Response to Reviewer #1

General comment: Globally, the paper is well written and structured. It is worth for publication, but minor revisions should be considered. For example, there are some results that are not shown in the paper (you mention these), but for the readers they do not know what it is. It could be better if these results can be shown more specifically.

We would like to thank Reviewer #1 for the positive feedback and constructive comments. We provided our responses (R, in blue) to each of the reviewer's comments (C, in black) below:

C1: 144 – 145: "temporal disaggregation is applied to CHIRP precipitation …". We know that precipitation is not a continuous variable. Disaggregation can lead to some unexpected errors. So why not using the satellite precipitation data that are sub-daily scale?

R1: We agree with Reviewer #1 that using sub-daily data should be ideal in our case. However, by the time we performed our analysis, only 0.05° global precipitation data (from CHIRPS) were available to us. As such, we used CHIRPS data and adopted the same temporal disaggregation as the previous research (e.g., McNally et al., 2017). Despite a possible additional precipitation uncertainty, using the disaggregated CHIRPS data in our development leads to an improved result. The 0.05° sub-daily global precipitation data can be used in the model simulation when they are available.

C2: 166 - 167: The temporal mean value of model simulated TWS is used to convert ΔTWS into absolute TWS. This could be accepted, but you use the period of 2003 to 2012. Why not use the whole simulation period? Because your simulation period is from 1981 to 2012.

R2: Reviewer #1 is correct that the model simulation (open-loop) is from 1981 to 2012. However, GRACE data are only assimilated between 2003 and 2012 due to their availability. The long-term mean value of 2003-2012 is used associated with the GRACE DA period. We reported the GRACE DA period in lines 381 – 383 of the submitted manuscript:

GRACE observations are assimilated into the CABLE 0.5° and CABLE 0.05° models (called GRACE DA 0.5° and GRACE DA 0.05°, respectively) between January 2003 and December 2012 (due to the availability of meteorological forcing and GRACE data).

To clarify this further, we will also add a description of the GRACE DA period in Sect. 2.3:

In this study, GRACE data are assimilated into CABLE between January 2003 and December 2012 (due to GRACE data availability).

C3: 301: What is the point of the phase estimates? Could you explain it more specifically?

R3: In this section, the phase estimate is used to demonstrate the spatial details of our model simulation. The phase shows more details than the amplitude, and we believe that showing both provides readers extra information on the improved spatial detail. The phase exhibits the timing when TWS reaches the maximum value (with respect to the beginning of the year). It illustrates the wet period of the year. For clarity, we will add the description of the phase estimate in Fig. 5's caption:

Figure 5: Annual amplitude (top) and phase (bottom) of the TWS estimates computed from CABLE 0.5° (a, c) and CABLE 0.05° (b, d). The insets in (a) and (b) show details in southeast Australia. The phase exhibits the timing when TWS reaches the maximum value (with respect to the beginning of the year). The unit of the phase is a calendar month, e.g., January (J), December (D).

C4: 307 – 308: For CABLE 0.5, the correlation length (CL) of August is the smallest. The CL of June is higher than that of seven months. For CABLE 0.05, the CL of May is the smallest but is not that small. Besides, the CLs of June and July is approximately equal to that of January and February. How to explain these?

R4: We thank Reviewer #1 for addressing this. Please note that the correlation length is computed across Australia, where the timing of wet/dry periods of TWS in different regions may also affect the correlation length estimates. Our analysis mainly relies on TWS variations in Northern and Southern regions, which are the most significant. Different spatial features of CABLE 0.5° and CABLE 0.05° model parameters may also play a role in the TWS spatial distribution. However, the overall temporal can be described as follows:

Wet and dry conditions lead to smoother (i.e., more uniform) spatial features, resulting in a larger correlation length. In wet seasons, an aquifer is slowly recharged and filled after several weeks (or months) of rainfall. This explains why the approximate peaks are observed around Feb-Mar and Sep-Oct. At the beginning of the wet season, scattered rainfall in part of the continent likely causes a gradient between dry/wet areas, resulting in a smaller correlation length (i.e., the spatial distribution is not as smooth as the very wet/dry case). The same is also observed at the end of wet or beginning of the dry season, e.g., May. Both Northern and Southern Australia are relatively dry in June, resulting in a larger correlation length.

For clarity, we will modify our explanation as follows:

…Larger correlation lengths are found during the rainy seasons (Jan – Apr in the North and Aug – Nov in the South) and during the dry season (e.g., Jun). Soil and aquifer storage increase during the wet seasons, leading to more uniform (and smoother) spatial moisture features. Similar uniformity can also be observed during the dry season. At the beginning of the wet season, scattered rainfall in part of the continent likely causes a gradient between dry/wet areas, resulting in smaller correlation lengths. It is noteworthy that our analysis only explains the overall temporal pattern of continental correlation lengths. The temporal pattern may also be affected by the local TWS wet/dry features or by the spatial distribution of model parameters.

