MADALGO
CENTER FOR MASSIVE DATA ALGORITHMICS


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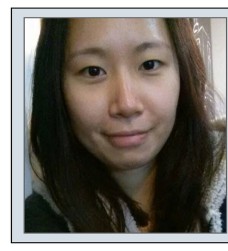
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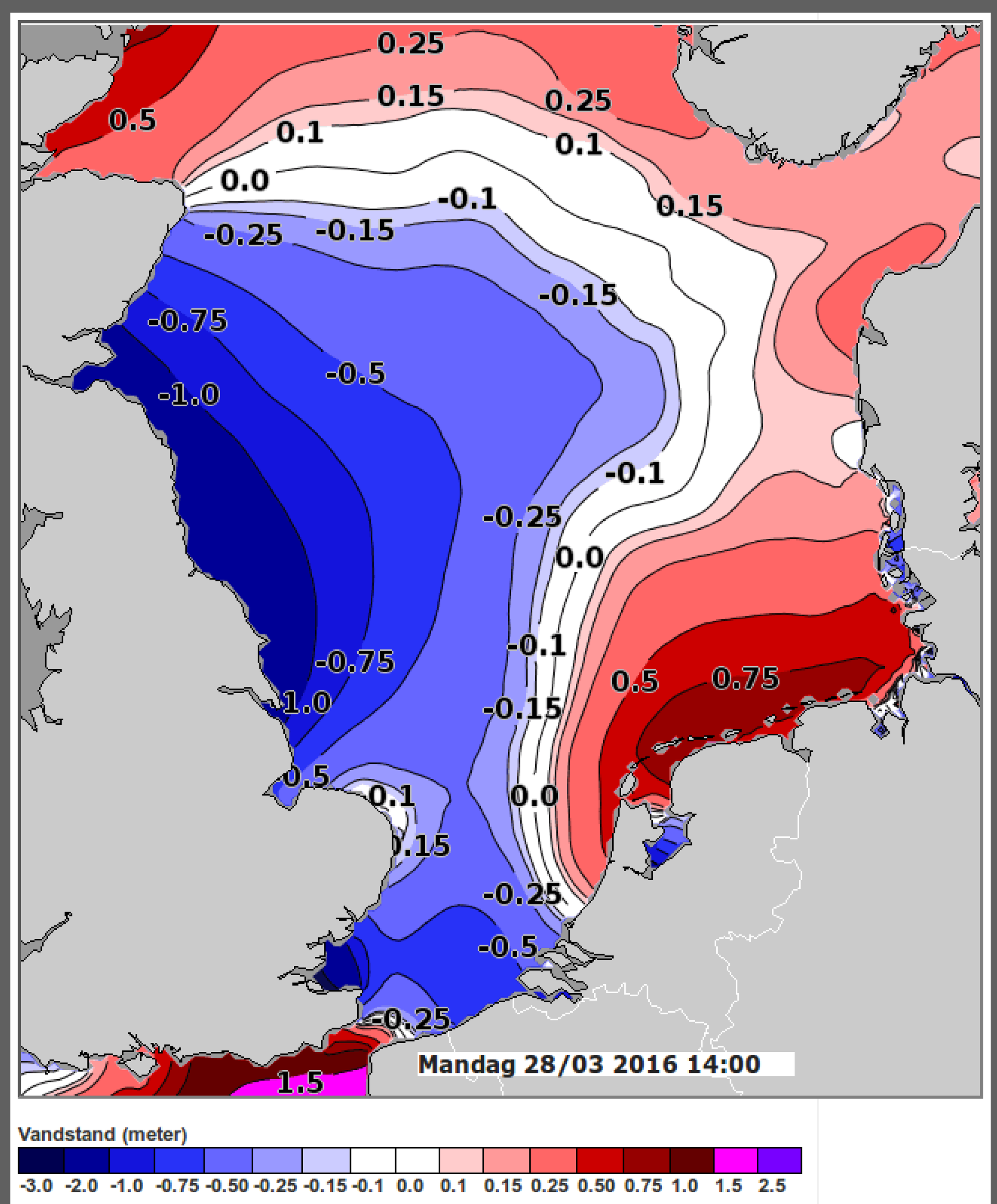
Non-uniform Sealevel Rise Flood Computation

