliffe model efficiency

$$E = 1 - \frac{\sum_{i=1}^{n}(I_t - I_s)^2}{\sum_{i=1}^{n}(I_t - \overline{I}_t)^2}$$

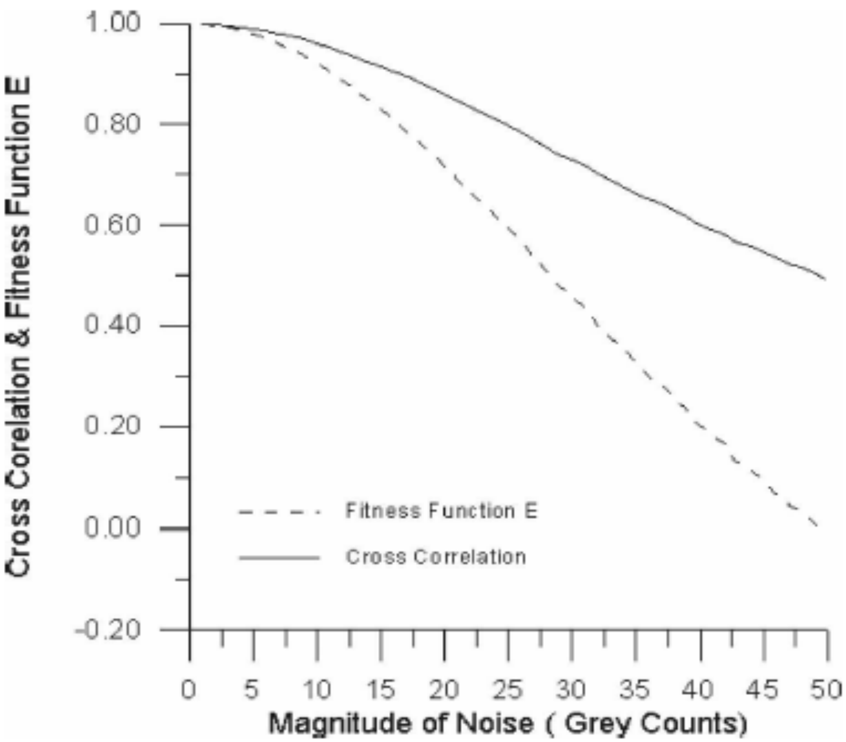


FIG. 3. The values of fitness function E (dashed) and MCC (solid) for varying noise levels.

- Source: Deb et. al 2008

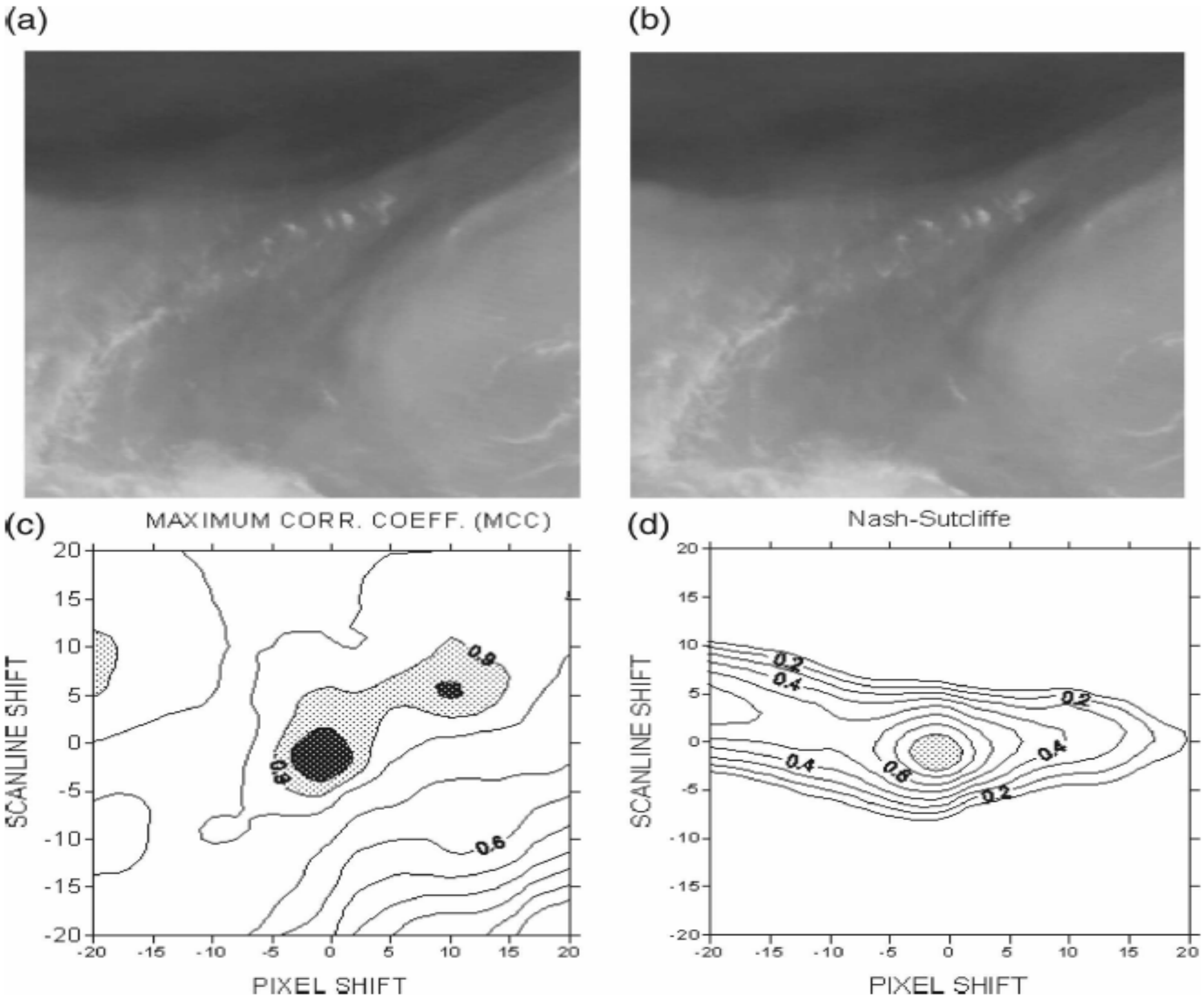
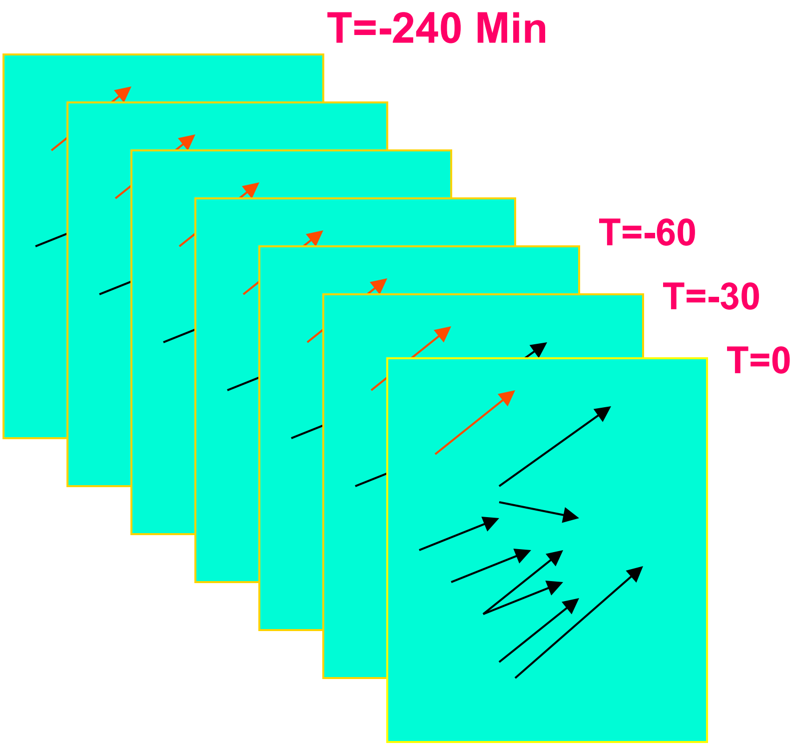


FIG. 2. *Meteosat-5* WV images at (a) 0000 and (b) 0030 UTC. The maximum (c) cross-correlation coefficient and (d) Nash–Sutcliffe efficiency coefficient, calculated during tracking between the image in (a) and the image in (b). Contour levels are −0.2, 0, 0.2, 0.4, 0.6, 0.8, and 0.9.

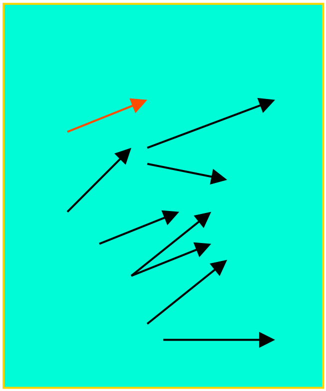
- Source: Deb et. al 2008

Buffer generation and Quality control

- 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.



Only 1 set retrieved
At a time



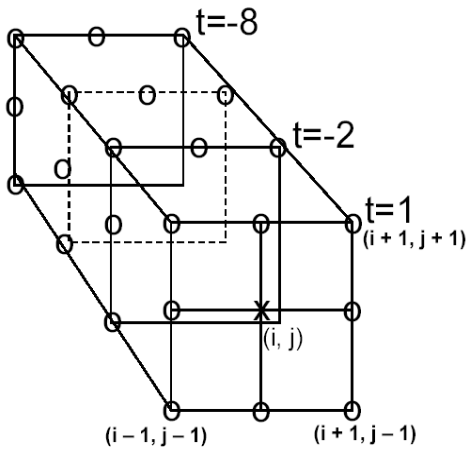
Vector-1

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

?? About the life cycle of cloud………

Combined Vector Selection and Quality Check

- 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 to be compared show similar BT characteristics (e.g. similar levels).



- Each vector difference (magnitude of complex number) is weighted according to distance and time difference from the current vector.
- If the difference of top 30% weighted differences is less than 1.1-pixel, the new vector is accepted, otherwise it is rejected.

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.
- Computationally Faster than previous version.

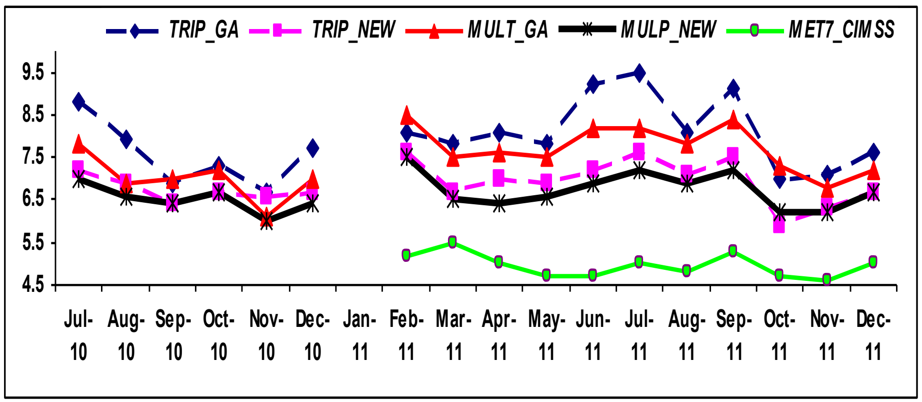
Height assignment - Collaboration with CIMSS/SSEC

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

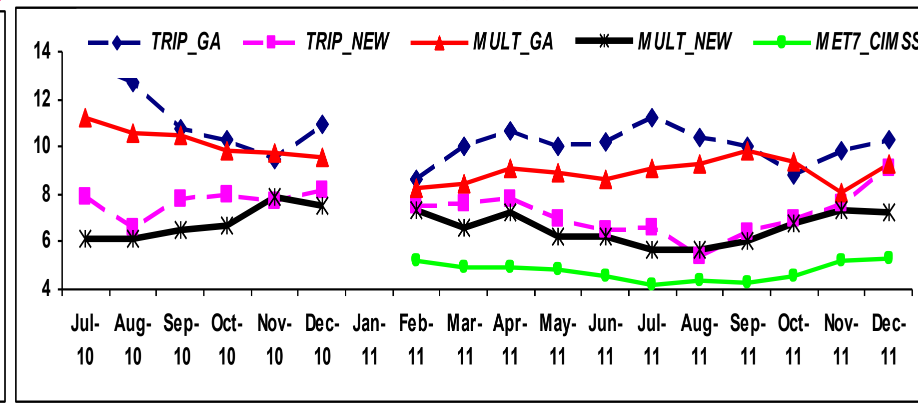
RMSVD

Validation statistics with radiosonde

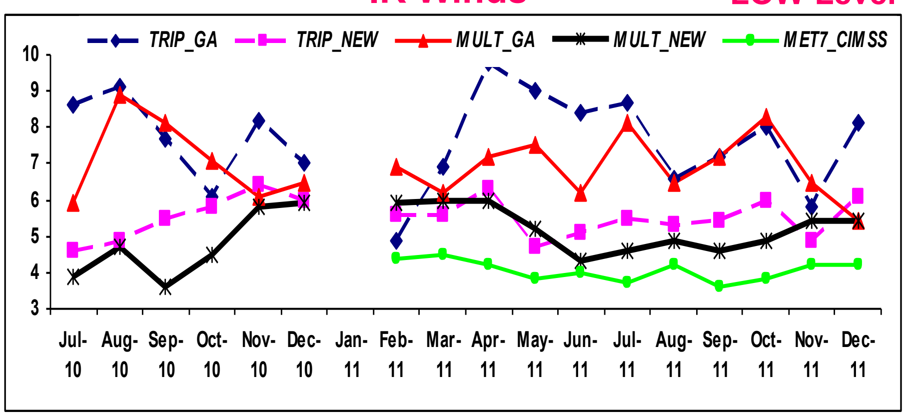
IR Winds HIGH-Level



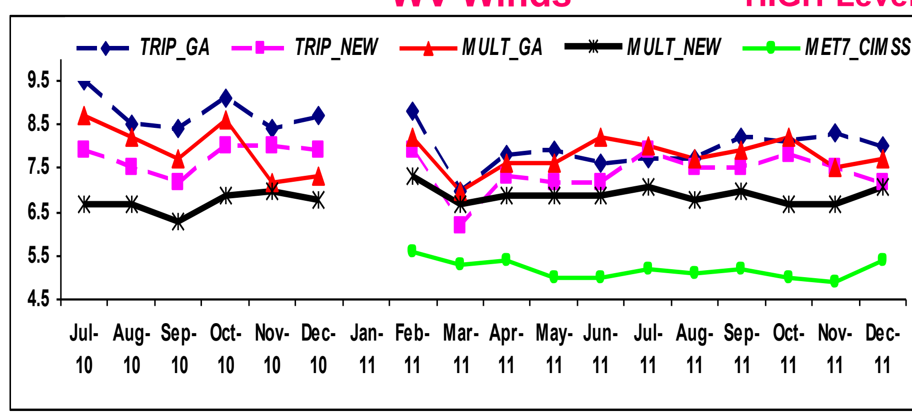
IR Winds MID-Level



IR Winds LOW-Level



WV Winds HIGH-Level



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

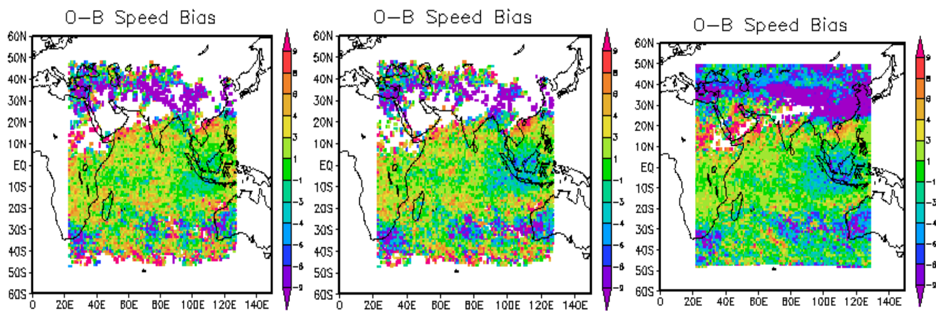
Approx. 7-9% of total collocations are affected due to these filters.

