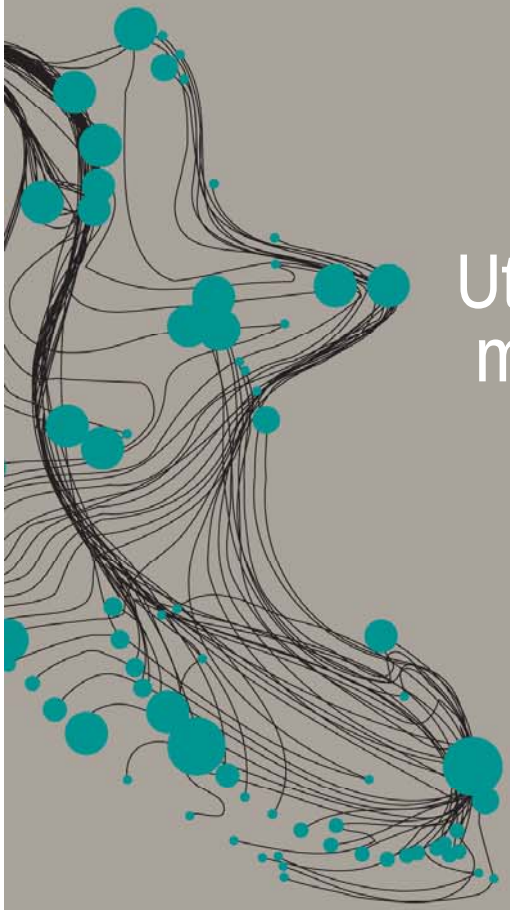
UNIVERSITY OF TWENTE.

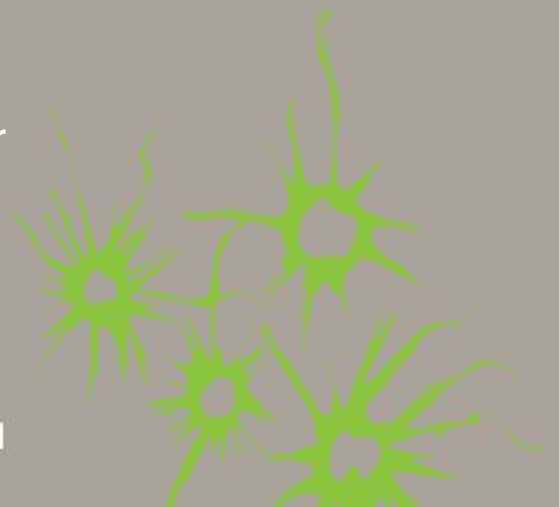


Utility of geo-informatics for disaster risk management: linking structural damage assessment, recovery and resilience

Dr. Norman Kerle, ESA Department

ITC-OOA-Group

ERDT Visiting Professor

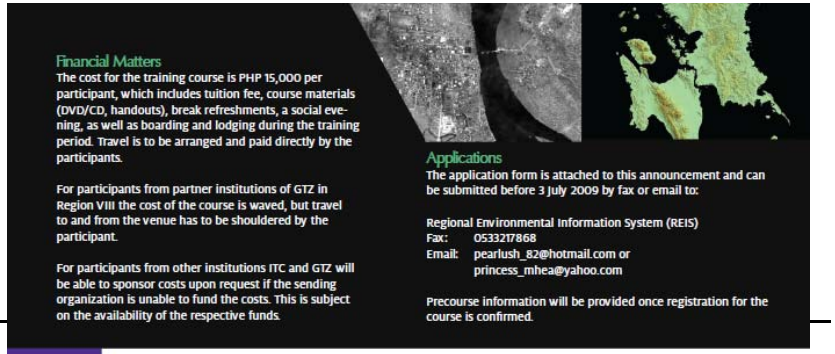


ITC FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

...back in Tacloban

Taught courses on geoinformatics for disaster risk management with UPVTC, REIS and GIT/GIZ (2009 and 2010)

- Focus on low-cost tools
- Practitioners, academics, NGO staff



Financial Matters

The cost for the training course is PHP 15,000 per participant, which includes tuition fee, course materials (DVD/CD, handouts), break refreshments, a social evening, as well as boarding and lodging during the training period. Travel is to be arranged and paid directly by the participants.

For participants from partner institutions of GTZ in Region VIII the cost of the course is waved, but travel to and from the venue has to be shouldered by the participant.

For participants from other institutions ITC and GTZ will be able to sponsor costs upon request if the sending organization is unable to fund the costs. This is subject on the availability of the respective funds.

Applications

The application form is attached to this announcement and can be submitted before 3 July 2009 by fax or email to:

Regional Environmental Information System (REIS)
Fax: 053321868
Email: pearlush_82@hotmail.com or princess_mhea@yahoo.com

Precourse information will be provided once registration for the course is confirmed.

GEOINFORMATICS FOR DISASTER RISK REDUCTION

Maximising the Potential of Low-Cost Tools

27 August to 4 September 2009 in Tacloban, Leyte

The main purpose of the course is to enhance the capabilities of professionals and technical staff working in disaster risk management or with geographical information system (GIS) by providing them with understanding of the use of spatial information in disaster risk management. Participants acquire a brief overview and some hands-on skills in the application of GIS and remote sensing (RS) in disaster risk management, and learn to work with satellite images and digital maps that are the key to a better understanding of hazard, vulnerability and risk. This leads to better informed decision making, whether it is at a community, provincial, or national level. The course will pay special attention to land use/land cover identification and low cost tools.

In the GRSDM course participants will learn how to:

- Evaluate the spatial data requirements in disaster risk management
- Assess spatial data availability and understand the importance of spatial data infrastructure (SDI), for data sharing by organizations involved in disaster risk management
- Understand the fundamentals of hazard, vulnerability and risk (HVR) assessment
- Apply remote sensing data and image processing techniques to identify land use/land cover and correlate this to vulnerability

For whom is the course relevant?

The course is targeted at professionals who apply – or are planning to apply – GIS and/or remote sensing to disaster risk reduction or management (DRR/DRM) issues. Due to the limited duration of the course, however, we will not provide extensive introductions to Geoinformatics principles, hence some relevant background is needed. Similarly, some prior exposure to DRM is preferable. Participants are welcome from a broad range of organizations including NGOs.

Admission Requirements

The course will include extensive exercises based on different GIS and image processing software. Therefore, participants should have a basic knowledge of GIS or RS. Furthermore a basic understanding of disaster risk management is advisable. All teaching and course materials are in English, thus it is essential that participants are fully conversant in English.

Resource Persons

From ITC in Enschede, Netherlands: Dr. Norman Kerle, Drs. Henk Kloosterman
From International Rice Research Institute: Dr. Kay Sumfleth

COURSE CURRICULUM

- Introduction to Geoinformatics for disaster management (DRM concepts and the spatial dimension)
- Disaster risk management and the use of ICT in the Philippines
- Discussion with participants on the use and prospects of GI for DM in their organization
- Practical basics on risk assessment with low-cost tools
- Landcover/use (LCLU) as basis for vulnerability and risk mapping & what is needed in the Philippines?
- Remote sensing data for LCLU assessment (Extracting LCLU data – data sources and methods, visual LCLU assessment, making a mapping plan, using multi-data - collaborating and matching map edges)
- Searching for and downloading of image data
- Mobile mapping/ mobile GIS
- Preparing data for the field (choosing data, devising mapping categories and sampling strategy, preparing database and IPaq, logistics)
- Field visit and mobile mapping (choosing and finding the right areas, navigating in the field with ArcPad, using prepared databases, adding databases, dealing with unexpected difficulties and uncertainties)
- Downloading, sorting and reviewing the field data
- Evaluating the field-mapped information and integration in the image analysis process incorporating the field data into the mapping process
- Accuracy evaluation and mapping conflict management
- Using LCLU information in risk assessment & next steps in the GTZ flood risk project
- Discussion on how participants will implement new knowledge

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Our Hope for Humankind

ween ITC and the United Nations University is directed at developing building in disaster management and in land administration, and at related issues.

gional Environmental Information System

al resources and then expanded to include any region. REIS produces primary and secondary region, land- use / cover topographic maps and other orginizations, REIS also offers hands-on ArcView GIS, seminars and training on GIS, ualization.

an enterprise for sustainable upports the German Govern- tives. In the Philippines the sayas Region works with local ous aspects of risk management, including the establishment of Flood e for mitigation, safe building practices, flood resistant crops, the inte- t planning process, as well as DRM in education. The project is funded

gtz Disaster Risk Management in Development Cooperation

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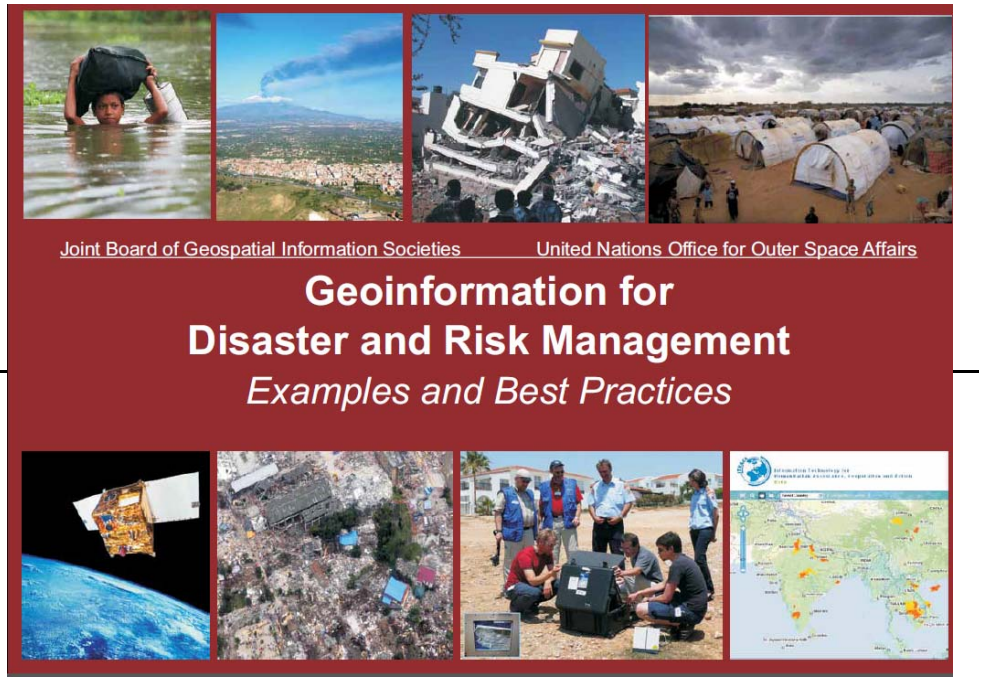
...back in Tacloban

United Nations JBGIS paper with Olaf Neussner, GIZ



Local Flood Early Warning Based on Low-Tech Geoinformatics Approaches and Community Involvement A Solution For Rural Areas in The Philippines

Norman Kerle[1] & Olaf Neussner[2]

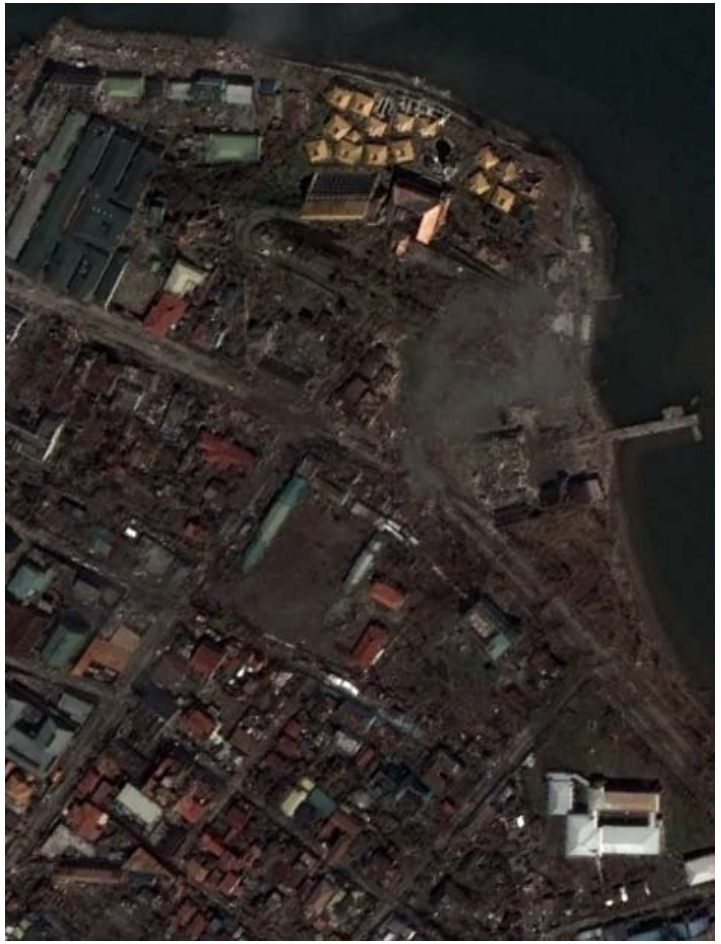
1 International Institute for Geoinformation Science and Earth Observation (ITC) Department of Earth Systems Analysis, Hengelosestraat 99, 7500AA Enschede, The Netherlands, Kerle@itc.nl
2 German Technical Cooperation, Gesellschaft für Technische Zusammenarbeit (GTZ), PhilAm Life Building, Justice Romualdez Street, Tacloban, Leyte, Philippines, drmon@web.de

Introduction and background

The vast majority of the more than 200 activations of the International Charter Space and Major Disasters to date (International Charter, 2009), including the very first event in 2001, have been in response to flood disasters. Such events come in various forms, at times related to excessive precipitation due to tropical storms, at others caused by snow melt, coastal or river dam breaks, volcano crater rim collapses or subglacial outbursts. With disasters defined as hazardous events causing damage that exceeds the coping capacity of the affected community, the spatial scale of such events is highly variable, depending largely on the distribution and accumulation of assets in threatened areas. Such accumulations are becoming increasingly common, reflecting both global population growth (and the consequent movement of frequently marginalized people into such areas), but also an increase in overall global asset wealth that may be adversely affected (Grimm et al., 2008;

