Critique of the Draft CSSR discussion of post-1900 Sea Level Rise

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Executive summary

In discussing global sea level rise since 1900, the draft Climate Science Special Report (CSSR) notes that the rate of rise since 1993 is significantly greater than the average rate of rise 1900-1990, but fails to mention the substantial and well-established decadal-scale fluctuations during the 20th century. In fact, the rates since 1993 are statistically indistinguishable from rates in the first half of the 20th century.

What the draft CSSR says

The Executive Summary of the CSSR draft (Page 26, line 8) reads:

> Global mean sea level (GMSL) has risen by about 7-8 inches (about 16-21 cm) since 1900, with about 3 of those inches (about 7 cm) occurring since 1993 *(very high confidence).*

Amplifying paragraphs appear in Section 12.4.1 of the main text (page 497, lines 11-28) [**bold** emphasis added]:

> A global tide gauge network provides the century-long observations of local RSL, whereas satellite altimetry provides broader coverage of sea surface heights outside the polar regions starting in 1993. GMSL can be estimated through statistical analyses of either data set. **GMSL trends over the 1901–1990 period vary slightly (Hay et al. 2015: 1.2 ± 0.2 mm/year [0.05 inches/year]; Church and White 2011: 1.5 ± 0.2 mm/year [0.06 inches/year])** with differences amounting to about 1 inch over 90 years. Thus, these results indicate about 11–14 cm (4–5 inches) of GMSL rise from 1901 to 1990.
>
> **Tide gauge analyses indicate that GMSL rose at a considerably faster rate of about 3 mm/year (0.12 inches/year) since 1993 (Hay et al. 2015; Church and White 2011), a result supported by satellite data indicating a trend of 3.4 ± 0.4 mm/year (0.13 ± 0.02 inches/year) over 1993–2015 (update to Nerem et al. 2010).** These results indicate an additional GMSL rise of about 7 cm (3 inches) rise since 1990 (Figure 12.2b, Figure 12.3a) and 18–21 cm (7–8 inches) since 1900. …

And a description of the evidence base is given on pg 509, lines 9-26:

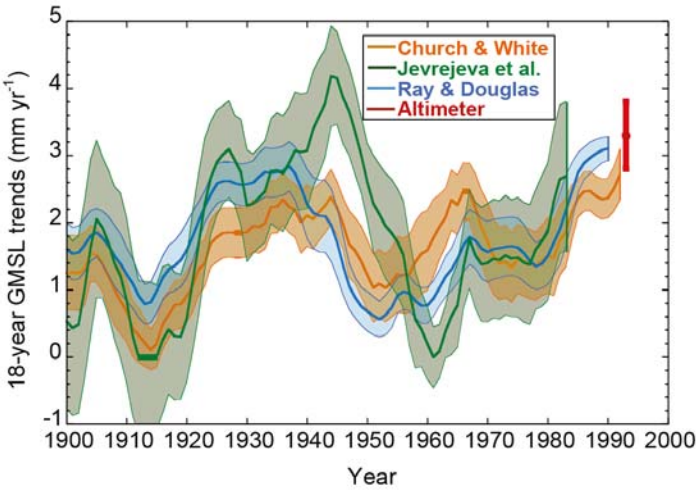
> Multiple researchers, using different statistical approaches, have integrated tide gauge records to estimate GMSL rise since the late nineteenth century (e.g., Church and White 2006, 2011; Hay et al. 2015; Jevrejeva et al. 2009). The most recent published rate estimates are 1.2 ± 0.2 (Hay et al. 2015) or 1.5 ± 0.2 (Church and White 2011) mm/year over 1901–1990. Thus, these results indicate about 11–14 cm (4–5 inches) of GMSL rise from 1901 to 1990. Tide gauge analyses indicate that GMSL rose at a considerably faster rate of about 3 mm/year (0.12 inches/year) since 1993 (Hay et al. 2015; Church and White 2011), a result supported by satellite data indicating a trend of 3.4 ± 0.4 mm/year (0.13 inches/year) over 1993–2015 (update to Nerem et al. 2010) (Figure 12.2a). These results indicate an additional GMSL rise of about 7 cm (3 inches) rise since 1990. Thus, total GMSL rise since 1900 is about 18–21 cm (7–8 inches).

