Himawari-8 Atmospheric Motion Vectors – Operational Generation and Assimilation

John Le Marshall[1], David Howard[1], Yi Xiao[1], Jamie Daniels[2], Steve Wanzong[3], Jim Jung [3], Wayne Bresky[4], Andrew Bailey[3], Chris Tingwell[1], Tan Le[1] and Denis Margetic[1]

[1] Bureau of Meteorology, Melbourne, Australia,
[2] NOAA/NESDIS, Maryland, USA,
[3] UW/CIMSS, Madison, USA,
[4] IMSG,Inc., Rockville, USA

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In October 2014 the Japanese Meteorological Agency (JMA) launched the new generation geostationary satellite Himawari-8. This satellite provides ten minute imagery in sixteen wavebands over the Asian and Australasian region. The imagery has been navigated, calibrated and subsequently used in the Bureau of Meteorology (BoM) to generate Atmospheric Motion Vectors (AMVs) over the full earth disk viewed from the satellite every ten minutes. Each vector has been error characterised and assigned an expected error. In preparation for the operational assimilation of the ten minute data, these high temporal and spatial resolution data were used with the BoM operational database to provide forecasts from the next generation operational forecast model ACCESS APS2 using 4D Var. Results from these tests indicate these locally generated Himawari-8 ten minute AMVs are of high density and quality and have the potential to improve numerical weather prediction (NWP) model initialisation and forecasts. The forecasts undertaken include cases associated with extreme weather. The results also provided the appropriate times, data selection and application methods for the effective use of these high temporal resolution data. As a result of these studies these wind data were approved for inclusion in the BoMs operational database and are used in operational forecasting.

1 Background

Atmospheric motion vectors have been generated in the Australian region for operational use from 1991 (Le Marshall et al. 1992). In the early nineteen nineties winds were generated from images separated either by one hour or by 30 minutes (around 00 UTC, 06 UTC, 12 UTC and 18 UTC). These hourly and half hourly winds have been demonstrated to have a beneficial effect on the operational Australian numerical analysis and forecast system (for example Le Marshall et al. 1992, 1993, 1994). The operational processing and use of hourly AMVs was first introduced into the Australian operational regional forecast system in the mid 1990's (Le Marshall et al. 1996) using intermittent data assimilation. It is of note such hourly winds have only been introduced into the operational database of other numerical forecast centres (e.g. ECMWF) in this decade. The significant benefit of hourly data to current operational numerical weather prediction using four-dimensional variational assimilation (4DVar) was recently documented in Le Marshall et al. (2013), where noteworthy benefits were recorded. In addition, the benefit of hourly AMVs to tropical cyclone forecasts is well established. It was first demonstrated in Le Marshall et al. (1996a) and later in Le Marshall et al. (1998, 1999) and Leslie et al. (1998).

Corresponding author: John Le Marshall, Bureau of Meteorology, GPO Box 1289, Melbourne, Australia 3001
Email: j.lemarshall@bom.gov.au

Here, we provide results from the work directed towards operationally deriving AMVs from ten-minute Himawari imagery and subsequently assimilating them into the Bureau of Meteorology's next generation operational regional forecast system. The Bureau is currently updating its operational numerical weather prediction (NWP) suite and needs to further develop its capability using ten minute AMVs. As part of the preparation for this upgrade and in particular for the operational assimilation of ten minute data from the full disk footprint of Himawari-8 some initial testing using ten minute wind data was completed using Himawari-6 observations. High temporal (ten minute) and spatial resolution wind data were generated over and around Australia from JMA rapid scan observations during the High Ice Water Content (HIWC) Study (see for example Le Marshall et al., 2016). These were combined with the Bureau's operational database to provide forecasts using the next generation operational regional forecast model ACCESS APS2. This model was used during the introduction of operational Himawari-8 data. This work is summarised below. The work has now been extended using Himawari-8 high temporal (ten minute) and spatial resolution (2km in the IR) data. The wind generation methods, error characterisation, data quality and data impact are described below. The reason for the extension of this work to Himawari-8 at the BoM is that this work provides higher density and more accurately error characterised AMV data in more channels than available from JMA over the Australian region and this has been shown to lead to improved operational forecasts in the recent past (e.g. Le Marshall et al., 2013).

2 The Generation of ten Minute Atmospheric Motion Vectors

2.1 MTSAT-1R (Himawari-6)

In the Bureau of Meteorology, the general method used to estimate AMVs from MTSAT-1R (Himawari-6) and MTSAT-2 (Himawari-7) high-rate information transmission (HRIT) data is described in Le Marshall et al. (2008, 2011). Three sequential images from MTSAT-1R (Himawari-6) and MTSAT-2 (Himawari-7) were re-navigated using land features to ensure that there is consistency between images used for estimating cloud displacement. In this system, target selection used orthogonal brightness temperature gradients and targets with suitable gradient features are subjected to spatial coherence analysis (Coakley and Bretherton 1982) using local mean and standard deviation of the IR window radiance field to determine if there is a single cloud layer. Tracking uses lagged correlation. Height assignment methods are similar to those employed in Le Marshall et al. (2008). The error characteristics of these vectors are determined and each vector is associated with error indicators such as the expected error (EE; Le Marshall et al. 2004), the quality indicator (QI; Holmlund 1998), as well as with a correlated error and the length scale. Figure 1 is a sample of local Himawari-6 infrared (IR) image-based AMVs generated from JMA special test observation ten minute imagery between 0010 UTC and 0050 UTC 28 January 2014 displayed over NE Australia.

