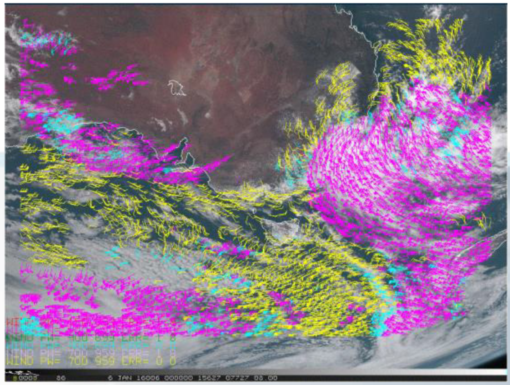
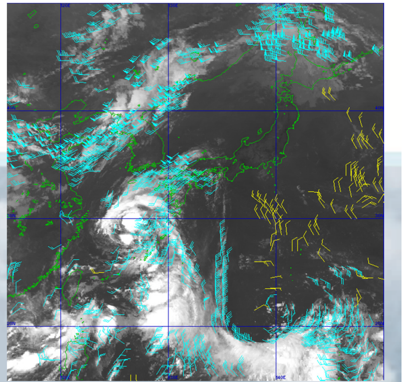
Australian Government
Bureau of Meteorology

Advanced Satellite Meteorology





Session 4: Training in the use of Cloud Drift Wind data

Bureau of Meteorology Training Centre
Australian VLab Centre of Excellence

Includes material from John LeMarshalls lecture and JMA presentations

Advanced Satellite Meteorology Course

Session 1 8th May	Advanced training in the use of visible and infrared satellite imagery.
Session 2 9th May	Advanced training in the use of water vapour satellite imagery.
Session 3 15th May	Training in the use of microwave scatterometer data
Session 4 15th May	Training in the use of cloud drift wind data
Session 5 17th May	Training in the use of rapid scan data.
Session 6 19th May	Training in the use of RGB products
Practical sessions (17th and 19th May)	Practical sessions focus upon Rapid Scan and RGB Product data
2 hour exam (26th May)	**Open book exam with resources on latitude**

Feedback from Operational Forecasters regarding the use of Atmospheric Motion Vector data (1)

Rebecca Patrick (Northern Territory Regional Forecasting Centre)

- We also use CIMSS cloud drift winds via website. Some time ago (probably over a year ago) we asked about having these in VWx but they couldn't be ingested at the time. It would be great to overlay this on water vapour imagery for analysing the 200hPa chart, and standard imagery for analysing other upper charts. Note that other CIMSS data (e.g. wind shear, divergence) is also used in TCWC operations/cyclogenesis assessments, although this would generally not be looked at by the newer Meteorologists.

Chris Davies (South Australian Regional Forecasting Centre)

- Unfortunately, the flow of AMVs into VW stopped when MTSAT was turned off. The Himawari-8 data is not being switched to Visual Weather which is very disappointing, we probably should be pushing for that.

REFERENCE

Feedback from Operational Forecasters regarding the use of Atmospheric Motion Vector data (2)

Richard Carlyon (Victorian Regional Forecasting Centre)

- 850hPa CDW would be good for smoke/fire monitoring, also arrival of southwesterly changes associated with a front, especially over ocean areas.
- Can use it on upper chart analysis – verifying models
- Cloud Drift Wind data is currently not going into Visual Weather

REFERENCE

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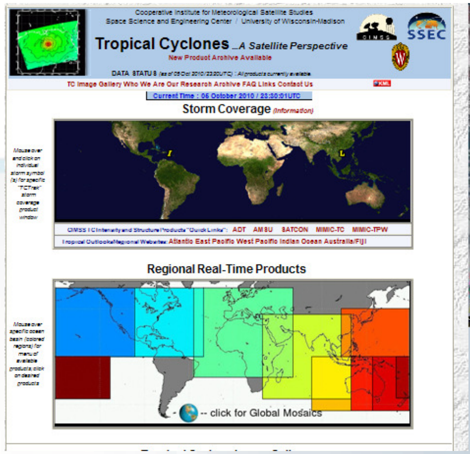
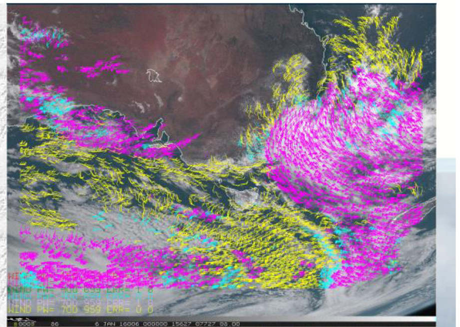
Important sources of Atmospheric Motion Vector data



CIMSS web page at http://tropic.ssec.wisc.edu/



- Currently used by particular Bureau staff within McIDAS
- Likely to be available within Visual Weather in future

Images courtesy BOM/JMA

Concept and history

Method of generating wind observations over large areas.

Uses sequential satellite imagery to track cloud motion. Distance / time gives velocity.

Height assignment carried out using:

- Infrared window technique
- H2O intercept method
- CO_2 slicing technique

1975 – Atmospheric Motion Vectors generated routinely in the USA

1987 – Routine generation of Atmospheric Motion Vectors in the Bureau of Meteorology Research Centre (BMRC)

REFERENCE

Applications of Atmospheric Motion Vectors

A. **Numerical Weather Prediction**
   A. Data thinned before assimilation

B. **Tropical Cyclone track prediction**
   A. Benefits can be dependent on assimilation method
   B. Benefits measured using impact studies and by comparing predicted cyclone tracks with observed tracks

C. **Assist in surface and upper chart analysis**

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Processing cloud drift wind data (CIMSS)

Image registration
Ensuring that satellite images are correctly mapped

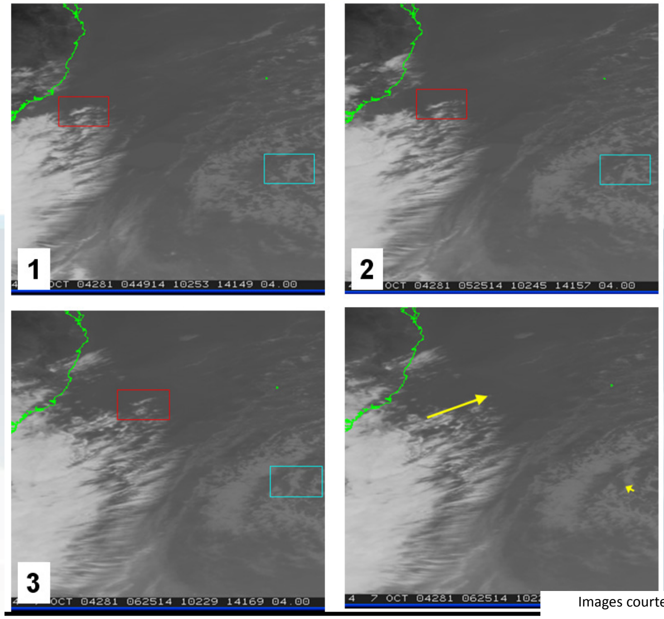
Image targeting and target height assignment
Cloud features, gradients in water vapour imagery. NWP data used to assist in height assignment

