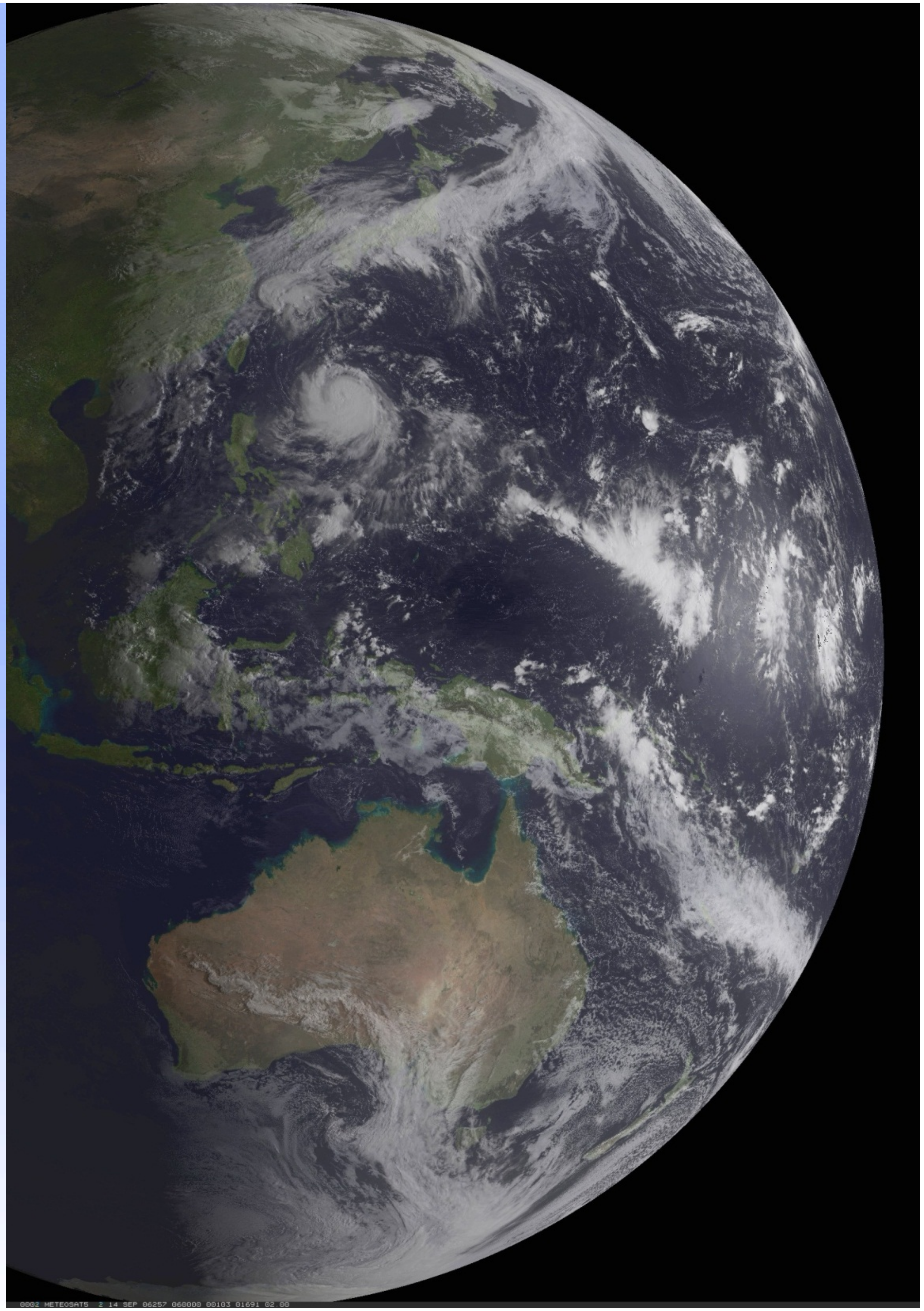
Australian Government
Bureau of Meteorology

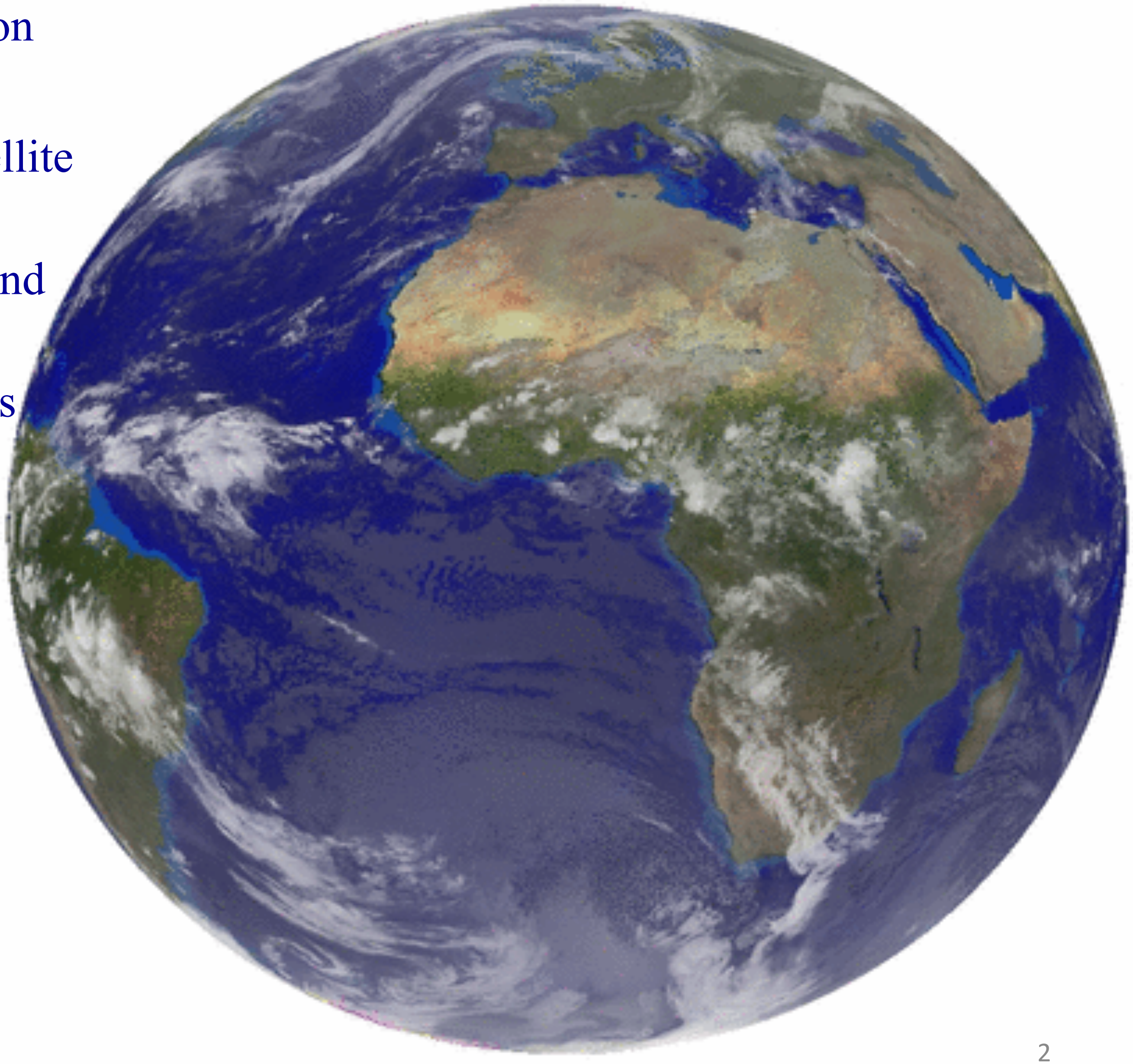
An Analysis of the Benefit of Earth Observation from Space On Australian and Global NWP

John Le Marshall [1,2], Jin Lee[1], Paul Gregory[1]
Jim Jung[2], Robert Norman[3], and Rolf Seecamp[1],
Kefie Zhang[4], Chris Tingwell[1] …



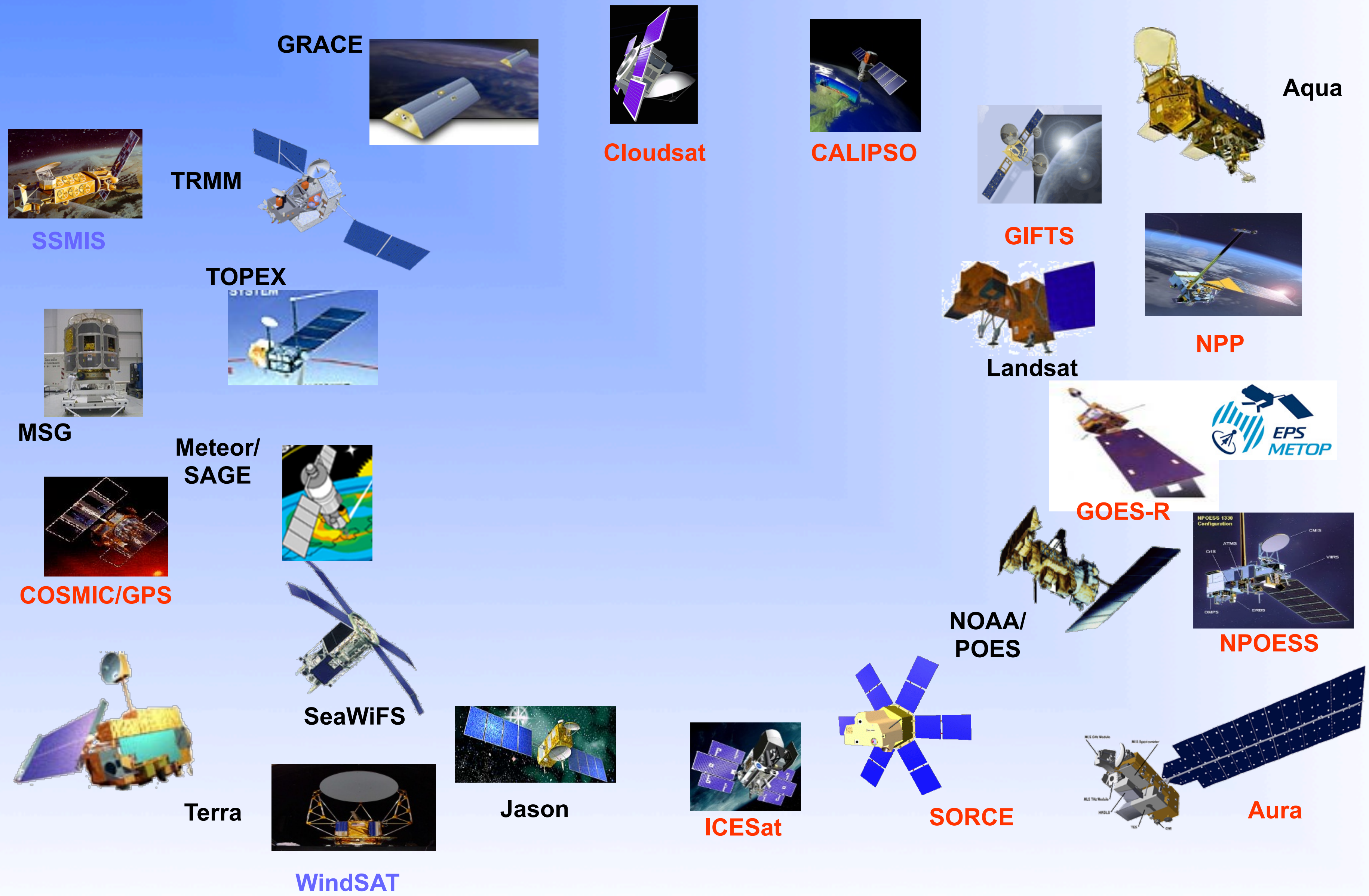
Overview

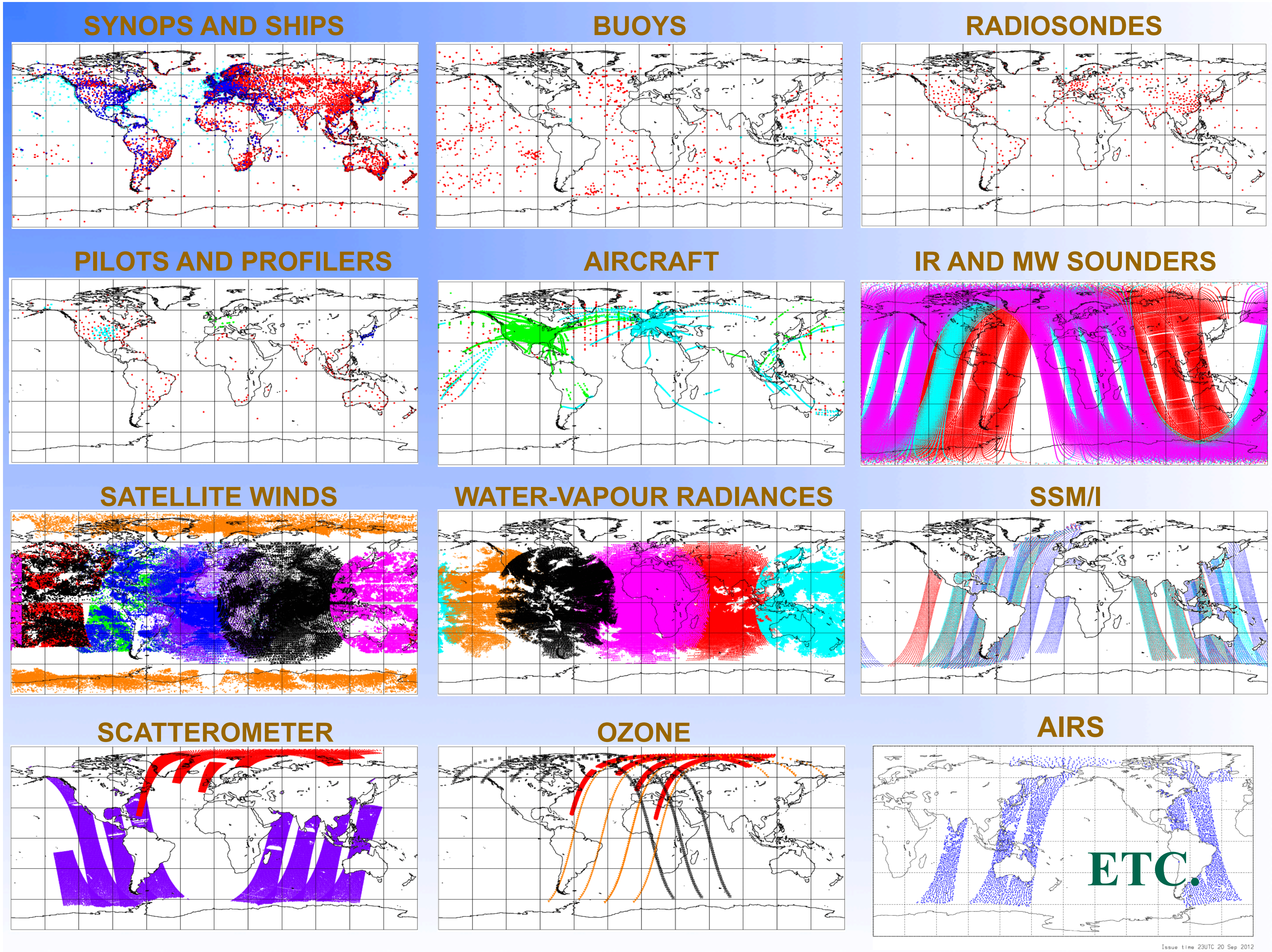
- Background/Introduction
- The Challenge
- The Importance of Satellite Data (in the SH)
- Advances in Analysis and Prediction, Monitoring the Climate – Examples
- Plans/Future Prospects
- Summary



Observing the atmosphere
Satellite systems

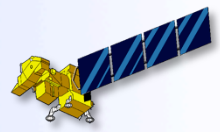
THE CHALLENGE



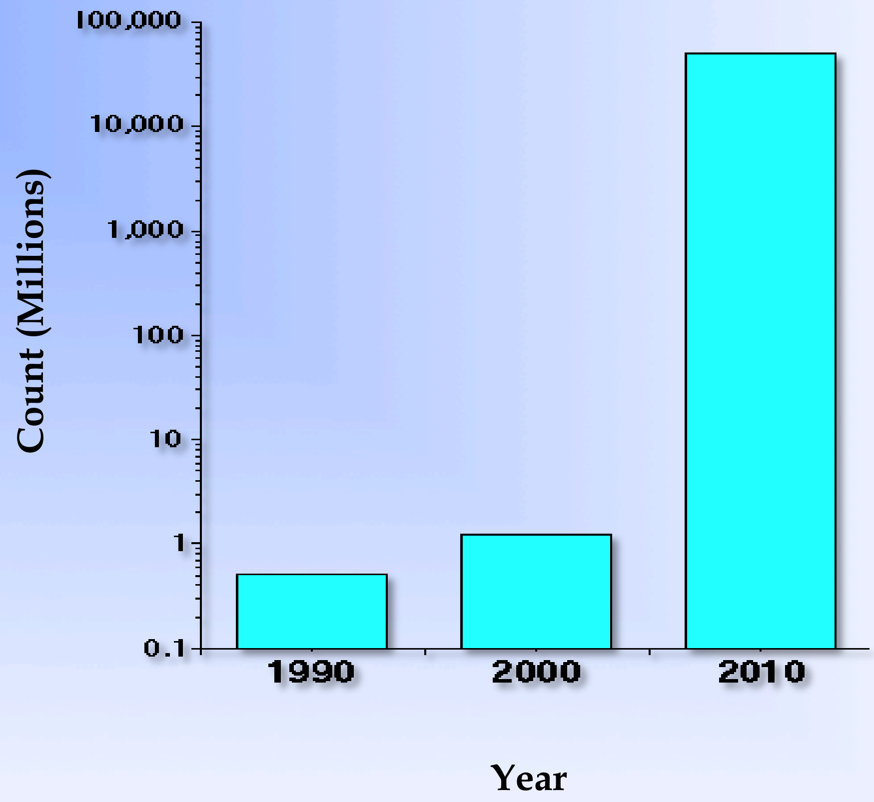

SYNOPS AND SHIPS
BUOYS
RADIOSONDES
PILOTS AND PROFILERS
AIRCRAFT
IR AND MW SOUNDERS
SATELLITE WINDS
WATER-VAPOUR RADIANCES
SSM/I
SCATTEROMETER
OZONE
AIRS
ETC.
Issue time 23UTC 20 Sep 2012

Earth observations from space

THE CHALLENGE



5-Order Magnitude Increase in satellite Data Over 10 Years



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

Australian Community Climate and Earth System Simulator (ACCESS) - G

The Characteristics of the ACCESS-G Forecast System

DOMAIN	GLOBAL
UM Horizontal Resolution (lat x lon)	640 X 481(`0.5625Deg X 0.375Deg) ~47km.
Analysis Horizontal resolution (lat x lon)	288 X 217 (1.250Deg X 0.833Deg) ~106km.
Vertical Resolution	L70
Observational Data Used (6h window)	AIRS, IASI, ATOVS, Scat, AMV, SYNOP, SHIP, BUOY,AMDARS, AIREPS, TEMP, PILOT, GPS-RO…
Sea Surface Temperature Analysis	Daily, global 1° sst analysis
Sea Ice analysis	Daily, global 1/12° sea ice analysis
Soil moisture Nudging	SURF once every 6 hours
Model Time Step	12 minutes (96 time steps per day)
Analysis Time Step	30 minutes
Suite Definition	SCS vn18.2

Table 1: N288L70 System Specification

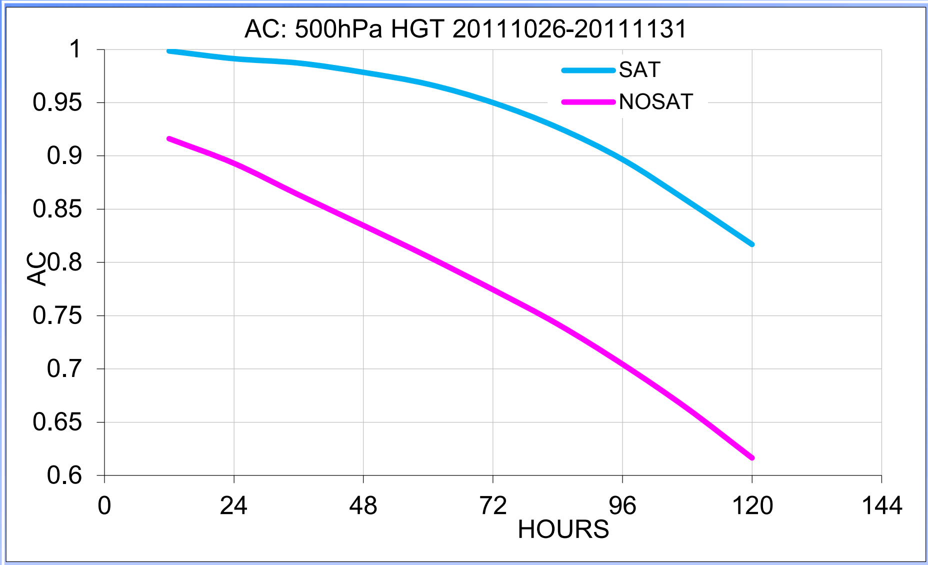
The Satellite Data Used by the NCEP GFS

HIRS sounder radiances	SSM/I precipitation rates
AIRS sounder radiances	SSMIS radiances
IASI sounder radiances	TRMM precipitation rates
AMSU-A sounder radiances	Ocean surface wind vectors
AMSU-B sounder radiances	AVHRR SST
GOES sounder radiances	AVHRR vegetation fraction
GOES, Meteosat atmospheric motion vectors	AVHRR surface type
MTSAT Motion Vectors	Multi-satellite snow cover
GOES precipitation rate	Multi-satellite sea-ice

The Conventional Data Used by the NCEP GFS

Rawinsonde temperature and humidity	Rawinsonde u and v
AIREP and PIREP aircraft temperatures	AIREP and PIREP aircraft u and v
ASDAR aircraft temperatures	ASDAR aircraft u and v
Flight-level reconnaissance and dropsonde temperature, humidity and station pressure	Flight-level reconnaissance and dropsonde u and v
MDCARS aircraft temperatures	MDCARS aircraft u and v
Surface marine ship, buoy and c-man temperature, humidity and station pressure	Surface marine ship, buoy and c-man u & v
Surface land synoptic and Metar temperature, humidity and station pressure	Surface land synoptic and metar u and v
Ship temperature, humidity and station pressure	Wind Profiler u and v
Pibal u and v	NEXRAD Vertical Azimuth Display u and v

Earth observations From Space



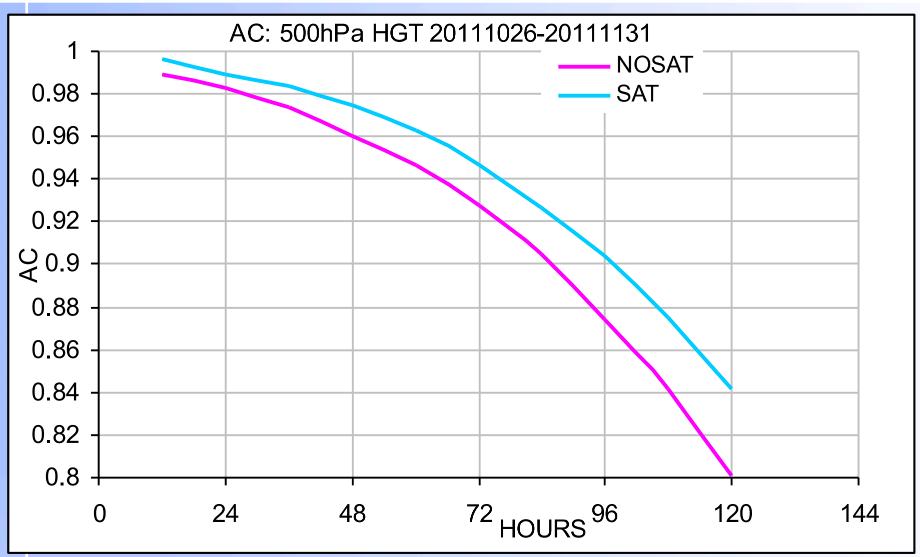
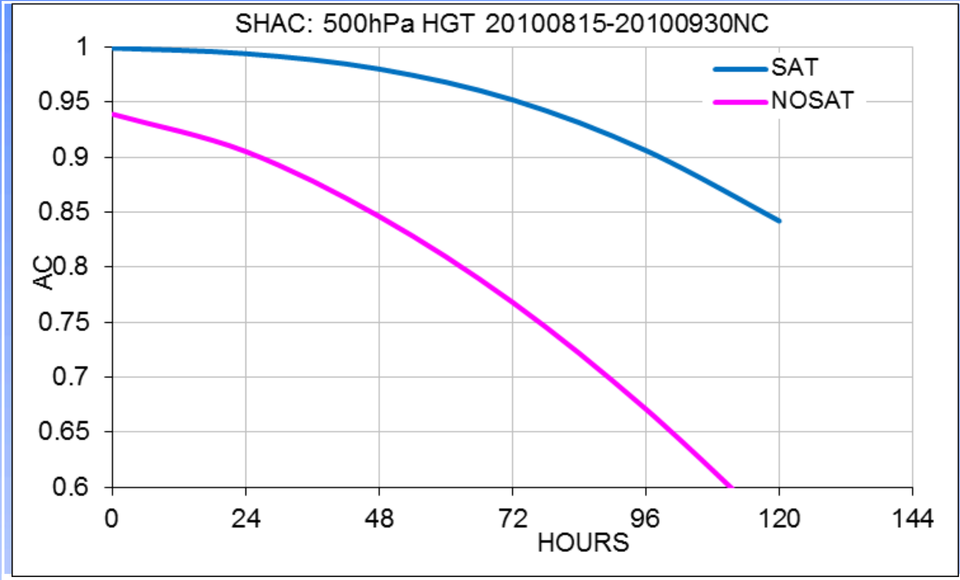


