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EO-Based Processing Frameworks for Urban Post-Disaster Response and Assessment

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The research works are partially supported by Public Safety Canada and CCMEO Water program, City of Calgary, Western University, …

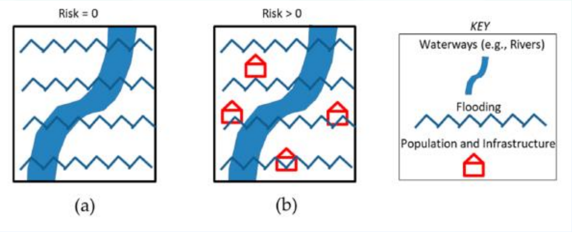
Canada

Introduction I

Focus of Natural Disaster Research at CCRS/CCMEO:

Development of earth observation based methodologies for urban flood mapping and detection of damaged buildings after major earthquakes in dense urban areas.

- ❖ Urbanization is on global trend. Majority (>80%) of Canadian are living in urbanized areas.
- ❖ The impacts of natural disasters in urban areas are significant on public safety and the economy.
- ❖ Urban remote sensing is challenging.



Introduction II

Challenges and Opportunities in Urban Disaster Applications of Remote Sensing:

- ❖ Urban areas are with complex landscape and diverse land surfaces. More efforts are needed for RS development to support urban disaster response.
- ❖ More high and very high resolution remote sensing sensors and platforms (small satellite constellation, space station, UAV, …) have became available.
- ❖ Timely information about affected locations is the key for response management. Automated technology development is needed for real-time information extraction from remote sensing imagery.

Two processing frameworks and case studies:

- ❖ Urban flood mapping
- ❖ Earthquake-induced building damage detection

Calgary Flood 2013

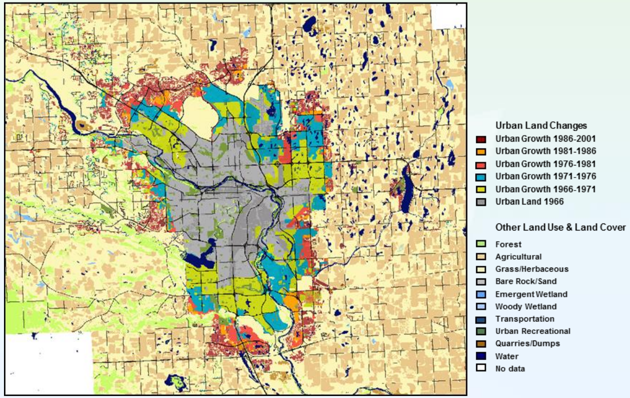
Research Objectives
for urban flood studies at CCRS

