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Group of Experts on Climate Change Impacts and Adaptation for Transport Networks and Nodes

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Climate Change and Transport Networks and Nodes: Presentations of initiatives at national and international levels

Sea level changes, guidelines and adaptation

Submitted by the Government of Iceland

I. Introduction

1. This document contains case study on sea level changes, guidelines and adaptation. The Group of Experts is invited to consider this case study and decide whether to include it in the Final Report.

II. Background

2. The government of Iceland has released a proposal for a national framework as basis for conducting infrastructure climate change impact assessments, as well as a nationwide plan for mitigation and adoption, including that of the Transport system. Expected sea level rise is accounted for in the construction of harbour facilities and the maintenance and reconstruction of old ones and recommendations are regularly updated by the Road and Coastal administration, the latest version issued in 2018 recommends the baseline of construction in Low-lying areas to be raised by 30 cm.

3. Iceland is experiencing climate change induced sea level changes, as well as all other coastal states. The situation of the island is though different to most because of it being situated just south of the Arctic circle, residing above a mantle plume on the Mid Atlantic Ocean ridge and due to glacial coverage of about 10% of the surface area.

4. This document briefly discusses relative changes in sea to land level along the coastline of Iceland and its implications to adaptation of transport infrastructure to climate change. Various processes are active in causing relative changes to sea-level. Firstly; the global sea level rise due to climate change. This is acting all around the island. Secondly the isostatic movements displayed by the rise or subduction of the crust give the sea-level rise different characteristics to most parts of the world. Finally, due to the proximity to the Greenland glacier the hypothesis is, that due to Greenland's Gravitational pull as it rises due

to its melting glaciers, only a part of the global seal level rise is predicted to be realised in Iceland.

5. The relative changes in sea to land level have different implications. In Iceland, like all over the world, the population is concentrated around the coast. Therefore, more and more low-lying areas are being developed, both naturally low-lying areas close to the coast as well as constructing on landfills. This requires the establishment official guidelines of acceptable land level.

6. In harbours due to the sea level rise quays and harbour areas must be raised timely to avoid flooding, in some areas breakwater and revetment exposed to depth limited waves have to be strengthened, while sea level rise has positive influence on water depth in harbours.

7. Rising sea level relative to land causes coastal erosion. Large areas in Iceland are and have been for considerable time affected by erosion and this might increase in years to come. Up to recently this erosion was more likely to be caused by isostatic changes and crustal movements rather than climate change.

8. The tidal inlet of Hornafjörður lies on the southeast coast of Iceland. Within the inlet lies an important fishing harbour. With the bay area of the inlet the rapid lifting of land is likely to affect the tidal prims of the inlet and the navigational depth over the ebb shoal towards the harbour.

III. Preconditions: Tidal measurements and crustal movements in Iceland

9. The process for assessments is based on two sets of measurements; tidal measurements in harbours and continuous GPS measurements of isostatic changes due to geological processes, as well as, climatological ones.

A. Tidal measurements

10. According to Annals and other historical written sources there are records of up to 290 storm surges, floods in coastal areas. Some of them minor, but others causing damages, such as the Basendafloð in 1799, when a powerful storm, combined with high spring tide, produced the worst, known flood in the southwest. The storm surge and related flood is named after a small trading post and fishing harbour, washed away and destroyed during the event.

11. Statistical analysis of the tidal record from the old harbour in Reykjavik shows that with a 30 cm rise of sea level the 100 to 200-year flood will have a 2-year return period.

12. Even so, Iceland has only one time-series of reliable tidal measurements. This is the record from the old harbour in Reykjavik that was started in 1956 and therefore spans more than 60 years.

13. The Icelandic Road and Coastal Administration is planning to build up a system of about 20 tidal recorders around Iceland. These will be distributed all around the Icelandic coast and placed within harbours.

B. Isostatic Land level changes

14. Iceland is located on the Mid-Atlantic Ridge, a divergent tectonic plate, which mostly results in horizontal crustal movements, the rate of seafloor spreading is on the average 2 cm/year. As the plates move away from the plate boundary the crust cools, densifies and subducts slowly, as is the case of the Northwest and the East, geologically the oldest parts of the country. In some areas there are, as well, local vertical movements, such as the tip of the Reykjanes peninsula, were the lowering of land, subduction, adds to the sea level rise. Thirdly, the crustal response of the increasingly fast melting of the Icelandic glaciers, some of which are predicted to lose all their ice-mass before the turn of the century. Of those,

Vatnajökull is the largest, causing relatively fast uplift in the southeast, where the rising of land outweighs the sea level rise due to climate change considerably on the coast, causing a unique problem for harbour infrastructure and its access through a narrow channel.

