Generation and Application of Local High Resolution AMVs for Operational NWP in the Australian Region

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[4] RMIT University, Melbourne, Australia

Overview

- The Importance of EOS in the SH
- Specification of the mass and wind field
- AMVs- MTSat -1R / -2 Himawari – 8/ – 9
- Application of the AMV data
- The Future
- Conclusions

The Importance of EOS (in the SH)

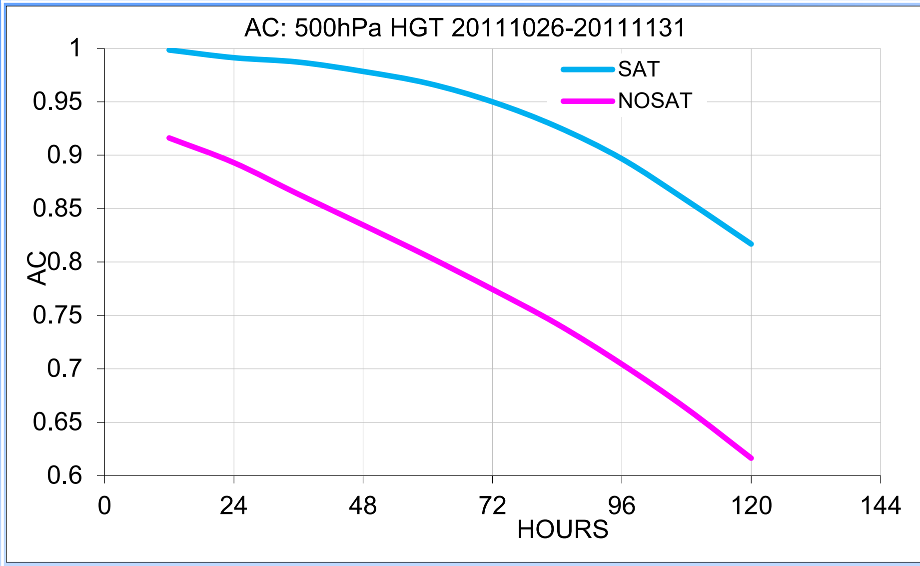
Observing System Experiments (OSEs)

With and Without Satellite Data

- **Systems Examined**
  - ACCESS (APS1) – Operational data base (Australian Op. Sys)
  - 28 October to 30 November 2011

  - GFS (2010) - Operational data base (US Op. Sys)
  - 15 August to 30 September 2010

Earth Observations From Space



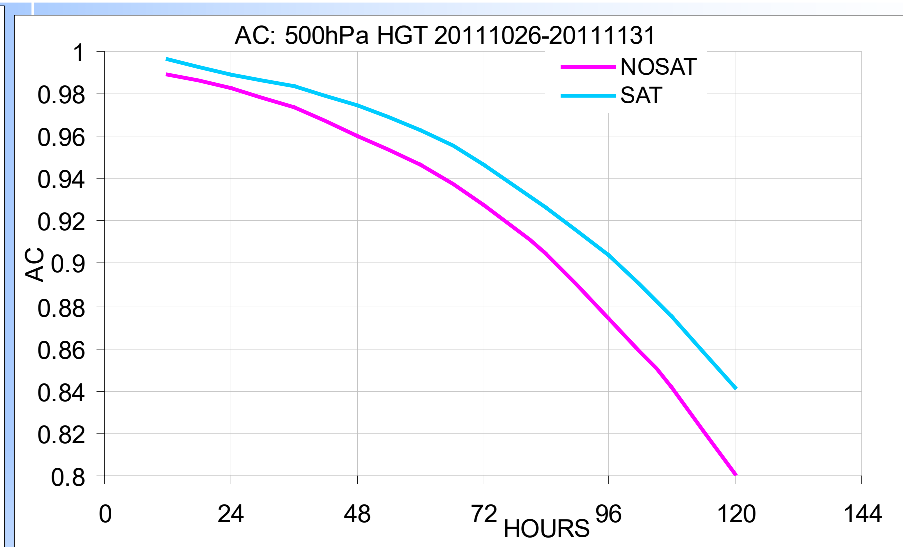
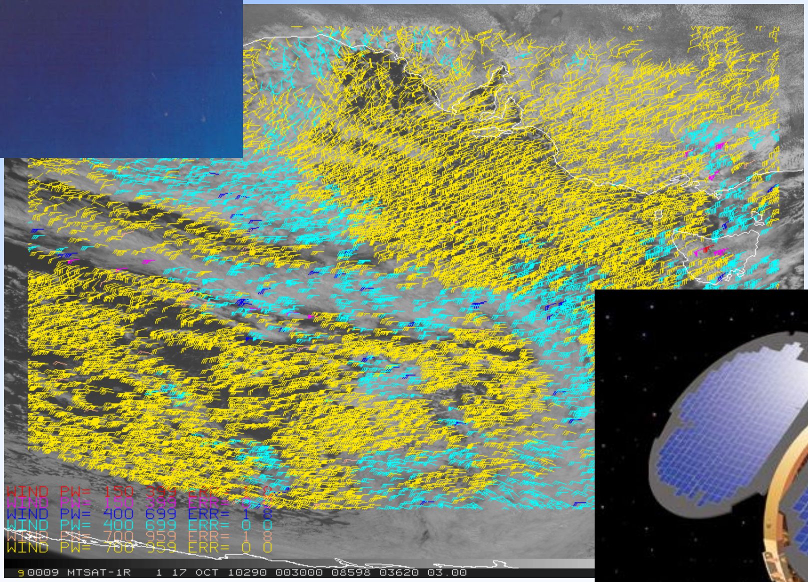


Fig. 8(c). SH 500hPa height anomaly correlation for the control (SAT) and no satellite (NOSAT), 28 October to 30 November 2011 using ACCESS and verifying against the control analysis

Fig. 8(f). NH 500hPa height anomaly correlation for the control (SAT) and no satellite (NOSAT), 28 October to 30 November 2011 using ACCESS and verifying against the control analysis

Specification of the Mass and Wind Field – Impact of Key Data

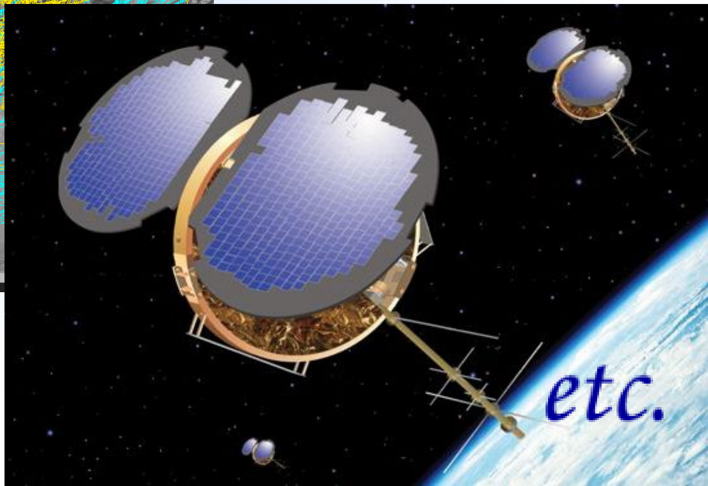
AMVs



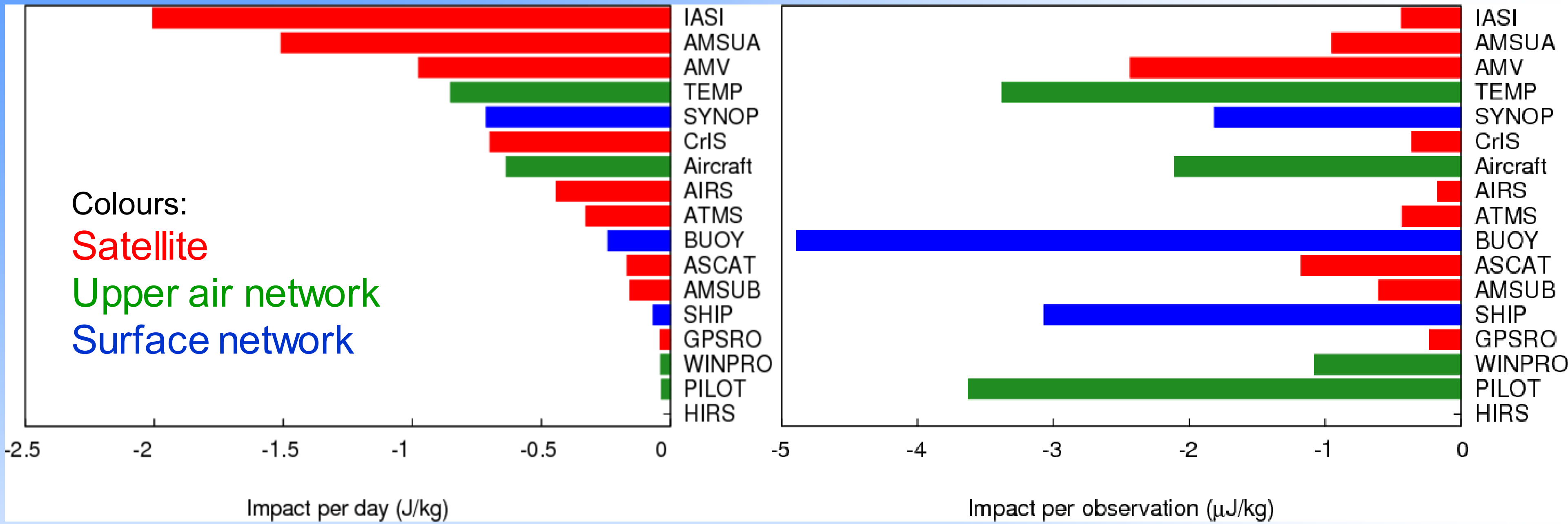
GPS RO

Ultraspectral Advanced Sounders

AIRS
IASI
CrIS



ACCESS APS2: Forecast Sensitivity to Observations



<u>Global 24-hour forecast error reduction from each of the observation types assimilated in ACCESS</u>

- Three months: April, May and June 2016. Himawari-8 AMVs included in full period.
- All types of observations are beneficial, i.e. reduce the forecast error.
- **Total impact (LH panel)** is dominated by satellite instruments (e.g. the **IASI**, **AMSU** and **CrIS** sounding instruments carried on polar orbiters and **AMV**s) - due to large numbers & global coverage.
- Greater **impact *per observation*** **(RH panel)** comes from balloon upper air measurements plus surface measurements from drifting and fixed buoys.

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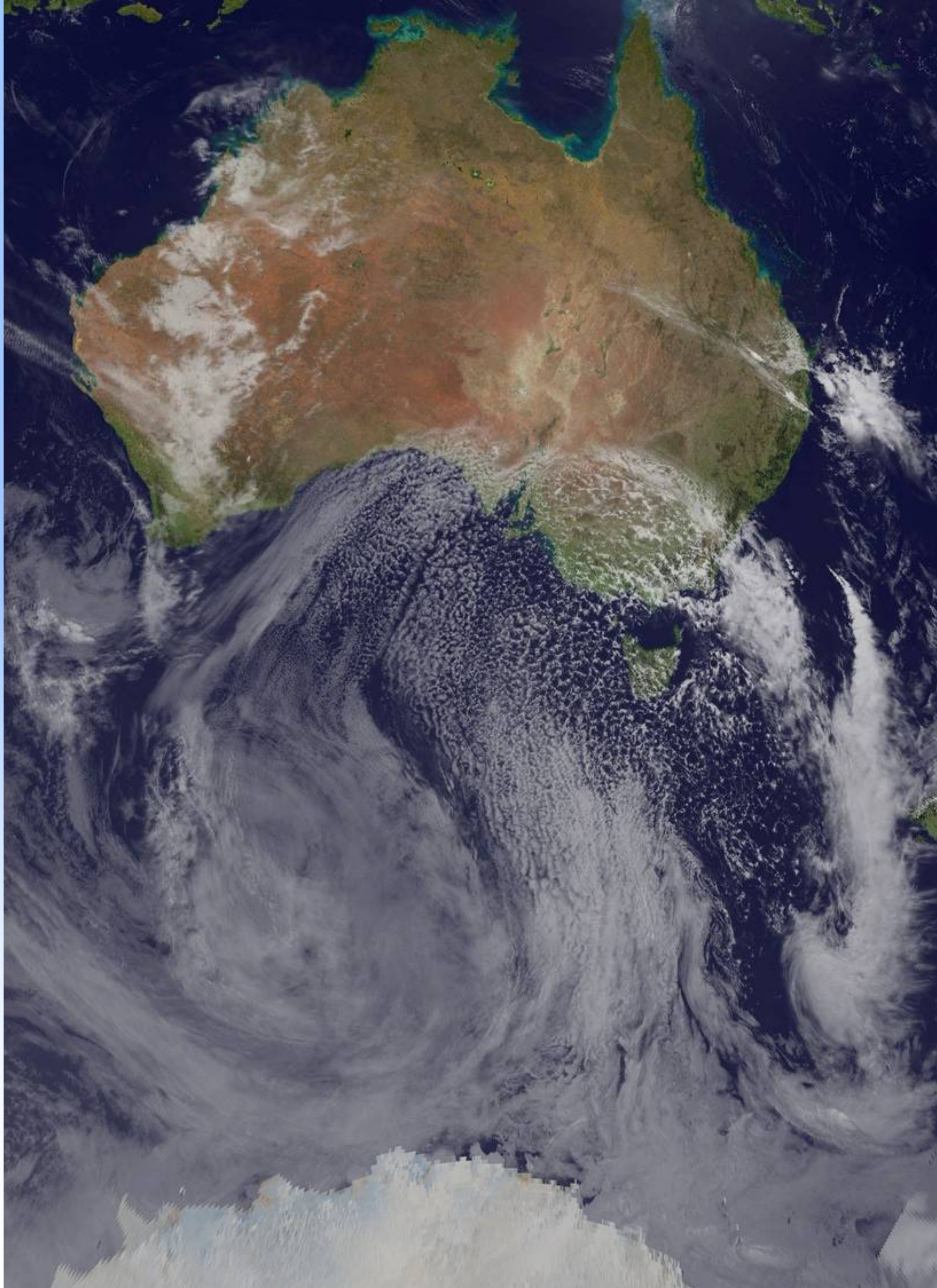
MTSAT-1R and 2 Himawari-8 Himawari-9

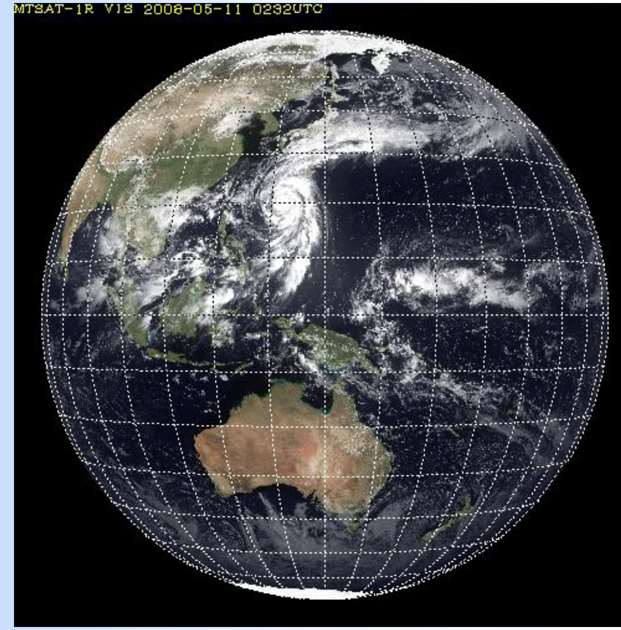
THE GENERATION AND ASSIMILATION OF CONTINUOUS ATMOSPHERIC MOTION VECTORS WITH 4DVAR