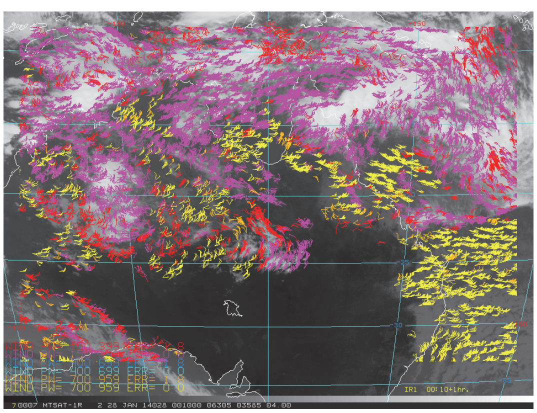

Fig. 1 A selection of Himawari-6 Atmospheric Motion Vectors over Eastern Australia generated from ten min imagery between 0010 UTC and 0050 UTC 28 January 2014.

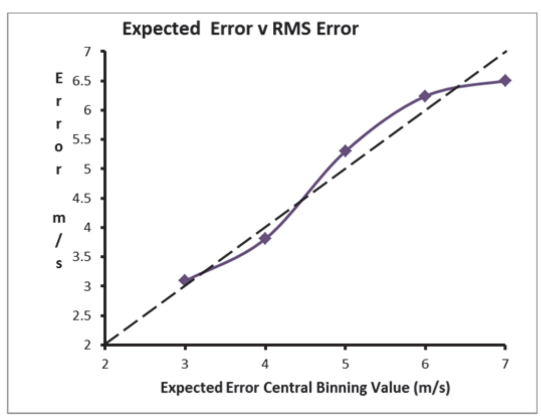

Fig. 2. Measured error (m/ s) vs Expected Error (m/s) for low-level Himawari-7 IR winds (1 January–31 January 2014).

In the then current operational environment, there was insufficient imagery for AMVs to be generated during this period 0010UTC-0050UTC 28 January 2014. In future however ten minute imagery will be available operationally, so this Field Experiment data provided an opportunity to prepare for this new improved data base. The study period used was selected because it represented challenging cloud fields associated with AMV generation and also a challenging meteorological situation.

In this study accurate error characterization and thorough quality control ensure that AMVs have a beneficial impact on NWP (Le Marshall et al. 2004). The error characterization employed here has used the Bureau's initial error flagging procedure (ERR), which involved a number of basic checks. These include the departure from a first guess provided by the Bureau's operational NWP model, a vector pair acceleration check, and a tracer constancy check. The QI (Holmlund 1998) and the Expected Error (EE) (Le Marshall et al. 2004) were also used.

The AMVs were systematically thinned using these error indicators to reduce the volume of data while maintaining good data coverage with average separations consistent with the length scale of the correlated error. The thinning methodology has also ensured that the average errors are generally no larger than the analysis background error field of the forecast model as measured at radiosonde sites. The approach is detailed in Le Marshall et al. (2004).

The total rms (root mean square) error component of the EE was used here. A typical comparison of the Expected Error (EE) with the measured error from radiosonde observations for low-level MTSAT-1R and -2 (Himawari-6 and -7) IR winds is seen in Fig. 2. The quality of data from the operational MTSAT-1R and -2 (Himawari-6 and 7) processing system can be close to that from Himawari-8 but data from the latter is much more plentiful.

2.2 Himawari-8

With the launch of Himawari-8 the image data used for AMV generation has a higher spatial, temporal and spectral resolution. The spatial, temporal and spectral characteristics of the Himawari-8 data are summarised in Table 1. The spatial resolution of Himawari-8 is four times that of MTSAT-1R and -2 (Himawari-6 and -7), the temporal resolution in the southern hemisphere has moved from one hour to ten minutes and the number of channels has increased from five to sixteen. Key channels for height assignment are 10, 13 14, 15 16 and for AMV generation are channels 2, 7, 8, 9, 10 and 14. Channel 14 is used for tracking here.

Channel	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Resolution km at SSP	1	1	0.5	1	2	2	2	2	2	2	2	2	2	2	2	2
Central Wavelength µm	.47	.51	.64	.86	1.6	2.3	3.9	6.2	6.9	7.3	8.6	9.6	10.4	11.2	12.4	13.3
Bandwidth	50 nm	20 nm	30 nm	20 nm	20 nm	20 nm	.22 µm	.37 µm	.12 µm	.17 µm	.32 µm	.18 µm	.30 µm	.20 µm	.30 µm	.20 µm

Table 1 Summary of the spatial and spectral characteristics of Himawari-8 ten minute imagery.

In the BoM, the method used to estimate AMVs from Himawari-8 HSF (Himawari Standard Format) data (and in research mode MTSAT -2 (Himawari-7) HRIT [High-rate Information Transmission] data) employs GEOCAT (Geostationary Cloud Algorithm Testbed - Geocat Manual, 2016) software, modified in a number of areas, in its initial processing. GEOCAT was employed because of efficiencies gained in the BoM using a common satellite data initial processor for many operational applications (for example, volcanic ash detection and sea surface temperature calculation). The AMV estimation methodology is similar to that described in the GOES-R Advanced Baseline Imager (ABI) Algorithm Theoretical Basis Document for Derived Motion Winds (Daniels 2010) with changes and additions which include elements of the BoM current operational system, particularly in the areas of error characterization and quality control. Three sequential images from Himawari-8 are used for estimating cloud displacement. In this system, target selection uses orthogonal brightness temperature gradients and targets are tracked employing nested tracking (Daniels, 2010, Bresky et al. 2012) which captures the dominant motion, estimated using a two-dimensional clustering algorithm, which allows wind estimation using local displacements of points belonging to the largest cluster in a target scene. Height assignment methods employed in the GEOCAT algorithms are similar to those described in GOES-R Advanced Baseline Imager (ABI) Algorithm Theoretical Basis Document for Cloud Height (Heidinger 2010). The error characteristics of these vectors are determined and each vector is associated with error indicators such as the expected error (EE; Le Marshall et al. 2004), the quality indicator (QI; Holmlund 1998), as well as with a correlated error and the length scale of the correlated error.