Spatial error analysis and density plot

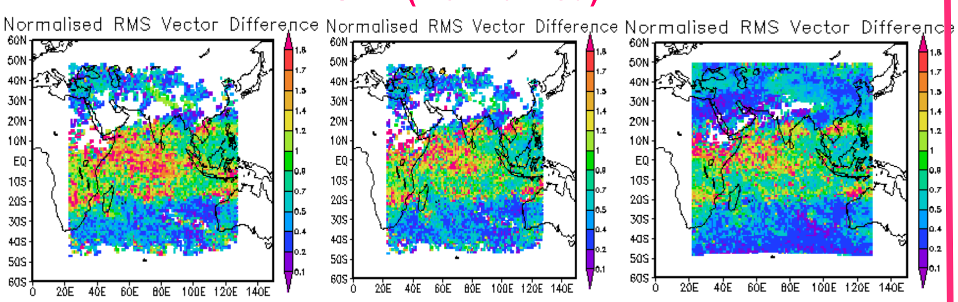
IR winds HIGH – Level Period: DEC2011

Bias

TRIP_GA | TRIP_NEW | MULT_NEW

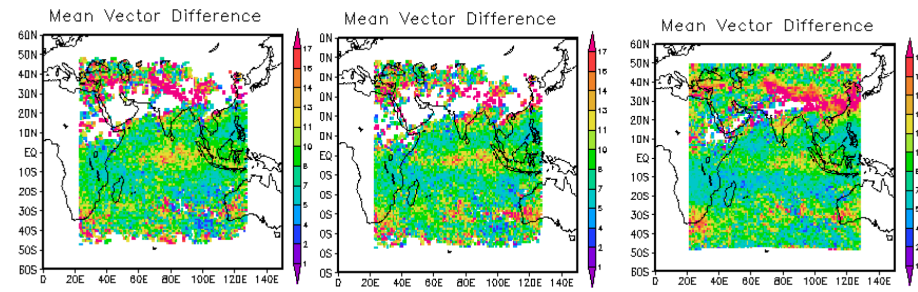


RMSVD (Normalized)

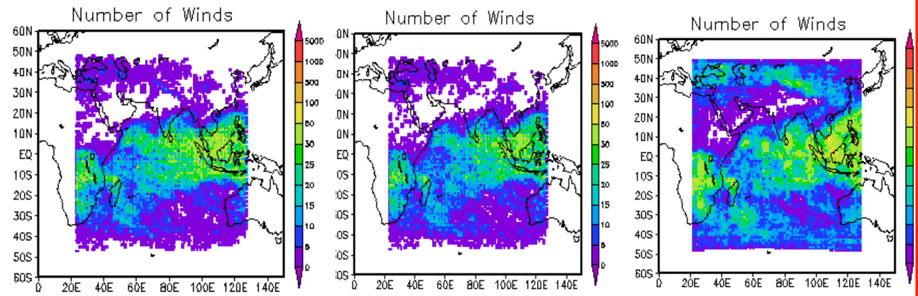


MVD

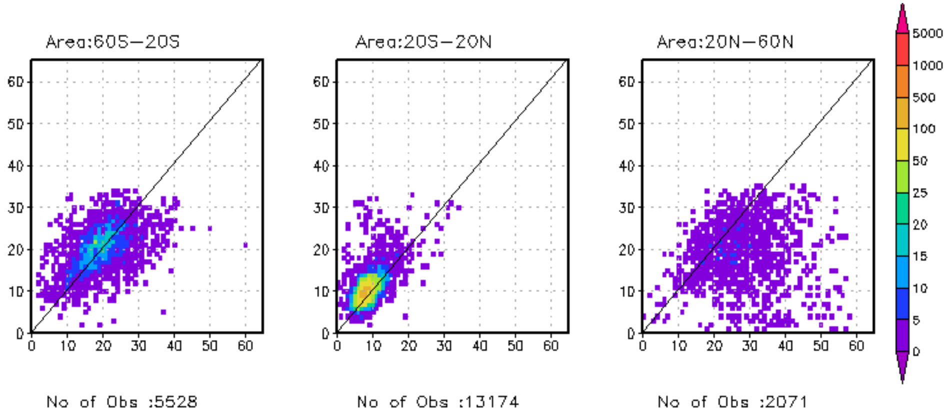
TRIP_GA | TRIP_NEW | MULT_NEW



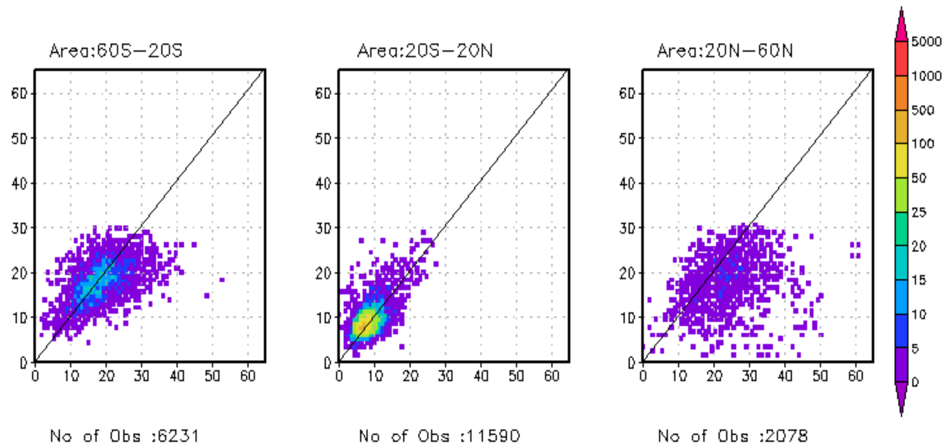
Collocations



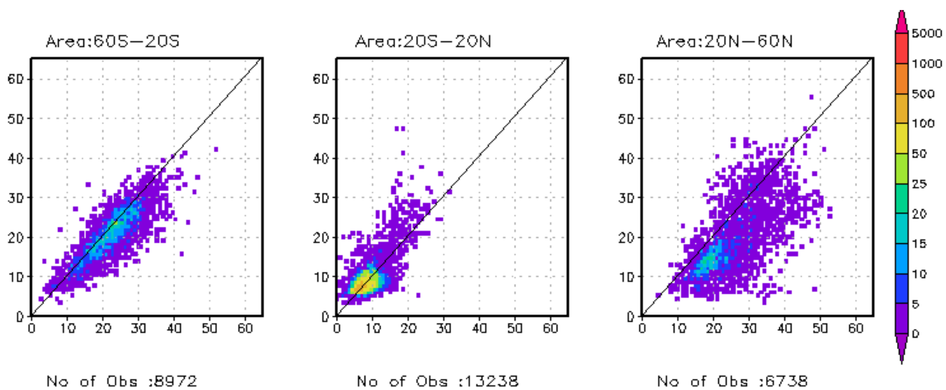
Density plot: IR winds HIGH – Level   Period: DEC2011



