MULTIPLET BASED TECHNIQUE TO DERIVE ATMOSPHERIC WINDS FROM KALPANA-1

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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 \( \{u_i : 1 \leq i \leq n\} \), for every member of the series some degree of dependence upon the preceding members can be deduced.

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

- Autocorrelation function:
  \[
  r_k = \frac{c_k}{c_0}
  \]
  where \( c_0 \) 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:
  \[
  c_k = \frac{1}{n} \sum_{i=1}^{n-k} (X_i - \bar{X})(Y_i - \bar{Y})
  \]
  where \( X \) and \( Y \) are two complex quantities.

- DECORRELATION 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.

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 $t_d \sim 18-24$ hours.
- Weakest winds occur in region over northern tip of Madagascar.
- In this region $t_d \sim 6$ hours.

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

Image-pair

Tracer Selection/tracking
Without Thresholding (IR winds)
For WV winds (same as triplet)
Tracking (same as triplet)

Detection and compilation of vector, and Mean/Max/Min BT for each template (20 X 20 box)

Combined operation
Vector Selection + Quality Check

Height assignment,
Spherical Geometric Correction,
Plotting etc
(same as Triplet scheme)

Update Buffer With Cyclic archive Method (Cycle=4-H)
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
A sample figure showing the difference of the density of quality-controlled vectors (using identical quality-control criteria) produced by two tracer selection methods: Gradient based tracer and Anomaly based tracer.
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.

\[
E = 1 - \frac{\sum_{i=1}^{n} (I_t - I_s)^2}{\sum_{i=1}^{n} (I_t - \bar{I})^2}
\]

Nash-Sutcliffe model efficiency

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

………..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.
• Infrared window technique (WIN).
• H₂O Intercept Method. (Nieman et. al 1993)
• Cloud Base Method (BASE). (LeMarshall et. al 1993)
• Few gross error checks.

RMSVD

Validation statistics with radiosonde

Height assignment - Collaboration with CIMSS/SSEC
### Statistics: Average of all 17 months

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### 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

No of Obs: 8528

No of Obs: 13174

No of Obs: 2071

No of Obs: 8231

No of Obs: 11596

No of Obs: 2078

No of Obs: 8972

No of Obs: 13238

No of Obs: 6738
IR winds: MID – Level  Period: DEC2011

 Bias
 TRIP_GA
 TRIP_NEW
 MULT_NEW

 RMSVD (Normalized)

 MVD
 TRIP_GA
 TRIP_NEW
 MULT_NEW

 Collocations

 Number of Winds
IR winds: MID – Level  Period: DEC2011

TRIP_GA

Area:80S–20S  No of Obs: 4312

Area:20S–20N  No of Obs: 6835

Area:20N–80N  No of Obs: 1378

TRIP_NEW

Area:80S–20S  No of Obs: 2396

Area:20S–20N  No of Obs: 2953

Area:20N–60N  No of Obs: 435

MULT_NEW

Area:80S–20S  No of Obs: 5439

Area:20S–20N  No of Obs: 5084

Area:20N–60N  No of Obs: 3484
IR winds LOW – Level Period: DEC2011
Density plot: IR winds LOW – Level Period: DEC2011

TRIP_GA

Area:80S–20S
No of Obs: 3940

Area:20S–20N
No of Obs: 3749

Area:20N–80N
No of Obs: 745

TRIP_NEW

Area:60S–20S
No of Obs: 2758

Area:20S–20N
No of Obs: 2637

Area:20N–80N
No of Obs: 433

MULT_NEW

Area:80S–20S
No of Obs: 4321

Area:20S–20N
No of Obs: 2473

Area:20N–80N
No of Obs: 1089
Examples

29 December 2011 12 UTC: Sample picture cyclone Thane

Kalpana-1-ISRO

Infrared winds

Meteosat7- CIMSS

- Thanks to CIMSS for Met7 winds
29 December 2011 12 UTC: Sample picture cyclone Thane

Kalpana-1-ISRO  Water vapor winds  Meteosat7- CIMSS

- 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 \( \mu \text{m} \) 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 - 27th December 2011: 00 UTC

Kalpana-1/ISRO

Meteosat7/CIMSS
Cyclone Thane: IR winds - 28\textsuperscript{th} December 2011: 00 UTC
Cyclone Thane: IR winds - 29th December 2011: 00 UTC
Cyclone Thane: WV winds - 25\textsuperscript{th} December 2011: 12 UTC
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
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