Communicating Earth Observation (EO)-based landslide mapping capabilities to practitioners


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EO-BASED LANDSLIDE MAPPING

From methodological developments to automated web-based information delivery
Abstract

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Austrian Research Promotion Agency (FFG)
Austrian Space Applications Programme (ASAP)
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Current remote sensing methods and the available Earth Observation (EO) data for landslide mapping already can support practitioners in their processes for gathering and for using landslide information. Information derived from EO data can support emergency services and authorities in rapid mapping after landslide-triggering events, in landslide monitoring and can serve as a relevant basis for hazard and risk mapping. These applications also concern owners, maintainers and insurers of infrastructure. Most often practitioners have a rough overview of the potential and limits of EO-based methods for landslide mapping. However, semi-automated image analysis techniques are still rarely used in practice. This limits the opportunity for user feedback, which would contribute to improve the methods for delivering fully adequate results in terms of accuracy, applicability and reliability. Moreover, practitioners miss information on the best way of integrating the methods in their daily processes. Practitioners require easy-to-grasp interfaces for testing new methods, which in turn would provide researchers with valuable user feedback.

We introduce ongoing work towards an innovative web service which will allow for fast and efficient provision of EO-based landslide information products and that supports online processing. We investigate the applicability of various very high resolution (VHR), e.g. WorldView-2/3, Pleiades, and high resolution (HR), e.g. Landsat, Sentinel-2, optical EO data for semi-automated mapping based on object-based image analysis (OBIA). The methods, i.e. knowledge-based and statistical OBIA routines, are evaluated regarding their suitability for inclusion in a web service that is easy to use with the least amount of necessary training. The pre-operational web service will be implemented for selected study areas in the Alps (Austria, Italy), where weather-induced landslides have happened in the past. We will test the service on its usability together with potential users from the Geological Survey of Austria (GBA), various geological services of provinces of Austria, Germany and Italy, the Austrian Service for Torrent and Avalanche Control (WLV), the Austrian Federal Forestry Office (ÖBF), the Austrian Mountaineering Club (ÖAV) and infrastructure owners like the Austrian Road Maintenance Agency (ASFINAG). The results will show how EO-based landslide information products can be made accessible to responsible authorities in an innovative and easy manner and how new analysis methods can be promoted among a broad audience. Thus, the communication and knowledge exchange between researchers, the public, stakeholders and practitioners can be improved.
The pre-operational service relies on a database of high resolution and very high resolution optical EO data from various sensors. Semi-automated mapping routines that are adaptable to changing EO data and geographical settings enable the identification of landslides. A web service gives access to EO data and integrates the mapping routines via a web processing chain. The user is able to map landslides and to identify landslide-affected infrastructure.
Satellites
- High Resolution
  - Landsat
  - SPOT 4/5
  - Sentinel-2
  - Rapideye
- Very High Resolution
  - Quickbird
  - Worldview 2/3
  - GeoEye-1
Other
- DEM data
- Etc.
Quickbird-2
Location: Haunsberg, Salzburg, Austria
Date: 28.04.2002
Resolution: 0.6m (pan), 2.4 (ms)
Bands: blue, green, red, infrared

Availability: commercial
Operator: DigitalGlobe
Reseller: European Space Imaging
Online Archive: http://iohs.euspaceimaging.com/smartsearch

Switch to Landsat-7
GeoEye-1
Location: Montafon, Vorarlberg, Austria
Date: 05.08.2015
Resolution: 0.5m (pan), 2.0 (ms)
Bands: blue, green, red, infrared

Availability: commercial
Operator: DigitalGlobe
Reseller: European Space Imaging
Online Archive: http://iohs.euspaceimaging.com.smartsearch
WorldView-2
Location: Montafon, Vorarlberg, Austria
Date: 29.08.2015
Resolution: 0.5m (pan), 2.0 (ms)
Bands: blue, green, red, infrared
Availability: commercial
Operator: DigitalGlobe
Reseller: European Space Imaging
Online Archive: http://iohs.europeanspaceimaging.com/smartsearch
Landsat-7
Location: Haunsberg, Salzburg, Austria
Date: 28.07.2002
Resolution: 15m (pan), 30m (ms)
Bands: blue, green, red, infrared, swir1, swir2, tir
Availability: free download
Operator: NASA
Provider: United States Geological Survey
Online Archive: http://earthexplorer.usgs.gov/
Rapideye
Location: Taxenbach, Salzburg, Austria
Date: 06.08.2013
Resolution: 5.0m (ms)
Bands: blue, green, red, red-edge, infrared
Availabilty: commercial
Operator: BlackBridge
Online Archive: http://eyefind.rapideye.com/

