In this document we do two things:

1. Respond to reviewers' comments and suggestions for minor revisions, as received on Jul 12 2016.
2. Identify improvements to the reanalysis results after rerunning the simulation. After the paper was submitted we identified there was an error in the wind forcing for approximately half of the 2-year period. The atmospheric forcing was corrected, and the model was re run. We present the improvements here. As expected, with the corrected forcing we find only small changes to the results, which are not significant to the overall presentation of the reanalysis performance. There are no significant changes to the discussion and conclusions.

***1. Changes made in response to reviewers' comments:***

*Reviewer 1 report on revised manuscript:*

*The authors have done a good job addressing my initial comments and concerns. I recommend publication subject to the following minor revisions:*

*(1) p3, line: "sensitivity of the ocean circulation" - sensitivity to what?*

We have replaced the phrase "and the minimistaion process can be used to understand the sensitivity of the ocean circulation" with "and the minimistaion process can be used to understand the sensitivity of the modelled ocean circulation to initial conditions, boundary and surface forcing, and model parameters".

*(2) p4, line 3 and 4: This sentence is still awkward. How about something like "We use ROMS to simulate the ocean circulation off the south eastern coast of Australia."*

We have replaced the awkward sentence "We use the Regional Ocean Modeling System (ROMS, version 3.4) to simulate the atmospherically-forced eddying ocean circulation in the south-eastern Australia oceanic region." with "We use the Regional Ocean Modeling System (ROMS, version 3.4) to simulate the atmospherically-forced eddying ocean circulation off the south eastern coast of Australia."

*(3) p7, line 18: Reword as "...variational calculus to solve for increments in model..."*

This has been changed accordingly.

*(4) p7, line 21: "normalized deviations" - of what?*

We have replaced the sentence "This is achieved by minimising an objective cost function, $J$, that measures normalised deviations from the observations as well as from the modelled background state (the model prior)." With "This is achieved by minimising an objective cost function, $J$, that measures normalised deviations of the

modelled ocean state from the observations as well as from the modelled background state (the model prior)."

*(5) Equations 1 and 2: In equation (1), t_{i-1} and t_i are used to denote a general time interval, while in equation (2) and beyond the notation is changed to t_0 and t_i. The use of t_i for two different times is confusing - this should be fixed. I assume that t_0 is the initial time for each data assimilation cycle? This should be stated in the text.*

This has been corrected. We thank the reviewer for this comment.

*(6) p9, lines 7-9: You imply in the text, and in your reply to the other reviewer, that because 4D-Var employs the model equations to constrain the circulation increments they are "consistent with the dynamics of the circulation." This will not generally be true for the circulation estimate at initial time, t_0. Unless dynamical balance (eg quasi-geostrophic balance) is explicitly imposed as a constraint at t_0, the initial condition increments can be quite unbalanced, leading to subsequent initialisation shocks and gravity wave generation. You should clarify this statement, or remove it.*

The increments are constrained to be a solution of the (TL) model equations. This does not imply dynamical balance of the initial conditions. We have removed this phrase.

*(7) p10, line 1: Reword as "THOSE 4 days after".*

It does not make sense to reword this phrase as so. We have clarified what we mean here by replacing, "We overlap the 5-day assimilation windows by one-day , such that the initial conditions for the subsequent assimilation window are 4 days after the start of the current window." with "We overlap the 5-day assimilation windows by one-day, such that each subsequent assimilation cycle is initialised 4 days after the start of the previous 5-day cycle."

*(8) p17, line 21: It is stated here that gamma>1 represents an under-estimate of the error covariances, while gamma<1 represents an over-estimate of the error covariances. This is not true in general. It would appear to be so for a system with one observations and a single grid point, but it is not possible to make such a unique claim about the background and observation error covariances based on the ratio of the cost function to its theoretical value for large dimensional systems. This statement should be removed. I suggest that you consult excellent discussions in the published literature of J vs Nobs/2 by Talagrand, Bennett and others to clarify this point.*

This statement has been removed.

*(9) p22, lines 26 and 27: To say that the system has been "rigorously tuned" through a "careful specification of the prior observation and model background uncertainties" is a big stretch and an overstatement. The covariances R and P are not even likely to be even remotely correct (i.e. you have assumed isotropic, homogeneous, univariate statistics for P, and uncorrelated errors for R). It is very likely that the background error statistics will be highly isotropic and non-homogeneous, and multivariate for the complicated flows that exist in this region. Furthermore,*

*satellite observation errors will be correlated so R will not be a diagonal matrix. You need to tone down this sentence - you are doing well, but probably not because you have nailed down the error statistics correctly as you imply here.*

We have replaced this phrase with “Overall, the prior assumptions of observation and model background uncertainties are considered reasonable and the assimilation achieves reduced analysis uncertainty by reduction of the cost function for each assimilation interval.”

*(10) p22, line 28: Change "match with" to "fit to"*

Changed

*(11) p22, line 32: Reword as "WIDE variety"*

Changed

***2. Changes made due to analysis of new simulation with forcing correction made:***

Abstract:

SSH mean spatially-averaged RMS residuals with observations, changed from 7cm to 7.6cm in the text (in fact the SSH mean spatially-averaged RMS residuals with observations changed from 7.4cm in the previous simulation to 7.6cm in the new corrected simulation, so rather than rounding up to 8cm we write 7.6cm in the abstract and conclusions).

