# Satellite data assimilation in the Bureau of Meteorology ACCESS NWP systems: an overview of current status and future plans.

Chris Tingwell, Jin Lee, Paul Gregory, Vinodkumar, Peter Steinle and John Le Marshall.

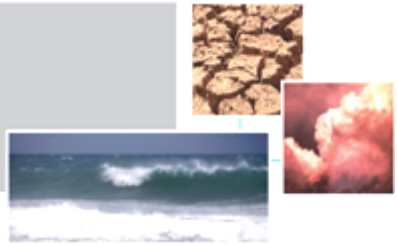
4th Asia-Oceania Meteorological Satellite Users Conference
October 9-11 2013, Melbourne.

Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

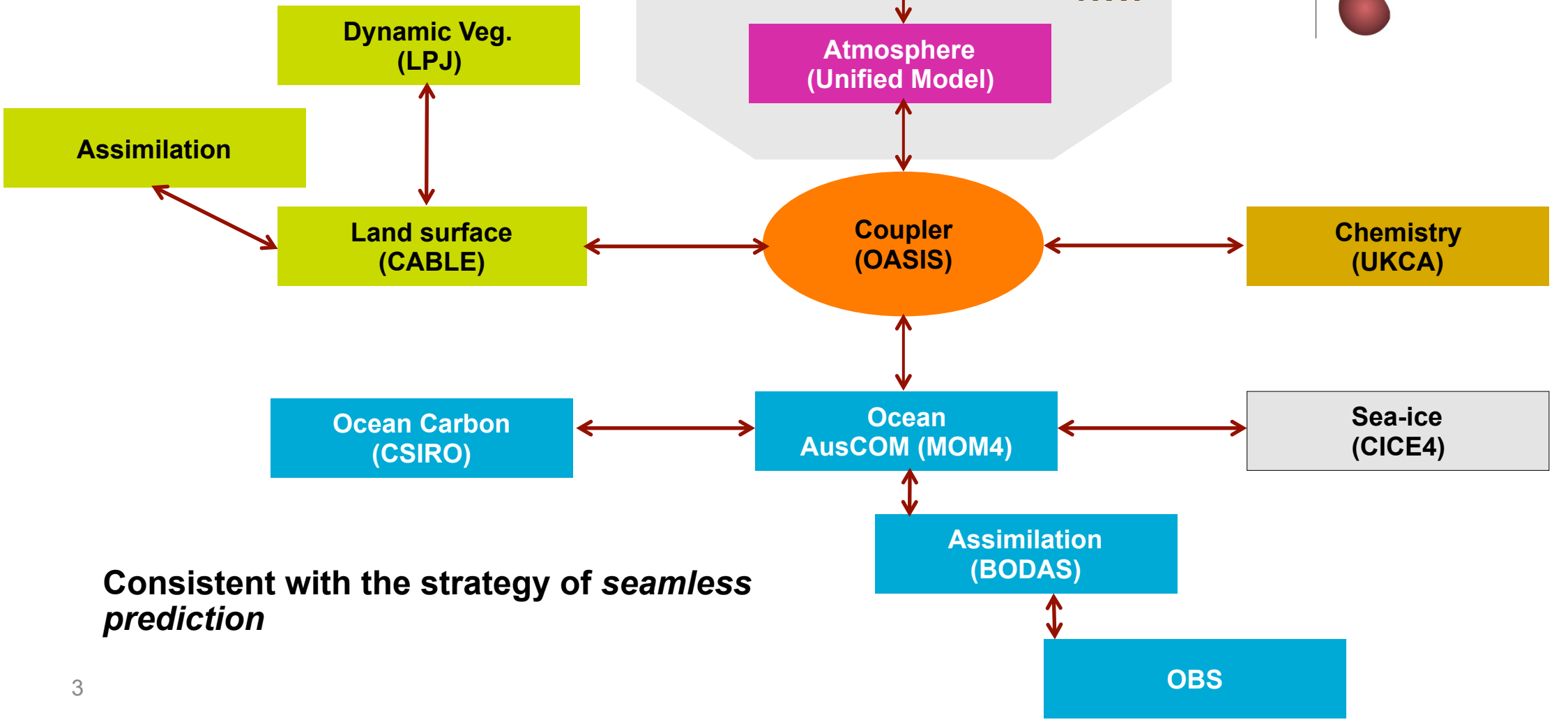
# Overview



- Introduction to ACCESS
- Summary of ACCESS observation processing and assimilation
- ACCESS NWP - recent history
- Satellite observation usage in ACCESS
- Some current work (and poster promotion)
- Some future work
- Final remarks

# What is ACCESS?

Australian Community Climate and Earth System Simulator

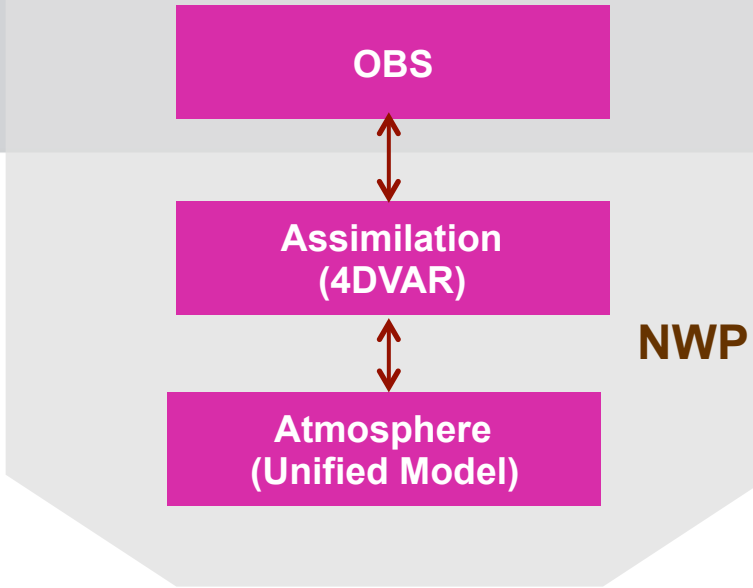



**Consistent with the strategy of *seamless prediction***



3

# What is ACCESS?




Australian Community Climate and Earth System Simulator

A collaboration between the Bureau of Meteorology, CSIRO and universities

**ACCESS-NWP**

Earth Systems Modelling Program: Kamal Puri

Atmospheric Modelling and Prediction Group: Gary Dietachmayer

High Res. Data Assimilation Team: Peter Steinle

Model Systems (NWP) Team: Robin Bowen

Atmospheric Physics team: Zhian Sun

Satellite Data Assimilation Team: Chris Tingwell

Atmosphere-Land Observation and Assessment Program: John Le Marshall

National Meteorological & Oceanographic Centre

Obs and Engineering, Info Technology Branches

**Special acknowledgement to the Met Office**

UK Met Office:

- OPS (Observations Processing System)
- VAR
- Unified Model
- Surf



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# Observation processing in ACCESS

Met Office

ECMWF

RTDB
MARS

BUFR

ODB

ODB

ODB

ODB

CAWCR

**OPS**
**1dVAR**
**QC**
**Thinning**
**Bias Correction**
**Cloud Screening**

**CX**
model values
at obs locations

VAROBS

**VAR**

AMV, scatterometer data, from centres via GTS
Locally processed AMVs

**Radiance bias monitoring**

**Updated bias predictors**

# Observation processing in ACCESS

Met Office

ECMWF

RTDB
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CAWCR

**OPS**
1dVAR
QC
Thinning
Bias Correction
Cloud Screening

**CX**
model values
at obs locations

VAROBS

**VAR**

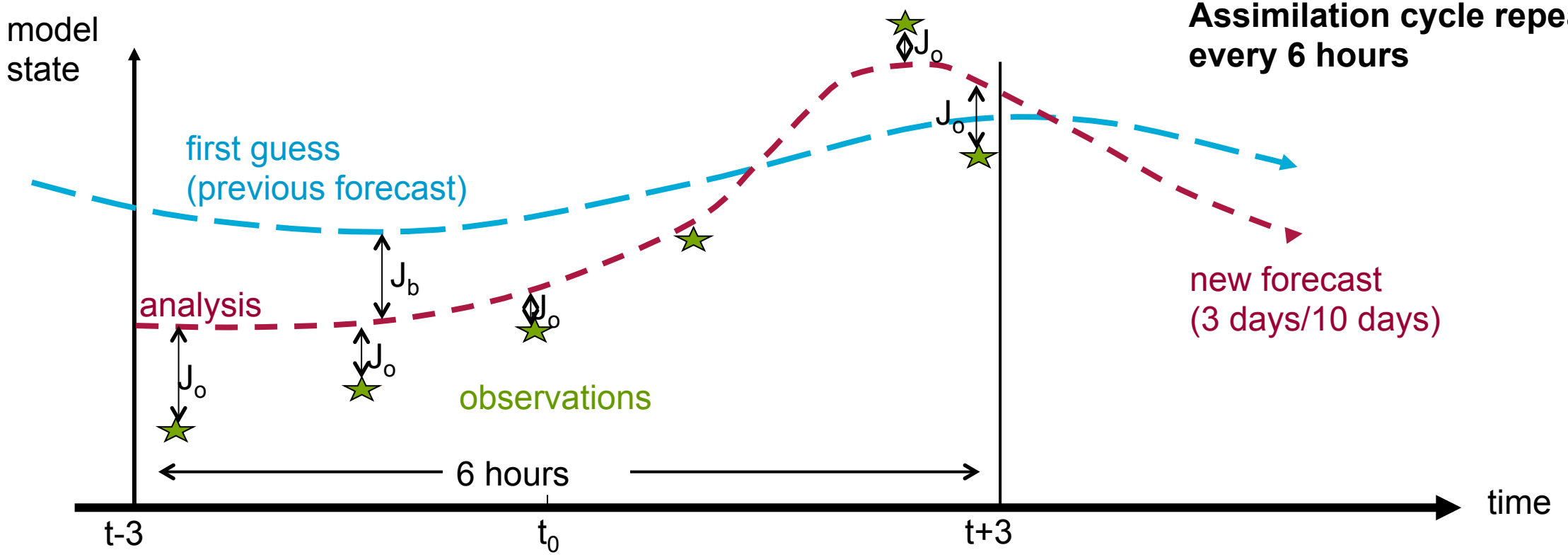
Sounder-radiance data: global datasets from Met Office, locally reception and processing, AP-RARS

