Sea-level Change

Expert Forum on Coastal Transportation Infrastructure May 17, 2018

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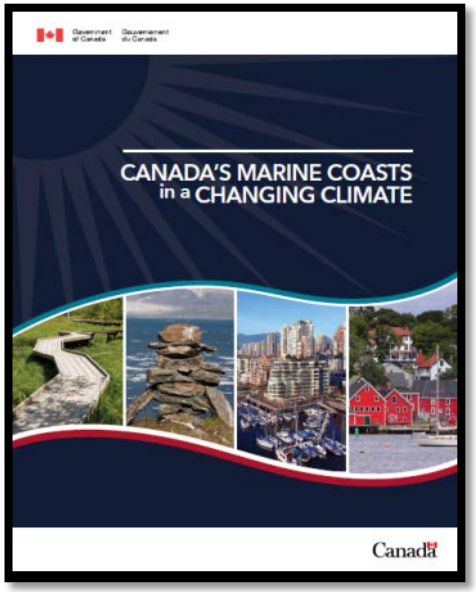
Acknowledgments

- Partnership with the Climate Change Impacts and Adaptation Division to produce a National Coastal Assessment:

Don Lemmen and Fiona Warren

Lemmen, D.S., Warren, F.J., James, T.S. and Mercer Clarke, C.S.L. editors (2016): Canada's Marine Coasts in a Changing Climate; Government of Canada, Ottawa, ON, 274p.



- Presentation today is based in part on a GSC Open-file report and related output:

Relative Sea-level Projections in Canada and the Adjacent Mainland United States; Geological Survey of Canada, Open File 7737, 72 p., doi:10.4095/295574, 2014.

- Co-authors: Joe Henton, Lucinda Leonard, Andrea Darlington, Don Forbes, and Mike Craymer (NRCan)

- This presentation is an output of the NRCan Climate Change Geoscience program.

Sea-level Rise

- Talk today describes projections of sea-level change
  - Based on Intergovernmental Panel on Climate Change 5th Assessment Report (2013), and recent scientific updates
  - For information and discussion

- Today's talk does not give new sea-level guidelines for BC and does not describe the existing guidelines in detail.

Outline

1. Introduction to coastal assessment and report.

2. Understanding sea-level change
    1. BC Guidelines on Sea-level Change
    2. Intergovernmental Panel on Climate Change 5th Assessment Report (2013) – IPCC AR5
    3. Emerging science on sea-level change
    4. Key messages

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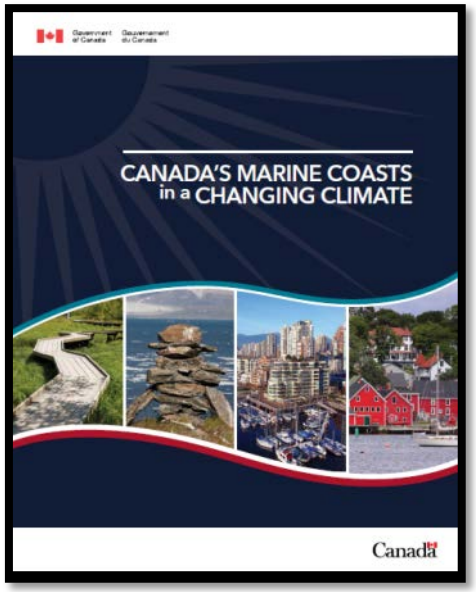
Latest NRCan science assessment of climate change impacts and adaptation

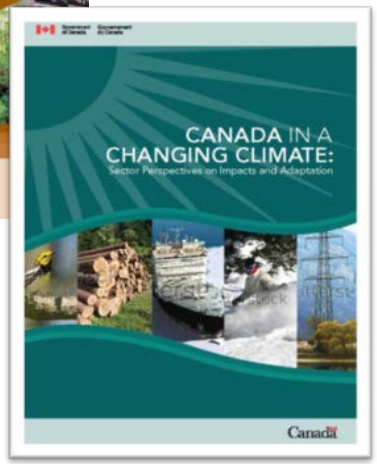


A rigorous assessment process, with:

- 14 advisory committee members
- 64 authors
- 74 external reviewers
- ~1300 references cited
- ~2500 review comments

= ***Credible, useful report***

2008

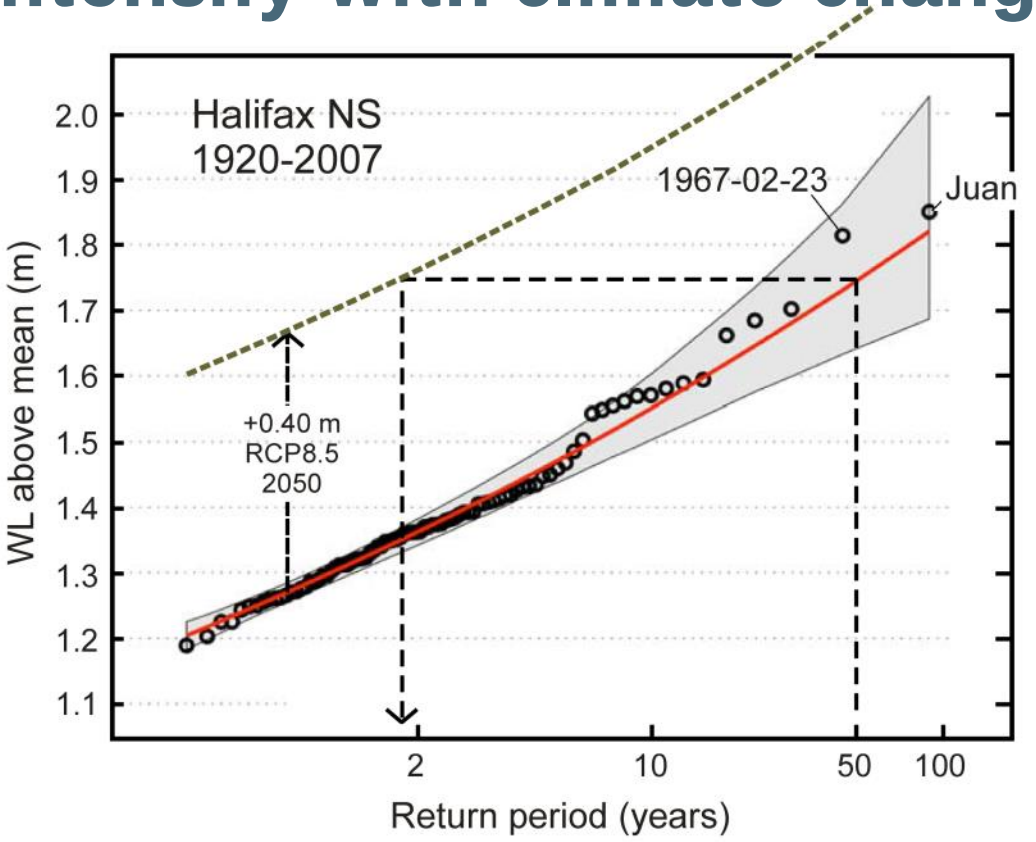


2014

Assessments are used:

To **raise awareness** of impacts and the need the adapt;
To **justify recommendations**; and
To **determine priorities** or policy direction

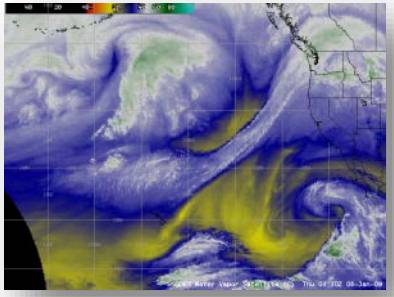
Extreme weather events and storm surge flooding are ongoing concerns, which may intensify with climate change



With 40 cm of sea level rise at Halifax, a one-in-50 year extreme water-level event would occur about every 2 years.

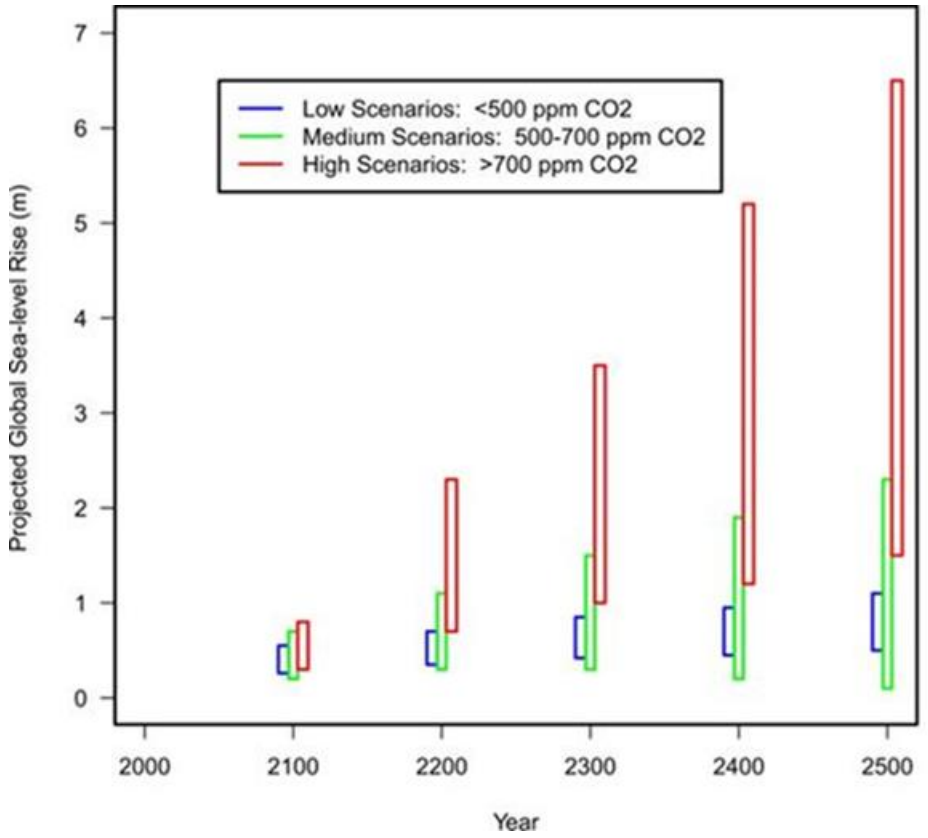
Hurricane Igor (Newfoundland, 2010)

Herschel Island, YK, storm surge (2010)



Atmospheric river (heavy rainfall event) (southern BC, 2009)

Impacts of changes in sea level will increase throughout this century and beyond



James et al., 2014; after Church et al., 2013

- Global sea level will continue to rise past 2100.
- With high emissions scenarios, sea level rise could reach 6 m by 2500.
- Low emissions scenarios would limit the rise to 1 metre.
- Sea level rise will result in increased risk of inundation, more frequent storm-surge flooding and greater rates of coastal erosion.

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Relative sea-level change

- Global sea-level change is referenced to the centre of Earth
- Relative sea-level change is relative to the solid surface of the Earth.
- Vertical land motion is a key factor for determining relative sea-level change in Canada

- If global sea-level rises by 100 cm, but the land rises by 60 cm at a specific location, then the relative sea-level change is

  100 – 60 = 40 cm.

BC guidance

Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use

Guidelines for Management of Coastal Flood Hazard Land Use (BC Min Env.)

- **Flood Construction Level =**

  Future Sea-Level Rise Allowance

  + Maximum High Tide (HHWLT)
  + Total Storm Surge during Designated Storm
  + Estimated Wave Effect
  + Freeboard