C5: 385 – 386: It is not surprised to obtain this result because you add the information of GRACE into the model. More information will lead to more similarities.

R5: Reviewer #1 is perfectly correct.

C6: 399: "You state that the GWS is the primary driver of the TWS trend in Line 321. However, the result show that the SMS is a major contributor of TWS. Could you explain it?

R6: Reviewer #1 is correct. The trend of TWS is mainly governed by GWS (line 321). However, the annual amplitude of TWS is dominated by SMS. To clarify this, we will modify the statement in Sect. 4.2 to:

… The contribution is calculated as a percent of the annual amplitude of TWS fluctuations. In CABLE 0.05° (Fig. 13a), the SMS is a major contributor to more than 90% of the TWS variation (i.e., annual amplitude). …

C7: 399 – 400: The GRACE mostly shows or indicates the changes of groundwater, so it is apparent to have this result.

R7: We thank Reviewer #1 for the suggestion. The results are shown in Fig. S1 (below figure):

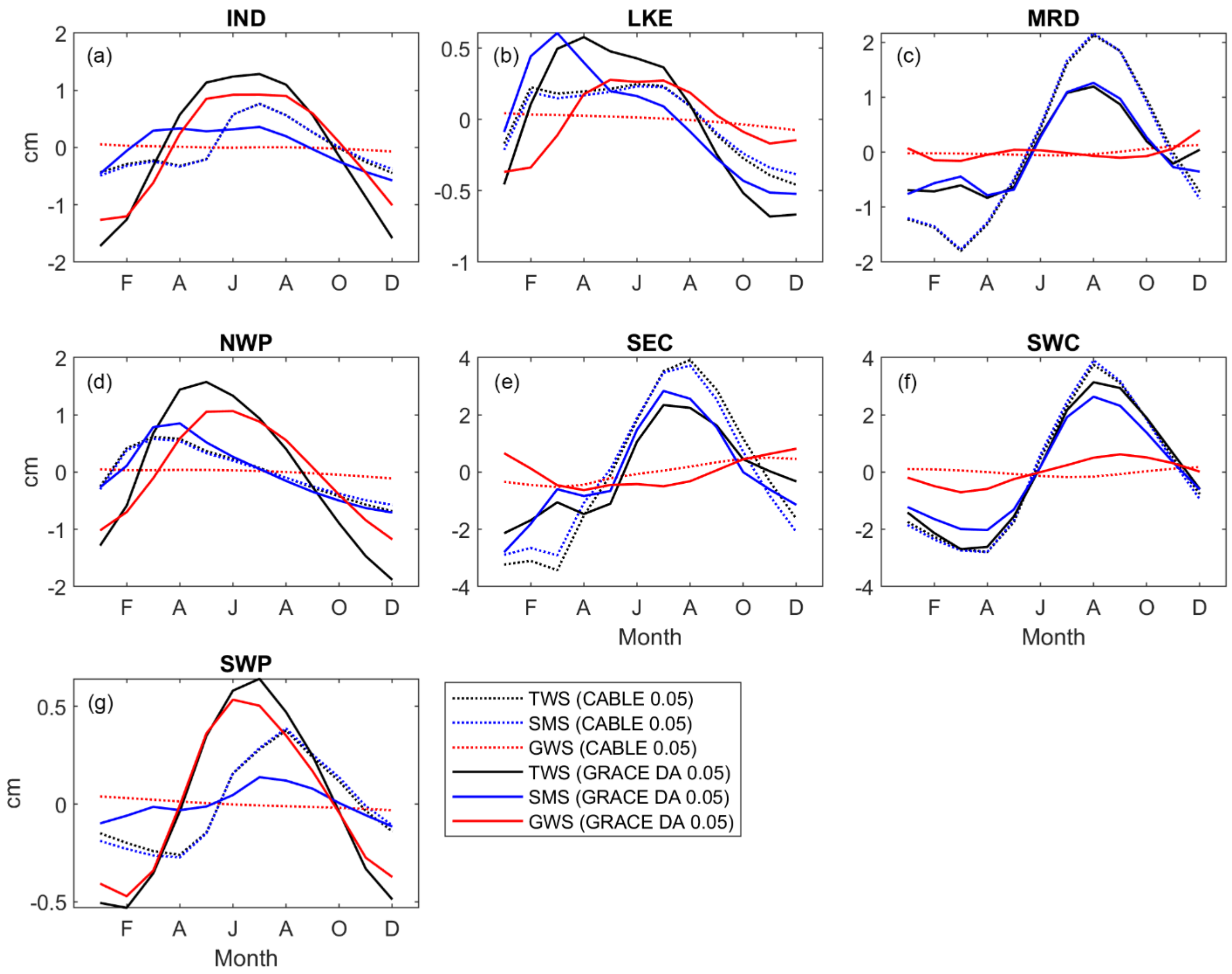


Fig. S1: Monthly basin averaged TWS, SMS, and GWS variations from CABLE 0.05° and GRACE DA 0.05°.