Time-mean Argo maximum RMS residual for subsurface temperature, changed from 1C to 0.9C

Figure 4 has been updated, but the changes are not significant

Previous version:

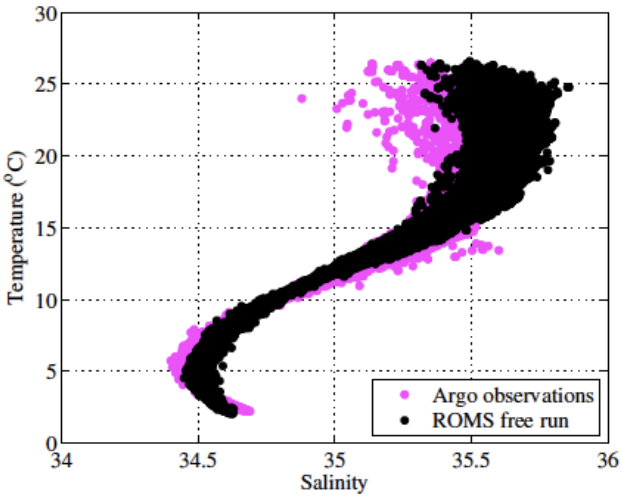



**Figure 4.** Temperature-Salinity diagram for the Argo observations and corresponding values from the 2yr free run for 2012-2013.

Updated version:

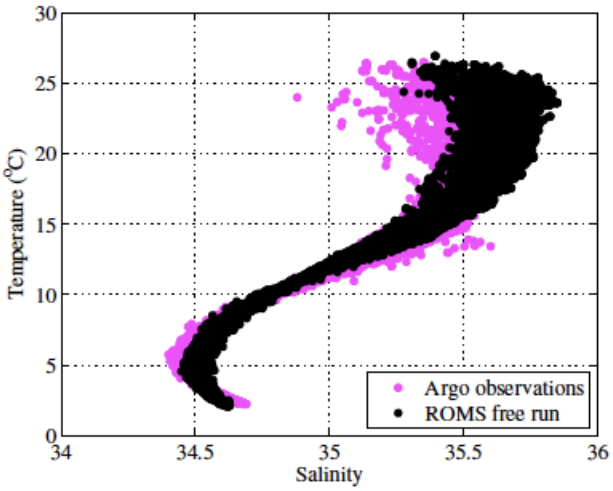



**Figure 4.** Temperature-Salinity diagram for the Argo observations and corresponding values from the 2yr free run for 2012-2013.

Page 17, line 7
SSH diagnosed errors, 4.1-8.6cm with a mean of 5.7cm changed to 4.1-8.4cm with a mean of 5.8cm
line 11
Subsurface temperature diagnosed errors, 0.50C changed to 0.48C
line 15
Radial diagnosed errors, 12m/s changed to 11m/s
lines 22-23

Optimality range from 0.44-1.66 with a mean of 0.84 changed to 0.43-1.72 with a mean of 0.81

Page 17, last line, page 18, line 1
NLM J reduction changed from 54% to 52%
Figure 8 has been updated, but the changes are not significant

Previous version:

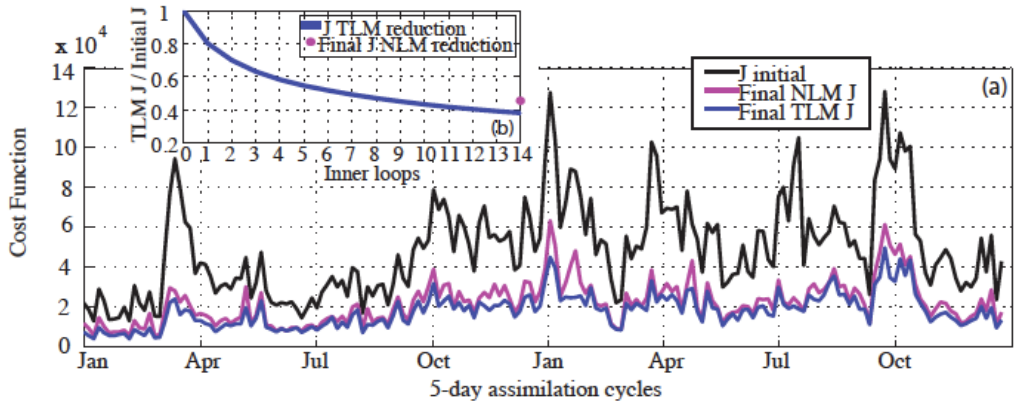



**Figure 8.** Initial nonlinear cost function and the reduction achieved in the final (14th) tangent linear model *inner loop* and the final nonlinear cost function, plotted for each assimilation interval, (a). Mean cost function reduction for each of the 14 *inner loops* for all 5-day assimilation intervals, (b).