Specification of “Himawari-8/9” Imager(AHI)

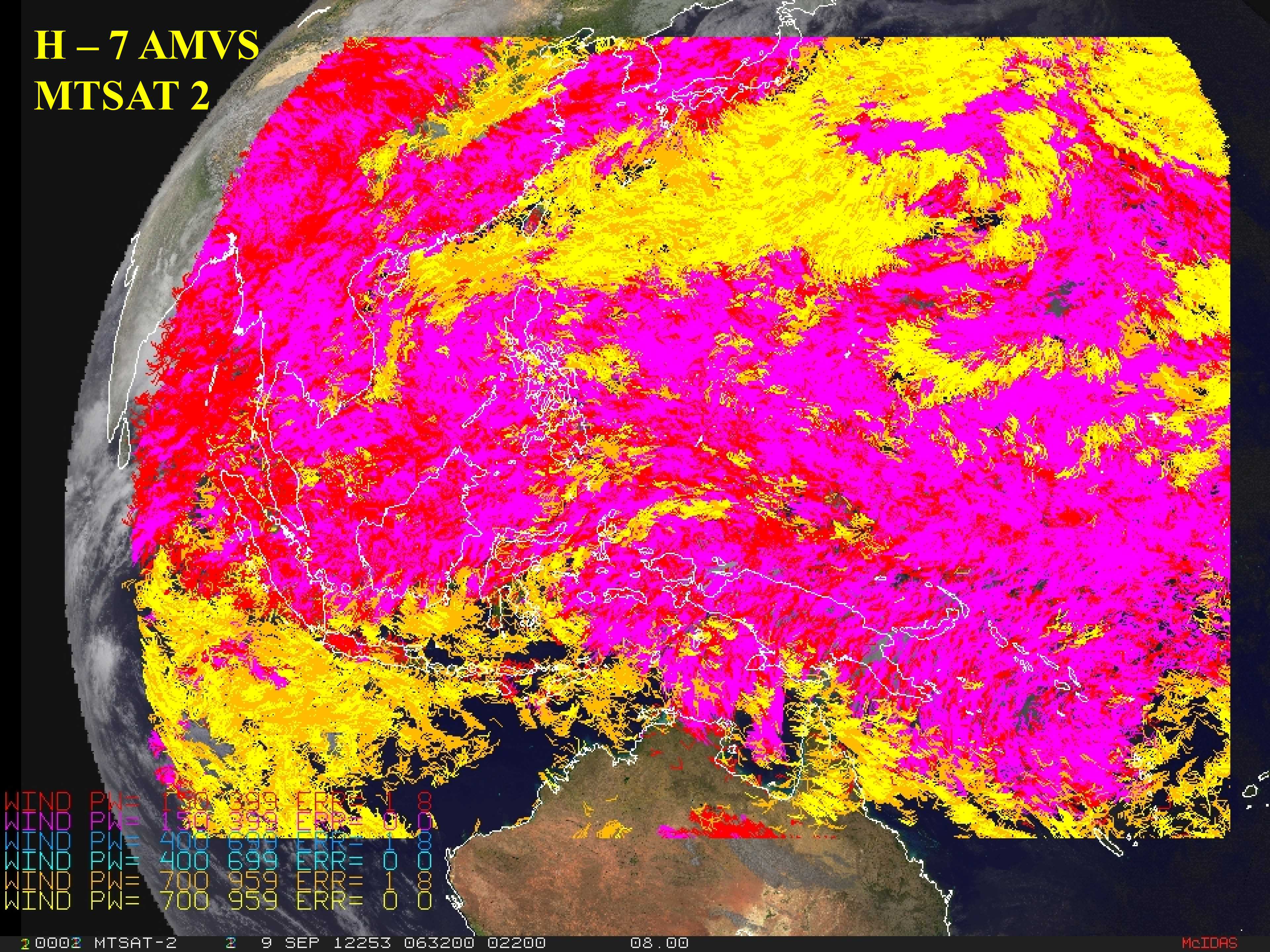
	Band	Central Wavelength [µm]	Spatial Resolution	
	1	0.43 -0.48	1Km	RGB Composited True Color Image
	2	0.50 -0.52	1Km	
X	3	0.63 -0.66	0.5Km	
X	4	0.85 -0.87	1Km	
X	5	1.60 -1.62	2Km	1.3 µm for GOES-R
	6	2.25 -2.27	2Km	
X	7	3.74 -3.96	2Km	
X	8	6.06 -6.43	2Km	Water Vapour
	9	6.89 -7.01	2Km	
X	10	7.26 -7.43	2Km	
X	11	8.44 -8.76	2Km	SO2
X	12	9.54 -9.72	2Km	O3
X	13	10.3 -10.6	2Km	Atmospheric Windows
	14	11.1-11.3	2Km	
X	15	12.2 -12.5	2Km	
X	16	13.2 -13.4	2Km	CO2

Full Disk Image
every 10 minutes



MTSAT-1R/2

Band	Central Wavelength [µm]	Spatial Resolution
1	0.55 –0.90	1Km
2	3.50 –4.00	4Km
3	6.50-7.00	4Km
4	10.3 –11.3	4Km
5	11.5 –12.5	4Km


H – 7 AMVS
MTSAT 2
WIND PW= 150 399 ERR= 1 8
WIND PW= 150 399 ERR= 0 0
WIND PW= 400 699 ERR= 1 8
WIND PW= 400 699 ERR= 0 0
WIND PW= 700 959 ERR= 1 8
WIND PW= 700 959 ERR= 0 0
0002 MTSAT-2 2 9 SEP 12253 063200 02200 08.00
McIDAS

NEAR RT TRIAL

OPERATIONAL SYSTEM

27 January – 23 February 2011

Used

■ Real Time Local Satellite Winds MTSAT-2 (EE, hourly since 96, TDB)

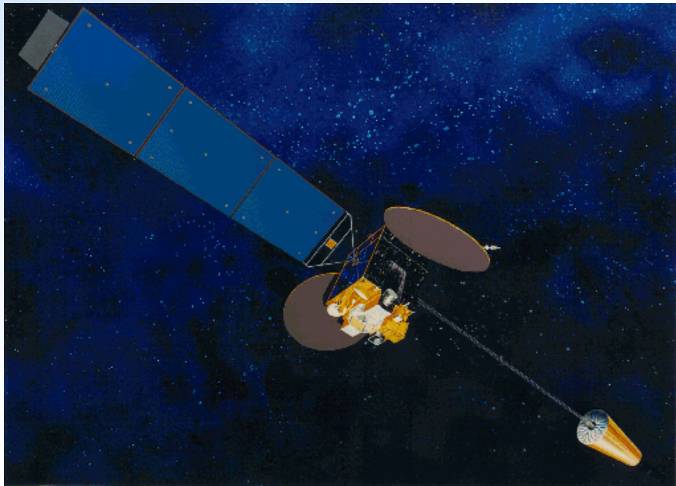
● 2 sets of quarter hourly motion vectors every six hours.

● Hourly motion Vectors

■ Operational Regional

Forecast Model (ACCESS-R) and

Data Base (Inc JMA AMVs)



HIMAWARI-7 NEAR RT TRIAL

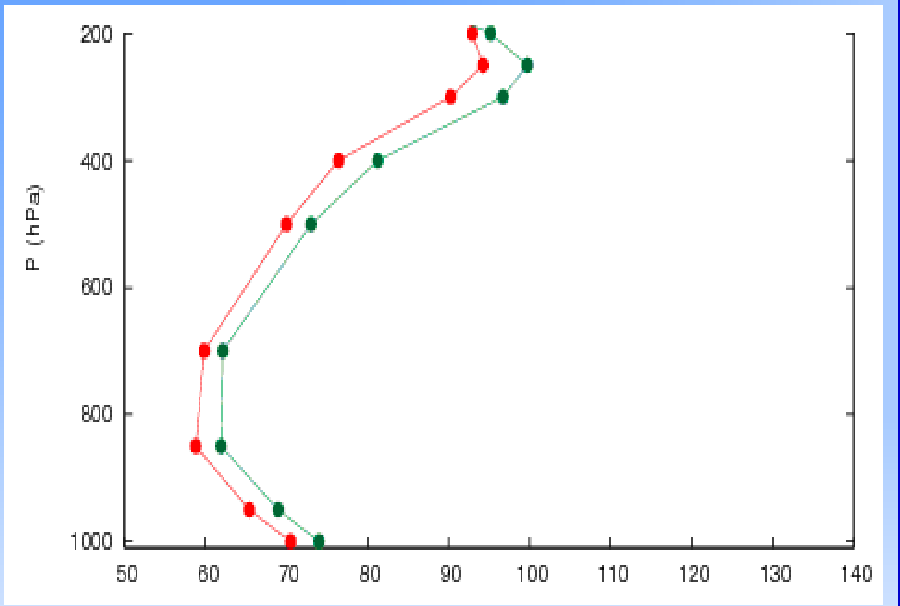


Fig.6(a). The RMS difference between forecast and verifying analysis geopotential height(m) at 24 hours for ACCESS-R (green) and ACCESS-R with hourly AMVs (red) for the period 27 January to 23 February 2011.

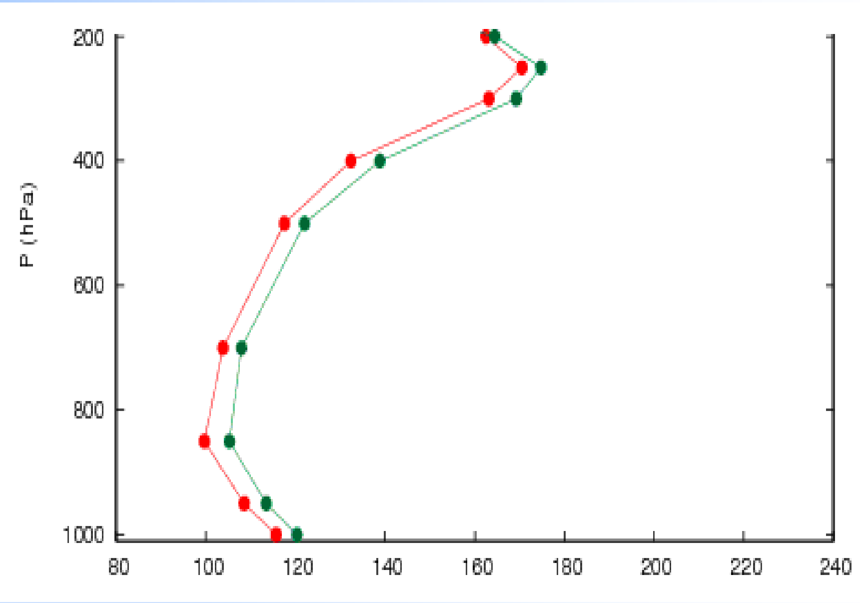


Fig.6(b). The RMS difference between forecast and verifying analysis geopotential height(m) at 48 hours for ACCESS-R (green) and ACCESS-R with hourly AMVs (red) for the period 27 January to 23 February 2011.

Note: 5 June, 1996 10:18 EUHSTCV 2 (**IWW3**)

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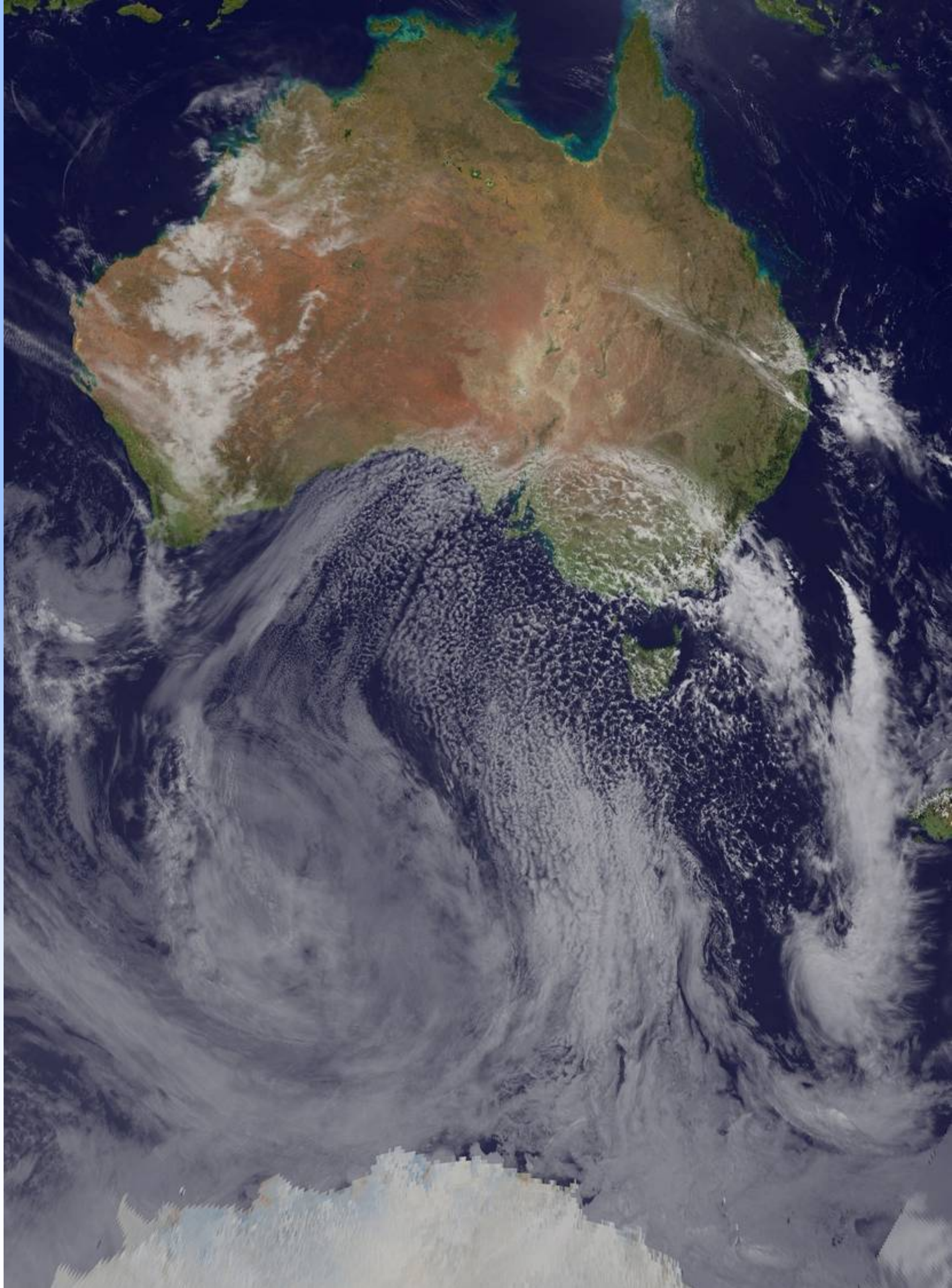
GENERATION AND ASSIMILATION OF CONTINUOUS (10 Minute) ATMOSPHERIC MOTION VECTORS FROM MTSAT-1R (HIMAWARI-6) USING 4DVAR