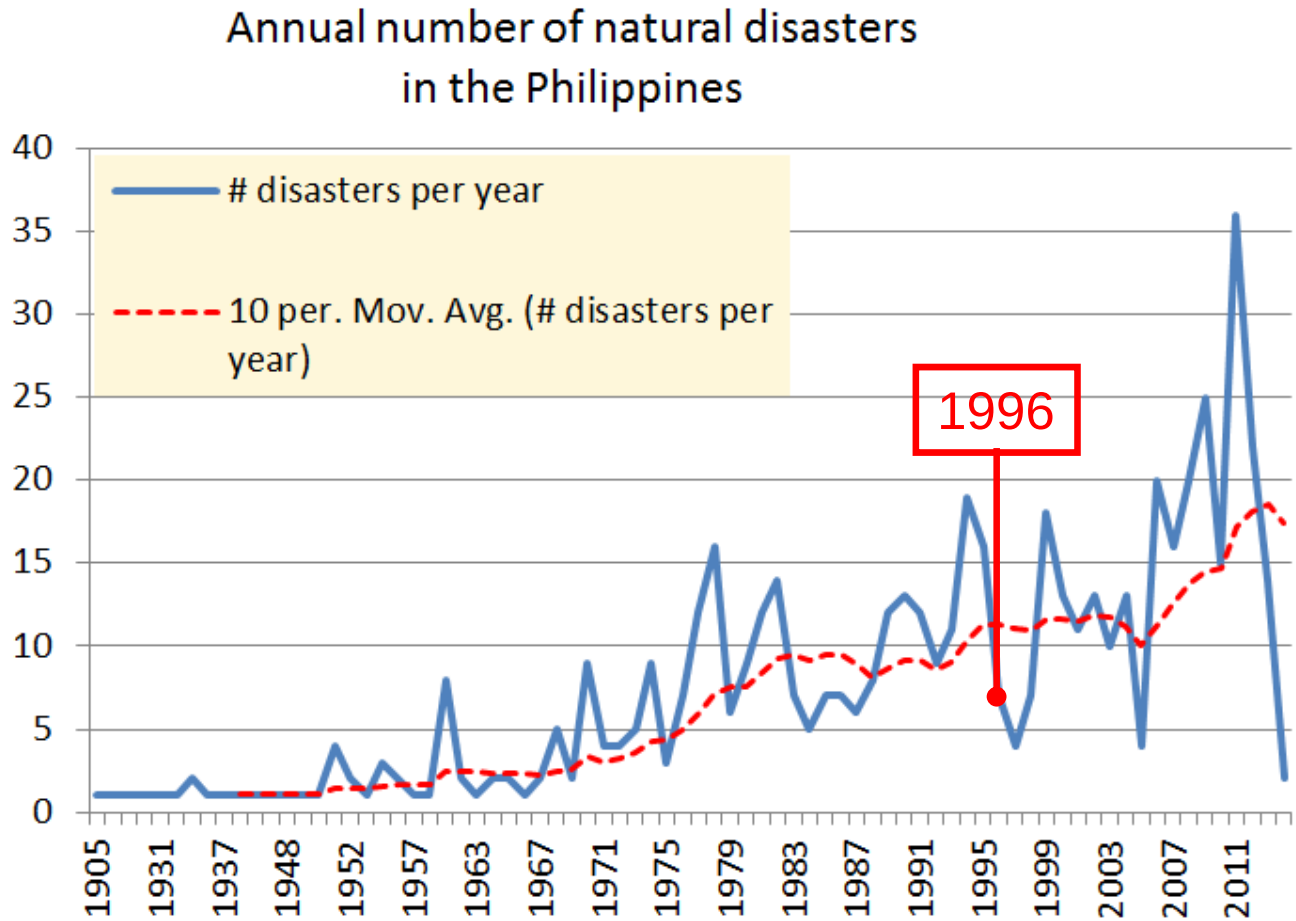
...back in Tacloban

- Did it make a difference during Yolanda?

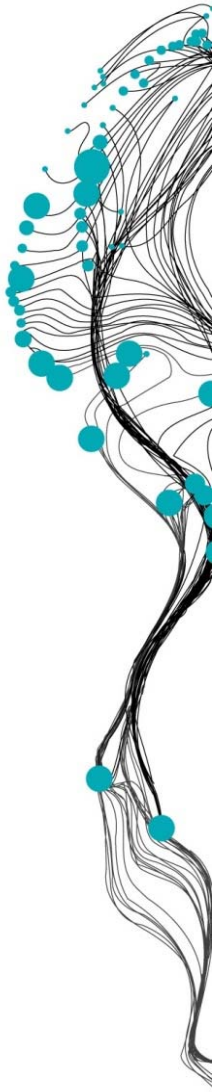


...back in the Philippines

- Disaster situation is getting worse



Source: CRED, 2014



Lecture outline

- My background
- Image-based damage mapping
  - Limits of vertical imagery and prospect of oblique data
  - Prospect of crowdsourcing
- Lack of coordination and user needs understanding
- What comes after a disaster – tracking recovery
- Linking recovery and resilience

Me @ ITC

ITC
UNIVERSITY OF TWENTE.

My background

- ITC/University of Twente (Enschede, The Netherlands)
- PhD in geography/ Volcano remote sensing (Uni Cambridge)
- Geoinformatics for disaster risk management (hazard/risk/vulnerability/damage)

UN Our Hope for Humankind

ITC an Associated Institution of the UNITED NATIONS UNIVERSITY

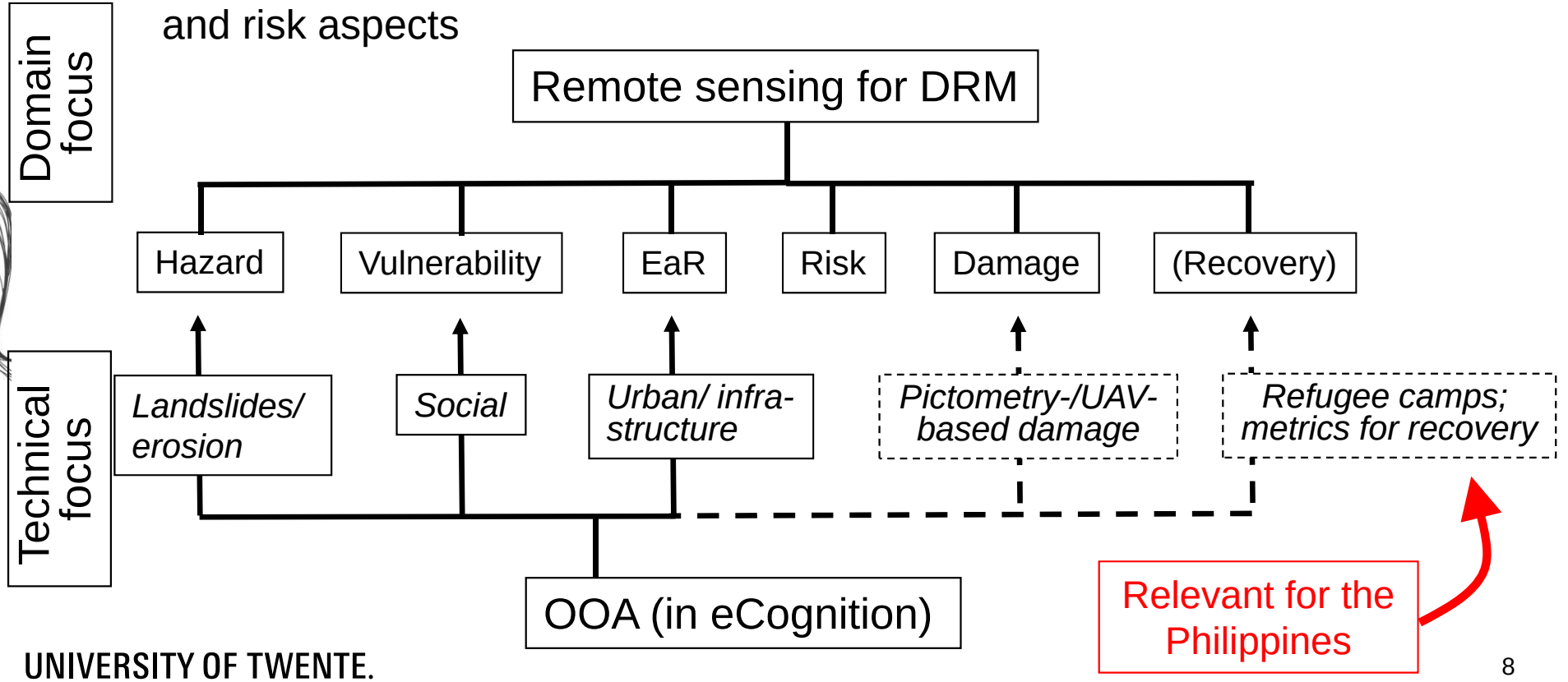
- Training & capacity building
- Knowledge development and research collaboration
- Advisory services

www.unu-drm.nl

Me @ ITC

DRM research

- Our group addresses
  - All aspects of disaster risk management (my focus is on post-disaster response/ recovery)
  - Use of object-oriented image analysis (OOA/OBIA) for different hazards and risk aspects



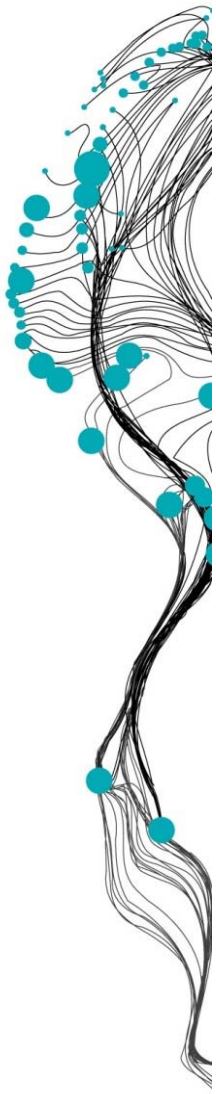
Post-disaster damage assessment

- Rapid and comprehensive damage information is critical
- Assessment is challenging

Rationale

Vertical image-based assessment has limitations

Port-au-Prince, Haiti



Principal questions and considerations

- What is damage?
  - Structural damage (destroyed buildings, etc.)
  - Damage to nature
  - Damage to systems/ functional damage (economic, social, economic, etc.)
  - Direct vs. indirect

  -> anything that is of value and can be adversely affected
- This is relevant for our discussion on hazards, since disasters can both highlight existing hazards, or change them

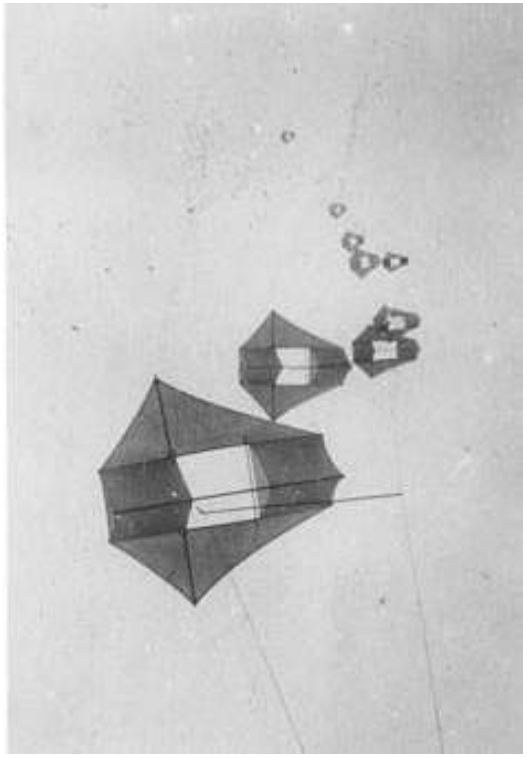
Principal questions and considerations

- What are we really trying to do?
  - Advise the government on the consequences of a disaster event?
  - Aid in immediate disaster response
  - Assess the potential for secondary disaster
  - Guide clean-up and reconstruction?
- **Rapid and comprehensive data suitable for many stakeholders are needed – only a remote sensing approach is useful**

Is damage mapping with remote sensing a new solution?

< 10 years | 10–20 years | 20–50 years | 50–100 years | >100 years

- No, it's as old as remote sensing
- First prominent attempt after 1906 San Francisco earthquake
- George Lawrence raised a 20 kg camera on a kite 600 m up



Source:
http://robroy.dyndns.info/lawrence/landscape.html

Is damage mapping with remote sensing a new solution?