Fig. 8(c). SH 500hPa height anomaly correlation for the control (SAT) and no satellite (NOSAT), 28 October to 30 November 2011 using ACCESS and verifying against the control analysis

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



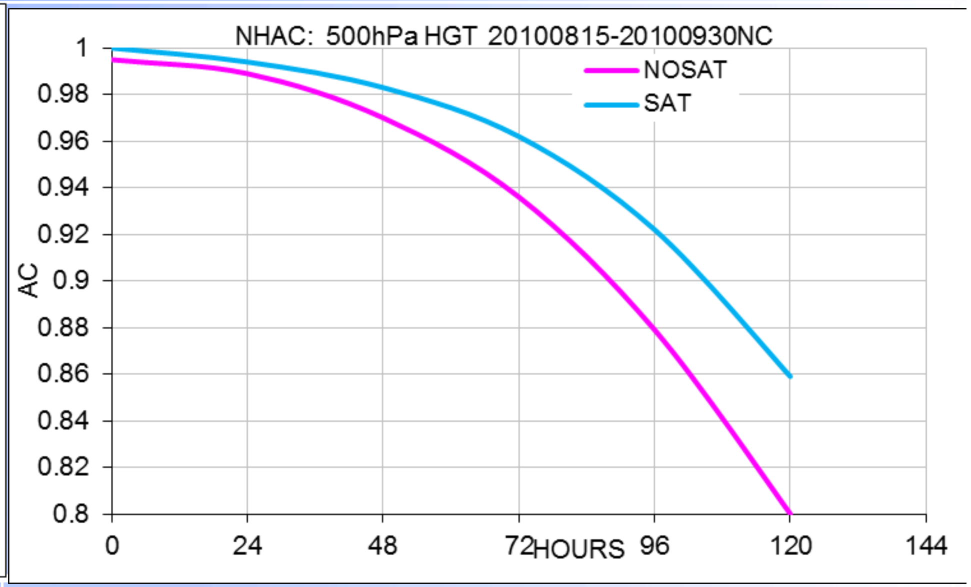
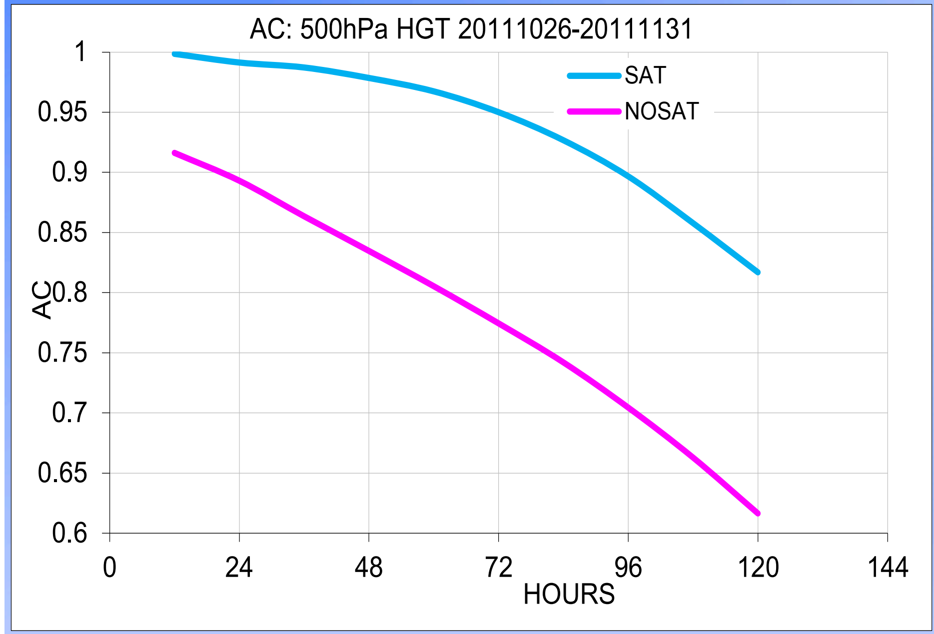
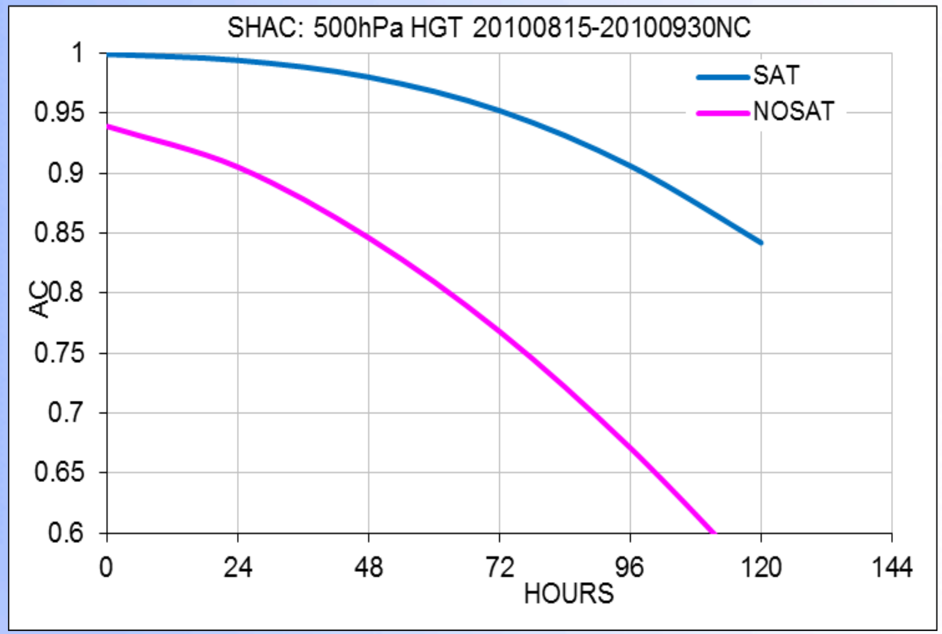


Fig. 8(g). SH 500hPa height anomaly correlation for the control (SAT) and no satellite (NOSAT), 15 August to 30 September 2010 using GFS and verifying against the control analysis

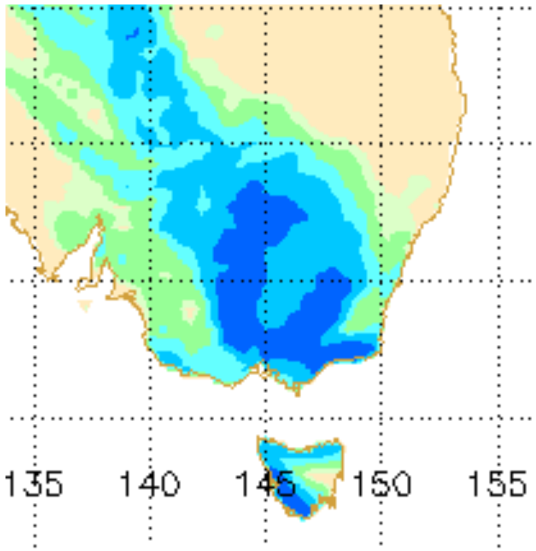
Fig. 8(hNH 500hPa height anomaly correlation for the control (SAT) and no satellite (NOSAT), 15 August to 30 September 2010 using the GFS and verifying against the control analysis



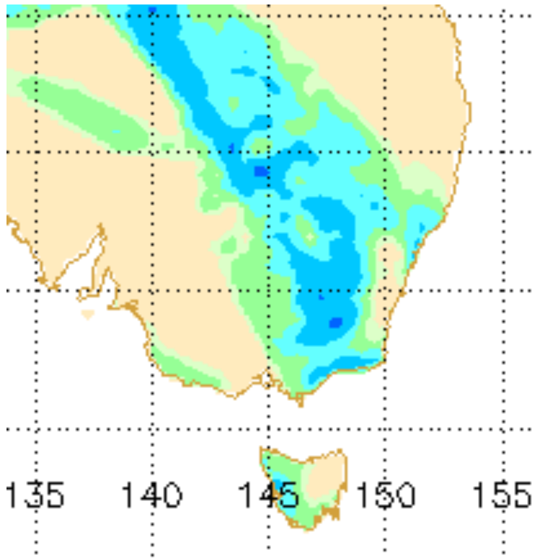


SH 500hPa height anomaly correlation for the control (SAT) and no satellite (NOSAT), 28 October to 30 November 2011 using ACCESS-G and verifying against the control analysis

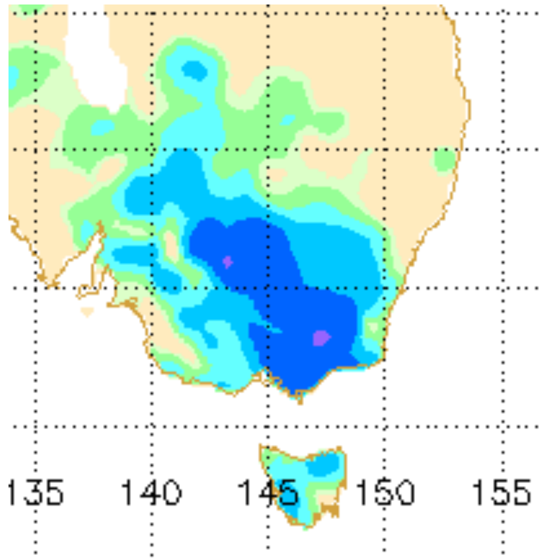
SH 500hPa height anomaly correlation for the control (SAT) and no satellite (NOSAT), 15 August to 30 September 2010 using GFS and verifying against the control analysis.



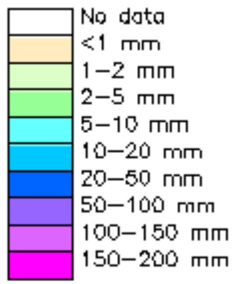
ACCESS-G 48 to 72 hour rainfall forecast for 9 November 2011 using satellite data.



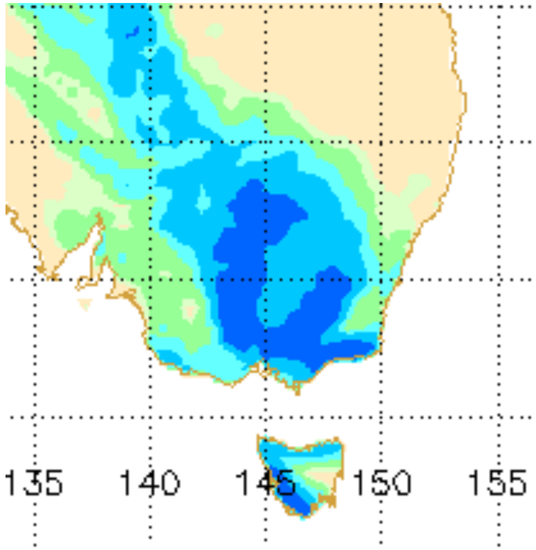
ACCESS-G 48 to 72 hour rainfall forecast for 9 November 2011 using no satellite data.



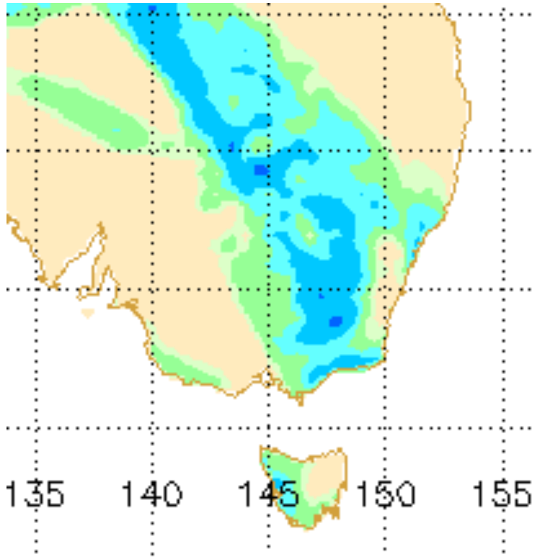
Daily rain gauge analysis for 9 November 2011.



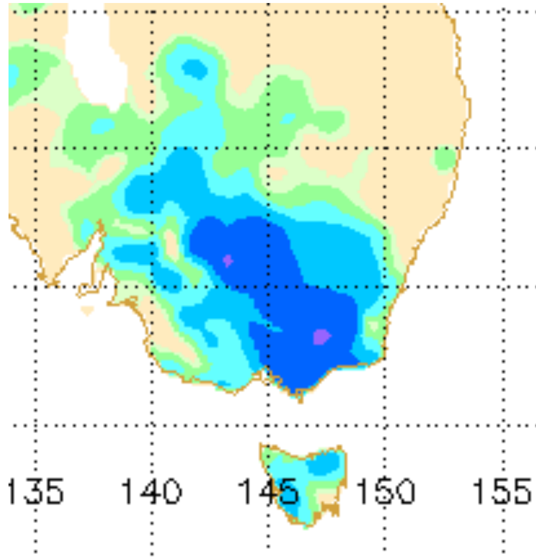
Daily rainfall values.



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

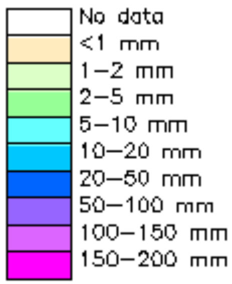


ACCESS-G 48 to 72 hour rainfall forecast for 9 November 2011 using no satellite data.



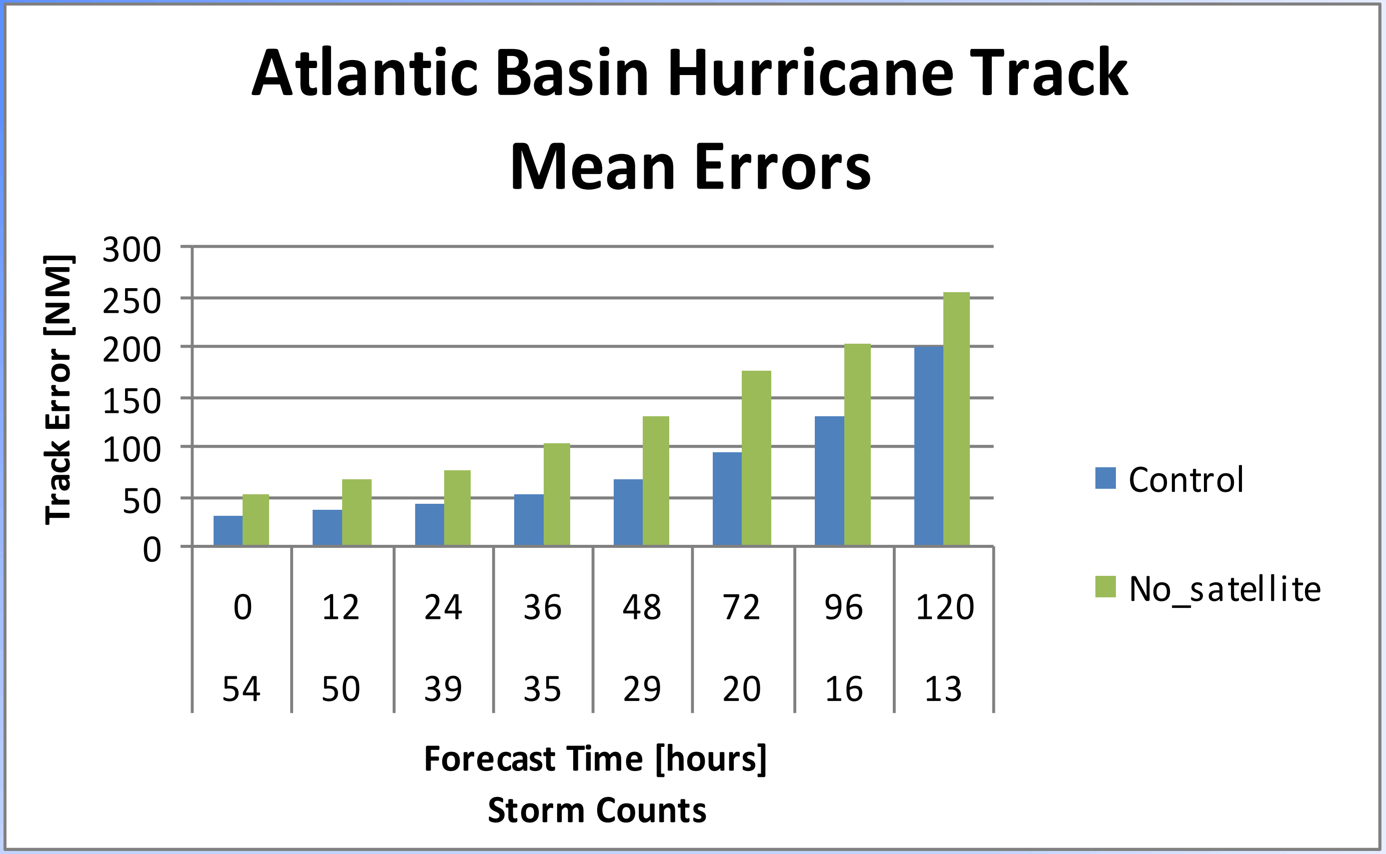
Daily rain gauge analysis for 9 November 2011.

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

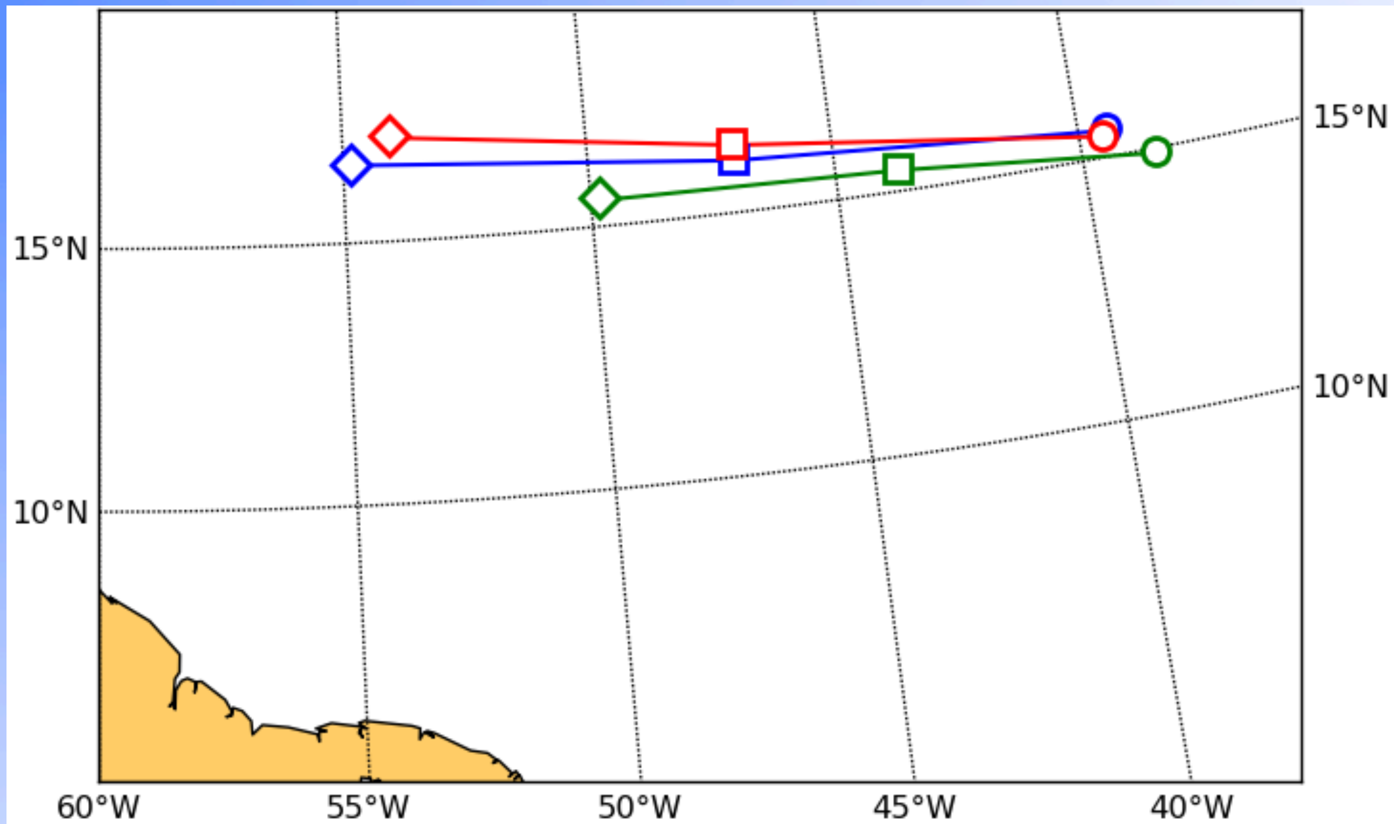


Daily rainfall values.

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



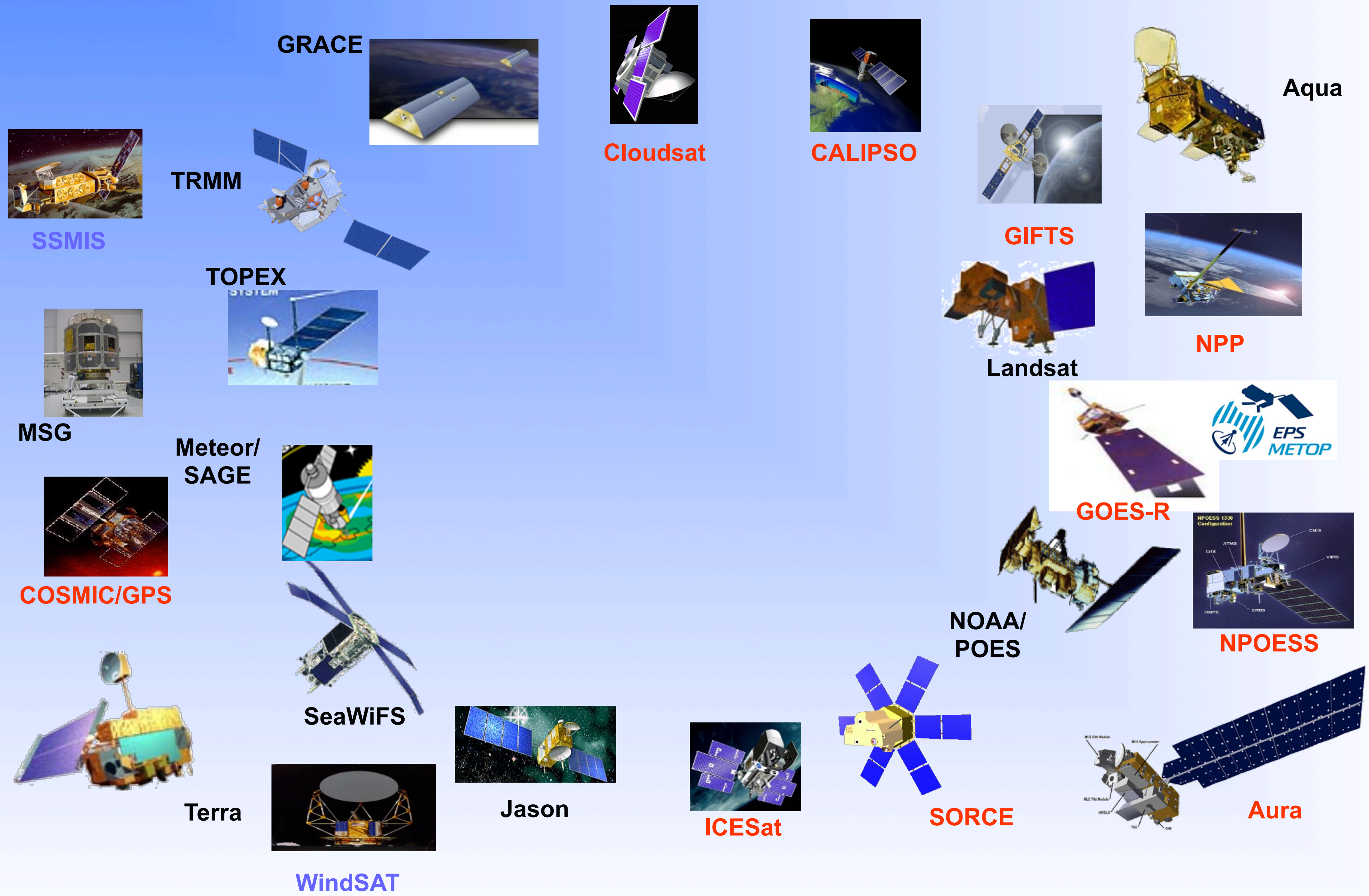
Atlantic basin mean hurricane track errors for the control (all data) and no satellite data case, 15 August to 30 September 2010 using GFS and verifying against the control (all data) analysis.