Using optical remote sensing imagery and existing geospatial data

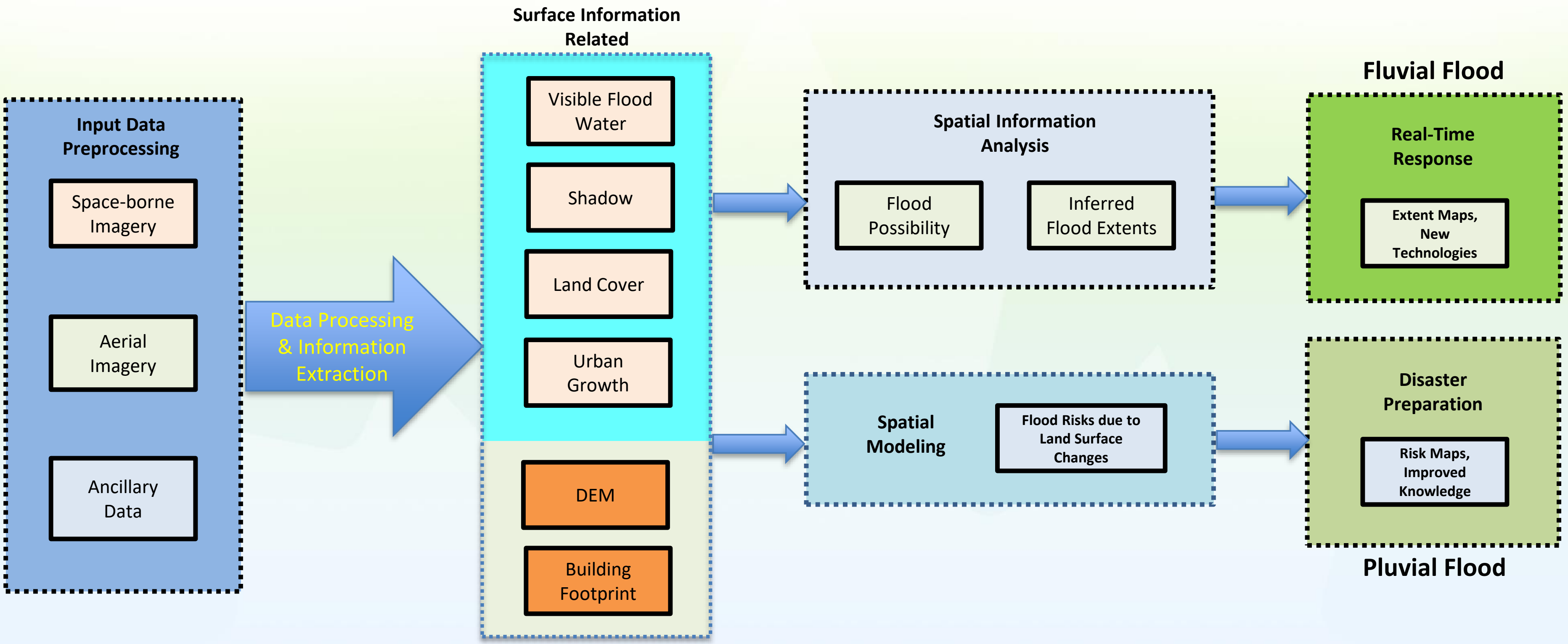
a. Post-disaster **Response**: to develop automated methodologies of real-time mapping and analysis of floodwater extents in dense built-up areas.

b. Pre-disaster **Preparation**: to develop and improve technologies for providing information inputs into urban flood risk analyses.