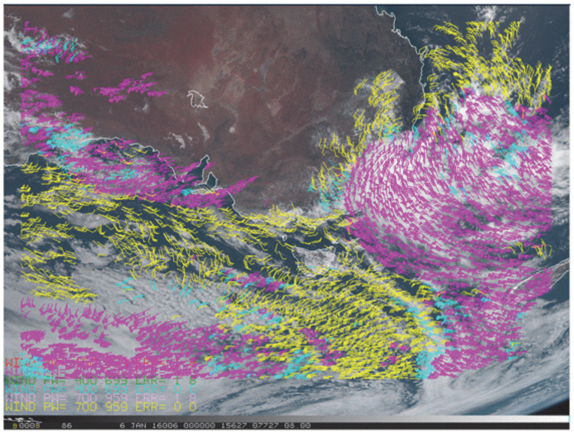

Fig.3 Himawari-8 AMVs tracked using IR (11 µm) channel 14 tracers at 00 UTC 16 January 2016 using the new generation operational system

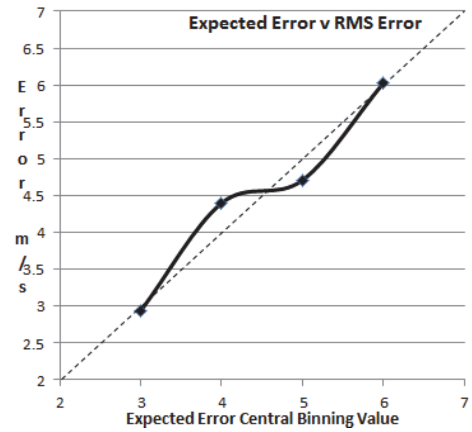

Fig. 4. Measured error (m/ s) vs Expected Error (m/s) for low-level Himawari-8 IR winds (31 August –29 September 2015)

Figure 3 is a sample of local Himawari-8 infrared (IR channel 14) image based ten minute AMVs generated from ten minute imagery around 0000 UTC on 16 January 2016 displayed over SE Australia. Water vapour and visible band winds are also generated from the Himawari-8 data stream in near real-time, error characterised and validated. They are currently not used in operational NWP however as ten minute infrared AMV data from Himawari-8 were found initially to fill initial available operational processing resources. These data are now being prepared for operational implementation.

As noted previously accurate error characterization and thorough quality control ensure that AMVs have a beneficial impact on NWP (Le Marshall et al. 2004). The error characterization employed here has again used the Bureau's initial error

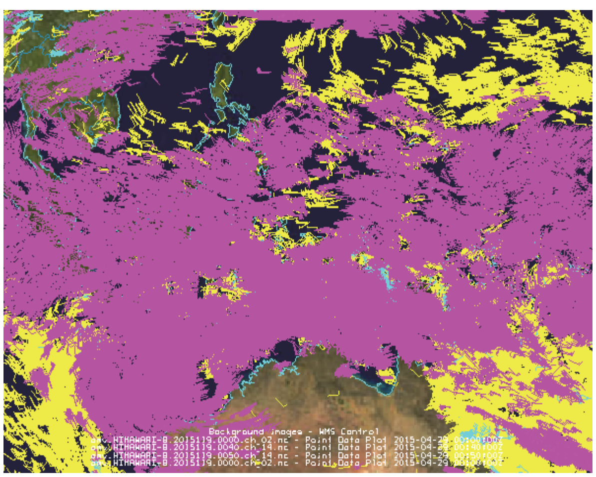

Fig. 5 Coverage of AMVs from Himawari-8 in the tropics to the north of Australia around 0000 UTC 29 April 2015

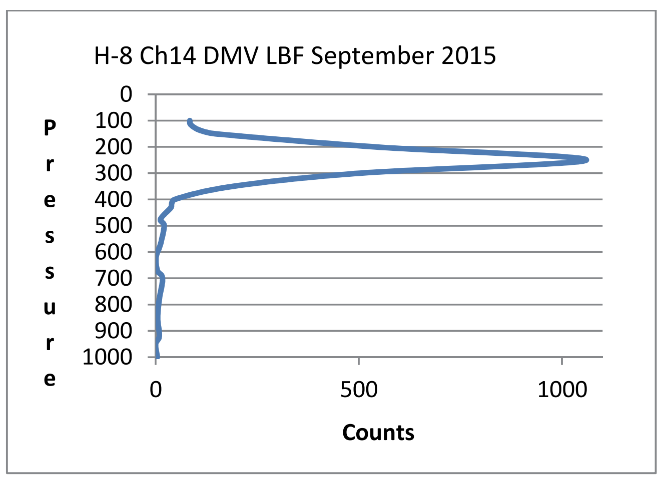

Fig. 6 Himawari-8 level of best fit height(hPa) assignment statistics for CH.14 AMVs for September 2015 (see text)

flagging procedure (ERR), which involved a number of basic checks. These include the departure from a first guess provided by the Bureau's operational NWP model, a vector pair acceleration check (checking the estimated wind speed calculated from adjacent image pairs does not change unrealistically), a tracer consistency check (checking the tracer does not change character too much between adjacent images), the QI and the Expected Error (EE).

The AMVs are systematically thinned using these error indicators to reduce the volume of data while maintaining good data coverage with average separations consistent with the length scale of the correlated error. The thinning methodology has also ensured that the average errors are generally no larger than the analysis background error field of the forecast model as measured at radiosonde sites. The total rms error component of the EE was again used here. A typical comparison of the Expected Error (EE) with the measured error from radiosonde observations for low-level Himawari-8 IR (channel 14) winds is seen in Figure 4.