Problem Description

Non-Uniform Sealevel Rise

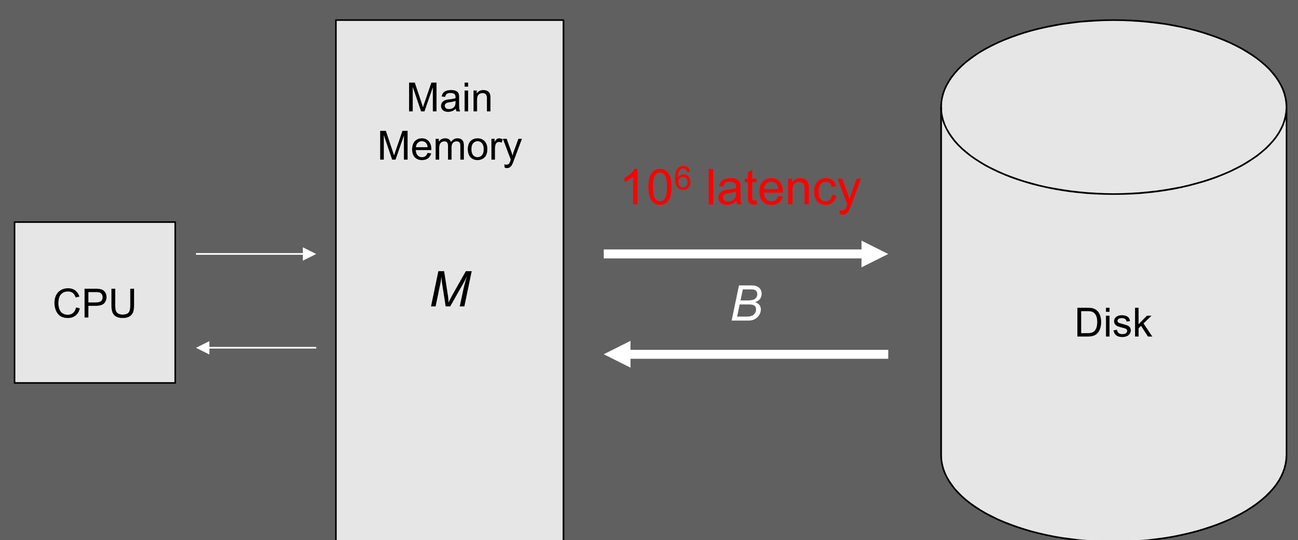
- Caused by temperature, current, wind, etc.



Danish Meteorological Institute, www.dmi.dk

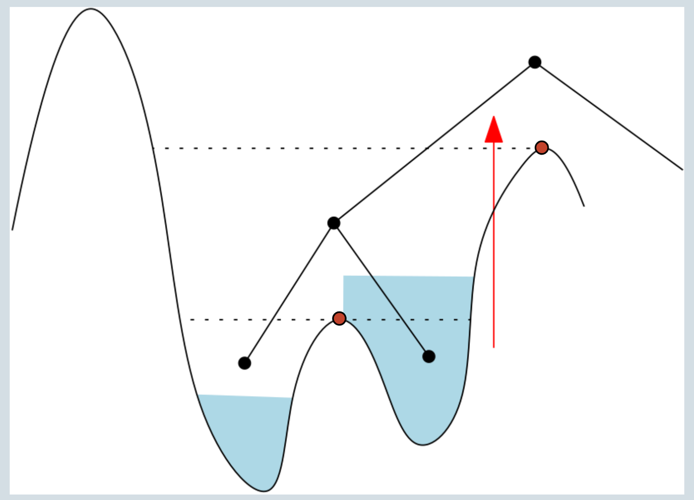
I/O Model [1]

