Estimating extreme water levels for climate-change adaptation planning in Halifax Harbour

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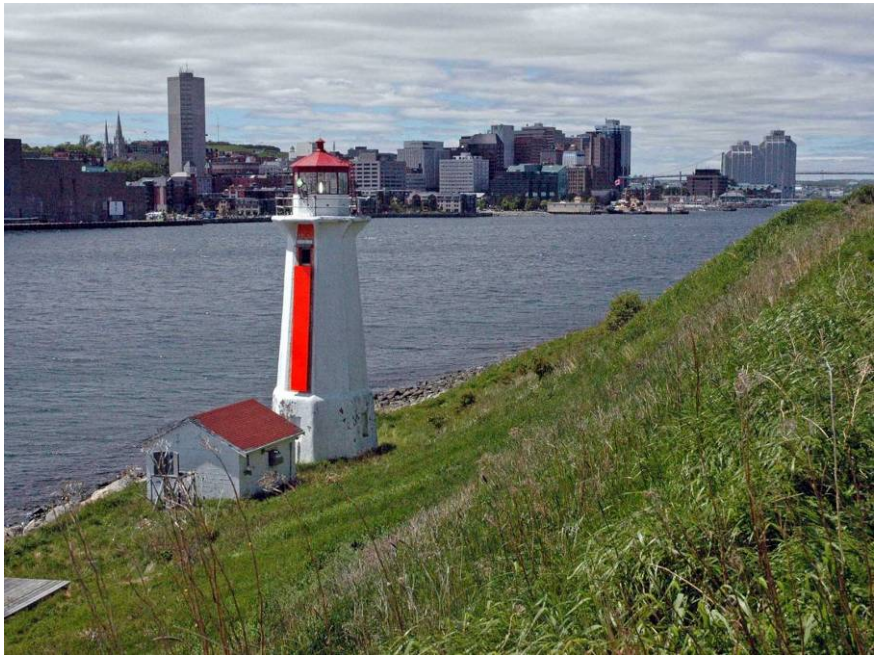

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11th International Workshop on Wave Hindcasting & Forecasting and 2nd Coastal Hazards Symposium, Halifax, NS, 18-23 Oct 2009

Motivation

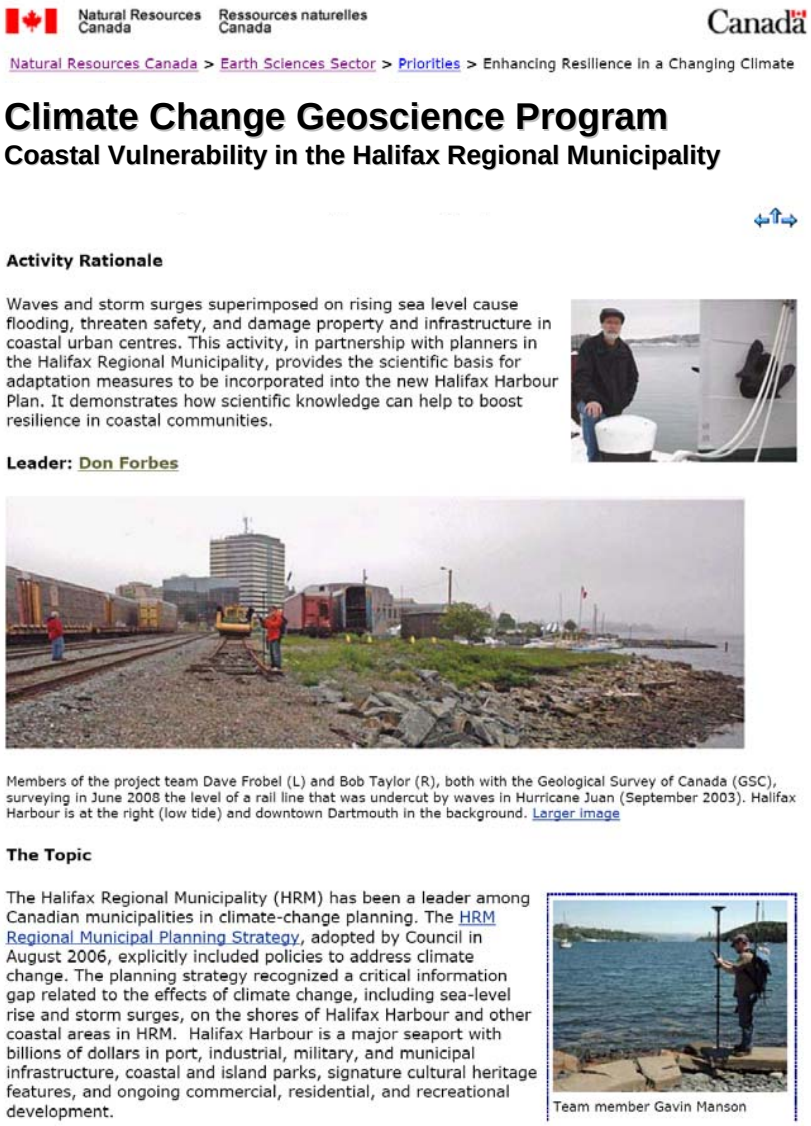
- Precautionary principle adopted in long-term plan
- Exceptional storm experienced 2003
- Climate-change adaptation incorporated in development of Halifax Harbour Plan from outset

Aftermath of Hurricane Juan, Dartmouth waterfront, 2 Oct 2003

Coastal vulnerability in the Halifax Regional Municipality (HRM)

- Scientific foundation for robust adaptation planning
- Precautionary principle and 100-year planning horizon
- Partnership between Natural Resources Canada, HRM, Province of Nova Scotia, Dalhousie University, NSCC, and others

http://ess.nrcan.gc.ca/ercc-rrcc/proj2/theme1/act2_e.php



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Natural Resources Canada > Earth Sciences Sector > Priorities > Enhancing Resilience in a Changing Climate

Climate Change Geoscience Program

Coastal Vulnerability in the Halifax Regional Municipality

Activity Rationale

Waves and storm surges superimposed on rising sea level cause flooding, threaten safety, and damage property and infrastructure in coastal urban centres. This activity, in partnership with planners in the Halifax Regional Municipality, provides the scientific basis for adaptation measures to be incorporated into the new Halifax Harbour Plan. It demonstrates how scientific knowledge can help to boost resilience in coastal communities.

Leader: Don Forbes

Members of the project team Dave Frobel (L) and Bob Taylor (R), both with the Geological Survey of Canada (GSC), surveying in June 2008 the level of a rail line that was undercut by waves in Hurricane Juan (September 2003). Halifax Harbour is at the right (low tide) and downtown Dartmouth in the background. Larger image

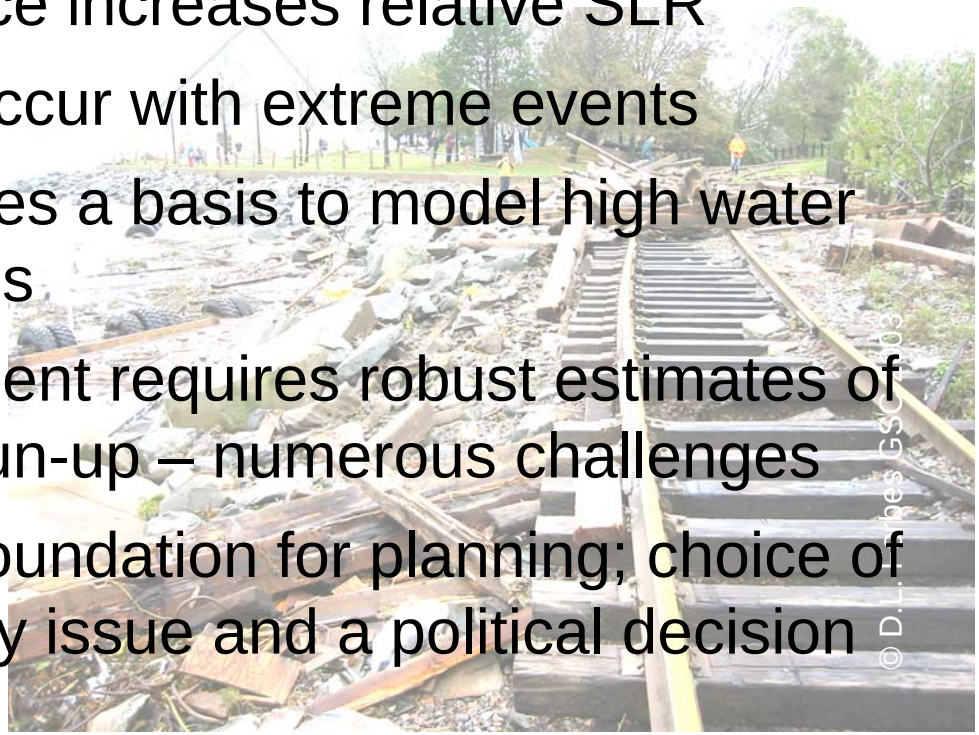
The Topic

The Halifax Regional Municipality (HRM) has been a leader among Canadian municipalities in climate-change planning. The HRM Regional Municipal Planning Strategy, adopted by Council in August 2006, explicitly included policies to address climate change. The planning strategy recognized a critical information gap related to the effects of climate change, including sea-level rise and storm surges, on the shores of Halifax Harbour and other coastal areas in HRM. Halifax Harbour is a major seaport with billions of dollars in port, industrial, military, and municipal infrastructure, coastal and island parks, signature cultural heritage features, and ongoing commercial, residential, and recreational development.

Team member Gavin Manson

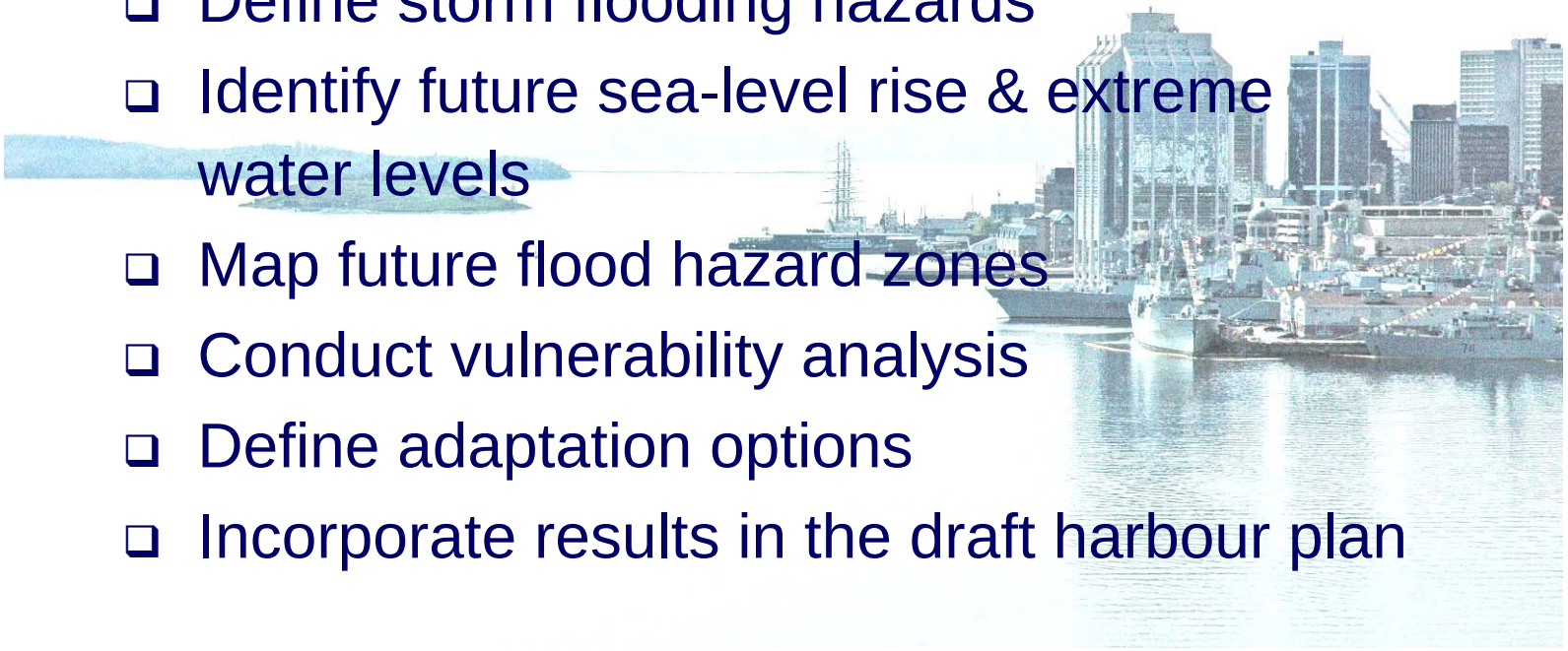
Take-home messages

- Sea level is rising now and will accelerate: 17-57 cm (IPCC), 68-172 cm (V&R *sub*.)
- Regional subsidence increases relative SLR
- Greatest impacts occur with extreme events
- LiDAR DEM provides a basis to model high water level flood scenarios
- Scenario development requires robust estimates of SLR, storm WLs, run-up – numerous challenges
- Science provides foundation for planning; choice of scenarios is a policy issue and a political decision



Science input to the Halifax Harbour Plan

- Create DEM using LiDAR
- Define storm flooding hazards
- Identify future sea-level rise & extreme water levels
- Map future flood hazard zones
- Conduct vulnerability analysis
- Define adaptation options
- Incorporate results in the draft harbour plan