TRIP_GA

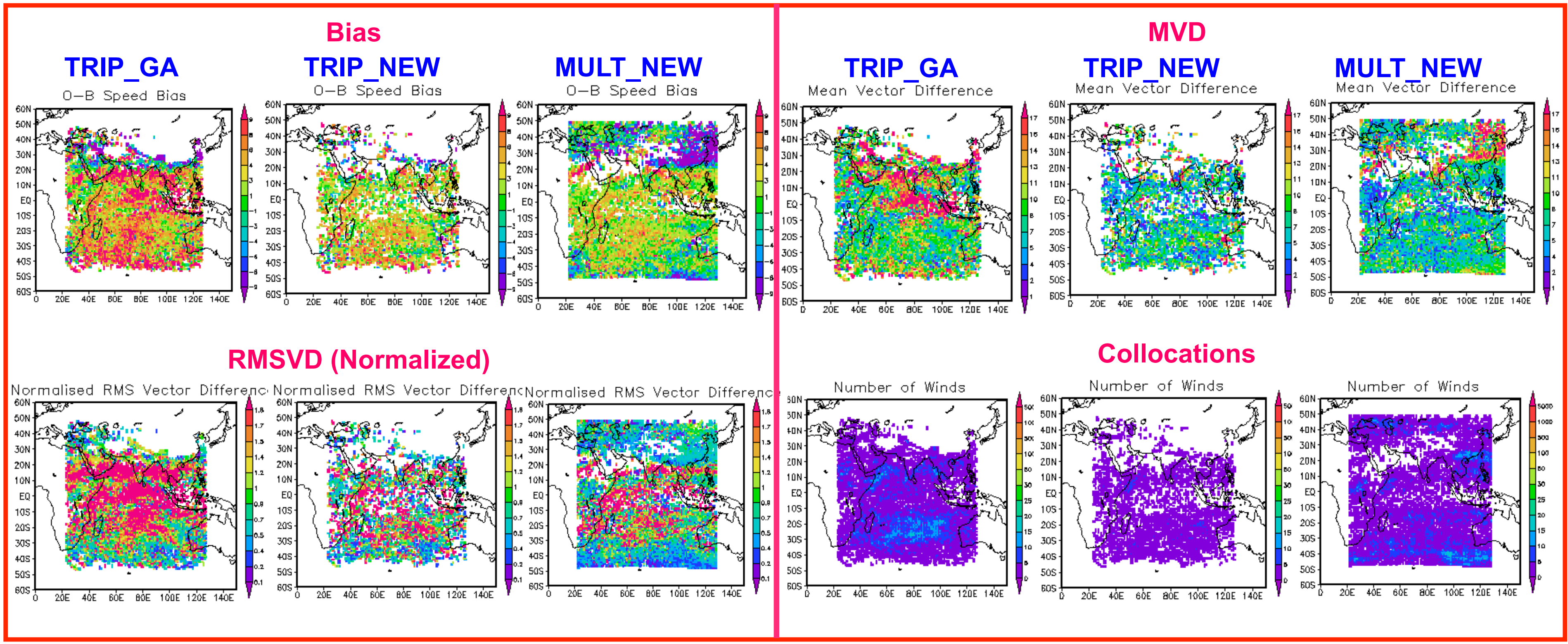


TRIP_NEW

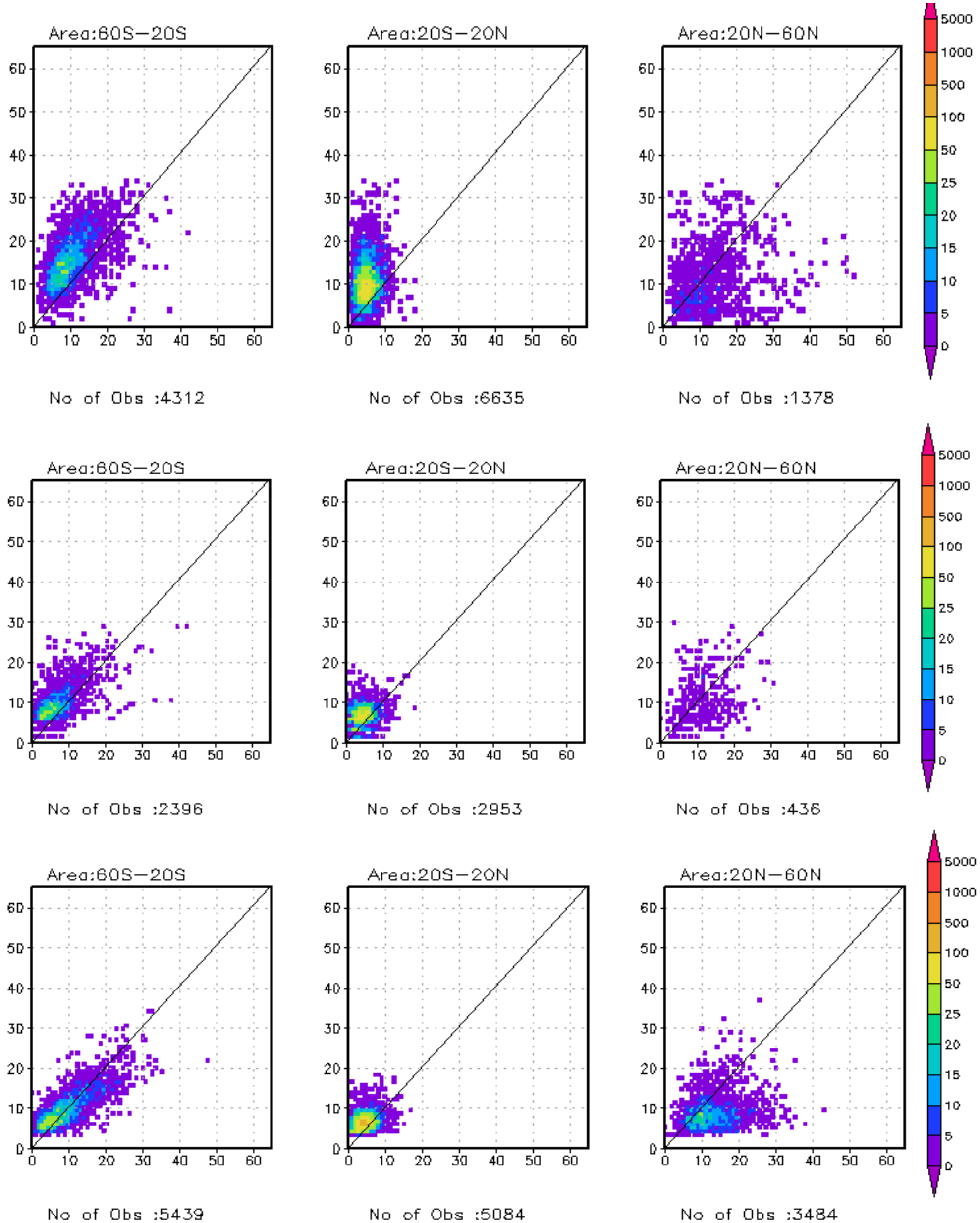


MULT_NEW

IR winds: MID – Level Period:DEC2011



IR winds: MID – Level Period:DEC2011

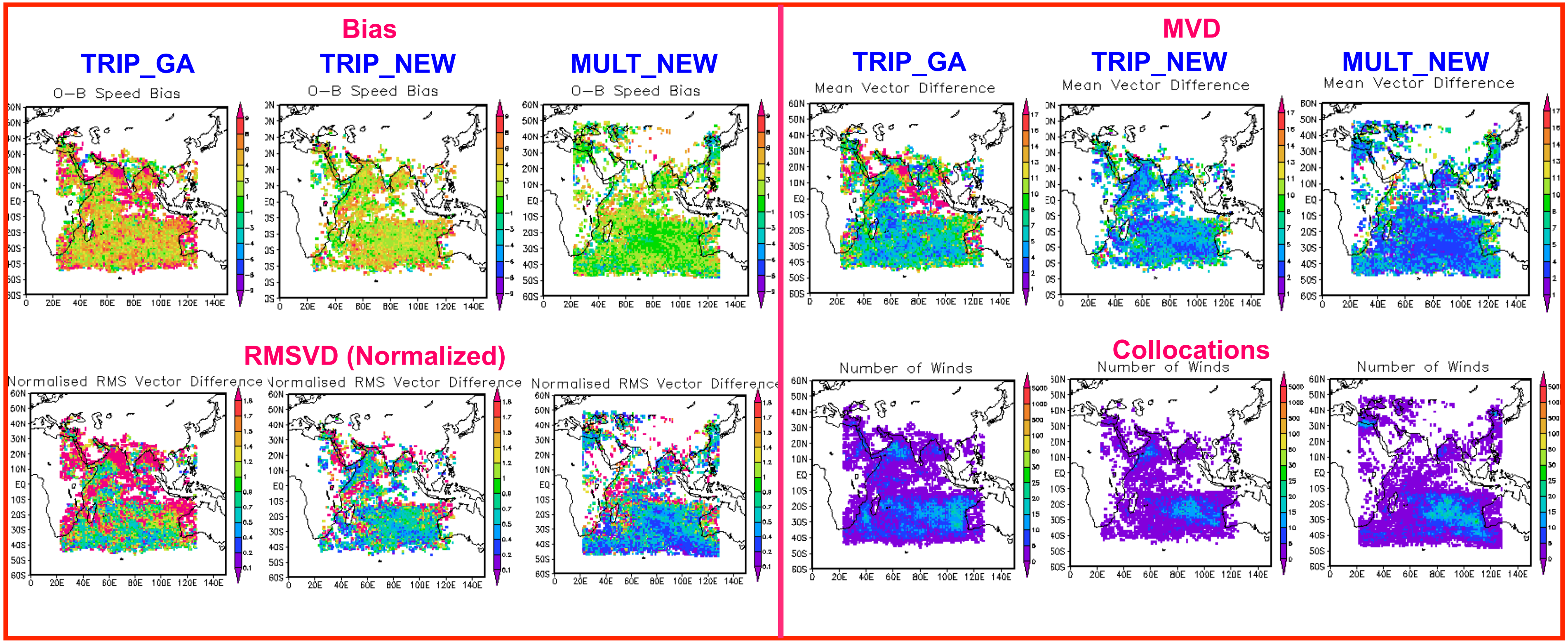


TRIP_GA

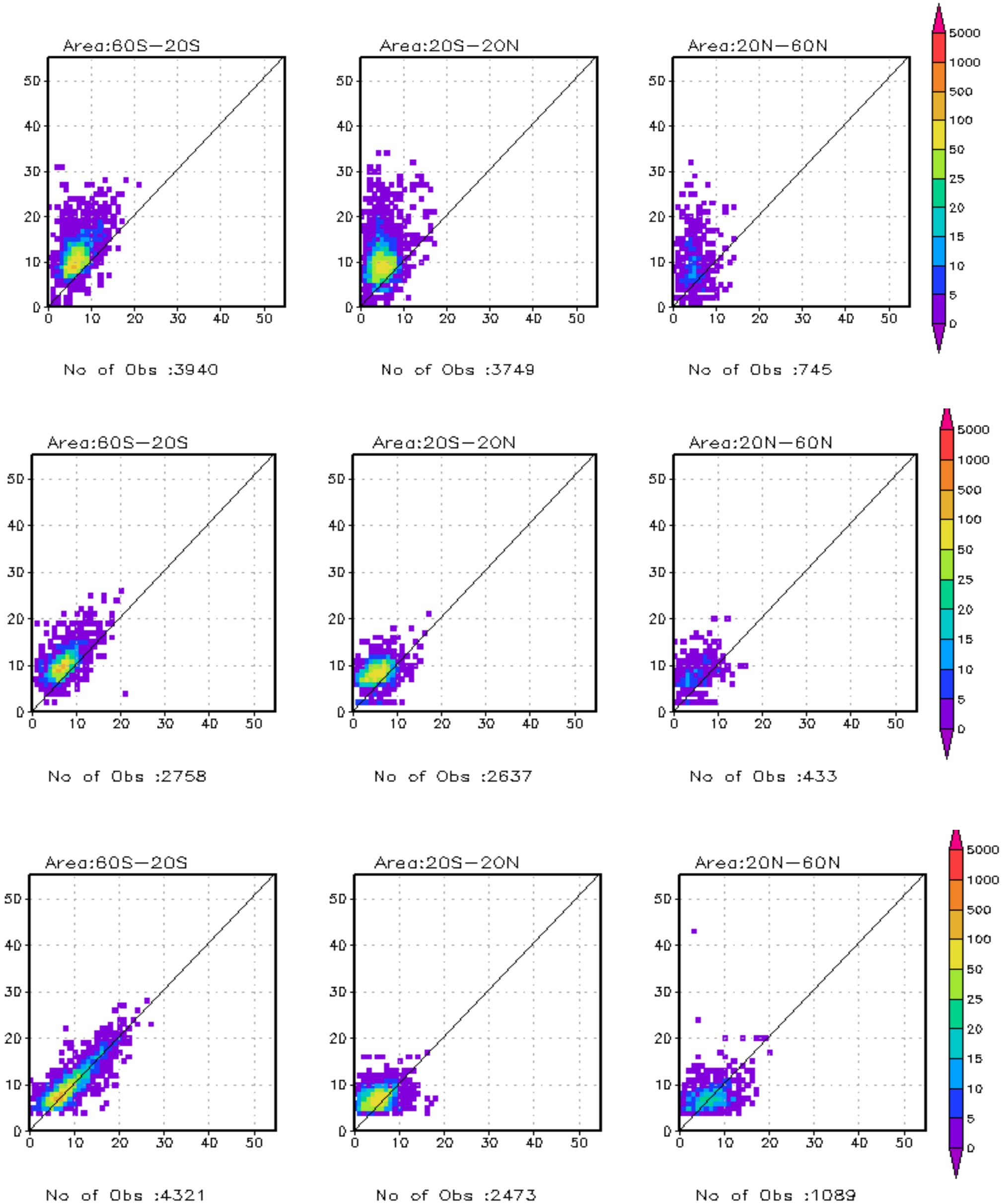
TRIP_NEW

MULT_NEW

IR winds LOW – Level   Period: DEC2011



Density plot: IR winds LOW – Level Period: DEC2011



TRIP_GA

TRIP_NEW

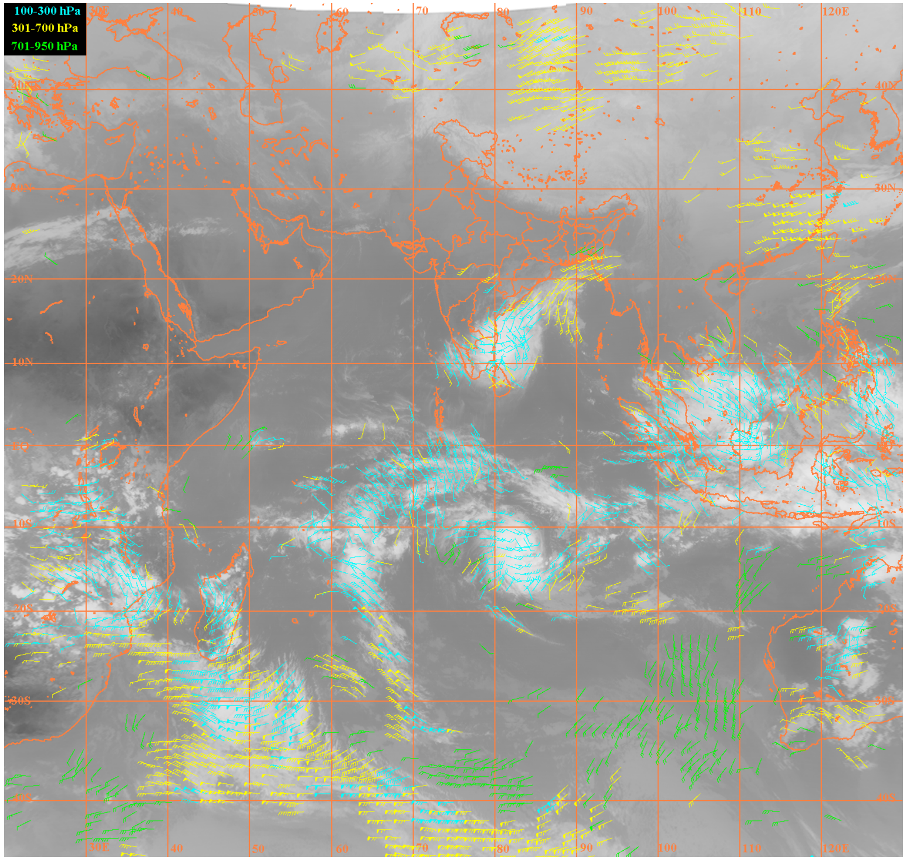
MULT_NEW

Examples

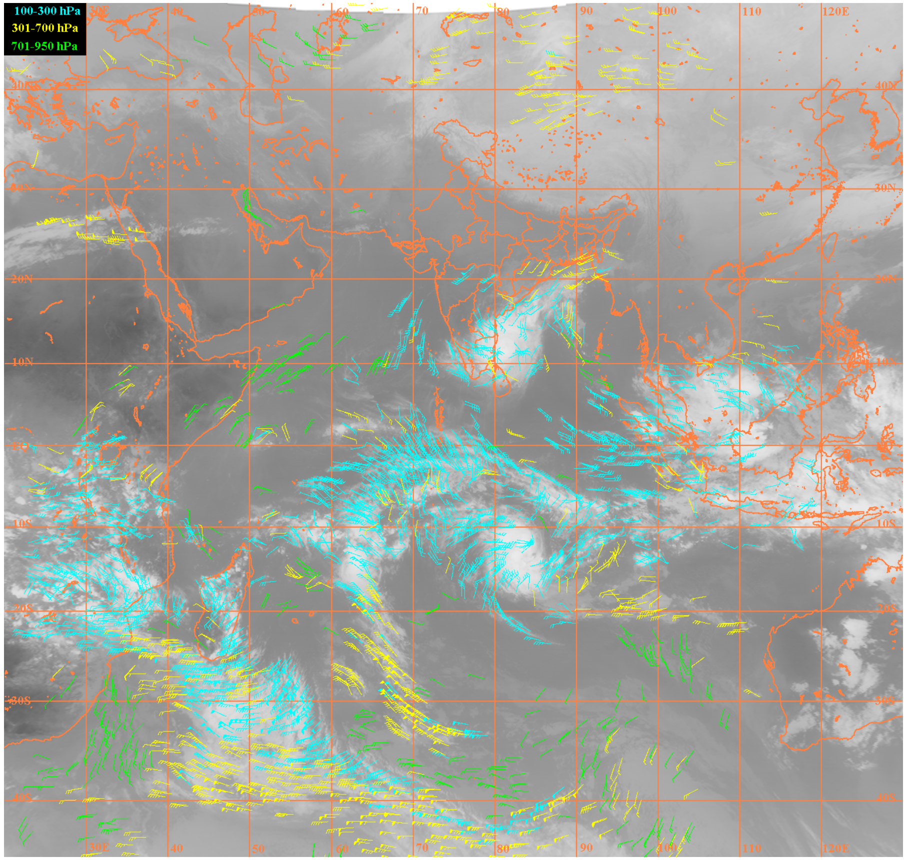
29 December 2011 12 UTC: Sample picture cyclone Thane

Infrared winds

Kalpana-1-ISRO



Meteosat7- CIMSS



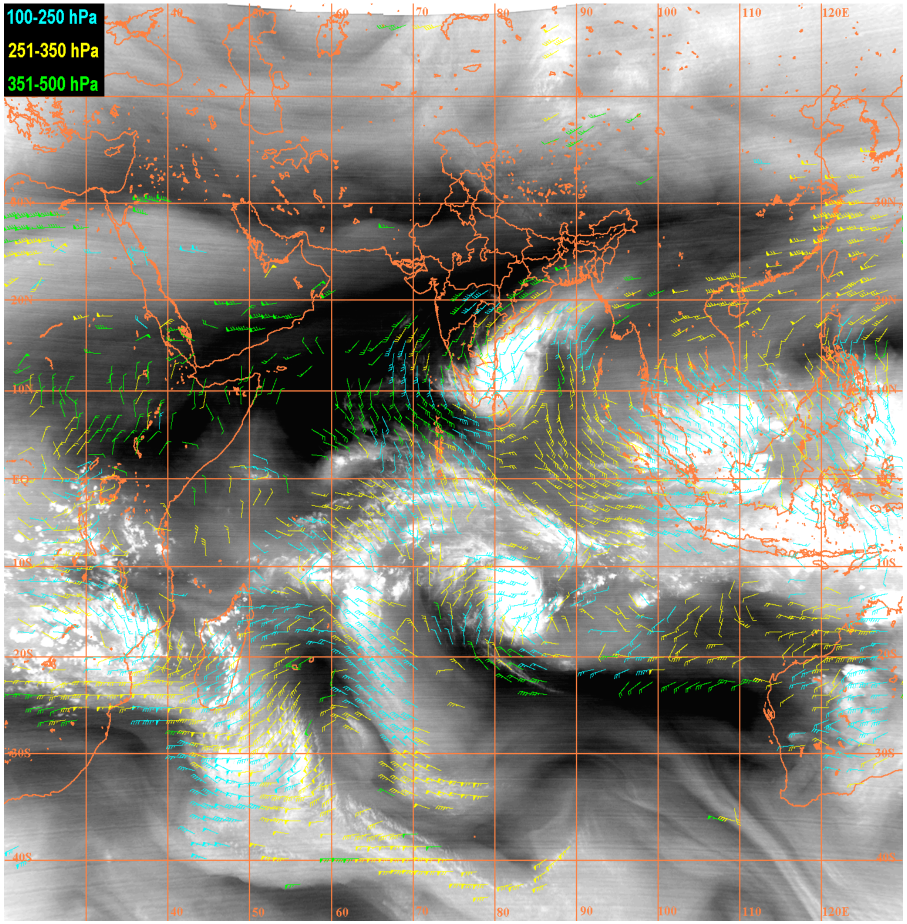
Start

- Thanks to CIMSS for Met7 winds

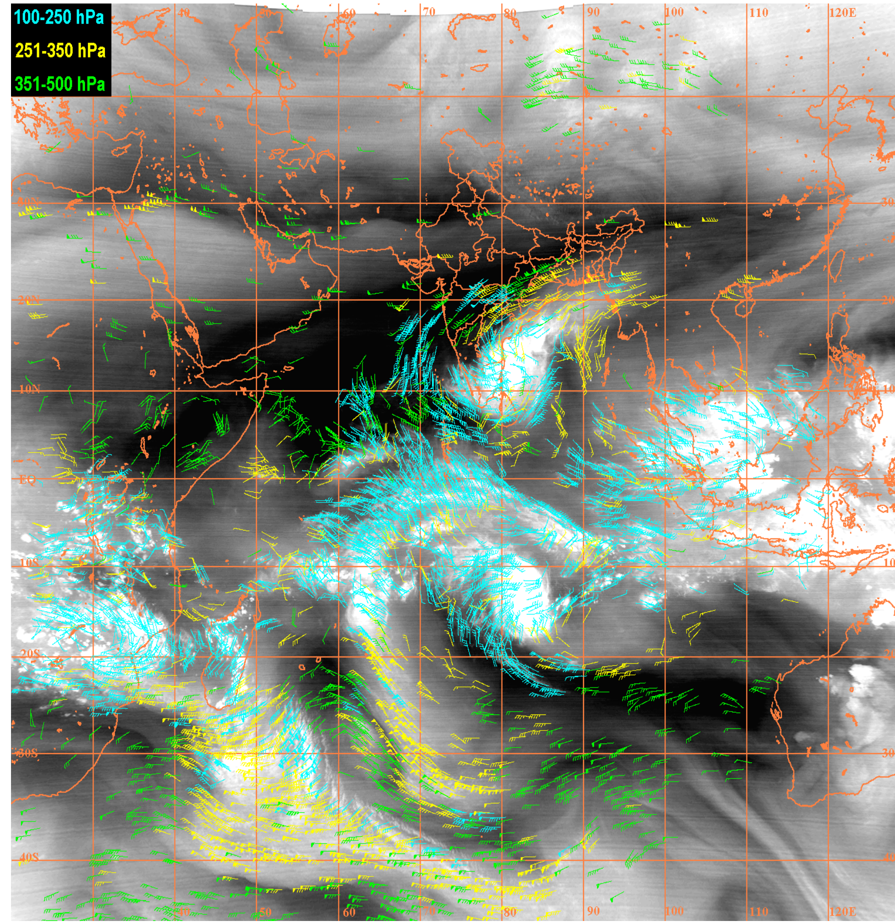
29 December 2011 12 UTC: Sample picture cyclone Thane

Water vapor winds

Kalpana-1-ISRO



Meteosat7- CIMSS



Start

- Thanks to CIMSS for Met7 winds

Findings from this study

- **New algorithm results in 25% more accurate vectors.**
- **Higher number of accurate retrievals in low level.**
- **Captures "meridional flow" at upper level better than triplet algorithm.**
- **Significant improvement due to new height assignment algorithm.**
  (RMSVD: high: 7.9 -> 6.8, mid: 10.4 -> 7.3, Low: 7.6 -> 5.5 and WV high: 8.2 -> 7.5)
- **However, some positive impact is noticed due to new MULTIPLET algorithm.**
  (RMSVD: high: 6.8 -> 6.6, mid: 7.3 -> 6.6, Low: 5.5 -> 5.0 and WV high: 7.5 -> 6.7)

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.

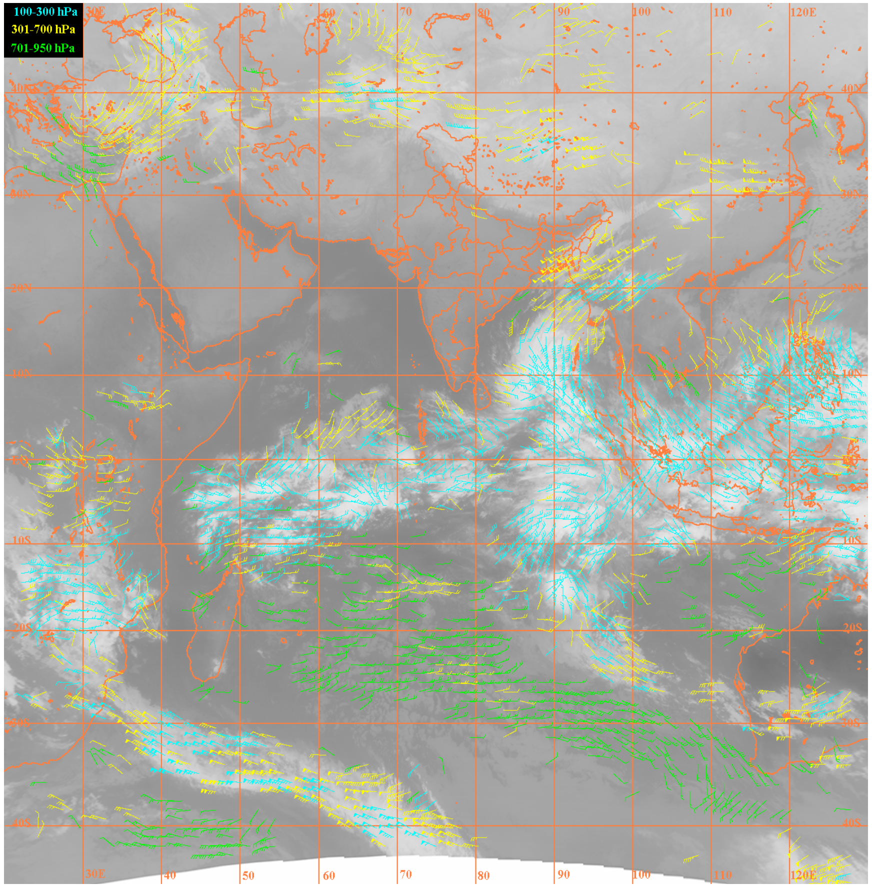
Acknowledgement

- 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.