Wind vector determination
Targets are tracked between successive image pairs, NWP forecast windfields used as first guess for tracking cloud features

Wind vector editing and quality control
Buddy checking of winds, comparing wind vector to background NWP

REFERENCE

Atmospheric Motion Vector Determination



Images courtesy BOM/JMA

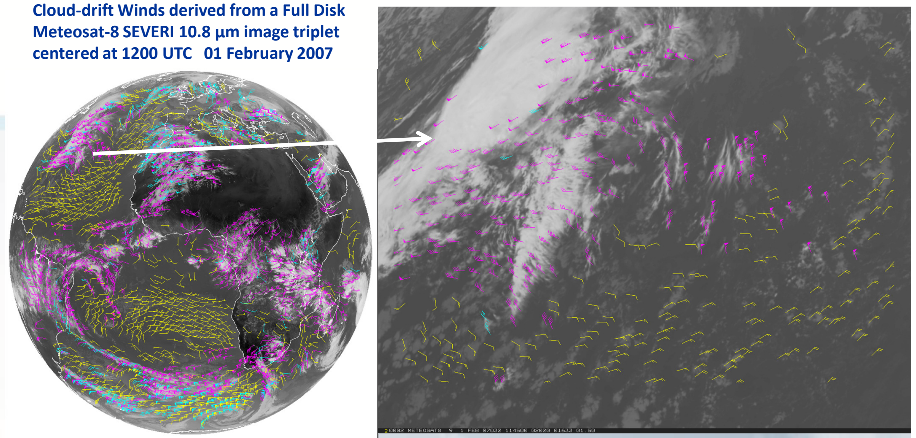
CIMSS Atmospheric Motion Vector determination (CIMSS)

- Atmospheric Motion Vectors derived using a sequence of three images. Features are targeted in the second image.
- Features include cirrus cloud edges, gradients in water vapour, small cumulus clouds, etc.
- Features are tracked within the first and third images, yielding two displacement vectors.
- These vectors are averaged to derive a final wind vector.

REFERENCE

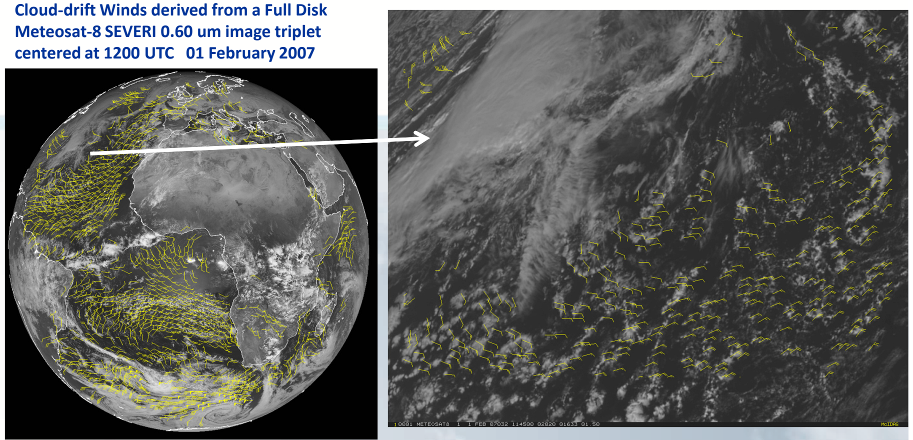
Example Output
Long-wave IR Cloud-drift Winds

Cloud-drift Winds derived from a Full Disk Meteosat-8 SEVERI 10.8 µm image triplet centered at 1200 UTC 01 February 2007



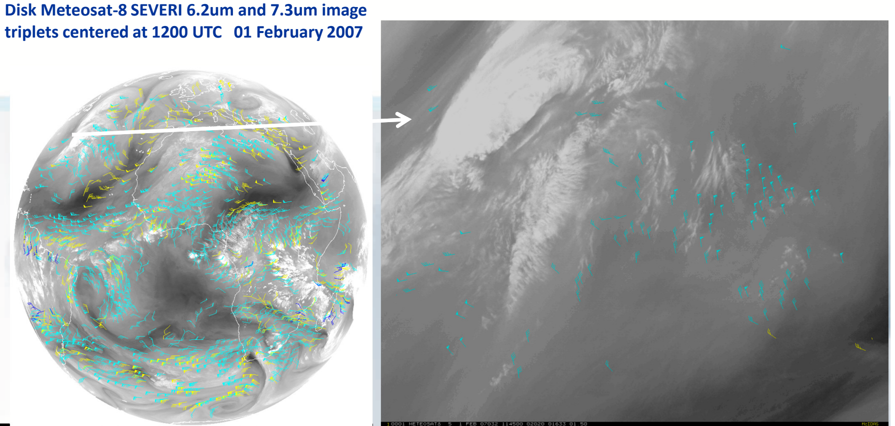
Example Output
Visible Cloud-drift Winds

Cloud-drift Winds derived from a Full Disk Meteosat-8 SEVERI 0.60 um image triplet centered at 1200 UTC 01 February 2007

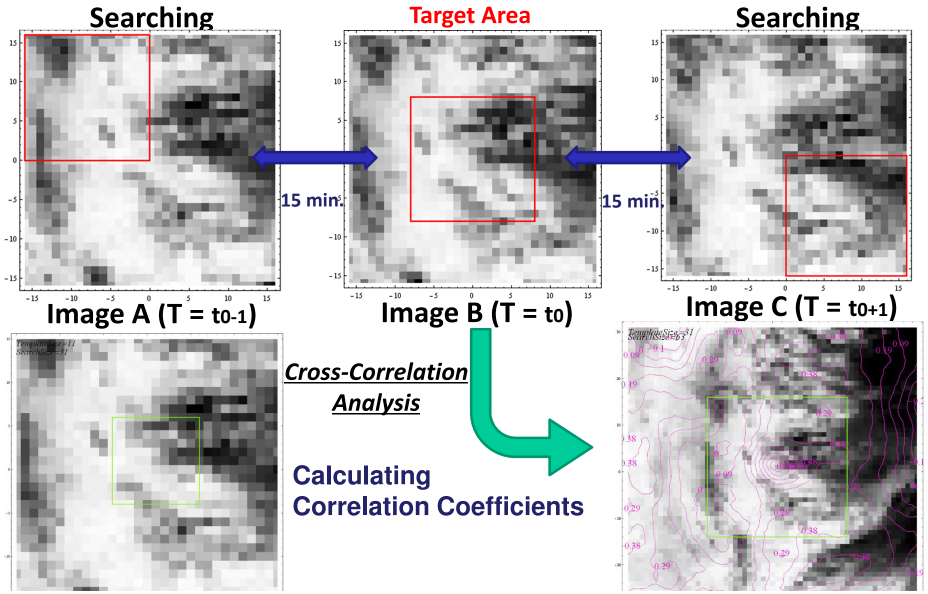


Example Output
Clear-Sky Water Vapor Winds

Clear-sky Water Vapor Winds derived from Full Disk Meteosat-8 SEVERI 6.2um and 7.3um image triplets centered at 1200 UTC 01 February 2007



