Advances in flood inundation modeling and opportunities for high resolution geospatial data resources

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Outline

- Trends in flood inundation modeling
- Recent experience
  - St. Francis dam-break study
  - Glasgow urban flooding study
- Opportunities for LAR-IAC

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Trends in flood inundation modeling

- Flood inundation models have long been used to predict flood zones (e.g., FEMA)
  - Exceedance probability floods
  - Dam-safety programs
- Model capabilities have steadily progressed
  - More physics, more detail, in parallel with computational power
  - Uniform flow -> Unsteady 1D -> Unsteady 2D -> Unsteady 3D
- Future progress will be controlled by data availability, resolution and accuracy.
  - University researchers just beginning to consider how geospatial datasets (imagery, DEMs, etc.) should be processed to support flood modeling objectives.

Important time of transition

- From model development to model parameterization and application for decision support
  - Models are robust and efficient
  - Reliability of predictions now limited by parameter uncertainty: ground elevation and flow resistance factors.
- Today's challenges
  - Data processing methodologies are needed to streamline the model parameterization and execution.
  - Need better understanding of information required for decision-making. Models need to be customized to deliver appropriate information.

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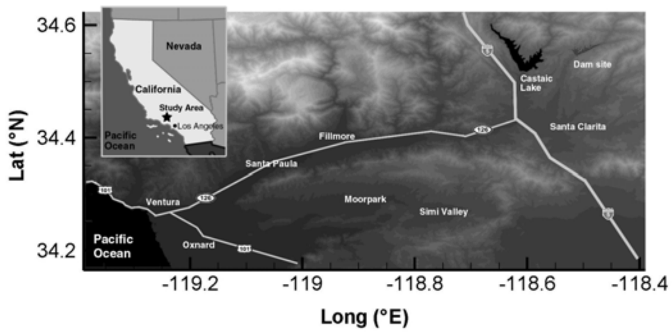
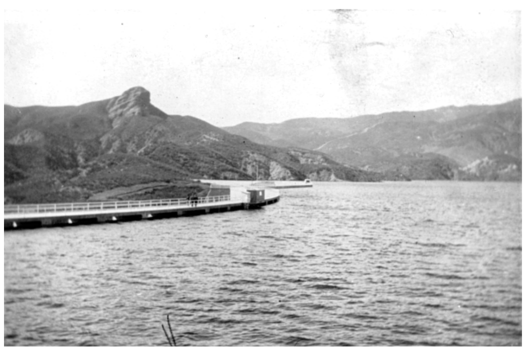
Research at UC Irvine

- Development of robust 2D flow modeling codes
  - Applications include river flooding, tidal circulation, storm surge inundation, dam-break flooding, etc.
- Performance Attributes of Models
  - Perfectly conserves fluid mass
    - Mass residual equal to numerical precision
  - Predictions are monotone
    - No spurious oscillations
  - Conditionally stable
    - Time step must satisfy CFL condition.
    - No constraint on terrain smoothness for stability.
  - Most practical applications will run on a desktop computer.
    - No need for supercomputing capability.

St. Francis Dam-Break Flood



St. Francis Dam, Near Los Angeles, built. 1924-1926



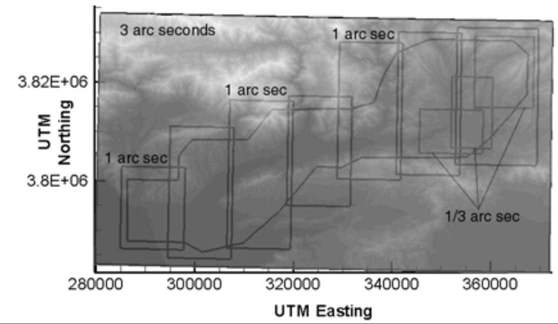
St. Francis Dam, First Fill, March 12, 1928

St. Francis Dam, After Failure, March 13, 1928

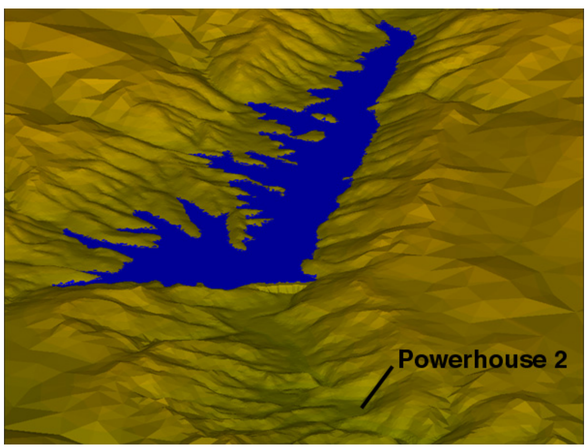
(Rogers and James 2003)