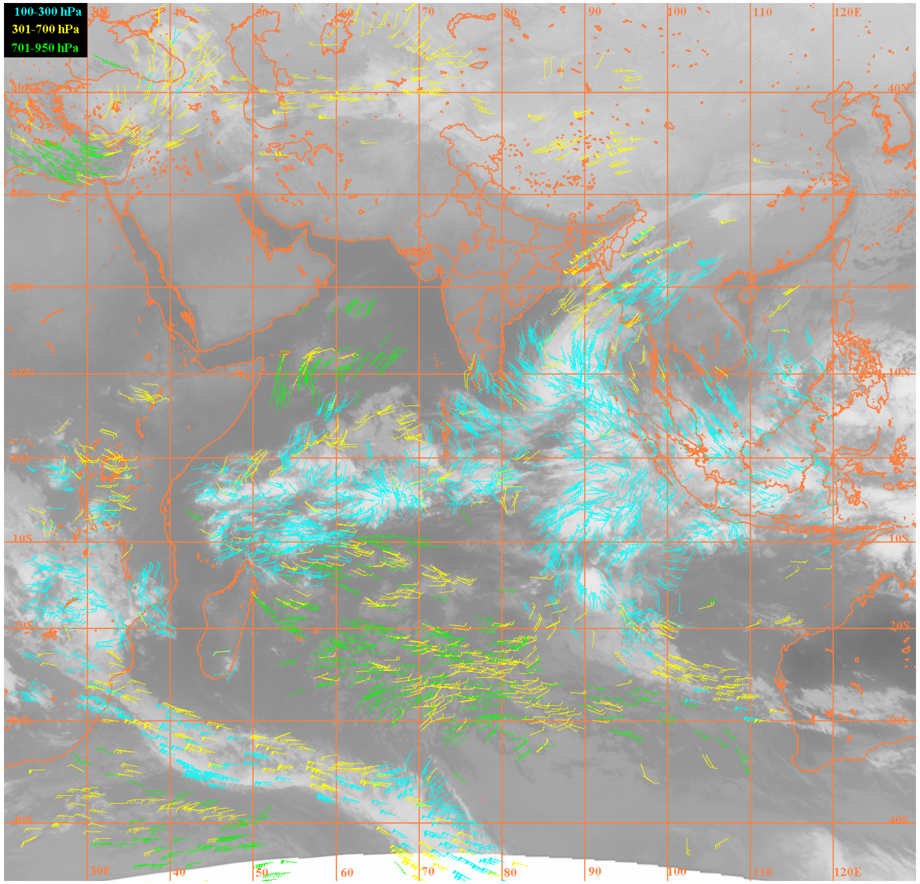
THANK YOU

Cyclone Thane: IR winds - 25th December 2011: 00 UTC

Kalpana-1/ISRO

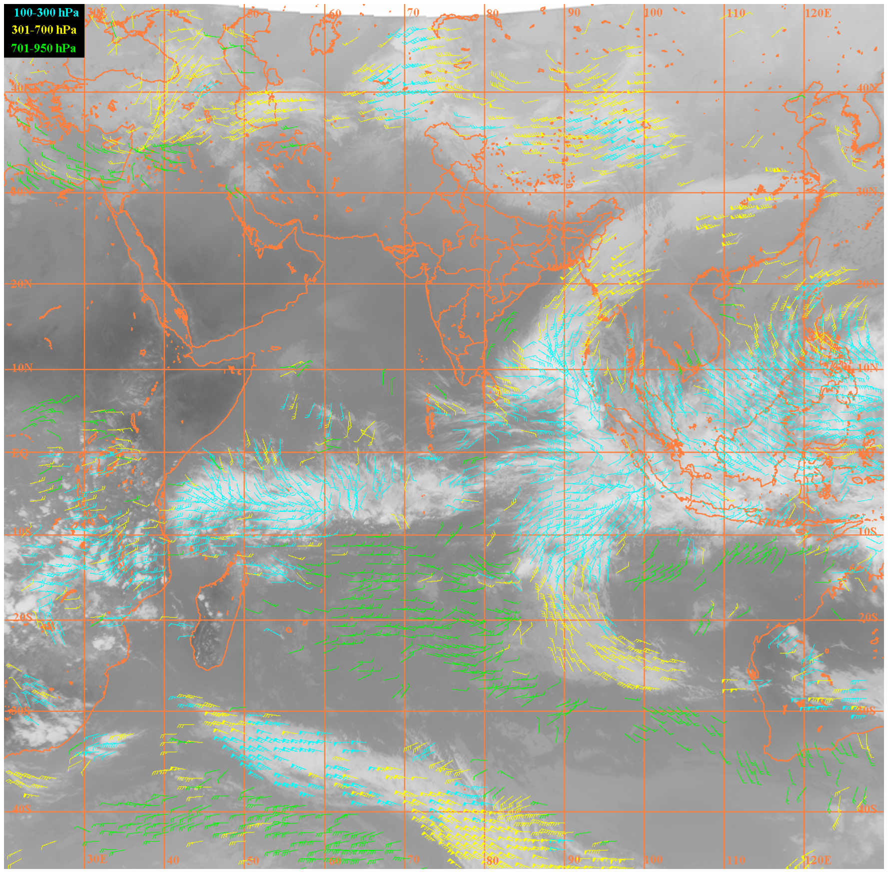


Meteosat7/CIMSS

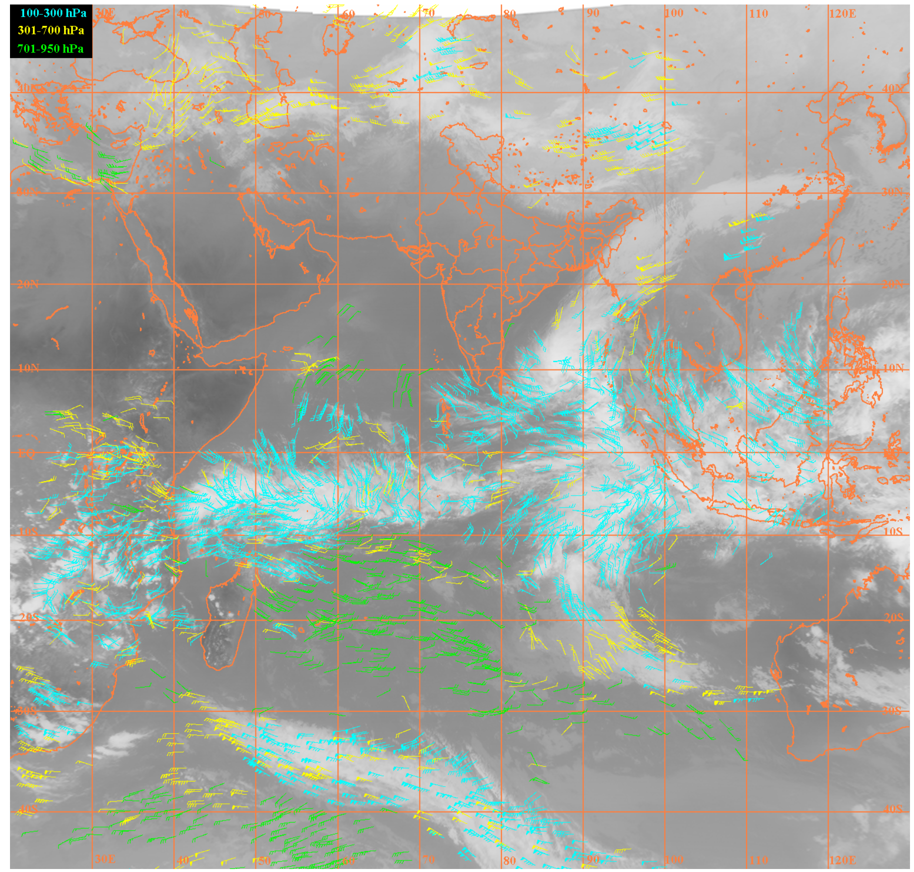


Cyclone Thane: IR winds - 25th December 2011: 12 UTC

Kalpana-1/ISRO

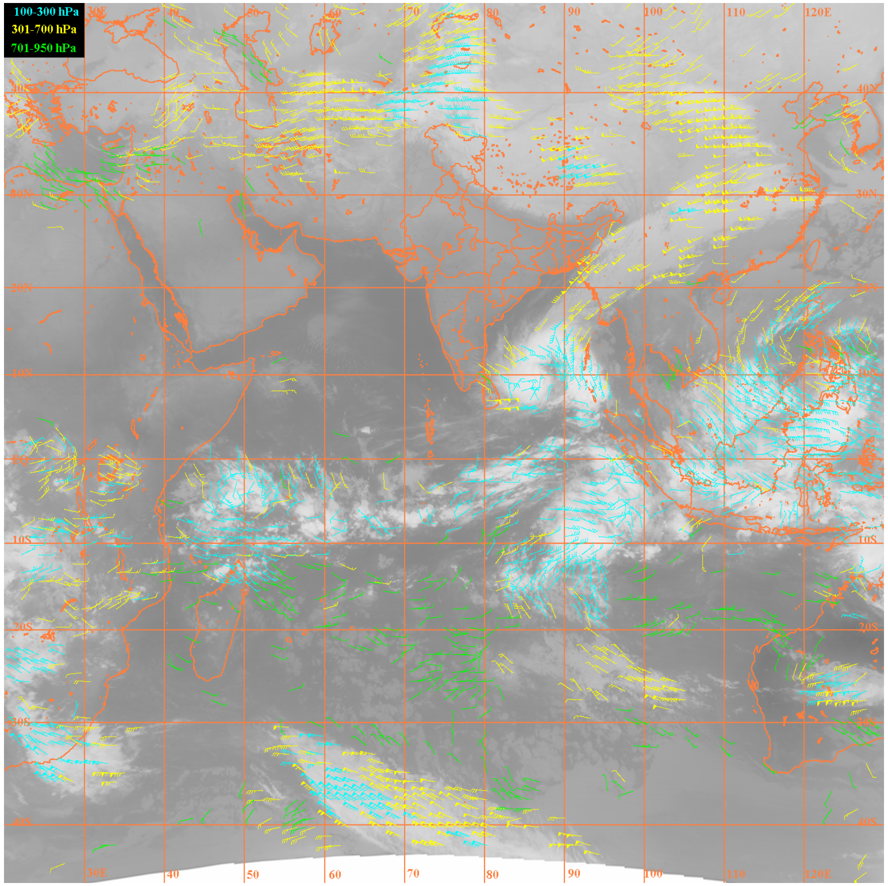


Meteosat7/CIMSS

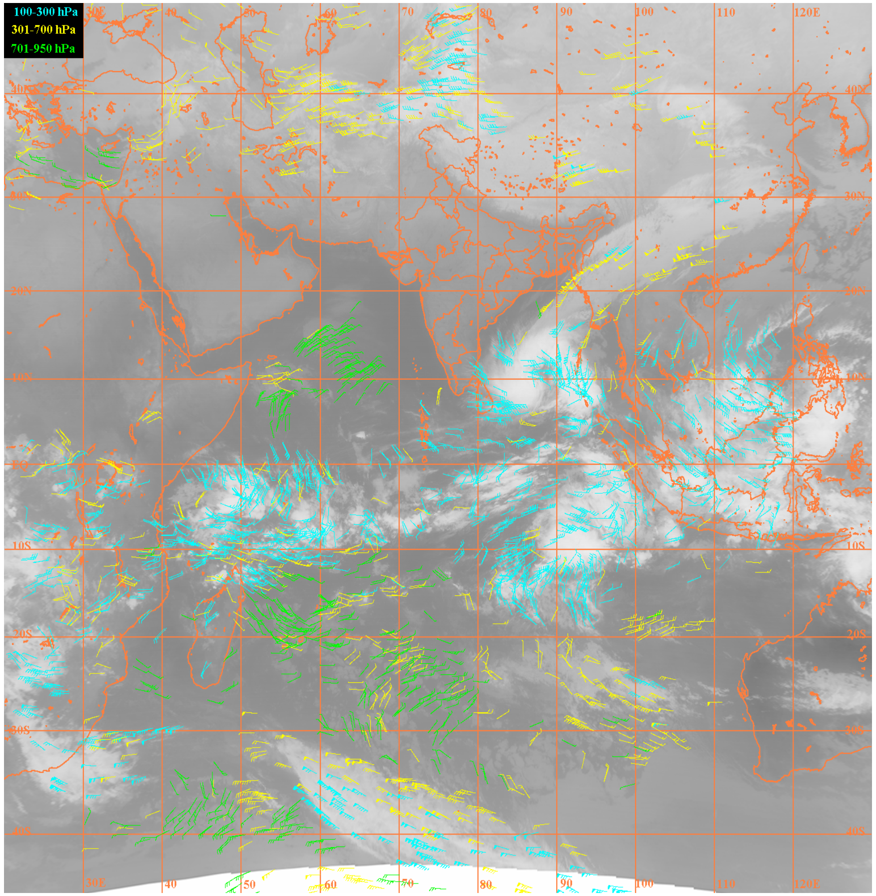


Cyclone Thane: IR winds - 26th December 2011: 00 UTC

Kalpana-1/ISRO



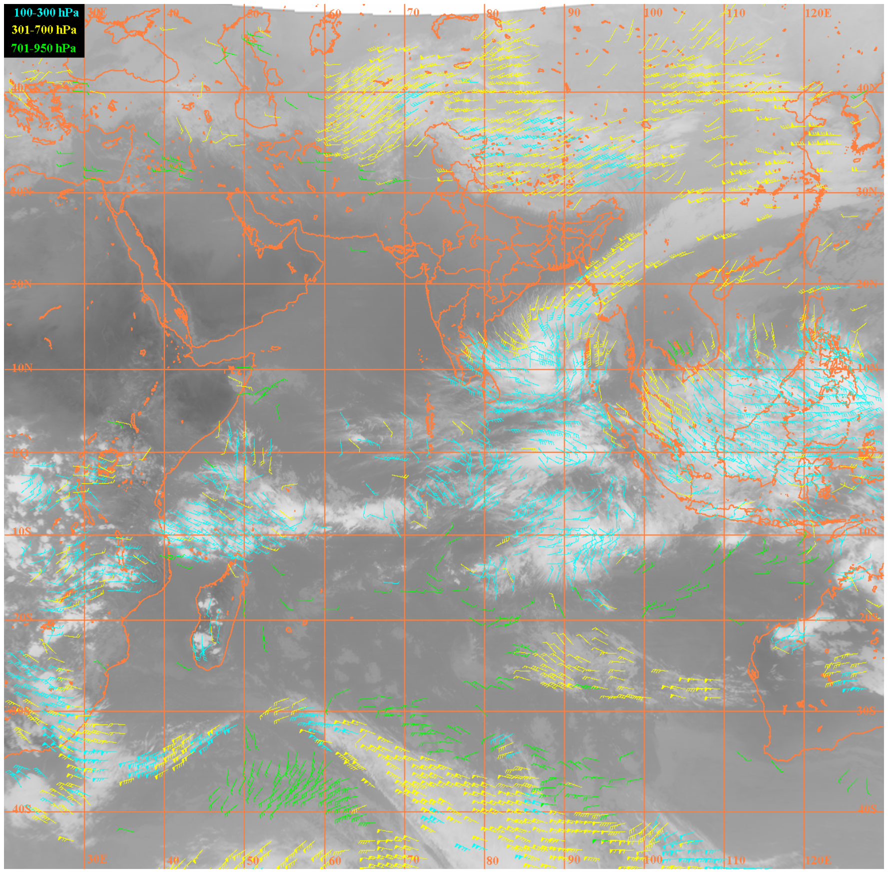
Meteosat7/CIMSS

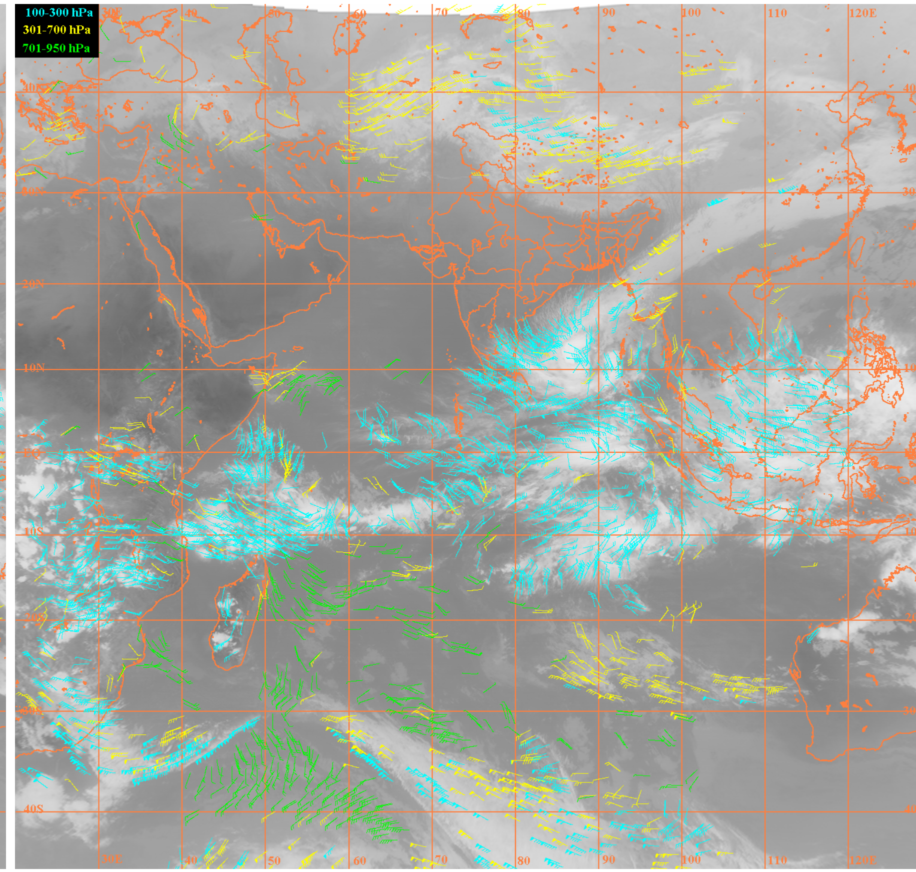