Tracking "Target" by Pattern Matching



Adapted from the presentation "Status of Japanese follow-on Geostationary Meteorological Satellites (T.Kurino, Y.Kumagai, Y.Shimizu) Joint Australian - Japanese Himawari-8/9 Symposium 22 May 2013, Canberra, Australia

Height determination – the Infrared Window Technique

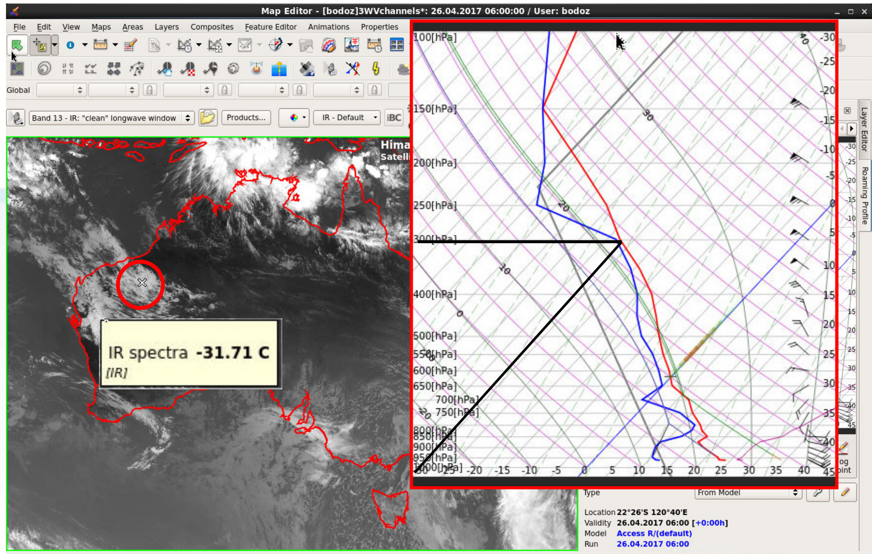


Image courtesy BOM/JMA

Image courtesy BOM

CIMSS Atmospheric Motion Vector height determination (Infrared Window technique)

Vector heights are assigned in a two-step process.

Target radiance is related to the spectral response function of the channel sampled. Brightness temperature of the target can be derived from this.

Initial height is estimated by comparing brightness temperature with collocated numerical model guess temperature profile (collocated radiosonde data within 3 hours and 150 km – BOM cloud drift winds).

The final vector height is derived in the post-processing of the vector field.

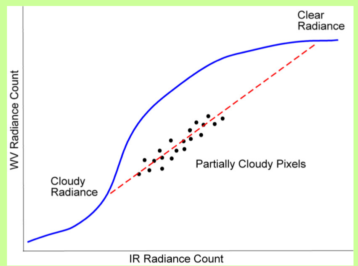
REFERENCE

Other height determination methods

(for semitransparent or broken cloud)

H2O Intercept Method (good for clouds higher than about 600 hPa)

- Compares measured radiances from WV channel (6.7 µm) and longwave IR window channel (10.7 µm) to calculated Plank blackbody radiances (uses profile estimates from model)
- Based on the fact that radiances from a single cloud deck vary linearly with height.
- Model guess temperature and humidity profiles are used for radiative transfer calculations. Measured and calculated radiances will agree for clear sky and opaque cloud conditions.
- Cloud top height is inferred from the linear extrapolation of radiances into the calculated curve of opaque cloud radiances.



REFERENCE

Other height determination methods
(for semitransparent or broken cloud)

CO_2 Slicing Technique (good for clouds higher than about 700 hPa)

- Combines radiances of CO_2 channel (13.3 µm) and longwave IR window channel (10.7 µm) that have different ice cloud emissivities and that are sensitive to different layers in the atmosphere.
- Cloud emissivities of the two channels are roughly the same for ice clouds.
- Ratio of clear and cloudy radiance differences gives a solution for the cloud top pressure of the cloud.
- The observed differences are compared to a series of radiative transfer calculations with different cloud pressures.
- The final height (cloud top pressure) matches the observations.

REFERENCE

Atmospheric Motion Vector quality control (CIMSS)

CIMSS uses two quality control processes to assure vector correctness and uniformity.

- Autoediting. Utilises conventional data assimilation, neighbouring wind "buddy" checks, and numerical model analyses for wind vector editing and height adjustments.
- EUMETSAT "Quality Indicator" (QI) methodology. A statistically-based scheme which highlights internal consistency between vectors without use of a background numerical model.

REFERENCE

From Himawari-8 Derived Motion Winds - Generation and Assimilation , Advanced Satellite Meteorology Lecture by John LeMarshall 2016

Himawari-8 Operational AMV Generation

Uses 3 images separated by 10 min in HSF format.

Employs modified GEOCAT (Geostationary Cloud Algorithm Testbed) software in initial processing.

Height assignment methods similar to GOES-R ABI ATBD For Cloud Height (Heidinger, A. 2010)

AMV estimation is similar to GOES-R ABI ATGD for Derived Motion Winds (Daniels, 2010)

Error characterization, data selection, QC via EE, QI, ERR etc. (Le Marshall et al., 2004, 2015)
Height assignment verification/ development uses Cloudsat/Calipso, RAOBS

