



Australian Government

Bureau of Meteorology

## **NMOC Operations Bulletin No. 85**

### **Operational Upgrades to the Gridded OCF and PME Systems 30 November 2010**

#### **1. Introduction**

The Gridded OCF (Operational Consensus Forecasting) and PME (Poor Man's Ensemble) systems run operationally by NMOC (National Meteorological and Oceanographic Centre) were upgraded on the 4<sup>th</sup> of May 2010 and on the 8<sup>th</sup> of June 2010 respectively. The first upgrade involved outputting additional fields and the second upgrade decreased the grid spacing to 0.5° for pre-existing fields in the Gridded OCF and PME systems. Since May 4 2010 the operational Gridded OCF system has been generating the following forecast fields out to 216 hours: hourly 2 metre (m) temperature, 2 m dew-point temperature, mean sea level pressure (MSLP) and 3-hourly total, low, middle and high level cloud cover.

These two upgrades were undertaken in response to requirements for the NexGenFWS (Next Generation Forecasting and Warning System), formerly known as GFE (Graphical Forecast Editor). NMOC's Operational Gridded OCF and PME systems provide first guess fields for the NexGenFWS. The Gridded OCF system produces weighted-average forecasts of gridded surface meteorological fields from an ensemble of bias-corrected NWP models.

The PME system is an ensemble rainfall prediction system using forecasts from several Australian and overseas NWP models. It uses a technique known as the "probability matched ensemble mean" to reassign the ensemble mean rain rates (Ebert, 2004). The upgraded daily and hourly PME systems generate ensemble mean and probability-matched mean forecasts of daily quantitative precipitation for lead times out to 8 days and 3-hourly quantitative precipitation for lead times out to 216 hours. The daily and hourly PME systems also produce probabilistic forecasts of the daily and 3-hourly quantitative precipitation exceeding 0.2, 1, 5, 10, 15, 25, 50 and 100mm.

Research and development work for these upgrades was undertaken by Tim Hume and Shaun Cooper of the Weather and Environmental Prediction Group of the Centre for Australian Weather and Climate Research (CAWCR), and implemented operationally by Xiaoxi Wu of NMOC. The upgrades are expected to provide better forecast guidance for operational use.

For further details of the Gridded OCF and PME systems, please refer to the NMOC Operations Bulletins No.74, No.81 and No.82, available from [http://www.bom.gov.au/australia/charts/bulletins/nmoc\\_bulletin.shtml](http://www.bom.gov.au/australia/charts/bulletins/nmoc_bulletin.shtml).

Both the Gridded OCF and PME systems run on the NMOC operational scheduler.

## 2. Features of the two upgrades

The main features of the upgrade on 4 May 2010 for the PME include:

- addition of a 0.2 mm PoP (Probability of Precipitation) field to the daily and three hourly rainfall.

The 4 May Gridded OCF upgrade includes:

- addition of low, middle and high level cloud cover fields output at 0.5° grid spacing
- grid spacing of total cloud cover field reduced from 1.25° to 0.5°.

The second upgrade on the 8<sup>th</sup> of June 2010 involved increasing the number of runs per day from two to four times (at 00, 06, 12 and 18Z). The main changes of the second upgrade on June 8 2010 for Gridded OCF are:

- reduce grid spacing from 1.25° to 0.5° for the remainder of fields.

And for both the Gridded OCF and 3 Hourly PME:

- The composite scheme had been outputting data at 6 hourly intervals in the first 96 hours, and at 12 hourly intervals from 96 hours to 216 hours. Since the upgrade data is being output from the composite scheme at 6 hourly intervals throughout the forecast period (0-216 hrs, with final output interpolated to either 1 hour or 3 hour steps.)

## 3. System descriptions

### 3.1 Overview of Gridded OCF and PME systems

#### a) Upgraded Gridded OCF system

The Gridded OCF system is documented in Operations Bulletin No. 74 (27 May 2008; available at [http://www.bom.gov.au/australia/charts/bulletins/nmoc\\_bulletin.shtml](http://www.bom.gov.au/australia/charts/bulletins/nmoc_bulletin.shtml)). From 10 December 2009, two additional changes were incorporated into the Gridded OCF system, which was described in Operations Bulletin No. 82 (8 February 2010).

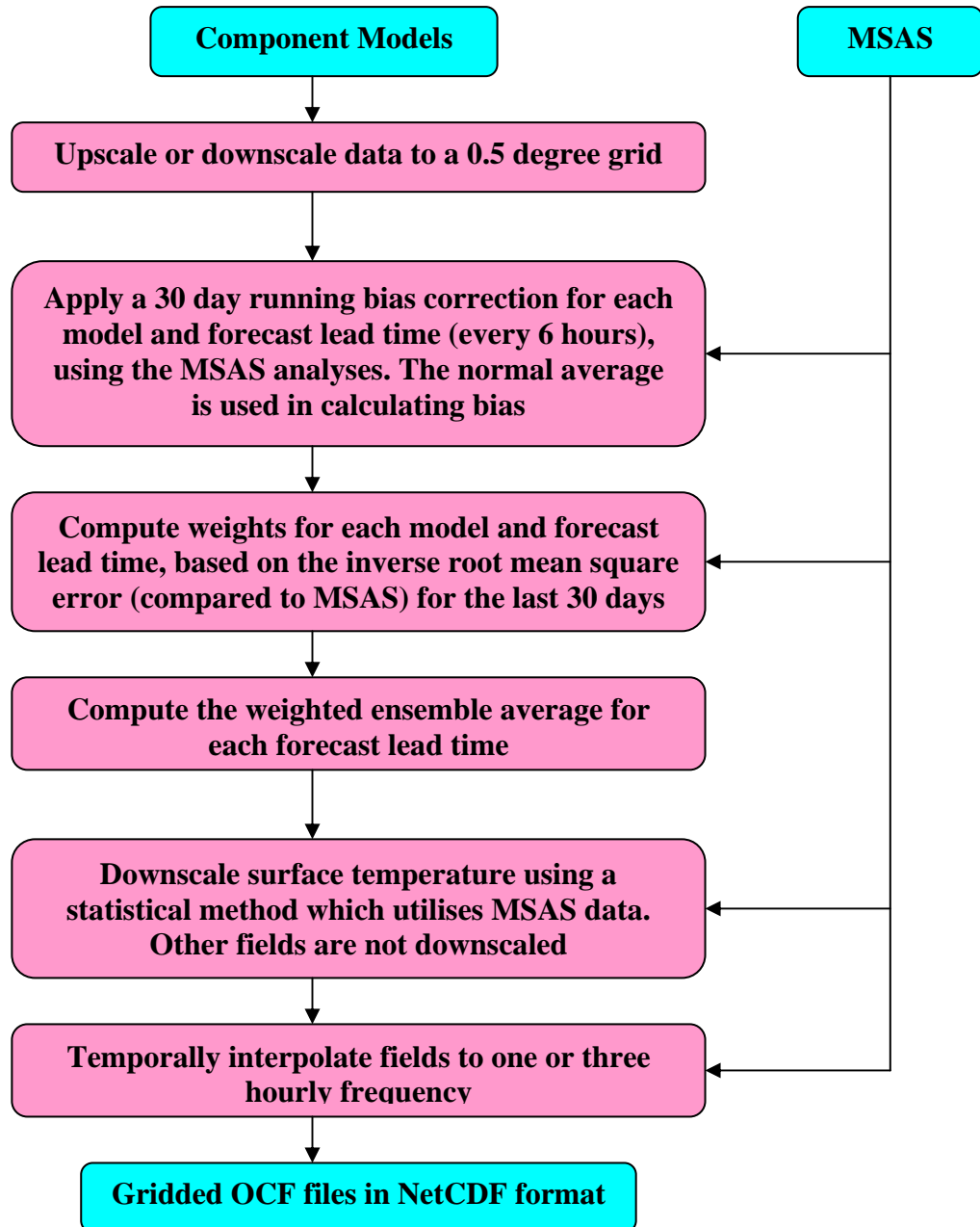
Mesoscale Surface Analysis System (MSAS) output is used in Gridded OCF

- to bias correct the raw NWP model data
- to compute the relative weights applied to each NWP model output
- in downscaling surface temperature
- to temporally interpolate the surface temperature.

Further information as to how MSAS is used in Gridded OCF can be found in Operations Bulletin No.74. Prior to July 2010 MSAS had used the mesoLAPS125 analysis as a first guess, subsequently it has used ACCESS-A.

Refer to Figure 1 for a schematic of the upgraded Gridded OCF system.

**Figure 1: Schematic of upgraded Gridded OCF system**



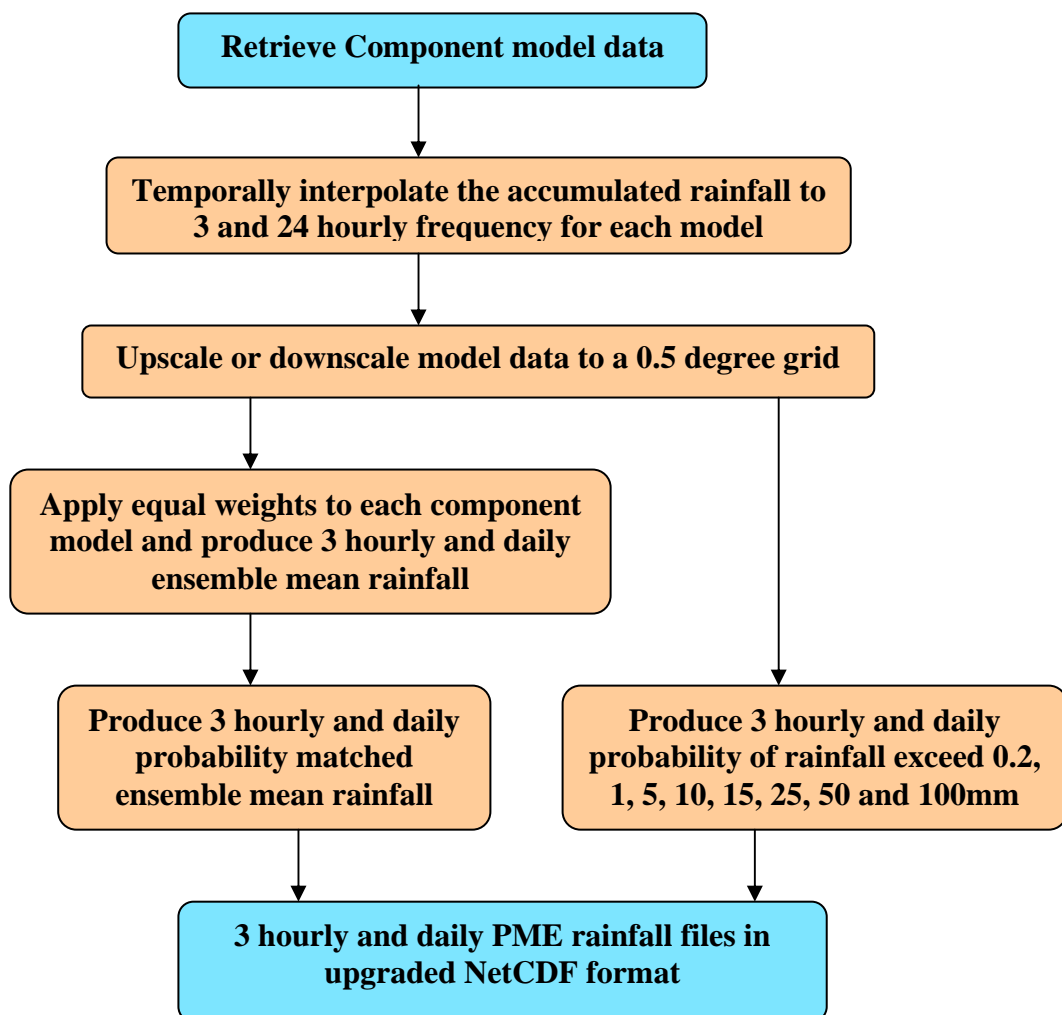
### **b) Upgraded PME system**

Operations Bulletin no 81 (14 August 2009;

[http://www.bom.gov.au/australia/charts/bulletins/nmoc\\_bulletin.shtml](http://www.bom.gov.au/australia/charts/bulletins/nmoc_bulletin.shtml)), describes the PME system prior to 8 June 2010.