Updated version:

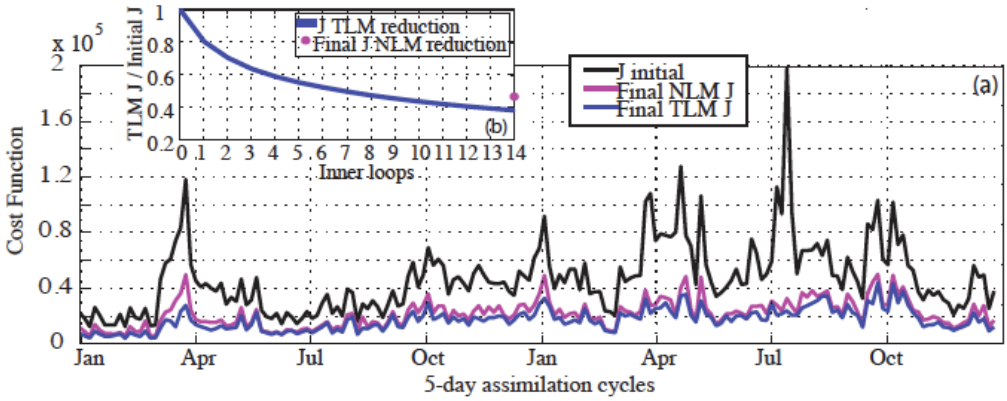



**Figure 8.** Initial nonlinear cost function and the reduction achieved in the final (14th) tangent linear model *inner loop* and the final nonlinear cost function, plotted for each assimilation interval, (a). Mean cost function reduction for each of the 14 *inner loops* for all 5-day assimilation intervals, (b).

Page 19 line 1
Time-mean spatially-averaged RMSD analysis – obs for SSH, 7.4cm changed to 7.6cm
Figure 9 has been updated, but the changes are not significant

Previous version:

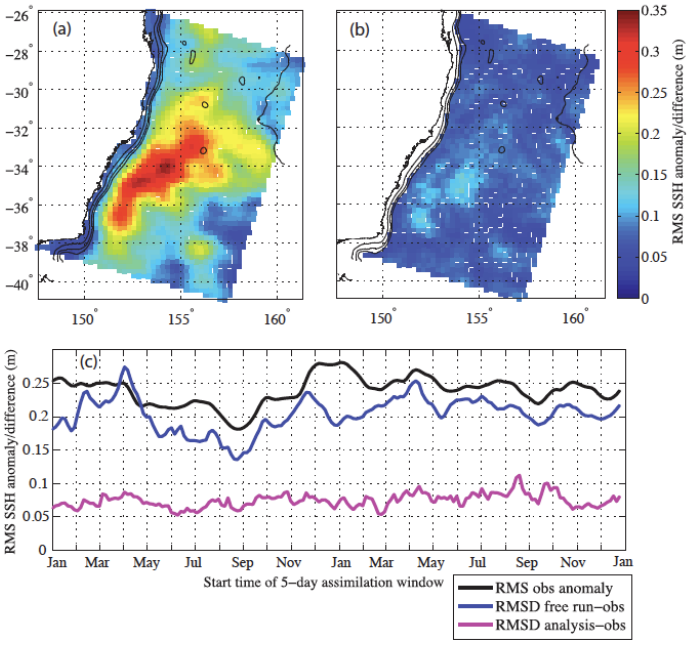



**Figure 9.** RMS SSH observation anomaly (a) and RMS SSH difference between the analysis and observations (b) for the 2-year assimilation window. Time-series of spatially-averaged RMS SSH observation anomaly, RMS SSH difference between the free run and observations, and RMS SSH difference between the analysis and observations, for each assimilation window (c).

Updated version:

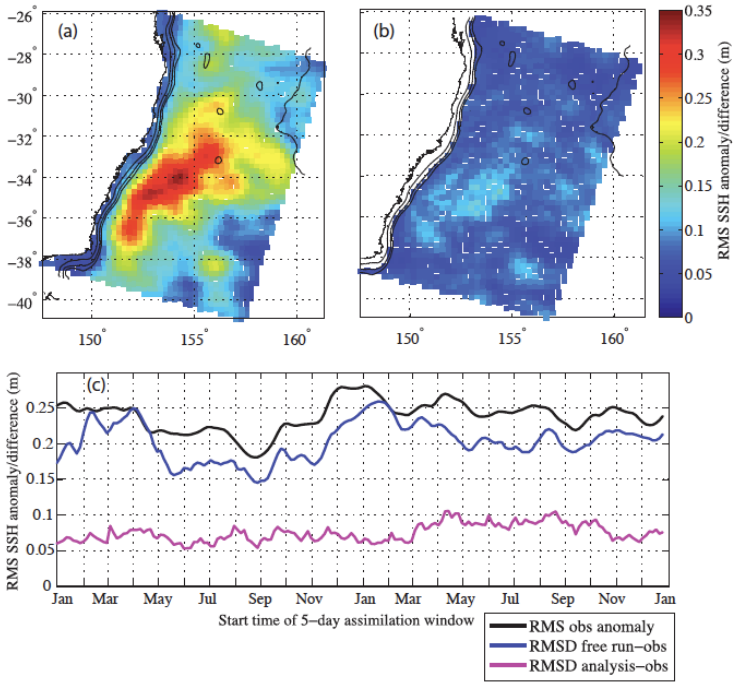



**Figure 9.** RMS SSH observation anomaly (a) and RMS SSH difference between the analysis and observations (b) for the 2-year assimilation window. Time-series of spatially-averaged RMS SSH observation anomaly, RMS SSH difference between the free run and observations, and RMS SSH difference between the analysis and observations, for each assimilation window (c).

