ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

IŞIK ÜNİVERSİTESİ

PHOTOGRAMMETRIC MONITORING OF AN ARTIFICIALLY GENERATED LAND SLIDE

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- **TRAMM** (**T**riggering of **Ra**pid **M**ass **M**ovements in Steep Terrain) an inter-disciplinary project conducted in cooperation of
  - Swiss Federal Research Institute WSL,
  - ETH Zurich, and
  - EPF Lausanne.

- The primary goal: to improve the **quantification** and **predictability** of hazardous mass movements, such as **landslides**.

- Artificial landslides were generated, and the **mass dynamics were studied numerically**.

- **Two artificial rainfall** events in Ruedlingen (Switzerland), conducted in
  - autumn 2008 and
  - spring 2009 (resulted in mobilising about 130 m^3 of debris).

- **Spatial behaviour** of the land slides was monitored using the photogrammetric technique.

CONTENT

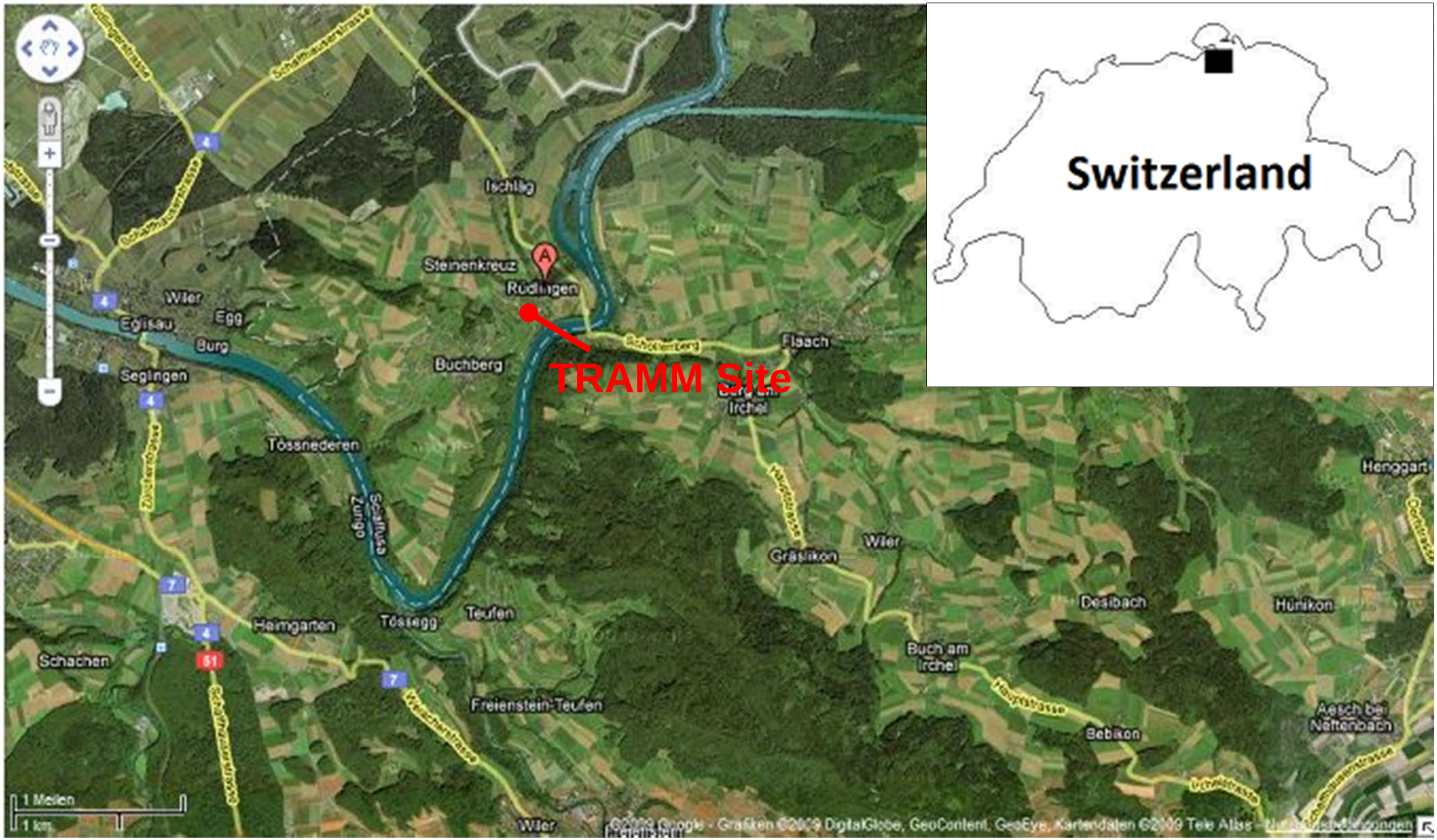
- **Test site in Ruedlingen**

- **The First Experiment**
  - Network design
  - Simulation
  - Equipments & installation
  - Calibration & orientation
  - Point positioning

- **The Second Experiment**
  - Network design
  - Calibration
  - Point positioning

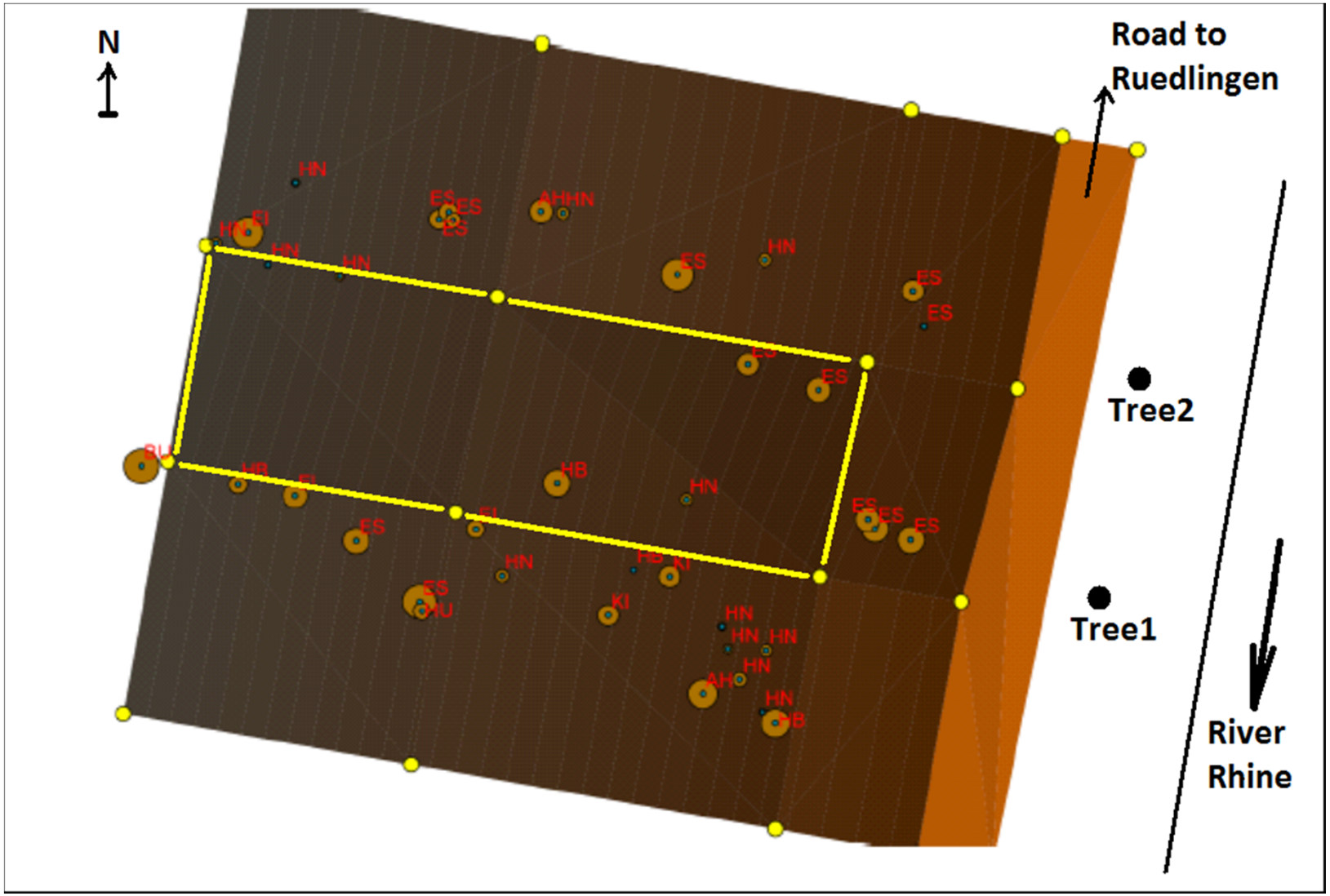
- **Land slide**
- **Conclusions**

Location: Close to Ruedlingen, a small town in the north of Switzerland.