REFERENCE

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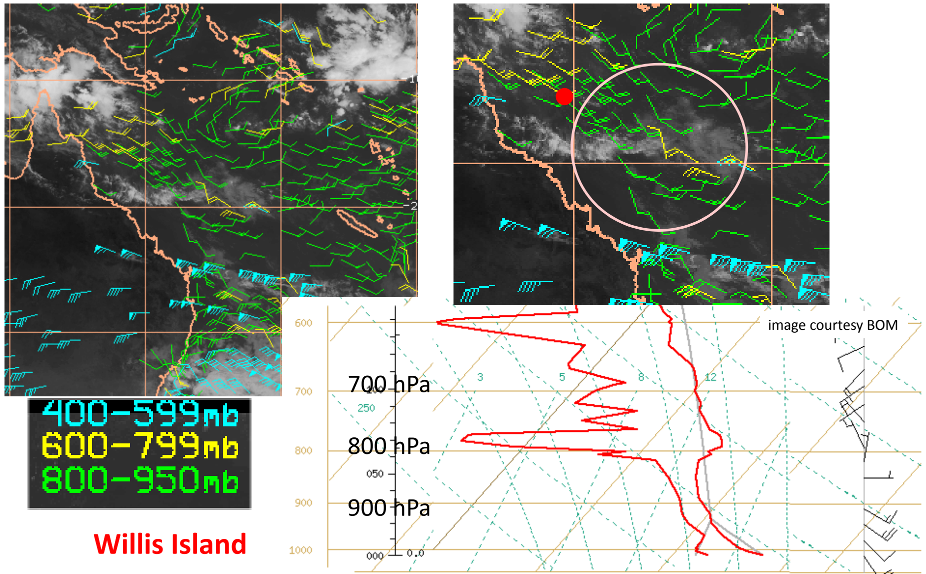
Wind Shear and Cloud Drift Winds.

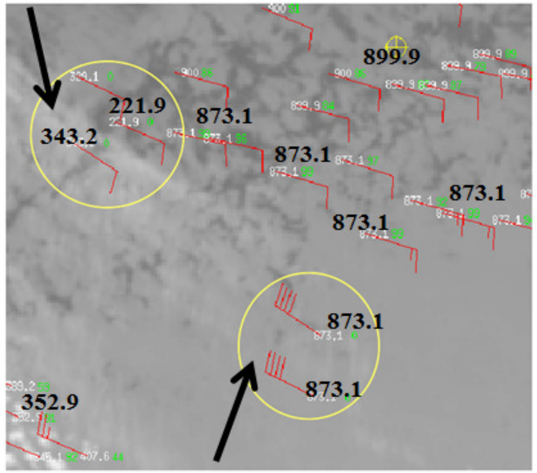
Coral Sea 30th April 2009 00UTC



AMV images courtesy University of Wisconsin – CIMSS

Thin Cirrus Cloud and Cloud Drift Winds

Vectors match with the low cloud motion but are assigned to high levels.



Vectors agree with motion at high levels but are assigned to low levels.

Thin high cloud overlying low cloud

image from "Satellite Winds", S.English, C.Lupu, K.Salonen. ECMWF, Satellite Data Training Course 2013

Sources of Error (summary – part 1)

Image navigation errors

- Registration errors of 3.5 km in 30 minute imagery could lead to wind errors of 2 m/s

Assumption that clouds and water vapour features are passive tracers of the wind field

- Clouds can evolve, change shape etc.

Incorrect Height assignment

- Especially problematic with large vertical wind shear. Several features in the target box moving with different speeds and directions, e.g. multi-level cloud
- Difficulties linking the height assignment to the features dominating the tracking. Example: Thin high cloud overlying the low cloud, multilevel cloud

REFERENCE

Sources of Error (summary – part 2)

NWP errors

- Errors in short-range NWP forecasts used in the height assignment.

For high and mid level clouds height is assigned to the cloud top, and for low level clouds to the cloud base.

- This is often representative of the levels controlling the motion of the clouds but exceptions exists.
- Should AMVs be considered as layer-average winds?

Intercomparison of AMV's derived by 5 producers from the same SEVIRI imagery (Genkova et al. 2010) :

Estimated median values for differences in Speed, Direction and Pressure as 2.99m/s, 22 degrees and 175 hPa

REFERENCE

Ranking of CDW in upper air chart analysis – from my time at the Darwin Regional Forecasting Centre

1 Sonde flights

2 Aircraft (AMDARS) – but time and height need checking

3 Radar tracked wind flights

4 Satellite derived winds (CDW)

5 NWP guidance

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In explaining CIMSS cloud drift winds and products, we shall be examining the case study of Tropical Cyclone Frances

image courtesy JMA/NRL Monterey

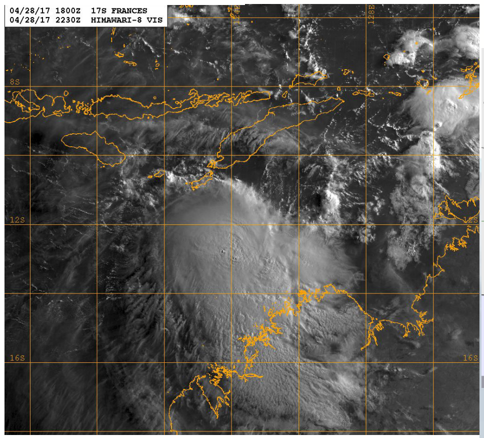
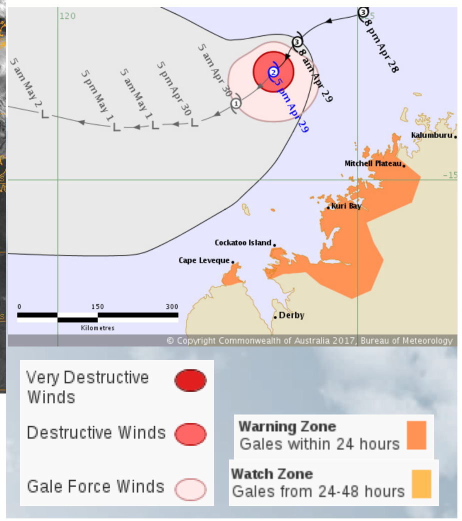


image courtesy Australian Bureau of Meteorology (BOM)



Severe Tropical Cyclone Frances Satellite image (2230 UTC, 28th April) and Threat Map morning of 29th April 2017

CIMSS Low to mid level infrared atmospheric motion vectors (28th April 2017, 21UTC)

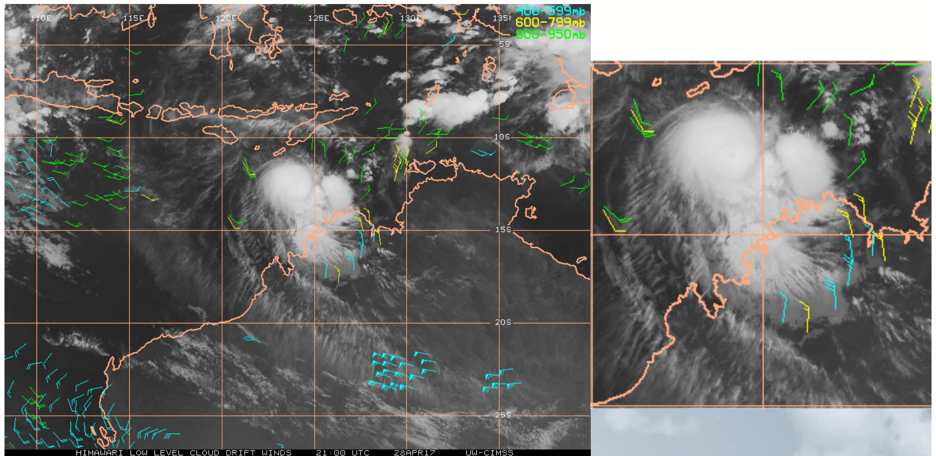


Image courtesy University of Wisconsin – CIMSS

QUESTION: why are there no cloud drift winds near Severe Tropical Cyclone Frances ?