Future Sea-level Rise (SLR) Allowance for BC

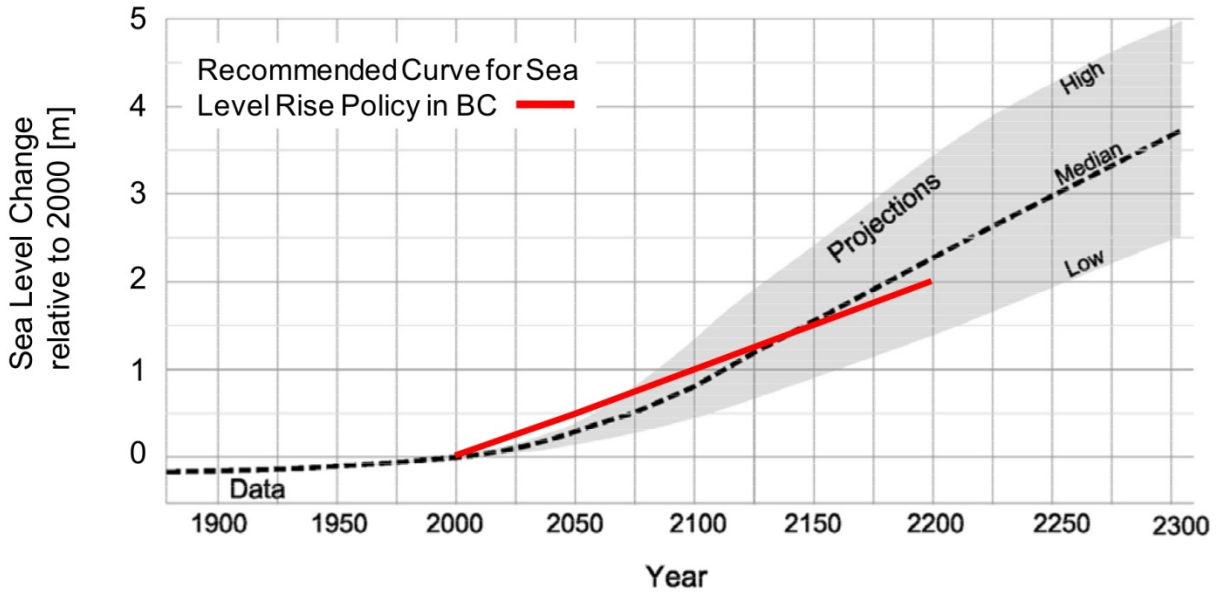

Fig 3-1, Sea Dike and Coastal Flood Hazard Guidelines

Recommended curve (red line) should be corrected for local vertical land motion.

Red line: 50 cm at 2050 and 100 cm at 2100 relative to 2000.

The guidelines provide two methods – shown is the more conservative method.

BC Guidance – Local Sea-level Rise

- The red line in the previous figure is 50 cm at 2050 and 100 cm at 2100, relative to 2000.
- Local SLR allowance is corrected for vertical land motion.
- Example: Campbell River, land rising at 4 mm/yr (rounded off), will rise 20 cm in 50 years and 40 cm in 100 years.
- So the local sea-level rise allowance is

  At 2050: 50 – 20 = 30 cm

  At 2100: 100 – 40 = 60 cm

For more information on BC Guidelines

BC web site on Integrated Flood Management:

https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/integrated-flood-hazard-management

Amended Flood Hazard Area Land Use management Guidelines will come into force Jan. 1, 2018:

https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/integrated-flood-hazard-mgmt/final_amendment_to_s_35_and_36_fhalumg_17-10-01.pdf

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Projected increases in global sea-level

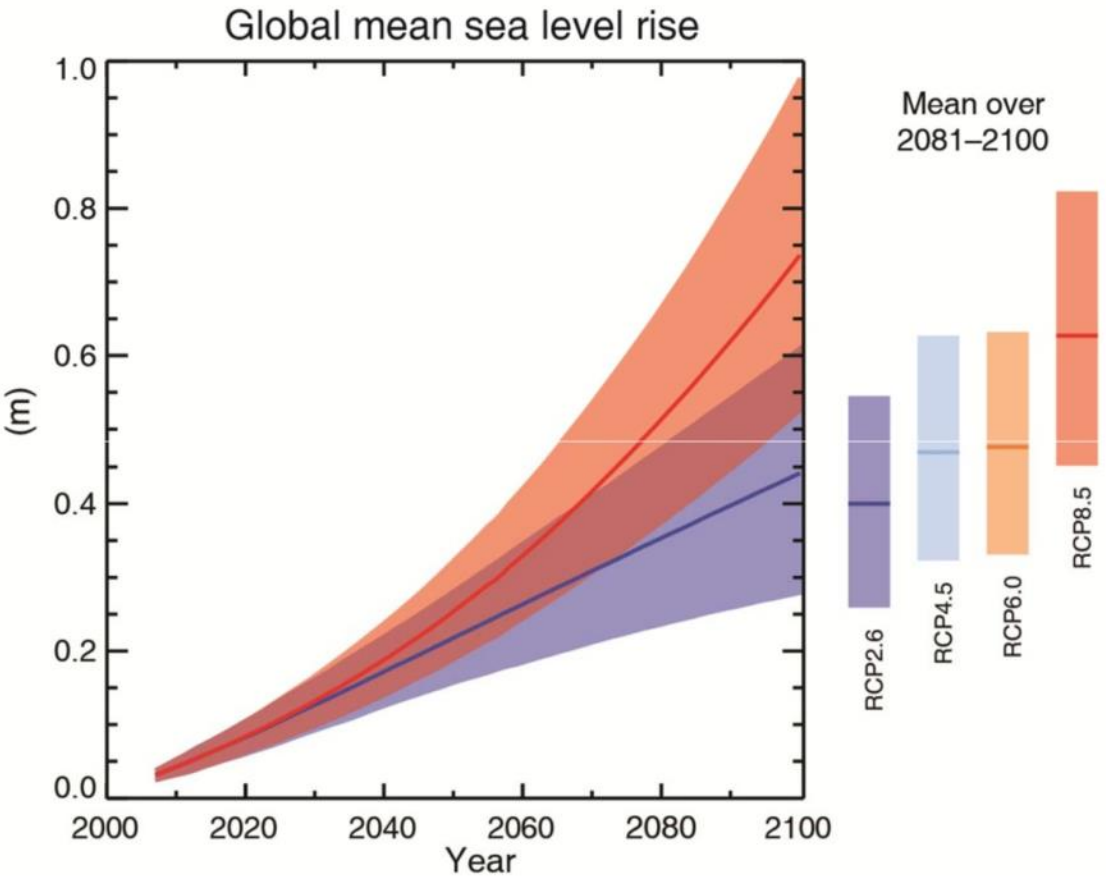


Fig. SPM.9, IPCC AR5

Envelopes give the 90% confidence range; i.e., 5% to 95%

Committed to more than 25 cm of sea-level rise by 2100

Maximum is nearly 1 m of sea-level rise by 2100 at 95%ile of RCP8.5

These envelopes of projections are considered *likely*, i.e., probability of 66% to 100%

