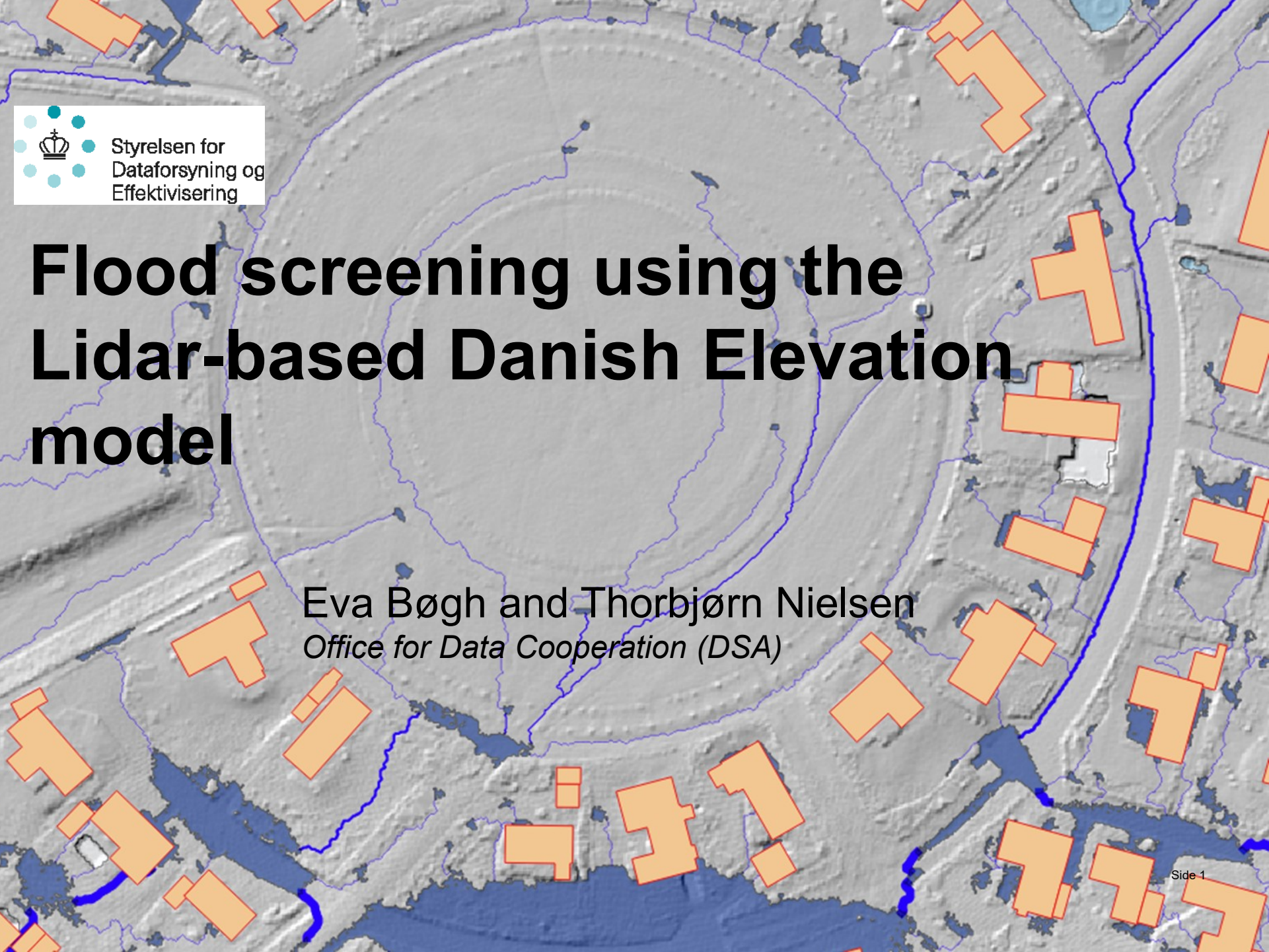


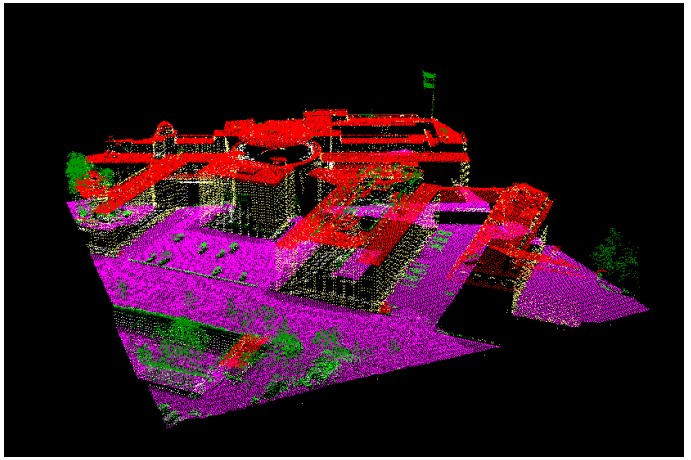
Styrelsen for Dataforsyning og Effektivisering

Flood screening using the Lidar-based Danish Elevation model

Eva Bøgh and Thorbjørn Nielsen
Office for Data Cooperation (DSA)

Danish Lidar-based Digital Elevation Model (DEM)

<u>The point cloud (2014/2015):</u>



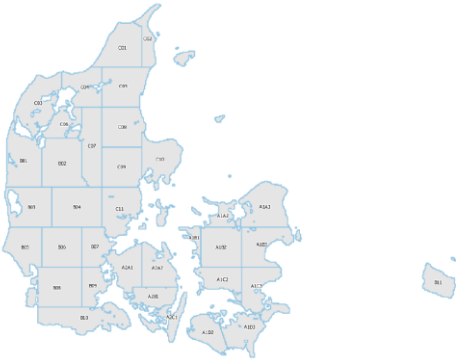
- Collected by 4 airplanes over 3 seasons
- 4,5 point per m²
- Total ca 415 billions points in Danmark
- Very high precision
- z value accuracy is 5 cm
- planar accuracy is 15 cm
- Full Waveform data included
- Point classification (ground, low-med-high vegetation, water, buildings, unclassified…)
- RGB-colour on all points in daytime recordings
- DEM/terrain (0.4 m grid)
- DEM/surface (0.4 m grid)