Figure I

Changes in vertical height over the 11 years period from 1993 and 2004 measured at the ISNET campaign GPS stations. Positive numbers indicate uplift and negative are subsidence, Valsson et al. 2007.

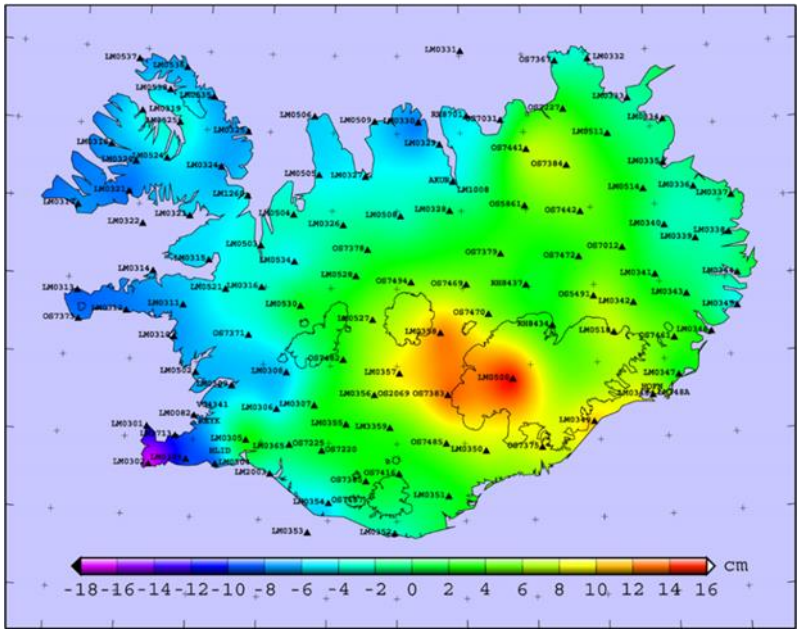

Table 1

Vertical velocities at selected locations around Iceland based on GPS measurements. Names of some locations have been changed over to the nearest town.

Location	*Measured period*	*Vertical velocites (mm/year)*
Reykjavík, SW	1996–2015	–1.49 [-1.56 – -1.42]
Ísafjörður, NW	2009–2015	–1.82 [-2.08 – -1.56]
Siglufjörður, N	2008–2012	–2.32 [-2.65 – -2.00]
Grímsey, N	2008–2014	–4.72 [-4.97 – -4.48]
Akureyri, N	2001–2015	3.39 [3.31 – 3.47]
Húsavík, NE	2002–2015	0.15 [0.07 – 0.23]
Raufarhöfn, NE	2001–2015	0.27 [0.22 – 0.33]
Hornafjörður, SW	1997–2015	12.03 [11.96 – 12.11]
Vestmannaeyjar, S	2000–2012	3.18 [3.12 – 3.24]
Þorlákshöfn, SW	2000–2007	–1.04 [-1.18 – -0.91]
Sandgerði, SW	2006–2014	–4.62 [-4.71 – -4.53]

Figure II

Changes in vertical height over the 12 years period from 2004 and 2016 measured at the ISNET campaign GPS stations. Positive numbers indicate uplift and negative are subsidence. Preliminary results from the National Land Survey of Iceland.