The PME system continues to output 3 hourly and daily products. Figure 2 is a schematic of the upgraded PME system.

**Figure 2: Schematic of the upgraded PME system**



### **3.2 NWP Models used in PME and Gridded OCF**

The following models are used in PME and Gridded OCF ensembles:

ACCESS-R, ACCESS-G, ECSP (lores and hires), JMAGSM, UKGC, USAVM, and CMC GEM (refer to Section 6 for definitions of the model names).

PME also uses the DWD model.

See Table 1 for configuration of component models in the PME and Gridded OCF systems.

**Table 1. Configuration of component models in PME and Gridded OCF system**

Model	Spatial resolution (deg)	Maximum forecast days	Contribute fields
ACCESS-R	0.375	3	all fields
ACCESS-G	1.25 (lon) x 0.833 (lat)	10	all fields
UKGC	1.25	3	t, mslp, prcp
USAVM	0.5	7.5	all fields except td
CMCGEM	0.6	6	t, td, mslp, prcp, ttl_cld
DWD <sup>1*</sup>	0.5	3	daily prcp only
Lores ECSP	1.5	10 <sup>2*</sup>	t, td, mslp, prcp, ttl_cld
Hires ECSP	0.5	8	t, td, mslp, prcp, ttl_cld
JMAGSM	1.25	8	t, mslp, prcp, ttl_cld

Legend - t = 2m air temperature; td = 2m dewpoint temperature; prcp = precipitation; ttl\_cld = total cloud; mslp = mean sea level pressure

<sup>1\*</sup> Please note DWD is only used for PME and not Gridded OCF.

<sup>2\*</sup> Please note for the first 8 forecast days lores ECSP is not used in PME and Gridded OCF. This avoids double weighting with hires ECSP during this forecast period.

### 3.3 Configuration of the upgraded Gridded OCF and PME systems

See Table 2 and 3 for the configuration of the upgraded Gridded OCF and PME systems.

**Table 2. Summary of the upgraded Gridded OCF configuration**

Domain	8.922°S to 45.125°S and 109.875°E to 156.076°E (temperature field) 5°S to 50°S and 105°E to 160°E (cloud field) 8.5°S to 45.5°S and 109.5°E to 156.5°E (other fields)
Spatial resolution	0.5° x 0.5° (coarse grid) 2.5' x 2.5' (fine grid: temperature only)
Temporal resolution	6 hours: 0–216 hour prognoses
Forecast fields and frequency	2m temperature (Hourly) 2m dew-point temperature (Hourly) Mean sea level pressure (Hourly) Total cloud cover (3 Hourly) Low level cloud cover (3 Hourly) Middle level cloud cover (3 Hourly) High level cloud cover (3 Hourly)
Runs	00Z, 06Z, 12Z and 18Z

**Table 3. Summary of the upgraded PME configuration**

<b>Domain</b>	<b>5°S to 45°S and 110°E to 160°E</b>
<b>Spatial resolution</b>	<b>0.5° x 0.5°</b>
<b>Temporal resolution</b>	<b>3 Hourly PME: 3 hours: 0–216 hour prognoses</b> <b>Daily PME: 24 hours: 0–192 hour prognoses</b>
<b>Forecast fields and Frequency</b>	<b>Quantitative precipitation (Ensemble mean, daily and 3 hourly)</b> <b>Quantitative precipitation (Probability-matched mean, daily and 3 hourly)</b> <b>Quantitative precipitation probability exceeding 0.2, 1, 5, 10, 15, 25, 50 and 100mm (daily and 3 hourly)</b>
<b>Runs</b>	<b>00Z, 06Z, 12Z and 18Z</b>

Please note the low resolution (pre-upgraded) daily PME is being produced in parallel at 00Z and 12Z with the high resolution PME system. But output from the low resolution system is only used for WATL (Water and Land) system. WATL currently can not handle high resolution PME data.

### 3.4 Composite scheme and issue times

The upgraded Gridded OCF and PME system runs 4 times each day. The details of the component models and the approximate issue times are summarised in Table 4.

**Table 4. Component models used in 00Z, 06Z, 12Z and 18Z runs and approximate issue times.**

<b>Runs</b>	<b>Component models</b>	<b>Approximate issue times (UTC)</b>	
<b>00Z</b>	<b>Previous day 12Z run for lores ECSP, JMA and ACCESS-G and current day 00Z run for other models</b>	<b>Gridded OCF</b>	<b>08:00</b>
		<b>Hourly PME</b>	<b>08:00</b>
		<b>Daily PME (Hires)</b>	<b>07:20</b>
		<b>Daily PME (Lores)</b>	<b>07:20</b>
<b>06Z</b>	<b>Previous day 12Z run for lores ECSP and JMA and 00Z run for other models</b>	<b>Gridded OCF</b>	<b>10:30</b>
		<b>Hourly PME</b>	<b>10:30</b>
		<b>Daily PME (Hires)</b>	<b>10:00</b>
<b>12Z</b>	<b>Previous day 12Z run for lores ECSP and JMA and current day 00Z ACCESS-G and current day 12Z run for other models</b>	<b>Gridded OCF</b>	<b>20:00</b>
		<b>Hourly PME</b>	<b>20:00</b>
		<b>Daily PME (Hires)</b>	<b>19:20</b>
		<b>Daily PME (Lores)</b>	<b>19:20</b>
<b>18Z</b>	<b>Current day 12Z run for all models</b>	<b>Gridded OCF</b>	<b>22:30</b>
		<b>Hourly PME</b>	<b>22:30</b>
		<b>Daily PME (Hires)</b>	<b>22:00</b>

Please note

- the Gridded OCF and PME systems do not use the 00Z JMA run. This is because the 00Z JMA run only produces forecasts out to 3 days.
- the lores ECSP only has a 12Z run and no 00Z run.

The composite scheme combines the various NWP inputs using the predetermined relative weighting to produce a single ensemble. In both the Gridded OCF and PME systems the composite scheme will run without input from a particular model, if that input is not available when the composite scheme starts to run. For example, the 00Z forecast normally includes the current day's 00Z USAVM model. However, if the 00Z USAVM is not available at the time of the Gridded OCF and PME composite schemes run, then the 00Z USAVM will not be included in the composite scheme.

## **4. Assessment of the system performance**

### **4.1 Verification of the higher resolution Gridded OCF forecasts**

To assess the accuracy of the new Gridded OCF system, Tim Hume, of CAWCR, produced comparison plots for December 2009 to March 2010 of 2m temperature, 2m dew-point temperature and mean sea level pressure for the both 1.25° and 0.5° runs. These forecasts were verified against their corresponding MSAS analysis. The figures in this section compare the RMSE (root mean square error) of the runs at both resolutions, and then show the difference in RMSE between the two runs. The MSAS analyses which were used to verify the OCF output combines surface observations with a background derived from hourly mesoLAPS model forecast fields. Hence the analyses themselves will only approximate the state of the atmosphere at the analysis time.

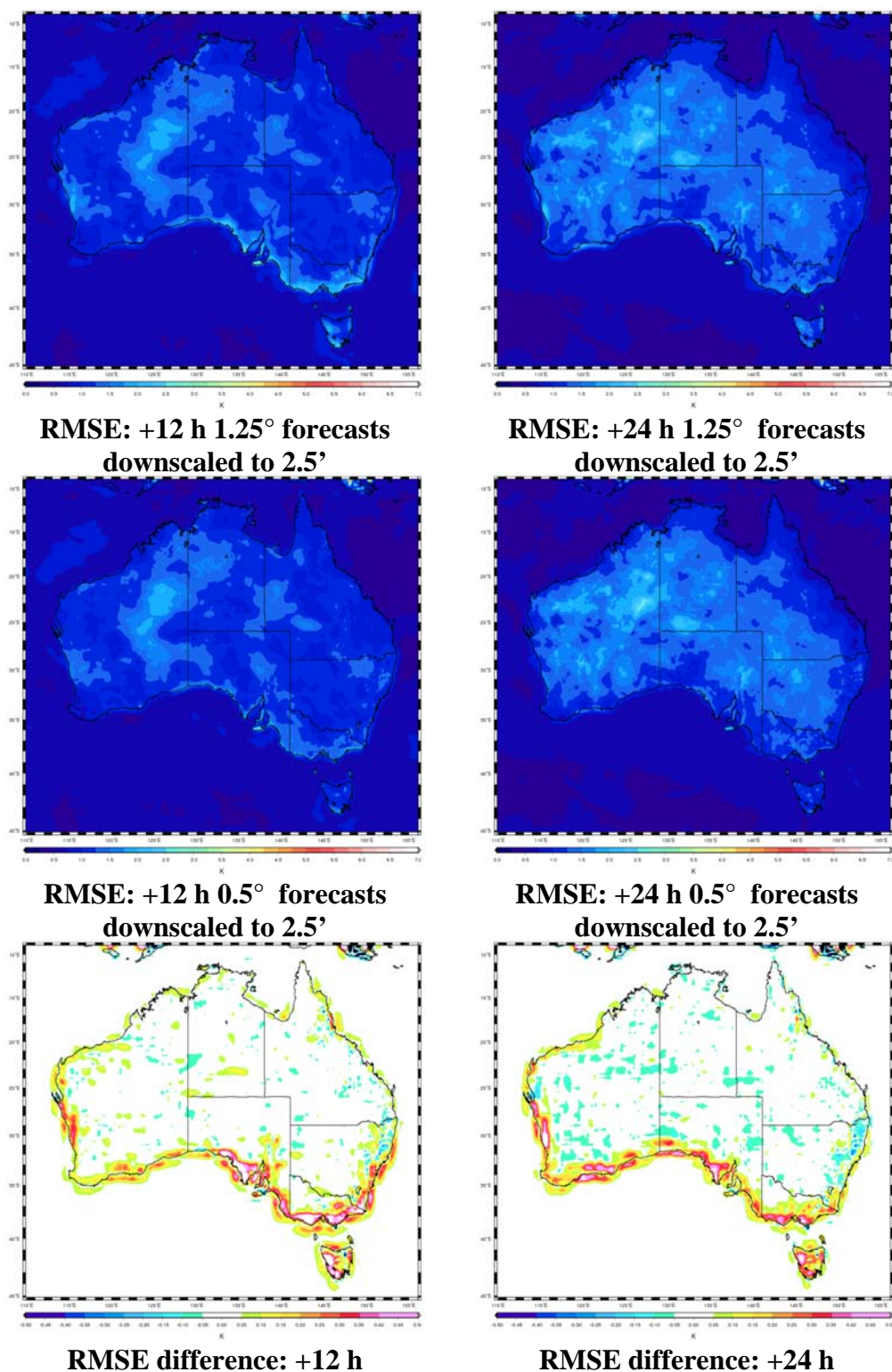
In the case of the 2m temperature runs, both the 0.5° and 1.25° forecasts were downscaled to 0.04166° prior to validation. In coastal regions the 0.5° 2m temperature forecasts are significantly better than the 1.25° forecasts (refer to Figures 3-7). The improvement in skill seen in the 0.5° runs is probably due to the higher resolution Gridded OCF resolving the surface temperature gradient near the coast better than the 1.25° runs.

In contrast to the 2m temperature runs, there is very little improvement in skill between the 1.25° and 0.5° 2m dew-point temperature (Figures 7-12) and mean sea level pressure (Figures 13-17) runs. The relative differences in RMSE between the two resolutions for these runs are small.

