Early Warning System for rainfall induced landslides

KLIMA 2050 PhD Presentation
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Norwegian University of Science and Technology

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Cover image from NGI

TOC

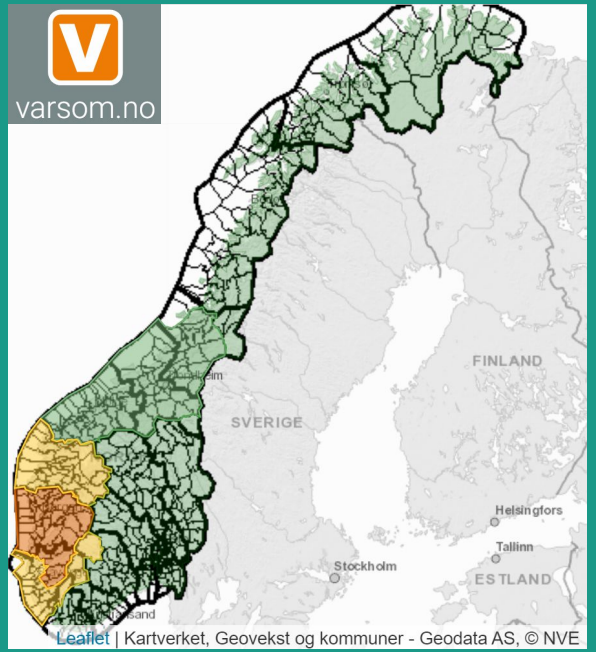
Background: KLIMA 2050 WP3

PhD & Supervision

Existing Landslide EWS

PhD focus areas

Preliminary results



About me:

Question for audience: What do these places have in common?

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Background

WP3.4 Early warning system based on short-term weather forecasts (now-casting) - Objectives

- Develop real time EWS for shallow landslides at a regional or local scale.
- Build on existing Norwegian debris flow EWS (implemented by NVE in 2013).
- EWS to be based on forecasted meteorological (e.g. rain or snow), hydrological, and geotechnical parameters.
- Develop a set of connected numerical simulations.

