G21B-0444

AGU Fall Meeting, December 16th, 2014

Emissions of Water and Carbon Dioxide from Fossil-Fuel Combustion Contribute Directly to Ocean Mass and Volume Increases

Andrew Skuce, Salt Spring Consulting Ltd, British Columbia, Canada agskuce@gmail.com

Purpose:

To estimate the direct effect on past and future sea level rise (SLR) of H_2O and CO_2 emissions from fossil-fuel combustion. This is currently not included in IPCC SLR inventories.

Method:

a) Estimate range of carbon/hydrogen content of typical fuels within the three classes: coal, oil and gas.
b) Use CDIAC CO_2 emissions to estimate historical $H_2$0 emissions using C/H ratios.
c) Use CO_2 emissions from RCP2.6 and RCP8.5 models to estimate future H_2O emissions.
d) Estimate ocean volume increase from absorption of fossil-fuel CO_2 , in CMIP5 Earth System Models.

Observations:

1. Estimates of water emissions are much more sensitive to uncertainties between fuel classes (e.g., coal vs gas) than within a single class (e.g., bitumen vs light oil).
2. A future shift from coal to gas will greatly increase H_2O emissions relative to CO_2.
3. Carbon capture and storage (RCP2.6) will reduce emissions to the atmosphere of CO_2, but not of H_2O.

Skeptical Science
Getting skeptical about global warming skepticism

Key findings

- Historical fossil-fuel emissions to 2010 have directly (i.e., with climate-related effects excluded) increased sea levels by ~2mm, with 60% of that coming from H_2O and 40% from CO_2. Later in this decade, the mass of water added from historic fossil-fuel combustion will exceed the mass of water in Lake Erie (~480 Pg).
- If we follow RCP8.5, we will add an additional ~9mm SLR (70% H_2O, 30% CO_2) and RCP2.6 ~5mm SLR (80% H_2O, 20% CO_2) by 2100. These SLR amounts are greater, for example, than the projected additions from glacier melt in South America.
- Historical, present and future ocean volume additions from fossil-fuel emissions represent 1-2% of the increase in ocean volume from the sum of all other major sources (i.e., glaciers, ice sheets, thermal expansion, land water storage and groundwater extraction).
- Although small, SLR from emissions will become more relevant as the amounts and uncertainties of residuals between contributions and observations in SLR balance-sheet studies continue to diminish.
- Other small sea-level contributions (e.g., land-use emissions, "produced water" from oil operations, melting of floating sea ice) and subtractions (e.g., water uptake in the biosphere, subsidence of the seabed above depleted oil and gas fields) have not been estimated here.
- More complete sea-level inventories will eventually have to include these factors.

Fuel	C/H mass content of fuels			H/C mol		
	Low H	Mid H	High H	Low H	Mid H	High H
Coal	16.07	15.43	14.32	0.74	0.77	0.83
Oil	6.72	6.29	6.03	1.77	1.90	1.98
Gas	3.06	3.02	2.98	3.89	3.95	4.00

Fossil-fuel emissions and SLR from water emissions only

Source		Coal	Oil	Gas	All fuels Mid	Min	Max
CDIAC	1751-2010 Pg C	175	129	52	356	328	384
	1751-2010 Pg CO2	643	472	189	1304	1203	1407
	1751-2010 Pg H20	102	183	153	437	403	471
	1751-2010 mm SLR (H2O only)	0.28	0.51	0.42	1.21	1.12	1.30
RCP8.5	2011-2100 Pg C	985	503	340	1828	1680	1969
	2011-2100 Pg CO2	3609	1845	1244	6698	6158	7214
	2011-2100 Pg H2O	571	716	1005	2291	2113	2463
	2011-2100 mm SLR (H2O only)	1.58	1.98	2.78	6.35	5.85	6.82
RCP2.6	2011-2100 Pg C	96	167	171	434	402	466
	2011-2100 Pg CO2	351	612	628	1591	1474	1708
	2011-2100 Pg H2O	195	249	928	1371	1248	1492
	2011-2100 mm SLR (H2O only)	0.54	0.69	2.57	3.80	3.46	4.13