Danish Lidar-based Digital Elevation Model (DEM)

Quality assessment of point cloud

Geometry

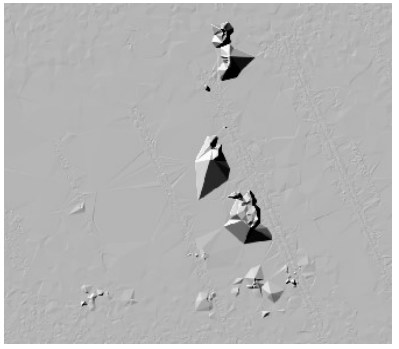
- Geometric processing of point cloud in blocks
- Z accuracy (5 cm) is calculated against 40-70 GCP's in each block
- XY accuracy (15 cm) is evaluated by calculating roof ridges and road centerlines and comparing these to GeoDanmark data



Processing blocks

Classification

- Automatic tests and manual corrections by human experts to reduce errors in point cloud classification and raster models
- Statistical analysis for spike detection → errorneous points reclassified to "unclassified"
- Vegetation below GeoDanmark buildings relassified as "outliers"
- High tension wires and bird flocks reclassified to "high noise" using a voxel filter (known high tension lines reclassified as "conducting wires")
- Water on fields give void data – filled with 2007 data



Bird flocks

Production system for the Danish Elevation model (DEM)

Danish Elevation model

DEM/Point cloud* (2014/15)

DEM/Terrain*

DEM/Surface*

Hydrological elevation models

DEM/Hydrological adjustments*

DEM/Rain*

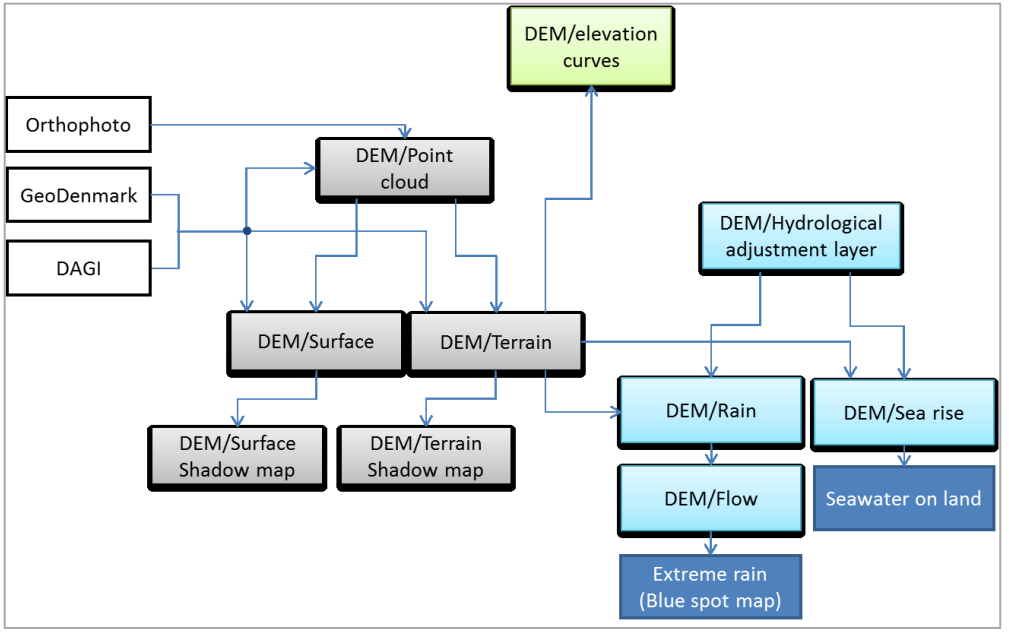
DEM/Sea rise*

Hydrological products

DEM/Flow

DEM/Seawater on land

DEM/Bluespot extreme rain



Production system

*corresponding dataset available for 2007 in 1,6 m grid

Data from the Danish Elevation model (DEM) - 0,4 m grid

Danish Elevation model

DEM/Point cloud* (2014/15)

