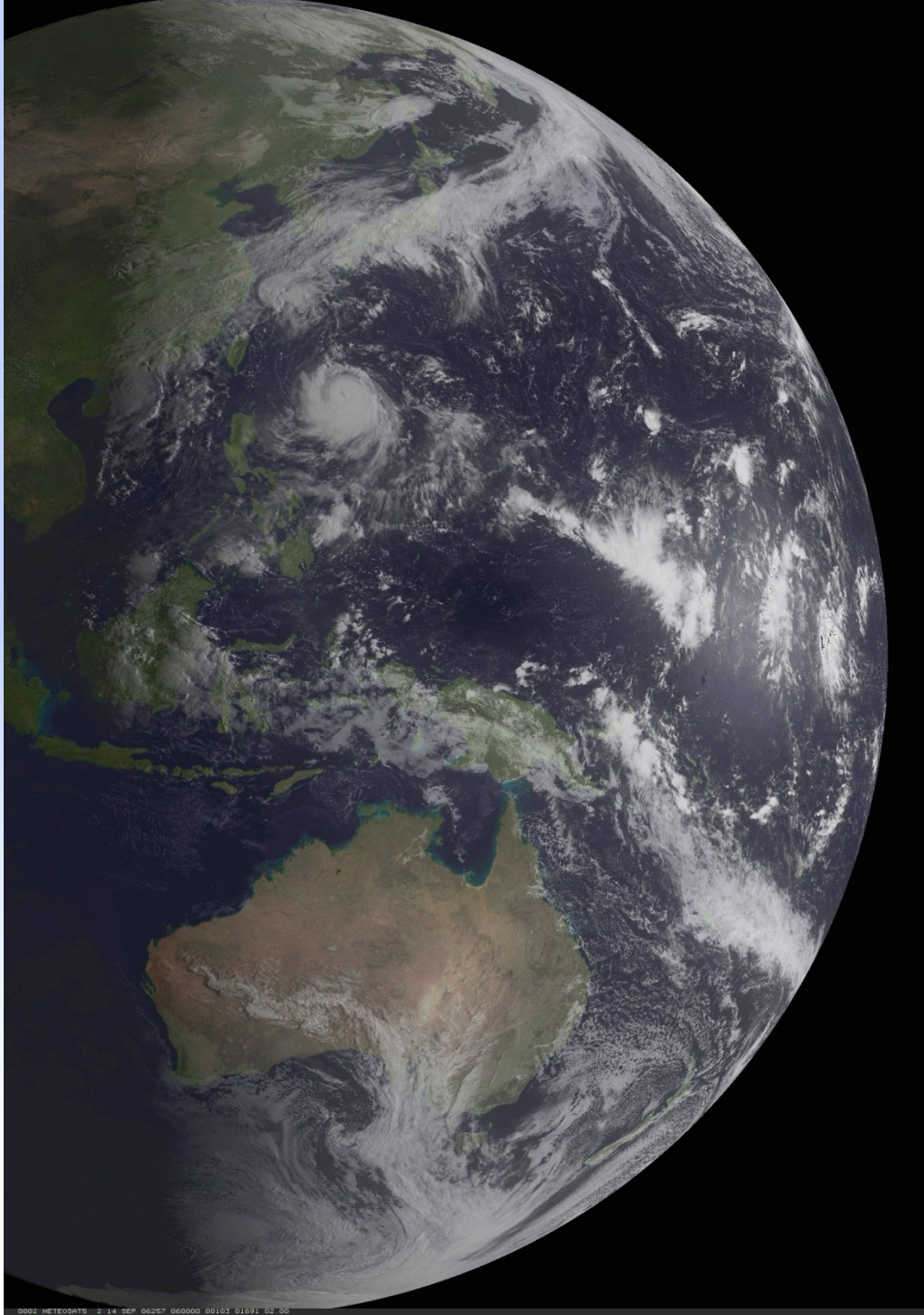
Australian Government
Bureau of Meteorology

Himawari-8 Derived Motion Winds - Operational Generation and Assimilation

John Le Marshall [1,5], David Howard[1], Yi Xiao[1], Jamie Daniels[2], Steve Wanzong[2], Jim Jung[3], Wayne Bresky[2], Andrew Bailey[2], Chris Tingwell[1], Paul Gregory[1], Tan Le[1], Tim Morrow[4] and Denis Margetic[1].

[1]Bureau of Meteorology, Australia, [2] NOAA/NESDIS USA, [3] JCSDA, Maryland,USA, [4]Melbourne University. [5]RMIT University



Overview

- Background/Introduction
- The Importance of Satellite Data (in the SH)
- The Challenge
- Atmospheric Motion Vectors - Himawari –7

  Himawari – 6 and 8
- Plans/Future Prospects
- Summary

The Importance of Satellite Data (in the SH)

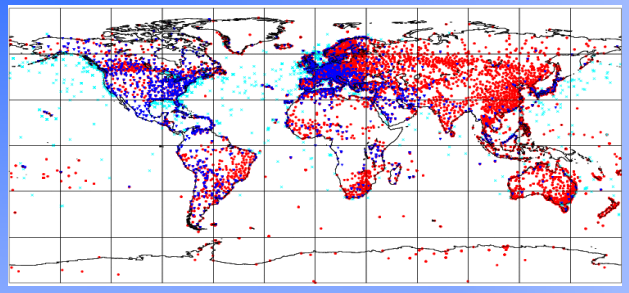
Observing System Experiments (OSEs)

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

SYNOPS AND SHIPS



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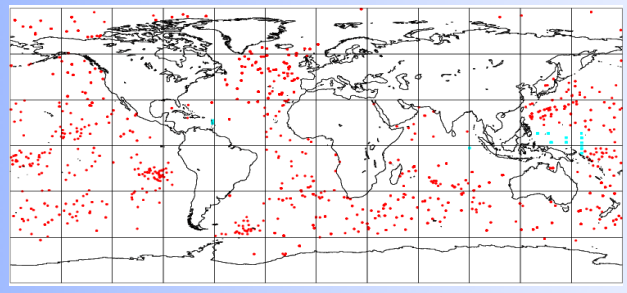

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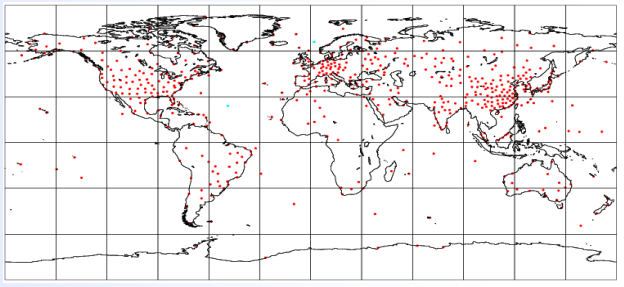
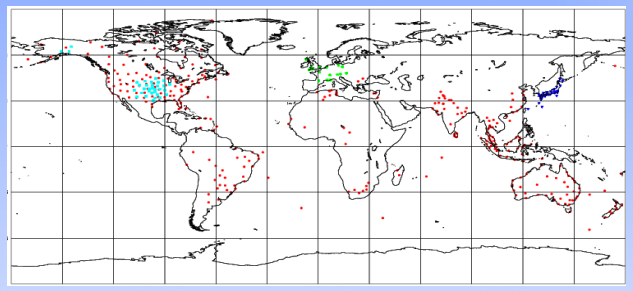


PILOTS AND PROFILERS



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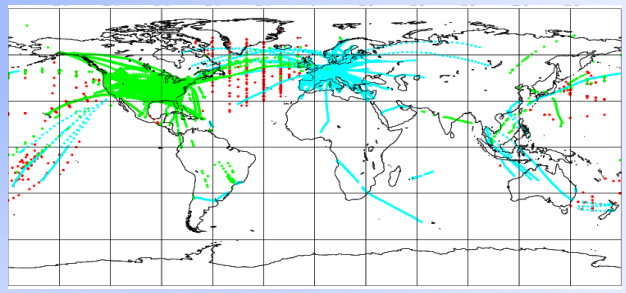
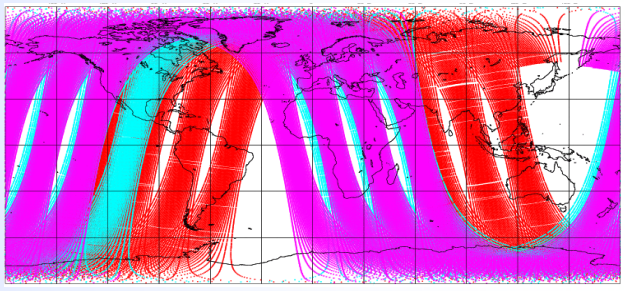
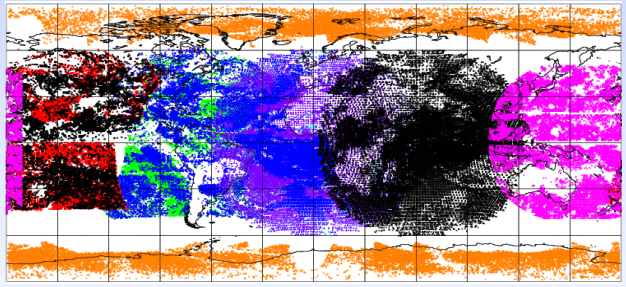


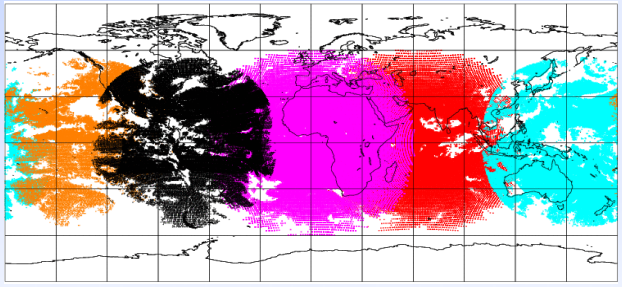
IR AND MW SOUNDERS



SATELLITE WINDS



WATER-VAPOUR RADIANCES



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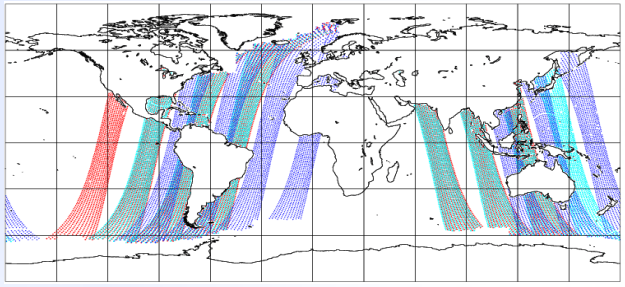

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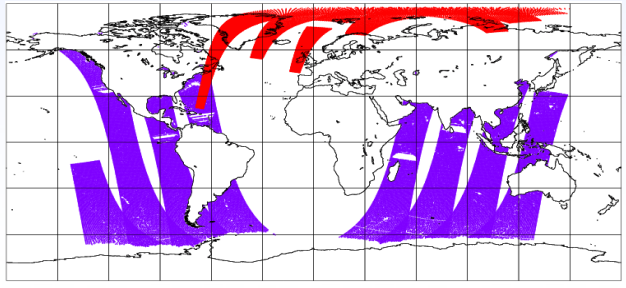

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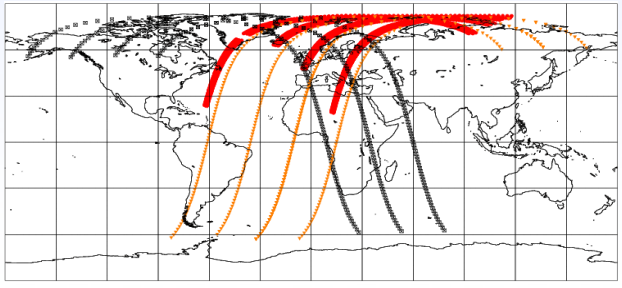

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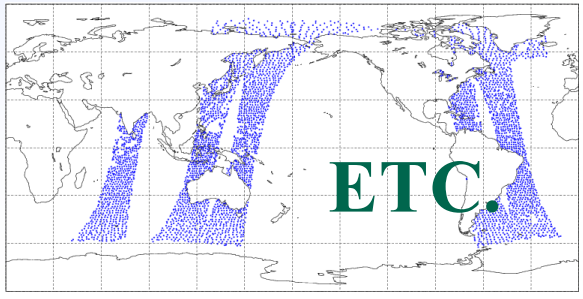


Issue time 23UTC 20 Sep 2012

Earth observations From Space

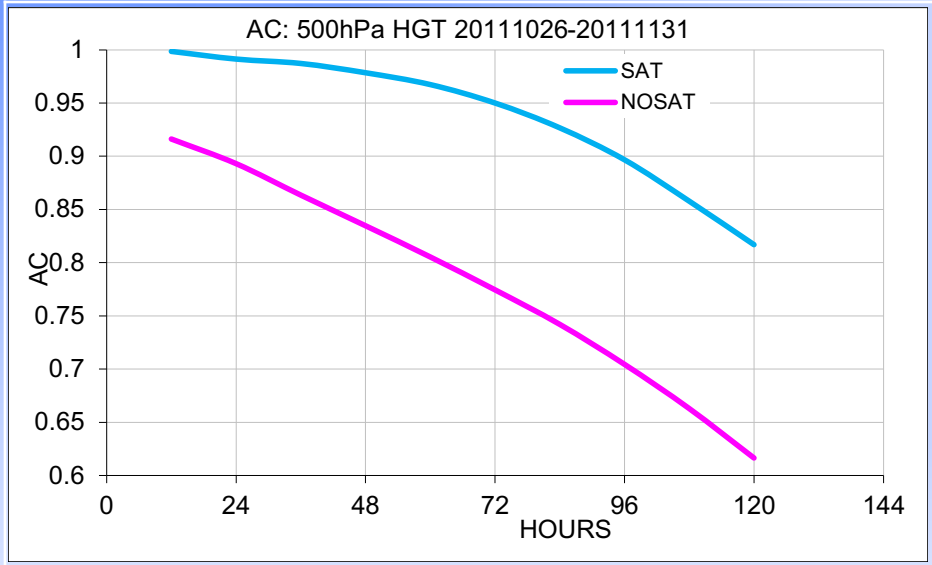


Fig. 8(c). SH 500hPa height anomaly correlation for the control (SAT) and no satellite (NOSAT), 28 October to 30 November 2011 using ACCESS and verifying against the control analysis

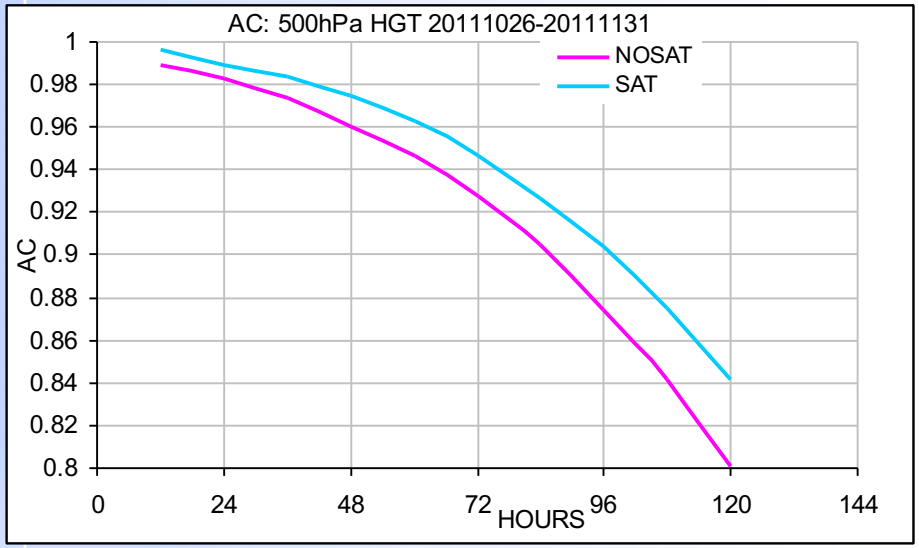


Fig. 8(f). NH 500hPa height anomaly correlation for the control (SAT) and no satellite (NOSAT), 28 October to 30 November 2011 using ACCESS and verifying against the control analysis

Earth observations From Space

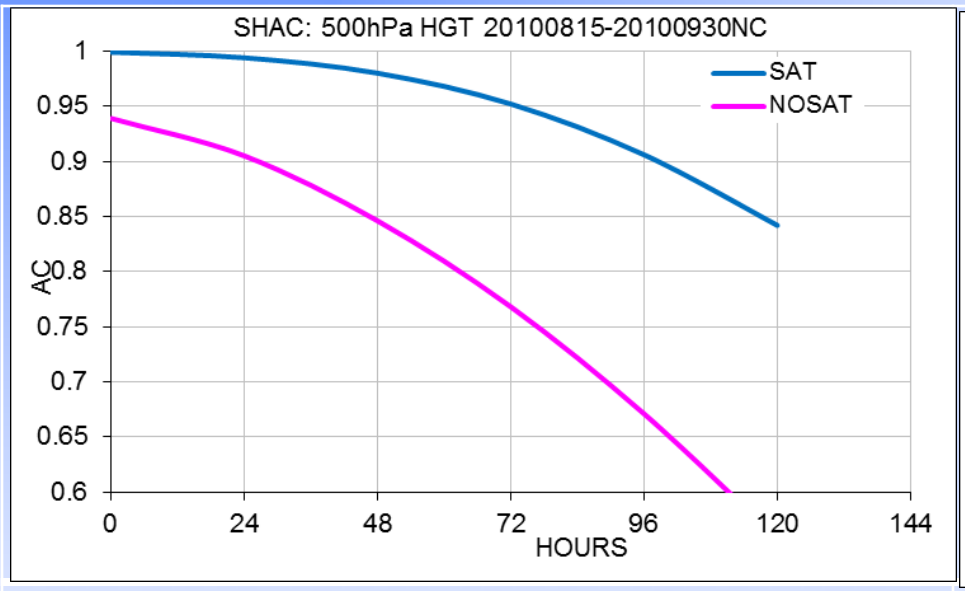


Fig. 8(g). SH 500hPa height anomaly correlation for the control (SAT) and no satellite (NOSAT), 15 August to 30 September 2010 using GFS and verifying against the control analysis

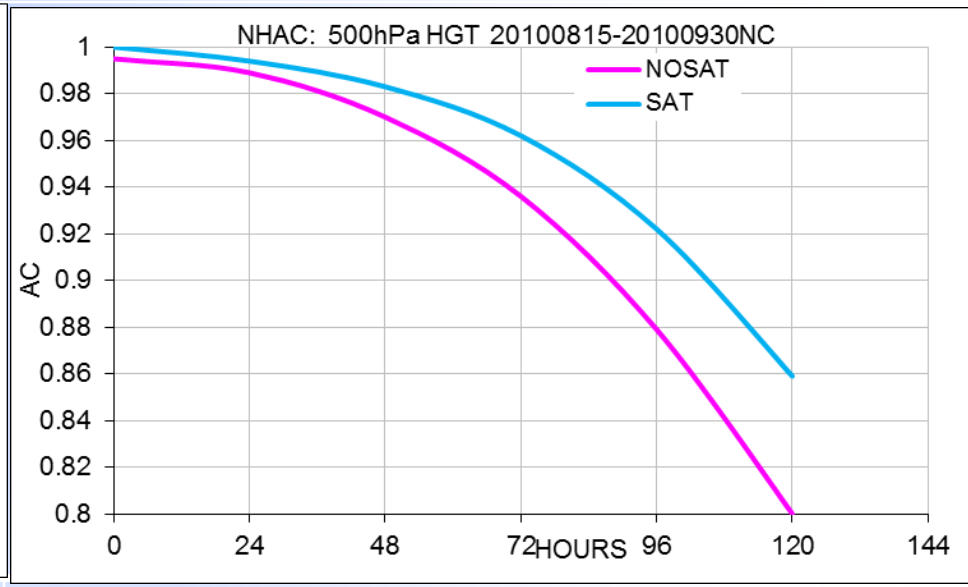
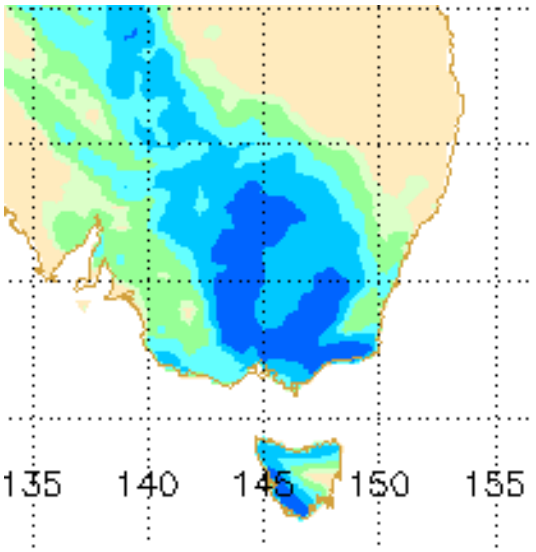
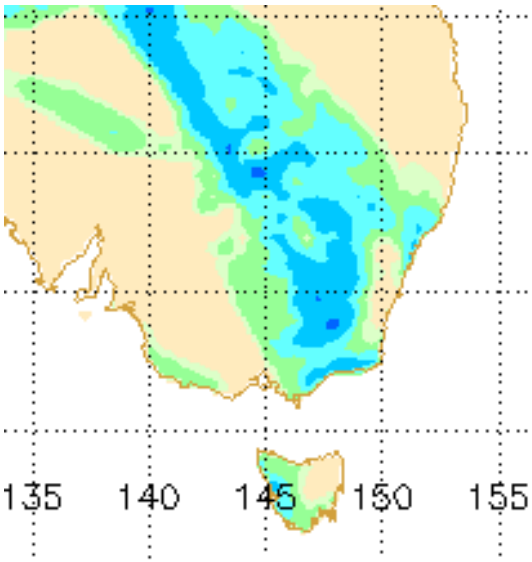


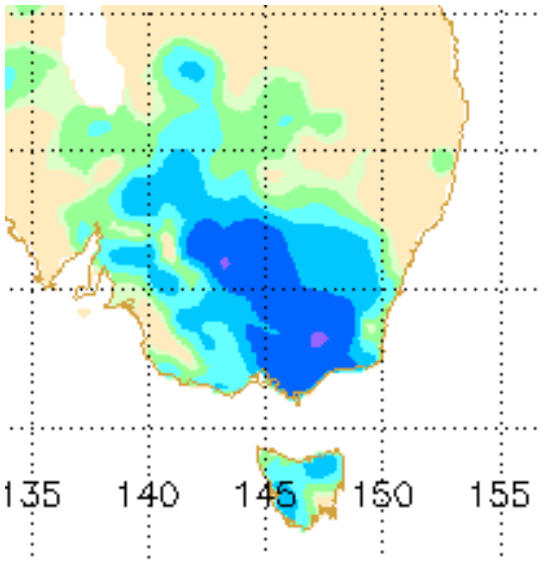
Fig. 8(hNH 500hPa height anomaly correlation for the control (SAT) and no satellite (NOSAT), 15 August to 30 September 2010 using the GFS and verifying against the control analysis



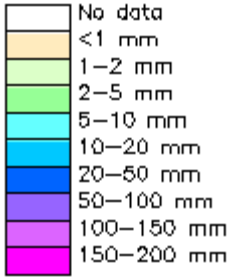
ACCESS-G 48 to 72 hour rainfall forecast for 9 November 2011 using satellite data.



ACCESS-G 48 to 72 hour rainfall forecast for 9 November 2011 using no satellite data.

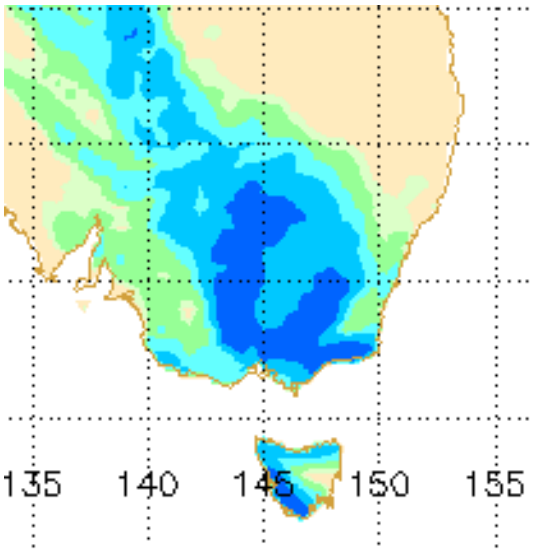


Daily rain gauge analysis for 9 November 2011.