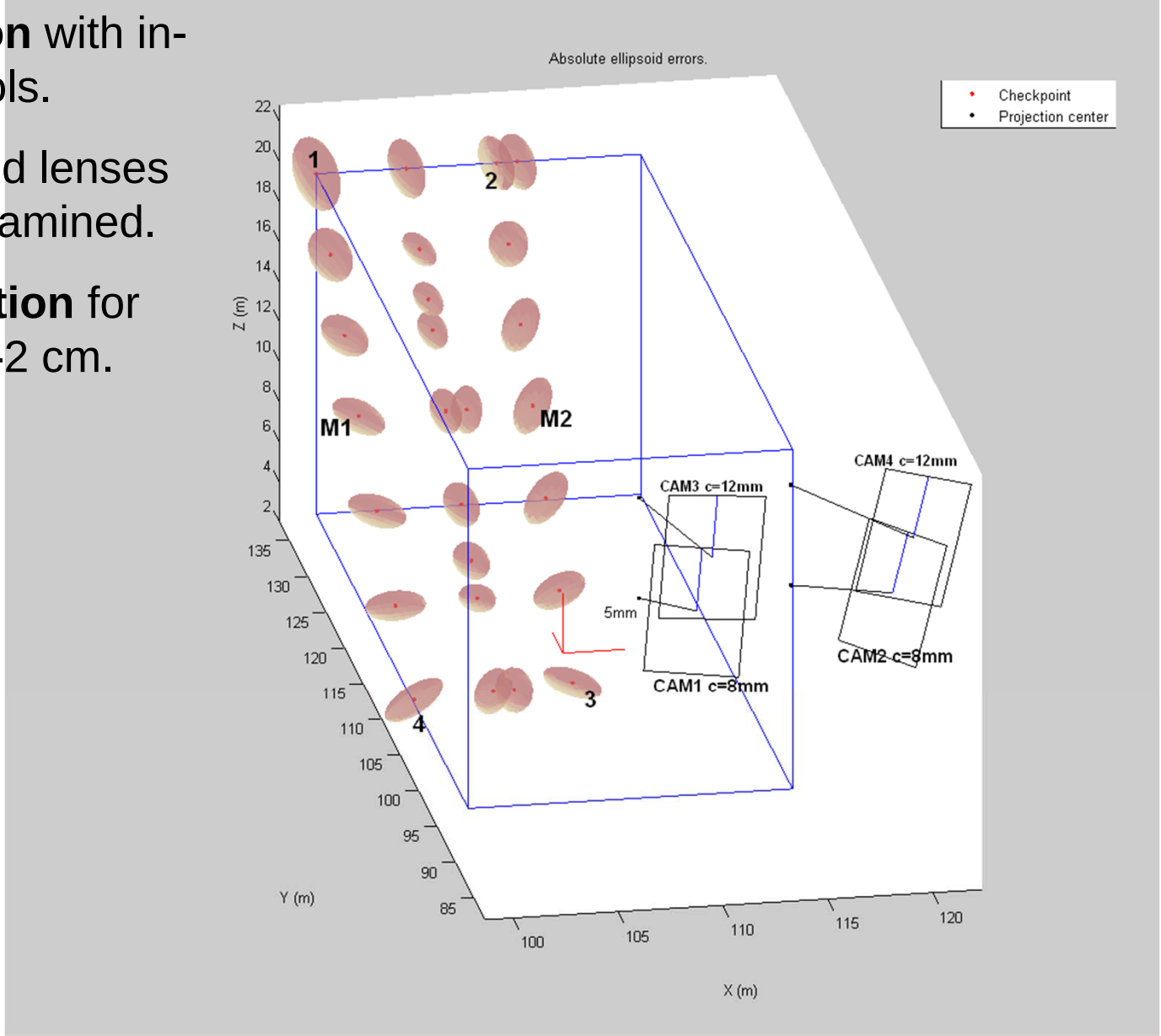


- **Size of the test site:** 10m x 35m.
- Average **slope** 38 degree.

- **Two tall trees** (Tree1 & Tree2), approx. 25m in height, selected to set-up the cameras.
- A **4-camera arrangement**, 2 cameras per tree.



- **Network simulation** with in-house developed tools.
- Camera formats and lenses were interactively examined.
- **Design consideration** for point positioning ± 1-2 cm.



Based on the network simulations, **hardware** components decided.

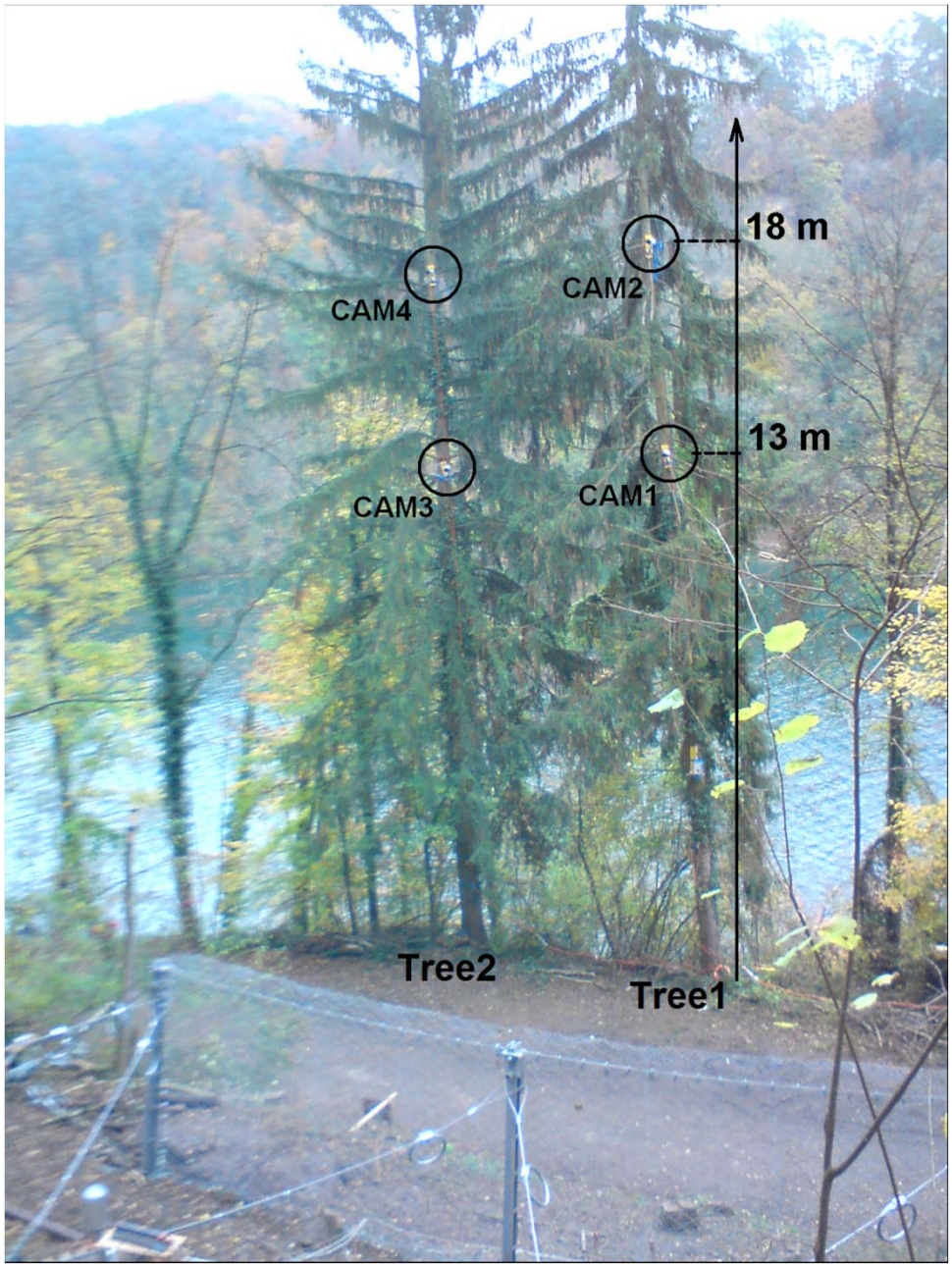
IDS UI-6240 M

- 1280 x 1024 pixel
- **CCD**, global shutter
- 14 fps
- 4.65 micron pixel pitch
- Gigabit Ethernet