DEM/Terrain*

DEM/Surface*

Hydrological elevation models

DEM/Hydrological adjustments*

DEM/Rain*

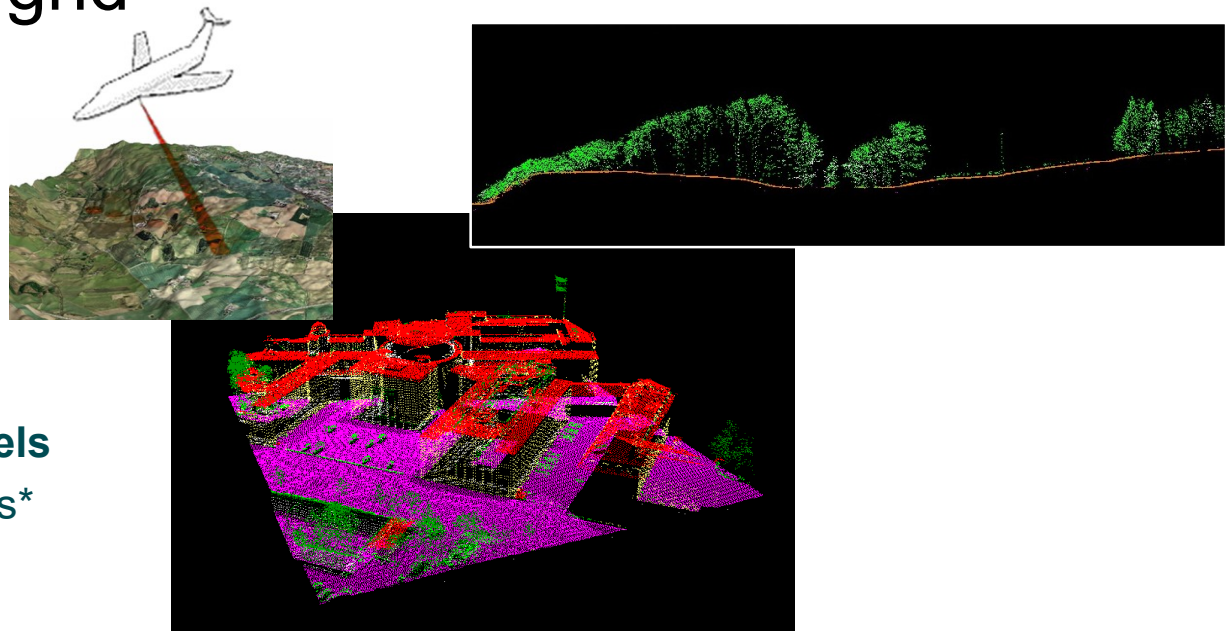
DEM/Sea rise*

Hydrological products

DEM/Flow

DEM/Seawater on land

DEM/Bluespot extreme rain



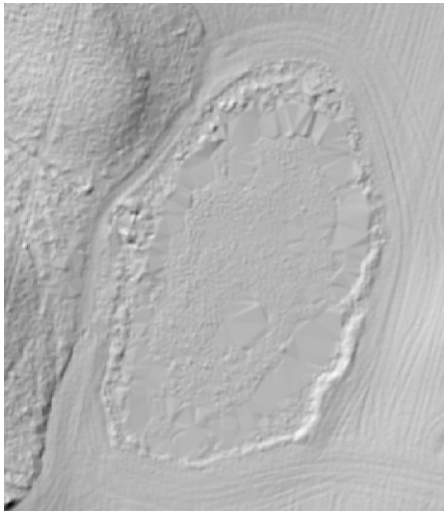
Digital elevation models (DVR 90) for the physical surface and terrain

Styrelsen for Dataforsyning og Effektivisering

Terrain model - lakes

Problem: Lakes are a flat surface but oscillates with waves, voids and noise.

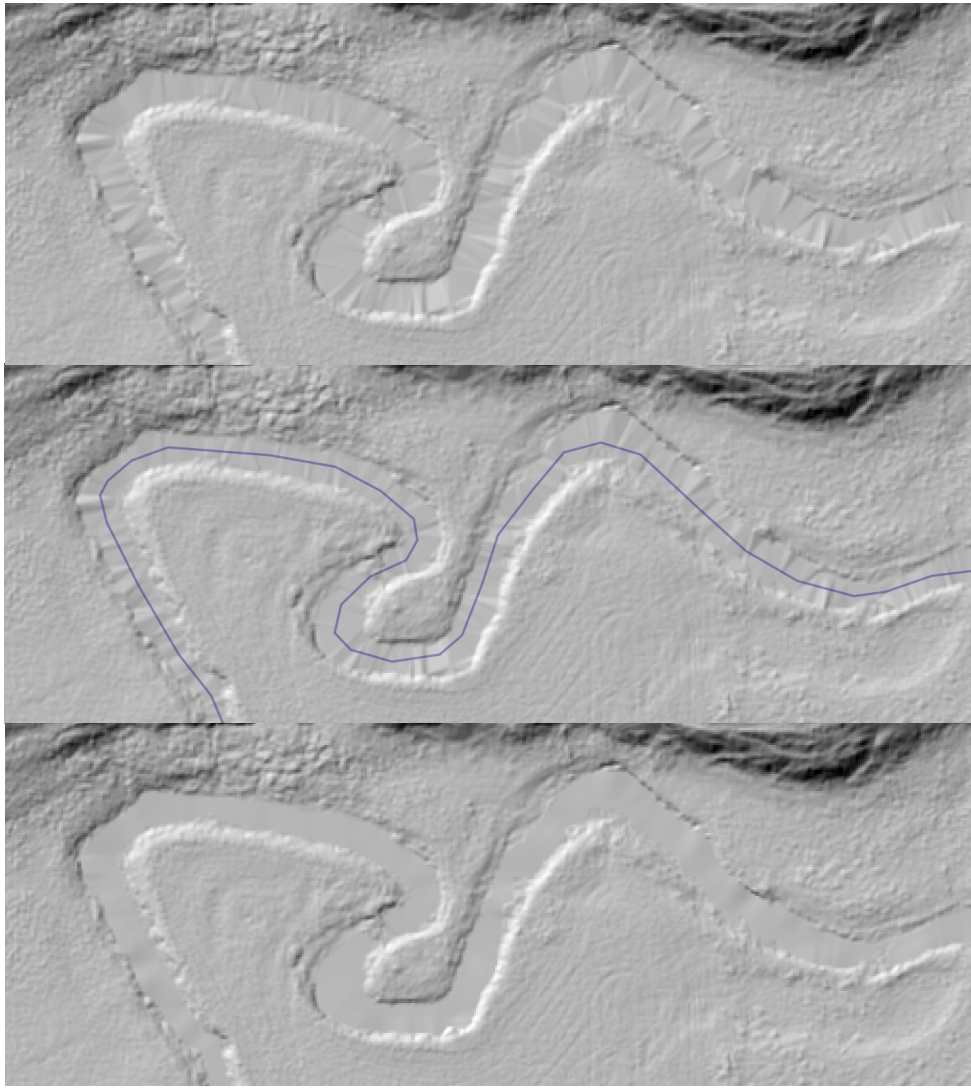
Solution: Lake features from GeoDanmark data is transformed onto the point cloud. If acceptable result, burn into DEM with average height.