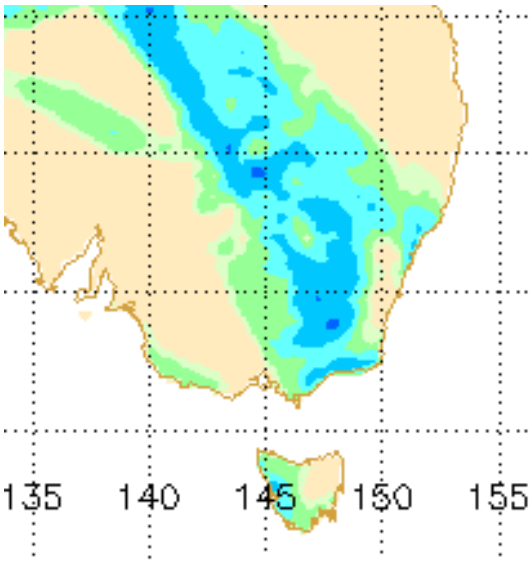


Daily rainfall values.

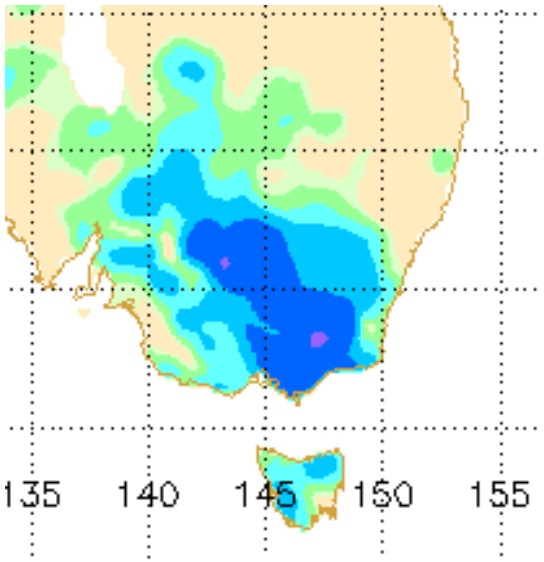
Extreme Weather



ACCESS-G 48 to 72 hour rainfall forecast for 9 November 2011 using satellite data.

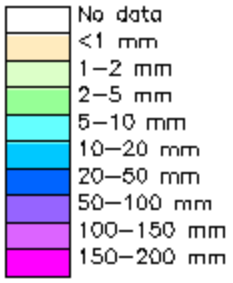


ACCESS-G 48 to 72 hour rainfall forecast for 9 November 2011 using no satellite data.



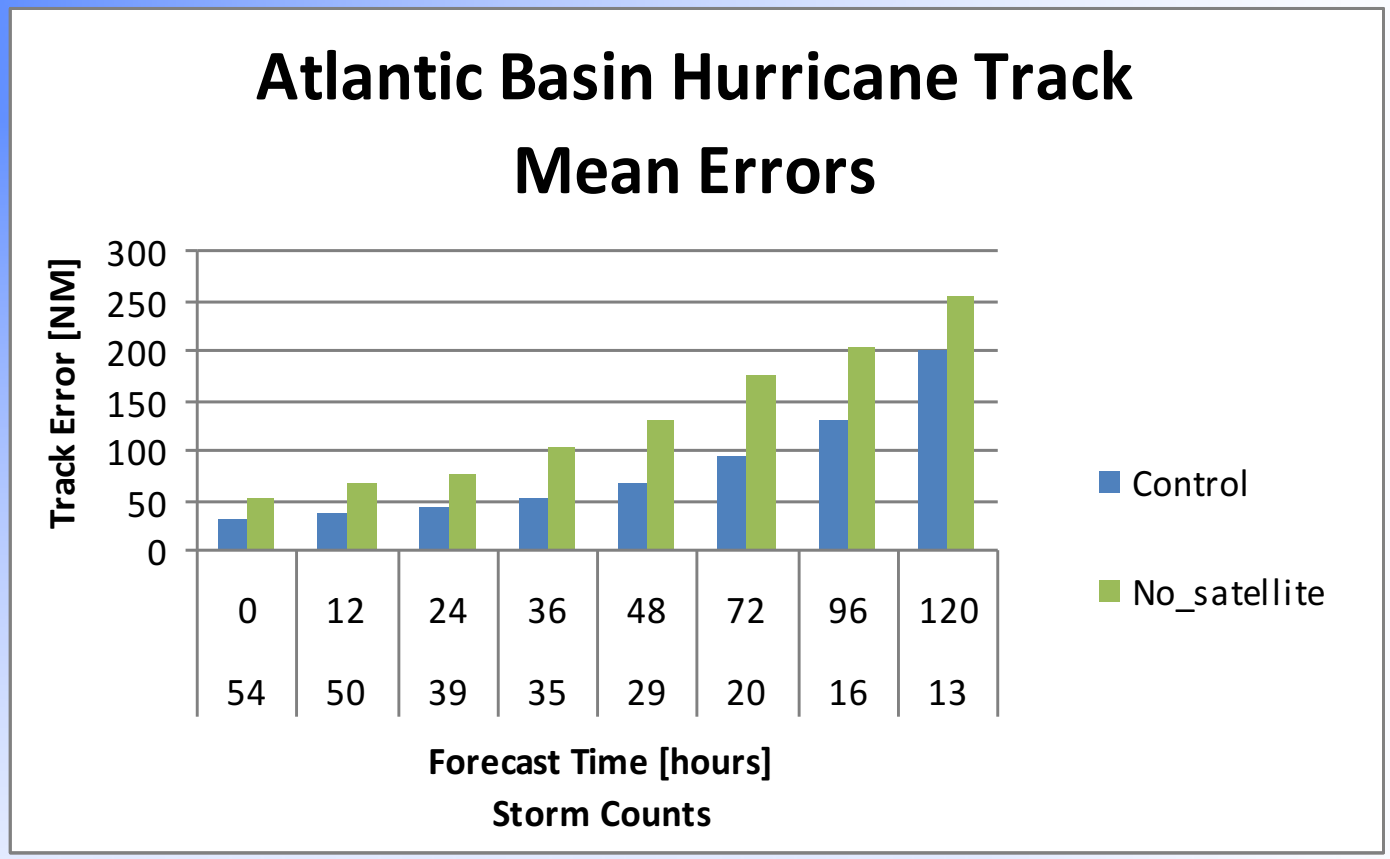
Daily rain gauge analysis for 9 November 2011.

9 November 2011	NOSAT	SAT
Correlation between observed and forecast rainfall (Aust. Region)	0.282	0.699
Hanssen and Kuipers (Aust. Region)	0.360	0.596



Daily rainfall values.

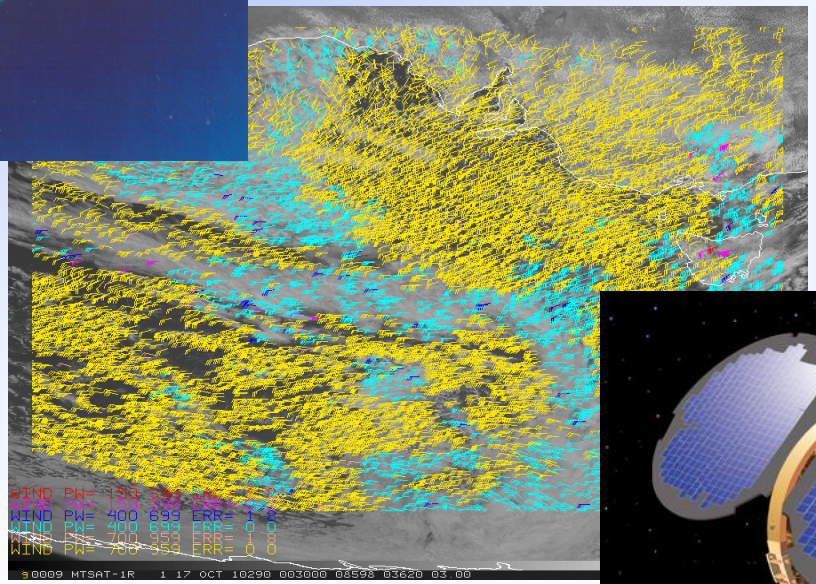
Table 1. ACCESS-G verification statistics for all of Australia for the month of November 2011 for forecasts produced with (SAT) and without (NOSAT) satellite data		
1 – 30 November 2011 (72-96 hrs)	**NOSAT**	**SAT**
Correlation between observed and forecast rainfall (Full Aust. Region)	0.25	0.41
Hanssen and Kuipers (Full Aust. Region)	0.36	0.51



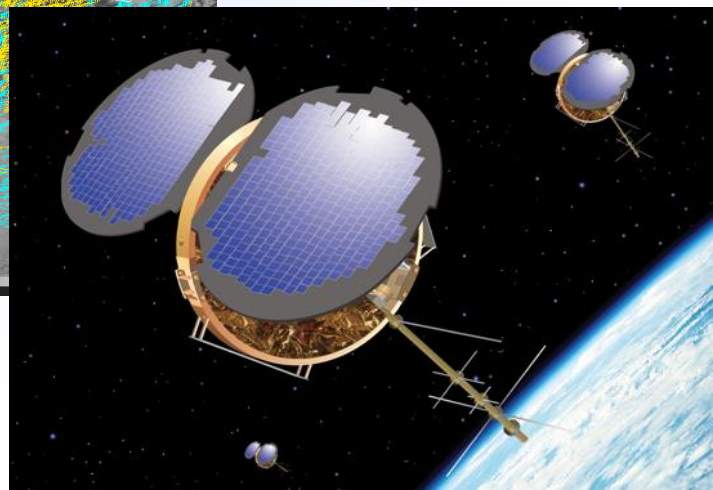
Atlantic basin mean hurricane track errors for the control (all data) and no satellite data case, 15 August to 30 September 2010 using GFS and verifying against the control (all data) analysis.

Three Key Observations Types

AMVs



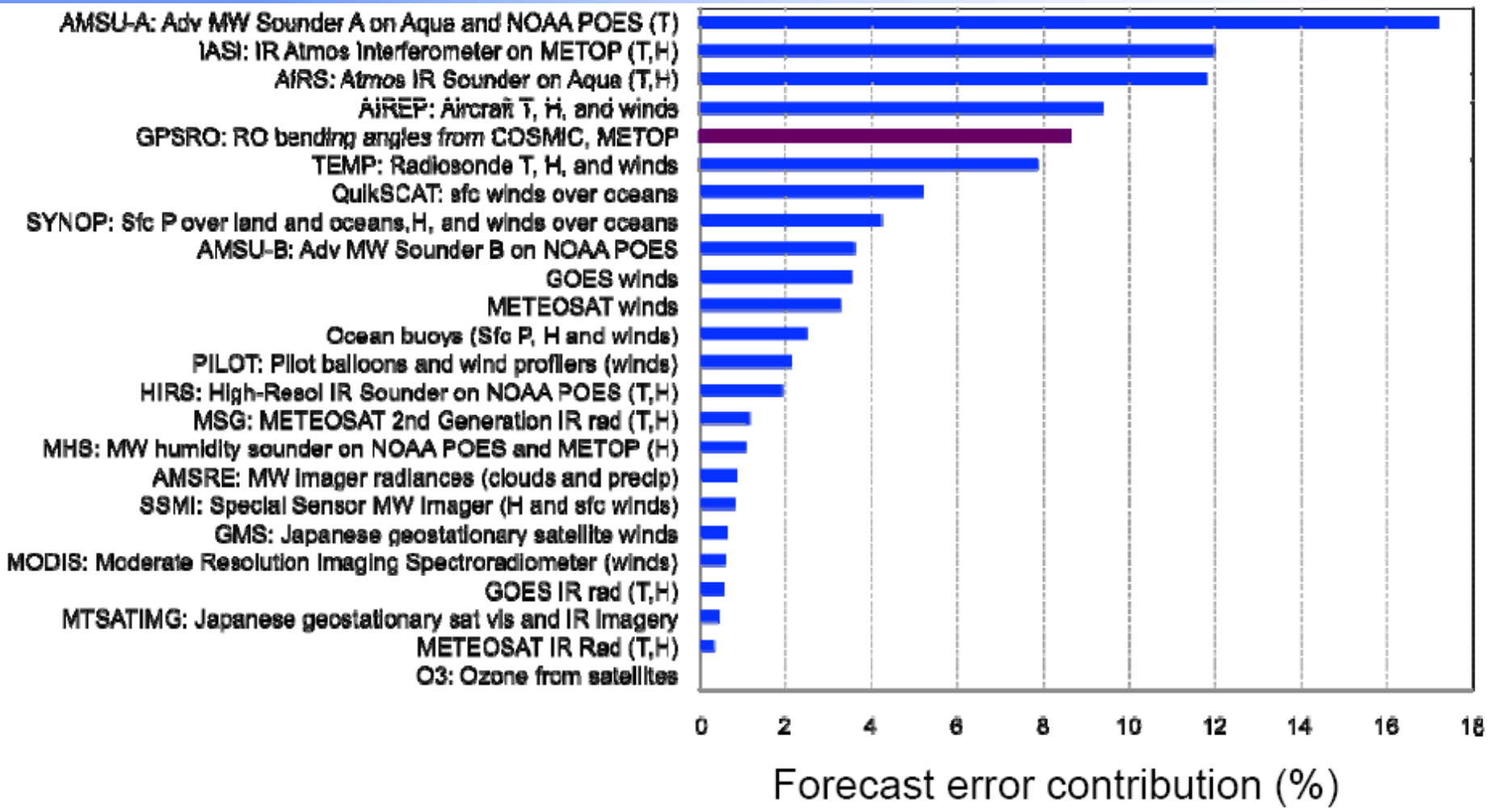
GPS RO



Ultraspectral
Advanced Sounders

AIRS
IASI
CrIS

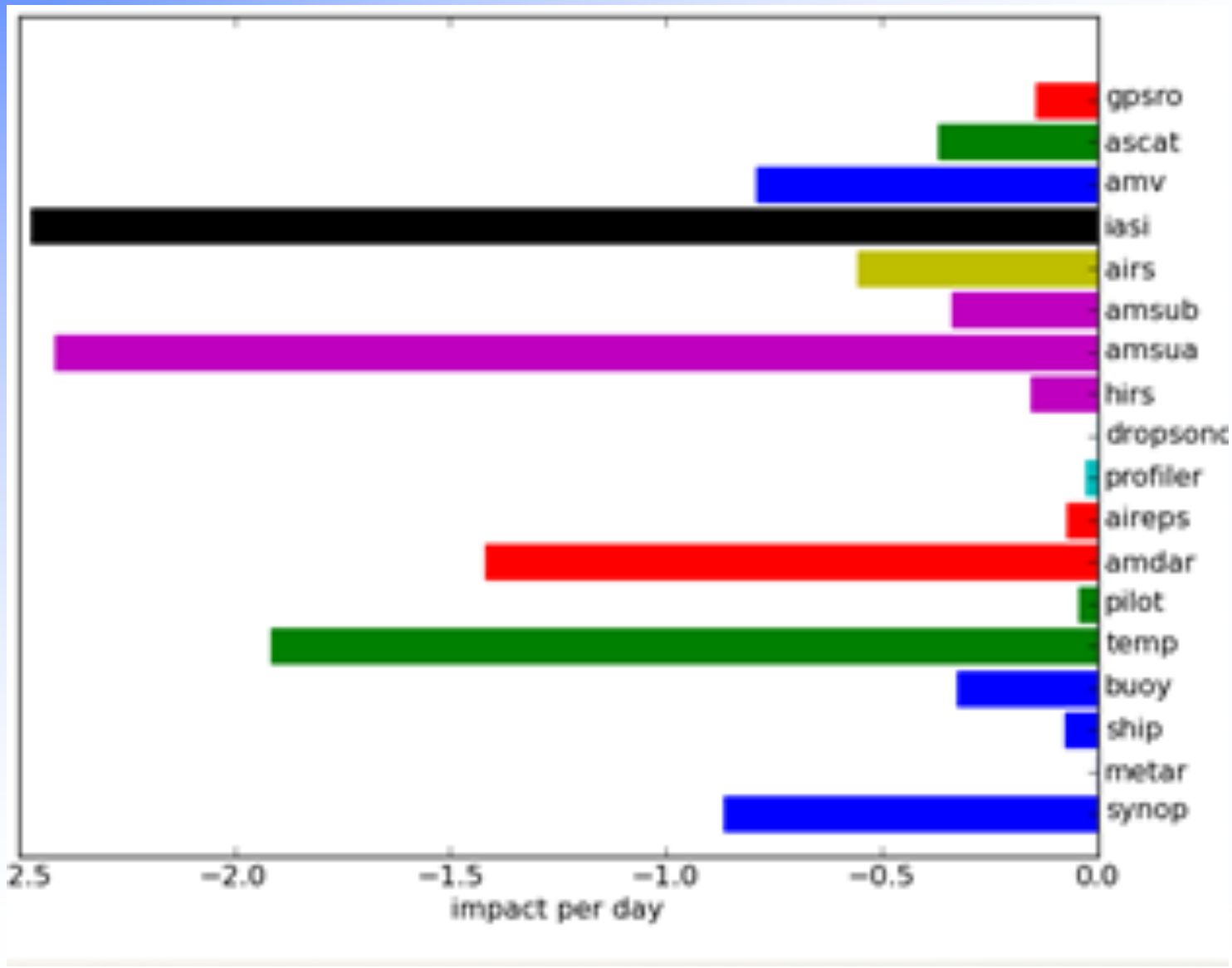
Operational ECMWF system September to December 2008. Averaged over all model layers and entire global atmosphere. % contribution of different observations to reduction in forecast error.

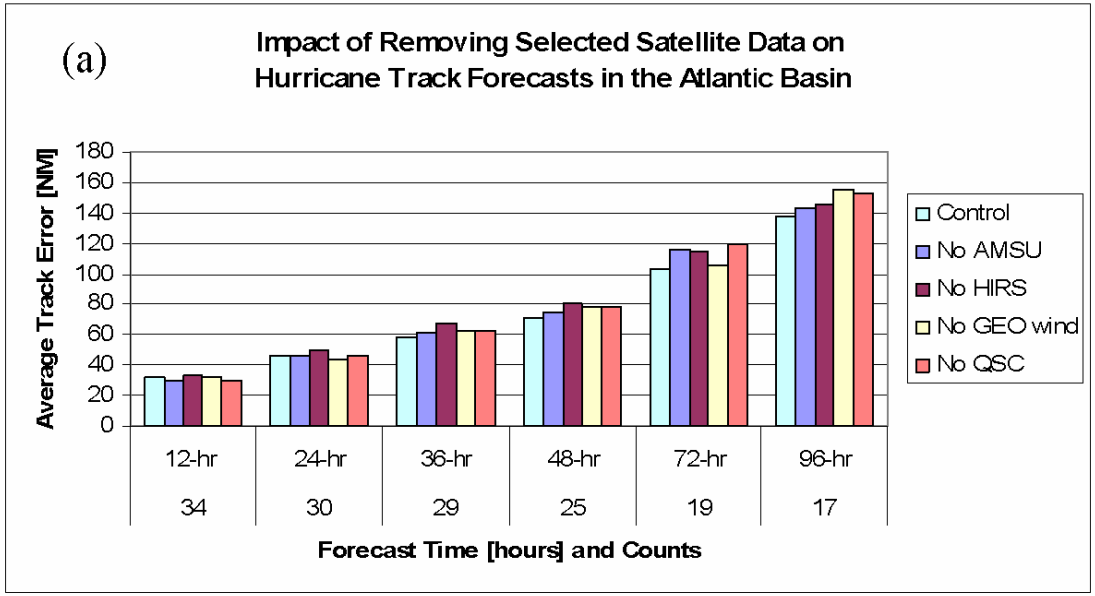


Advanced Sounders have largest single instrument impact in reducing forecast errors.

Courtesy: Carla Cardinali and Sean Healy, ECMWF 22 Oct. 2009

IMPACT PER DAY





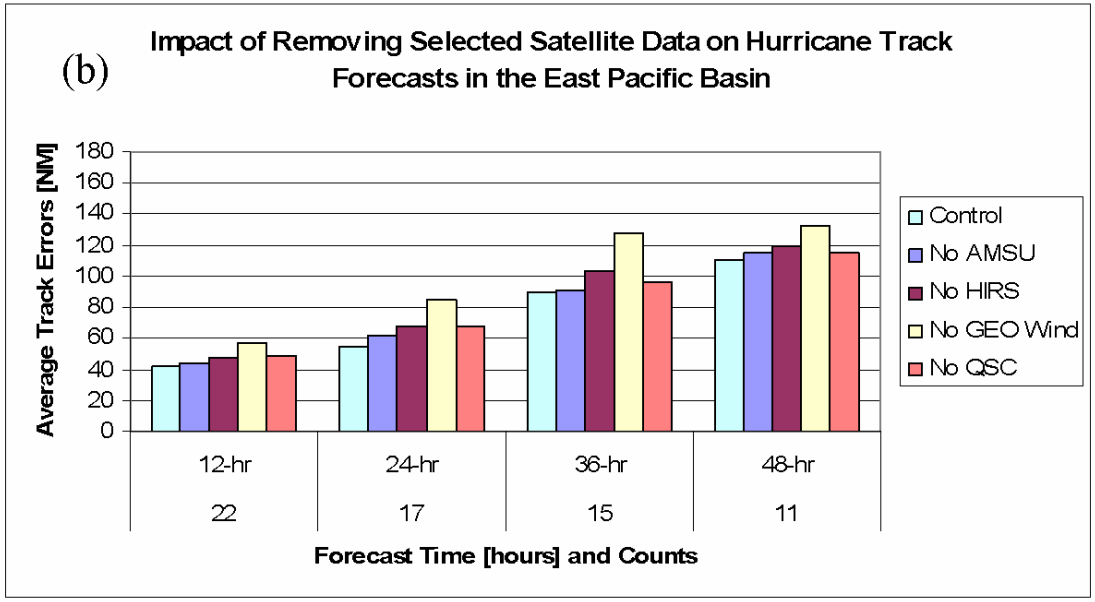


Fig. 10. Average track error (NM) by forecast hour for the control simulation and experiments where AMSU, HIRS, GEO winds and QuikSCAT were denied. The Atlantic Basin results are shown in (a), and the Eastern Pacific Basin results are shown in (b). A small sample size in the number of hurricanes precludes presenting the 96 hour results in the Eastern Pacific Ocean.

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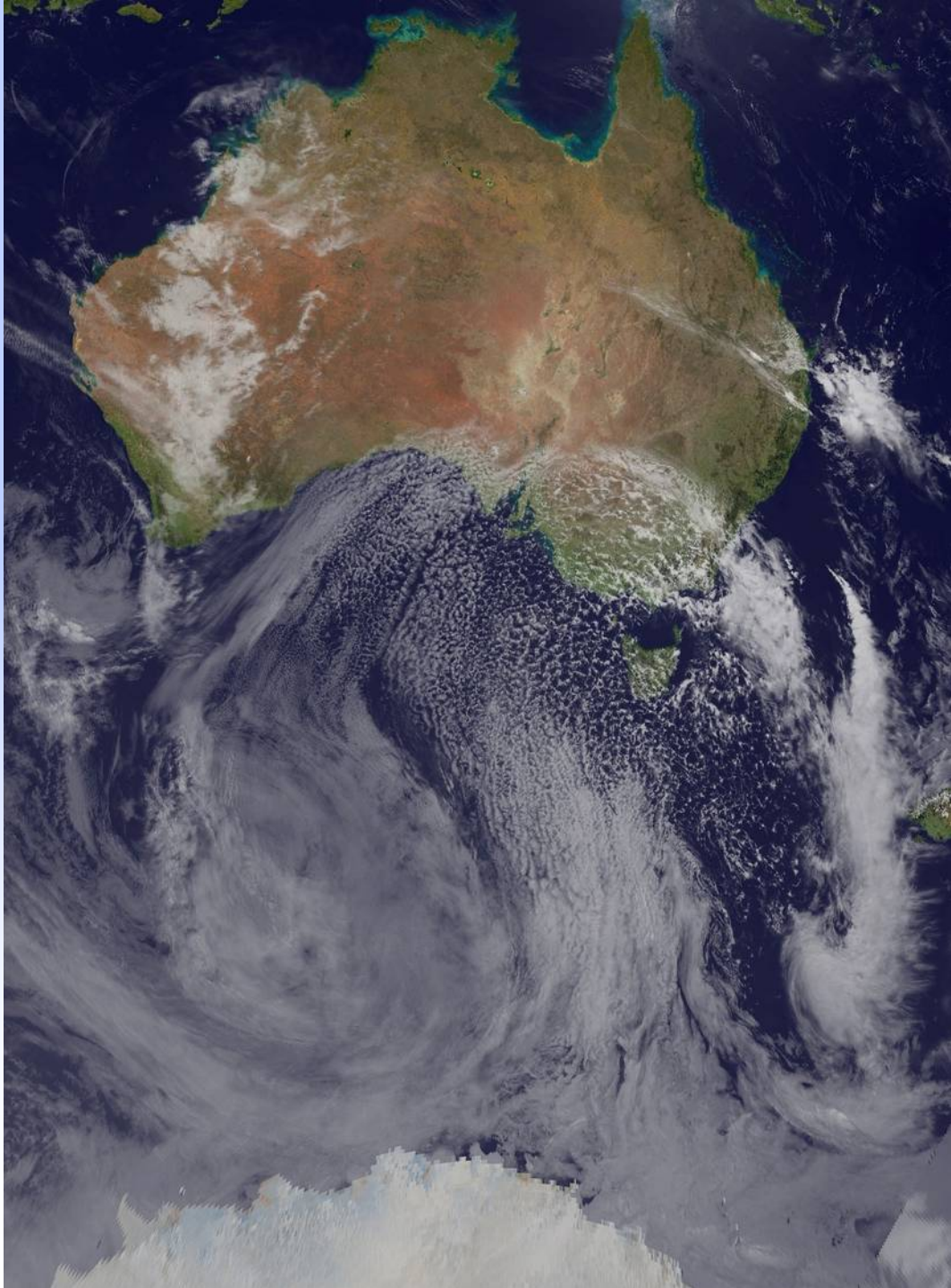
THE GENERATION AND ASSIMILATION OF CONTINUOUS (HOURLY) ATMOSPHERIC MOTION VECTORS WITH 4DVAR



MTSaT-1R/2 Operational AMV Generation

Uses 3 images separated by 15, 30 or 60 min.