- The highest resolution of Denmark terrain is 0.4 m
- Terrain data : $(43{,}094 \times 10^6) / (0.4 \times 0.4) \times 4$ Bytes = 1 TB
- Data does not fit in main memory - consider I/O complexity
- M : memory size
- B : I/O block size
- N : input size



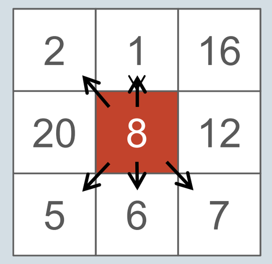
Merge Tree Algorithm [2, 3, 5]

- Sweep up

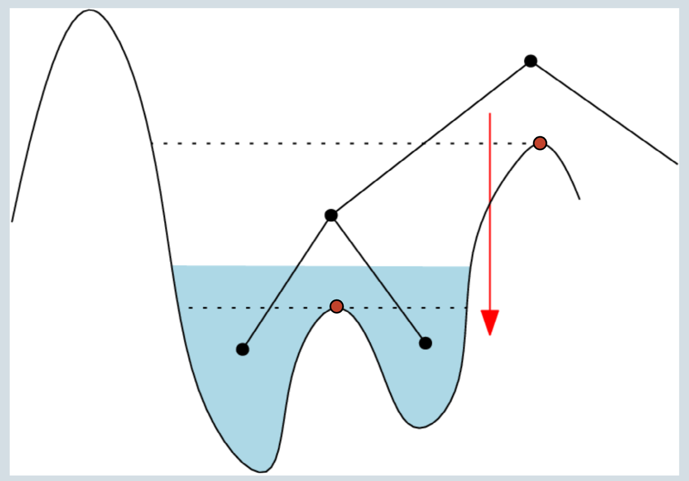


- Store the height of water
- Succeed the water height if it is higher than the saddle height
- Keep the highest value during sweep up phase

Saddle : A point which has at least 2 discrete downstreams.
Represented as red dots in the merge tree figures.
In the example on the right, each number on the box represents the height of the terrain. Water flows from 8 to 2, 1 and 5, 6, 7.
Therefore 8 is a saddle point.



- Sweep down



- Inherit the water height value over the children
- If a node has water height, the height will be delivered to its all descendant