Terrain model - streams

Problem: Streams oscillates with waves, voids and is largely a function of stream edges rather than the surface - sometimes obstructing natural water flow

Solution: Smoothing of triangles intersecting stream centre line (GeoDanmark)



Data from the Danish Elevation model (DEM) - 0,4 m grid

Danish Elevation model

DEM/Point cloud* (2014/15)

DEM/Terrain*

DEM/Surface*

Hydrological elevation models

DEM/Hydrological adjustments*

DEM/Rain*

DEM/Sea rise*

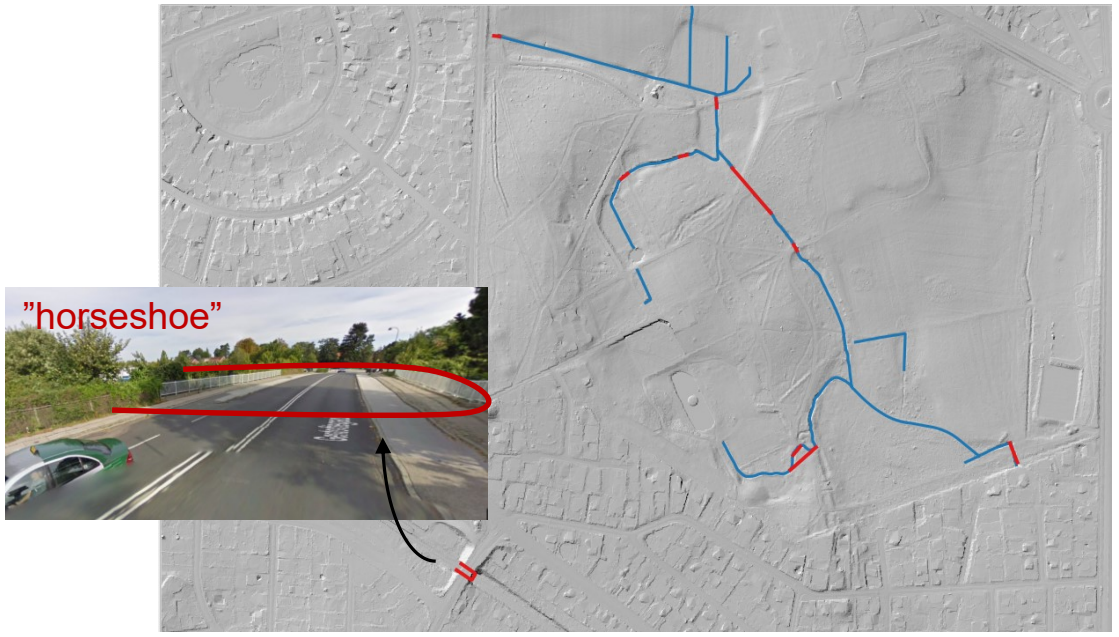
Hydrological products

DEM/Flow

DEM/Seawater on land

DEM/Bluespot extreme rain

DEM/Hydrological adjustments include:
126813 lines and 22828 ”horseshoes”



Hydrological elevation models are targetted application for climate protection towards cloudbursts and increasing seawater level (incl. storm floods)

- DEM/Rain: added piped stream sections (< 50 m), openings in bridges and sluices permitting flow of water towards the sea

- DEM/Seawater rise: as DEM/Rain, but with closed sluices

Hydrological adjustments

Purpose: make possible to simulate water flow on terrain and in streams and the resulting accumulation of water in ”Bluespot” depressions using DEM

Requires: identification of areas where elevation data need to be lowered due to

- Piped watercourses
- Bridges
- Sluices (sluices may be opened og closed)
- Does not consider sub-ground drains (agriculture) and sewers

Two hydrologically adjusted DEM’s:

DEM/Rain

DEM/Sea rise

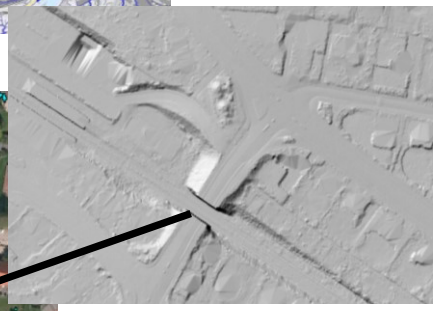
The figure illustrates a highway that crosses a stream. In order to model the water flow under the highway the stream has been cut into the DEM.

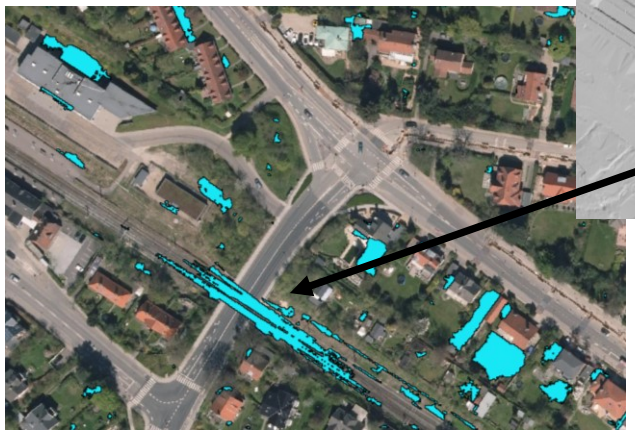
DEM/Sea rise: rain sluices closed

The rain sluice will prevent sea water to move into land through the stream channel.

During normal sea levels, the rain sluice will be open to allow rain water in the stream to pass and run into the sea.

Data from the Danish Elevation model (DEM) - 0,4 m grid





Danish Elevation model

DEM/Point cloud* (2014/15)