Uses H_20 intercept method for upper level AMVs (Schmetz et al., 1993) or Window Method.

Uses cloud base assignment for lower level AMVs (Le Marshall et al. 1997) or Window Method

Q.C. via EE, QI, ERR, RFF etc.

No autoedit

Height assignment verification/development uses Cloudsat/Calipso, RAOBS

Table 1. Real time schedule for SH MTSat-1R Atmospheric Motion Vectors at the Bureau of Meteorology. Sub-satellite image resolution, frequency and time of wind extraction and separations of the image triplets used for wind generation (ΔT) are indicated.

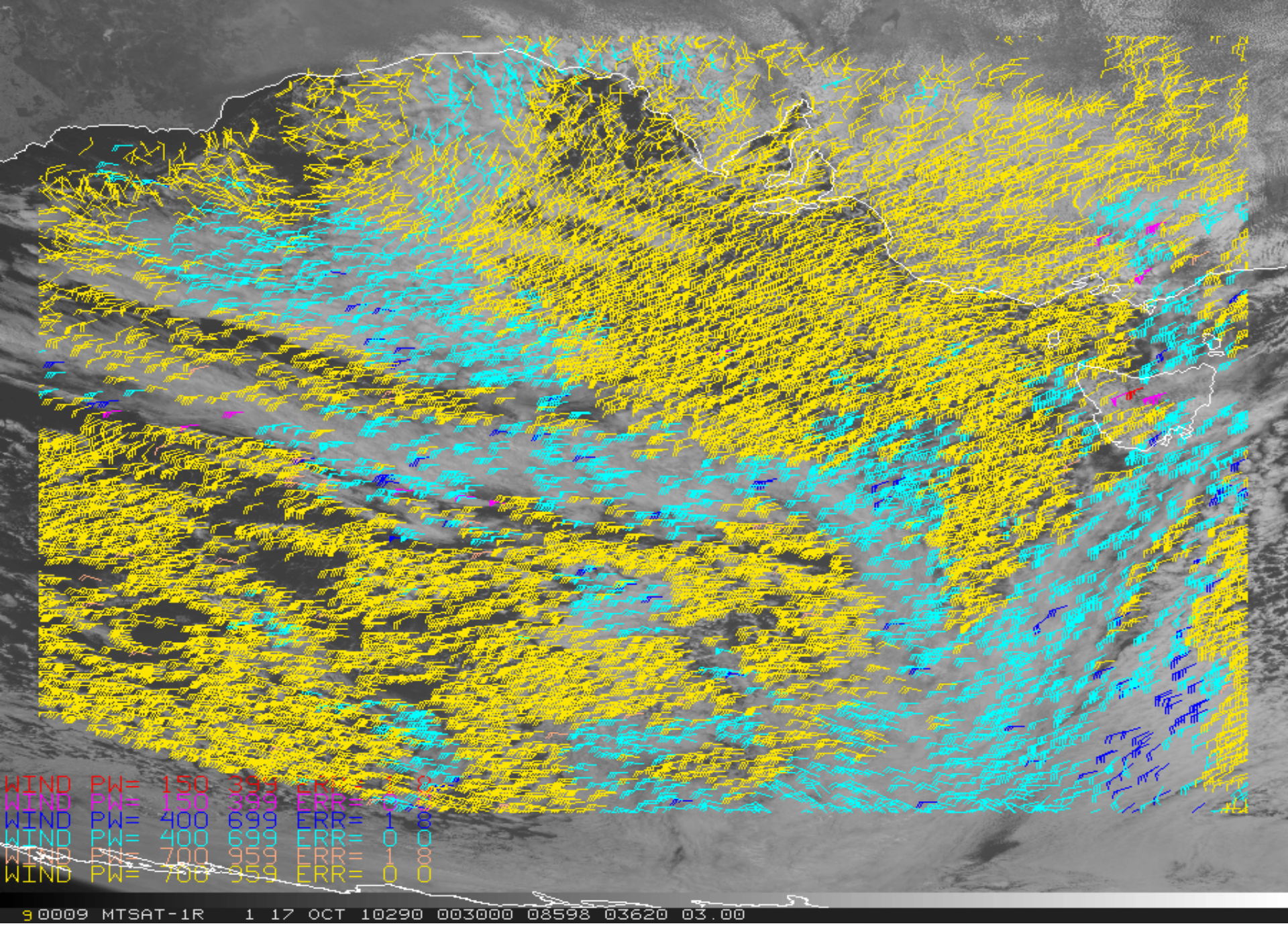
Wind Type	Resolution	Frequency-Times (UTC)	Image Separation
Real Time IR/VIS*	4 km	6-hourly – 00, 06, 12, 18	15 minutes
Real Time IR/VIS* (hourly)	4 km	Hourly – 00, 01, 02, 03, 04, 05, . . . , 23	1 hour

*daytime

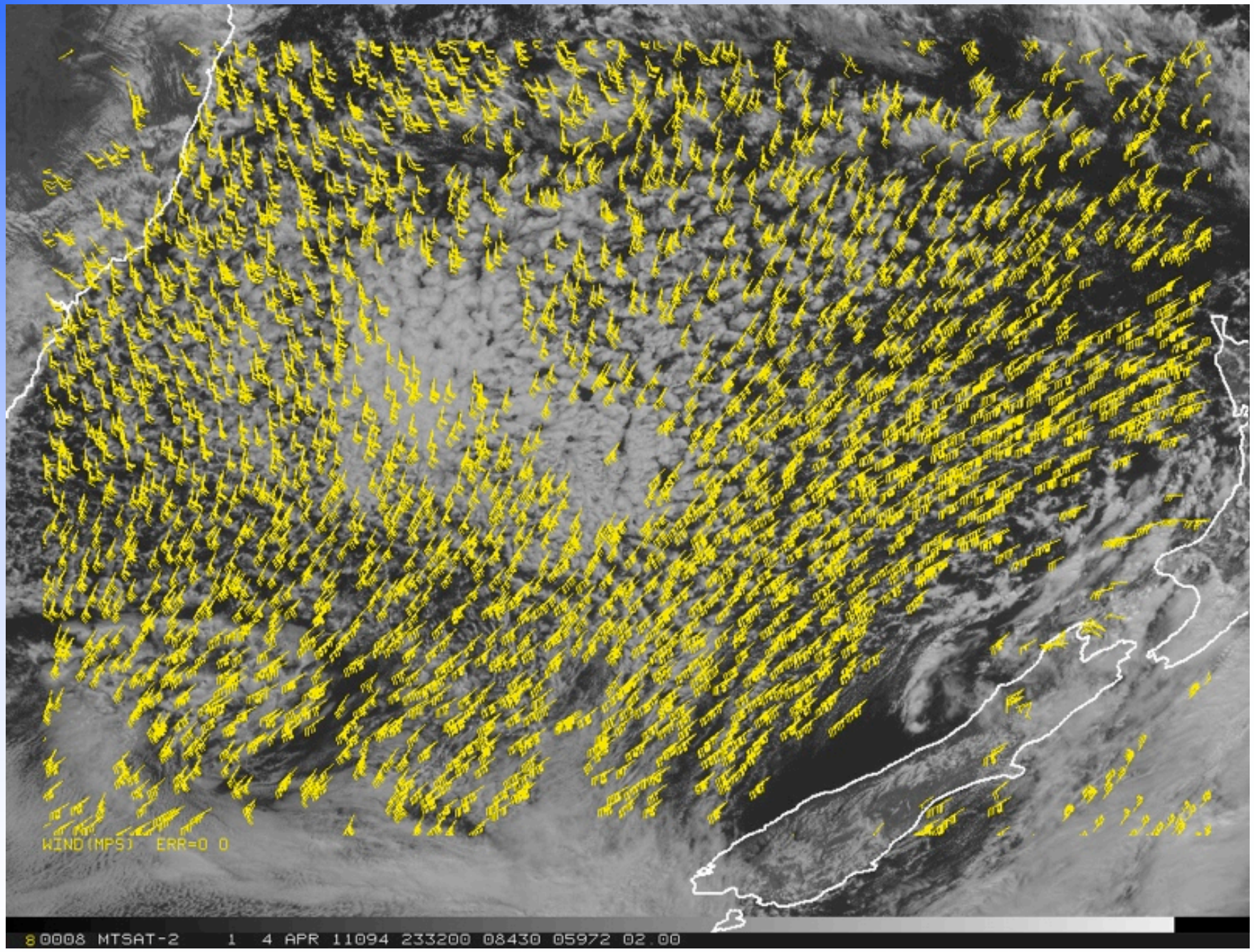
Part of the schedule for Southern Hemisphere wind generation from MTSAT-1R images. This part provides 26 Infrared Channel (IR1) based wind data sets, 24 High Resolution Visible (HRV) image and 4 Water Vapour (WV) image based data sets from the full disc and northern hemisphere images listed.

DATE	HHMM 1	HHMM 2	HHMM 3	IR1	HRV	WV
16 June 2008	2230	2330	0030			
16 June 2008	2330	2357	0013			
16 June 2008	2357	0013	0030			
17 June 2008	0030	0130	0230			
17 June 2008	0130	0230	0330			
17 June 2008	0230	0330	0430			
17 June 2008	0330	0430	0530			
17 June 2008	0430	0530	0630			
17 June 2008	0530	0557	0613			
17 June 2008	0557	0613	0630			
17 June 2008	0630	0730	0830			
17 June 2008	0730	0830	0930			
17 June 2008	0830	0930	1030			

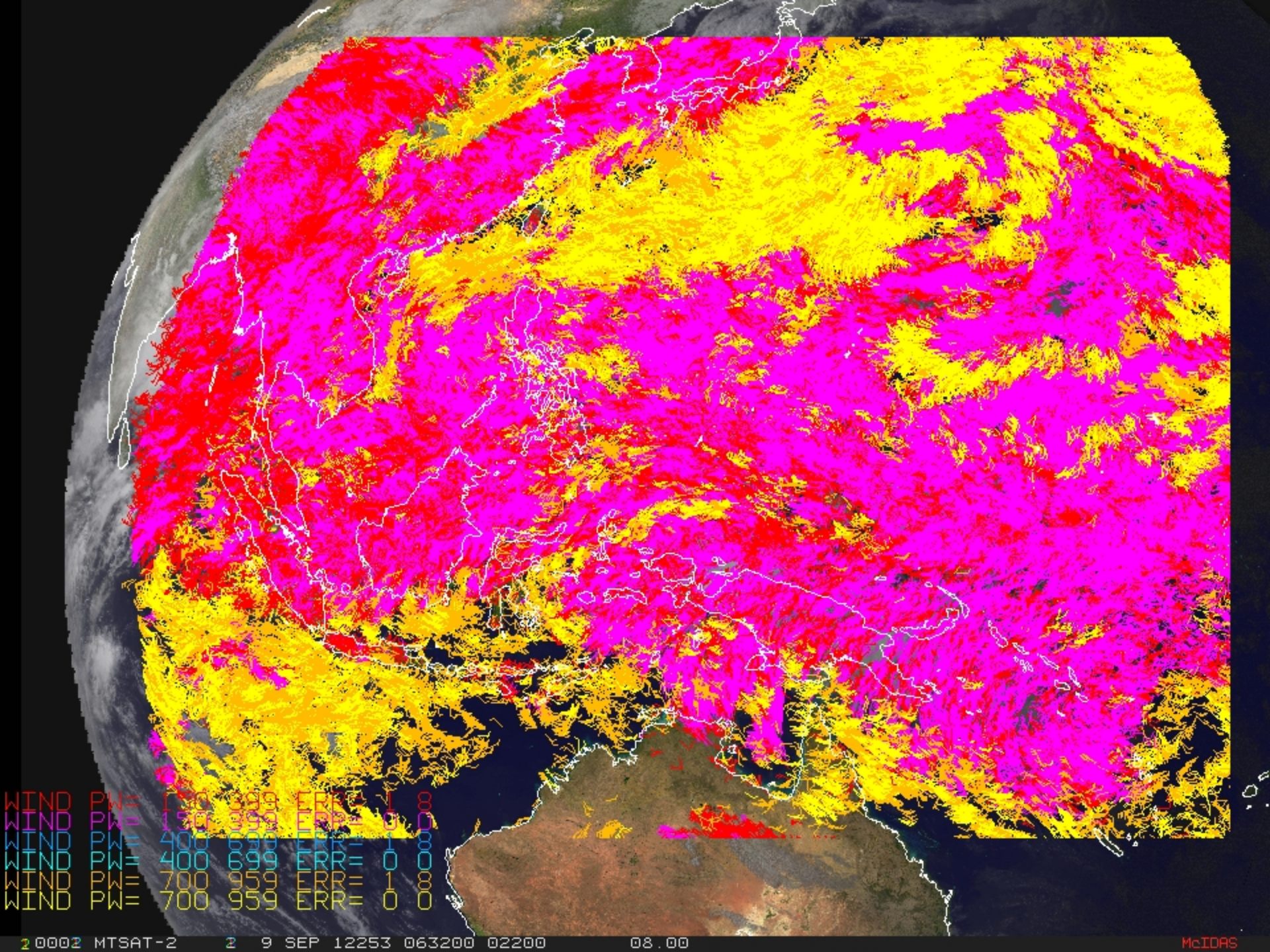
Full Disc Image
Southern Hemisphere Image



MTSat-1R VIS AMVs generated around 00 UTC on 17 October 2010.