Dam Break Modeling

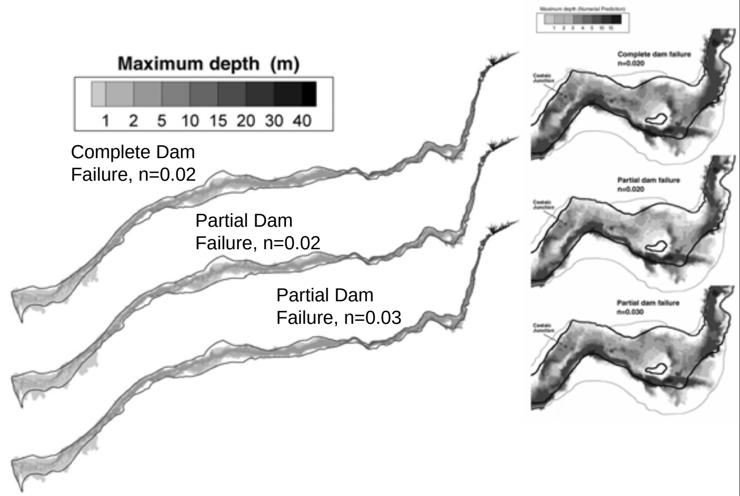
Terrain data obtained from USGS 3, 1 and 1/3 sec NED
http://seamless.usgs.gov
Spatially uniform Manning coefficient used to scale resistance.



St. Francis Dam-Break Simulation



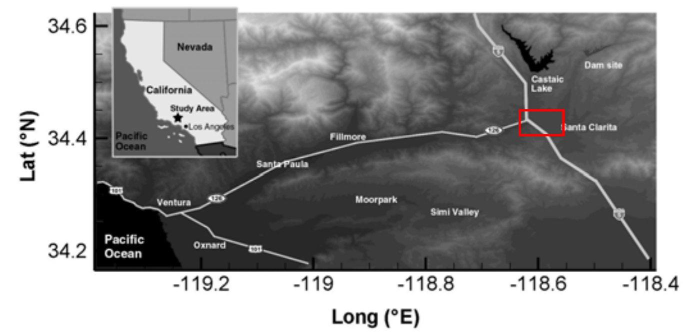
Movies by Lorenzo Begnudelli, U. Ferrara, Italy.



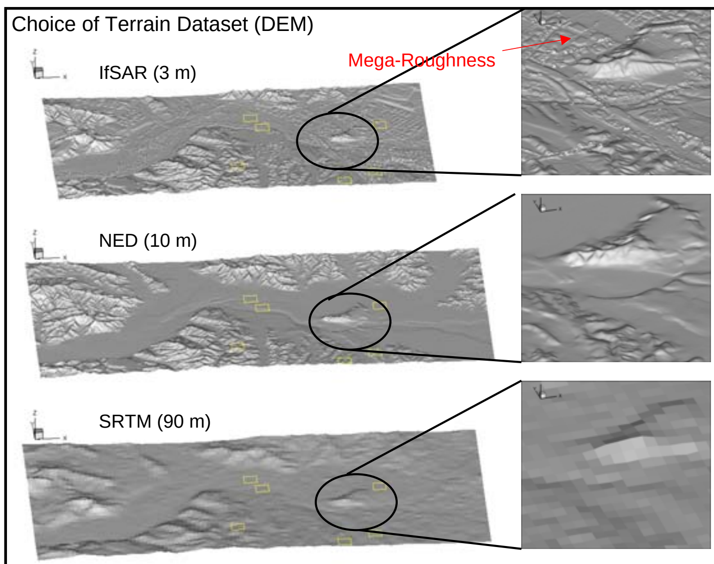
Model Accuracy

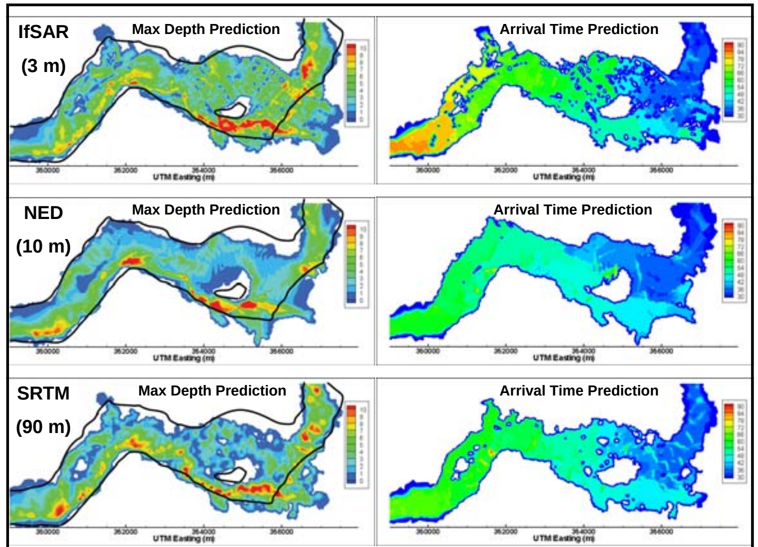
- Area of inundation predicted within 2-3% of measurements.
  - Area of inundation not sensitive to 50% change in Manning coefficient or change to breach configuration
  - Peak Q decreases with increasing n due to wave attenuation
- Arrival times predicted (by calibration) within 10% of observations.
  - Arrival time sensitive to Manning coefficient.
    - Santa Clara Valley: 25% error with 50% change in n
    - San Francisquito Canyon: 10% error with 50% change
    - n=0.02 gave best agreement.

