Carly Tozer
Palaeohydrologist
Antarctic Climate & Ecosystems Cooperative Research Centre
University of Tasmania
Hobart TAS 7001 Australia
T: +61 3 6226 6969
Email: Carly.Tozer@utas.edu.au

26th February 2016

Dear Handling Editor

Thank you for providing the opportunity to address the comments made by the two referees of the paper "An ice core derived 1013-year catchment scale annual rainfall reconstruction in subtropical eastern Australia" (Manuscript #: hess-2015-456).

Both referees suggest that the paper is well written though some additional discussion is required. The key comments and suggestions made by the referees are presented below along with our response and details indicating how we propose to revise the paper.

Referee #1 (Anonymous)

1. *"The authors need to address the lack of (statistical) evidence shown for the skill of the reconstruction."*

AUTHOR RESPONSE:

We propose to add an additional table (Table 2, reproduced below) which features Root Mean Square Error (RMSE) and Reduction in Error (RE) statistics for the rainfall reconstruction relative to rainfall recorded at gauge 61010 and the AWAP catchment average. The RMSE gives an indication of the average difference between the reconstructed and instrumental rainfall but not the direction of the difference. In regards to the RE, a value greater than zero indicates that the reconstruction is skilful and has better predictive skill than climatology (Cook, 1992). While improved RMSE and RE statistics were recorded for the most recent Interdecadal Pacific Oscillation (IPO) positive (1979-1997) phase relative to the full record, first IPO positive and IPO negative phases, it is clear that the reconstruction has skill across the 1900-2010 instrumental period. For the full instrumental record, the reconstruction has a RMSE of around 25% of the instrumental rainfall with an RE value greater than zero.

We intend to include the new table in Section 5.2 along with the above discussion. Note that the existing Table 2 will become Table 3.

Table 2. Root Mean Square Error in mm/year (%) and Reduction in Error between the rainfall reconstruction and 12 month average (October-September) rainfall recorded at gauge 61010 and the AWAP Williams River catchment average for the 1900-2010 period and IPO phases.

Time Period	61010		AWAP catchment average	
	RMSE mm (%)	RE	RMSE mm (%)	RE
Full record (1900-2010)	267 (25.1)	0.07	254 (23.1)	0.08
IPO positive (1924-1941, 1979-1997)	239 (22.5)	0.14	202 (18.4)	0.25
IPO positive (1924-1941)	254 (23.9)	0.10	187 (17.0)	0.08
IPO positive (1979-1997)	223 (21.0)	0.11	216 (19.6)	0.33
IPO negative (1947-1975)	254 (23.9)	0.10	306 (27.8)	0.02

2. *The referee suggests that the "existence of multiple reconstructions lends itself to the development of interval estimates". In addition, "the existence of other proxies along with QLD/NSW coastal strip should be recognised".*

AUTHOR RESPONSE:

We acknowledge that rainfall reconstructions exist in eastern Australia. These are summarised below:

- Lough (2007; 2011) developed an October-March rainfall reconstruction for northeast QLD for the 1639-1981 period based on coral luminescence.
- Gergis et al. (2012) produced a multi-proxy based annual rainfall reconstruction for southeast Australia for the 1783-1988 period.
- Ho et al. (2015a, 2015b) developed multi-proxy based annual rainfall reconstructions for the Murray Darling Basin for 749 (before common era (BCE)) -1980 period.
- Heinrich et al. (2009) developed a rainfall reconstruction for Brisbane from Australian red cedar trees for the 1854-2000 period.

The majority of these are for regions outside of the Eastern Seaboard, which, as we have discussed in the paper, is a unique climate region. Therefore care needs to be taken in comparing these to our rainfall reconstruction. The Heinrich et al. (2009) reconstruction fits within the Eastern Seaboard, though it is considerably further north of the Williams River catchment. We also note that this reconstruction is only for the 1854-2000 period, which limits our ability to compare it to the 1013-year record developed here. Furthermore, the Heinrich et al. (2009) reconstruction is produced based on a calibration period of 1950-2000 with no explanation as to why this calibration period was selected as opposed to the full post-1900 period for which high quality instrumental data is available (and which was used in our study). Nonetheless, we accept that some discussion surrounding this nearby record should be included in this study.