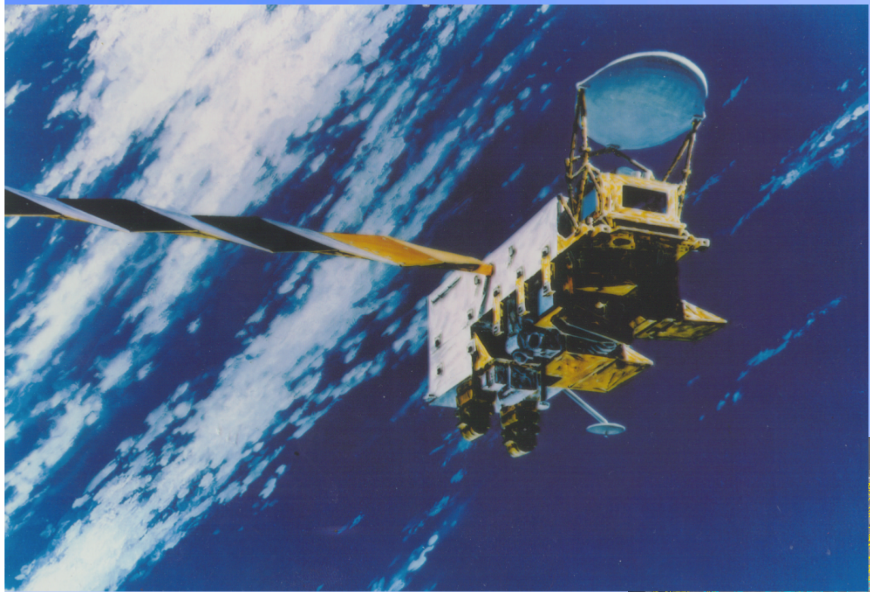
Atlantic basin tracks for hurricane Earl commencing 00UTC 27 August 2010. The control (all data) forecast is red and the no satellite data forecast case is green. The blue line is the best track. Circles represent 00 UTC on 27 August, squares 00 UTC on 28 August and diamonds 00 UTC on 29 August 2010.

Observing the atmosphere
Satellite systems

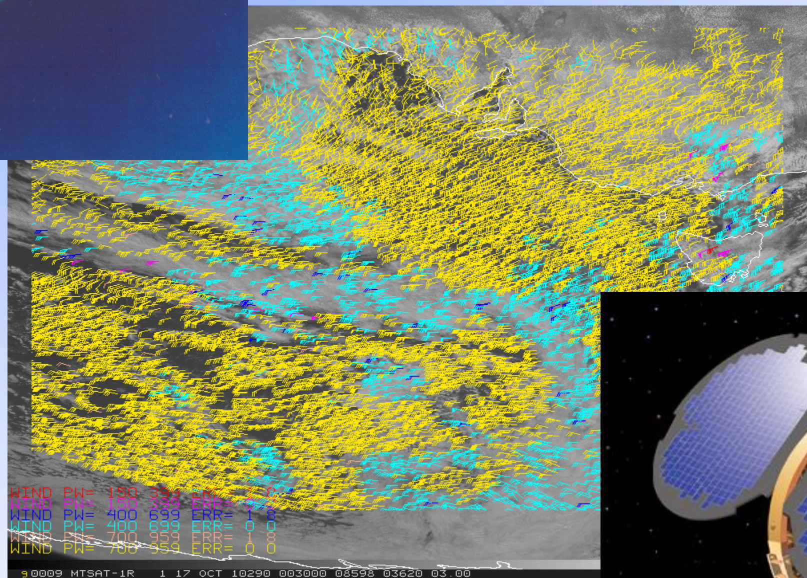
THE CHALLENGE



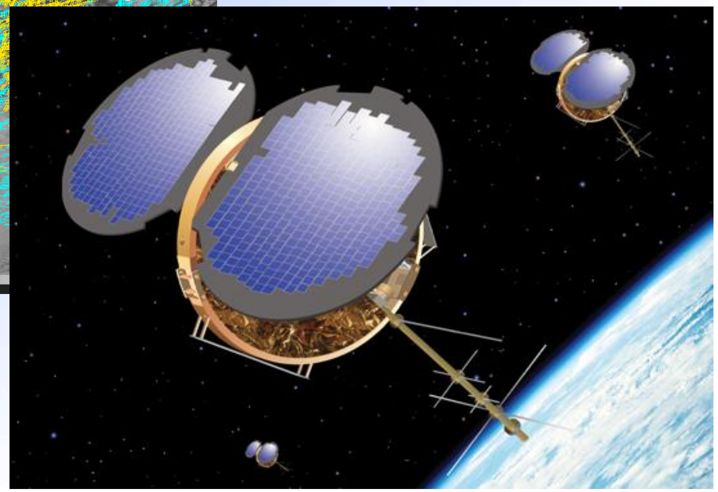
Three Key Observations Types



AMVs



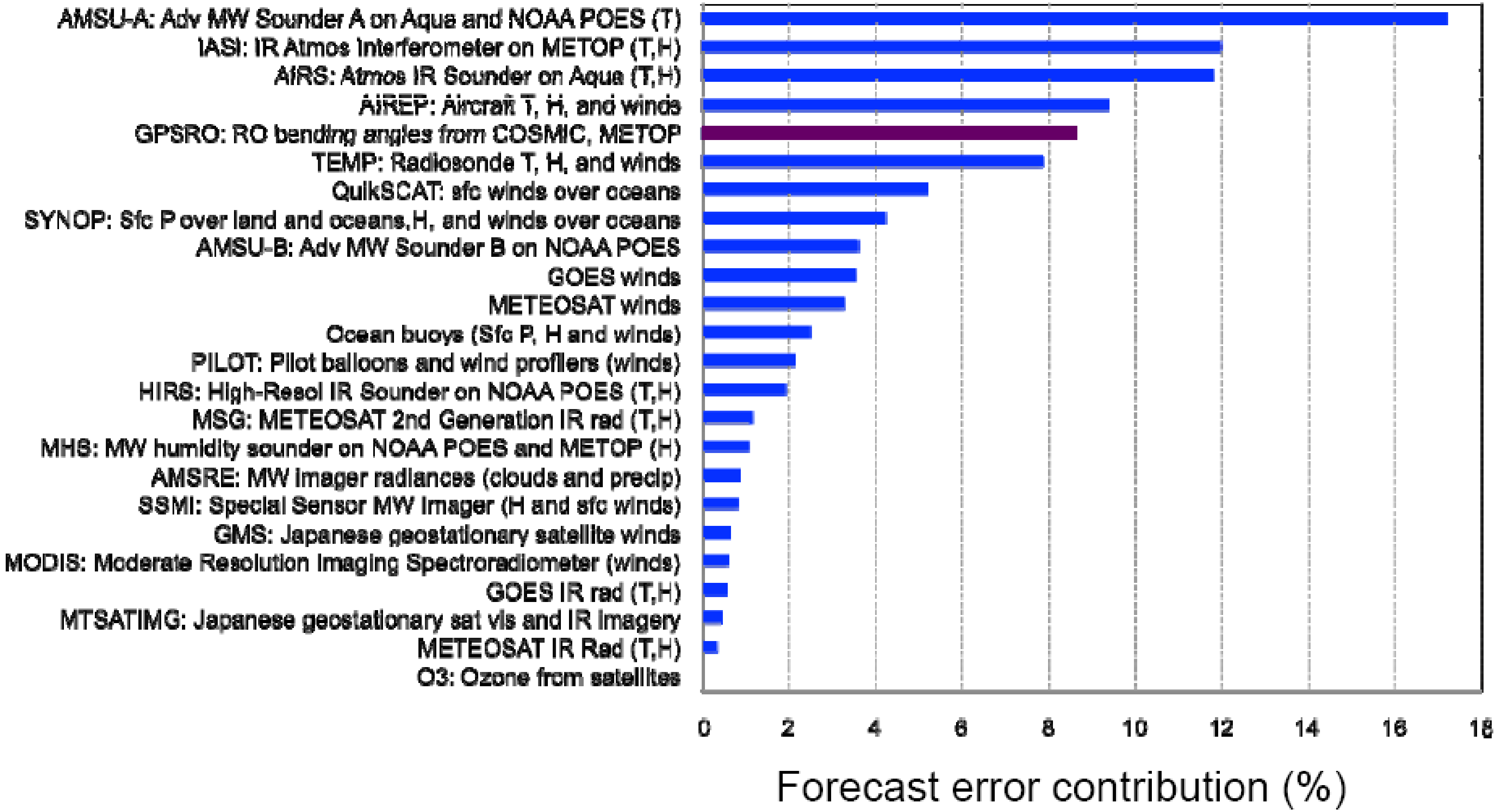
GPS RO



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

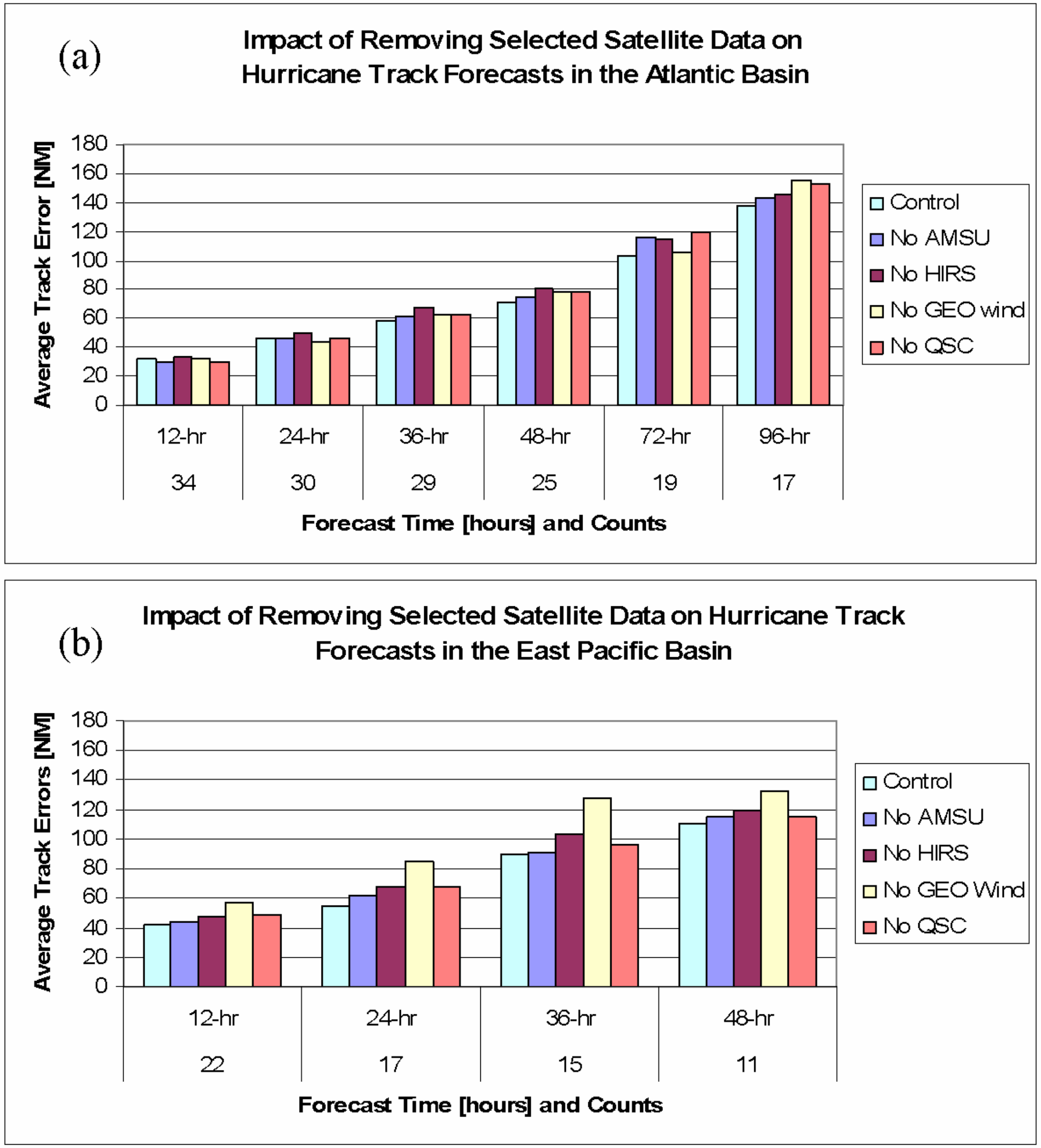
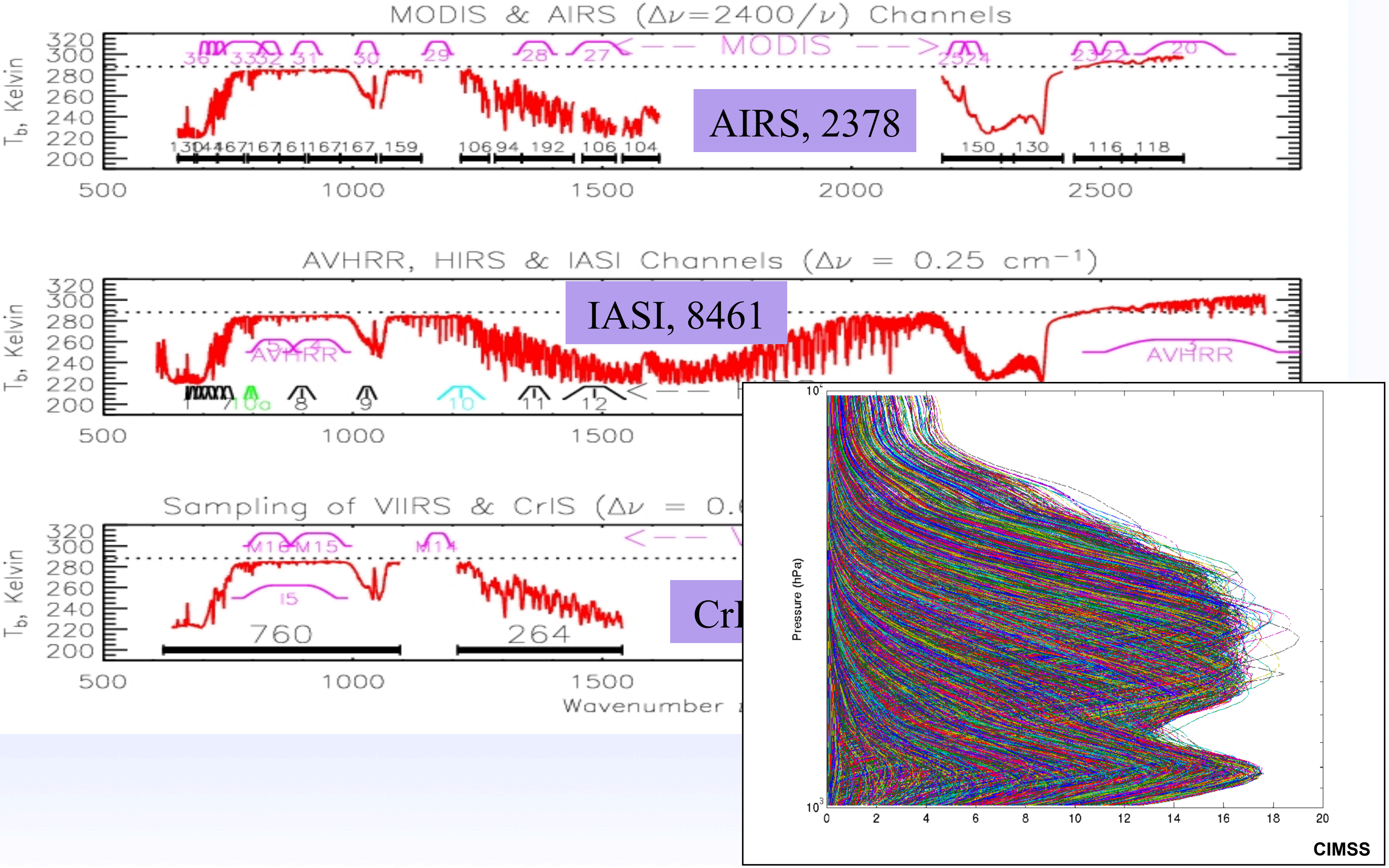


Fig. 10. Average track error (NM) by forecast hour for the control simulation and experiments where AMSU, HIRS, GEO winds and QuikSCAT were denied. The Atlantic Basin results are shown in (a), and the Eastern Pacific Basin results are shown in (b). A small sample size in the number of hurricanes precludes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

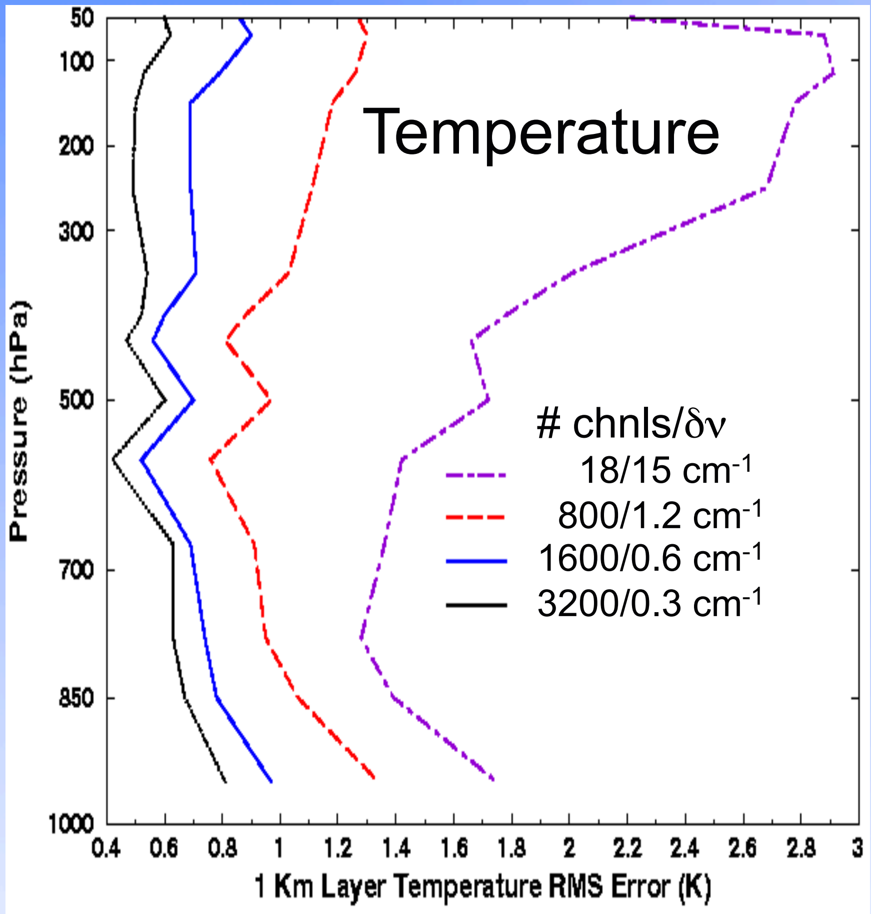
Ultraspectral Advanced Sounders

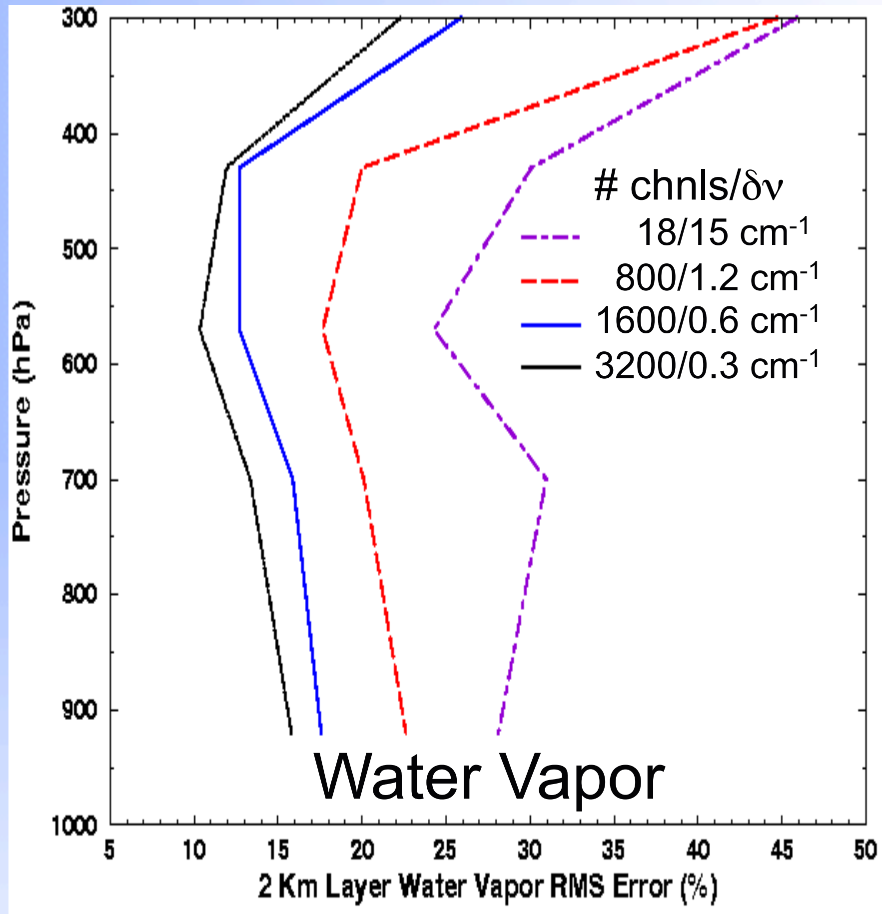
AIRS
IASI
CrIS

Spectral Coverage and Example Observations of AIRS, IASI, and CrIS



Retrieval Accuracy Vs Spectral Resolution (i.e., number of spectral radiance observations)





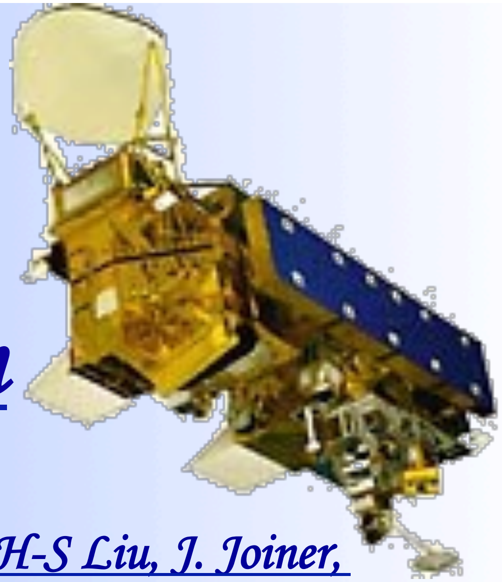
The vertical resolution and accuracy increases greatly going from multi-spectral to ultra-spectral resolution. The improvement in ultra-spectral performance is proportional to the square root of the number of channels (i.e., S/N)

AIRS Data Assimilation

J. Le Marshall, J. Jung, J. Derber, R. Treadon,

S.J. Lord, M. Goldberg, C. Barnet, W. Wolf and H-S Liu, J. Joiner,

and J Woollen……



1 January 2004 – 31 January 2004

Used operational GFS system as Control

Used Operational GFS system Plus AIRS as Experimental System

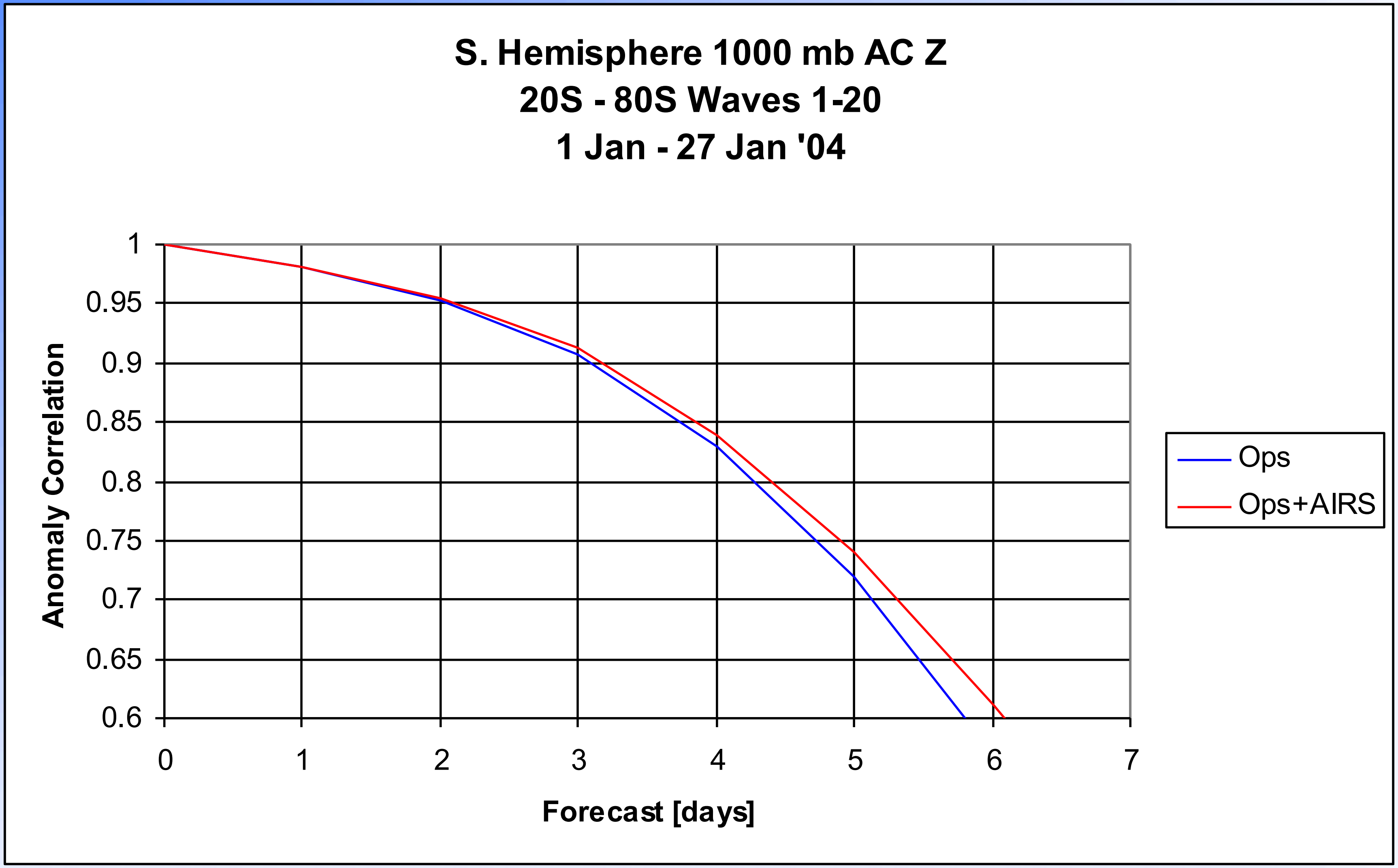
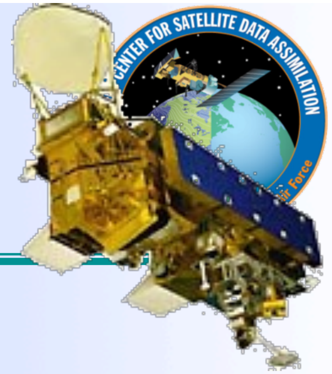


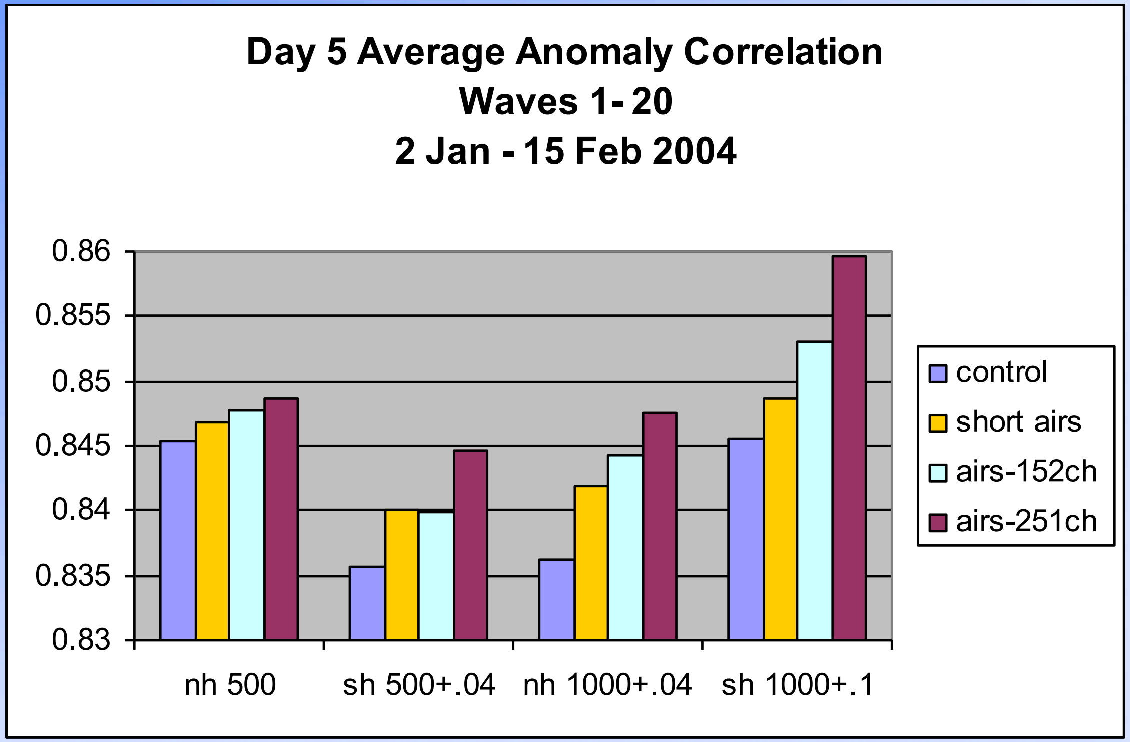
Figure1(a). 1000hPa Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, January 2004



AIRS Data Assimilation

Impact of Spectral coverage...