**Radiance bias monitoring**

**Updated bias predictors**

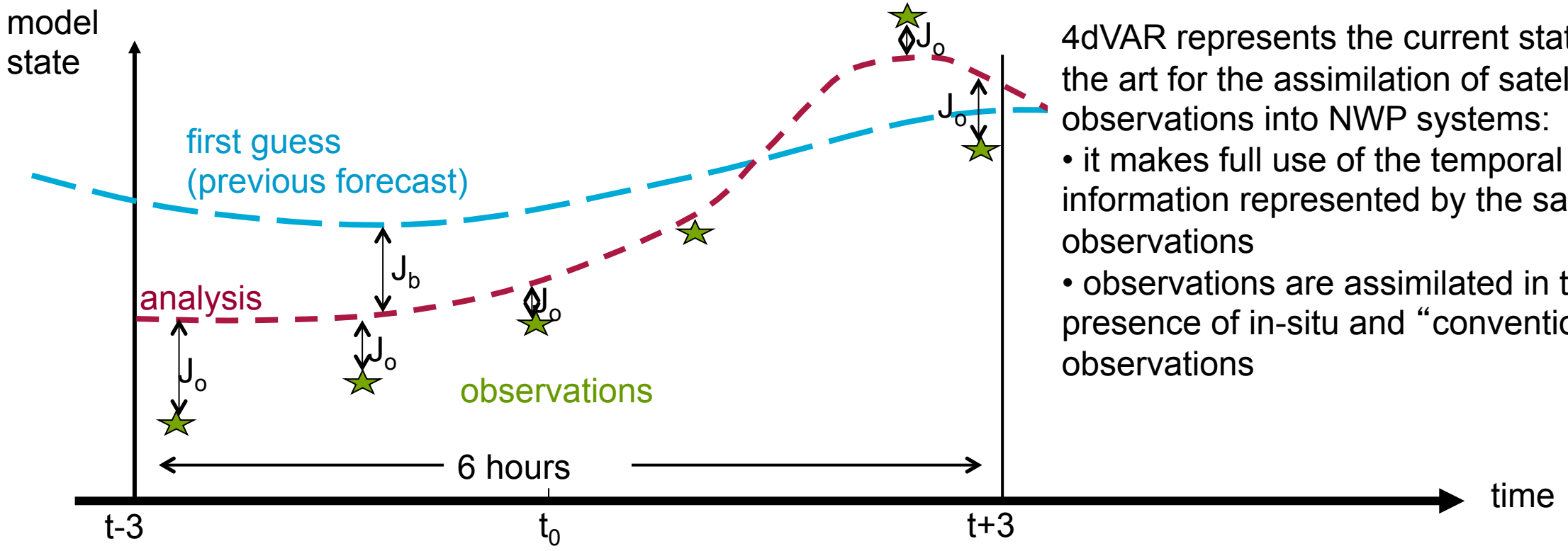
# Data Assimilation: 4dVAR (1)

$$J(\delta \mathbf{w}) = \tfrac{1}{2}\left(\delta \mathbf{w} - \delta \mathbf{w}^b\right)^T \mathbf{B}^{-1}\left(\delta \mathbf{w} - \delta \mathbf{w}^b\right) + \tfrac{1}{2}\left(\mathbf{y} - \mathbf{y}^o\right)^T (\mathbf{E}+\mathbf{F})^{-1}\left(\mathbf{y} - \mathbf{y}^o\right)$$



# Data Assimilation: 4dVAR (1)

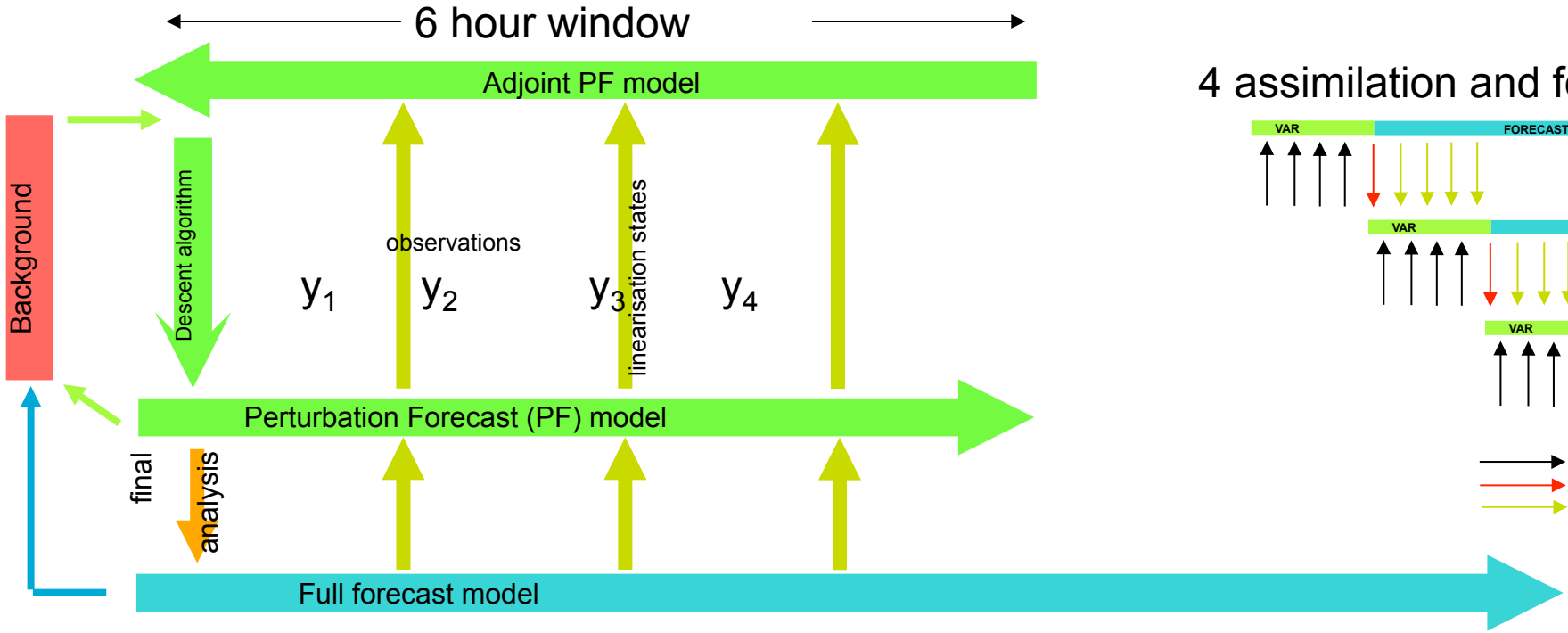
$$J(\delta\mathbf{w}) = \tfrac{1}{2}\left(\delta\mathbf{w} - \delta\mathbf{w}^b\right)^T \mathbf{B}^{-1}\left(\delta\mathbf{w} - \delta\mathbf{w}^b\right) + \tfrac{1}{2}\left(\mathbf{y} - \mathbf{y}^o\right)^T (\mathbf{E}+\mathbf{F})^{-1}\left(\mathbf{y} - \mathbf{y}^o\right)$$

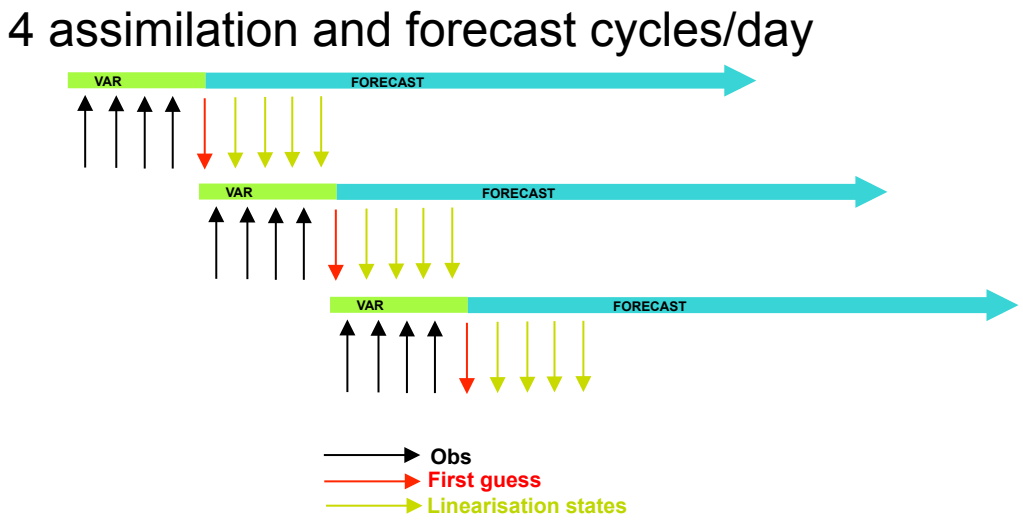



4dVAR represents the current state of the art for the assimilation of satellite observations into NWP systems:

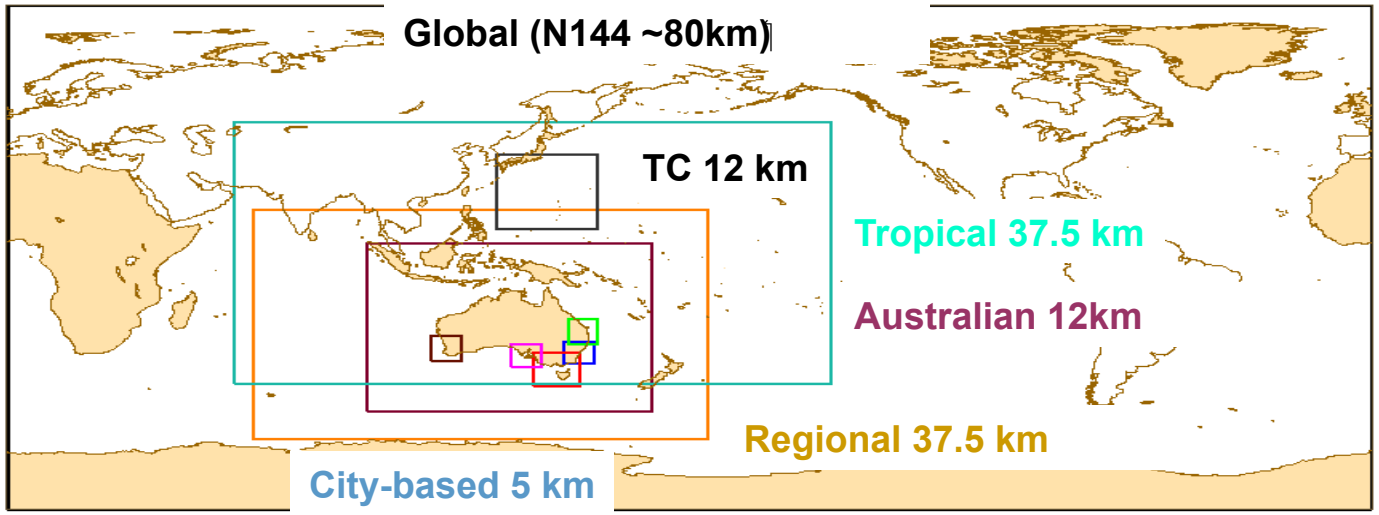
- it makes full use of the temporal information represented by the satellite observations
- observations are assimilated in the presence of in-situ and "conventional" observations

# Data Assimilation: 4dVAR (2)

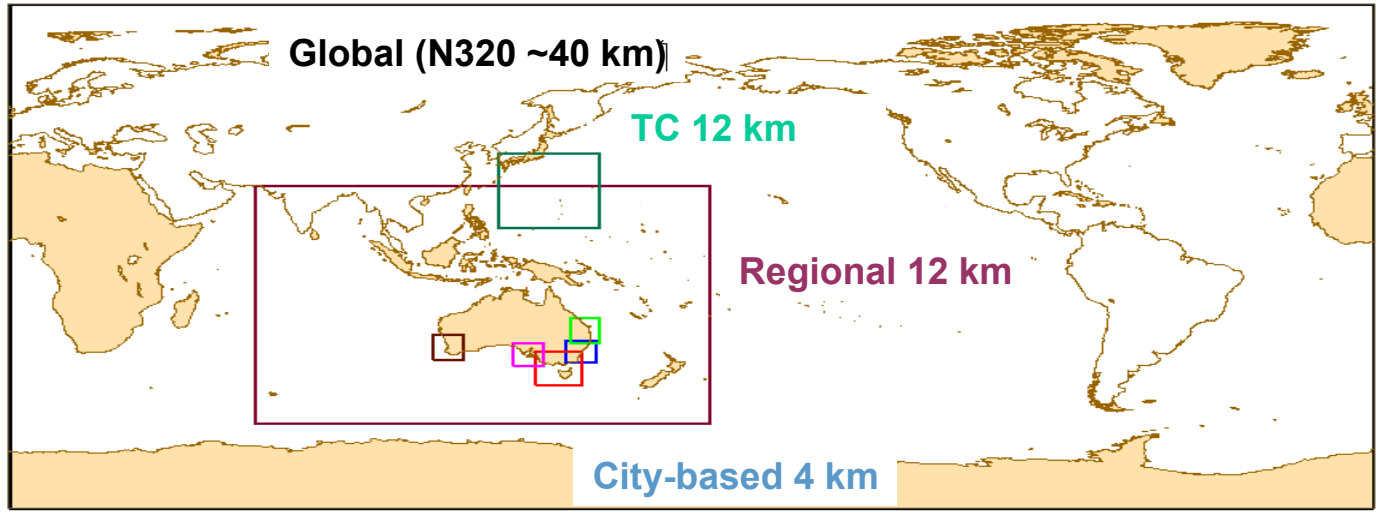


# ACCESS NWP Suites and domains

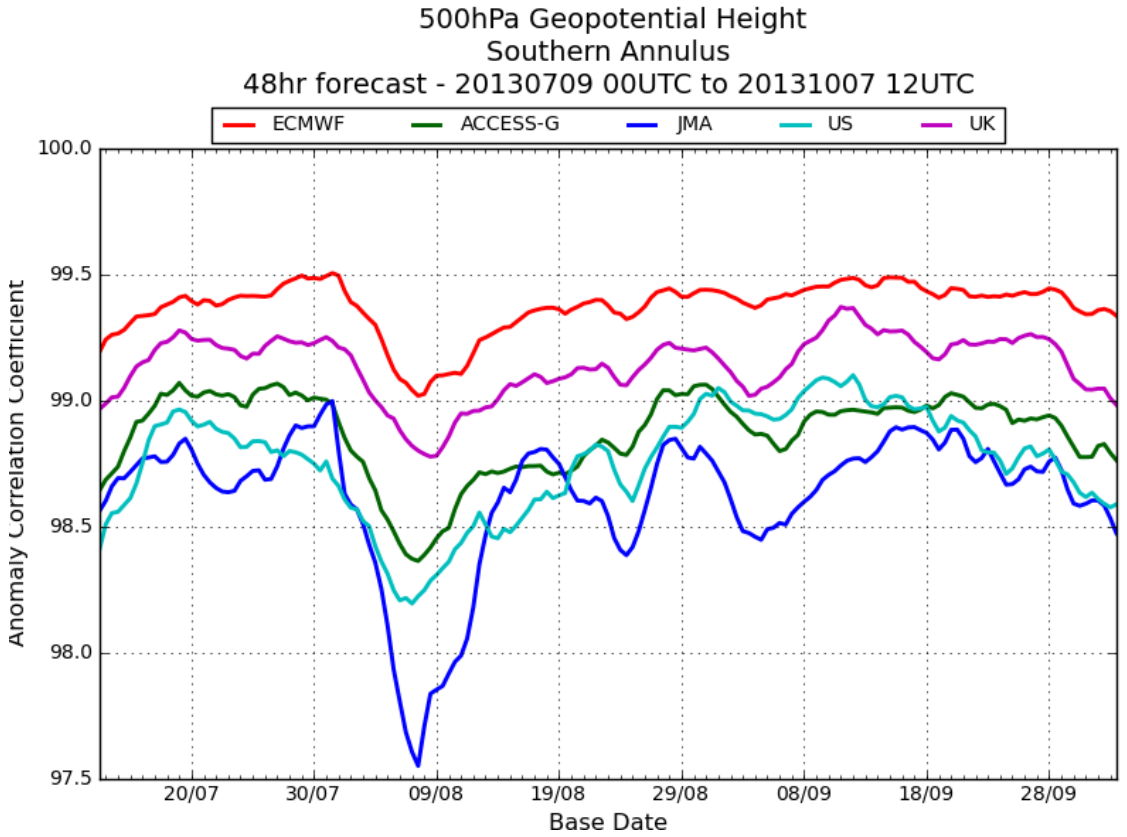


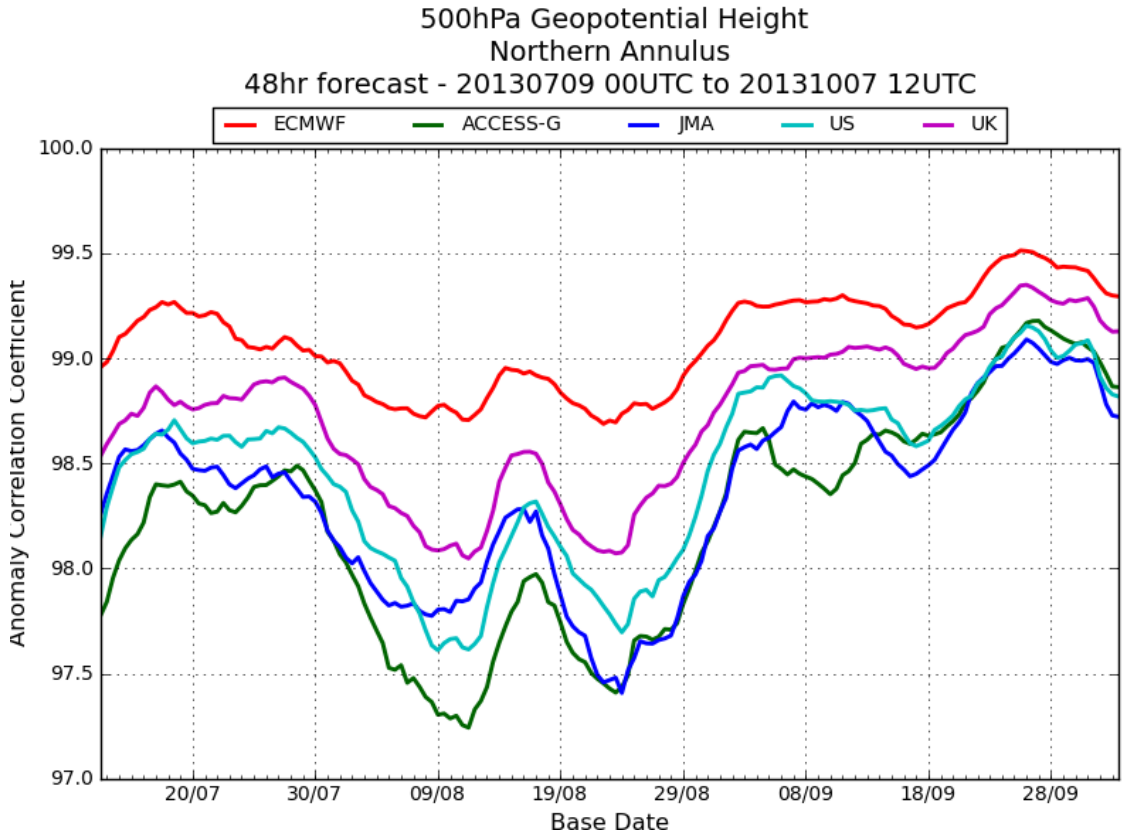

Phase 1: APS0
Operational in September 2009
Major improvement in performance relative to Bureau's previous systems