However, we found that Fig. S1 might be redundant to Fig. 13 (TWS contribution in the main text). As readers can also access this report, we decide to show only Fig. 13 in the paper to avoid redundancy.

C8: 428: A positive value means the former (vertical) is better than the latter (horizontal), right? So the negative value (-0.1) implies that CABLE 0.05 (OL) has a lower correlation than the GRACE DA 0.5 (DA), if I understand it correctly.

R8: We highly appreciate Review #1 for pointing this out. We accidentally switched the order between GRACE DA 0.5° and CABLE 0.05° here. We will correct the error as follows:

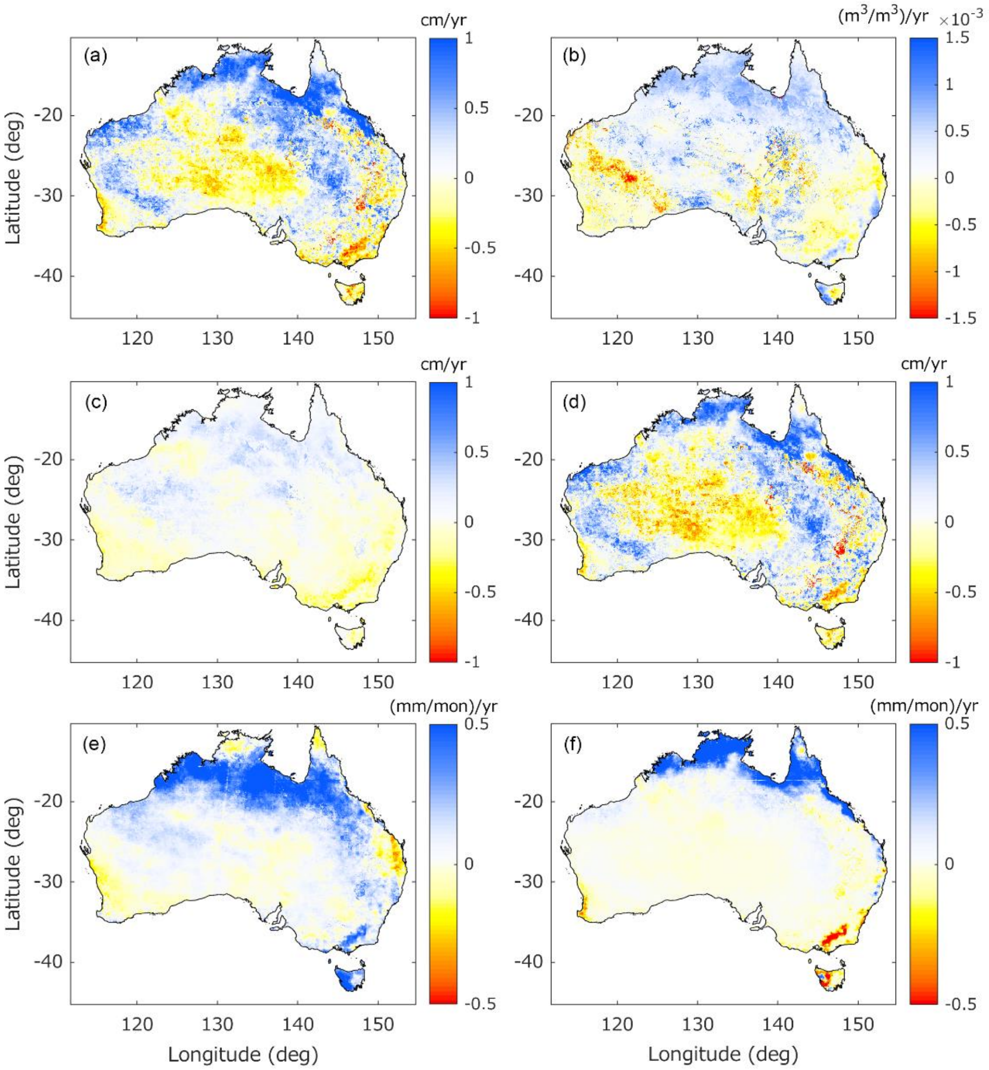
… we find that the GRACE DA 0.5° (DA) shows a higher correlation value than the CABLE 0.05° (OL) by 0.1 (see Fig. 14d3). This indicates that improving model state estimates via DA is more effective than improving model parameters via increased resolution.