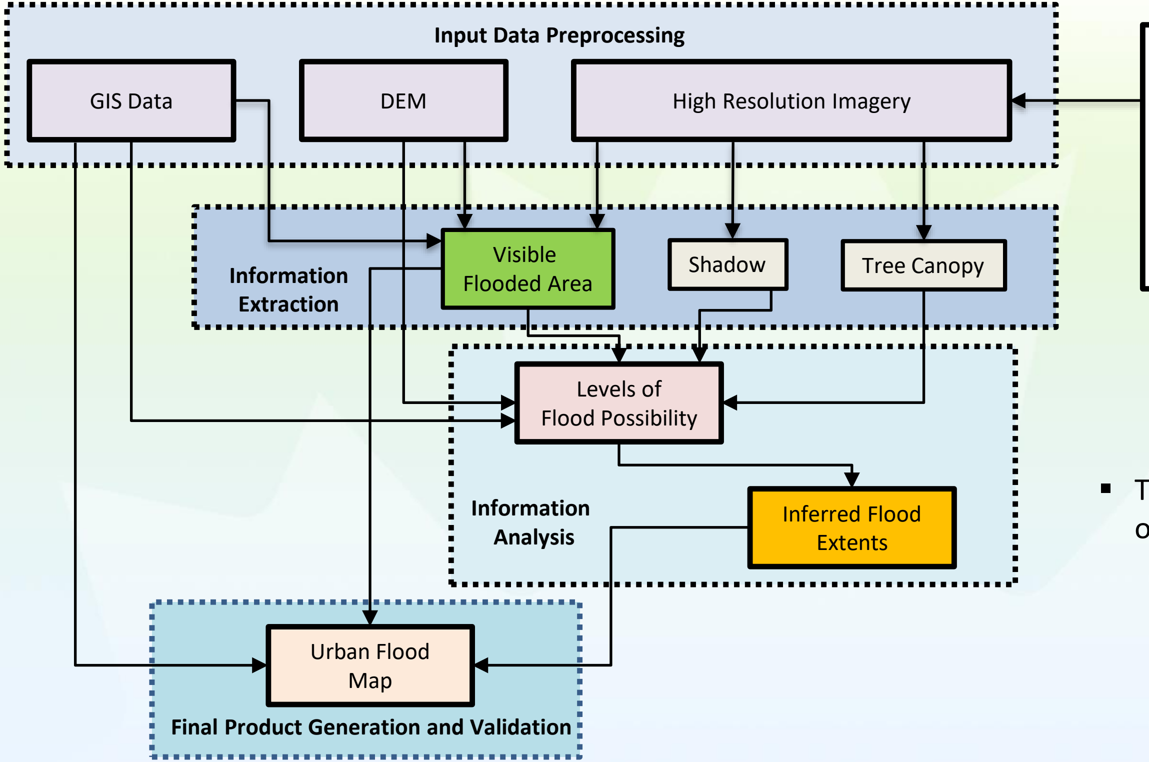
Calgary Urban Growth, 1966-2001



Earth Observation Based Urban Flood Information Processing



Remote Sensing Based
Urban Fluvial Floodwater Mapping



Possible Image Data Sources

- Aerial Plane (cost)
- HR Optical Satellite (cloudy-sky, low temporal flexibility except for constellation)
- International Space Station (resolution, atmospheric effect)
- SAR Satellite (only for open landscape)
- UAV (permission)

- The flooded areas visible in imagery are only part of the flooded extents

Remote Sensing Data
Case: Calgary Flood June 2013

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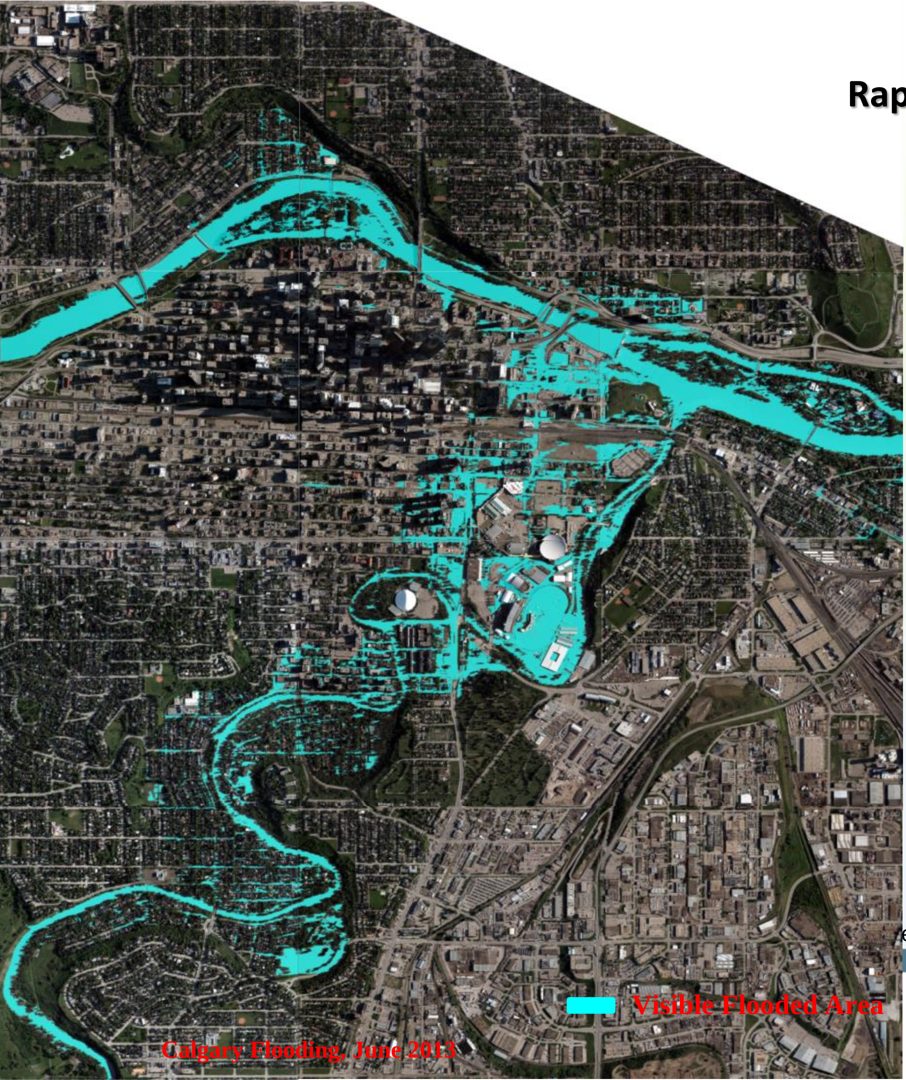
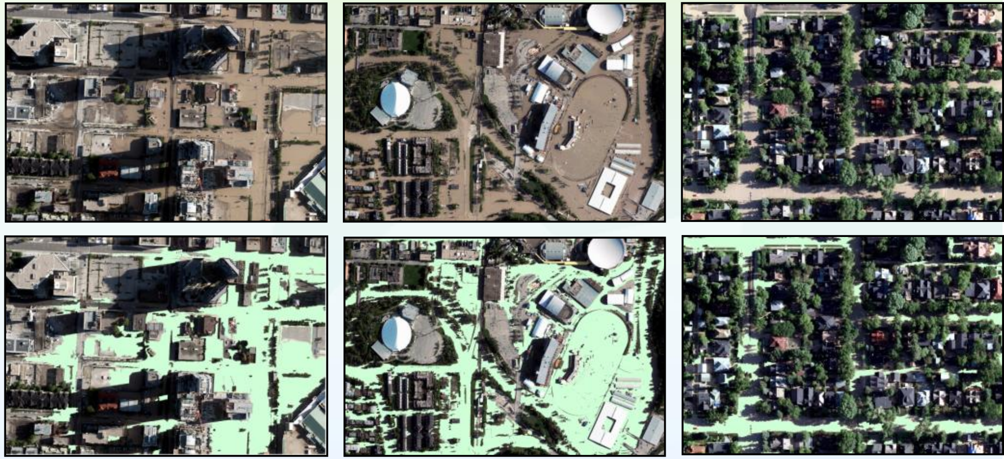