There also exists an aridity index (note this is not a rainfall reconstruction) that has been produced based on cave deposits in Wombeyan Caves (McDonald et al., 2013), which is just within the western boundary of the Eastern Seaboard. McDonald et al. (2013)'s record indicates dry and wet periods for the 749 BCE-2001 period. It is suggested that while the cave samples were taken at a high resolution the rainfall signal is an integration of rainfall signals over a decadal scale.

In addition to the above, we are aware of current work from Stradbroke Island lake deposits that we are very interested in comparing to the Law Dome records, however this research is not yet published and so cannot be discussed in our paper at this stage.

It is clear that existing rainfall reconstructions in eastern Australia are either outside of the eastern seaboard, cover different time periods or are at varying resolutions to our reconstruction. Care therefore needs to be taken when comparing these reconstructions to ours and we do not believe it is appropriate to produce interval estimates using these reconstructions at this point. That said, we will certainly add more text to Section 5.3 (paragraph 2) which discusses broad commonalities and differences between dry and wet periods identified in the existing eastern Australian rainfall reconstructions and the Williams River rainfall reconstruction.

3. *"The authors should also explain the regression technique used in more detail – e.g. tell the readers why this regression technique was used, its strengths and weaknesses."*

AUTHOR RESPONSE:

We intend to add the following information regarding the Marquardt-Levenberg method to Section 4:

"This re-evaluation was via a damped least-squares regression between AWAP grid-cell data and the LD_{SSS} record using the Marquardt-Levenberg method; a method capable of multi-variate and non-linear regression, although it was only used for uni-variate linear regression herein (but the method was selected for compatibility with planned future work)."

4. *"The difference in the variability of the reconstruction vs the instrumental data requires a fuller discussion."*

AUTHOR RESPONSE:

We propose to add the following points to the existing discussion on the differences between the reconstruction and instrumental data (paragraph 1, Section 5.2).

- The instrumental mean is captured by the reconstruction but the range of variability is underestimated.
- While the magnitude of extremes is important, the key focus is that the reconstruction matches the duration and timing of the wet and dry periods. The thinking behind this is

that a short, but extreme (in terms of rainfall deficit) drought, for example, will have less severe implications on water security in a catchment than a drought of long duration with consistently below average (but not necessarily extremely below average) rainfall. Furthermore, a short wet event will not likely break a drought.

- The reconstruction (Figure 4) exhibits below average rainfall during the mid-1930s to mid-1940s and 2000s, suggesting that it captures the major World War II and "Big Dry" droughts.
- In terms of IPO phases, it is clear that the reconstruction is in better agreement with the instrumental record for the most recent IPO positive phase (1979-1997) relative to the first IPO positive phase and the IPO negative phase. This is no surprise given the higher correlation between LD_{SSS} and Williams River rainfall in the recent IPO positive period i.e. LD_{SSS} variability captures around 40% of the Williams River rainfall variability (Table 1). In addition, in the same way that all El Niño events are different, it is more than likely that different phases of the IPO have different spatial signatures, and it is quite possible that different positive phases have a different effect both on circulation in the Southern Hemisphere (impacts for the Law Dome records) and rainfall variability in Australia. Assessing this however is beyond the scope of this study.

In addition to the above points we will add the new performance measures (Table 2 and associated discussion) outlined in our response to comment #1 above.

It is also important to note that we are working on improving the utility of multiple Law Dome ice core data streams to reconstruct rainfall variability in eastern Australia in the IPO negative phase, hence the use of the Marquardt-Levenberg method, which can be adapted for nonlinear and multi-variate reconstructions. This paper demonstrates the potential for using LD_{SSS} to reconstruct rainfall variability in the Williams River catchment. We note that our current areas of active research are in developing the utility of Law Dome (and other East Antarctic ice core records as they become available) for climate reconstruction in Australia.

5. *The referee requests more information about the non-stationarity in the relationship between LD_{SSS} and annual rainfall in the Williams River catchment. The referee suggests limiting the reconstruction to IPO positive phases only i.e. they ask: "Is the relationship in IPO positive phases 'stable enough' to provide a skilful reconstruction?". Also, specifically referring to Page 12495, line 1, the referee would like us to further explore the differences between the LD_{SSS} –Williams River rainfall relationship in both IPO negative and positive phases i.e. "How does the relationship differ in the IPO positive phase vs the IPO negative phases for eg?".*

AUTHOR RESPONSE:

In the paper we noted that the strong relationship between LD_{SSS} and Williams River rainfall revealed in the most recent IPO positive phase (1979-1997) is not present in the first IPO positive phase (1924-1941). Therefore we do not believe the relationship in IPO positive is stable enough to base the reconstruction on these periods. We have few tools at our disposal to assess whether different IPO positive phases have slightly different spatial signatures in terms of SST and atmospheric circulation, or whether this is related to the lower quality data in the first IPO positive period (i.e. it is well known that sea surface temperature data decreases in quality as one goes back in time, discussed further below). Beyond noting this in the revised manuscript, this is beyond the scope of this work.