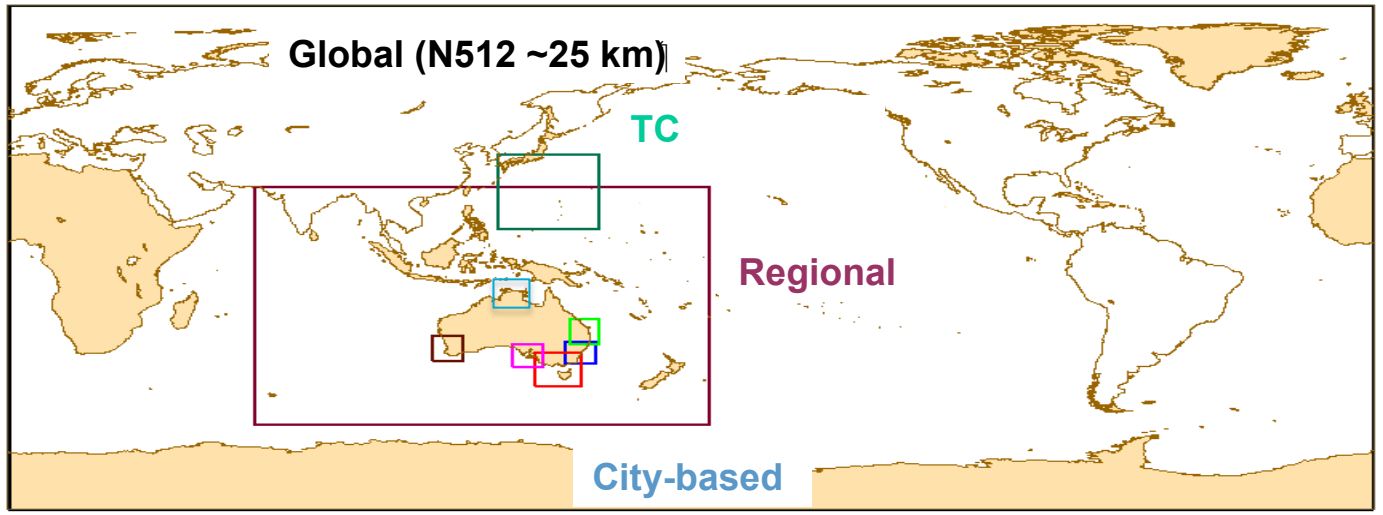

Phase 2: APS1
Completed this week
Global: 80km → 40km, L50 → L70
Regional: 0.375° → 0.11°, L50 → L70
City: 5km → 4km, L50 → L70
Newer version of UM, extra observation types.
No tropical or Australian domain

# Comparative forecast performance from ACCESS-G (APS1)

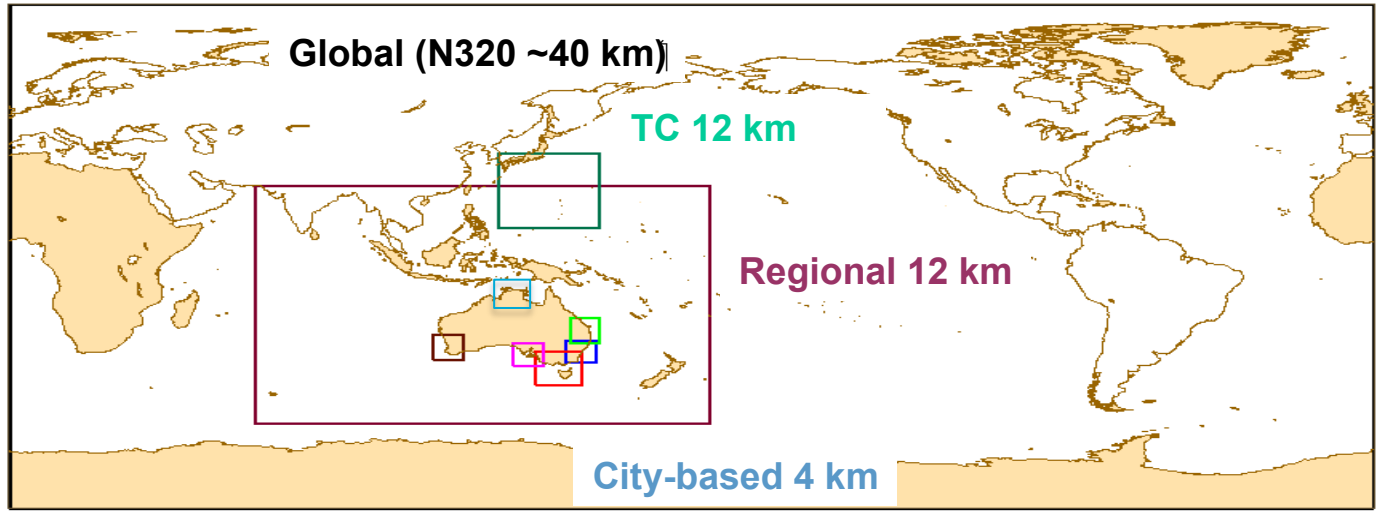


# ACCESS NWP Suites and domains




Phase 3: APS2
2014
Global: 40km → 25km
Newer version of UM, extra observation types.




Phase 2: APS1
Completed this week
Global: 80km → 40km, L50 → L70
Regional: 0.375° → 0.11°, L50 → L70
City: 5km → 4km, L50 → L70
Newer version of UM, extra observation types.
No tropical or Australian domain

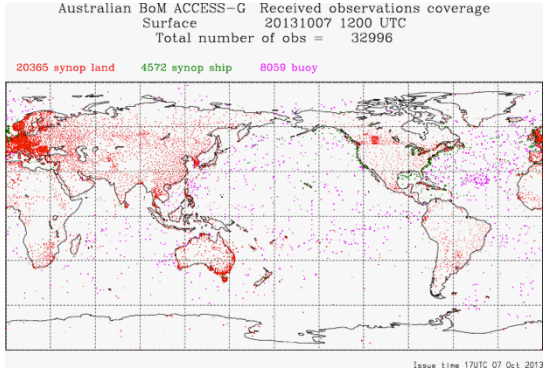
# Observation types assimilated: APS0, APS1

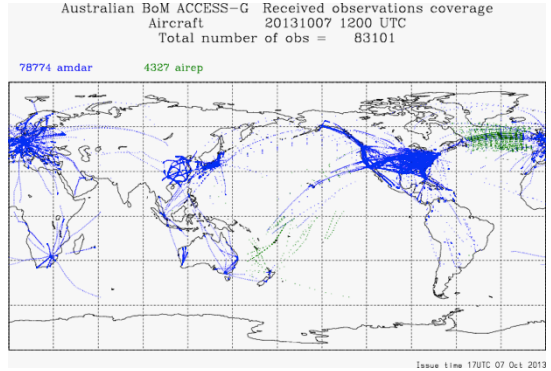
| | |
|---|---|
| **APS0** | Surface: synop, ship, buoy<br>Sondes, wind profilers<br>Aircraft: AIREPS, AMDARS<br><br>**Satellite observations**<br><br>Winds<br>Scatterometer surface winds (ASCAT), Atmospheric Motion Vector tropospheric winds<br>Radiances<br>Microwave: ATOVS (AMSU A,B and MHS)<br>Infrared: ATOVS (HIRS), AIRS |
| **APS1** | All of the above, plus:<br>IASI Infrared radiances<br>GPS-RO bending angle observations |

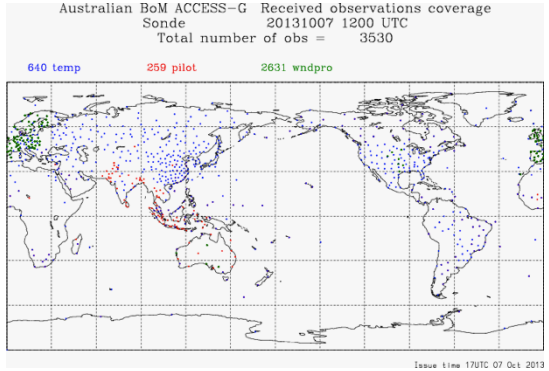
# Observation types assimilated: APS2

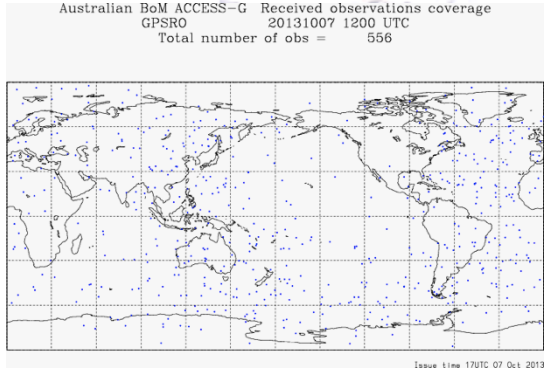
| | |
|---|---|
| **APS0** | Surface: synop, ship, buoy<br>Sondes, wind profilers<br>Aircraft: AIREPS, AMDARS<br><br>**Satellite observations**<br><br>Winds<br>Scatterometer surface winds (ASCAT), Atmospheric Motion Vector tropospheric winds<br>Radiances<br>Microwave: ATOVS (AMSU A,B and MHS)<br>Infrared: ATOVS (HIRS), AIRS |
| **APS1** | All of the above, plus:<br>IASI Infrared radiances<br>GPS-RO bending angle observations |
| **APS2** | All of the above, plus:<br>CrIS, ATMS<br>SSMIS from F17, F18; additional scatterometer data. |