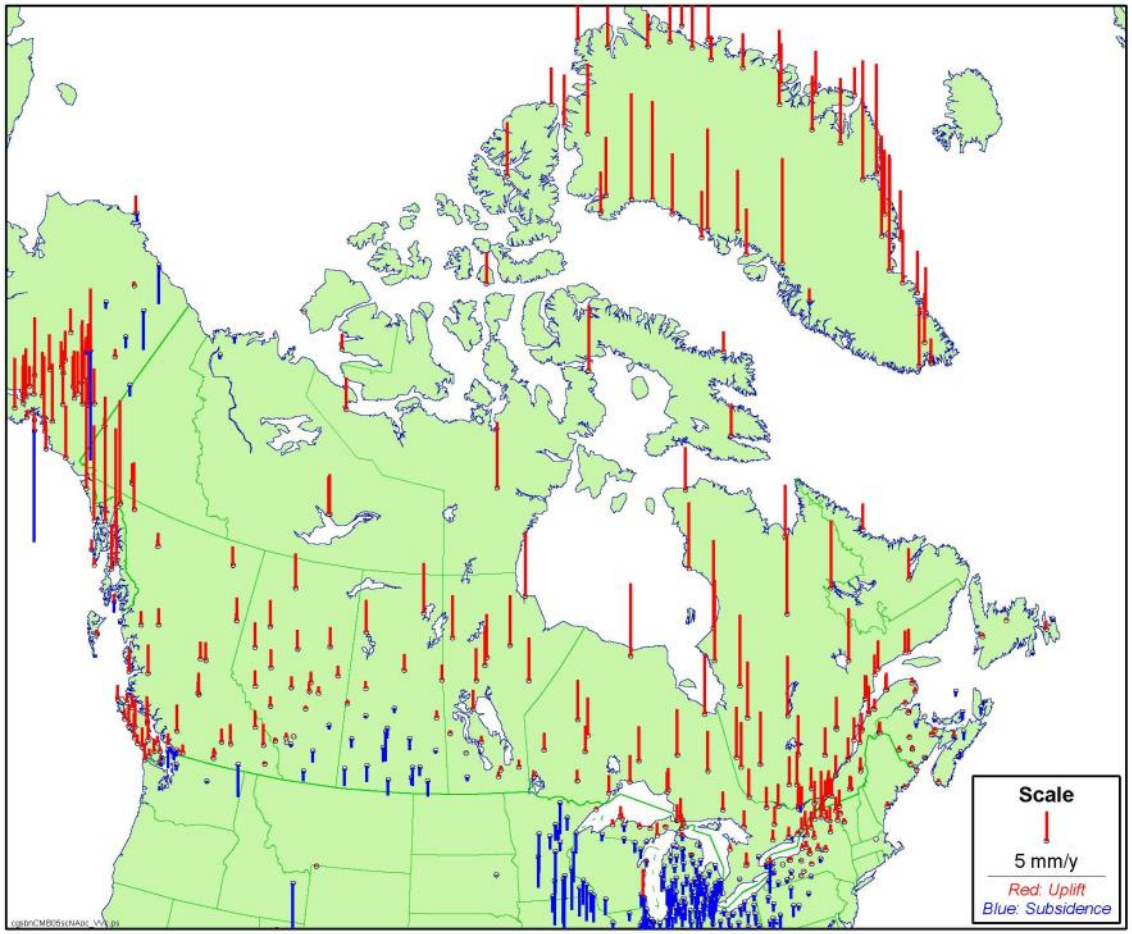
Antarctic Ice Sheet stability is poorly understood

- "*Based on current understanding, only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause global mean sea level to rise substantially above the* likely *range during the 21st century. However, there is* medium confidence *that this additional contribution would not exceed several tenths of a metre of sea level rise during the 21st century*." (SPM, IPCC AR5)

- For Canadian sea-level projections, we constructed one additional scenario by assuming that West Antarctica contributes an additional 65 cm of sea-level rise to RCP8.5 (65 cm is the average of four values quoted in IPCC AR5)

- This gives a total of 139 cm rise by 2100 (RCP8.5 median of 74 cm plus West Antarctic 65 cm)