The dense coverage of Himawari-8 AMVs over the tropics to the north of Australia around 0000 UTC 29 April 2015 is shown in Figure 5. In these images, low level vectors are coloured yellow (700-950 hPa), middle level cyan (400-699 hPa) and upper level (150-399 hPa) vectors magenta, with higher accuracy vectors being displayed. An indication of the accuracy of height assignment in the local Himawari-8 system AMV system is also shown in Figure 6. Here for Channel 14 Himawari-8 AMVs which have been height assigned between 230hPa and 270hPa, the number of winds (AMVs) in a pressure range (~50hPa) are plotted against the level of best fit (the level at which the AMV velocity best fits the radiosonde wind trace) for September 2015. Radiosonde/AMV separation is ≤ 50km. Overall the AMVs are associated with a height assignment accuracy which renders them suitable for NWP.

An indication of the distribution of the wind data in three dimensions can be gained from Figures 7-10. This displays thinned AMV data where upper level AMVs are coloured magenta, middle level vectors cyan and lower level vectors yellow. It is important to note that adjacent ten minute AMV data sets can provide different and at the same time important observations to the analysis system, an indication of the importance of continuous data sets for analysis. These continuous data can also help in quality control.

Verification statistics for August – September 2015 are also shown in Table 2 for Himawari-8 before final thinning and selection prior to being passed to the NWP system. In the table MMVD is the mean magnitude of vector difference, SDVD is the standard deviation of the vector difference and RMSVD is the root mean square vector difference. The Bias is the mean difference between radiosonde and AMV wind speed. In these cases the Standard Deviation SDVD is roughly half or more of the MMVD. In the table, <50km (<150km) means the statistics are for radiosonde and AMV separations of less than 50km (150km) respectively.

Although the initial wind error estimates for the Himawari-8 are near to those from MTSAT-2 (Himawari-7), it needs be noted that, due to the vast increase in wind data numbers in the case of Himawari-8, the Himawari-8 wind observations can be thinned using for example the Expected Error associated with each vector and other error characterisation data, to produce a far denser and more accurate wind field than previously available. This process provides fields suitable for assimilation in NWP, with errors being similar to or less than the errors of the NWP background field at radiosonde sites. It is anticipated that use of these data in operational NWP has the potential to provide improved analysis, reanalysis and numerical prediction. Studies examining full use of the data to this end are expanding as further denser data sets become available. Early work in this area has already been completed using ten minute Himawari-6 special observations collected in 2014 and additional advanced sounder data in the Bureau of Meteorology's next-generation operational forecast model APS-2. Here we also report on a study using locally generated ten minute Himawari-8 AMV data in the BoM's next generation operational forecast model.

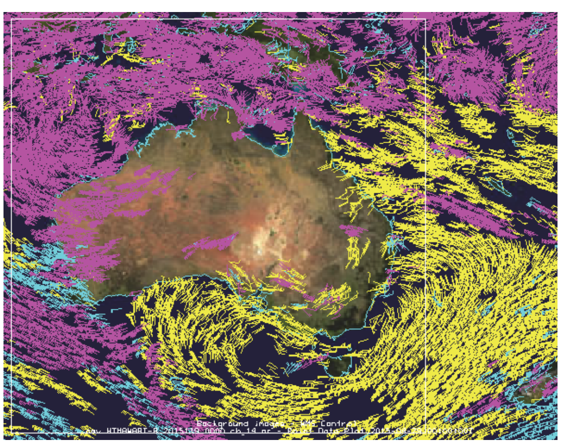

Fig.7 AMVs generated around Australia 0000UTC 29 April 2015 – Note box around Australia.

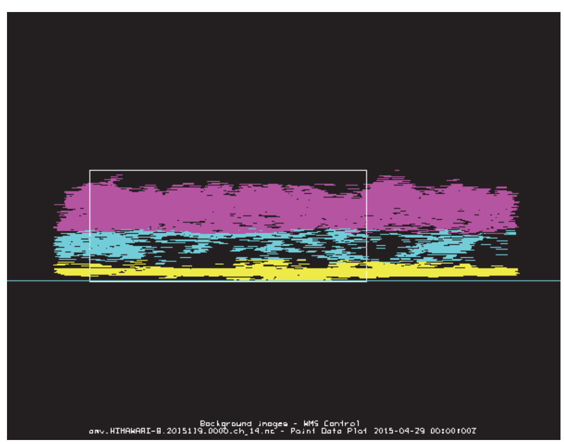

Fig.8 AMVs generated around Australia 0000UTC 29 April 2015 – View from the south.

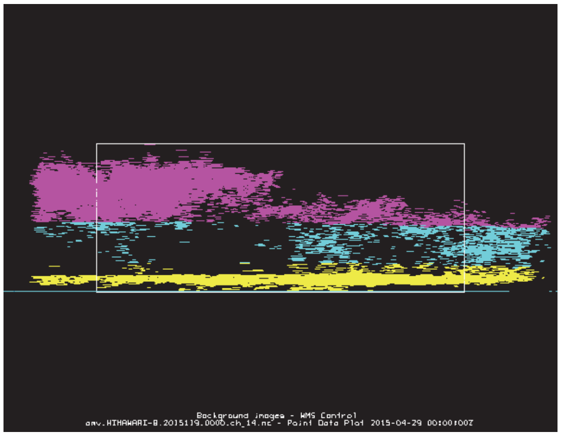

Fig.9AMVs generated around Australia 0000UTC 29 April 2015 – View from the west.

