Climate Change and Coastal Shores in British Columbia

January 2010

What is "climate change"?

Climate change refers to long-term changes in average temperature, precipitation and weather events such as storm frequency and intensity. In geologic time, climate change was caused by natural forces, but today, it is human activities associated with the release of "greenhouse gases" (GHGs) that are the primary concern.

The atmosphere contains naturally occurring GHGs - water vapour, carbon dioxide, ozone, methane and nitrous oxides, which collectively create a natural warming blanket around the Earth. Without it, the Earth's surface temperature would be up to 33°C colder than the present average of 15°C.

Human activities such as the burning of fossil fuels, release more GHGs, especially carbon dioxide (CO_2), than the Earth's natural carbon "sinks" (forests and oceans) can absorb. The result is the accelerated warming of our atmosphere (Figure 1).

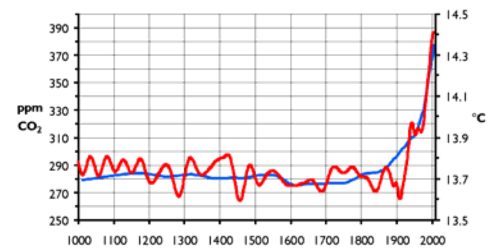

Figure 1: Correlation between atmospheric CO_2 (blue) and mean global temperature (red) over the last 1000 years. *Source: UNEP 2009, citing Hanno 2009.*

How is climate change affecting coastal areas?

Among the greatest risks from climate change from a coastal perspective is relative sea level rise (SLR). Around the world, human populations, infrastructure and economic activity are concentrated along coastlines and are highly vulnerable to any significant change in water levels.

Over geological time, global sea levels have varied profoundly. Twenty thousand years ago, at the peak of the last ice age when a large percentage of water was held in continental glaciers, oceans were on average 120 m *lower* than today. Sea levels rose dramatically in the post-ice age era, but for the last 2000 to 3000 years, global sea levels have been relatively stable (Figure 2). However, records show that over the last century, global sea levels have risen 20 cm. Recent studies suggest that sea levels are expected to rise several times this amount by 2100.

Estimating sea level change is among the most controversial aspects of climate change predictions. In its most recent Assessment Report, the Intergovernmental Panel on Climate Change's (IPCC) estimated global sea level to rise by 18 to 59 cm by 2100.[1] However, many of the world's most reputable SLR experts and modellers think that the IPCC's conclusions are a serious underestimate, given new evidence of accelerated erosion of glaciers and ice sheets and other effects of atmospheric warming.

As the Earth's temperature increases, there are three major drivers of global SLR:

1. **Thermal expansion of oceans** – sea water expands as it warms , causing the ocean's volume to increase.
2. **Melting of Greenland and Antarctic ice caps** – published evidence from 2006 onwards has shown that these ice sheets have been melting at rates higher than in previous decades. Recent observations also demonstrate that melting of ice caps is

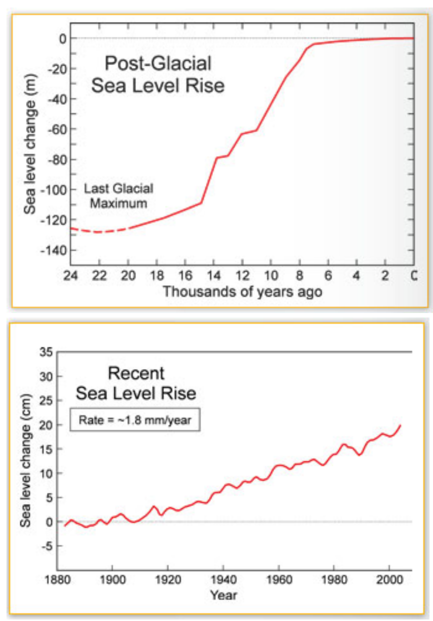

Figure 2: Post-glacial and recent changes in global mean seal level. *Source: Bornhold, 2008*

[1] International Panel on Climate Change (IPCC), 2007. Summary for Policy Makers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S. et al (eds)].

subject to "feedback loops". Snow and ice reflect sunlight, but as the temperature increases and ice sheets melt, there is less ice to reflect sunlight and more dark water to absorb it – intensifying the warming effect. This means that melting and the related SLR will likely not follow a predictable, linear rate but rather will increase abruptly in association with major melting events, such as the 2002 disintegration of the Larsen B ice shelf in Antarctica.