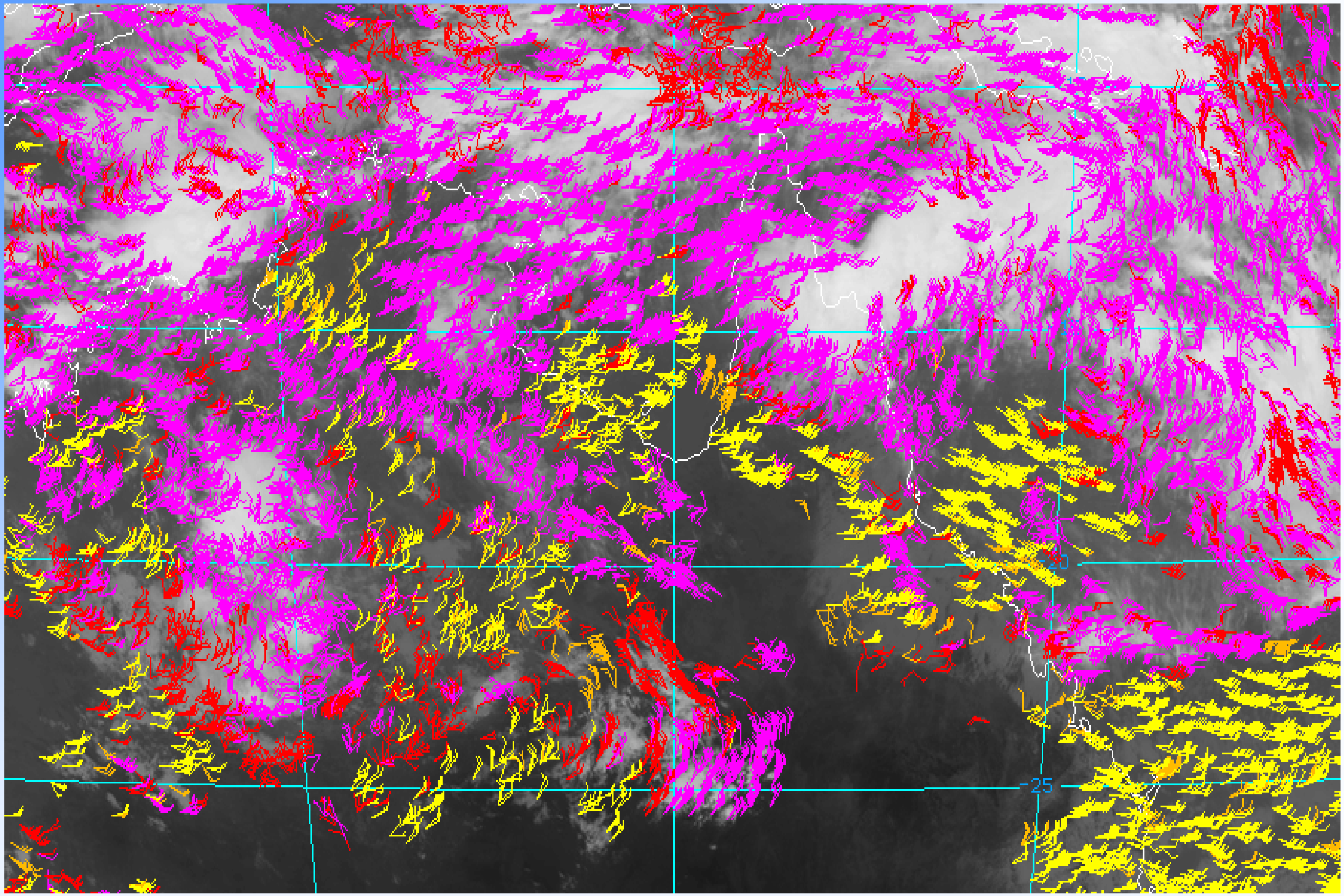


Fig. 1 A selection of Himawari-6 Atmospheric Motion Vectors over North-Eastern Australia generated from 10 min imagery between 0010 UTC and 0050 UTC 28 January 2014.

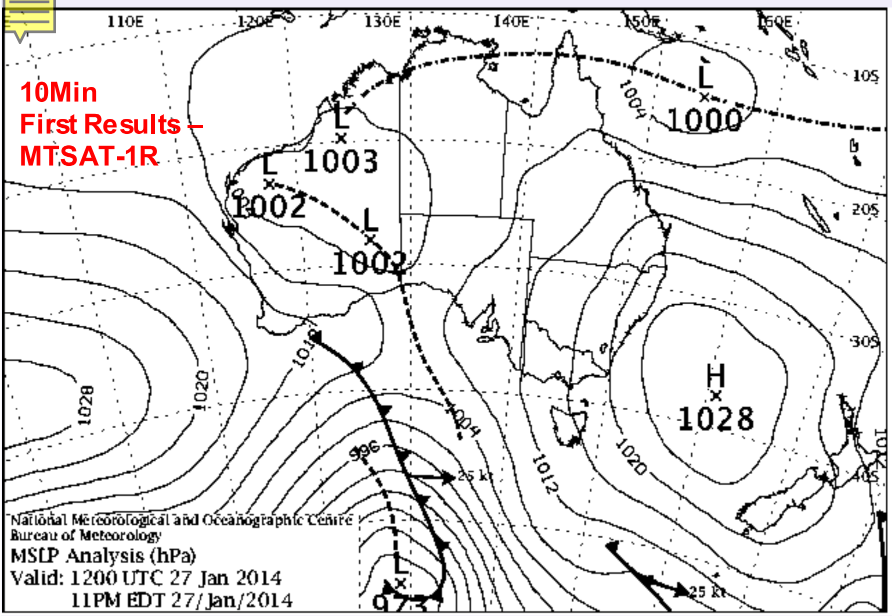


Fig. 13 Bureau of Meteorology Analysis for 12 UTC on 27 January 2014.

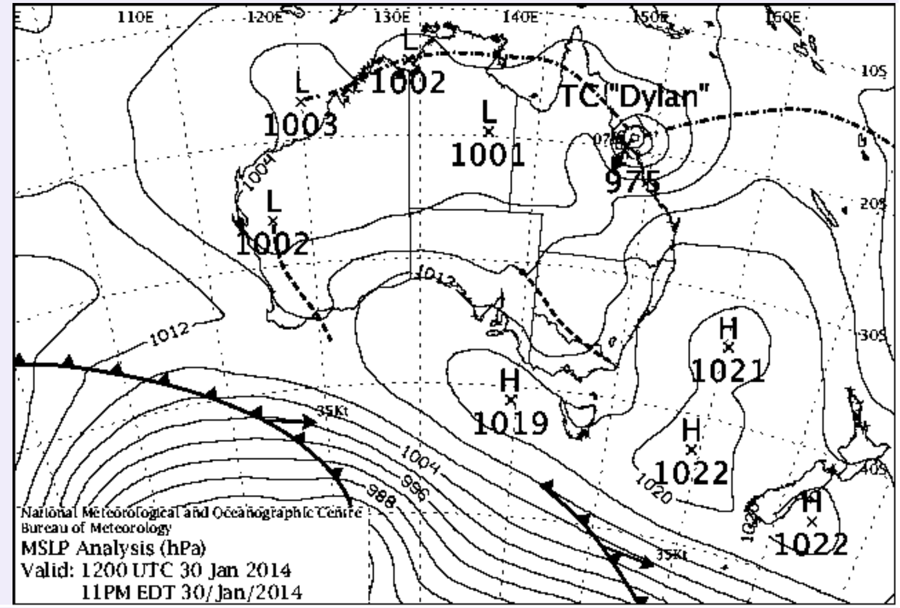


Fig. 14. Bureau of Meteorology Analysis for 12 UTC on 30 January 2014

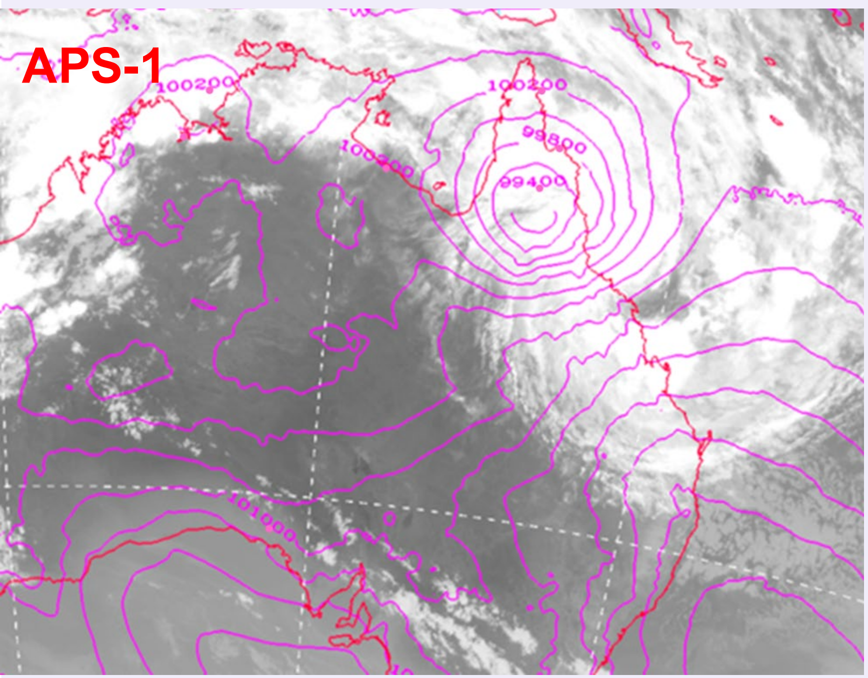


Fig. 15 The Bureau of Meteorology operational three-day MSLP (hPa) forecast valid 1200 UTC 30 January 2014, shown remapped over an MTSat infrared image, valid at the same time.

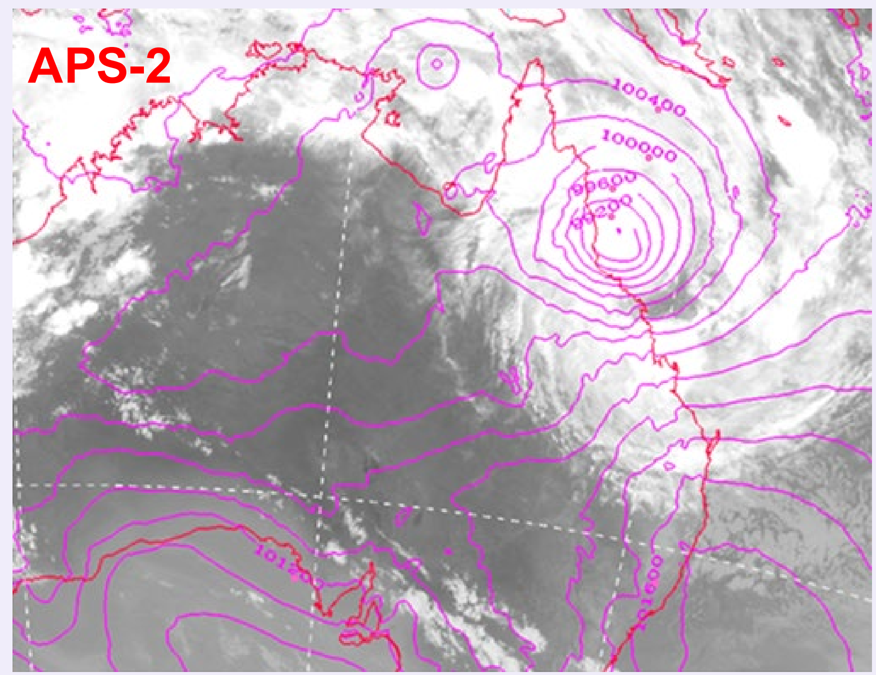


Fig. 16 The Bureau of Meteorology three-day MSLP (hPa) forecast valid, 1200 UTC 30 January 2014 using the next generation operational regional forecasting system with ten, fifteen and sixty minute AMV data from MTSat-1R and MTSat-2. The forecast remapped over the 1200 UTC MTSat image.

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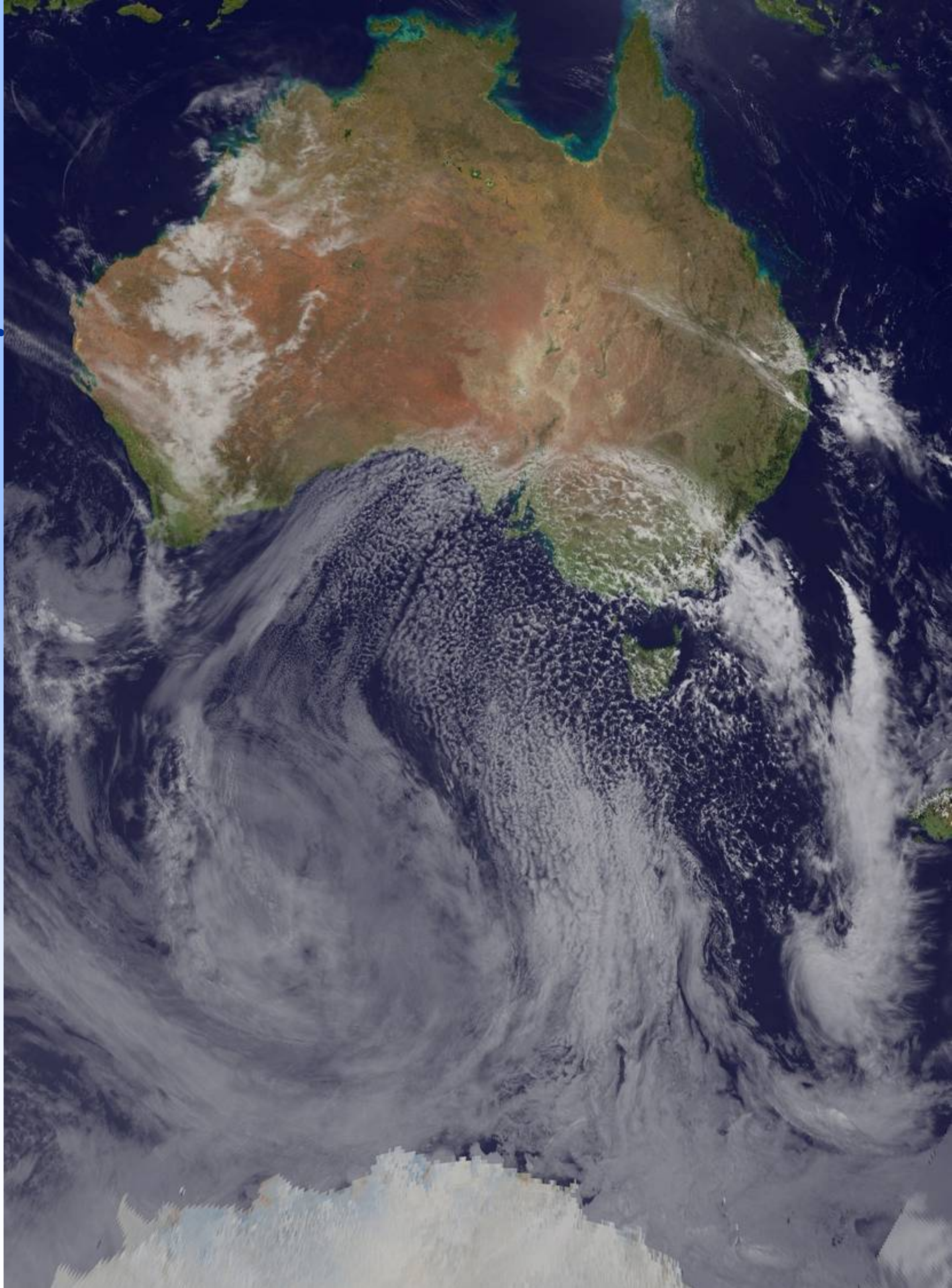
RECENT GENERATION AND ASSIMILATION OF CONTINUOUS (10 Minute) H-8 (9) ATMOSPHERIC MOTION VECTORS, With GEOCAT AND 4DVAR



Himawari-8 Operational AMV Generation

Uses all image triplets (separated by 10 min in HSF format).