MTSAT-2 IR and VIS AMVs generated over the Tasman Sea around 00 UTC on 5April 2011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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
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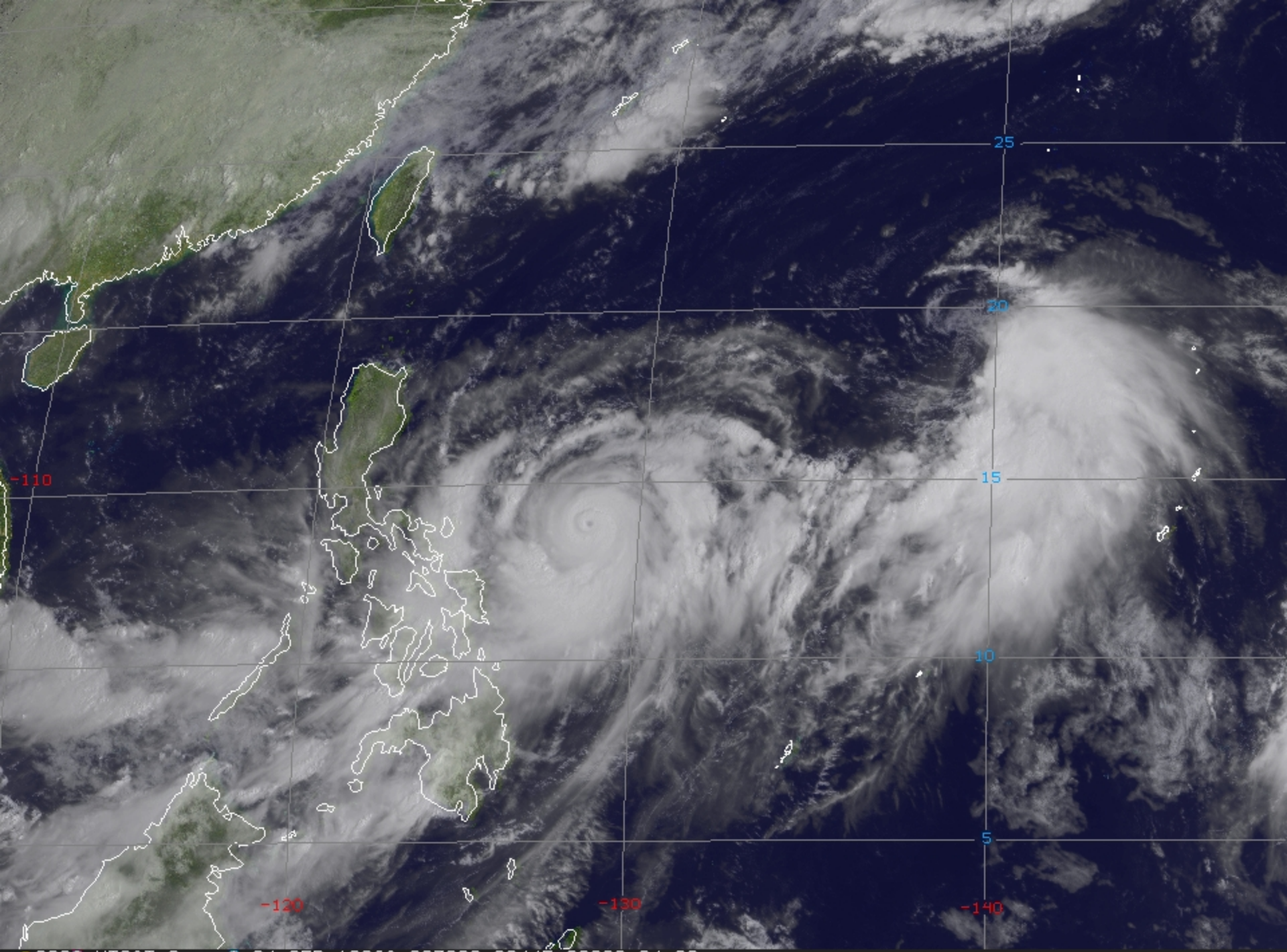
McIDAS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15
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-110
-120
-130
-140
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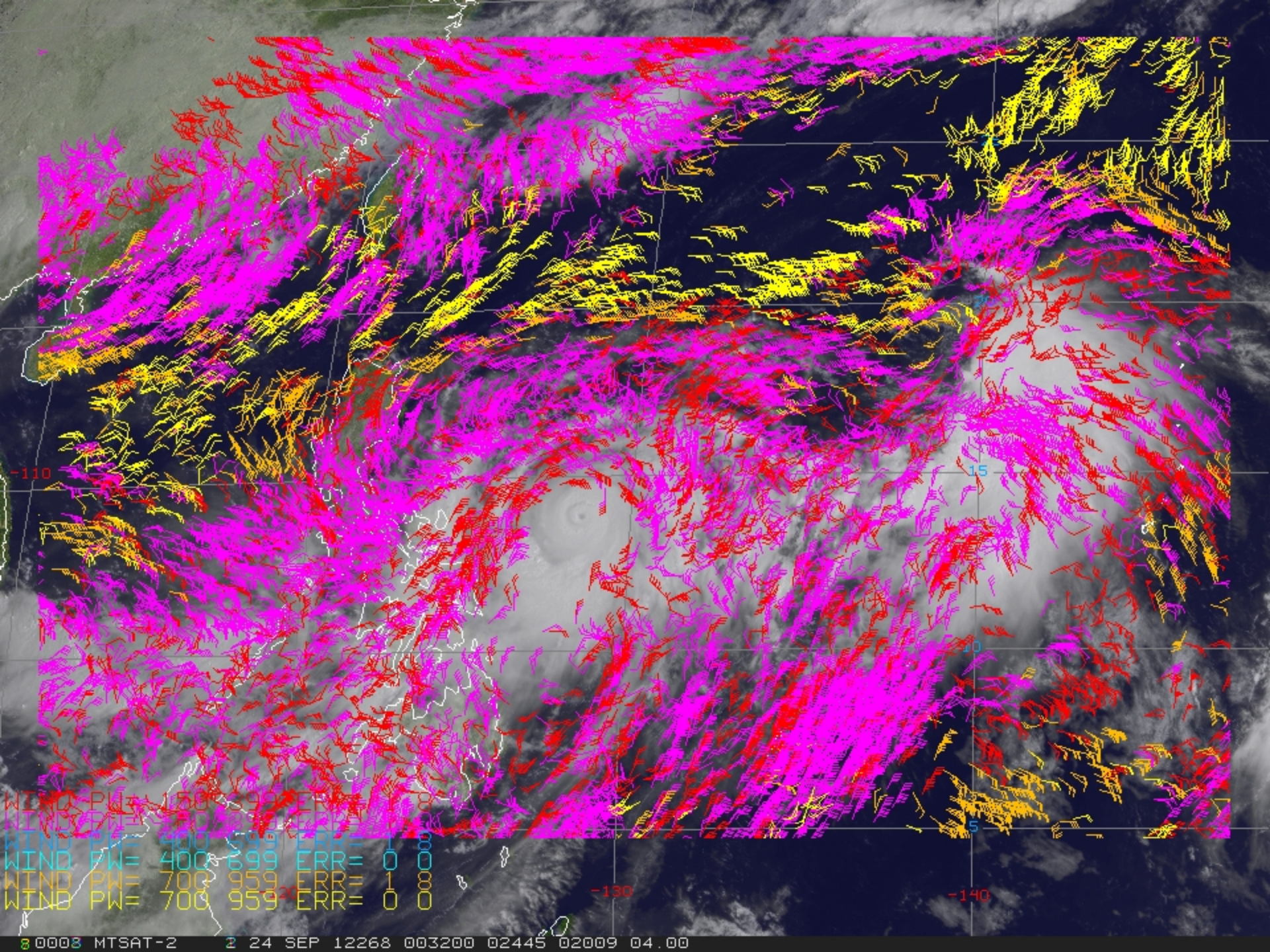
-110
15
10
5
-130
-140
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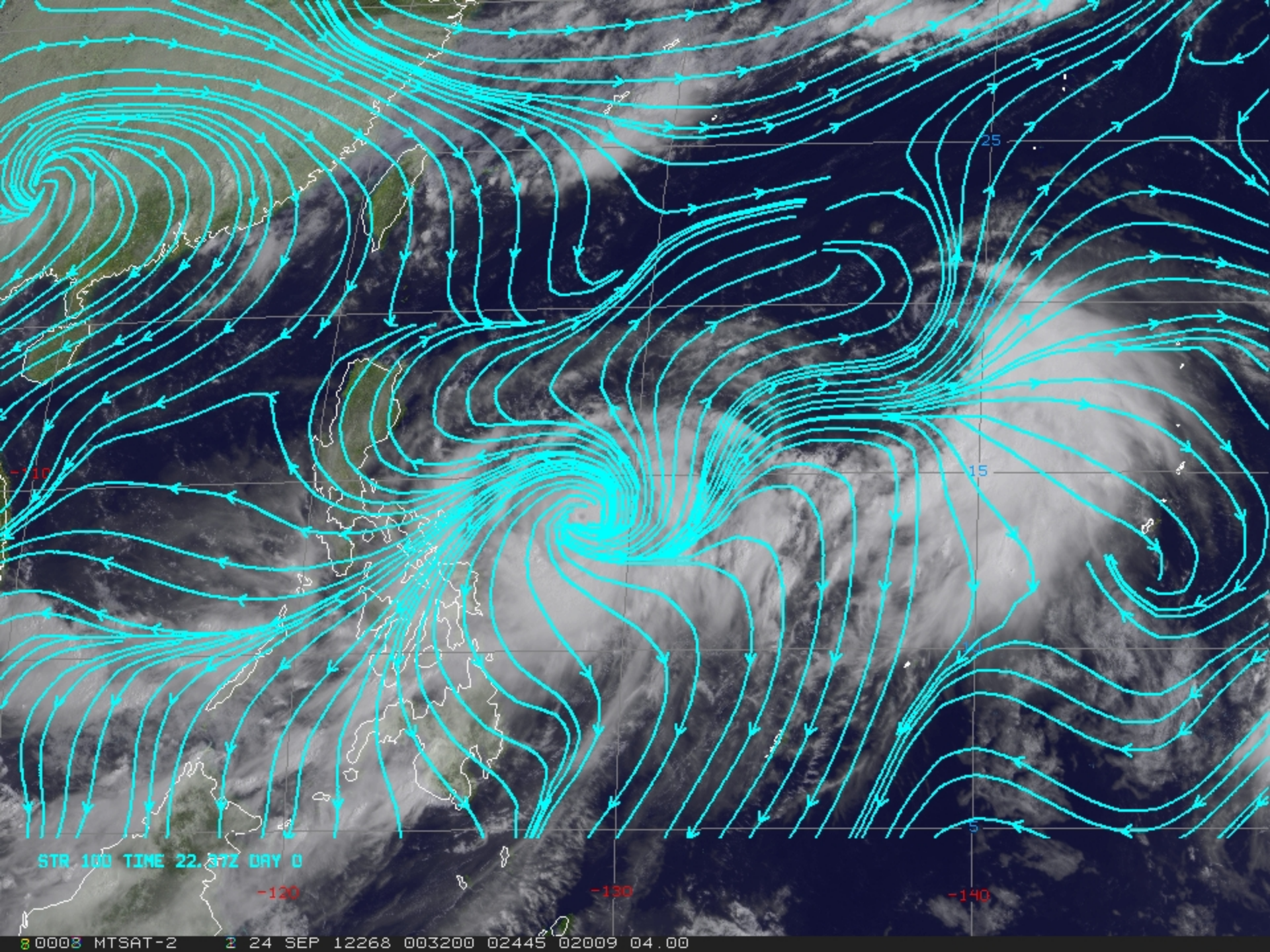
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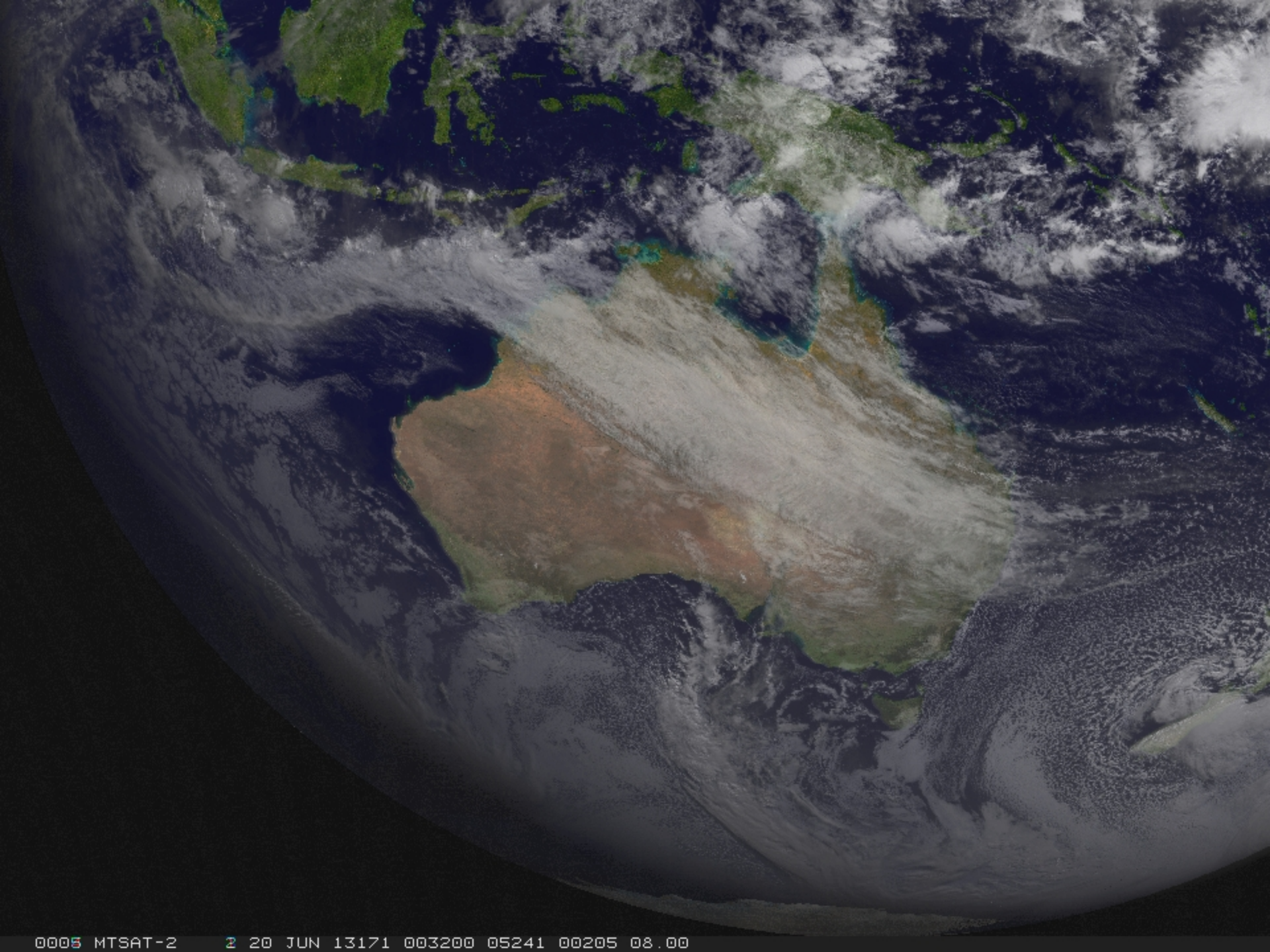
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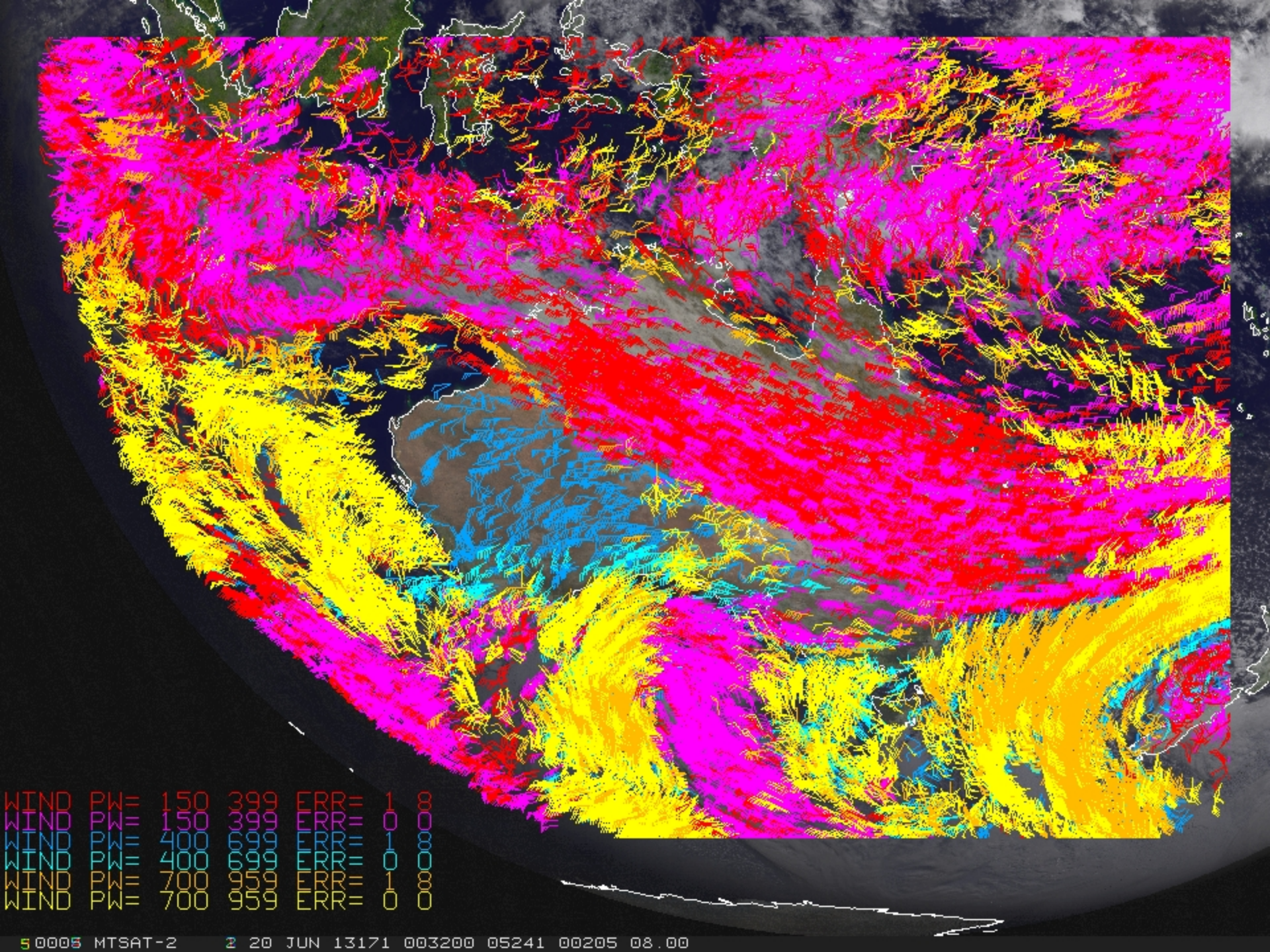
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WIND PW= 400 699 ERR= 0 0
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WIND PW= 700 959 ERR= 0 0
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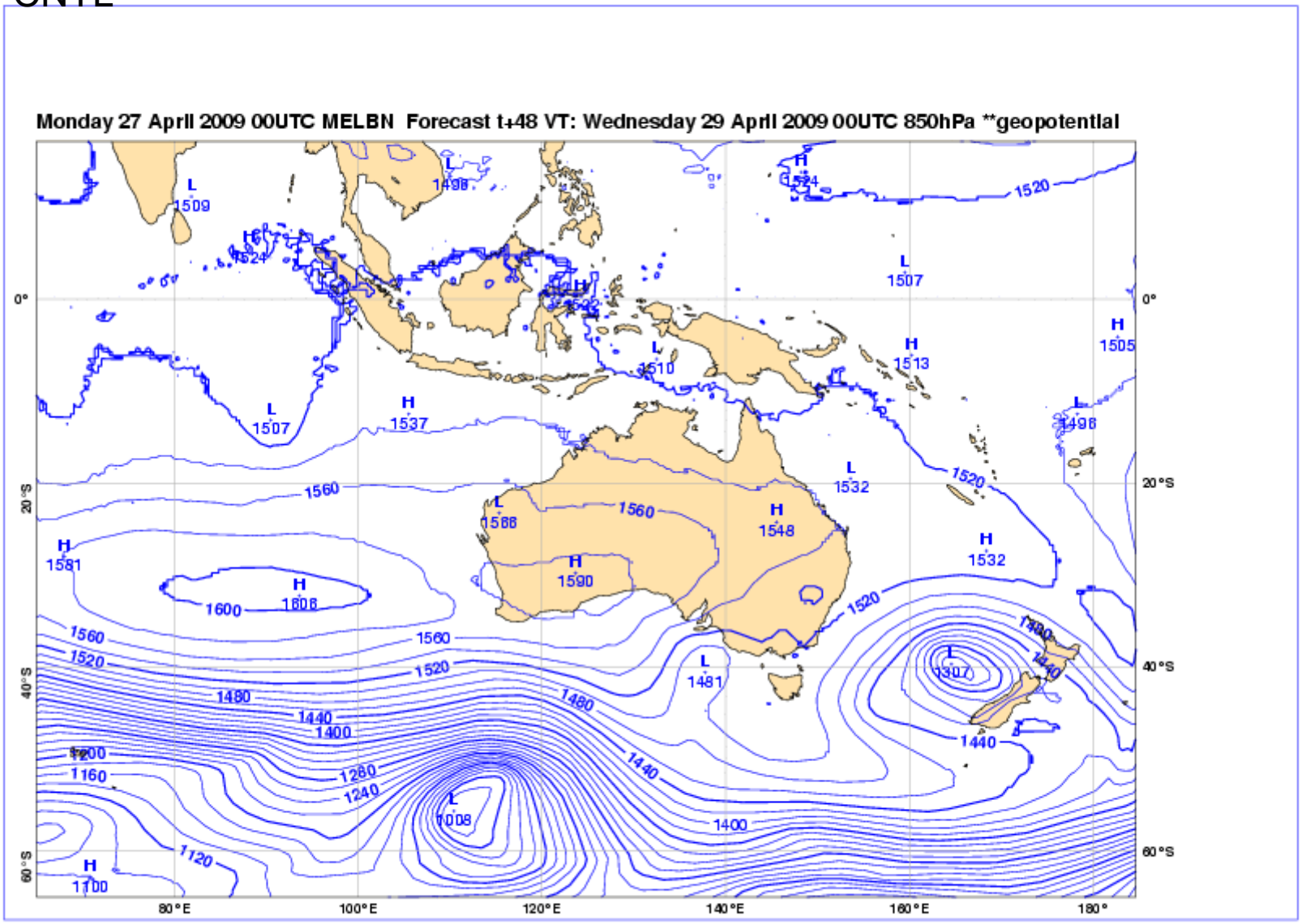
Australian Community Climate and Earth System Simulator (ACCESS)

ACCESS - R uses

- The Met. Office Unified Model (UKUM)
- 4DVAR Analysis System (VAR)
- Observation Processing System (OPS)
- The Surface Fields Processing system (SURF)

CNTL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20°S
40°S
60°S
80°E
100°E
120°E
140°E
160°E
180°
L 1509
L 1498
H 1524
H 1524
1520
L 1507
H 1505
H 1513
L 1510
L 1507
H 1537
L 1496
1560
L 1532
L 1586
H 1548
1560
H 1581
H 1532
H 1590
H 1606
1600
1560
1520
1560
1520
1480
1480
1440
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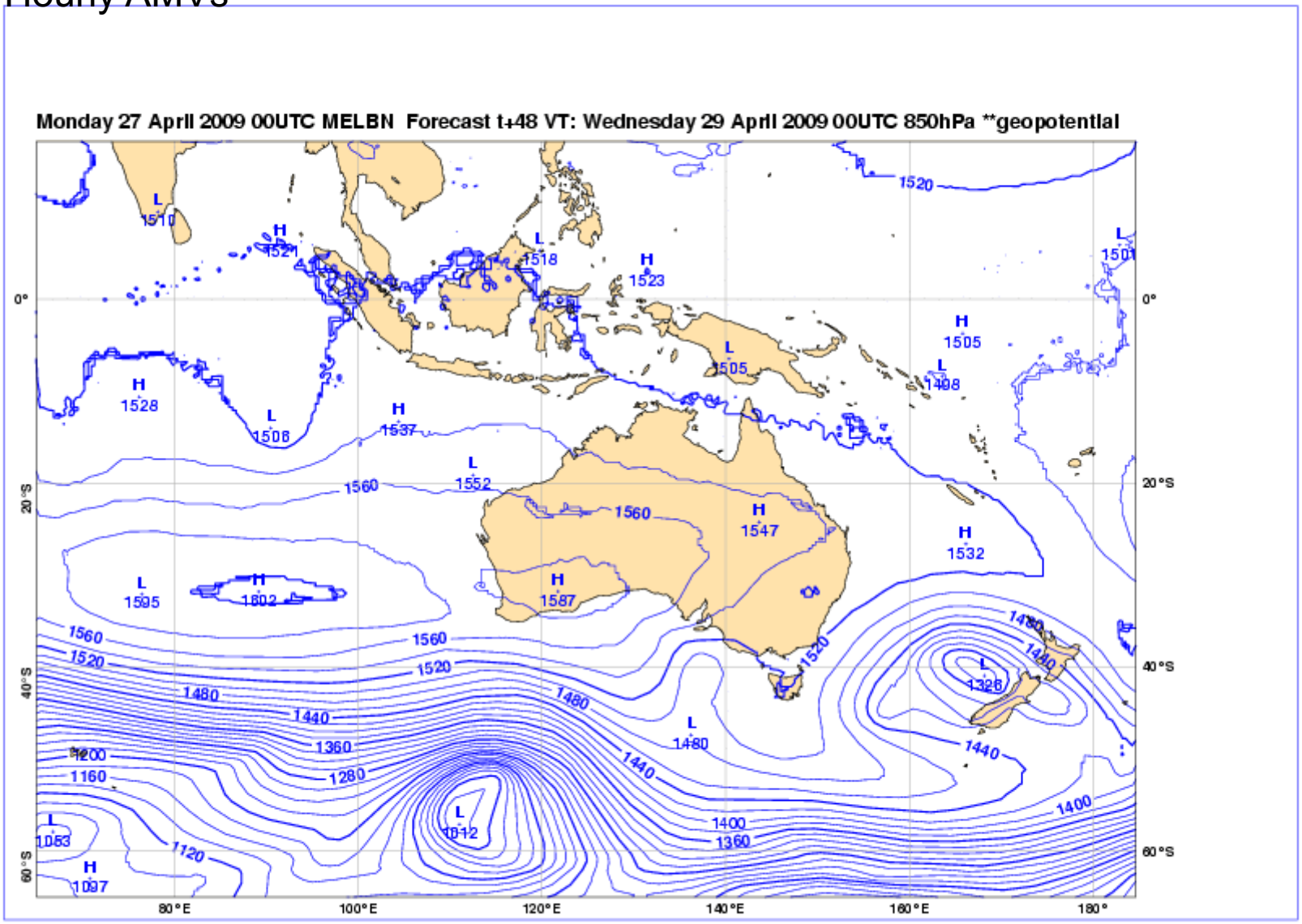
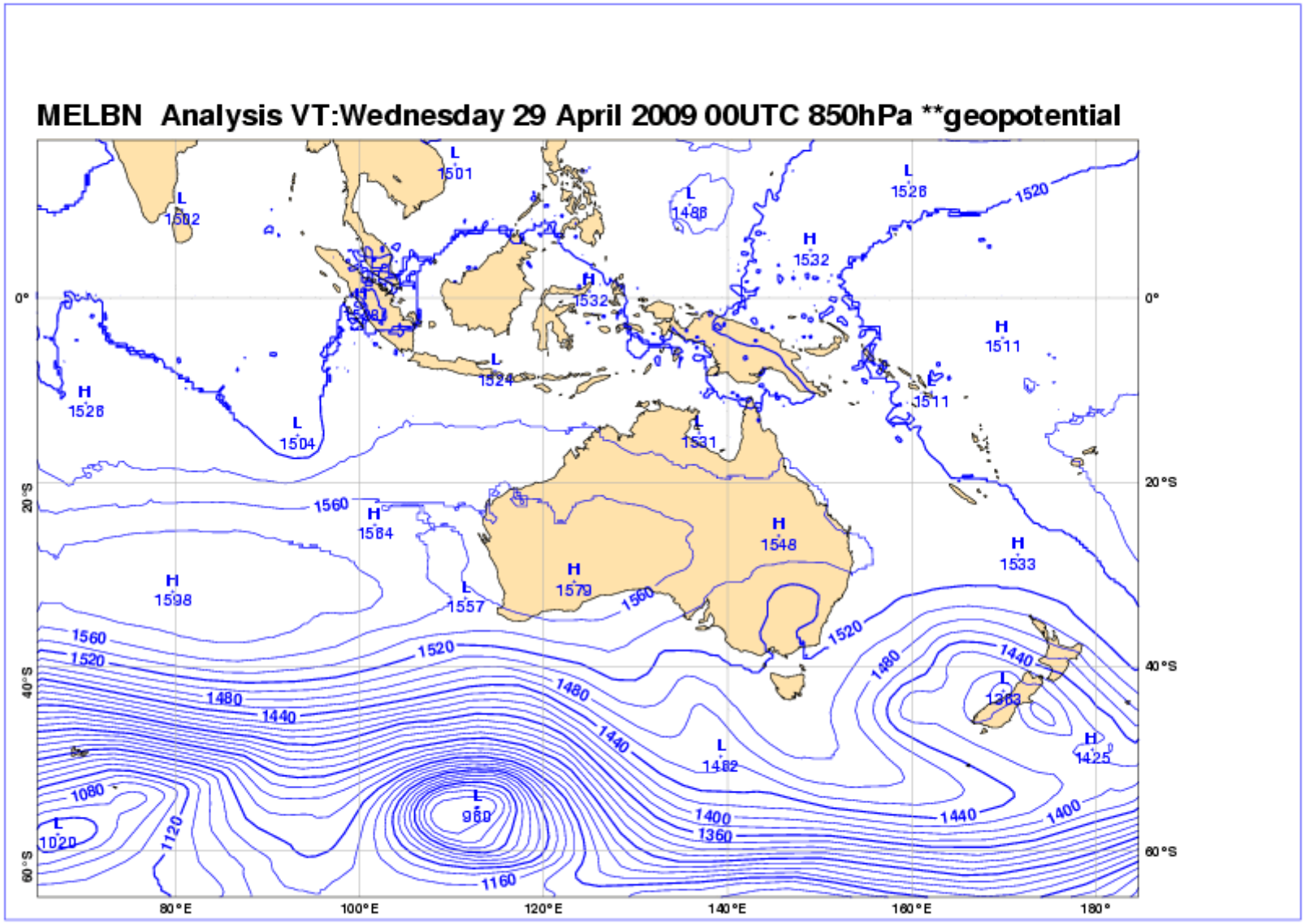
1400
1120
H 1100

Hourly AMVs


Monday 27 April 2009 00UTC MELBN Forecast t+48 VT: Wednesday 29 April 2009 00UTC 850hPa **geopotential
0°
20°S
40°S
60°S
80°E
100°E
120°E
140°E
160°E
180°
L 1510
H 1521
L 1518
H 1523
1520
L 1501
H 1505
L 1505
L 1498
H 1528
L 1506
H 1537
L 1552
1560
H 1547
H 1532
L 1595
H 1602
H 1587
1560
1520
1480
1440
1360
1280
1200
1160
L 1053
H 1097
1120
L 1012
1400
1360
L 1480
L 1326


MELBN Analysis VT:Wednesday 29 April 2009 00UTC 850hPa **geopotential
L 1501
L 1502
L 1488
L 1528
H 1532
H 1532
H 1511
L 1524
H 1528
L 1504
L 1511
L 1531
1560
H 1564
H 1548
H 1533
H 1598
H 1579
L 1557
1560
1520
1560
1520
1480
1440
1520
1480
1440
1480
1440
L 1482
L 1303
H 1425
1080
L 1020
1120
L 960
1400
1360
1440
1400
1160
0°
20°S
40°S
60°S
80°E
100°E
120°E
140°E
160°E
180°

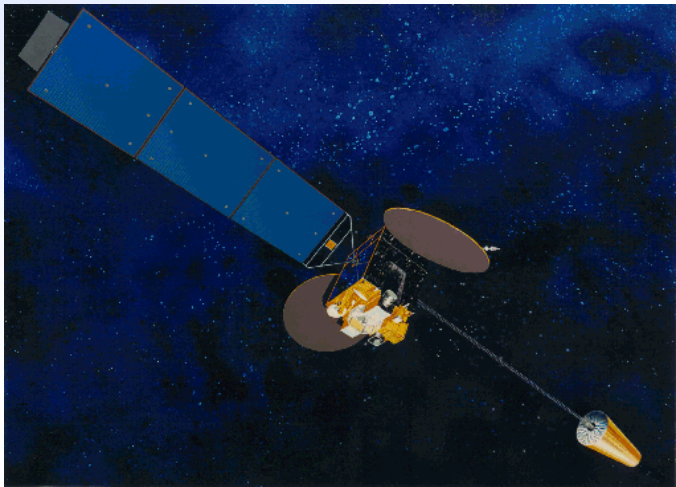
NEAR RT TRIAL

NEW OPERATIONAL SYSTEM

1 September – 10 October 2009

Used

- Real Time Local Satellite Winds MTSAT-1R
  - 2 sets of quarter hourly motion vectors every six hours.
  - Hourly motion Vectors
- New Operational Regional Forecast Model (ACCESS-R) and Data Base (Inc JMA AMVs)