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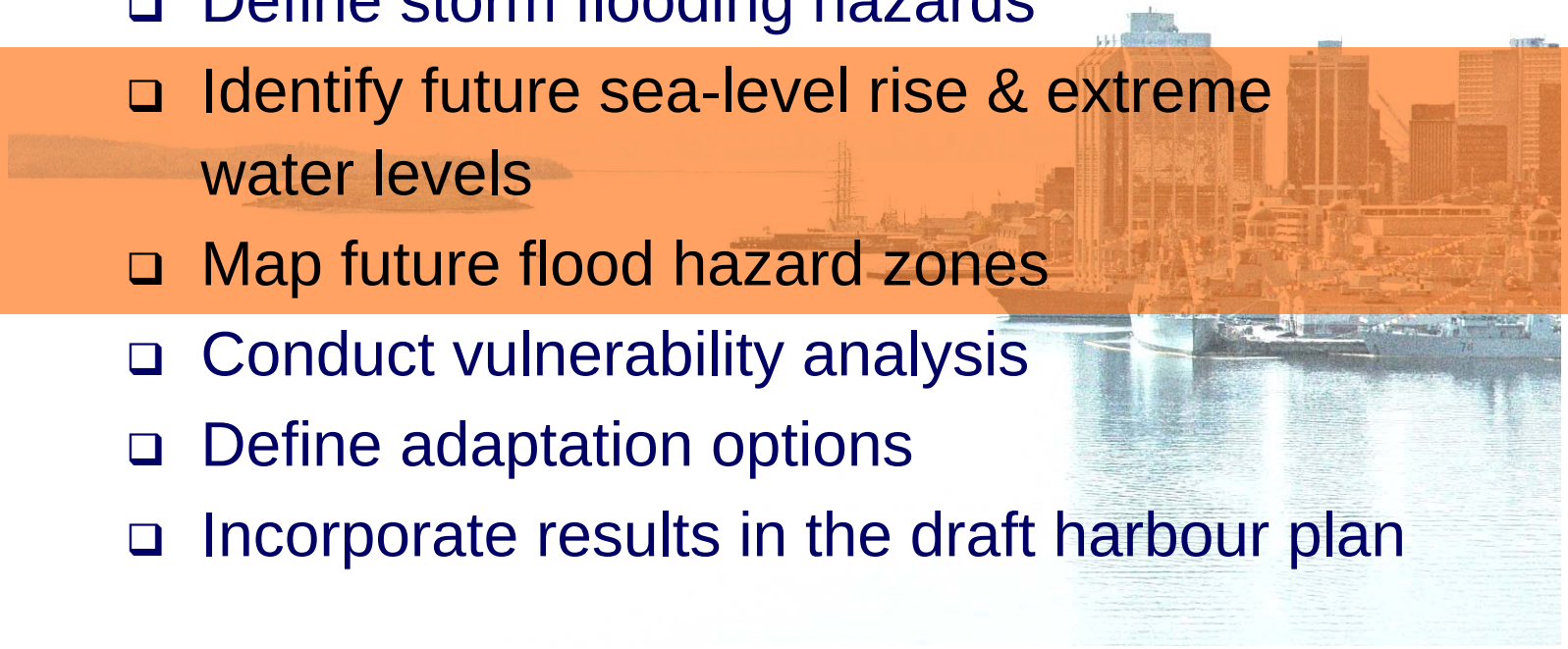
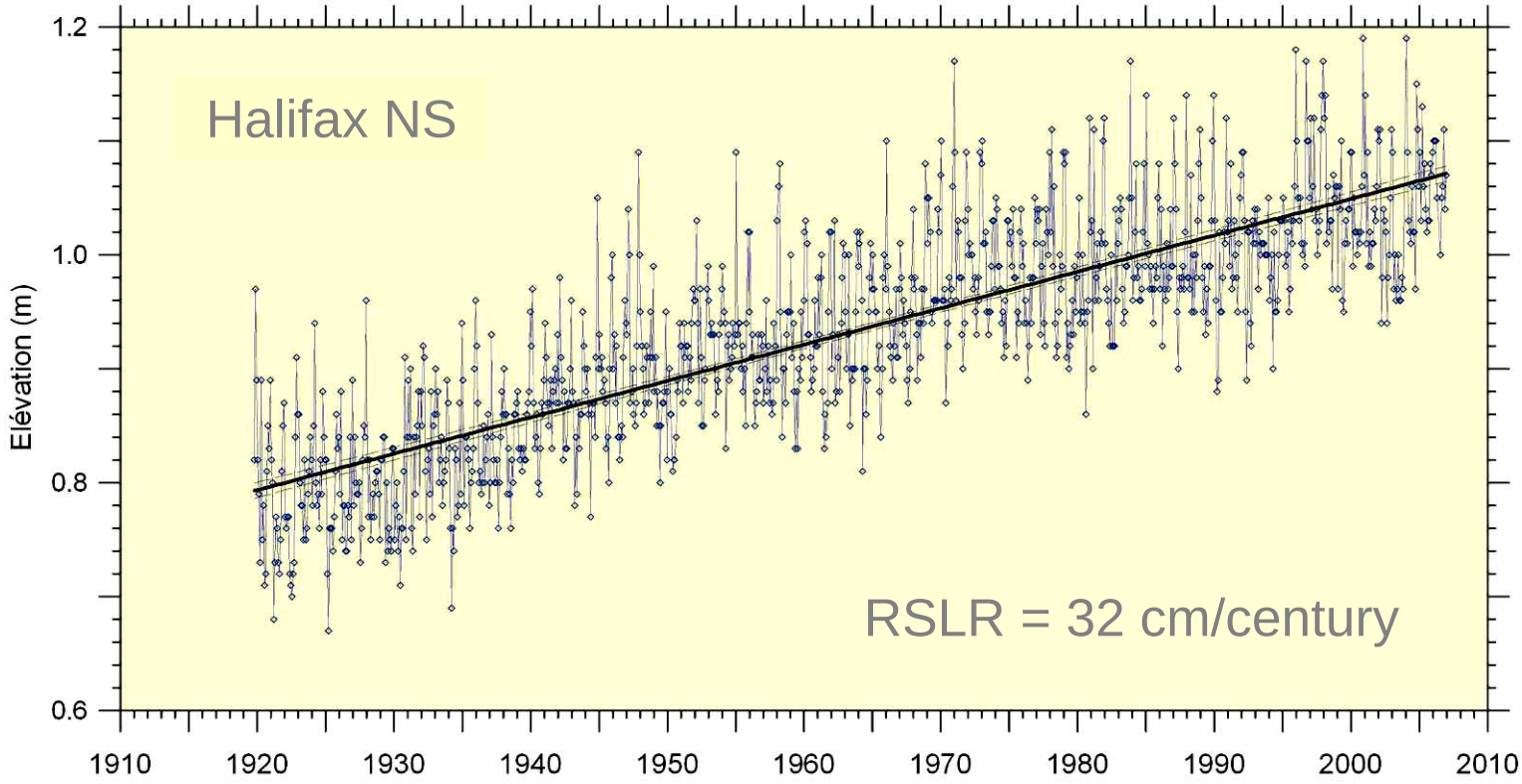


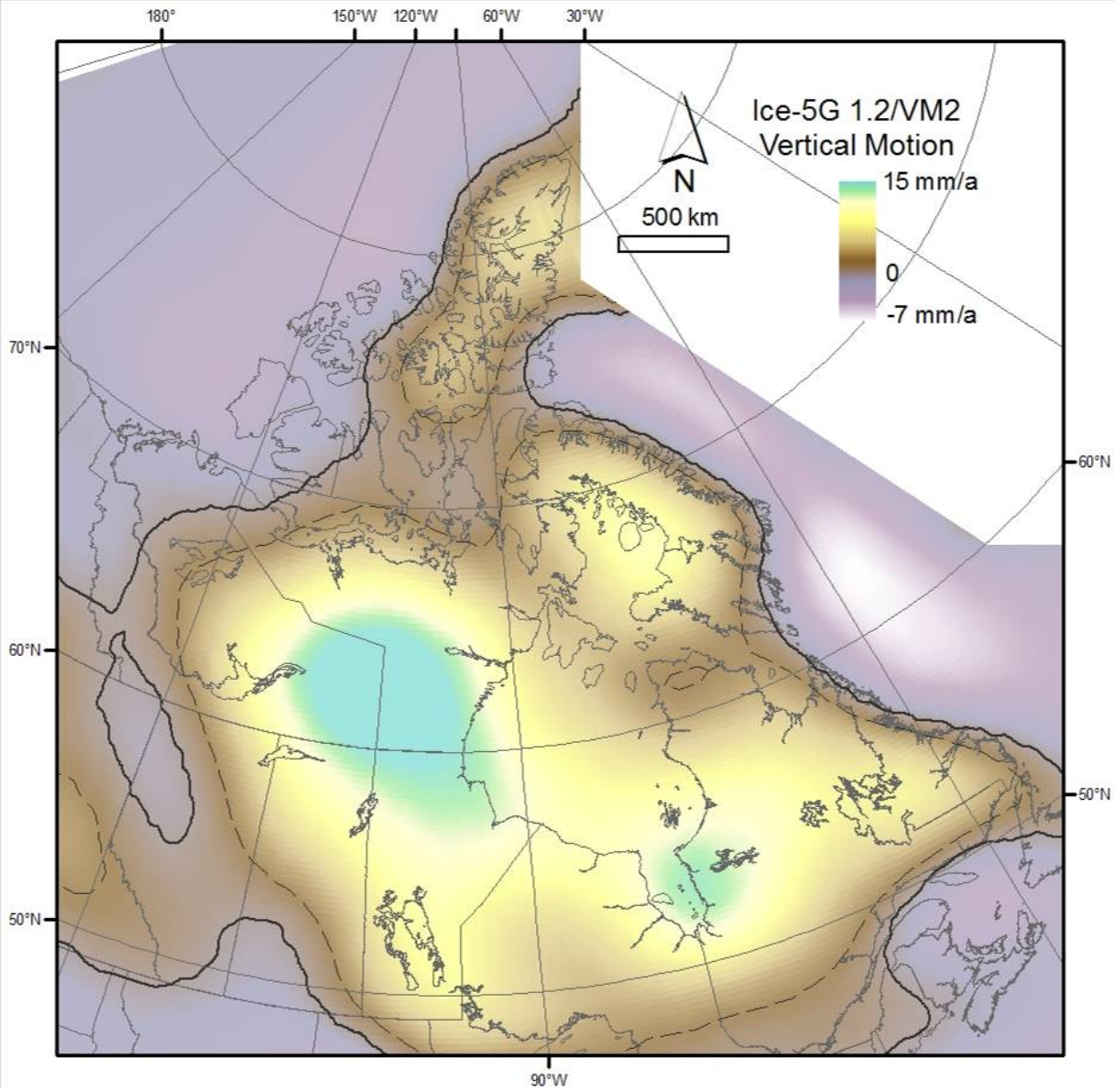
Relative sea-level rise is happening now ...

• change of high-tide line at Fortress of Louisbourg NS

Storm-surge flooding & coastal erosion are problems that are with us today …

- Even **without** global warming, these problems would get worse due to ongoing submergence in the region





Changing relative sea level relates to ***both***:

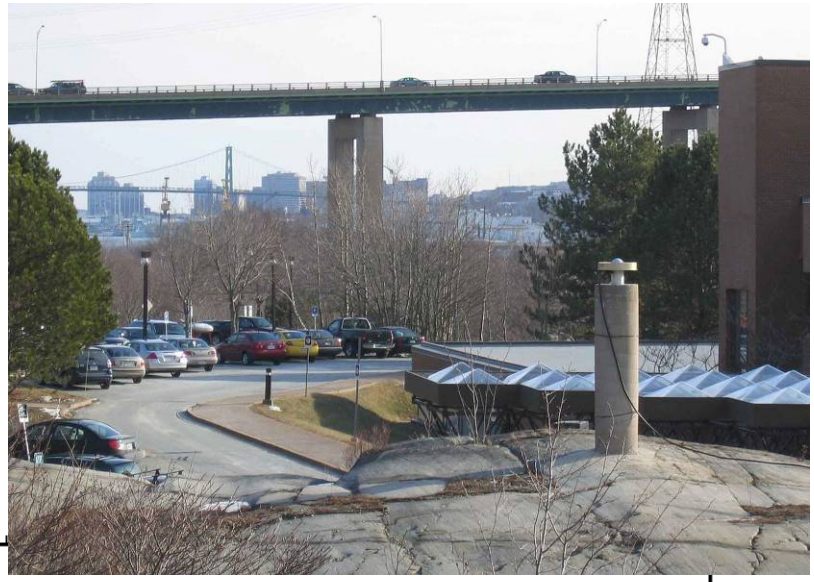
- global/regional sea-level rise

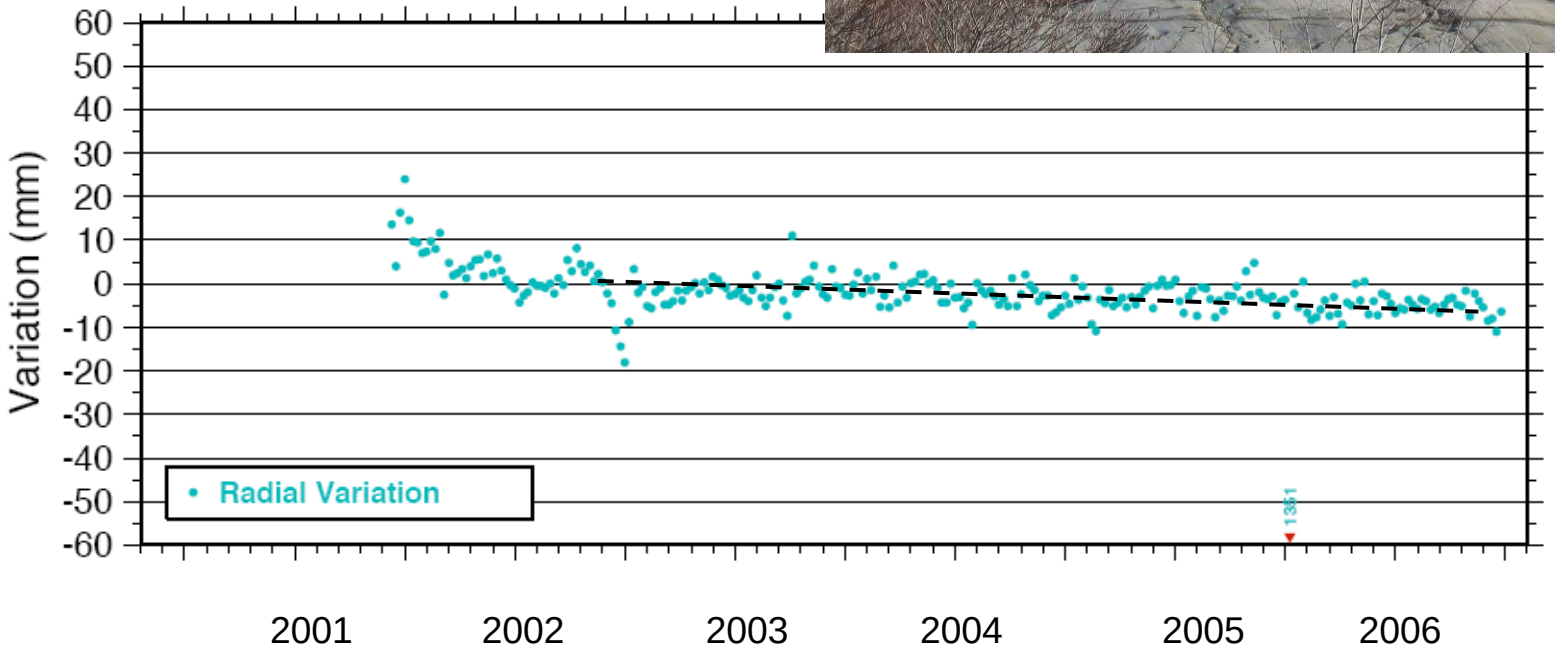
  and

- vertical crustal motion

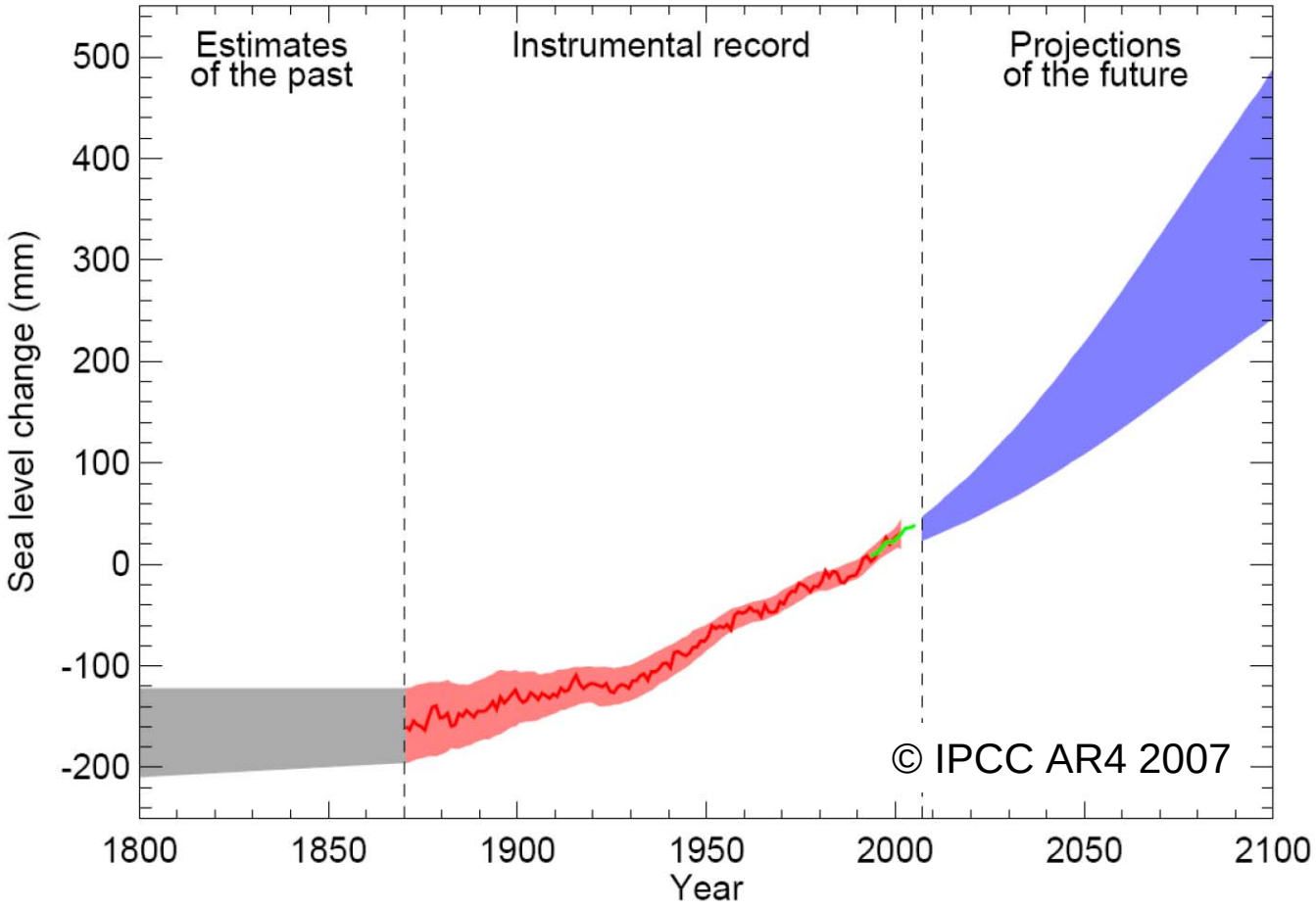
Ongoing Subsidence

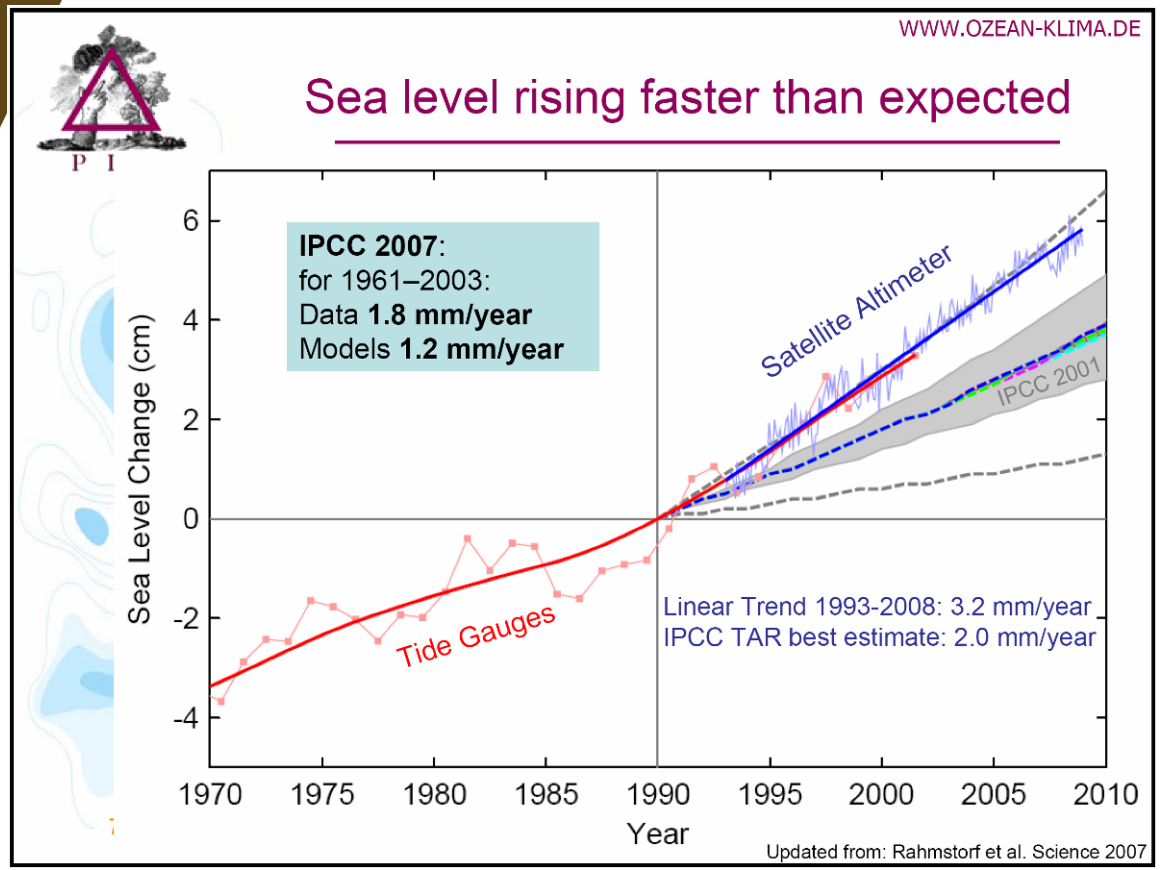
- GPS data from the pillar at BIO measures crustal subsidence at Halifax
- Rate is about -1.6 mm/a (equivalent to -16 cm/century)





Past, Present and Future Global Sea Level



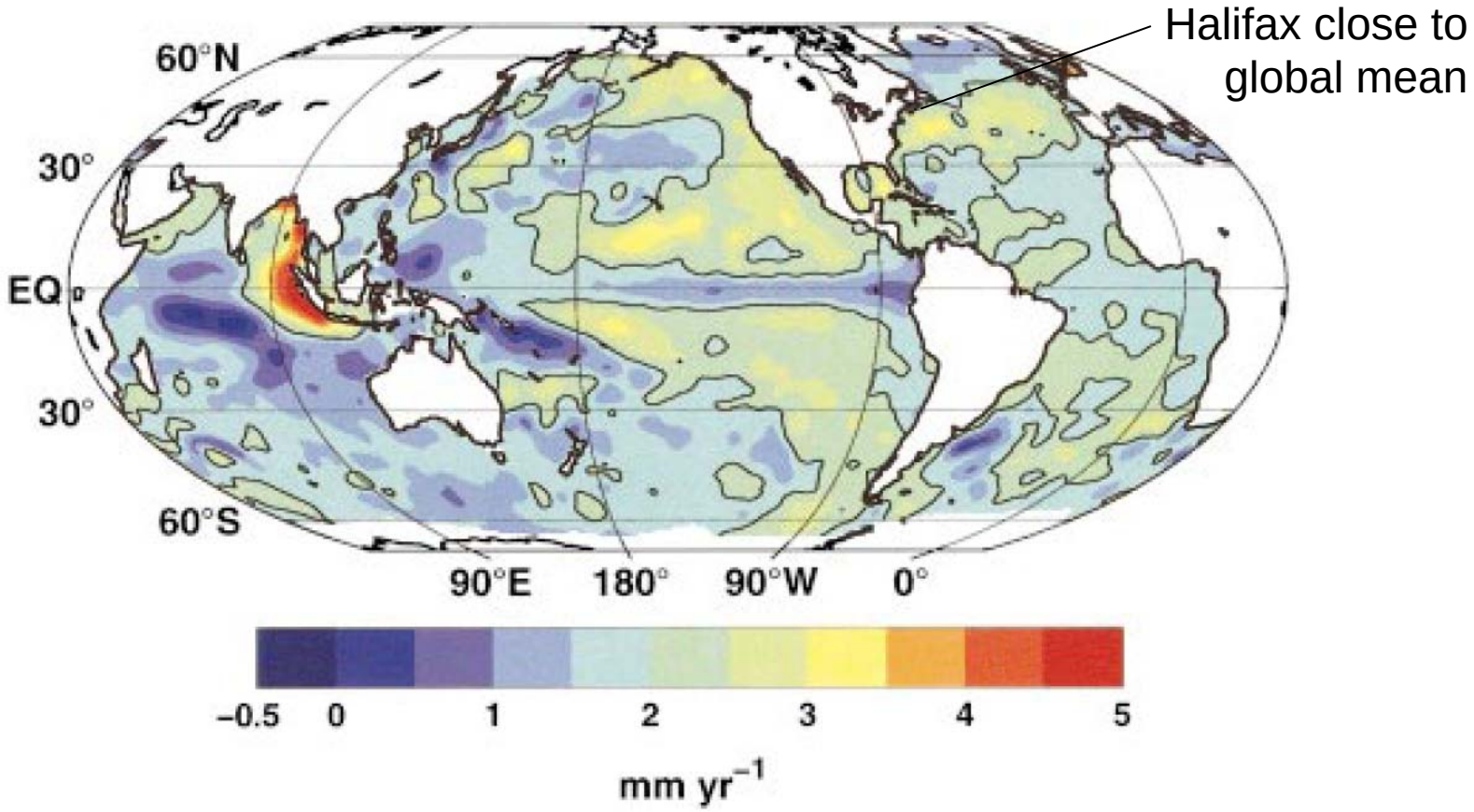


Observed sea-level rise is tracking the highest projections from the IPCC Third Assessment, above the uppermost AR4 projections