Supervision, and KLIMA 2050 support network

Steinar Nordal

NTNU

Lena Rubensdotter

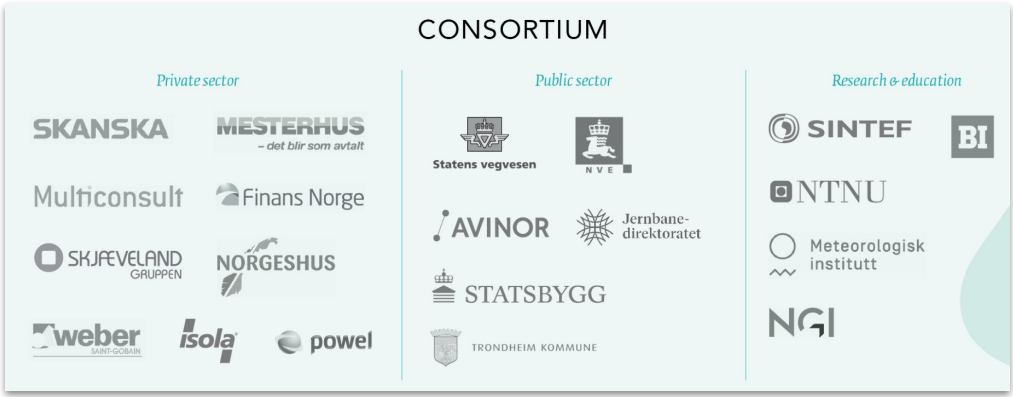
NORGES GEOLOGISKE UNDERSØKELSE - NGU -

Graziella Devoli

NVE

Jose Cepeda,
Regula Frauenfelder

NGI



Existing landslide EWS in Norway

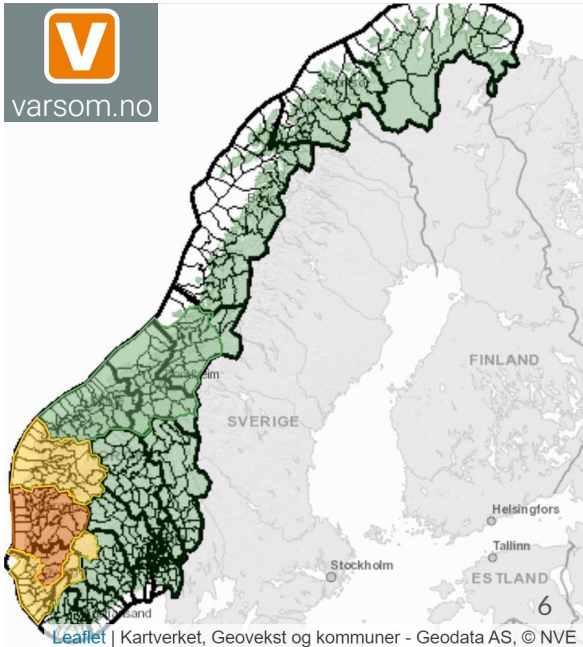
- Joint initiative by public agencies
- Launched 2013 and managed by NVE
- Warn of potentially dangerous hydrological situations (3 days ahead)
- Warnings are based on:
  - MET forecasts
  - Landslide thresholds
  - Real time observations (temp, precipitation, discharge, groundwater)
  - National landslide susceptibility maps and historic landslides
- On-duty forecaster considers model, and decides which warning level to issue in each region (updated twice daily)

NVE

Norwegian Meteorological Institute

Norwegian Public Roads Administration

Norwegian National Rail Administration



Improvements since 2009...

Landslide prevention in Norway improved significantly:

- Better coordination between national and local
- More systematic mapping of landslides (NVE, NGU, SVV...)
- Knowledge of landslide processes (SVV, NVE, Universities, NGU, NiFS project, ...)
- Assistance to municip. - spatial planning, emergency response
- Development of national database

Operational regional landslide EWS (rainfall-induced landslides and slush flows) with 95% correct forecasts!!

Issues remaining

1. Few stations measuring precipitation in landslide source areas.

   Summer storms problematic to predict.

   - Rainfall initiation thresholds??

2. Landslide susceptibility maps limited by resolution of input data.

   e.g. Landslide in Hordaland 8/12/17

   - NVE hazard level → orange
   - Susceptibility not susceptible.
     - 1:250,000 quaternary map → bare bedrock

3. Historic landslide database is incomplete (landslide no., and size) and spatially biased along roads and railways.

   Difficult to use database to determine rainfall thresholds, hazard mapping, etc.

4. Information about local thresholds is only available for some areas of Norway.

5. Geotechnical properties not included in EWS forecast model

Future landslide EWS in Norway

Users of landslide EWS would benefit from warnings at a more ‘local’ scale, in order to best plan contractor response to a given hazard situation.

- NVE working with MET in use of radar and 3h thresholds

Road cleared after debris flow in Almåskroken, Gauldalen, taken from helicopter shortly after the event (Adressa.no).

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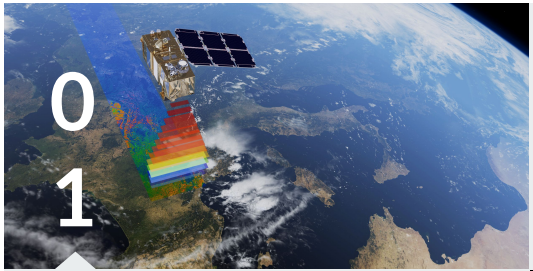
KLIMA 2050 possible research focus

Improve understanding of local threshold values and forecasting capabilities by:

A. Predicting future needs for a landslide database (2050)
B. Incorporating geotechnical properties into the landslide EWS
C. Systematic (semi-automated) identification of landslides from remote sensing images

Innovation potential:

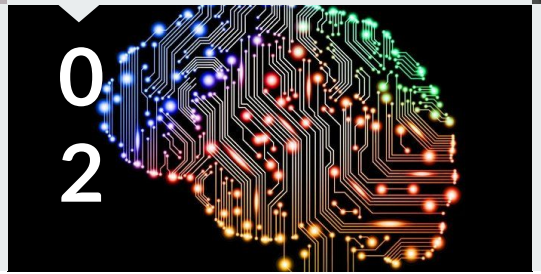


Detect landslides using satellites

Take advantage of free, frequent high resolution satellite data from ESAs new Sentinel-2 satellite. Apply machine learning to recognise landslide features, given a sudden loss of vegetation.

Machine learning for forecasting

Improve NVE forecasting capabilities, using artificial neural-network to train an algorithm for predicting number and magnitude of landslides for given conditions.



Update forecast tool with improved landslide event data

After it is has been shown possible to reliably detect landslides, the landslide prediction algorithm should be retrained (Bayesian updating) on the new data-set

A. Vision - National landslide database

- Literature review - current SOTA: Landslide EWSs
- Predict future data sharing needs
- Identify technological developments that may enable improvements
- Shared vision of Norwegian landslide database (2050)
    - Encourage cooperation between global and local stakeholders

B. Regional trends in geotechnical properties of susceptible soils

- Literature review - SOTA: Landslide EWSs
- Master student - Emilie O Hauge
  - Investigating potential regional trends in geotechnical properties (shear strength and drainage) from a selection of Norwegian glacial tills (norsk: *morene*)
- Master student - Frieda Lange
  - Investigating susceptibility of thawing soil to landslides in different climate conditions

C. Systematic identification of LSs from remote sensing images

- Courses: Statistical pattern recognition, Computer intensive statistical methods
- Literature review:
  - How have machine learning and image classification been used in landslide identification?
  - What type of imagery has been used previously?
- Master student - Mads Fjeld
  - Investigating potential for using ESAs Sentinel 2 multi-spectral optical satellite to identify landslides in Norwegian conditions
- ‘Pilot project (?)- Using Sentinel satellite data to identify LS. Supported by Romsenter.