Rapid Delineation and Extraction of Visible Flooded Areas From Aerial Photos

with CCRS Developed Methodology

Calgary, June 2013

Test Site a | Test Site b | Test Site c



Visible Flooded Area

esources, 2017

Canada

Inference of Floodwater Distribution Processing in GIS

Inference Input

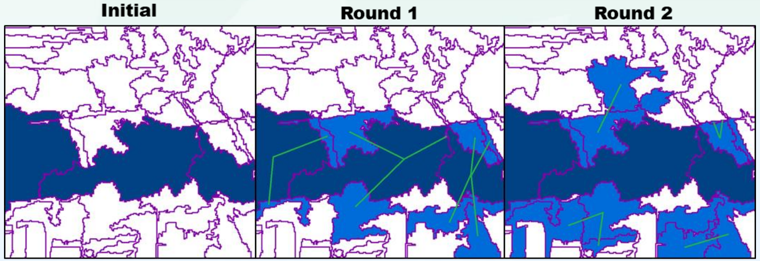
- Visible flood water (FFI)
- Unknown flood water (IXX):
  - Tree canopy
  - Shadows
- Non-flooded (NNI)
- Buildings (BLD)
- DEM

Difference in DEM between the visible flood patch and its neighbour patches with potentials.

Inference Output

- Visible flood water (FFI)
- Inferred Flood Water:
  - High Confidence (DFH)
  - Medium Confidence (DFM)
  - Low Confidence (DFL)
  - Possible Flood (DFP)
- Presumed Non-Flooded (IXX)
- Buildings (BLD)
- Non-flooded (NNI)

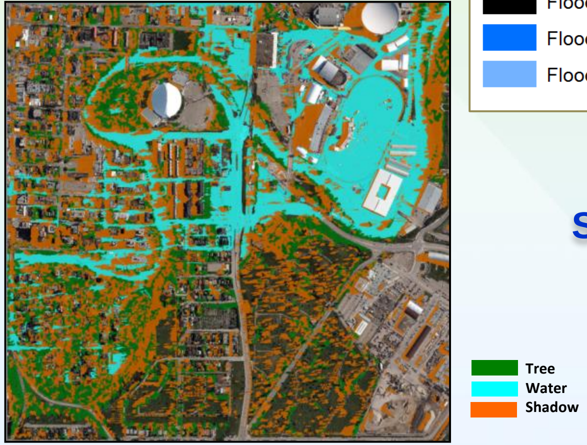
CLASS	RELATIONSHIP	ELIGIBLE NEIGHBOUR CLASS FOR INFERENCE
HIGH CONFIDENCE	Subject Maximum Elevation < Neighbour Minimum Elevation	Visible Flood High-Confidence Flood
MEDIUM CONFIDENCE	Subject Mean Elevation + Subject St. Dev. of Elevation < Neighbour Mean Elevation	Visible Flood High-Confidence Flood Medium-Confidence Flood
LOW CONFIDENCE	Subject Mean Elevation < Neighbour Mean Elevation	Visible Flood High-Confidence Flood Medium-Confidence Flood Low-Confidence Flood
POSSIBLE FLOOD	Subject Mean Elevation < Neighbour Mean Elevation + t * Subject St. Dev. Of Elevation, AND Neighbour Mean Elevation - Subject Mean Elevation < Cap	All Flood Classes

