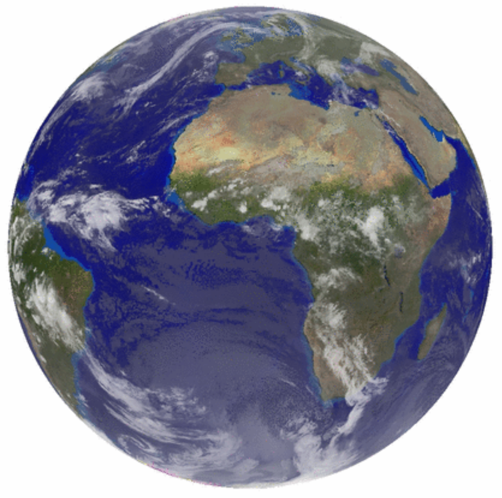


# Operational Generation And Assimilation Of Himawari-8

# Atmospheric Motion Vectors

John Le Marshall[1], David Howard[1], Xingbao Wang[1], Yi Xiao[1], Jim Jung[2], Jaime Daniels[4] ,Steve Wanzong[2] , Joan Fernon[1] , Agnes Lim[2] , Wayne Bresky[5], Andrew Bailey[5] Chris Tingwell[1] , Robert Norman[3] Tim Morrow [1]

[1] Bureau of Meteorology, Melbourne, Australia

[2] UW/CIMSS, Madison,USA

[3] RMIT University, Melbourne, Australia

[4] NOAA/NESDIS/STAR, College Park, USA

[5] IMSG

# *Overview*

- *Importance of EOS*
- *Improvements in specification of the mass and wind field*
- *AMVs- MTSat -1R, -2 Himawari – 8, Himawari – 9*
- *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

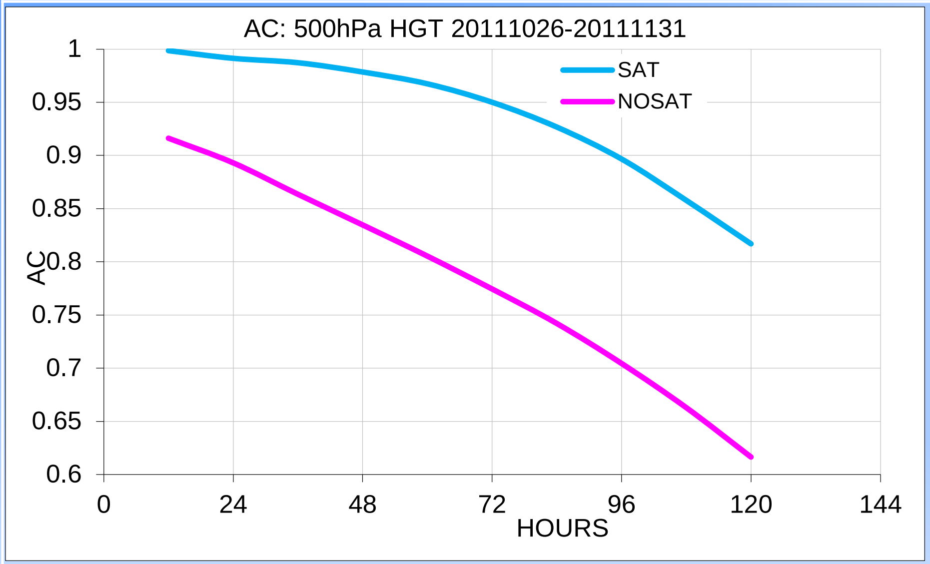



Fig. 8(c). SH 500hPa height anomaly correlation for the control (SAT) and no satellite (NOSAT), 28 October to 30 November 2011 using ACCESS and verifying against the control analysis

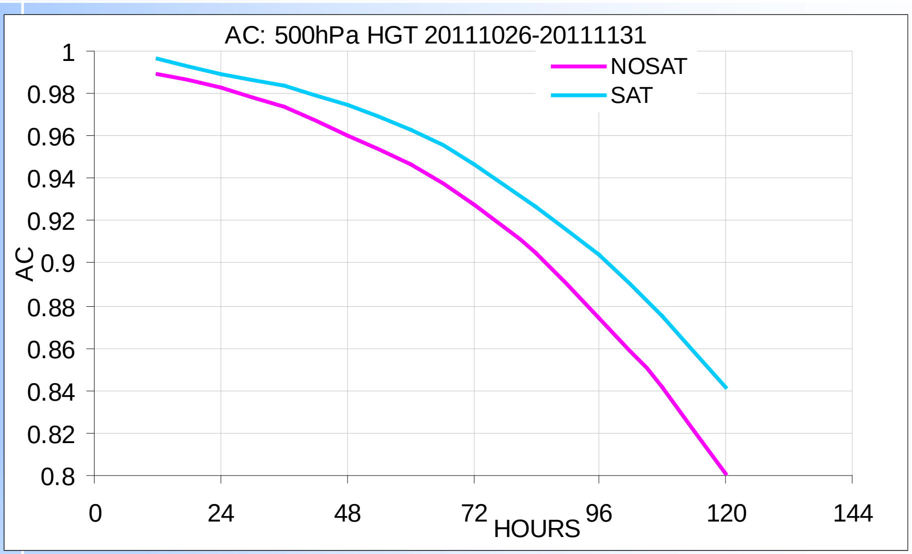
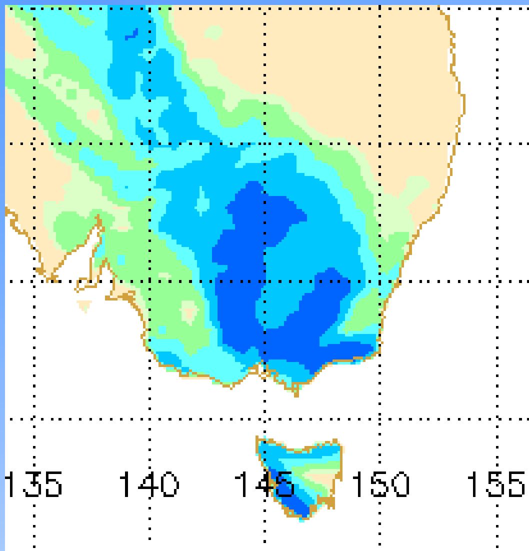
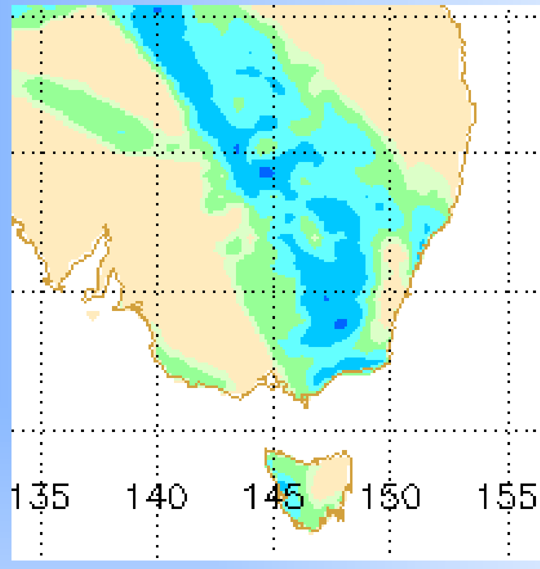



Fig. 8(f). NH 500hPa height anomaly correlation for the control (SAT) and no satellite (NOSAT), 28 October to 30 November 2011 using ACCESS and verifying against the control analysis

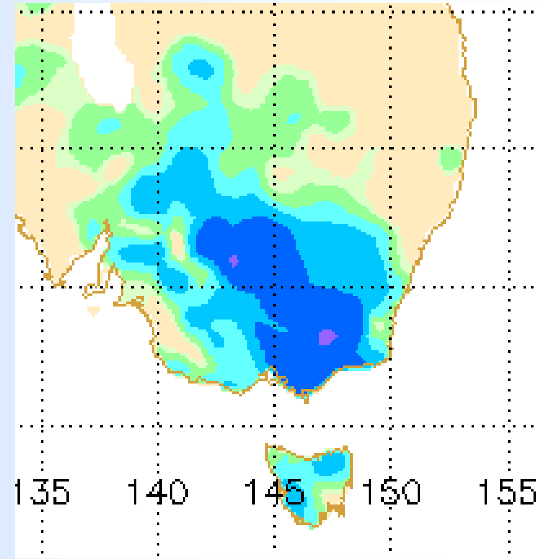
# Hi Impact Weather




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

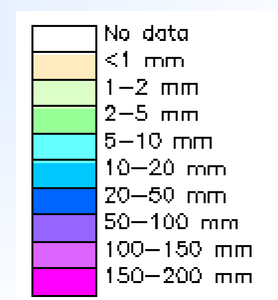



**ACCESS-G 48 to 72 hour rainfall forecast for 9 November 2011 using no satellite data.**

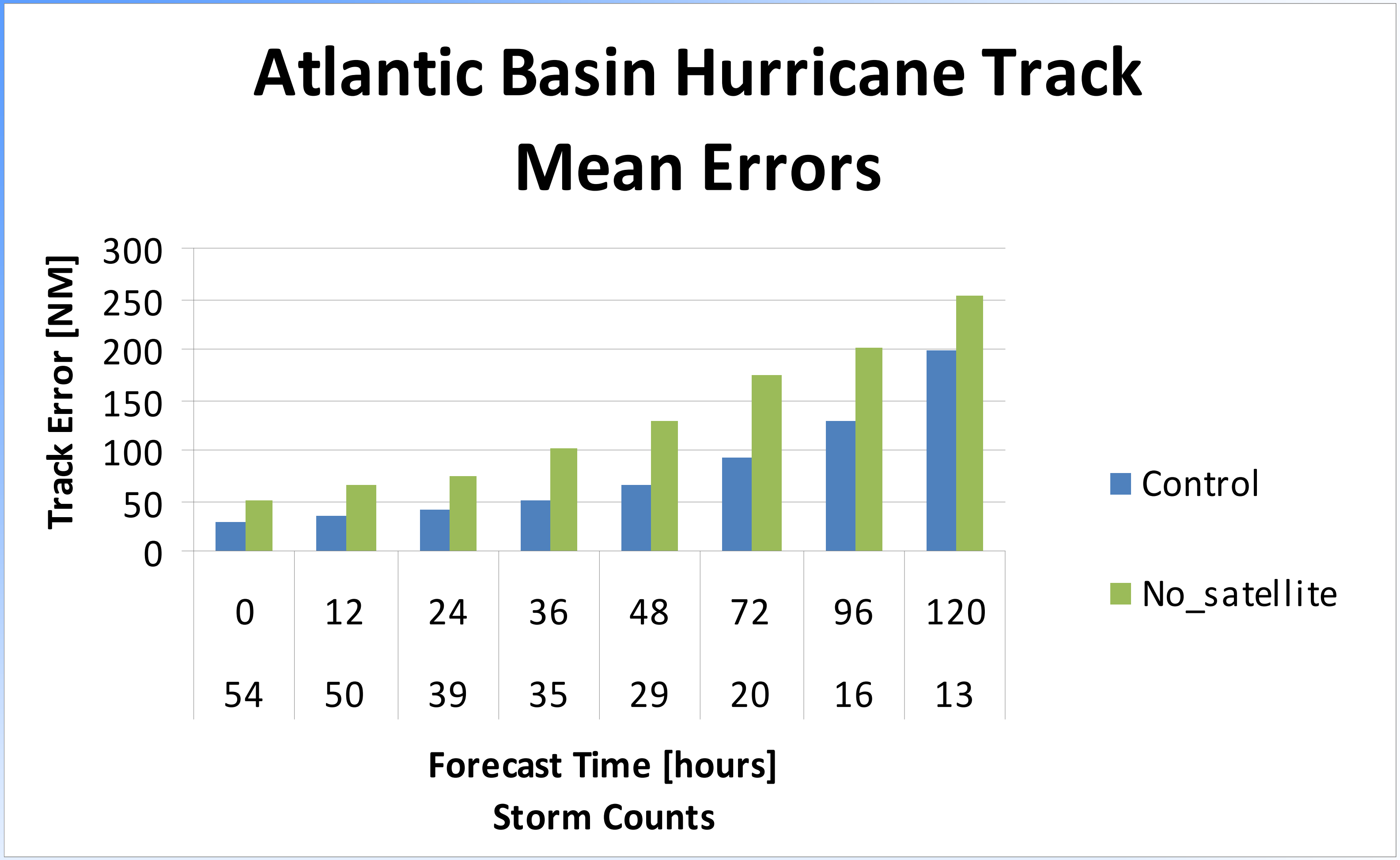



**Daily rain gauge analysis for 9 November 2011.**

| 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 |



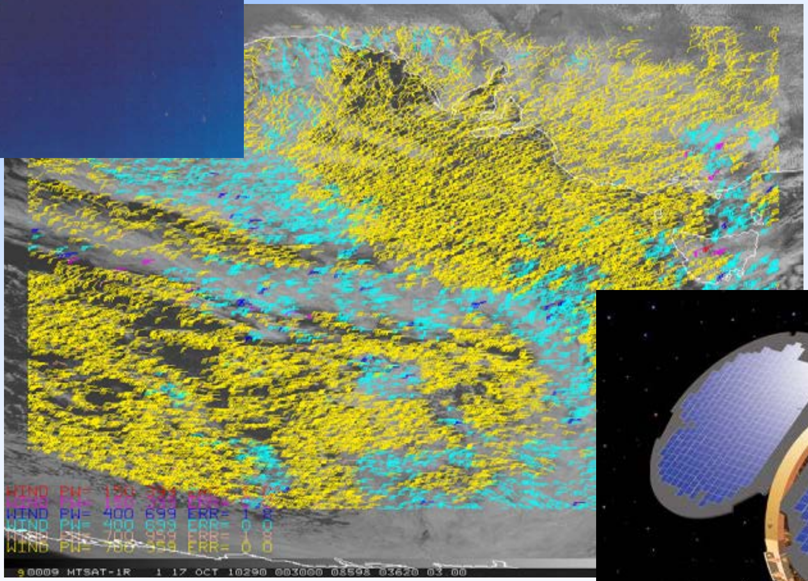

**Daily rainfall values.**




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.