CIMSS Low to mid level infrared atmospheric motion vectors

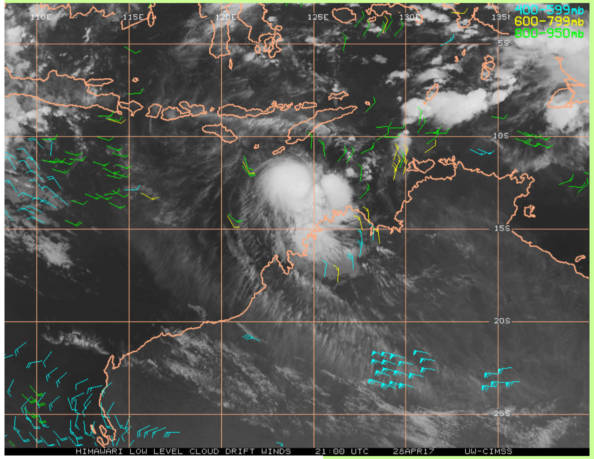


Image courtesy University of Wisconsin – CIMSS

Tracking cloud edges over a sequence of infrared images. Uses levels between 500 and 950 hPa.

Use of this data: Low-level rotation of developing tropical waves and mid-level steering currents can be identified.

REFERENCE

CIMSS Lower level atmospheric convergence.

(28th April 2017, 21UTC)

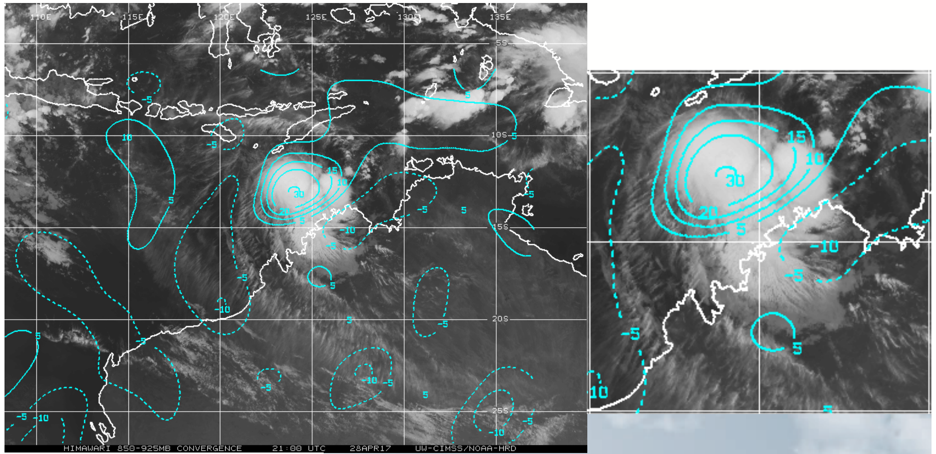


Image courtesy University of Wisconsin – CIMSS

Positive values are convergence as solid lines, divergence is dashed.

CIMSS Lower level atmospheric convergence

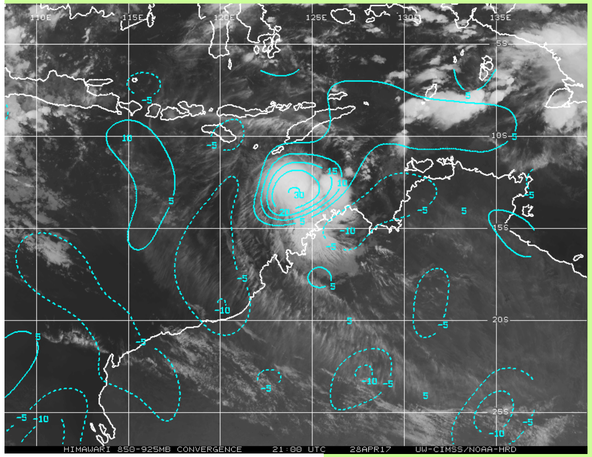


Image courtesy University of Wisconsin – CIMSS

Uses gridded u and v atmospheric motion vector components averaged over the 850, 925 hPa levels.

Convergence is computed using finite differencing of -(du/dx + dv/dy), where x and y are the horizontal grid spacing.

Positive values are convergence as solid lines, divergence is dashed.

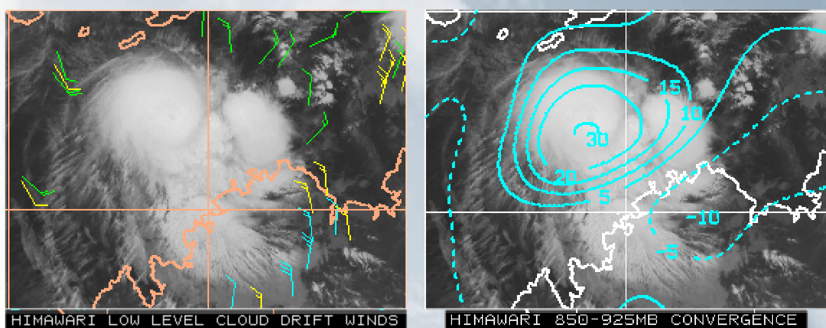
REFERENCE

A question regarding CIMSS Cloud Drift Winds

What models are used in constructing CDW?.

- The background model used is usually the United States Navy's NOGAPS, but NOAA's GFS model serves as a back up.