DEM/Terrain*

DEM/Surface*

Hydrological elevation models

DEM/Hydrological adjustments*

DEM/Rain*

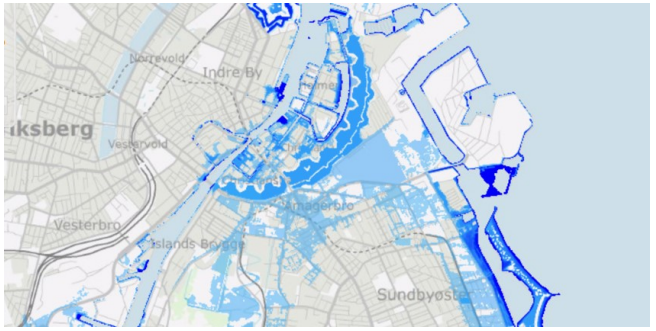
DEM/Sea rise*

Hydrological products

DEM/Flow

DEM/Seawater on land

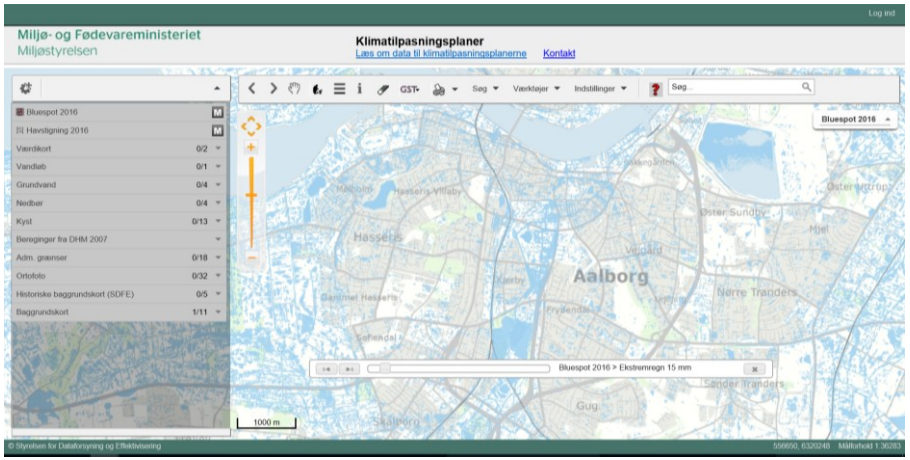
DEM/Bluespot extreme rain

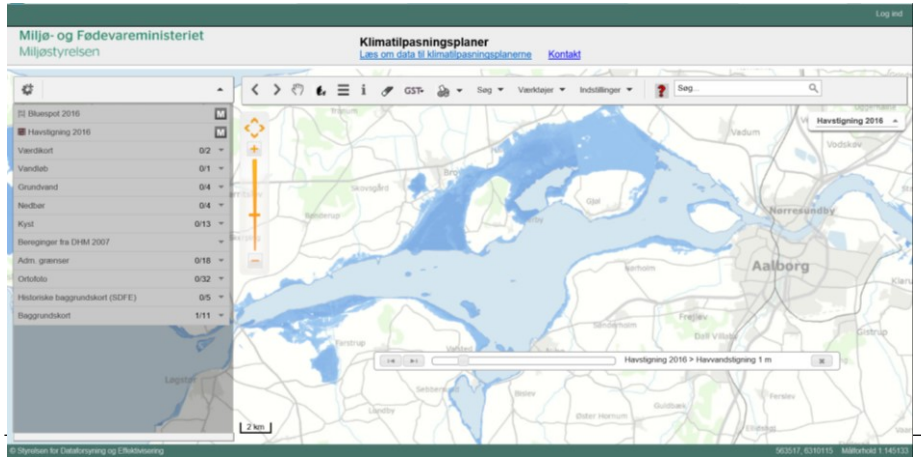


Download at https://download.kortforsyningen.dk/

Webservices and applications

”DEM/Seawater on land” and ”DEM/Bluespot ekstreme rain” webservices





After annoucment 3rd May 2017 :

”DEM/Seawater on land” had 1 million requests per hour at 11 am.

”DEM/Bluespot Ekstreme rain” had ½ million requests at the same time.

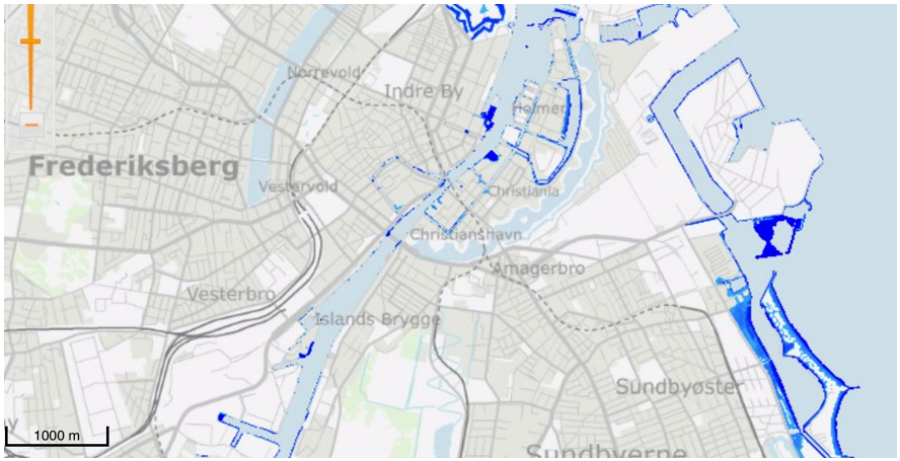
The storm *Ingolf* sunday 29-Oct 2017:

between 30.000 – 110.000 service call per hour to ”DEM/Seawater on land”.

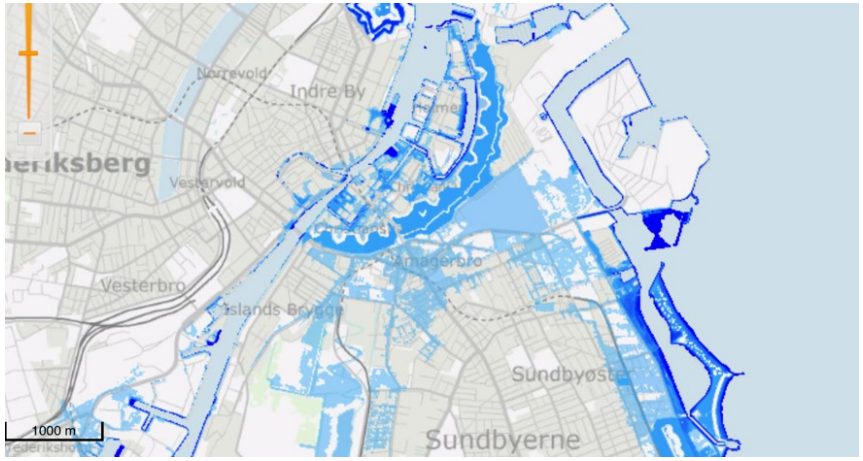
http://miljoegis.mim.dk/spatialmap?&profile=miljoegis-klimatilpasningsplaner