Note that these are the draft's only discussions of SLR observations during and after the 20th Century, although other sections of the draft talk about the causes of SLR. Despite the CSSR emphasis

on the higher rate of rise post-1990 relative to the average over 1900-1990, the draft does not have a figure showing details of the rate during the 20th century.

What the literature says

Considerable decadal-scale fluctuations in the rate of SLR during the 20th Century are well-established and discussed extensively in the literature. IPCC AR5 provides the figure below



18-year trends of GMSL rise estimated at 1-year intervals. The time is the start date of the 18-year period, and the shading represents the 90% confidence. The estimate from satellite altimetry is also given, with the 90% confidence given as an error bar. Uncertainty is estimated by the variance of the residuals about the fit, and accounts for serial correlation in the residuals as quantified by the lag-1 autocorrelation. Data source: IPCC's Fifth Annual Report (2013), Working Group I, Figure 3.14

and notes that **"It is *likely* that similarly high rates [of global averaged sea level rise] occurred between 1920 and 1950 [as those from 1993-2010]."** [SPM §B.4]

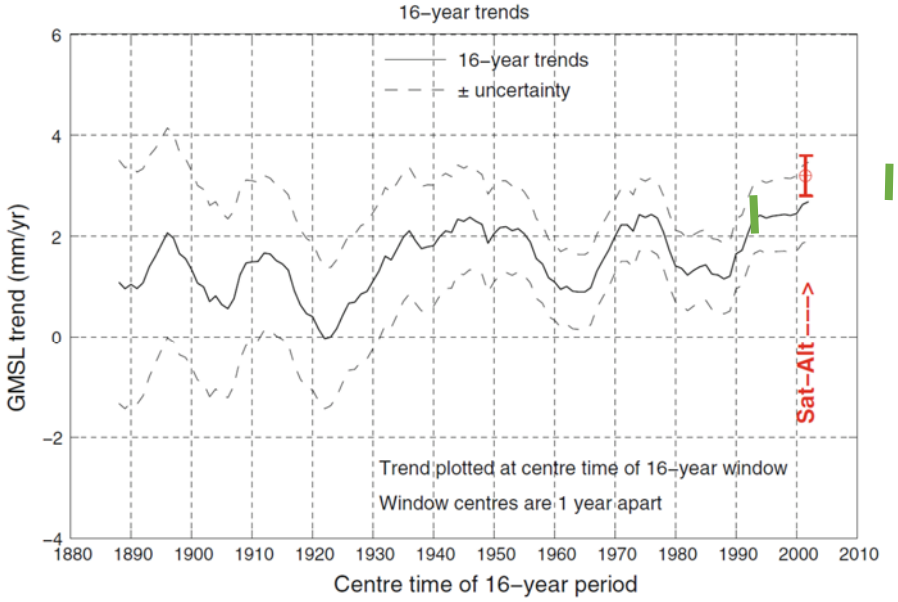


Fig. 8 Linear trends in sea level over successive 16 year periods for the yearly averaged reconstructed sea-level data. The trend from the satellite altimeter data are shown at the end of the time series

Further, the Church and White 2011 reference in the CSSR draft contains the following text (their p 599; **bold** emphasis added) and the figure left (green bars explained below):

"In addition to the overall increase in the rate of sea-level rise, there is also considerable variability in the rate. Using the yearly average data, we computed trends for successive 16 year periods (close to the length of the altimeter data set) from 1880 to the present (Fig. 8). We find maxima in the rates of sea-level rise of over 2 mm year^{-1}

in the 1940s and 1970s and nearly 3 mm year^{-1} in the 1990s (Fig. 8). As in earlier studies (using 10 and 20 year windows; Church and White 2006; Church et al. 2008), **the most recent rate of rise over these short 16 year windows is at the upper end of a histogram of trends but is not statistically higher than the peaks during the 1940s and 1970s.**"