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

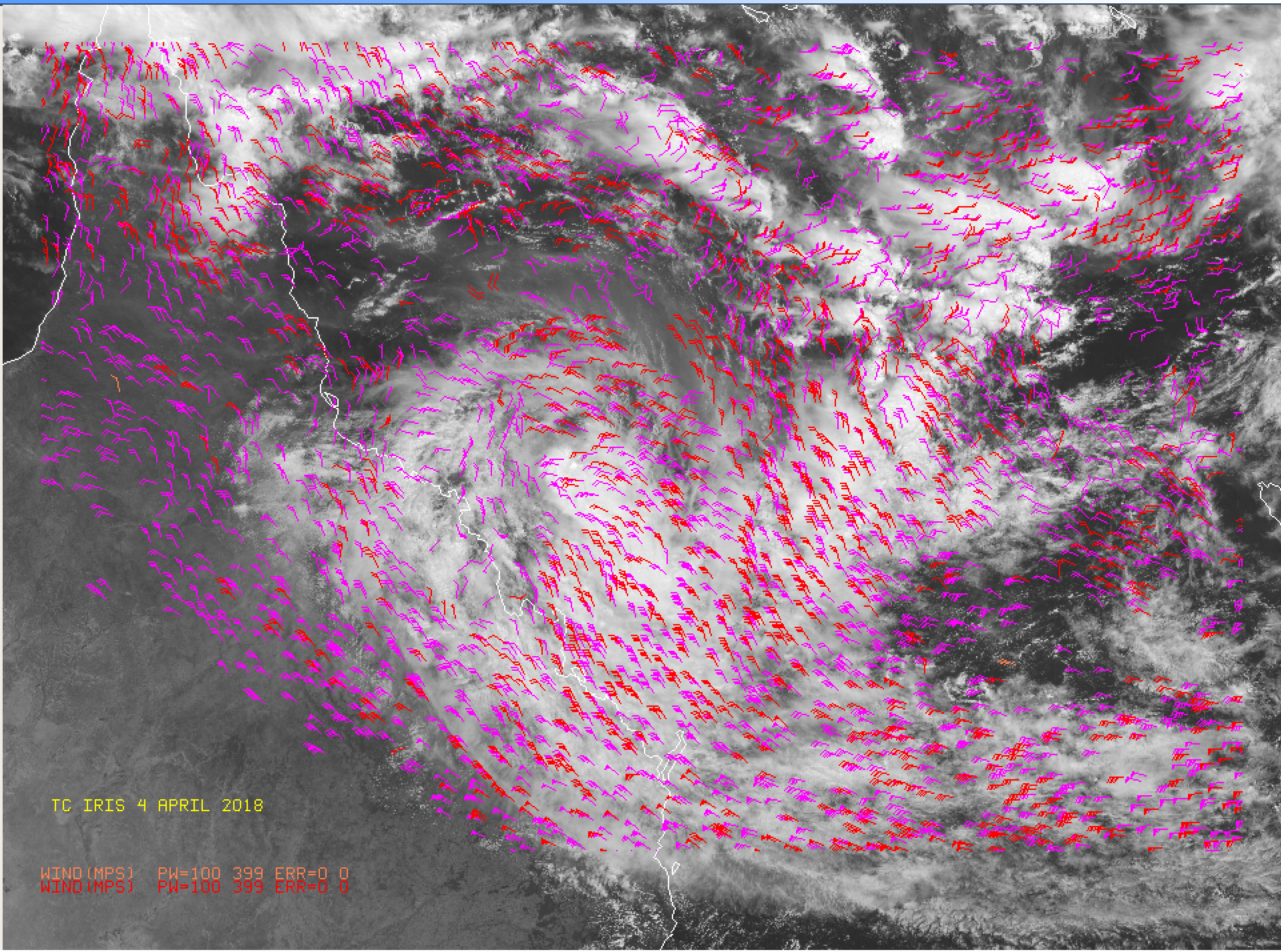
Height assignment methods similar to GOES-R ABI ATBD For Cloud Height (Heidinger, A. 2010)

AMV estimation is similar to GOES-R ABI ATBD for Derived Motion Winds (Daniels, 2010) / BoM system

Error characterization, data selection, QC via EE, QI, ERR etc. (Le Marshall et al., 2004, 2015)

Height assignment verification Cloudsat/Calipso, RAOBS

(System also used for H-7)


TC IRIS 4 APRIL 2018
WIND(MPS) PW=100 399 ERR=0 0
WIND(MPS) PW=100 399 ERR=0 0

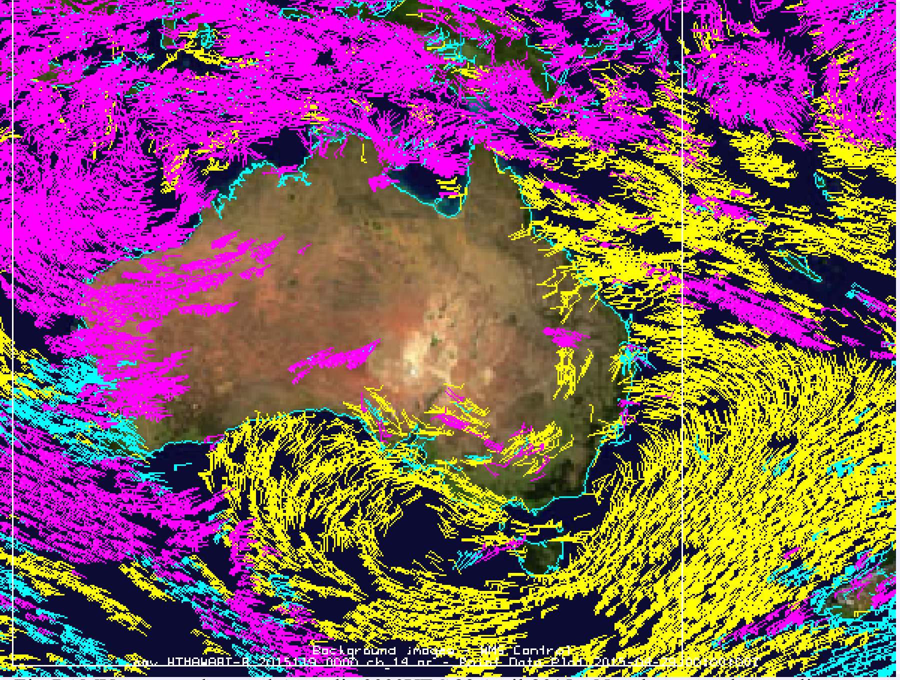


Fig.7 AMVs generated around Australia 0000UTC 29 April 2015 – Note box around Australia.

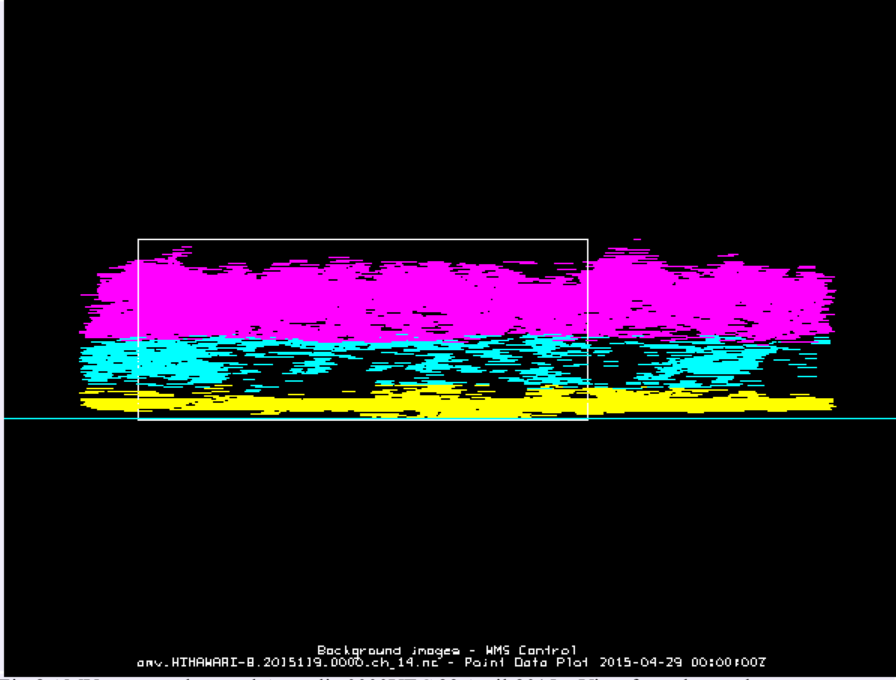


Fig.8 AMVs generated around Australia 0000UTC 29 April 2015 – View from the south.

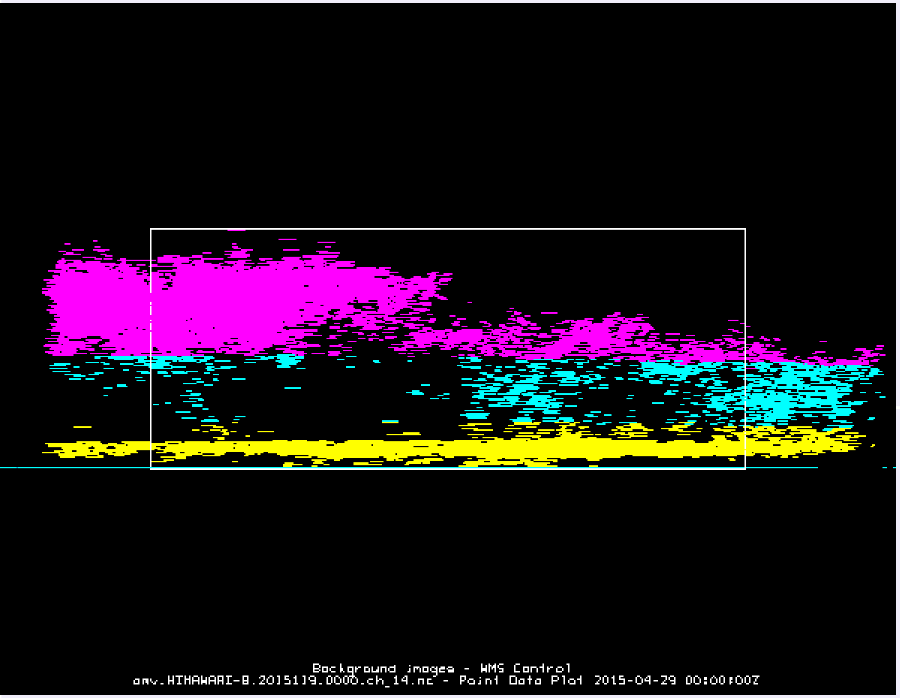


Fig.9AMVs generated around Australia 0000UTC 29 April 2015 – View from the west.

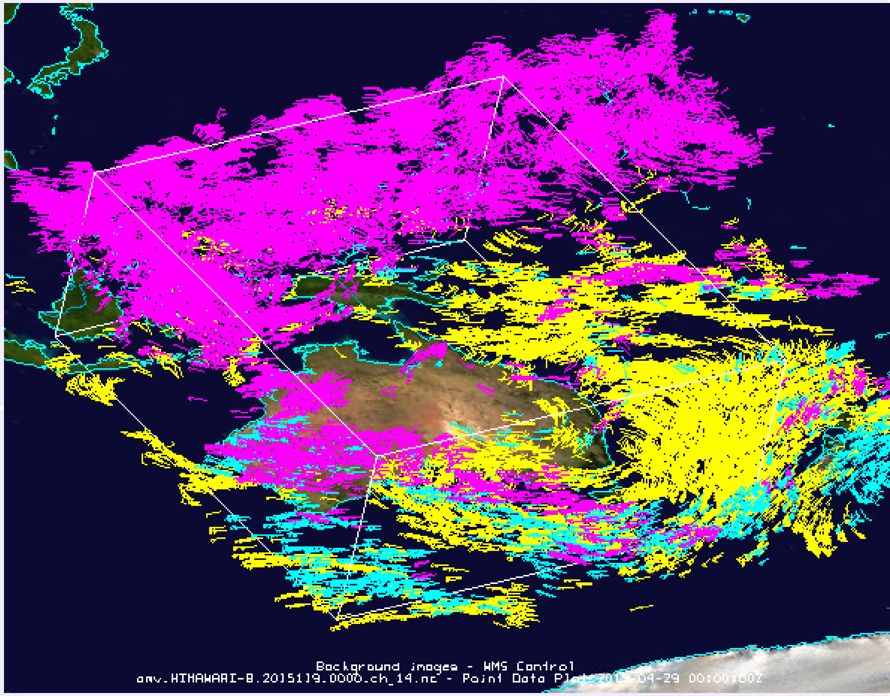


Fig.10AMVs generated around Australia 0000UTC 29 April 2015 – Slant view from southwest.

Table 1 Verification Table for Himawari-8 IR (Channel 14) AMVs compared to radiosondes 1 March - 31 March 2017			
AMV Type	Category	m/s	NOBS
Low Sep <50 km	MMVD	2.5161	660
	RMSVD	2.9618	
	BIAS	-0.0991	
High Sep <50 km	MMVD	3.2834	2958
	RMSVD	3.9624	
	BIAS	-0.4998	

Table 2 Verification Table for Himawari-8 VIS (Channel 3) AMVs compared to radiosondes 1 March - 31 March 2017			
AMV Type	Category	m/s	NOBS
Low Sep <50 km	MMVD	2.4808	473
	RMSVD	2.8381	
	BIAS	0.2875	
High Sep <50 km	MMVD	2.9777	710
	RMSVD	3.6743	
	BIAS	-0.8148	

Processing every 10 minutes

NRT Testing in ACCESS G2 Completed.
NB. 2018 Int. Study

Length Scale of the Correlated Error

The correlation function used was the second order auto-regressive (SOAR) function (Daley 1991), namely

$$R(r) = R_{00} + R_0\,(1 + r/L)\,\mathrm{e}^{\,r/L} \quad ,$$

where $R(r)$ is the error correlation, with fitting parameters R_{00}, R_0 (greater than 0), and L is the length scale, and 'r' is the separation of the correlates.

Initial parameter estimates derived using the methods referenced in ***Le Marshall, 2004*** *(for example for low level Ch14 AMVs;*
$L=128$, $R_0=0.56$ and $R_{00}= 0.01$)

are not inconsistent with the current analysis method. These estimates are still being improved as the match database being used is expanding rapidly.

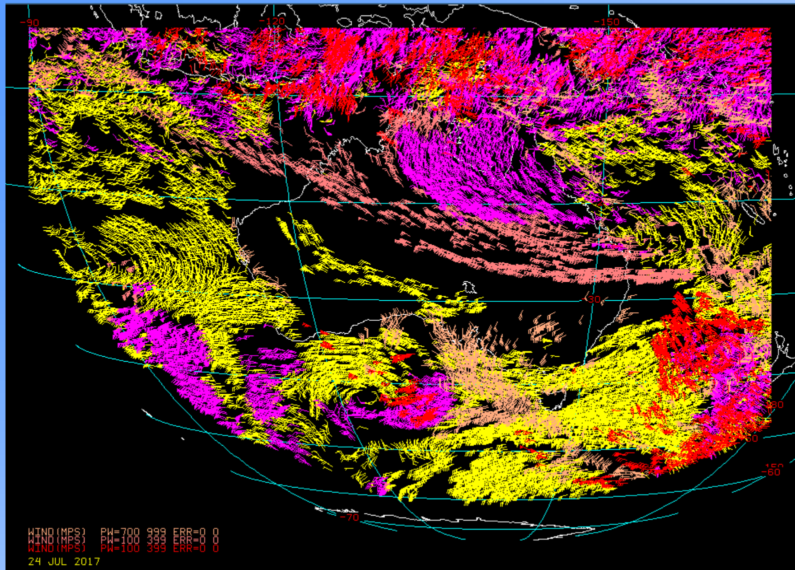


Fig.3 Thinned Himawari-8 AMVs tracked using tracers from channel 14, 9 and 2 images at 00 UTC 24 July 2017.