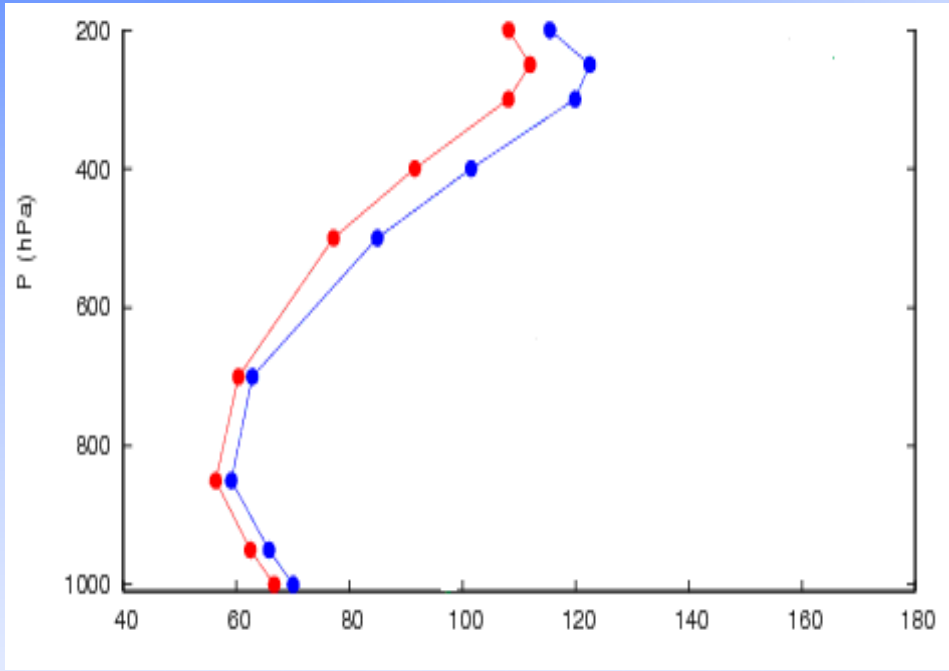


Fig.5 (a). The RMS difference between forecast and verifying analysis geopotential height(m) at 24 hours for ACCESS-R (blue) and ACCESS-R with AMVs (red) for the period 1 September to 10 October 2009

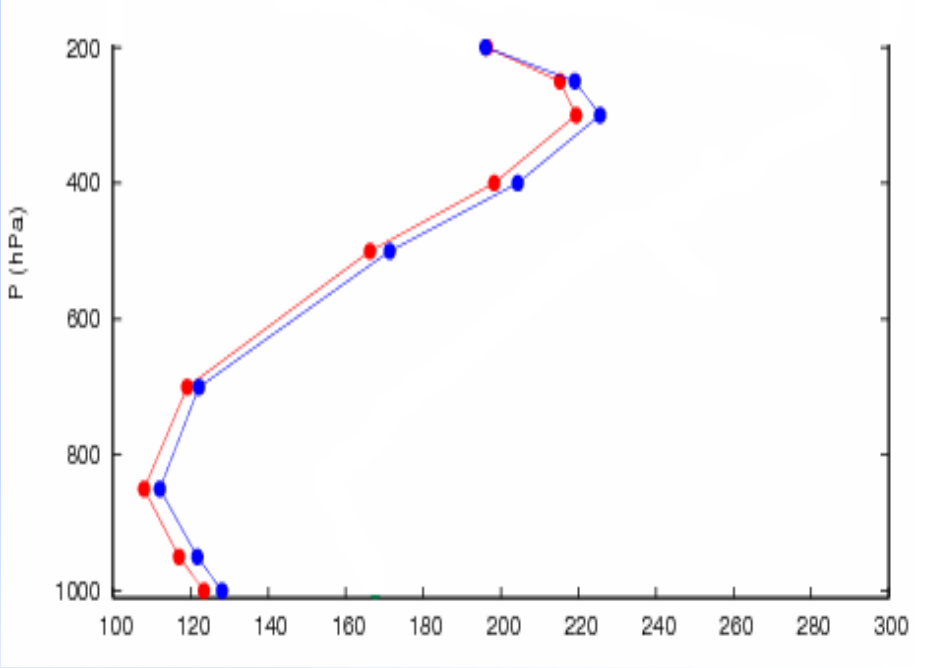


Fig.5(b). The RMS difference between forecast and verifying analysis geopotential height(m) at 48 hours for ACCESS-R (blue) and ACCESS-R with AMVs (red) for the period 1 September to 10 October 2009

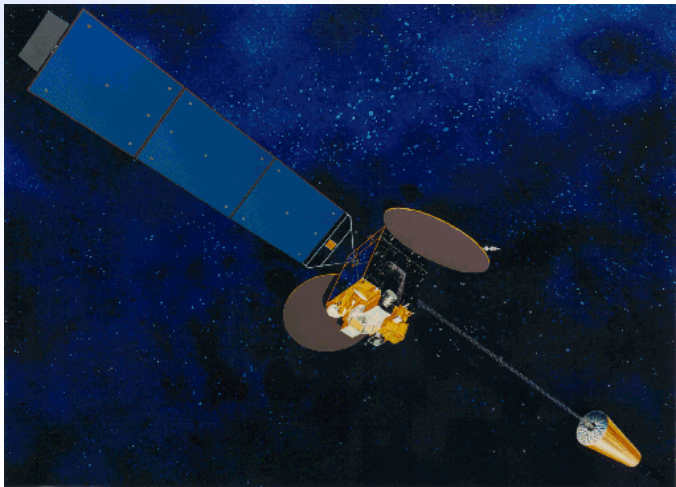
NEAR RT TRIAL

NEW OPERATIONAL SYSTEM

27 January – 23 February 2011

Used

- Real Time Local Satellite Winds MTSAT-2
  - 2 sets of quarter hourly motion vectors every six hours.
  - Hourly motion Vectors
- New Operational Regional Forecast Model (ACCESS-R) and Data Base (Inc JMA AMVs)



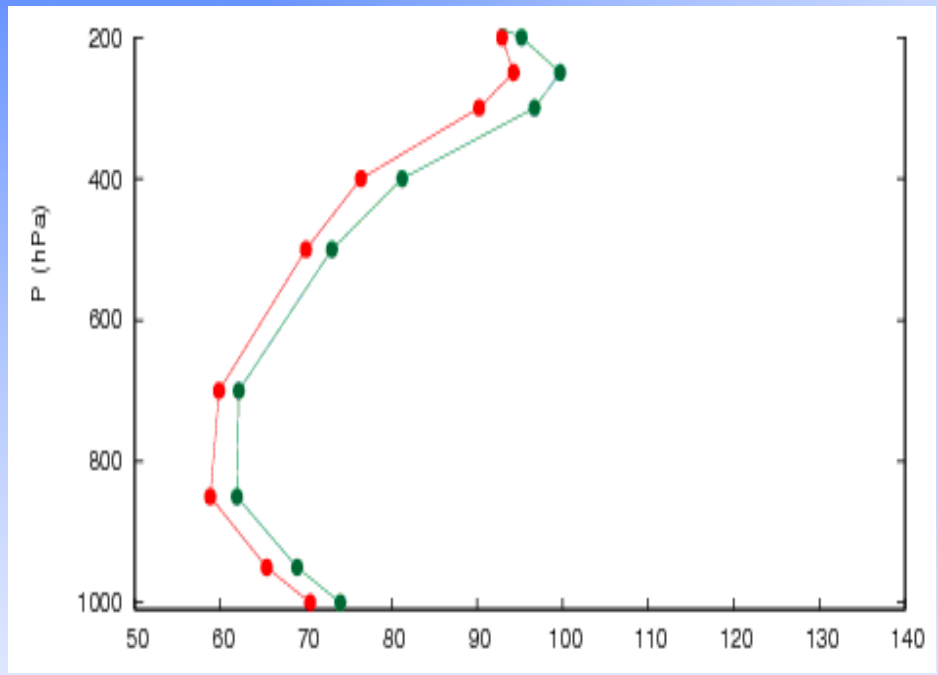


Fig.6(a). The RMS difference between forecast and verifying analysis geopotential height(m) at 24 hours for ACCESS-R (green) and ACCESS-R with AMVs (red) for the period 27 January to 23 February 2011.

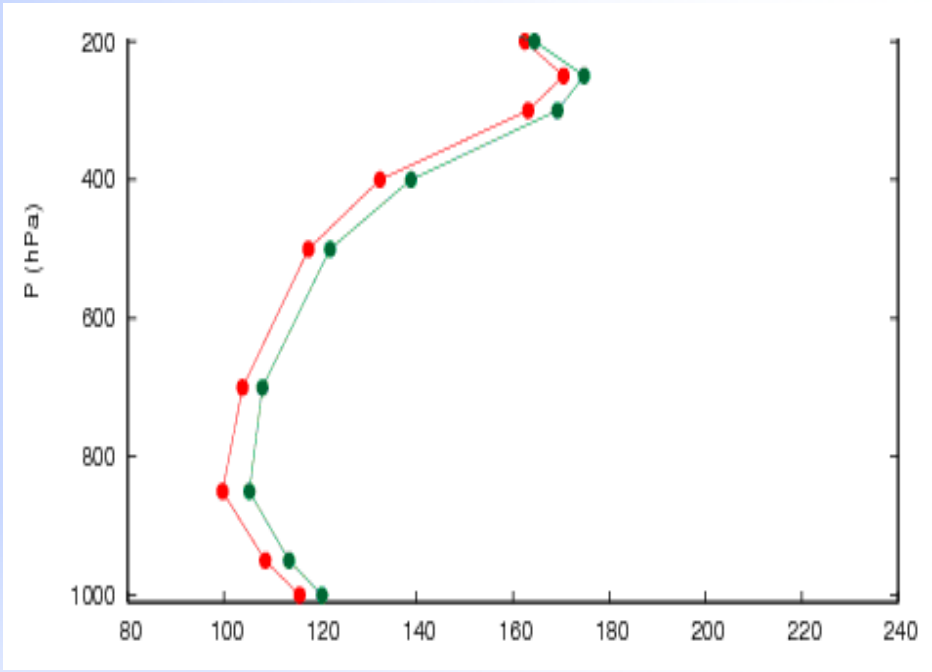
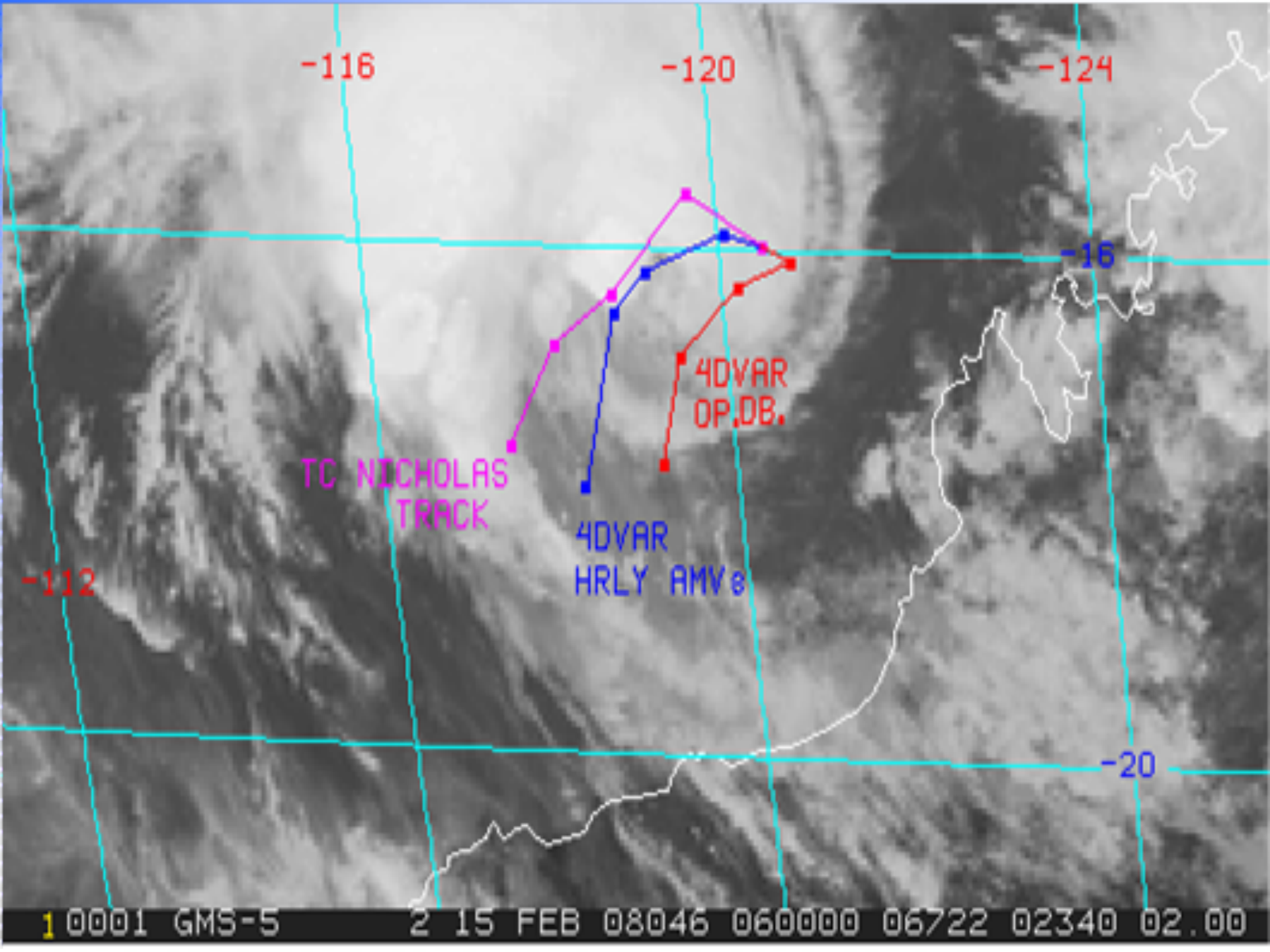


Fig.6(b). The RMS difference between forecast and verifying analysis geopotential height(m) at 48 hours for ACCESS-R (green) and ACCESS-R with AMVs (red) for the period 27 January to 23 February 2011.


-116
-120
-124
-16
-20
-112
TC NICHOLAS
TRACK
4DVAR
OP.DB.
4DVAR
HRLY AMVs
1 0001 GMS-5 2 15 FEB 08046 060000 06722 02340 02.00

Summary

- Geo-stationery AMVs have been shown to make a significant contribution globally to operational analysis and forecasting.

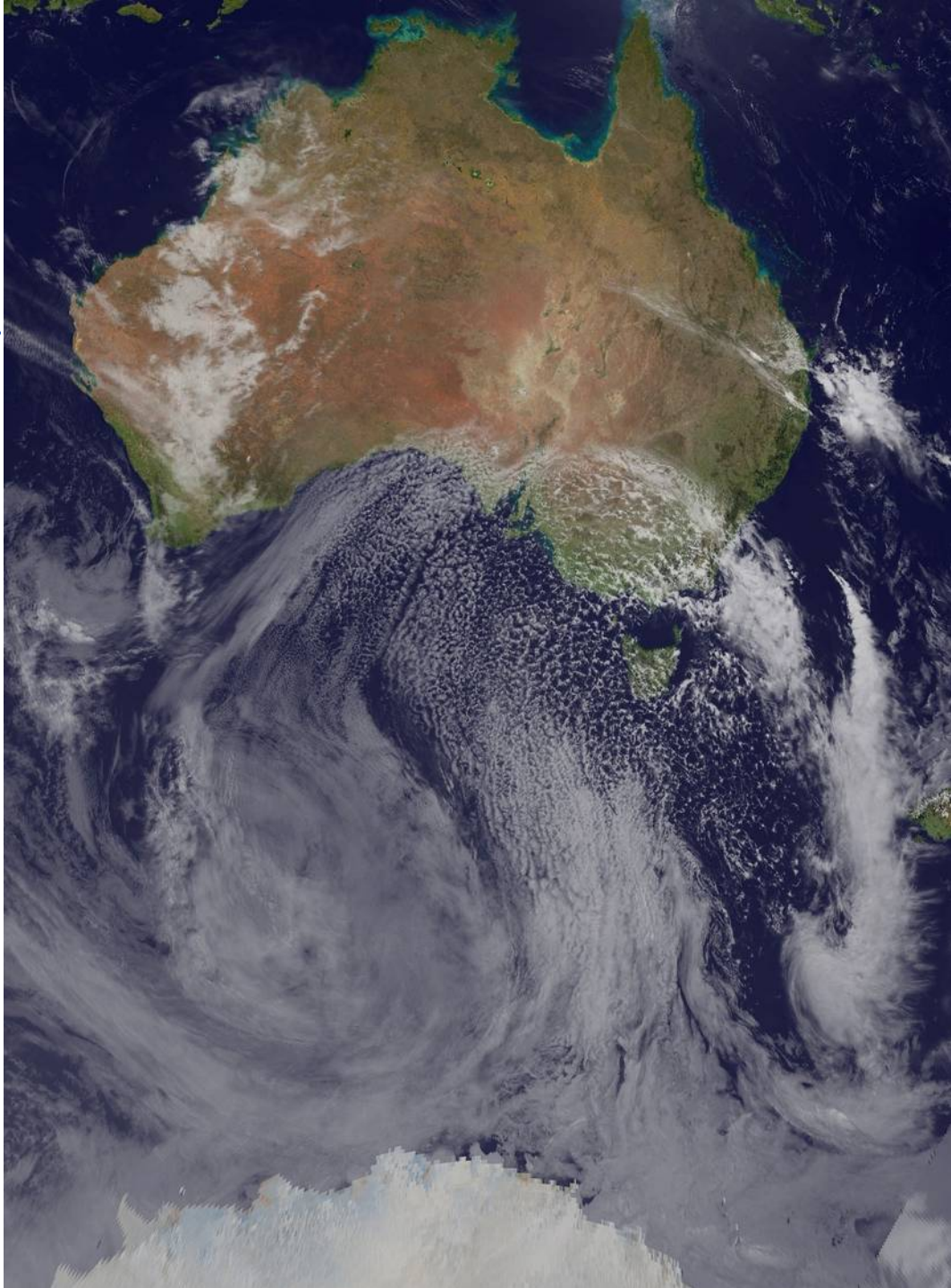
- High spatial and temporal resolution MTSaT-1R/2 AMVs have been generated at the Australian BoM and have been shown to provide significant benefits in the Australian region.

- The successful application of high resolution MTSaT-1R/2 AMVs has been facilitated by the careful use of quality-control parameters such as the ERR, EE and QI.

- Assimilation studies with UKUM based ACCESS model using 4DVAR show improved forecast skill

Australian Government
Bureau of Meteorology

RECENT GENERATION AND ASSIMILATION OF CONTINUOUS (10 Minute) ATMOSPHERIC MOTION VECTORS , GEOCAT AND 4DVAR



Himawari-6 Test-Op. AMV Generation

Uses 3 images separated by 10 min.

Uses H_20 intercept method for upper level AMVs (Schmetz et al., 1993) or Window Method.

Uses cloud base assignment for lower level AMVs (Le Marshall et al. 1997) or Window Method

Data selection, QC via EE, QI, ERR, RFF etc.

Height assignment verification/ development uses Cloudsat/Calipso, RAOBS

Himawari-7 Test AMV Generation

Uses 3 images separated by 15, 30 or 60 min.

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

Height assignment methods similar to GOES-R 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/ development uses Cloudsat/Calipso, RAOBS

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 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/ development uses Cloudsat/Calipso, RAOBS

Table 1. Real time schedule for Full disk Himawari-8 Atmospheric Motion Vectors at the Bureau of Meteorology. Sub-satellite image resolution, frequency and time of wind extraction and separations of the image triplets used for wind generation (/\T) are indicated.

Wind Type	Resolution	Frequency-Times (UTC)	Image Separation
Real Time IR	2 km	Every ten minutes	10 minutes
Real Time VIS*/WV	2 km	Every ten minutes	10 minutes