10 August – 20 September 2004


Day 5 Average Anomaly Correlation
Waves 1- 20
2 Jan - 15 Feb 2004
0.86
0.855
0.85
0.845
0.84
0.835
0.83
nh 500
sh 500+.04
nh 1000+.04
sh 1000+.1
control
short airs
airs-152ch
airs-251ch

AIRS Data Assimilation

Impact of Moisture Channels…

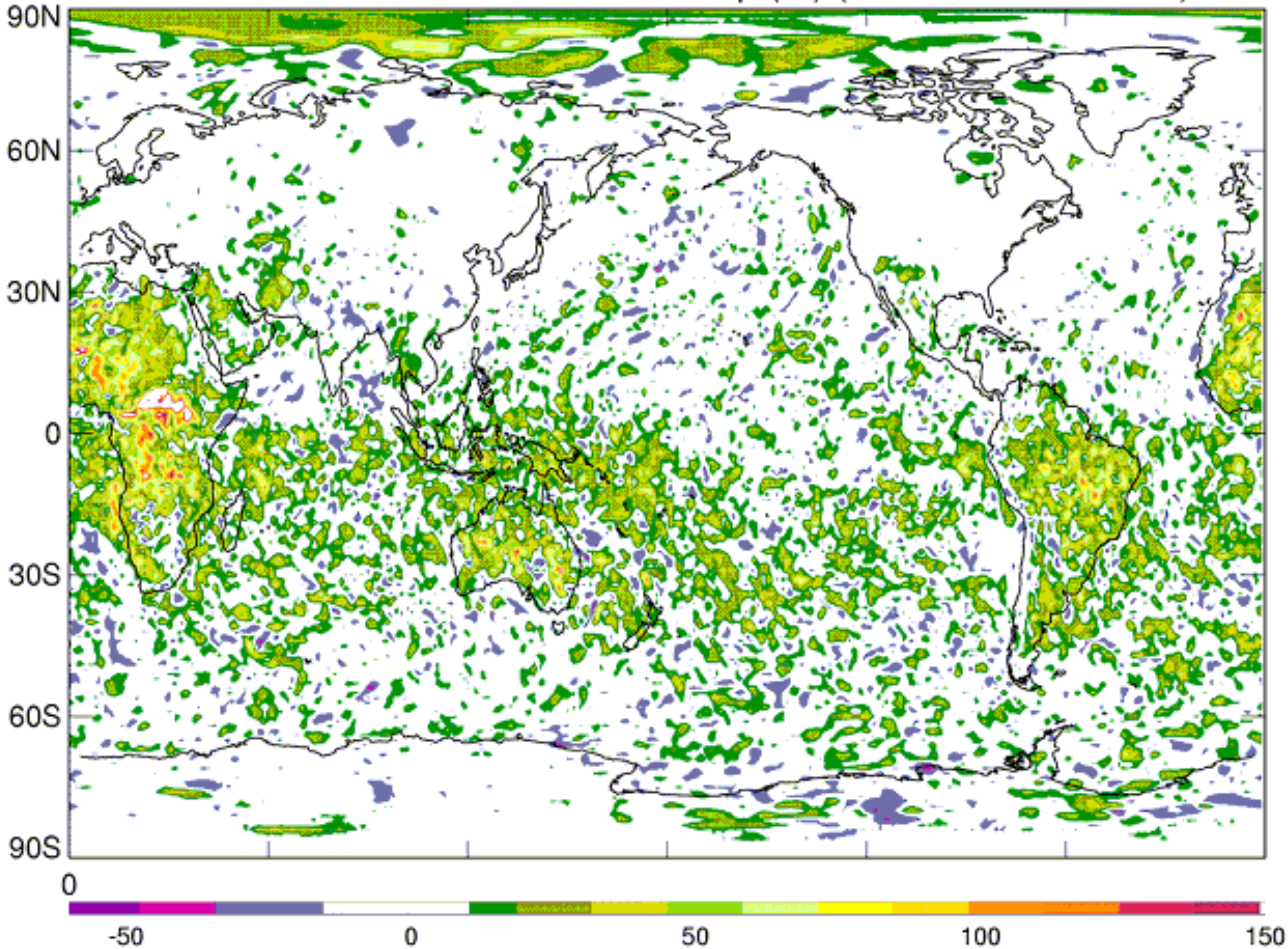
MOISTURE

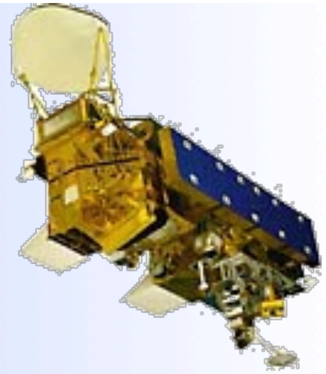
Forecast Impact evaluates which forecast (with or without AIRS) is closer to the analysis valid at the same time.

Impact = 100* [Err(Cntl) – Err(AIRS)]/Err(Cntl)

Where the first term on the right is the error in the Cntl forecast. The second term is the error in the AIRS forecast. Dividing by the error in the control forecast and multiplying by 100 normalizes the results and provides a percent improvement/degradation. A positive Forecast Impact means the forecast is better with AIRS included.

AIRSC 024-HR 925 hPa RH Fcst Imp (%) (15 Jan-15 Feb 2004)





AIRS /IASI Data Assimilation

Using Moisture Channels

1 March – 31 May, 2010

Table 1(b) Conventional data used by the control forecasts

Rawinsonde temperature and humidity	Rawinsonde u and v
AIREP and PIREP aircraft temperatures	AIREP and PIREP aircraft u and v
ASDAR aircraft temperatures	ASDAR aircraft u and v
Flight-level reconnaissance and dropsonde temperature, humidity and station pressure	Flight-level reconnaissance and dropsonde u and v
MDCARS aircraft temperatures	MDCARS aircraft u and v
Surface marine ship, buoy and c-man temperature, humidity and station pressure	Surface marine ship, buoy and c-man u & v
Surface land synoptic and Metar temperature, humidity and station pressure	Surface land synoptic and metar u and v
Ship temperature, humidity and station pressure	Wind Profiler u and v
Pibal u and v	NEXRAD Vertical Azimuth Display u and v

Table 1(a): The satellite data used by the control forecasts

HIRS sounder radiances	SSM/I precipitation rates
AIRS sounder radiances	TRMM precipitation rates
IASI sounder radiances	ERS-2 ocean surface wind vectors
AMSU-A sounder radiances	Quikscat ocean surface wind vectors
AMSU-B sounder radiances	AVHRR SST
GOES sounder radiances GOES, Meteosat atmospheric motion vectors	AVHRR vegetation fraction AVHRR surface type
MTSAT Motion Vectors	Multi-satellite snow cover
GOES precipitation rate	Multi-satellite sea-ice
SSM/I ocean surface wind speeds	SBUV/2 ozone profile and total ozone

The AIRS and IASI water vapour channels added to the operational data base for the water vapour experimental runs.	
Tropospheric Channels	**AIRS tropospheric channels** (2378 channel set): 1301, 1304, 1449, 1455, 1477, 1500, 1519, ….27AIRS Channels
	IASI tropospheric channels (8461 channel set): 2701, 2741, 2819, 2889, 2907, 2910, 2939, …53 IASI Channels
Stratospheric Channels	**AIRS Channels:** AIRS stratospheric channels (2378 channel set): 1466, 1614, …..9 AIRS Channels
	IASI Channels: IASI stratospheric channels (8461 channel set): 3168, 3248, …31 IASI Channels

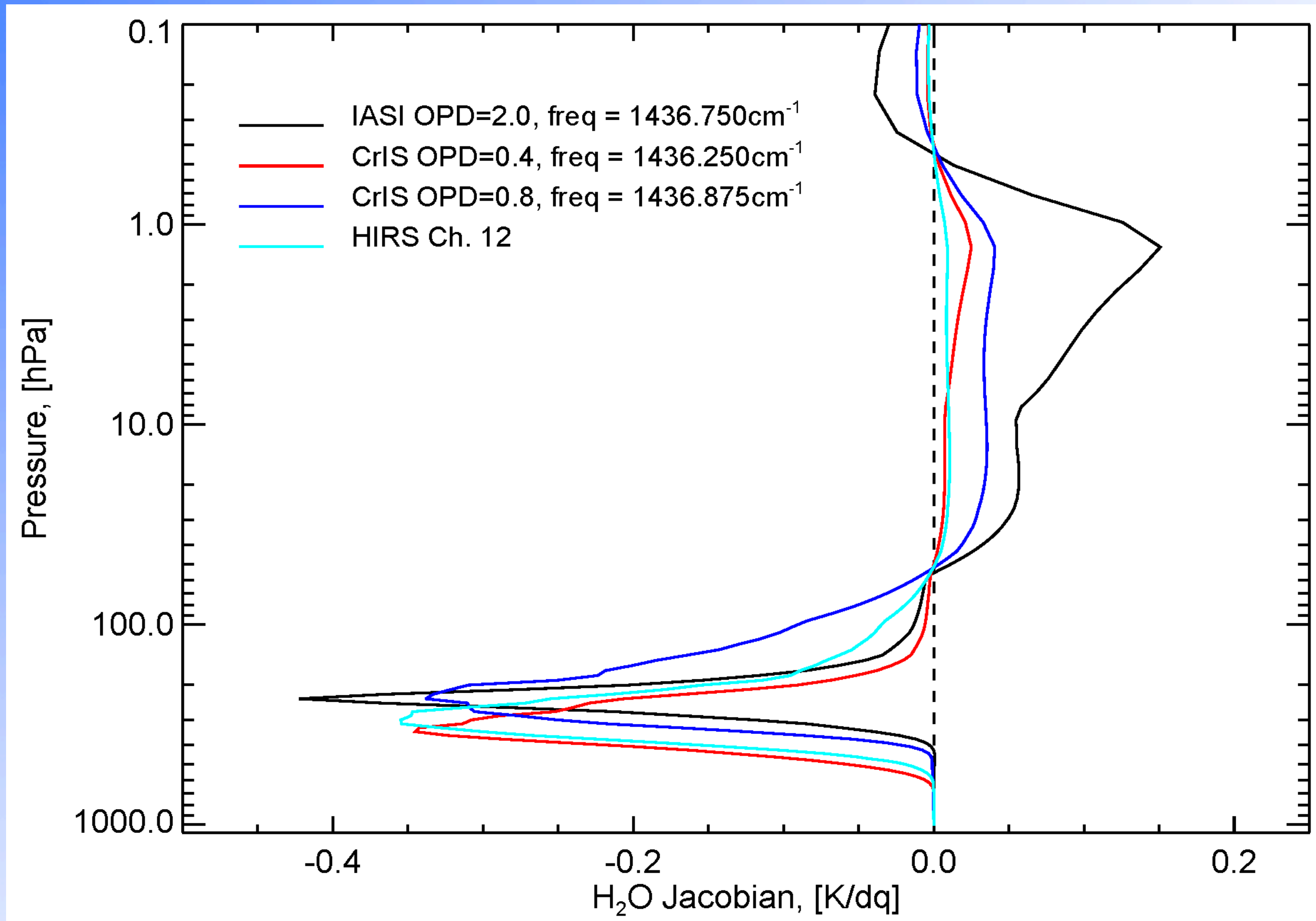
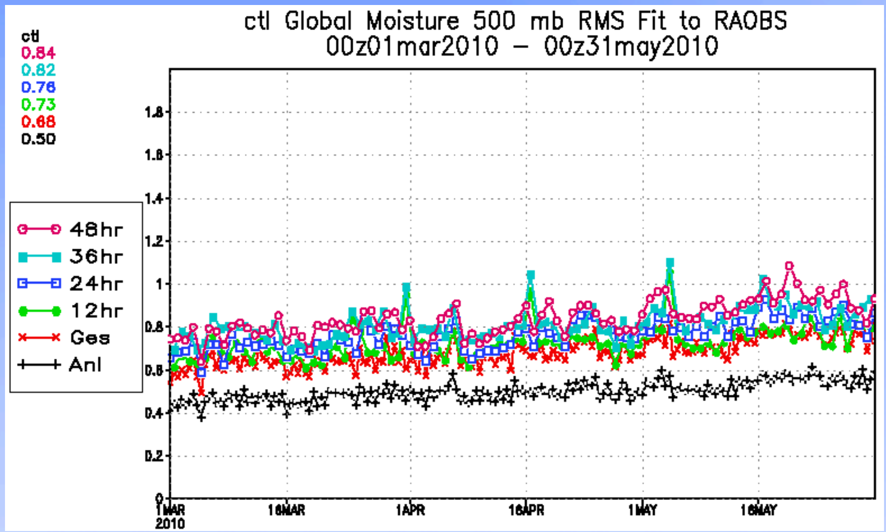


Figure 2: Water Vapor Jacobians for IASI channel 3168 (black), which is sensitive to moisture in the Stratosphere, similar CrIS channels half (red) and full (dark blue) spectral resolution and the HIRS channel 12(light blue).

Analysing Tropospheric Moisture by Assimilating Hyperspectral Infrared Water Vapor Channels

control



experiment

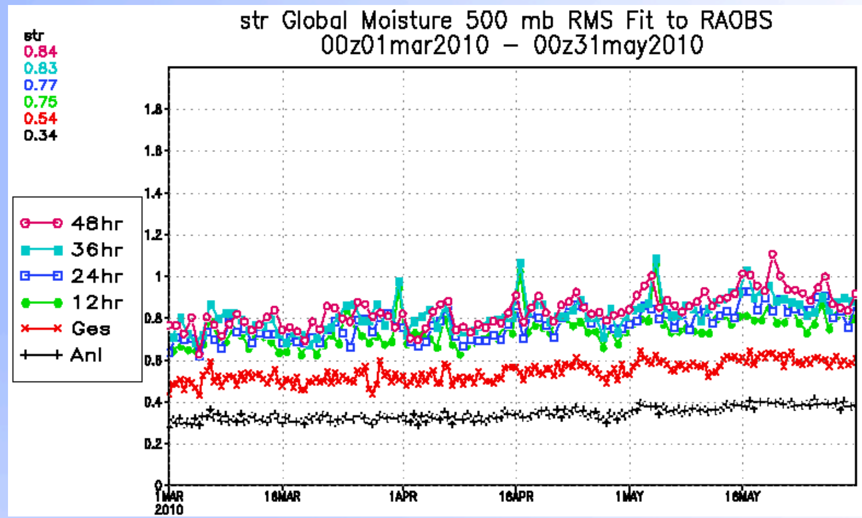


Figure 3: Specific humidity fits to rawinsondes humidity data during the time period March to May 2010 for the analysis, 6(Ges)- , 12- , 24- , 36- and 48-hour forecasts. Note the considerable improvement in the 6-hour and 12-hour forecasts.

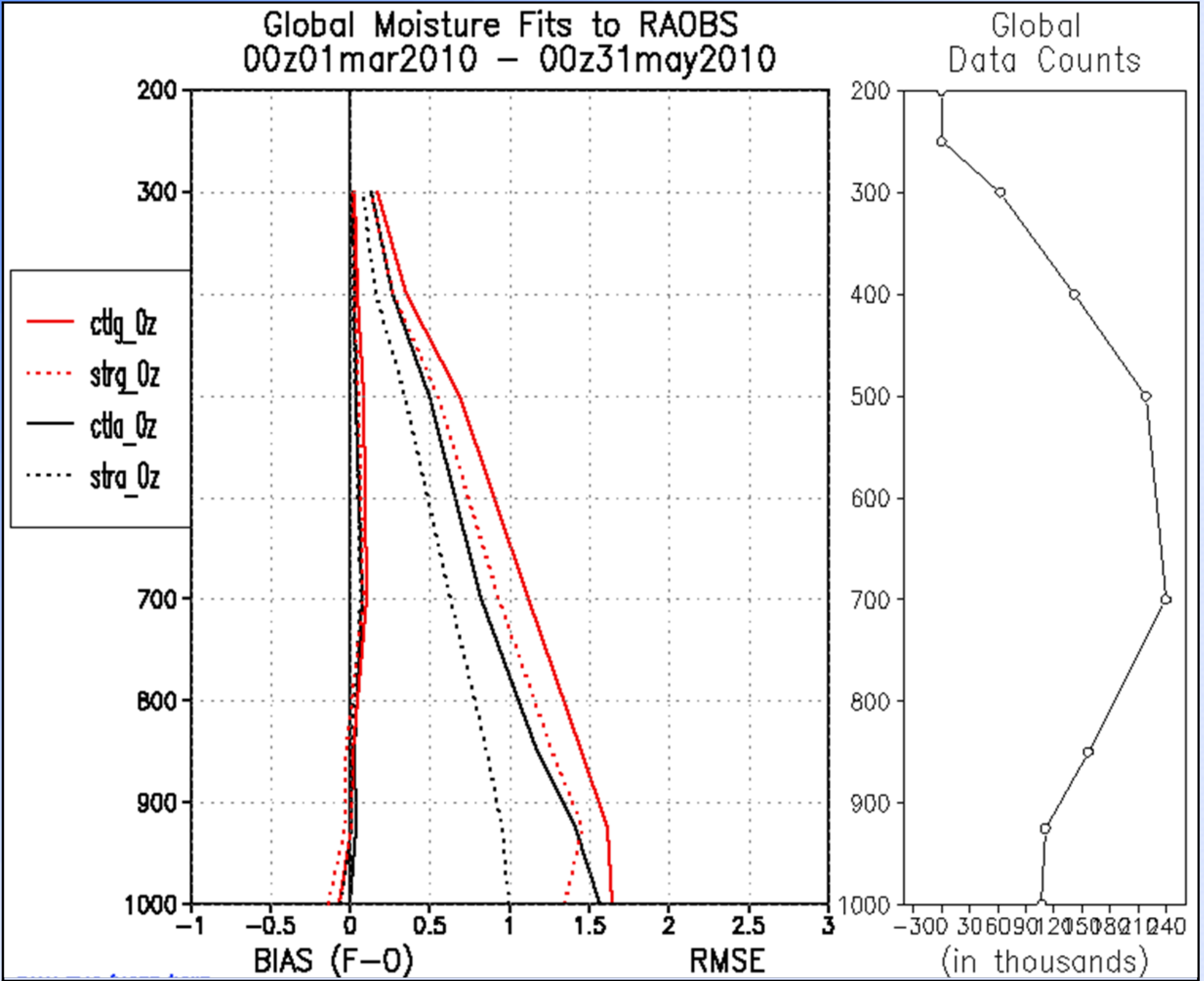
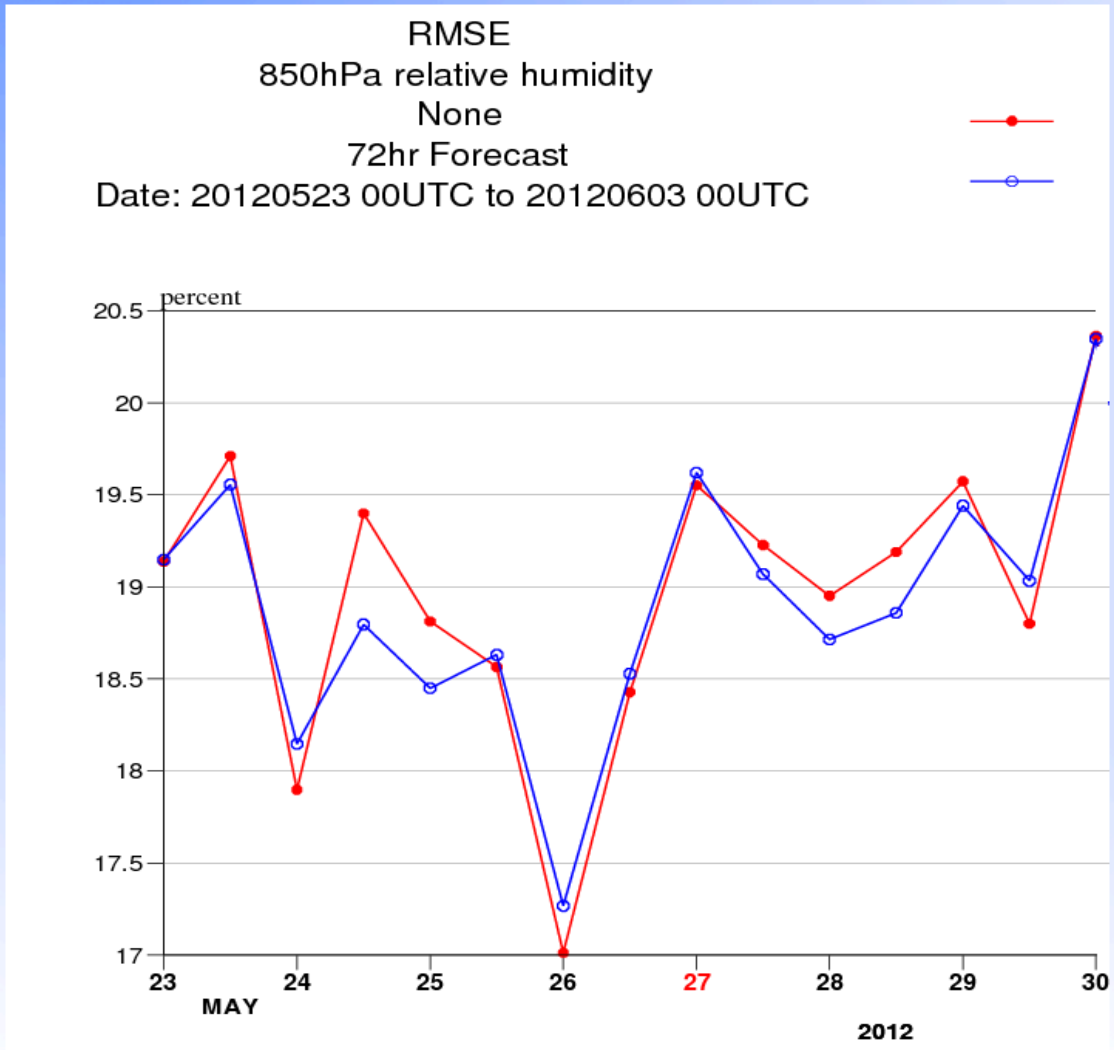


Figure 4: Specific humidity vertical profile of bias (left) and RMSE (right) with respect to rawinsonde data during Mar-Apr-May 2010. The solid lines are the Control and the dotted lines are the Water Vapor Experiment. Red are the first guess, black are the analysis.