- 2 Cams x 8.0mm lens
- 2 Cams x 12.0mm lens

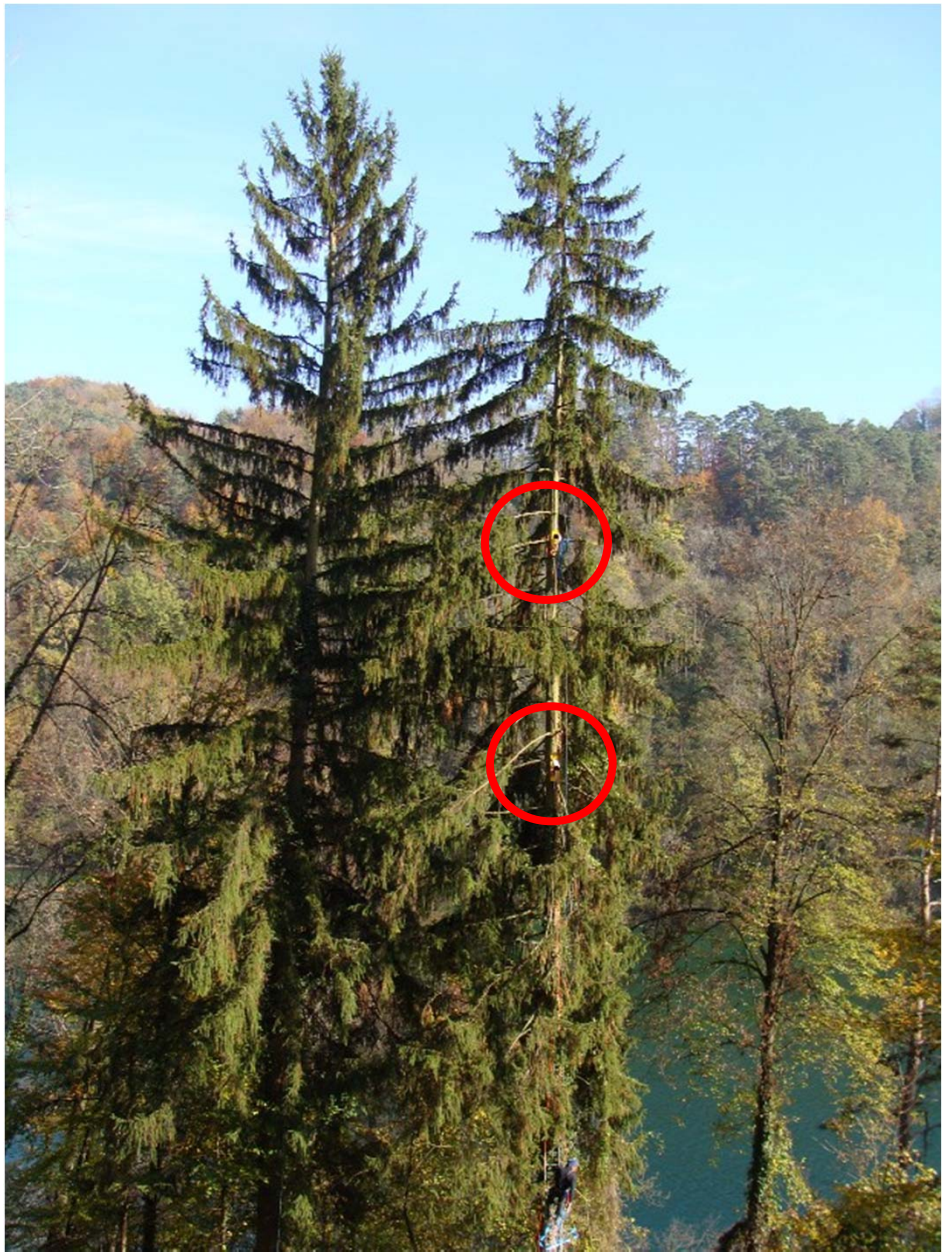
Equipments and installation

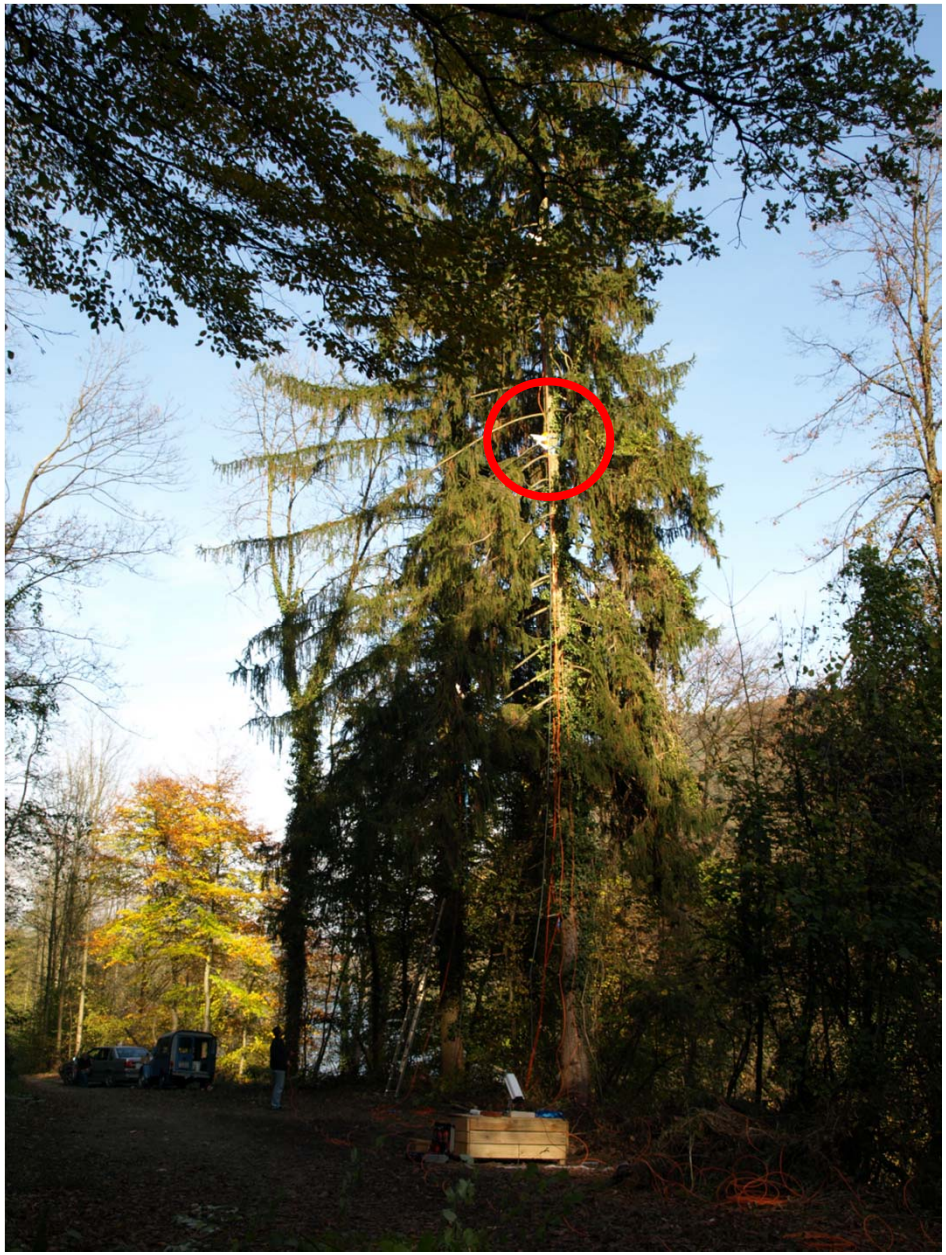
- CAM1 and CAM3, equipped with **8 mm** C-mount lenses, directed towards the **bottom** side,
- CAM2, and CAM4, equippped with **12 mm** C-mount lenses, directed towards the **upper** side.



Cameras placed in **housing shields**, which protect them against snow, rain and other environmental effects.