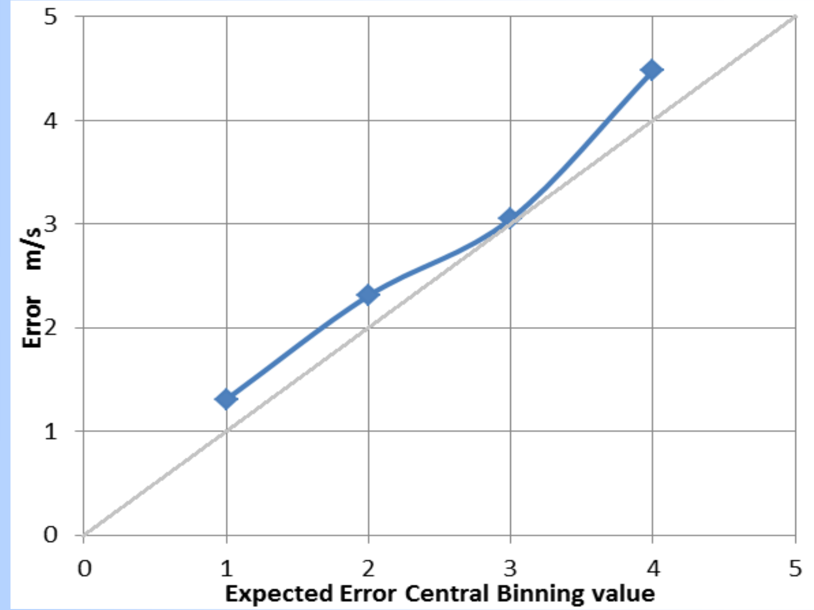


Fig. 4. Measured error (m/ s) vs Expected Error (m/s) for low-level Himawari-8 IR winds (1 31 August –29 2016).

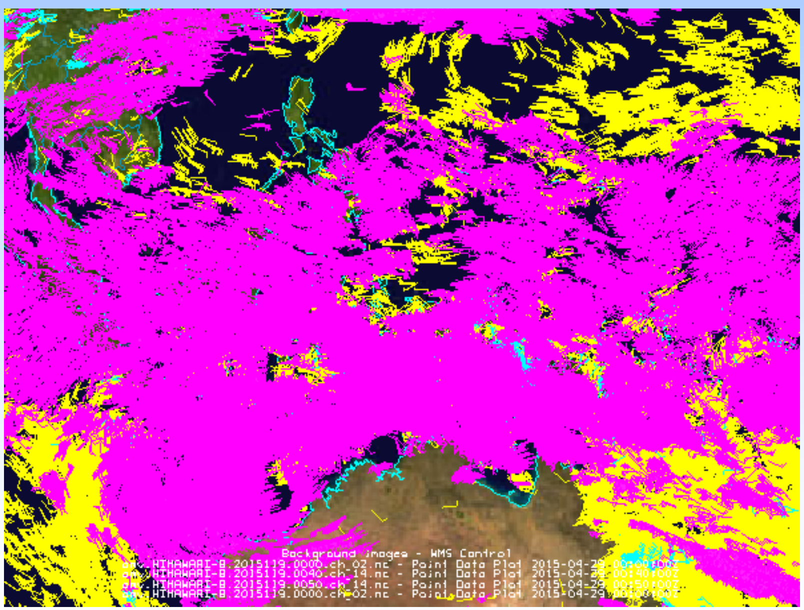


Fig. 5 Coverage of AMVs from Himawari-8 in the tropics to the north of Australia around 0000 UTC 29 April 2015

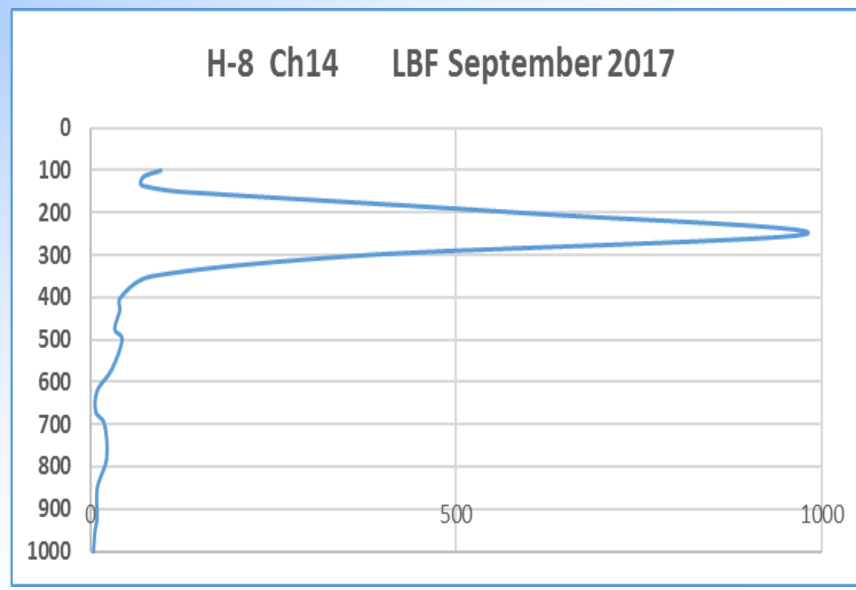
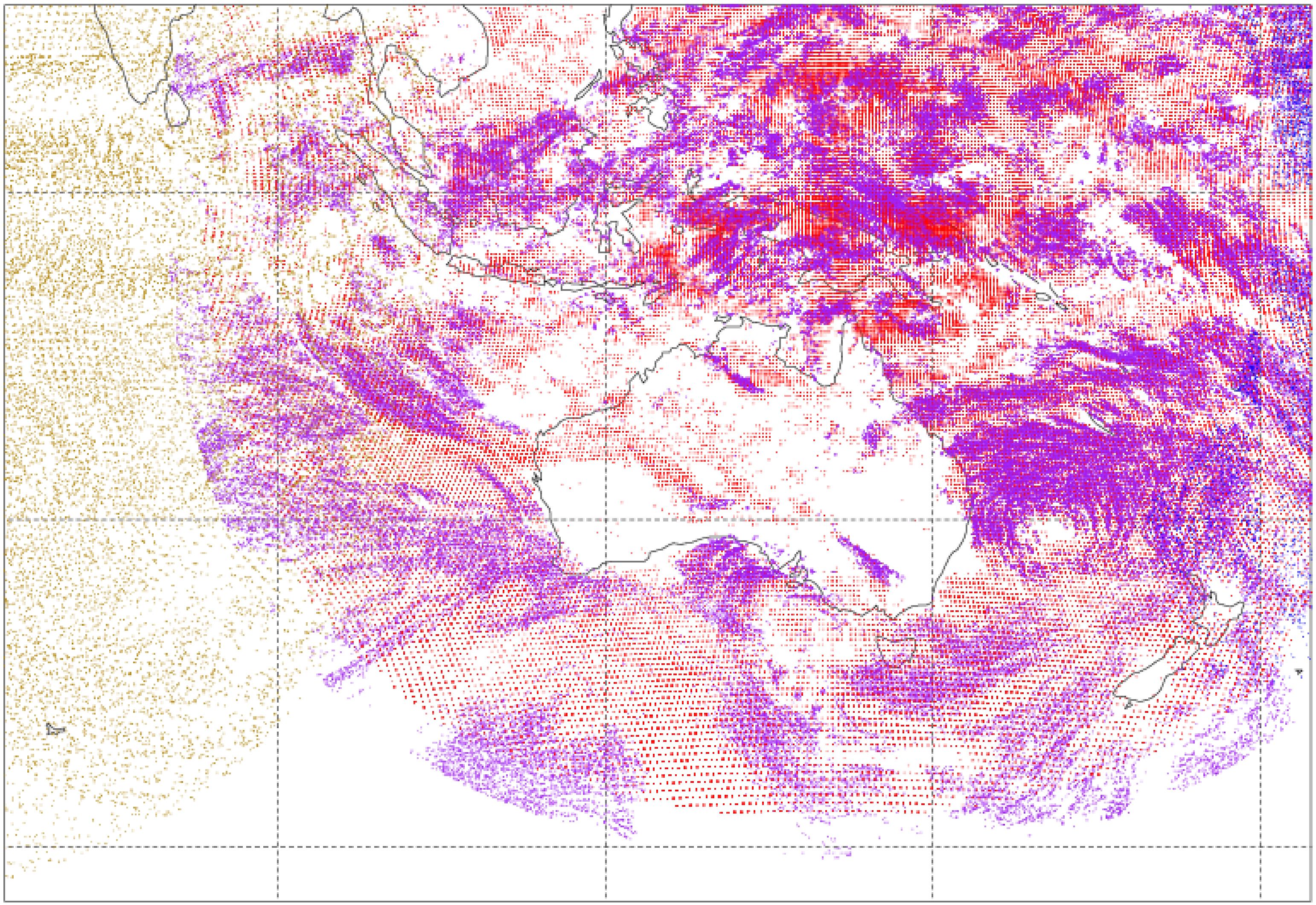


Fig6 Himawari-8 level of best fit height assignment statistics for CH.14 230-270 Hpa AMVs for September 2017

Australian BoM ACCESS-R Received observations coverage
Satwind 20180412 0000 UTC
Total number of obs = 410349

4424 GOES 0 ESAC 208805 AUS 175997 JMA 21123 MSG



Issue time 01UTC 12 Apr 2018

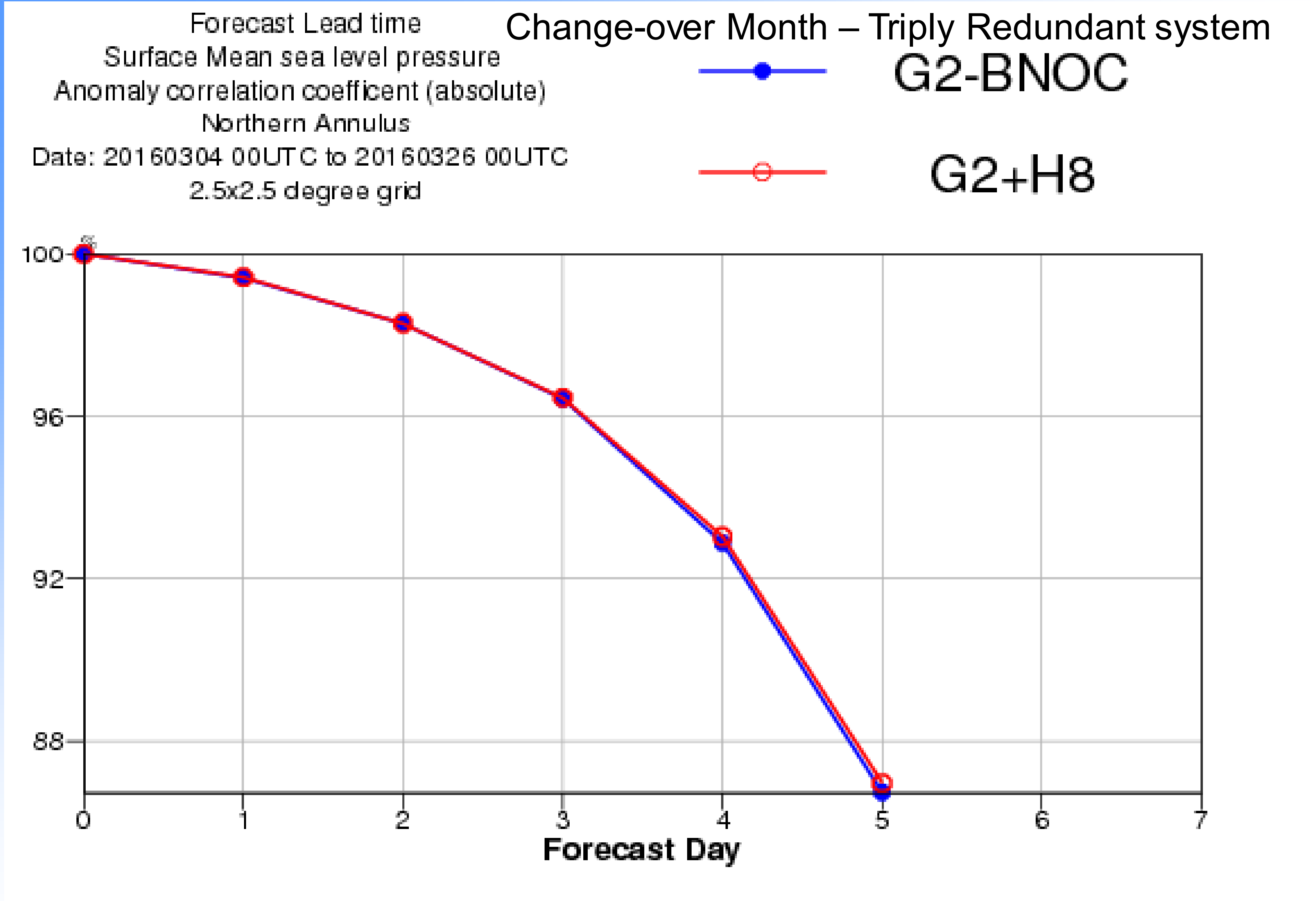
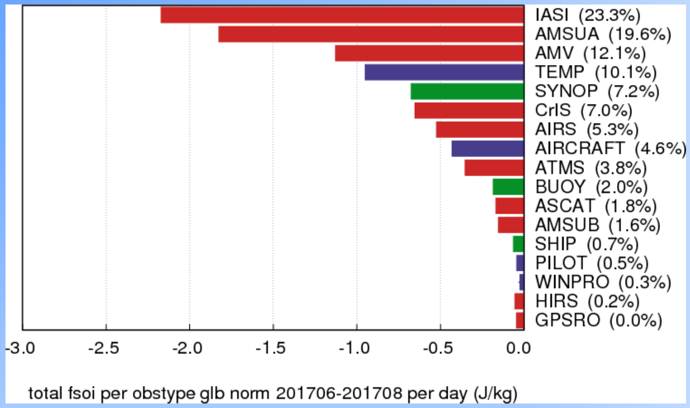
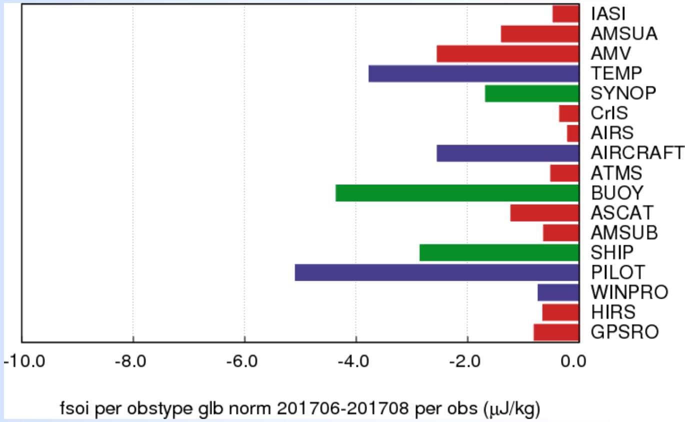


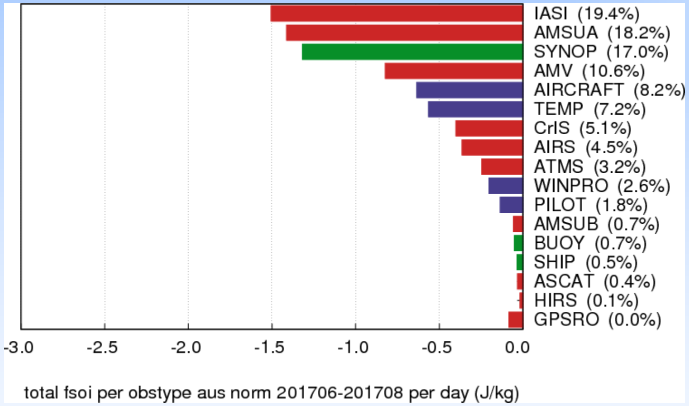
Fig.13 MSLP anomaly correlation coefficients for the Northern Hemisphere Annulus for the operational system (blue) and for the operational test system for 4 – 26 March 2016.