# *Specification of the Mass and Wind Field – Key Data*

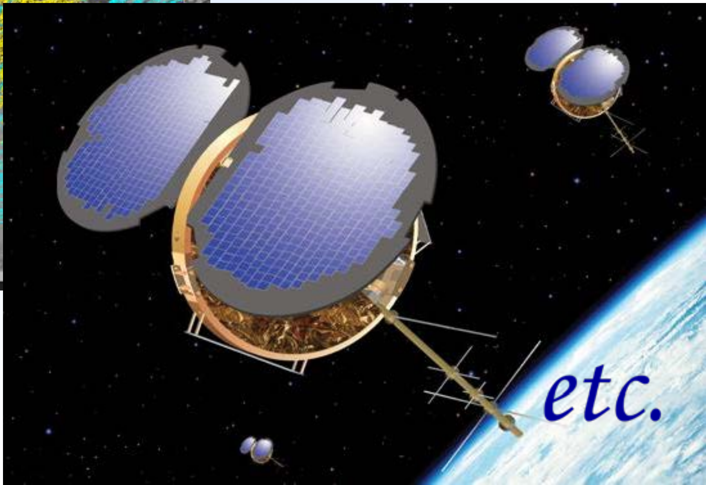
*AMVs*



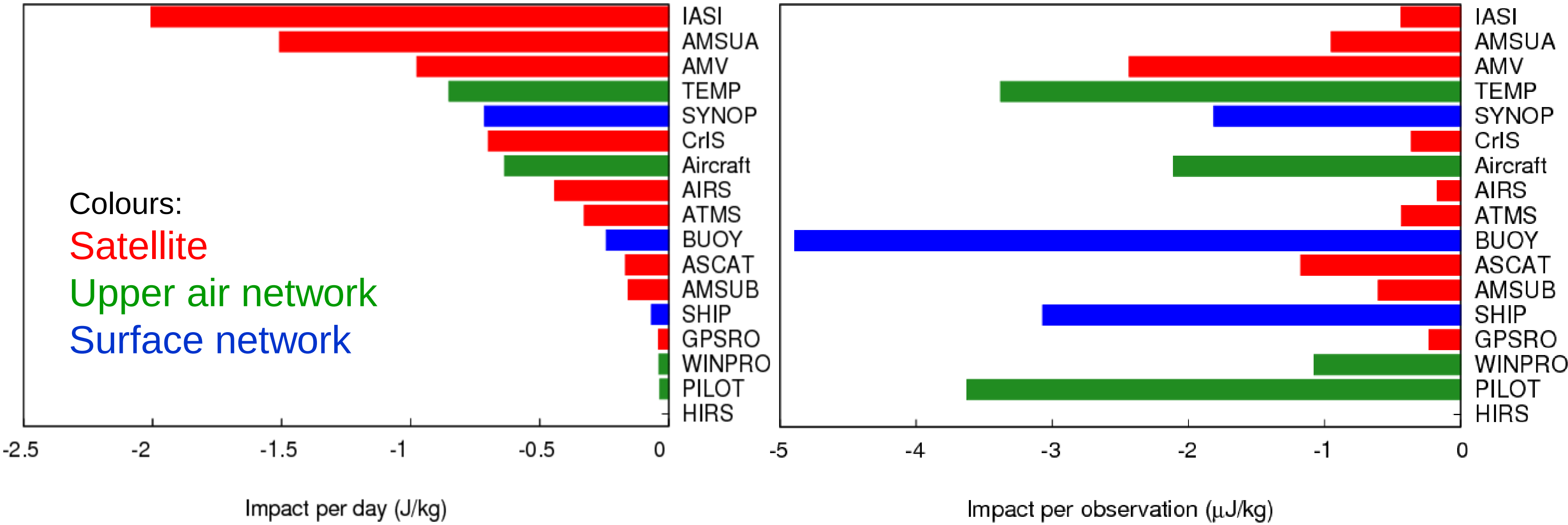
*GPS RO*

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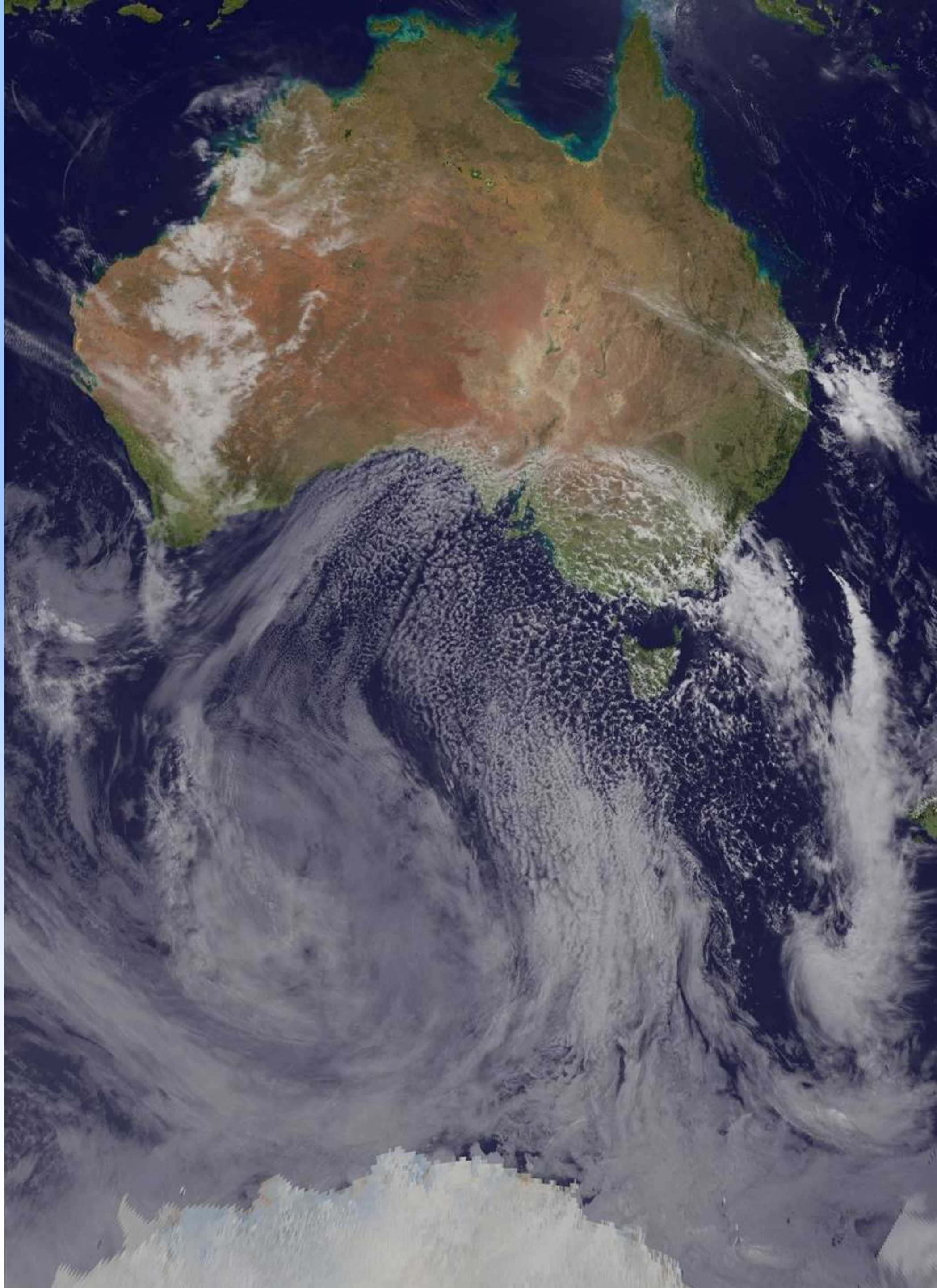
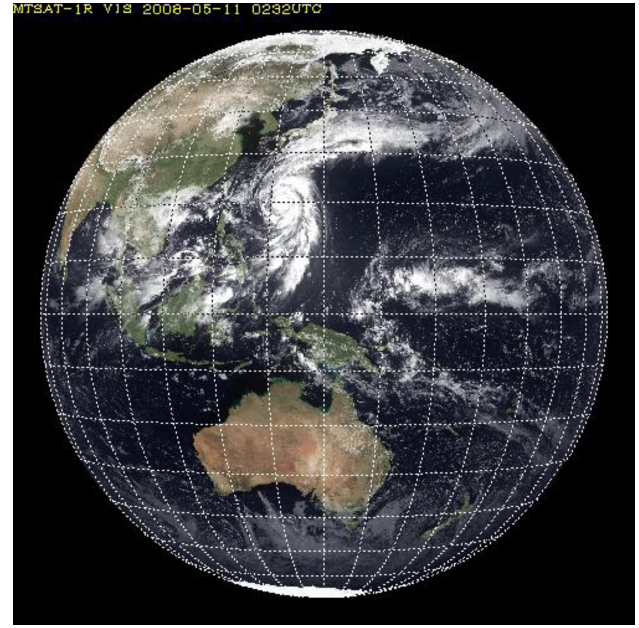
# MTSAT -1R and 2
# Himawari-8 Himawari-9

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



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

**Full Disk Image**
every 10 minutes

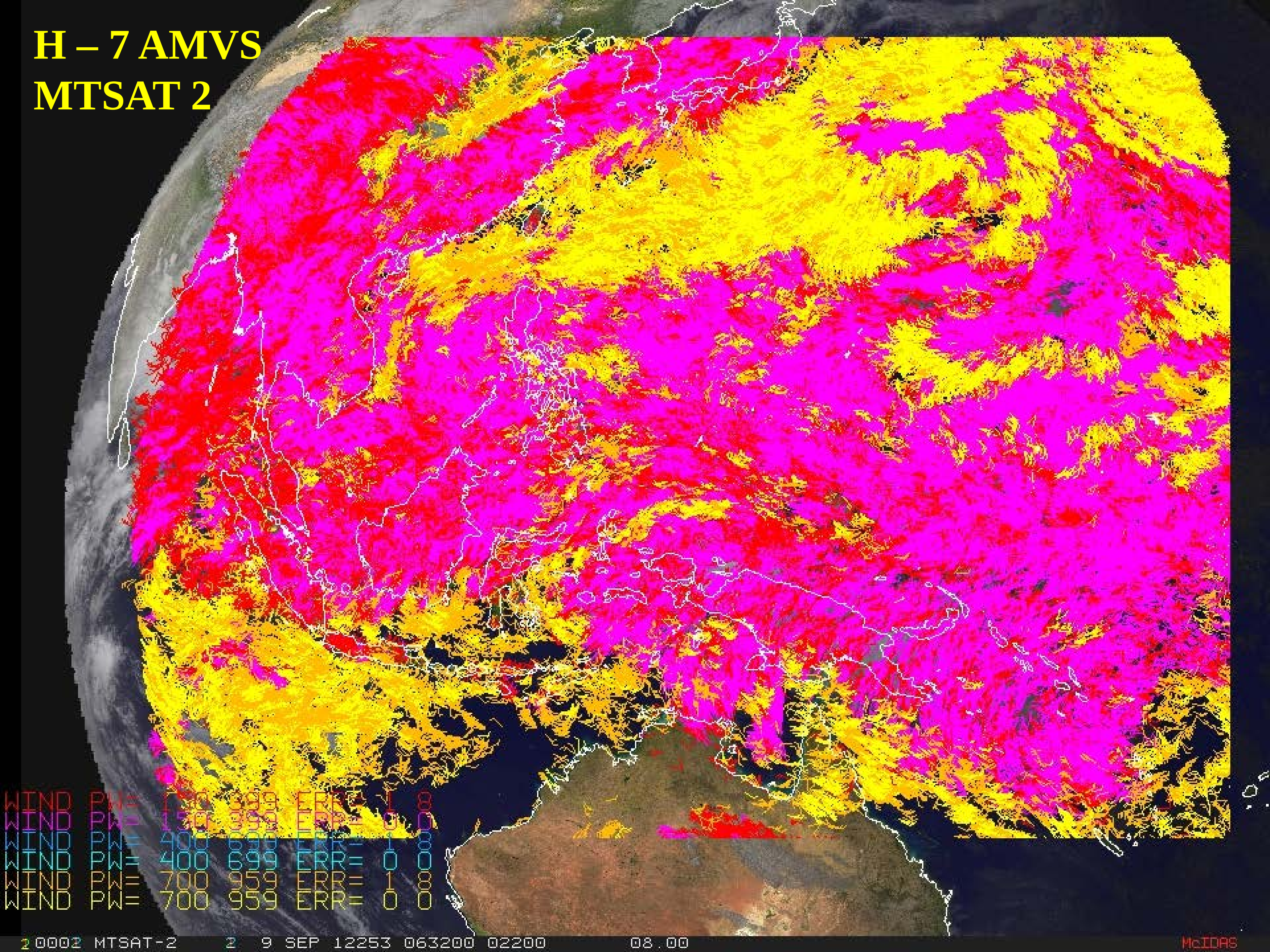



| | Band | Central Wavelength [µm] | Spatial Resolution | |
|---|---|---|---|---|
| | 1 | 0.43 -0.48 | 1Km | RGB Composited True Color Image |
| | 2 | 0.50 -0.52 | 1Km | |
| X | 3 | 0.63 -0.66 | 0.5Km | |
| X | 4 | 0.85 -0.87 | 1Km | |
| X | 5 | 1.60 -1.62 | 2Km | 1.3 µm for GOES-R |
| | 6 | 2.25 -2.27 | 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 |

**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



# *NEAR RT TRIAL*

## *OPERATIONAL SYSTEM*

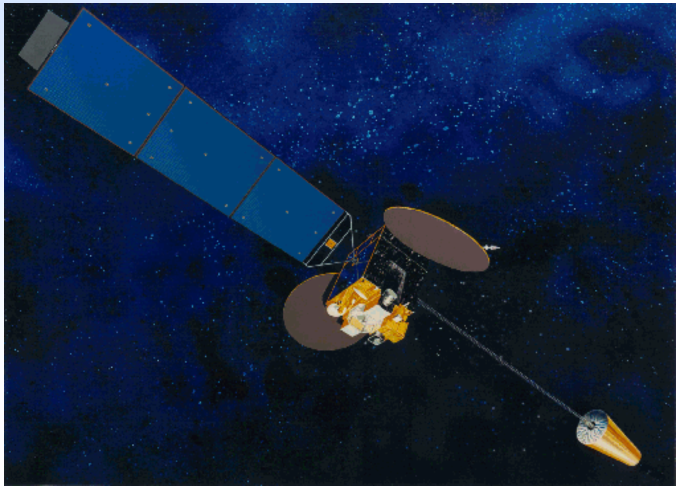
27 January – 23 February 2011

Used

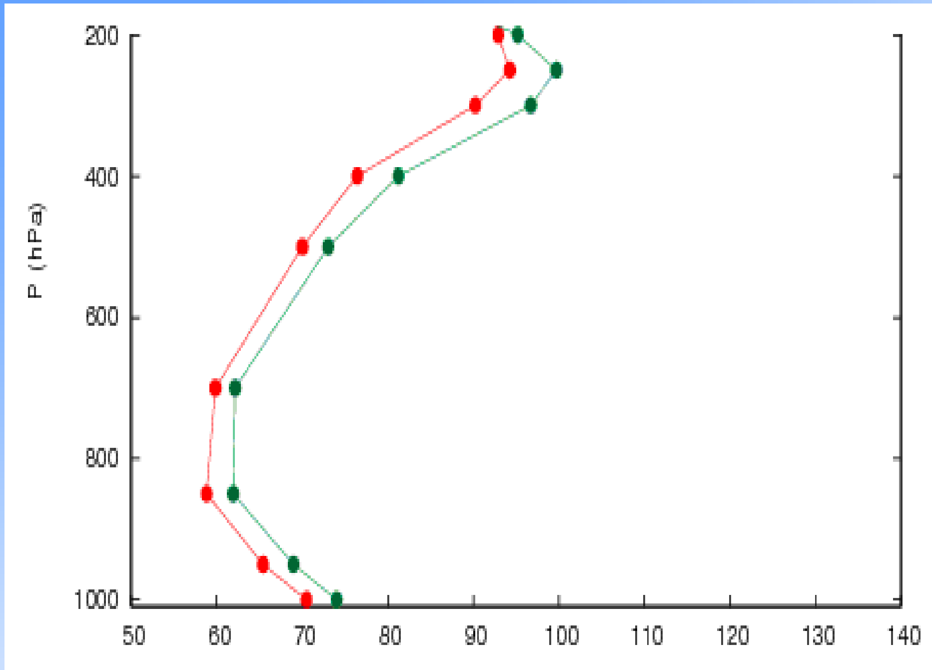
■ Real Time Local Satellite Winds MTSAT-2 (EE, hourly since 96, TDB)

- 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



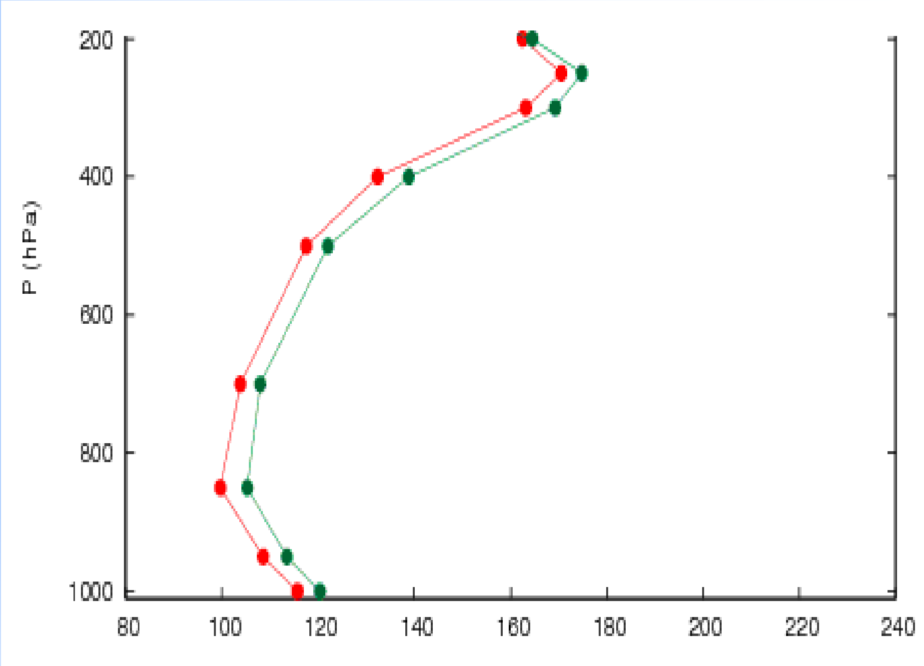




**Fig.6(a). The RMS difference between forecast and verifying analysis geopotential height(m) at 24 hours for ACCESS-R (green) and ACCESS-R with hourly AMVs (red) for the period 27 January to 23 February 2011.**

**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.**

**Table 6 : The SI skill scores for the hourly IR and VIS CDW assimilation (CLAPS2) and matching control Forecasts (CLAPS1) for the period and 05 September to 08 December 1995**

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

| Period | 05 September to 25 September 1995 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Level | MSLP | | 850 hPa | | 500 hPa | | 300 hPa | |
| Assim. Type | CLAPS1 | CLAPS2 | CLAPS1 | CLAPS2 | CLAPS1 | CLAPS2 | CLAPS1 | CLAPS2 |
| No. of cases | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| Skill score | 27.1 | 26.1 | 28.2 | 27.0 | 18.6 | 18.5 | 16.4 | 16.0 |

| Period | 03 December to 08 December 1995 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Level | MSLP | | 850 hPa | | 500 hPa | | 300 hPa | |
| Assim. Type | CLAPS1 | CLAPS2 | CLAPS1 | CLAPS2 | CLAPS1 | CLAPS2 | CLAPS1 | CLAPS2 |
| No. of cases | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Skill score | 29.0 | 28.3 | 31.9 | 29.5 | 20.2 | 19.3 | 17.0 | 16.3 |