*daytime

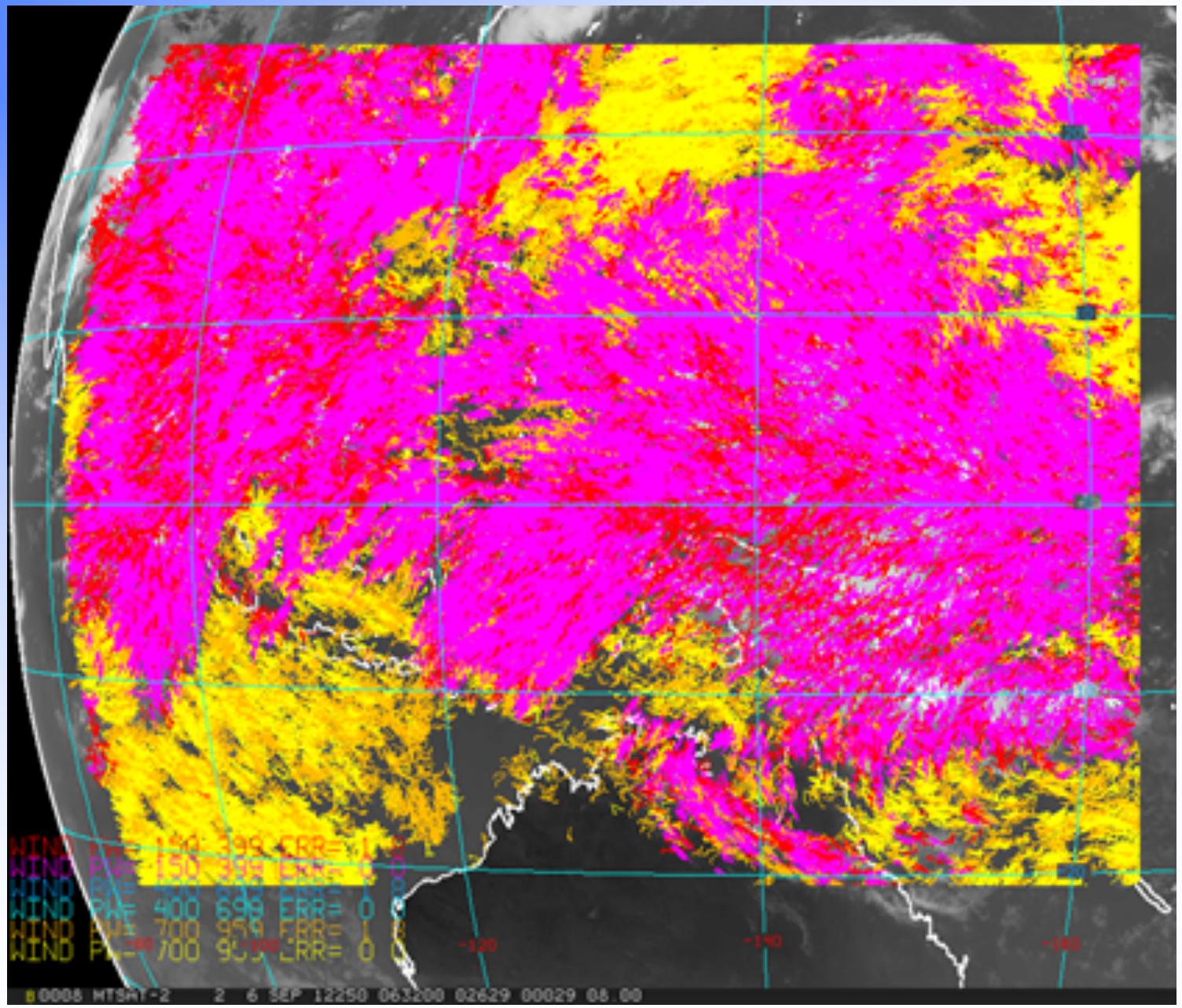
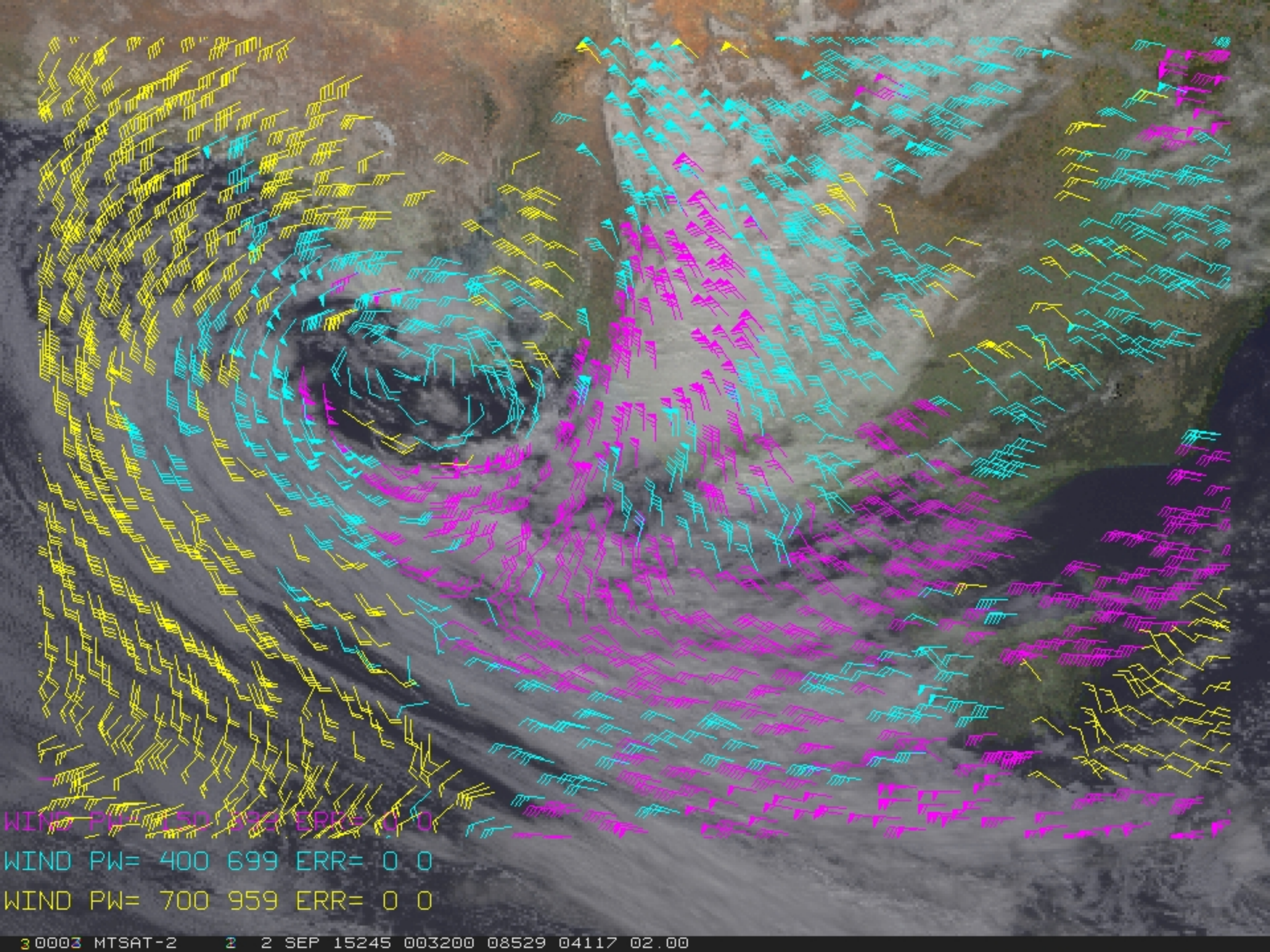
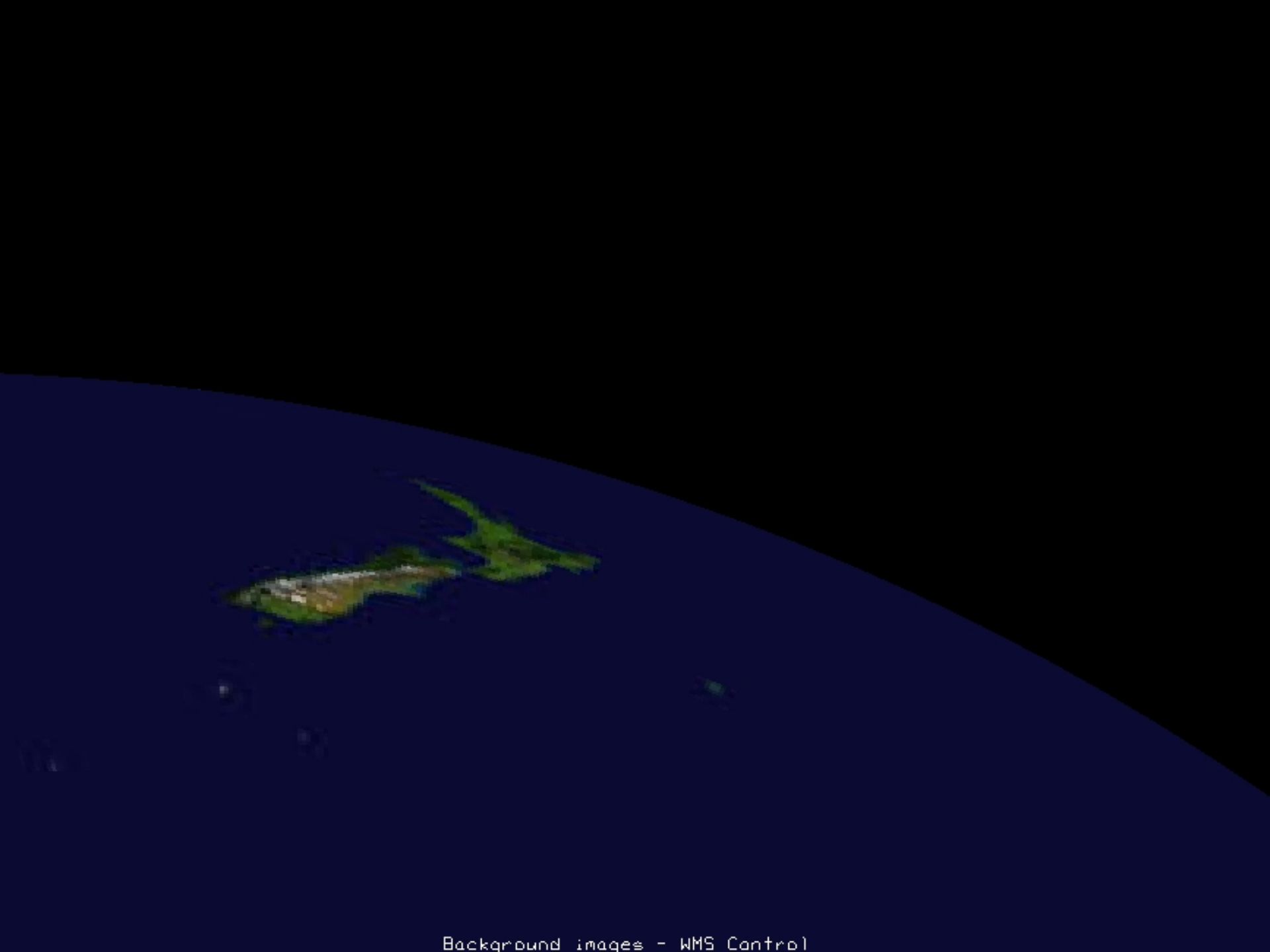
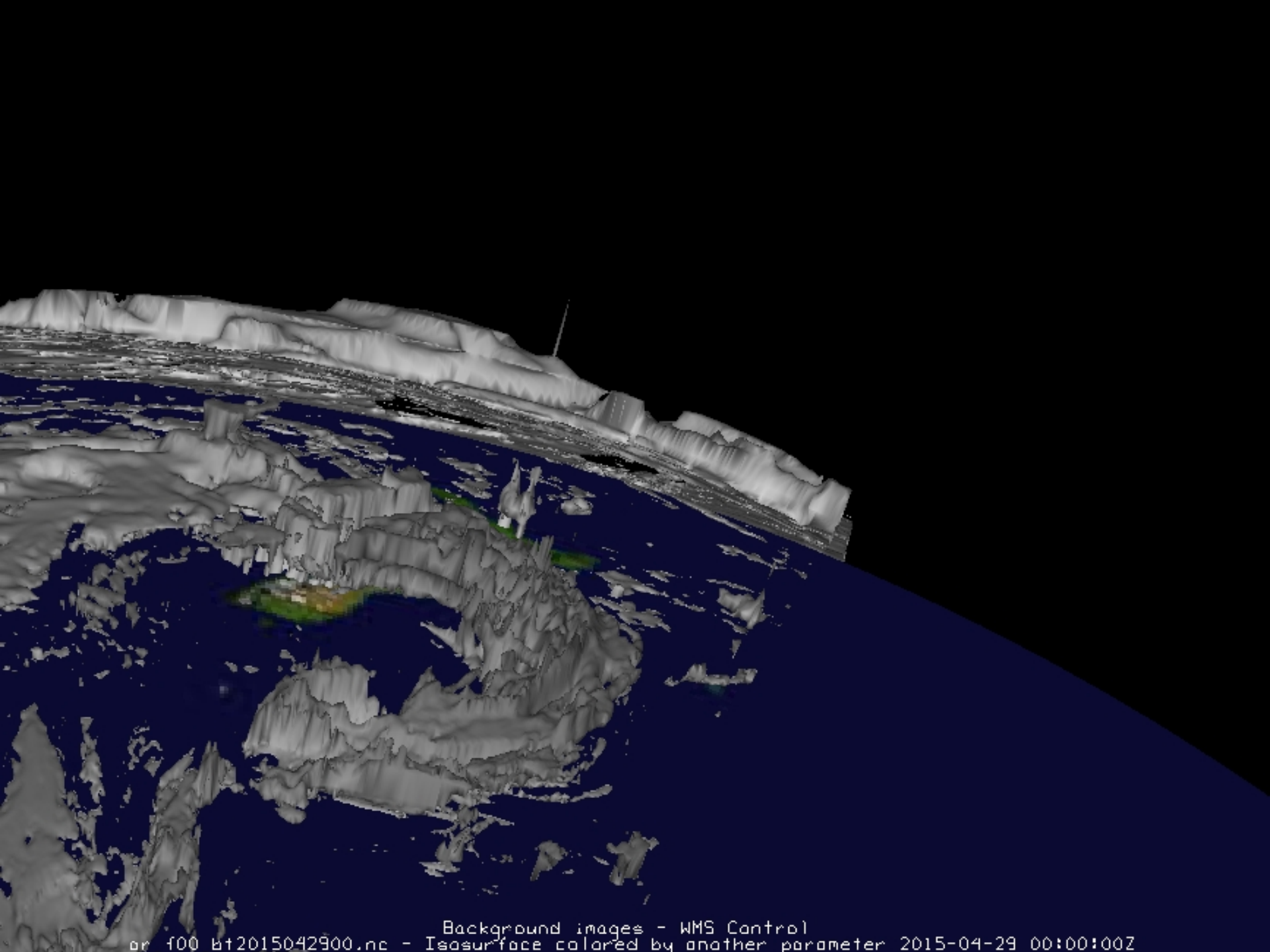
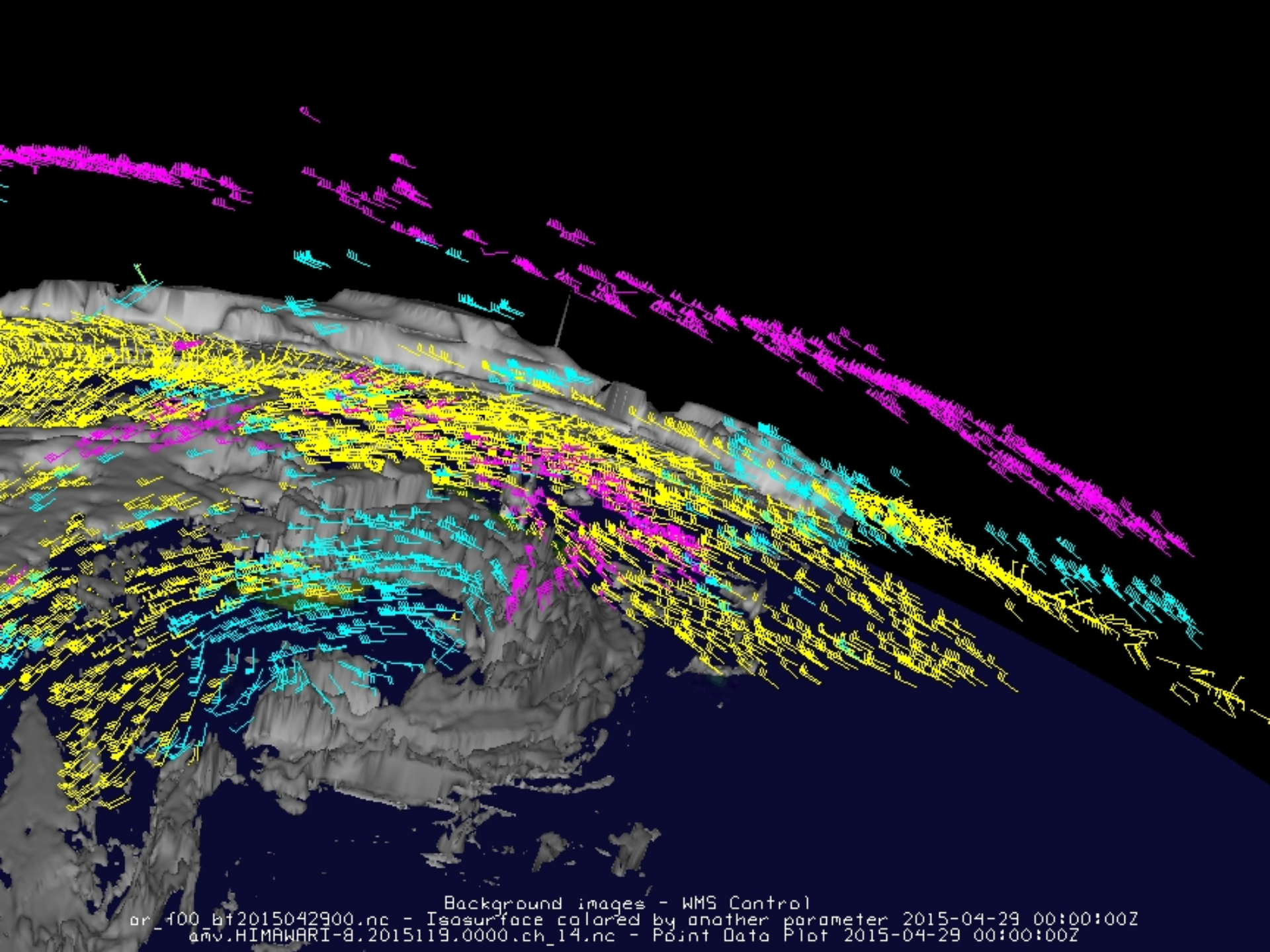


Fig. 5 Coverage of AMVs from Himawari-8 in the tropics to the north of Australia 06 UTC 6 September 2015


WIND PW= 150 399 ERR= 0 0
WIND PW= 400 699 ERR= 0 0
WIND PW= 700 959 ERR= 0 0
3 0003 MTSAT-2 2 2 SEP 15245 003200 08529 04117 02.00


Background images - WMS Control


Background images - WMS Control
or f00 bt2015042900.nc - Isosurface colored by another parameter 2015-04-29 00:00:00Z


Background images - WMS Control
or_f00_bt2015042900.nc - Isosurface colored by another parameter 2015-04-29 00:00:00Z
amv.HIMAWARI-8.2015119.0000.ch_14.nc - Point Data Plot 2015-04-29 00:00:00Z

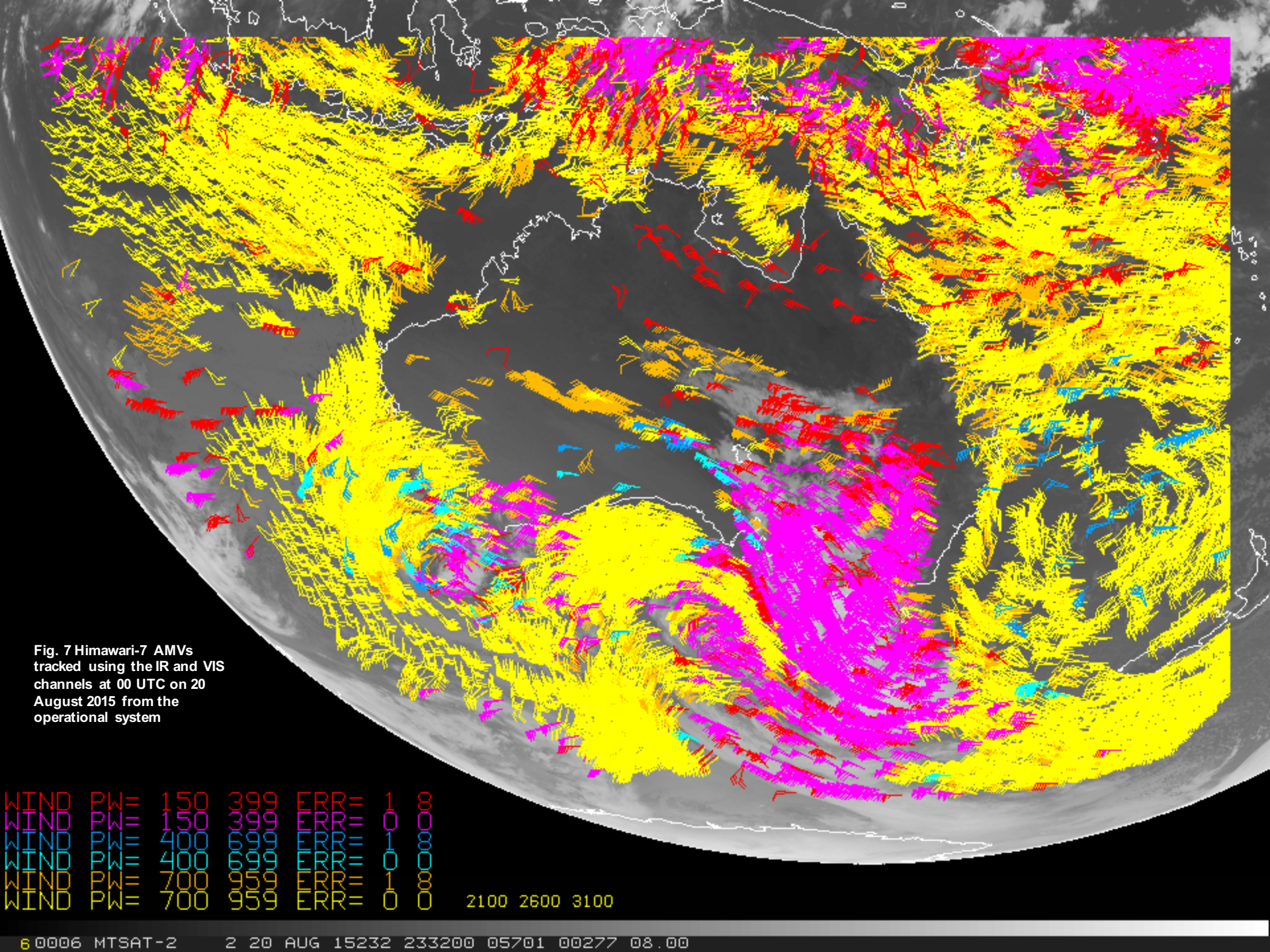


Fig. 7 Himawari-7 AMVs tracked using the IR and VIS channels at 00 UTC on 20 August 2015 from the operational system

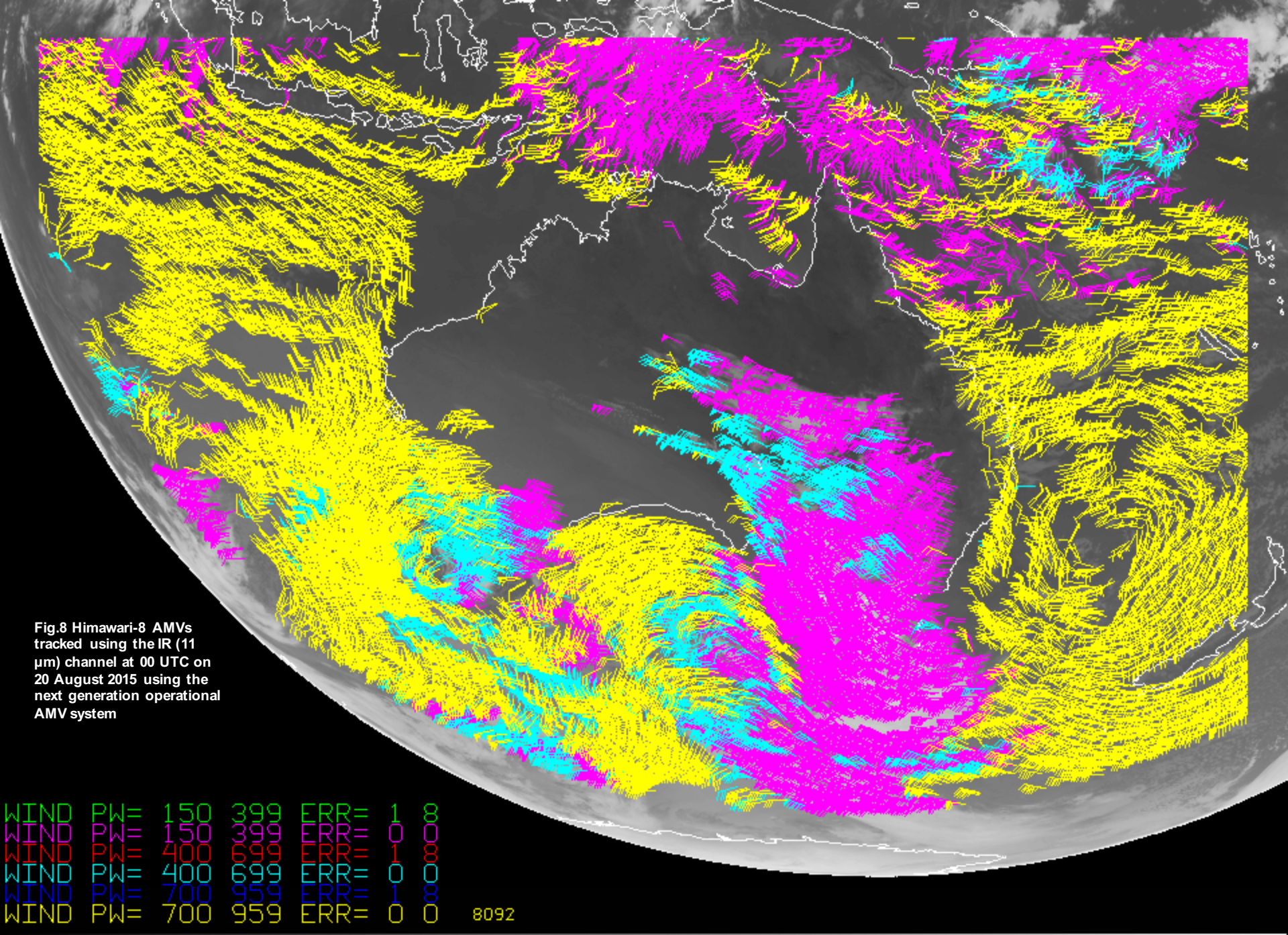


Fig.8 Himawari-8 AMVs tracked using the IR (11 μm) channel at 00 UTC on 20 August 2015 using the next generation operational AMV system

Table 1 Verification Table for Himawari-8 IR (channel 14) AMVs compared to radiosondes 18 August – 18 September 2015

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

Verification for real time vectors from Himawari-7 and Himawari-8

Table 2 Verification Table for Himawari-8 IR (channel 14) AMVs compared to radiosondes 1 March – 31 March 2016

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

Table 3 Verification Table for Himawari-7 IR (channel 14) AMVs compared to radiosondes 1 March – 20 March 2016

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

Australian Government
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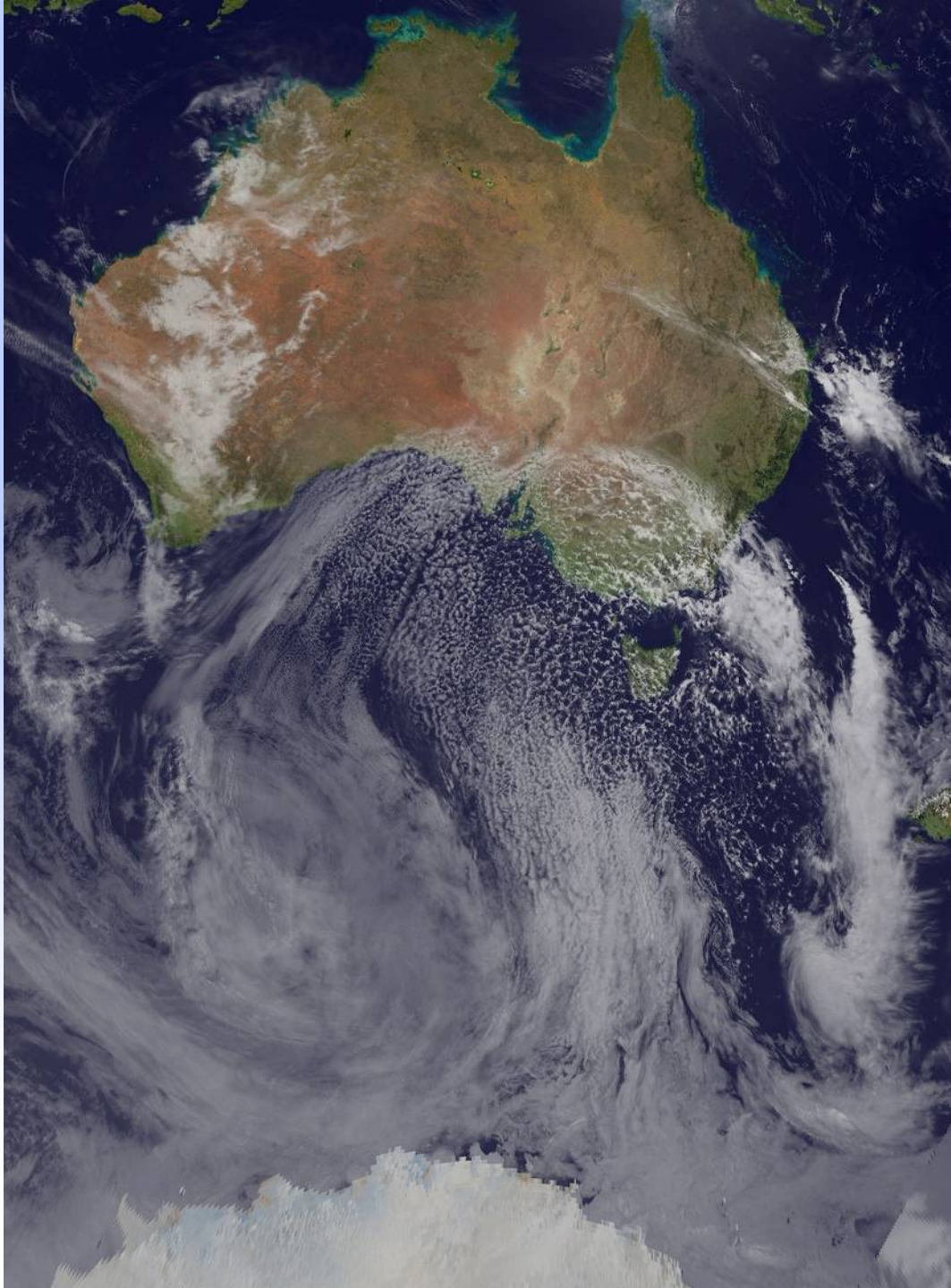
GENERATION AND ASSIMILATION OF CONTINUOUS (10 Minute) ATMOSPHERIC MOTION VECTORS FROM MTSAT-1R

USING 4DVAR



Himawari-6 Test-Op. AMV Generation

Uses 3 images separated by 10 min.