GPS measures vertical crustal motion



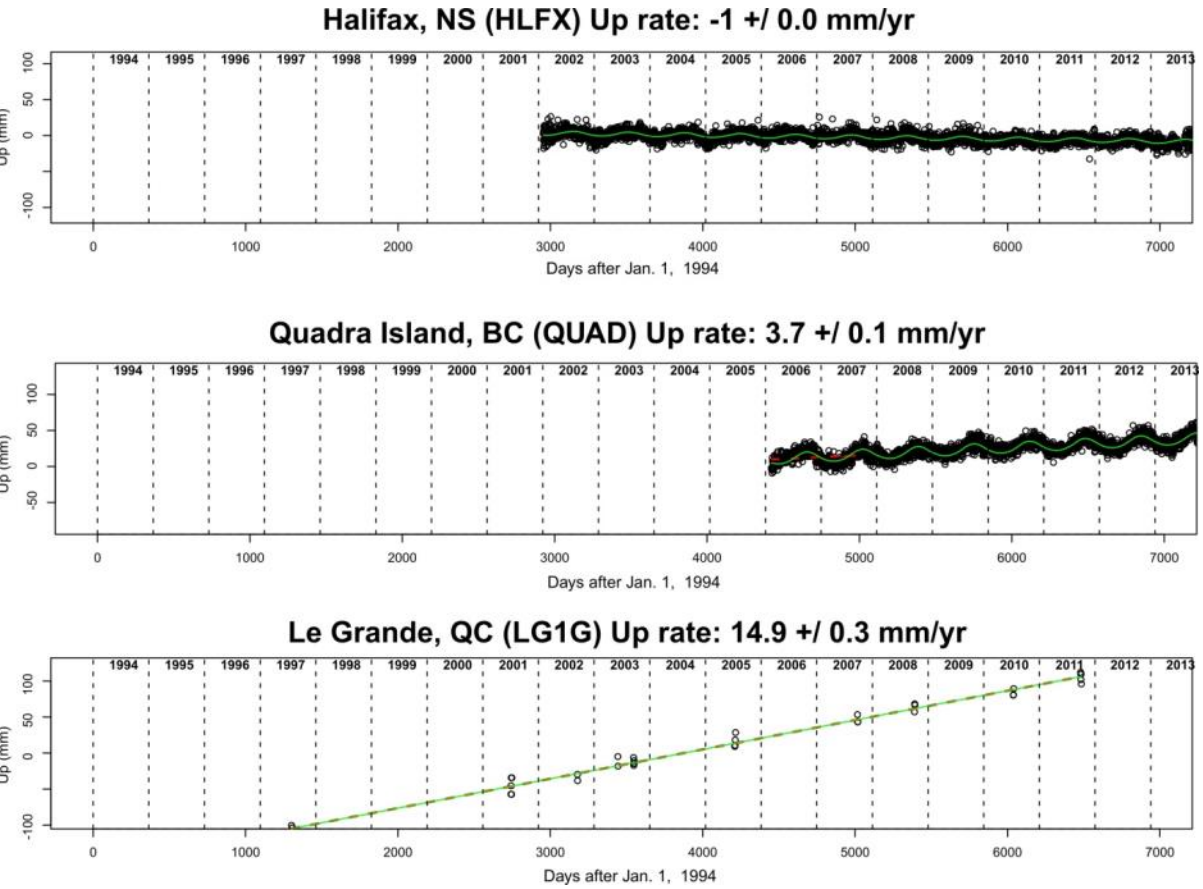
GPS is Global Positioning System

For much of Canada, vertical land motion is largely due to glacial isostatic adjustment, aka postglacial rebound.

Also influence of tectonics on west coast and recent and present-day ice mass change (west coast, Arctic)

Craymer et al., 2011 (Canadian Geodetic Survey, LMS, NRCan)

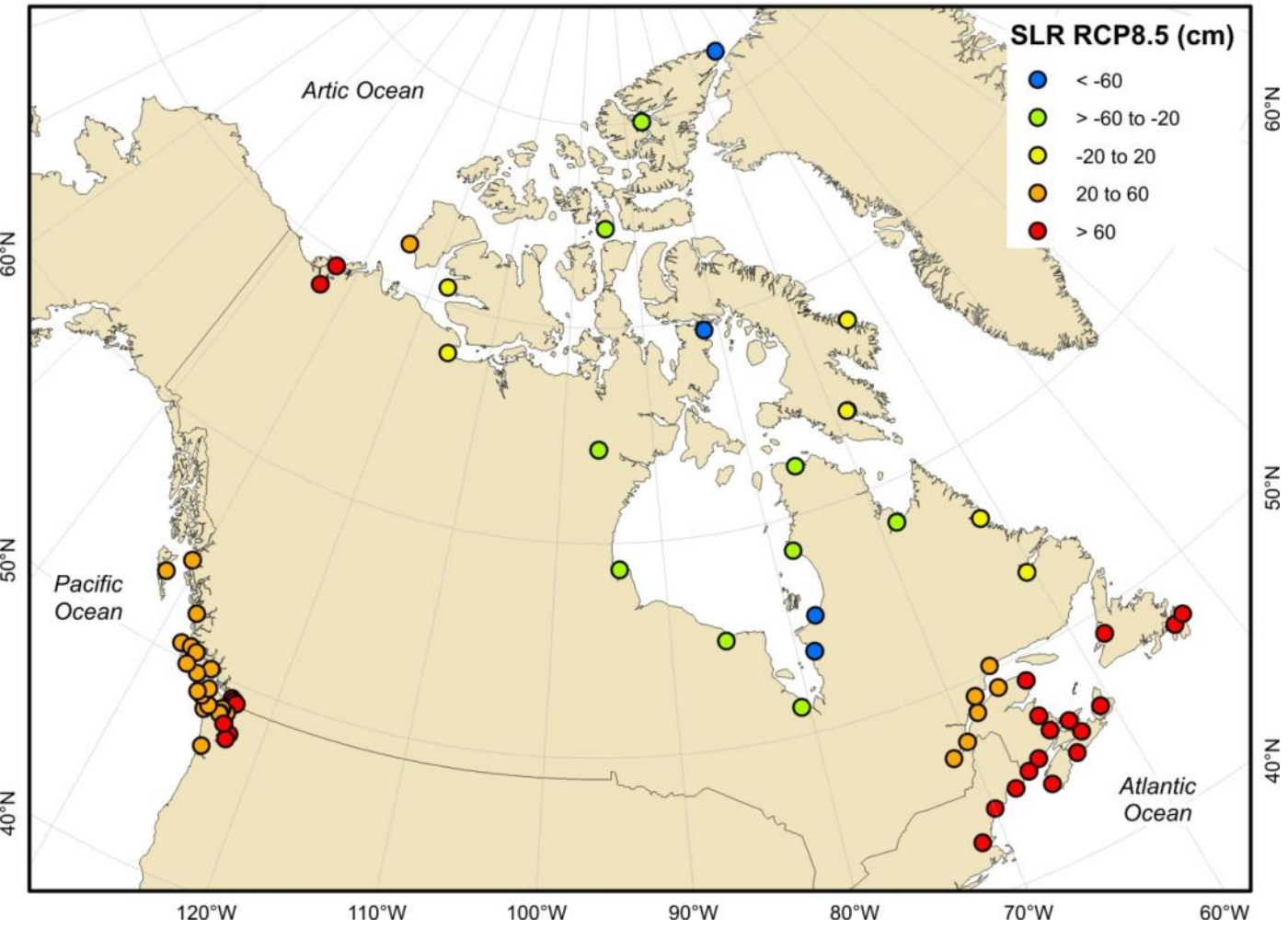
Vertical motion from GPS



Analyzed GPS data to end of 2013;
Used uplift rates in sea-level projections.