DEM/Seawater on Land

simulated using closed rain sluices



Sea rise + 1.5 m



Sea rise + 1.75 m

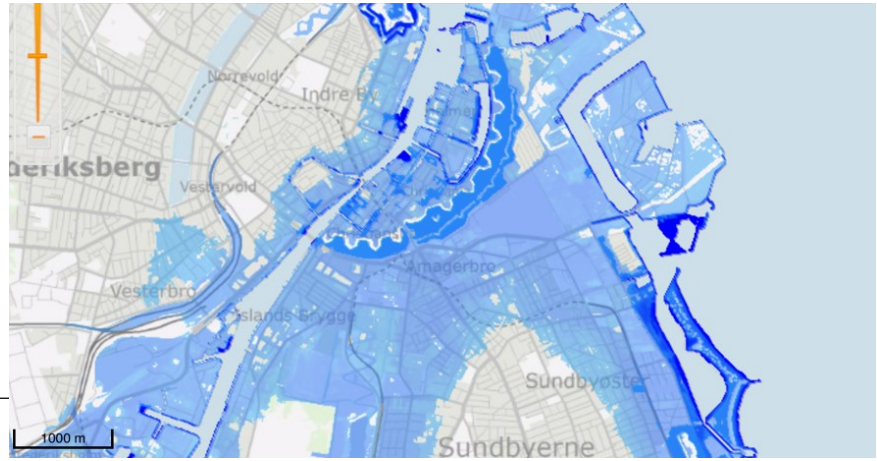
Screening tool

DEM/Sea water on land (0.4 m)

Copenhagen is safe up to 1.7 m sea level rise

The storm *Bodil* raised sea level to 1.69 m

New dikes north and south of Copenhagen will secure Copenhagen to resist a 1000-year storm event in 2100.



Sea rise + 2.0 m

Updating the DEM

Data

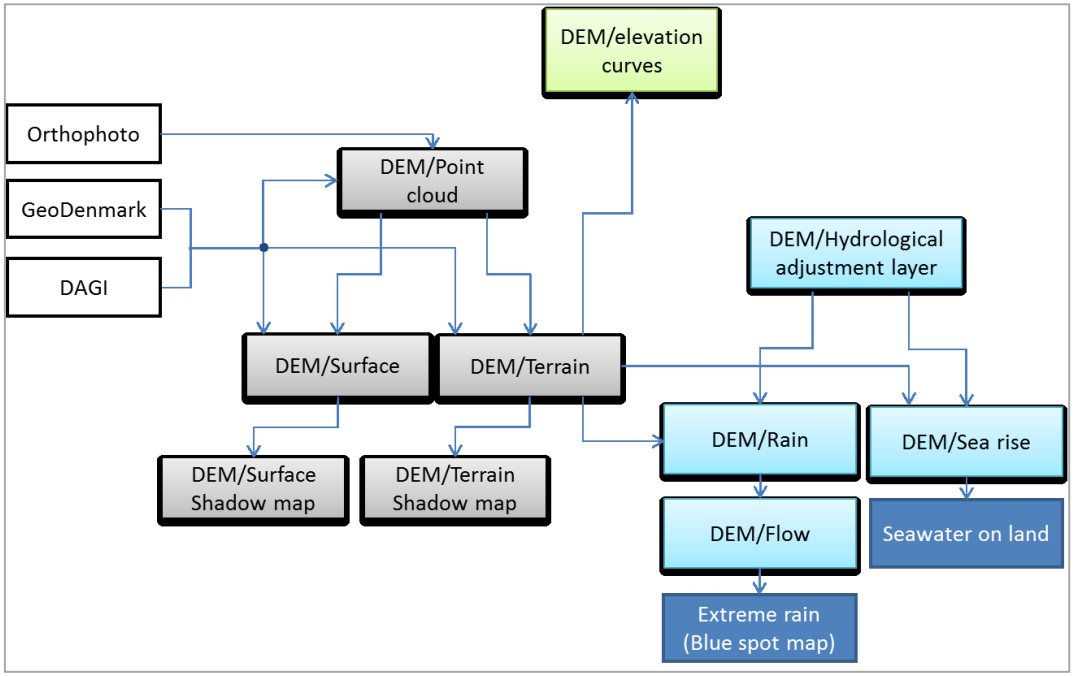
DEM/Point cloud

▪ Strategy for updating DEM expected in 2018. Experiments using

- airborne *single-photon* lidar
- drones
- GeoDanmark oblique imagery
- (users upload of data)

DEM/Hydrological adaptations

▪ Included in GeoDanmark



Production system

▪ Model for updating point cloud data, Surface and Terrain in 2018.

▪ Open source python script (malstrøm) for quality assessment and updating of hydrological products (Flow, Extreme rain)