Cyclone Thane: IR winds - 26th December 2011: 12 UTC

Kalpana-1/ISRO

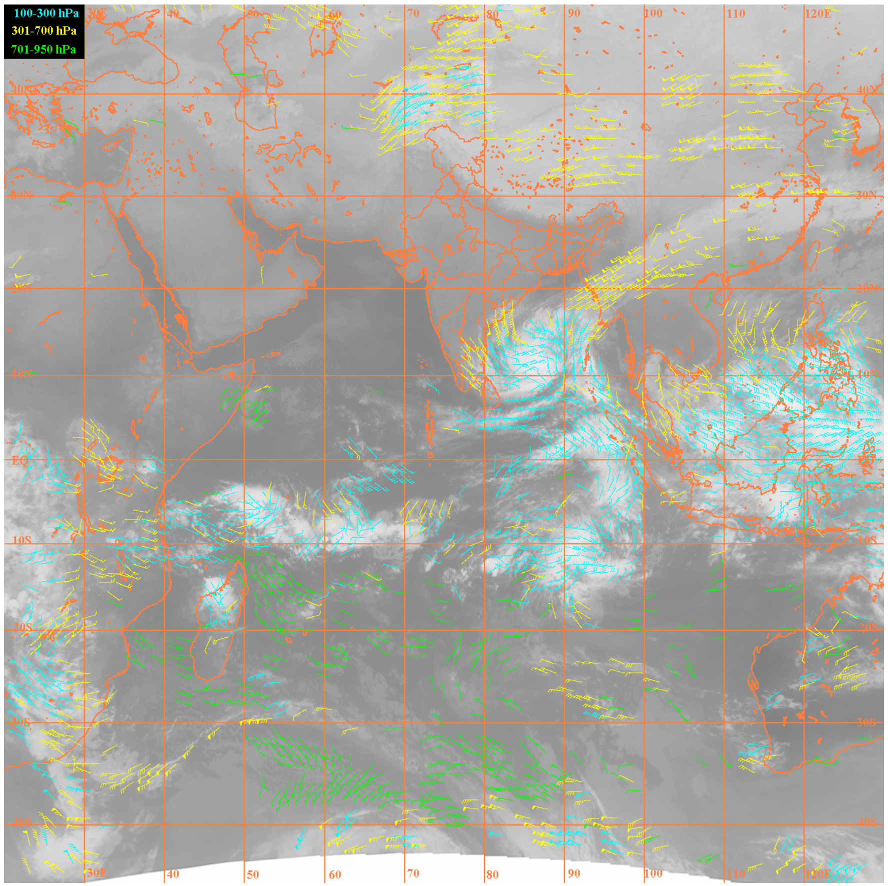
Meteosat7/CIMSS



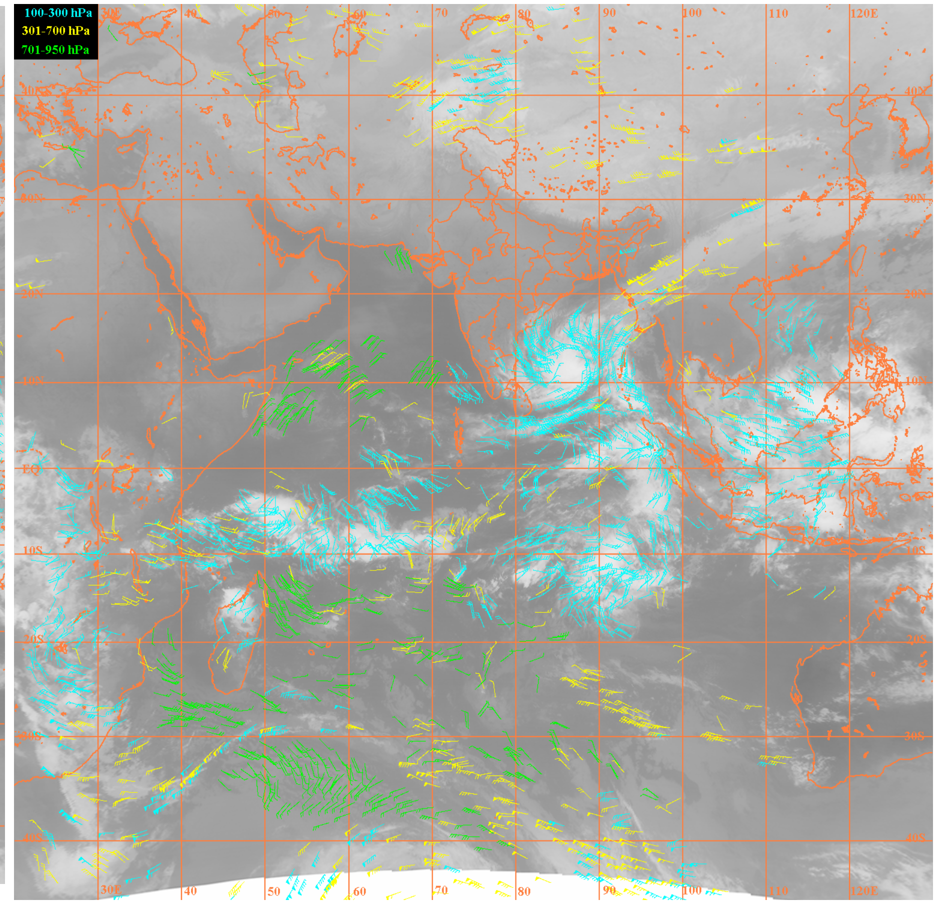


Cyclone Thane: IR winds - 27th December 2011: 00 UTC

Kalpana-1/ISRO

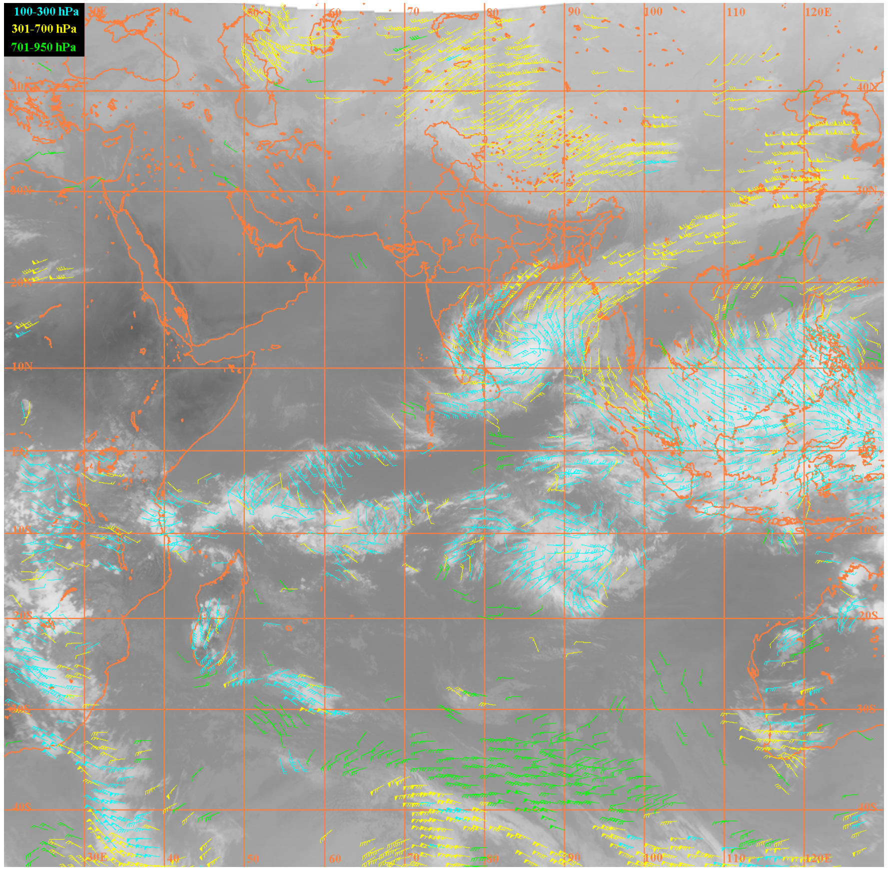


Meteosat7/CIMSS

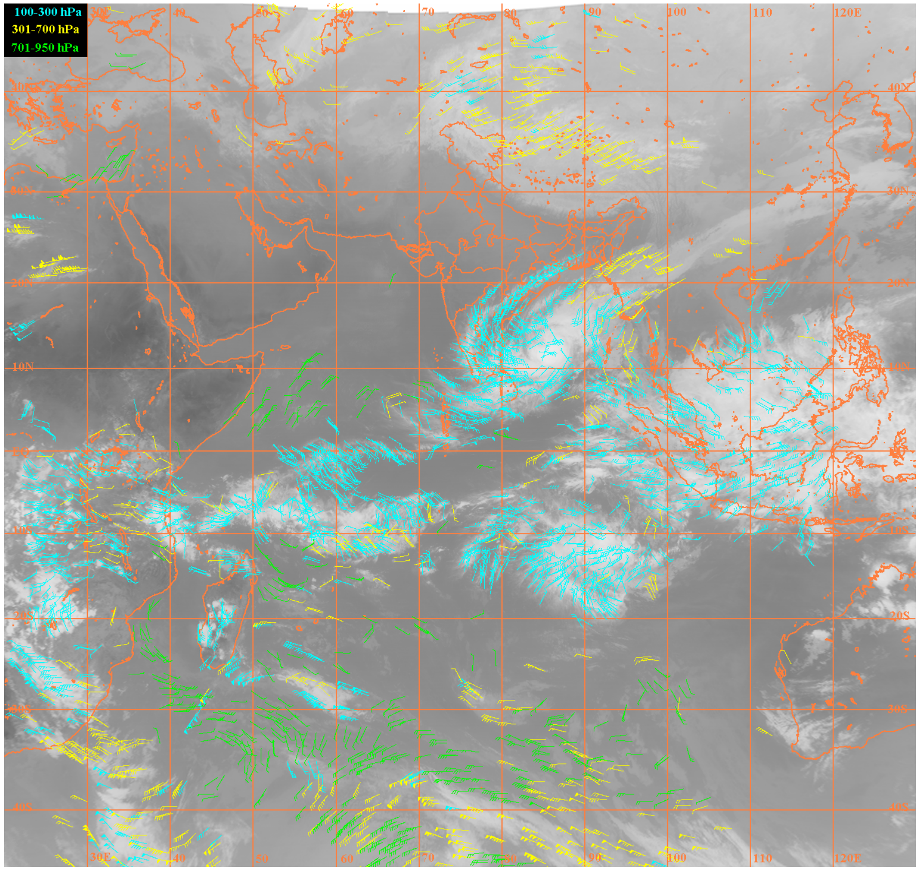


Cyclone Thane: IR winds - 27th December 2011: 12 UTC

Kalpana-1/ISRO

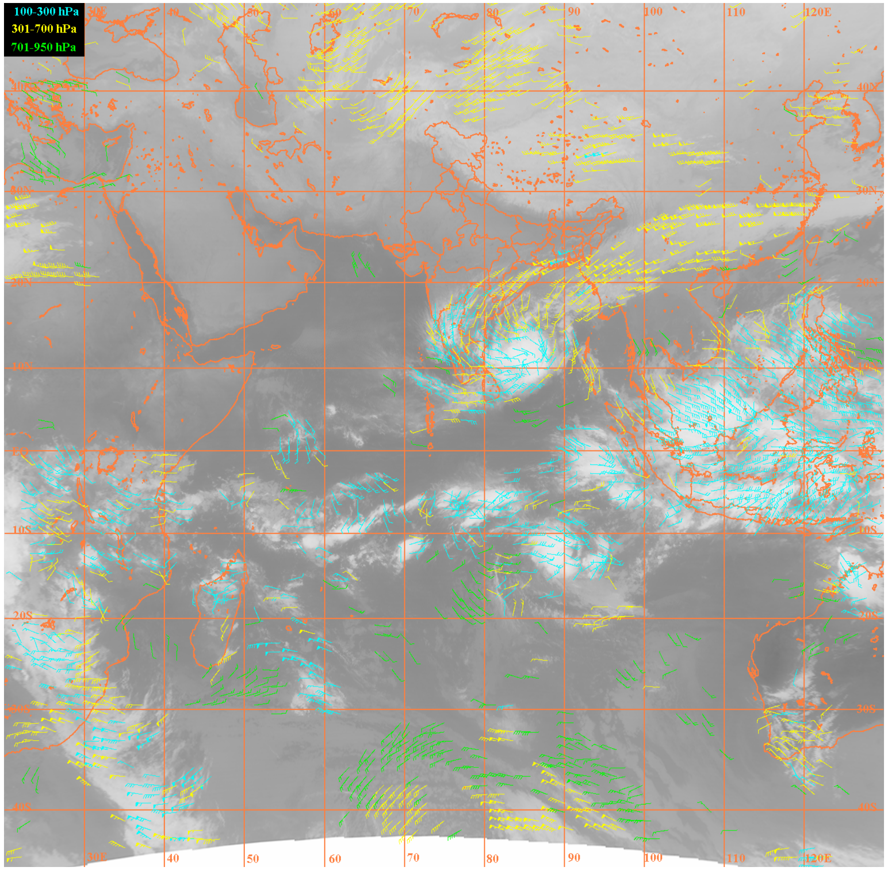


Meteosat7/CIMSS

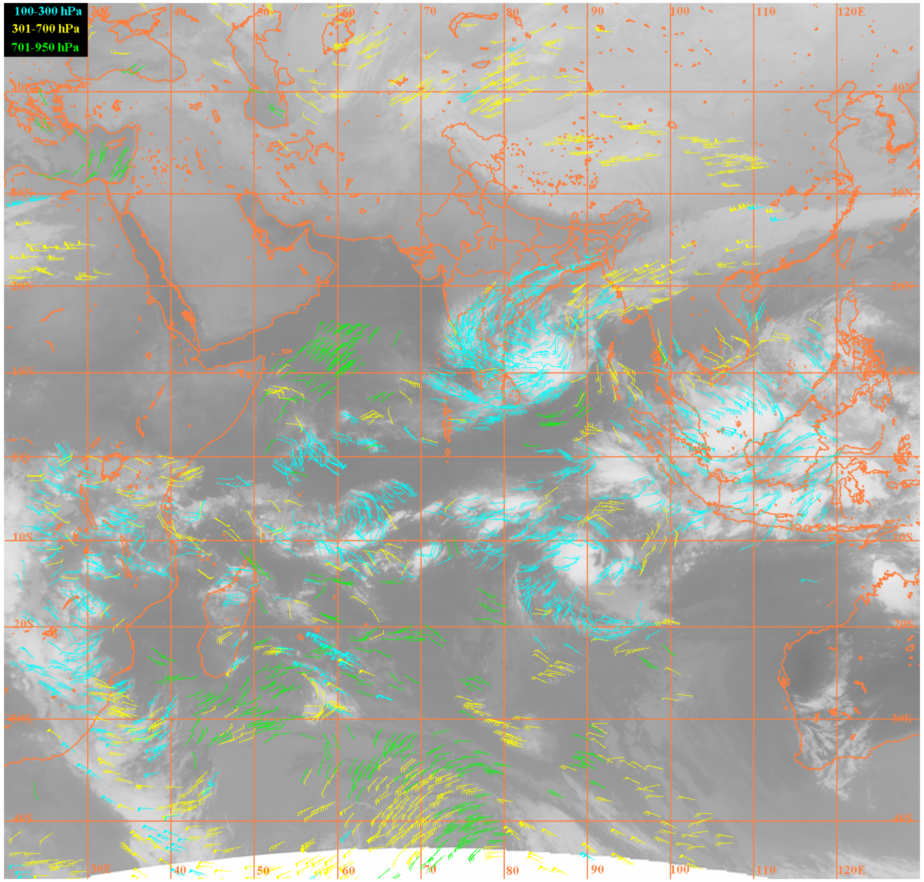


Cyclone Thane: IR winds - 28th December 2011: 00 UTC

Kalpana-1/ISRO