St. Francis Dam-Break Flood
Terrain Data Options



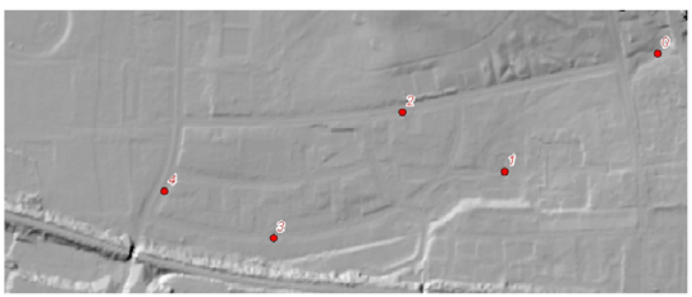
Choice of Terrain Dataset (DEM)



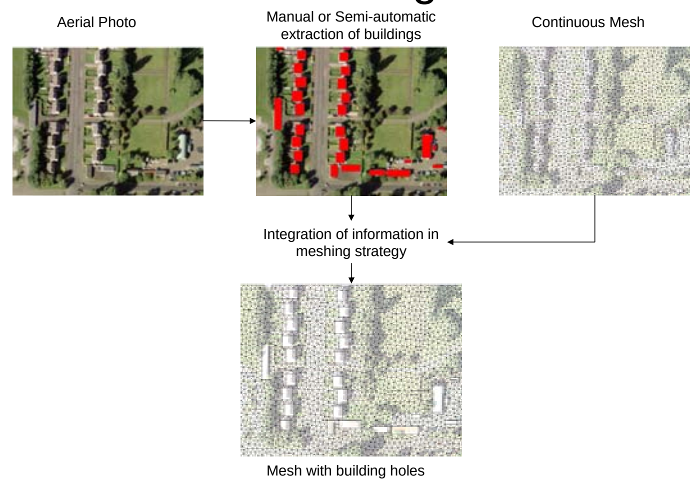


Urban flooding case study: Glasgow, Scotland

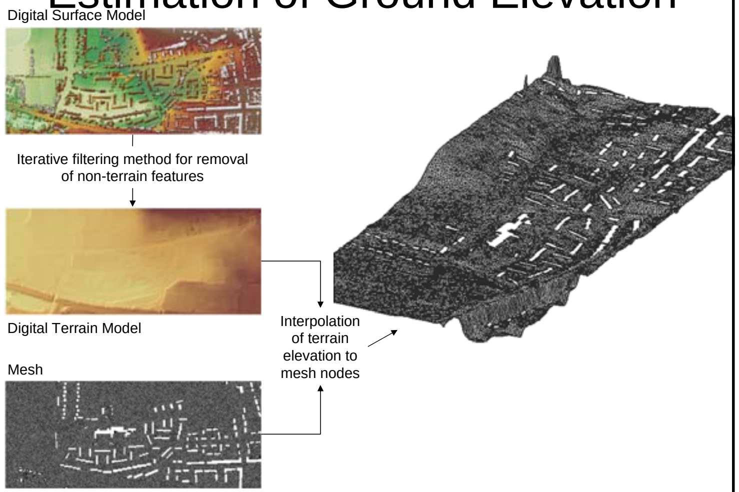
Aerial Photography obtained from Bluesky International Ltd
LiDAR data obtained from Infoterra
Supported by UK Flood Risk Management Research Consortium