Why do they have convergence if there is no wind there ?.



images courtesy JMA/NRL Monterey

A question regarding CIMSS Cloud Drift Winds

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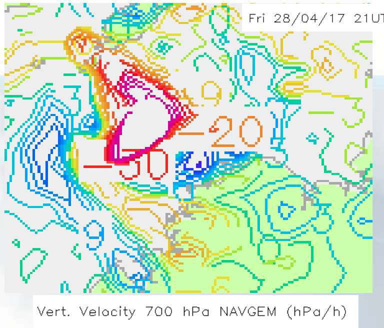
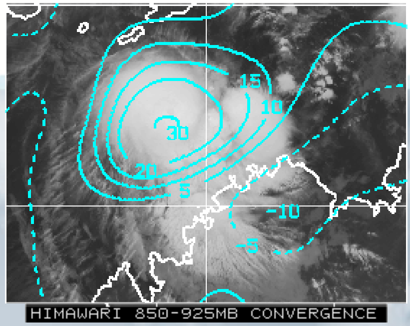


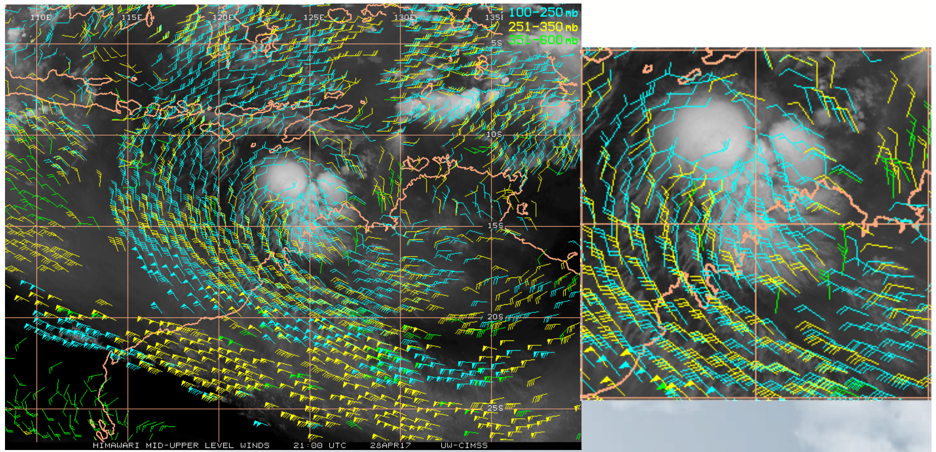


In data sparse regions at each height, numerical model output is used.

images courtesy JMA/NRL Monterey

CIMSS upper level water vapour and infrared atmospheric motion vectors (28th April 2017, 21UTC)

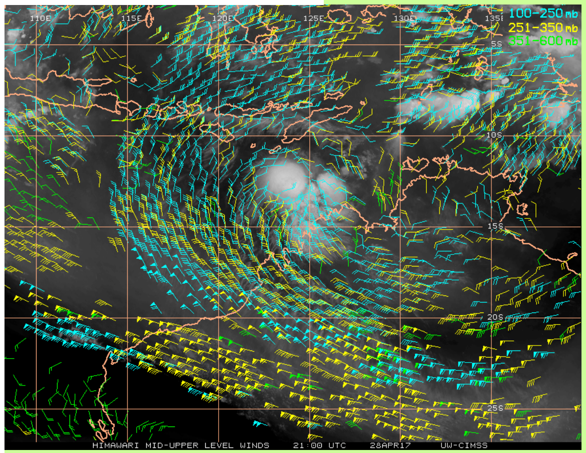
Image courtesy University of Wisconsin – CIMSS



QUESTION: with the forecast west-south west movement of TC Frances, what features may enhance / inhibit its development ?

CIMSS upper level water vapour and infrared atmospheric motion vectors

Image courtesy University of Wisconsin – CIMSS



Tracking gradients in a sequence of WV images and cloud edges in IR imagery. Uses levels between 100 and 500 hPa.

REFERENCE

Use of this data: Jet regions, steering currents, TUTTs, upper lows and tropical cyclone (TC) upper-level outflow regions can be identified.

CIMMS upper level atmospheric divergence.

(28th April 2017, 21UTC)

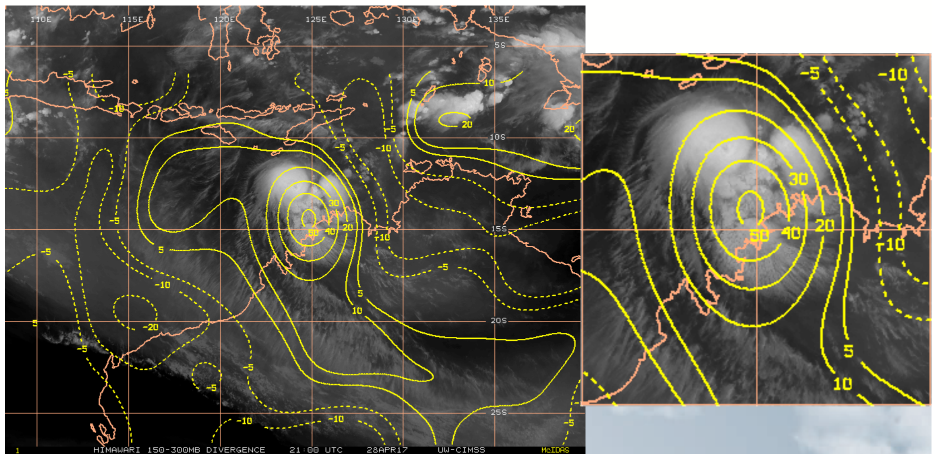
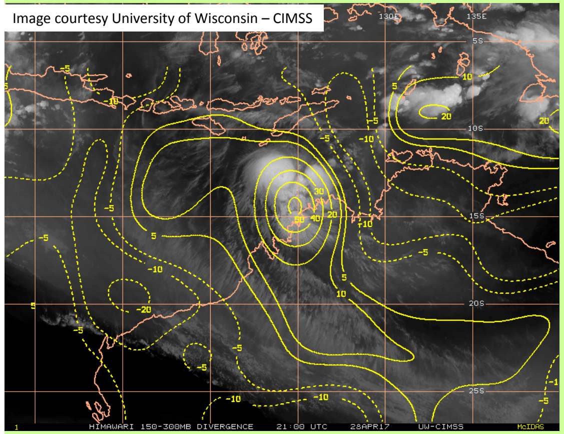


Image courtesy University of Wisconsin – CIMSS

Positive values are divergence as solid lines, convergence is dashed.

CIMSS upper level atmospheric divergence

Image courtesy University of Wisconsin – CIMSS



Uses gridded u and v atmospheric motion vector components averaged over the 150, 200, 250 and 300 hPa levels.

Divergence is computed using finite differencing of (du/dx + dv/dy), where x and y are the horizontal grid spacing.

Positive values are divergence as solid lines, convergence is dashed.

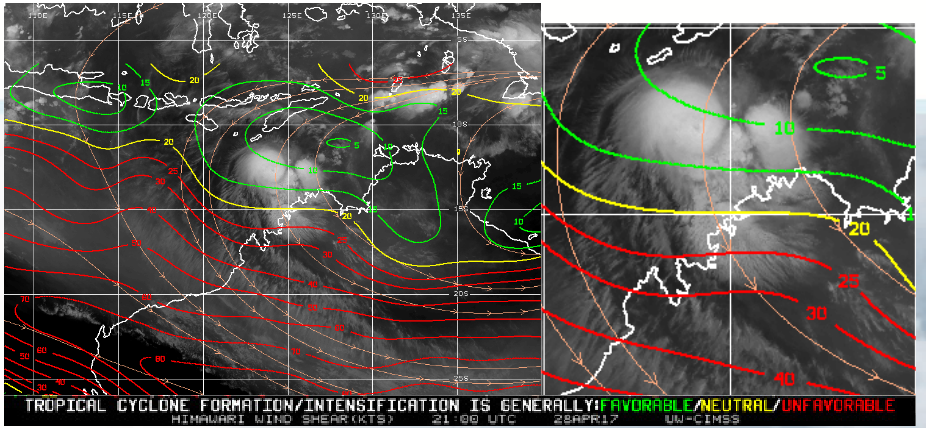
Use of this data: Upper-level atmospheric divergence = strength of the Tropical Cyclone secondary circulation.