Quadra Island,BC (QUAD)
Photo credit: CCDS, NRCan

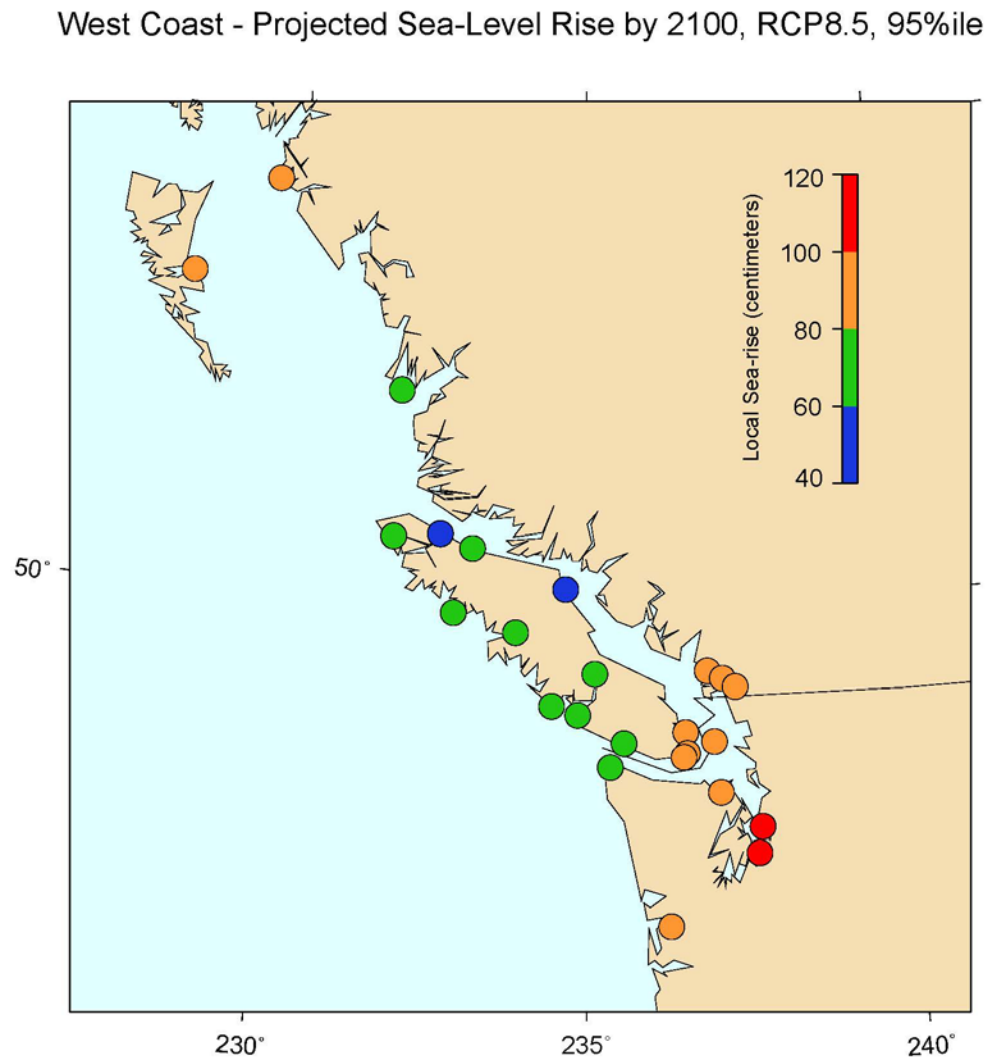
Sea-level projection for high-emissions scenario at 2100



Vertical crustal motion exerts a dominant control on relative sea-level projections

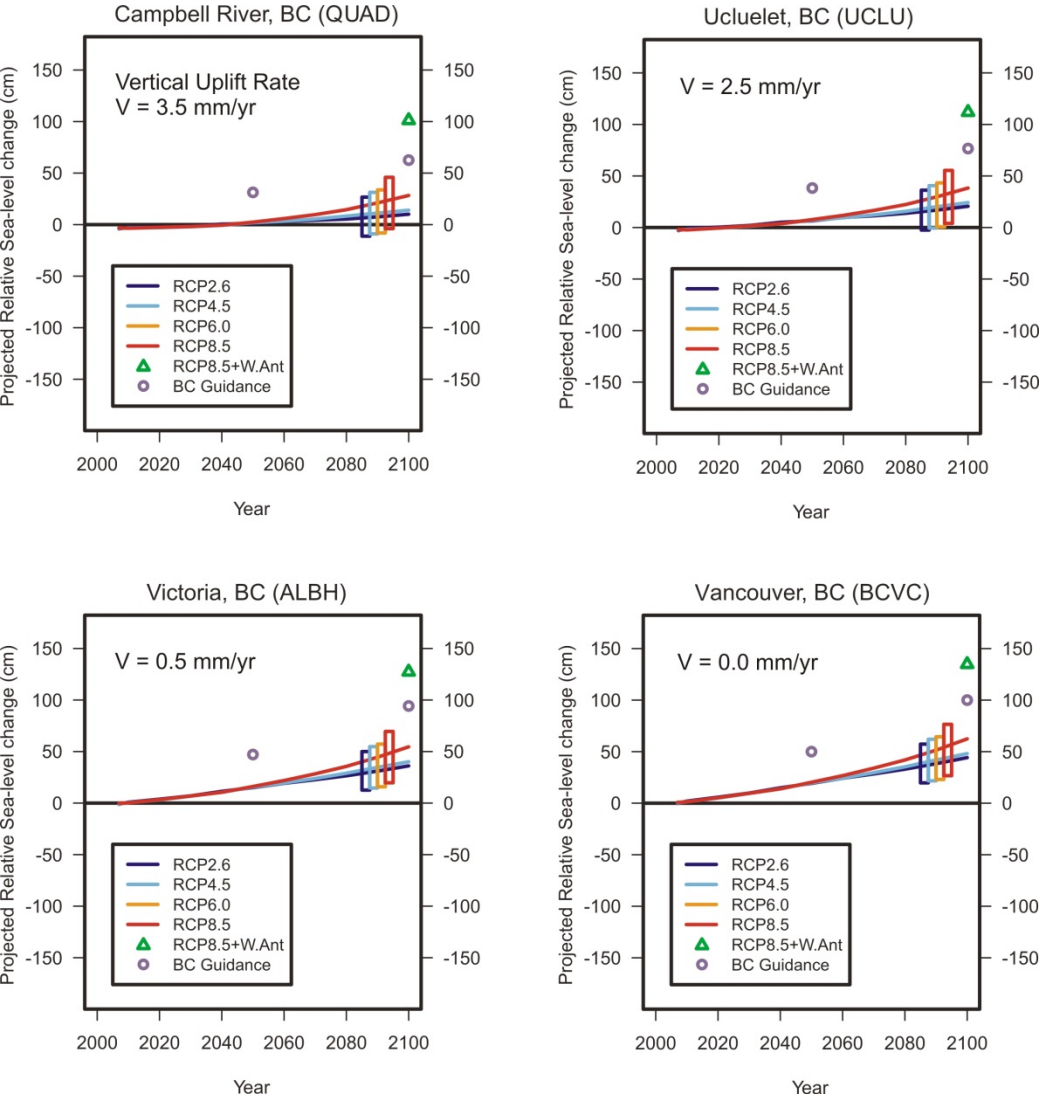
Shows all sites for which projections are provided.