Fossil-fuel CO2 emissions and ocean fraction SLR

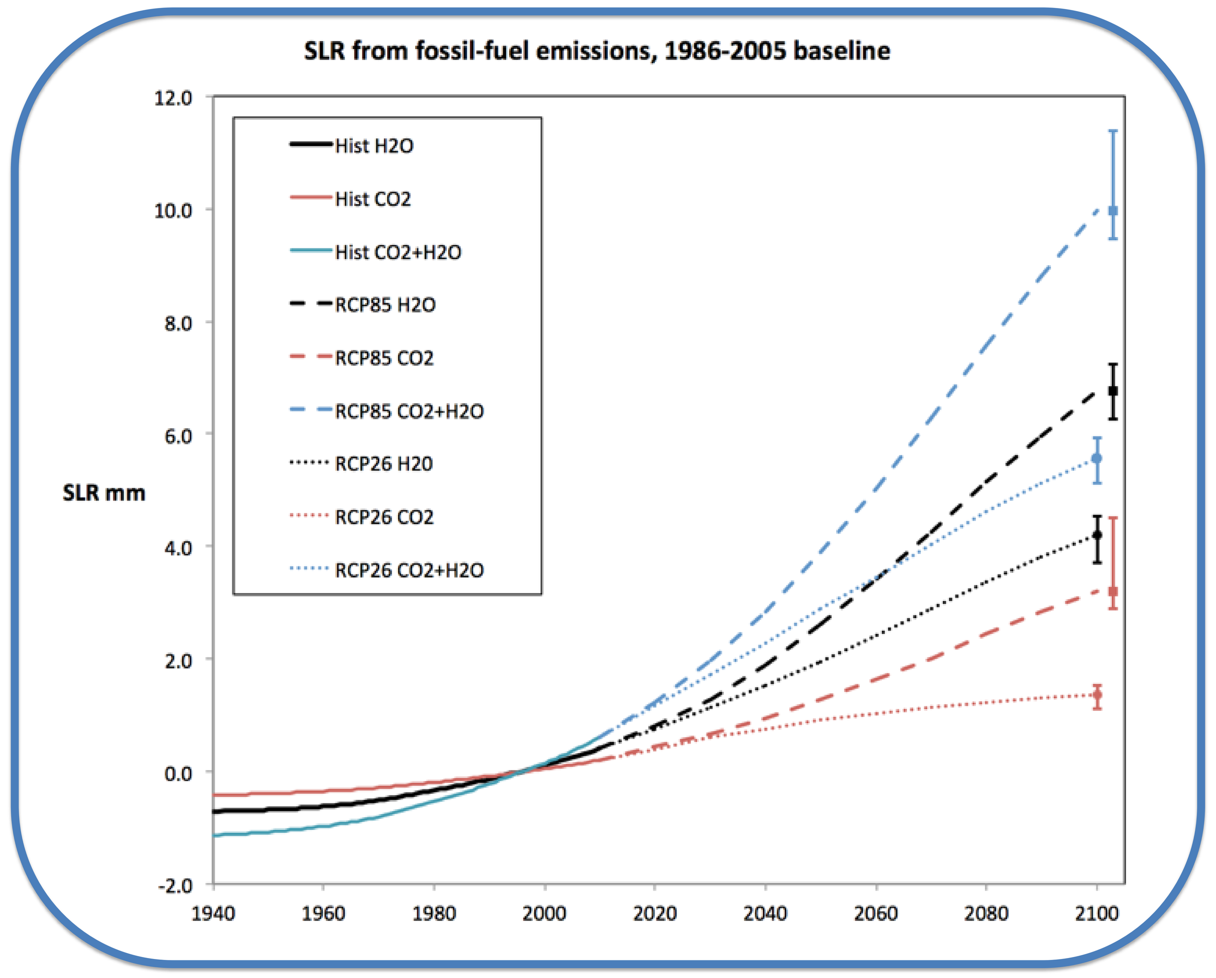
Source	Time period	Fossil fuel CO2 emissions Pg: CO2 total	CO2 ocean fraction Mid	Min	Max	Sea level rise from CO2 ocean fraction mm: Mid	Min	Max
IPCC/ CDIAC	1750-2010	1302.8	361	321	486	0.74	0.65	0.99
	2010	31.9	7.2	5.7	8.6	0.015	0.012	0.018
RCP8.5	2011-2100	6209	1471	1310	2104	3.00	2.67	4.30
RCP2.6	2011-2100	1024	555	440	642	1.13	0.90	1.31