Projected global temperature increase and sea level rise by 2100

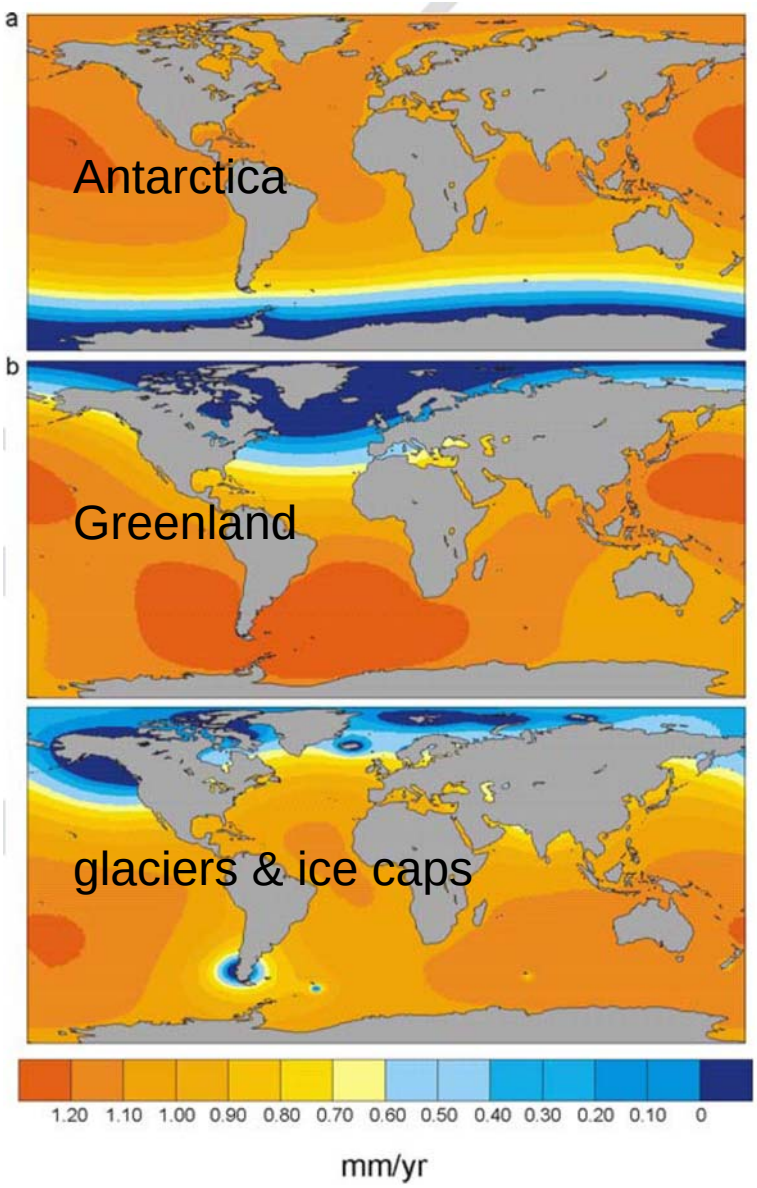
	Temperature Change (°C at 2090-2099 relative to 1980-1999) [a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
Case	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations [c]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Source: IPCC WG1 (2007) Summary for Policy Makers



The regional distribution of sea level rise between Jan 1950 and Dec 2000 from the reconstructed sea level fields using the tide gauge data. The solid line is 2.0 mm yr^{-1} and the contour interval is 0.5 mm yr^{-1}.

Source: Church et al. 2004. Estimates of the regional distribution of sea level rise over the 1950-200 period. *Journal of Climate*, **17**, 2609-2625.



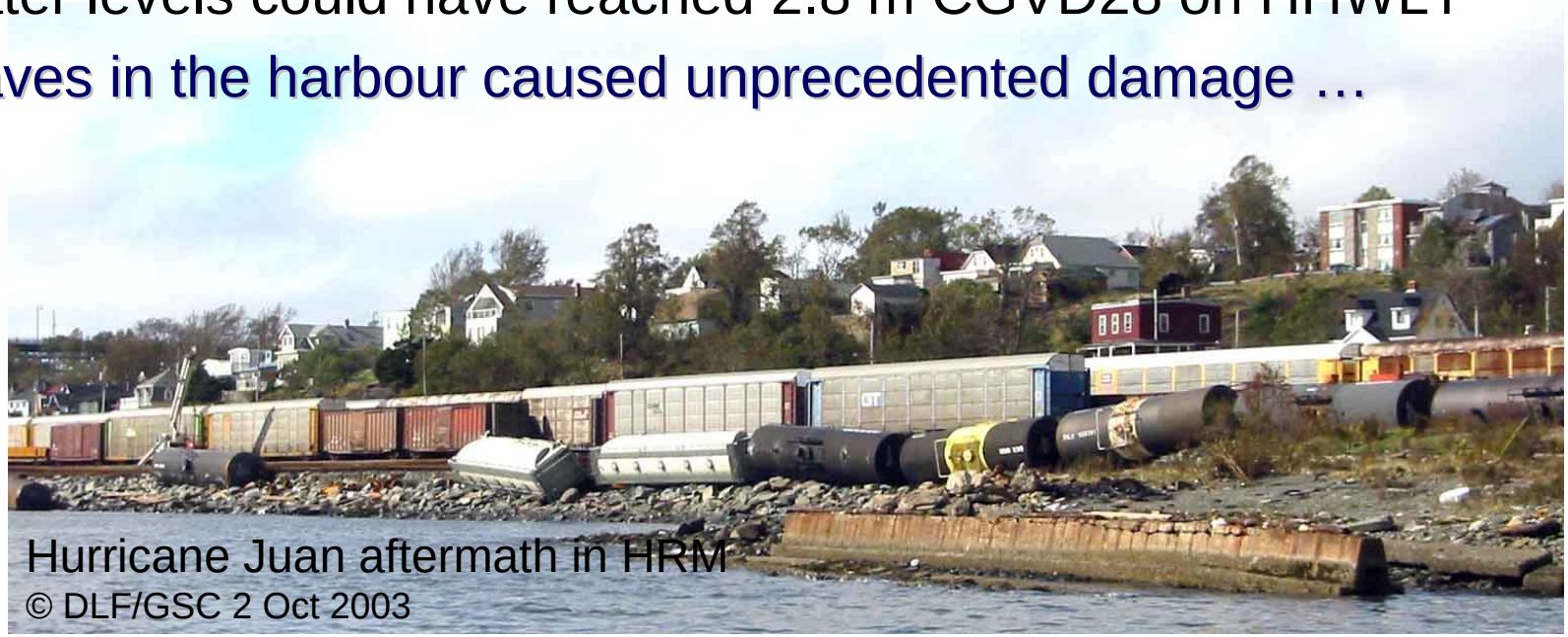
Sea-level fingerprinting: the gravitational effect

In Atlantic Canada, for ice melt contribution to SLR

- from Antarctica – 110%
- from Greenland – <0 to 20%
- from glaciers & ice caps – 100%

Hurricane Juan – September 29, 2003

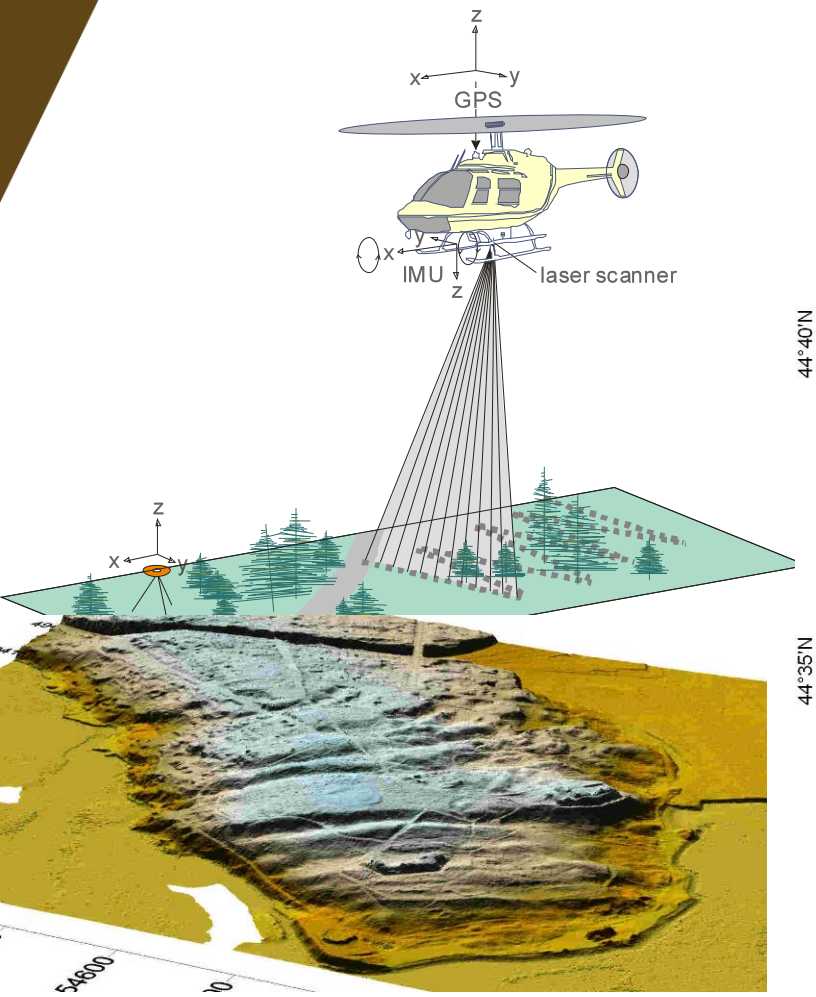
- Juan made landfall as a weak Class 2 hurricane
- Eastern eyewall passed directly over Halifax Harbour
- Water levels reached 2.1 m CGVD28 in Halifax on a 1.5 m surge
- The surge did not coincide with high tide
- Water levels could have reached 2.8 m CGVD28 on HHWLT
- Waves in the harbour caused unprecedented damage …

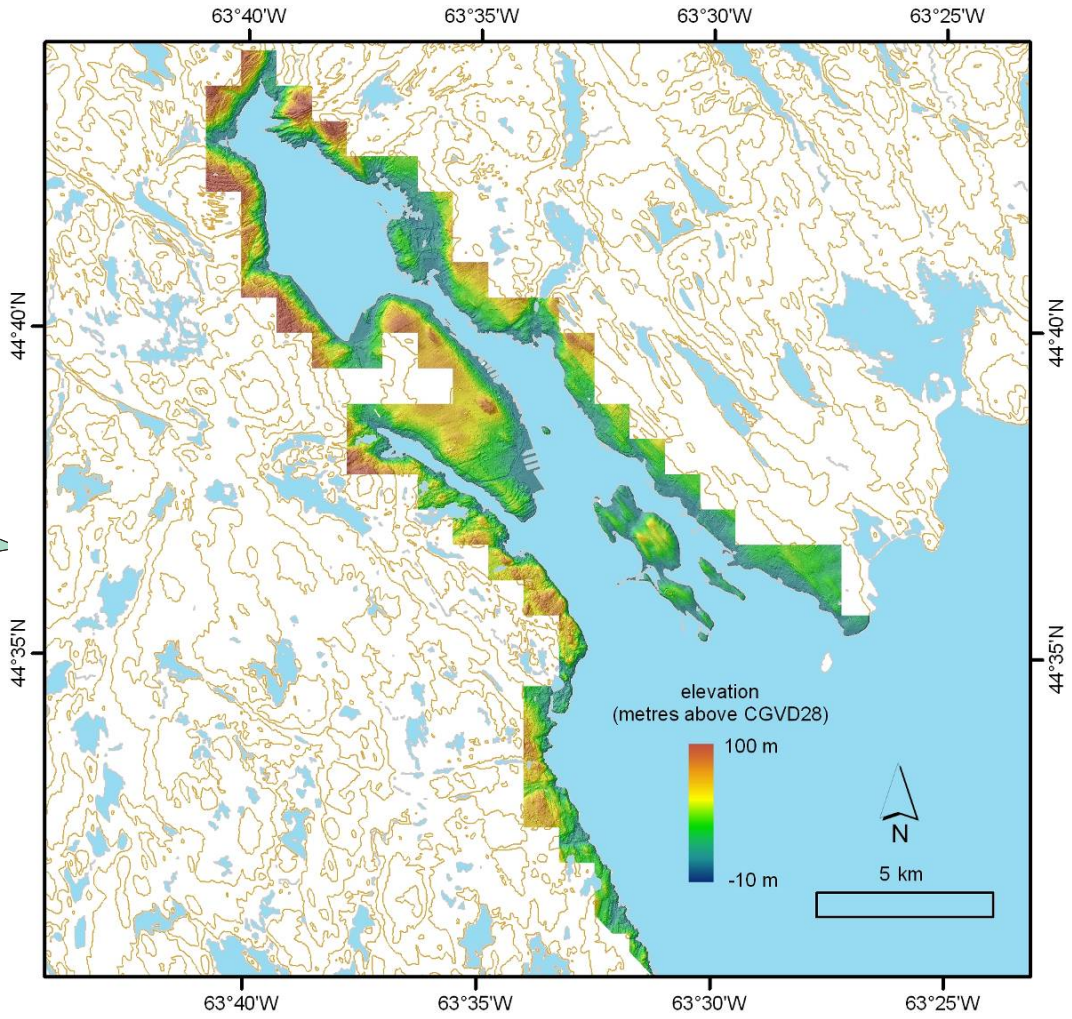


Hurricane Juan aftermath in HRM
© DLF/GSC 2 Oct 2003

Airborne LiDAR:

a tool for building high-resolution DEMs





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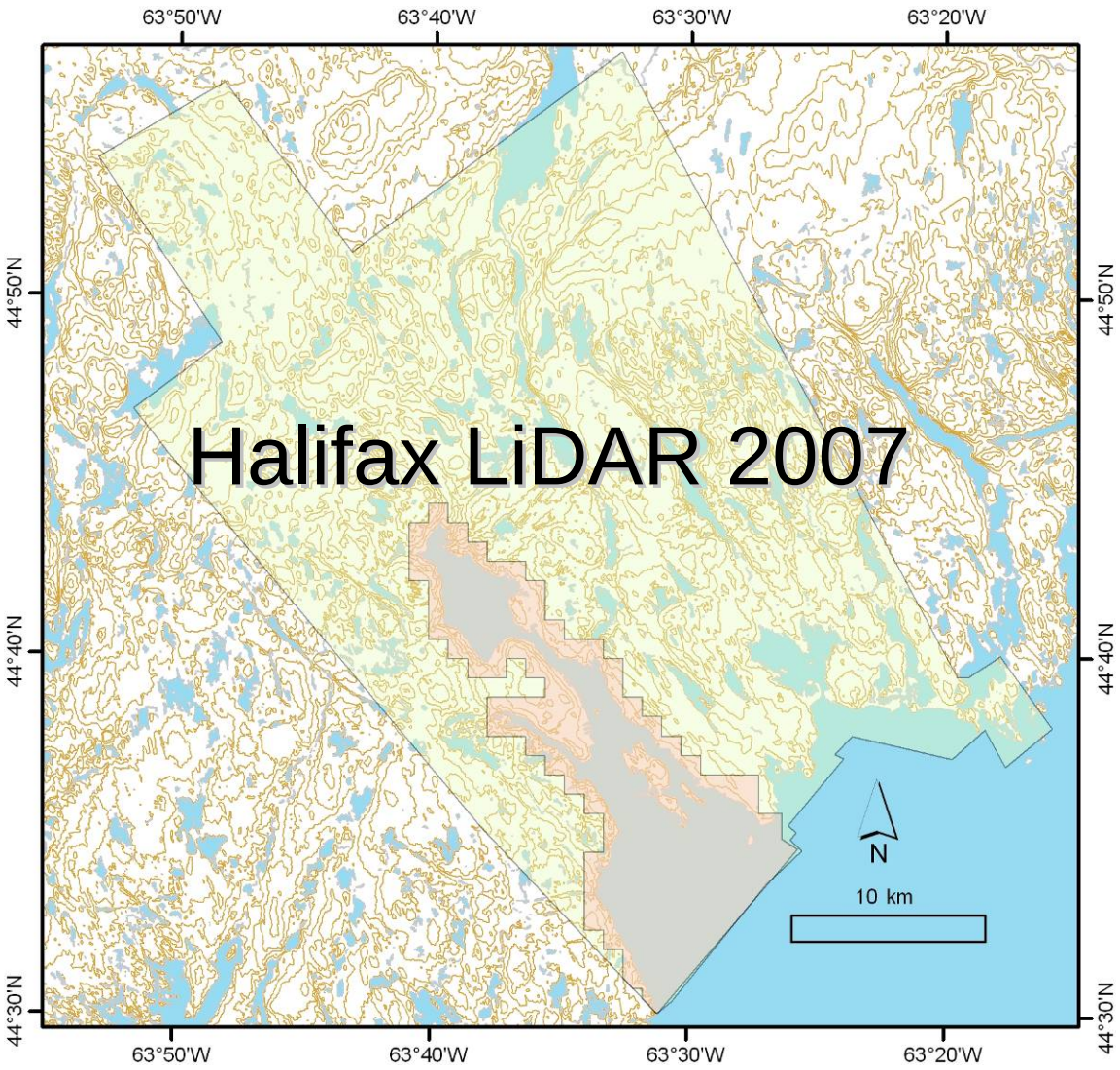
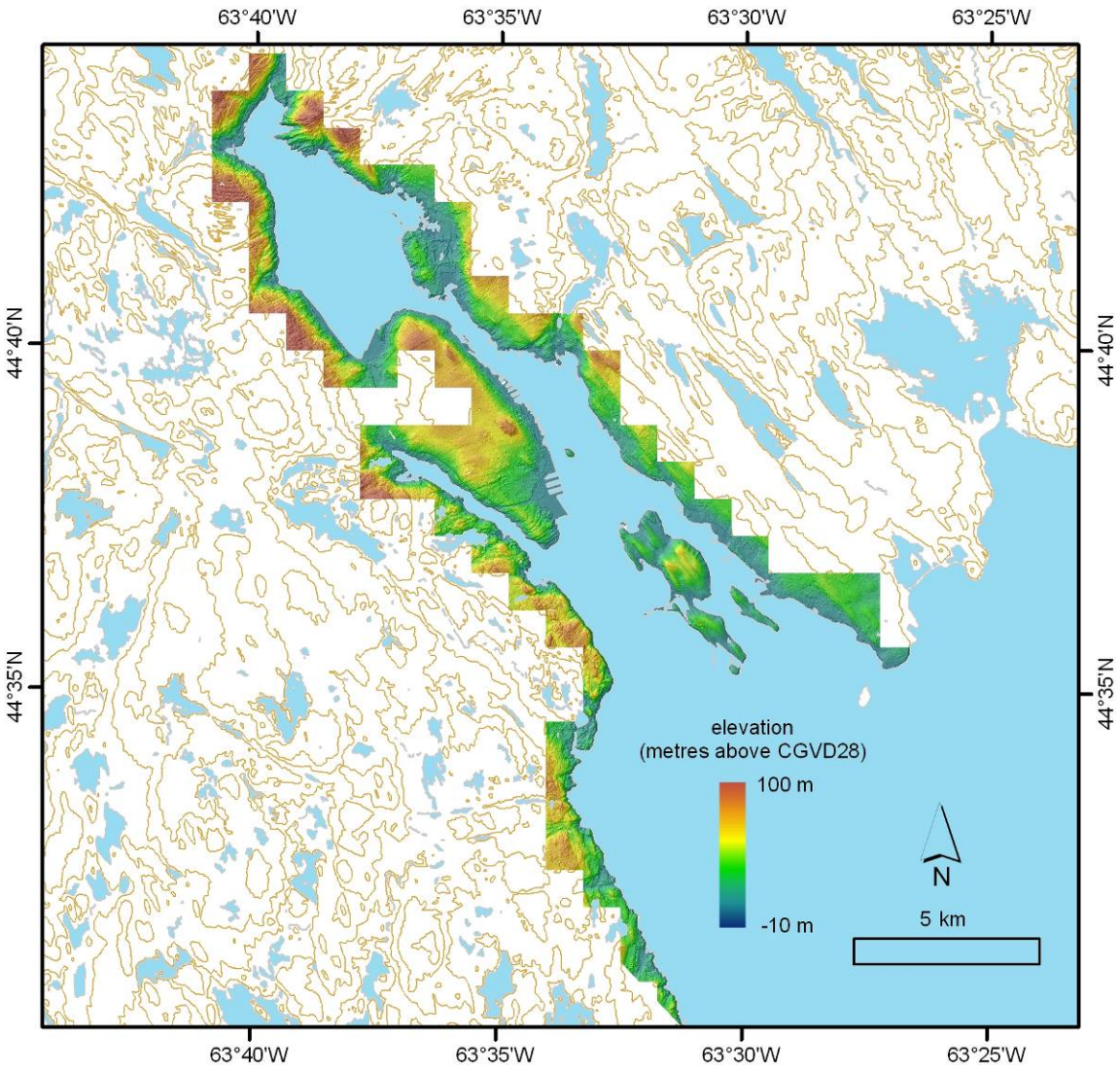
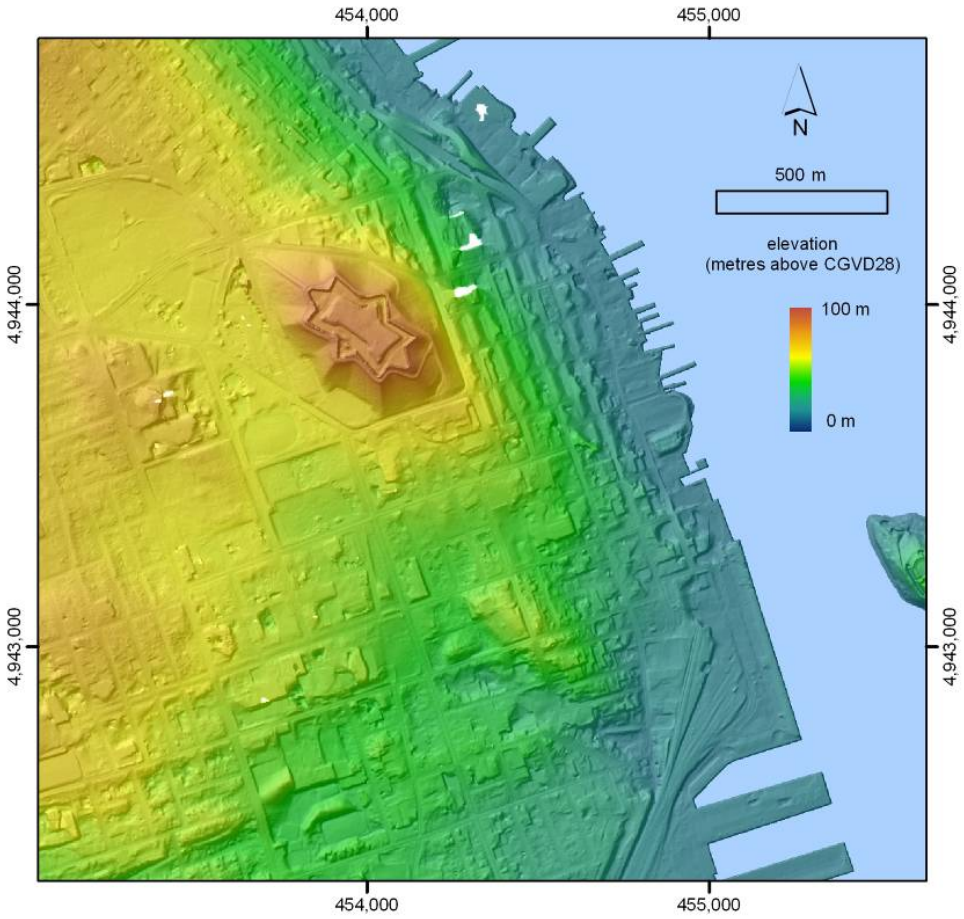
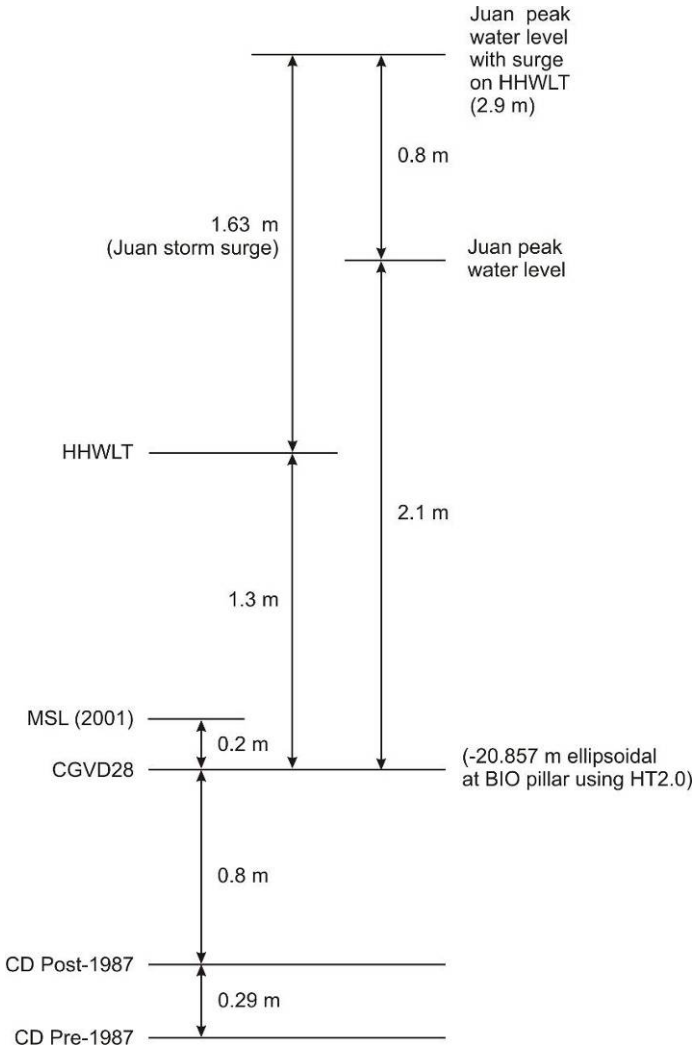

63°50'W
63°40'W
63°30'W
63°20'W
44°50'N
44°40'N
44°30'N
Halifax LiDAR 2007
N
10 km