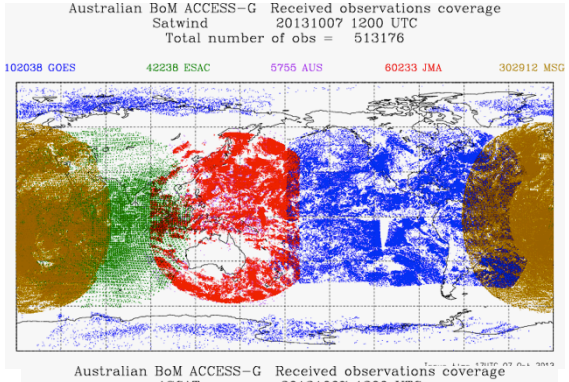
# Global observation coverage - received

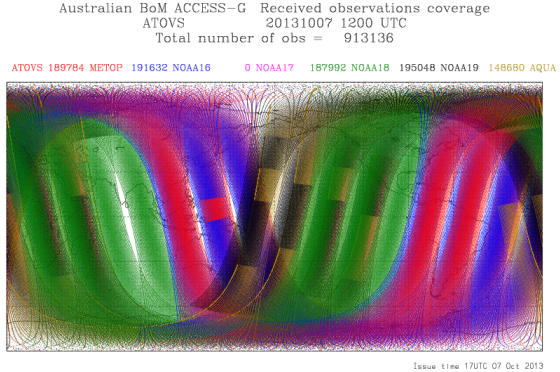


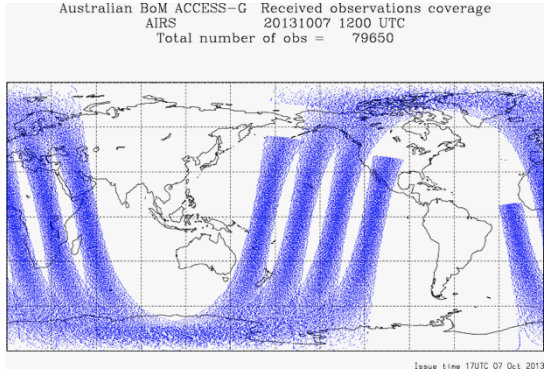



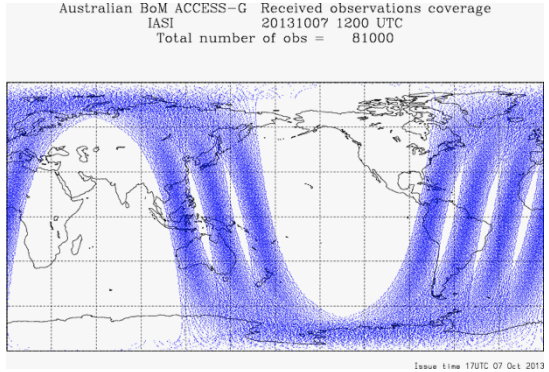



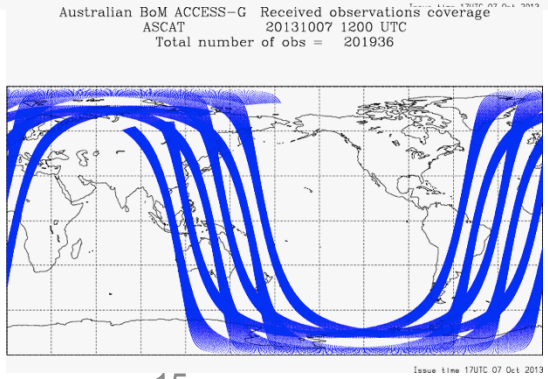



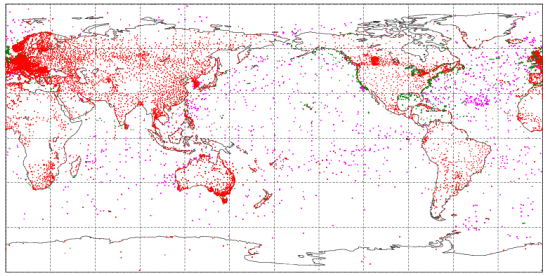



# Global observation coverage - assimilated

Australian BoM ACCESS-G Accepted observations coverage
Surface 20131007 1200 UTC
Total number of obs = 28976

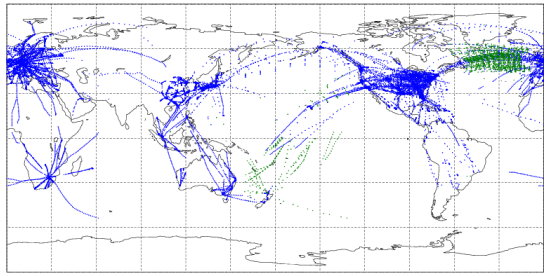
20134 synop land 3257 synop ship 5585 buoy



Issue time 17UTC 07 Oct 2013

Australian BoM ACCESS-G Accepted observations coverage
Aircraft 20131007 1200 UTC
Total number of obs = 21549

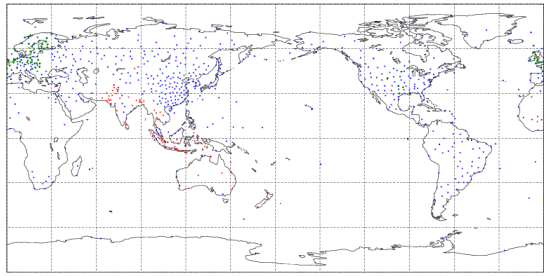
18533 amdar 3016 airep



Issue time 17UTC 07 Oct 2013

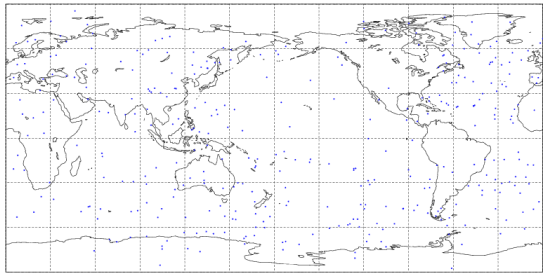
Australian BoM ACCESS-G Accepted observations coverage
Sonde 20131007 1200 UTC
Total number of obs = 1105

633 temp 100 pilot 372 wndpro



Issue time 17UTC 07 Oct 2013

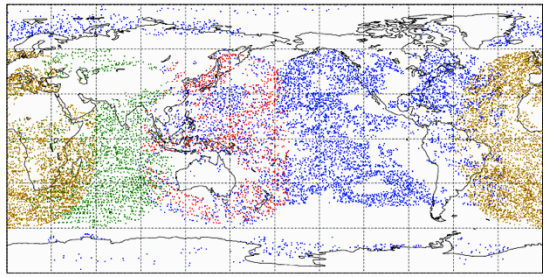
Australian BoM ACCESS-G Accepted observations coverage
GPSRO 20131007 1200 UTC
Total number of obs = 356



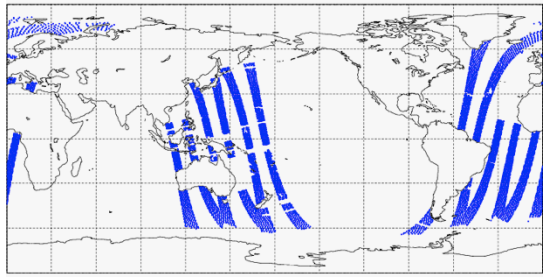
Issue time 17UTC 07 Oct 2013

Australian BoM ACCESS-G Accepted observations coverage
Satwind 20131007 1200 UTC
Total number of obs = 16261

6502 GOES 2109 ESAC 1266 JMA 6384 MSG

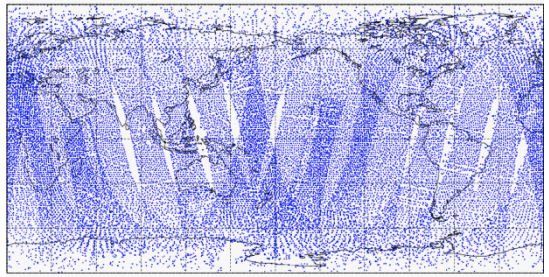


Australian BoM ACCESS-G Accepted observations coverage
Scatwind 20131007 1200 UTC
Total number of obs = 6654



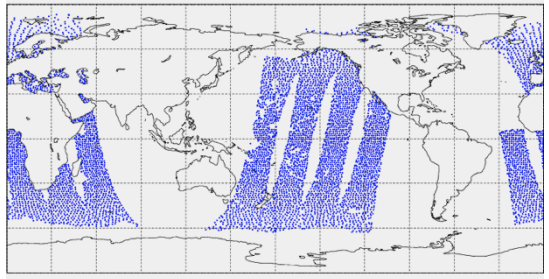
Issue time 17UTC 07 Oct 2013

Australian BoM ACCESS-G Accepted observations coverage
ATOVS 20131007 1200 UTC
Total number of obs = 30692



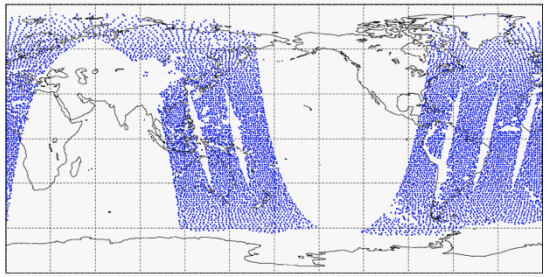
Issue time 17UTC 07 Oct 2013

Australian BoM ACCESS-G Accepted observations coverage
AIRS 20131007 1200 UTC
Total number of obs = 6241



Issue time 17UTC 07 Oct 2013

Australian BoM ACCESS-G Accepted observations coverage
IASI 20131007 1200 UTC
Total number of obs = 8658



Issue time 17UTC 07 Oct 2013

# Southern hemisphere dependence on satellite data

- Southern hemisphere sparseness of in-situ observations means that NWP forecast skill is highly dependent on satellite observations
- Withholding satellite observations degrades forecast skill by ~3.5 days in the southern hemisphere, only ½ day in the northern hemisphere.