Figure 10 has been updated, but the changes are not significant, no change to text for SST or SSS

Previous version:

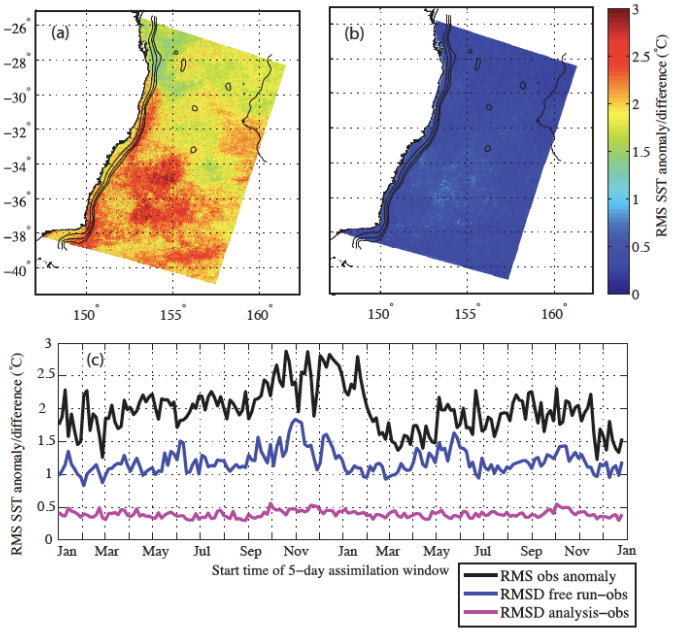



**Figure 10.** RMS SST observation anomaly, including seasonal cycle, (a) and RMS SST difference between the analysis and observations (b) for the 2-year assimilation window. Time-series of spatially-averaged RMS SST observation anomaly, RMS SSH difference between the free run and observations, and RMS SSH difference between the analysis and observations, for each assimilation window (c).

Updated version:

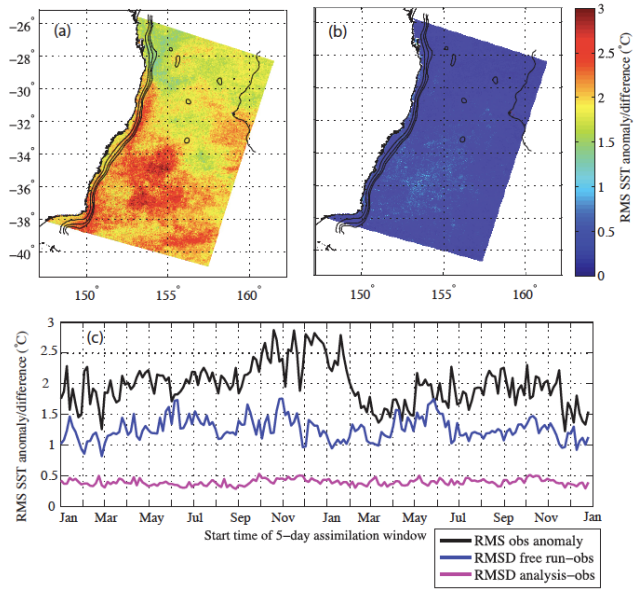



**Figure 10.** RMS SST observation anomaly, including seasonal cycle, (a) and RMS SST difference between the analysis and observations (b) for the 2-year assimilation window. Time-series of spatially-averaged RMS SST observation anomaly, RMS SSH difference between the free run and observations, and RMS SSH difference between the analysis and observations, for each assimilation window (c).

Page 19, line 30
Argo free run error and analysis error in upper 500m, ‘1.6C reduced to 0.8C’ changed to ‘1.7C reduced to 0.8C’
line 31
XBT free run error and analysis error in upper 500m, ‘reduced to 1.2C from 2.0C’ changed to ‘reduced to 0.7C from 1.9C’
Page 20, line 3
Glider free run error and analysis error in upper 100m, ‘1.9 reduced to 0.9’ changed to ‘2.1 reduced to 0.7’

Page 20, lines 13-20
This paragraph has been updated, as there is now a more significant bias between the free run and the glider observations in the upper 100m. This is corrected for in the assimilation, so the reduction in RMSD in the analysis is due to both bias reduction and improved representation of dynamical features. Specifically, we have replaced this paragraph:

“The vast majority of glider observations are taken on the continental shelf in water depths less than 100m. For these shallow observations, the bias between the free run and the observations is small, the $RMSD_{Freerun-Obs}$ and the RMSD between the free run and the ‘bias adjusted observations’ match closely, and the RMSD reduction in the analysis represents improved representation of the dynamical features. The glider observations below 100m represent only 2 separate glider missions (refer to Section 3.4.9), so the bias has little meaning.”

with

“The vast majority of glider observations are taken on the continental shelf in water depths less than 100m. For these shallow glider observations, the bias between the free run and the observations is approximately 1.5C (not shown). The bias in the analysis is close to zero and this reduction in bias contributes to the reduction in the $RMSD_{Analysis-Obs}$ compared to the free run (the RMSD between the free run and the ‘bias adjusted observations’ (grey dashed line) is less than the $RMSD_{Freerun-Obs}$ (blue line)). There is further reduction in the $RMSD_{Anslysis-Obs}$ (magenta line) compared to the RMSD between the free run and the ‘bias adjusted observations’ (grey dashed line) indicating improved representation of dynamical features. It should be noted that the glider observations below 100m represent only 2 separate glider missions (refer to Section 3.4.9), so the bias has little meaning over this depth range.”