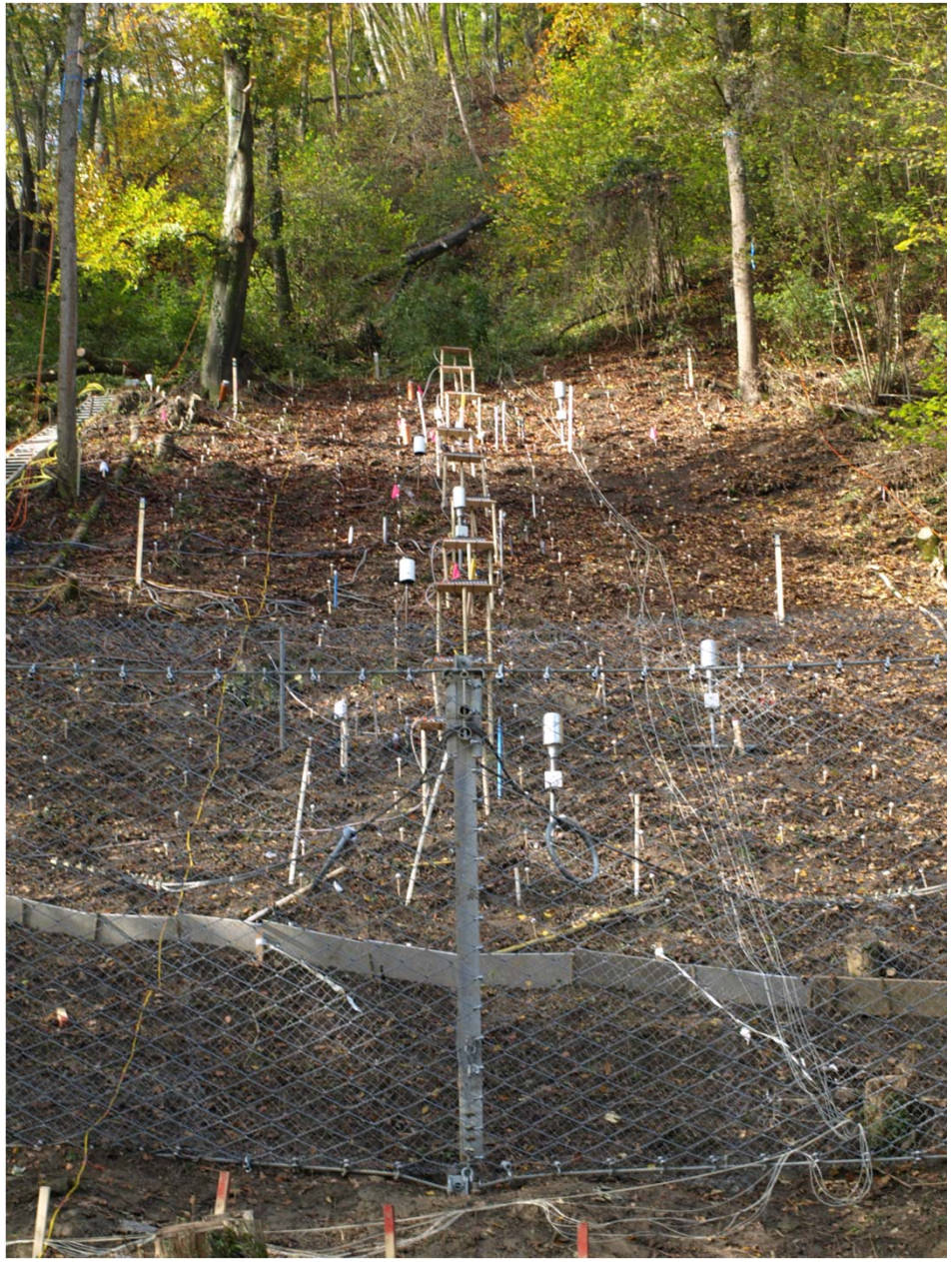
Four cameras fixed on **two** trees by **a professional climber**.



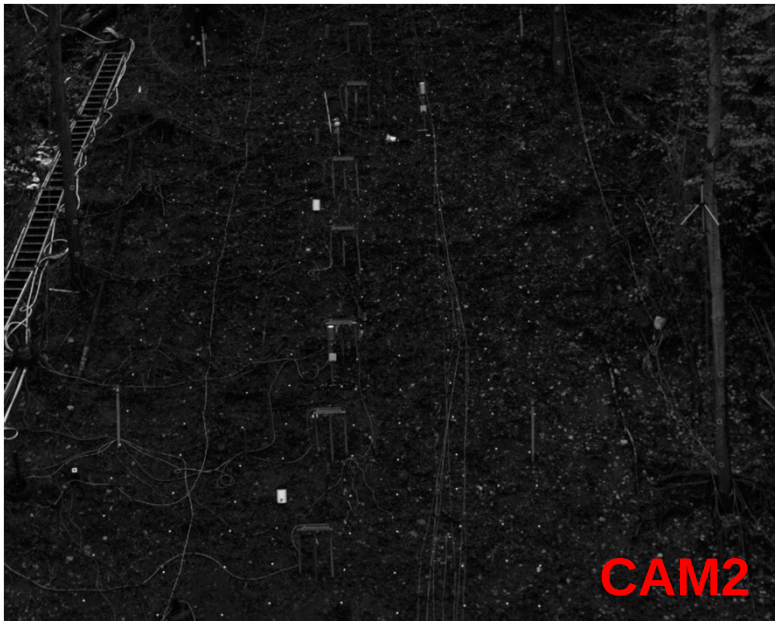


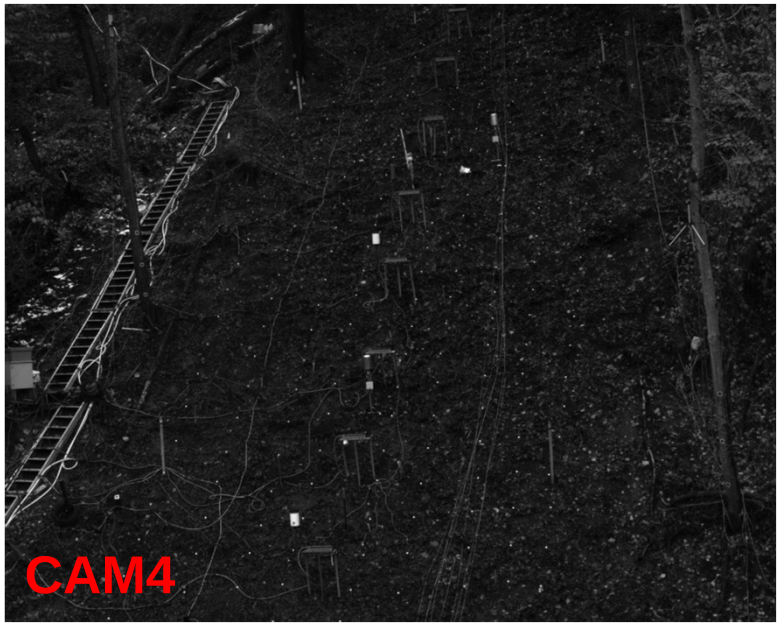
- Cameras connected to a central computer using 100 m **Cat-6** Ethernet cables.
- The control computer was a **Supermicro server**
  - Intel Xeon QuadCore 2.33 GHz CPU,
  - 4 GB DDR2 RAM memory,
  - 16x 250 GB 7200 rpm SATA II harddisks and
  - MS Windows Server 2003 R2 Enterprise OS.
- An Intel Pro/1000 PT Quad Port **NIC** used for the **Ethernet protocol comm**.

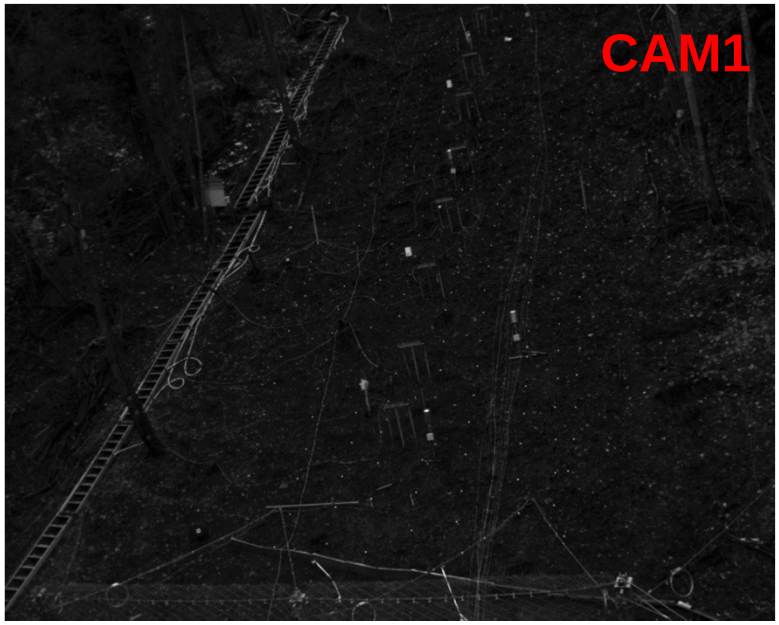
250 white **ping-pong balls** (with 40 millimeter diameter) glued on 20-30 centimeter wooden sticks.