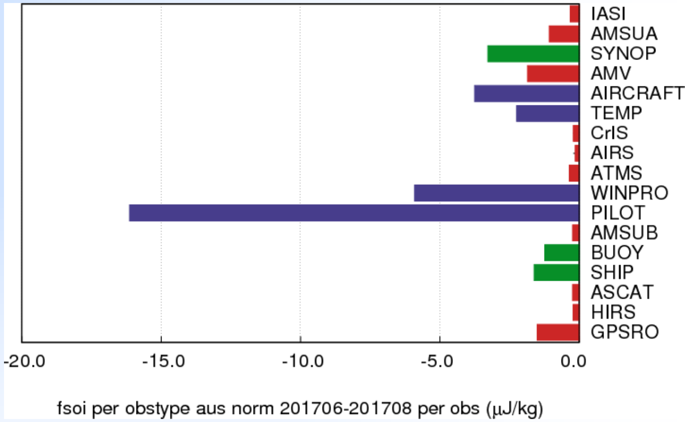
FSOI for major observation types & instruments 2017 Jun - Aug

Satellite
Upper-air
Surface

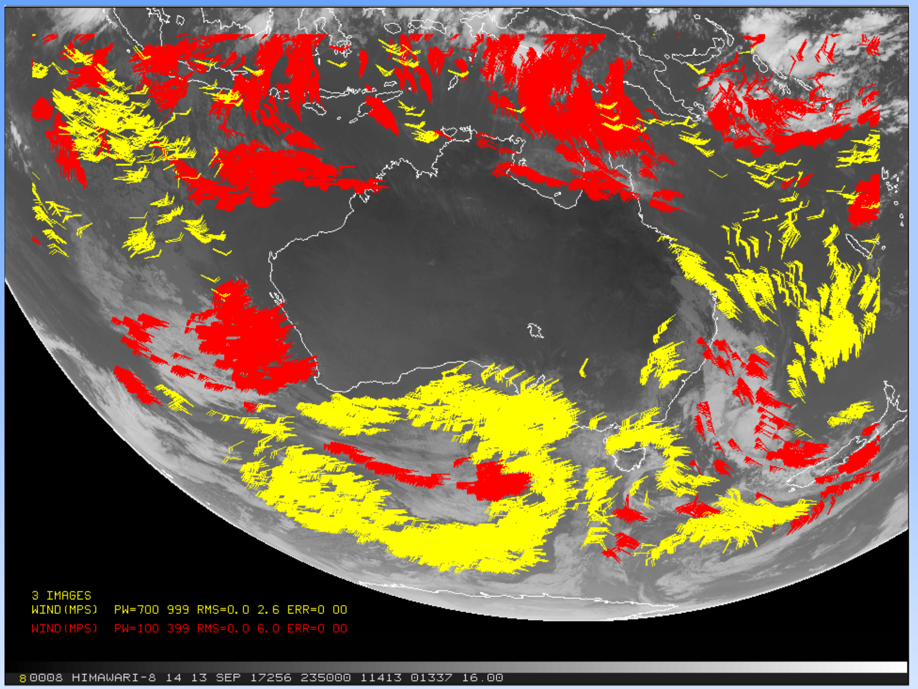








Effective Utilisation of the AMV Database



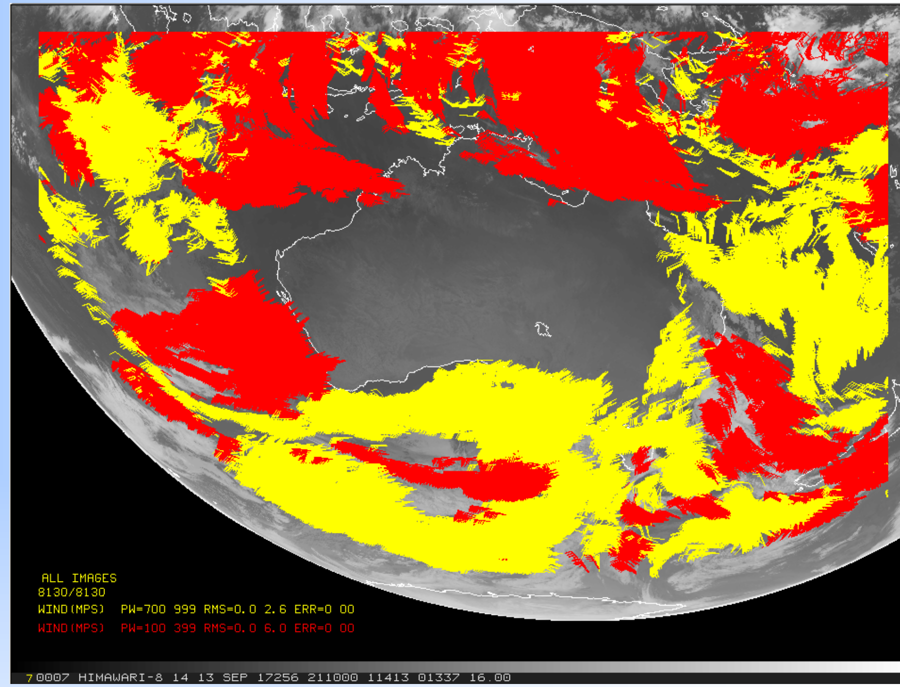


Figure 10(a) shows Channel 14 (IR) low level AMVs (yellow) with expected errors less than 2.6m/s and upper level AMVs (red) with expected errors less than 6.0m/s generated by one image triplet.

Figure 10(b) shows Channel 14 (IR) low level AMVs (yellow) with expected errors less than 2.6m/s and upper level AMVs (red) with expected errors less than 6.0m/s generated by six image triplets.

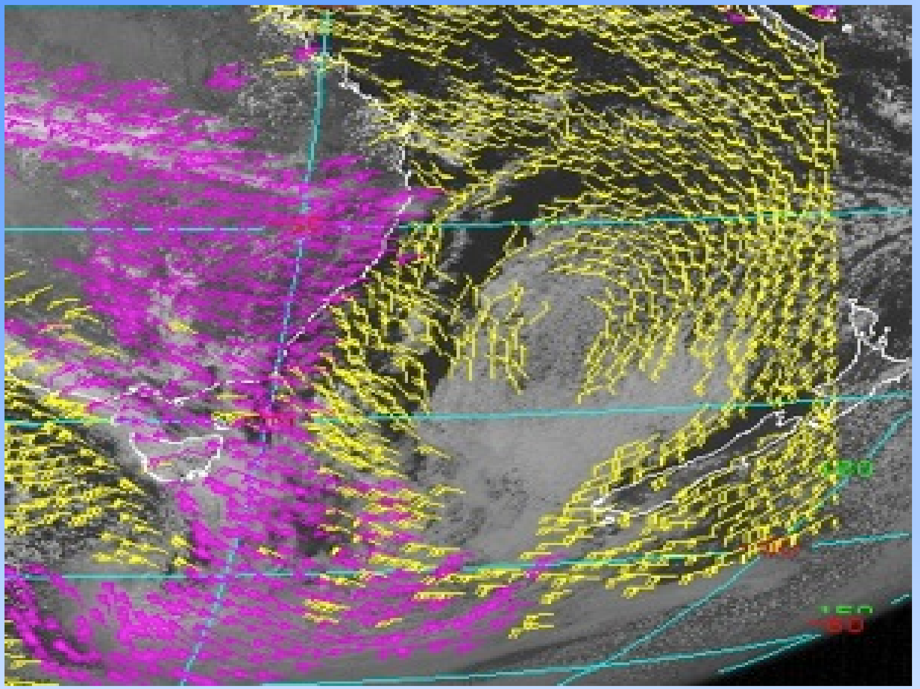


Fig. 8(a) Thinned IR Channel 14 10 minute AMVs from Himawari-8 images at 00UTC 1 May 2017

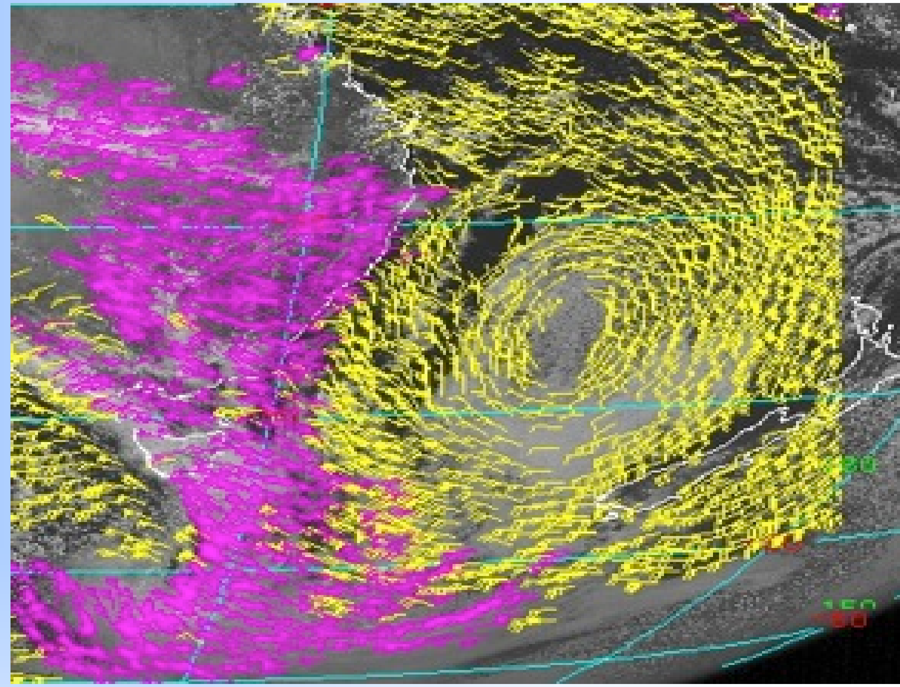
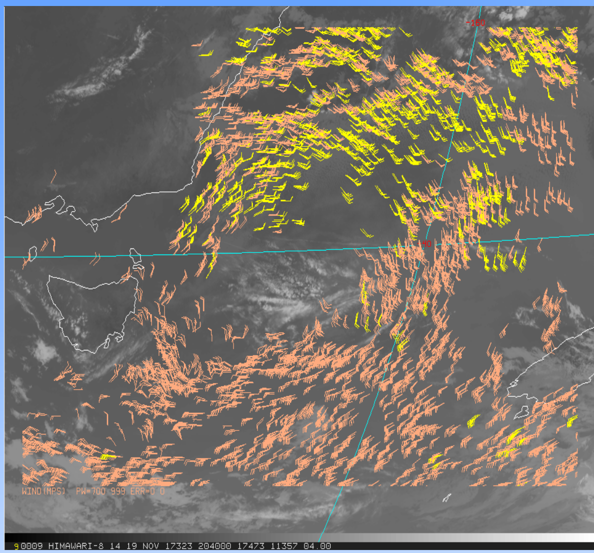
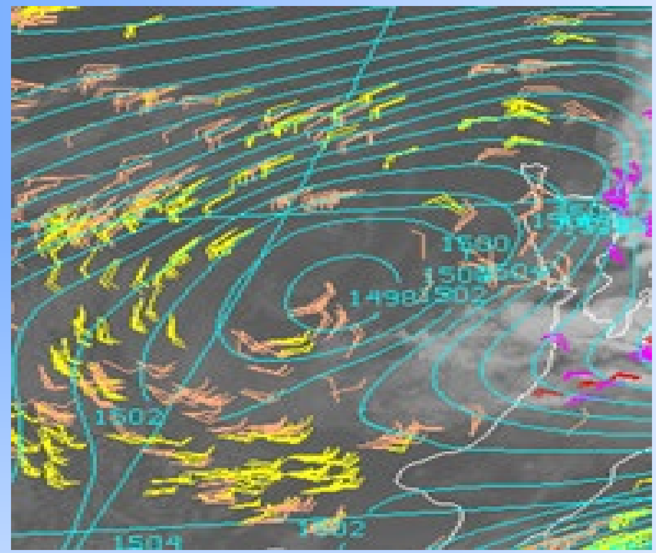
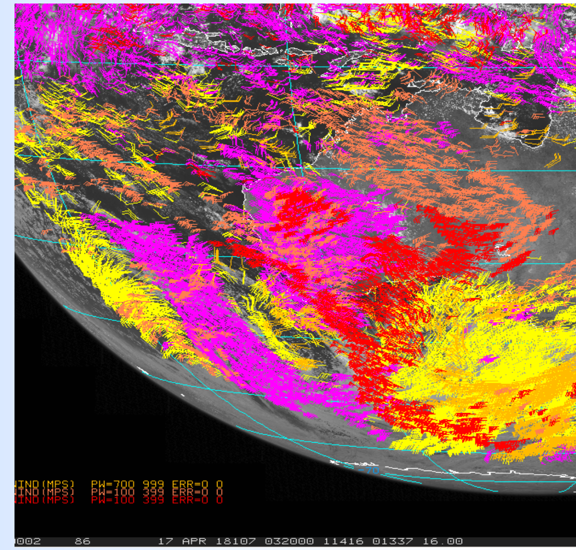