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<sup>1</sup>To clearly read the labels on the figures, zoom in to about 400%.

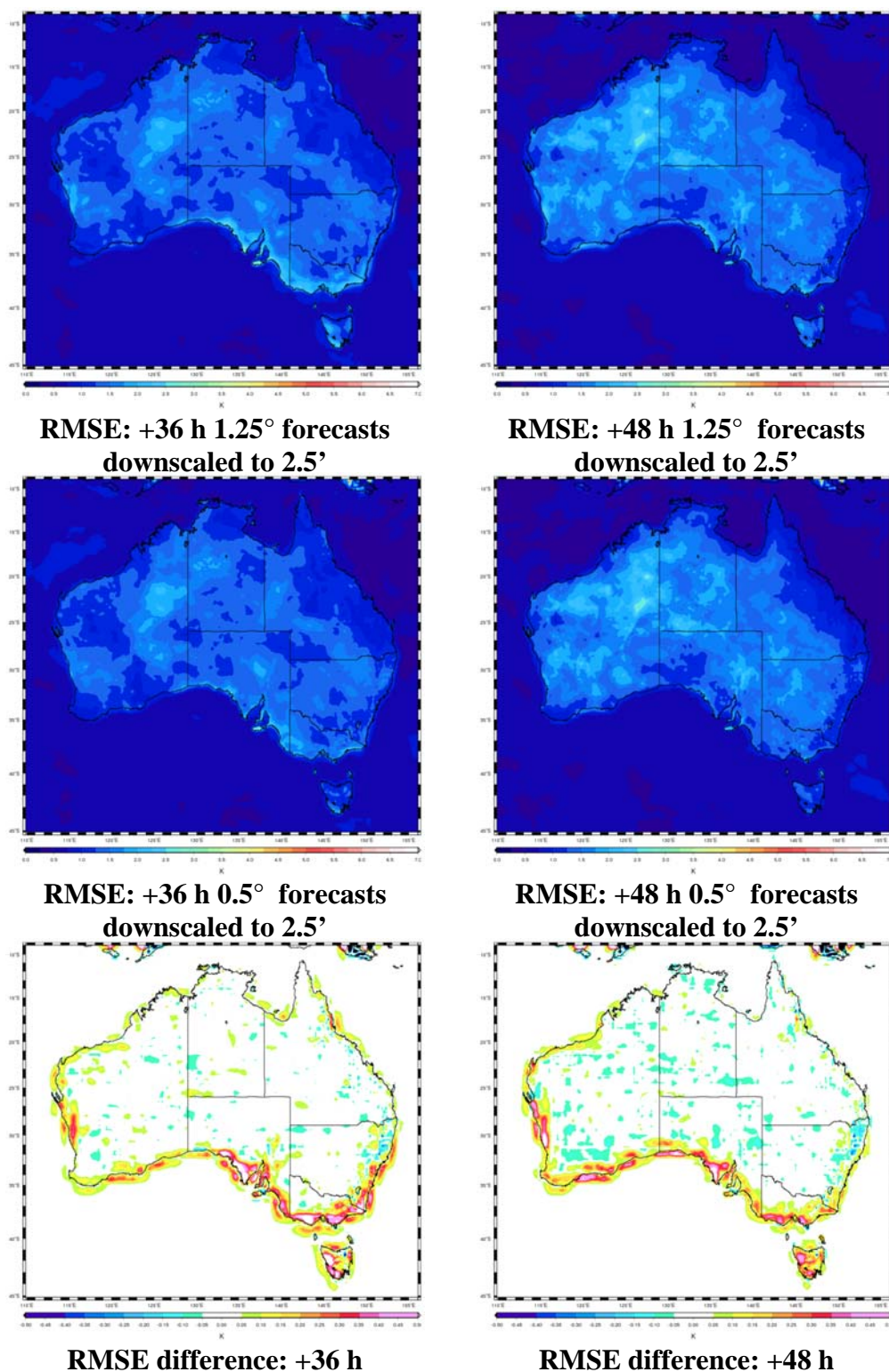
## 2m Temperature: 12-24 h



**Figure 3: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**

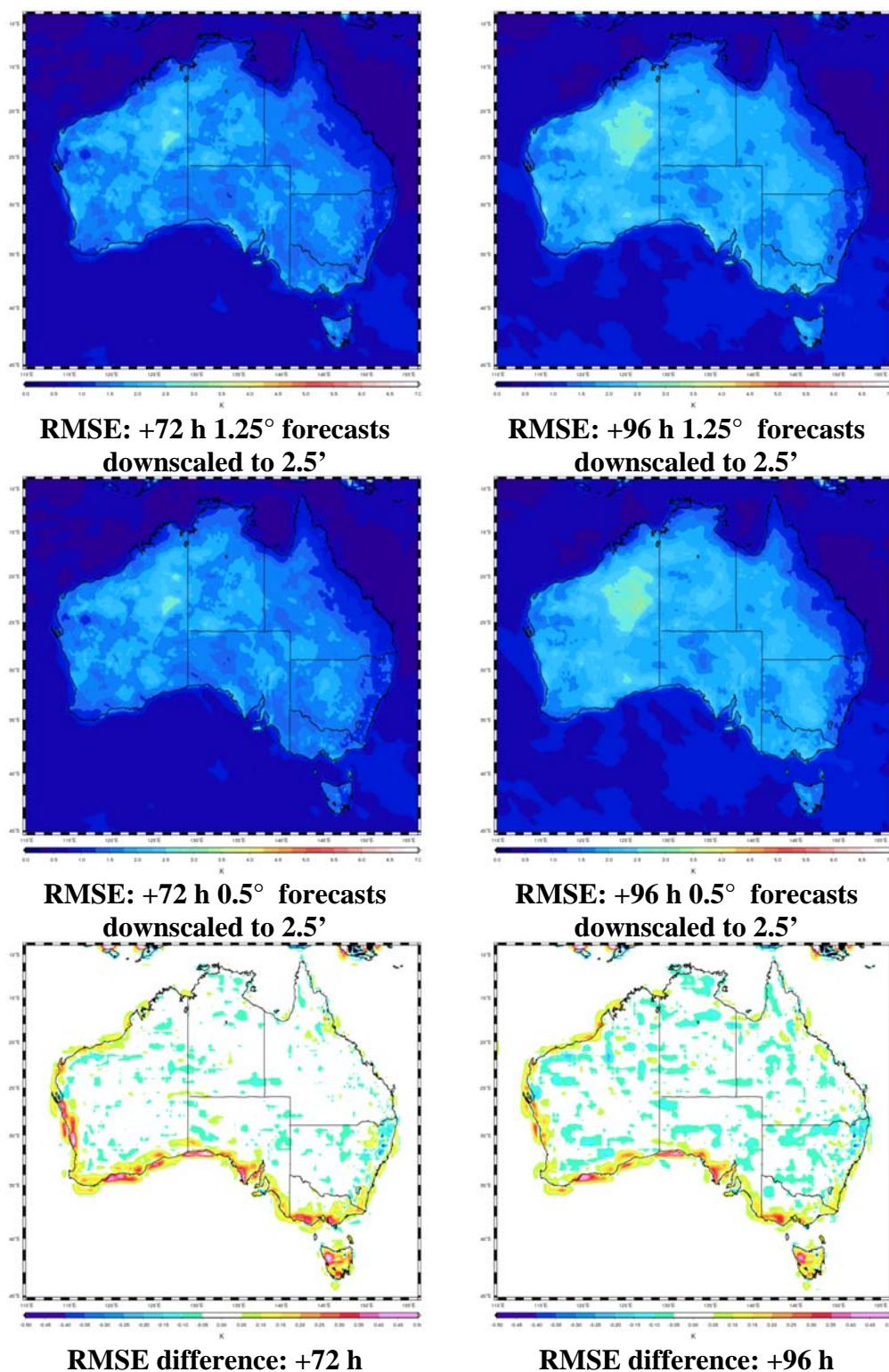


## 2m Temperature: 36-48 h



**Figure 4: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**

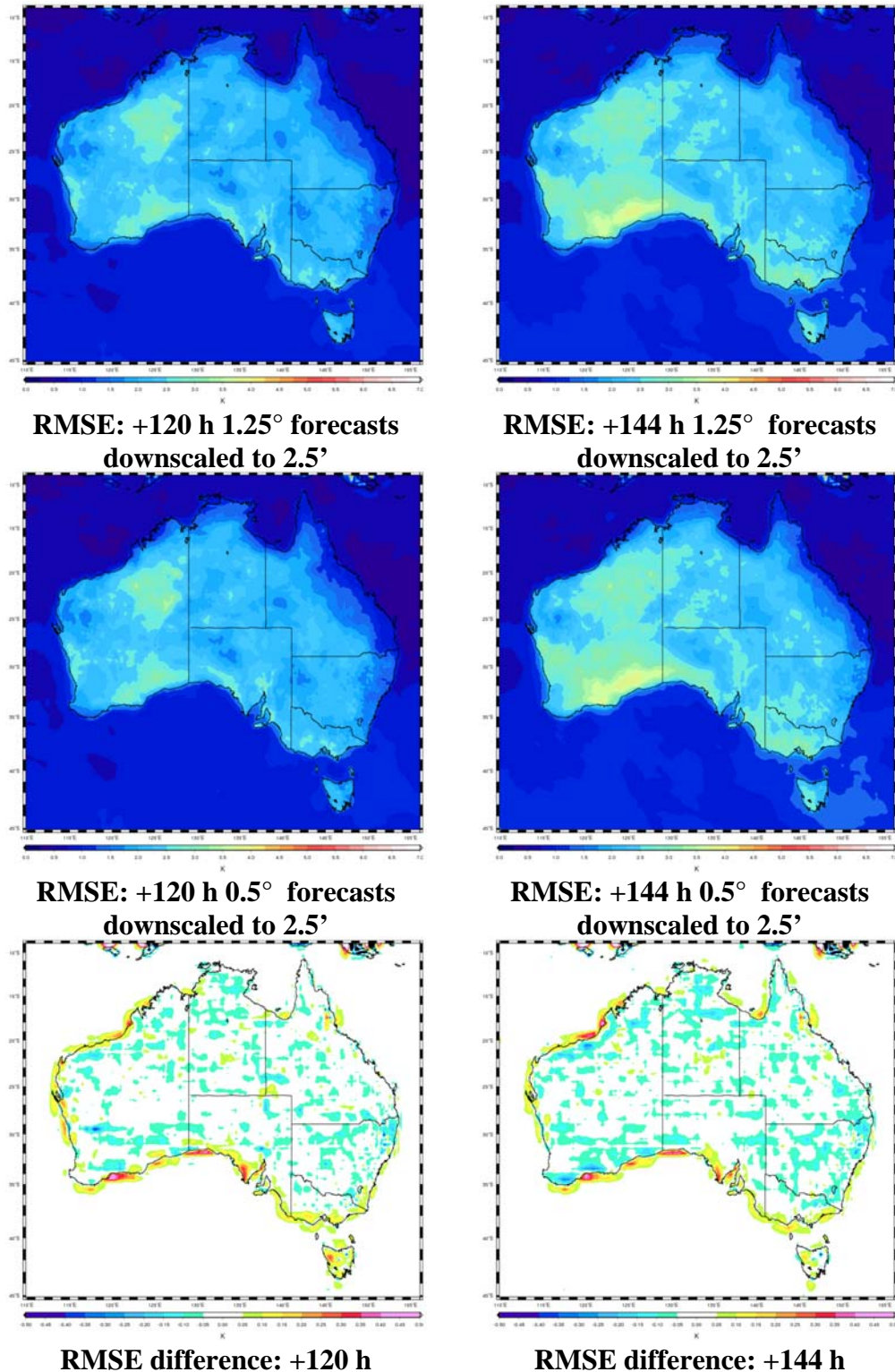
## 2m Temperature: 72-96 h



**Figure 5: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**

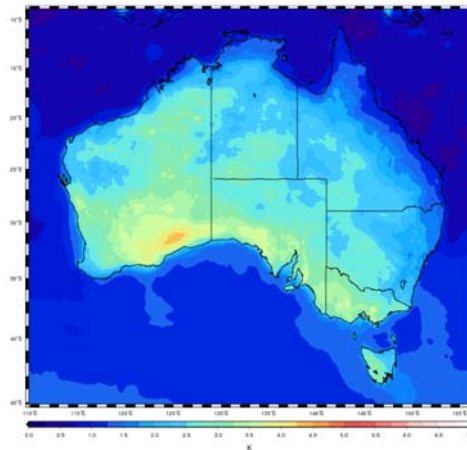