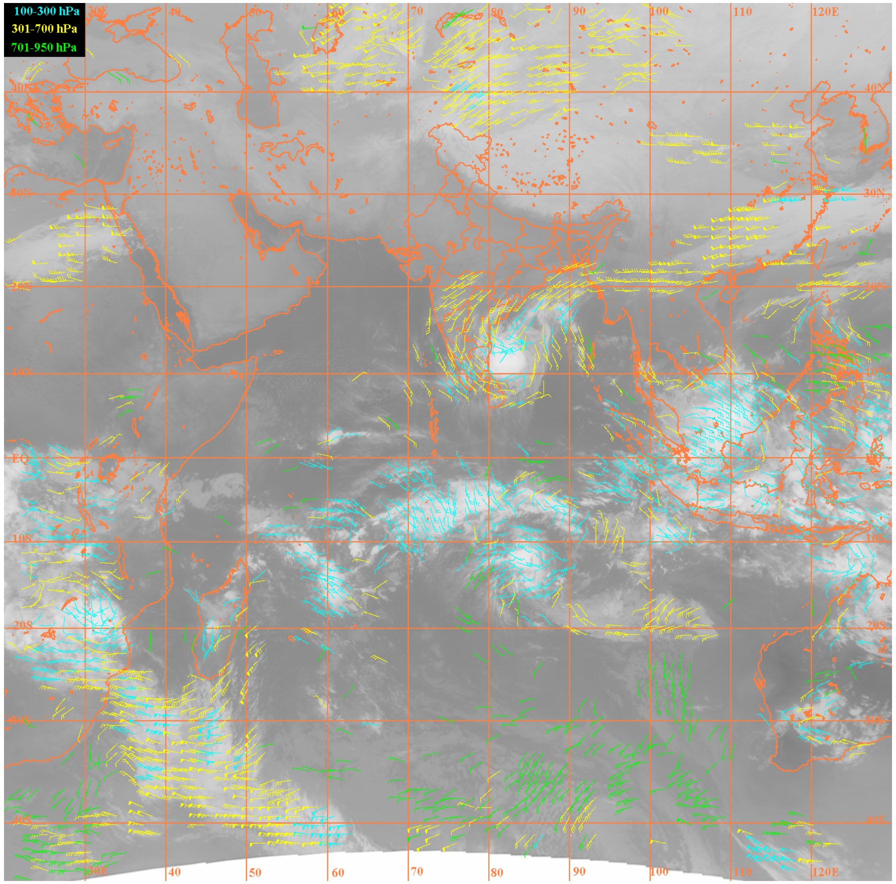


Meteosat7/CIMSS

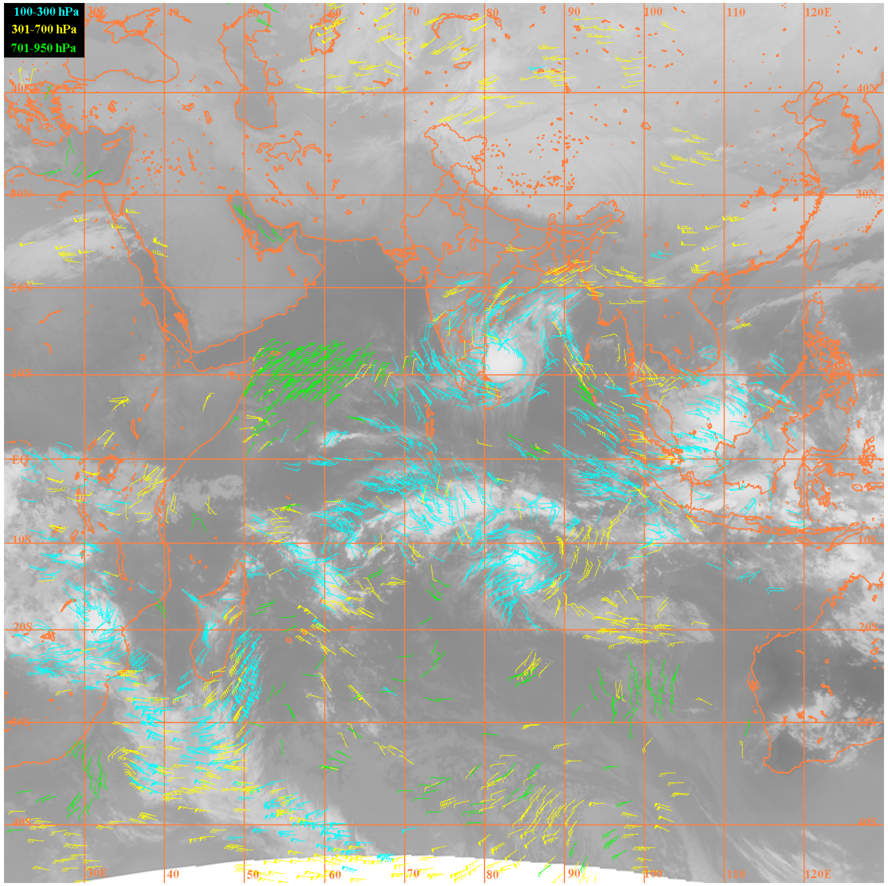


Cyclone Thane: IR winds - 29th December 2011: 00 UTC

Kalpana-1/ISRO

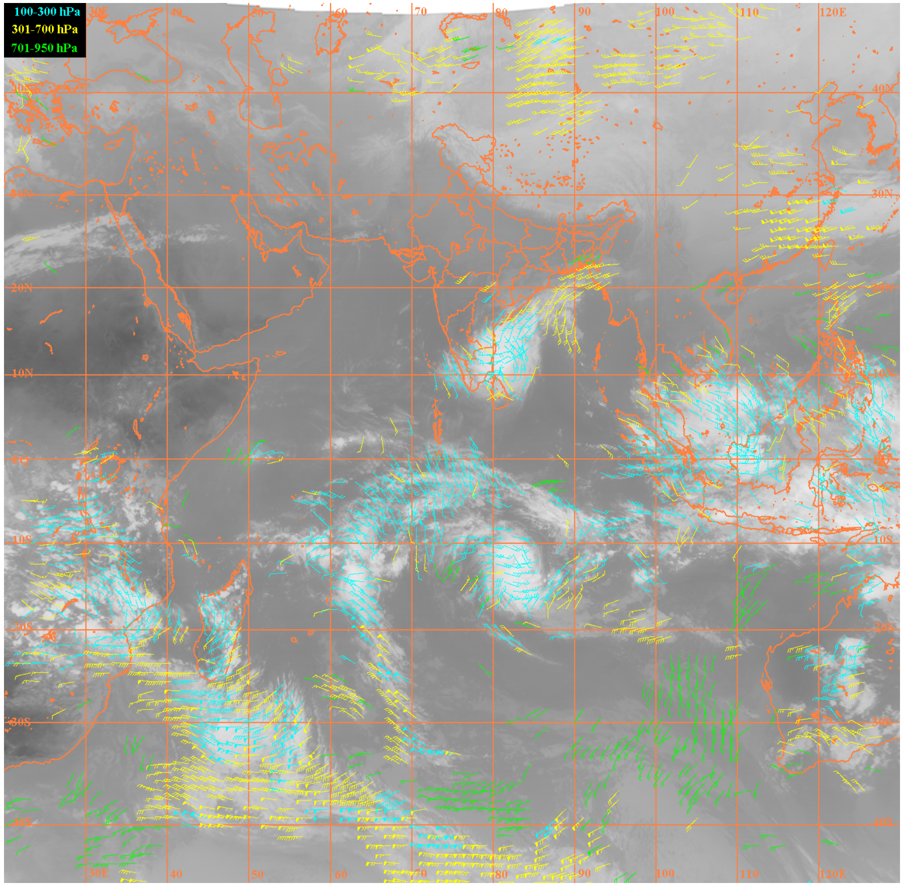


Meteosat7/CIMSS

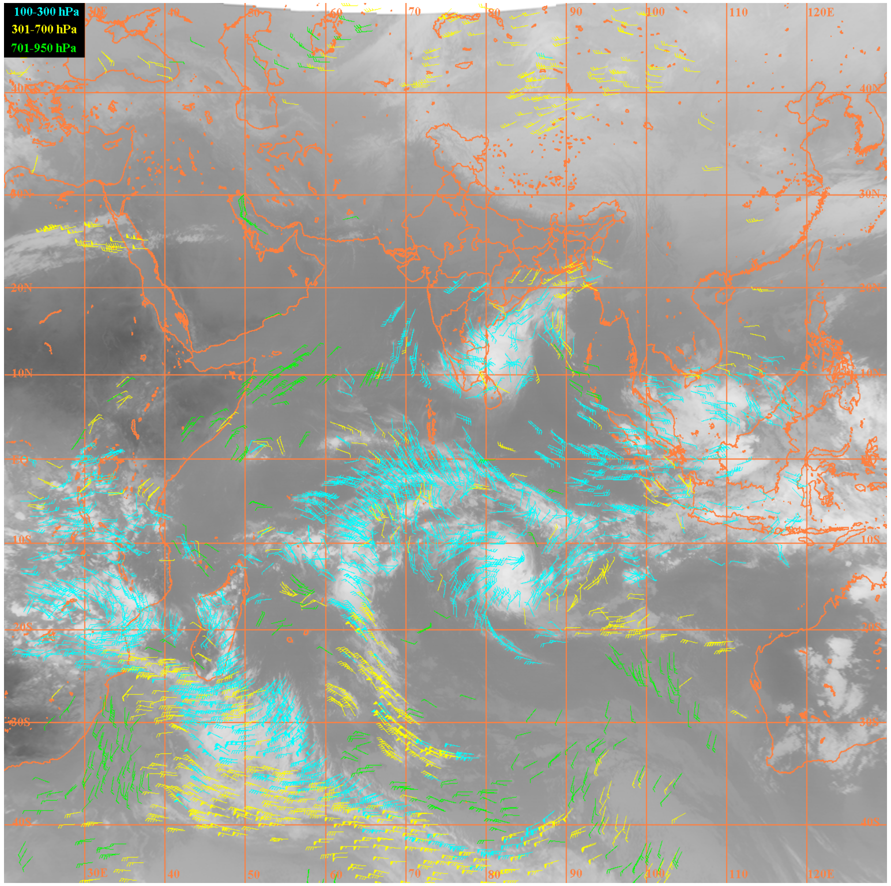


Cyclone Thane: IR winds - 29th December 2011: 12 UTC

Kalpana-1/ISRO



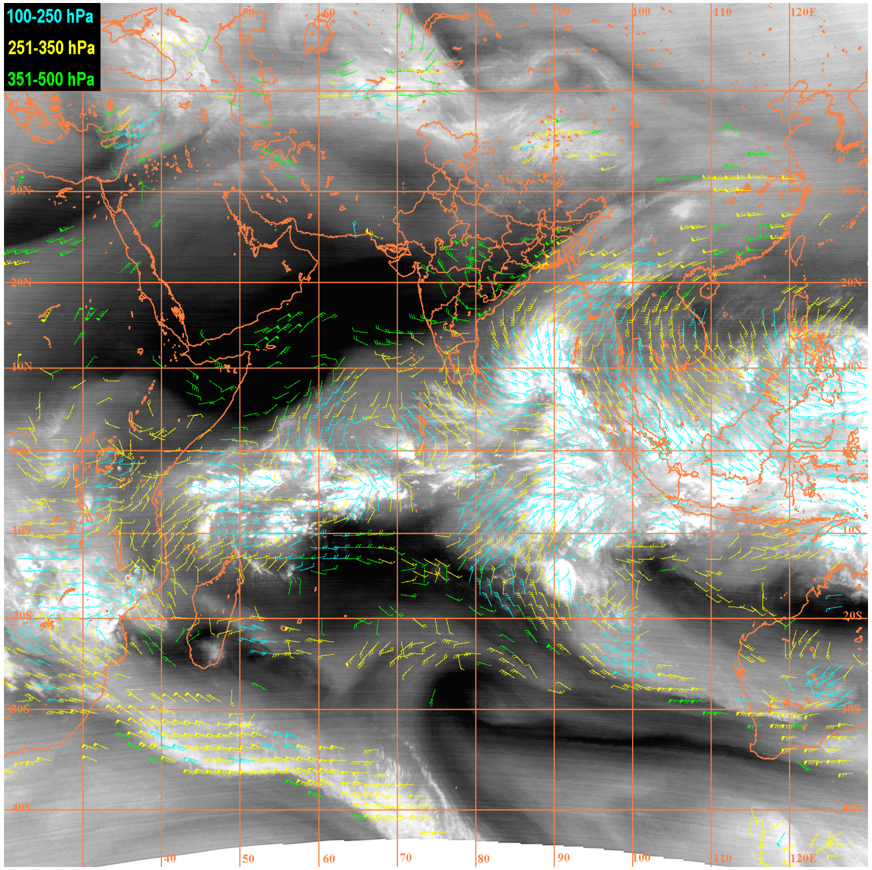
Meteosat7/CIMSS



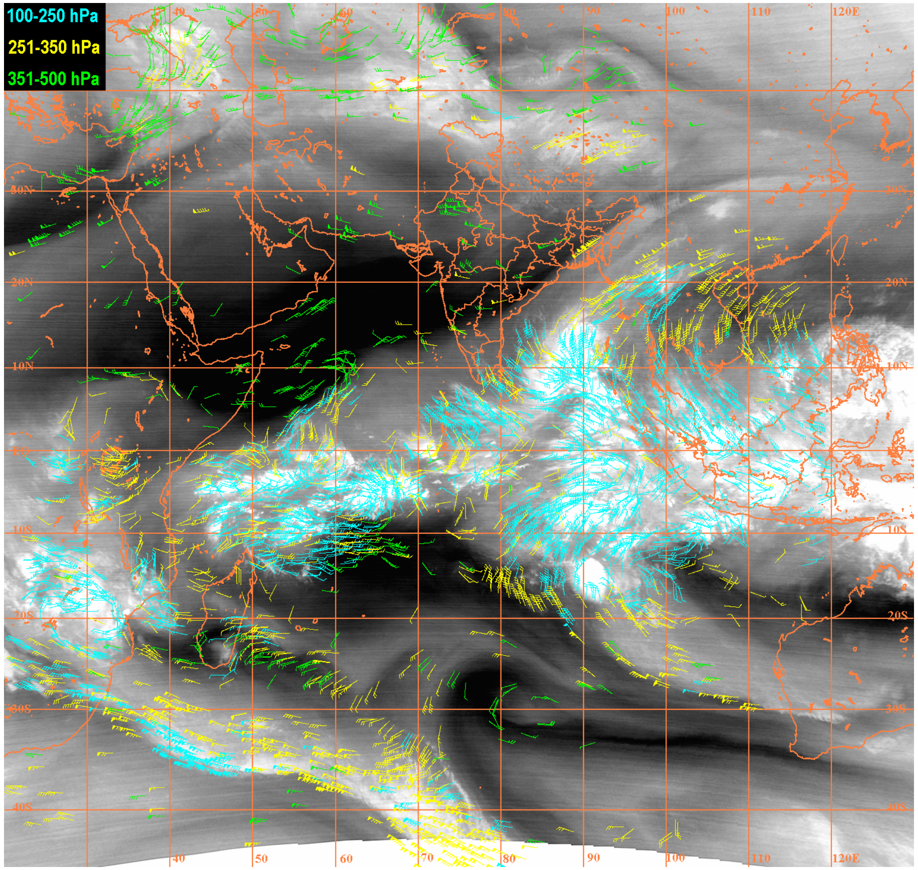
BACK

Cyclone Thane: WV winds - 25th December 2011: 00 UTC

Kalpana-1/ISRO

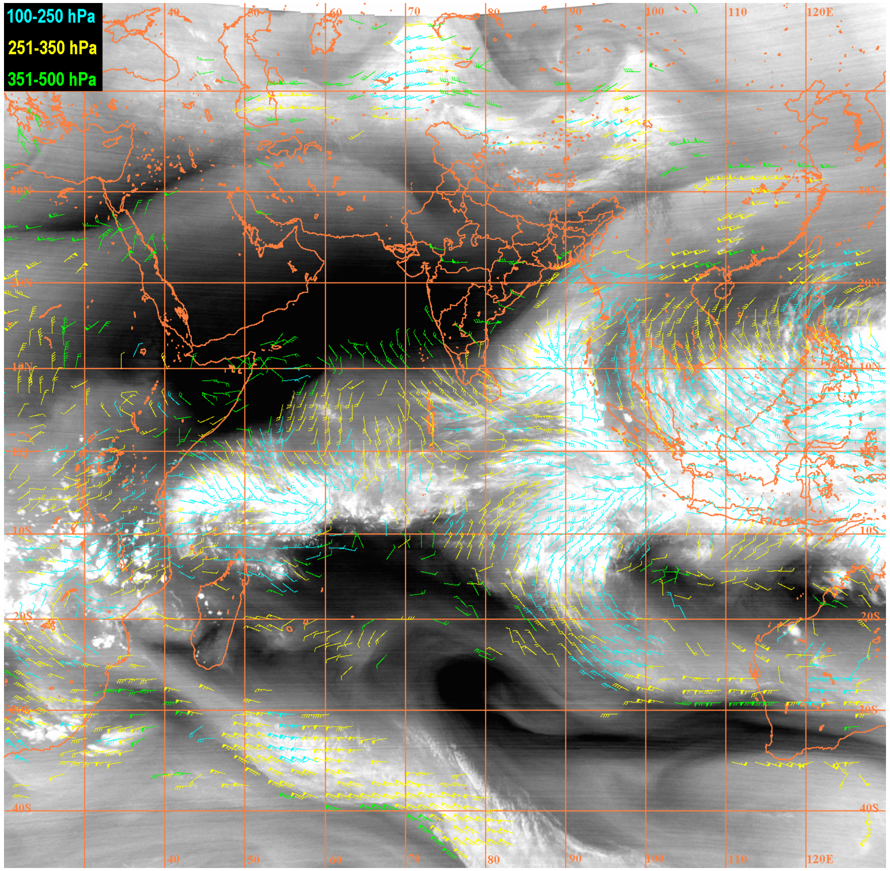


Meteosat7/CIMSS