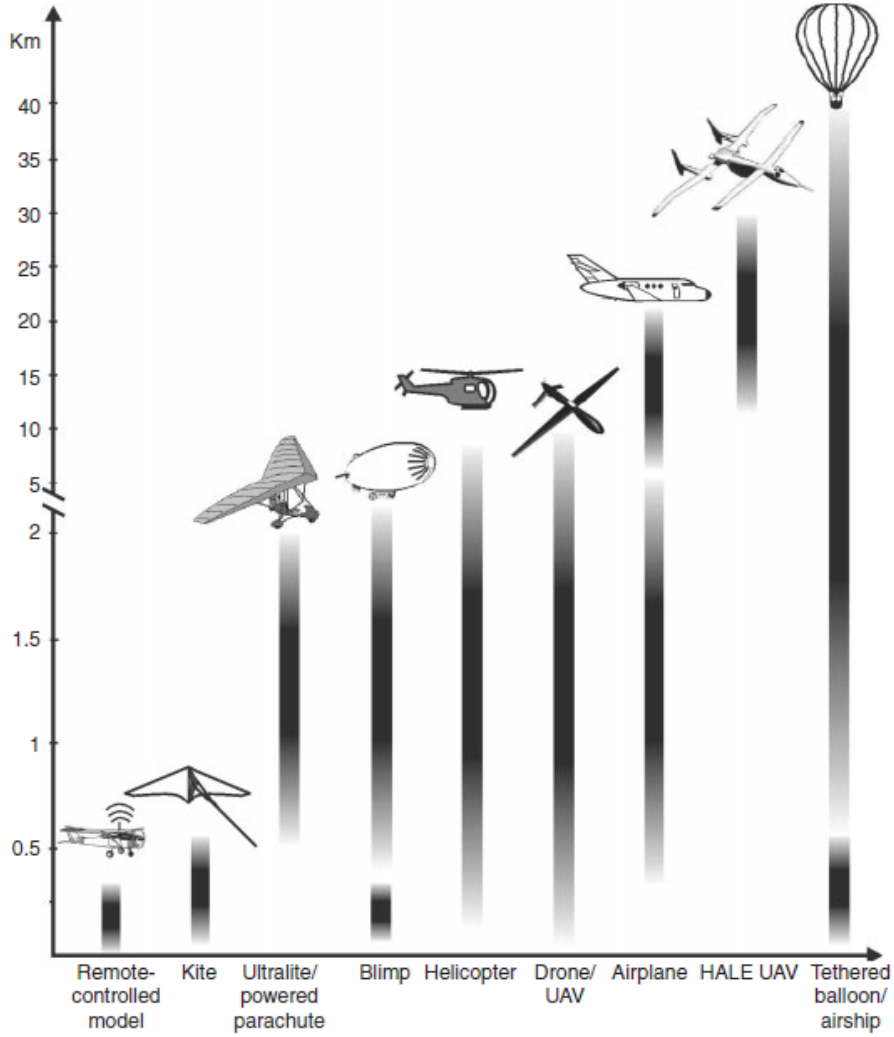
San Francisco after the 1906 earthquake

Source: http://airandspace.si.edu/exhibitions/lae/images/LE110L11.jpg

Resulting in a damage map

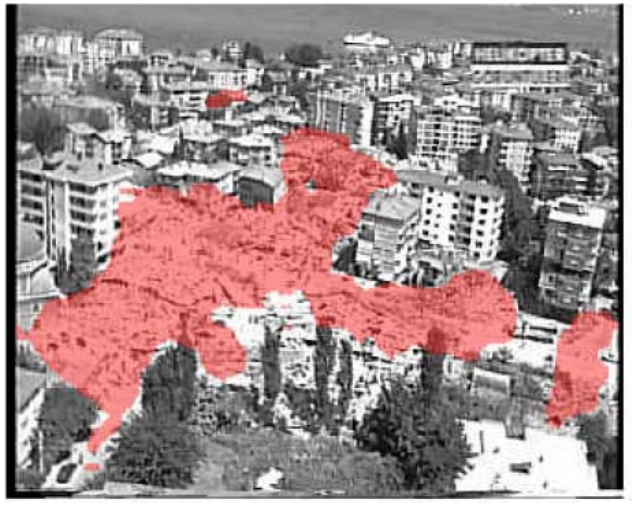
Remote sensing data of any kind can be used

- Virtually any type of ground,- air- or spaceborne RS sensor has been used for damage assessment
- Many platforms other than geostationary satellites or polar orbiters
- Some examples:



Remote sensing data of any kind can be used

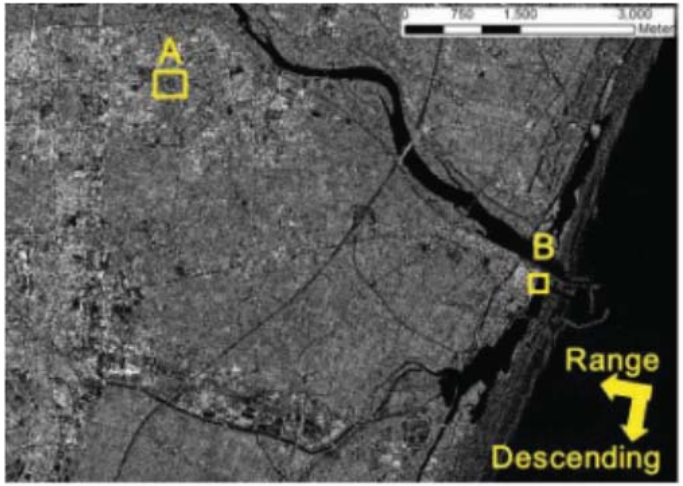
Airborne
TV streams

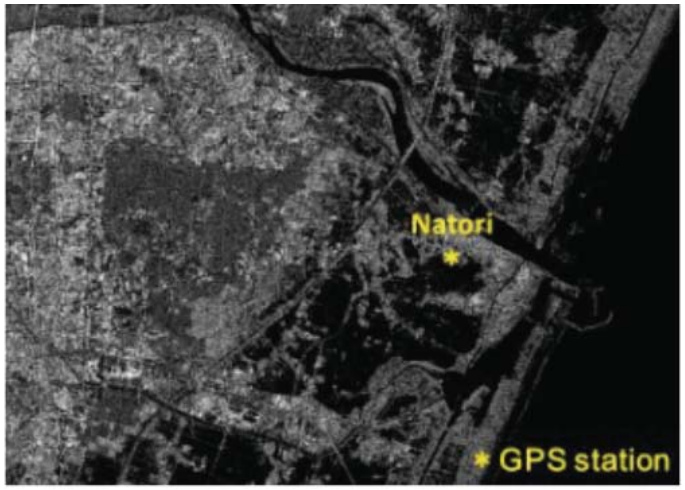


Source: Ozisik, 2004 (ITC MSc thesis)

(not the same area)

Radar

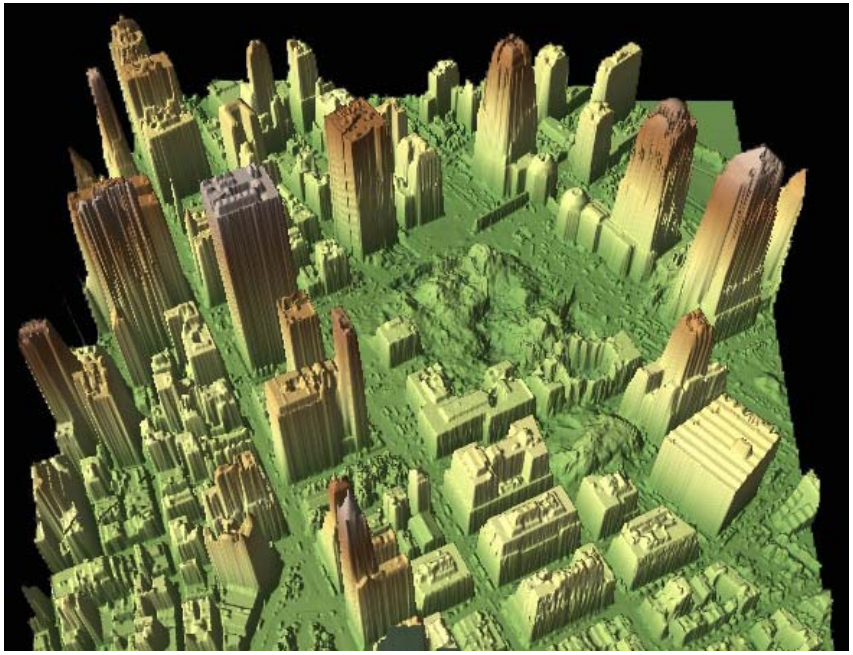


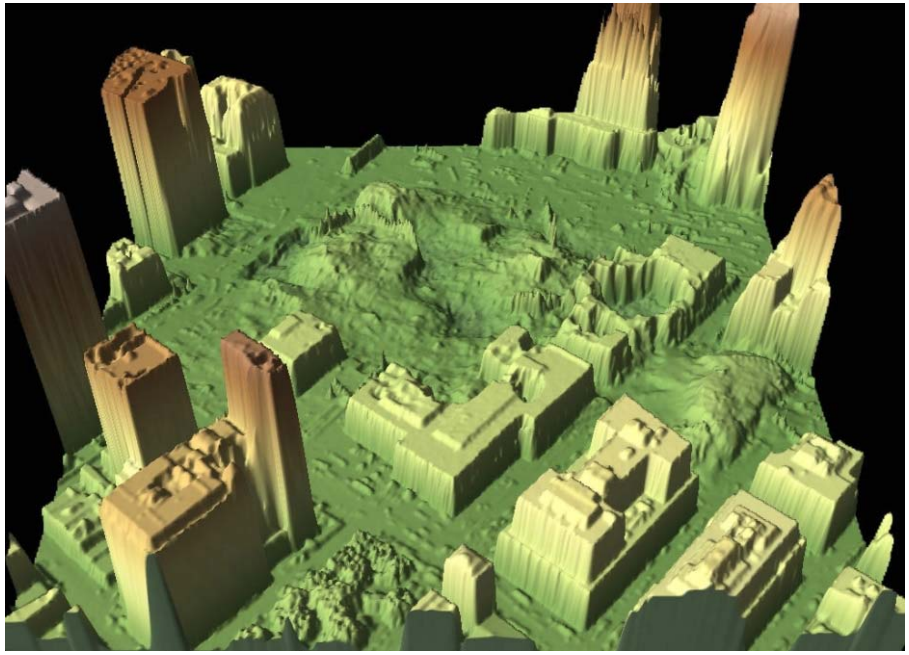


Source: Liu et al., 2012

Remote sensing data of any kind can be used

Lidar

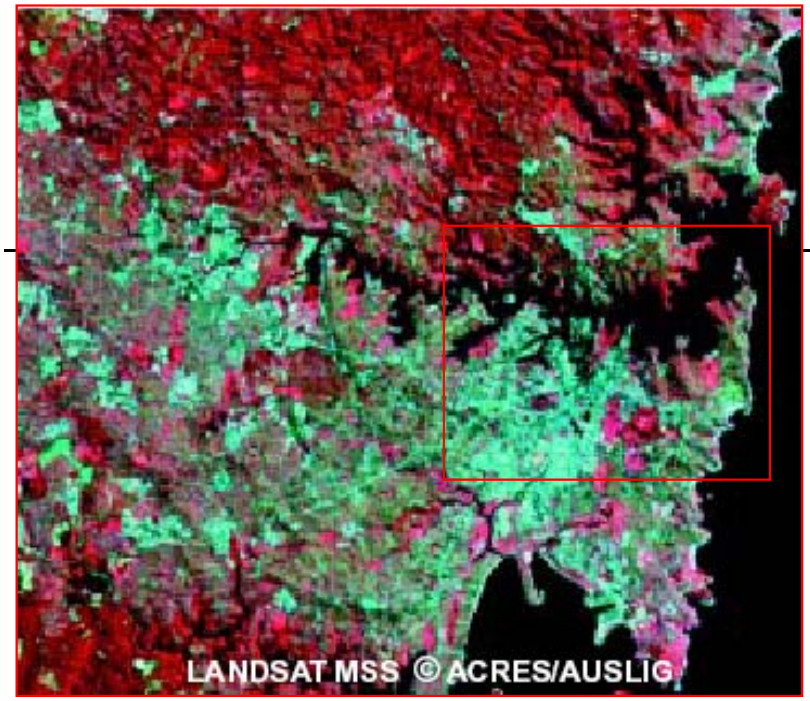


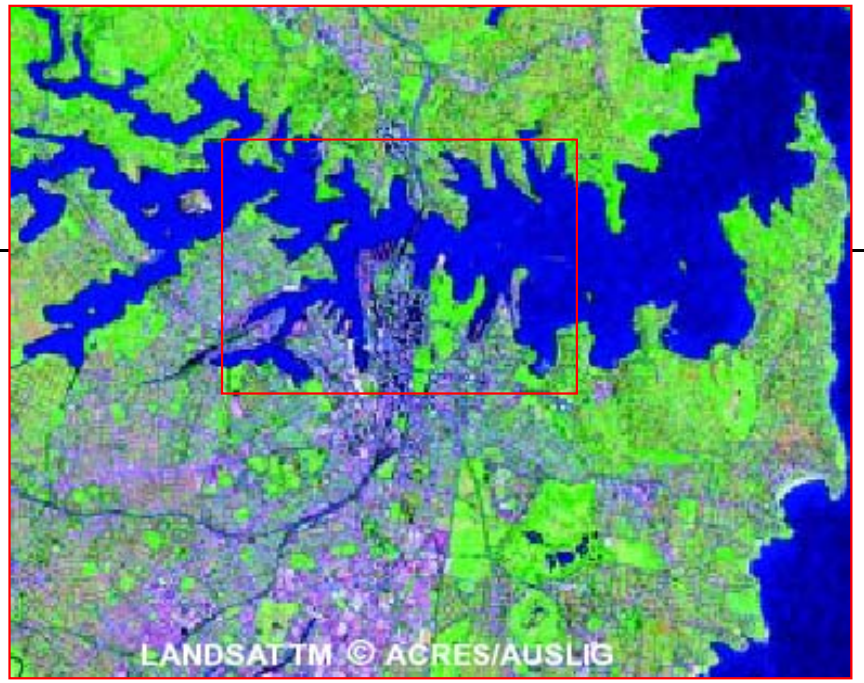


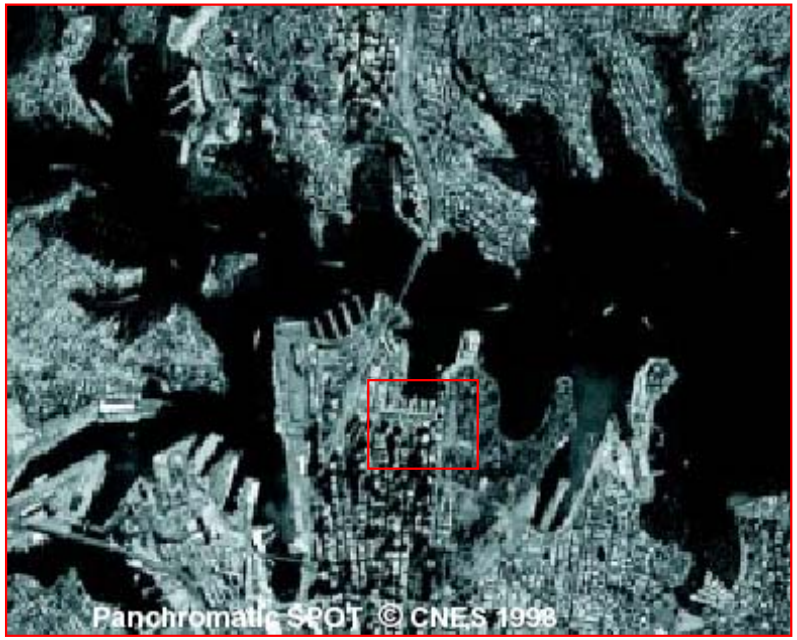
WTC attack on 9/11 first prominent example

So which data type do we choose?