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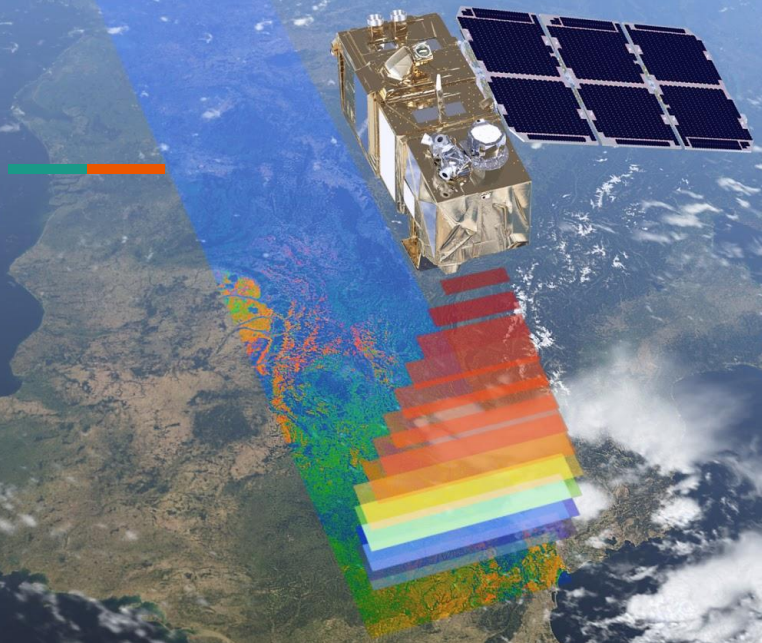
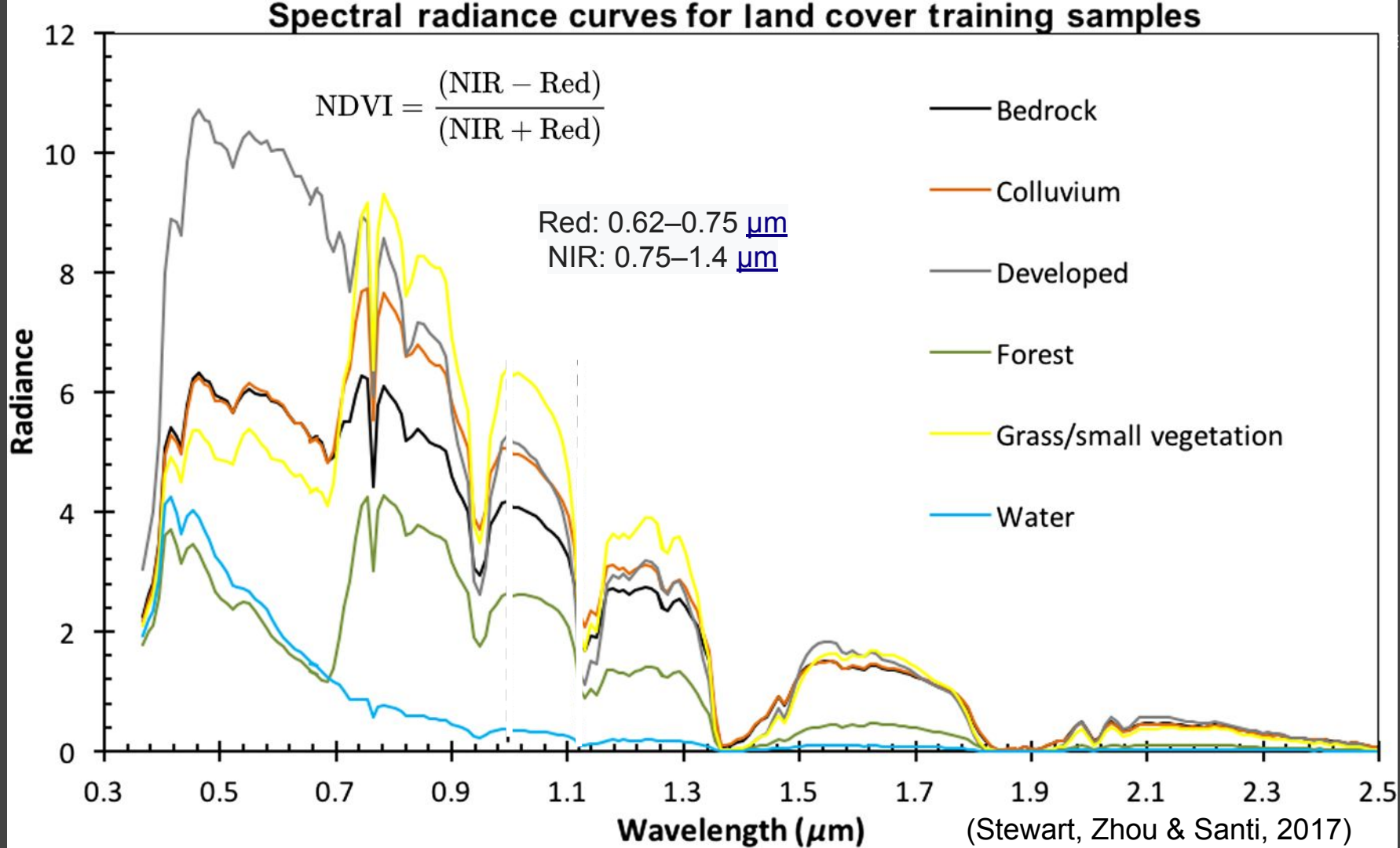


Landslide detection with Sentinel 2

- Multi-spectral satellite for land use monitoring
- Freely available data, revisit time 1-2 days, pixel resolution 10-60m
- Compare subsequent images to identify LOSS of vegetation
- Normalized difference vegetation index (NDVI) used to detect vegetation or bare soil
- Use statistical pattern recognition techniques to distinguish landslides