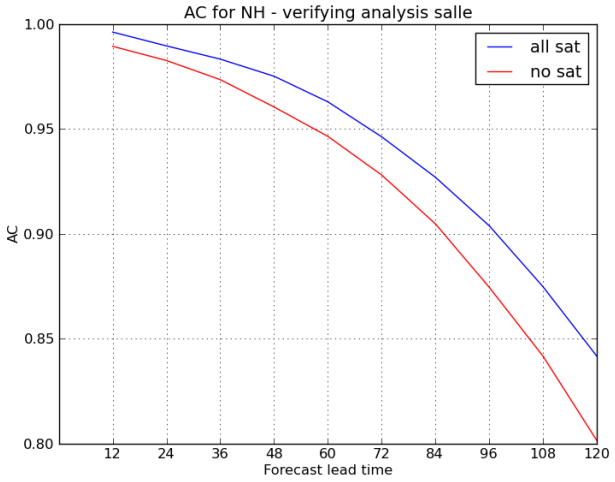



**Figure 6.** Anomaly correlations of mean sea-level pressure for the control run (blue) and the data-denial run (red) as a function of forecast lead times. The control analyses were used as verifying analyses. The verification scores were calculated for the Northern Hemisphere.

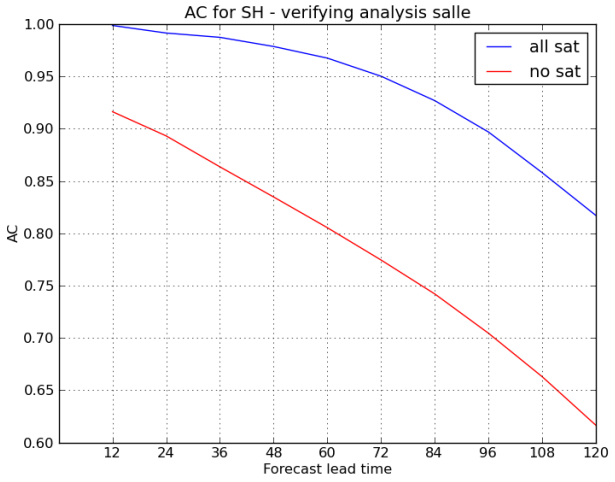
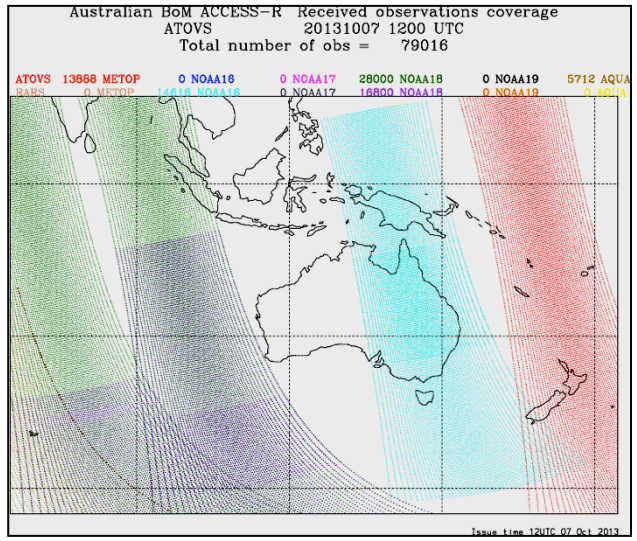
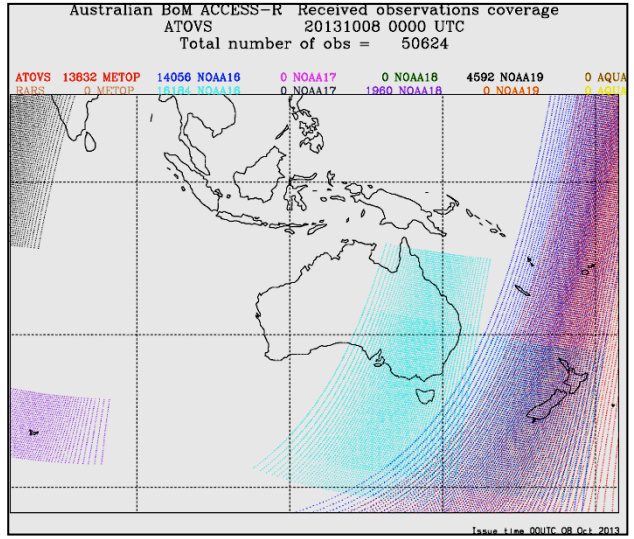



**Figure 7.** Same as for Figure 6, but for the Southern Hemisphere

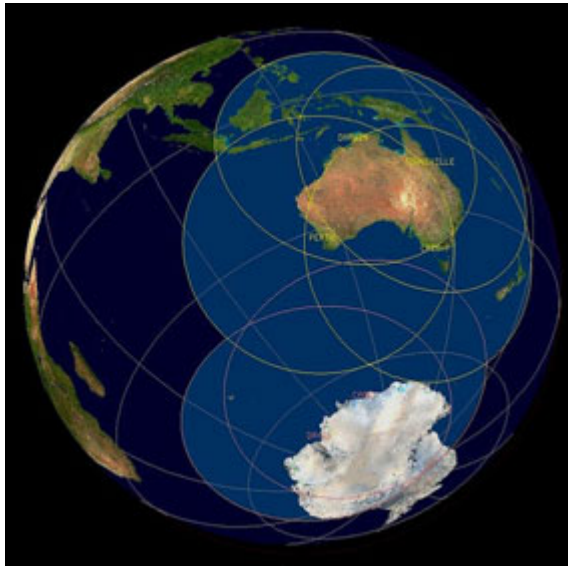
**Impact of Satellite Observations on Southern Hemisphere Forecasts from Operational ACCESS-G NWP Model**
J. Lee, J. Le Marshall, C. Tingwell, B. Roux, CAWCR Research Letters Issue 10, August 2013

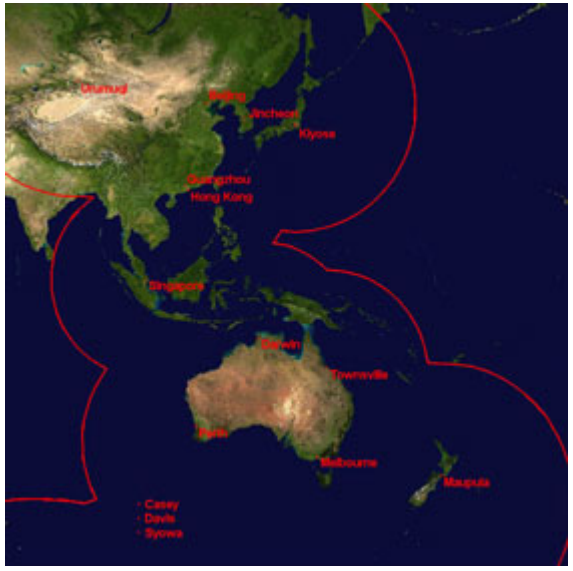
# Regional observation coverage




- The regional ACCESS system requires a very short data cut-off for the 00/12 UTC assimilation-forecast cycles to ensure timely forecast generation.
- Locally received and processed radiance data is important for improving coverage.