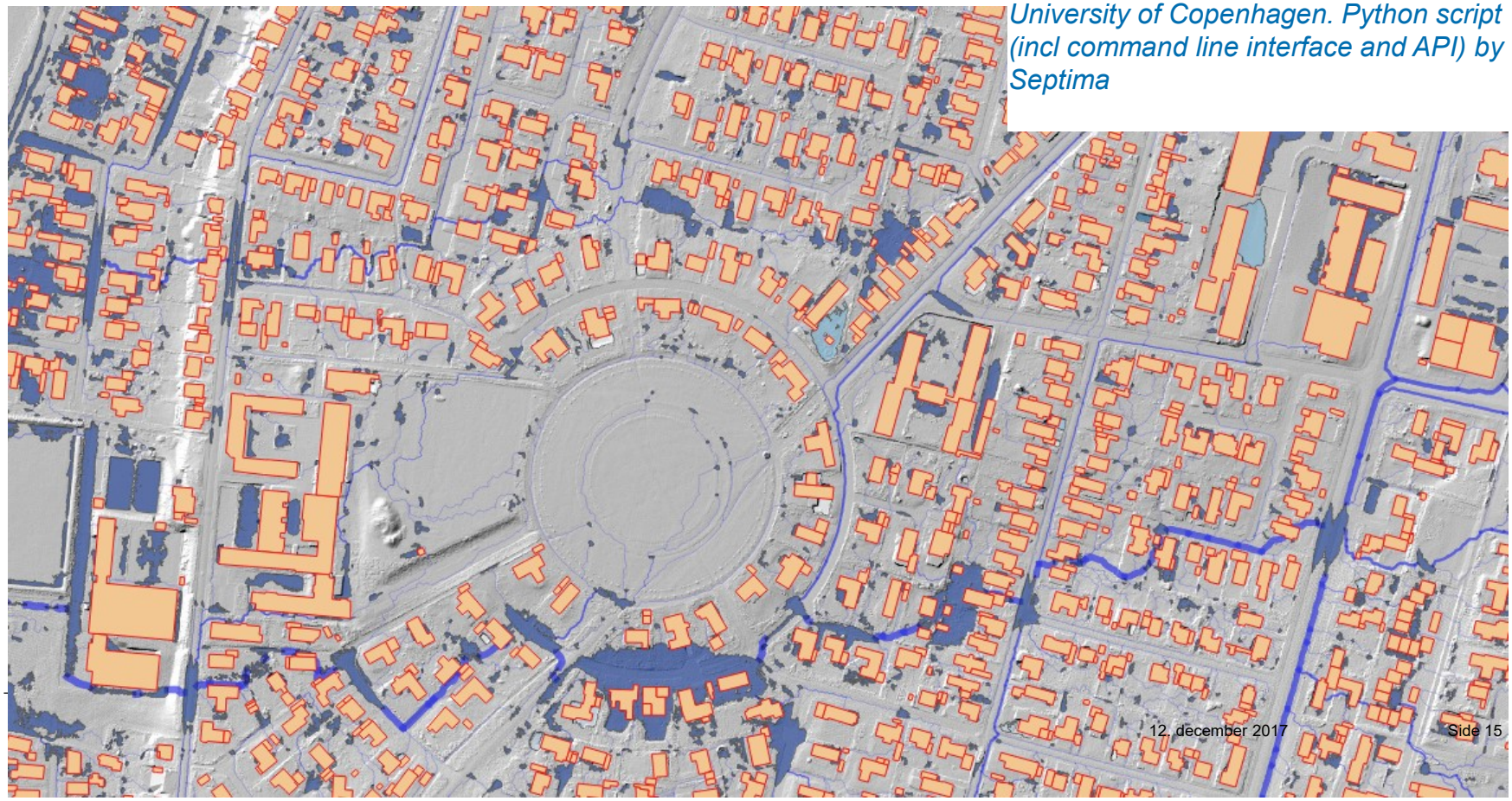
▪ Kortforsyningen, Datafordeleren

Quality assessment and updating

Open source python script ”malstrøm” for mapping
bluespots, flow direction, fill volumes, overflow volumes and more

http://malstroem.readthedocs.io/en/latest/

Method developed by Thomas Balstrøm, University of Copenhagen. Python script (incl command line interface and API) by Septima



http://malstroem.readthedocs.io/en/latest/

malstroem provides command line tools and a python api to calculate:

Depressionless (filled, hydrologically conditioned) terrain models

Surface flow directions

Accumulated flow

Blue spots

Local watershed for each bluespot

Pour points (point where water leaves blue spot when it is filled to its maximum capacity)