Ultimately, one of the key difficulties in understanding the non-stationarity in the climate of the Southern Hemisphere is the lack of quality atmospheric/oceanic data in the Southern Ocean in the pre-1979 satellite era, particularly in the Indian/West pacific sector. Underpinning the above issue is that variability in the Australian climate record can be up to the centennial scale which cannot be resolved using short instrumental datasets (Gallant et al., 2013). Ultimately, for the purposes of this initial reconstruction, we have assumed stationarity in the LD_{SSS}-Williams River rainfall relationship. We did, however, attempt to identify potential sources of non-stationarity in the LD_{SSS}-Williams River rainfall relationship and these were briefly discussed in Section 4 of the paper. We focused on the IPO and East Coast Lows and based on suggestions from the referee will now add more information about these potential sources of non-stationarity in the relationship as well as other sources (e.g. Southern Annular Mode, Subtropical Ridge) – see our response to comment #6 below.

Also note that the statistics we have added (new Table 2, see response to comment #1) demonstrate that our reconstruction has useful skill across the full instrumental record (1900-2010) and provides some validation for our assumption of stationarity.

6. *The referee would like more information about other drivers of annual rainfall variability in the Williams River catchment, in addition to East Coast Lows i.e. "What other factors might have an important influence?". Specifically, Page 12493, line 21 to Page 12494, line 12 – The referee would like more detail about other influences in addition to ECLs, plus more detail about the relative influence of ECLs in various months. Page 12496, line 20-25 – the referee again questions our reference to only ECLs as the sole cause for non-stationarity in the LD_{SSS}-Williams River rainfall relationship. Furthermore, the referee asks "What happens to the correlations between precipitation and LD_{SSS} if the very few values that cause the strong negative correlation in the 1950s are removed?"*

AUTHOR RESPONSE:

The relative influence of East Coast Lows (ECLs) on monthly rainfall in the Eastern Seaboard is currently being researched as part of the Eastern Seaboard Climate Change Initiative (ESCCI, discussed in the paper), and co-author, A. S. Kiem is strongly involved with this project. To the best of our knowledge there are currently no published papers with this specific information. That said, we neglected to include a paper by Pepler et al. (2014) that investigates the impact of ECLs on inter-annual rainfall variability across the Eastern Seaboard. Pepler et al. (2014) found that on average, ECLs contribute 23% of annual rainfall on the Eastern

Seaboard. Based on interpretation of Figure 3 in Pepler et al. (2014) this ranges from 20-30% for the Williams River region and is predominantly in the warm season (November-April). Pepler et al. (2014) also note that ECLs have the strongest signature on the coastal fringe i.e. where the Williams River catchment is located. It is important to note however that Pepler et al. (2014) only assessed the 1970-2006 period, a predominantly IPO positive period. We propose to add the above information to Section 2 (where rainfall variability in the Williams River catchment is discussed) and Section 4 (where the relationship between LD_{SSS} and Williams River rainfall is discussed). We believe this additional information further confirms the strong influence of ECLs on the Williams River catchment and therefore further validates our suggestion that ECLs play a major role in governing the strength of the relationship between LD_{SSS} and Williams River rainfall. As such we don't believe that modification of the data (i.e. through removal of values) is required to test this hypothesis.

In addition to the above, we will expand (in Section 2 and 4) on the information we have already provided about other influences on annual rainfall variability in the Williams River catchment. Some studies suggest that there is a reduced impact of the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) on the Eastern Seaboard relative to the rest of Australia (e.g. Timbal, 2010;Pepler et al., 2014;Verdon and Franks, 2005). Risbey et al. (2009), however, found that ENSO variability is related to rainfall variability in the Eastern Seaboard in summer and spring and to a lesser extent in autumn. In addition, Kiem and Franks (2004) found ENSO to impact rainfall and streamflow variability in the Williams River catchment region with increased (decreased) streamflow during La Niña (El Niño) events. Furthermore, they found that the positive (negative) IPO phase is associated with increased (decreased) drought risk in the catchment. In regards to the IOD, Risbey et al. (2009) found no real impact on the Eastern Seaboard during the June to October period (the active period for the IOD) but when considered in combination with ENSO there is some relationship between IOD and rainfall in the Eastern Seaboard.