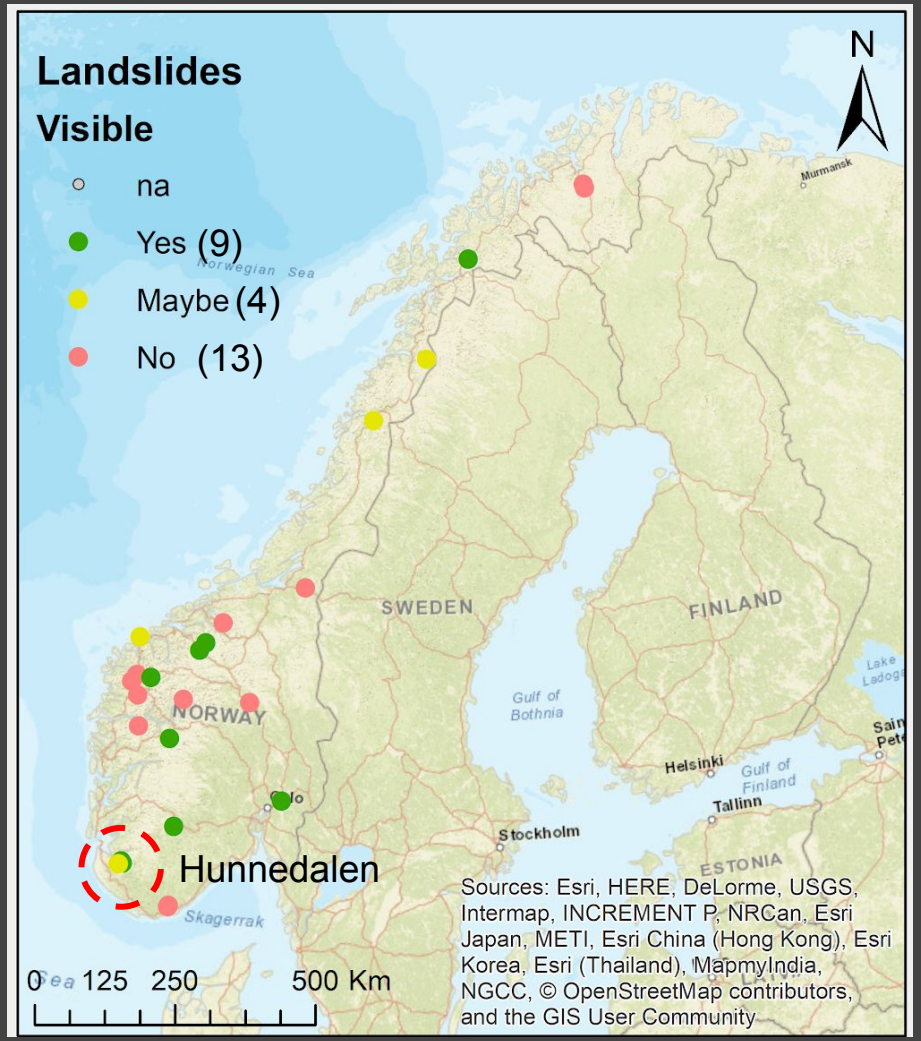
(Stewart, Zhou & Santi, 2017)