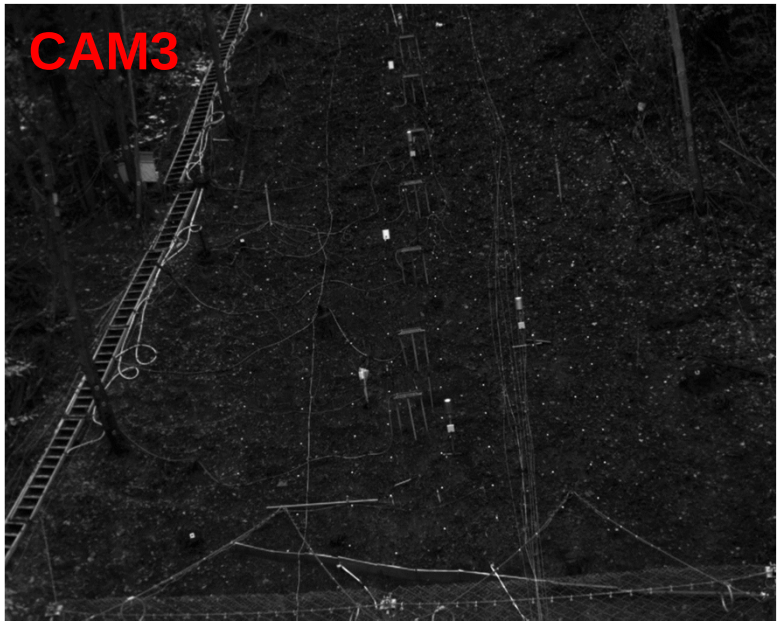


- The **camera calibration** was performed in the field.
- **Ten consecutive image frames** were measured for each of the four cameras.
- The collected image measurements were input to a **self-calibrating bundle block adjustment** procedure.
- Since the camera stations on two tall trees were **not stable platforms** and were moving with the wind, the exterior orientations of the cameras were calculated for each camera/image frame **individually**, by use of the GCPs.


CAM2


CAM4


CAM1


CAM3

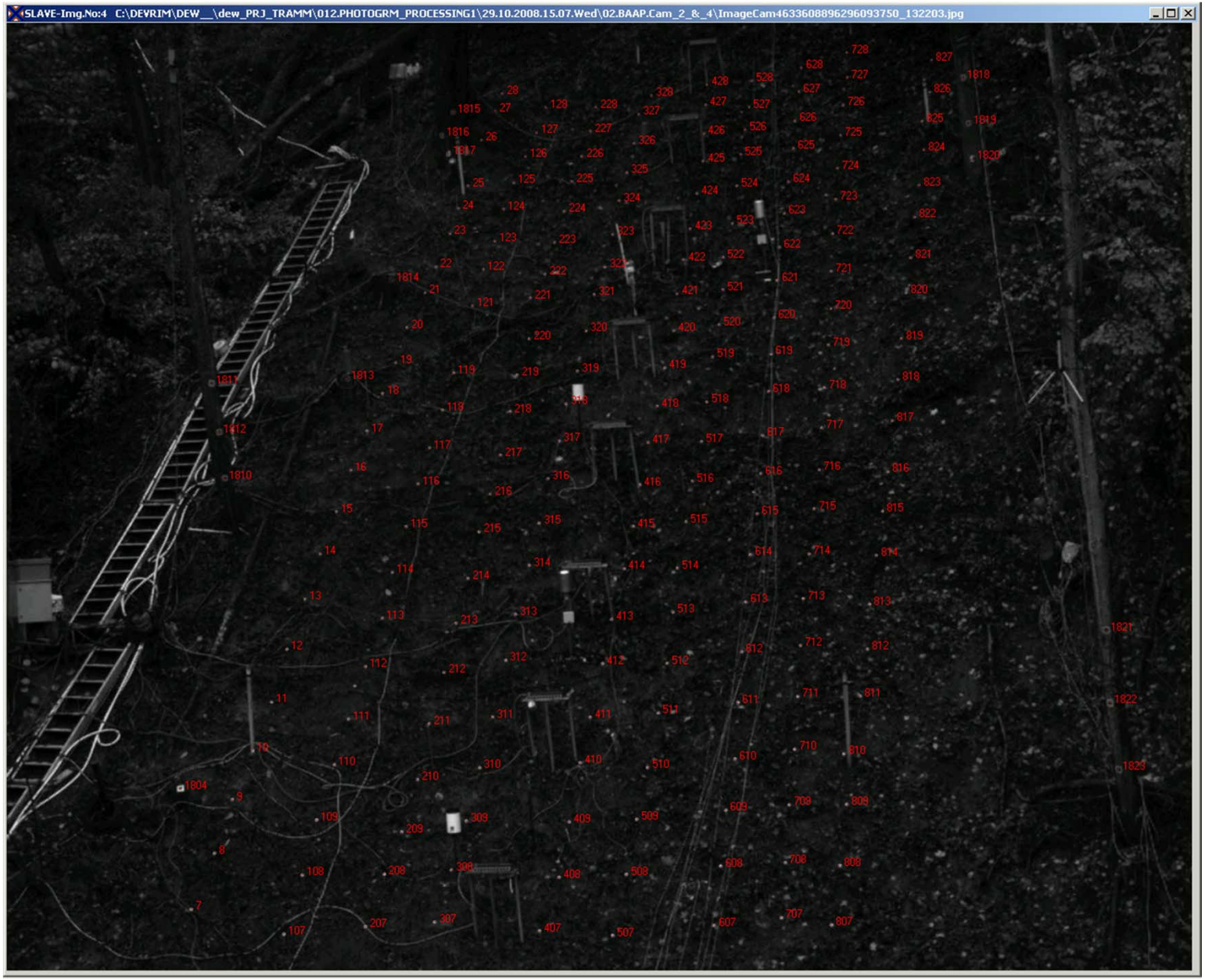
- The **TRAMM-I experiment** started on October 28, 2008.
- The **four cameras continuously** worked on **four days.**
- Gathered approximately **350 GB of** image data.

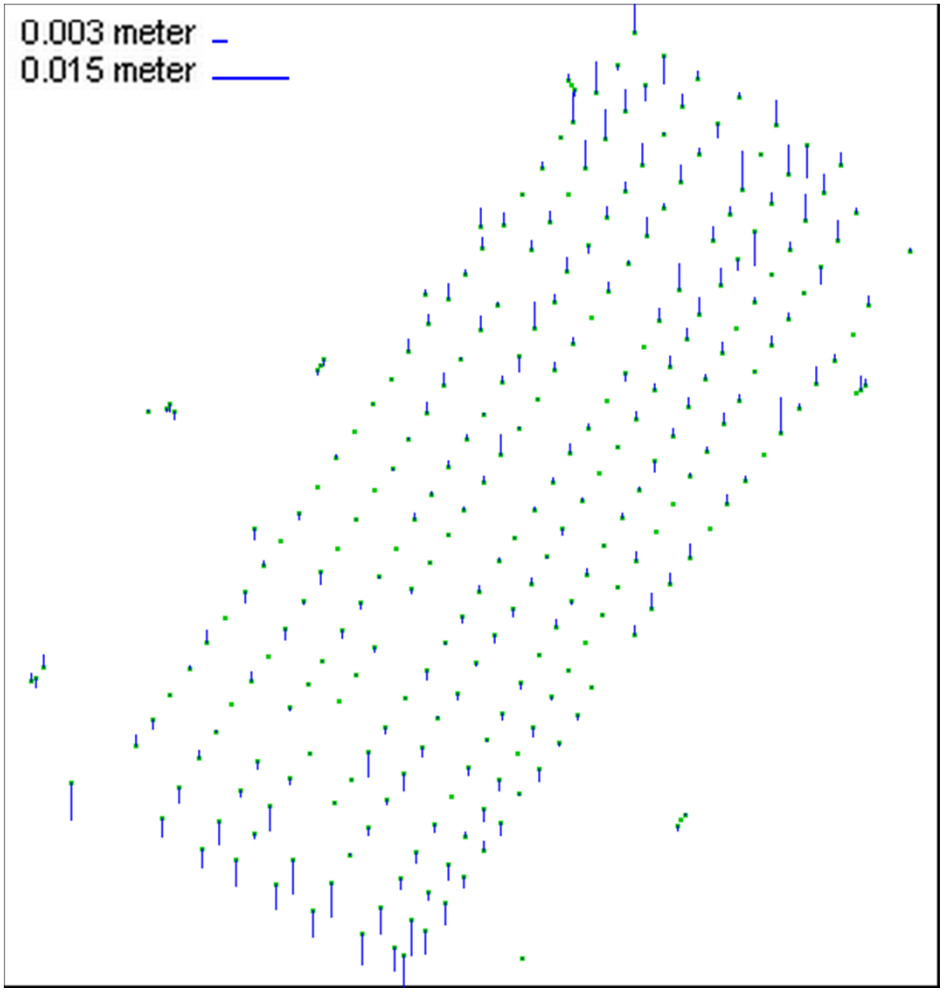
- Some deformations were measured in the top right quarter of the field, but the **landslide did not occur**.

- Only **three epochs** of the entire image set were processed.
  - **October 28**, at 3:12 pm,
  - **October 30**, at 3:16 pm,
  - **October 31**, at 3:00 pm.