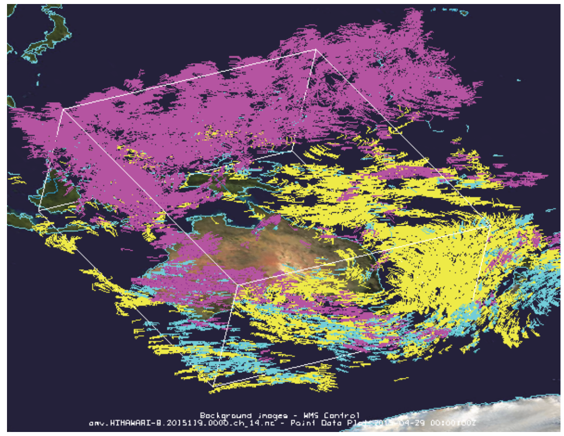

Fig.10AMVs generated around Australia 0000UTC 29 April 2015 – Slant view from southwest.

AMV Type	Category	m/s	NOBS
Low	MMVD	3.00	4911
Sep.	RMSVD	3.61	
<150 km	SDVD	2.01	
	BIAS	0.71	
Low	MMVD	2.36	473
Sep.	RMSVD	2.75	
<50 km	SDVD	1.41	
	BIAS	0.29	
Middle	MMVD	3.16	1202
Sep.	RMSVD	3.78	
<150 km	SDVD	2.07	
	BIAS	-0.61	
High	MMVD	4.11	15688
Sep.	RMSVD	4.88	
<150 km	SDVD	2.63	
	BIAS	-0.64	

Table 2 Verification Table for Himawari-8 IR (channel 14) AMVs compared to radiosondes 18 August – 18 September 2015

An insight into the relative data coverage of the current operational MTSAT-2 (Himawari-7) and the next generation operational Himawari-8 AMV systems is seen below. Local MTSAT-2 (Himawari-7) 11 µm IR and Visible feature tracked winds at 0000 UTC 20 August 2015 are shown in Figure 11 and local 11 µm IR feature tracked winds for Himawari-8 over the same MTSAT-2 (Himawari-7) image are shown in Figure 12. The increasing data density in the case of Himawari-8 due to a small reduction in times between the images used in AMV production and also due to increased spatial resolution is clearly apparent.

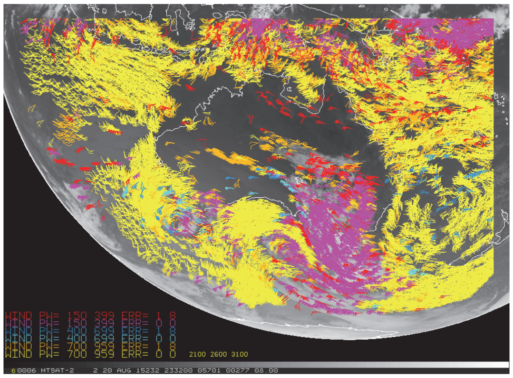

Fig. 11 MTSAT-2 (Himawari-7) AMVs tracked using the IR and VIS channels at 0000 UTC 20 August 2015 from the operational system

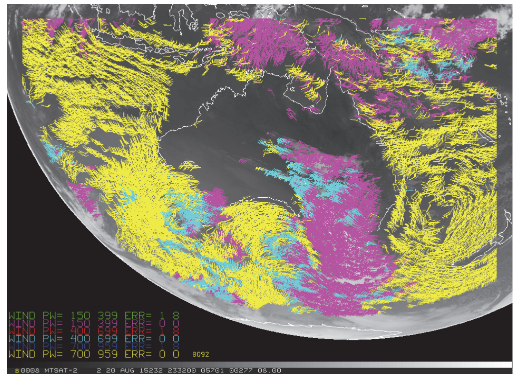

Fig. 12 Himawari-8 AMVs tracked using the IR (11 µm) channel at 0000 UTC 20 August 2015 using the next generation operational AMV system

Verification data for real time vectors from MTSAT-2 (Himawari-7) and Himawari-8 are shown below.

AMV Type	Category	m/s	NOBS
Low Sep. <50 km	MMVD	2.4	358
	RMSVD	2.8	
	SDVD	1.4	
	BIAS	0.3	
High Sep. <50 km	MMVD	3.3	1460
	RMSVD	3.9	
	SDVD	2.1	
	BIAS	-0.6	

Table 3 Verification Table for Himawari-8 IR (channel 14) AMVs compared to radiosondes 1 March – 31 March 2016

AMV Type	Category	m/s	NOBS
Low Sep. <50 km	MMVD	2.5	57
	RMSVD	2.9	
	SDVD	1.5	
	BIAS	-0.6	
High Sep. <50 km	MMVD	3.5	291
	RMSVD	3.9	
	SDVD	1.7	
	BIAS	-1.4	

Table 4 Verification Table for Himawari-7 IR (channel 2) AMVs compared to radiosondes 1 March – 20 March 2016

As noted above the initial wind error estimates from Himawari-8 are near to those for Himawari-7. Due to the vast increase in wind data in the case of Himawari-8, however the Himawari-8 wind observations can be thinned to produce more accurate wind fields which are still far denser than those previously available. Biases in Table 3 generated through nested-tracking are small, but changed image resolution and the limited sample preclude at this stage a more definitive statement about nested tracking and bias estimation.

3 The Assimilation of the ten Minute Atmospheric Motion Vectors

Ten minute wind data have been generated from MTSat-1R data using the methods described above and subsequently converted into BUFR (Binary Universal Form for the Representation of meteorological data) format and passed through the Bureau's test next-generation operational regional forecast model. This model was the operational regional forecast model when Himawari-8 data became available during last half of 2015. The number of winds produced from the Rapid Scan MTSat-1R images in the test area was dependent on the synoptic situation but was typically over 4,000 infrared (IR) and 19,000 visible (VIS) higher quality vectors for each ten minutes within the Australian region test area. These winds have been combined with the local and also JMA MTSat-2 fifteen, thirty and sixty minute wind data and have been subsequently assimilated in hourly blocks using 4DVar into the new regional forecast system. The hourly blocks of data were developed to have good spatial and temporal coverage centred around the box middle time, with data density consistent with the analysis data selection methodology.