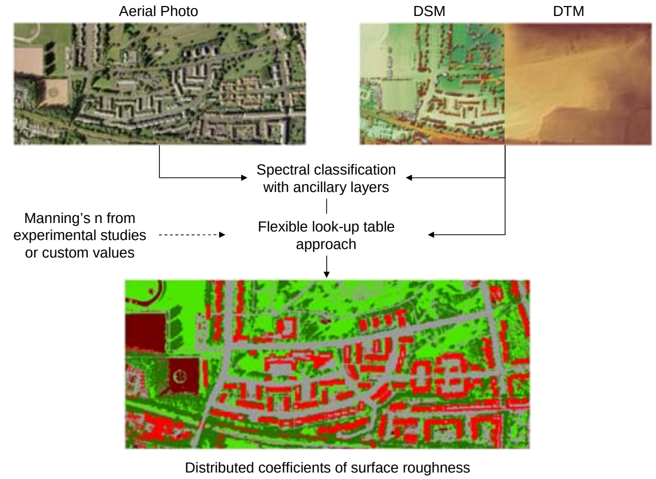
Meshing

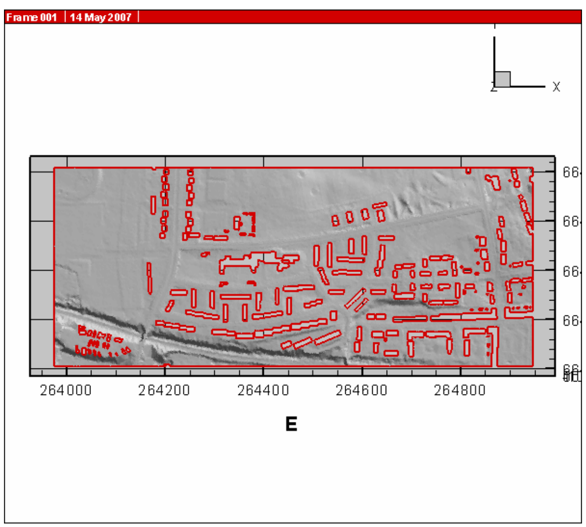


Estimation of Ground Elevation

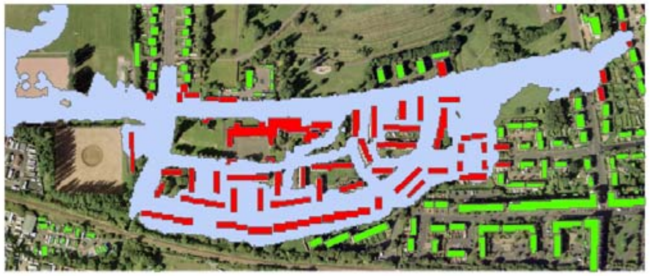


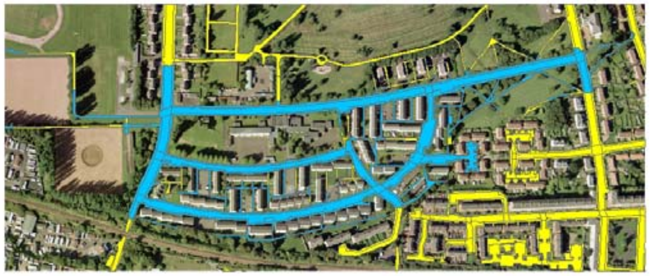
Resistance Coefficients





Flooding Extent





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Research Objectives: 2007-2008

- Automate meshing process
  - How can we use vector datasets to guide meshing?
- Resistance parameterization
  - Can this be automated based on land surface properties?
  - What degree of granularity is appropriate for Manning n (or chezy C, or darcy f)?
- How to model the effect of buildings
  - Impact on storage, conveyance and resistance
  - Will test use of porosity
- Improve algorithm efficiency
  - Meshing with holes vs. structured grids. (Vector vs. Raster) Examine tradeoffs.
  - How do we accurately coarsen mesh?
    - Blending “mesh hole” and “porosity” methods.
  - Faster numerical methods.
- Research must be done within a practical context
  - LA County test sites under review, will use LAR-IAC data.

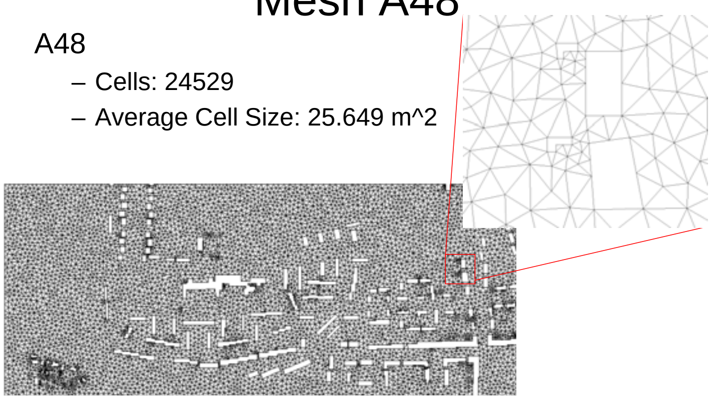
UC Water Resources Center Grant

Long Term Research Objectives

- Integration of flood simulation algorithms into GIS for decision making purposes
  - Planning Mode
    - Permitting, insurance, and infrastructure management
  - Response Mode
    - Evacuations, traffic management, first response efforts
    - Requires integration of real-time precipitation and/or stream flow data.
- Range of flooding scenarios: intense rainfall, dam-break, extreme tides, tsunamis, channels blocked by debris, water main breaks, blocked sewers, etc.
- A better understanding of the information required by decision managers is needed.
  - Would welcome your input and opportunities to partner.