Uses H_20 intercept method for upper level AMVs (Schmetz et al., 1993) or Window Method.

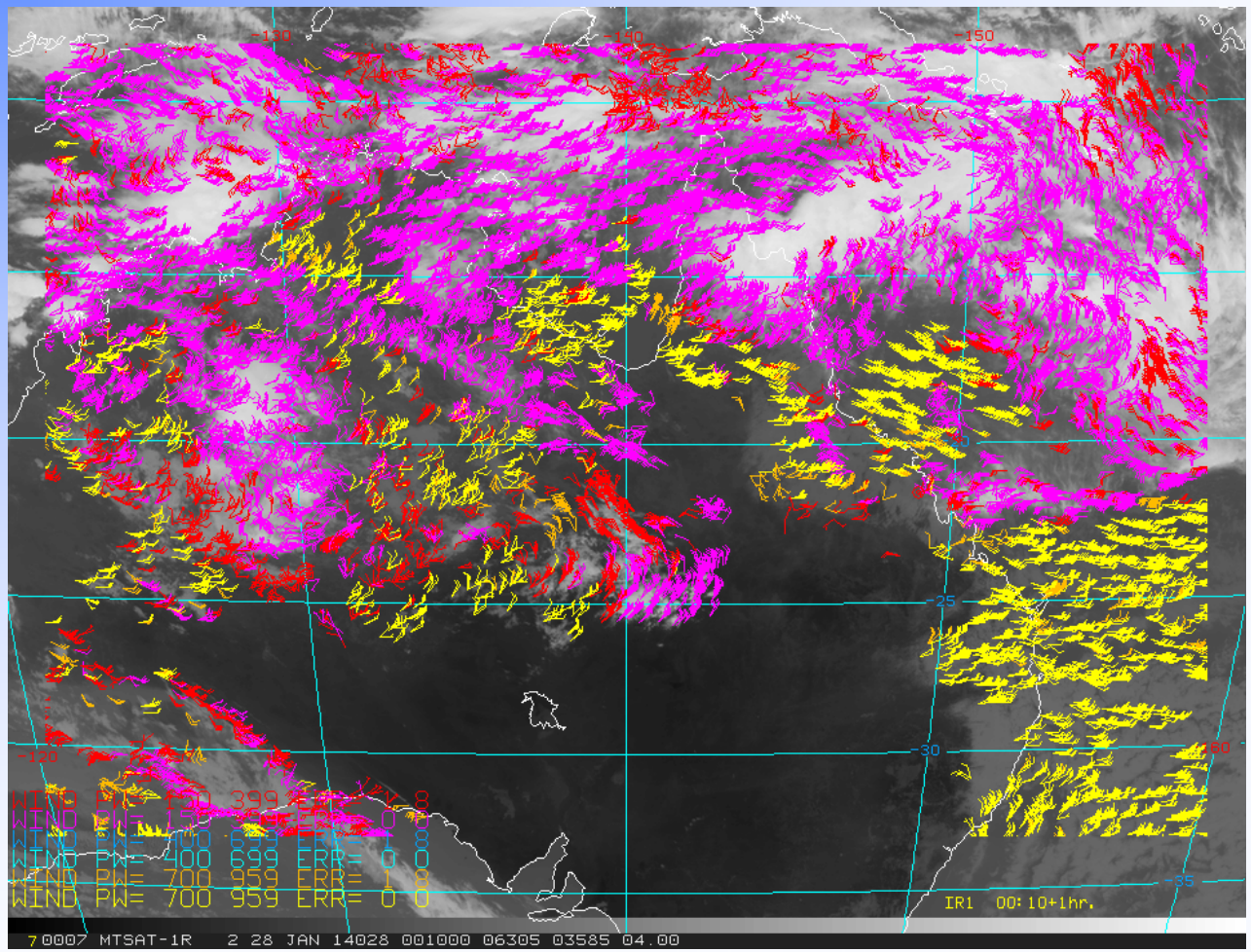
Uses cloud base assignment for lower level AMVs (Le Marshall et al. 1997) or Window Method

Data selection, QC via EE, QI, ERR, RFF etc.

No autoedit

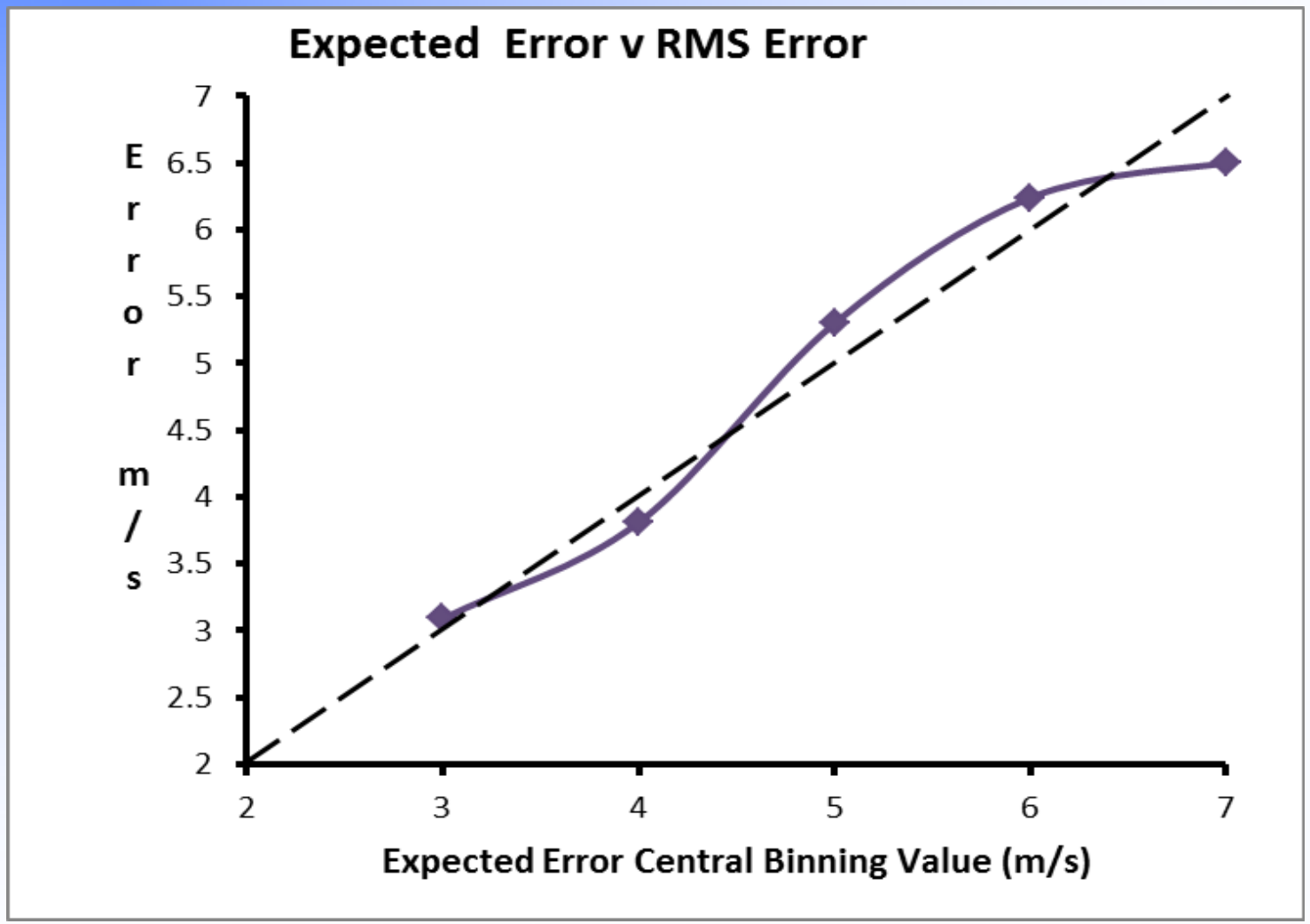
December 2114 – March 2015

10 Minute H-6 AMVS



A selection of Atmospheric Motion Vectors over Eastern Australia generated from five triplets 10 min imagery between 00:10 UTC and 00:50 UTC on 28 January 2014.

Generation and Assimilation of 10 minute H-6 AMVS



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

Assimilation of 10 minute Himawari-6 AMVS

Assimilation period 12 UTC 26 January - 12 UTC 27 2014

Winds centred on 0000, 0010,0020…. 0050, 0100, 0110UTC
0120,0130, 0140, 0150, 0200
0210……., 0250…. etc.
ie. new AMVs every 10 minutes.

Used ACCESS-G2 (new Op. Fcst system)

Assimilation

The high resolution data was assimilated between 12 UTC 26 January and 12 UTC 27 January 2014
AMVs were provided and used every ten minutes

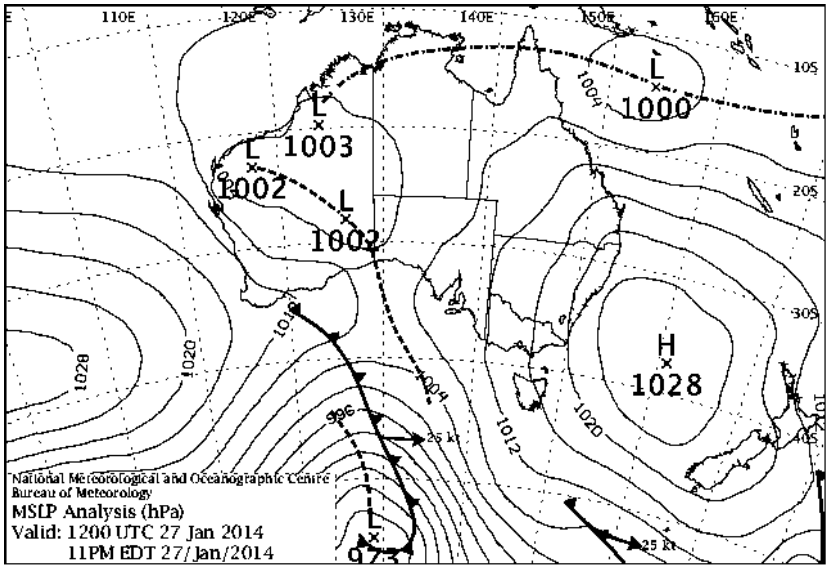


Fig. 9 Bureau of Meteorology Analysis for 12 UTC on 27 January 2014.

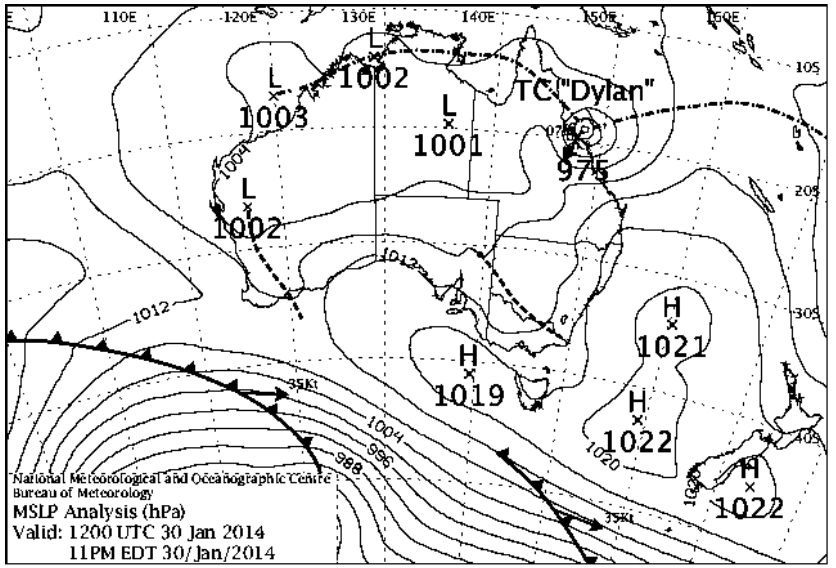


Fig. 10.Bureau of Meteorology Analysis for 12 UTC on 30 January 2014

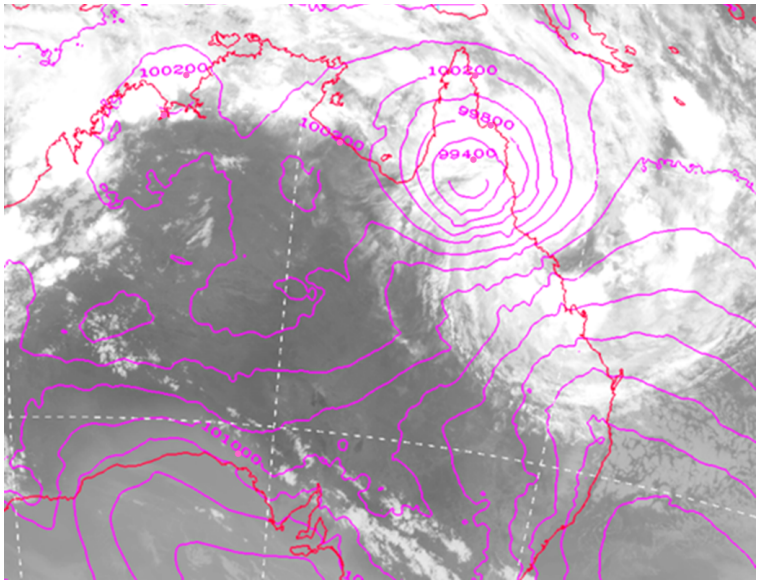


Fig.11 The Bureau of Meteorology operational three-day MSLP (hPa) forecast valid 12 UTC on 30 January 2014, shown remapped over an MTSat infrared image, valid at the same time.

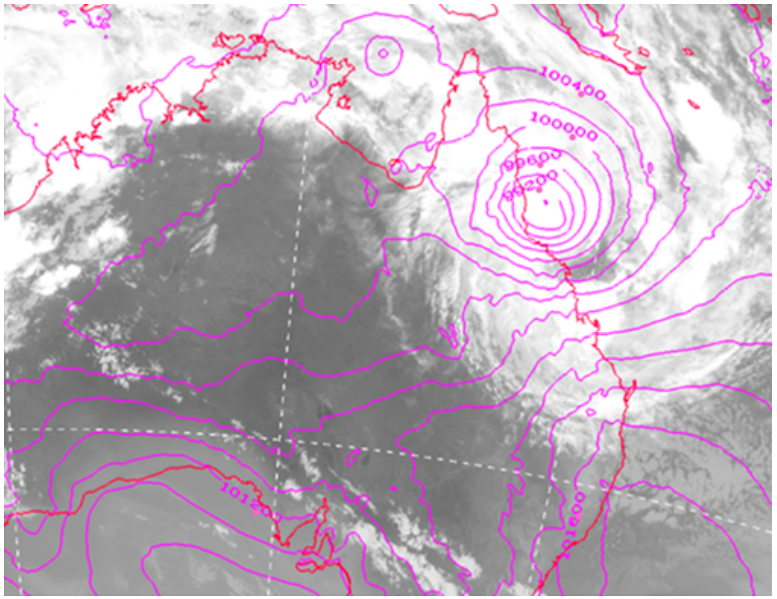


Fig.12 The Bureau of Meteorology three-day MSLP (hPa) forecast valid, 12 UTC on 30 January 2014 using the next generation operational regional forecasting system with ten, fifteen and sixty minute AMV data from MTSat-1R and MTSat-2. The forecast is again remapped over the 12 UTC MTSat image.

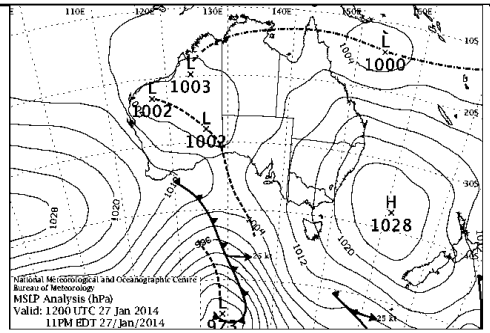


Fig. 9 Bureau of Meteorology Analysis for 12 UTC on 27 January 2014.

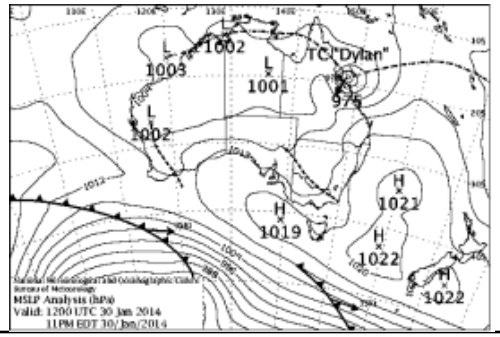


Fig. 10.Bureau of Meteorology Analysis for 12 UTC on 30 January 2014

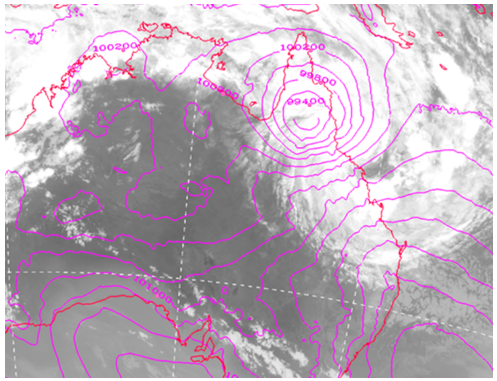


Fig.11 The Bureau of Meteorology operational three-day MSLP (hPa) forecast valid 12 UTC on 30 January 2014, shown remapped over an MTSat infrared image, valid at the same time.

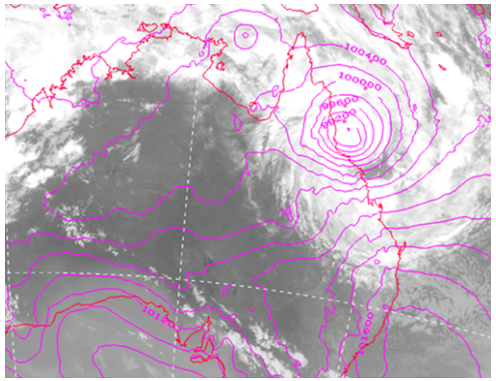
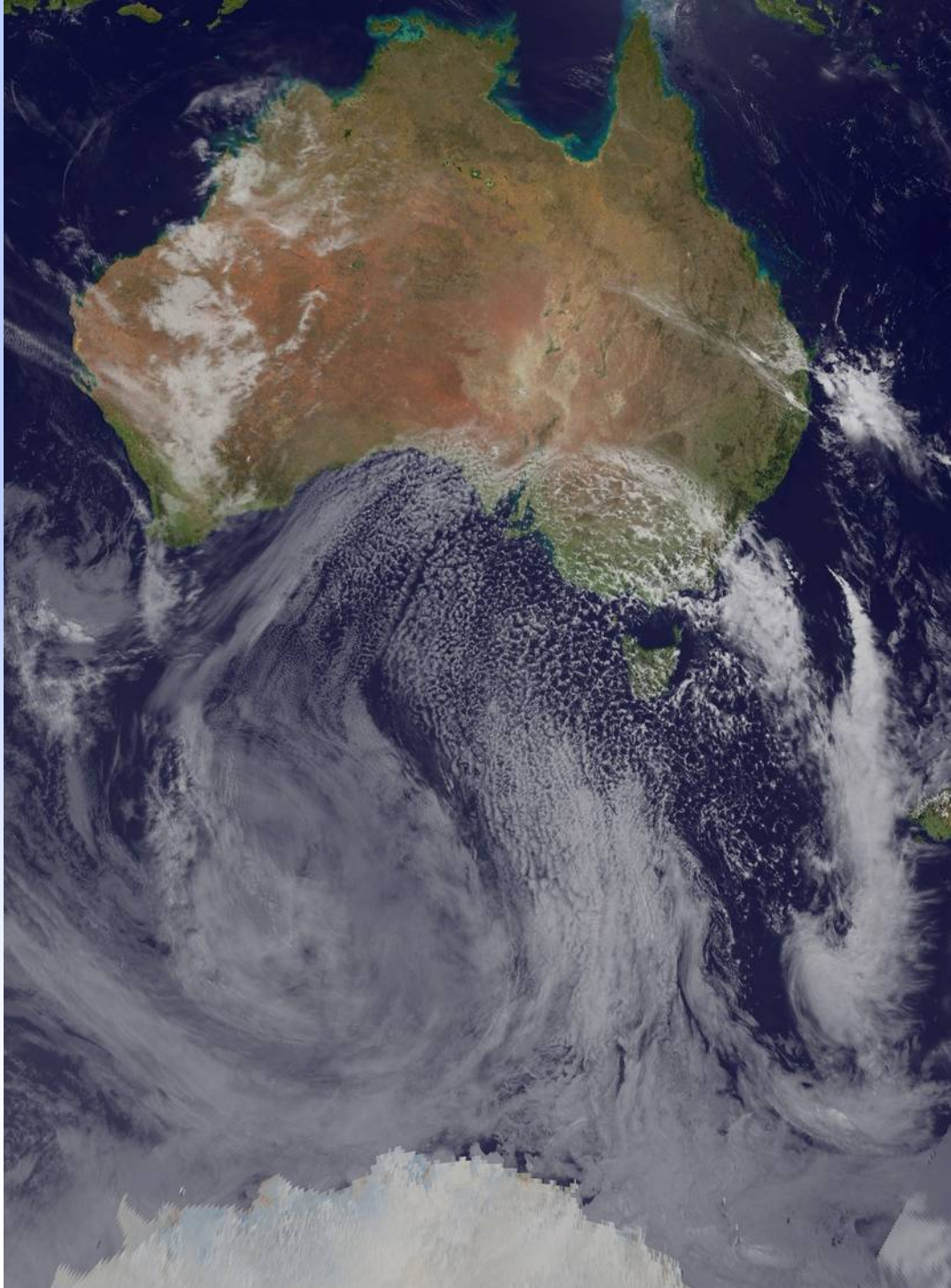


Fig.12 The Bureau of Meteorology three-day MSLP (hPa) forecast valid, 12 UTC on 30 January 2014 using the next generation operational regional forecasting system with ten, fifteen and sixty minute AMV data from MTSat-1R and MTSat-2. The forecast is again remapped over the 12 UTC MTSat image.