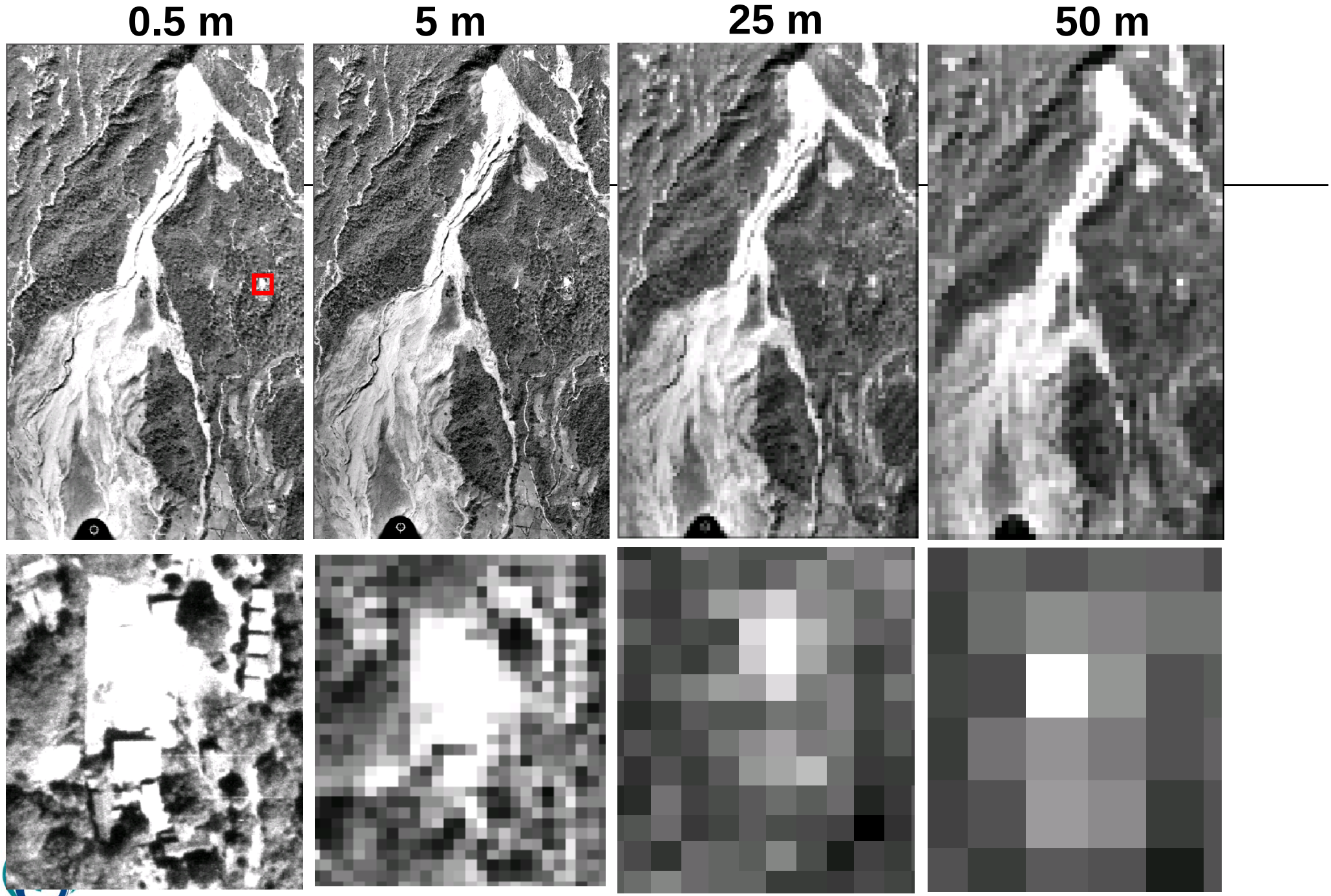
The scale factor







Resolution:



Structure density

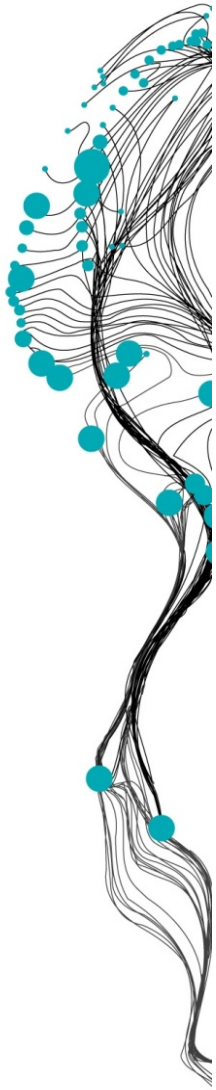
Both very dense and widely distributed structures pose problems

Port-au-Prince, Haiti

Structure density

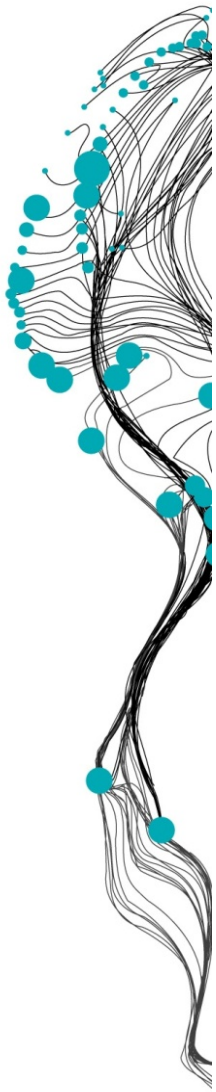
Both very dense and widely distributed structures pose problems

Post 2008-Bantul earthquake (Java)



Best satellite type?

- There is not perfect data type
- Optical imagery is most often used (low number of radar)
- High-spatial resolution is clearly best suited
- But severe limits remain
- International Charter “Space and Major Disasters”
  - Image processing still done manually

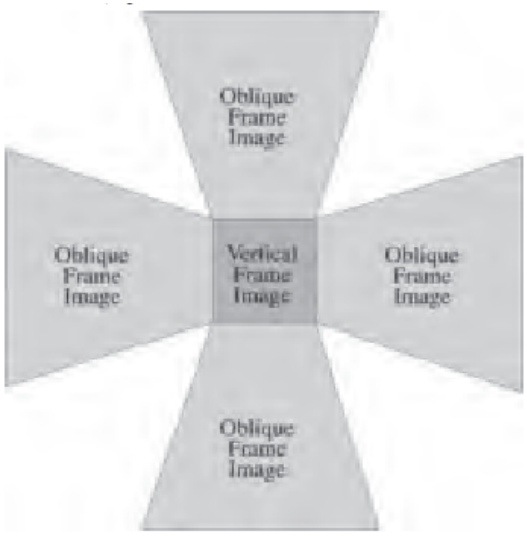


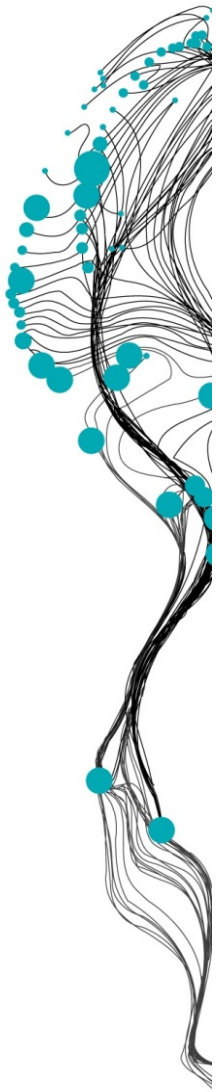
Limits of image-based damage mapping

- There are inherent **limitations to image-based damage mapping**
  - Damage is more of a concept than a physical entity
  - Damage is a complex 3- (maybe even 4-) dimensional feature
  - Internal damage can’t (usually) be seen
  - The relationship between a damage feature and it’s effect on structural integrity is not always clear
  - Damage features do not add up linearly to a per-building damage scale

Instead: airborne oblique (Pictometry)

- 5 digital cameras (1 nadir, 4 oblique)
- Spatial resolution of 15cm (nadir images, flying height ca. 1000m)
- 60% overlap for stereo





Objectives

- Expectations were limited (recent visual analysis mapping of Haiti damage by Cambridge Architectural Research Ltd. (CAR) led to poor results)
- Which Pictometry features allow damage mapping? (elevation, geometrics features, textures, etc.)
- Identification of planar (=intact) and spectrally homogenous facades and roof sections
- Supervised classification of image segments

Damage mapping: methodology

- Photogrammetric processing
- Dense matching of stereo images
- Extraction of 3D point cloud, basis for a digital surface model (DSM)
- DSM filtering to derive ground surface (DTM and nDSM)
- Removal of vegetation

Damage mapping: methodology

- Orthorectification of oblique images and depth maps
- Feature extraction from these images and the DSM

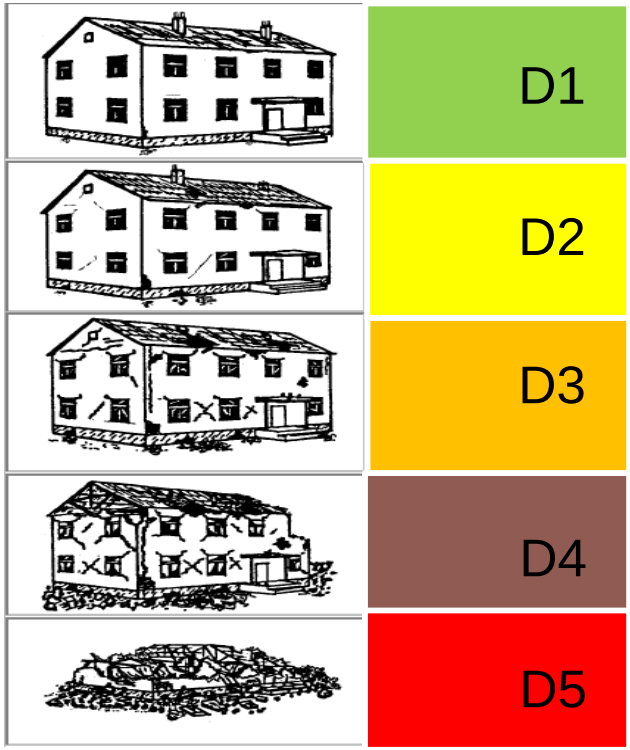
- **Assumption: intact buildings have planar surfaces**
- Find evidence for planarity through
  - Geometric homogeneity
  - Image information (radiometric homogeneity)
  - 3D point cloud segmentation to find planar surfaces

Earthquake damage assessment
Classification of image segments

- 5 classes were defined:
  a. Intact roof
  b. Broken roof/ rubble
  c. Intact facade
  d. Bare ground
  e. Vegetation

  } Direct damage indicators

- Training data by two interpreters
- Classification using a total of 22 features in machine learning approach
- Final step: combination per building



Earthquake damage assessment

- Test on a 6 block area of Port au Prince, Haiti

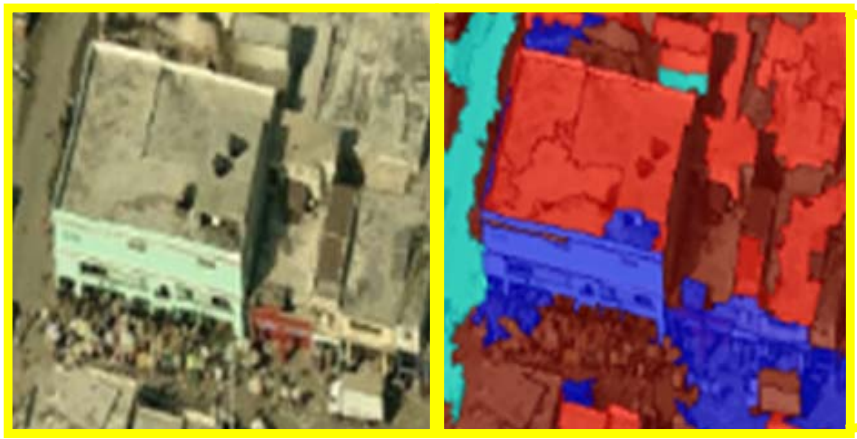
- Depth images from stereo pairs (for different views)
- 3D point cloud

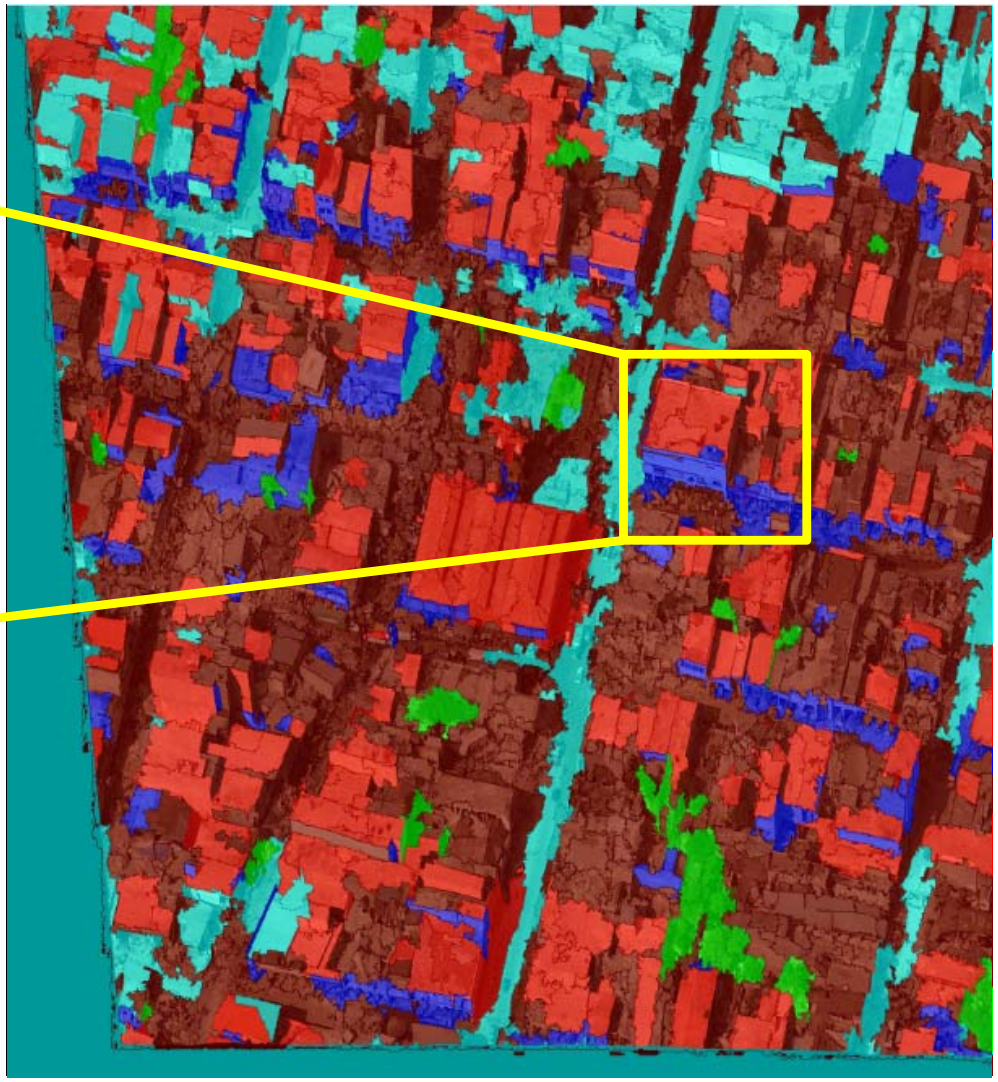
Earthquake damage assessment
Parallax disparity for image pair – merging of multiple views