Research topic

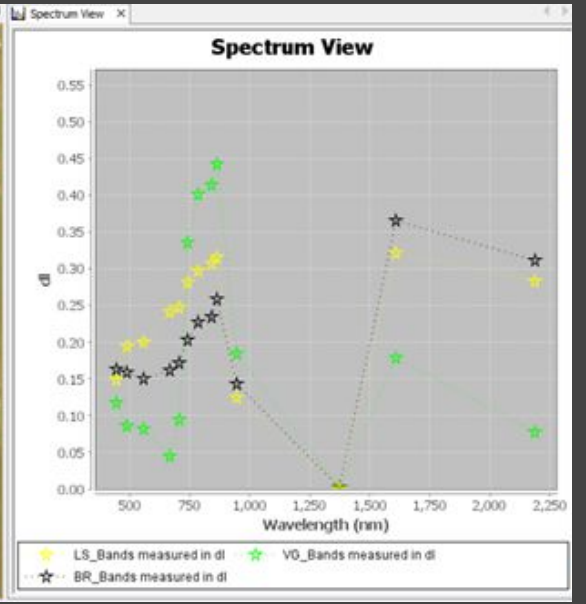
Master project
Mads Fjeld

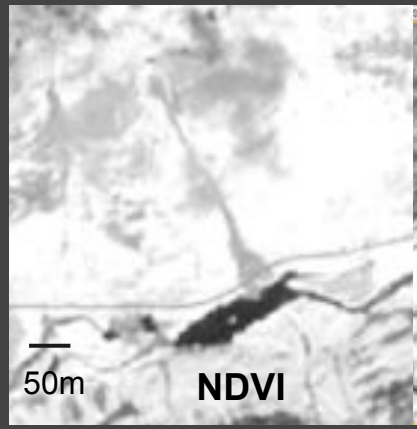
Feasibility of using Sentinel 2 data to detect landslides in Norway, considering:

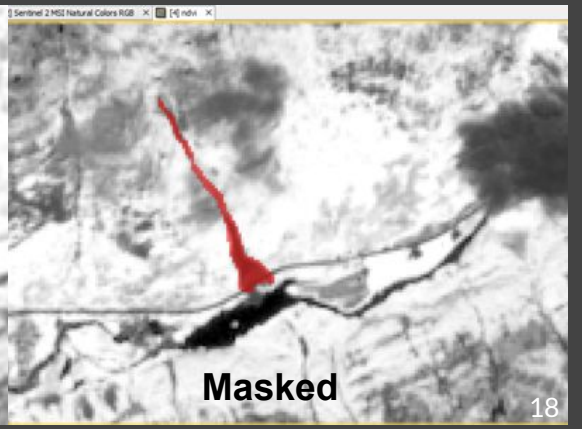
- Detectable event size
- Lighting conditions
- Cloud cover
- Terrain type (slope)
- Geology/quaternary cover
- Season
- Snow cover


Landslides
Visible
na
Yes (9)
Maybe (4)
No (13)
N
Murmansk
Norwegian Sea
SWEDEN
FINLAND
NORWAY
Gulf of Bothnia
Lake Ladoga
Helsinki
Gulf of Finland
Tallinn
Stockholm
ESTONIA
Oslo
Skagerrak
Hunnedalen
0 125 250 500 Km
Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community


BR
VG
LS
Natural colour composite


Spectrum View
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
500
750
1,000
1,250
1,500
1,750
2,000
2,250
Wavelength (nm)
LS_Bands measured in dl
V0_Bands measured in dl
BR_Bands measured in dl


50m
NDVI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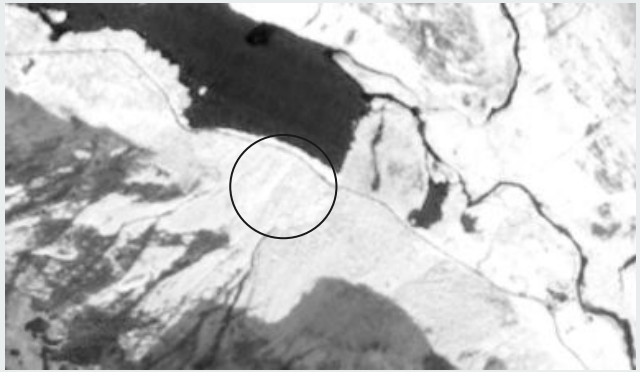
Summary



Pre-event NDVI (21.07.17)

Post-event NDVI (26.07.17)

Results:
Less than half of queried events detectable using this method (so far)

Greatest challenges:
Illumination (slope or season) and cloud cover

Potential:
General idea is still complementary to international efforts in this field which don't address issues with landslide detection - e.g. NASA 'now-casting' using GPM satellite mission.

