«Se havnivå i kart»
Norway’s coastal service for visualizing sea-level rise and storm surge by maps

Workshop on sea level rise
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Norway is at relatively low physical vulnerability to sea-level rise, but will face some challenges.

- Steep topography
- Bedrock resistant to erosion
- Extensive recent coastal development, expensive infrastructure
- Many homes and cabins next to the sea
- Coastal cultural monuments, e.g., “Bryggen” in Bergen
- Harsh weather
- Low lying industrial areas

The recommended sea-level increase for use in planning along the Norwegian coast ranges between 40 and 82 cm.
Projections for future sea-level change and return-levels for storm surge have been available since 2015

- ...as text, figures, and tables
- The numbers alone do not communicate the full consequences of higher sea-level and storm surges
- The use of projections and return levels requires expert knowledge

https://kartverket.no/en/sehavniva/
“Se havnivå i kart” is a coastal service for visualizing the consequences of sea-level rise and storm surges

karverket.no/en/sehavniva/visualize-sea-level/
"Se havnivå i kart" is made for both professional users and the public

Guidelines from the Norwegian Directorate for Civil Protection recommend that the top of the likely range of RCP8.5 is used for planning.

The available storm surge heights correspond to safety classes in current buildings acts and regulations for Norway.

The sea level can be set between 1 and 5 m above present Mean High Water by a slider.
Professional users may download the inundation layers for use in custom GIS-applications.

Geonorge.no is the national website for map data and other location information in Norway.

“Se havnivå i kart” is primarily focused on providing information that can be used in climate adaption work.
The inundation maps are made by combining sea-level projections and storm-surge heights with a 1 x 1 m DEM from LiDAR and registers of buildings, land cover, and roads.

A “bathtub” approach was used for identifying flooded areas. A cell in the DEM is flooded if:

1) The height of the cell is below the given sea-level scenario or storm surge return height

2) The cell is hydrologically connected to the sea

[DEM: Digital Elevation Model]
To combine elevation data, sea-level scenarios, and storm-surge heights, knowledge of transformations between different vertical reference systems is required.

Sea-level projections and storm surge heights are given with respect to Mean Sea Level.

The elevation data are given in NN2000 (Norway’s national vertical reference system).

In general, the height of Mean Sea Level in NN2000 is accurately known only at 23 tide gauges along the Norwegian coast.
Norwegian registers of buildings and roads do not include attributes that allow structures above the water surface to be removed from the statistics.

<table>
<thead>
<tr>
<th>MHW-bias</th>
<th>Buildings</th>
<th>Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present Mean High Water</td>
<td>40072</td>
<td>180 km</td>
</tr>
</tbody>
</table>
Future work should address how known uncertainties can be incorporated and visualized in our inundation maps.

<table>
<thead>
<tr>
<th>Contributor</th>
<th>Uncertainty [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEM</td>
<td>0.26</td>
</tr>
<tr>
<td>HREF</td>
<td>0.01-0.10</td>
</tr>
<tr>
<td>Height of MSL in NN2000</td>
<td>0.02-0.10</td>
</tr>
<tr>
<td>Height of MHW in NN2000</td>
<td>0.02-0.10</td>
</tr>
<tr>
<td>Horizontal position of buildings</td>
<td>0.20-2</td>
</tr>
<tr>
<td>Horizontal position of roads and areas</td>
<td>2-50</td>
</tr>
</tbody>
</table>

The effect of the DEM-error on the mapping depends on the slope of the terrain.

We believe that the effect of the sum of these mapping errors are generally smaller than the projected sea-level rise.
The number of buildings, roads, and areas affected by a 200-year storm surge, will increase considerably from now to 2090.

Left bars: Present. Right bars: 2090
For each water level, the percentages indicate the increase from present to 2090.
To summarize: For the first time, sea level projections and storm-surge heights are combined with a high accuracy DEM and geospatial data in order to map coastal flooding in Norway.

“Se havnivå i kart” is made for both professional users and the public.

This is no exact mapping, local knowledge and site visits may still be appropriate.

[kartverket.no/en/sehavniva/visualize-sea-level/]