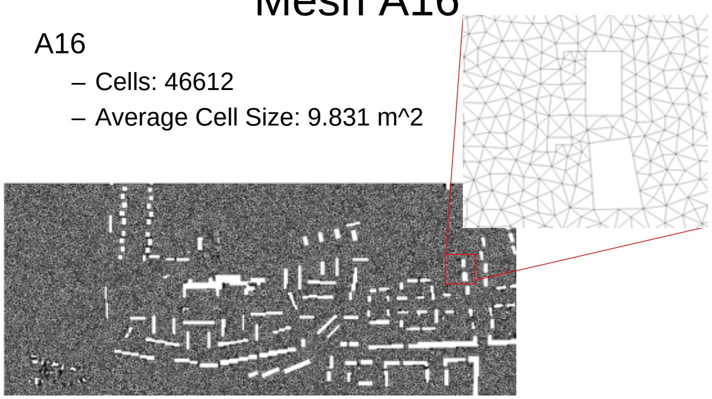
Mesh A48

A48
- Cells: 24529
- Average Cell Size: 25.649 m^2



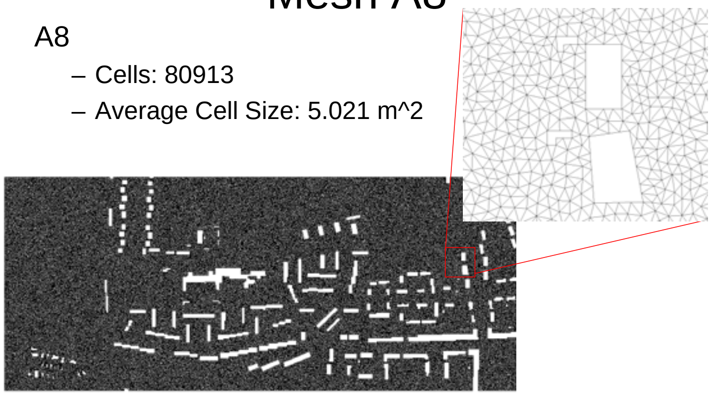
Mesh A16

A16
- Cells: 46612
- Average Cell Size: 9.831 m^2



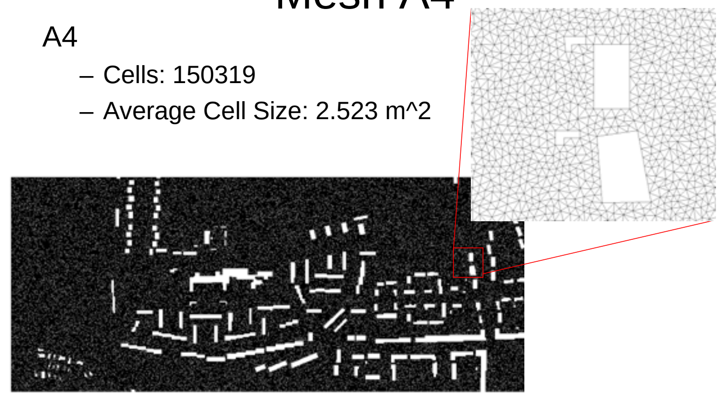
Mesh A8

A8
- Cells: 80913
- Average Cell Size: 5.021 m^2



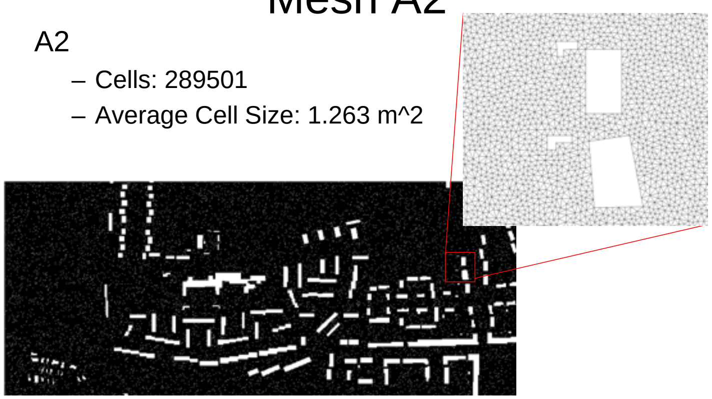
Mesh A4

A4
- Cells: 150319
- Average Cell Size: 2.523 m^2



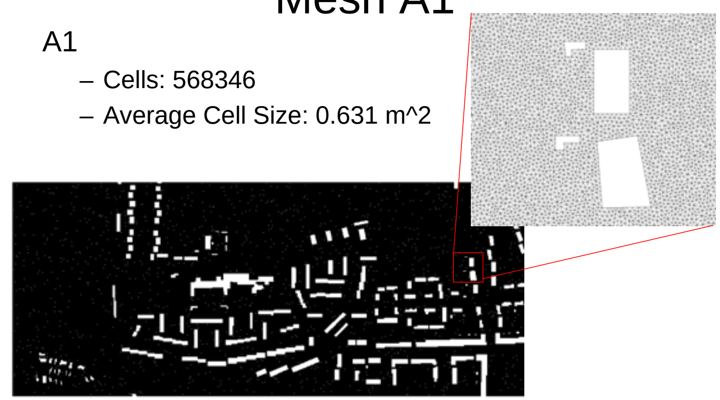
Mesh A2

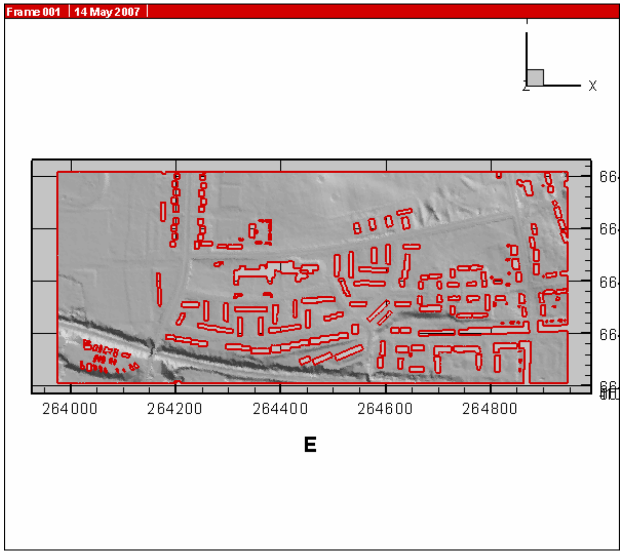
A2
- Cells: 289501
- Average Cell Size: 1.263 m^2