## 2m Temperature: 120-144 h

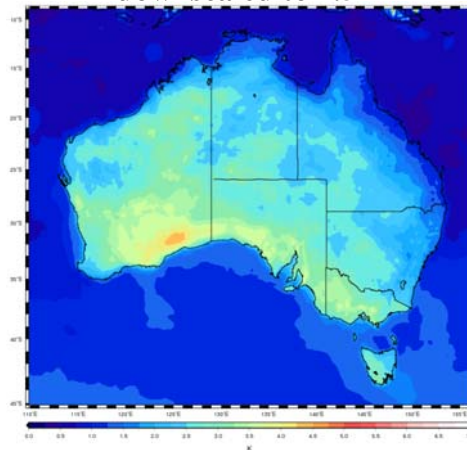


**Figure 6: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**

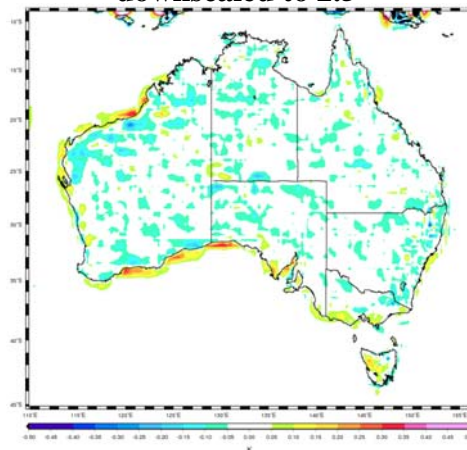
## 2m Temperature: 168 h



**RMSE: +168 h 1.25° forecasts  
downscaled to 2.5'**



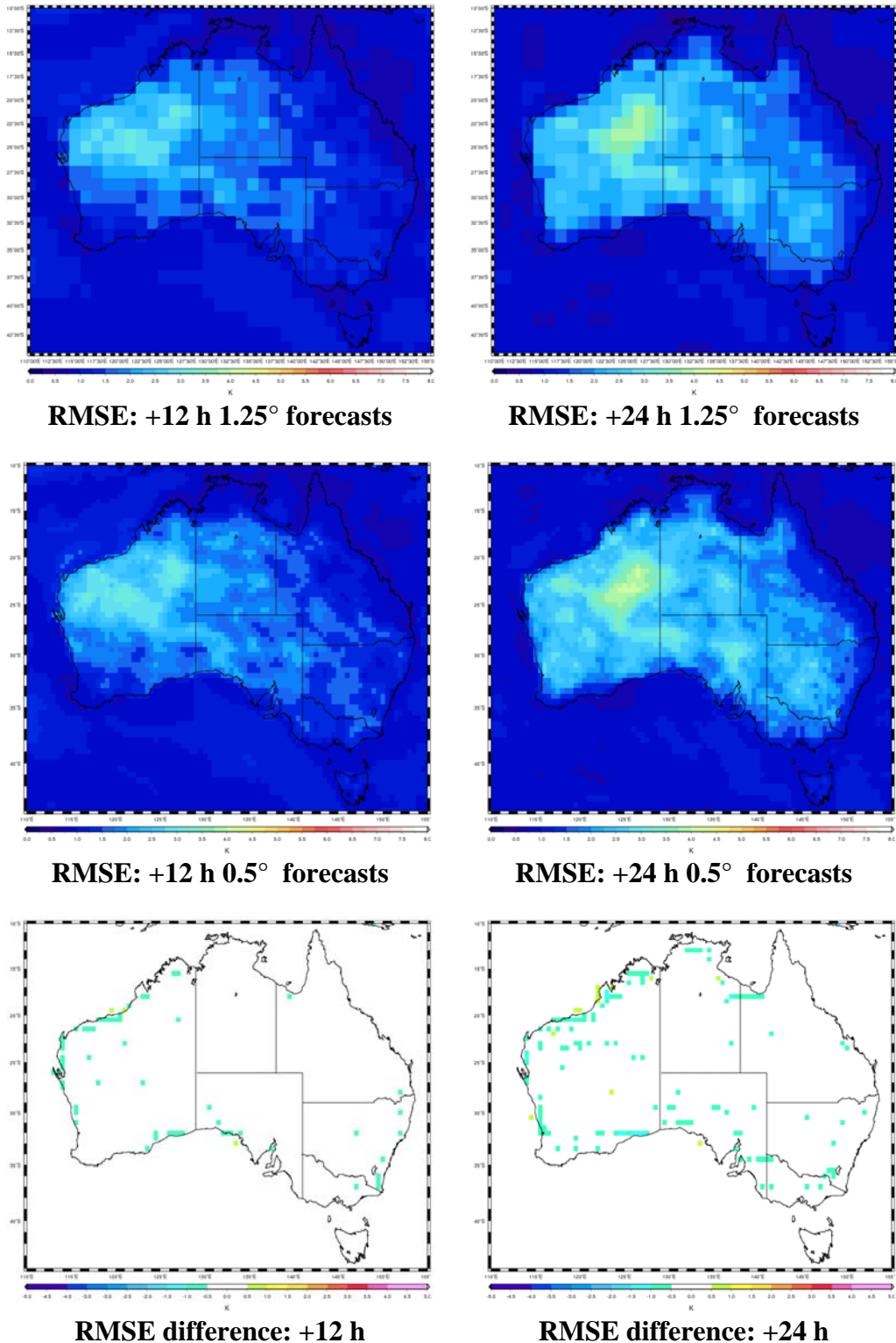
**RMSE: +168 h 0.5° forecasts  
downscaled to 2.5'**



**RMSE difference: +168 h**

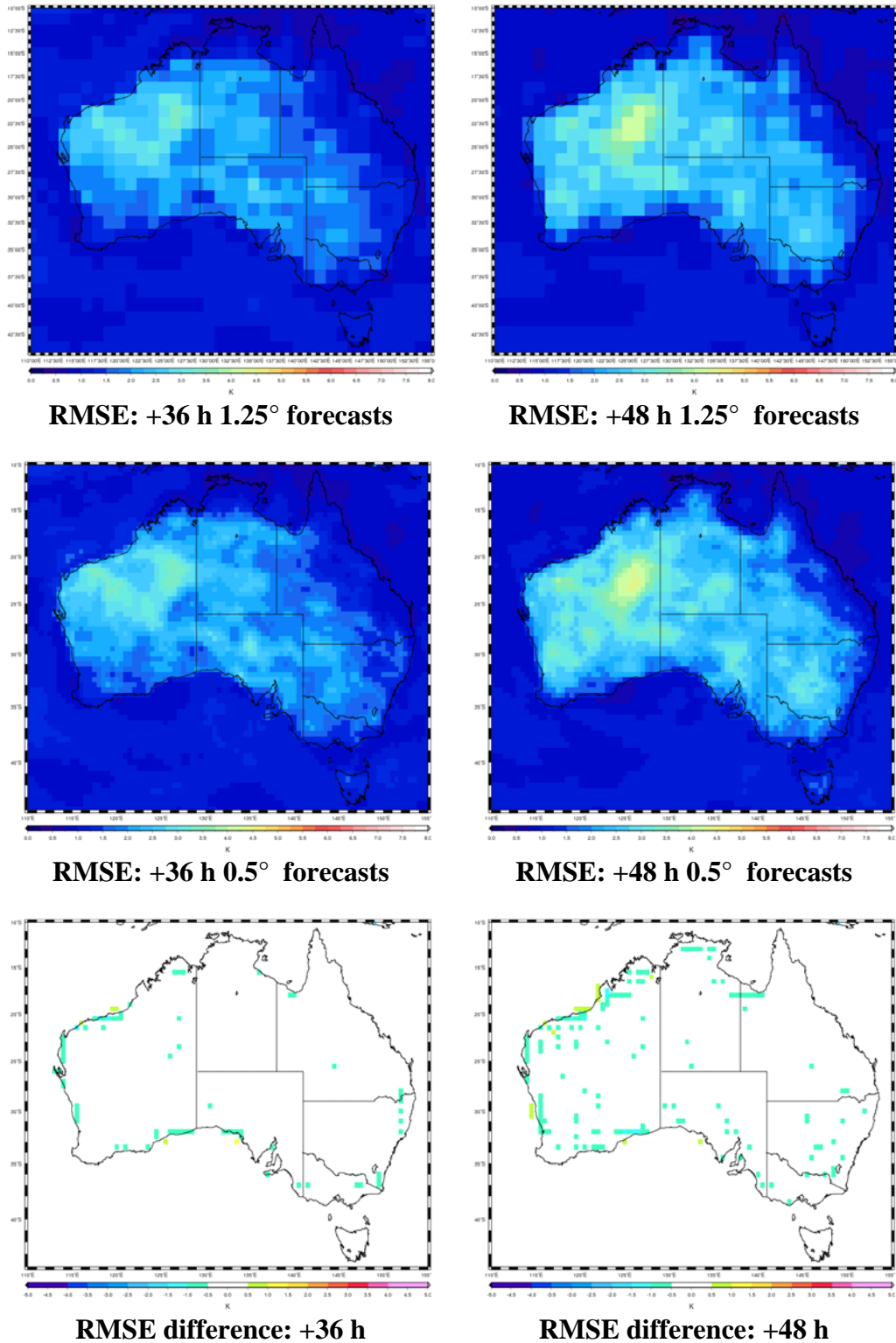
**Figure 7: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**