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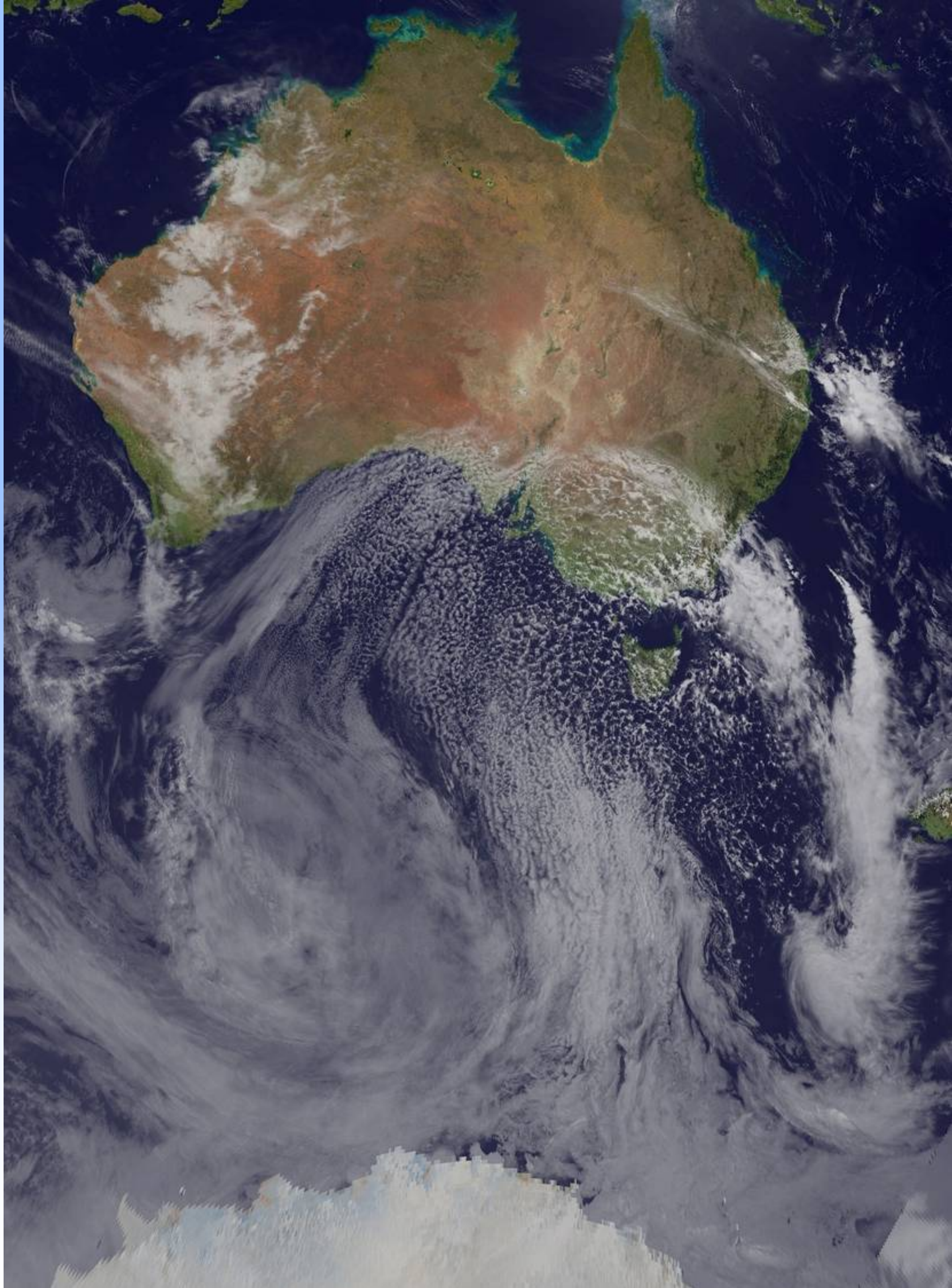
# GENERATION AND ASSIMILATION OF CONTINUOUS (10 Minute) ATMOSPHERIC MOTION VECTORS FROM MTSAT-1R (HIMAWARI-6) USING 4DVAR



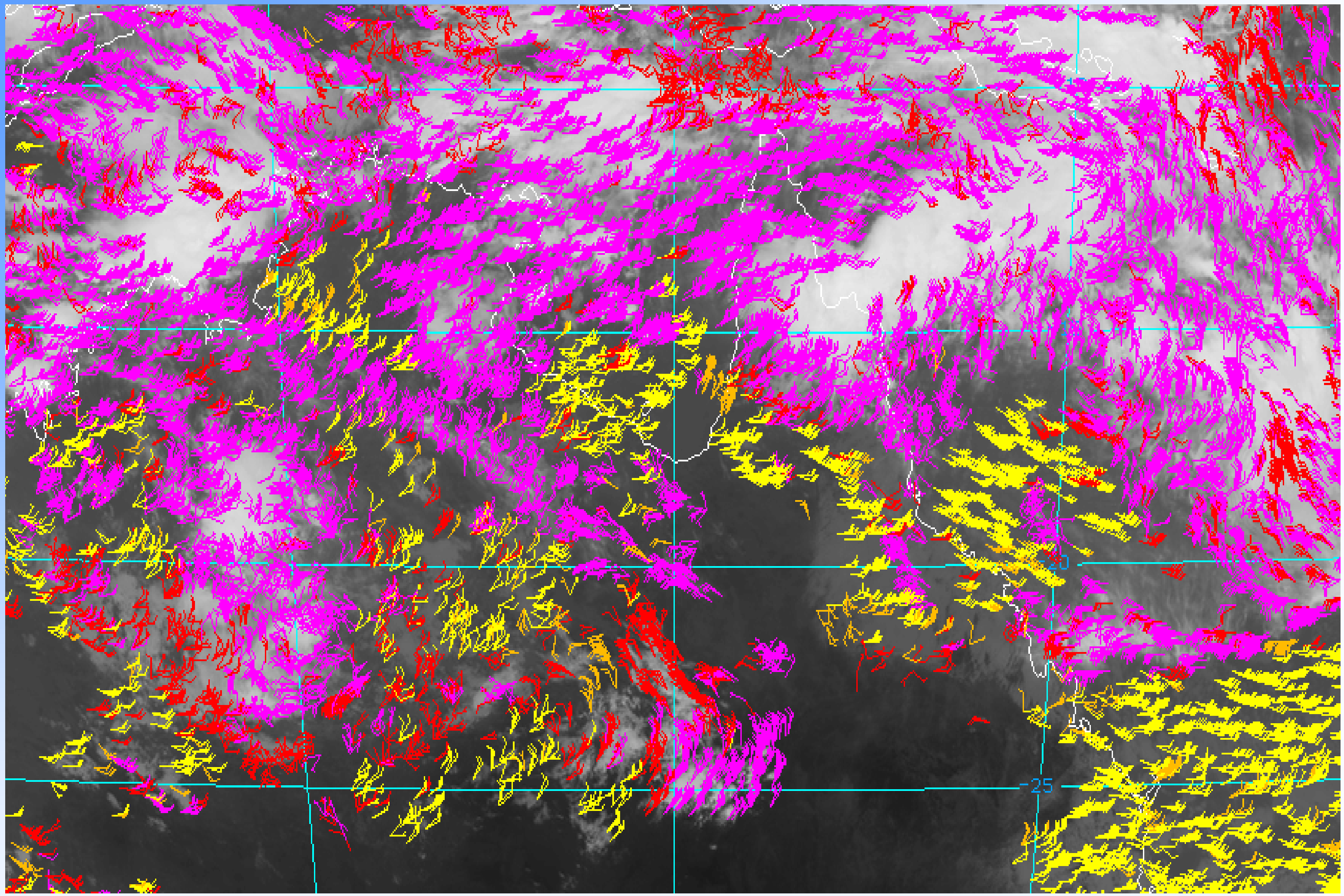



Fig. 1 A selection of Himawari-6 Atmospheric Motion Vectors over North-Eastern Australia generated from 10 min imagery between 0010 UTC and 0050 UTC 28 January 2014.

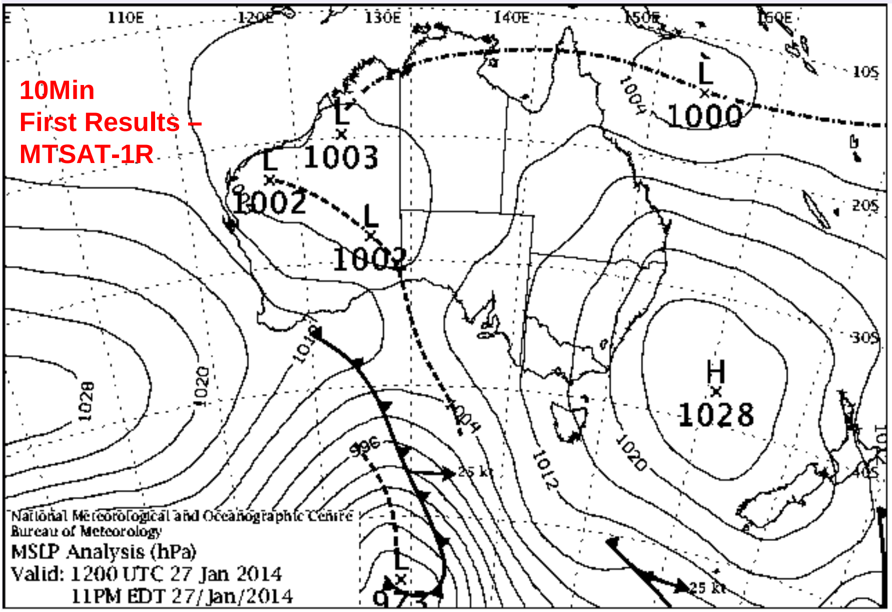



Fig. 13 Bureau of Meteorology Analysis for 12 UTC on 27 January 2014.

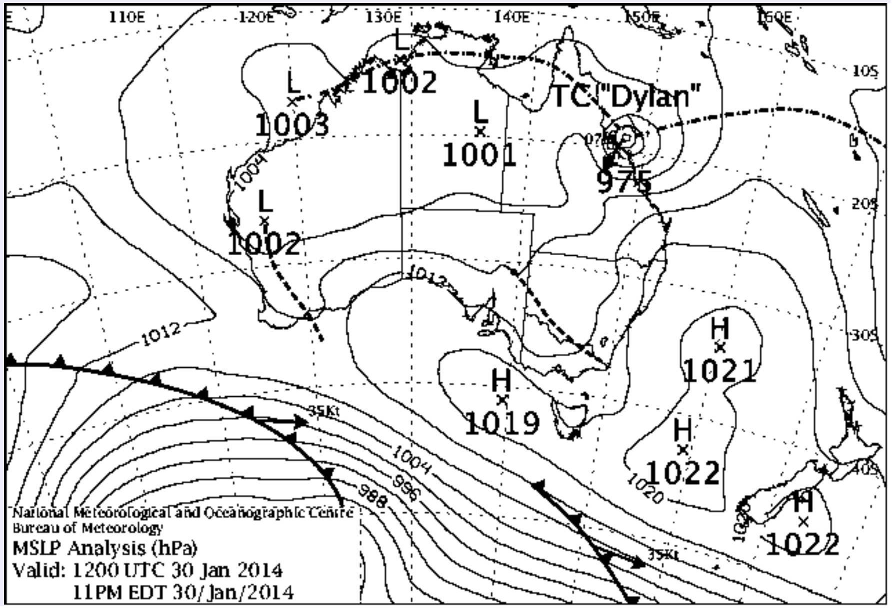



Fig. 14. Bureau of Meteorology Analysis for 12 UTC on 30 January 2014

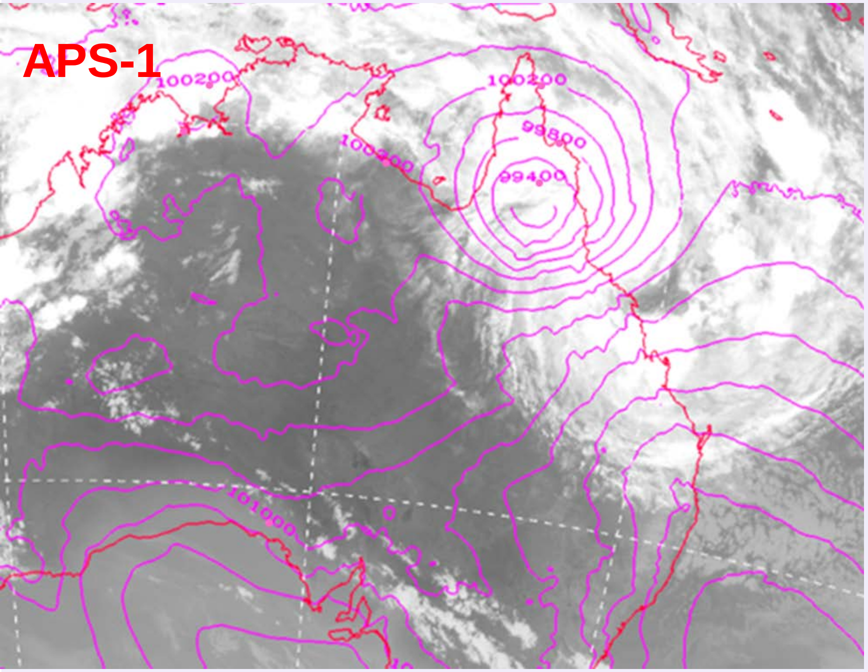



Fig.15 The Bureau of Meteorology operational three-day MSLP (hPa) forecast valid 1200 UTC 30 January 2014, shown remapped over an MTSat infrared image, valid at the same time.

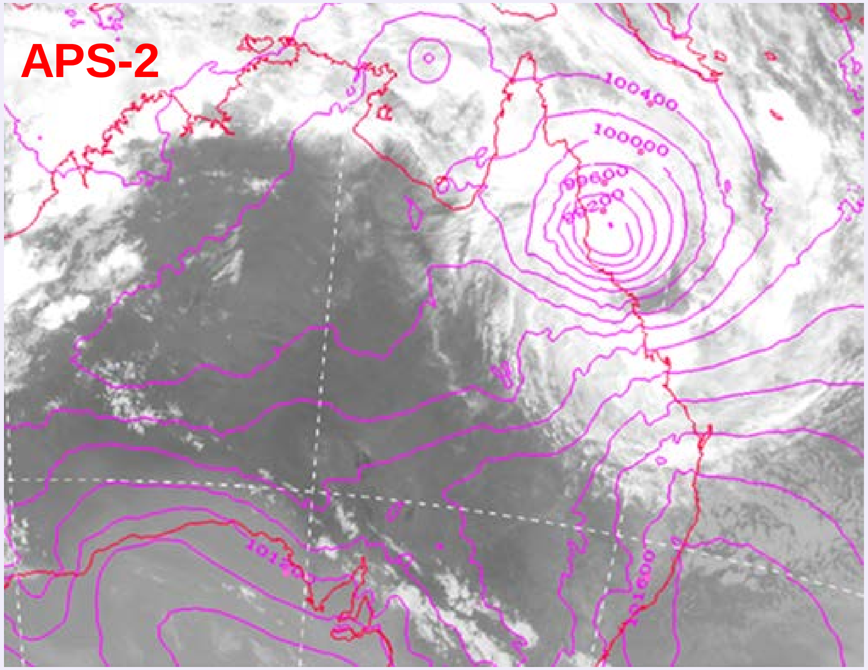
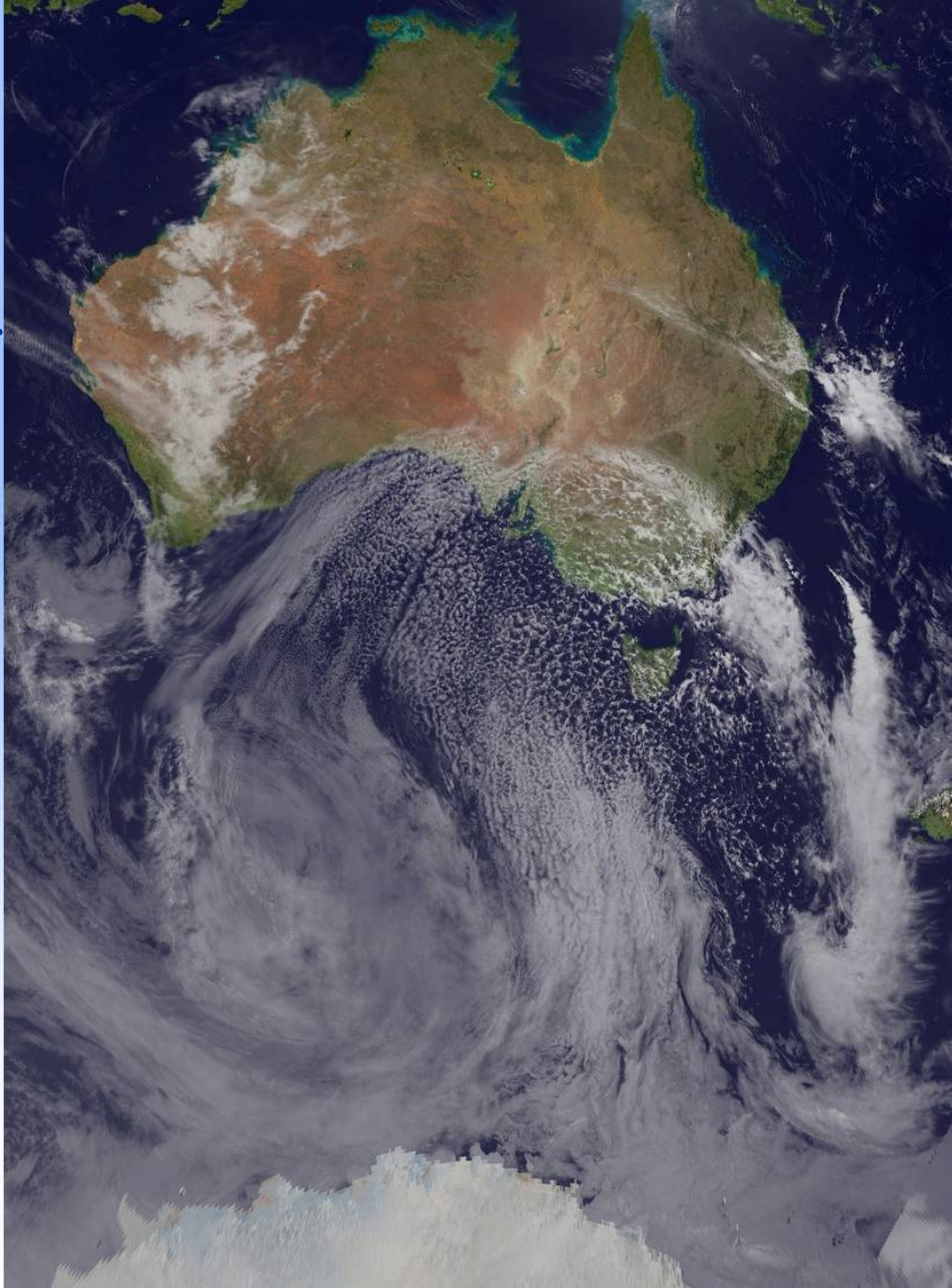



Fig.16 The Bureau of Meteorology three-day MSLP (hPa) forecast valid, 1200 UTC 30 January 2014 using the next generation operational regional forecasting system with ten, fifteen and sixty minute AMV data from MTSat-1R and MTSat-2. The forecast remapped over the 1200 UTC MTSat image.