ACCESS WV Channet Assim.

11 water vapour AIRS channels were switched on and were presented to 4DVAR: 1614, 1644, 1674, 1681, 1717, 1751, 1763, 1780, 1783, 1803, 1812



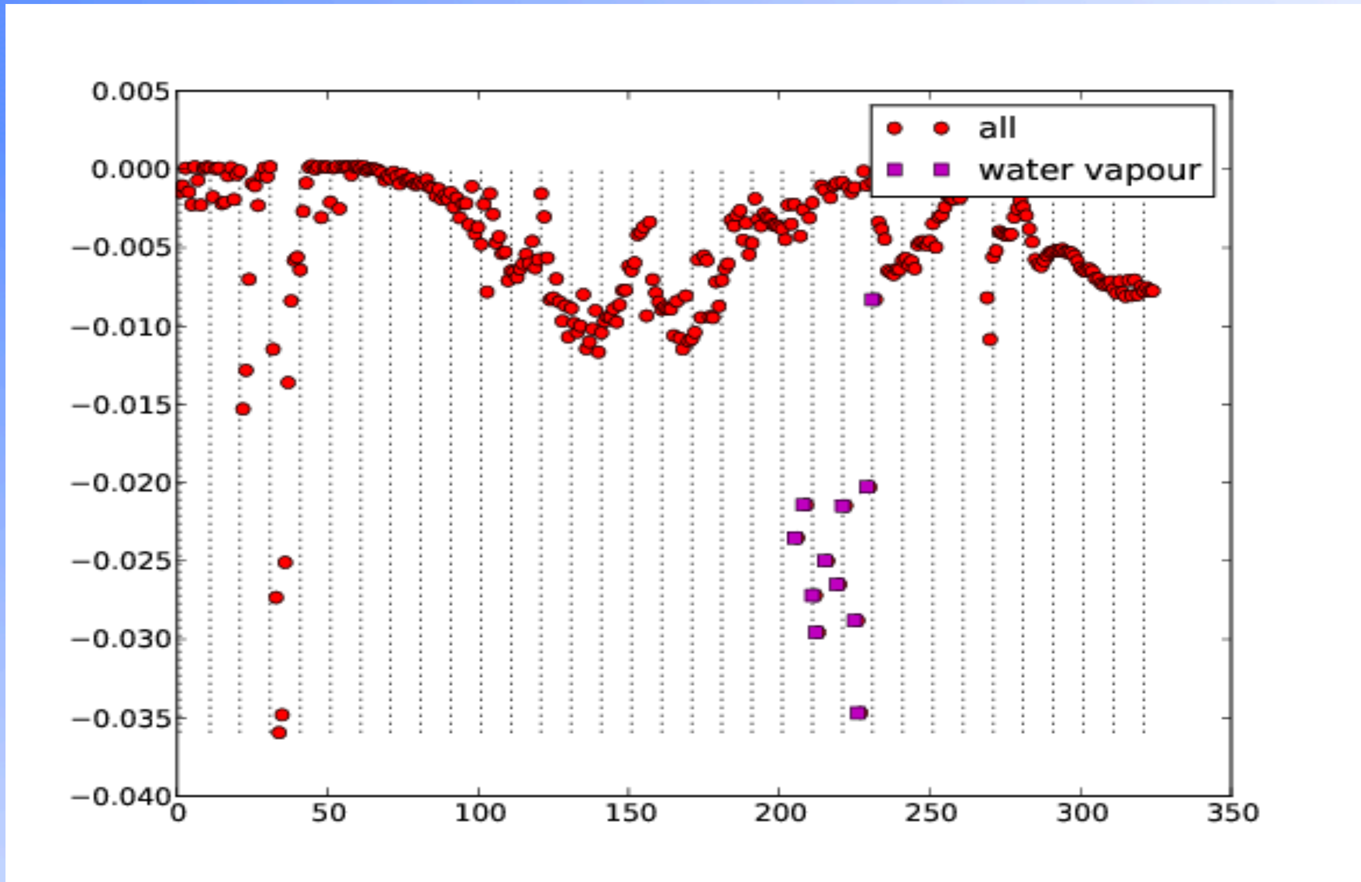
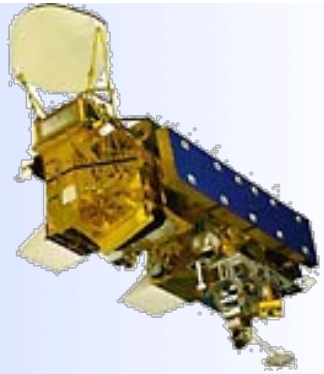


Figure 8. Difference in the RMS of globally averaged innovations (corrected minus background). Difference is EXP minus CTRL.



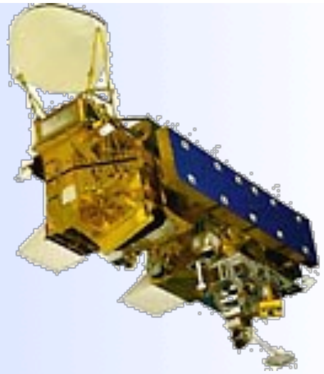
AIRS Data Assimilation

Using Cloudy Fields of View

1 January – 24 February 2007

AIRS Data Assimilation

Using Cloudy Fields of View



Initial Experiments: 1 January – 24 February 2007

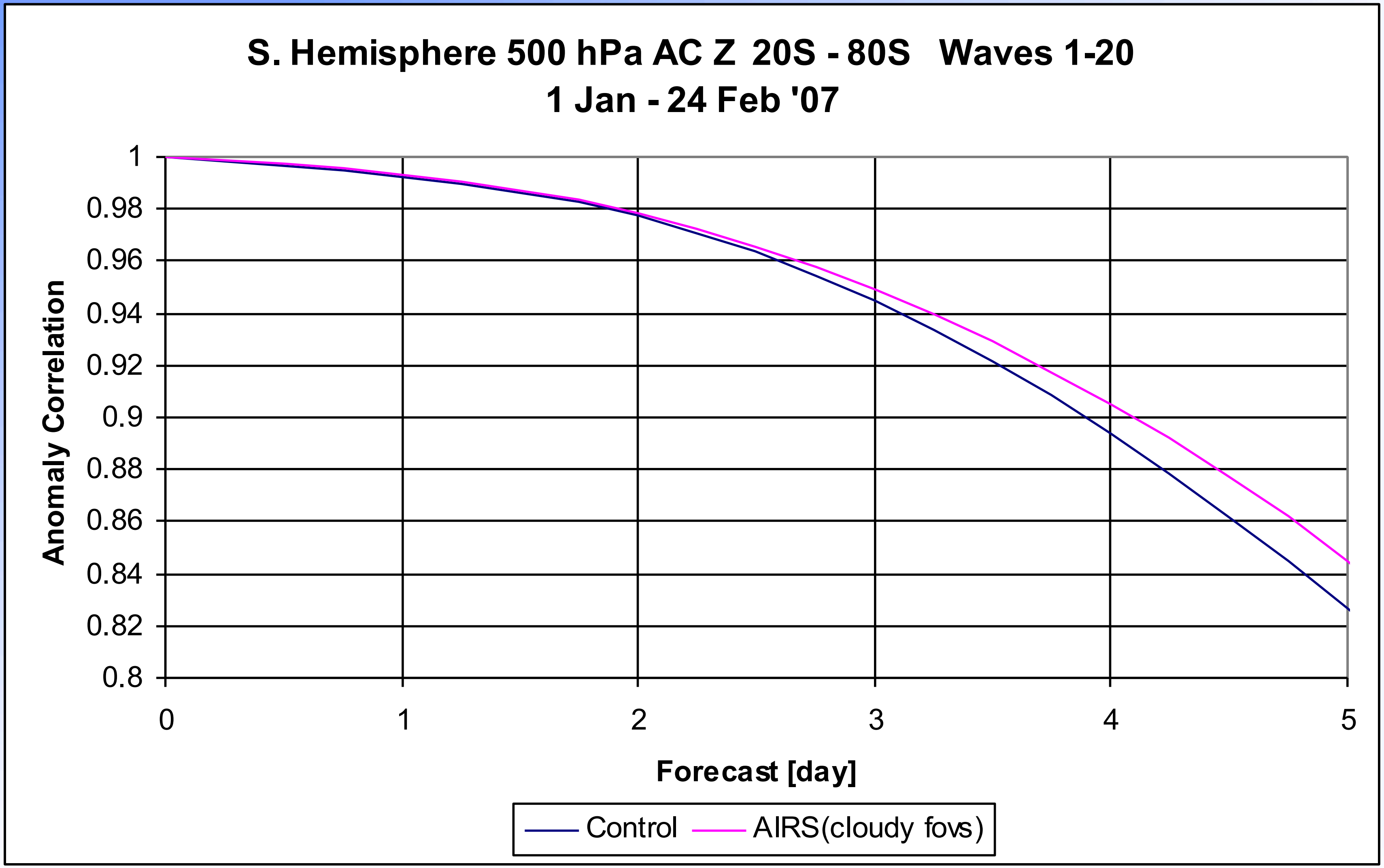
Intention:

Assimilate radiances from cloudy fovs preferably with single level cloud.

Initially use radiances where cloud coverage and uniformity of fovs allow accurate estimation of radiances from clear part of fovs

Initially measure impact from use of clear air radiances

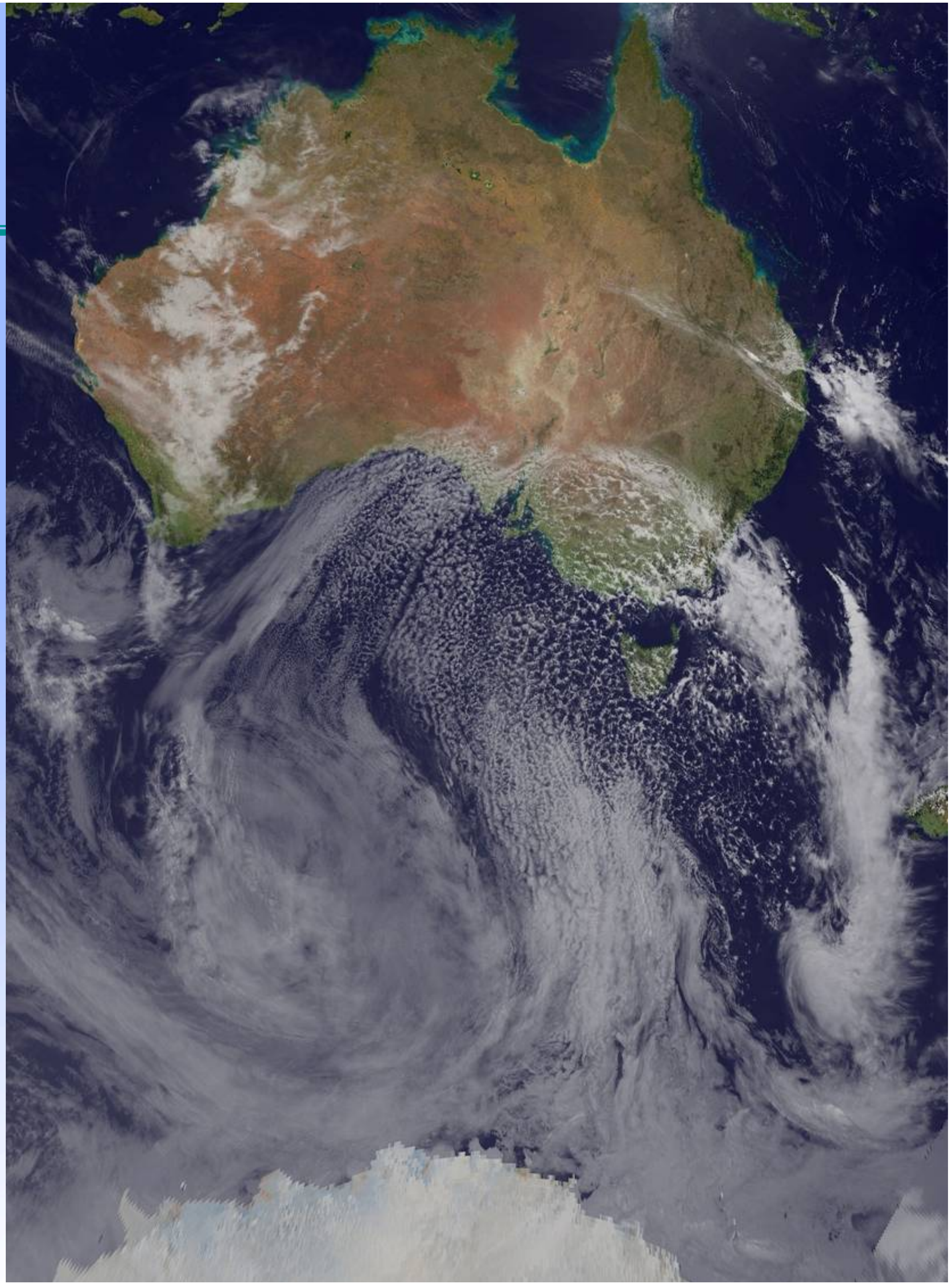
(Later use α and p_c in 3D Var.)


S. Hemisphere 500 hPa AC Z 20S - 80S Waves 1-20
1 Jan - 24 Feb '07
Anomaly Correlation
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
0.8
0
1
2
3
4
5
Forecast [day]
Control
AIRS(cloudy fovs)

Australian Government

Bureau of Meteorology

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.

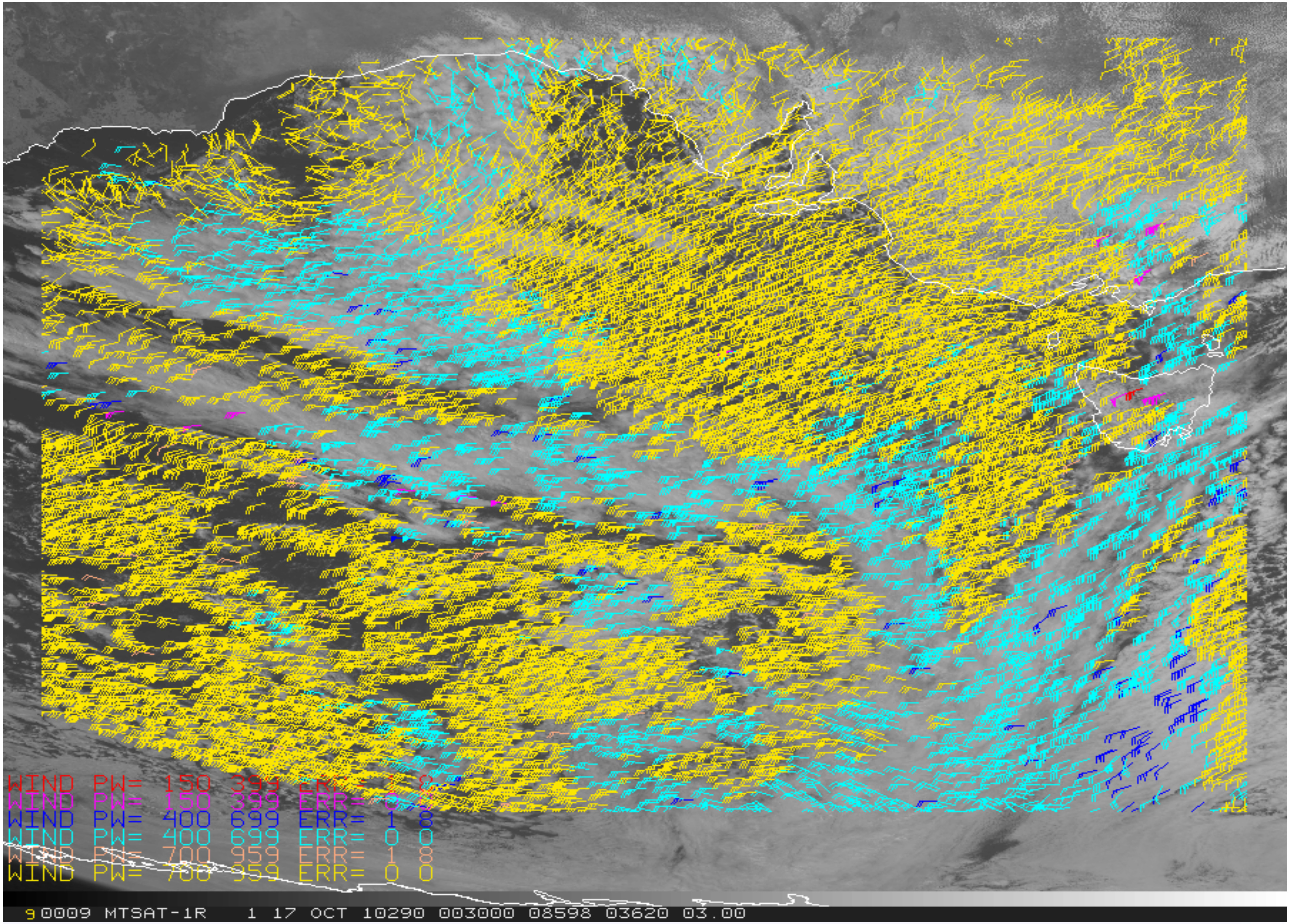
Wind Type	Resolution	Frequency-Times (UTC)	Image Separation
Real Time IR/ VIS*	4 km	6-hourly – 00, 06, 12, 18	15 minutes
Real Time IR/ VIS* (hourly)	4 km	Hourly – 00, 01, 02, 03, 04, 05, . . . , 23	1 hour

*daytime

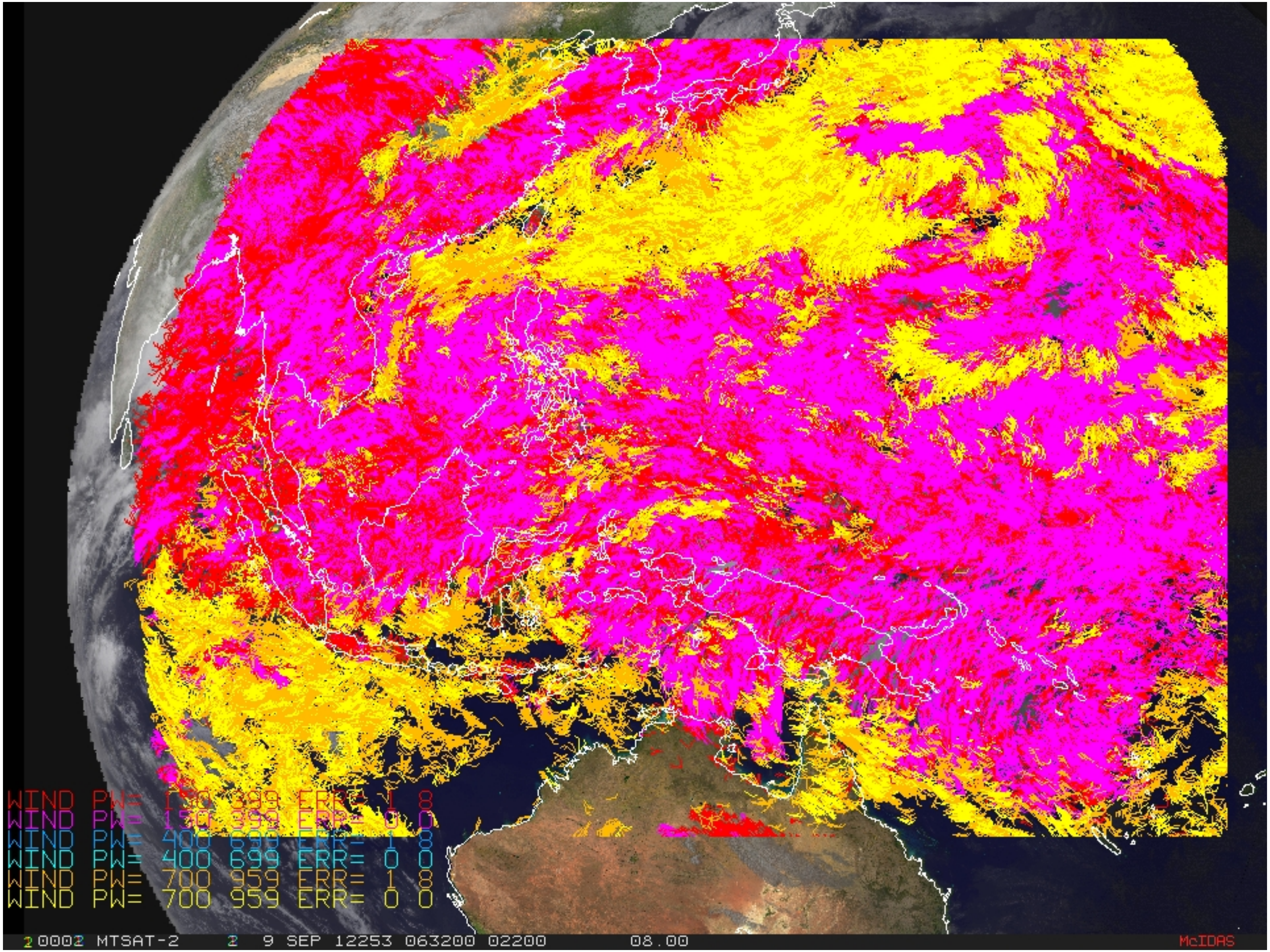
Part of the schedule for Southern Hemisphere wind generation from MTSAT-1R images. This part provides 26 Infrared Channel (IR1) based wind data sets, 24 High Resolution Visible (HRV) image and 4 Water Vapour (WV) image based data sets from the full disc and northern hemisphere images listed.

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			

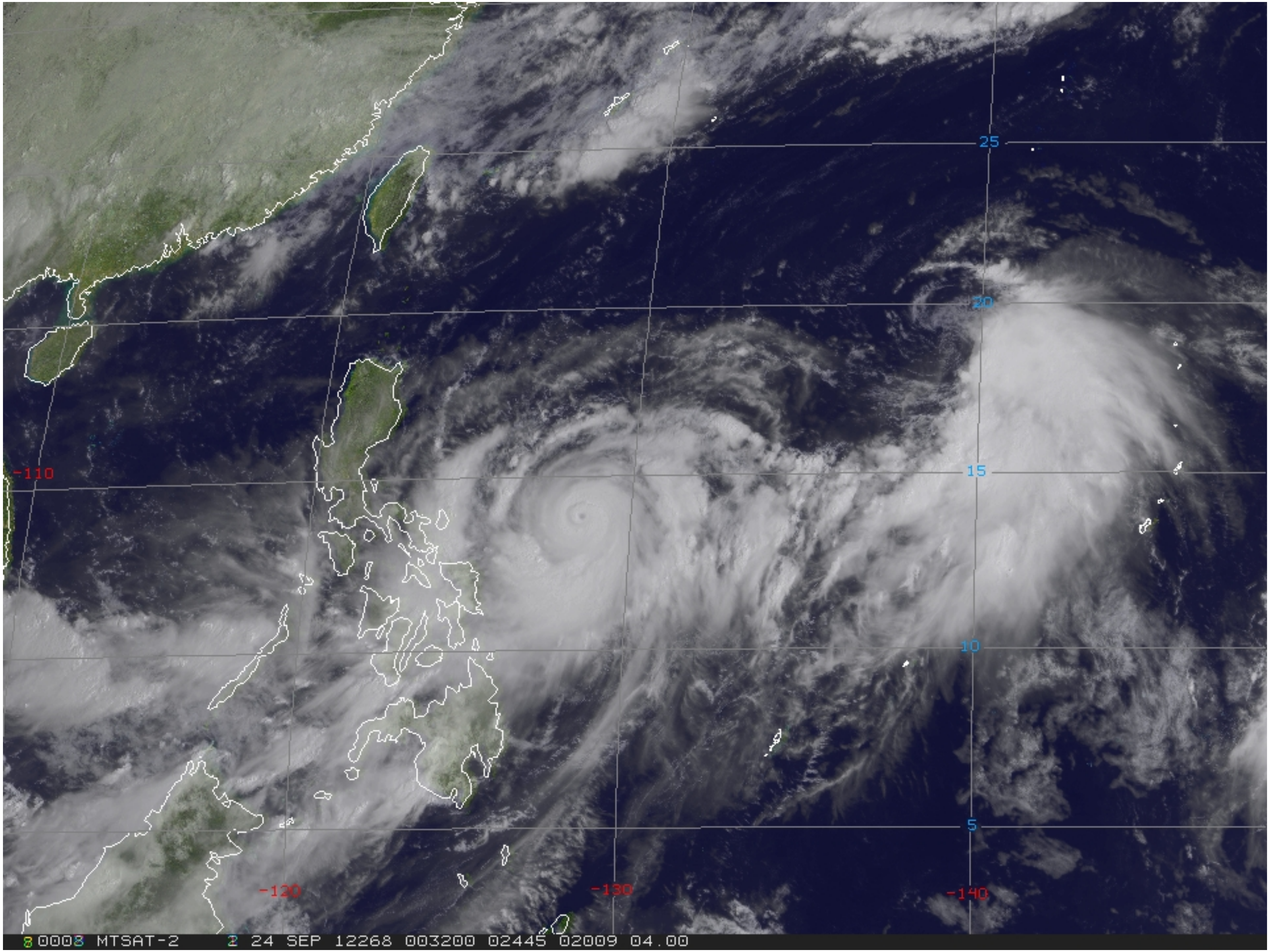
Full Disc Image
Southern Hemisphere Image