3.1 First Results-MTSAT-1R

The merged and quality controlled wind data sets from MTSAT-1R and MTSAT-2 (including ten minute wind coverage over the Australian region between 0º and 42º S and 110º and 160º E) provided much improved coverage over the region. They were assimilated as hourly blocks of data in the next generation regional forecast system, ACCESS-R APS2 using 4DVar (see, for example, Le Marshall et al., 2013). The resolution of the new regional model is 12 km with 70 levels in the vertical. The high resolution data was assimilated between 1200 UTC 26 January and 1200 UTC 27 January 2014 and used to provide a 3-day forecast for 1200 UTC 30 January 2014. Bureau analyses for the Australian Region at these times are given in Figs. 13 and 14, respectively. The three-day forecast from the Bureau's operational forecast system in 2014 and the forecast from the Bureau's next generation forecast system including the ten minute winds are seen in Figures 15 and 16 respectively.

It can be seen that the new forecast system with the inclusion of ten minute wind data and data from the new enhanced forecast system, including a more expansive satellite data base has provided a significantly improved forecast. The genesis and final positioning of (Category two) Tropical Cyclone Dylan in relation to the coastline is greatly improved. What was a challenging operational forecast which proved difficult for some operational centres has in this case become a very good forecast of genesis and a very good three day forecast. It should be noted, this improvement has resulted from an improved wind field, resulting from the use of quality controlled ten minute winds, an improved mass field (additional sounding data – for example, Cross-track Interferometer Sounder [CrIS] data) and the next generation operational forecast model APS2. This first test of the next generation operational assimilation system with ten-minute winds, was an opportunity to optimise quality control and data selection for the new wind data and to assure effective integration of the data into the new operational data base.

3.2 Results - Himawari-8

Himawari-8 winds have been produced in the Bureau of Meteorology from July 2015 and are currently being generated every ten minutes in Real Time from image data collected via FTP from JMA. This FTP data is now the operational data source. The image and wind quality is continuously monitored. The locally-generated Himawari-8 ten minute wind data has also been used in data transmission and assimilation tests.

BUFR output containing AMV information from the Himawari-8 processing system is designed to be used by the current and future operational systems. Verification data for real time vectors from Himawari-7 and Himawari-8 have been shown in Tables 3 and 4 for March 2016. The quality and number of Himawari-8 AMVs exceeds that of operational MTSAT-2 (Himawari-7) AMVs which were generated and used operationally in the Bureau of Meteorology over previous years.

Locally produced Himawari-8 AMVs, generated using operational code on the BoM new virtual machines have been used in an assimilation test for a period during March 2016. The test ran from 4 March to 26 March 2016 and analysed the effect of adding local Himawari-8 AMVs to the operational data base then containing JMA MTSat-2 (Himawari-7) AMVs, Local BoM MTSat-2 (Himawari-7) AMVs and JMA Himawari-8 AMVs.

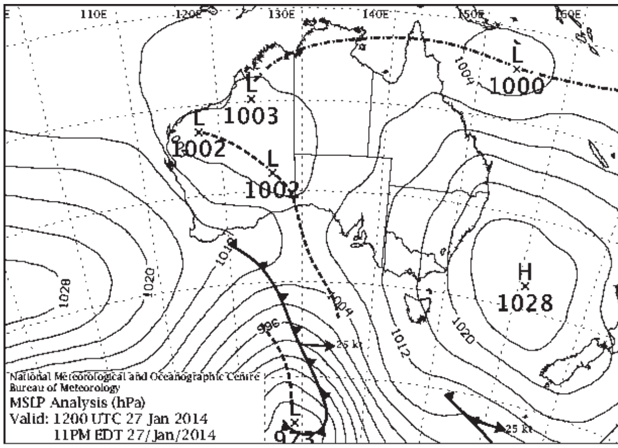

Fig. 13 Bureau of Meteorology Analysis for 12 UTC on 27 January 2014.

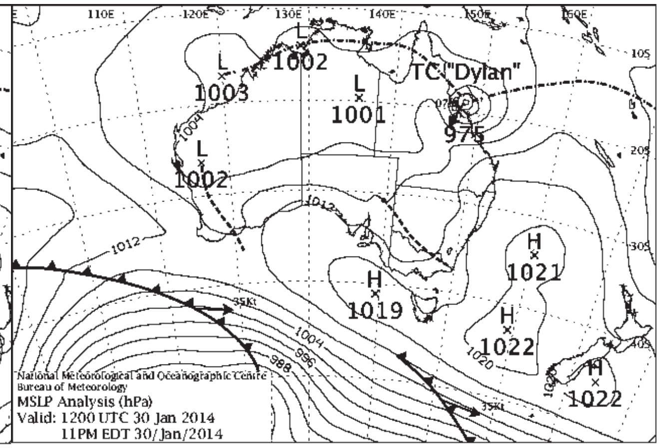

Fig. 14.Bureau of Meteorology Analysis for 12 UTC on 30 January 2014

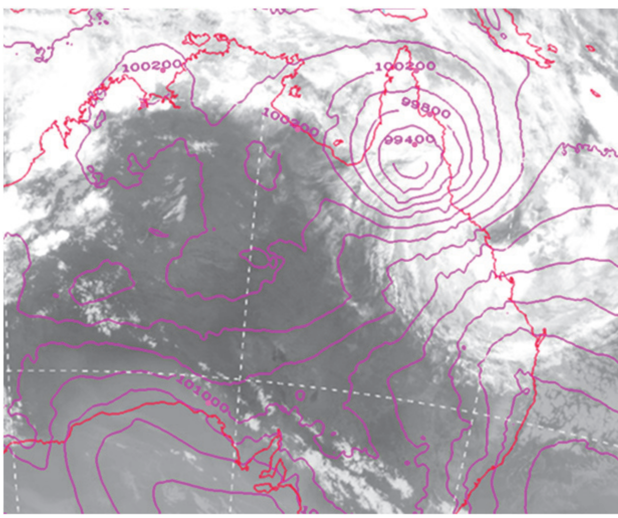

Fig.15 The Bureau of Meteorology operational three-day MSLP (hPa) forecast valid 1200 UTC 30 January 2014, shown remapped over an MTSat infrared image, valid at the same time.