## 2m Dewpoint Temperature: 12-24 h



**Figure 8: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**

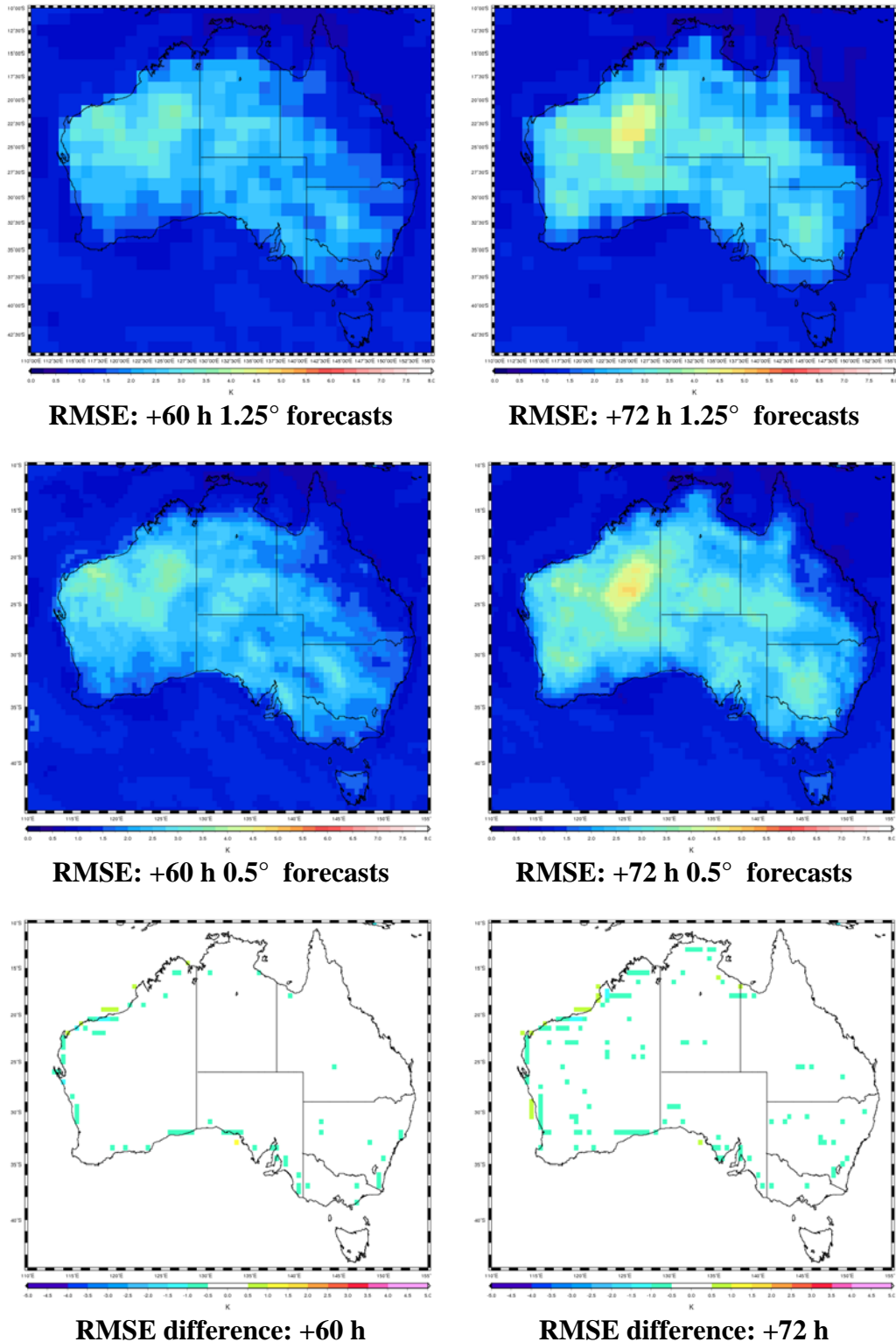
## 2m Dewpoint Temperature: 36-48 h



**Figure 9: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**

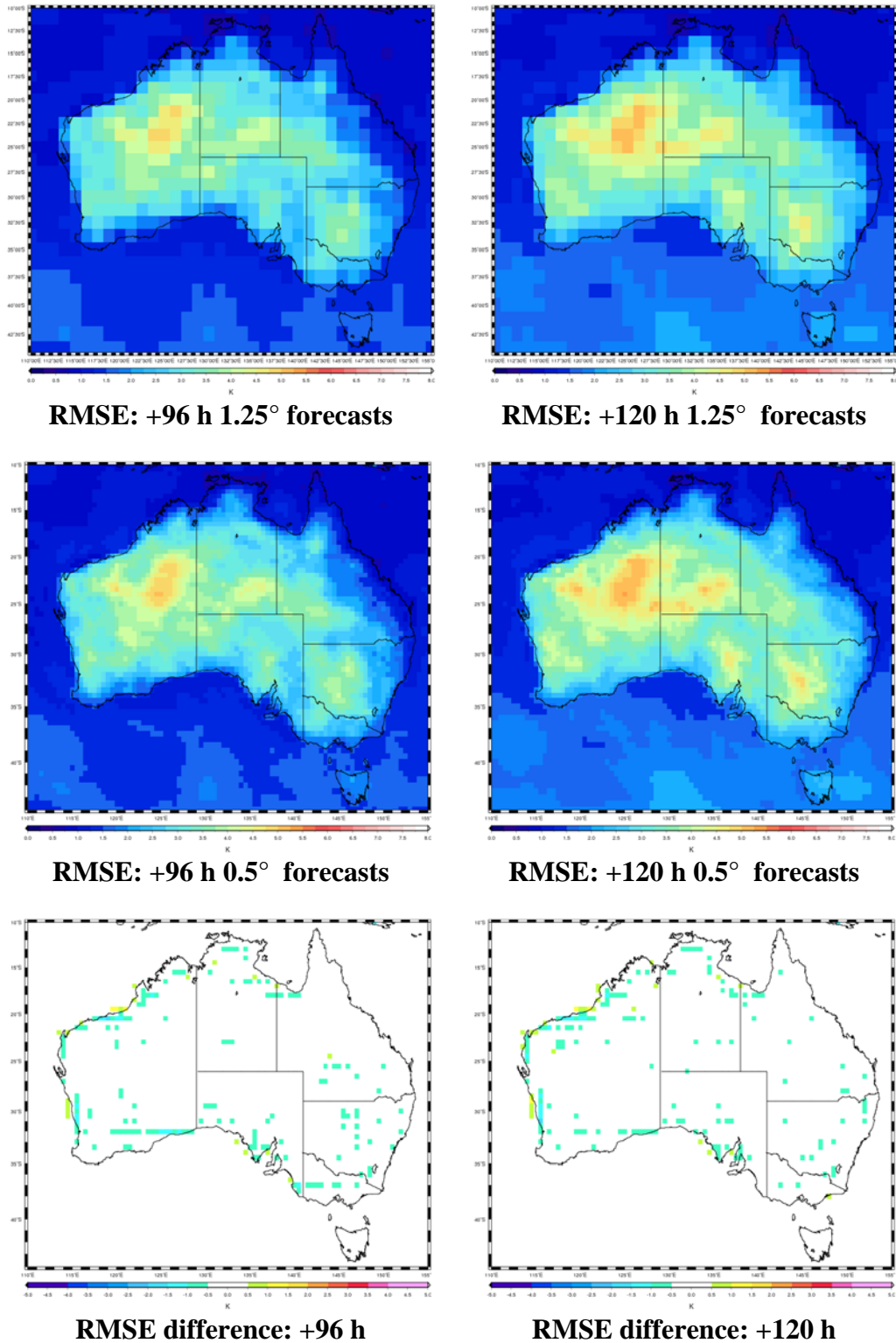


## 2m Dewpoint Temperature: 60-72 h



**Figure 10: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**

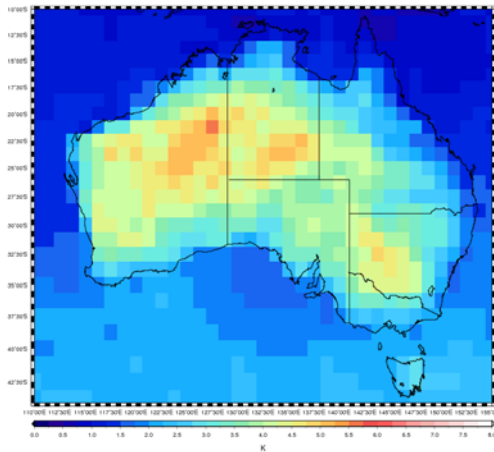
## 2m Dewpoint Temperature: 96-120 h



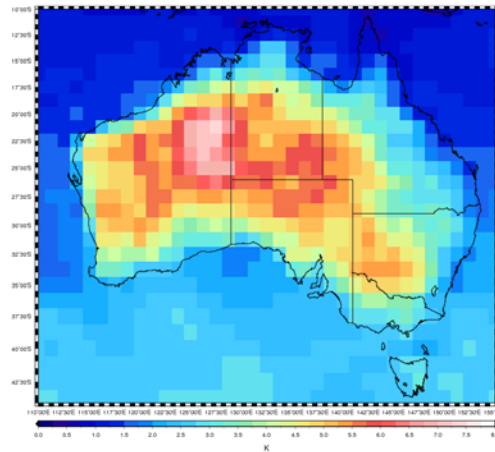
**Figure 11: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**