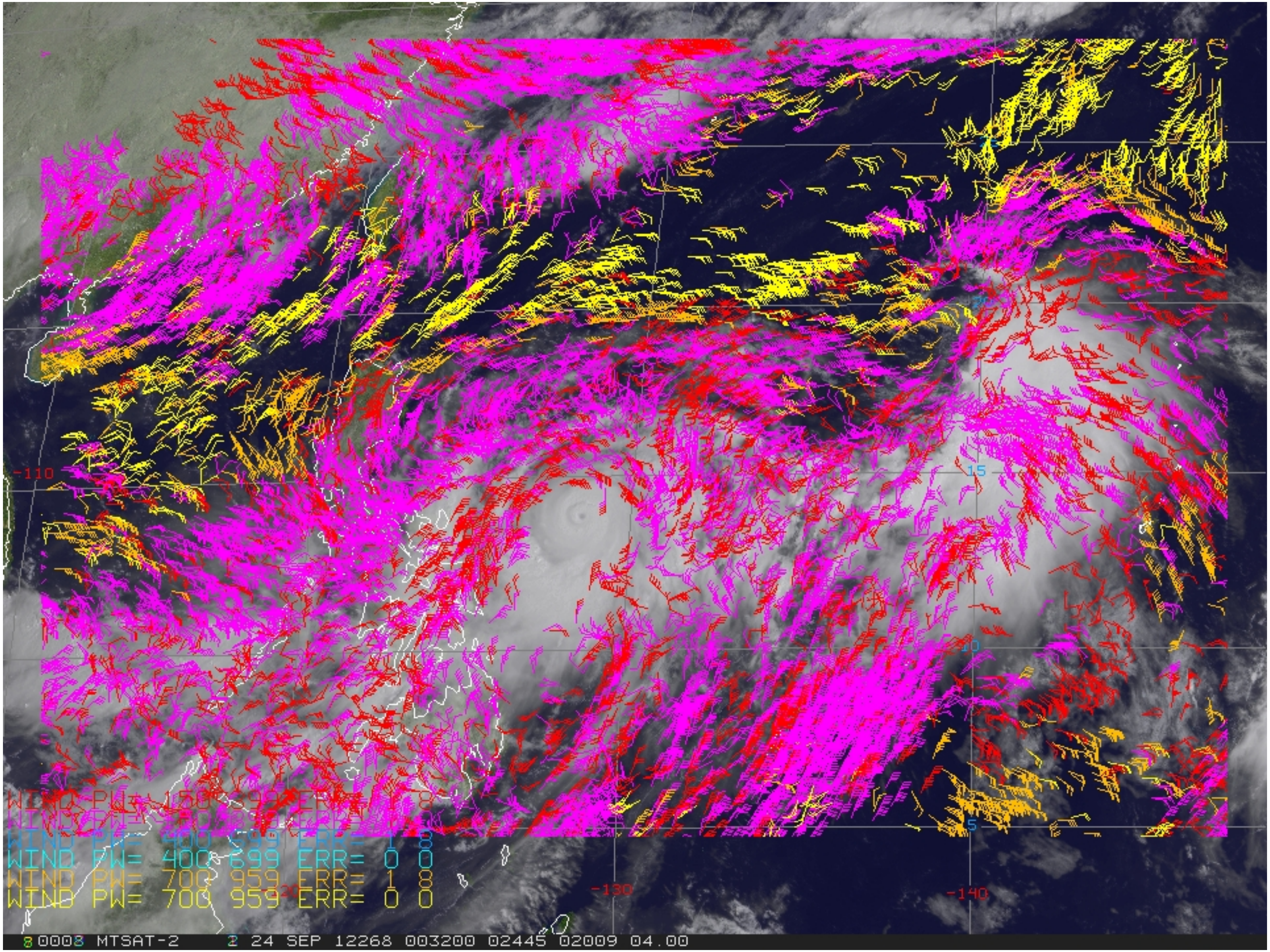


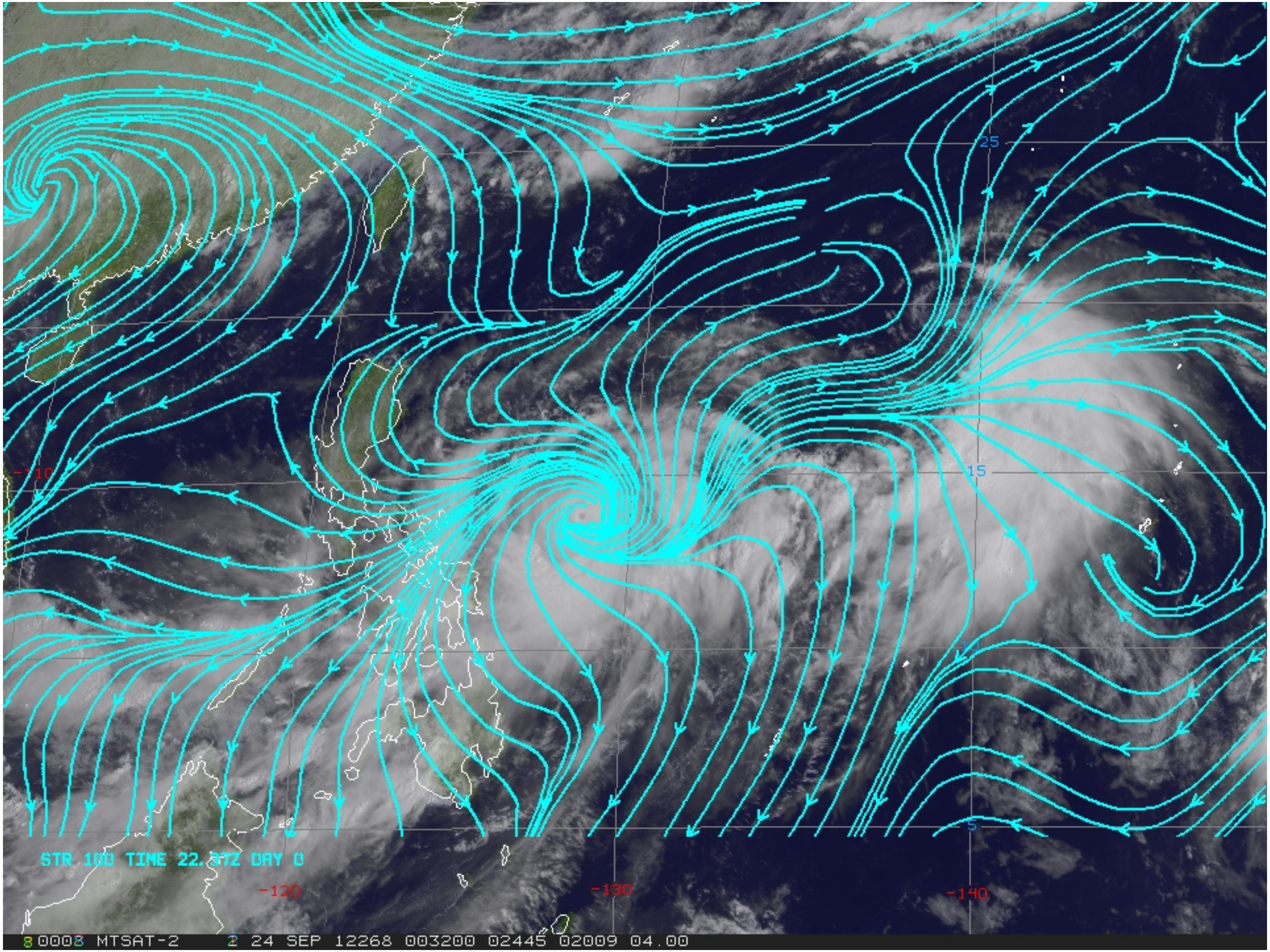
MTSat-1R VIS AMVs generated around 00 UTC on 17 October 2010.



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
2 0002 MTSAT-2 2 9 SEP 12253 063200 02200 08.00
McIDAS


25
20
15
10
5
-110
-120
-130
-140
8 0008 MTSAT-2 2 24 SEP 12268 003200 02445 02009 04.00


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
-110
-130
-140
15
10
5
8 0008 MTSAT-2 2 24 SEP 12268 003200 02445 02009 04.00

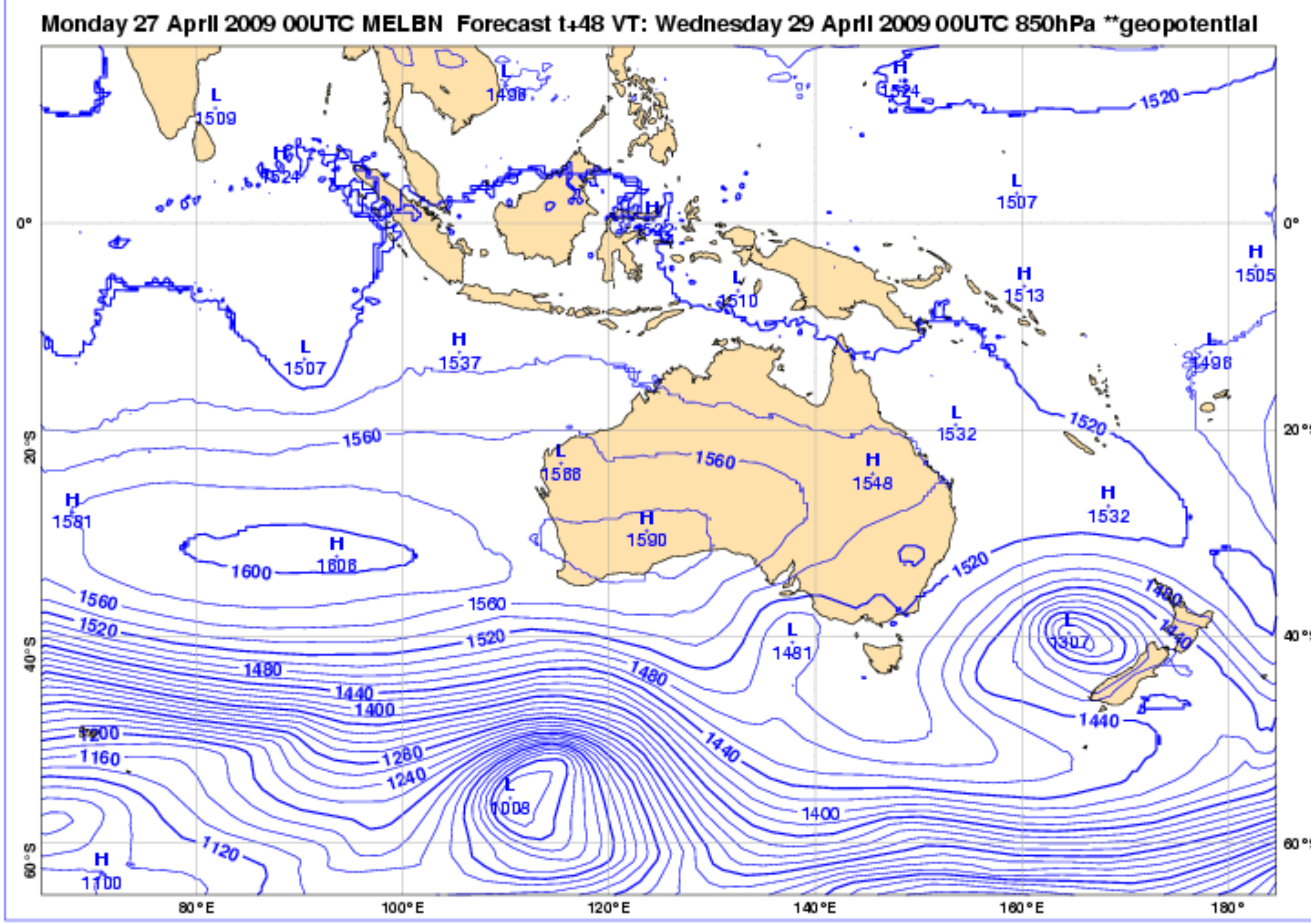

25
15
5
-110
STR 100 TIME 22.37Z DAY 0
-120
-130
-140
8 0008 MTSAT-2 2 24 SEP 12268 003200 02445 02009 04.00

Australian Community Climate and Earth System Simulator (ACCESS)

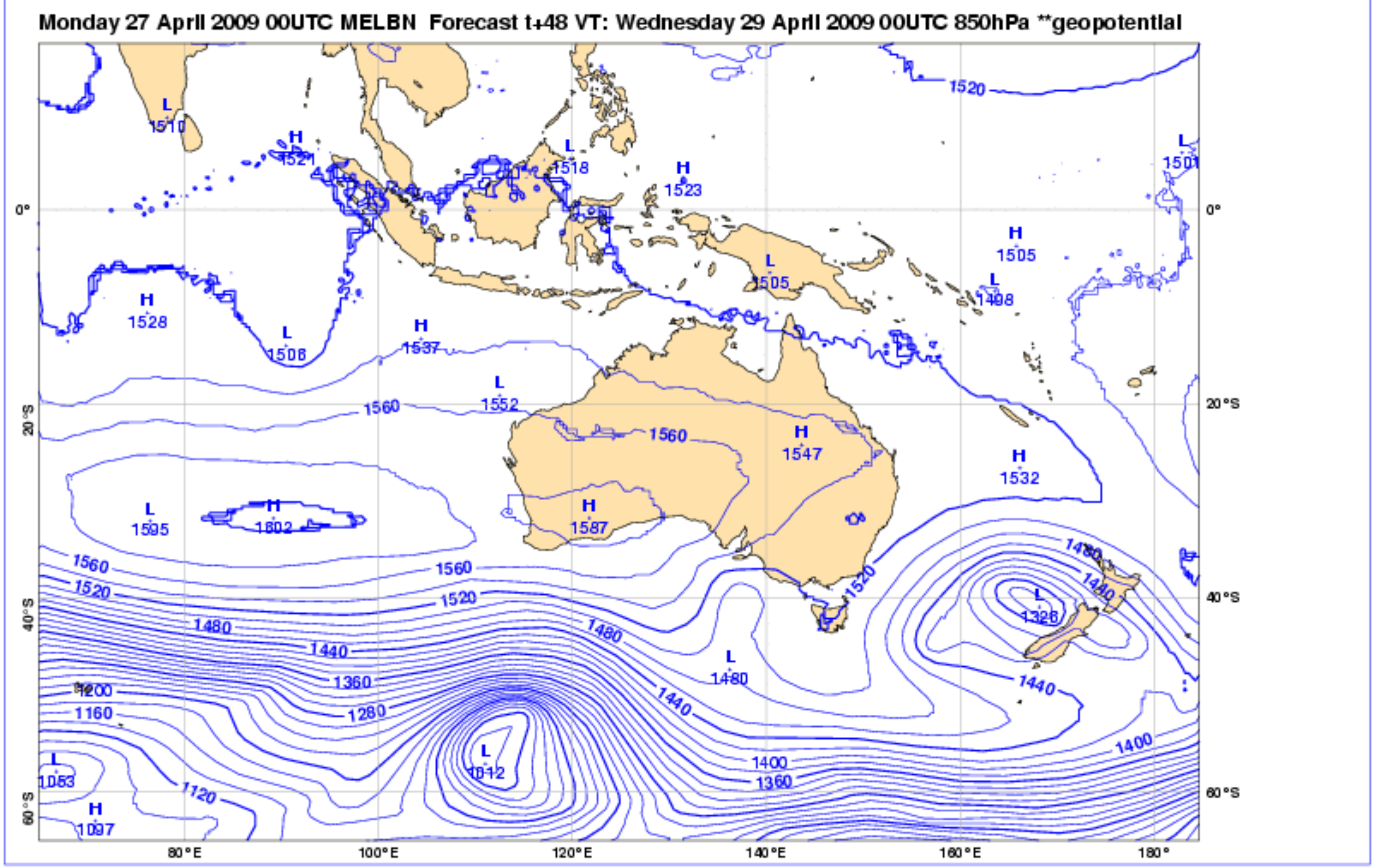
ACCESS - R uses

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

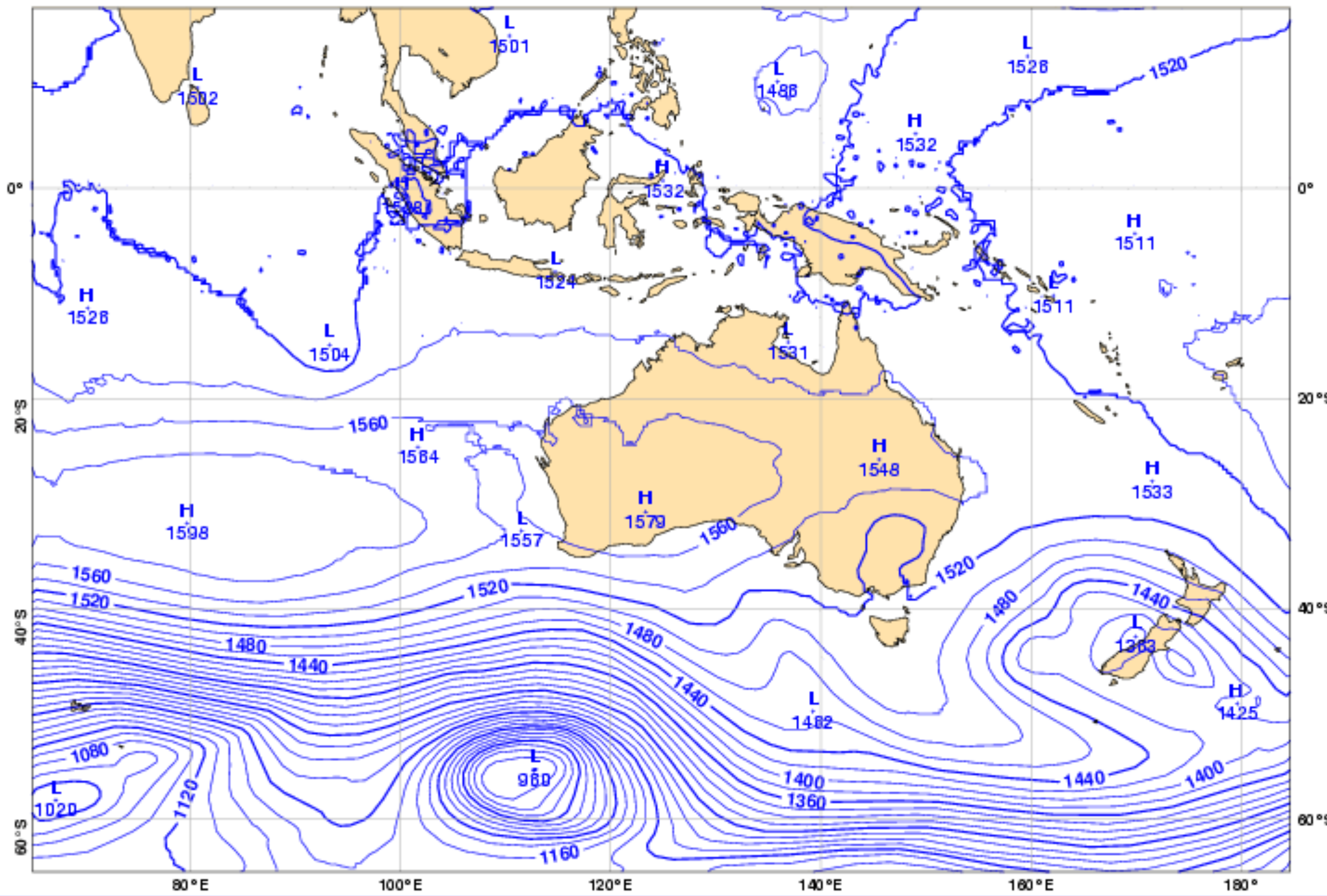
CNTL


Monday 27 April 2009 00UTC MELBN Forecast t+48 VT: Wednesday 29 April 2009 00UTC 850hPa **geopotential
80°E
100°E
120°E
140°E
160°E
180°
0°
20°S
40°S
60°S

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°
1520
1560
1480
1440
1400
1360
1280
1200
1160
1120
H 1602
L 1595
H 1587
H 1547
H 1532
L 1326
L 1012
L 1480
L 1063
H 1097
H 1528
L 1506
H 1537
L 1552
L 1510
H 1521
L 1518
H 1523
L 1505
H 1505
L 1498
L 1501

MELBN Analysis VT:Wednesday 29 April 2009 00UTC 850hPa **geopotential



NEAR RT TRIAL

NEW OPERATIONAL SYSTEM

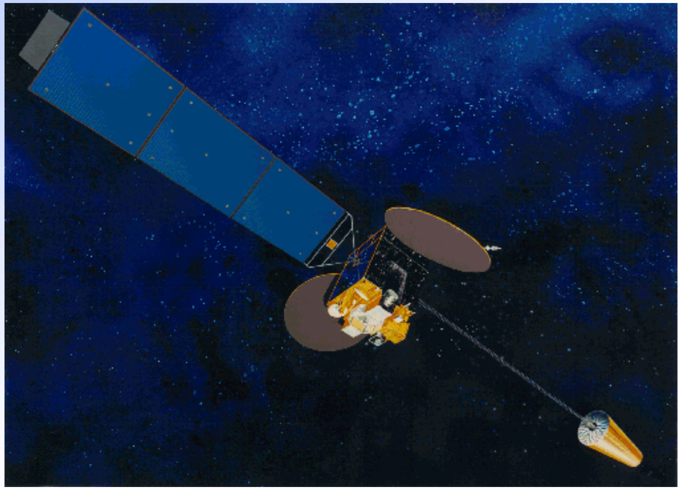
27 January – 23 February 2011

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)



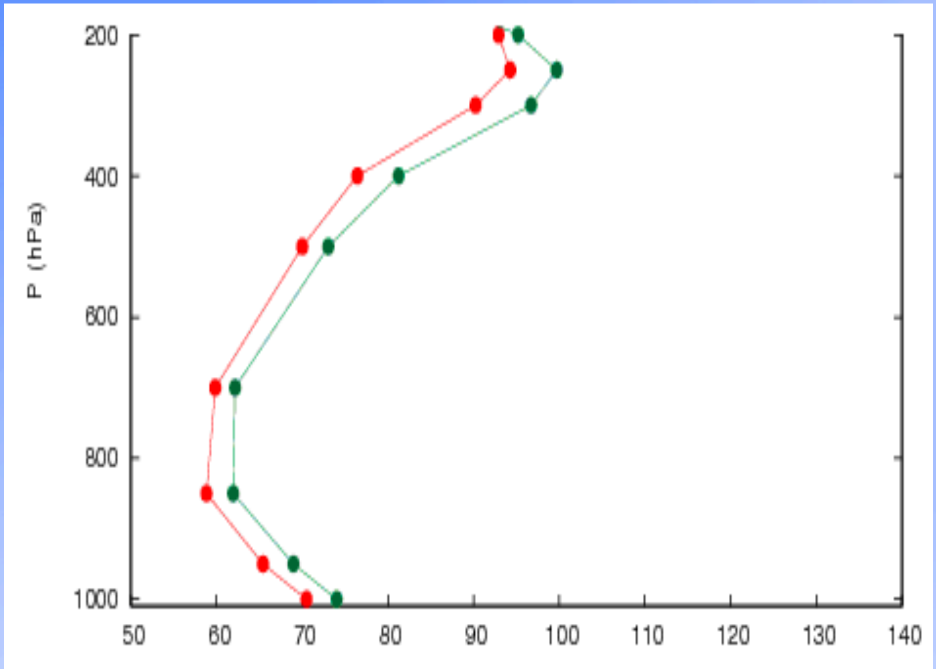


Fig.6(a). The RMS difference between forecast and verifying analysis geopotential height(m) at 24 hours for ACCESS-R (green) and ACCESS-R with AMVs (red) for the period 27 January to 23 February 2011.