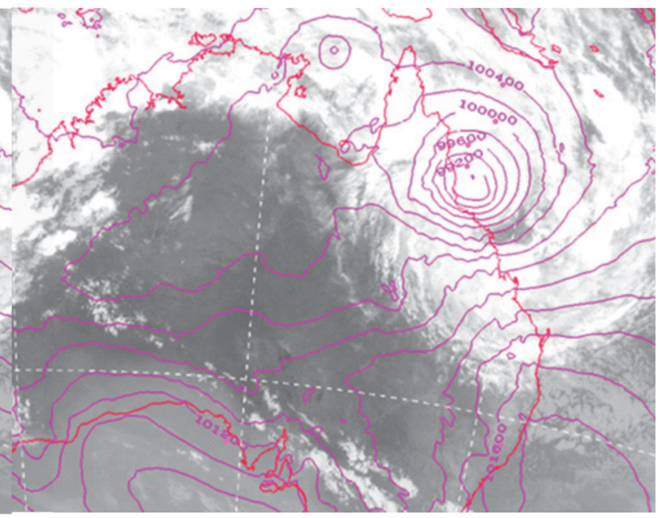

Fig.16 The Bureau of Meteorology three-day MSLP (hPa) forecast valid, 1200 UTC 30 January 2014 using the next generation operational regional forecasting system with ten, fifteen and sixty minute AMV data from MTSat-1R and MTSat-2. The forecast remapped over the 1200 UTC MTSat image.

The test system contained JMA MTSat-2 (Himawari-7) AMVs, Local BoM MTSat-2 (Himawari-7) AMVs, JMA Himawari-8 AMVs and local BoM high resolution Himawari-8 AMVs The test not only involved assimilation but also transfer of the buffer data into the forecast system through the operational CMSS communications system.

The data transfer of this high resolution data was effective and the assimilation results show the successful use of the data by the operational NWP system. Typical impact is seen in Figs. 17 and 18. The impact is small but this is not surprising as the operational system at this stage had 3 complete and quite redundant sets of winds covering the same geographical area and the Test system had 4 complete and quite redundant sets of winds covering the same geographical area. After March only two AMV datasets were available as Himawari-7 data were no longer produced, with the satellite going into backup mode.

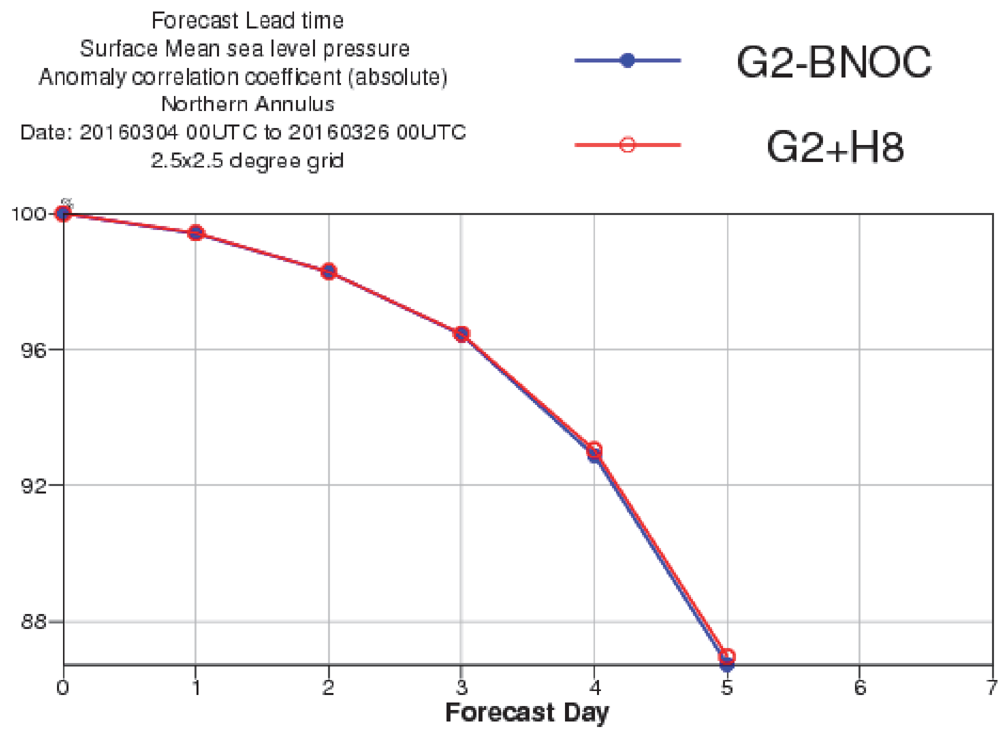

Fig.17 MSLP anomaly correlation coefficients for the Northern Hemisphere Annulus (20N – 60N) for the operational system (blue) and for the operational test system for 4 – 26 March 2016.

It should be noted that the time period of the test involved use of redundant AMV data sets in operations. However, from April 2016 onwards, two data sets are available (JMA and BoM Himawari-8 data sets), providing a resilient database and during summer, for example, only local BoM winds will be available in time for the important 0000 UTC operational analysis.