Figure 11 has been updated, with the main significant change being for the gliders (right panel)

Previous version:

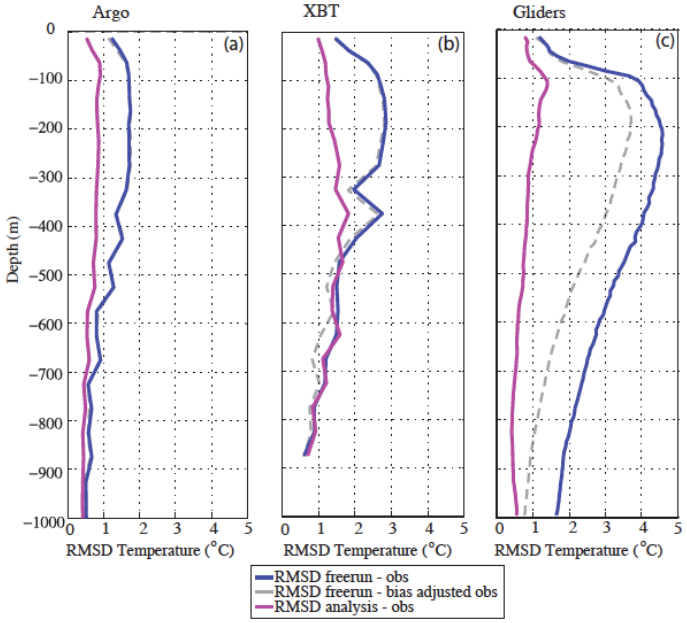



**Figure 11.** RMS difference between the free run and observations, the free run and the bias adjusted observations, and the analysis and observations for Argo (a), XBT (b) and Glider (c) observations in nominal depth bins for the 2-year assimilation window. Argo and XBT depth bins are 25m from the surface to 200m and 50m below 200m, Glider bins are 10m throughout the water column.

Updated version:

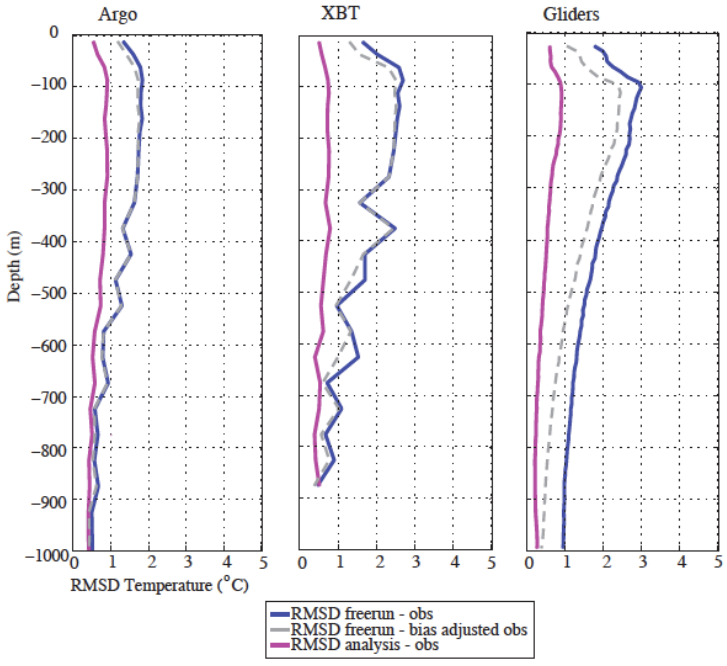



**Figure 11.** RMS difference between the free run and observations, the free run and the bias adjusted observations, and the analysis and observations for Argo (a), XBT (b) and Glider (c) observations in nominal depth bins for the 2-year assimilation window. Argo and XBT depth bins are 25m from the surface to 200m and 50m below 200m, Glider bins are 10m throughout the water column.

Page 20, line 26
RMSD analysis –obs for Argo potential density peaks at 0.24kg/m3, changed to 0.23kg/m3

Figure 12 has been updated, but the changes are not significant

Previous version:

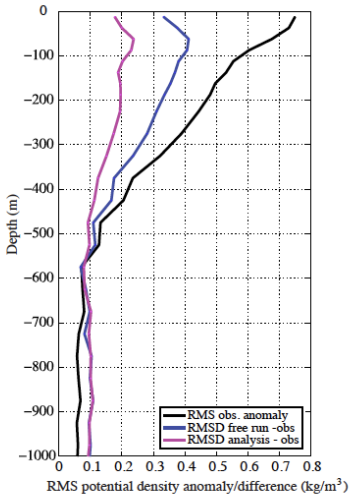



**Figure 12.** RMS potential density observation anomaly and RMS difference between the free run and observations, and the analysis and observations for Argo float observations. Observations are grouped into nominal depth bins of 25m from the surface to 200m and 50m below 200m.

Updated version:

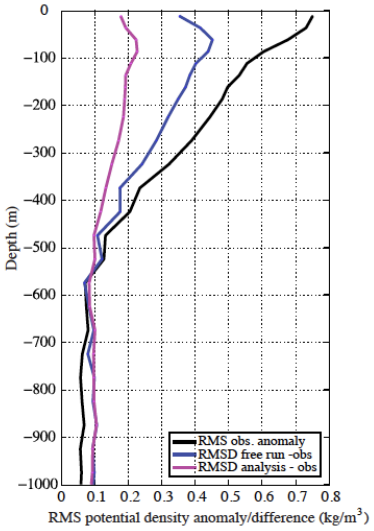



**Figure 12.** RMS potential density observation anomaly and RMS difference between the free run and observations, and the analysis and observations for Argo float observations. Observations are grouped into nominal depth bins of 25m from the surface to 200m and 50m below 200m.