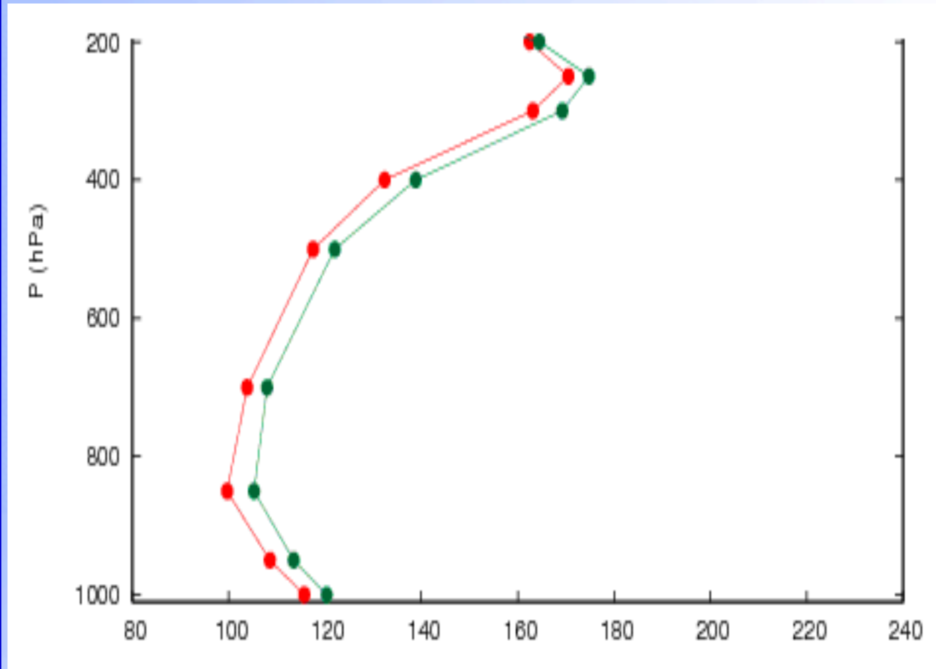
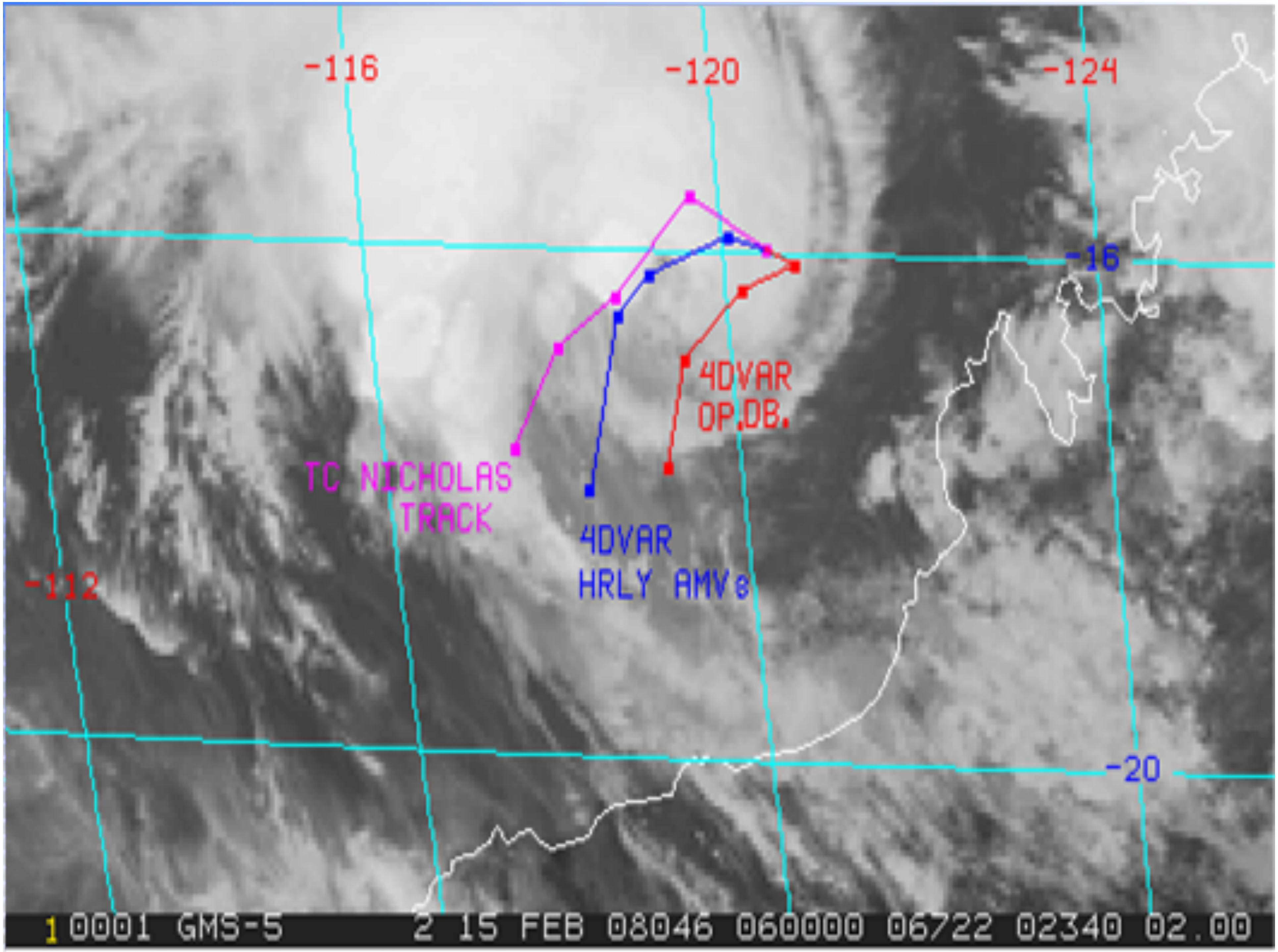


Fig.6(b). The RMS difference between forecast and verifying analysis geopotential height(m) at 48 hours for ACCESS-R (green) and ACCESS-R with AMVs (red) for the period 27 January to 23 February 2011.


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

Summary

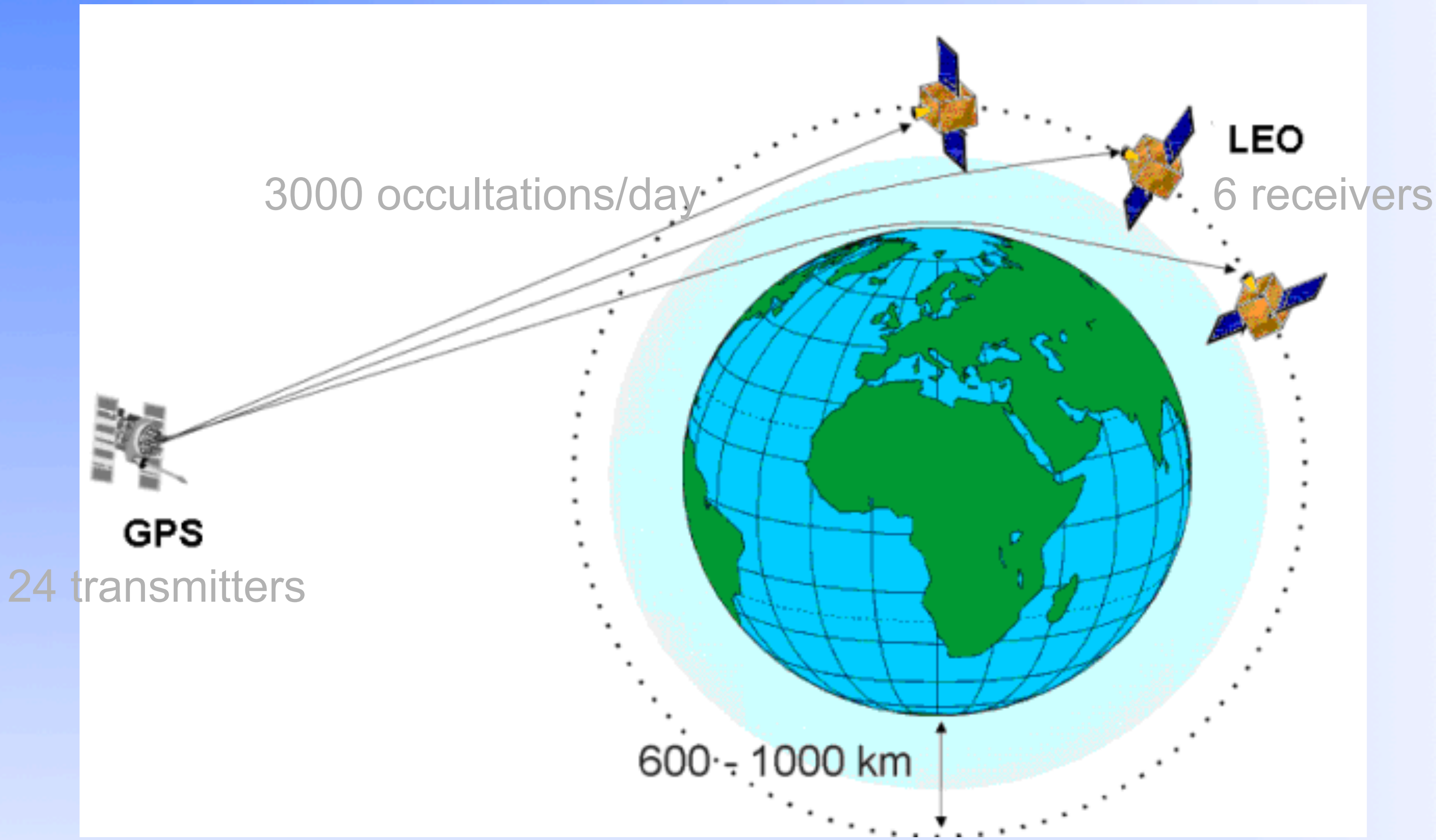
- Geo-stationery AMVs have been shown to make a significant contribution globally to operational analysis and forecasting.

- 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 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. Further improvements with Himawari-8

GPS/COSMIC RADIO OCCULTATION



OPERATIONAL TRIAL

NEW OPERATIONAL SYSTEM ACCESS-G

26 February – 26 March 2009

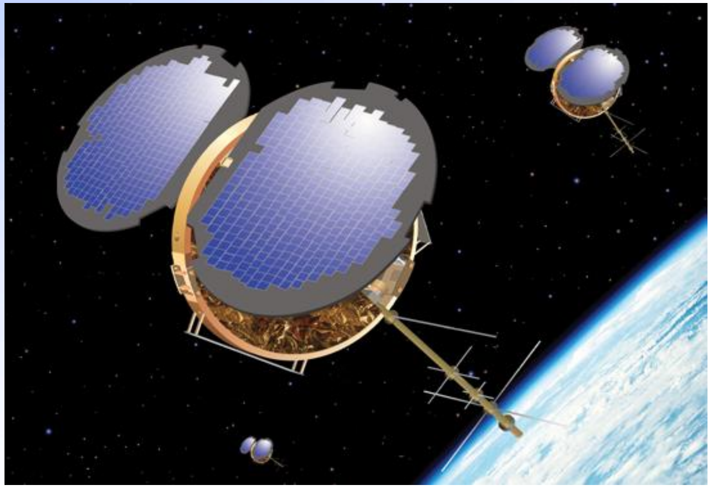
Used

■ Refractivity Data from

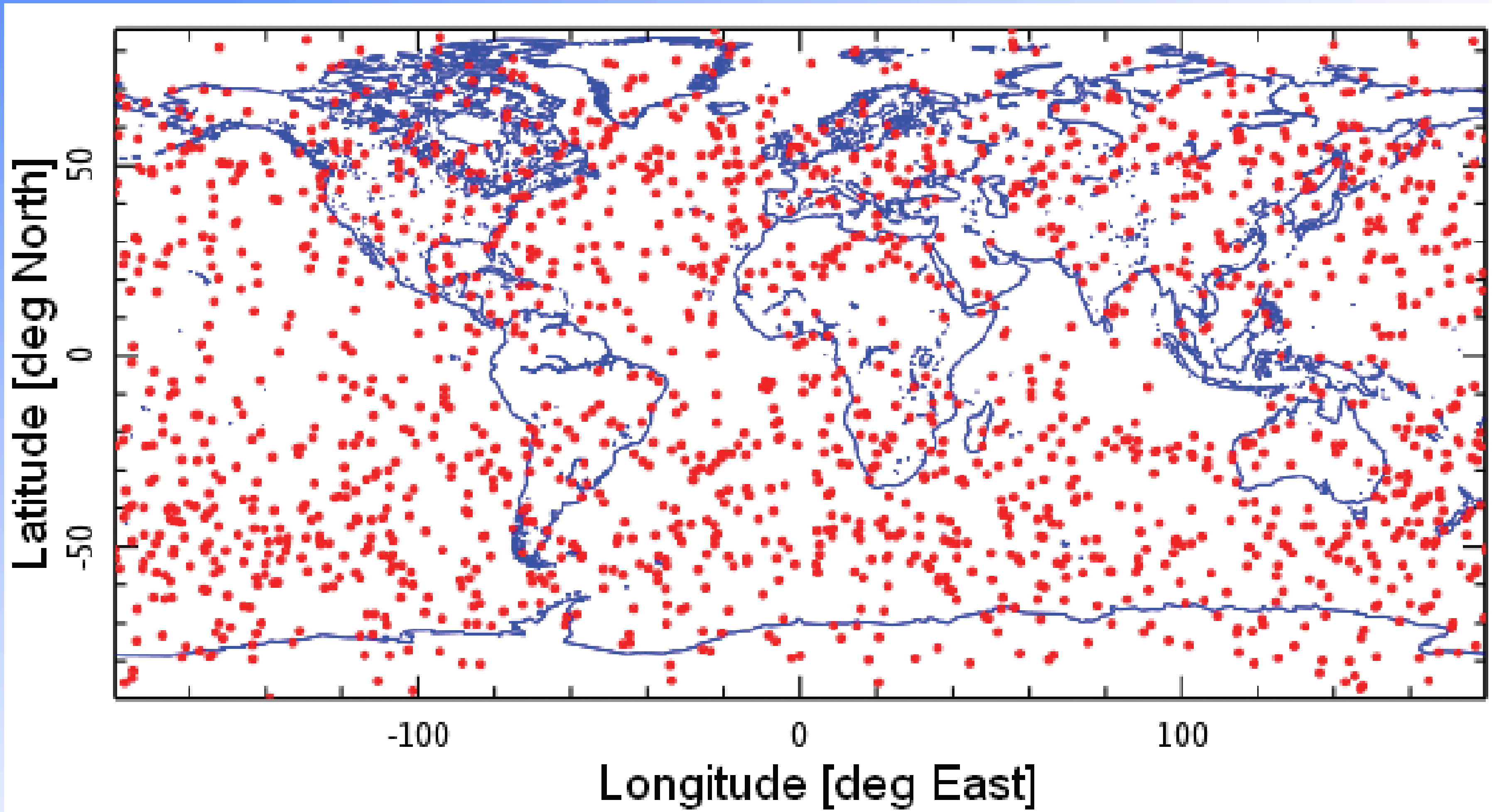
● the COSMIC Constellation

● GRACE and METOP

■ New Operational Global Forecast Model (ACCESS-G N144 L50) and Operational Data Base



GPS/COSMIC



GPS radio occultation sounding positions for 15 March 2009.
(Image courtesy of UCAR.)

OPERATIONAL TRIAL - 26 February to 26 March, 2009

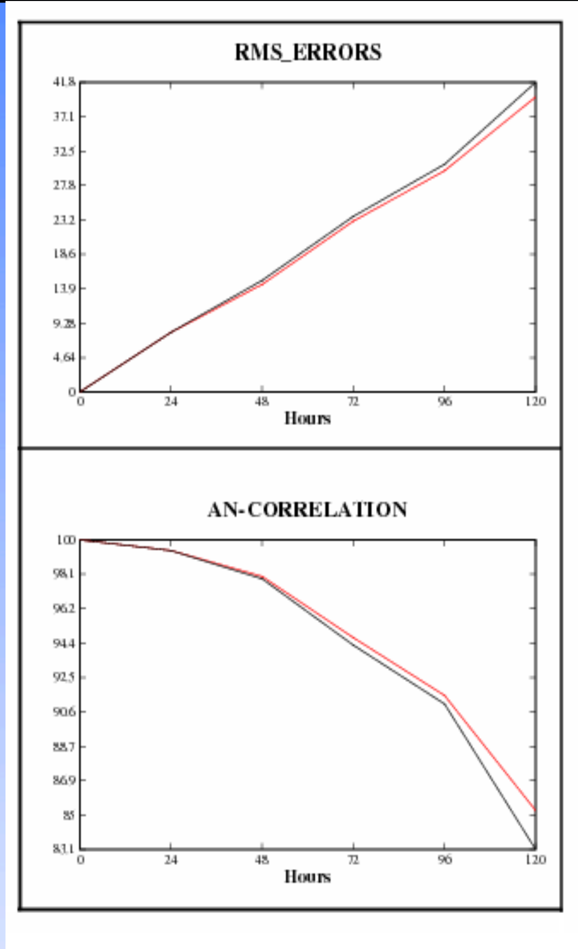


Figure 8(a). RMS Errors and anomaly correlations for ACCESS-G MSLP forecasts to five days, for the Australian region. Control (black), and with GPS RO data (red) for the period 26 February to 26 March, 2009.

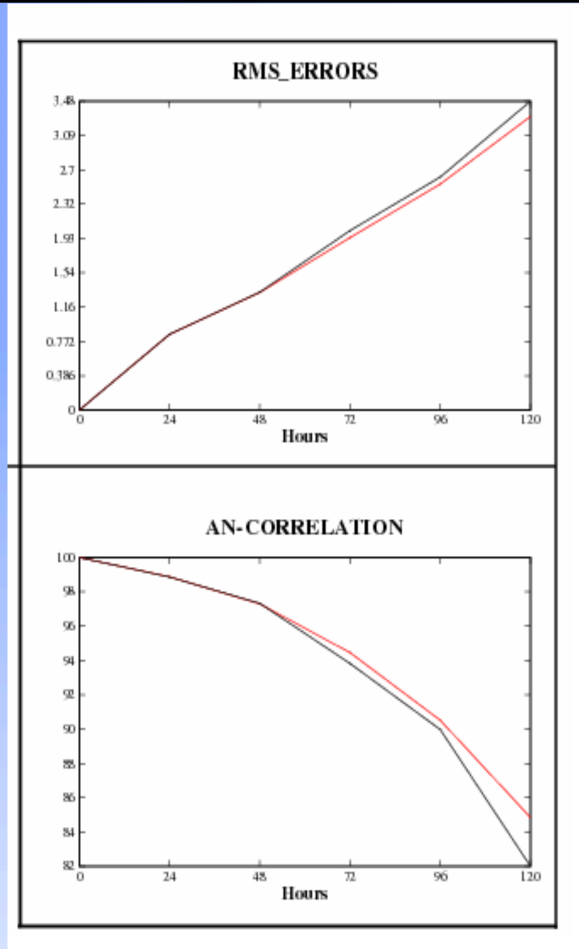


Figure 8(b). RMS errors and anomaly correlations for ACCESS-G 500hPa forecasts to five days, for the Australian region. Control (black) and with GPS RO data (red) for the period 26 February to 26 March, 2009.

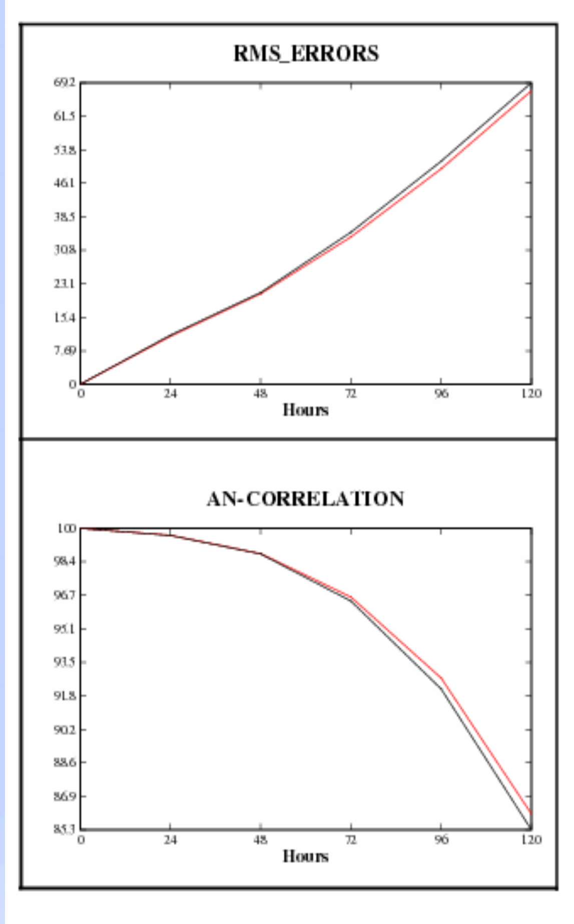


Figure 8(c). RMS errors and anomaly correlations for ACCESS-G 200hPa forecasts to five days, for the Australian region. Control (black) and with GPS RO data (red) for the period 26 February to 26 March, 2009.

OPERATIONAL TRIAL

NEW OPERATIONAL SYSTEM ACCESS-G (APS-1)

1 November – 30 November 2010

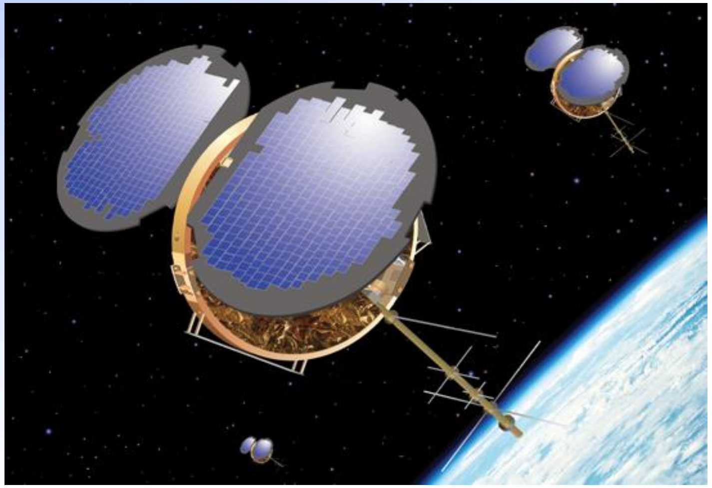
Used

■ Bending Angle data from

● the COSMIC Constellation

● GRACE and METOP

■ New Operational Global Forecast Model (ACCESS-G N144 L50) and Operational Data Base



OPERATIONAL TRIAL - 1 November to 30 November, 2010

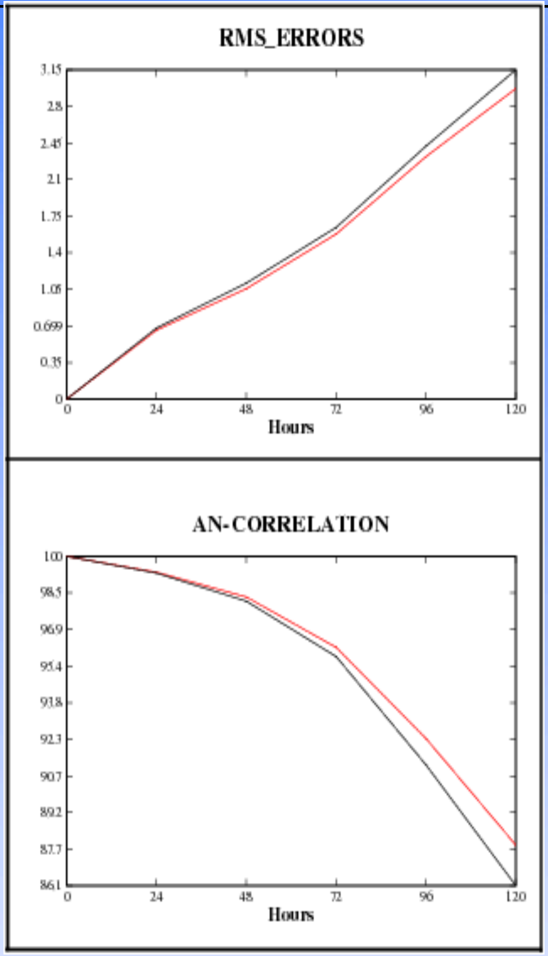


Figure 10(a). RMS Errors and anomaly correlations for ACCESS-G MSLP forecasts to five days, for the Australian region. Shown are results for Control (black), and with GPS RO data (red) for the period 1 November to 30 November 2010.

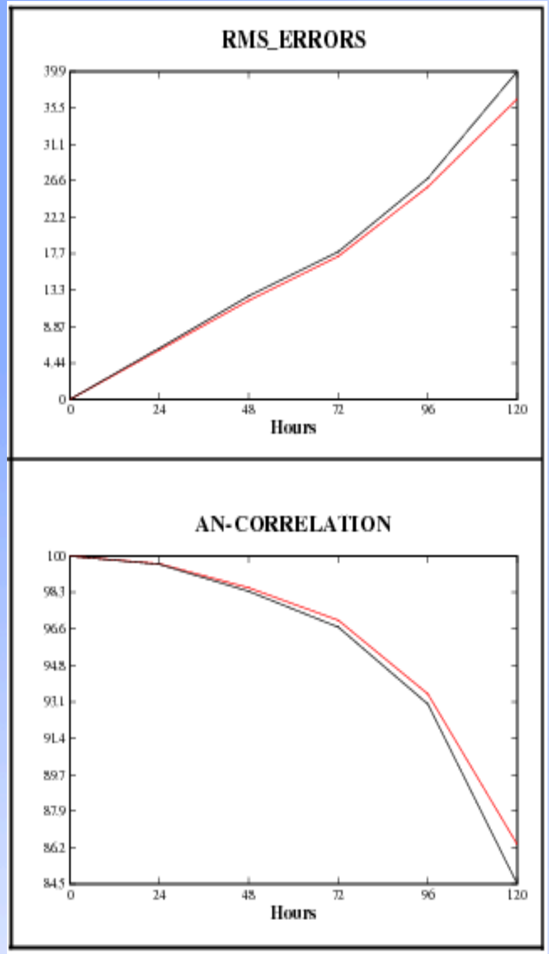


Figure 10(b). RMS errors and anomaly correlations for ACCESS-G 500hPa forecasts to five days, for the Australian region. Shown are results for Control (black) and with GPS RO data (red) for the period 1 November to 30 November 2010.

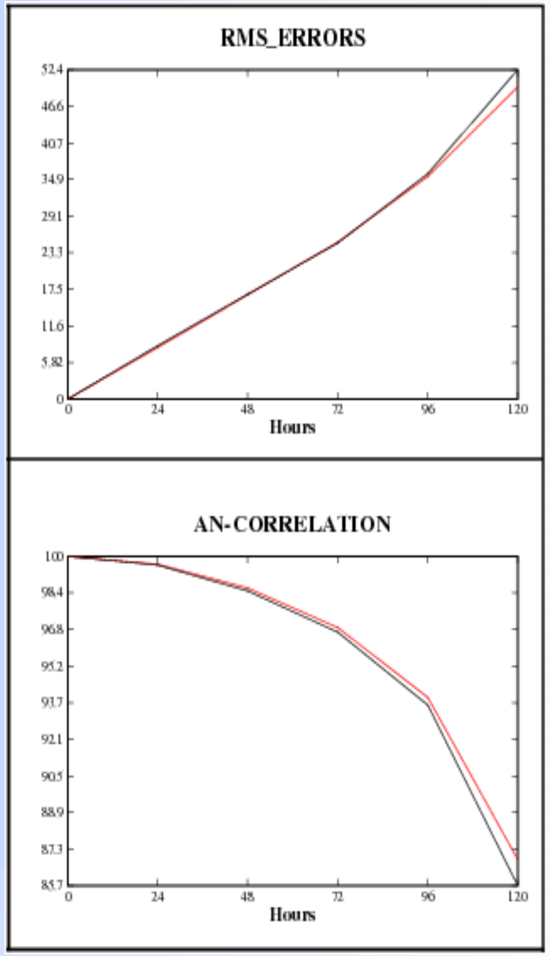


Figure 10(c). RMS errors and anomaly correlations for ACCESS-G 200hPa forecasts to five days, for the Australian region. Shown are results for Control (black) and with GPS RO data (red) for the period 1 November to 30 November 2010.