REFERENCE

CIMSS Atmospheric Shear. (28th April 2017, 21UTC)

QUESTION: with the forecast south-eastward movement of Tropical Cyclone Frances, what features may enhance / inhibit its development ?

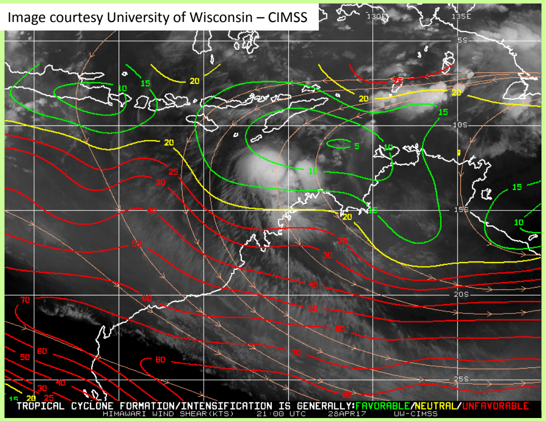
Image courtesy University of Wisconsin – CIMSS



Streamlines indicate direction of shear

CIMSS Atmospheric Shear

Image courtesy University of Wisconsin – CIMSS



Uses gridded u and v atmospheric motion vector components averaged over an upper layer (150, 200, 250, 300 hPa) and a lower layer (700, 775, 850, 925 hPa).

Difference in these components is used to compute shear between upper and lower layers.

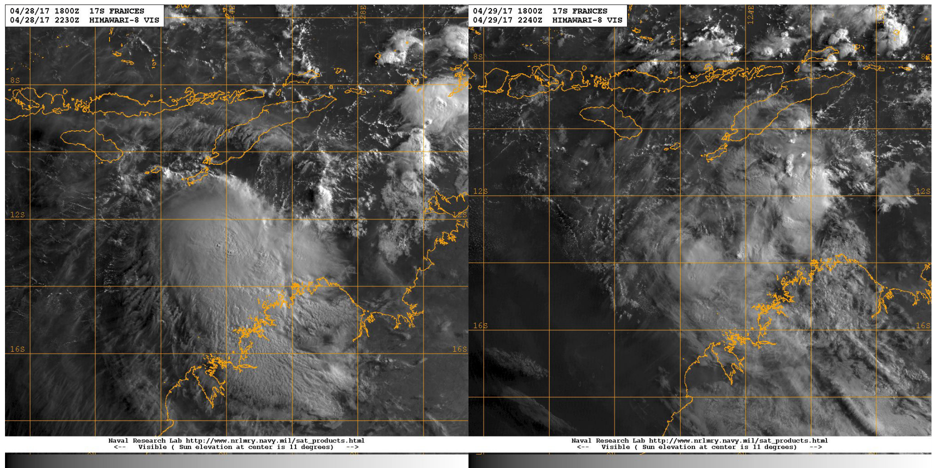
Use of this data: Shear values below 10 m/s (20 kts) are considered low enough for tropical cyclogenesis.

Streamlines indicate direction of shear

REFERENCE

Evolution of Severe Tropical Cyclone Frances

(current image compared to image +1 day)

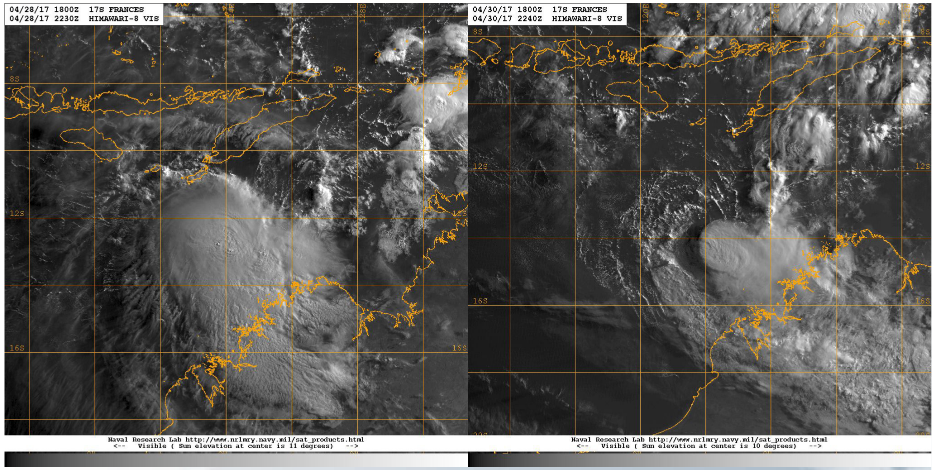


2230UTC, 28th April 2017 — 2240UTC, 29th April 2017

images courtesy JMA/NRL Monterey

Evolution of Severe Tropical Cyclone Frances

(current image compared to image +2 days)



2230UTC, 28th April 2017 | 2240UTC, 30th April 2017

images courtesy JMA/NRL Monterey

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Science Week 2013 presentation at
http://www.virtuallab.bom.gov.au/archive/science-week-2013/subjectsandcomments/

Sea Surface Wind Estimation Using Rapid Scan AMVs

Masahiro Hayashi (Mr.),
Meteorological Satellite Center (MSC) /
Japan Meteorological Agency (JMA)

Science Week 2013 1

REFERENCE

AMVs by short-time interval imageries

- We cannot track *short-lifetime cloud system* with *long-interval imageries*
- AMVs from *shorter-interval imageries* (*Rapid Scan-AMVs*) can track *short-lived cloud system*
- Rapid Scan AMV can be derived even in the area around TC center, where clouds deform rapidly

From the presentation "Sea Surface Wind Estimation Using Rapid Scan AMV's" (M. Hayashi,)
Advanced Forecaster Course (Science Week) presentation, BMTC 2013

Impact of higher sampling rates and higher spatial resolution; MTSAT-2 (Himawari-7) vs Himawari-8