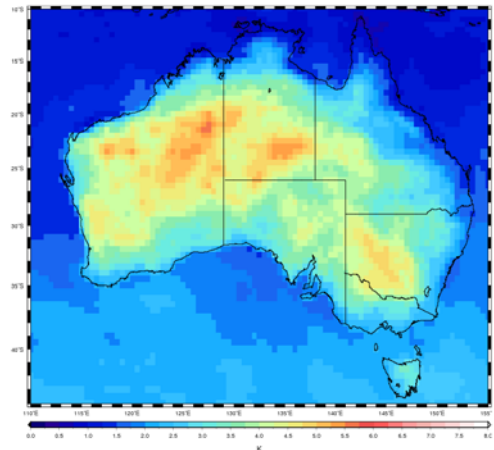
## 2m Dewpoint Temperature: 144-168 h



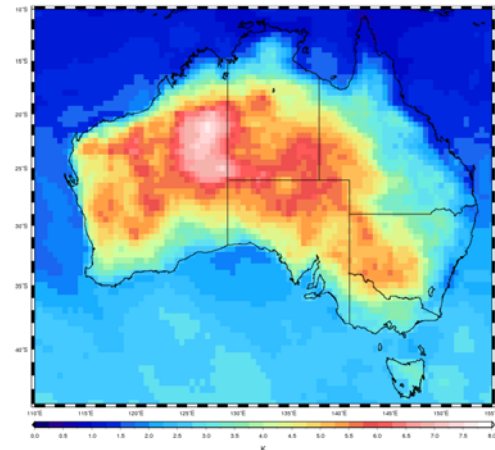
**RMSE: +144 h 1.25° forecasts**



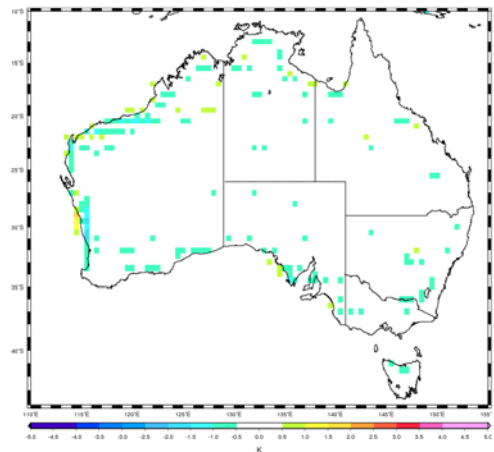
**RMSE: +168 h 1.25° forecasts**



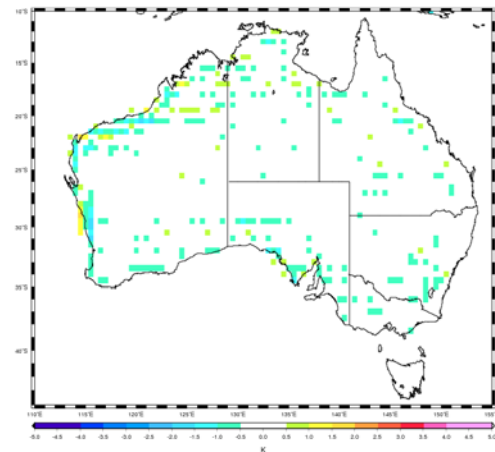
**RMSE: +144 h 0.5° forecasts**



**RMSE: +168 h 0.5° forecasts**



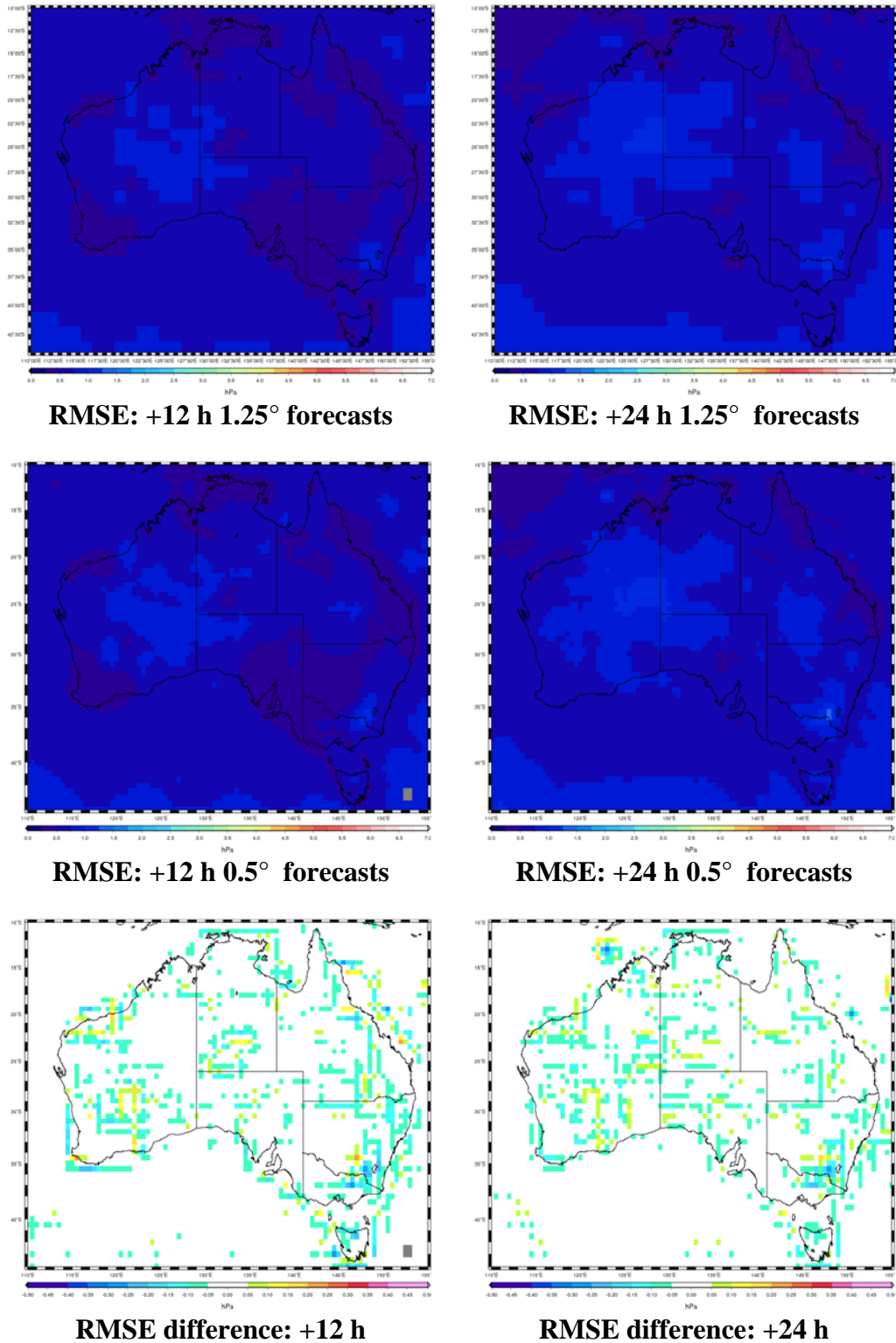
**RMSE difference: +144 h**



**RMSE difference: +168 h**

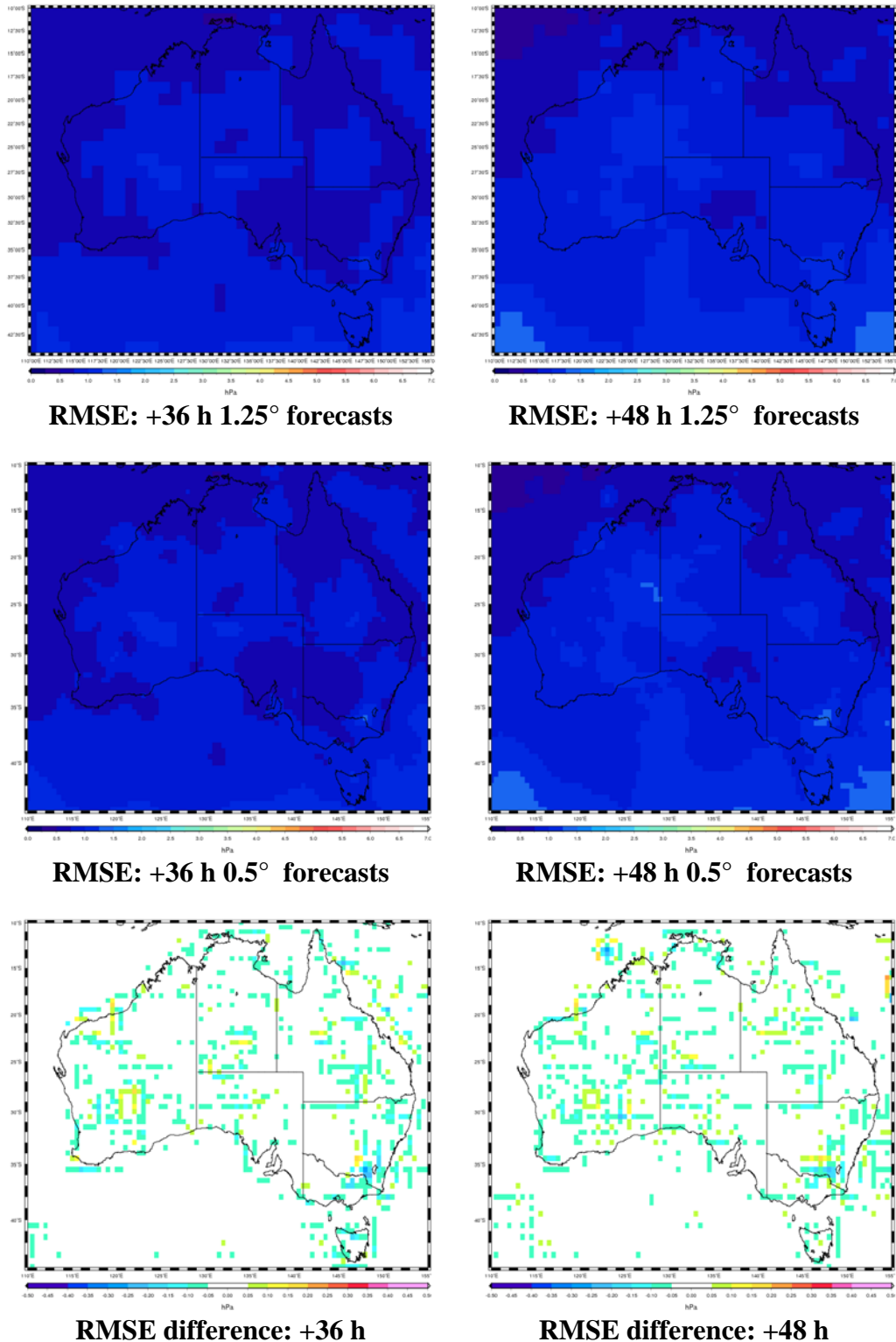
**Figure 12: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**

## Mean Sea Level Pressure: 12-24 h



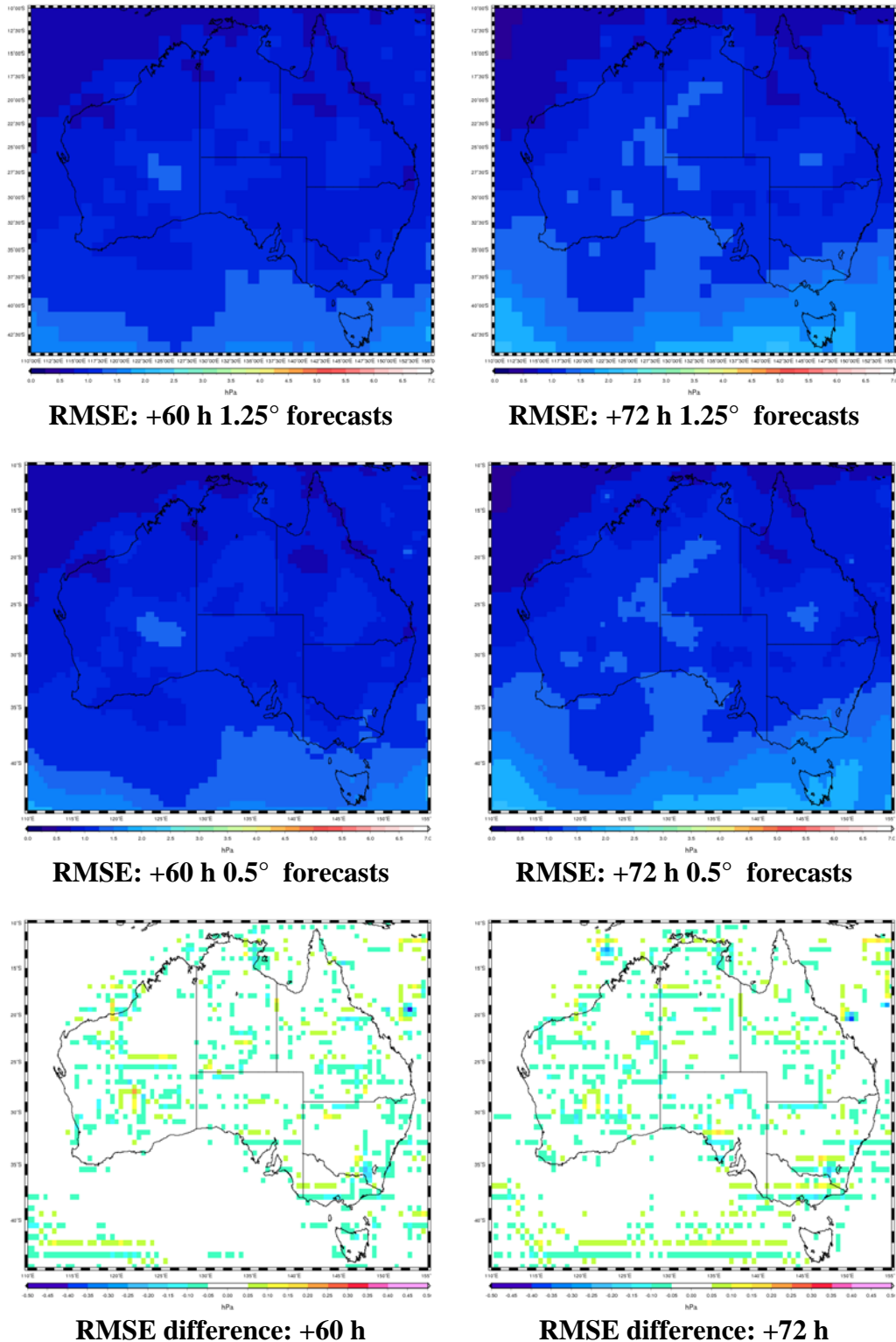
**Figure 13: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**

## Mean Sea Level Pressure: 36-48 h



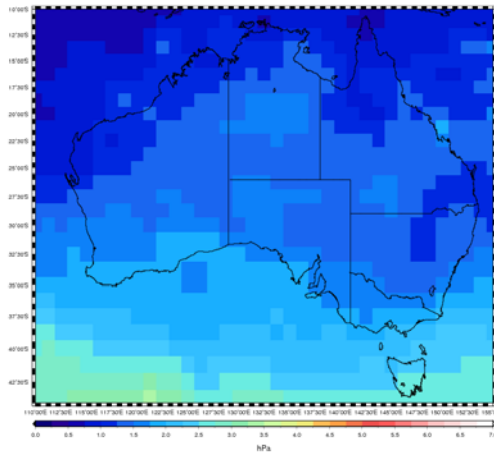
**Figure 14: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**