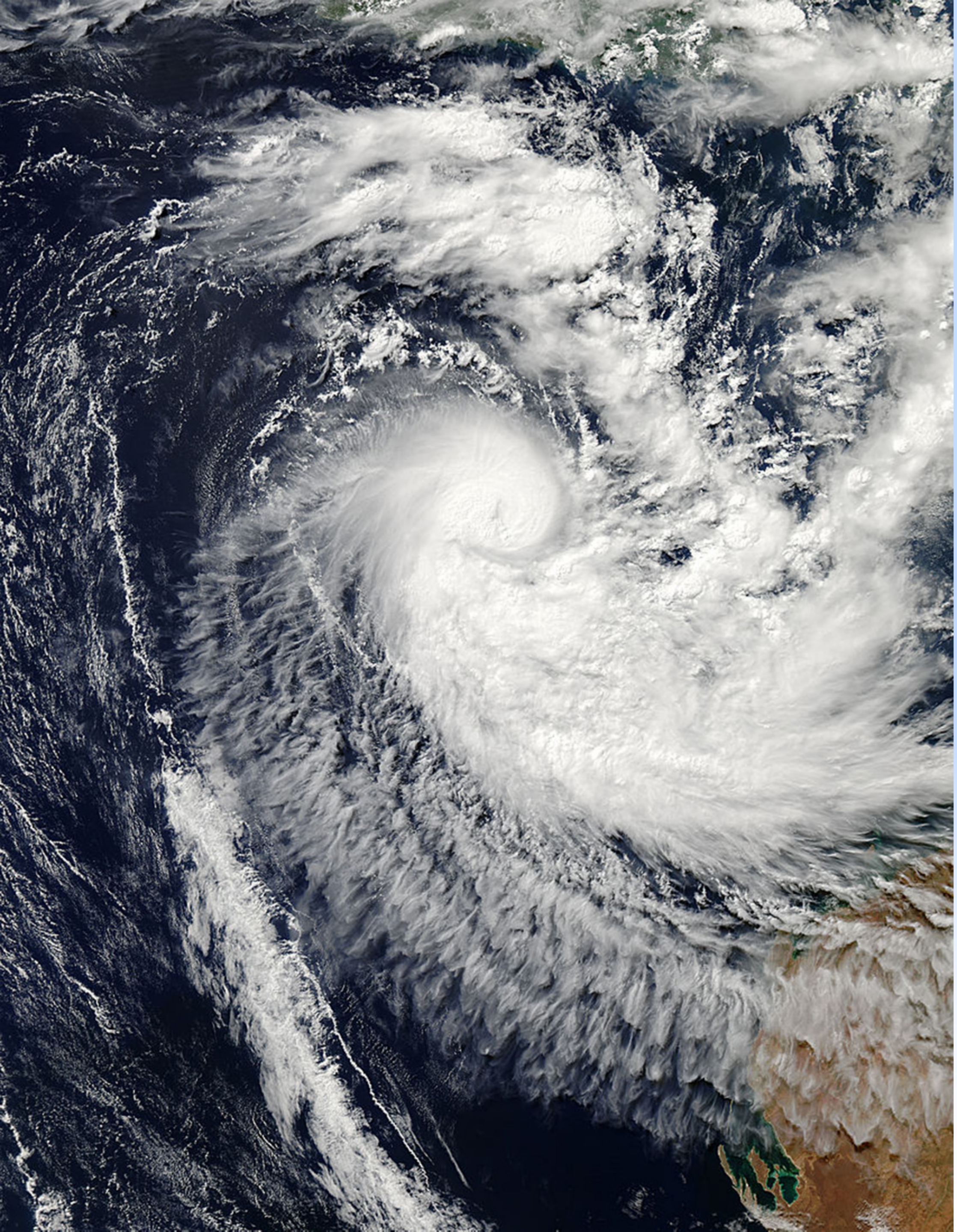
Fig. 8(b) IR plus Visible Channel 2 10 minute AMVs from Himawari-8 images 00UTC 1 May 2017







IR Channel 14 (yellow) and Visible Channel 2 (Beige) 10 minute AMVs from Himawari-8 images at 00UTC 18 October 2017, IR Channel 14 (yellow) and Visible Channel 2 (Beige) 10 minute AMVs from Himawari-8 images at 00UTC 18 October 2017 and IR, Visible and WV AMVs from 17 April 2018.



An Example

Tropical Cyclone Quang

Visible image on April 29 at 06:35 UTC (2:35 a.m. EDT) from the MODIS instrument on NASA's Aqua satellite of Tropical Cyclone Quang in the Southern Indian Ocean.

Credit: NASA Goddard MODIS

TC Quang Himawari-8 AMV Generation And Assimilation

Used Operational 4km res. 4DVar TCX system over Timor Sea

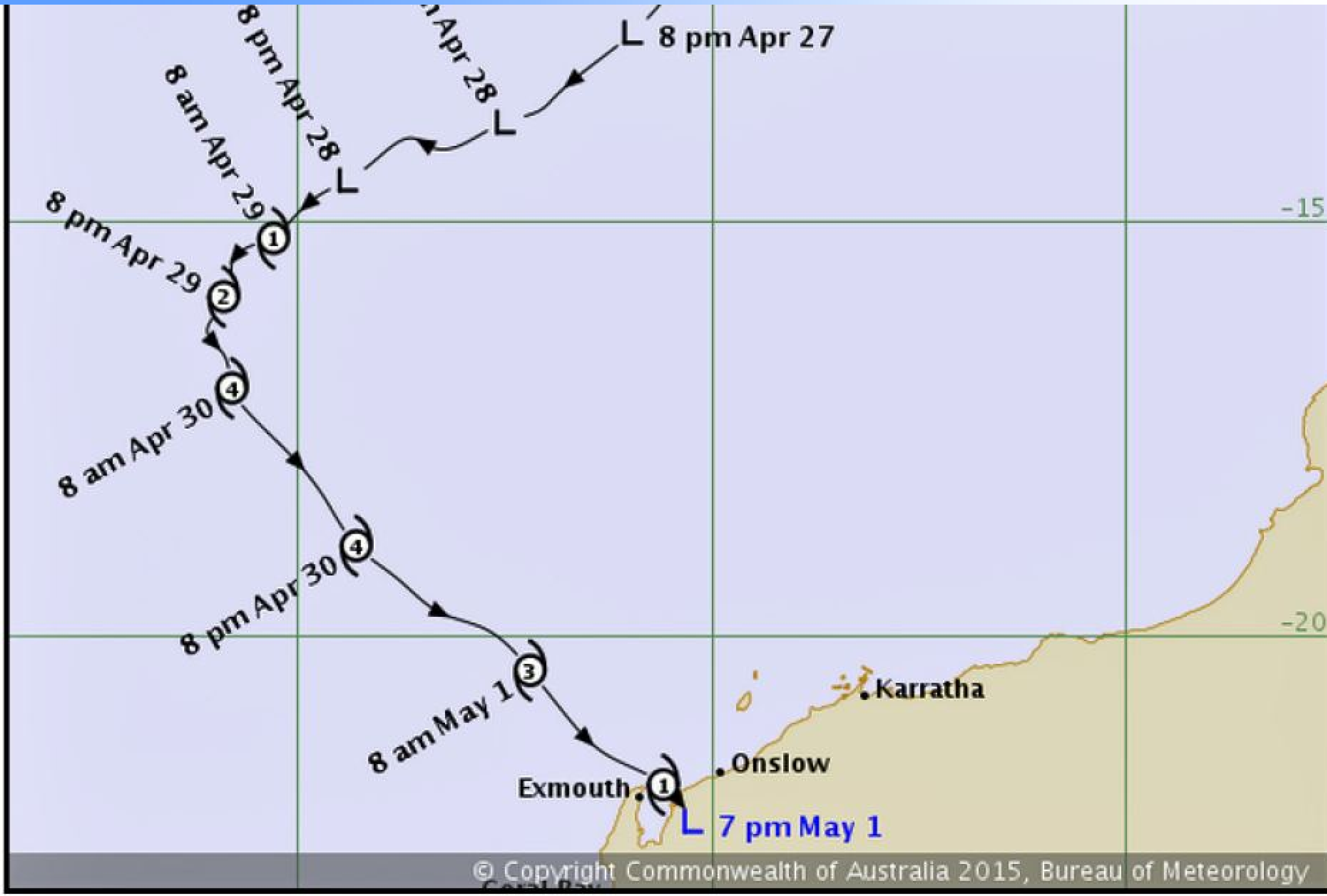
Used <u>all</u> Vis/IR image triplets (separated by 10 min/HSF format). (2km ch 14 IR, 1km ch 2 VIS)

Employs modified GEOCAT software in initial processing.

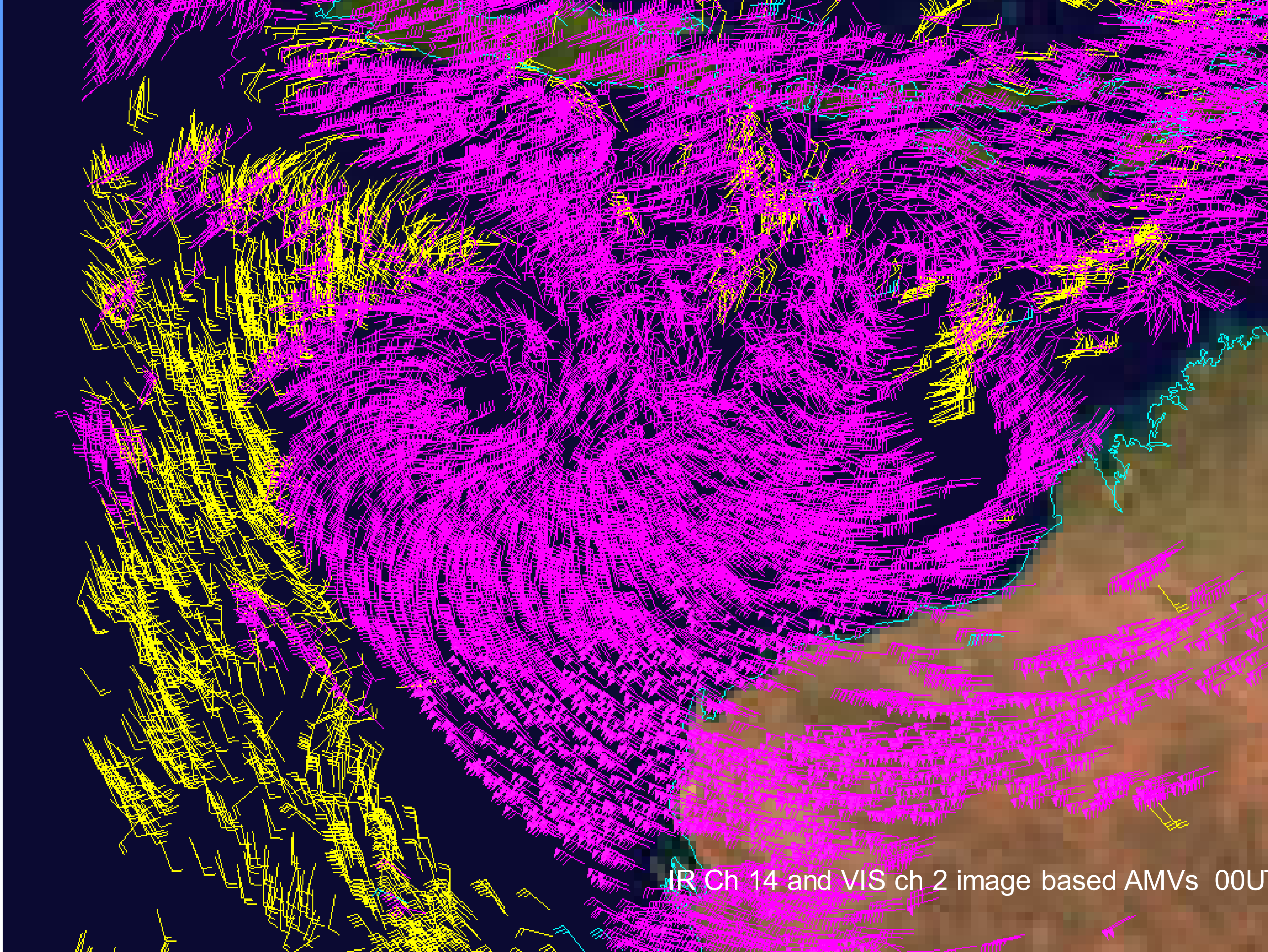
Height assignment methods similar to GOES-R ABI ATBD

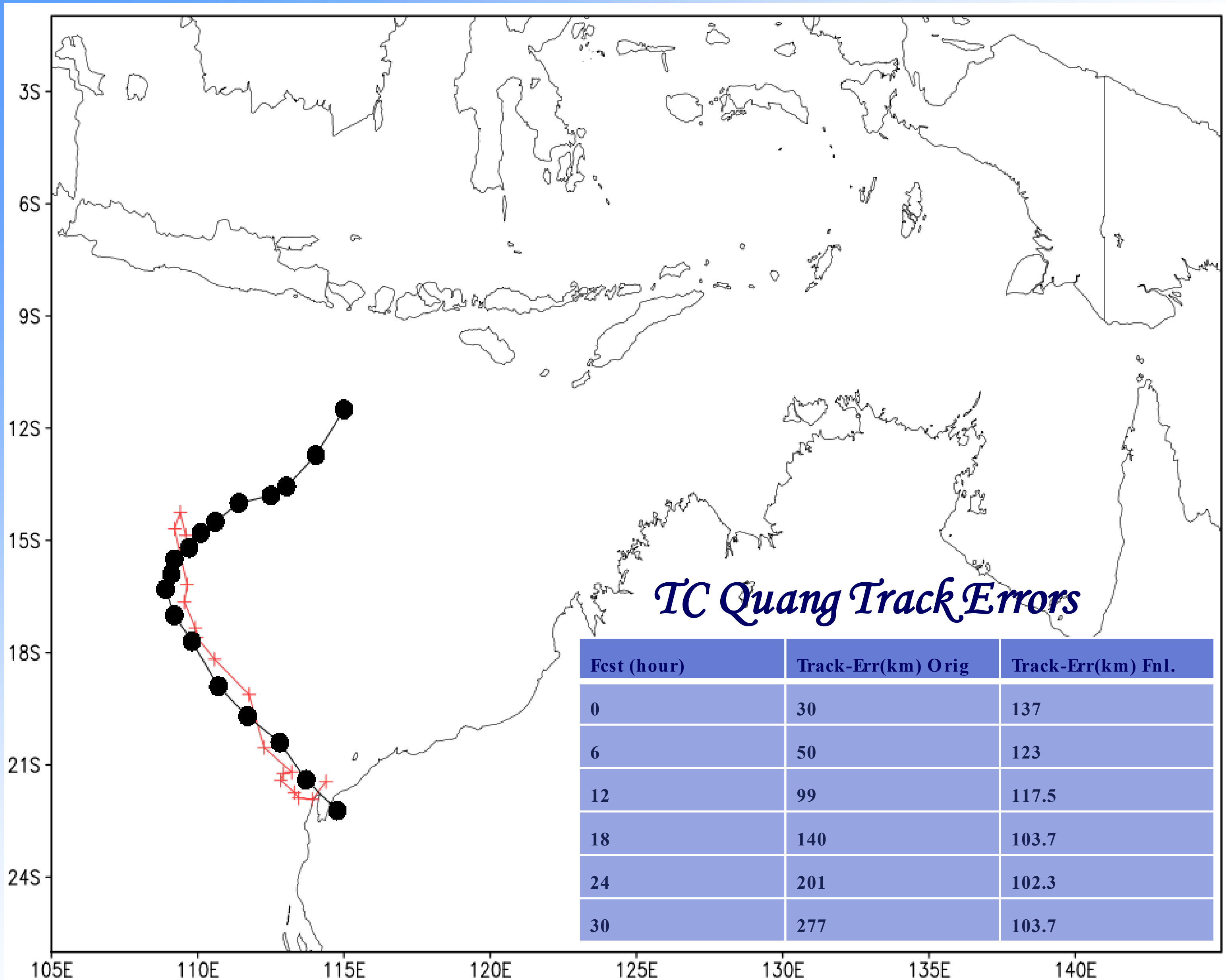
AMV estimation is similar to GOES-R ABI ATBD and BoM system

Error characterization, selection, QC via EE, QI, ERR etc.