Australian Government
Bureau of Meteorology

GENERATION AND ASSIMILATION OF CONTINUOUS (10 Minute) ATMOSPHERIC MOTION VECTORS FROM HIMAWARI-8 USING 4DVAR



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.

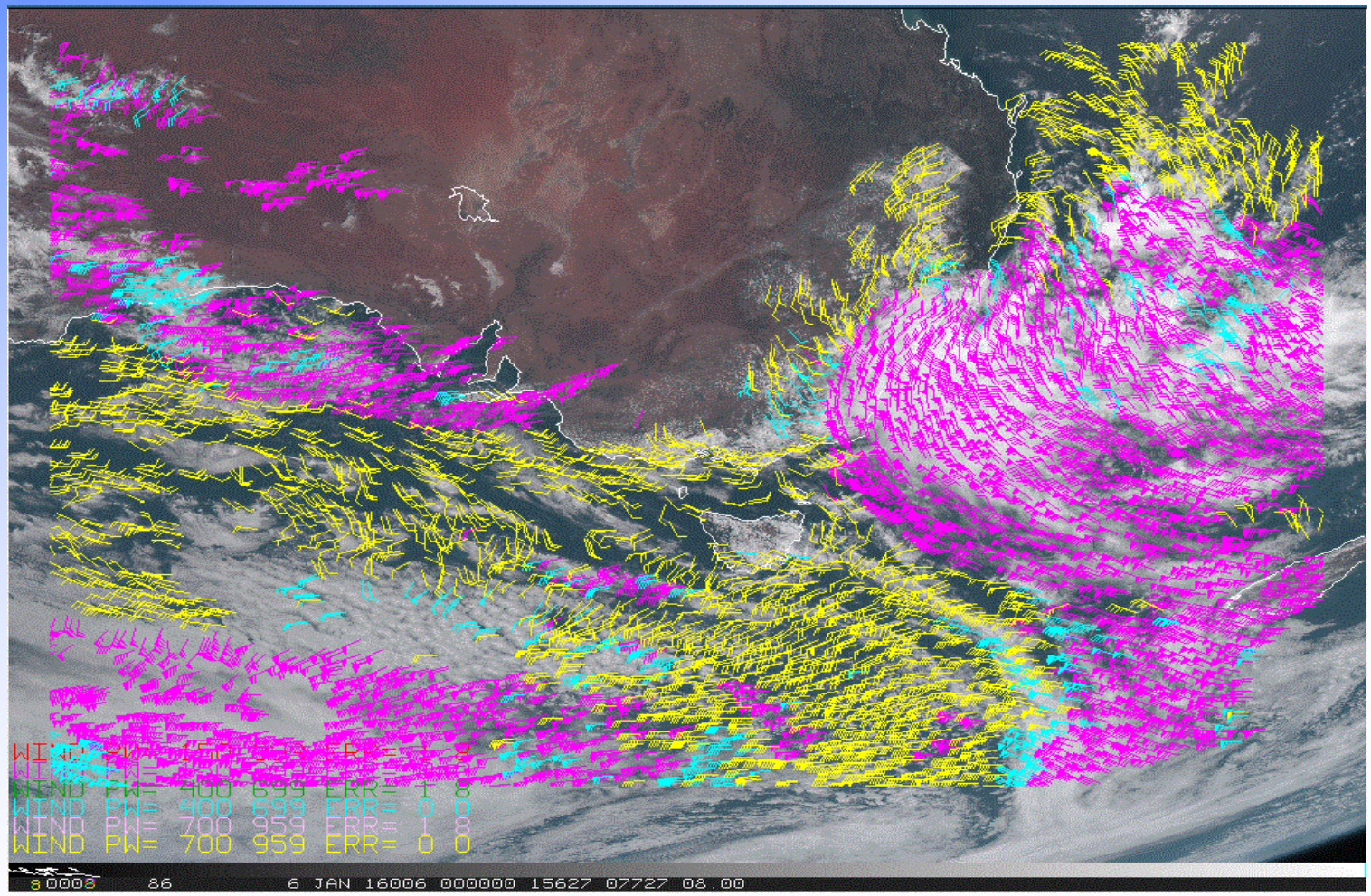
Height assignment methods similar to GOES-R ABI ATBD For Cloud Height (Heidinger, A. 2010)

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

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

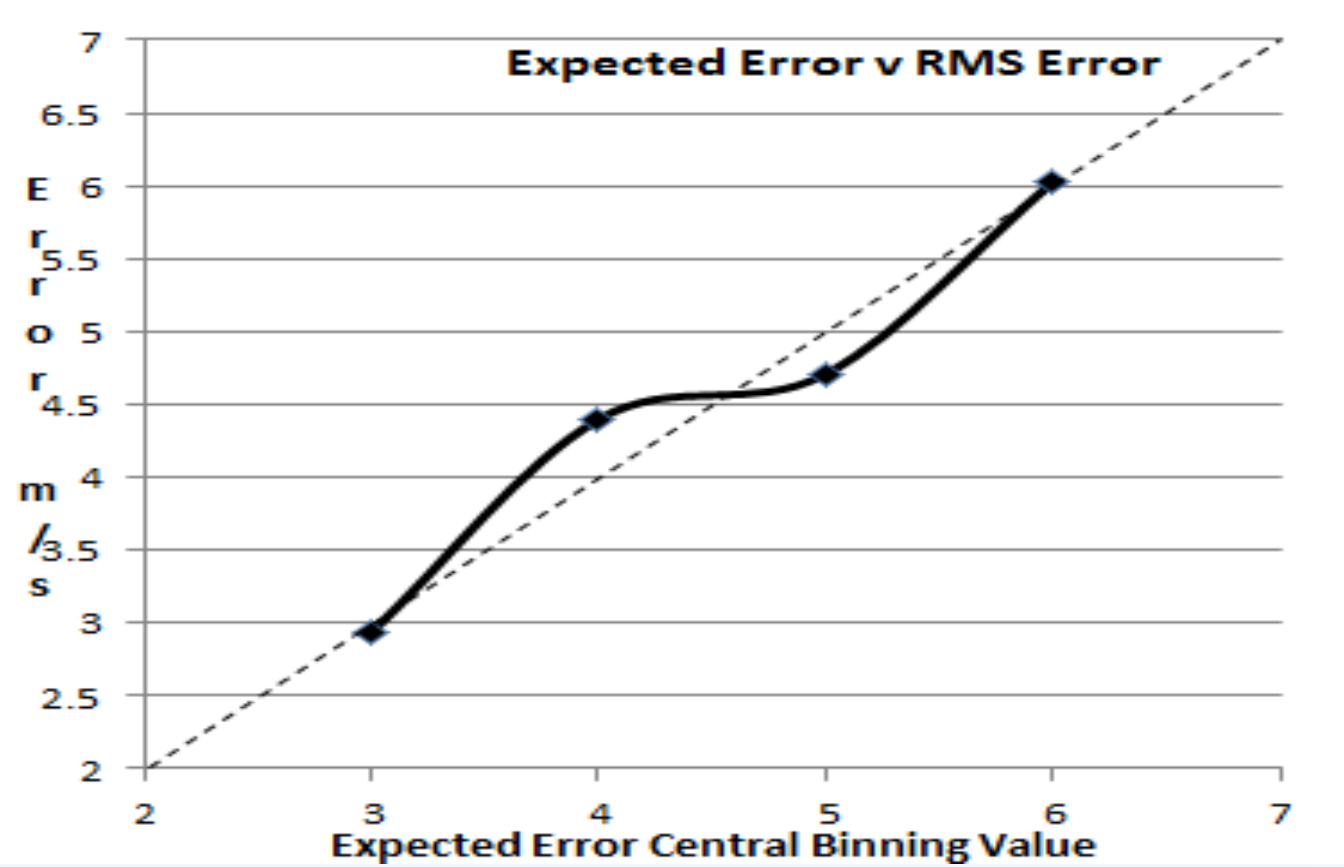
Height assignment verification/ development uses Cloudsat/Calipso, RAOBS

10 Minute H-8 AMVS



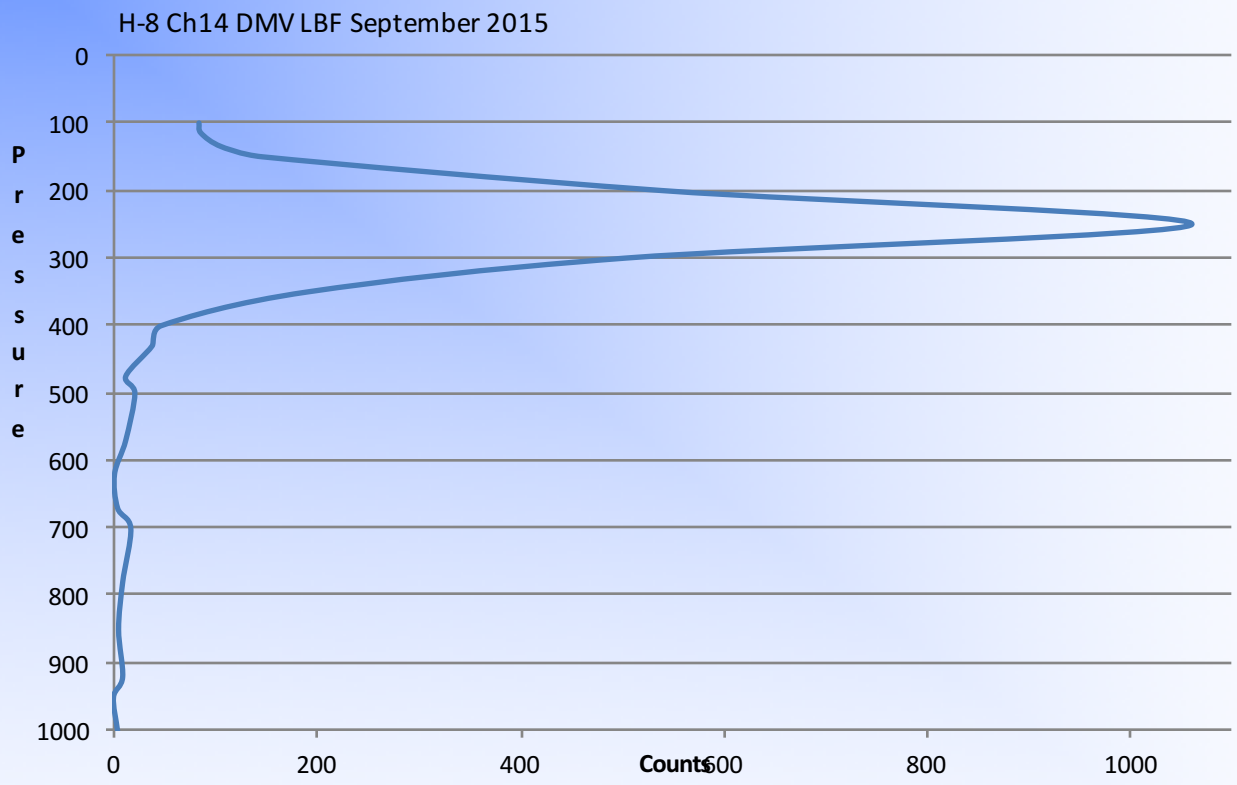
Himawari-8 AMVs tracked using IR (11 μm) channel 14 tracers at 00 UTC on 16 January 2016 using the new generation operational system

Generation and Assimilation of 10 minute H-8 AMVS



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

Generation and Assimilation of 10 minute H-8 AMVS



Himawari-8 level of best fit height assignment statistics for CH.14 AMVs for September 2015 (Channel 14 Himawari-8 AMVs height assigned to between 230hPa and 270hPa)

Assimilation of 10 minute Himawari-8 AMVS

Assimilation period 4 March 2014 - 26 March 2014

Winds centred on 0050, 0000, 0110UTC
0150,0200, 0210
0250……etc.

Used ACCESS-G2 (new Op. Fcst system)

Control OP. database included

H-7 AMVs from JMA
Local HR H-7 AMVs from BoM
H-8 AMVs from JMA

Expt added Local HR H-8 AMVs from BoM

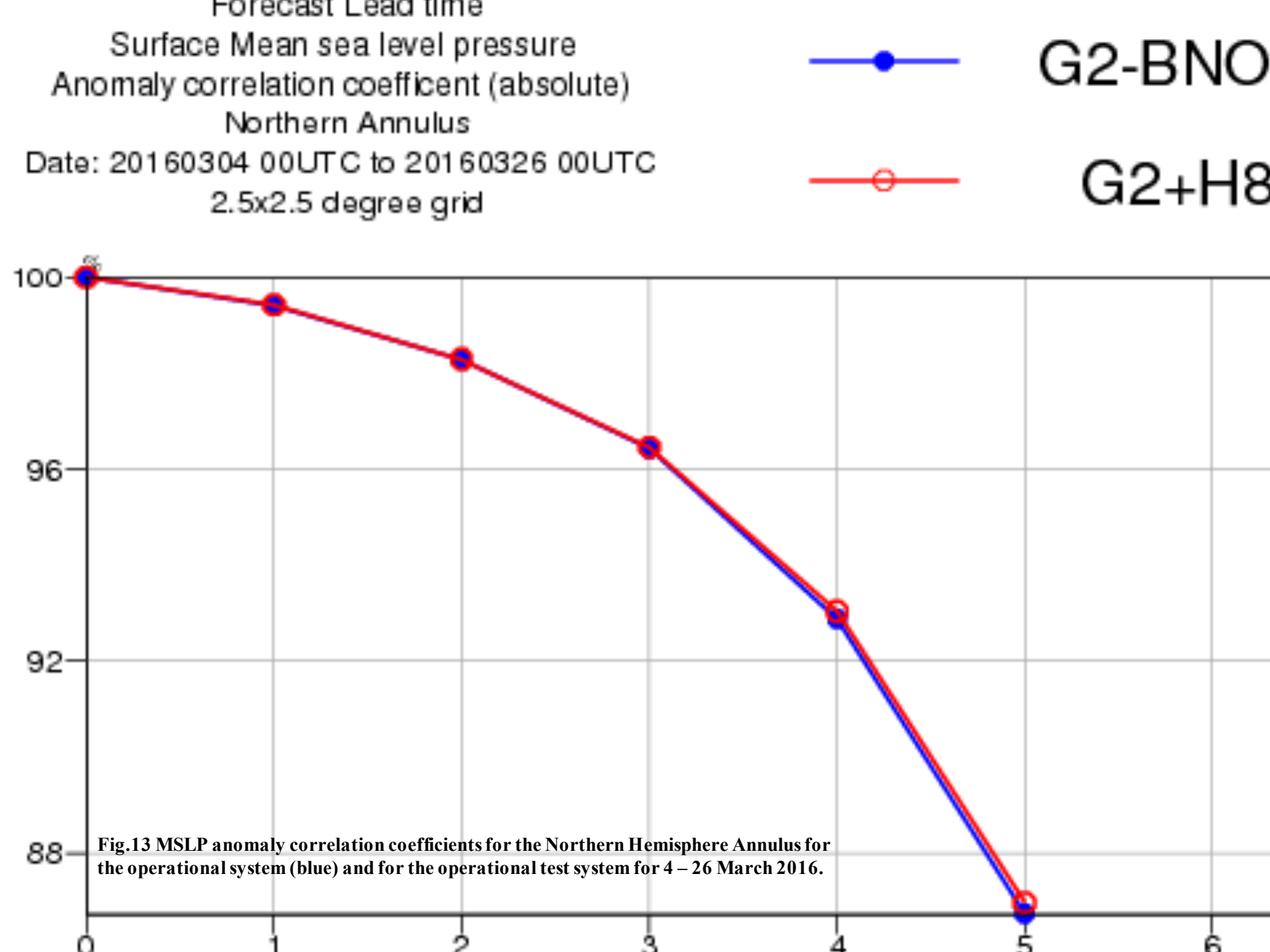
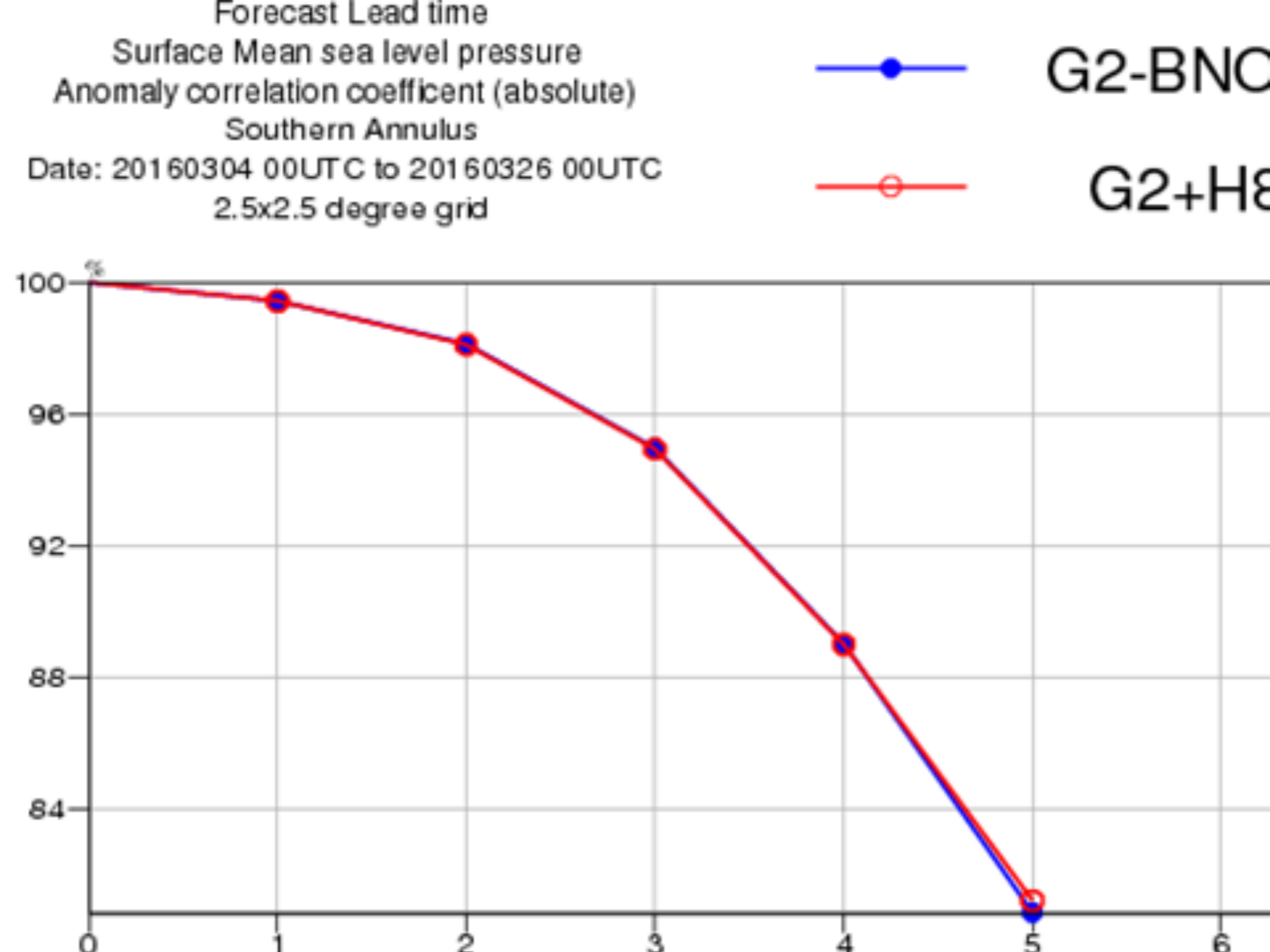


Fig.13 MSLP anomaly correlation coefficients for the Northern Hemisphere Annulus for the operational system (blue) and for the operational test system for 4 – 26 March 2016.


Forecast Lead time
Surface Mean sea level pressure
Anomaly correlation coefficent (absolute)
Southern Annulus
Date: 20160304 00UTC to 20160326 00UTC
2.5x2.5 degree grid
G2-BNC
G2+H8
%
100
96
92
88
84
0
1
2
3
4
5
6

Summary and Conclusions

10-minute winds are being continuously generated in the Australian region and assimilated operationally with 4D Var.

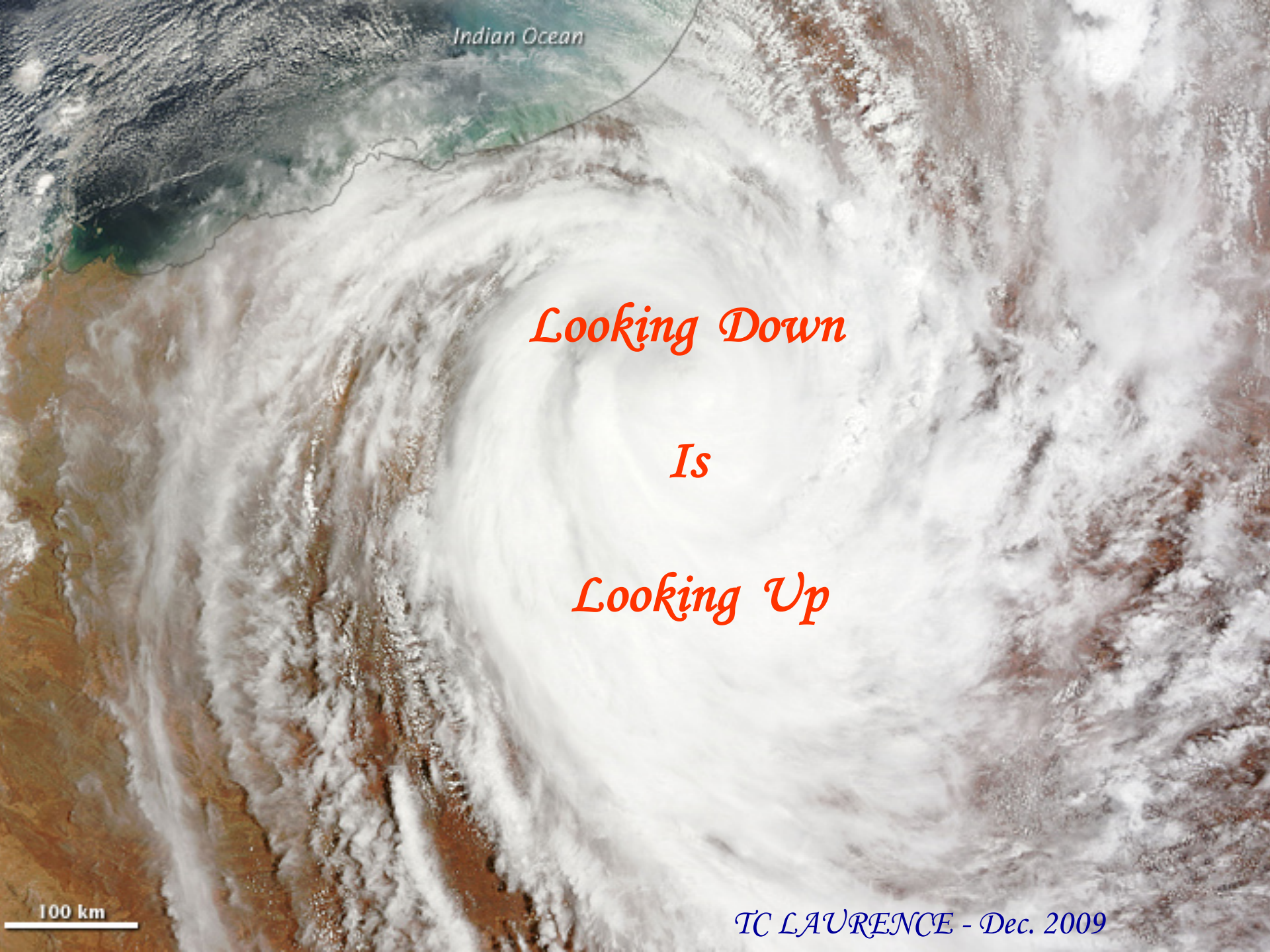
H-8 10 minute DMVs provide an improved spatial and temporal resolution database for analysis and forecasting.

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

If the data is thinned to equal spatial density, *the quality of the H-8 data exceeds that of the operational H7 data*.

Data assimilation tests showed 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 system is underway. This involves use of all 10 minute data and includes the prediction of TC activity and severe weather.



Looking Down

Is

Looking Up

TC LAURENCE - Dec. 2009