Page 21, line 4-5
Depth-averaged complex correlations for
CH100, 0.69 and 0.91 changed to 0.68 and 0.91
SYD100, 0.5 and 0.83 changed to 0.37 and 0.84
SYD140, 0.48 and 0.87 changed to 0.36 and 0.87

Figure 13 has been updated, but the changes are not significant

Previous version:

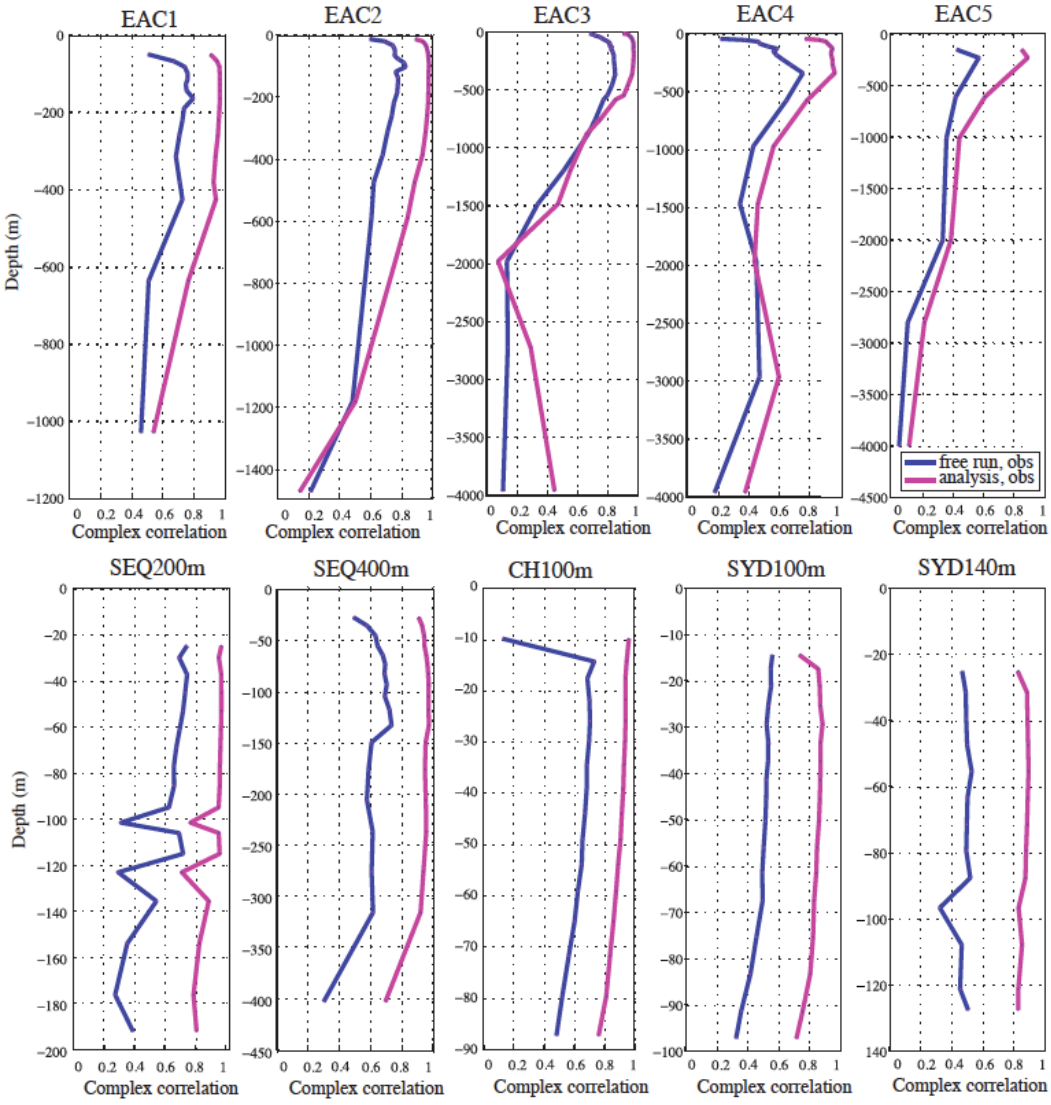
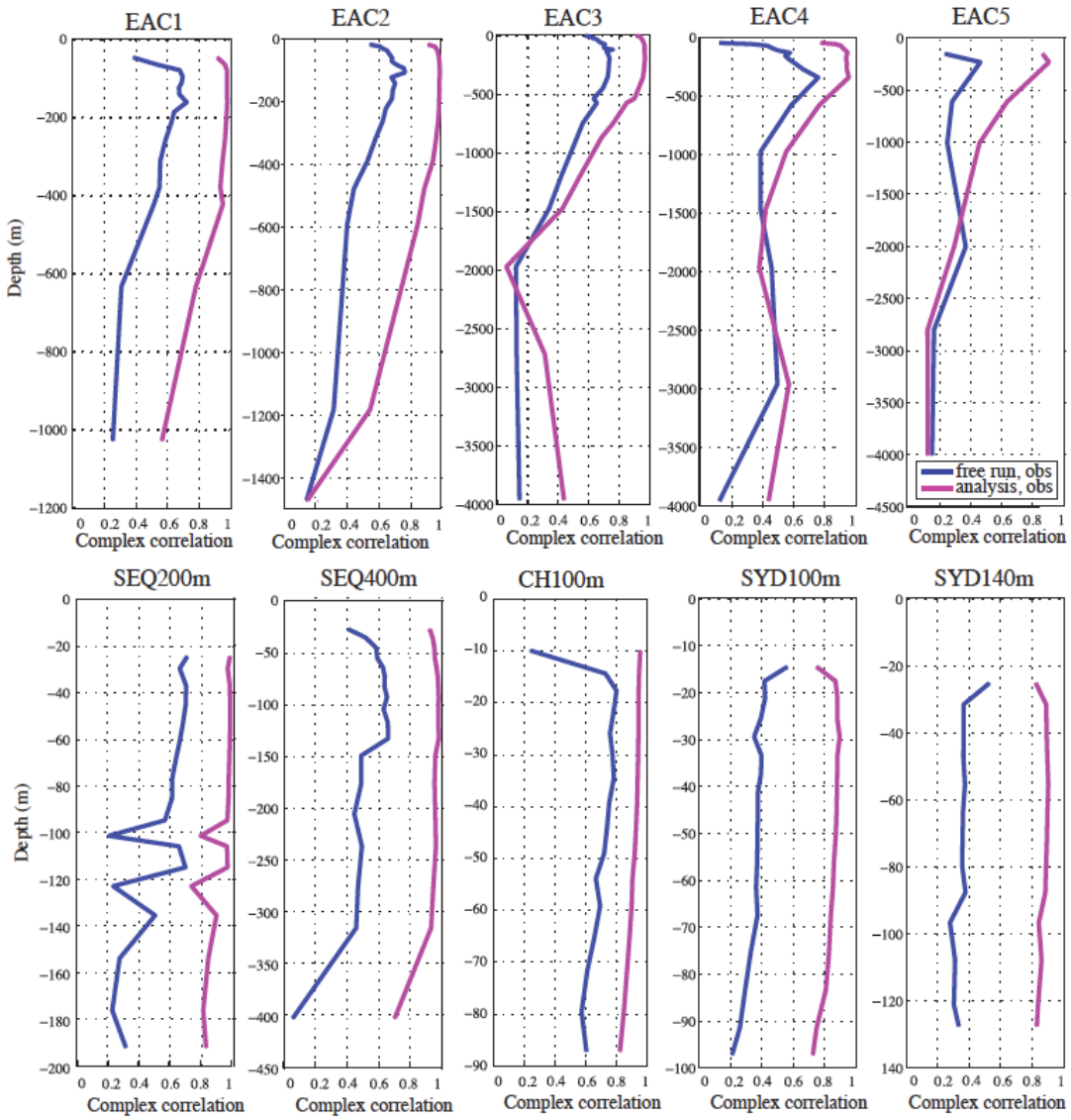