8 pm Apr 27
Apr 28
8 pm Apr 28
8 am Apr 29
8 pm Apr 29
8 am Apr 30
8 pm Apr 30
8 am May 1
7 pm May 1
-15
-20
Karratha
Onslow
Exmouth
© Copyright Commonwealth of Australia 2015, Bureau of Meteorology


IR Ch 14 and VIS ch 2 image based AMVs 00U



TC Quang Track Errors

Fcst (hour)	Track-Err(km) Orig	Track-Err(km) Fnl.
0	30	137
6	50	123
12	99	117.5
18	140	103.7
24	201	102.3
30	277	103.7

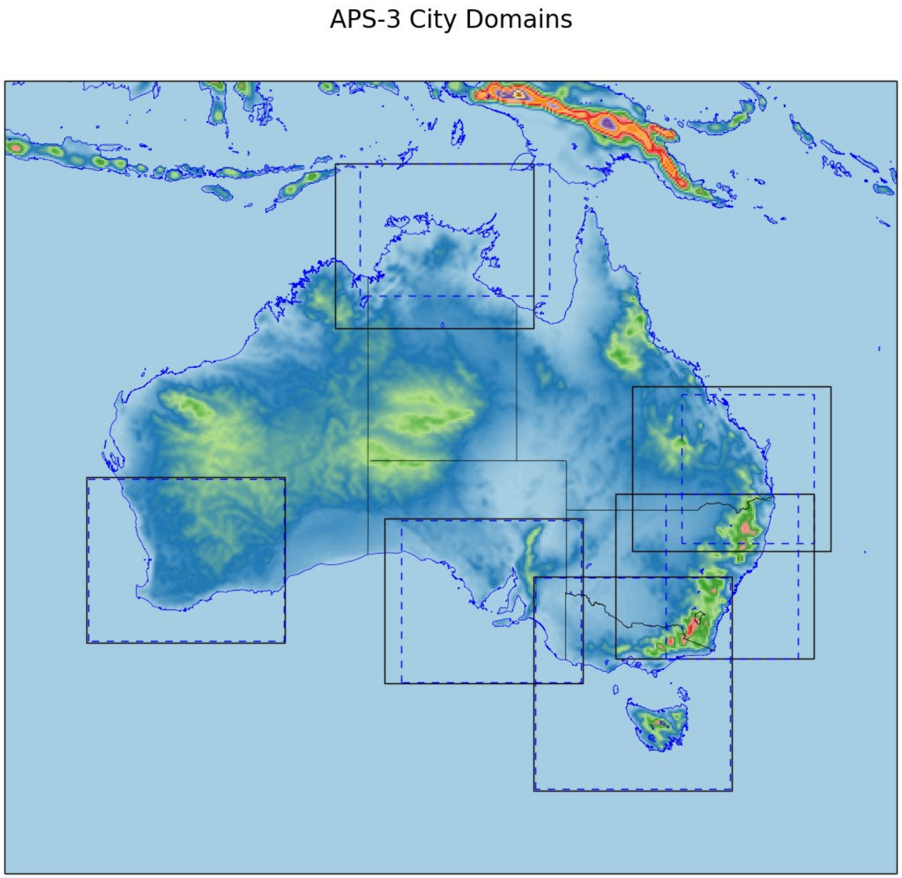
Fig. 14(a) The forecast track of tropical cyclone Quang from 00 UTC 29 April 2015 (red) and the best track (Black), both in six hour intervals

Operational Assimilation of AMVs

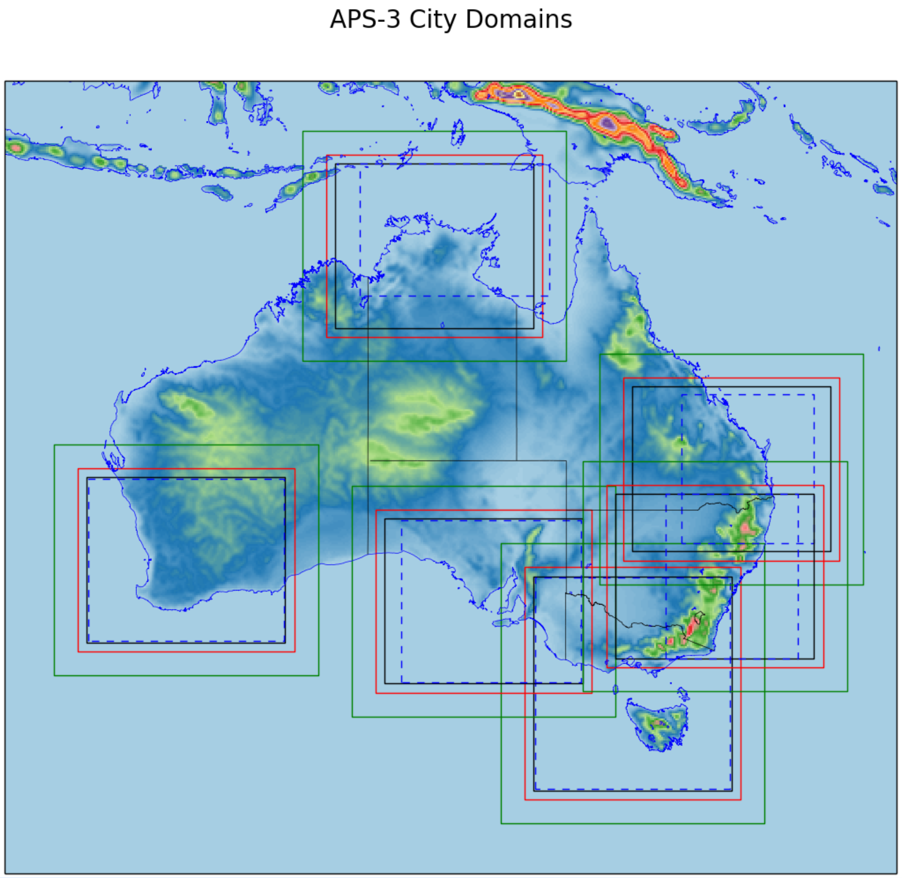
- Global System APS3 (G3)
- 12km Res.
- AMVs including local 10 minute winds assimilated with 4D Var every 6 hours.

- Capital City System APS3 (C3) and TC3 System
- 1.5km Res.
- AMVs assimilated with 4D Var in 10 minute bundles every hour.
- Local ten minute AMVs can be the only Upper Air wind Obs. in a C3 assim. cycle.

Capital City Models



Inner 1.5 km region

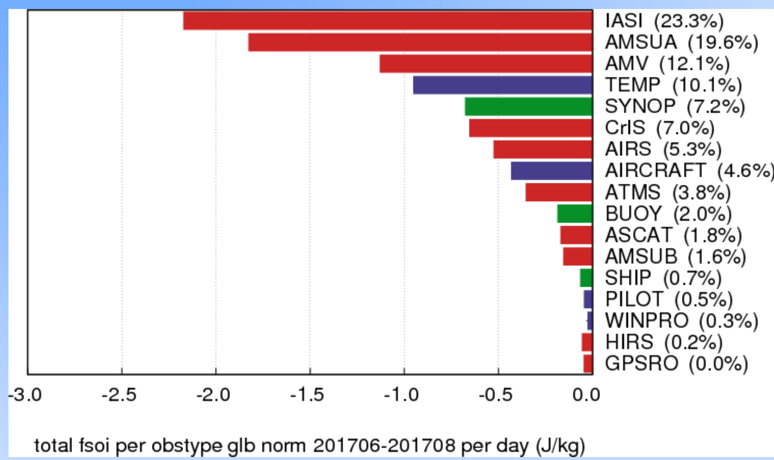


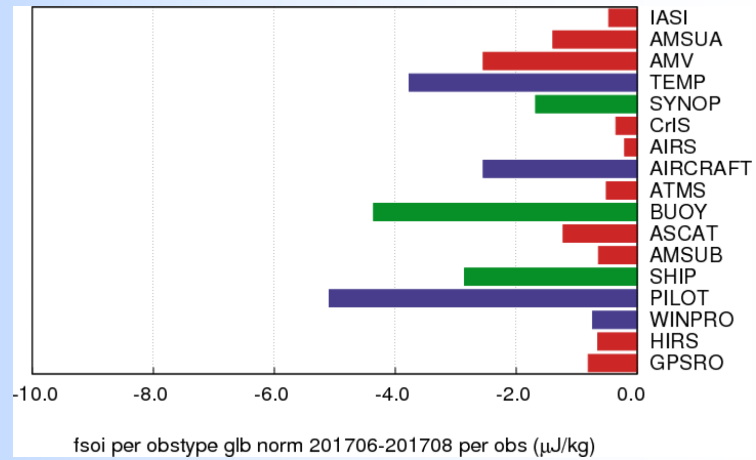
Full domain showing transition to 4 km resolution

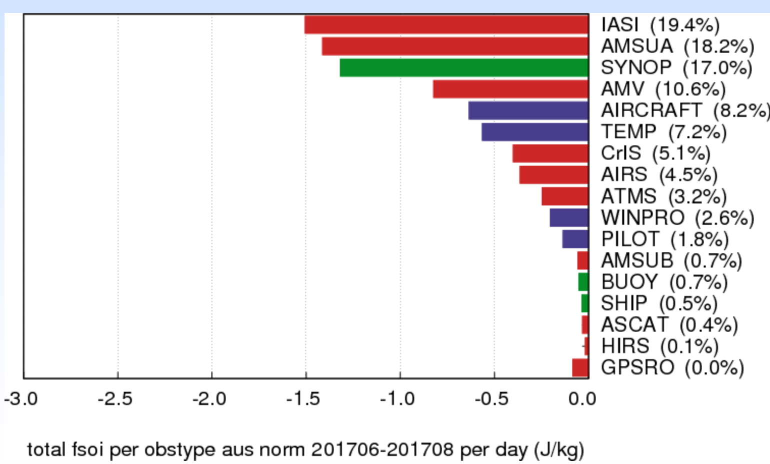
ACCESS APS2: Forecast Sensitivity to Observations

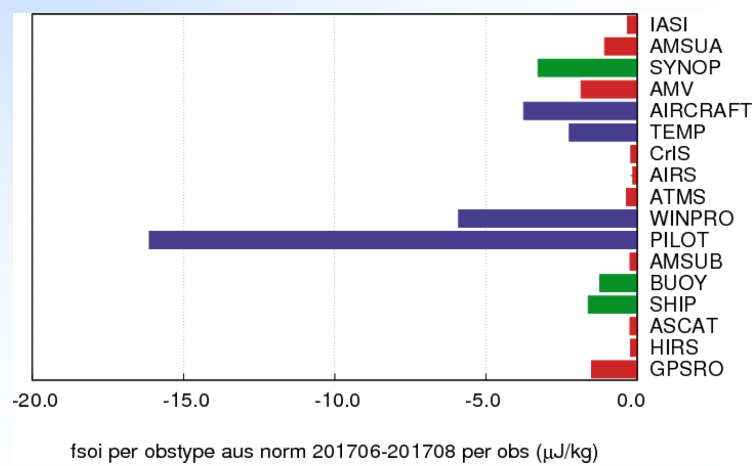
FSOI for major observation types & instruments 2017 Jun - Aug

Satellite
Upper-air
Surface

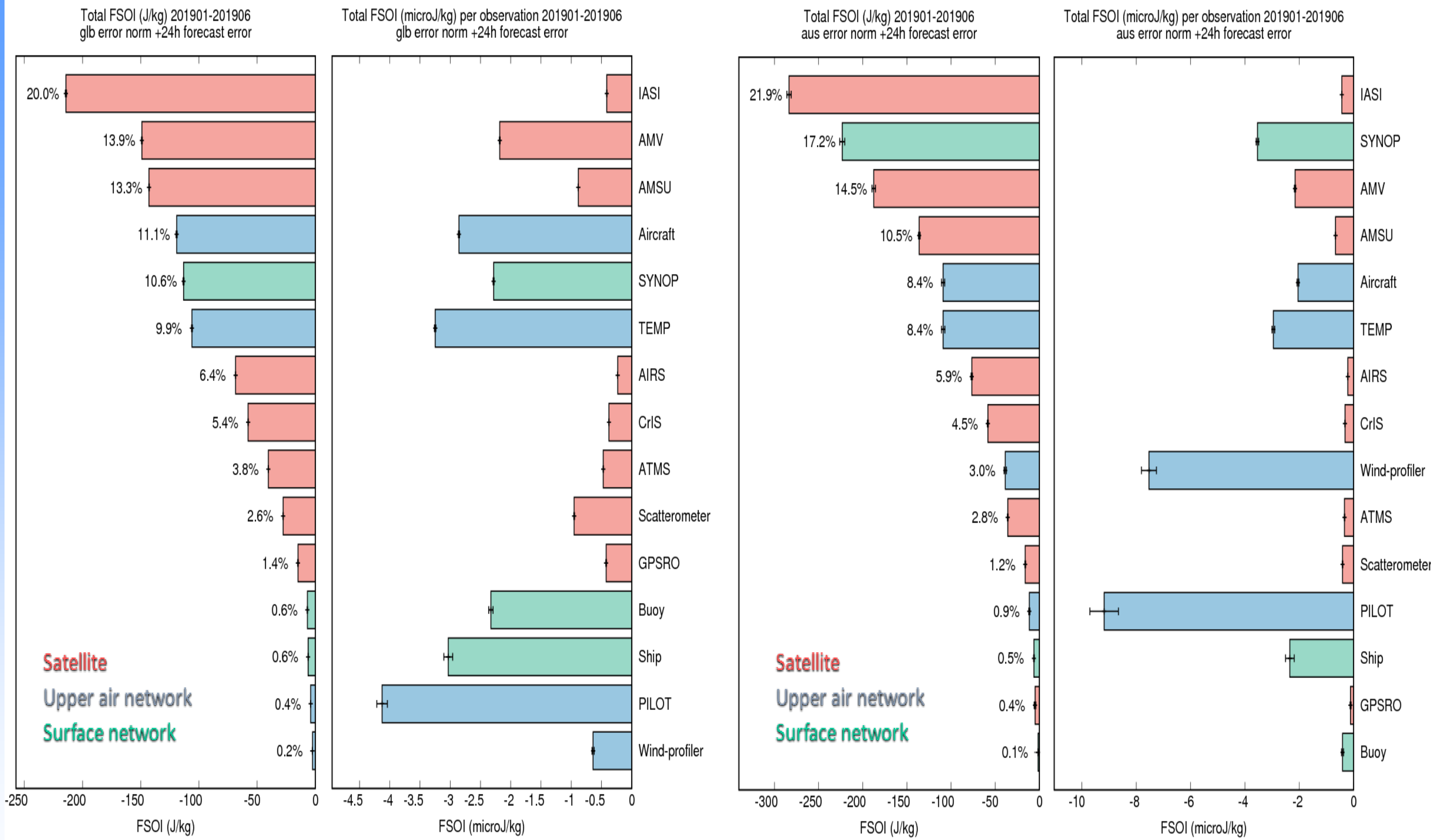








ACCESS APS2: Forecast Sensitivity to Observations



Current/Near Future Local Operational AMV Applications

Operational C3 1.5km Resolution Capital City Nested Model
Operational TC3 1.5 km Tropical Cyclone Nested Model.

Products for high resolution City/TC Model, low latency requirement (also for G3)

- 10 minute Himawari Ch14 AMVs (operational)
- 10 minute Himawari visible AMVs (in transition)
- 10 minute water vapour AMVs (tested, under trial for transition)
- (GEO-KOMPSAT 2A AMVs)

Summary and Conclusions

10-minute winds are being operationally continuously generated and assimilated in the Australian region with 4D Var at 12 and 1.5km resolution

H-8/9 10 minute AMVs have provided a necessary improved spatial and temporal resolution database for analysis and forecasting.

The quality of these higher spatial, temporal and spectral density data is of a level which renders them beneficial for NWP.

Local high spatial and temporal resolution winds are required in support of our 1.5 km high resolution operational analysis and forecast system and sometimes they are the only upper level wind data available for an analysis cycle.

Data assimilation tests have shown successful transfer of data into operations and successful use of the data by the NWP system.

Further quantification of the impact of these data in our current operational prediction systems is underway. This includes the use of all 10 minute data in the prediction of High Impact Weather and TC activity.

Future

Further improvement in the provision, use and error characterization of AMV data for NWP, at high temporal and spatial resolution.

Faster Processing to enable timely use of very high resolution data sets in high resolution NWP.

Stereo Processing to improve height assignment.

Optimisation of use of the AMV data in NWP in concert with other components of the database (such as clear wv radiances with 4DVar) at high temporal and spatial resolution.

…and finally