Australian Government

Bureau of Meteorology

# 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.

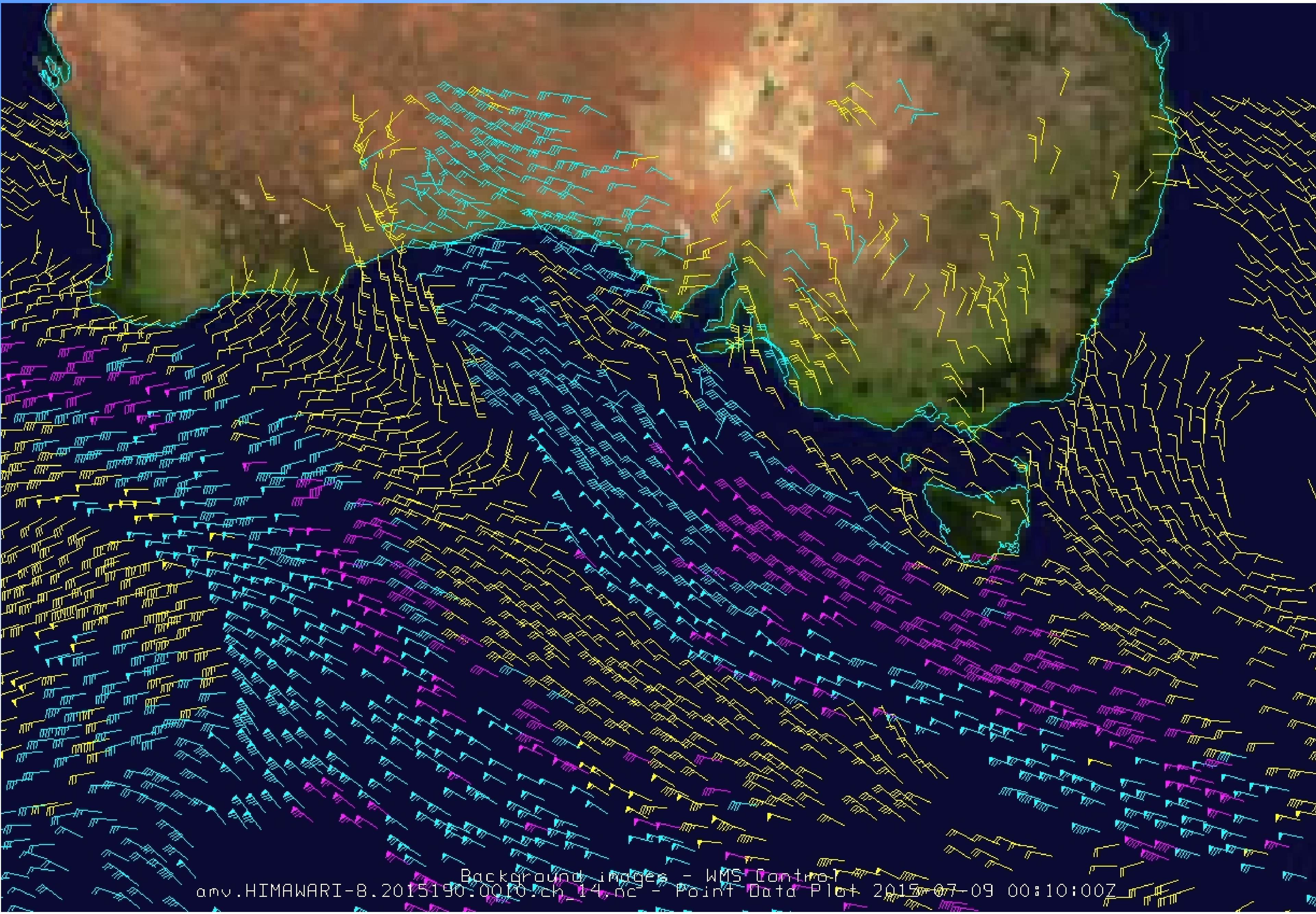
Height assignment methods similar to GOES-R ABI ATBD For Cloud Height (Heidinger, A. 2010)

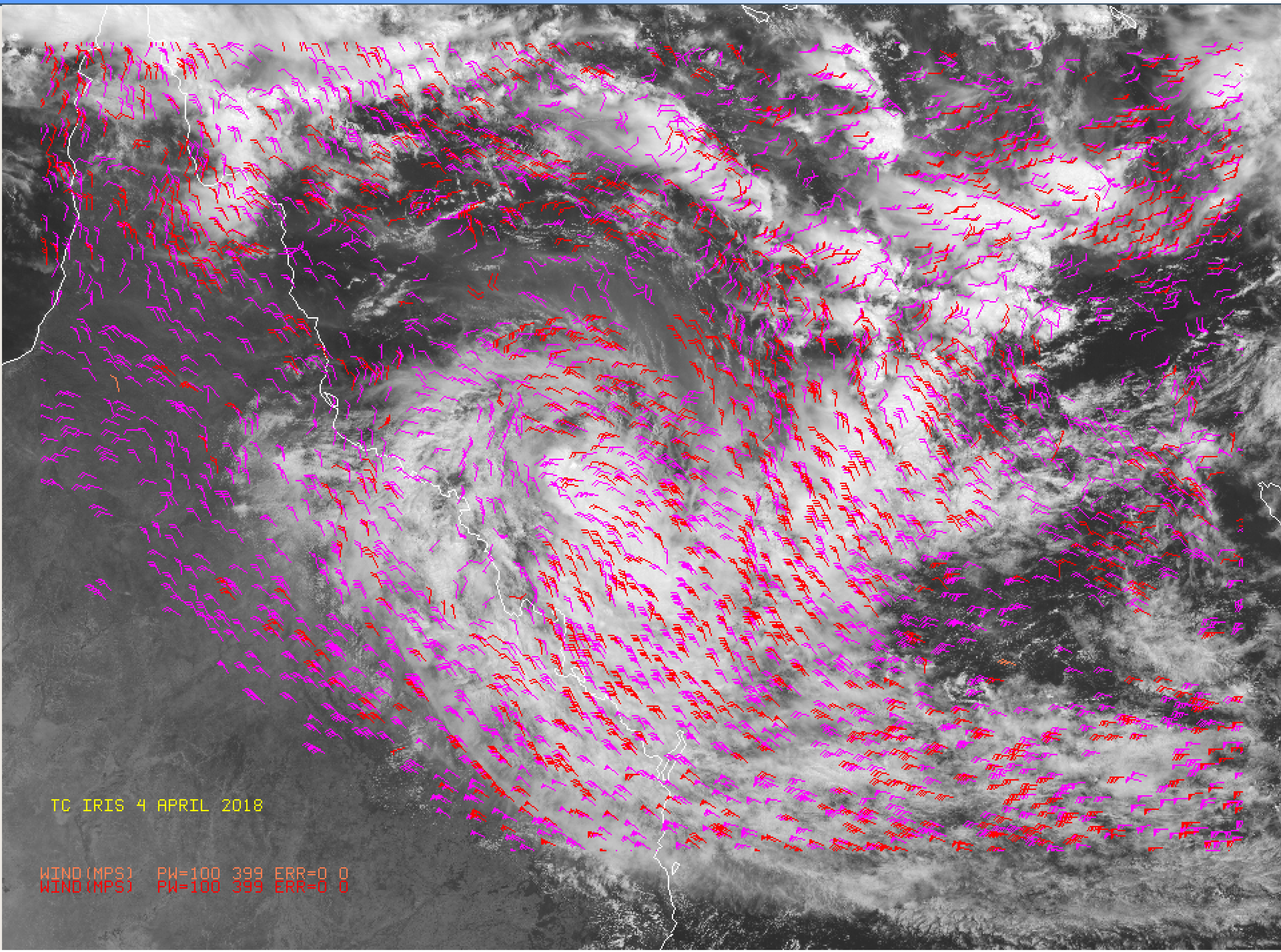
AMV estimation is similar to GOES-R ABI ATBD for Derived Motion Winds (Daniels, 2010) / BoM system

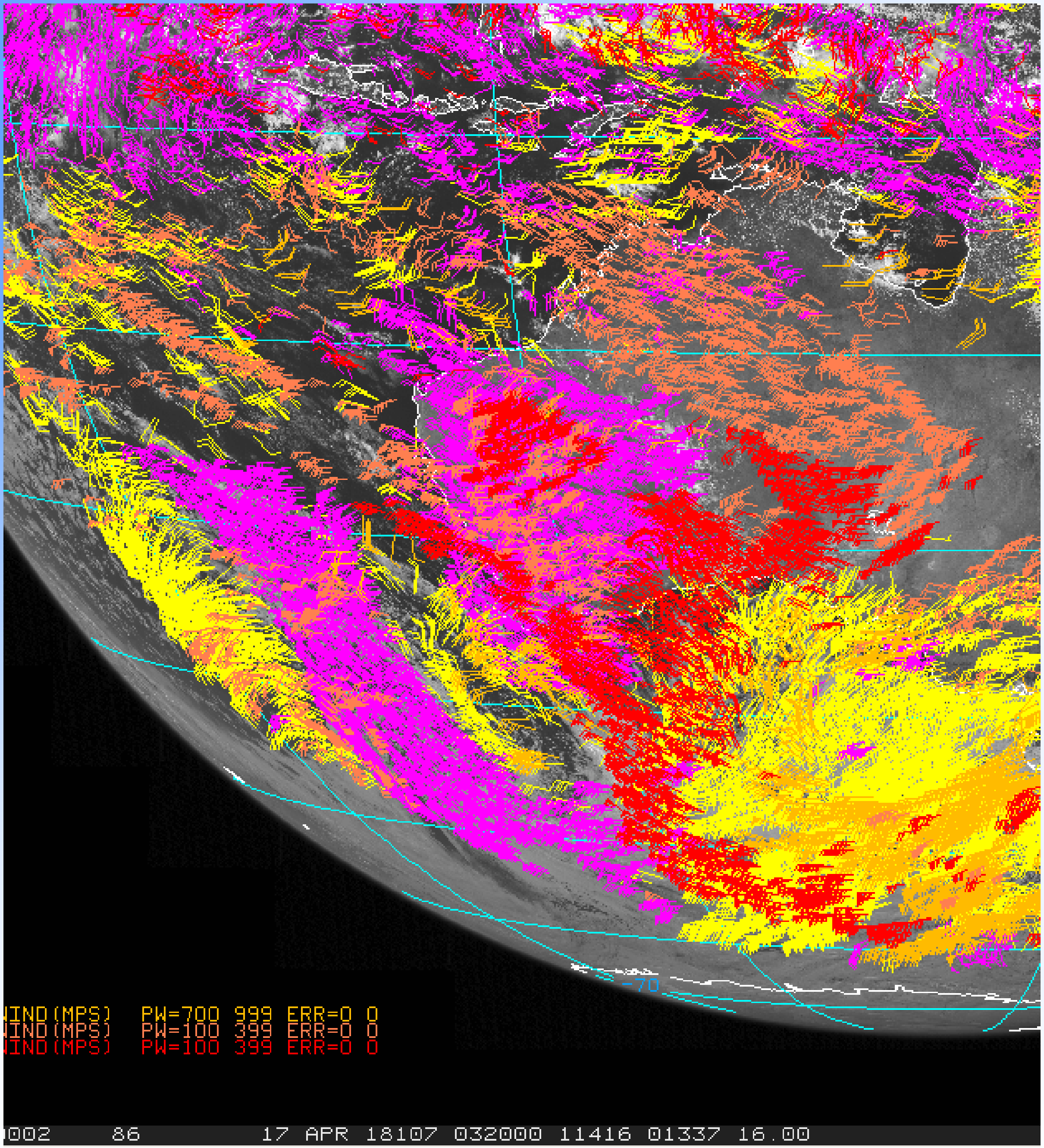
Error characterization, data selection, QC via EE, QI, ERR etc. (Le Marshall et al., 2004, 2015)

*Height assignment verification Cloudsat/Calipso, RAOBS*

*(System also used for H-7)*


Background images - WMS Control
amv.HIMAWARI-8.2015190.0010.ch_14.nc - Point Data Plot 2015-07-09 00:10:00Z


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




00UTC 17 April 2018

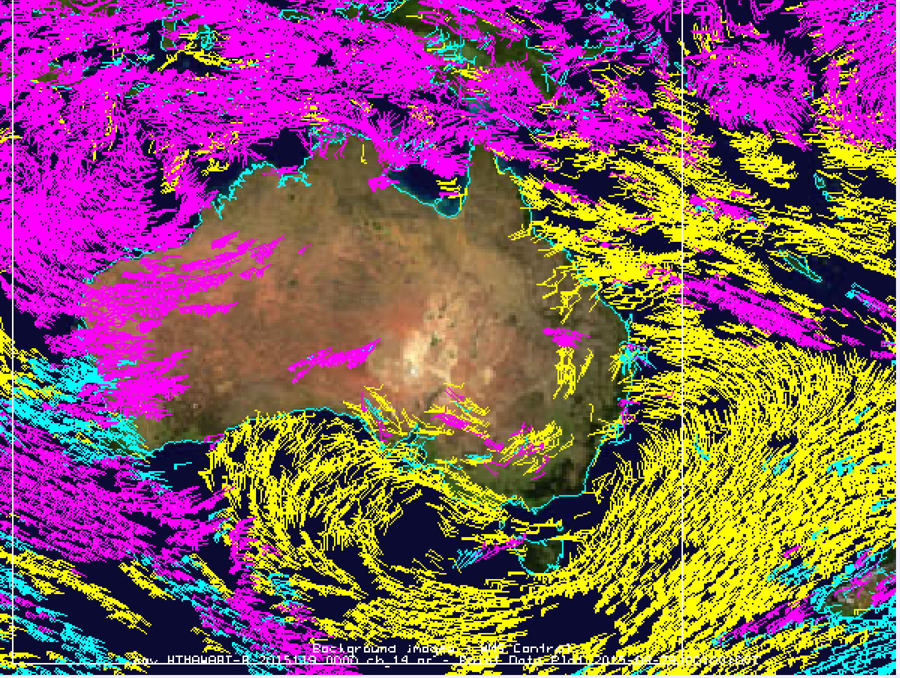



Fig.7 AMVs generated around Australia 0000UTC 29 April 2015 – Note box around Australia.

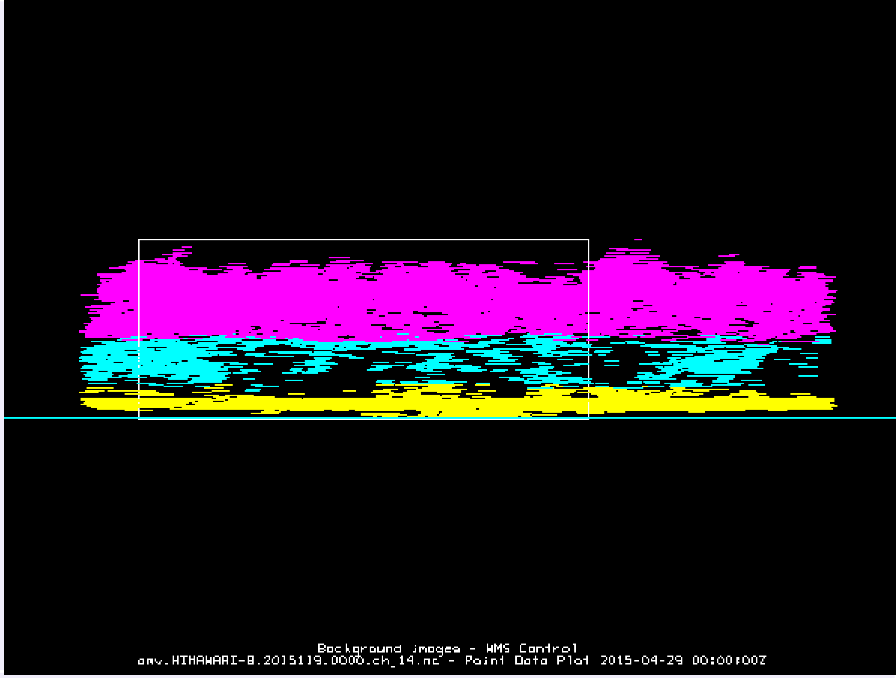



Fig.8 AMVs generated around Australia 0000UTC 29 April 2015 – View from the south.

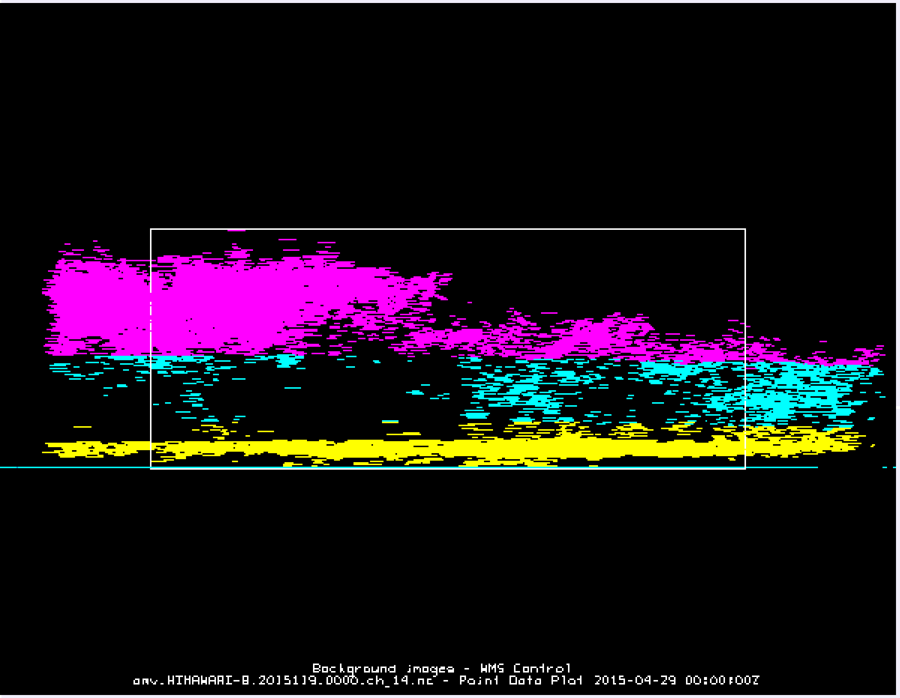



Fig.9AMVs generated around Australia 0000UTC 29 April 2015 – View from the west.