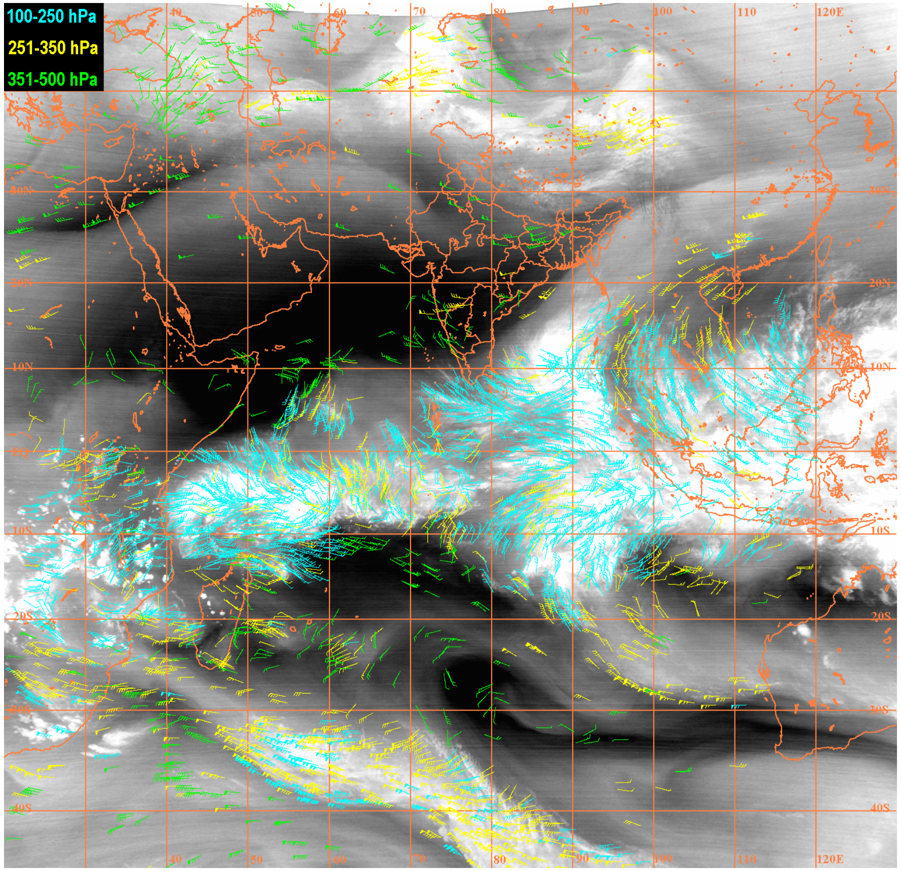


Cyclone Thane: WV winds - 25th December 2011: 12 UTC

Kalpana-1/ISRO

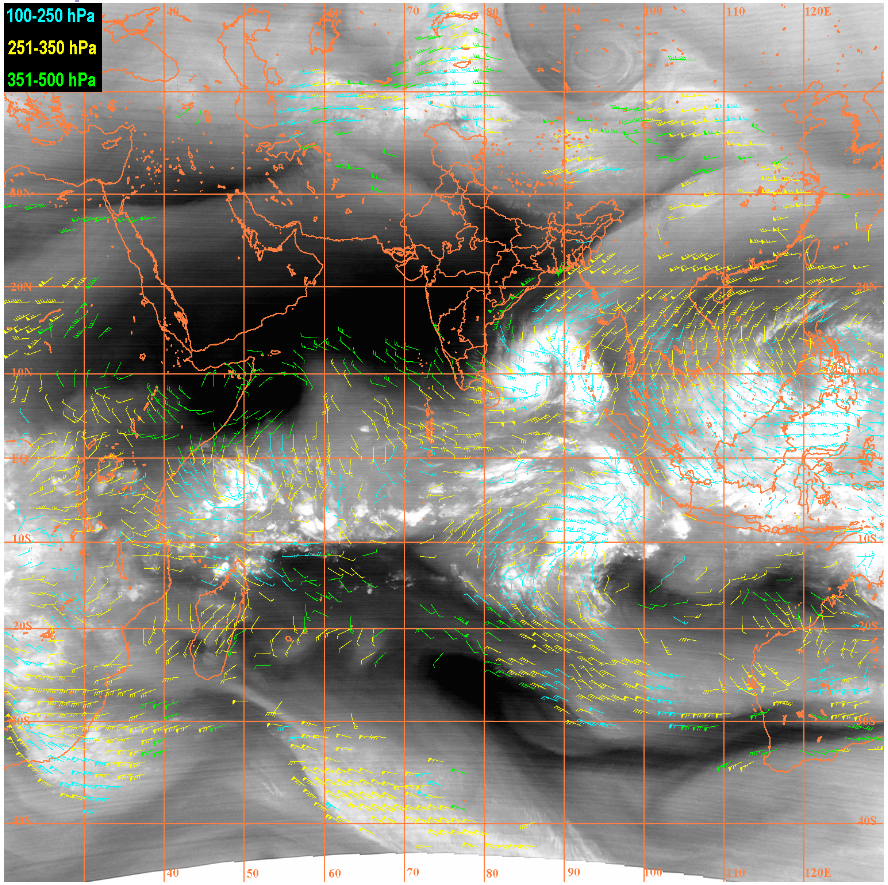


Meteosat7/CIMSS

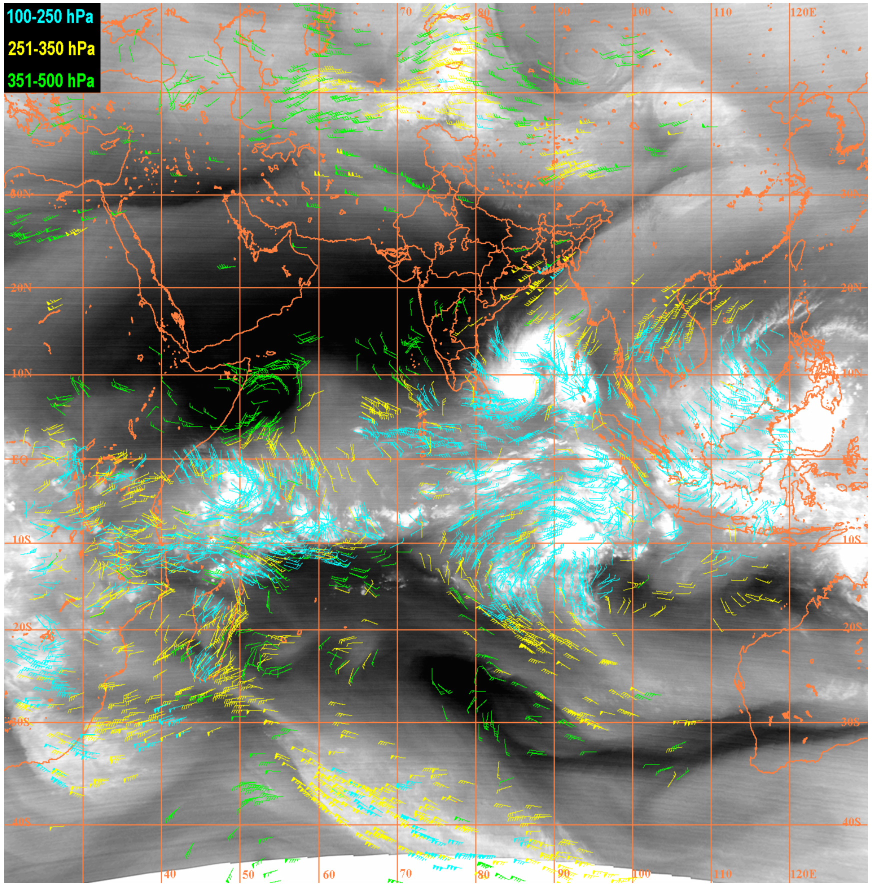


Cyclone Thane: WV winds - 26th December 2011: 00 UTC

Kalpana-1/ISRO

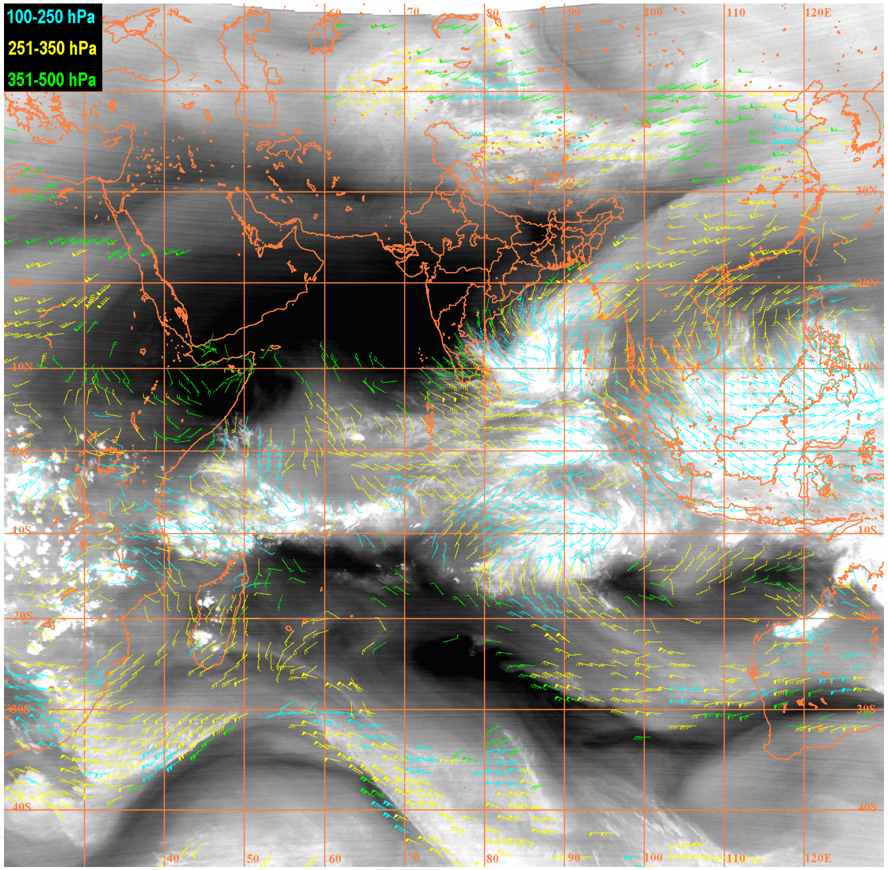


Meteosat7/CIMSS

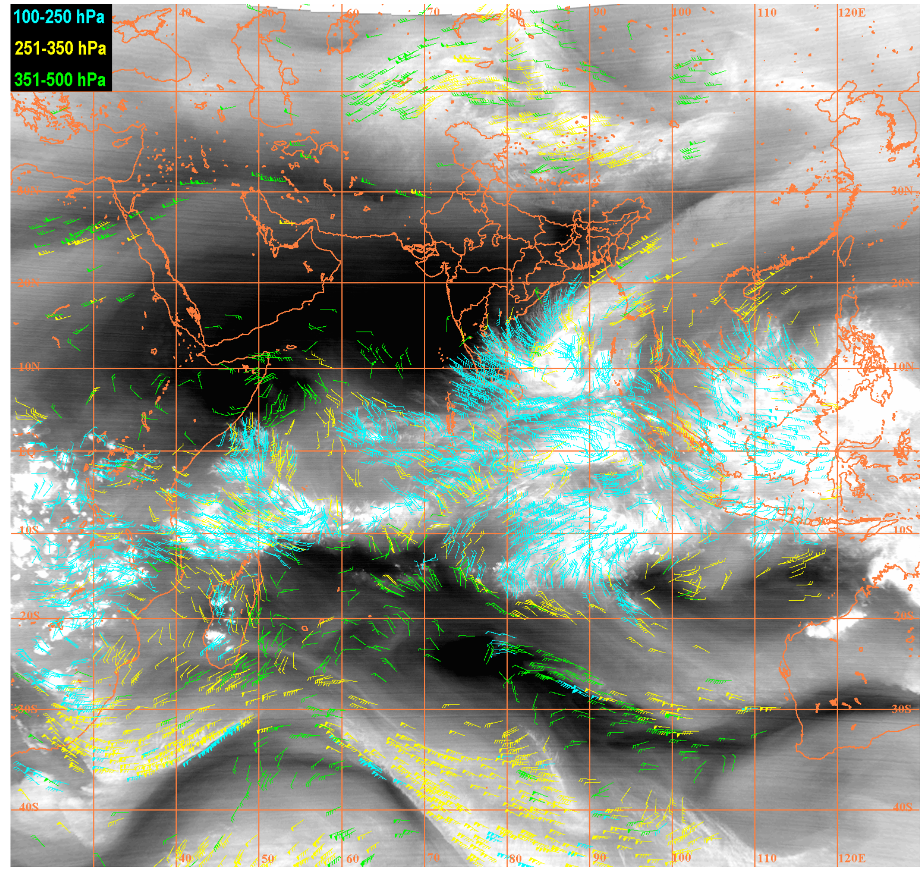


Cyclone Thane: WV winds - 26th December 2011: 12 UTC

Kalpana-1/ISRO

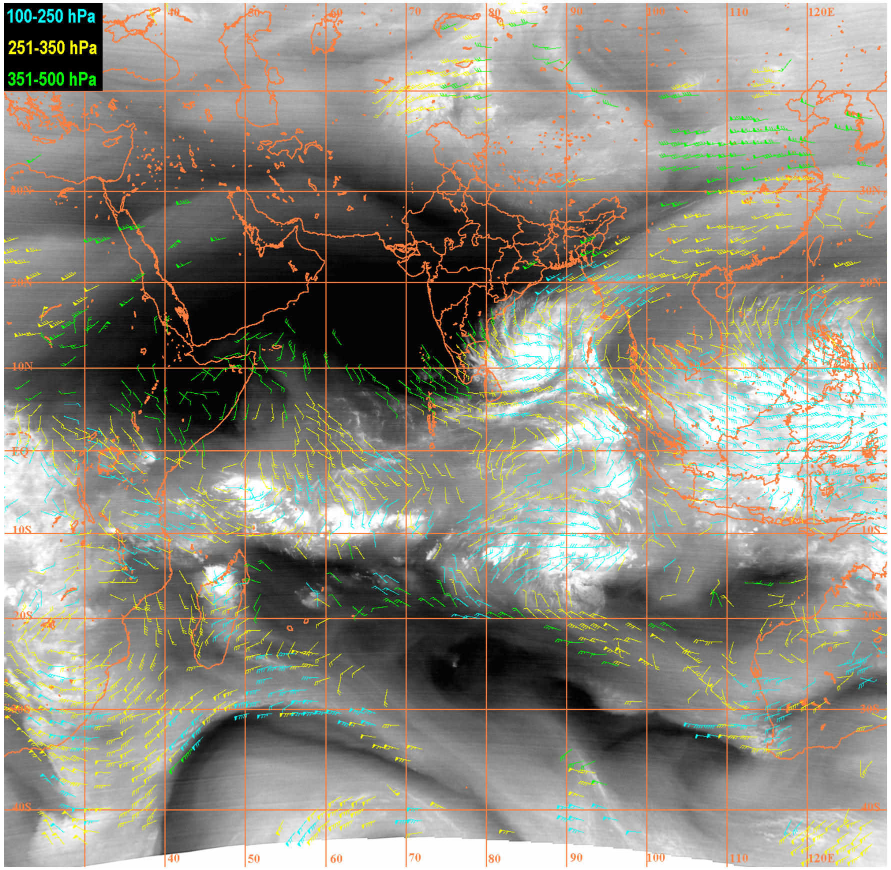


Meteosat7/CIMSS

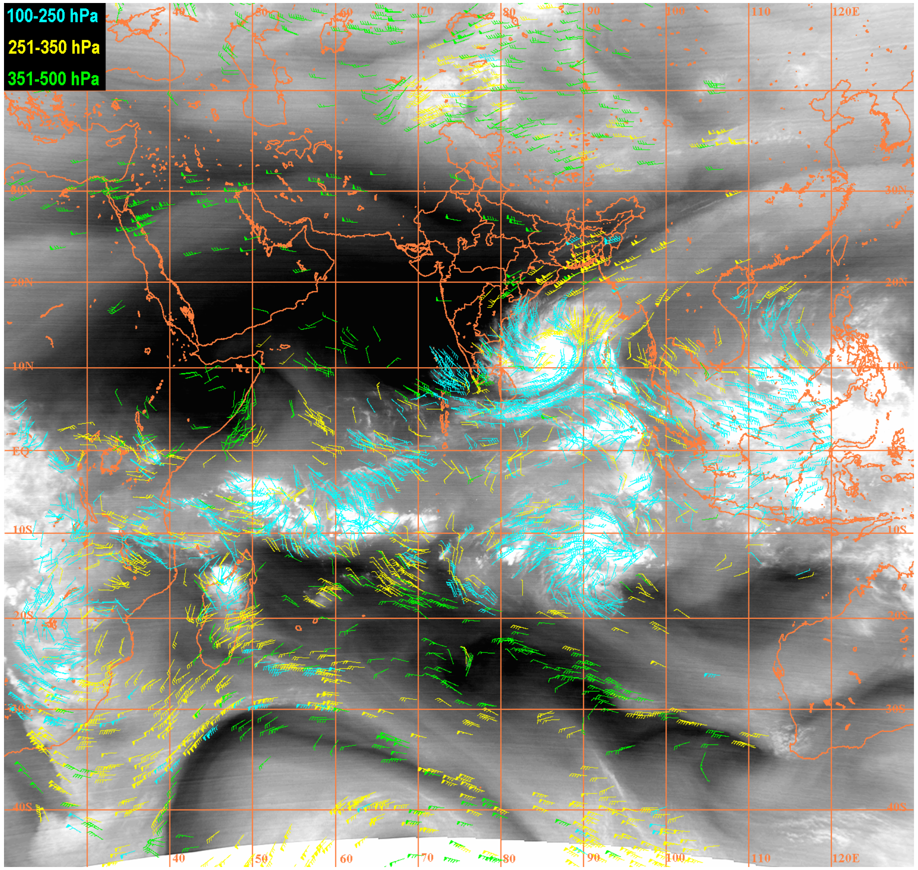


Cyclone Thane: WV winds - 27th December 2011: 00 UTC