## Mean Sea Level Pressure: 60-72 h

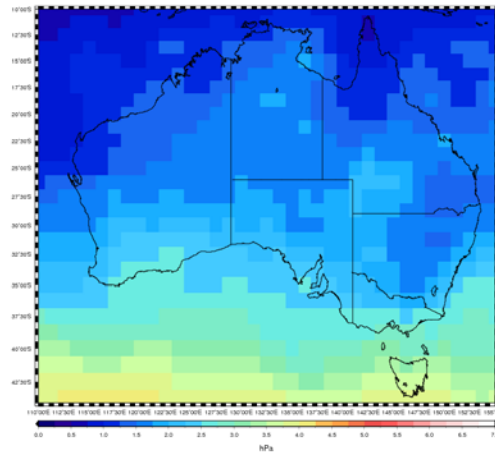


**Figure 15: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**

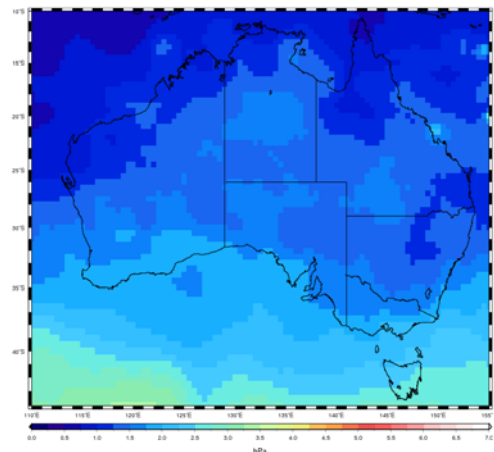
## Mean Sea Level Pressure: 96-120 h



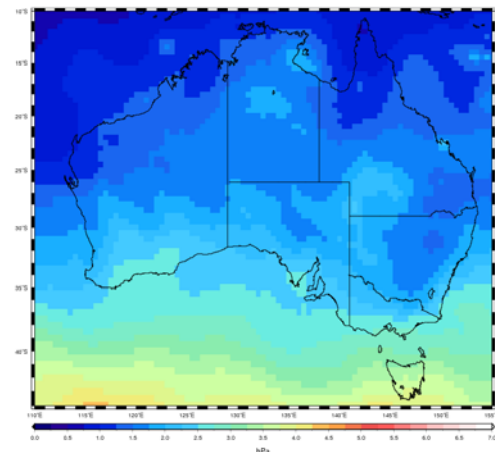
**RMSE: +96 h 1.25° forecasts**



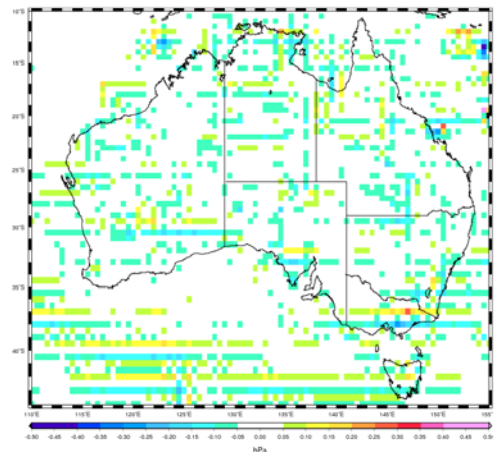
**RMSE: +120 h 1.25° forecasts**



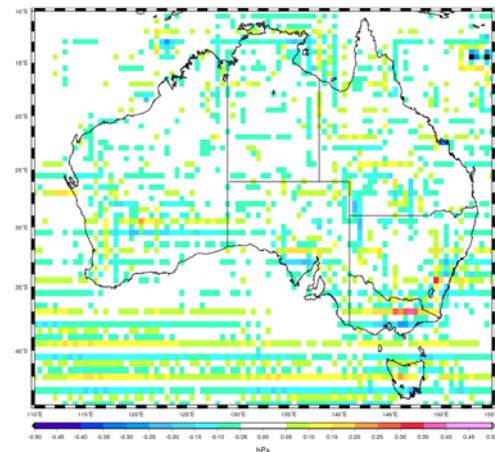
**RMSE: +96 h 0.5° forecasts**



**RMSE: +120 h 0.5° forecasts**



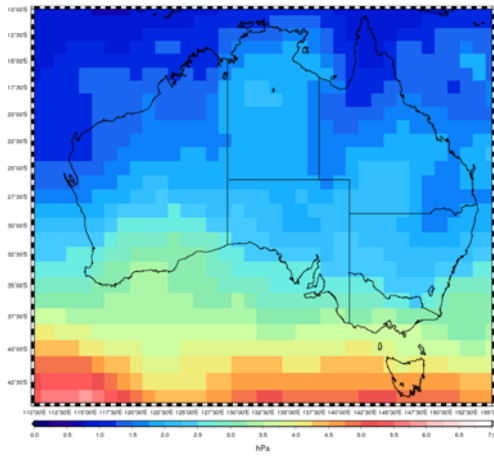
**RMSE difference: +96 h**



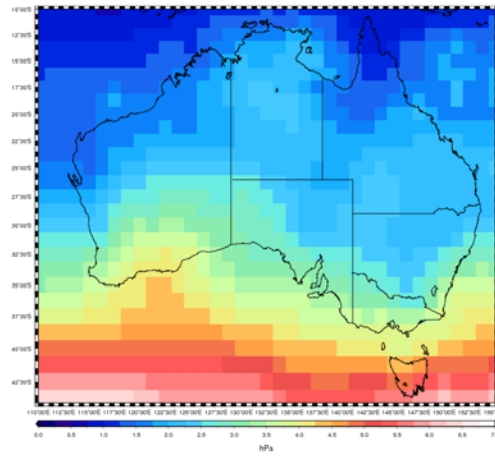
**RMSE difference: +120 h**

**Figure 16: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**

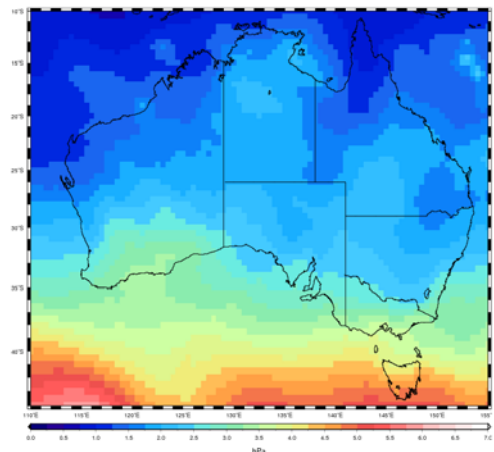
## Mean Sea Level Pressure: 144-168 h



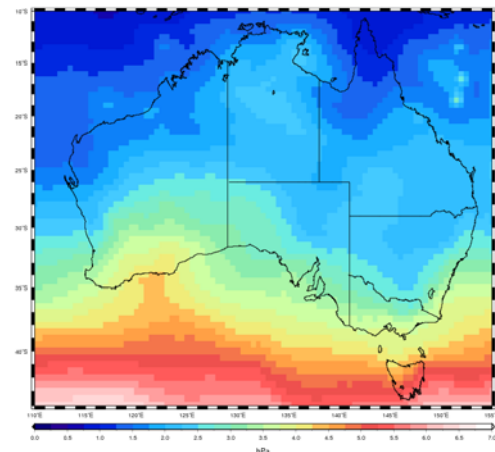
**RMSE: +144 h 1.25° forecasts**



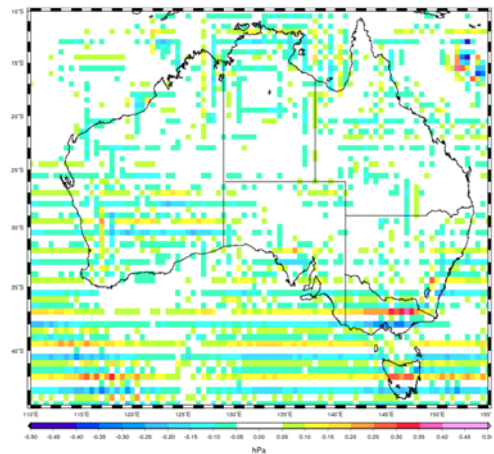
**RMSE: +168 h 1.25° forecasts**



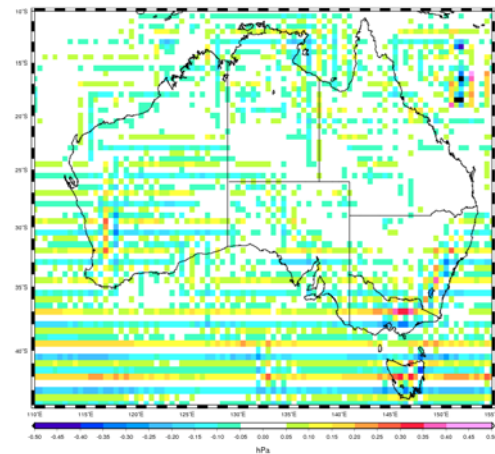
**RMSE: +144 h 0.5° forecasts**



**RMSE: +168 h 0.5° forecasts**



**RMSE difference: +144 h**



**RMSE difference: +168 h**

**Figure 17: Top Panels: RMSE of 1.25° Gridded OCF runs between 1 December 2009 and 17 March 2010. Middle Panels: As for top panel, but for the 0.5° runs. Bottom Panels: Difference in RMSE between the low and high resolution Gridded OCF runs. Positive values indicate the high resolution runs have a smaller RMSE.**



## 4.2 Verification of the higher resolution PME rainfall forecast

To check the performance of the PME rainfall forecasts, forecasts from 1 June 2010 to 15 November 2010 made using the new 0.5° grid and the old 1.0° grid were compared. In order to produce a valid comparison, the 0.5° results were first smoothed to a 1.0° grid, except in the case of maximum rainfall intensity, in which case the 0.5° system resolution was not degraded to 1.0°. The rainfall amounts and intensities, and the occurrence or non-occurrence of rainfall, produced by each forecast system were compared to the Australian rainfall analysis (Weymouth et al. 1999) produced by National Climate Centre for forecasts from 1 to 5 days ahead.

There were negligible differences in the average rain area, rain volume and average intensity forecast by the two systems. The ratio of forecast to observed (ie analysed) maximum intensity did differ between the two, as shown in Figure 18, with the new system performing better than the old. The RMS error in rainfall amount (Figure 19) is less in the 0.5° system than the earlier 1.0° system, and the correlation between forecast and observed rainfall amount higher (Figure 20). The higher resolution forecasts also produced a higher Equitable Threat Score when the occurrence/non-occurrence of rain above the threshold of 0.2mm was considered (Figure 21). These four measures are consistent in indicating that the 0.5° resolution system performs slightly better than the 1.0° system.

*Note:* the Equitable Threat Score is defined as

$$ETS = \frac{\text{hits} - \text{hits}_{\text{random}}}{\text{hits} + \text{misses} + \text{false alarms} - \text{hits}_{\text{random}}}$$

It answers the question: How well did the forecast "yes" events correspond to the observed "yes" events when hits due to chance ( $\text{hits}_{\text{random}}$ ) are accounted for? The ETS ranges from -1/3 to 1, with 0 indicating no skill and 1 a perfect forecast.