- Planar areas have limited disparity
- Rubble and broken features appear noisy

Damage mapping results: Western view example

- Ortho image
- Detected damage





Intact roof

Broken roof/ rubble

Intact facade

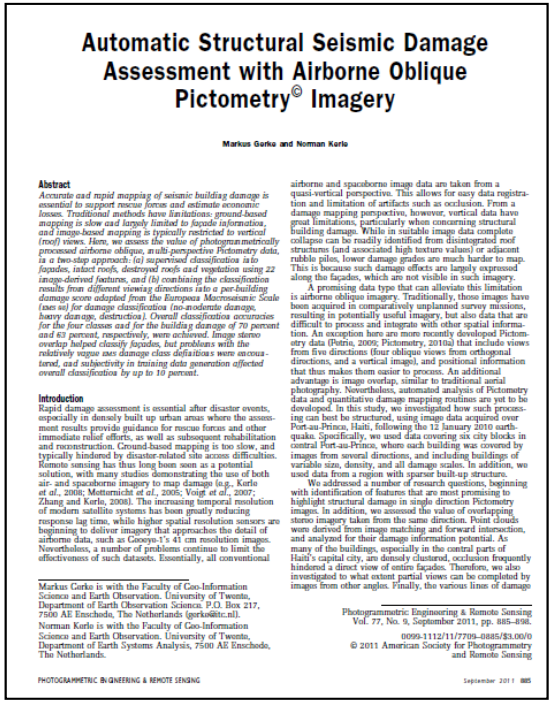
Bare ground

Vegetation

Damage mapping results: per-building aggregation

Results using training data by 2 analysts

For details see PE&RS paper, Gerke & Kerle, 2011



Automatic Structural Seismic Damage Assessment with Airborne Oblique Pictometry© Imagery

Markus Gerke and Norman Kerle

Abstract

Accurate and rapid mapping of seismic building damage is essential to support rescue forces and estimate economic losses. Traditional methods have limitations: ground-based mapping is slow and largely limited to façade information, and image-based mapping is typically restricted to vertical (roof) views. Here, we assess the value of photogrammetrically processed airborne oblique, multi-perspective Pictometry data, in a two-step approach: (a) supervised classification into façades, intact roofs, destroyed roofs and vegetation using 22 image-derived features, and (b) combining the classification results from different viewing directions into a per-building damage score adapted from the European Macroseismic Scale (ems-98) for damage classification (no-moderate damage, heavy damage, destruction). Overall classification accuracies for the four classes and for the building damage of 70 percent and 63 percent, respectively, were achieved. Image stereo overlap helped classify façades, but problems with the relatively vague ems damage class definitions were encountered, and subjectivity in training data generation affected overall classification by up to 10 percent.

Introduction

Rapid damage assessment is essential after disaster events, especially in densely built up urban areas where the assessment results provide guidance for rescue forces and other immediate relief efforts, as well as subsequent rehabilitation and reconstruction. Ground-based mapping is too slow, and typically hindered by disaster-related site access difficulties. Remote sensing has thus long been seen as a potential solution, with many studies demonstrating the use of both air- and spaceborne imagery to map damage (e.g., Kerle *et al.*, 2003; Mettenicht *et al.*, 2005; Voigt *et al.*, 2007; Zhang and Kerle, 2008). The increasing temporal resolution of modern satellite systems has been greatly reducing response lag time, while higher spatial resolution sensors are beginning to deliver imagery that approaches the detail of airborne data, such as Geoeye-1's 41 cm resolution images. Nevertheless, a number of problems continue to limit the effectiveness of such datasets. Essentially, all conventional airborne and spaceborne image data are taken from a quasi-vertical perspective. This allows for easy data registration and limitation of artifacts such as occlusion. From a damage mapping perspective, however, vertical data have great limitations, particularly when concerning structural building damage. While in suitable image data complete collapse can be readily identified from disintegrated roof structures (and associated high texture values) or adjacent rubble piles, lower damage grades are much harder to map. This is because such damage effects are largely expressed along the façades, which are not visible in such imagery.

A promising data type that can alleviate this limitation is airborne oblique imagery. Traditionally, these images have been acquired in comparatively unplanned survey missions, resulting in potentially useful imagery, but also data that are difficult to process and integrate with other spatial information. An exception here are more recently developed Pictometry data (Petrie, 2009; Pictometry, 2010a) that include views from five directions (four oblique views from orthogonal directions, and a vertical image), and positional information that thus makes them easier to process. An additional advantage is image overlap, similar to traditional aerial photography. Nevertheless, automated analysis of Pictometry data and quantitative damage mapping routines are yet to be developed. In this study, we investigated how such processing can best be structured, using image data acquired over Port-au-Prince, Haiti, following the 12 January 2010 earthquake. Specifically, we used data covering six city blocks in central Port-au-Prince, where each building was covered by images from several directions, and including buildings of variable size, density, and all damage scales. In addition, we used data from a region with sparser built-up structure.

We addressed a number of research questions, beginning with identification of features that are most promising to highlight structural damage in single direction Pictometry images. In addition, we assessed the value of overlapping stereo imagery taken from the same direction. Point clouds were derived from image matching and forward intersection, and analyzed for their damage information potential. As many of the buildings, especially in the central parts of Haiti's capital city, are densely clustered, occlusion frequently hindered a direct view of entire façades. Therefore, we also investigated to what extent partial views can be completed by images from other angles. Finally, the various lines of damage

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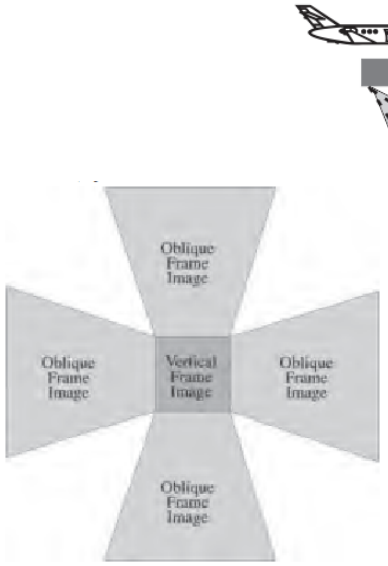
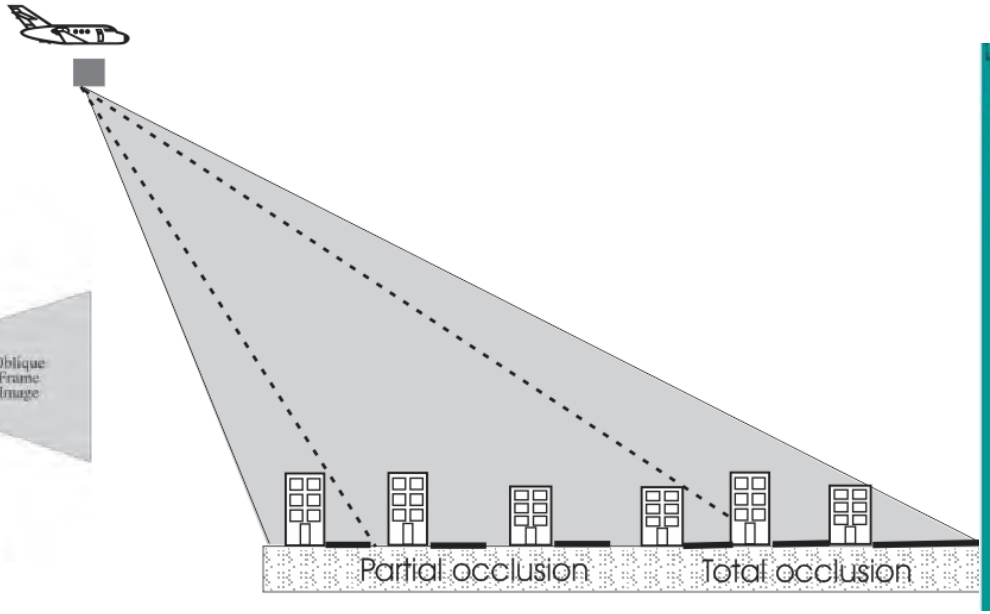
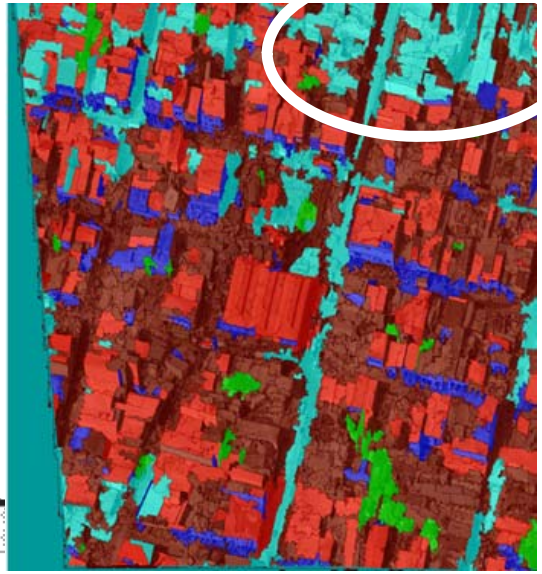
Accuracy assessment & conclusions

- Overall accuracy of approx. 70% (63% per building)
- Errors at image top where heights were missing







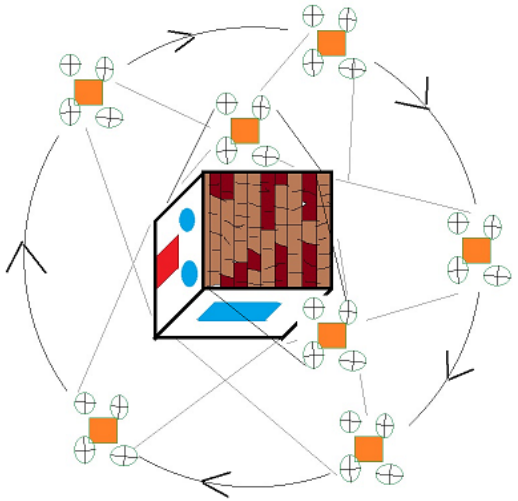
- **Problem: damage indicators do not add up linearly**

Ongoing research: using UAV data & eCognition for the classification instead of training data

- Limitations:
  - Expensive Pictometry data
  - Single view, limited control
- Solution:
  - Get your own UAV and eCognition
  - Identify damage indicators in multi-perspective images with OOA

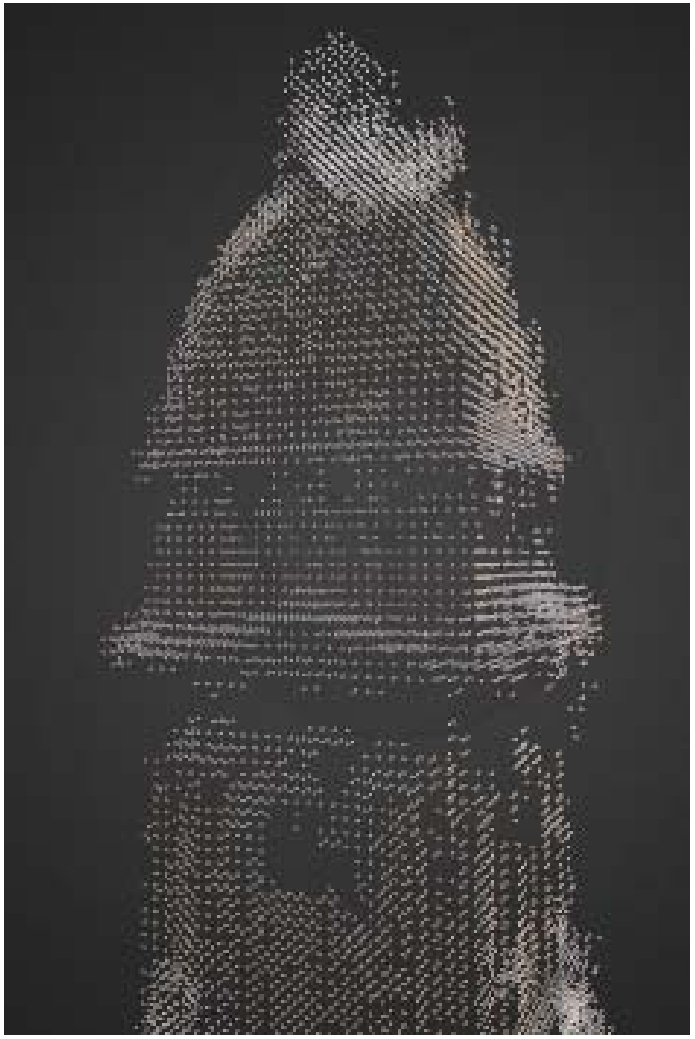
Aibot X6 (Aibotix)