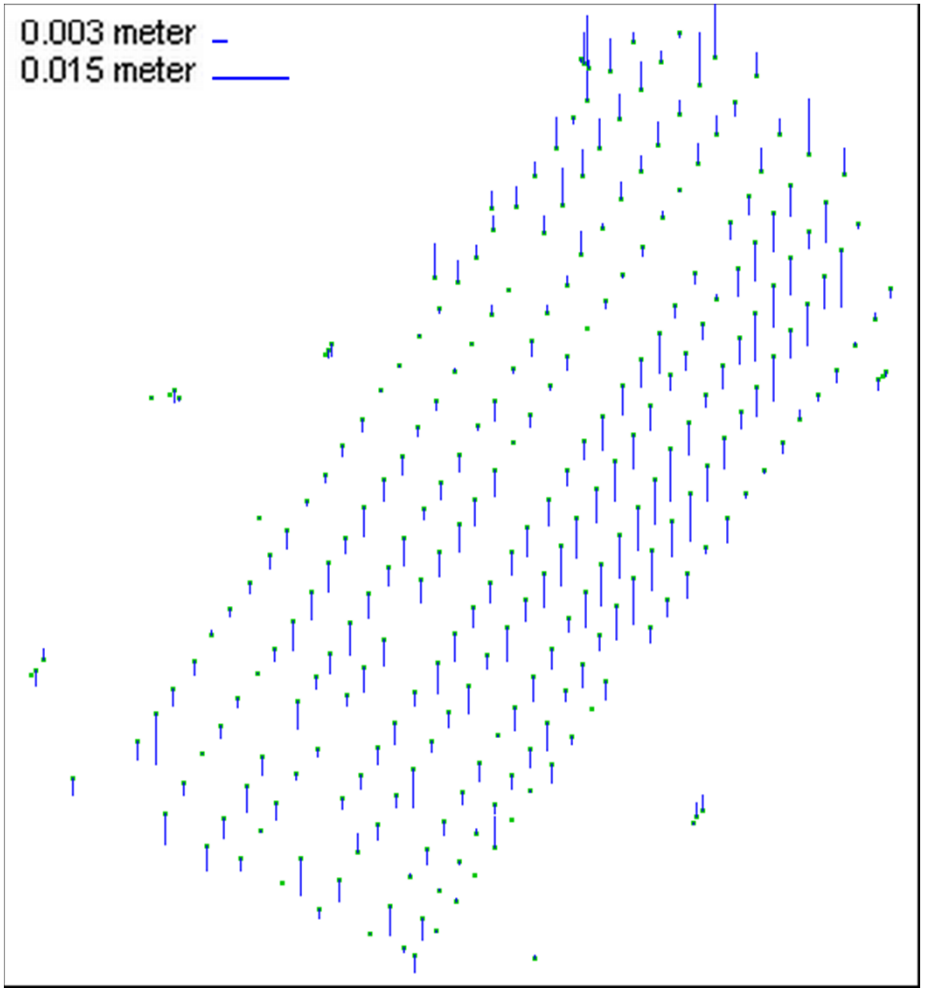
An example of the **CAM4** day time images.

Semi-automatic **Image measurement** with BAAP software.





Surface deformation between October 28 – October 29.



Surface deformation between October 28 – October 31.

THE SECOND TRAMM EXPERIMENT

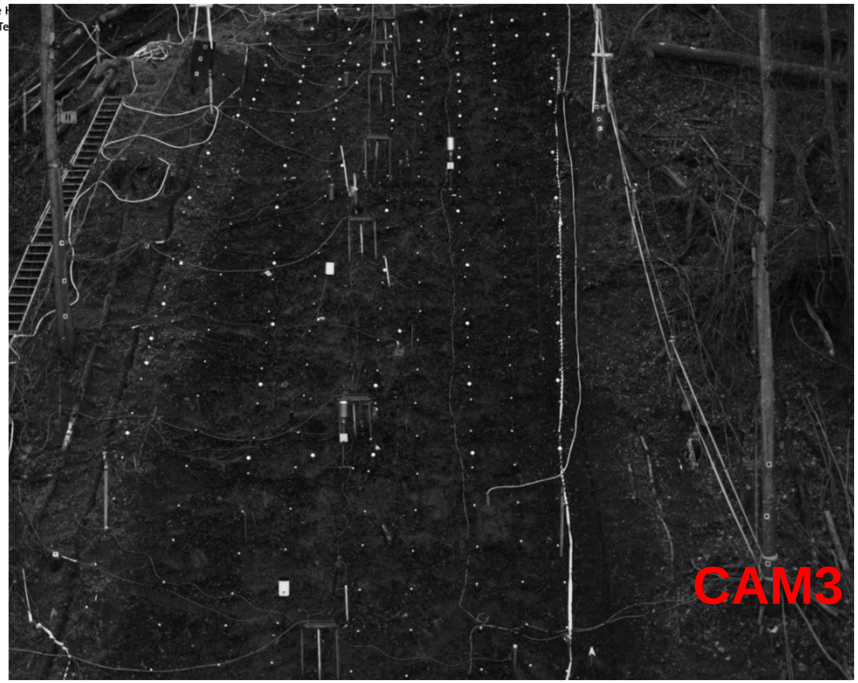
- There was less permeable base rock underlying the top of slope.
- Therefore, **the area of interest** was moved approx. 5 meters up the slope.

- Photogrammetric network design & simulation steps repeated.
- Similar camera arrangement.
- Ping-pong balls → **tennis balls**.

Laboratory Camera Calibration

- In-door testfield
- Self calibrating bundle adjustment
- Point measurement with LS image matching

	So	Average StdDev X-Y-Z at CHK+TIE points		
CAM1	0.34 micron	0.221	0.477	0.151 mm.
CAM2	0.34	0.187	0.330	0.129
CAM3	0.40	0.141	0.331	0.114
CAM4	0.35	0.134	0.365	0.120