The Subtropical Ridge (STR) and Southern Annular Mode (SAM) also impact rainfall variability in the Eastern Seaboard. A positive SAM phase has been related to increased daily rainfall in summer and spring (Risbey et al., 2009;Hendon et al., 2007) while variability in the position of the STR is significantly correlated with rainfall in the Eastern Seaboard. That is, a shift south of the STR is associated with increased rainfall in the region (Timbal, 2010;Whan et al., 2013). Variability in the intensity of the STR is also related to rainfall variability in the Eastern Seaboard though to a lesser extent than variability in the STR position.

In addition to the influence of these large scale climate processes there are local influences from the Great Dividing Range to the west which provides orographic enhancement and the Tasman Sea to the east which brings in moisture to the region (Pepler et al., 2014).

Thus, along with ECLs, there are local topographical and large scale influences (IPO, ENSO, STR, SAM and to a lesser extent the IOD) on the Williams River catchment. An understanding of the percent of annual rainfall in the Williams River catchment that these other processes provide is not clear. That is, future studies need to be undertaken to determine how much of the 70-80% of the catchment's annual rainfall variability that ECLs do not account for is driven by these other processes. An understanding of this will further aid in characterising non-stationarity in the LD_{SSS}-Williams River rainfall relationship.

7. *Page 12487, line 28 – The referee questions the accuracy of saying "no local" suggesting that "depending on your version of 'local' this isn't correct".*

AUTHOR RESPONSE:

The sentence that referee 1 is referring to is: "The region has hydroclimate features that are distinct from the rest of Australia and no local, high resolution palaeoclimate proxies (Ho et al. 2014)." We propose to change the sentence as follows: "The region has hydroclimate features that are distinct from the rest of Australia and lacks high resolution palaeoclimate proxies (Ho et al. 2014)." Ho et al. (2014) indeed indicate that, to date, there is a lack of high resolution proxies in the Eastern Seaboard region. Also see our response to referee comment #2.

Page 12490, line 10 – The referee requires clarification i.e. "A dating accuracy of +/- 1 yr for the Law Dome core from 894 – 1807 and then accurate to the year beyond that. Later in paper the authors indicate that they are identifying individual years of dry/wet conditions – but prior to 1807 dating accuracy is +/- 1 year. Perhaps another short sentence can be added to clarify."

AUTHOR RESPONSE:

The referee is referring to the dry/wet time periods extracted from the reconstruction and presented in Table 3. We propose to add a sentence to Section 5.3 (where Table 3 is initially referenced) which notes the ±1 year LD_{SSS} dating accuracy issue.

8. *Page 12492, line 9 – "A test for low frequency modulation could be done". The referee refers to Gershunov et al. (2001).*

AUTHOR RESPONSE:

The Gershunov et al. (2001) paper (suggested by the referee) suggests using the bootstrap technique to determine if low frequency modulation of relationships between climate signals is significant. The Mudelsee (2003) method used to determine the confidence intervals for the correlations between Williams River rainfall and LD_{SSS} (presented in Table 1) uses bootstrapping techniques which automatically address issues of low frequency modulation. Hence we feel we have already addressed this issue. We will add this clarification in the paper.

9. *Page 12493, line 6-20 – The referee has asked "What about the different seasonal window used?" compared with* Vance et al. *(2015).*

AUTHOR RESPONSE:

We propose to add a sentence to clarify that in addition to the different study locations between our study and Vance et al. (2015), a different seasonal analysis window was used which may also account for differences in results. Where Vance et al. (2015) focused on a general calendar year period (Jan – Dec), we used a catchment specific seasonal window (Oct – Sep).