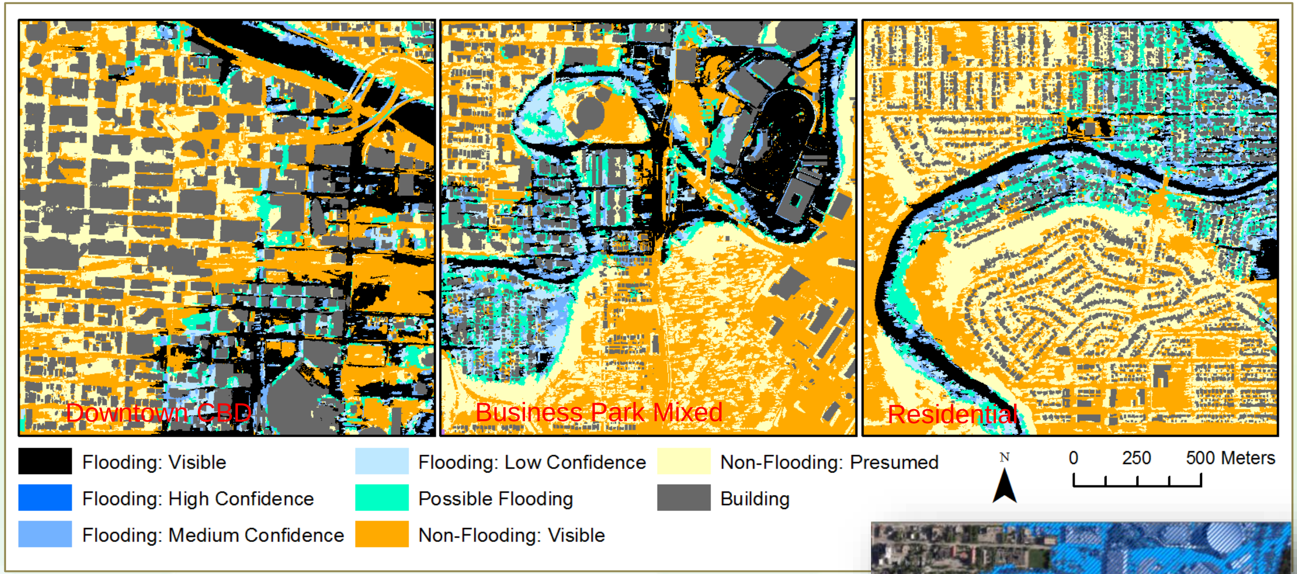


Pre-existing flood objects

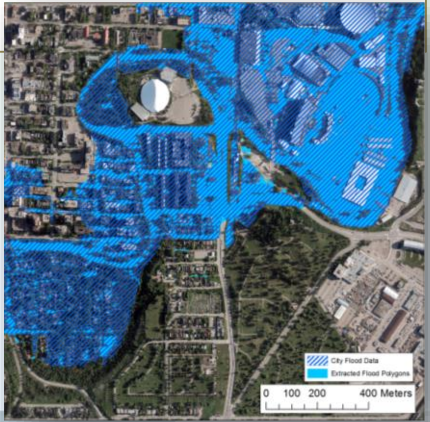
Objects neighbouring pre-existing flood objects are classified