Mesh A1

A1
- Cells: 568346
- Average Cell Size: 0.631 m^2

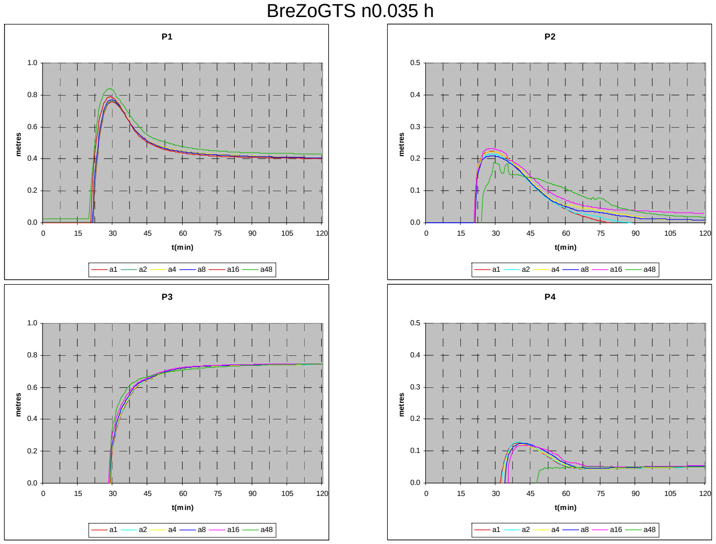




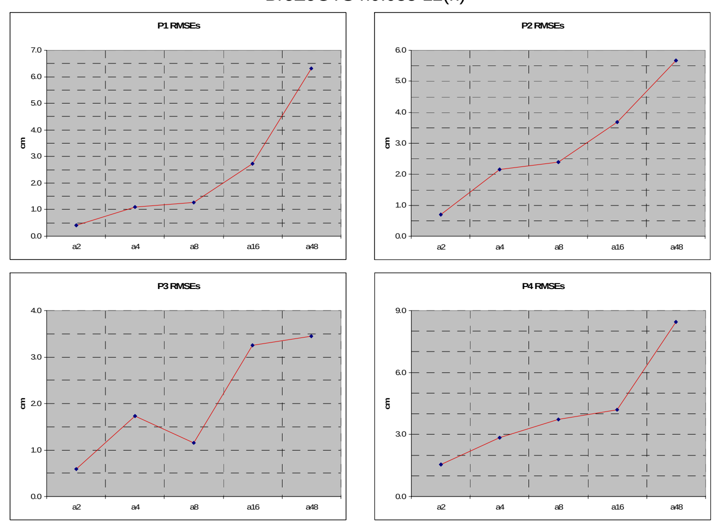
Possible Application Areas

- Impacts of sea level rise
  - Flood vulnerability
  - Drainage issues: pumping, sewers, etc.
  - Siting of critical infrastructure (hospitals, emergence response units, power substations), grading of roads, etc.
  - Public health issues (pathogens in surface waters)
- Forecasts of localized flooding (by coupling real-time precipitation data)
  - Flooded streets and highways (hydroplaning hazards)
- Real time response to flood events
  - Evacuations
  - Traffic Management
  - Routing of first responders

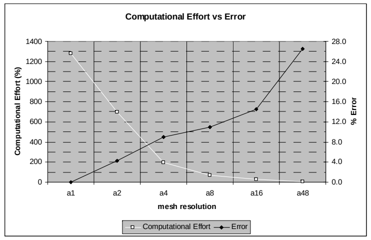
BreZoGTS n0.035 h

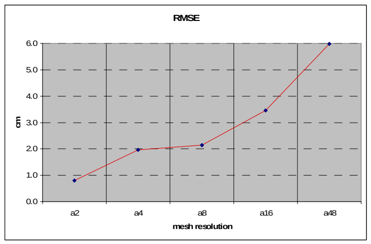


BreZoGTS n0.035 L2(h)