Recommendation:
Consider alternative types of remote sensing - e.g. higher resolution satellites, drones, aerial photos.

Takk for meg!

Questions?

KLIMA 2050 Potential pilot project objectives

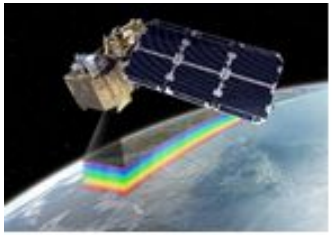
Improve understanding of local threshold values and forecasting capabilities by:

1. Improving landslide event database, utilising satellite data for cost-effective systematic mapping.
2. Semi-automate daily reporting and forecasting process
3. Installing ground-based monitoring in vulnerable areas.

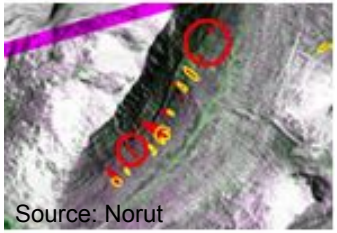
1. Landslide mapping, classification and prediction system

- Identify new landslides using satellite images.
- Use ML to identify and classify landslides.
- Retrieve and analyse local MET data to better understand local trigger thresholds.

Acquire and prepare data

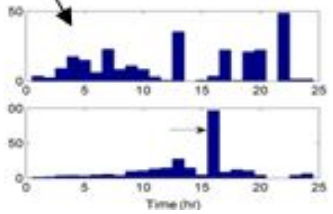


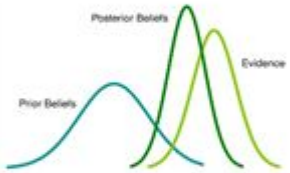
Detect landslides

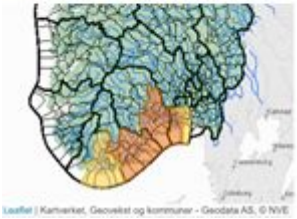


Assign event geometry

Acquire met. data from nearest stn.



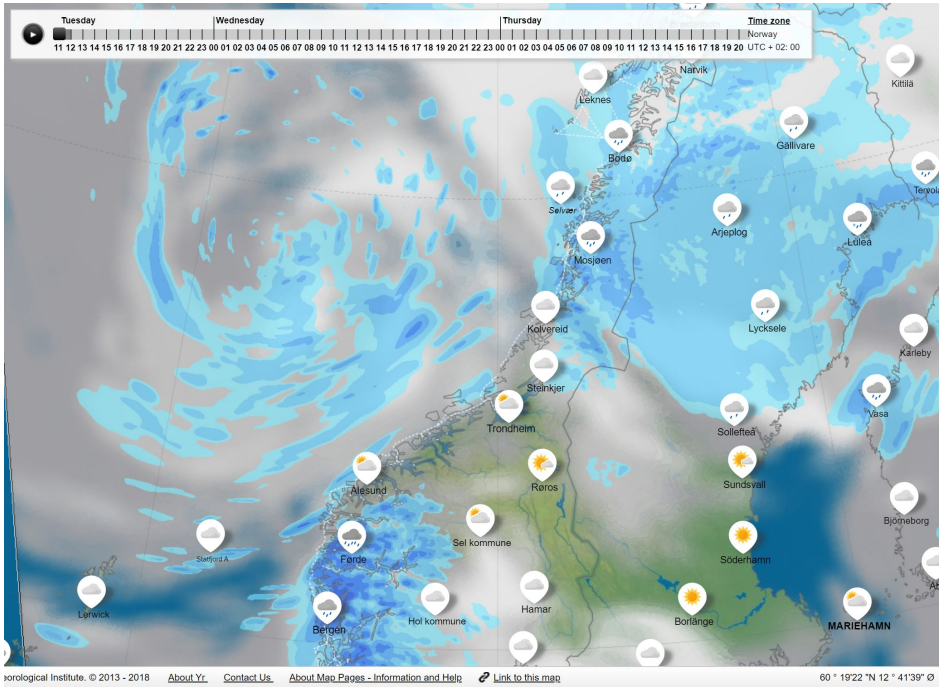




Determine trigger, and any other relevant info. Update prediction model.