Objects neighbouring round 1 flood objects are classified





Spatial Inference of Floodwater Extents Using Land Surface Information



Research Objective

for detection of earthquake-induced building damages in dense urban areas

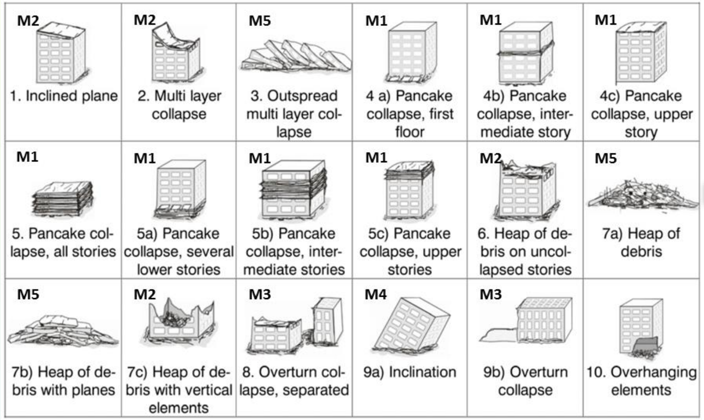
Research Objective

Using LiDAR data (pre-event), multispectral imagery and existing geospatial data, to develop effective processing frameworks and methodologies for timely mapping of damaged buildings in dense urban areas after a major earthquake.

Vancouver, Canada

Photos from sources in the Internet

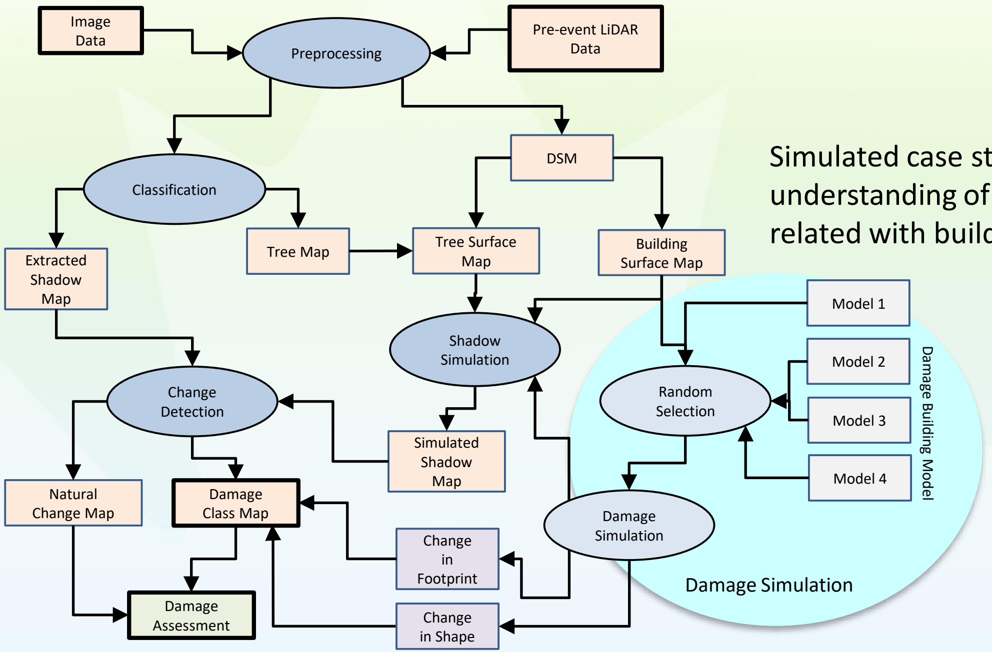
Compilation of Earthquake-induced Building Damages
(Schweier and Markus, 2004)



Reclassification of Building Damage Types for Use of Satellite Imagery

Damage Model	Damage Type Number (Schweier and Markus, 2004)	Name of Damage	Description of Damage	Usefulness of Shadow Information
Model 1	4, 4b, 4c, 5, 5a, 5b, 5c	Height Reduction without damaged roof	Reduction in height due to pancaked collapse, with undamaged roof.	Difficult to be detected in image without shadow information. Shadow information is essential.
Model 2	1, 2, 6, 7	Height Reduction with damaged roof	Reduction in height due to pancaked collapse, roof totally or partly damaged, with changed shape of the building top.	Difficult to be detected in image without shadow information. Shadow information is essential.
Model 3	8, 9b	Overturn	Overturn collapse, parts are separated.	Easy to be detected directly in image. Shadow information is useful.
Model 4	9a	Leaning/inclination	Inclination of whole building with shifting roof from footprint	From difficult to easy to be detected in image, depending on the inclination angle. Shadow information is essential.
Model 5	3, 7a, 7b	Total collapse	The building is totally collapsed and easy to be detected in image without using shadow information	Obvious in imagery. Easy to be detected directly in image. Shadow information is useful.
Model 6	10	Overhang element	Damage on parts of the building bottom.	Undetectable in imagery with or without shadow information.