CAM3

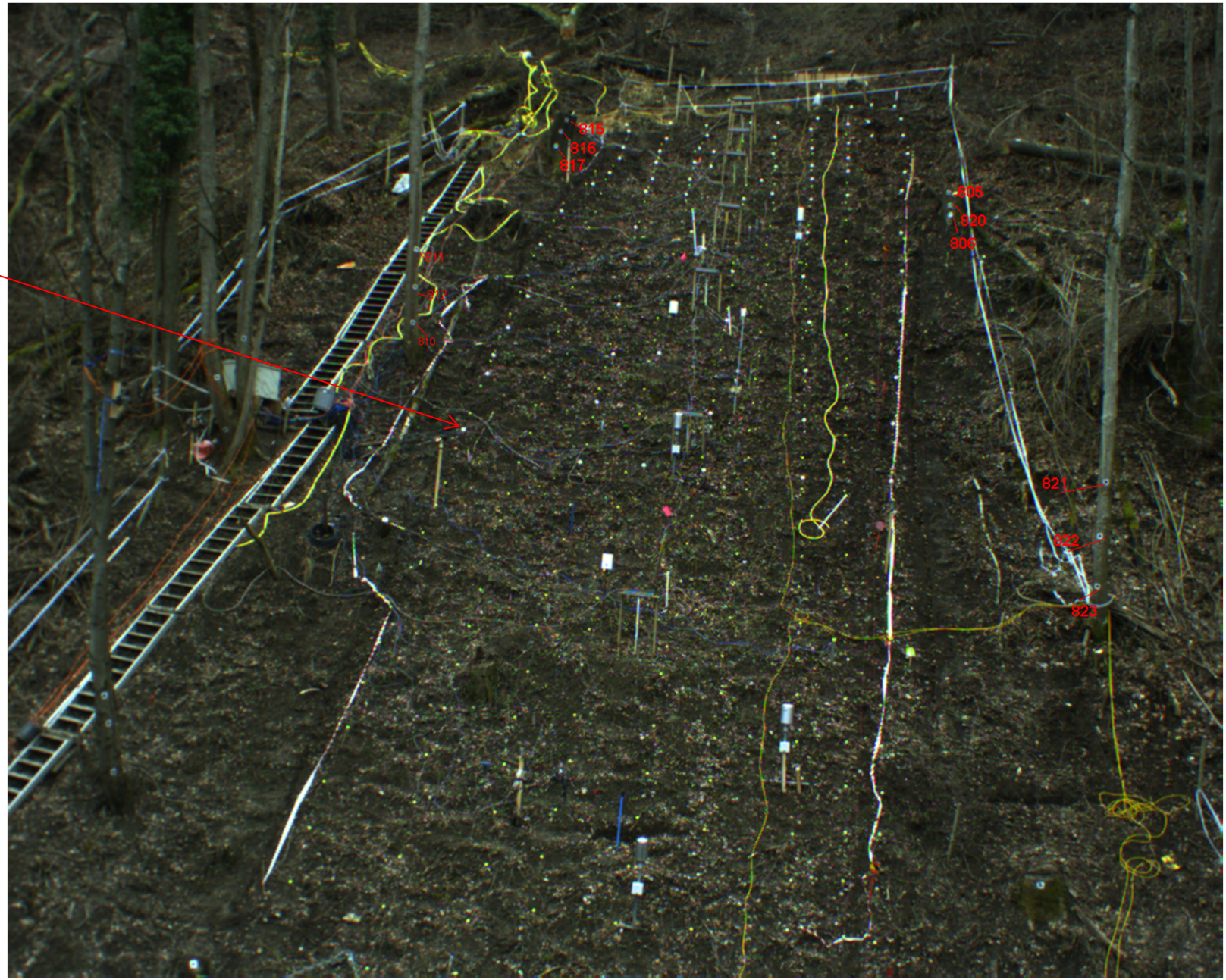

CAM4


CAM1

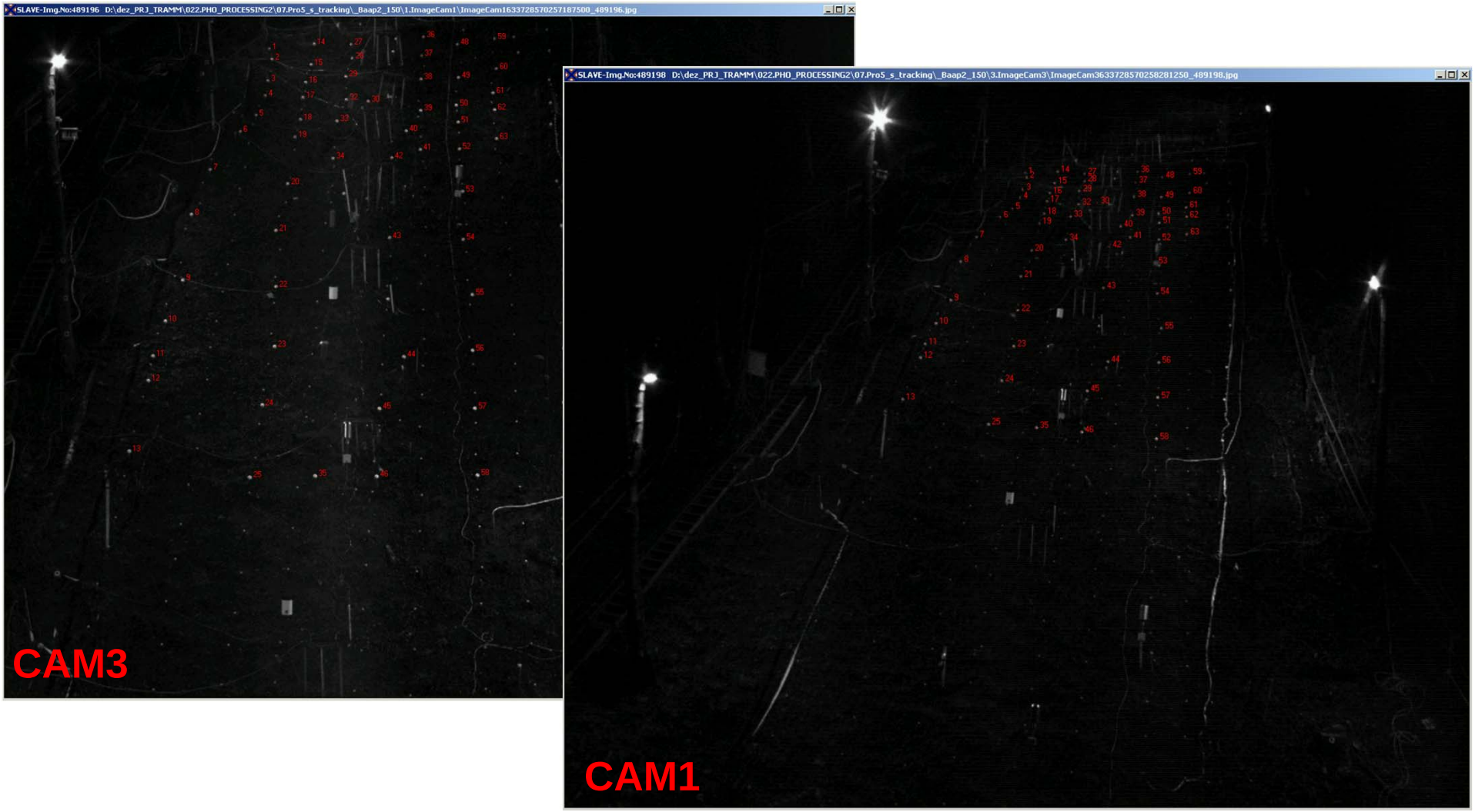

CAM2

12 GCPs

Tennis balls as targets



Automatic Image Tracking & Measurement



Automatic image measurement with image tracking + cross-correlation

- **TRAMM-II** experiment was started on March 16, 2009 at 3:28 pm.
- The **land slide occurred** on March 17, at 3:23 am.
- It took 36 seconds **to mobilize about 130 m3** of soil and roots.

[MOVIE]

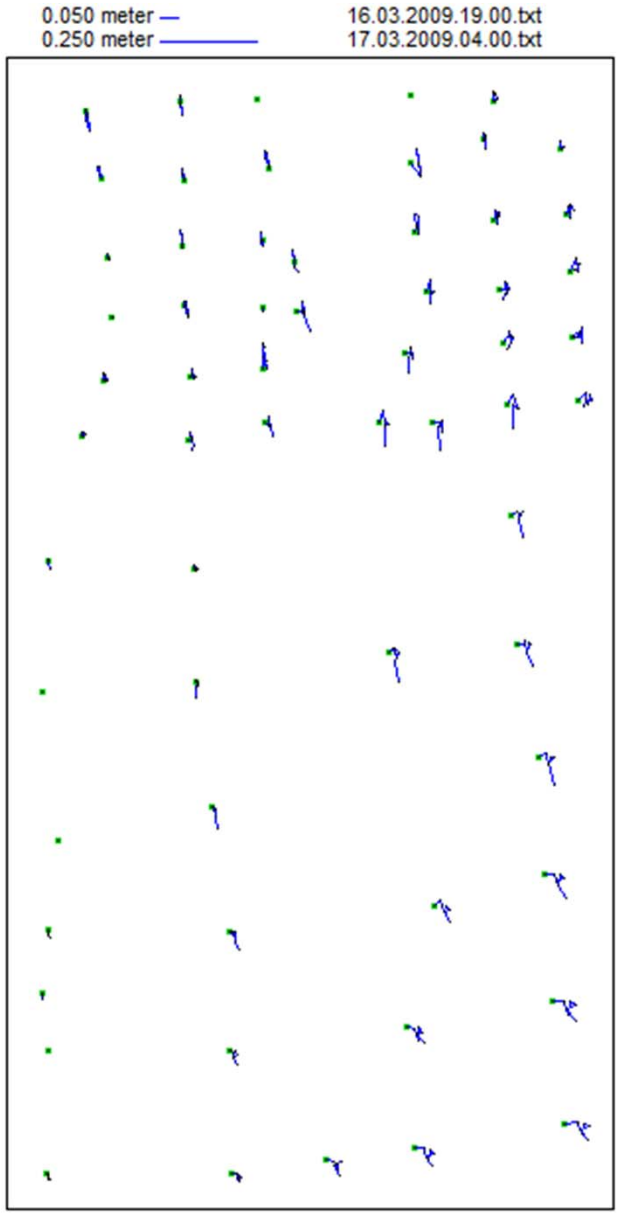
The images were processed in **three temporal frequency** groups:

• **Hour-by-hour**:
1 frame per hour (**1 fph**) starting from 6:00 pm until 3:00 am,
totally 8 epochs, and 8x4 = **32 images**.

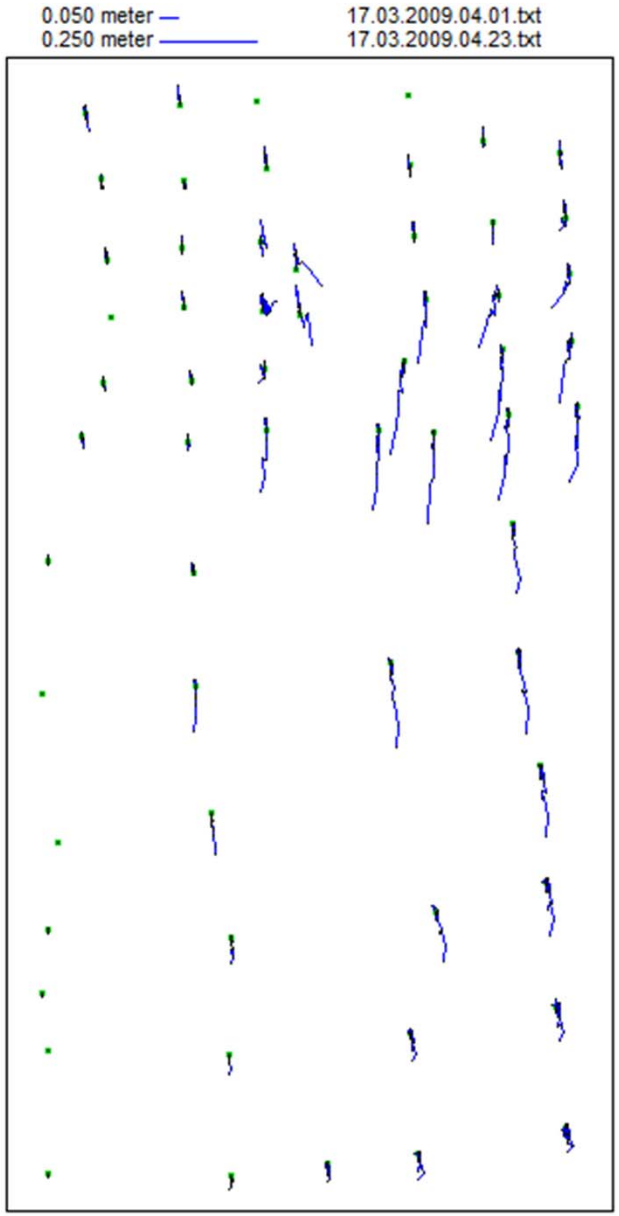
• **Minute-by-minute**:
1 frame per minute (**1 fpm**) starting from 3:01 am until 3:23 am,
totally 23 epochs, and 23x4 = **92 images**.