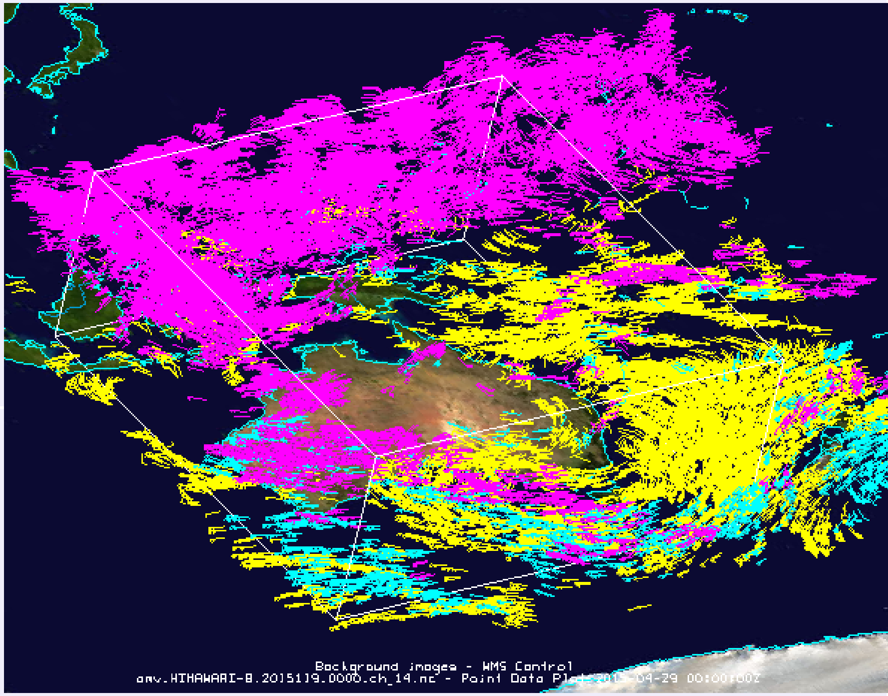



Fig.10AMVs generated around Australia 0000UTC 29 April 2015 – Slant view from southwest.

**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

# *Length Scale of the Correlated Error*

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

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

*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.*

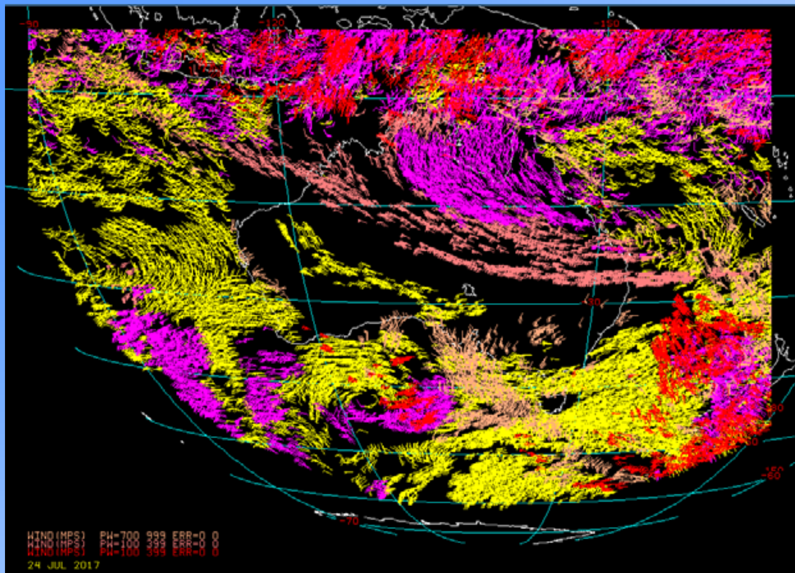


**Fig.3 Thinned Himawari-8 AMVs tracked using tracers from channel 14, 9 and 2 images at 00 UTC 24 July 2017.**

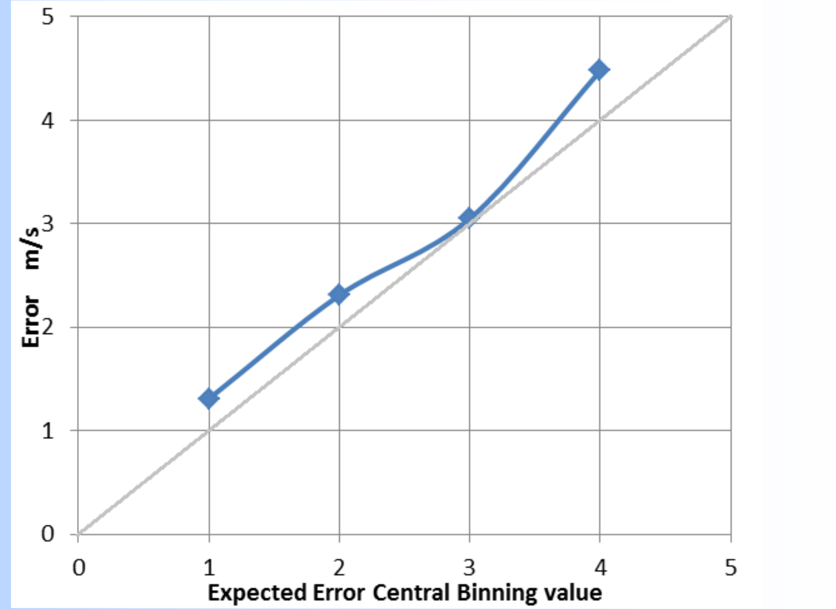



Fig. 4. Measured error (m/ s) vs Expected Error (m/s) for low-level Himawari-8 IR winds (1 31 August –29 2016).

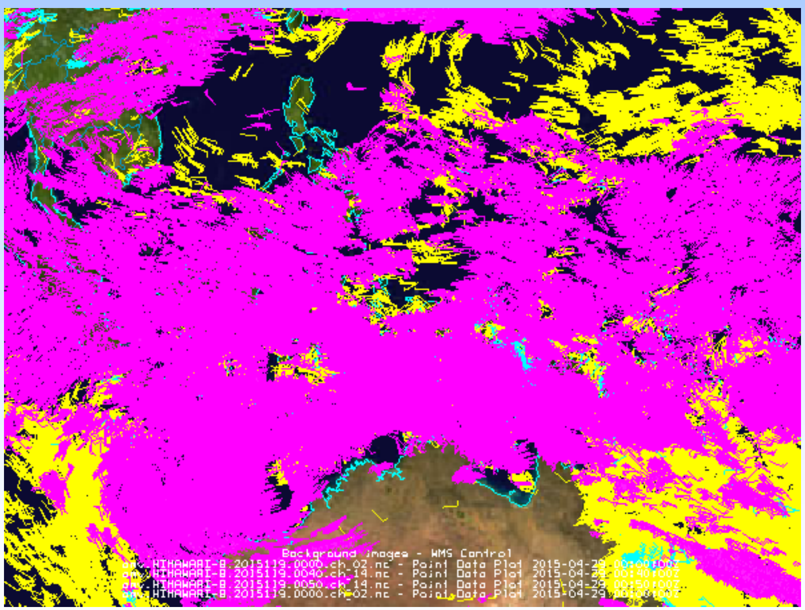


Fig. 5 Coverage of AMVs from Himawari-8 in the tropics to the north of Australia around 0000 UTC 29 April 2015

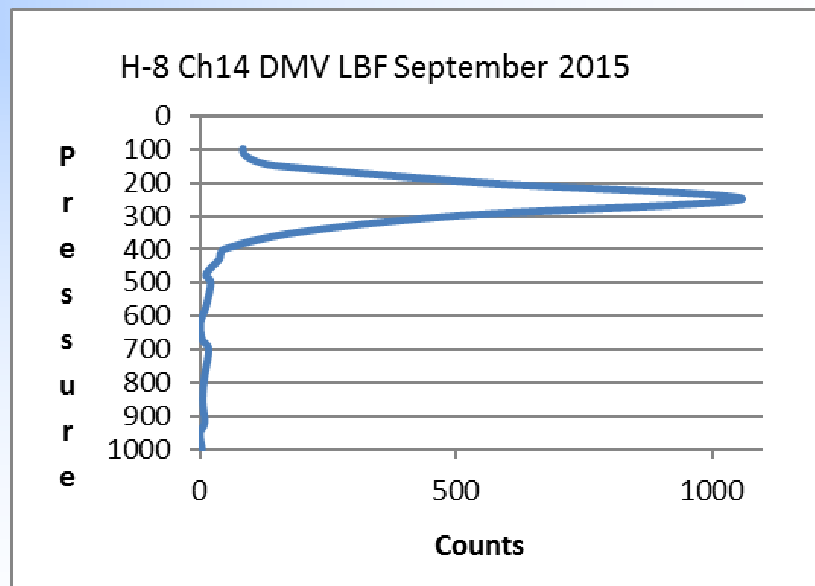



Fig. 6 Himawari-8 level of best fit height assignment statistics for CH.14 AMVs for September 2015 (see text)

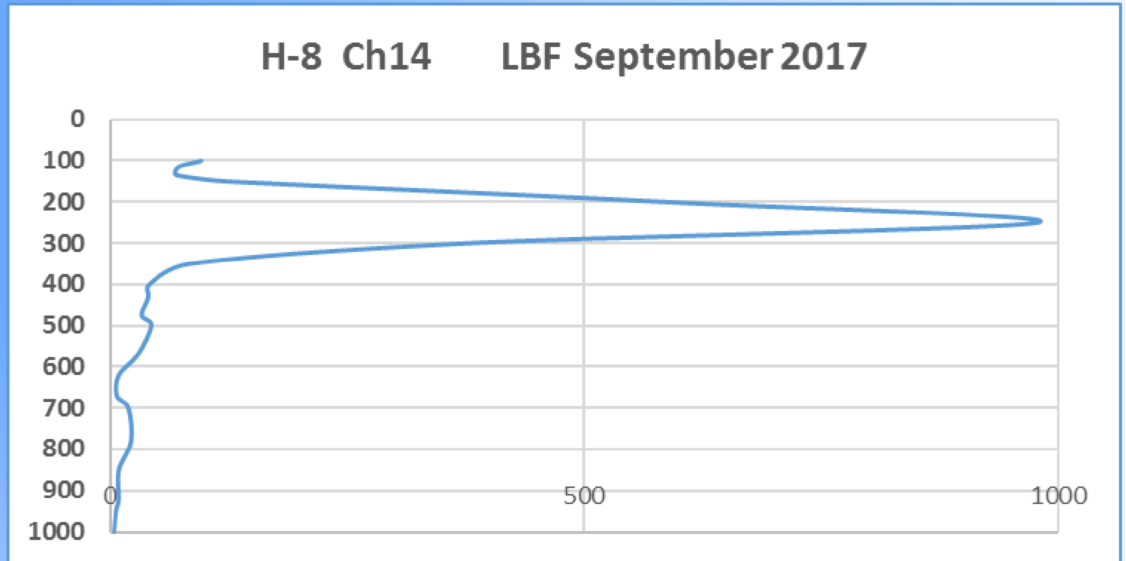



Fig8 Himawari-8 level of best fit height assignment statistics for CH.14 230-270 Hpa AMVs for September 2017 (see text)

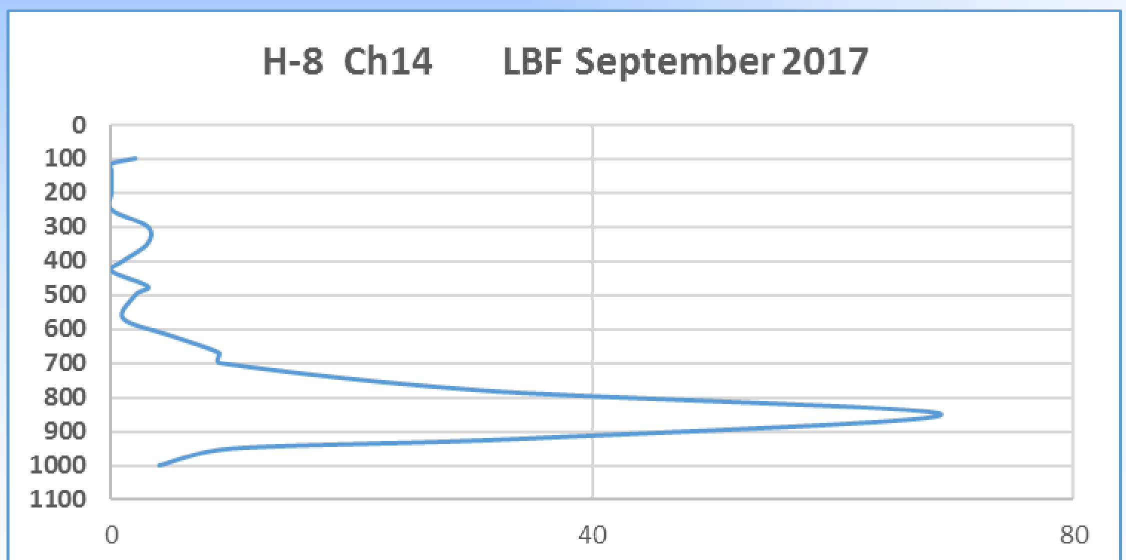
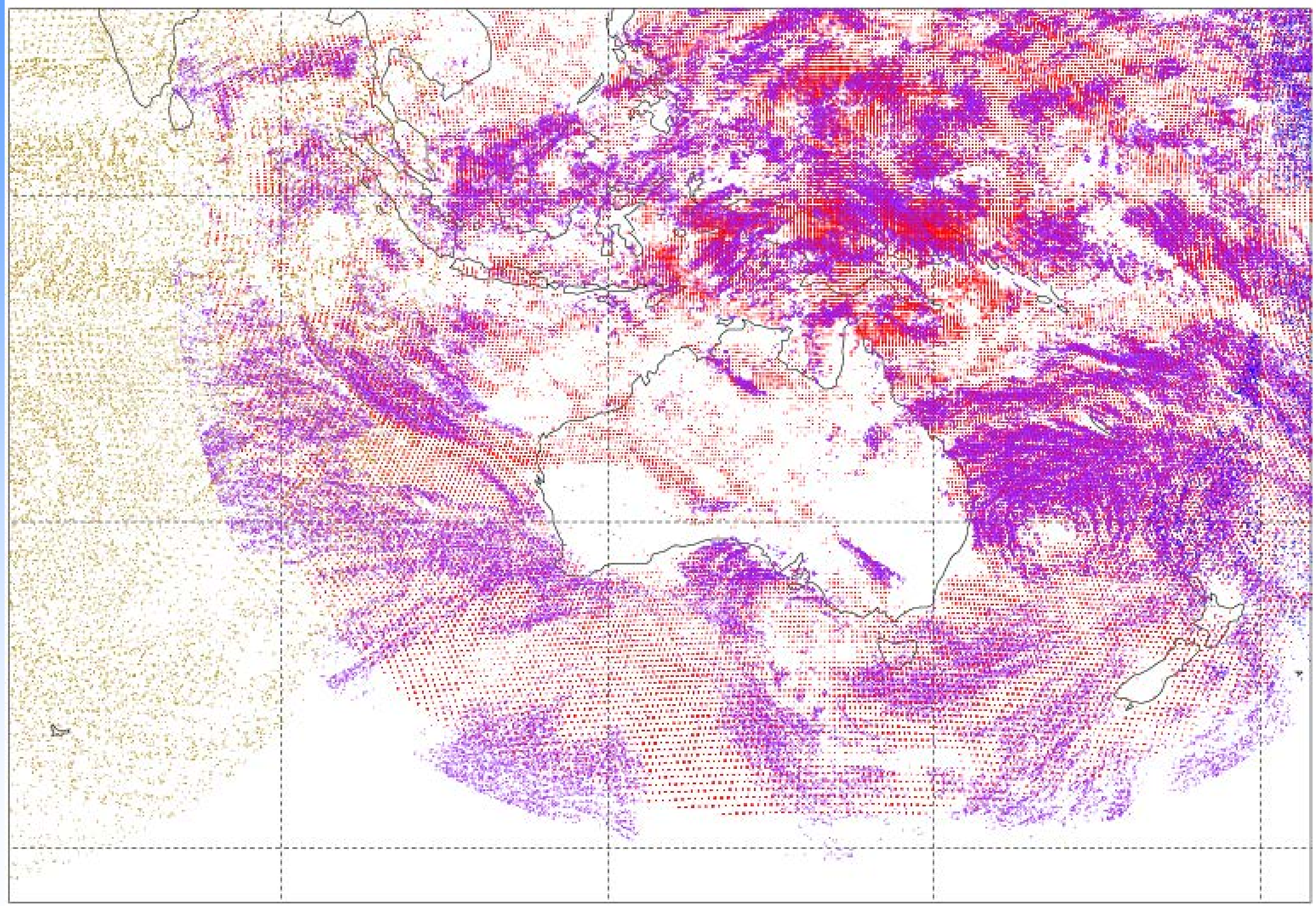