Relative Sea-level Projections in British Columbia



For a high-emissions scenario, sea-level is projected to rise by 0.4 to 1.2 m by 2100 in BC.

Sea-level Projections for British Columbia



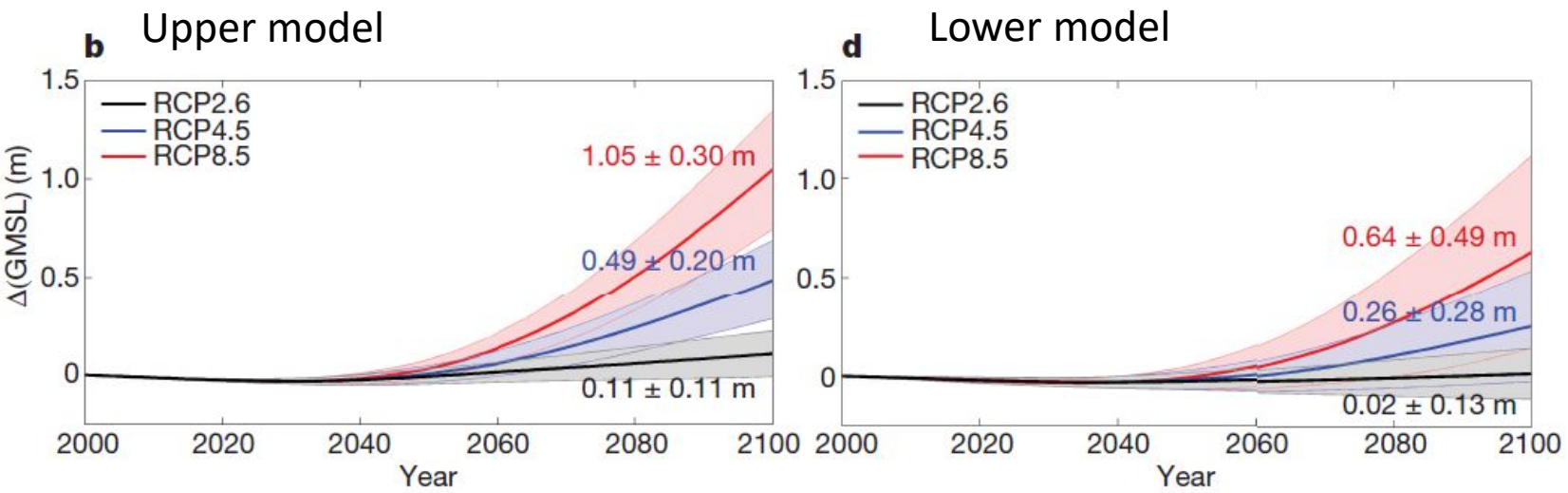
Projections shown for four locations with different amounts of vertical crustal motion.

Additional 65 cm of meltwater from West Antarctica added to RCP8.5 is the green triangle.

Rectangles are 2081-2100 means, relative to 1986-2005.

BC guidance lies above RCP8.5 and below RCP8.5+W.Ant.

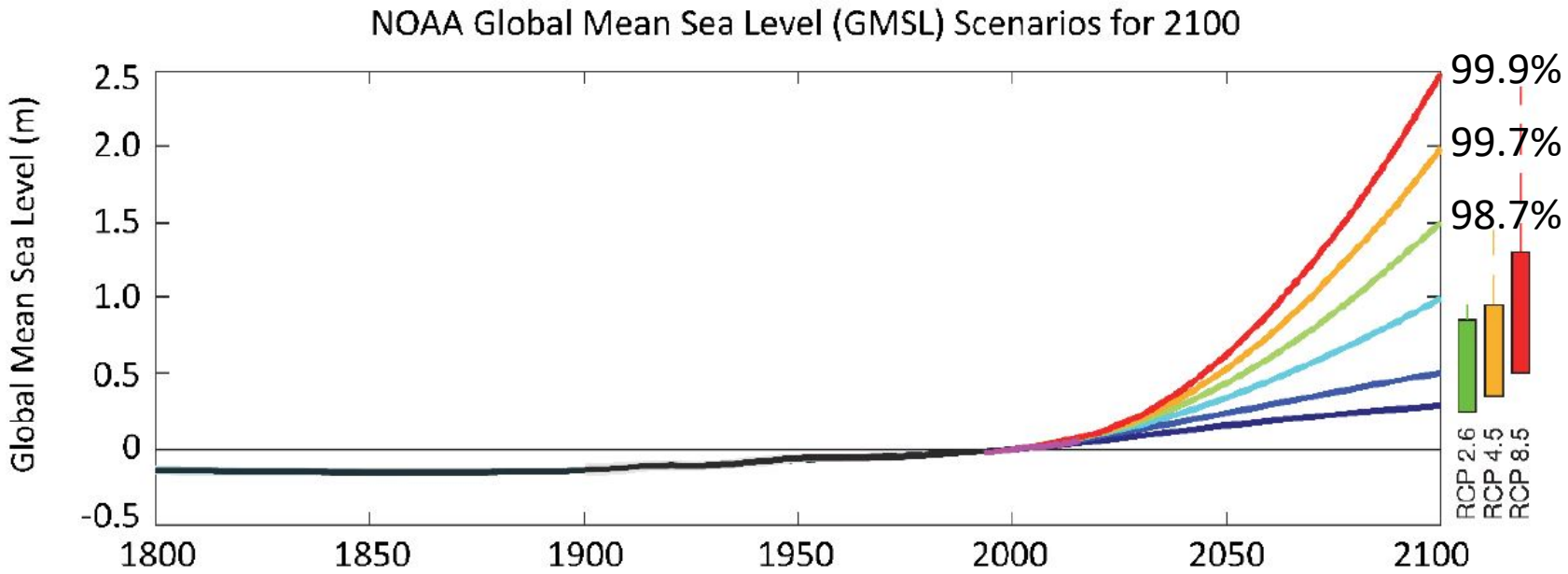
Antarctic ice sheet modelling has progressed. It gives pathways for a larger contribution to sea-level rise than in the IPCC AR5. Most recent publications give up to 30 cm of sea-level rise from Antarctica. Shown are results from a study with larger amounts of projected sea-level change.