Switch to SPOT
Switch to Sentinel-2
Back
SPOT-5
Location: Taxenbach, Salzburg, Austria
Date: 10.09.2011
Resolution: 2.5m (pan), 10.0m (ms)
Bands: green, red, infrared, swir (20m)
Availability: commercial
Operator: Airbus Defense & Space
Online Archive: http://www.geo-airbusds.com/geostore/
**Sentinel-2**

- **Location:** Taxenbach, Salzburg, Austria
- **Date:** 18.08.2015
- **Resolution:** 10.0m, 20.0m, 60.0m
- **Bands:** 12 bands, multispectral

**Availability:** free download

**Operator:** European Space Agency

**Online Archive:**
https://scihub.copernicus.eu/
Semi-automated mapping routines that are adaptable to changing EO data and geographical settings enable the identification of landslides.

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Web Service
High level layer structure for implementation

User Interface Layer
A collection of user stories is available that describes the interactions that the user wants to perform with the service, e.g., running a ruleset for landslide information extraction on a satellite image, or displaying extraction results in a map view.

Web Server Layer
The web server hosts the basic functionality of handling geodata, including EO satellite images, and extended functionality for the processing of geodata. Through the user interface layer, it receives the user input for performing processes. It reads and writes the specified data from the database layer.

Database Layer
The database stores all the required data, structured by a comprehensive data model. It includes (but is not limited to) EO data, other geodata, metadata, indices, classification rulesets, etc.

A web service gives access to EO data and integrates the mapping routines via a web processing chain. The user is able to map landslides and to identify landslide-affected infrastructure.

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User Feedback
Communication with users

Performed user involvement
- Interviews for user requirements gathering
- Follow-on discussion on preliminary results

Planned further steps of user involvement
- Conduct tests for defined cases
- Perform tests with their own images/data
- Give feedback via an online validation form
- Participate in a validation workshop
User Requirements
Identified needs of users within their scenarios

User types
- Austrian Alpine Association
- Austrian Federal Forestry Office
- Regional geological and surveying agencies
- Austrian Service for Torrent and Avalanche Control

Scenarios
- Rapid Mapping
- Documentation
- Monitoring

Needs & Requirements
- Need for information about new landslides
- Need for information about activity of known landslide or in debris retainers
- Need for information about damaged infrastructure
- Need for collection of / access to raw data on landslides
- Need for processing raw data to landslide information
- Need for easy-to-use comparison tools that analyse information about landslides and related assets
- Need for access to geodata for comparison
- Need for tools for reporting landslide information

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**Landslide Rapid Mapping**

for immediate response

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**Situation:** Heavy rainfalls occur that may have triggered landslides

**Event:** Early warning system (or other source) alerts infrastructure manager to assess need for cleanup and repair operations

**User’s expectation to EO data:**
- EO data may help in providing a more comprehensive overview for prioritizing cleanup activities

**Selected user requirement – the issue of time**
- EO data acquisition and landslide mapping as soon as possible after the event (best case: within 48 hours; if info is not available within 7 days, it has very limited added value; existing reporting workflows provide full information for organizing cleanup within 14 days)