Kalpana-1/ISRO

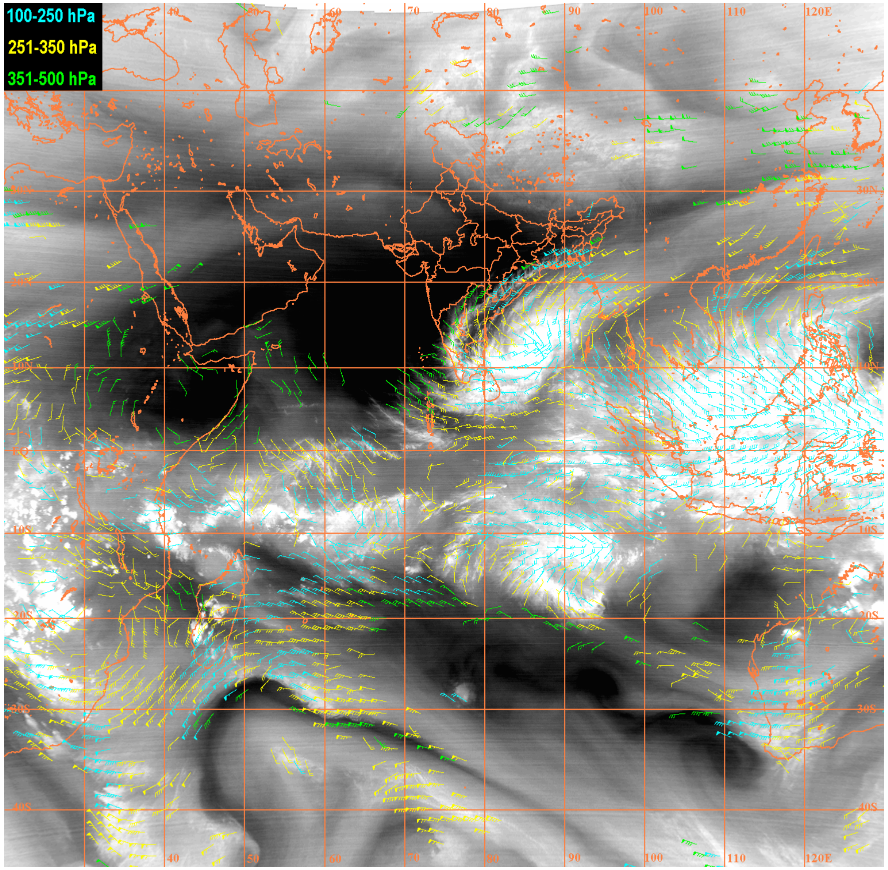


Meteosat7/CIMSS

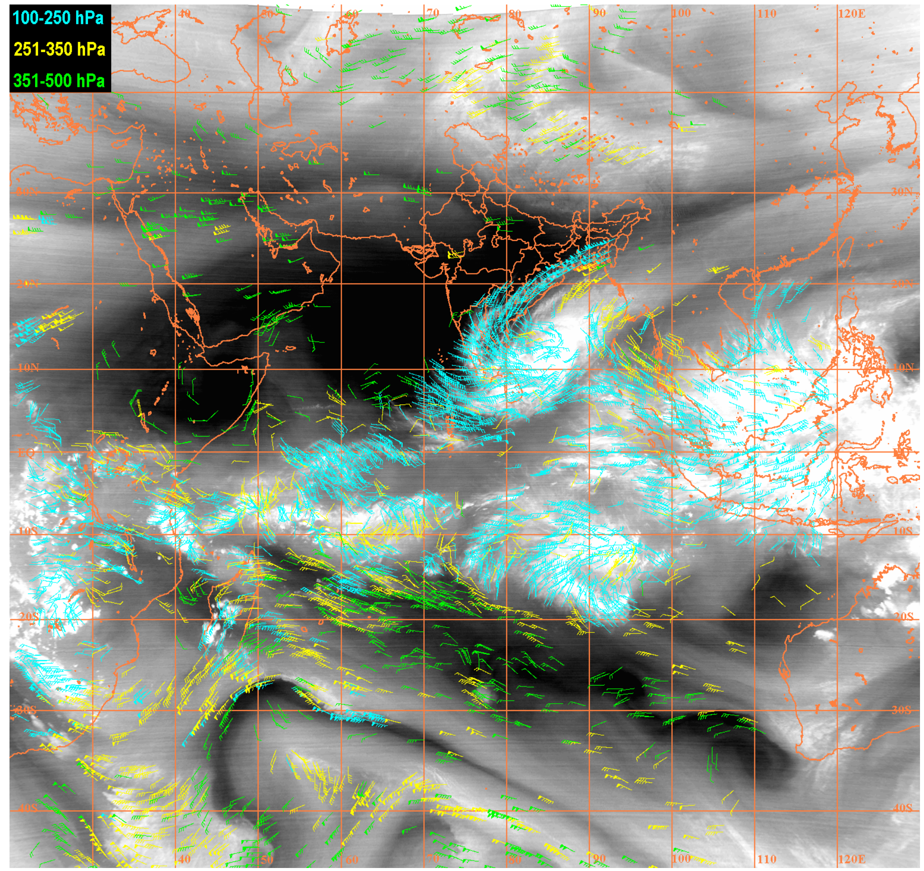


Cyclone Thane: WV winds - 27th December 2011: 12 UTC

Kalpana-1/ISRO

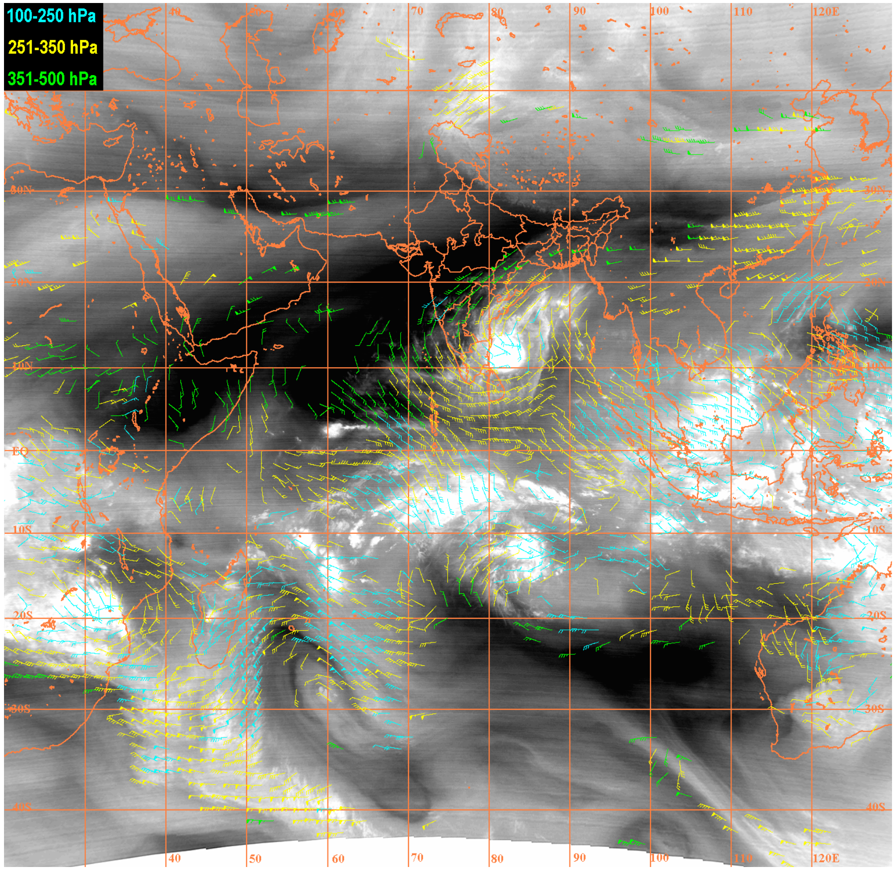


Meteosat7/CIMSS

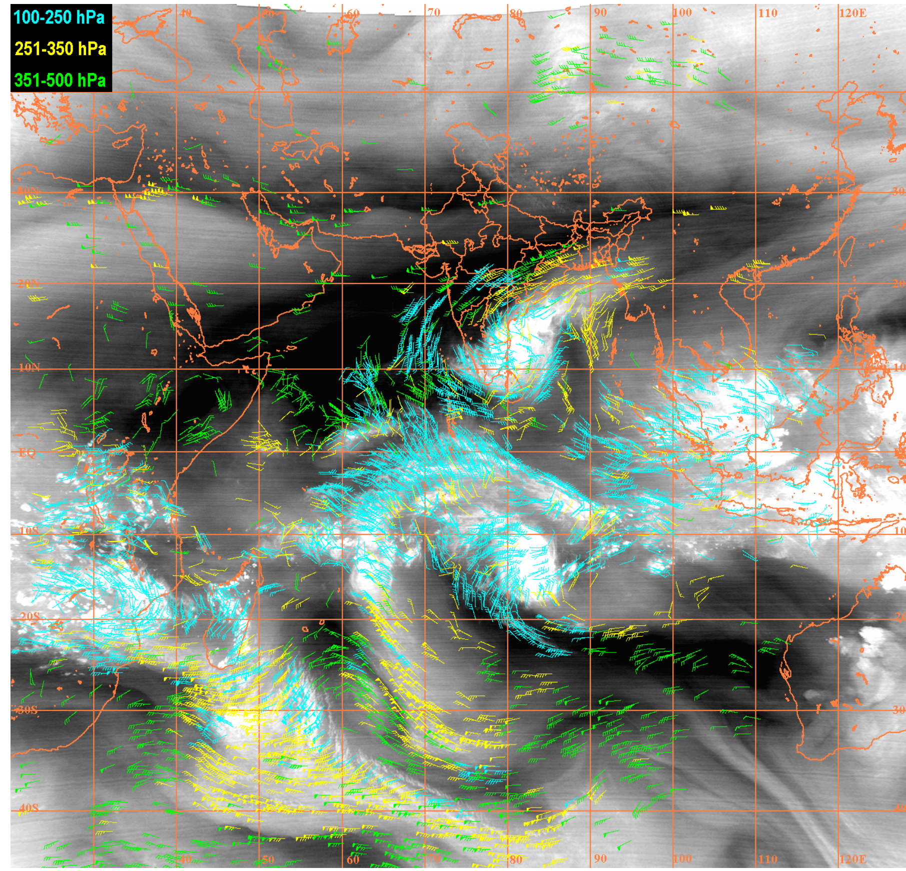


Cyclone Thane: WV winds - 29th December 2011: 00 UTC

Kalpana-1/ISRO



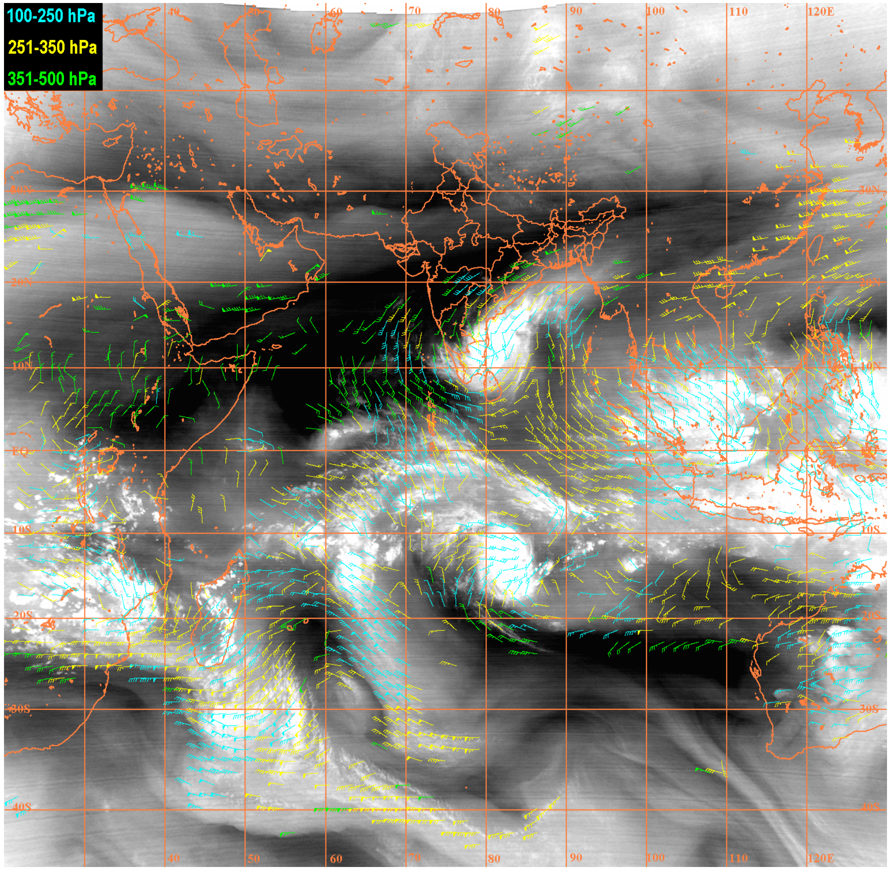
Meteosat7/CIMSS

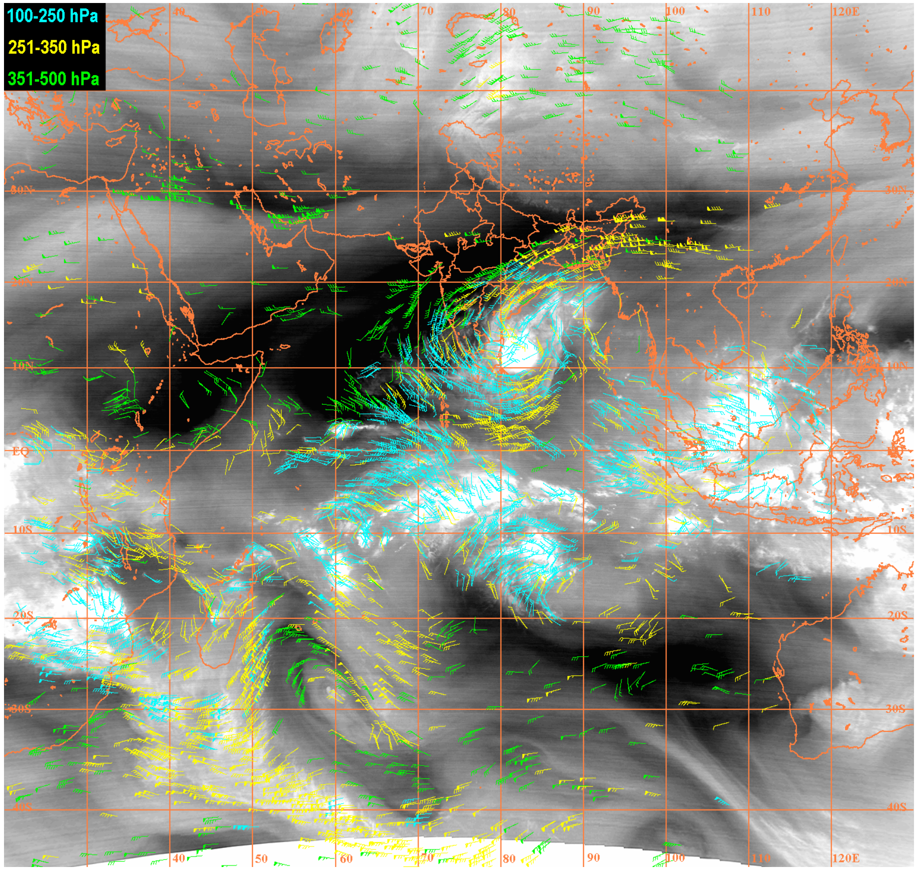


Cyclone Thane: WV winds - 29th December 2011: 12 UTC

Kalpana-1/ISRO

Meteosat7/CIMSS





BACK