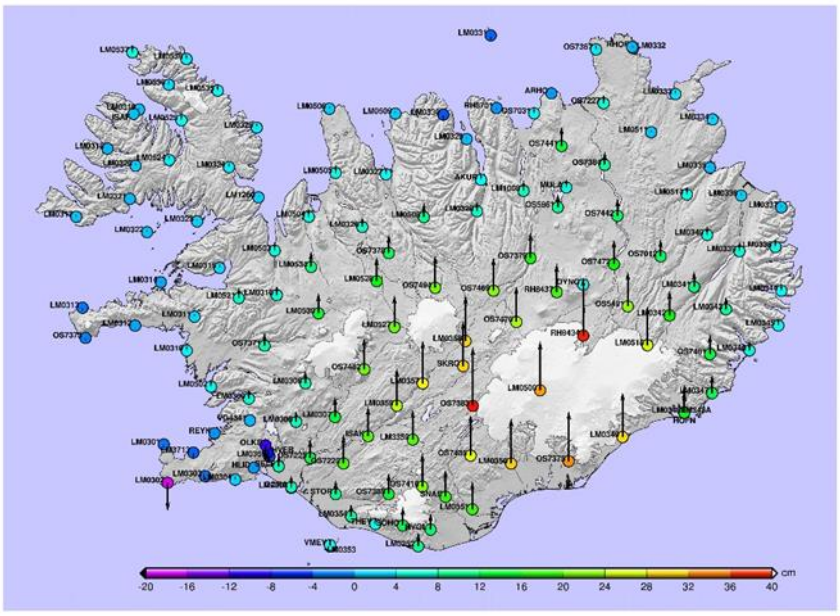

Table 2

Changes in vertical height measured by GPS around Iceland. From the report Global Climate Change and their impact in Iceland by The Scientific Committee on Climate Change.

Region	*Crustal elevation changes (cm)*	*Part of global climatic SLR*	*Global climatic SLR*		
			50 cm	*75 cm*	*100 cm*
			Total local SLR (cm)		
SW to NW Iceland	–20 to –10	30 to 34 %	25 to 37	33 to 45	40 to 54
NW and inland N Iceland	10 to 30	28 to 30 %	–16 to 5	–9 to 13	–2 to 20
Promontories on N Iceland	–30 to –10	28 to 30%	24 to 45	31 to 53	38 to 60
E part of N Iceland	0 to 20	30% to 32%	–5 to 16	3 to 24	10 to 32
NE Iceland	0 to 10	32 to 38%	6 to 19	14 to 29	22 to 38
E Iceland	0 to 20	38 to 40%	–1 to 20	9 to 30	18 to 40
SE Iceland	100 to 200	20 to 28%	–190 to –86	–185 to –79	–180 to –72
S Iceland	20 to 40	30 to 32%	–25 to –4	–18 to 4	–10 to 12
S and W Reykjanes peninsula	–30 to –10	32 to 34%	26 to 47	34 to 56	42 to 64

IV. The Icelandic guideline for construction in low-lying areas

15. Ports are critical infrastructure assets that serve as catalysts of economic growth and development especially on an island, depending on harbours for freight in and out of the country. The Icelandic Maritime council as well as other stakeholders are aware of the importance of raising level of knowledge for resilience and preparedness among our ports

16. To prepare for heightened sea level is simply a common sense. In 2018 the Icelandic Road and Coastal Administration published recommendations, a new guideline, for construction in low-lying areas, including harbour infrastructure. In the guideline some 30 cm are added to the former minimum land-height due to rising sea-level. Due to the varying conditions along the coast due to isostatic movement, mainly due to melting glaciers, the guideline recommendation must be interpreted accordingly.

The case of The Associated Ports in Southwest Iceland

17. Although the present recommendation by the Icelandic Road and Coastal Administration is the for new construction and larger maintenance projects is that the minimum land-height should be raised by 30 cm, the harbours in the Metropolitan area around the Faxafloi bay – The Associated Icelandic Ports have taken a step further. In the construction of the new Sundabakki berth with a life expectancy of 50 years, the minimum land height is 70 cm higher due to estimated impact of sea level changes. Even though it is a costly process, the board of directors has stated that the it is a safer move, the extra cost justified by less uncertainty.

V. Conclusions and forecast

18. Iceland is already experiencing the impact of sea level changes on its coastal infrastructure. The impact varies from one part of the country to another due to its young geology and active glaciers causing crustal movements or drifting, and isostatic uplift as the glaciers retreat and lose their ice mass. Different models predict different results although most agree that Iceland may experience the average sea level changes. To begin with the Southeast of the country sea level rise will be slower than the isostatic uplift due to the swift loss of ice-mass, where as in other parts the ocean will rise faster due to the subduction of the cooling crust. The greatest uncertainty for Iceland lies with the prediction of the impact of the Gravitational pull of Greenland as it lifts up, on the sea level around Iceland.

19. The Road and Coastal administration as well as the Ministry of Transport and its Maritime council are effectively working on an adaption plan to minimize the economic impact of the changes by knowledge sharing and already the official recommendation is to heighten infrastructure in low-lying areas to meet the challenges of our fast changing environment.

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