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<table>
<thead>
<tr>
<th>Specific User Scenarios</th>
<th>Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure damage assessment for planning/coordinating</td>
<td>ÖBF, Austrian Federal Forestry Office;</td>
</tr>
<tr>
<td>planning/coordinating maintenance activities</td>
<td>ÖAV, Austrian Alpine Association</td>
</tr>
<tr>
<td></td>
<td>Geol-Südtirol, Office for Geology and Building Materials Testing of</td>
</tr>
<tr>
<td></td>
<td>South Tyrol, Italy</td>
</tr>
<tr>
<td>Planning emergency and recovery activities</td>
<td>VermVBG, Vorarlberg State Office for Surveying and Geoinformation,</td>
</tr>
<tr>
<td></td>
<td>Austria</td>
</tr>
<tr>
<td>Timely provision of post-event orthophotos</td>
<td>VermVBG; Geol-Südtirol</td>
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</tbody>
</table>

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**Back**
### Landslide Documentation and Mapping

**e.g. for damage assessment**

#### Specific User Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management and planning of infrastructure that is (potentially) affected</td>
<td>ÖBF, Austrian Federal Forestry Office;</td>
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<tr>
<td>by landslides, and planning of protective measures</td>
<td>Geol-SBG, Geological Agency of the State of Salzburg, Austria,</td>
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<tr>
<td></td>
<td>WLV-OÖ, WLV Upper Austria, Austrian Service for Torrent and Avalanche Control,</td>
</tr>
<tr>
<td>Management of planning objectives for landslide-affected forestry stands</td>
<td>ÖBF, Austrian Federal Forestry Office</td>
</tr>
<tr>
<td>Update of maps (hiking maps, geological maps)</td>
<td>ÖAV, Austrian Alpine Association</td>
</tr>
<tr>
<td></td>
<td>Geol-Südtirol, Office for Geology and Building Materials Testing of South Tyrol, Italy</td>
</tr>
<tr>
<td>Publish official reports/documentation on major landslide events</td>
<td>VermVBG, Vorarlberg State Office for Surveying and Geoinformation, Austria;</td>
</tr>
<tr>
<td></td>
<td>Geol-Südtirol;</td>
</tr>
<tr>
<td></td>
<td>Geol-Bayern, Geological Survey of Bavaria, Bavarian Environment Agency, Germany</td>
</tr>
<tr>
<td>Generate/update and share a (standards-conform) regional landslide inventory</td>
<td>Geol-Südtirol, GBA, Geol-Bayern</td>
</tr>
<tr>
<td>Landslide susceptibility mapping and establishing an appropriate basis for it</td>
<td>Geol-SBG, WLV-OÖ, GBA</td>
</tr>
</tbody>
</table>

#### User’s expectation to EO data:

- EO data can provide a comprehensive coverage of the mapped region and thereby may improve the completeness of landslide documentation

#### Selected user requirement – the issue of time

- EO data acquisition as soon as possible after the event (best case: landslides have not yet been cleaned away), landslide information product available within 6 months

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**Situation:** Heavy rainfalls have triggered landslides

**Event:** Regional authority and others request information on landslides, damages, changes and updated susceptibility

**Landslide expert identifies region where landslides have happened**

**Landslide expert documents all the landslides**

**Landslide expert analyses damages, changes and updates susceptibility information**

**Landslide expert reports requested information**

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**Landslide Monitoring** for an alert system

**Situation:** Persisting risk for (re-)activation / triggering of landslides

**Event:** Authorities decide to install a monitoring system

- The monitoring system is designed and installed
- The monitoring system checks the status of the observed area
  - If relevant changes are observed
  - If no changes are observed

**Alert of identified landslide activity**

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**Specific User Scenarios**

<table>
<thead>
<tr>
<th>Monitoring the status of debris retainers</th>
<th>Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring of slow-moving landslides and reactivated landslides that endanger infrastructure/people</td>
<td>WLV-OÖ, WLV Upper Austria, Austrian Service for Torrent and Avalanche Control; VermVBG, Vorarlberg State Office for Surveying and Geoinformation, Austria; WLV-OÖ; Geol-SBG, Geological Agency of the State of Salzburg, Austria</td>
</tr>
</tbody>
</table>

**User’s expectation to EO data:**
- EO data may also be able to identify relevant changes that result in a need for an alert

**Selected user requirement – the issue of time**
- Identify changes that indicate reactivation of old landslides or indicate new landslides; e.g. through regularly repeated EO data acquisition for the identification of changes in surface reflectance

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**Opportunity for Sentinel-2**

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