4 Summary and Conclusions

We have described the generation of ten minute Himawari-6 AMVs over a test area covering the Australian region. It was done using ten minute MTSAT-1R imagery from the test period in January 2014. Tracer selection, height assignment and the quality control of the AMV's has been described. The quality of these data was near to that from the operational Himawari-8 processing system although the operational Himawari-8 system with the advantage of higher spatial and spectral density provides more high quality vectors for selection for assimilation.

In this first test of the future operational assimilation system with ten-minute winds, an initial effort to optimise data selection and gauge the utility of the data in the new operational database has been described. The ten minute data over the test area in the Australian region has been combined with the lower temporal resolution (hourly) data covering the MTSat full disc, present in the operational database. The resultant forecast from the next generation operational regional forecast system shows an improvement over the earlier operational product in this case for a tropical cyclone forecast that was challenging for a number of operational centres. Detailed quantification of the impact of these ten minute data in numerical analysis and prediction will be provided now that ten minute wind data are regularly available over the full disk area viewed by Himawari-8. However, these early results strongly suggested a potential for improvement which may be provided by the new operational forecast system. It is also interesting to note early tests of the science processing system now used with Himawari-8 also provided AMV data of a quality near that described above when being used with MTSAT image data.

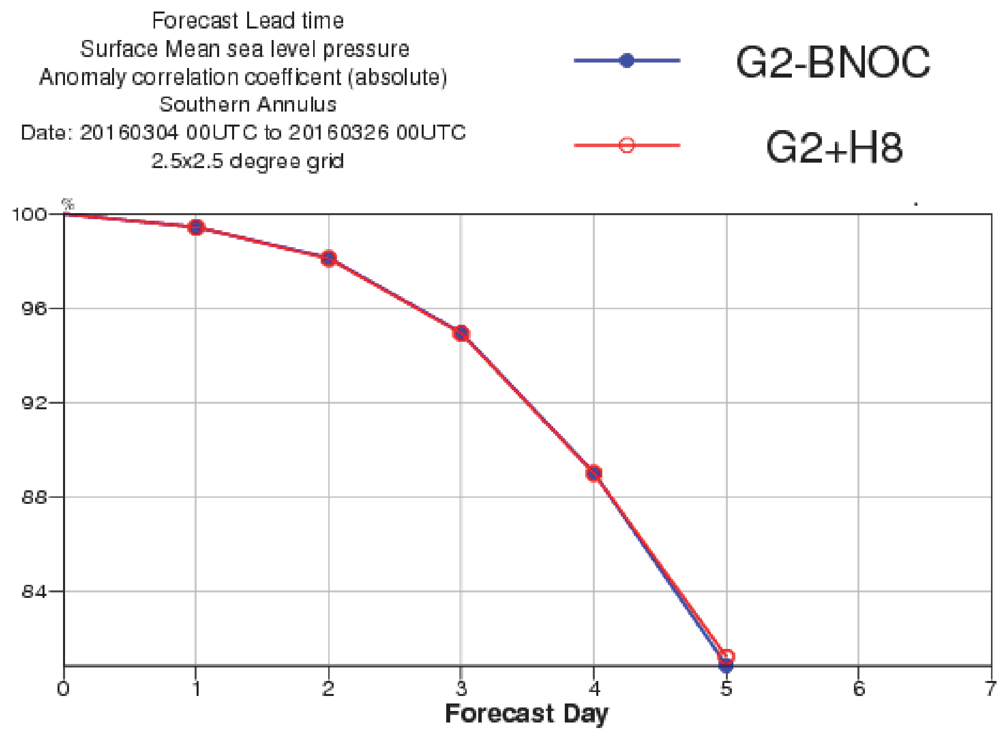

Fig.18 MSLP anomaly correlation coefficients for the Southern hemisphere annulus (20S-60s) for the operational system (blue) and for the operational test system for 4 – 26 March 2016.

In summary, ten-minute winds were continuously generated for the first time in the Australian region and assimilated with 4D Var. This early evidence suggested that ten minute data from MTSat-1R(Himawari-6) provide a much improved spatial and temporal database for operational analysis and forecasting. Early indications suggest the new operational 4DVar system has the potential to extract additional information from this and other components of the improved next generation database with resultant improvement in forecast accuracy.

After the launch of Himawari-8, AMVs were generated at the BoM from July 2015. We have described the generation of ten minute Himawari-8 AMVs over the Australian region and beyond. This was performed using ten minute imagery obtained in close to real time (RT) via FTP from JMA since July 2015. These data provided an improved spatial and temporal resolution database for analysis and forecasting. The quality of these higher spatial, temporal and spectral density data (see Table 3 and Table 4) is of a level which renders them beneficial for NWP. If the data is thinned to equal spatial density, *the quality of the Himawari-8 data exceeds that of the operational MTSAT-2 (Himawari-7) data*. Locally produced Himawari-8 AMVs have also been used in an assimilation test for a period during March 2016 where the effect of adding local Himawari-8 AMVs to the then, quite redundant operational AMV data base (then containing 3 complete different sets of data) was recorded. The test showed successful transfer of data and successful use of the data by the NWP system.

Further quantification of the impact of these data in our current operational prediction system is underway. This includes use of all ten minute data in the prediction of TC activity and severe weather. It also includes use of visible and water vapour band AMVs and further testing of the nested tracking algorithm, error characterisation and other parts of the AMV generation process which are already producing high-quality AMVs suitable for use in operational NWP.

In summary we have noted operational considerations related to the processing of Himawari-8 winds and have summarised the current status of the Himawari-8 wind processing system and the operational assimilation of these data. Overall the data provide an improved data base for operational NWP and are ready for fuller exploitation.

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