3. **Melting of land-based glaciers** – about 60% of global ice loss since 1993 is from smaller glaciers rather than the major ice sheets; the increased glacial melt could contribute 0.1 to 0.25 meter of additional global SLR by 2100 beyond estimates made by the IPCC in 2007.[2]

Based on these analyses since the IPCC 2007 report, revised estimates place global mean SLR in the range of 1 meter or greater[3] by 2100.

What effects will climate change have on BC's coast?

A recent study by BC scientists (Thomson *et al.*, 2008[4]) summarizes the current understanding of sea level variability and presents estimates for sea level rise along BC's coast (Table 1). When it comes to changes in sea level, it is important to recognize that climate change is not the only phenomenon to consider. The Thomson *et al.* study describes various processes affecting relative sea levels and how they might influence the manifestation of global climate change on our coast. These processes include:

- **Post glacial rebound -** Most of coastal BC is still rebounding from the loss of the immense weight of glaciers during the last ice age. This process is increasing the height of most of BC's coast at a small rate (0 to 0.5 mm per year), which may moderate any local SLR associated with climate change.[5]
- **Tectonic forces -**The Juan de Fuca plate off BC's coast continues to move under the North American plate, resulting in annual uplift of 2-3 mm off west Vancouver Island that diminishes eastward to zero near Vancouver. While this uplift may counteract sea level rise in this region, it would be partially reversed by a large earthquake (magnitude 9), which happens every 500 years or so. Such an event could result in an instantaneous *lowering* of the land and a relative rise in sea level of 0.5 to 2 m along west Vancouver Island, and 0.2 metres in Victoria. The rest of coastal BC is expected to be less impacted.[6]
- **Sediment compaction –** The gradual compaction of sediments in the Fraser River Delta is resulting in subsidence rates of 1-2 mm per year, affecting municipalities like Richmond and Delta.[7] Subsidence rates of greater than 3 millimetres per year are mostly connected to large construction projects such as BC Ferries Terminal in Tsawwassen, Deltaport, and the Vancouver International Airport.[8]
- **Atmospheric forces** - Atmospheric conditions influence sea levels seasonally - such as wintertime storms that have historically elevated sea level on the outer coast by up to 0.9 meters. There are also conditions that occur over longer periods. 'Warm' El Niño and 'cool' La Niña cycles, occurring over 6-18 months, alter water temperature, storm intensity and sea levels; for

"The possibility of increased storm intensity and duration associated with global warming could also lead to higher wind waves and swell in winter which would, in turn, lead to greater land erosion and flooding during periods of high tide.." (Thomson *et al.*, 2008: v)

[2] Meier *et al.*, 2009. Glaciers dominate eustatic sea-level rise in the 21st Century. Science, 317 (5841): 1064 – 1067.

[3] E.g., the report from the 2009 Copenhagen Climate Congress states: "The new observations of the increasing loss of mass from glaciers, ice caps and the Greenland and Antarctic ice sheets lead to predictions of global mean sea level rises of 1 m (±0.5 m) during the next century. The updated estimates of the future global mean sea level rise are about double the IPCC projections from 2007." (Richardson *et al.*, 2009: 9)

[4] Thomson, R.E., Bornhold, B.D., and Mazzotti, S. 2008. *An examination of the factors affecting relative and absolute sea level in coastal British Columbia.* Can. Tech.Rep. Hydrogr.Ocean Sci. 260: v + 49 p.; Bornhold, B. 2008. *Projected sea level changes for British Columbia in the 21st century.* 12 p

[5] Thomson *et al*., 2008

[6] Thomson *et al*., 2008

[7] Mazzotti et al 2008. Natural and anthropogenic subsidence of the Fraser River Delta. Geology (in press). As Cited in Thomson *et al*., 2008

[8] Thomson *et al*., 2008

Location	Sea Level Rise based on *extreme low* estimate of global sea level rise (m)	Sea Level Rise based on *mean* estimate of global sea level rise (m)	Sea Level Rise based on *extreme high* estimate of global sea level rise (m)
Prince Rupert	0.10–0.31	0.25–0.46	0.95–1.16
Nanaimo	–0.04	0.11	0.80
Victoria	0.02–0.04	0.17–0.19	0.89–0.94
Vancouver	0.04–0.18	0.20–0.33	0.89–1.03
Fraser River Delta	0.35	0.50	1.20

Table 1: Estimated Relative Sea Level Rise by 2100 over 2007 levels for representative locations along BC's coast. The "mean" estimate is based a global mean SLR of 18-59 cm (from the IPCC 2007 estimates) and the "extreme high" estimate is based on a global mean SLR of 1 meter. *Source: Bornhold, 2008: 8*

example, during El Niño phases, sea levels off BC may rise due to the warmer water. A "perfect storm" from a coastal hazard perspective may consist of a major winter storm occurring at a high spring tide during a strong El Niño year. Current studies indicate that climate change may result in increased frequency and intensity of such storms, which in turn, could create larger wind waves, swell heights and related water levels.