C9: 780: Should it be Fig. 14?

R9: We again greatly thank Reviewer #1 for the correction. The typo will be corrected to Fig. 14 (a-c).

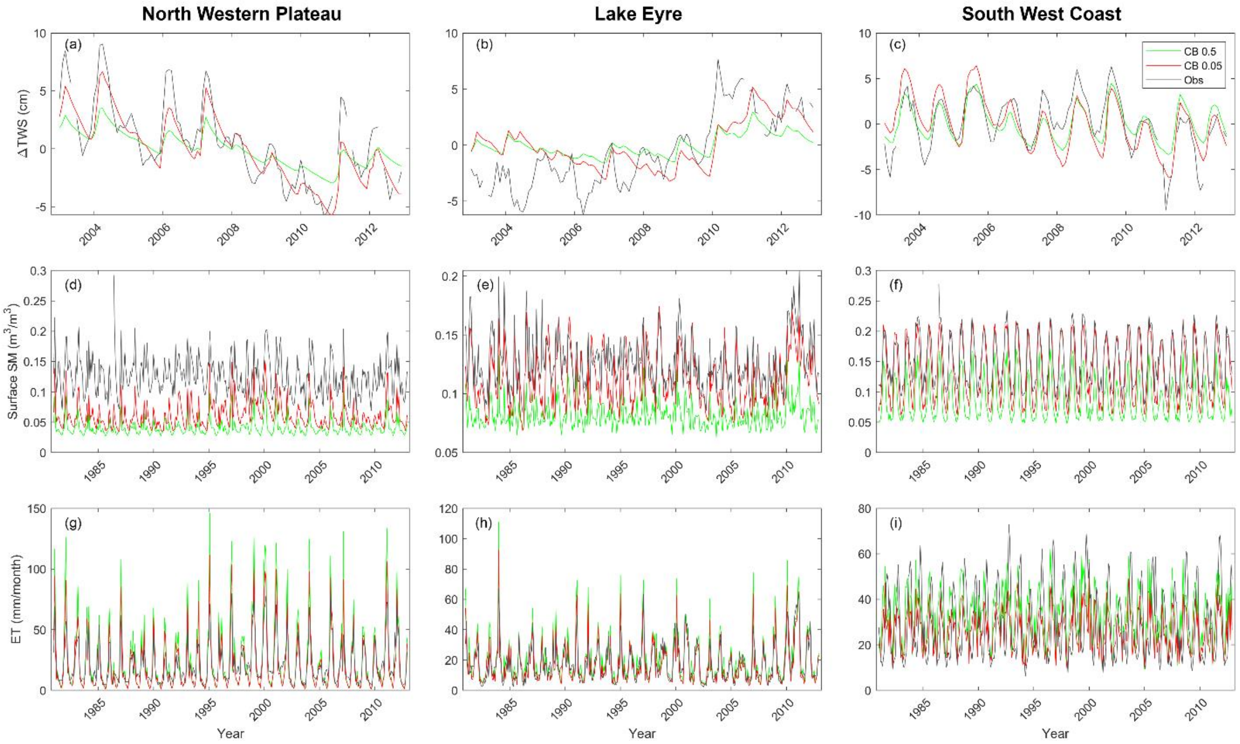
C10: 805: How about use the same color bar for Fig. 7c with Fig. 7a and d, so that the figure will show more details about the relationship and the comparison.

R10: We thank Reviewer #1 for the suggestion. The same color scale will be used for variables with the same unit in the revised paper.



C11: 822: What is the unit of x axis for the delta TWS (the first row)? Please add the unit for the figures if necessary.

R11: The unit of the x-axis is year. For clarity, we change our x-axis to a full year. The label of the x-axis is also given.



C12: 823 - 824: Why not conduct the analysis over basins not for the whole Australia? Since you do the analysis for the whole area in the previous analysis.

R12: We believe Reviewer #1 means "why conduct the analysis over basins not for the whole Australia". Please note that the analysis over the entire Australia is already shown in Fig. 10 (as Reviewer #1 mentioned). We analyze the basin-average time series here since the characteristics of the estimate variables are not uniform across Australia. Displaying the average time series of all Australia leads to the same conclusion but omits small temporal details that can only be seen at the basin level.

We finally would like to thank Reviewer #1 again for taking the valuable time to review our manuscript. We hope that our responses clarify Reviewer #1 concerns. All suggestions will be implemented in our revised manuscript.