Earthquake damage mapping using the coherence of persistent scatterers

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- This work was supported by the FP7 Project APHORISM (http://www.aphorism-project.eu)
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APHORISM is an EC FP7 project (SPACE-2013-1)

It proposes the development and testing of two new methods to combine different types of Earth Observation satellite data and ground data:

- one addresses ash monitoring (volcanic crises)
- one addresses damage mapping (seismic crises)

The work presented here contributes to the seismic crises product development
Background

- After an Earthquake earth observation methods can support the damage assessment.
- Primarily VHR optical and SAR data are used for this, especially for the assessment of damage at “single-building scale”
- Here we use HR SAR data (ENVISAT)
- Using HR SAR data InSAR coherence showed promising results in the past – but this at “block scale”
Christchurch, NZ
M7.0 on 4-Sep-2010

PALSAR
differential interferogram
Christchurch, NZ
M6.1 on 22-Feb-2011

PALSAR
differential interferogram
Christchurch damage mapping (using PALSAR)

Coherence loss in built up area indicates damage
red: interseismic coherence, green/blue: co-seismic coherence

M7.0 on 4-Sep-2010  M6.1 on 22-Feb-2011
Objective of our work

- PSI provides information (height, deformation) for individual scatterers (single pixels) → “single-building scale” potential
- Use “PSI coherence” to map building damage?
  → PS = selection of high coherence scatterers
  → develop methodology
  → apply it to specific case
  → assess potential and limitations
PSI coherence

- PSI temporal coherence
  Estimators:
  - deviation from (linear) phase model
  - deviation from spatially filtered value

- PSI spatial coherence
  Estimator:
  - as for 2D InSAR but only considering PS

For damage mapping spatial coherence is of interest (depends on individual pair only)
PSI coherence reduction approach to map building damage

1) PSI processing of pre-seismic stack (→ point heights, deformation rates, atmospheric delays)

2) Calculate point differential interferogram for co-seismic pairs (considering model from pre-seismic analysis)

3) Determining spatial coherence for co-seismic pair(s) and for pre-seismic pairs with similar characteristics (baseline, time interval, season)

4) Determine coherence differences between corresponding pre- and co-seismic pairs; use coherence reduction as damage indicator
Application over Christchurch, NZ

- Darfield Earthquake M7.0 on 4-Sep-2010
- Causing damage in parts of Christchurch
- ENVISAT ASAR stack with 36 pre-seismic and 1 post-seismic scenes (17-Sep-2010)
Christchurch, PSI velocity map from ENVISAT
36 pre-seismic scenes
Mapping Darfield Earthquake damage in Christchurch area using ENVISAT PSI coherence reduction

Reduction of spatial coherence of Persistent Scatterers in co-seismic pair (as compared to pre-seismic pairs).

Green: no reduction
Yellow: intermediate reduction
Red: strong reduction
PSI coherence reduction

Detailed view in a residential area of Christchurch (visualized in Google Earth)

Green: no reduction
Yellow: intermediate reduction
Red: strong reduction
PSI coherence reduction

Detailed view in a residential area of Christchurch (visualized in Google Earth)

Green: no reduction
Yellow: intermediate reduction
Red: strong reduction

In-situ damage assessment:
Red areas indicate “evidence of liquefaction visible at ground surface” (as shown in the Geotechnical land damage assessment & reinstatement report, stage 1, Oct. 2010, as found on New Zealand government web-site [1].)
1) Damage mapping methodology based on PSI coherence reduction was presented

2) Methodology was applied to map damage of the Darfield Earthquake in Christchurch using ENVISAT ASAR

3) Comparison with in-situ information showed good correspondence of PSI coherence reduction with liquefaction areas, indicating a good potential of the method in this case

4) An advantage of considering persistent scatterers is the high level of the pre-seismic coherence
Limitations identified

5) Estimation of spatial coherence requires multiple scatterers, therefore “single-building scale” may not necessarily be achieved

6) Undamaged building among damaged buildings will not be identified

7) Scatter mechanism may depend only on one part of a building (e.g. 1 wall) and so damage to another part (e.g. roof) may not change the PSI phase and coherence

→ More cases should be investigated
L’Aquila, PSI velocity map

Average linear deformation rate from ENVISAT (20021110 to 20090308). The red cross indicates the reference point, the red arrow the look direction.
L’Aquila, PSI coherence reduction

PSI coherence reduction caused by the l’Aquila earthquake, determined using ENVISAT ASAR data.

Damage inventory for single buildings in l’Aquila, done in-situ by INGV.