- **Water temperature and salinity** – Finally, climate change may change hydrological regimes in major watersheds. More freshwater runoff can increase ocean temperatures and reduce salinity along the coast, and warmer, fresher water occupies more volume than colder, saltier water.[9]

Consequently, the estimates for relative sea level rise along the BC coast (Table 1) vary significantly from locale to locale, based on the influence of these regional and local factors on global sea level rise. While the "extreme high" estimates are greater than the IPCC projections, recent studies indicate that overall, sea level rise is likely to be significantly higher than the IPCC 2007 estimates because of previous under-estimates in the amount of ice melt from the Antarctica and Greenland ice sheets.[10] Estimates for BC may need to be revised to reflect our evolving understanding of the effects of climate change at both global and regional levels.

The bottom line ….

While there is still a lot of uncertainty in estimating the effects of climate change on sea level, recent observations suggest that current global climate models are underestimating future sea level rise. To be on the safe side, **coastal BC communities in general should prepare for a relative sea level rise of one metre by 2100,** with regional variations due to local natural processes. For example:

- Counteracted slightly by post glacial uplift, Vancouver, Victoria and Prince Rupert could experience sea level rise of 0.9 to 1.0 metre.
- Due to sedimentation subsidence, areas in the Fraser River Delta (Richmond, Delta, etc.) could experience a 0.50 to 1.2 metre relative SLR.
- In contrast, relative sea level in Tofino may rise by only 5-18 cm due to the countering effect of tectonic uplift; however, the uplift could be reversed in the event of an extreme earthquake which could cause an instantaneous coastal subsidence of 0.5 to 2 m.
- In the Fraser Delta, a one metre SLR would inundate 4,600 hectares of farmland and put more than 15,000 hectares of residential, commercial and industrial lands at risk.[11]

[9] Bornhold, 2008.

[10] Richardson *et al.*, 2009

[11] Yin, Y. 2001. *Designing an Integrated Approach for Evaluating Adaptation Options to Reduce Climate Change Vulnerability in the Georgia Basin*. Climate Change Impacts and Adaptation Program Report, Natural Resources Canada.

What can we do about it?

To understand the potential impacts of climate change and SLR, coastal communities and developers need to conduct vulnerability and risk assessments as a part of site assessments, long range planning and risk management. Some of the impacts of climate change on coastal areas that should be accounted for include:

- More frequent landslides and coastal flooding.
- Reduced effectiveness of sea walls and other protective structures.
- Increased erosion of dunes, beaches, bluffs and other natural features.
- Loss of existing coastal wetlands and other coastal habitats, creation of new coastal wetlands in former upland areas
- Increased damage to coastal infrastructure – roads, bridges, docks, ports, walkways, marinas, etc.
- Saltwater intrusion into coastal aquifers due to sea level rise
- Increased risk of pollution from coastal stormwater, sanitary sewer and hazardous waste sites.
- Loss of coastal cultural and historical sites.

Actions to reduce risk include greater setbacks from the shoreline for new development and enhanced shoreline protection for existing development. It may be economically feasible to 'hold the line' on shorelines in high density areas where large populations and a range of economic activities are affected, and where sufficient revenues can be generated to warrant these expensive measures. However, in low density residential and rural areas, planned retreat and relocation of homes and buildings may be the best solution – economically, aesthetically and environmentally.

Relocation of house back from eroding coastline on New Zealand's west coast. *Source: New Zealand Ministry of Environment, 2008*

There are a variety of resources available to help communities assess and plan for the effects of climate change – see the following list for a start.

> "As a society, we cannot afford to stand and fight the sea on all of our coasts. We must plan an organized retreat from the encroaching sea or alternatively face expending vast amounts of money and other resources only to fail and retreat grudgingly in a disorganized fashion".
>
> *(Bush et al., 1996. Living by the Rules of the Sea, p. 97)*

Resources

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The authors gratefully acknowledge the assistance of Dr. Brian Bornhold, Coastal and Ocean Resources Inc. and Tina Neale, Climate Adaptation Secretariat, BC Ministry of Environment for their advice on the many drafts of this issue sheet.