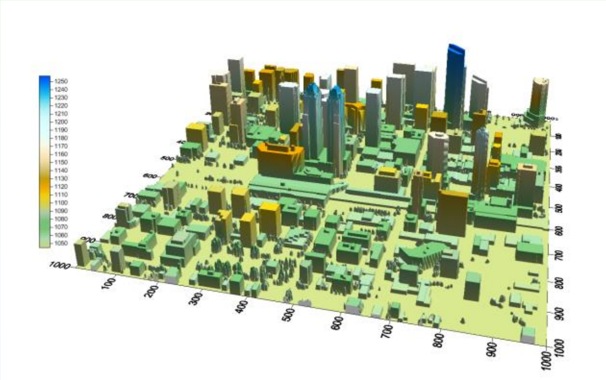
Outline of Processing Framework for Building Damage Detection and Assessment



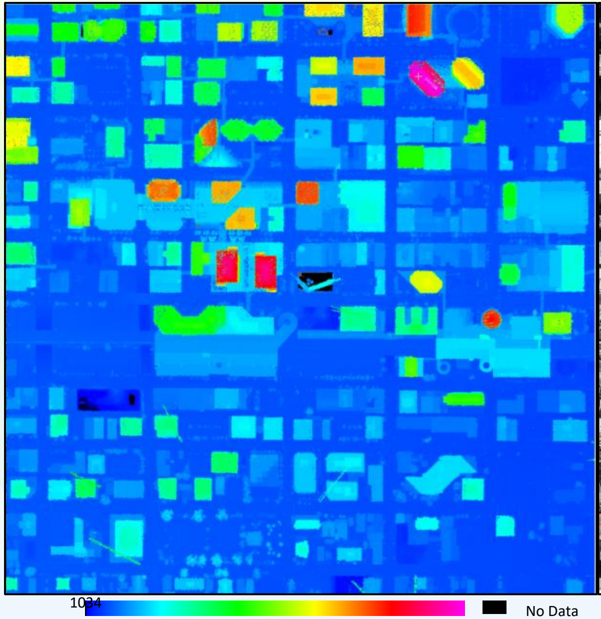
Simulated case study: To improve understanding of shadow changes related with building damages