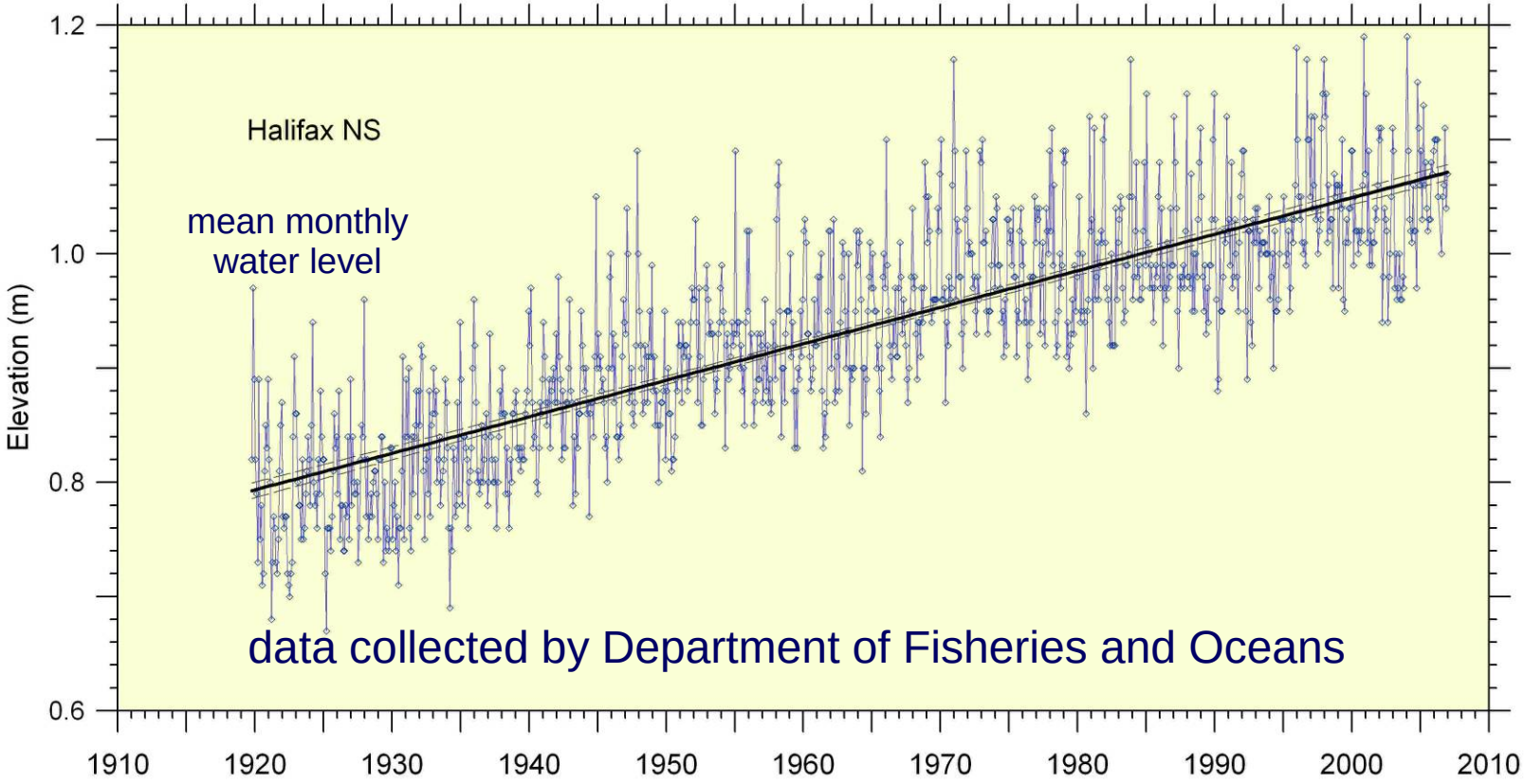

63°40'W
63°35'W
63°30'W
63°25'W
44°40'N
44°35'N
elevation
(metres above CGVD28)
100 m
-10 m
N
5 km


454,000
455,000
N
500 m
elevation
(metres above CGVD28)
100 m
0 m
4,944,000
4,943,000


Juan peak water level with surge on HHWLT (2.9 m)
0.8 m
1.63 m
(Juan storm surge)
Juan peak water level
HHWLT
2.1 m
1.3 m
MSL (2001)
0.2 m
CGVD28
(-20.857 m ellipsoidal at BIO pillar using HT2.0)
0.8 m
CD Post-1987
0.29 m
CD Pre-1987

Halifax RSL

long-term trend = +3.2 ± 0.013 mm/yr (= 32 ± 1 cm/century)



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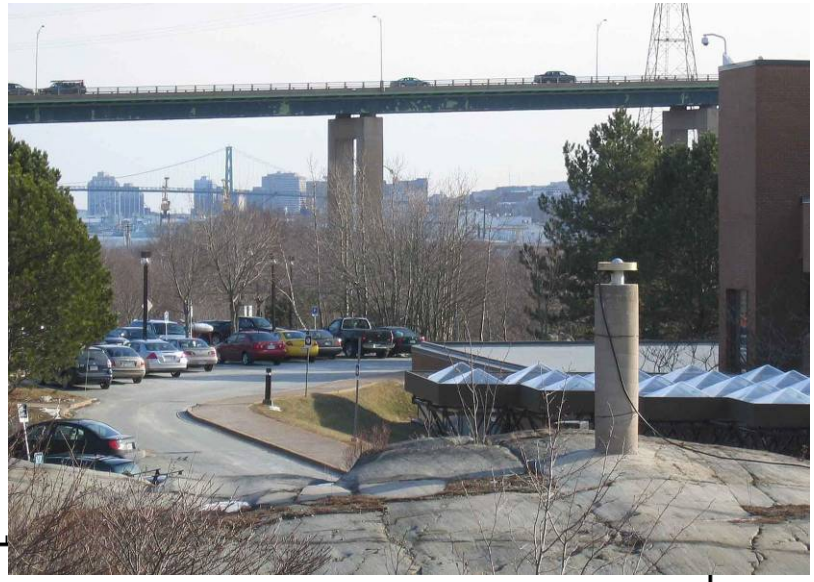
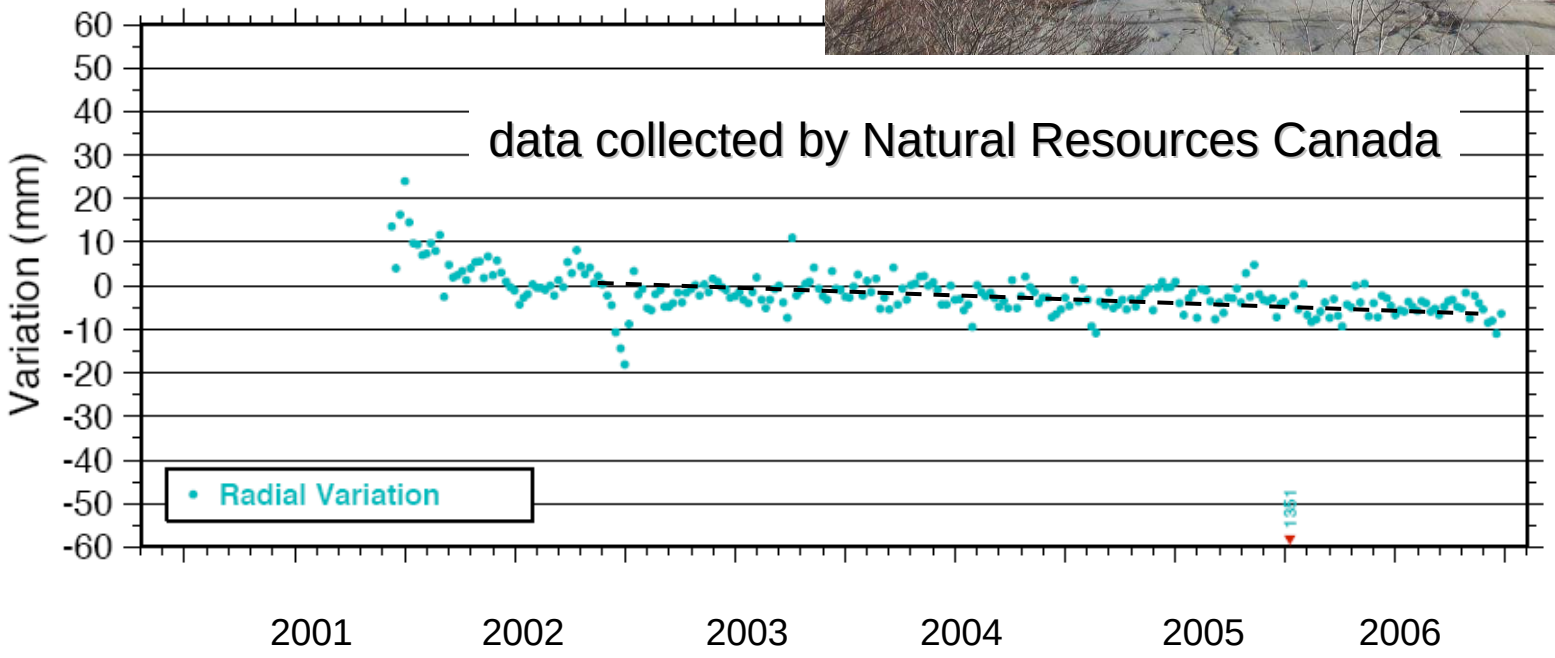
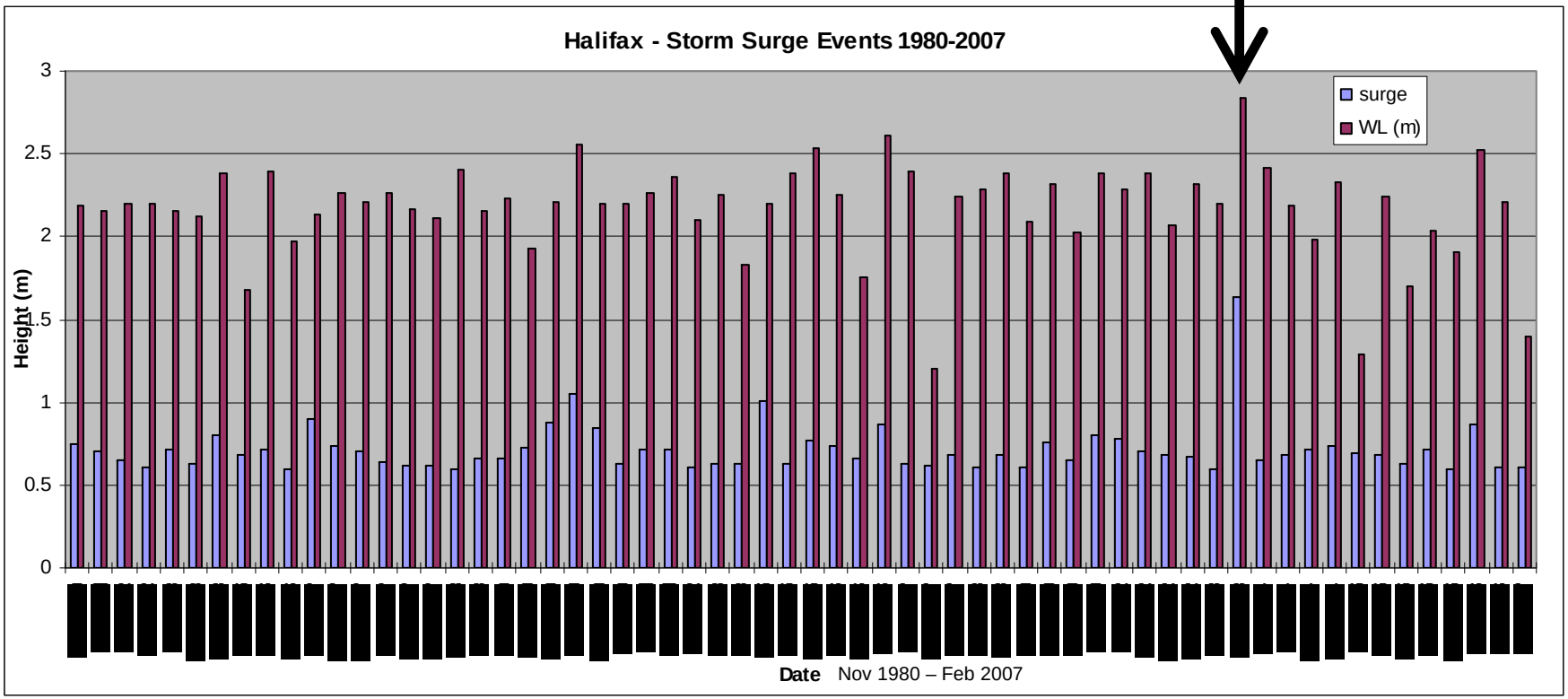
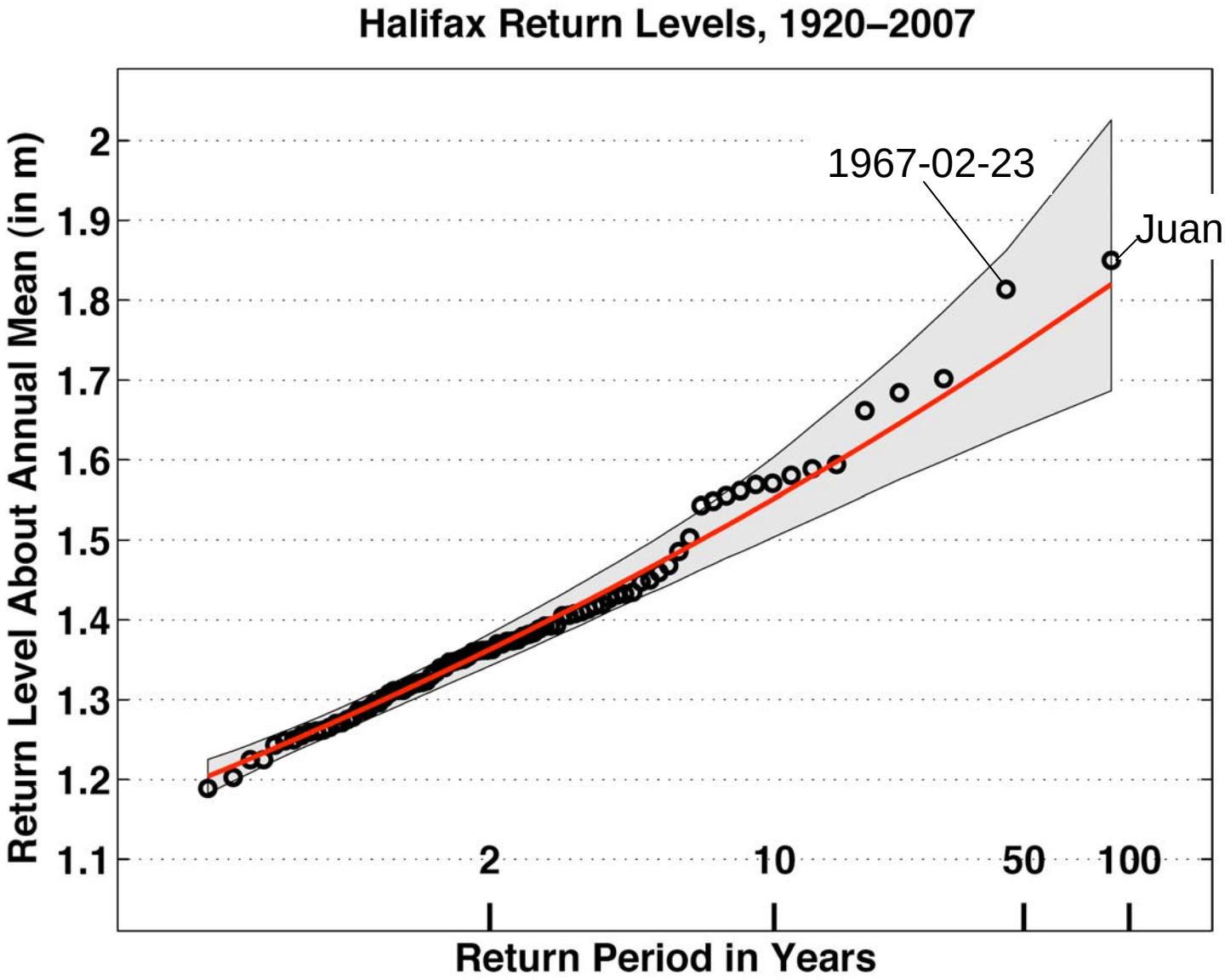