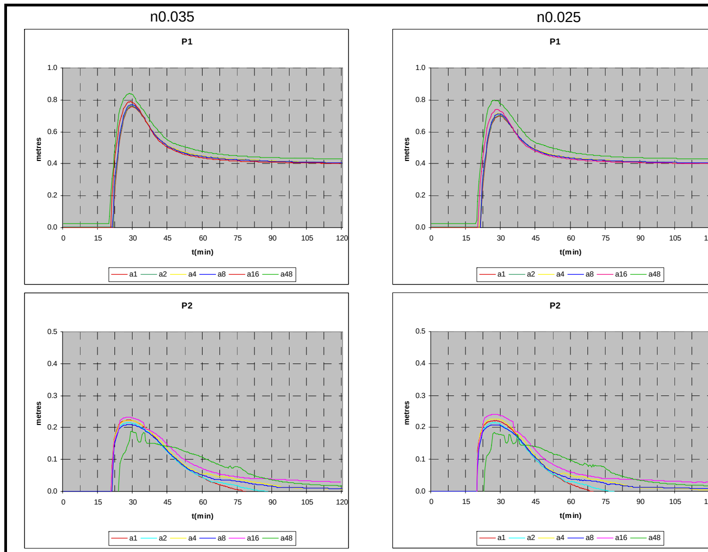


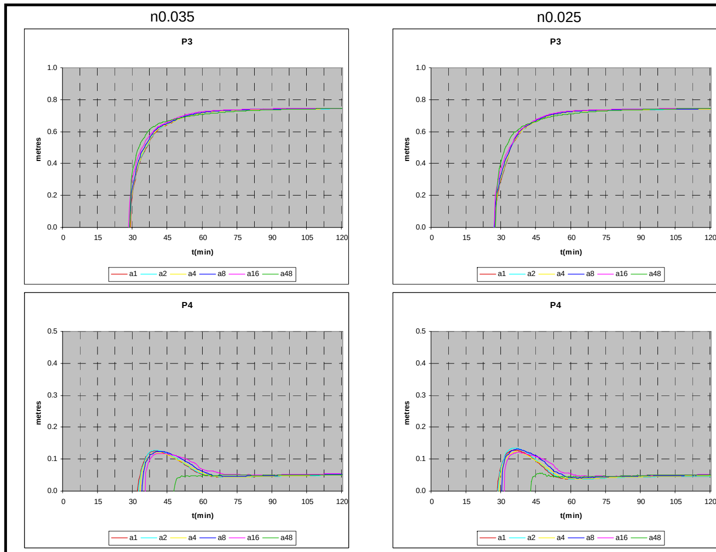
BreZoGTS n0.035



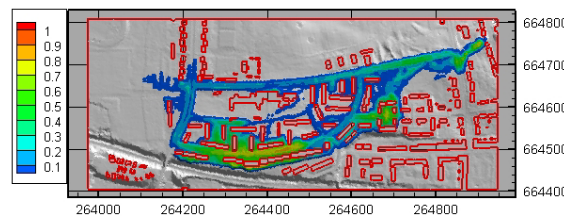


Real time = 2hours

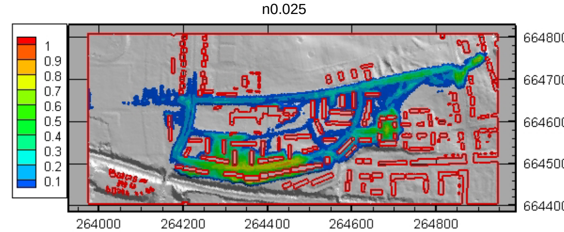




n0.035

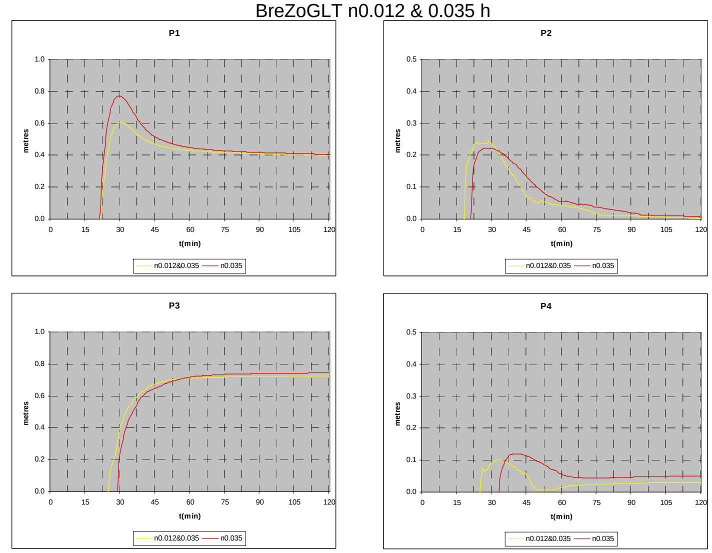


n0.025

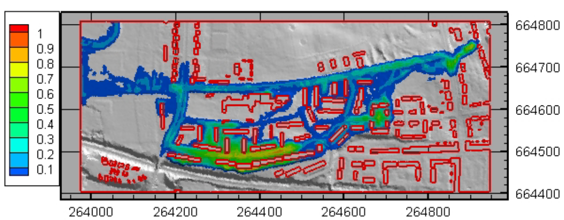


n 0.012 & 0.035

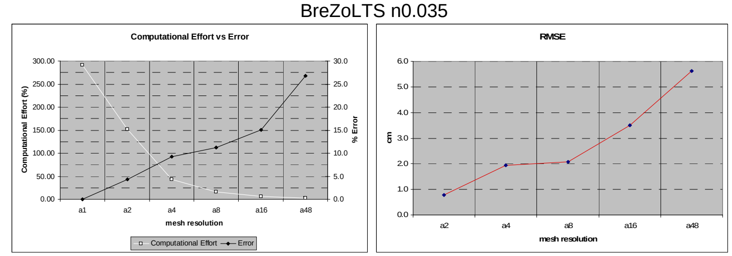
BreZoGLT n0.012 & 0.035 h