Data acquisition

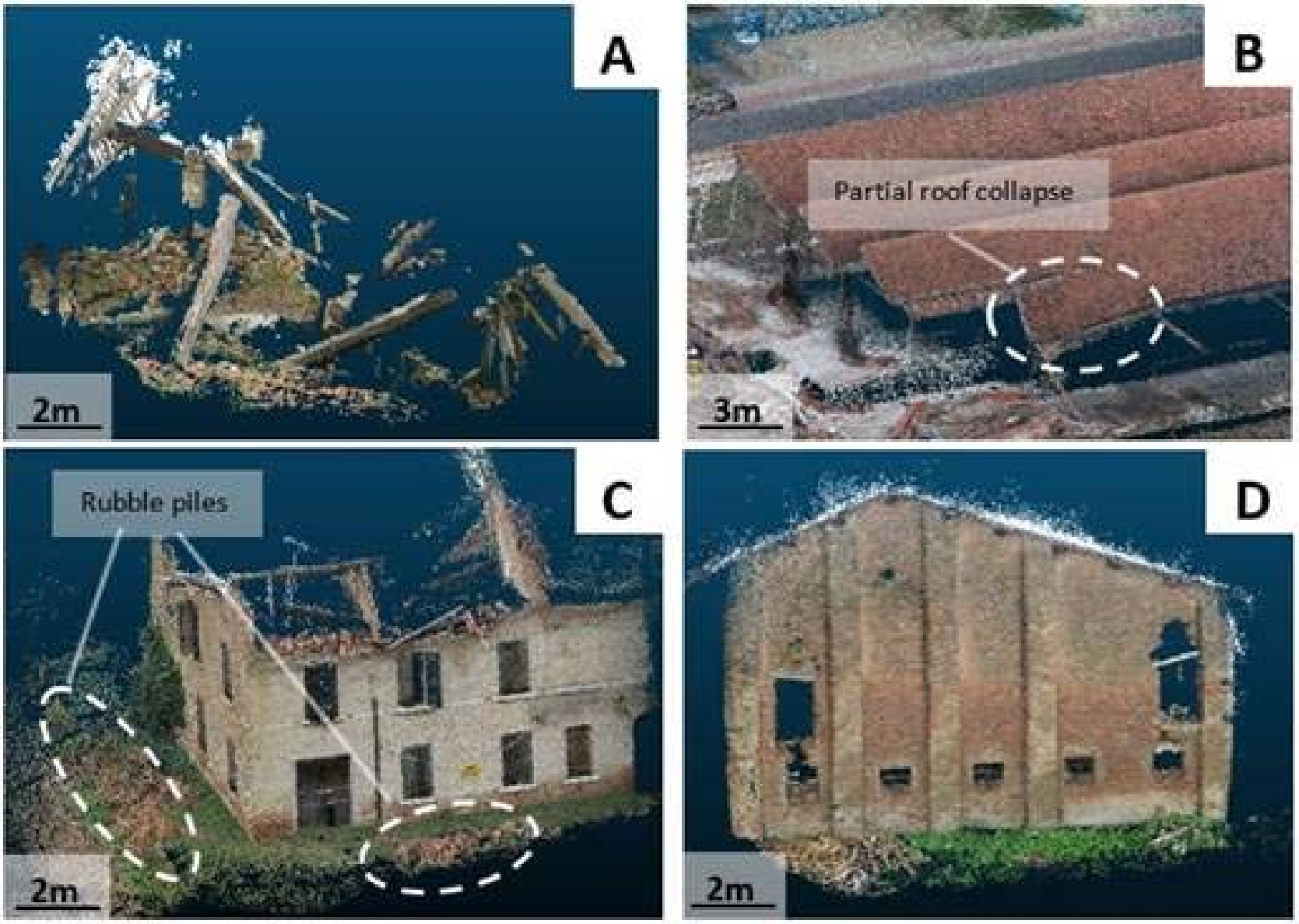


Data collection in Italy, Germany & the Netherlands

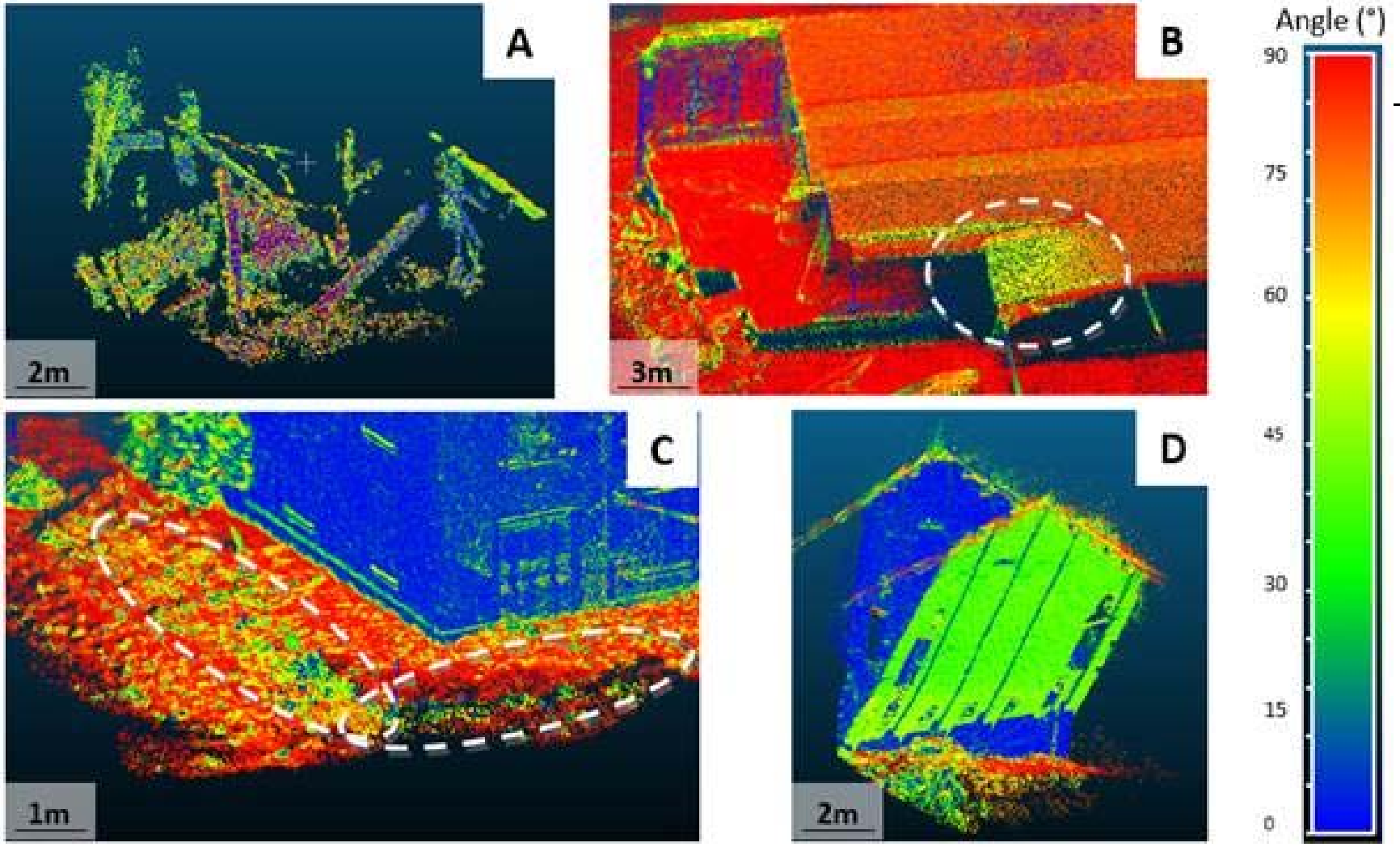
Damage detection with point clouds



Damage detection with point clouds



Damage detection with point clouds



Damage mapping with UAV data
Fernandez Galarreta et al., in review

Expert-based assessment

- In

Image-based damage mapping - issues

- Problems with the approach *per se*
- There are many players in this business
- Following Haiti some 2000 damage map products were generated
- This is wasteful and overwhelms the potential user
- Actual user needs are not well understood
- Actual image data are not usually made available to end users or researchers

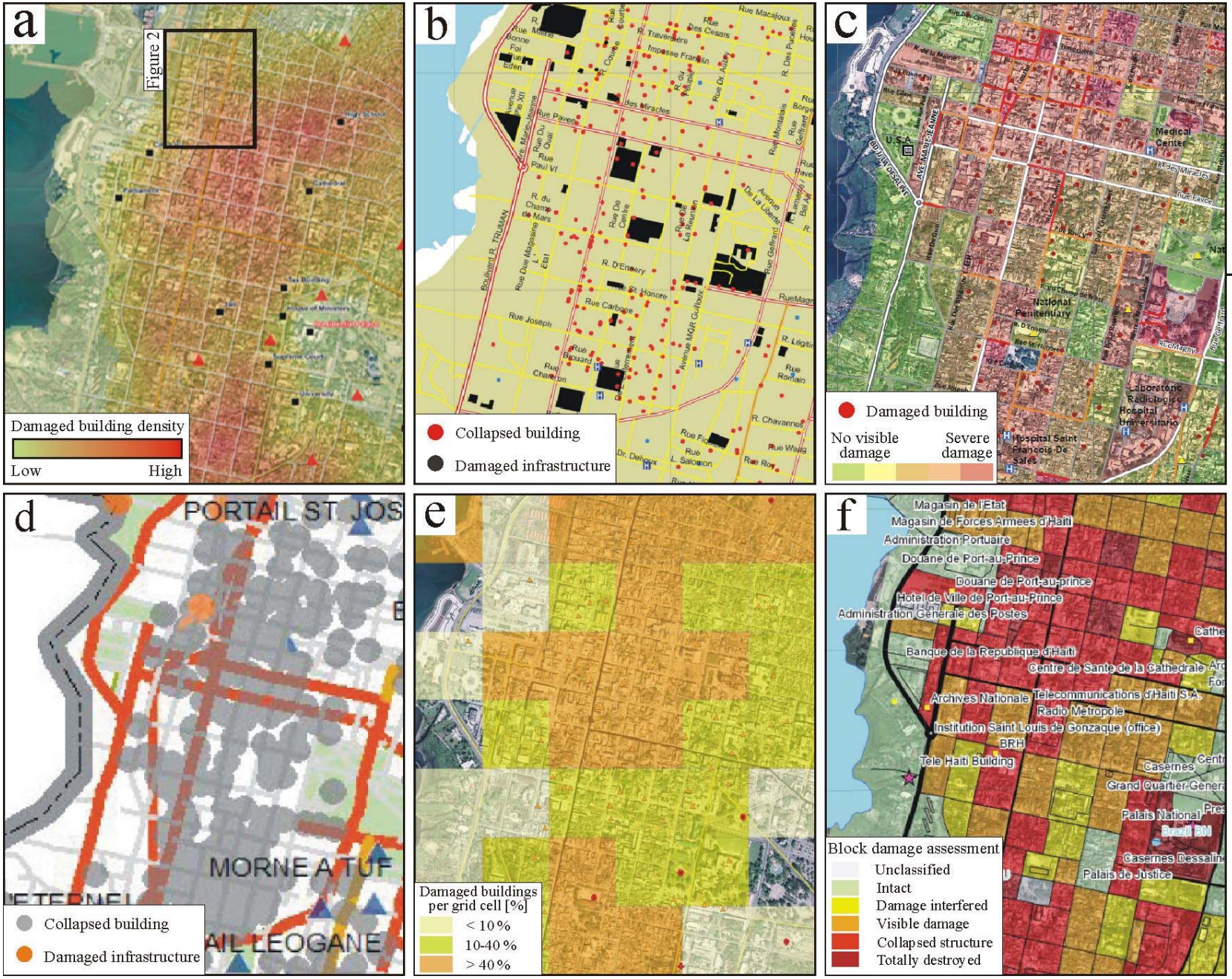
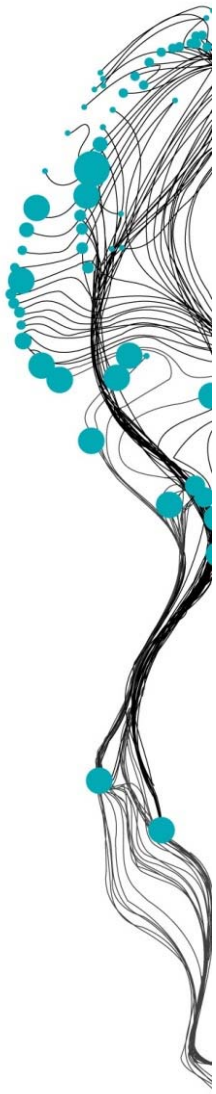


Image-based damage maps of Port-au-Prince by a- SERTIT, b- ITHACA, c- UNSC, d- iMMAP, e- DLR-ZKI, f- e-GEOS

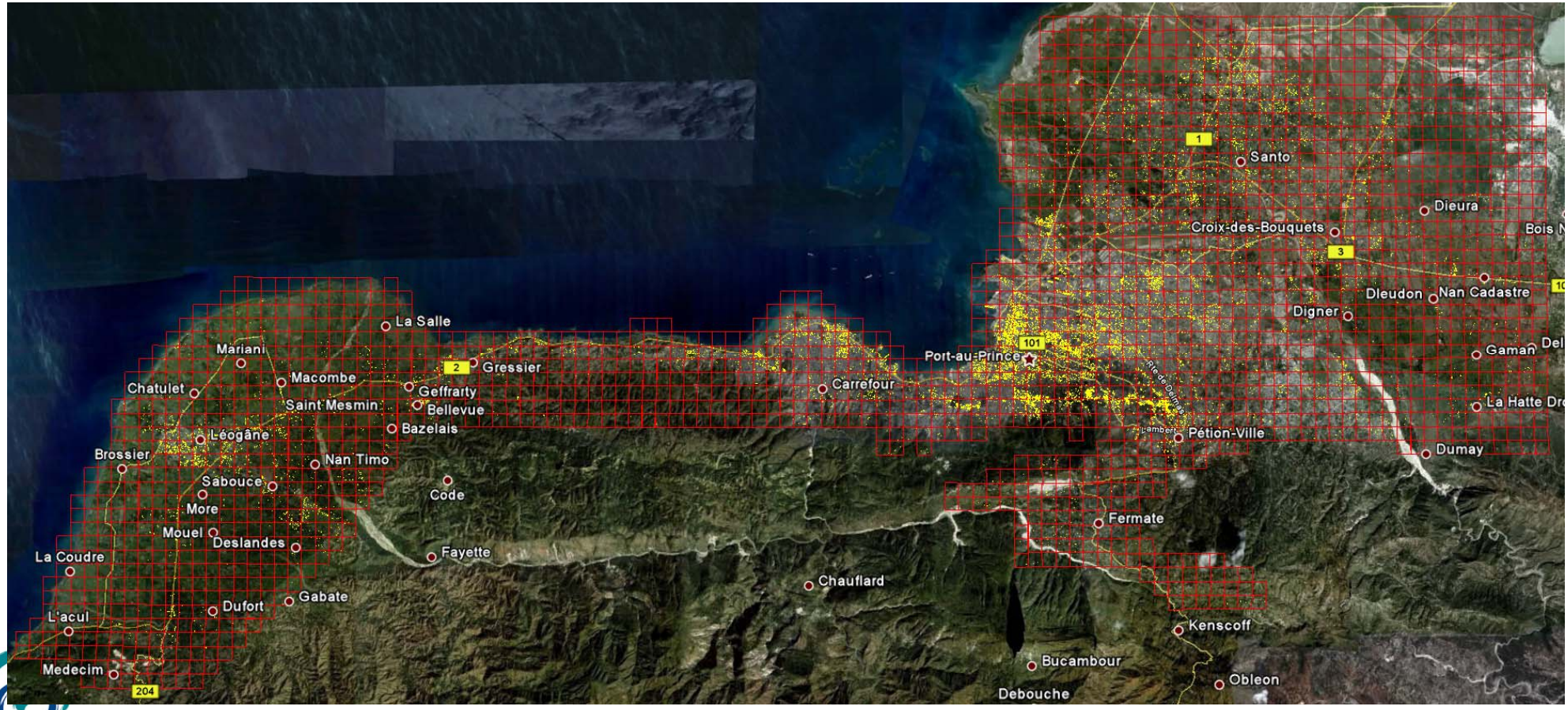


Damage mapping with crowdsourcing (VGI)