- Complexity

$O(Sort(N) + Scan(X \cdot H))$ I/Os

X = number of sinks

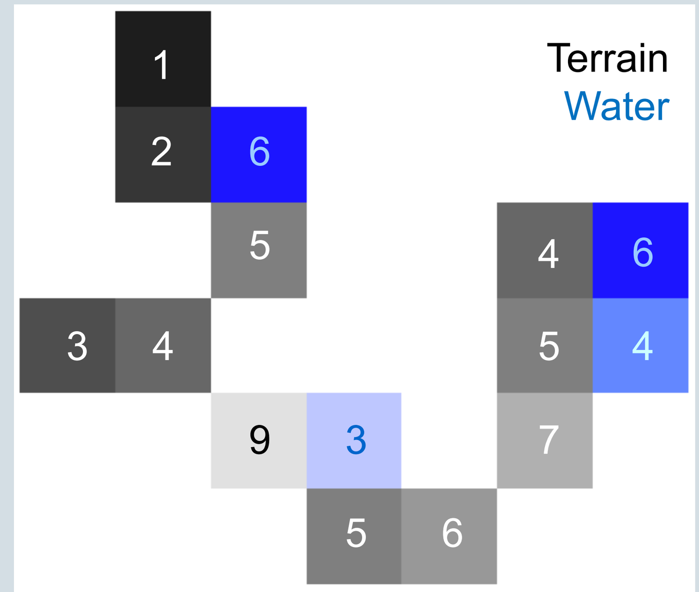
H = height of merge tree

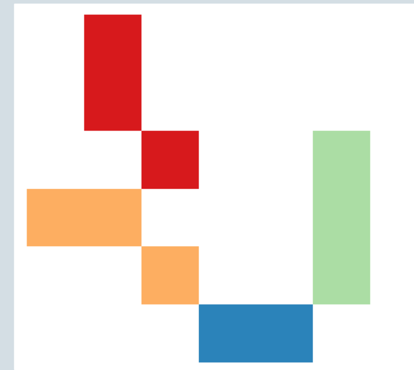
$Scan(N) = N/B$

$Sort(N) = N/B \cdot \log_{M/B} N/B$

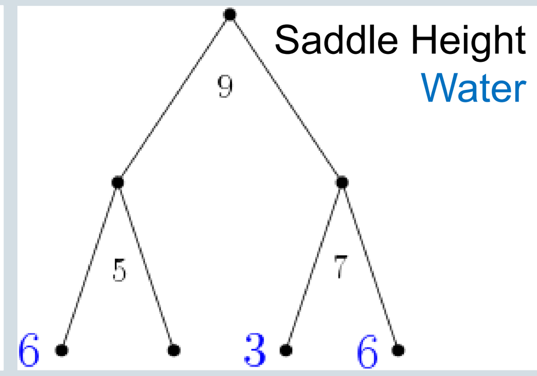
Simulation

Input



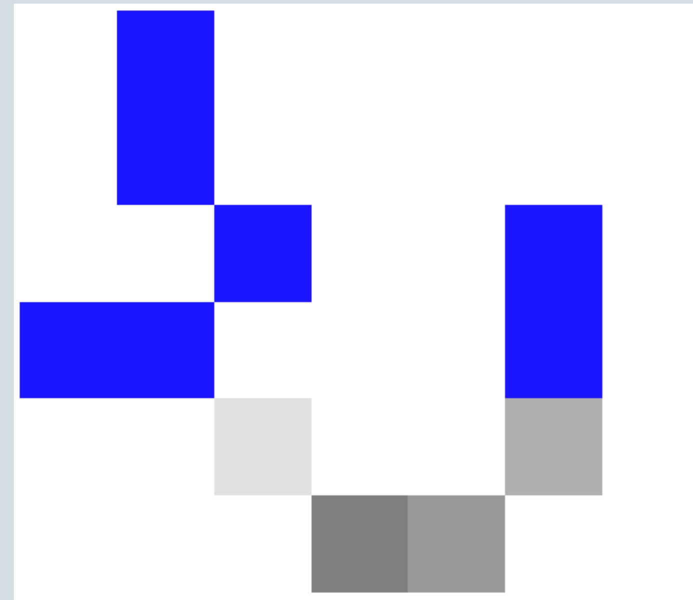


Watersheds



Merge tree

Output



- Water 6 (left) fills two watersheds (spill over saddle 5)
- Water 6 (right) floods only terrain height < 6 (Water 4 is ignored)
- Water 3 cannot flood on any terrain

Open Problems

Resolution Integration

- Working on input with different resolution
- Practical model of terrain/seawater

Using connected components by scan the terrain

- Can we have linear I/O complexity?

Related Works

Flash flood event computation based on non-uniform rain event [4]

- Using merge tree
- $O(Sort(N) + Scan(X \cdot H))$ I/Os

Sealevel rise flood computation

- TerraSTREAM Hydrological tools
- Based on uniform sealevel rise scenario
- $O(Scan(N))$ I/Os

References

[1] A. Aggarwal and J. Vitter. *The Input/Output Complexity of Sorting and Related Problems*. CACM 31(9), 1988.

[2] A. Danner. *I/O Efficient Algorithms and Applications in Geographic Information Systems*, PhD thesis, Duke University, 2006.

[3] A. Danner et al. *TerraStream: From Elevation Data to Watershed Hierarchies.* Manuscript, 2007.

[4] L. Arge et al. *I/O-Efficient Event Based Depression Flood Risk.* 7th Workshop on Massive Data Algorithms, 2015.

[5] L. Arge et al. *I/O-efficient Computation of Water Flow Across a Terrain.* Proc. 26th Annual Symposium on Computational Geometry, 2010.

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