No change until around 2050, up to a metre of global sea-level rise by 2100.

DeConto and Pollard, 2016

US Sea-level Scenarios
Input for
Fourth National Climate Assessment (NCA4)



Percentages are the probability that sea-level rise will fall below the value and are for a high-emissions scenario (RCP8.5)

Sweet et al., 2017. "**Global and Regional Sea Level Rise Scenarios for the United States**", NOAA Tech. Rep.

Messaging Surrounding Recent US Sea-level Results

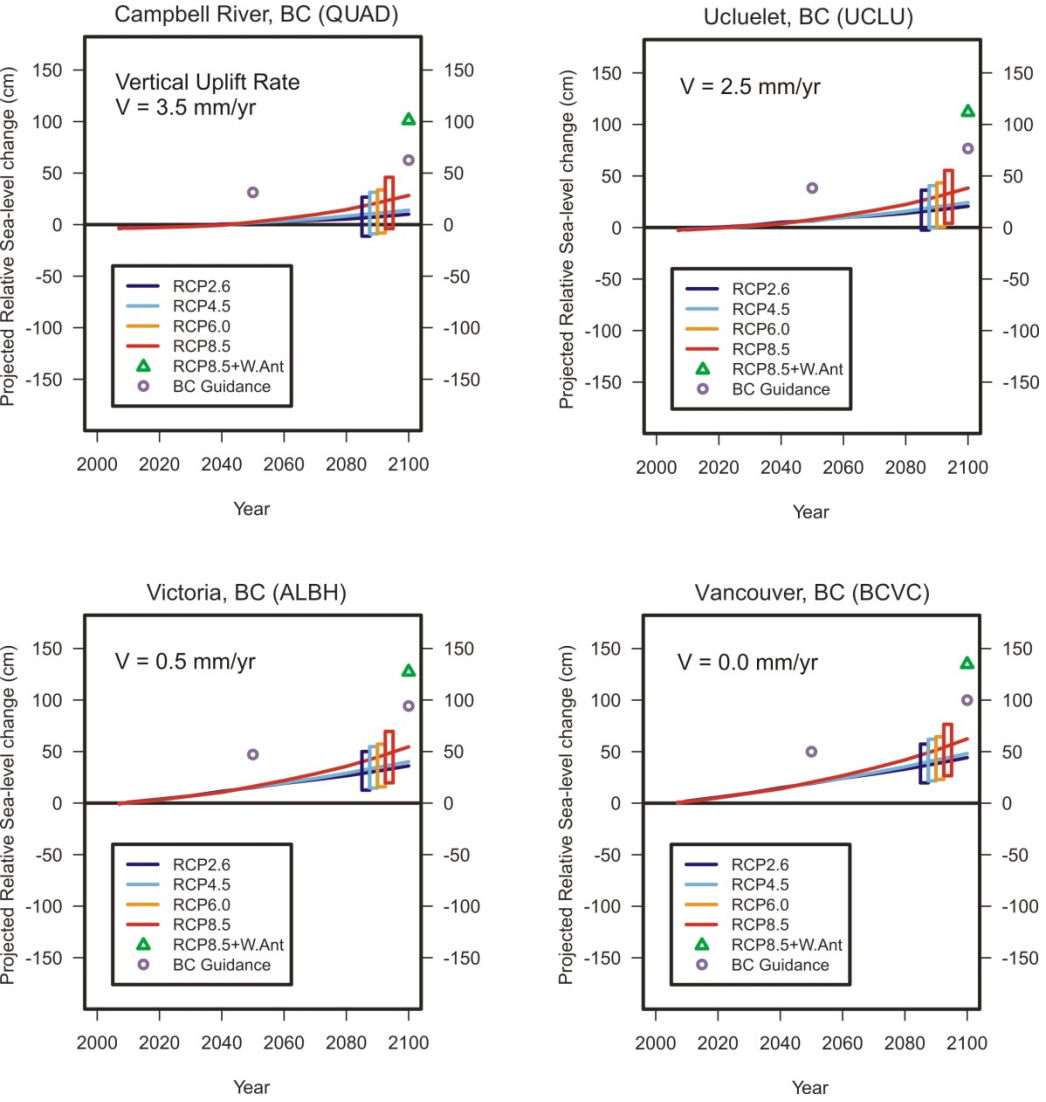
Extreme scenario (2.5 m) of US Climate Change Report was developed to

"test plans and policies against extreme cases with a low probability of occurrence but severe consequences if realized." (Sweet et al., 2017)

Sea-level projections (Garner et al., 2017)
"…end-users of sea-level rise projections should be cognizant of single-study bias: these simulations should be viewed as expanding scientific understanding of the space of physically coherent, rather than as offering firm projections of what will be." (Kopp et al., 2017; technical supplement for Garner et al., 2017)

Conclusion: Assessment processes such as those offered by the IPCC provide an important service in evaluating, assessing, and synthesizing recent scientific findings.

Sea-level Projections for British Columbia



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Key messages

- Sea-level projections are robust up to about 2050 and don't strongly depend on scenario.
- Recent results highlight importance of mitigation of carbon emissions – strong mitigation will avoid the extreme values of global sea-level rise shown today
- BC guidelines lie above the IPCC AR5 projections and offer a measure of safety; designed to be periodically reviewed in light of new scientific findings.
- Emerging scientific results indicate that amounts of sea-level rise much larger than given in the IPCC AR5 is possible.

Key messages

- Adaptation measures should be undertaken in the context of risk tolerance – for a low tolerance to risk of sea-level rise, choose unlikely, high value of sea-level rise.
  - E.g., generating plant (Parris et al., 2012)
- Adaptation is a process - choose no regrets options (if possible), where adjustments can be made in the future