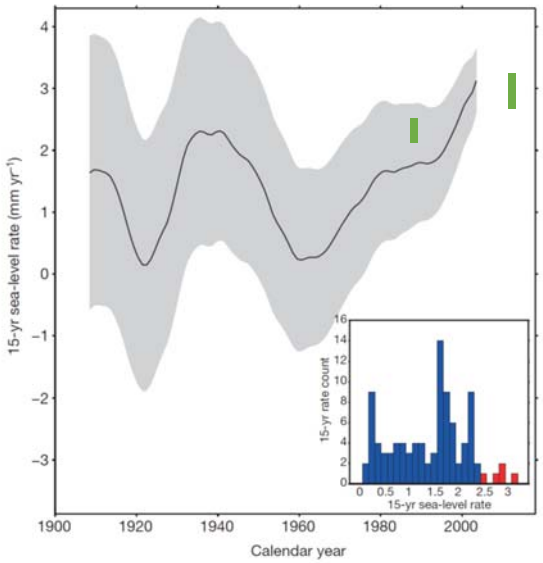


Figure 4 | Moving 15-year averages of GMSL rate estimated using the KS reconstruction of sea level across the entire interval 1901–2010. The *x*-axis represents the mid-point of each 15-year averaging window, and the shading gives the 1σ uncertainty range. Inset, histogram of 15-year mean GMSL rate estimates (mm yr^{-1}) for all time windows. The five most recent windows are shown in red.

The Church and White 2011 analysis extends to 2009. The analysis in the Hay et al. 2015 reference cited by the draft CSSR only goes one year further to 2010 (their Figure 4 is shown at left) and finds similar situation: the difference between their most recent rate and their peak at about 1940 can be estimated from the figure as a non-significant 0.8 ± 1.8 mm/yr. More interestingly, Chen et al 2017 (published after the CSSR literature closing date) give new satellite altimetry rates, corrected for small systematic observational drifts. (For example, instantaneous rates of 2.4 ± 0.2 mm/yr in 1993 and 2.9 ± 0.3 mm/yr in 2014). These have been approximately overplotted in green on the Church and White 2011 and the Hay et al figures.

Correcting the CSSR draft

Comparison with the literature shows that the CSSR draft misleads by omission in not mentioning both the strong decadal-scale variability of GMSL rates during the 20th century and the fact that the most recent values of the rate are statistically indistinguishable from those during the first half of the 20th century.

This deficiency in the CSSR draft should be remedied before the report is released. For example, the draft CSSR Executive Summary statements quoted at the beginning of this document should be replaced with something like:

> GMSL has risen 16-21 cm since 1900, continuing a trend that began in the 19th century. The rate of rise has averaged 1.3 mm/yr since 1900, but has oscillated between about 0 and 2.5 mm/yr, with uncertainties of ±(1-2) mm/yr. The rates since 1993 are at the high end of this range, but are not statistically different from those during the first half of the 20th Century.

Other modifications of the CSSR text itself follow straightforwardly, and a figure similar to one of the two immediately above should be included. It would also be useful to refer to that figure when discussing the projected average rates of rise for the various scenarios shown in Figure 12.4(a). For example, a rise of 2 meters (~six feet) by 2100 is equivalent to an <u>average</u> rate of ~24 mm/yr for the rest of this century, some 8 times larger than the highest observed rate to date. That would help illustrate for the non-expert reader just how dramatic the projected changes are.

With such changes, the CSSR would more fully and correctly describe the data and would not misleadingly alarm the non-expert reader into believing that recent rates of rise are unprecedented.

References cited by the CSSR

Church, J.A. and N.J. White, 2006: A 20th century acceleration in global sea-level rise. Geophysical Research Letters, 33, L01602. http://dx.doi.org/10.1029/2005GL024826

Church, J.A. and N.J. White, 2011: Sea-level rise from the late 19th to the early 21st century. Surveys in Geophysics, 32, 585-602. http://dx.doi.org/10.1007/s10712-011-9119-1

Hay, C.C., E. Morrow, R.E. Kopp, and J.X. Mitrovica, 2015: Probabilistic reanalysis of twentieth-century sea-level rise. Nature, 517, 481-484. http://dx.doi.org/10.1038/nature14093

Jevrejeva, S., A. Grinsted, and J.C. Moore, 2009: Anthropogenic forcing dominates sea level rise since 1850. Geophysical Research Letters, 36, L20706. http://dx.doi.org/10.1029/2009GL040216

Additional reference

Chen, X., X. Shang, J.A. Church, C.S. Watson, M.A. King, D. Monselesan, B. Legresy, and C. Harig, 2017: The increasing rate of global mean sea-level rise during 1993-2014. Nature Climate Change, 7, 492-495. http://dx.doi.org/10.1038/NCLIMATE3325