- Lay persons or qualified volunteers have been used for **visual damage mapping**
- First in 2008 (Wenchuan [China] earthquake, typhoon Nargis [Myanmar])
- Prominent example: 2010 Haiti earthquake
  - Some 600 volunteers mapped damage
  - First using Geoeye imagery, later aerial photographs

Damage mapping with crowdsourcing

- Very difficult job
- Large area mapped



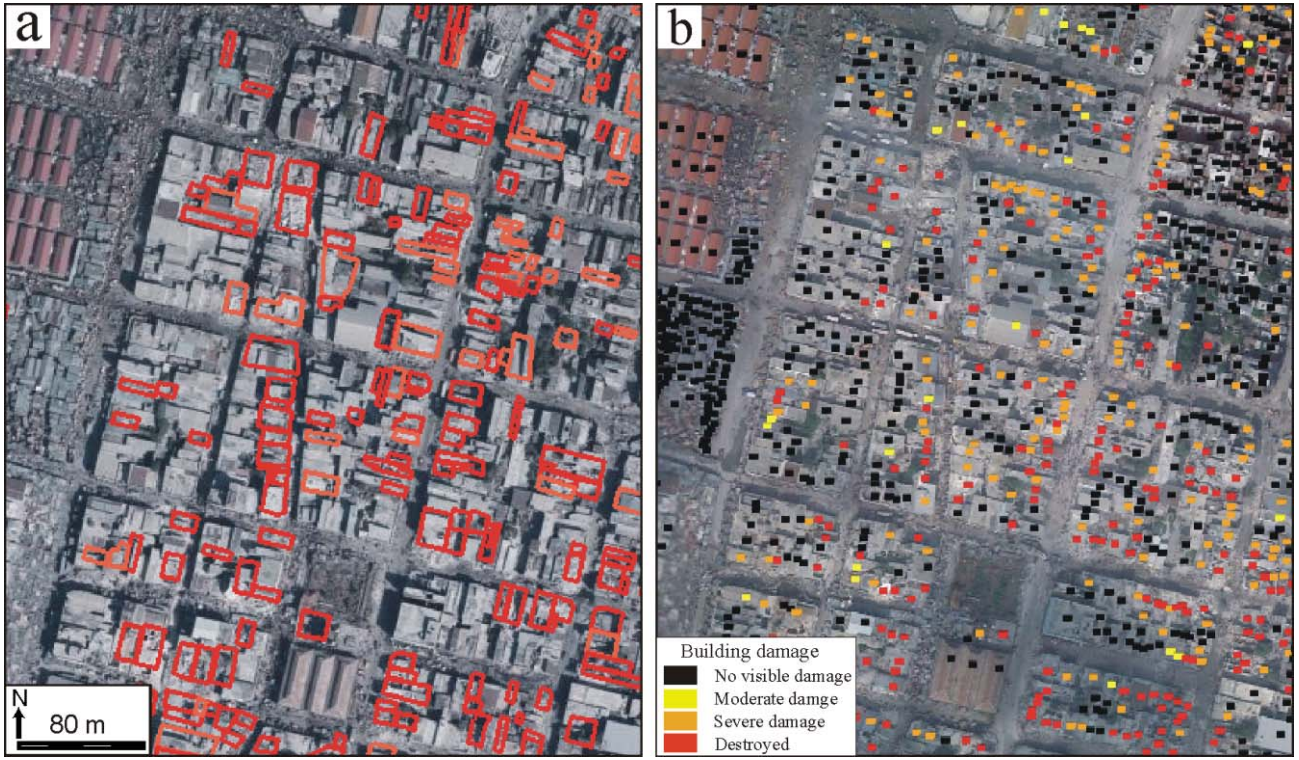
Damage mapping with crowdsourcing

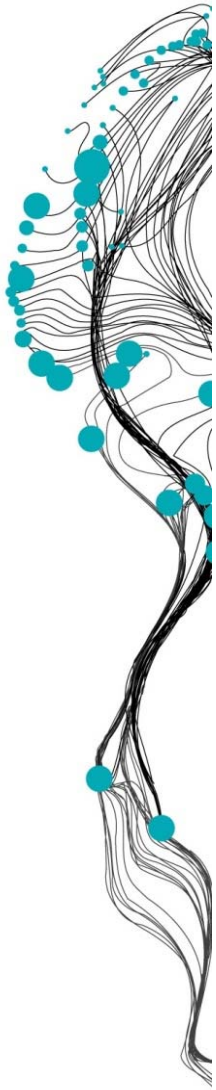
What do we see?

Pre-disaster image can help
(but notice resolution differences)

Damage mapping with crowdsourcing

- Problems
  - Difficult to instruct volunteers
  - Difficult to validate and integrate results
  - Lots of intransparent post-processing

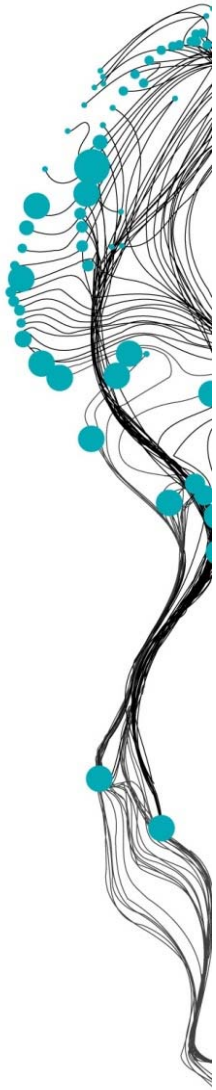




What comes after damage mapping?

- Knowledge on damage is only the first step
- Little effort on tracking rehabilitation and recovery
- Focus quickly switches to the next disaster
- Lack of mandate, no donated images
- Lots of changes to track
  - Debris removal
  - People leaving, coming back
  - Settlement camps
  - Secondary disasters – more/ different damage
  - Slow recovery/ rebuilding
- Response vs. reconstruction vs. rehabilitation vs. recovery

Is Tacloban recovering?

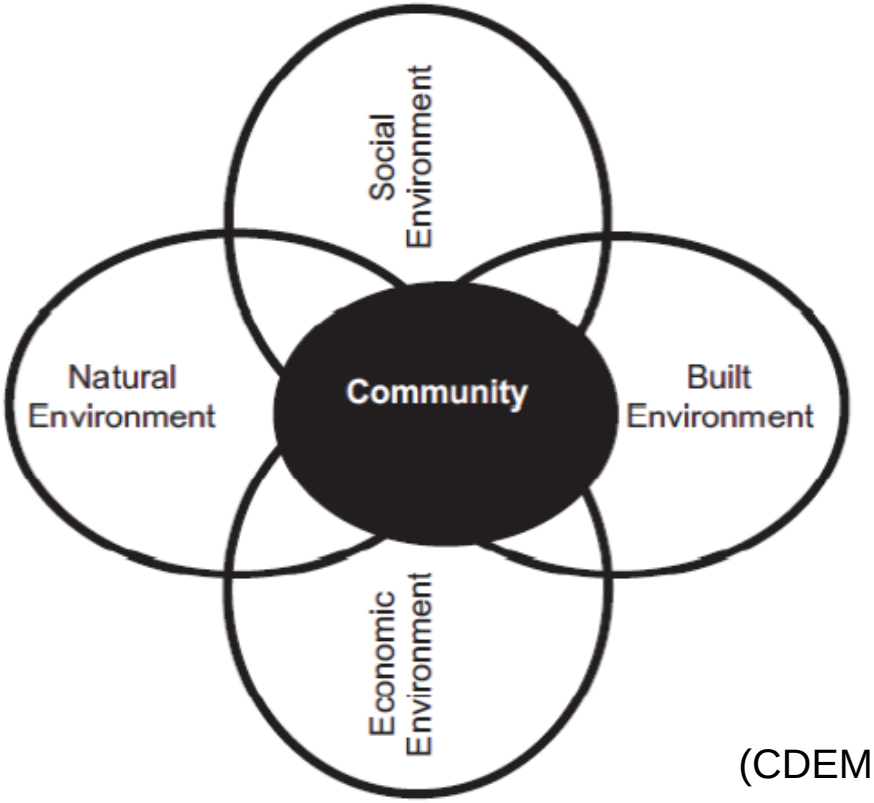


Is Tacloban recovering?

- Initial response to Haiyan was a success (no outbreak of disease, no widespread breakdown in law and order, and enough supplies of emergency food and clean water)
- After six months, less than 150 permanent new houses had been built. The master-plan calls for 200,000
- Finding suitable land has been a challenge

How to monitor recovery

- Mostly physical
- Tells us little (for example unoccupied resettlement sites in Haiti)
- Far more interesting: system recovery



(CDEM, 2005)

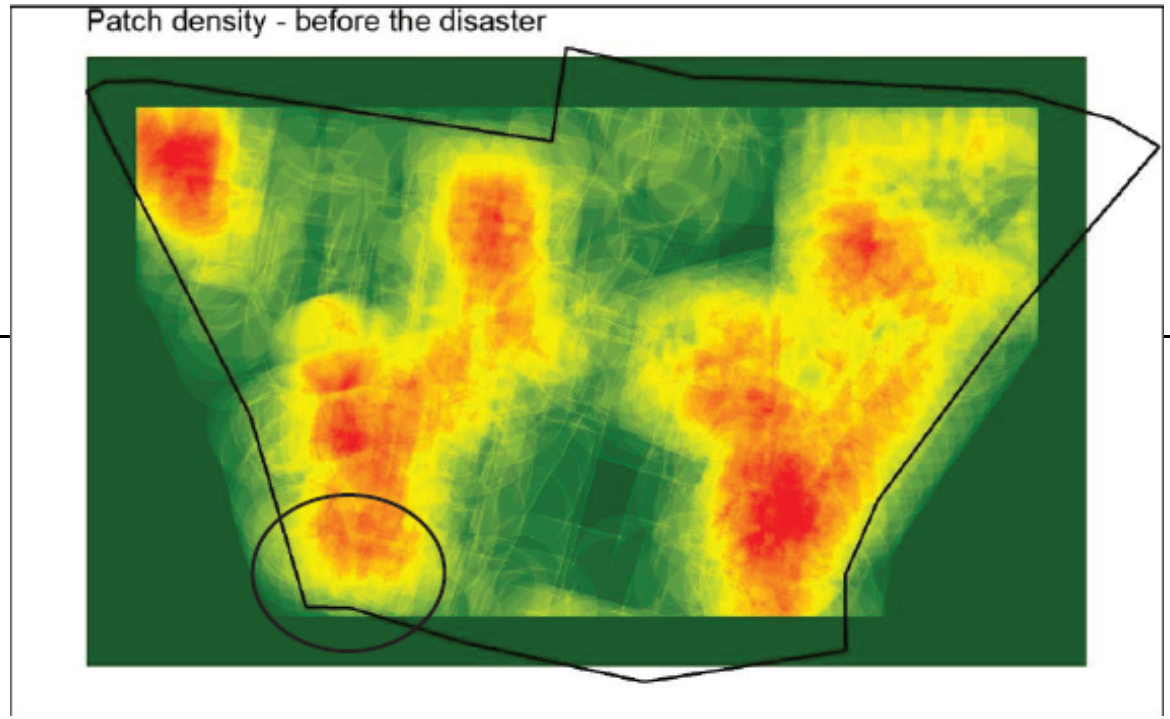
How to monitor recovery

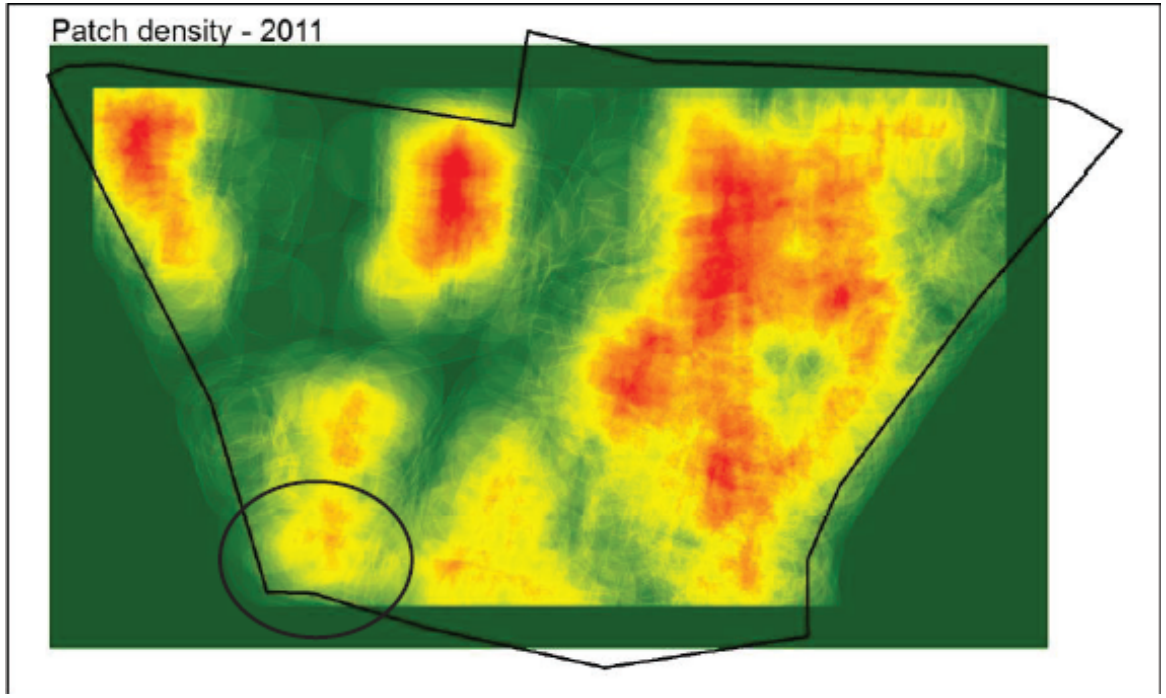
- Work at ITC on recovery assessment (developments following explosion of a fireworks factory in Enschede in 2000)