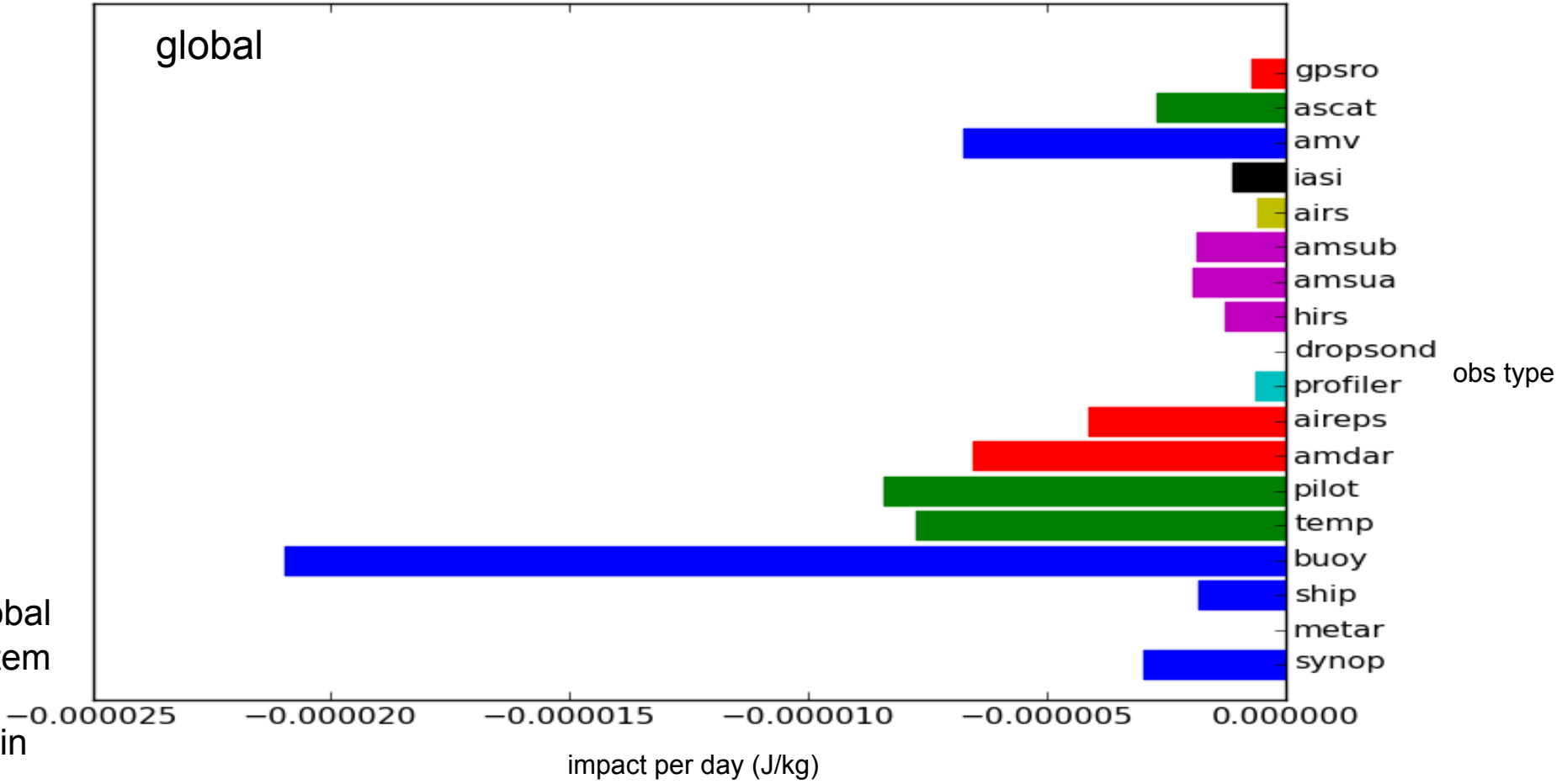

Images from http://www.bom.gov.au/australia/satellite/rars.shtml

# Forecast Sensitivity: relative impact per observation

The adjoint model in VAR enables adjoint-based determination of Forecast Sensitivity to observations

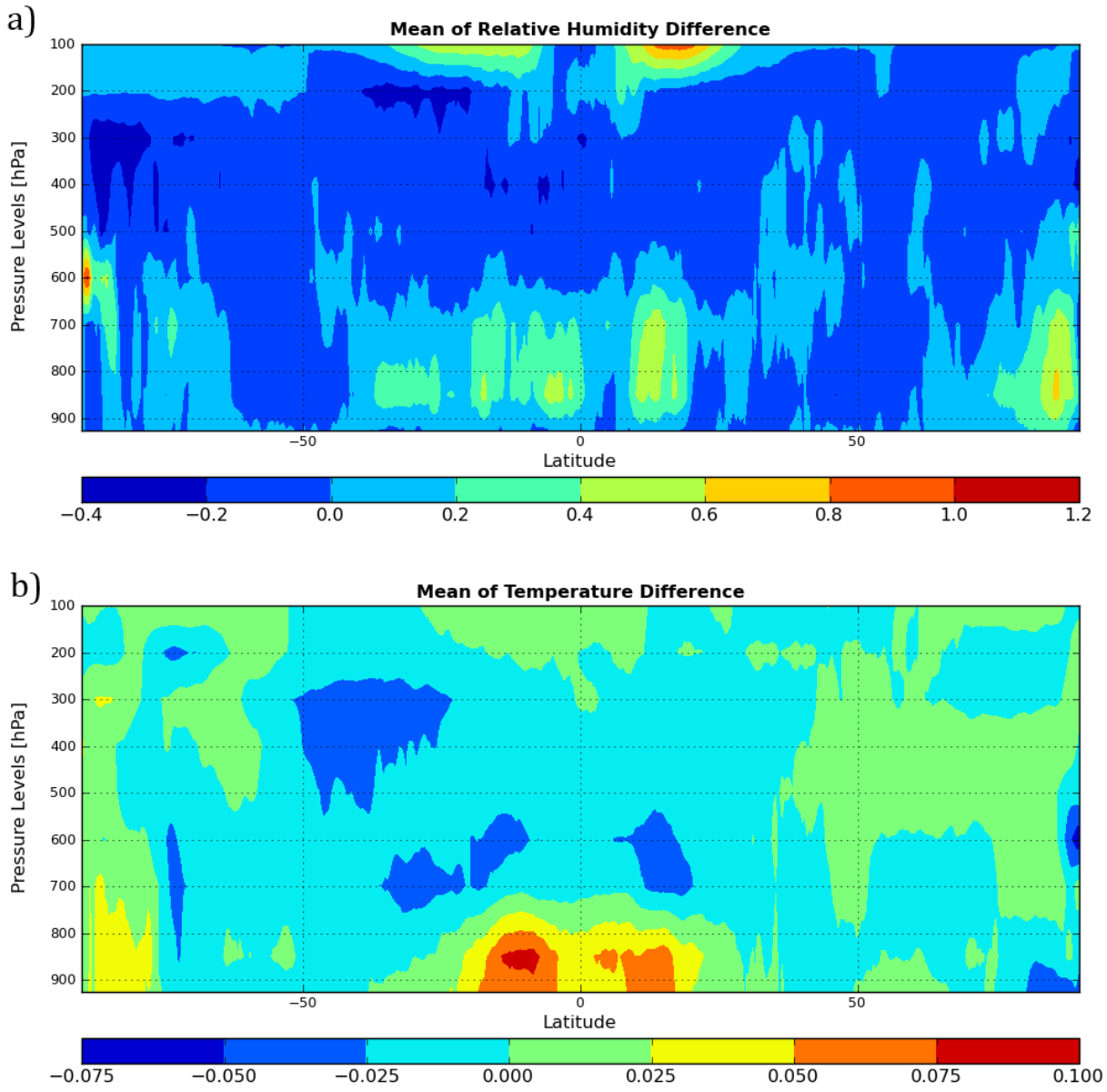
Significant new technique which can inform
- new channel choice
- obs-network assessment and planning

Poster:
Assessing the ACCESS-G Global 4DVAR Data Assimilation System Using Adjoint-Based Forecast Sensitivity to Observations – Jin Lee and Paul Gregory



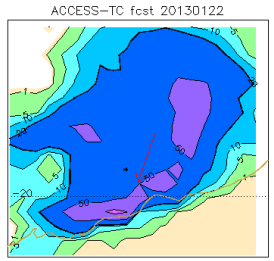
# Assimilation of SSMIS radiance data in ACCESS

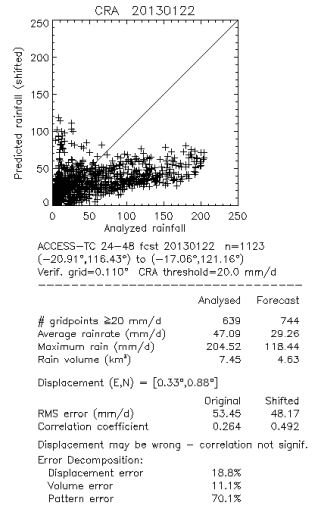
- Trial of F16 SSMIS data in global NWP system: ACCESS-G. (Southern summer).
- At right: mean analysis difference between SSMIS trial and control. Increase in relative humidity near tropopause and lower troposphere.
- SSMIS partially offsets known dry-bias in UM.
- Slight positive impact on forecast skill in the southern hemisphere; improved AMSU fitting statistics.
- Plan to begin testing F17 and F18 SSMIS data soon
- Poster: "Evaluation of SSMIS Radiances for assimilation in ACCESS NWP System" - Vinodkumar

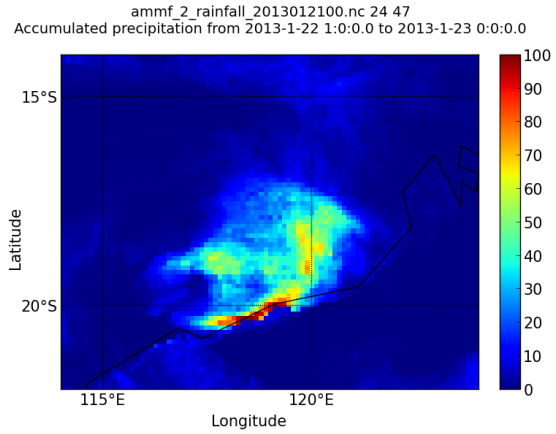


# SSMIS in tropical cyclone forecasting

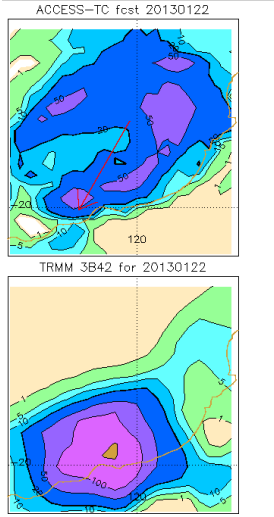
- Tests of SSMIS in the ACCESS tropical cyclone system (ACCESS-TC)
- Results are mixed, in the example at left - SSMIS assimilation in combination with a TC bogus:
  - Rain volume forecast <u>improves</u>
  - Track forecast <u>degrades</u>
- Improved bias correction and a better background error specification may help
- Poster "Satellite data assimilation for improved Tropical Cyclone Forecasts" Paul Gregory