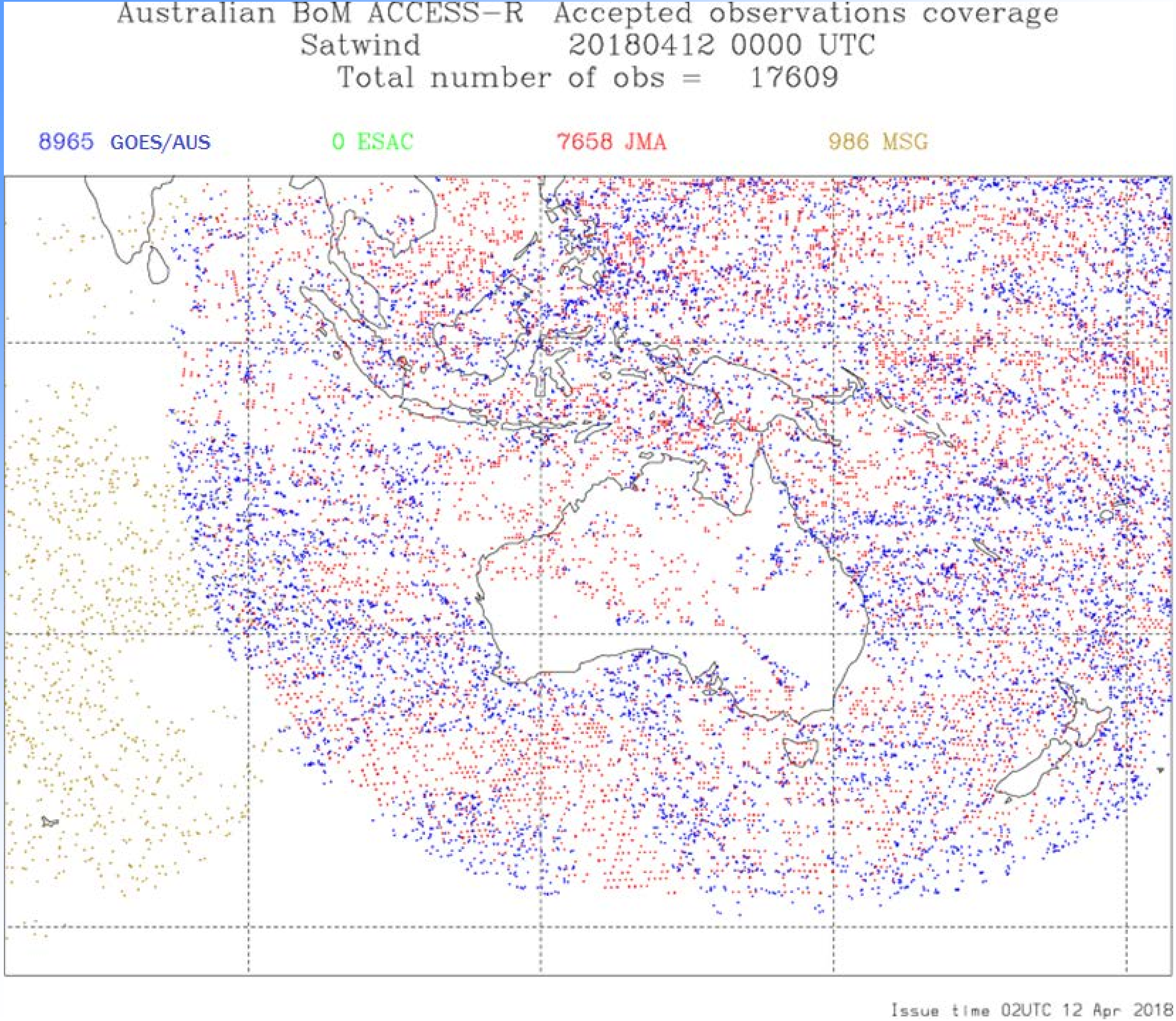

Fig7 Himawari-8 level of best fit height assignment statistics for CH.14 830-870 Hpa AMVs for September 2017 (see text)

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


Australian BoM ACCESS-R Accepted observations coverage
Satwind 20180412 0000 UTC
Total number of obs = 17609
8965 GOES/AUS
0 ESAC
7658 JMA
986 MSG
Issue time 02UTC 12 Apr 2018

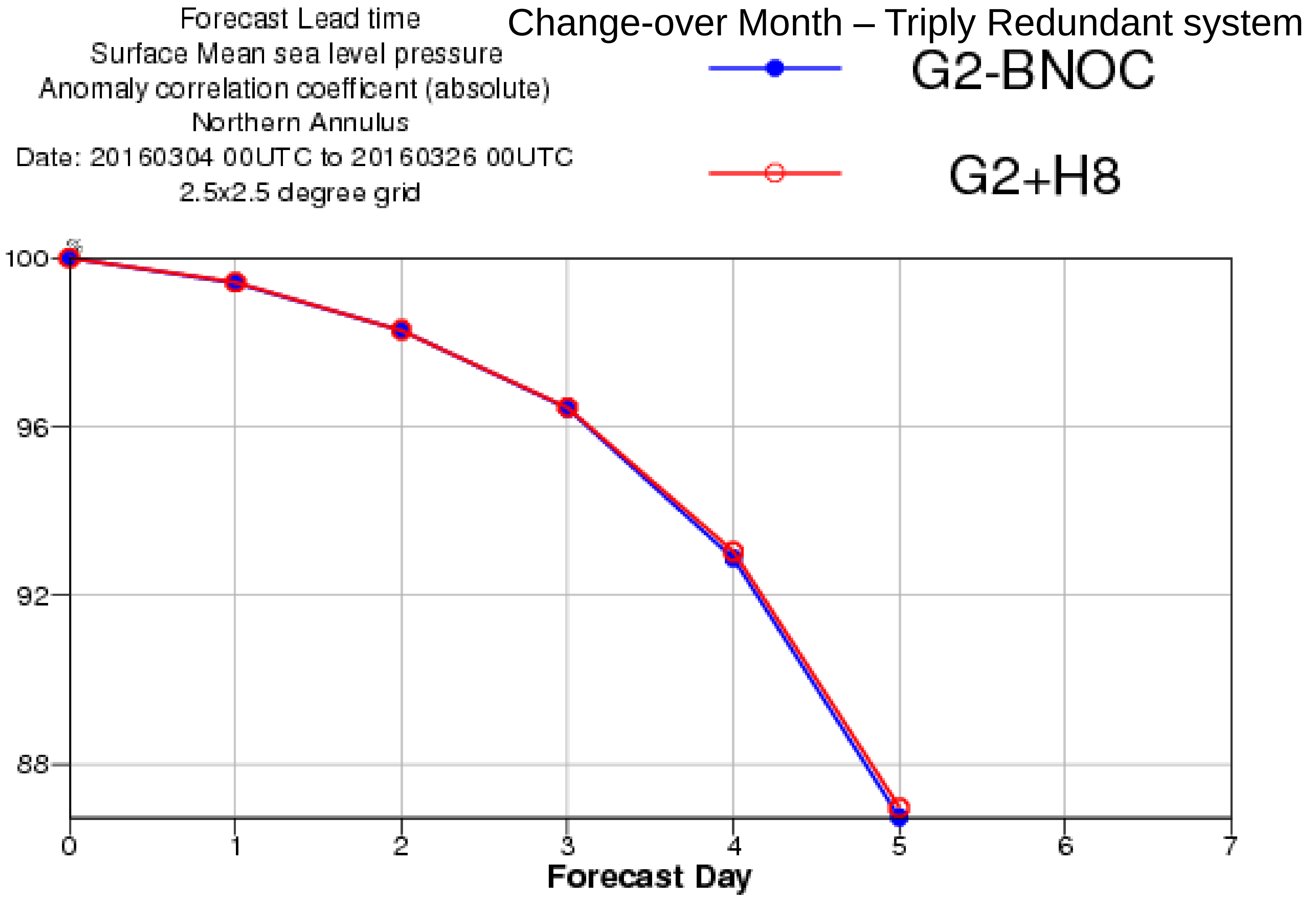
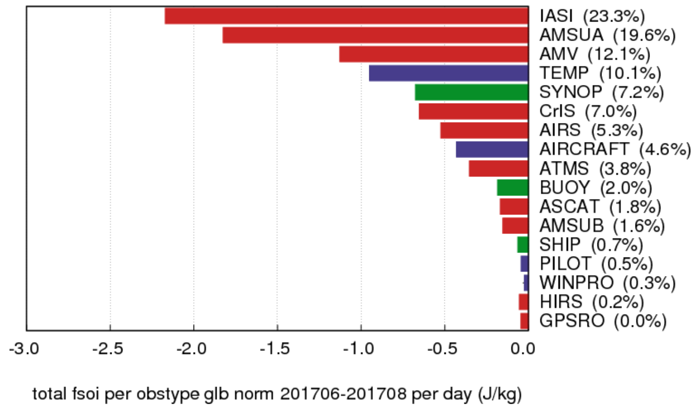
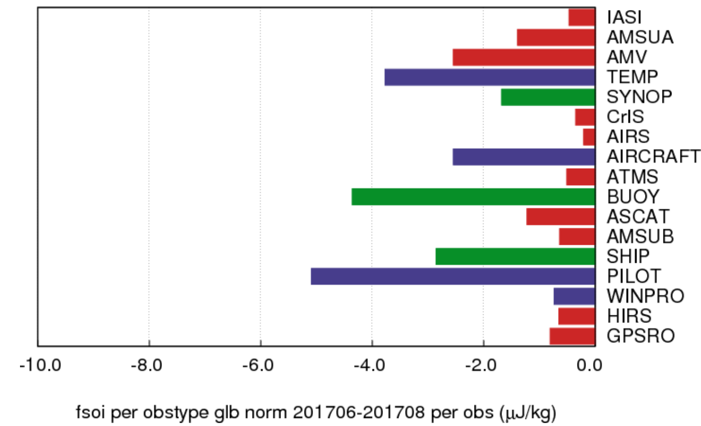


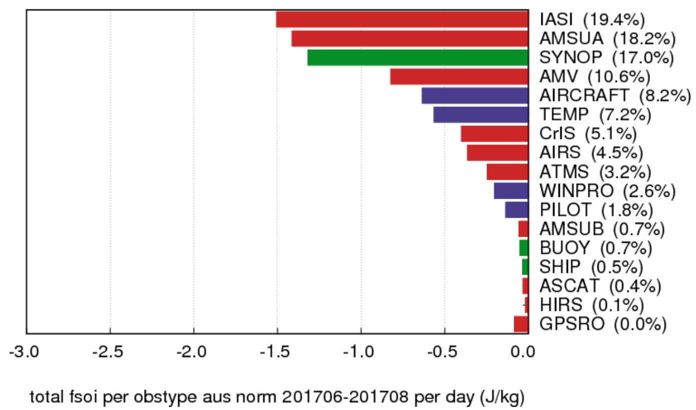

**Fig.13 MSLP anomaly correlation coefficients for the Northern Hemisphere Annulus for the operational system (blue) and for the operational test system for 4 – 26 March 2016.**

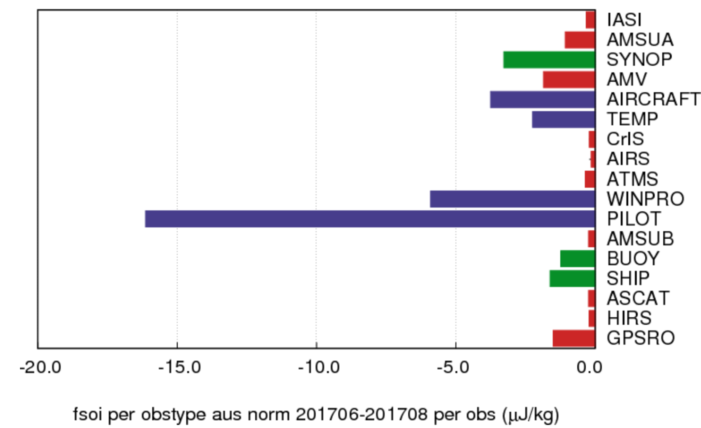
# FSOI for major observation types & instruments 2017 Jun - Aug

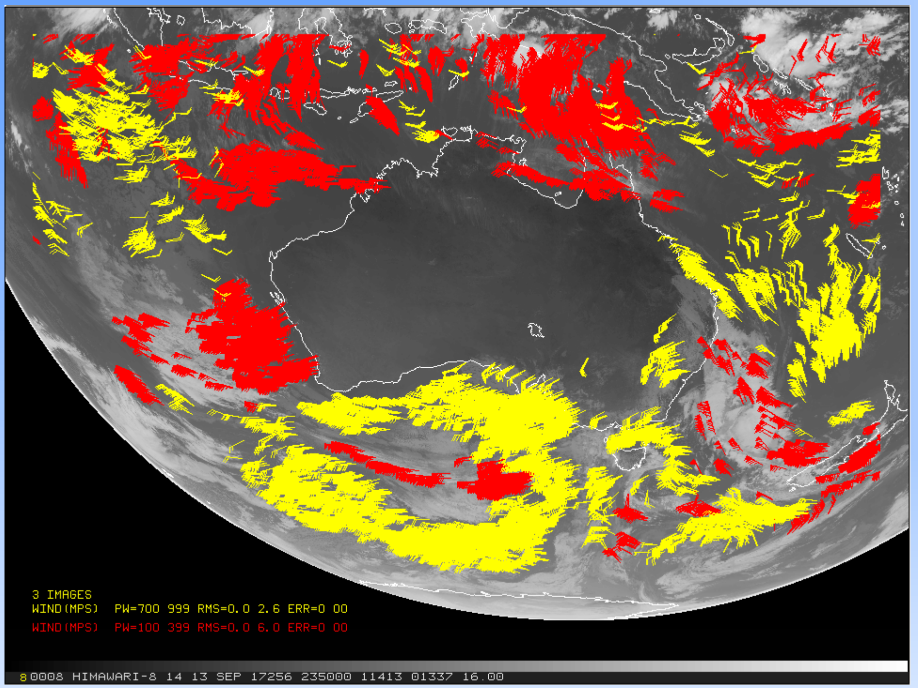
Satellite
Upper-air
Surface





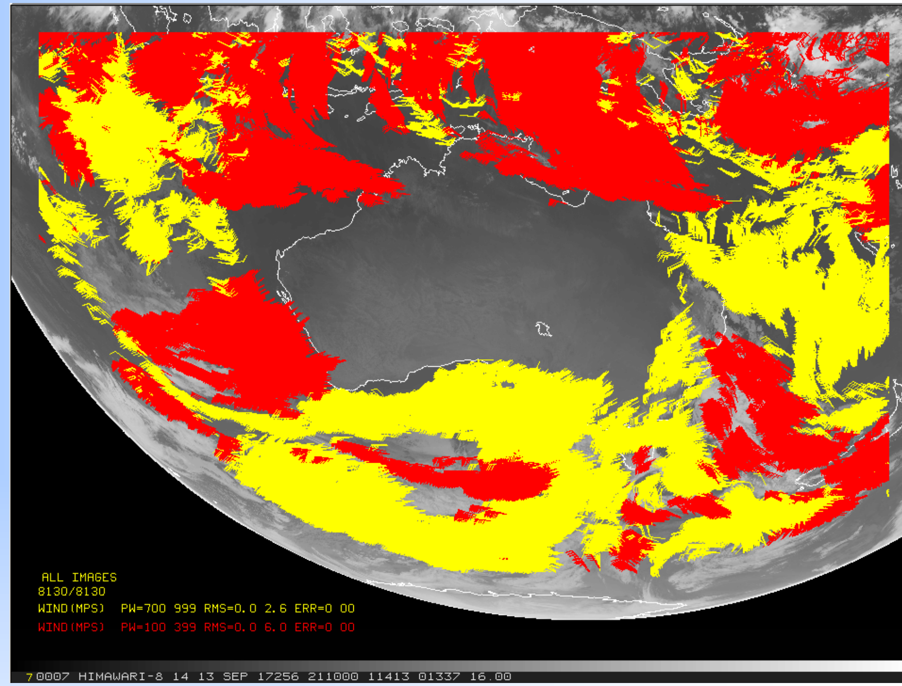
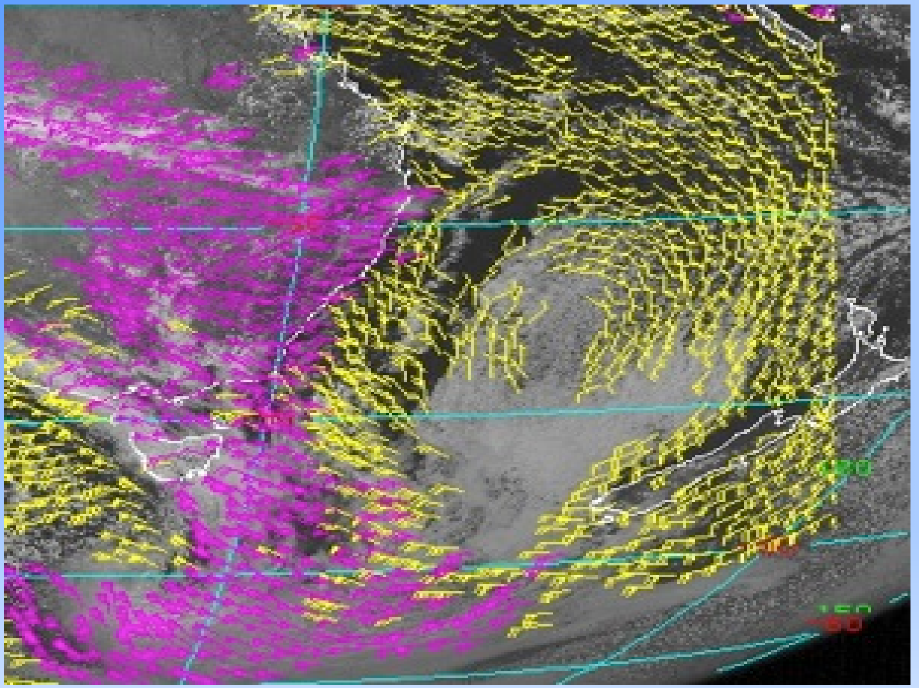