MSc research
Alexandra Costa
Vieira, 2014

How to monitor recovery

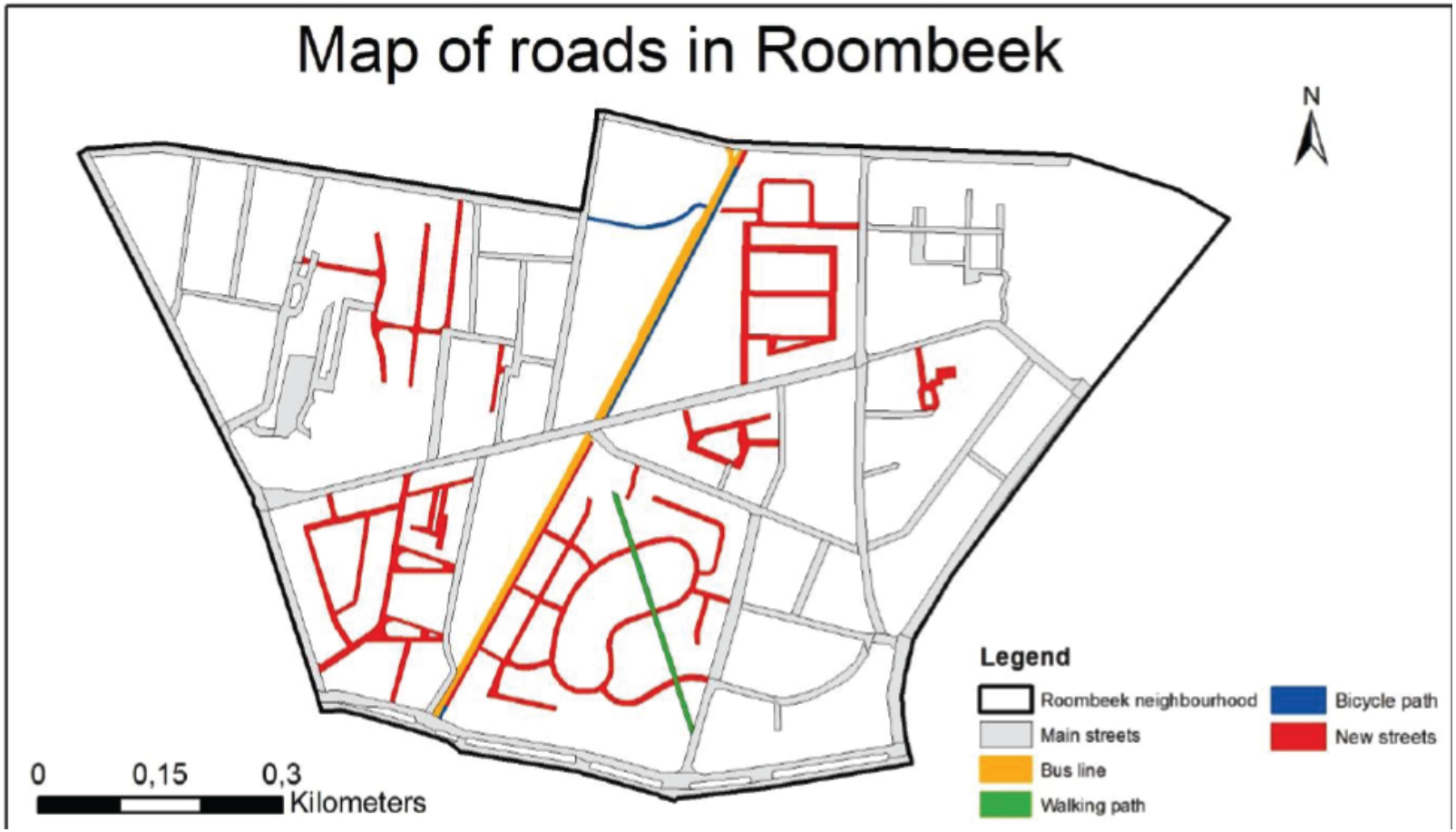
- We can track the physical
- Interpretation of the meaning is difficult





How to monitor recovery

- Network analysis is possible



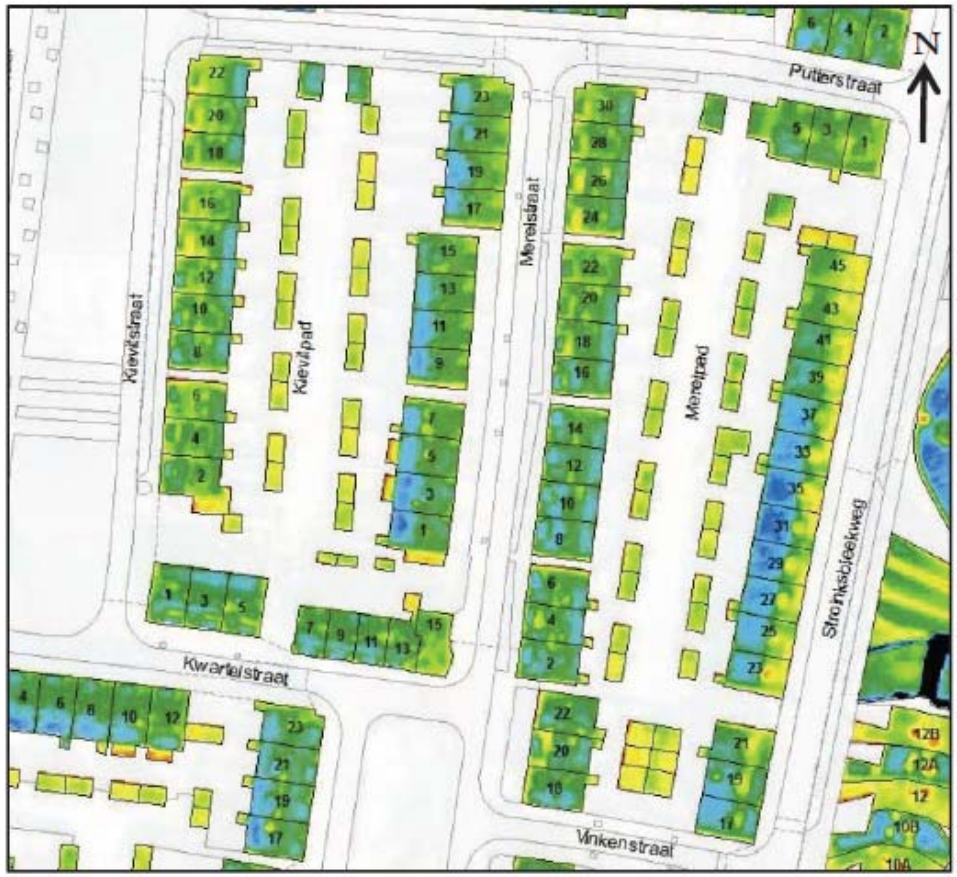
How to monitor recovery

- Housing quality (insulation in this case)

ND	No insulation detected
G	Good insulation
M	Medium insulation
L	Low insulation
N	No insulation

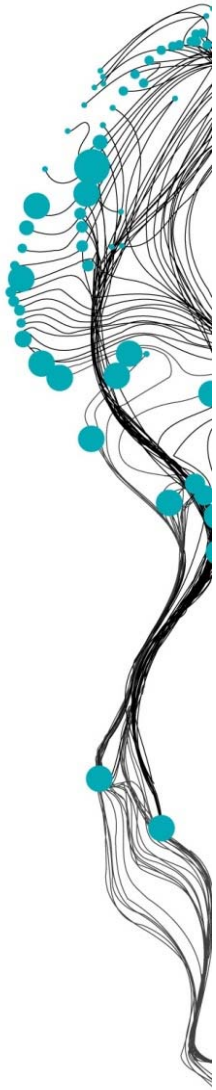
Reference neighborhood

Rebuilt disaster area



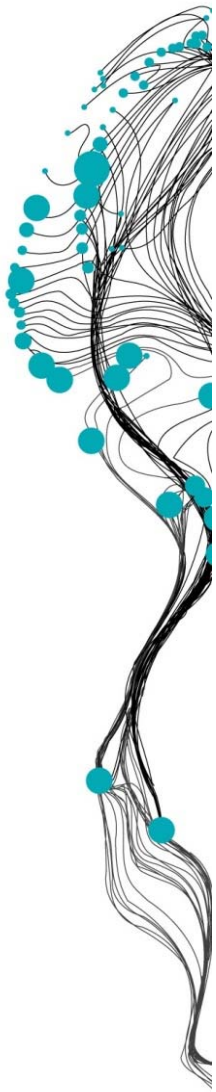
One important concept left out: resilience/ resiliency

- Focus of the 3rd ERDT Congress
- "Resilient communities"- stated goal of PHIVOLCS
- *Risk* is full of ambiguously defined and used terms - many overlap or are related



One important concept left out: resilience/ resiliency

- Resilience is important concept in risk assessment and mitigation
- Old term that is still not part of operational risk quantification
- Risk is a difficult concept (R=H x V)
- Often not complete: resilience, coping capacity missing
- Function of many aspects (social, political, environmental, economic)
- Preparedness, early earning, evacuation, etc. all play a role here and determine **how quickly a place bounces back**
- Resilience and recovery are related parameters



A forest of terms

Robustness

Vulnerability

Persistence

Flexibility

Sensitivity

Resistance

Impact

Reliability

Adaptability

Adaptive capacity

Transformation

Adaptation

Efficiency

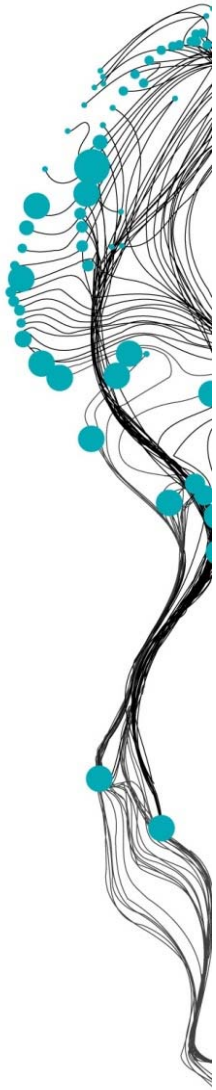
Sustainability

Resilience

Mitigation

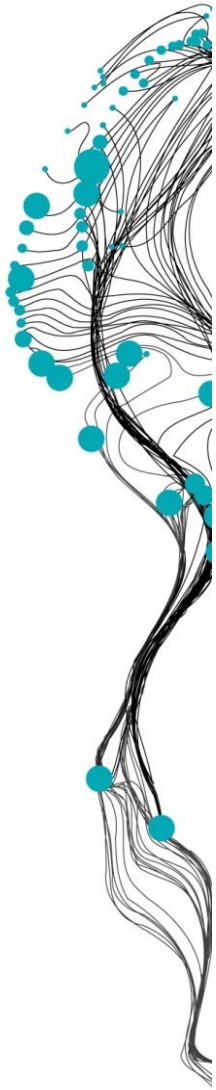
Stability

Redundancy



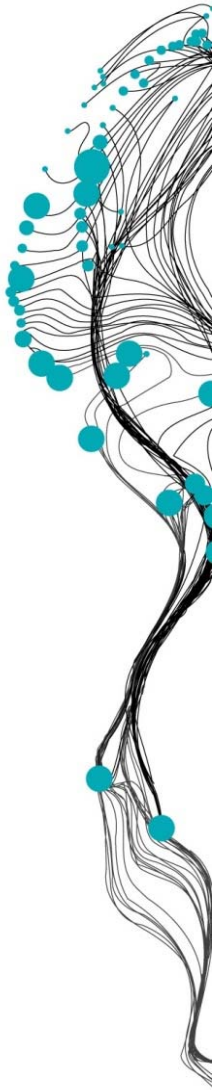
A research proposal

- Proposal with an economist colleague (Tatiana Filatova)
- Couple image analysis and macro-economic agent-based modelling
- Idea: resilience is not directly detectable. However, areas that recover more quickly than others must be more resilient
- Add to that economic modelling to explain the developments in terms of socio-economic drivers
- Use that to predict recovery trends, but also to influence them



A research proposal

- Leyte could be a great case study
- Many remote sensing images exist, 2 DREAM LiDAR surveys, ground information
- Hazard maps have been created for Yolanda rehabilitation
- Could involve the Yolanda Rehabilitation Scientific Information Center (YoRInfoCenter)



Summary

- Image-based damage assessment remains the only practical way
- However, there are inherent accuracy limitations
- Multi-perspective oblique stereo images are ideal (though also have limitations)
- Crowdsourcing is a great tool for many problems, but not for structural damage mapping
- More coordinated image-based damage mapping is needed, which takes better account of user needs and abilities
- Far more focus is to understand post-disaster recovery, find better ways to map and quantify is, and link it to resilience

= key to steer the process to a more desirable outcome

Questions?

- Our disaster damage assessment, as well as OOA work continues – check www.itc.nl/ooa-group for updates
- Same for full references
- Papers also on

https://www.researchgate.net/profile/Norman_Kerle

- Or email: n.kerle@utwente.nl

Thank you