Image Data and DSM

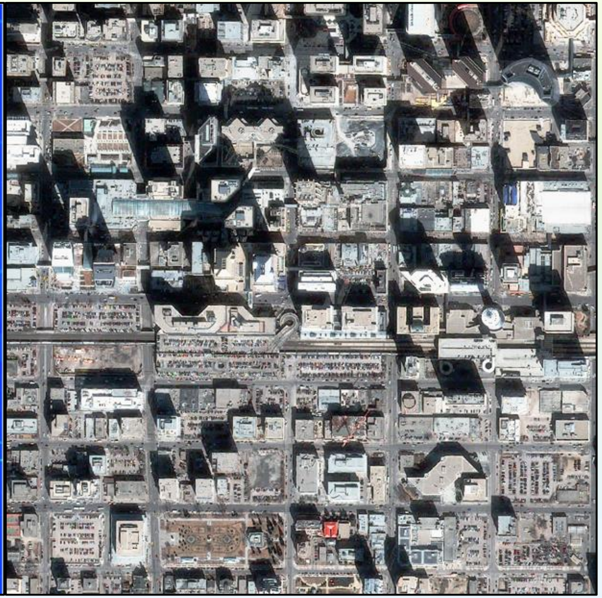
DSM from LiDAR



LiDAR



Multispectral

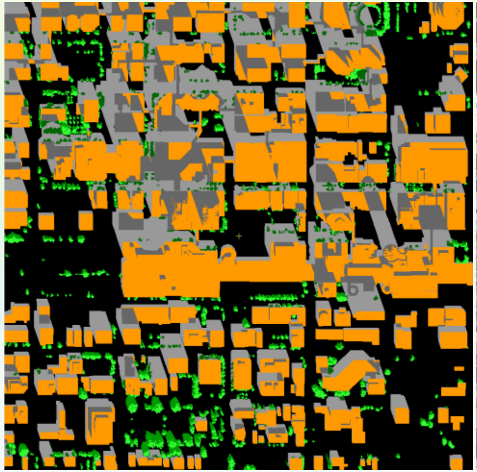


Building roof on sunlight
Shadow on ground marched well
Shadow on roof marched well
Shadow on ground not in image
Shadow on roof in image only
Shadow on roof not in image
Shadow on ground in image only
Tree canopy
Tree shadow
Tree in shadow

Shadow Maps
Extracted and Simulated

Baseline shadow difference

Shadow Simulated Based on DSM



Building shadow
Tree shadow
Building rooftop
Tree
Building roof in shadow
Tree in shadow

Pleiades PAN Sharpened Image

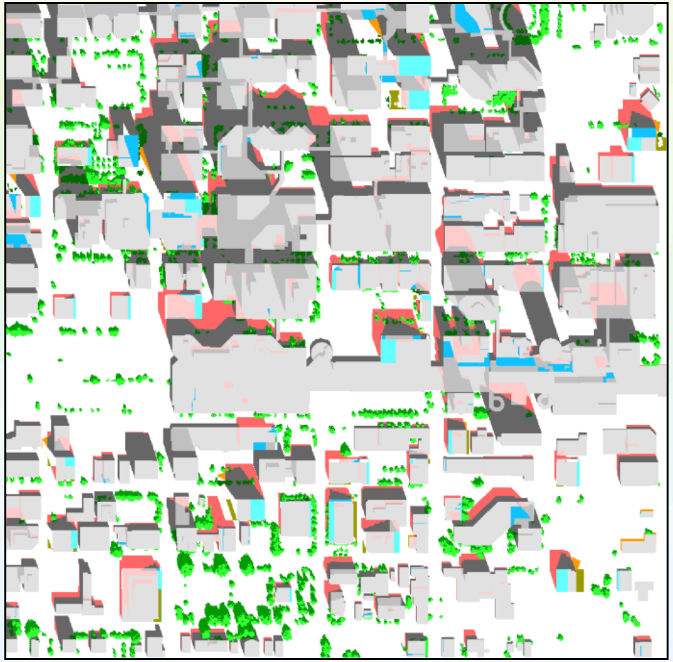
Shadow Extracted

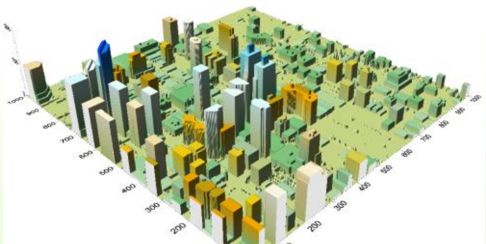
Shadow extracted

Simulated Changes in Building Shadows

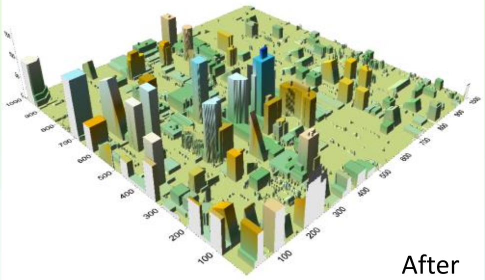
Before and after Damages

- Through proof of concept case studies, with scenarios based on simulations of both building damage and shadow, image understandings are improved for real-time response practices.





Before



After

- Building roof
- Building shadow cast on ground
- Building shadow cast on roof
- Building shadow cast on tree
- Tree
- Tree shadow
- Reduced in shadow on ground
- Reduced in shadow on roof
- Increased in shadow on roof
- Increased wall in image

Summary

- Two EO-based information processing frameworks are proposed to support post-event response and assessment, which are for urban flood mapping and detection of earthquake-induced building damages in dense built-up urban areas. Case studies show promising applications.
- 'Multi approach' processing frameworks (incl. remote sensing image processing, spatial analysis and model simulation) are effective for generation of spatial information about urban disasters.
- It is a long way from research to operational applications. More case studies and methodology improvements are needed. Collaborations are welcome.

Thank You

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