Gazing at Grass:
Estimating surface deformation over fast-decorrelating pasture using InSAR

Yu Morishita and Ramon Hanssen
60% below the high-water levels of the sea, river, and lakes:

Flood risk is the main natural hazard
Average vertical deformation rates 1992-2011 (excluding Holocene dynamics)
Pasture on drained peat soils
Penetrating the landscape
THIS IS PEAT
MORE PEAT!
Yuk!

Clay

Peat
Different core drillings

- **Surface**
- **Water table -40 cm**
- **Water table -80 cm**

Legend:
- Sand
- Peat
- Clay

1. No subsidence
2. No subsidence if water > -40 cm
3. Subsidence
4. Subsidence
Estimation of expected subsidence based on interpolated drillings

Peat compaction (=subsidence) for a water table of -40 cm b.s.

- No subsidence
- Reclaimed lakes: peat removed: No subsidence

250 m grid cell
Pasture on drained peat soils

- Typical Dutch landscape
- Drainage (to keep the land dry) results in subsidence
- Below sea level (1~7m)
- Increased flood risk
Drainage and subsidence

Decomposition

CO₂, CH₄, N₂O

peat

ditch

peat

sea
Problems due to peat oxidation

- Holland is sinking even further (flood risk)
- Land use has to change (no more cattle $\rightarrow$ swamp)
- Damage to cities
- Greenhouse gas emission
- Wet feet
Horizontal variability

Land subsidence 1966-2003

Legend

- < 0.10 m
- 0.10-0.20 m
- 0.20-0.30 m
- 0.30-0.40 m
- 0.40-0.50 m
- 0.50-0.60 m
- 0.60-0.70 m
- > 0.70 m

Van den Akker, 2005
Target area

Pasture on drained peat soils

NDVI (Normalized Difference Vegetation Index)
NDVI > 0.7 : pasture area
## Data sets

<table>
<thead>
<tr>
<th>Satellite</th>
<th>ALOS</th>
<th>ERS-1 (Ice Phase)</th>
<th>Envisat</th>
<th>RS2</th>
<th>TSX</th>
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<tbody>
<tr>
<td>Subscript</td>
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<td>-</td>
<td>HH, HV</td>
<td>A, D</td>
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<td>Wavelength (mm)</td>
<td>236 (L-band)</td>
<td>56 (C-band)</td>
<td>31 (X-band)</td>
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<td>Revisit time (day)</td>
<td>46</td>
<td>3</td>
<td>35</td>
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<td>Critical baseline (m)</td>
<td>7000 (FBD)</td>
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<td>14000 (FBS)</td>
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<td>Ground resolution Rg × Az (m)</td>
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<td>23 × 5</td>
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<td>N/L</td>
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<td>-</td>
<td>VV</td>
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<td>06/12/20</td>
<td>92/01/29</td>
<td>93/12/25</td>
<td>03/02/12</td>
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<td>To (yy/mm/dd)</td>
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<td>Master (yy/mm/dd)</td>
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<td>No. of scenes</td>
<td>10 (FBD)</td>
<td>10 (FBD)</td>
<td>20</td>
<td>34</td>
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Temporal decorrelation in DInSAR

ALOS
46 days

Envisat
35 days

TSX
11 days

t=1 \rightarrow t=2 \rightarrow t=3

Urban: keeps coherence
Pasture: loses coherence
PSI results

ALOS Asc

Envisat Desc

TSX Asc

Fringe, Frascati, 20150325
SBAS results

Fringe, Frascati, 20150325
SqueeSAR test - PSI after inversion
SqueeSAR test - PSI after inversion

Coherence matrix
Coherence decrease with time interval

L-band: All year

C-, X-band: Only winter
Temporal decorrelation model

- Coherence estimator is biased, never reaches zero.

\[ \gamma = \gamma_0 e^{-\frac{t}{\tau}} \]

\[ \gamma = (\gamma_0 - \gamma_\infty)e^{-\frac{t}{\tau}} + \gamma_\infty \]

\( \gamma_\infty \): bias of coherence

Estimated model parameters for ERS

\[ \gamma = (\gamma_0 - \gamma_\infty) e^{-\frac{t}{\tau}} + \gamma_\infty \]

(A) Urban
High \( \gamma_0 \)
High \( \gamma_\infty \)
Low \( \tau \)

(B) Pasture
High \( \gamma_0 \)
Low \( \gamma_\infty \)
Moderate \( \tau \)

(C) Water
Low \( \gamma_0 \)
Low \( \gamma_\infty \)
Low \( \tau \)

New approach, combine all possible SAR data

1. Use all available satellites and data
2. Average to 230 x 230 m grid
3. Estimate linear plus sinusoidal signal

Fig. 4. All available SAR images and baseline configuration. Baselines are normalized to the critical baseline [20]. The lines indicate selected interferograms based on coherence, see section IV-A. A box with dashed line indicates the time period shown in Fig. 6.
Coherence estimation

- Coregistration to single master
- Spectral filter in order to mitigate spatial decorrelation
- Compute topographic phase
- Geocoding
- Adjacent coherence windows (230m x 230m) based on geographical coordinates of pixels to estimate coherence in the same area between all data sets
Find statistically homogeneous pixels

(a) Optical image (Google Earth)

(b) Reference pixels and SHP
Estimated parameters

Subsidence rate

Amplitude of seasonal component

Time offset of seasonal component

DEM correction
Estimated parameters

(a) Linear subsidence rate, $v_y$ (mm/y)

(b) Amplitude of the periodic annual signal, $A_y$ (mm)

(c) Time offset $\Delta t$ of the sinusoidal signal (day)

(d) DEM error $\Delta z$ (m)
Interpretation
Conclusions

• Over pastures, single sensor techniques did not work

• Good results were obtained by:
  1. Combining all available sensors
  2. Reducing spatial resolution
  3. Estimating parameters in a least-squares sense