10. *Table 2 – "Why are there longer duration events as the criterion becomes stricter?"*

AUTHOR RESPONSE:

We assume the referee is asking why there are longer duration events as the standard deviation is increased. Based on equation 1 (reproduced below), the range increases as the standard deviation increases and therefore we are extracting longer duration events. For example, for a standard deviation of 0.1 (and annual reconstruction average of 1100 mm), the range is 1092.6-1107.4 mm. That is, a wet year will be defined as any year with annual rainfall greater than 1092.6 mm and a dry year as any year with annual rainfall less than 1107.4 mm. For a standard deviation of 0.3, the range is 1077.8-1122.2 mm (wet year > 1077.8 mm, dry year < 1122.2 mm) and hence longer duration events are picked up.

$$wet = years\ where\ rainfall > mean - x\ \times standard\ deviation \qquad (1)$$

$$dry = years\ where\ rainfall < mean + x\ \times standard\ deviation$$

This methodology allows us to identify multiyear or multidecadal wet and dry epochs and avoids the situation where a generally consistent wet or dry period is broken by a single year that crosses the mean. The thinking behind this is that a year that is only 0.1 standard deviations above the annual average, for example, is not likely to provide enough rainfall to break a drought or fill reservoirs. We propose to add further discussion and examples to Section 5.3 (where Equation 1 is presented) to clarify our methodology.

11. *Figure 6 and Figure 7 – the referee believes that "the importance of this information has not been drawn out." They suggest that "we would expect different centuries to differ in terms of the numbers of wet/dry events, but are there large differences? What about the changes in duration of wet/dry events in different centuries? Some further analysis/discussion would be useful here."*

AUTHOR RESPONSE: We intend to add further discussion about these figures. For example we will discuss more about centuries that are dominated by longer duration wet periods (e.g. 1400s, 1500s, 1800s in Figure 6) compared with centuries that experience shorter wet periods and hence are more dry (e.g. 1100s, 1200s in Figure 6).

12. *Page 12497, line 14-15 – The referee requires clarification of the term "mid-range". "Mid-range in the context of the values chosen, not in absolute terms".*

AUTHOR RESPONSE: Yes, in this case the selected standard deviation of 0.3 is 'mid-range' in the context of the range of standard deviation thresholds (0.1 – 0.5) we assessed. We will add this clarification to the text.

13. Page 12497, line 16 – "Reference to table is confusing".

AUTHOR RESPONSE:

We agree and propose to add 'section' headings (A, B, C and D) to Table 2 (now Table 3, reproduced below). This will allow us to reference the table without confusion.

Mean (mm) used to determine wet/dry	SD (mm) used to determine wet/dry	*x* value used to determine wet/dry (Threshold = Mean ±*x*×SD)	Duration of longest DRY period (years)	DRY period	Duration of longest WET period (years)	WET period
A		AWAP catchment average rainfall (1900–2010)				
1100.0 (1900–2010)	264.6 (1900–2010)	0 (Mean)	8	1935–1942	5	1927–1931
		0.1	8	1935–1942	8	1925–1932
		0.2	8	1935–1942	8	1925–1932
		0.3	8	1935–1942	8	1925–1932
		0.4	8	1935–1942	9	1948–1956
		0.5	9	1979–1987	9	1924–1932, 1948–1956, 1971–1979
B		Reconstructed Rainfall (1900–2010)				
1100.0 (1900–2010)	73.9 (1900–2010)	0 (Mean)	7	1936–1942	7	1907–1913
		0.1	7	1936–1942	8	1907–1914
		0.2	8	1935–1942	10	1905–1914
		0.3	8	1935–1942	10	1905–1914
		0.4	9	1973–1981	10	1905–1914
		0.5	11	1973–1983	10	1905–1914
C		Reconstructed Rainfall (1000–2012)				
1100.0	73.9	0 (Mean)	7	1936–1942	16	1499–1605, 1834–1849
(1900–2010)	(1900–2010)	0.1	9	1215–1223	26	1831–1856
		0.2	9	1215–1223	27	1830–1856
		0.3	12	1193–1204	39	1830–1868
		0.4	12	1193–1204	39	1830–1868
		0.5	12	1193–1204, 1212–1223	39	1830–1868
D		Reconstructed Rainfall (1000–2012)				
1126.1 (1000–2012)	83.0 (1000–2012)	0 (Mean)	12	1193–1204	16	1834–1849
		0.1	12	1193–1204	16	1834–1849
		0.2	12	1193–1204	16	1834–1849
		0.3	17	1117–1133	16	1589–1605, 1834–1849
		0.4	17	1117–1133	26	1831–1856
		0.5	18	1206–1223	27	1830–1856

14. *"Rework the conclusions to highlight the most important findings once additional discussion/analysis of non-stationarity and presentation of some model statistics shown in earlier sections"*

AUTHOR RESPONSE:

We propose to rework the conclusions in light of the following additional discussion and analysis that will be added:

- Table 2 – new reconstruction performance measures as per our response to referee comment #1
- Additional discussion on non-stationarity in the LD_{SSS}-Williams River rainfall relationship as per our response to referee comment #5
- Additional discussion of climatic influences on the Eastern Seaboard as per our response to referee comment #6
- Additional discussion of existing climate proxies as per our response to referee comment #2
- Additional discussion of Figure 6 and Figure 7 as per our response to referee comment #11

15. *Page 12498, line 5 – the referee would like to change the sentence "Results suggest that" to "the most important features of the study are".*

AUTHOR RESPONSE: We are happy to accommodate this request noting that this sentence is within the conclusions and may change anyway as a result of updating the conclusions section (see response to comment #14).