**Figure 13.** Complex correlation between observed velocities and free run and analysis velocities at mooring locations.

Updated version:




Page 21, lines 18-22
For the radial current speeds, RMSD free run - obs
inside the 200m contour , 0.2-0.4m/s changed to 0.1-0.4m/s
between 200-2000m contour, 0.4-0.7m/s changed to 0.2-0.6m/s
offshore of 2000m contour , 0.4-0.5m/s changed to 0.3-0.5m/s

RMSD analysis – obs, 0.1-0.25m/s, unchanged

Ratio of RMSD/ RMS obs anomaly
Free run, 0.6-1 changed to 0.5-1

Analysis, 0.2-0.4 changed to 0.2-0.5

Figure 14 has been updated. The complex correlations between the free run and the observations are higher that in the previous simulation (left panel).

Previous version:

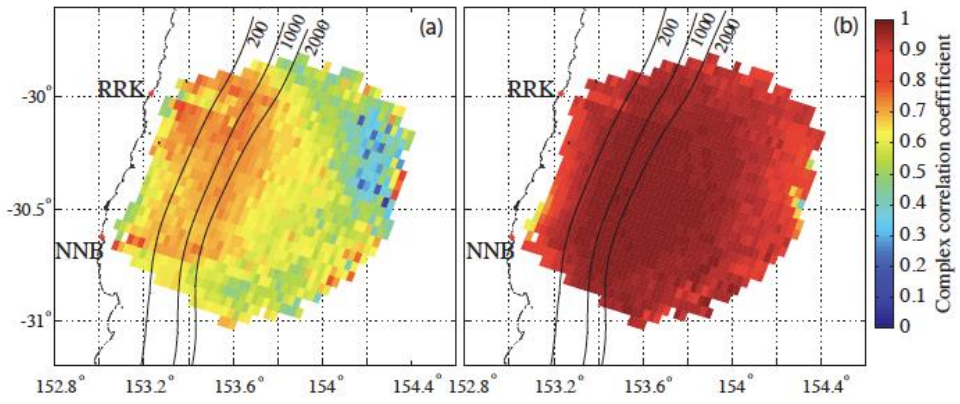



**Figure 14.** Complex correlation of surface velocities computed from the assimilated HF radar radials, and surface velocities computed from the corresponding free run (a) and analysis (b) radials. 200m, 1000m and 2000m bathymetry contours are shown.