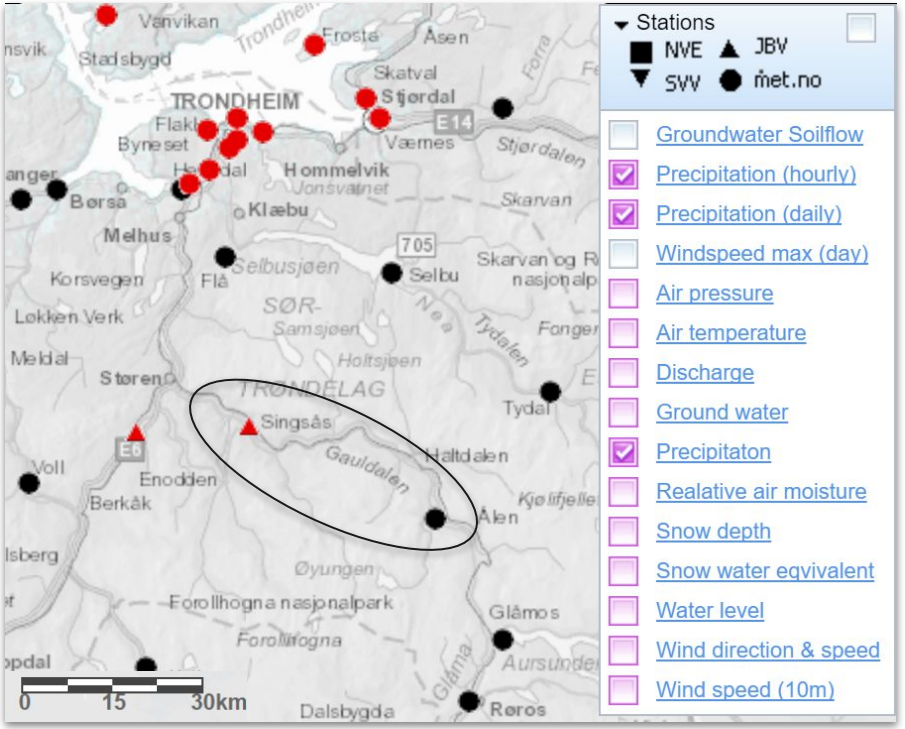
2. Semi-automate daily reporting and forecast process (NVE)

- Challenges: manual, time consuming, repetitive task. Information manually extracted after.
- Benefits:
  - improve efficiency, and consistency in reporting.
  - Retrieve and use historic forecasts to improve models more easily.
  - Trial using pattern recognition on forecasted weather formations.
- Recommend: Multi-consult to support NVE?



3. Improve meteorological monitoring in vulnerable areas

- Target problematic areas with insufficient monitoring.
- Install equipment and collect data.
- Analyse local triggering thresholds.



xgeo.no

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Knowledge gaps to be filled by KLIMA 2050 (WP3)

- **Consistent and verifiable procedures for the mapping of hazard, susceptibility, vulnerability and risk for debris flows at a local or regional scale.**
- Accurate methods for the vulnerability assessment of critical infrastructure to water-triggered landslides, including interactions with other hazards and cascading risks.
- **Reliable local/regional early warning systems for debris- and mudflows.**
- **Reliable regional geomechanical models for real-time assessment of landslide hazard during a storm event.**
- Environmentally friendly methods for the improvement of drainage and slope stabilization.
- Cost-effective and sustainable methods for constructions to act as barriers and/or diversion structures to protect the elements of risk from landslides, particularly in challenging terrain.
- Relevant procedures for managing landslide risk at various levels (municipality, regional).

Extract/summary from project description dated 2014-11-24