OPERATIONAL TRIAL - 1 November to 30 November, 2010

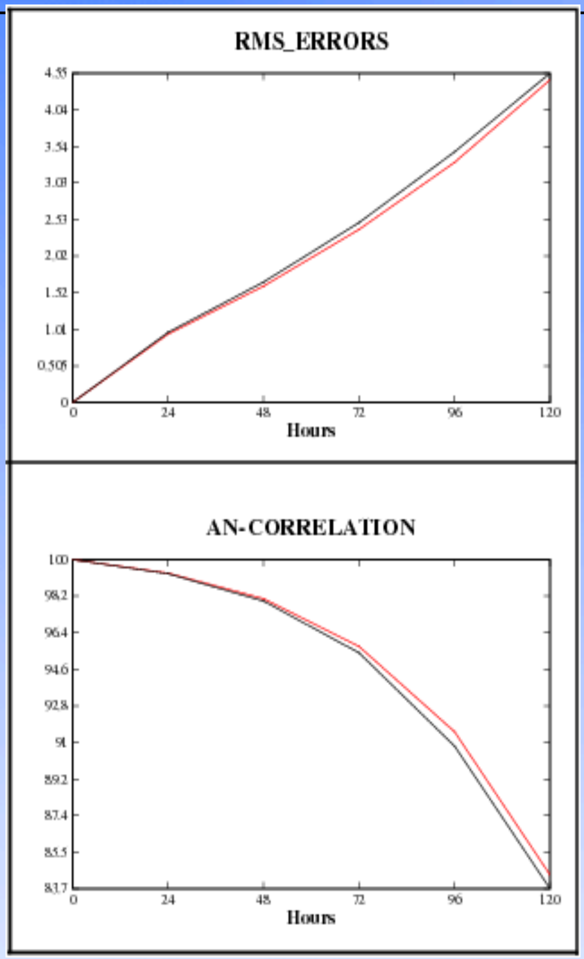


Figure 11(a). RMS Errors and anomaly correlations for ACCESS-G MSLP forecasts to five days, for Southern Hemisphere. Control (black), and with GPS RO data (red) for the period 1 November to 30 November 2010.

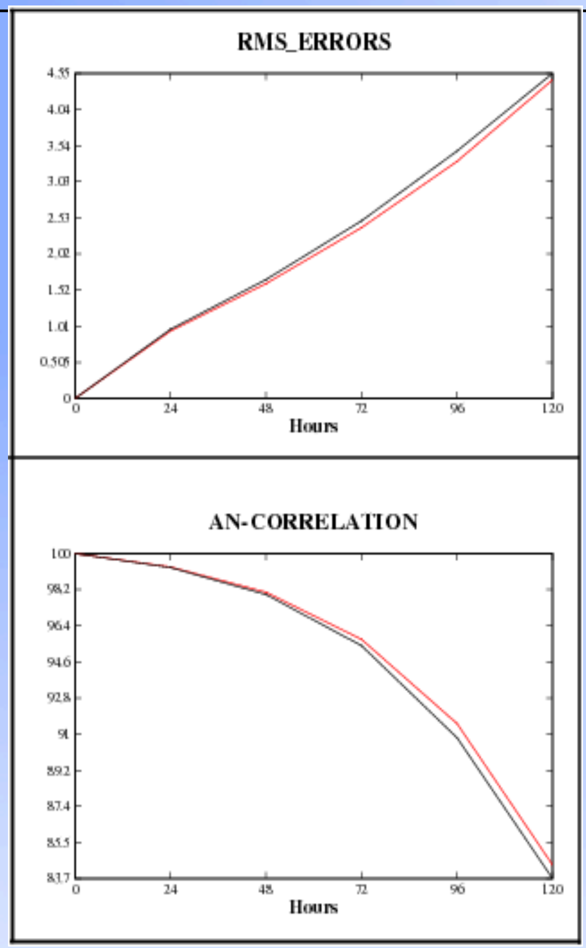


Figure 11(b). RMS errors and anomaly correlations for ACCESS-G 500hPa forecasts to five days, for Southern Hemisphere. Control (black) and with GPS RO data (red) for the period 1 November to 30 November 2010.

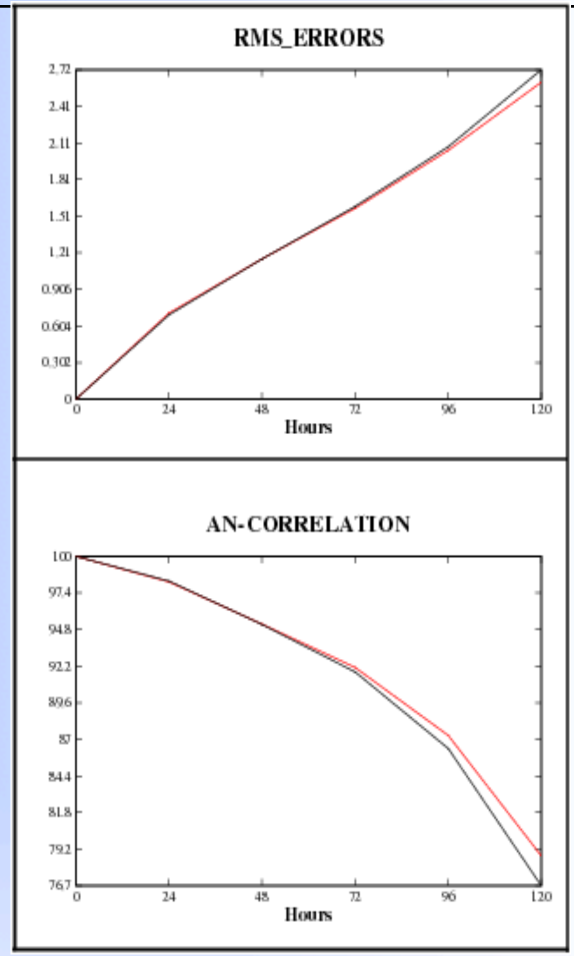


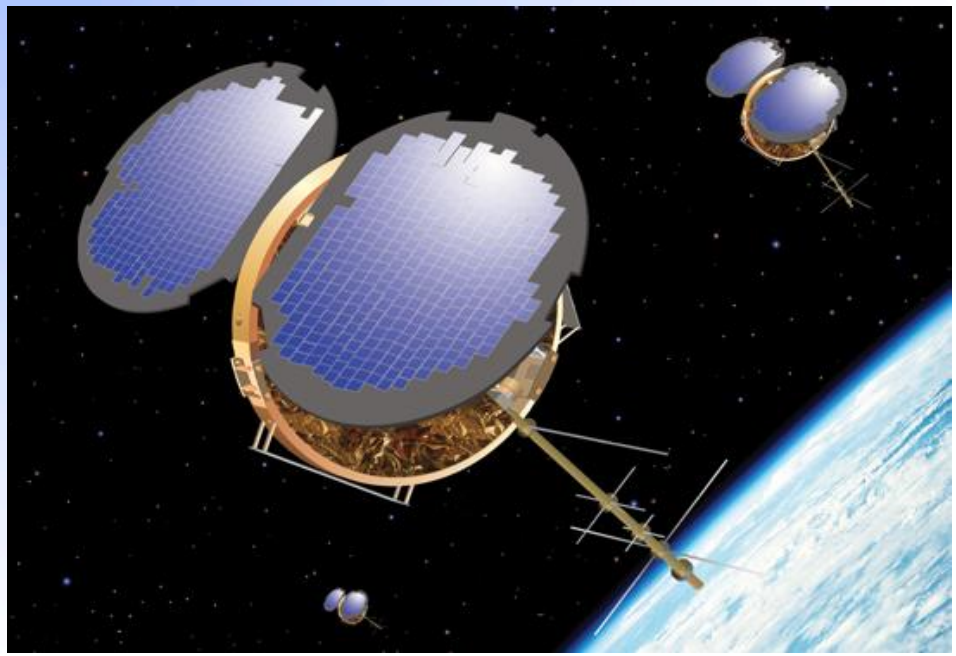
Figure 11(c). RMS errors and anomaly correlations for ACCESS-G 200hPa temperature forecasts to five days, for the Australian region. Control (black) and with GPS RO data (red) for the period 1 November to 30 November 2010.

Monitoring the Climate

2006 - 2010

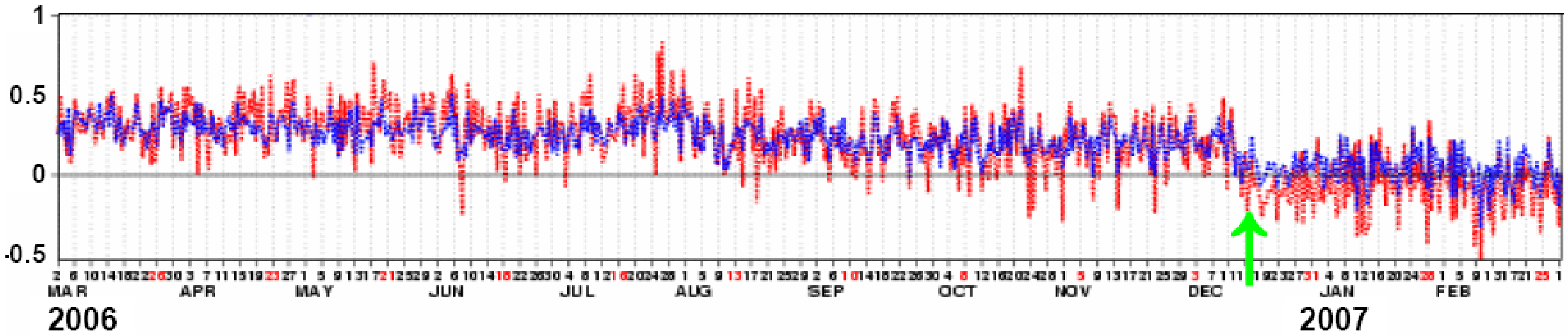
Used

- Sounding Data from UCAR
- the COSMIC Constellation



ECMWF Operational implementation of GPSRO on Dec 12, 2006

Mean departures of analysis (blue) and background (red) from southern hemisphere radiosonde temperatures (K) at 100hPa



Obvious improvement in time series for operational ECMWF model.

Dec 12, 2006 Operational implementation represented a quite conservative use of data. No measurements assimilated below 4 km, no rising occultations.

Nov 6, 2007 Operational assimilation of rising and setting occultations down to surface

Courtesy R. Anthes.

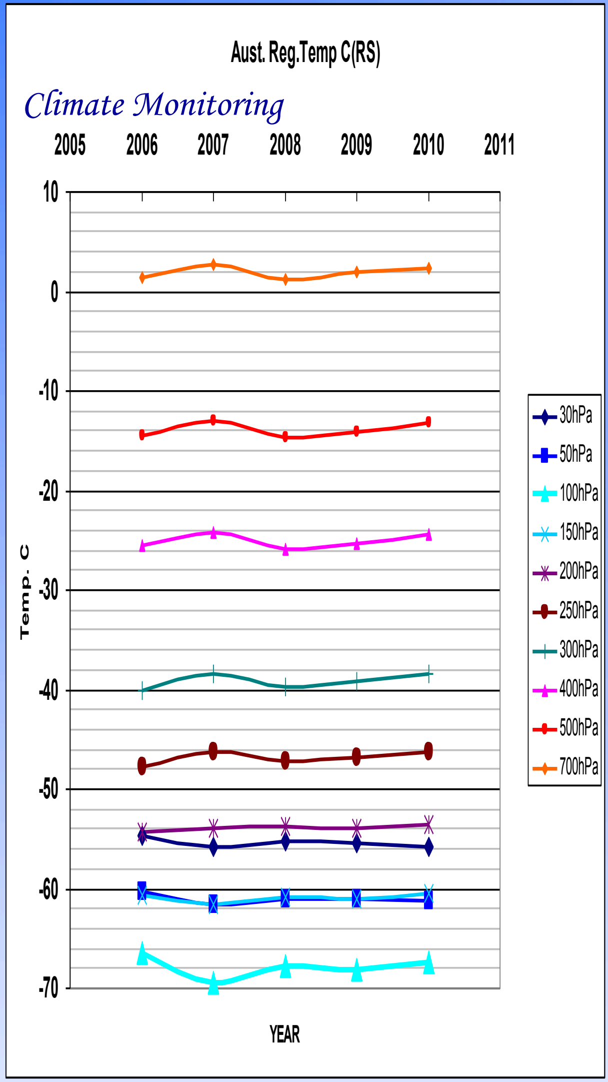


Figure 2(a).Mean Annual AtmosphericTemperatures (°C) 2007 to 2010 in the Australian region measured by radiosonde (2006 is an incomplete year-see text)

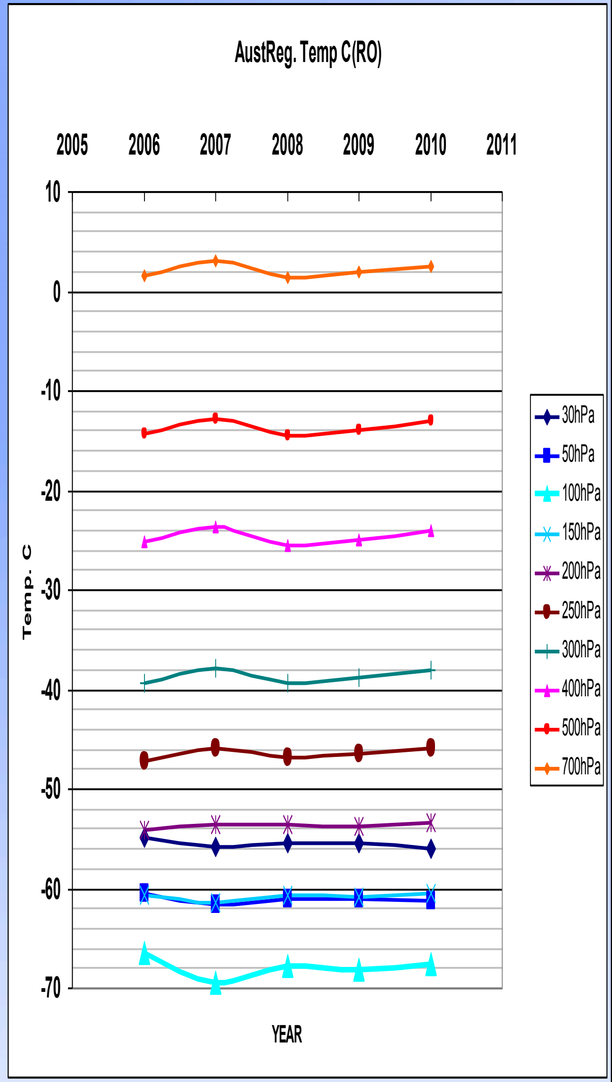


Figure 2(b).Mean Annual AtmosphericTemperatures (°C) 2007 to 2010 in the Australian region measured by radio occultation at radiosonde sites (2006 is an incomplete year-see text)

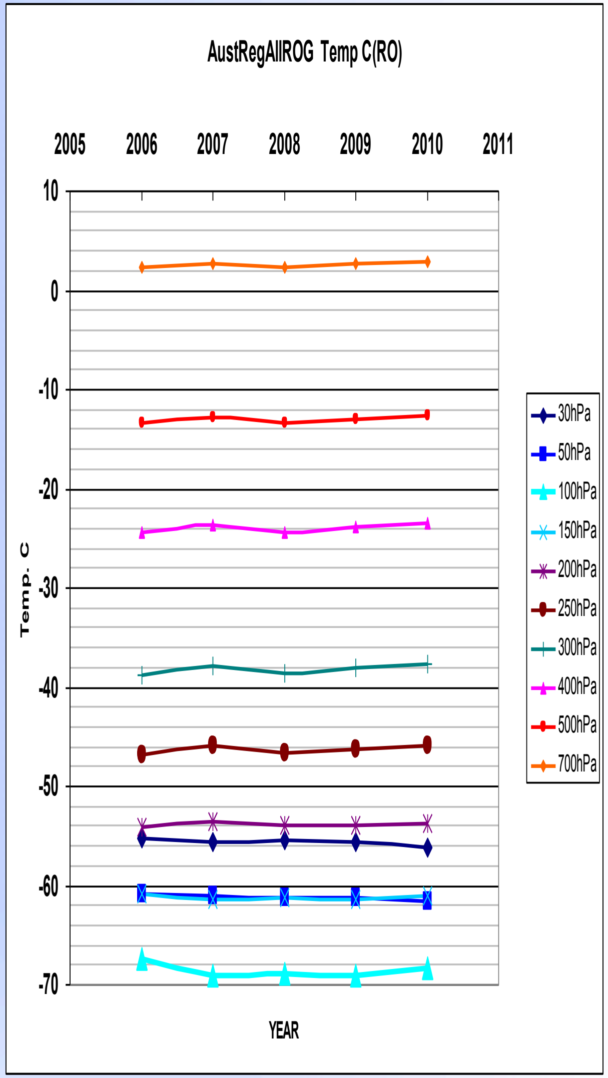


Figure 2(c).Mean Annual AtmosphericTemperatures (°C) 2007 to 2010 in the Australian region measured by area weighting all radio occultation observations in the Australian region(2006 is an incomplete year-see text)

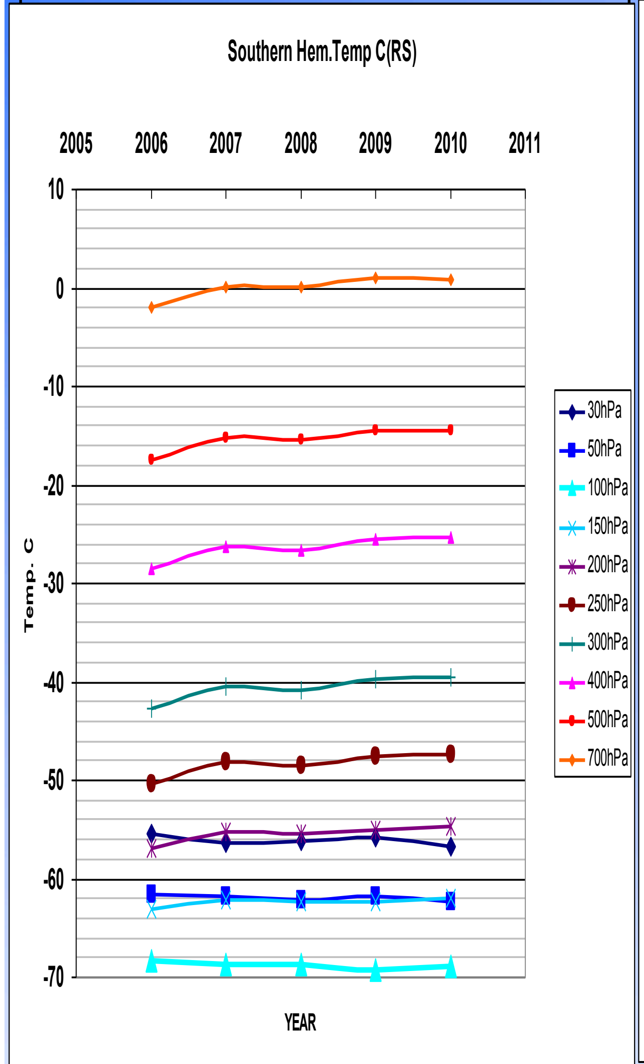


Figure 3(a).Mean Annual AtmosphericTemperatures (°C) 2007 to 2010 over the Southern Hemisphere measured by radiosonde (2006 is an incomplete year-see text)

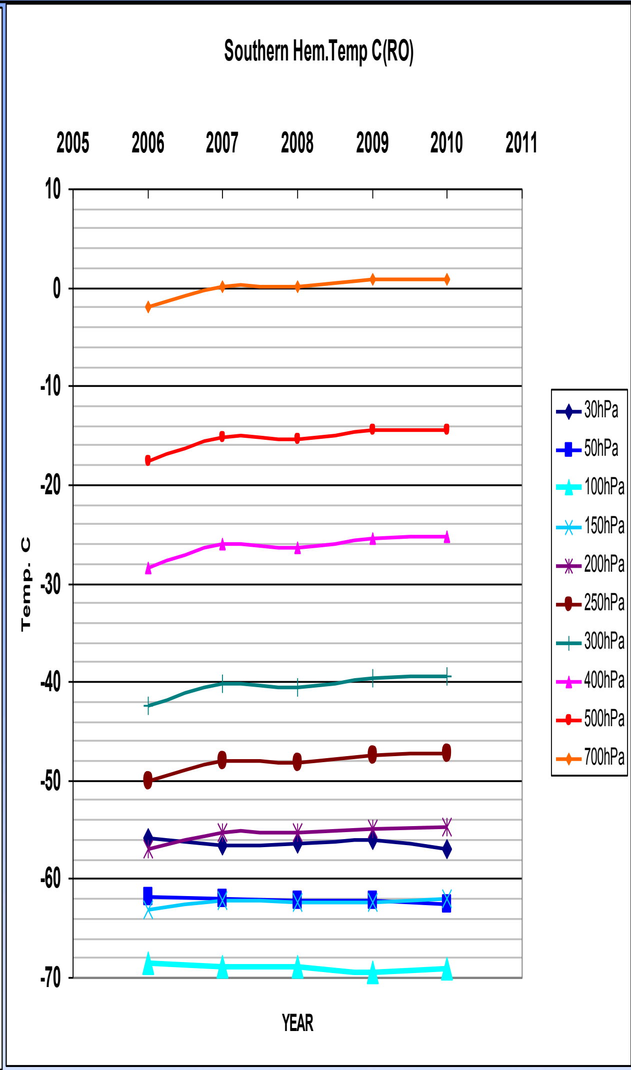


Figure 3(b).Mean Annual AtmosphericTemperatures (°C) 2007 to 2010 over the Southern Hemisphere measured by radio occultation at a radiosonde sites (2006 is an incomplete year-see text)

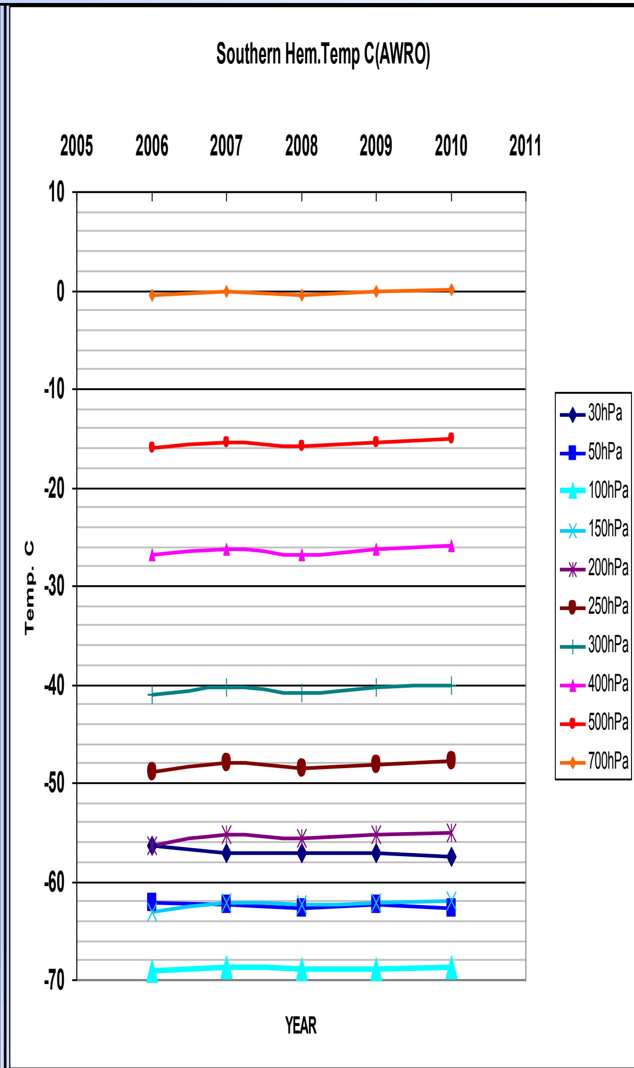


Figure 3(c).Mean Annual AtmosphericTemperatures (°C) 2007 to 2010 over the Southern Hemisphere measured by area weighting all radio occultation observations over the Southern Hemisphere (2006 is an incomplete year-see text)

Summary

- The great benefit of current RO data in the Australian Region and Southern Hemisphere have been recorded using data impact studies

- COSMIC, GRACE and METOP data have been successfully assimilated into the current ACCESS system and the data are now being used in the BoMs new operational forecast system

- The data are important for climate quality analyses

- The data are important for climate monitoring

Summary

Environmental/Climate monitoring, analysis /prediction using current and future satellite systems have been examined.

The great benefits from recent advances using current Earth Observations from Space have been noted.

The potential for greatly increased benefit from current and future satellite and assimilation systems has been noted.

Increasing benefits will continue to accrue from current and next generation advanced instruments, which represent an investment of billions of dollars by the international community. (SMOS, CrIS, ATMS, VIIRS, ADM, …ASCENDS….). This will need co-investment in infrastructure, research and trained staff.


Indian Ocean
100 km
Respiciens
est
Aspiciens
TC LAURENCE - Dec. 2009


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