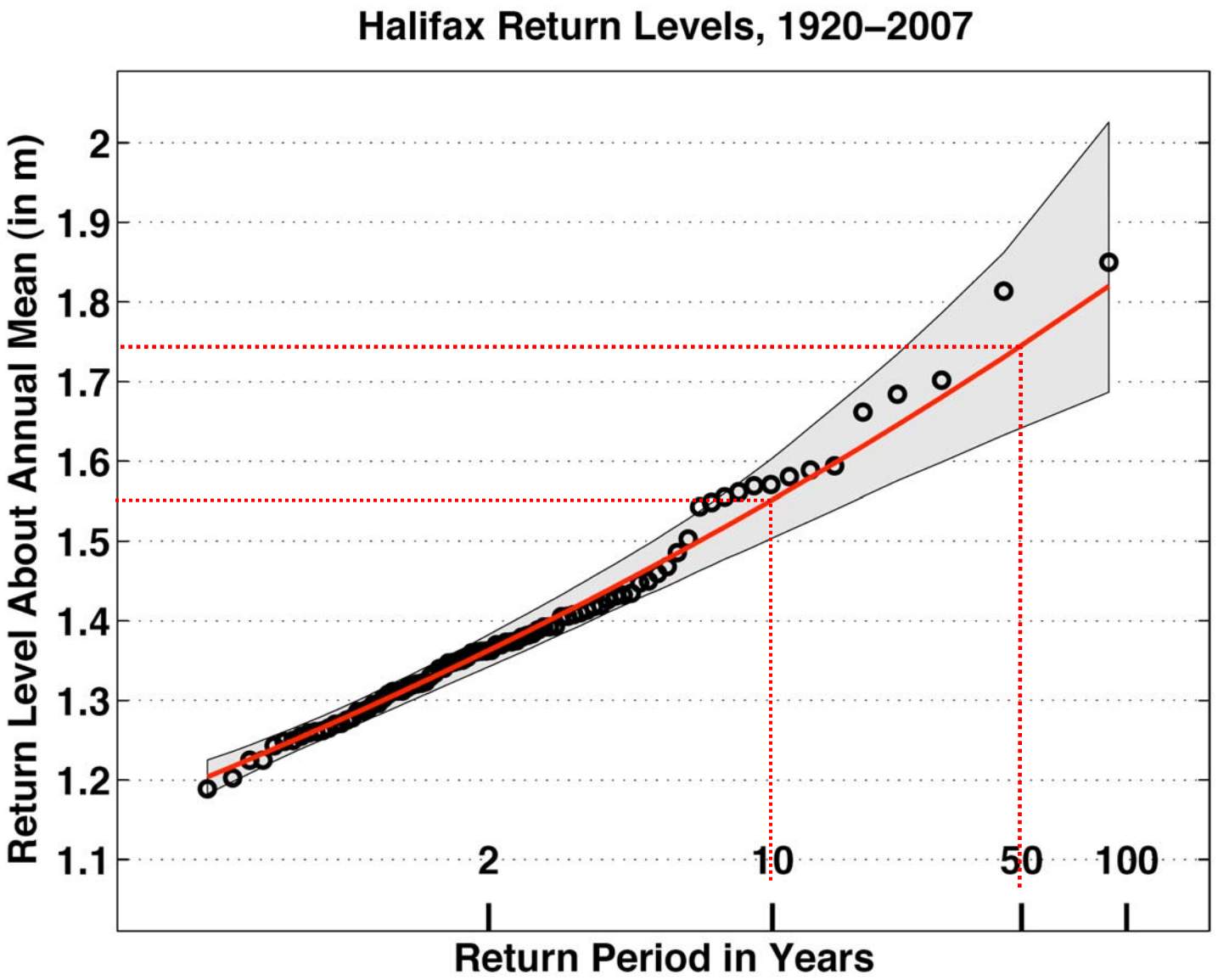


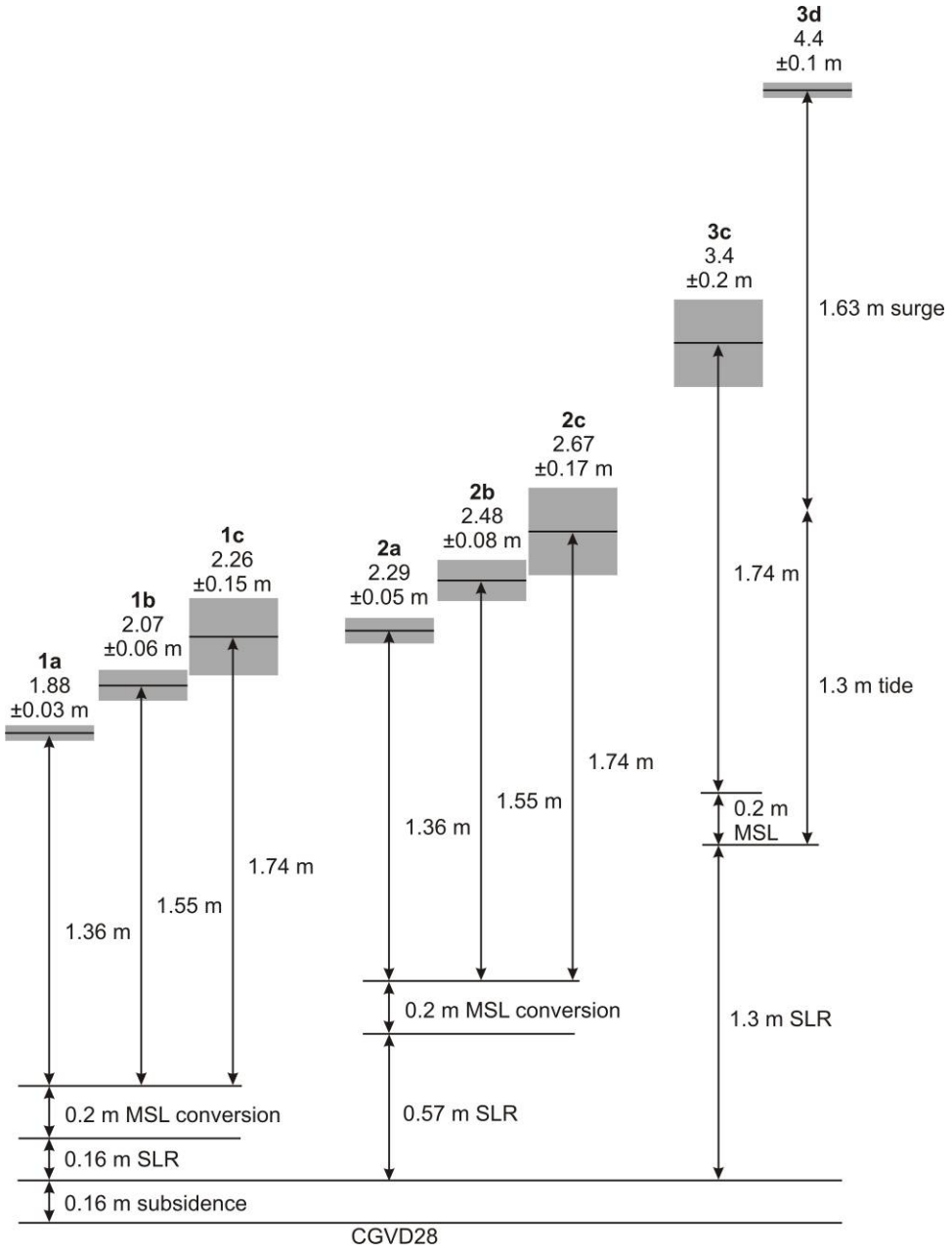
Hurricane Juan record WL and record surge





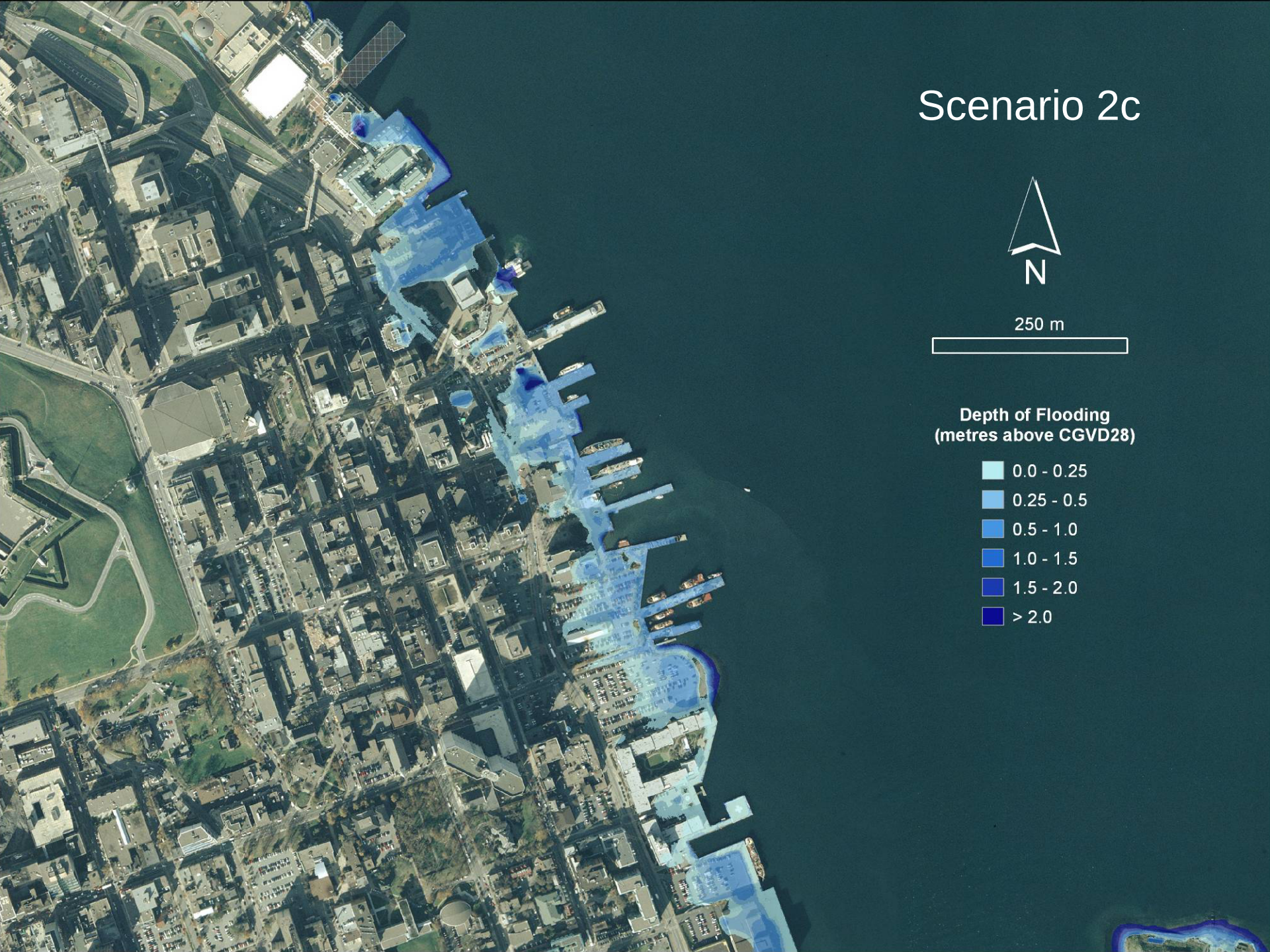
Courtesy of Keith Thompson, Dalhousie University