**Figure 10(a) shows Channel 14 (IR) low level AMVs (yellow) with expected errors less than 2.6m/s and upper level AMVs (red) with expected errors less than 6.0m/s generated by one image triplet.**

**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.**



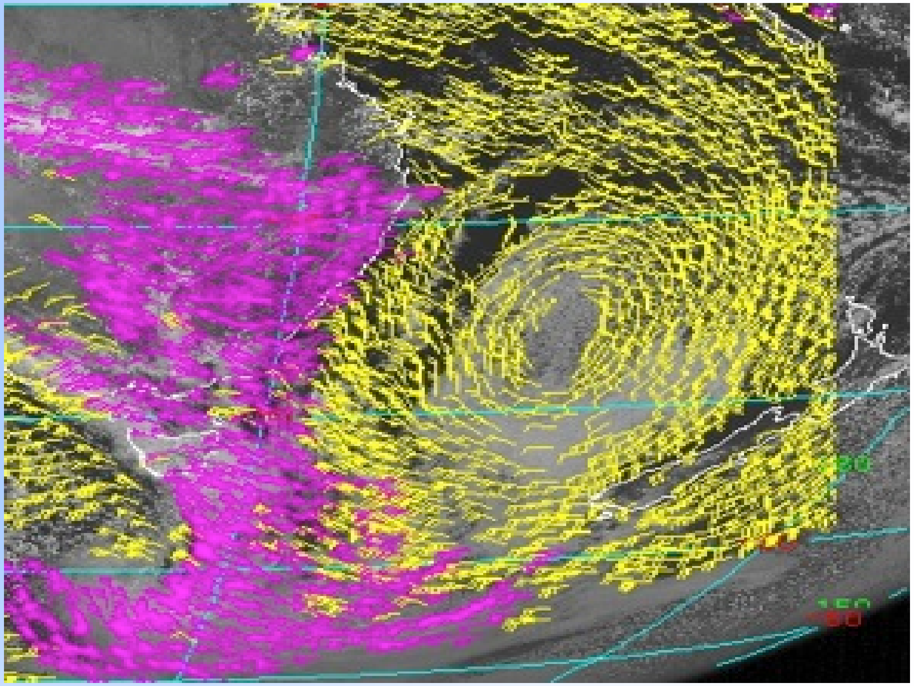


**Fig. 8(a) Thinned IR Channel 14 10 minute AMVs from Himawari-8 images at 00UTC 1 May 2017**

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

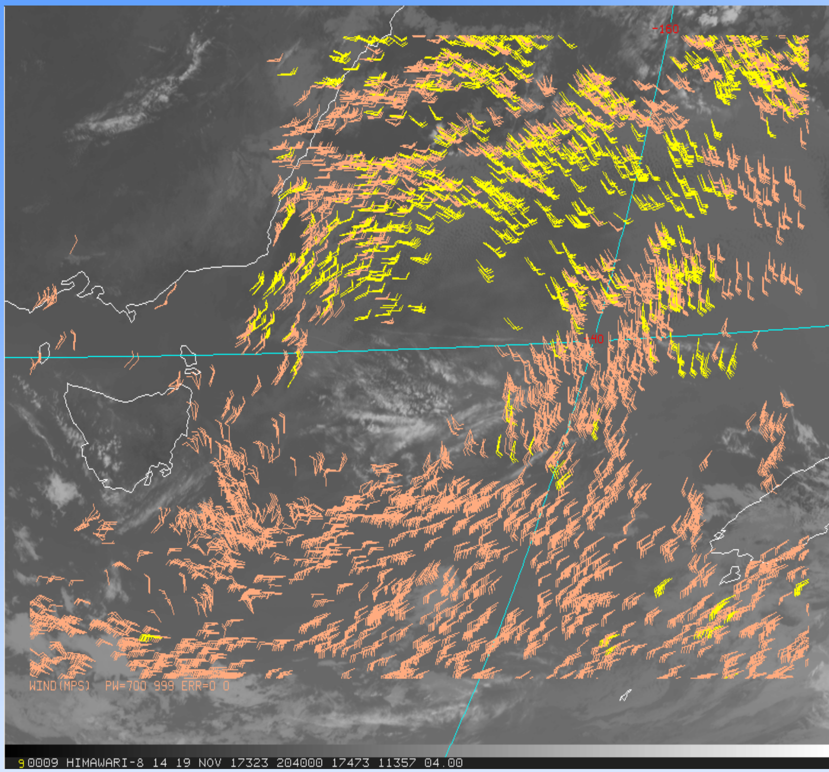



**Fig 9(c) IR Channel 14 (yellow) and Visible Channel 2 (Beige) 10 minute AMVs from Himawari-8 images at 00UTC 18 October 2017**

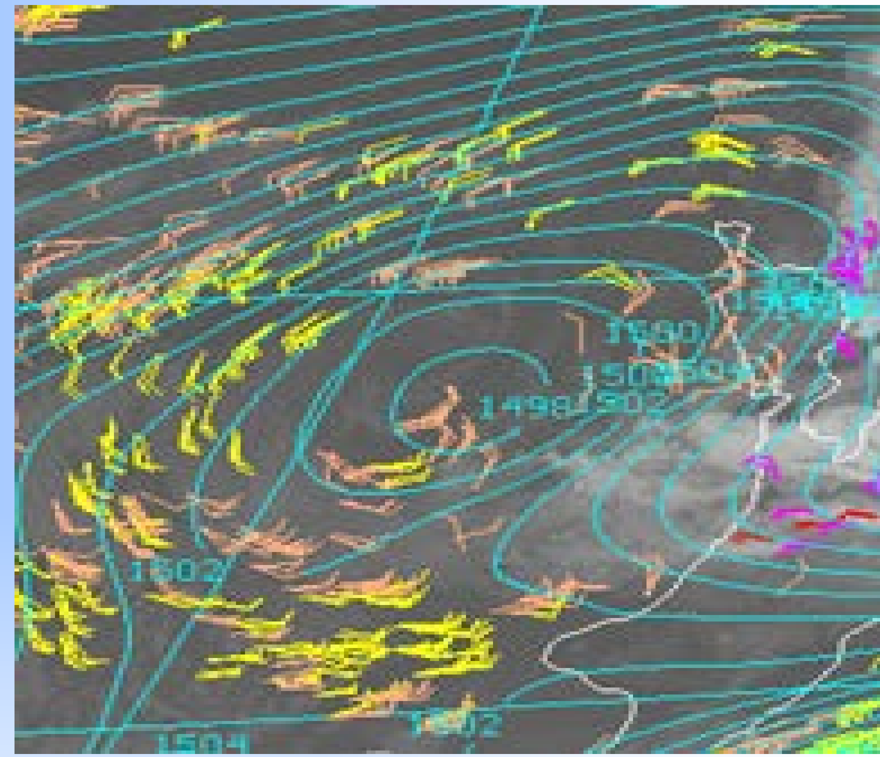
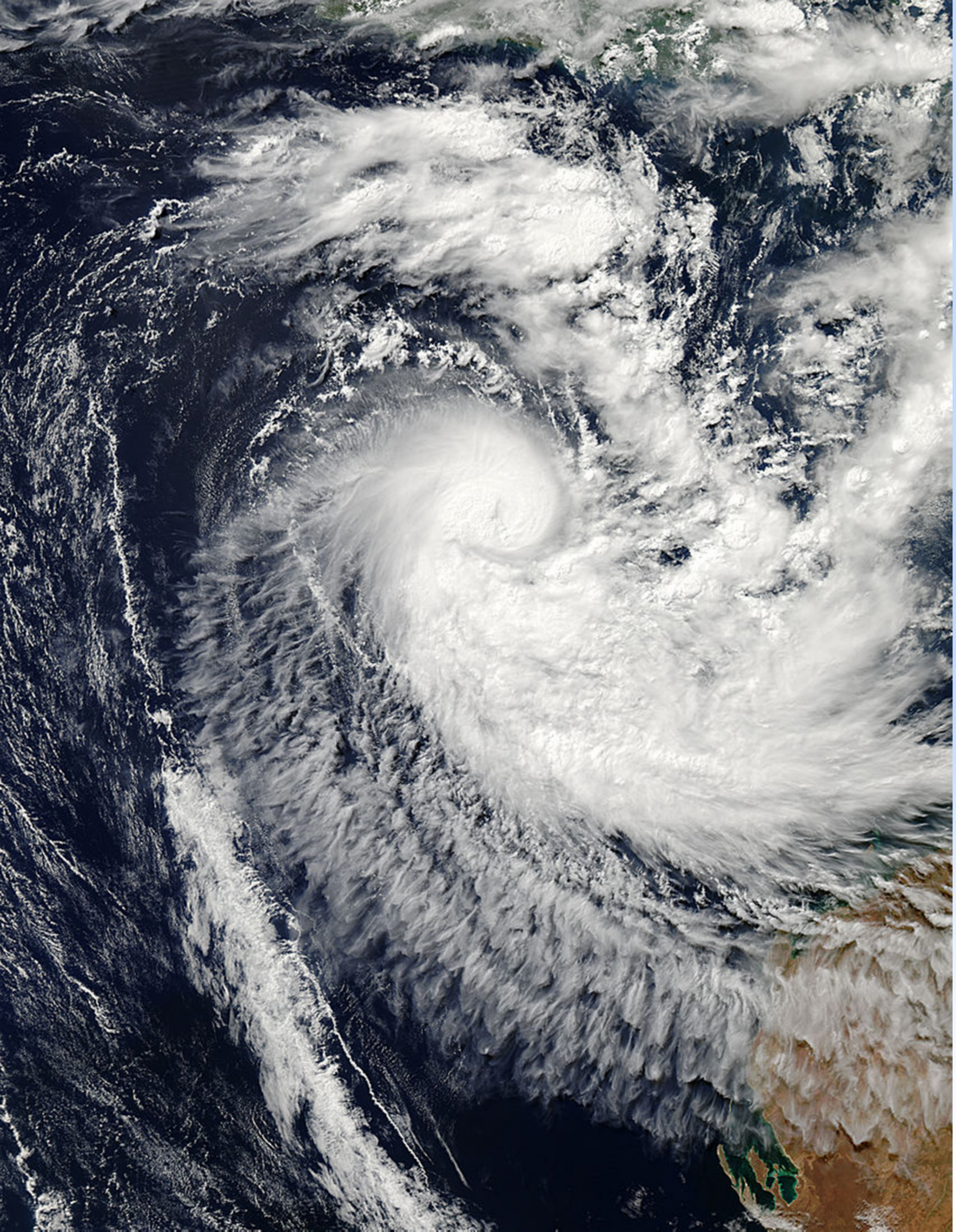


**Fig. 9(d) IR Channel 14 (yellow) and Visible Channel 2 (Beige) 10 minute AMVs from Himawari-8 images near 00UTC 18 July 2017**



# *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*

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 / BoM system

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

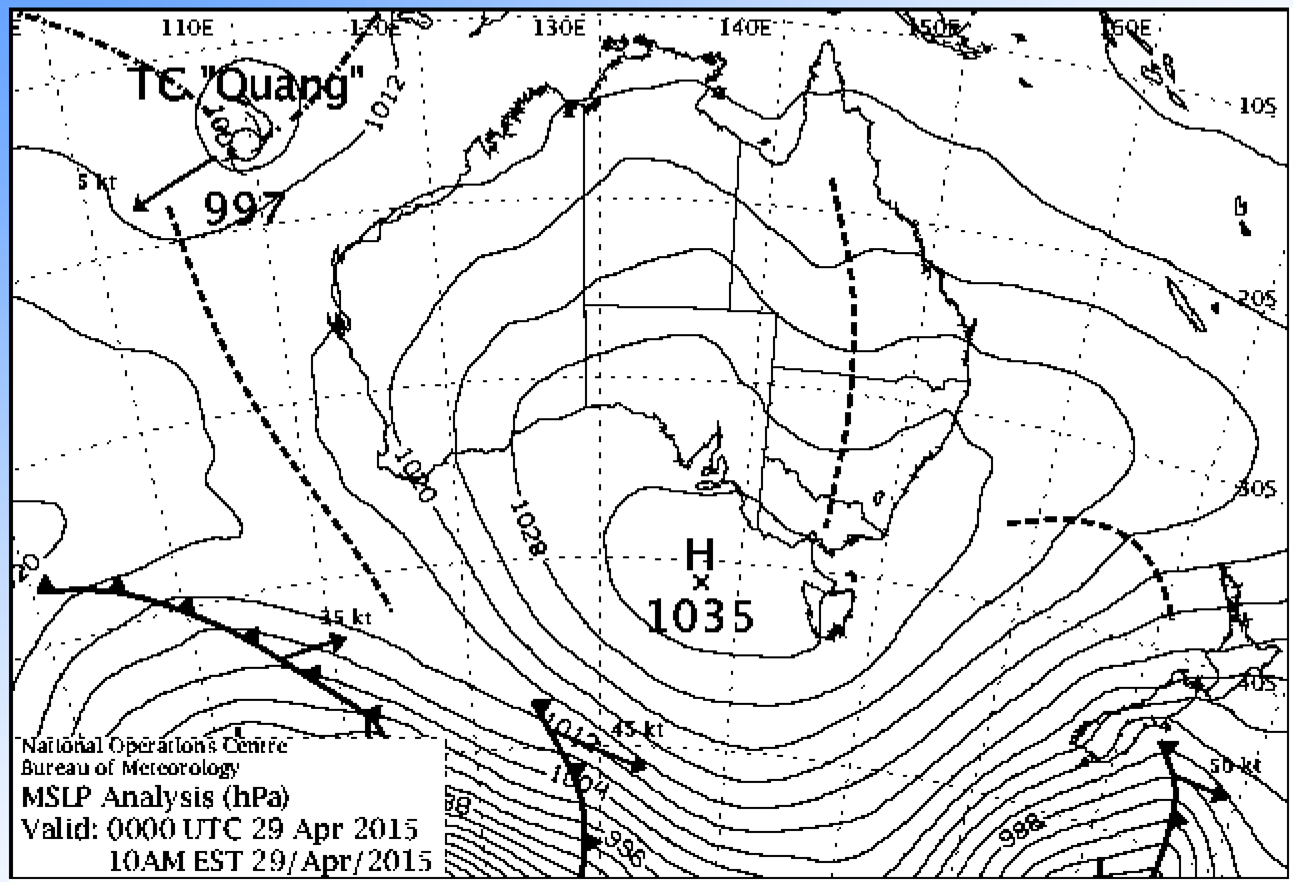
# *TC Quang Himawari-8 AMV Assimilation*

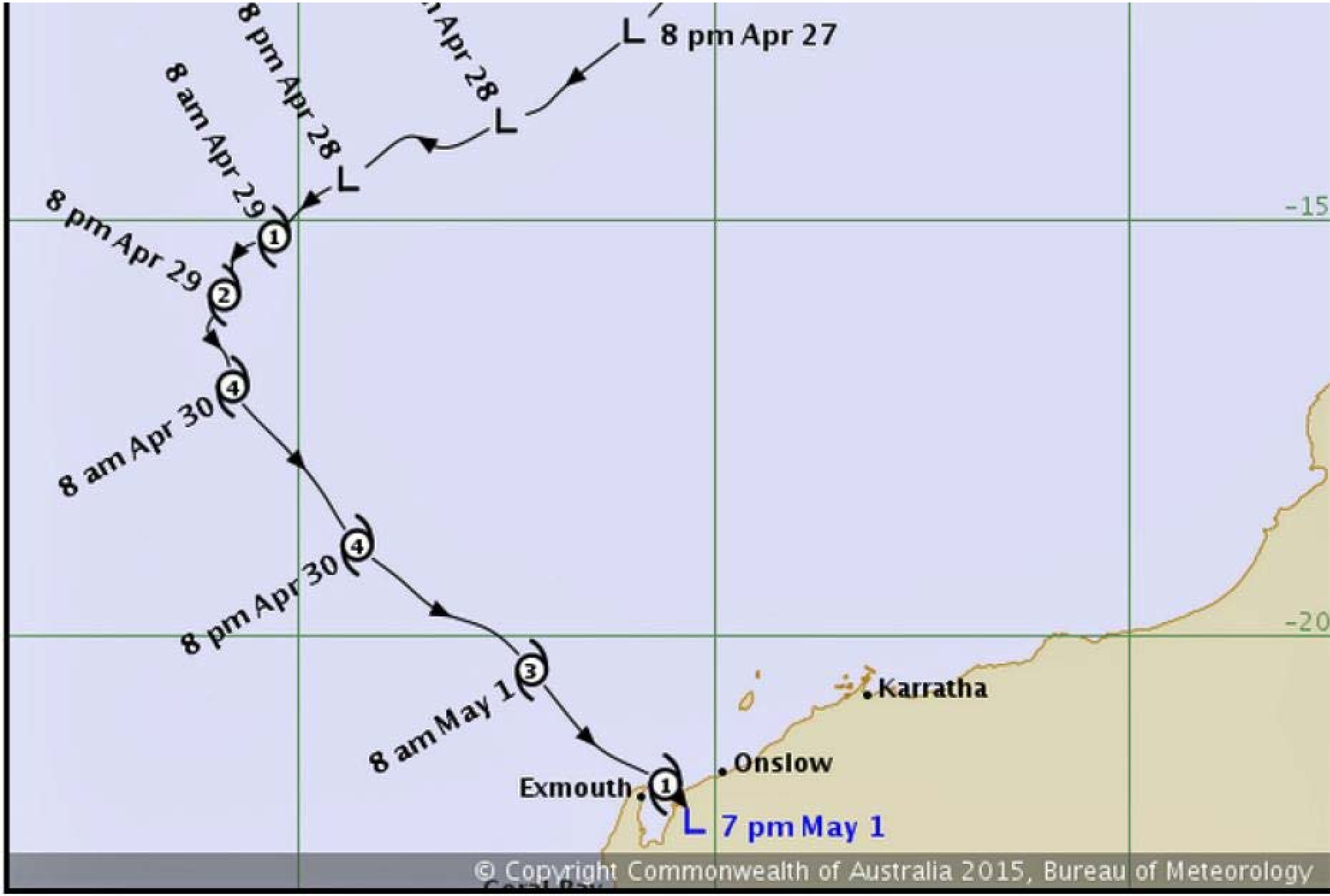
Used operational TCX system over Timor Sea.