16. *Page 12498, line 24 – the referee would like the sentence "and anywhere else with similar teleconnections with East Antarctica" reworded because "as presently written, it seems to indicate all 'answers' to the climate of regions that have apparent teleconnections with the Antarctic will be explained by those teleconnections alone (and hence that LDSSS will be representative of climate in any of those locations)."*

AUTHOR RESPONSE:

Original sentence: "Fig. 3 (and Fig. 4a in Vance et al. (2015)) suggest that the same is true for most of eastern Australia, and anywhere else with similar teleconnections with East Antarctica."

The figures referred to in the sentence are focused on Australia and we acknowledge that in the text it is not clear that we are specifically referring to regions in Australia. As such we propose to update the sentence to read: "Fig. 3 (and Fig. 4a in Vance et al. (2015)) suggest that the same is true for most of eastern Australia and indeed may also be the case for other regions in

Australia that are identified as (or yet to be identified as) having similar teleconnections with East Antarctica e.g. southwest Western Australia (van Ommen and Morgan, 2010)."

17. Figure 3 – the referee requests the marker to be modified as it is barely visible

AUTHOR RESPONSE: The marker colour and size will be changed.

18. Figure 4 – the referee requests a mean/median line to be added

AUTHOR RESPONSE: A line indicating the mean of the reconstruction will be added to Figure 4.

19. Figure 5 – the referee requests the IPO positive phases to be overlain on the figure

AUTHOR RESPONSE:

In considering the referee's comments we realise that we have not made it clear that the relationship between Williams River rainfall, LD_{SSS} and IPO phase is not as strong as that identified between the focus region of Vance et al. (2015) and LD_{SSS} and hence, reconstruction skill is not as dependent on IPO phase. This is likely due to the additional, differing climatic influences on this region i.e. ECLs, orographic effect from Great Dividing Range, coastal impacts, SAM, STR. Note that we intend on providing additional discussion about these influences (see response to comment #6 above). As such we do not think it is appropriate to add the IPO reconstruction to Figure 5 as for this region IPO phase is not necessarily indicative of reconstruction skill. Instead we propose to add the instrumental IPO record to Figure 3f to graphically illustrate that decadal variability in the Williams River rainfall-LD_{SSS} relationship is not always tied to IPO phase shifts. We believe this, in addition to added statistics in Table 2, will provide further clarification as to the role of IPO in governing the strength of the relationship between LD_{SSS} and Williams River rainfall. It is also important to note that the causes of decadal variability in the relationship between LD_{SSS} & Williams River rainfall is an area of active research for our group, and we recognise the importance of further investigation into the mechanistic factors determining the decadal variability in the rainfall signal at Law Dome.

Referee #2 (Associate Professor Patrick Moss)

1. *The referee requests further discussion on additional factors that could be impacting the link between Law Dome and rainfall variability in the Williams River catchment i.e. "the orographic influence and coastal location of the William River catchment."*

AUTHOR RESPONSE:

Please see response to referee 1, comment #6 above.

2. *Page 12486, line 5: Kiem et al. (2003) needs to be added to the reference list.*

AUTHOR RESPONSE: This reference has now been added to the reference list.

3. *Page 12488, line 22: Delete 'Williams River' from the sentence.*

AUTHOR RESPONSE: 'Williams River' will be removed from the sentence as requested.

4. *Page 12489, line 14: Rewrite or delete to improve sentence structure.*

AUTHOR RESPONSE: This sentence will be rewritten in line with added discussion of climate mechanisms impacting the ESB (see response to comment #1).

5. *Page 12495, lines 15 to 16: Delete brackets.*

AUTHOR RESPONSE: Brackets will be deleted as requested.

6. *Page 12496, line 3: Should read 20th Century (rather than 20 Century).*

AUTHOR RESPONSE: This will be updated as requested.