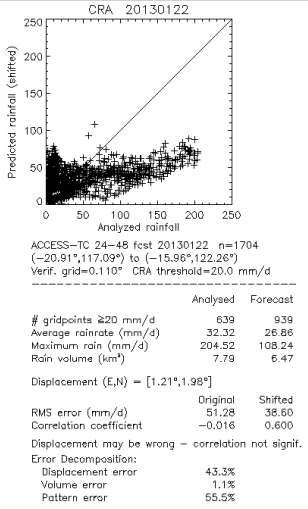


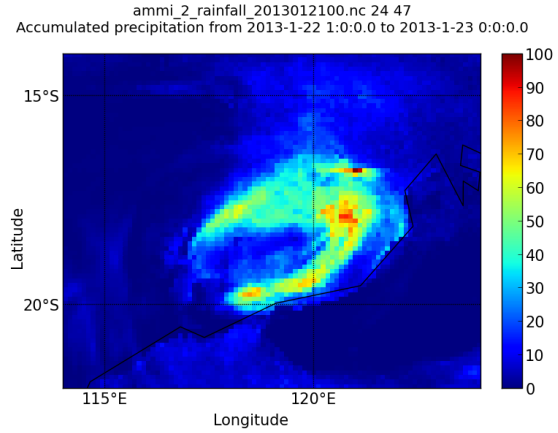




Control



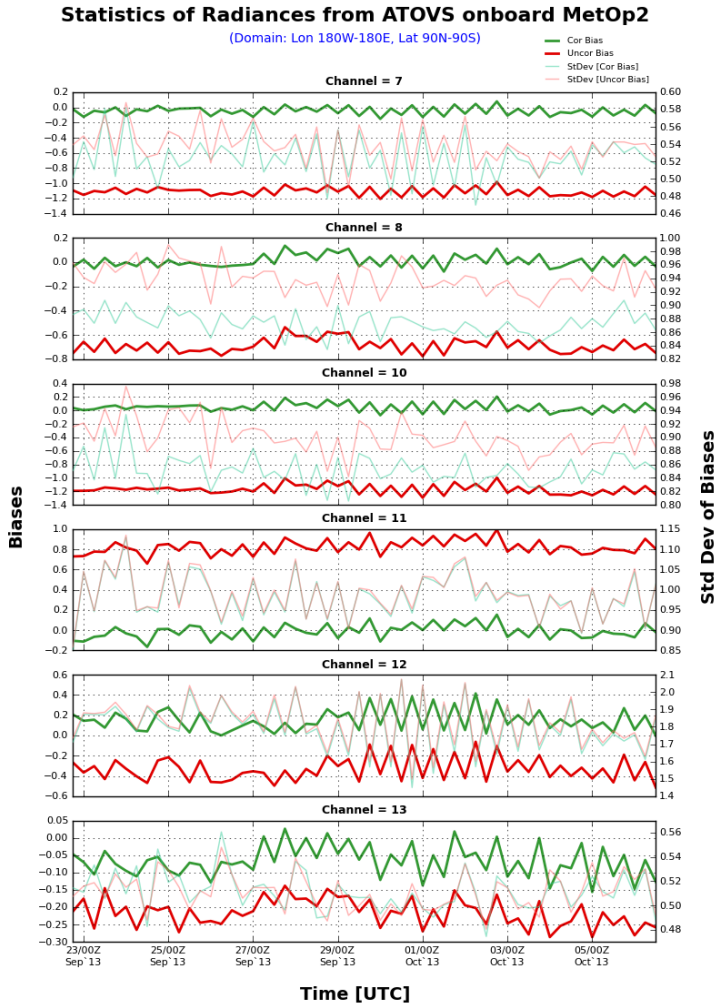




SSMIS + bogus



# Observations monitoring

- Consistent real-time monitoring of sounder radiance biases and std-devs before/after bias correction
- Tests effectiveness of bias correction and reveals instrumental degradation
- Time series, maps and Hovmoller plots
- Todo:
  - AMV statistics
  - Unified presentation of all obs-types
  - Operational status
  - Public web



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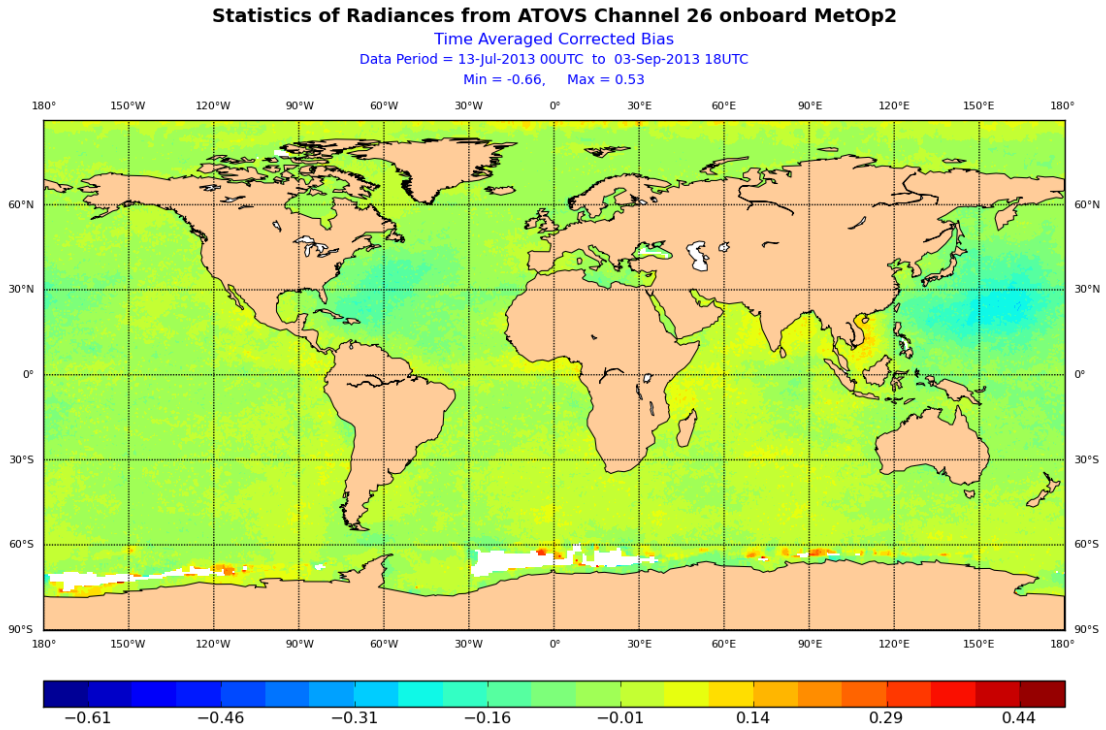
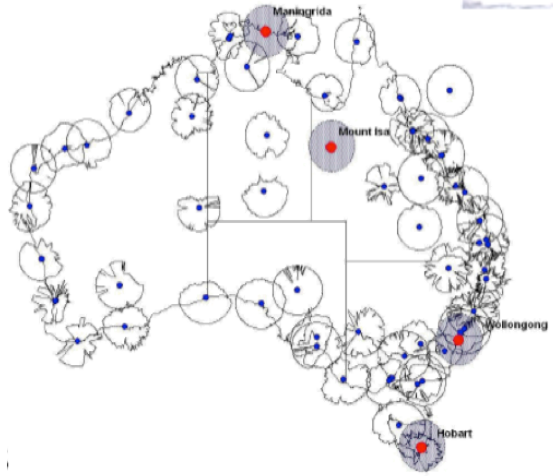


# Satellite data in high resolution and convective scale NWP

- Major effort to provide mesoscale (~1.5 km) city-based assimilation and prediction systems
  - Part of wider project to significantly upgrade Bureau's generation and use of Radar data
  - Also driven by very high priority given to improvement of severe weather and hydrological forecasting

**SREP**: Strategic Radar Enhancement Project




- Radar assimilation (Doppler-winds, rain-rate via latent heat nudging)
- 3dVAR Rapid Update Cycle (RUC): ± 1hour assim window
- Plans include a relocatable system for severe weather
- Integration with other data including geostationary and polar-orbiter satellite radiances.

- High resolution ACCESS NWP represents the priority ACCESS application for Himawari-8 data:
  - IR radiance assimilation to provide moisture information
  - Cloud top pressure data to constrain model convection
- Locally received and processed moisture sensitive microwave data (e.g. MHS) will also be assimilated

# Some additional future work

- CrIS/ATMS
- F17, F18 SSMIS
- assimilation of water-vapour AMVs
- GNSS: ground based GPS: total zenith delay giving total precipitable water
- assimilation of cloud affected radiances
- assimilation of increased numbers of IR channels
- increased use of radiances over land
- assess diurnal variation of SSTs on radiance data pre-processing
- assimilation of retrieved soil moisture

# Last remarks

- Satellite and other remotely sensed data will become increasingly important for NWP, driven by both technology and policy
- As old instruments fail, the capacity to assimilate new instruments and observation-types is essential to maintain forecast performance: not to move forwards is necessarily to move backwards
- The ability to make sophisticated assessments of forecast sensitivity to observations, individual instrument channels etc. will be vital
- Increasingly, high resolution NWP analyses will become important as products in themselves, not just as initial conditions for forecasts.

# Thank you

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