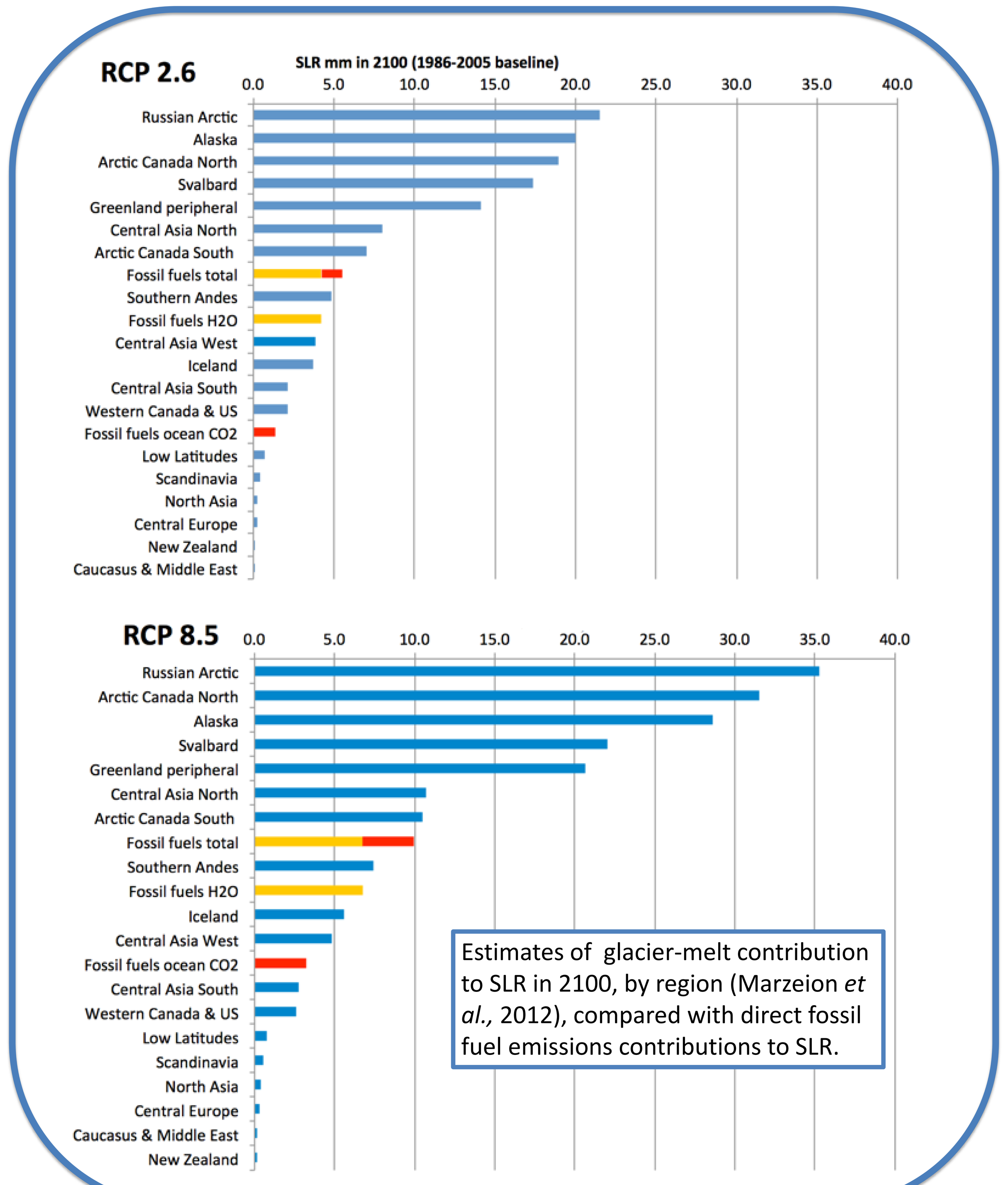
SLR from fossil fuel emissions of water and CO2