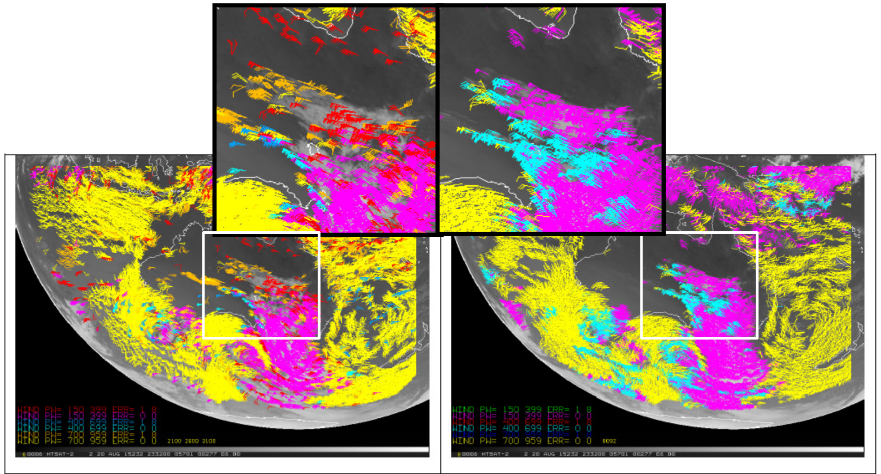
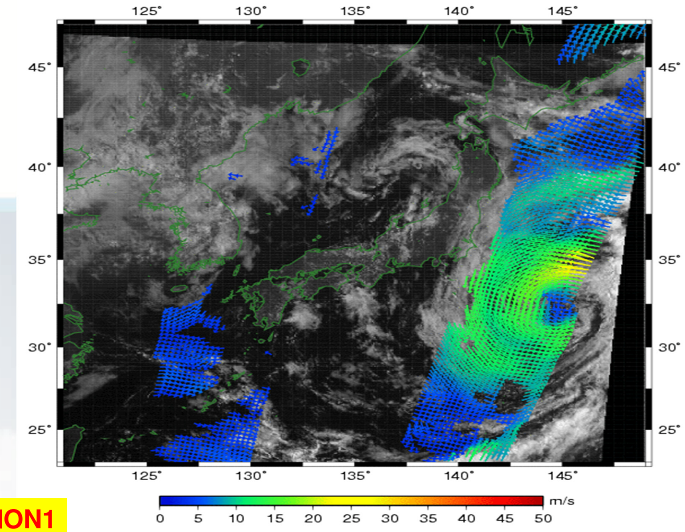


Fig. 7 Himawari-7 AMVs tracked using the IR and VIS channels at 0000 UTC 20 August 2015 from the operational system	Fig. 8 Himawari-8 AMVs tracked using the IR (11 μm) channel at 0000 UTC 20 August 2015 using the next generation operational AMV system

images sourced from Operational Generation and Assimilation of Himawari-8 Atmospheric Motion Vectors Le Marshall et al. Proceedings for the 13th International Winds Workshop 27 June - 1 July 2016, Monterey, California, USA

To validate the quality of Rapid-Scan AMVs, we had compared AMVs from MTSAT-1R visible channel and ASCAT winds in typhoon vicinity (up to 1000 km from TC center)



ANIMATION1

From the presentation "Sea Surface Wind Estimation Using Rapid Scan AMV's" (M. Hayashi,)
Advanced Forecaster Course (Science Week) presentation, BMTC 2013

Derivation of Now Casting AMVs from MTSAT-1R Rapid-Scan observation Comparison with ASCAT in the case of typhoon

REFERENCE

(background)
Rapid-Scan AMVs are considered to be useful tools for the typhoon nowcasting for extracting low-level cloud winds in the data space area of offshore

Comparison of Rapid Scan AMVs (visible) with ASCAT in the case of typhoon Ma-on in 2011 as a trial

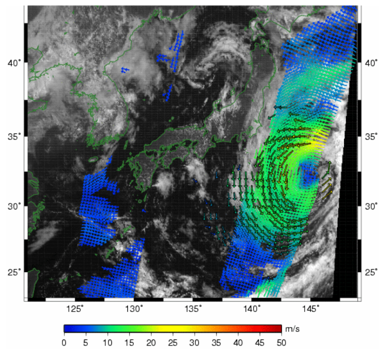
Collocation condition
- ✓± 1 hour
- ✓± 0.2 deg. (Nearest Neighbor)
- ✓ ≤ 1000 km from JMA's TC best track

Statistics period
- ✓ 17th to 23rd of July 2011

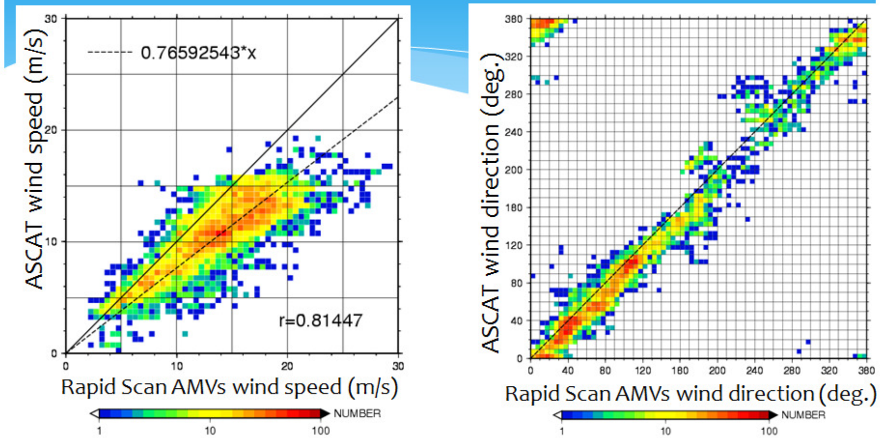
Quality control
- ✓QI > 0.8 (AMV)
- ✓Rejecting land, ice and rain flag

etc. **(Hayashi and Shimoji, 2012)**

From the presentation "Sea Surface Wind Estimation Using Rapid Scan AMV's" (M. Hayashi,) Advanced Forecaster Course (Science Week) presentation, BMTC 2013



Rapid-Scan AMV vs. ASCAT winds



Period: 2011 – 2012 (case of MA-ON is not included)

Rapid-Scan AMVs and ASCAT winds shows good correlation in typhoon vicinity

From the presentation "Sea Surface Wind Estimation Using Rapid Scan AMV's" (M. Hayashi,)
Advanced Forecaster Course (Science Week) presentation, BMTC 2013

Summary

- Explained the concept and applications of Atmospheric Motion Vectors (AMV) / Cloud Drift Winds
- Gave a brief overview of the processing of AMV's
- Highlighted sources of error in the data and ranking of Atmospheric Motion Vectors in Meteorological Analysis.
- CIMSS AMV products explained, with an operational example
- Future developments – Himawari 8/9 10 minute data and AMV's, comparison with ASCAT data (material from presentation by M. Hayashi, JMA/MSC). Unifying Sessions 3 and 4.