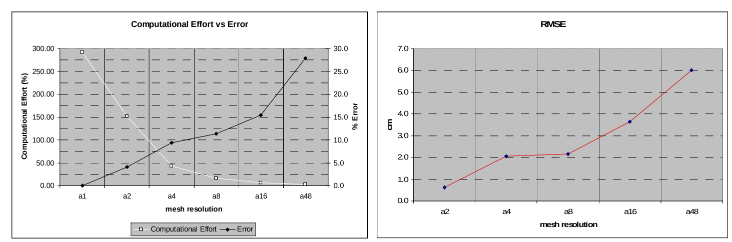
n 0.012 & 0.035



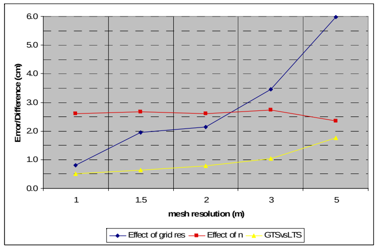
BreZoLTS n0.035



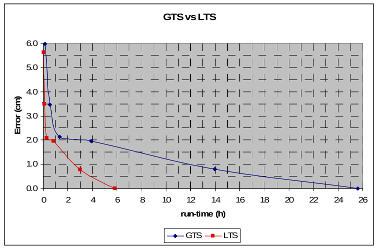
BreZoLTS n0.025



Summary



Error/Difference (cm)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
1.5
2
3
5
mesh resolution (m)
Effect of grid res
Effect of n
GTSvsLTS



GTS vs LTS
Error (cm)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
run-time (h)
GTS
LTS