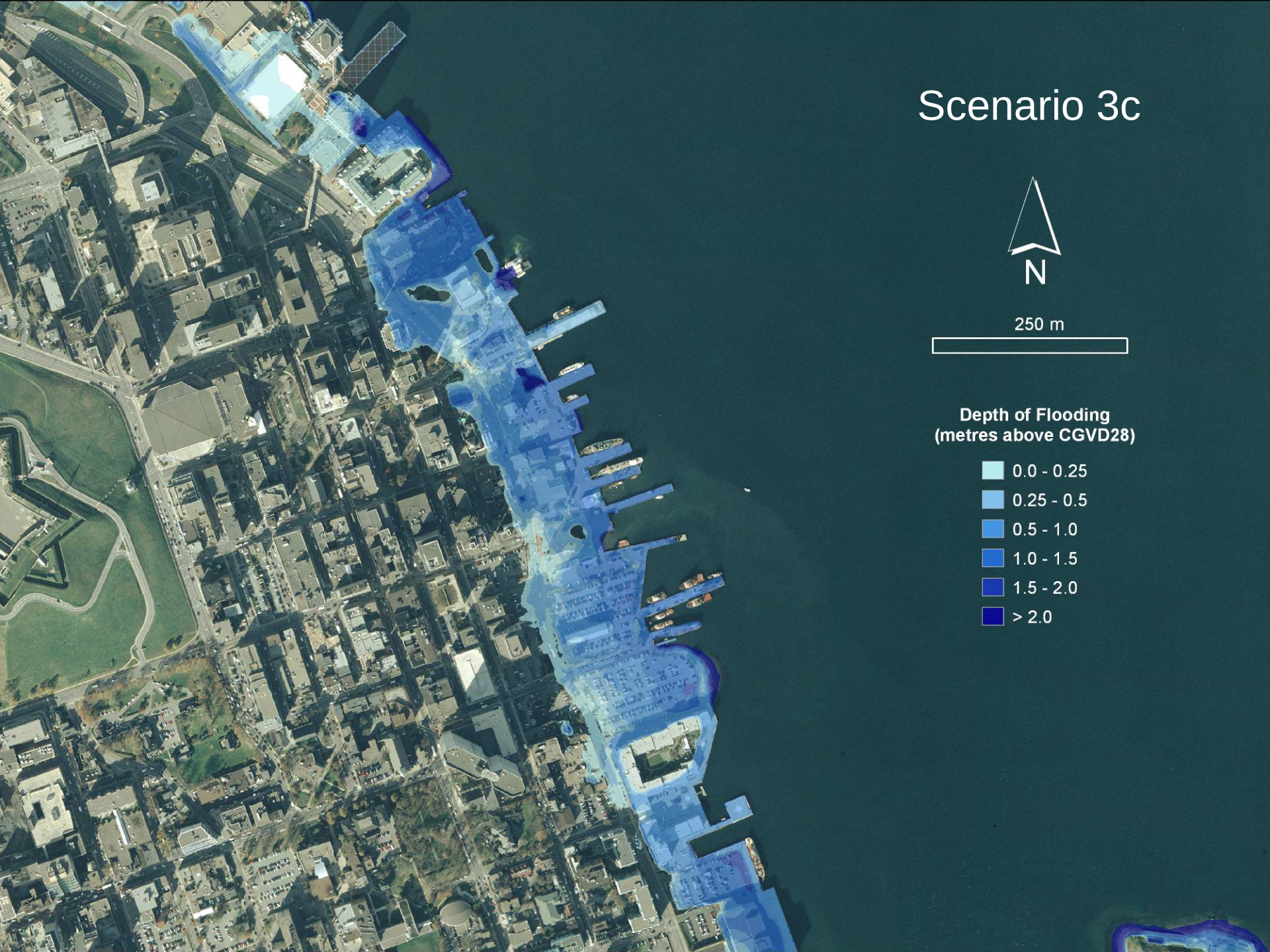

Halifax Return Levels, 1920–2007
Return Level About Annual Mean (in m)
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
2
10
50
100
Return Period in Years

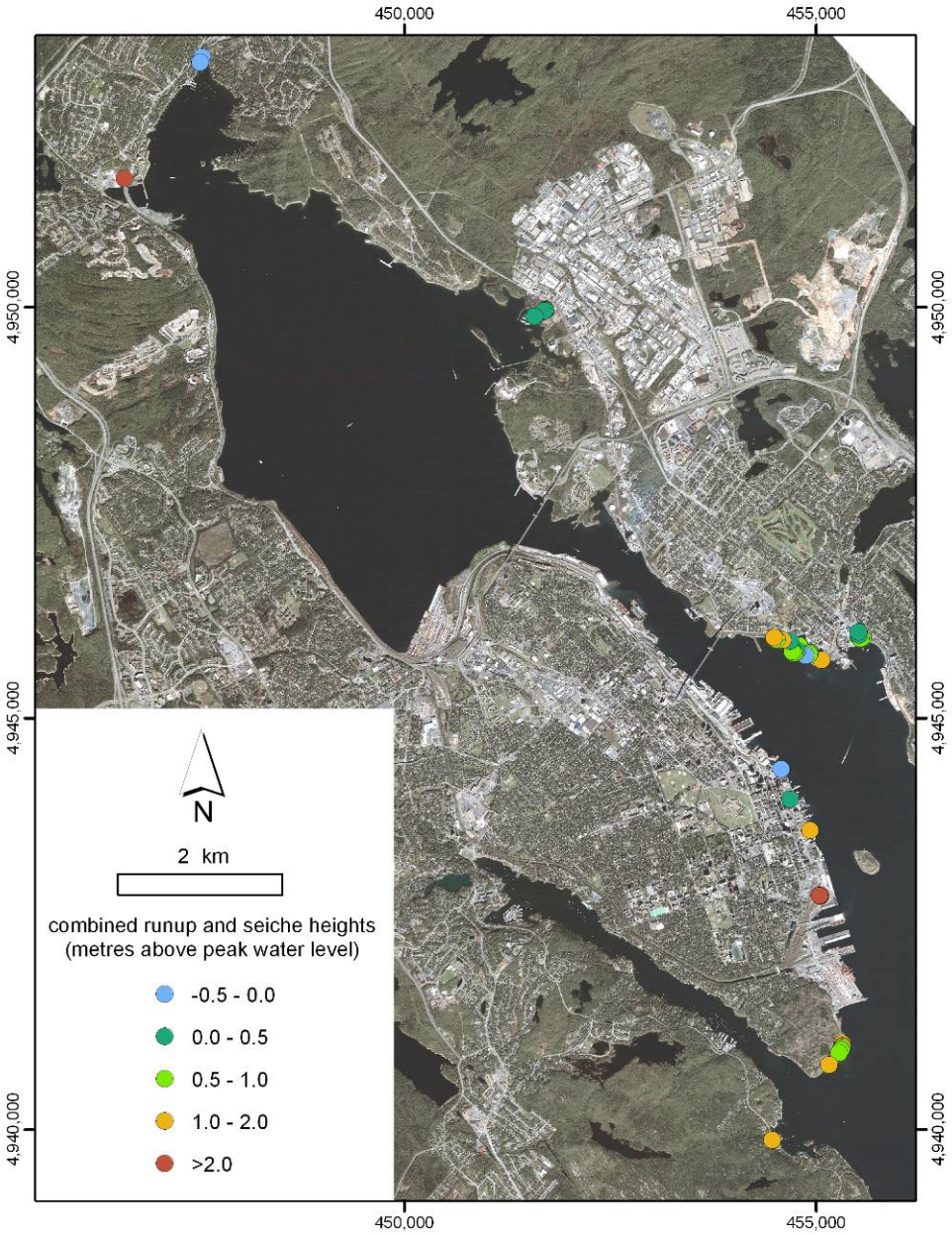


Three scenarios for extreme water levels

- Scenario 1
  - Sea level rises at current rate (no climate change)
  - 1a, 1b, 1c are events with return periods 2, 10, 50 yr
- Scenario 2
  - Sea level rises at upper bound of A1FI scenario (IPCC, 2007)
  - 2a, 2b, 2c as above
- Scenario 3
  - Sea level rises1.3 m
  - 3c is 50-year event (like 2c)
  - 3d is Juan storm surge on highest tide


Scenario 2c
N
250 m
Depth of Flooding
(metres above CGVD28)
0.0 - 0.25
0.25 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0


Scenario 3c
N
250 m
Depth of Flooding
(metres above CGVD28)
0.0 - 0.25
0.25 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0



Wave runup

Hurricane Juan
September 2003

Science to policy – challenge & next steps

- Science can and should inform the planning process
- Potential impacts of climate change identified
- Outputs appropriate to the planning process
- Proactive adaptation less costly than reactive
- Choice of scenario (risk tolerance) is a policy decision
- We have time to adapt but need to start now
- Adaptation needs to be adaptable
  - trends will be revised/refined
  - vulnerability will change

Take-home messages

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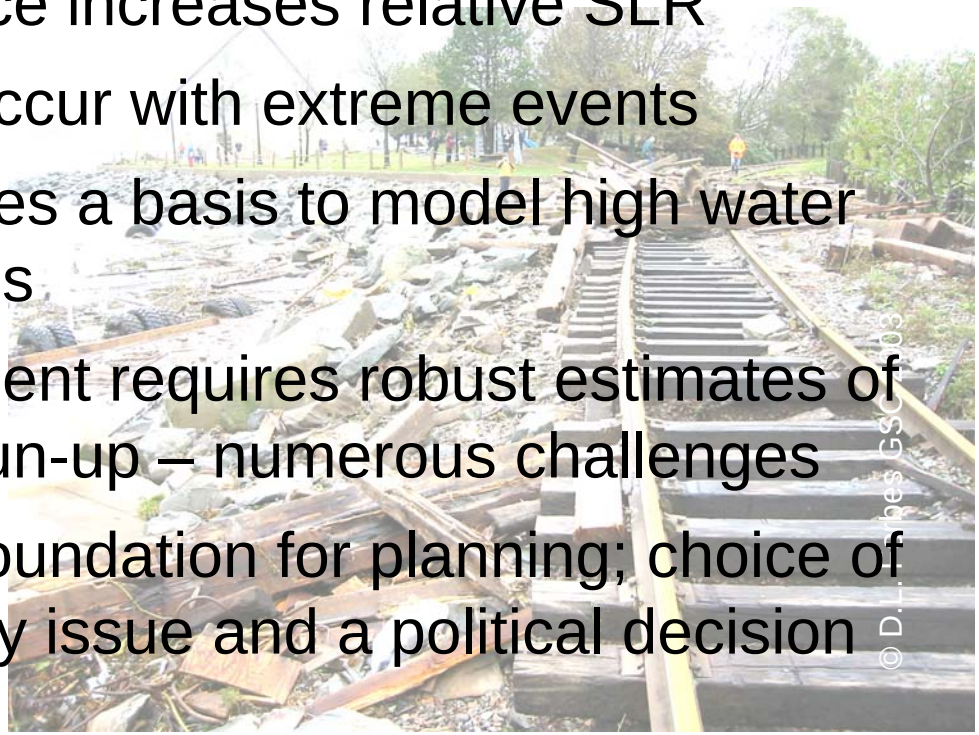

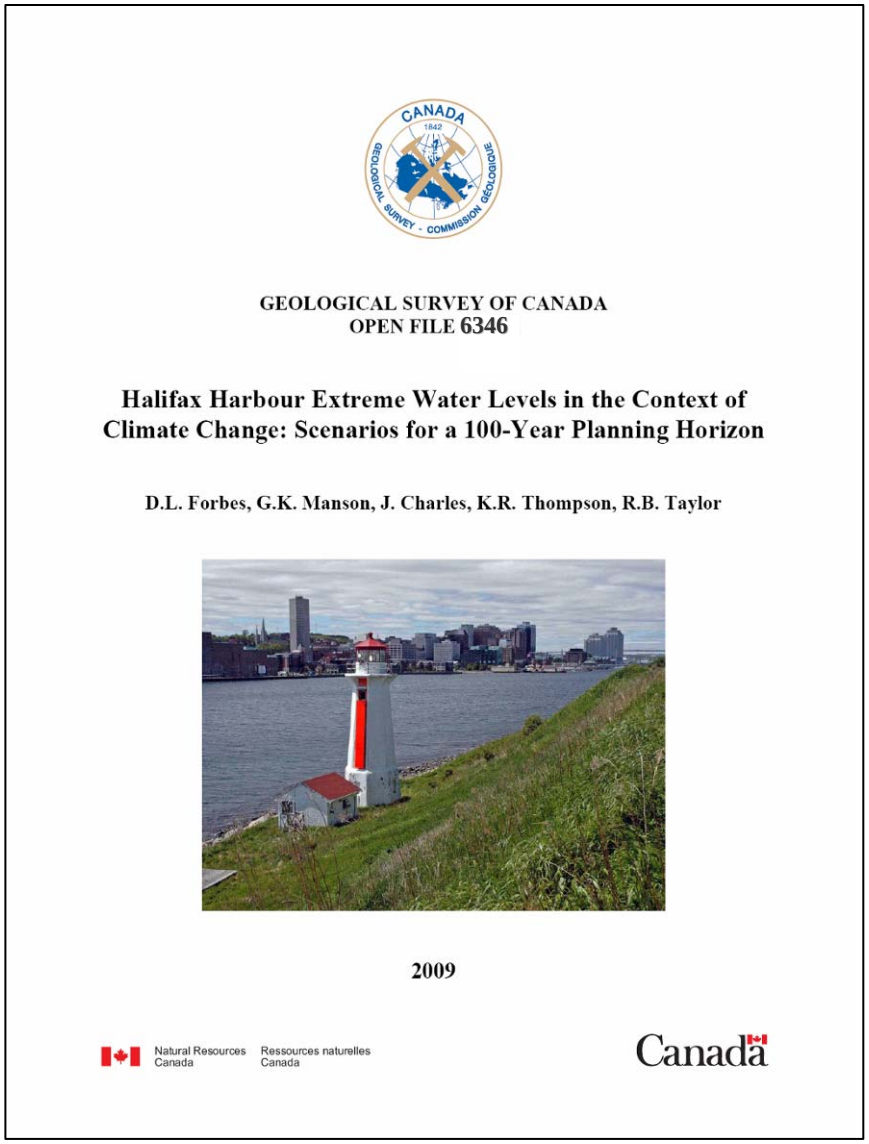

Technical Report

GSC Open File 6346

2009

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