Updated version:

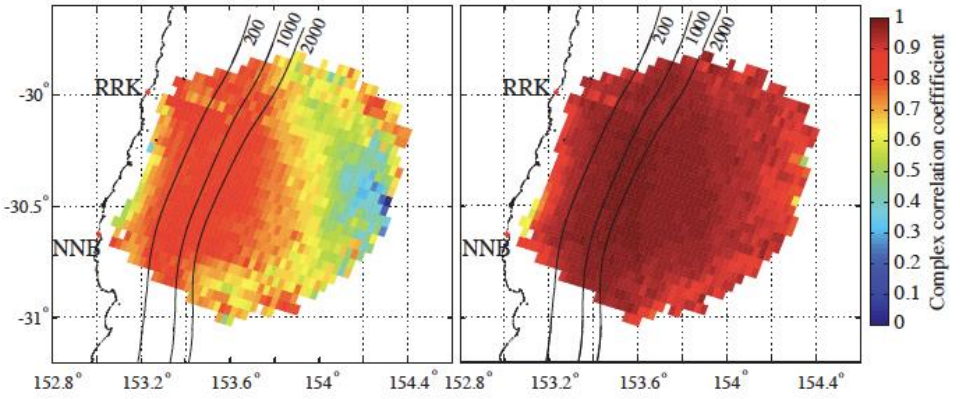



**Figure 14.** Complex correlation of surface velocities computed from the assimilated HF radar radials, and surface velocities computed from the corresponding free run (a) and analysis (b) radials. 200m, 1000m and 2000m bathymetry contours are shown.

Page 21, line 7
RMSD free run – obs of '0.35kg/m3 is reduced to 0.18kg/m3', changed to, '0.33kg/m3 reduced to 0.17kg/m3'

Figure 15 has been updated, but the changes are not significant. Note the depth binning was also changed from 20m in the upper 200m, to 50m everywhere, for a smoother curve.

Previous version:

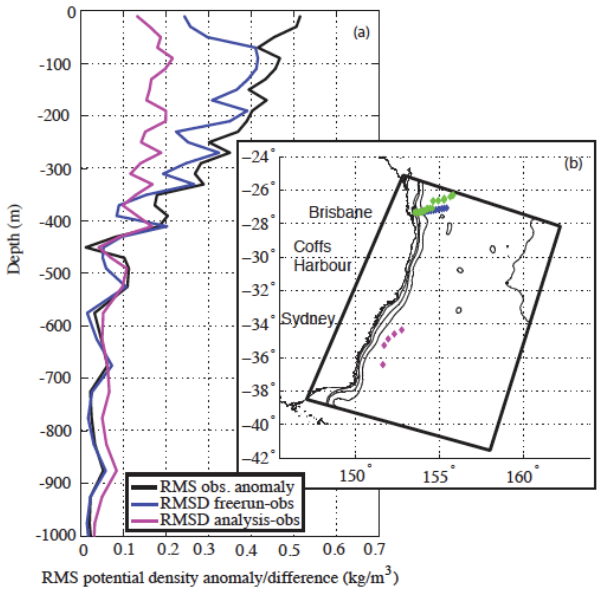



**Figure 15.** RMS potential density observation anomaly and RMS difference between the free run and observations, and the analysis and observations for independent CTD cast observations mapped to model vertical levels, (a). Observations are grouped into nominal depth bins of 20m from the surface to 500m depth and 50m below 500m. Locations of the CTD casts for the three separate cruises, described in Section 4.4, are shown in (b).

Updated version:

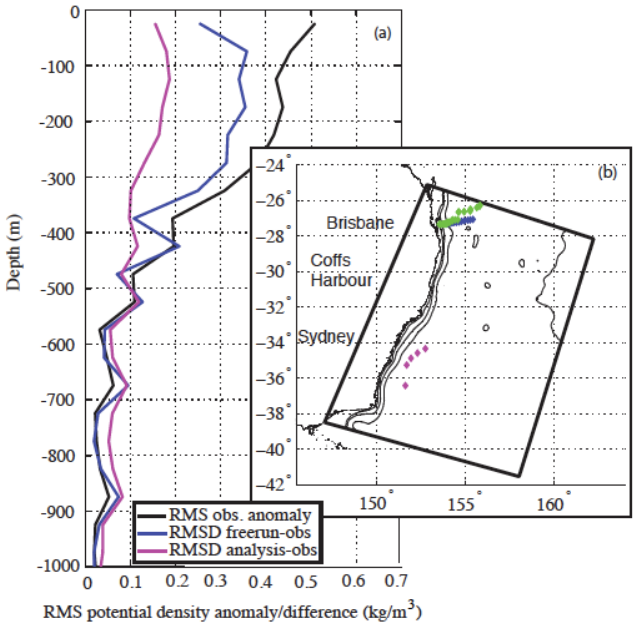



**Figure 15.** RMS potential density observation anomaly and RMS difference between the free run and observations, and the analysis and observations for independent CTD cast observations mapped to model vertical levels, (a). Observations are grouped into nominal depth bins of 50m. Locations of the CTD casts for the three separate cruises, described in Section 4.4, are shown in (b).

Page 22 line 20 - Conclusions
Changed 7cm to 7.6cm for SSH, as per abstract
Changed “The RMS residual profile for temperature has a subsurface maximum of 1C for Argo float observations, 1.4C for ocean glider observations and 1.7C for XBT observations.”
To
“The RMS residual profile for temperature has a subsurface maximum of 0.9C for Argo float observations, 0.9C for ocean glider observations and 0.8C for XBT observations.”