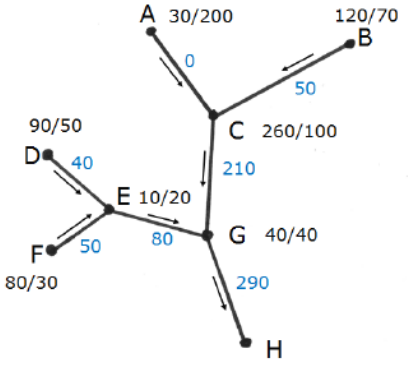
Flow paths between blue spots

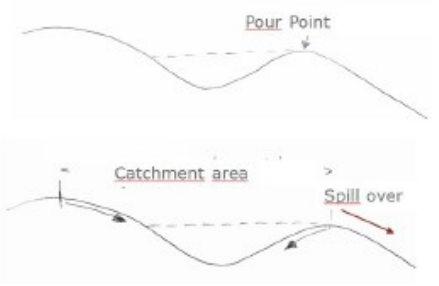
Fill volume at specified rain incidents

Spill over between blue spots at specified rain incidents

Malstrøm – flood analysis

Bluespot pourpoint, spill over volume and flow direction

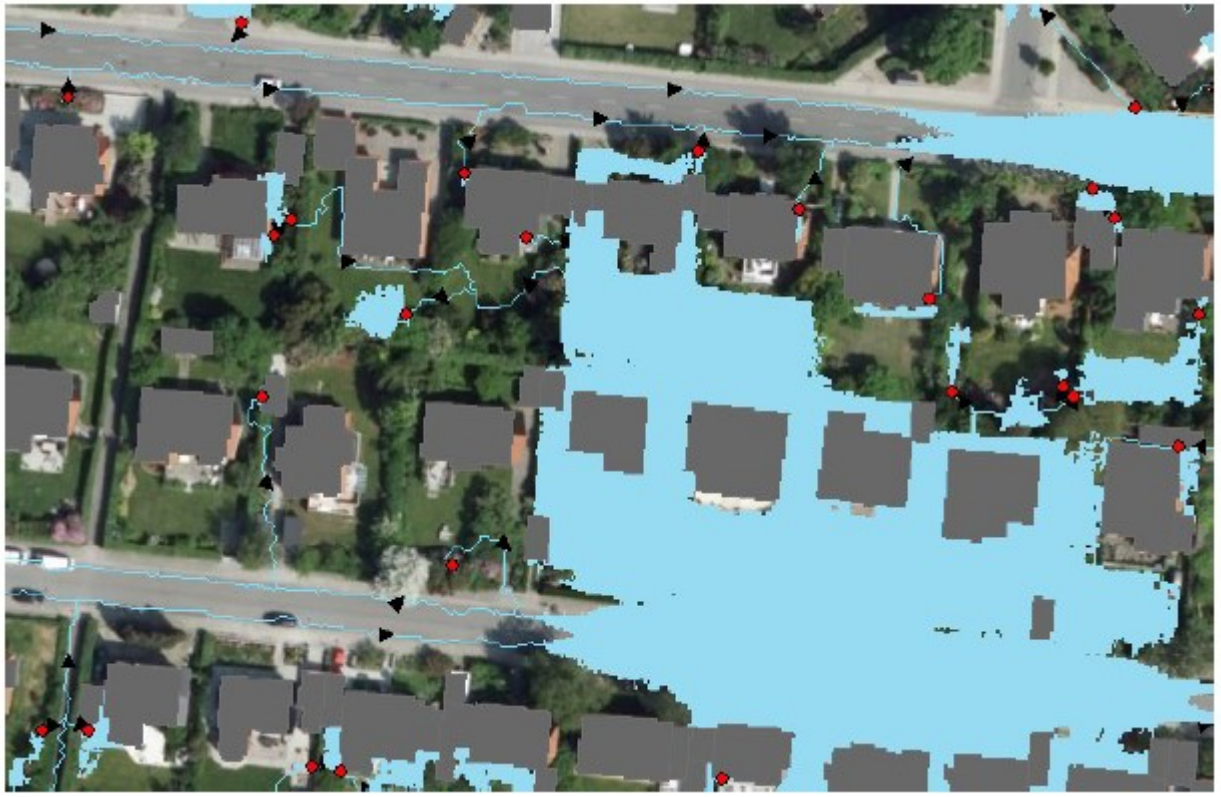


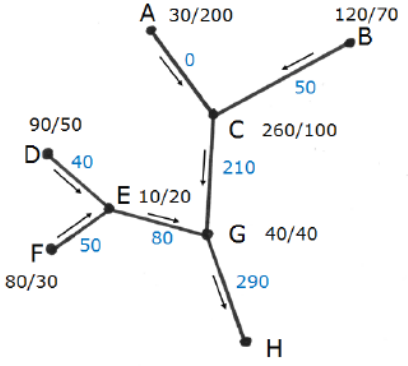


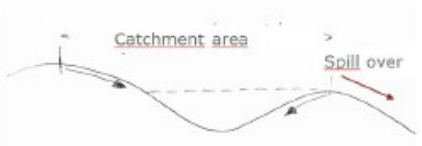
Note the flow along curbs on roads

Malstrøm – flood analysis

Bluespot pourpoint, spill over volume and flow direction



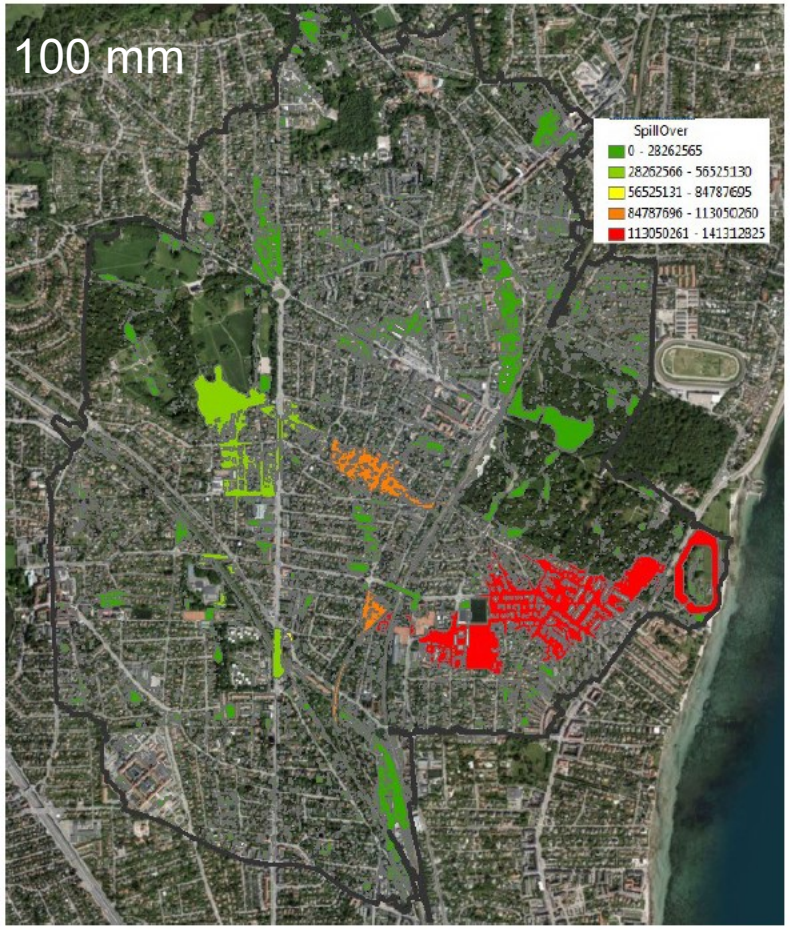




Note the flow along curbs on roads
Potential for integration with sewer capacity data

Malstrøm – flood analysis

Spill over (m^3)



Sewers not considered. No time consideration. Terrain assumed impervious (no soil moisture/groundwater consideration).

Summary

- High-quality national lidar-based data, elevation model and derived hydrological products (maps) are freely available for research, innovation and commercial applications. https://download.kortforsyningen.dk/

- Data from the Danish national elevation model (DEM) includes hydrological elevation models in 0,4 m grid, hydrological adjustment data (lines and horseshoes) and hydrological products (maps) for screening of flood risk due to cloudburst and storm floods.

- A production system has been built to support high quality and efficient updating of DEM. A strategy for updating is expected in 2018.

- Open-source python script ”malstrøm” is freely available for further surface flow analysis

- DEM data and webservices are widely used by researchers, engineering and consulting companies, citizens, emergency agencies, insurance companies and housing associations to assess flood risk from storm floods and cloud bursts.