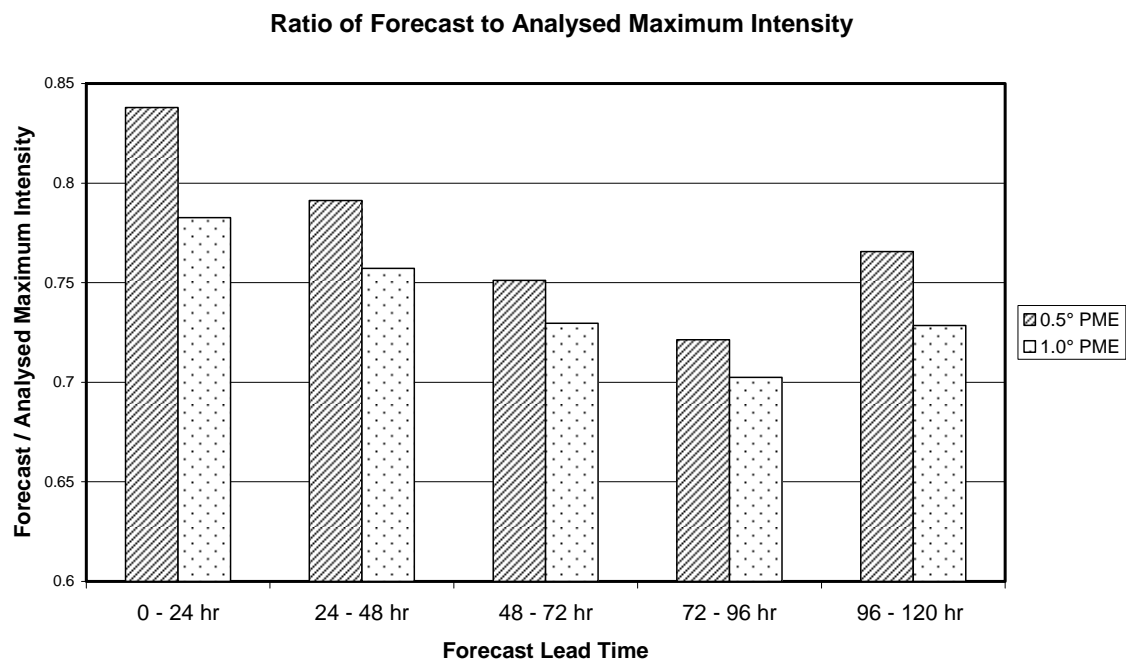


Figure 18. Ratio of Forecast Maximum Rainfall Intensity (mm/day) to the analysed value for the new (0.5°) and old (1.0°) PME operational systems over the period 1 June – 15 November 2010.

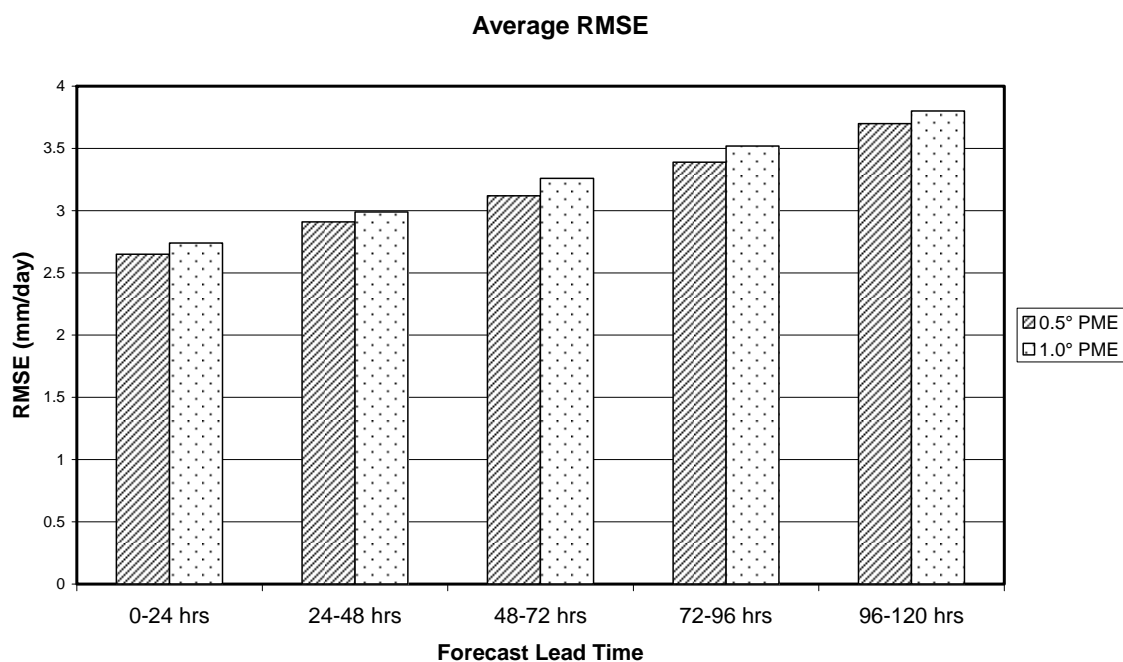


Figure 19 Average RMSE in rain amount (mm/day) forecast by the new (0.5°) and old (1.0°) PME operational systems over the period 1 June – 15 November 2010.



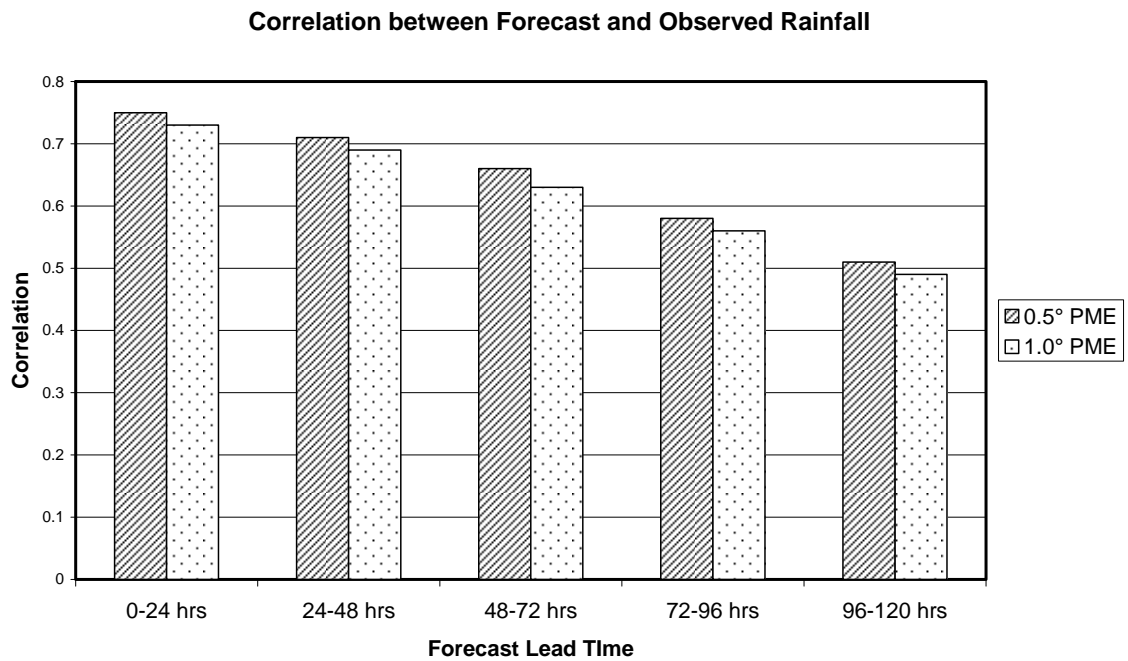


Figure 20 Average correlation between analysed values of observed rainfall and that forecast by the new (0.5°) and old (1.0°) PME operational systems over the period 1 June – 15 November 2010.

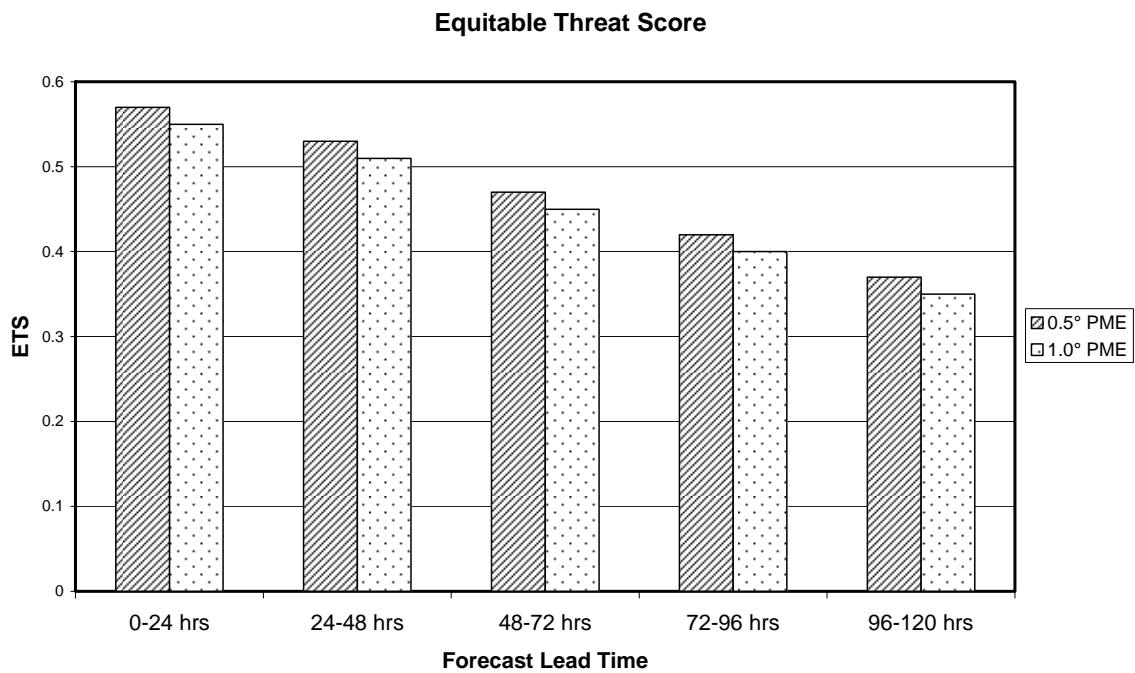


Figure 21 Average Equitable Threat Scores of the new (0.5°) and old (1.0°) PME operational systems over the period 1 June – 15 November 2010.

## 5. Output products

Currently the lores daily PME products in graphic format are delivered to external users at the WATL website <http://www.bom.gov.au/jsp/watl/rainfall/pme.jsp>. Products are available at around 08:00UTC for 00Z run and 19:50UTC for 12Z run.

**INTERNAL PRODUCT AVAILABILITY DETAILS – please refer to Appendix**

## 6. Model Names

### **ACCESS-R**

Australian Community Climate and Earth-System Simulator System - Regional domain (Australian Bureau of Meteorology)

### **ACCESS-G**

Australian Community Climate and Earth-System Simulator System - Global domain (Australian Bureau of Meteorology)

### **ECSP**

European Centre Spectral Prognosis (European Centre for Medium-Range Weather Forecasting)  
lores and hires refer to low and high resolution output, respectively

### **JMAGSM**

Japan Meteorological Agency Global Spectral Model (Japan Meteorological Agency)

### **UKGC**

United Kingdom Grid Code (United Kingdom Met Office)

### **USAVM**

United States Global Forecast System which used to be known as United States Aviation Model (National Centers for Environmental Prediction (NCEP), USA )

### **CMCGEM**

Canadian Meteorological Centre Global Environmental Multiscale model (Canadian Meteorological Centre)

### **DWD**

Deutscher Wetterdienst (German Weather Service)

## 7. Future Developments

Enhancements to the current operational configuration are expected to include:

- PME rainfall recalibration
- Gridded OCF wind speed and direction forecasts
- Replace JMAGSM with higher resolution ( $0.25^\circ$ )

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**NMOC Operations Bulletin No 74 (Operational Implementation of Gridded OCF)** – <http://www.bom.gov.au/australia/charts/bulletins/APOB74.pdf>

**NMOC Operations Bulletin No 81 (Operational Description of the Daily PME System)** – <http://www.bom.gov.au/australia/charts/bulletins/apob81.pdf>

**NMOC Operations Bulletin No 82 (Operational Implementation of the new Gridded OCF and PME suite)** – <http://www.bom.gov.au/australia/charts/bulletins/apob82.pdf>

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