Source	Time period	SLR mm Water	CO2	Total SLR mm Mid	Min	Max
IPCC/ CDIAC	1750-2010	1.21	0.74	1.95	1.84	2.22
	2010	0.033	0.015	0.048	0.044	0.051
RCP8.5	2011-2100	6.35	3.00	9.35	8.84	10.75
RCP2.6	2011-2100	3.80	1.13	4.93	4.50	5.29

a) Fossil-fuel emissions 2010 (this study)				mmSLR (water only)		
	C Pg	CO2 Pg	H2O Pg	Mid	Min	Max
Coal	3.84	14.08	2.23	0.0062	0.0054	0.0071
Oil	3.11	11.41	4.43	0.0123	0.0105	0.0137
Gas+flare	1.76	6.45	5.21	0.0144	0.0126	0.0162
Total	8.72	31.94	11.87	0.0329	0.0303	0.0354
b) Fossil-fuel emissions 1980-1989 average per year (this study)				**mmSLR (water only)**		
	C Pg	CO2 Pg	H2O Pg	Mid	Min	Max
Coal	2.17	7.96	1.26	0.0035	0.0031	0.0040
Oil	2.29	8.41	3.26	0.0090	0.0077	0.0101
Gas+flare	0.88	3.23	2.61	0.0072	0.0063	0.0081
Total	5.35	19.60	7.13	0.0198	0.0182	0.0213
c) Fossil-fuel emissions 1980-1989 average per year (Gornitz et al., 1997)				**mmSLR (water only)**		
	C Pg	CO2 Pg	H2O Pg			
Coal	2.13	7.80	1.30	0.0036		
Oil	2.28	8.36	3.63	0.0101		
Gas	0.81	2.97	2.43	0.0068		
Total	5.22	19.13	7.36	0.0205		

"Max" and "Min" bracket the 90% confidence interval and were calculated by Monte Carlo analysis.





Estimates of glacier-melt contribution to SLR in 2100, by region (Marzeion *et al.*, 2012), compared with direct fossil fuel emissions contributions to SLR.

Key references

- Boden, T.A., G. Marland, and R.J. Andres. (2013): Global, Regional, and National Fossil-Fuel CO_2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A.
- Bradshaw, A. (1973): The effect of carbon dioxide on the specific volume of seawater. *Limnology and Oceanography*, *18*(1), 95-105.
- Ciais, P., *et al*. (2013): Carbon and Other Biogeochemical Cycles. In: *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., *et al*. (eds.)].
- Gornitz, V., C. Rosenzweig, and D. Hillel. (1997): Effects of anthropogenic intervention in the land hydrological cycle on global sea level rise. *Global and Planetary Change*, **14**, 147-161.
- Marzeion, B., A.H. Jarosch and D.M.Hofer. (2012) Past and future sea-level change from the surface mass balance of glaciers, *The Cryosphere Discuss*., 6, 3177-3241.
- Riahi, K., *et al.* (2011): RCP 8.5—A scenario of comparatively high greenhouse gas emissions. *Climatic Change* 109.1-2: 33-57.
- Song, Y., B. Chen, M. Nishio and M. Akai. (2005): The study on density change of carbon dioxide seawater solution at high pressure and low temperature. *Energy*, 30(11), 2298-2307.
- van Vuuren, D.P., *et al.* RCP 2.6 (2011). Exploring the possibility to keep global mean temperature increase below 2 degrees. C. *Climatic Change* 109.1-2 : 95-116.

My blog: http://critical-angle.net/

Critical Angle
Reflections on the refractory problems of climate and energy