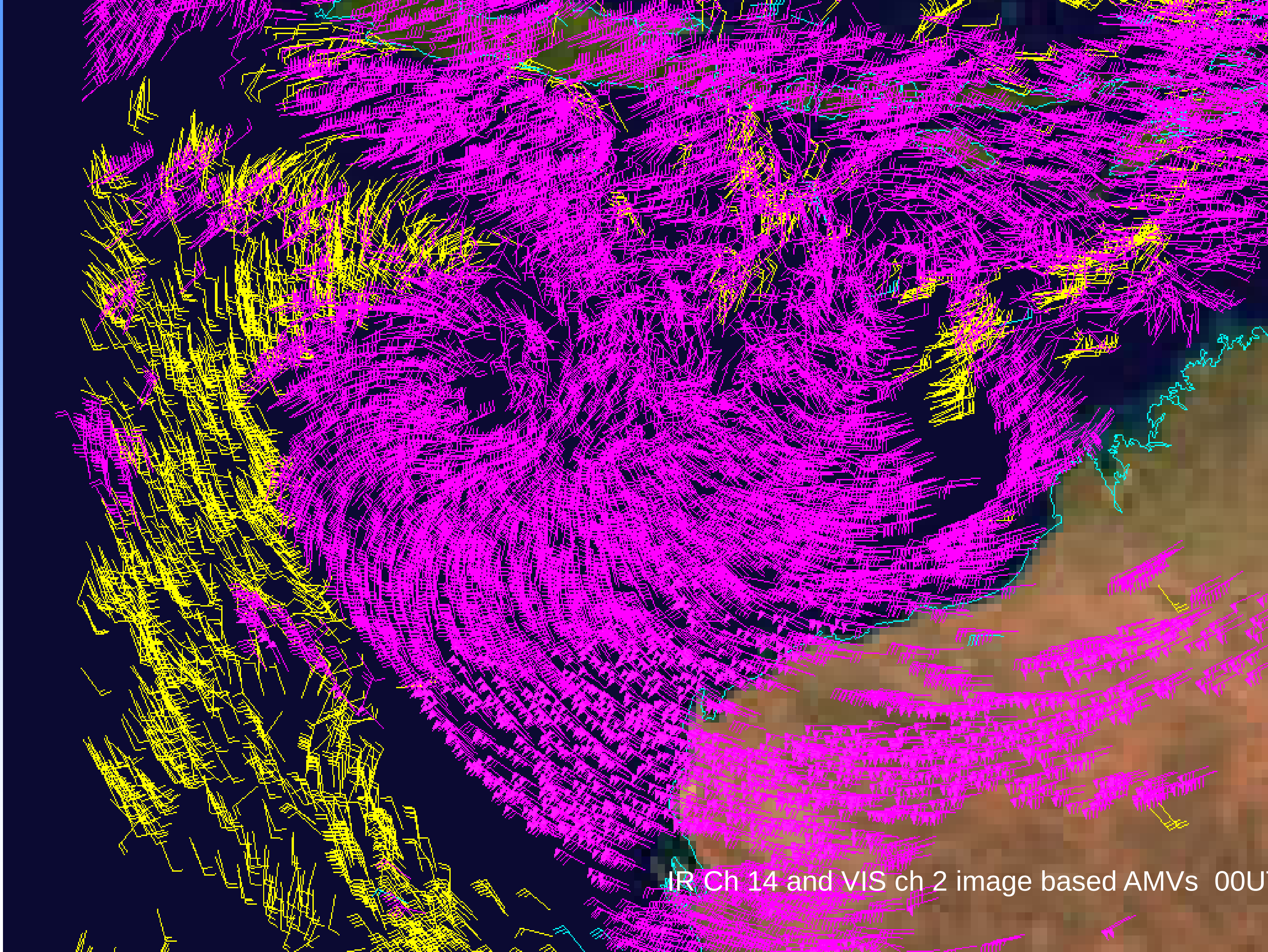
Used all Vis/IR image triplets (separated by 10 min/HSF format). (2km IR, 1km VIS) plus full operational data base.

TCX is a nested TC model (nested in APS-2 ACCESS-G) of 4km resolution and has 70 levels .

Forecast start time 00UTS 29 April 2015


110E
120E
130E
140E
150E
160E
10S
20S
30S
40S
TC "Quang"
1012
5 kt
997
1020
1028
H
1035
35 kt
45 kt
50 kt
1012
1004
996
988
National Operations Centre
Bureau of Meteorology
MSLP Analysis (hPa)
Valid: 0000 UTC 29 Apr 2015
10AM EST 29/Apr/2015


8 pm Apr 27
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
Karratha
Onslow
Exmouth
-15
-20
© Copyright Commonwealth of Australia 2015, Bureau of Meteorology


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

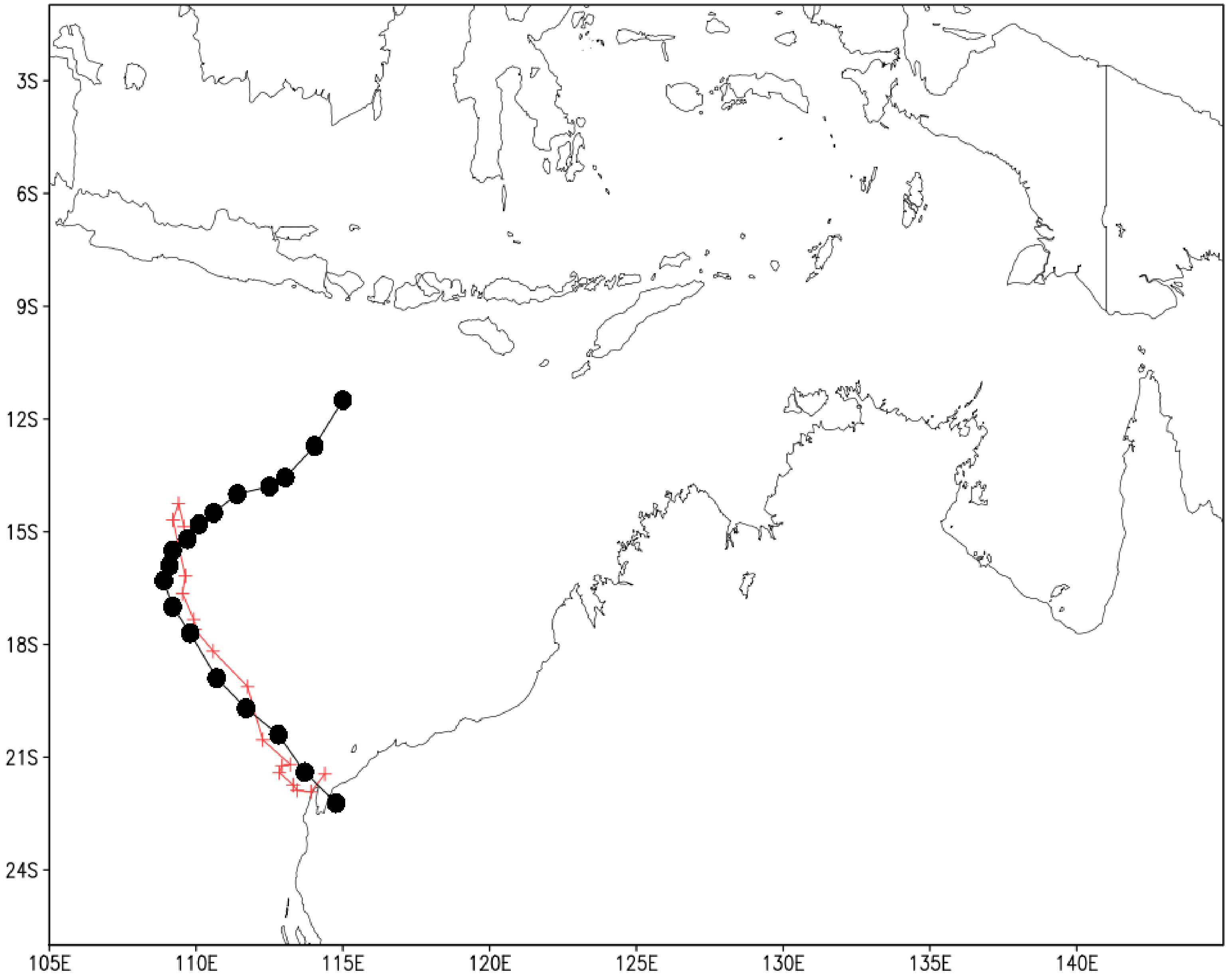



**Fig. 14(a) The forecast track of tropical cyclone Quang from 00 UTC 29 April 2015 (red) and the best track (Black), both in six hour intervals**

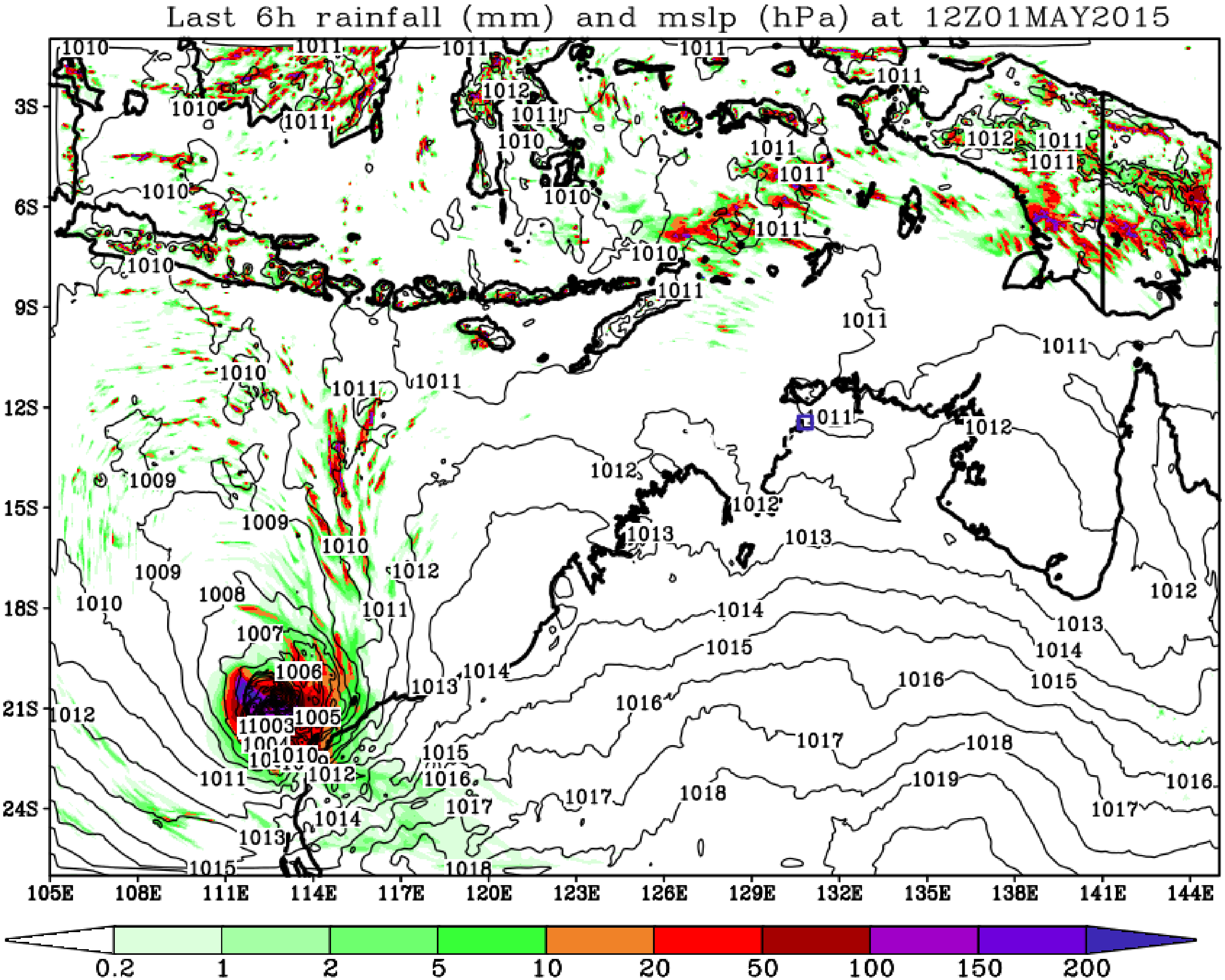



Fig. 14(b) Forecast position of tropical cyclone Quang and 6hr accumulated rainfall at 12 UTC 1 May 2015

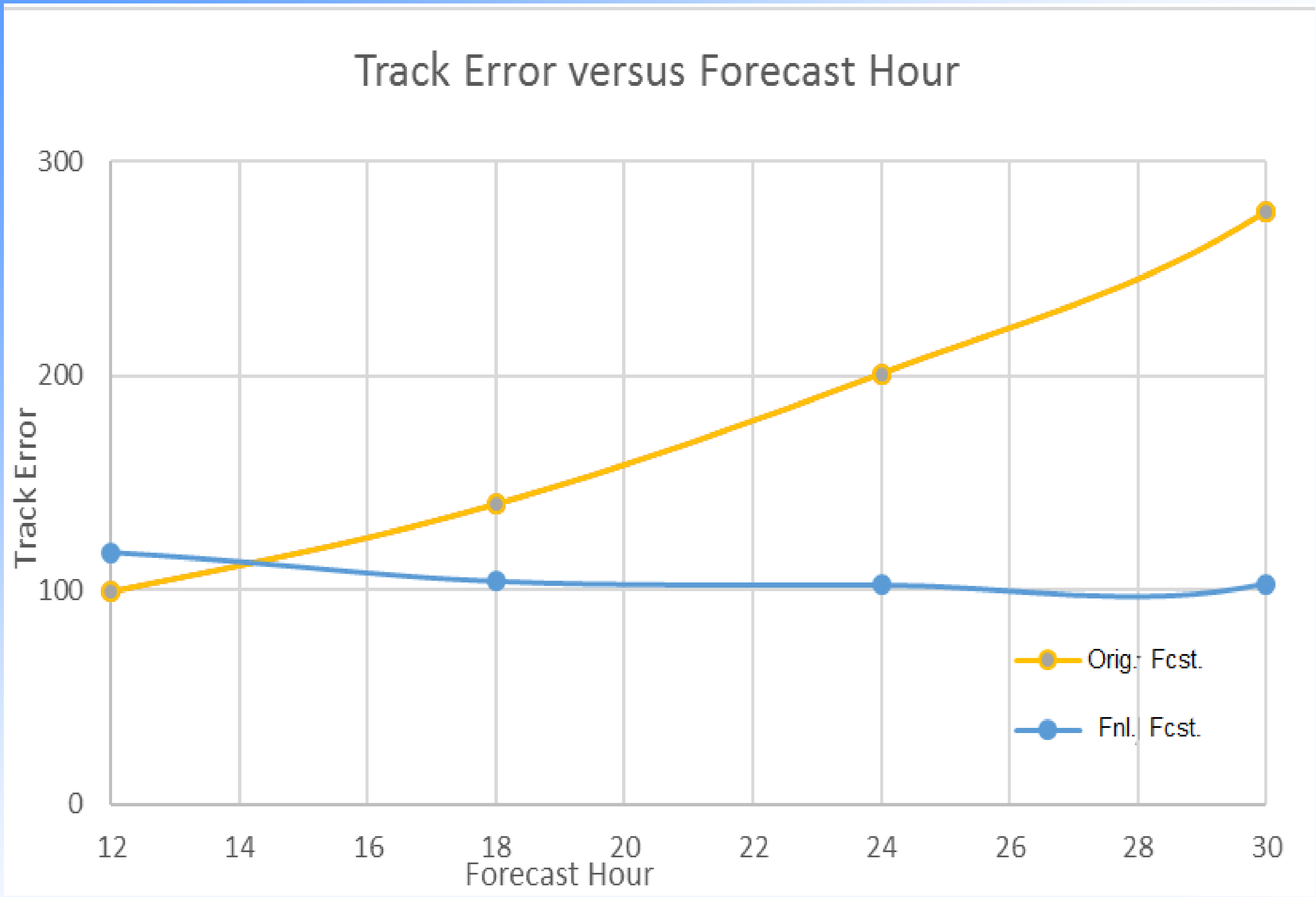



Fig. 15 The original forecast track error of tropical cyclone Quang from 00 UTC 29 April 2015 (yellow) and the final track error (Blue), both in six hour intervals (see text).

# Summary and Conclusions

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

H-8 10 minute DMVs have provided 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 also involves use of all 10 minute data in the prediction of TC activity and severe weather.

# Future

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

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

Increasing benefits will continue to accrue from current and next generation advanced instruments, which represent considerable investment by the international community. (eg. CrIS, IASI, VIIRS,EPS-SG ,ABI, AHI, MTG, FY-4, …GK-2A….). This will need co-investment in staff, infrastructure, research and R2O.


Indian Ocean
Looking Down
Is
Looking Up
N
100 km
TC LAURENCE - Dec. 2009