• **Original imaging frequency**:
5 frames per second (**5 fps**) starting from 3:23:00.000 am until 3:24:00.909 am,
totally 263 epochs, and 263x4 = **1052 images**.

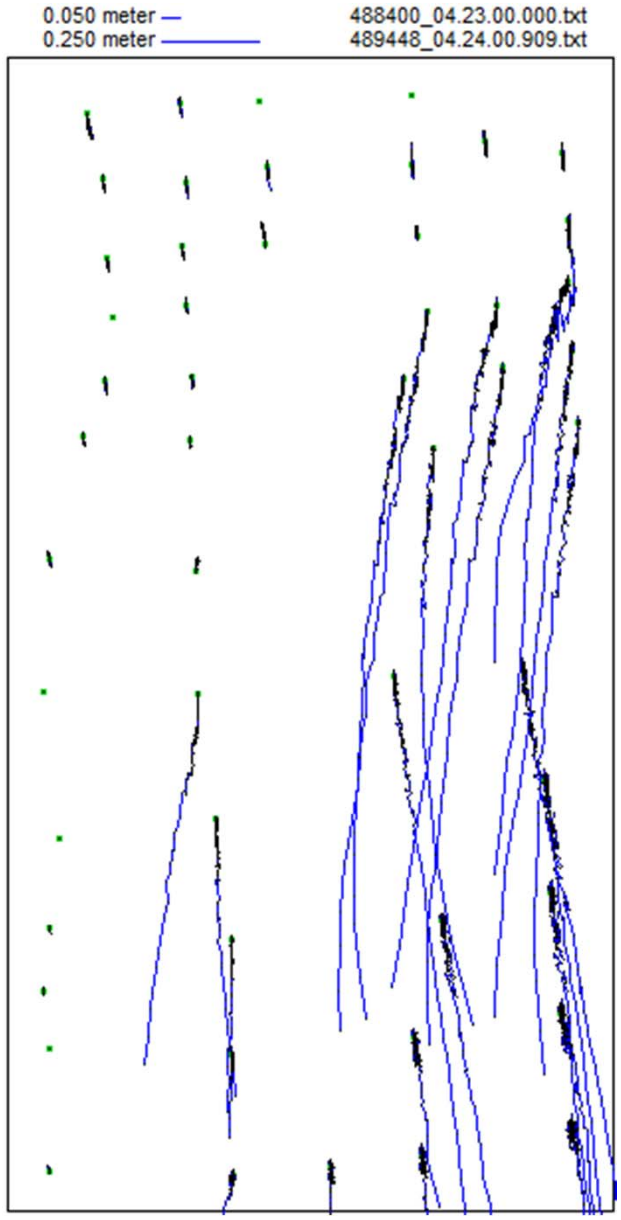
Horizontal displacements of the tennis balls



1 fph between
6:00 pm and 3:00 am

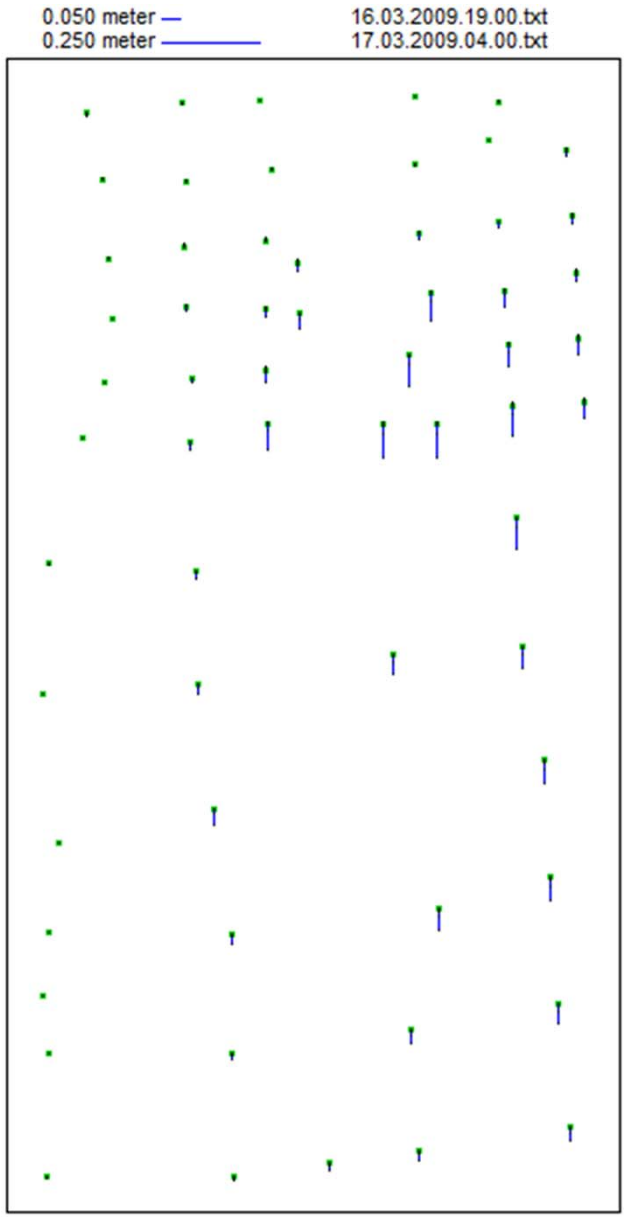


1 fpm between
3:01 am and 3:23 am

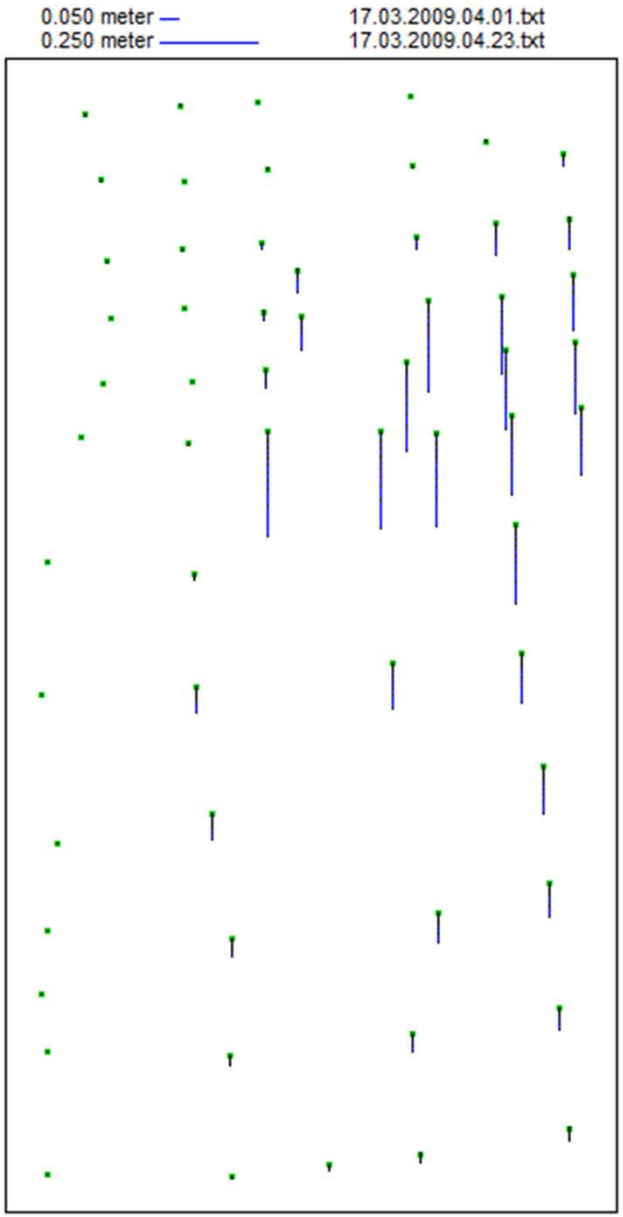


5 fps between
3:23 am and 3:24 am

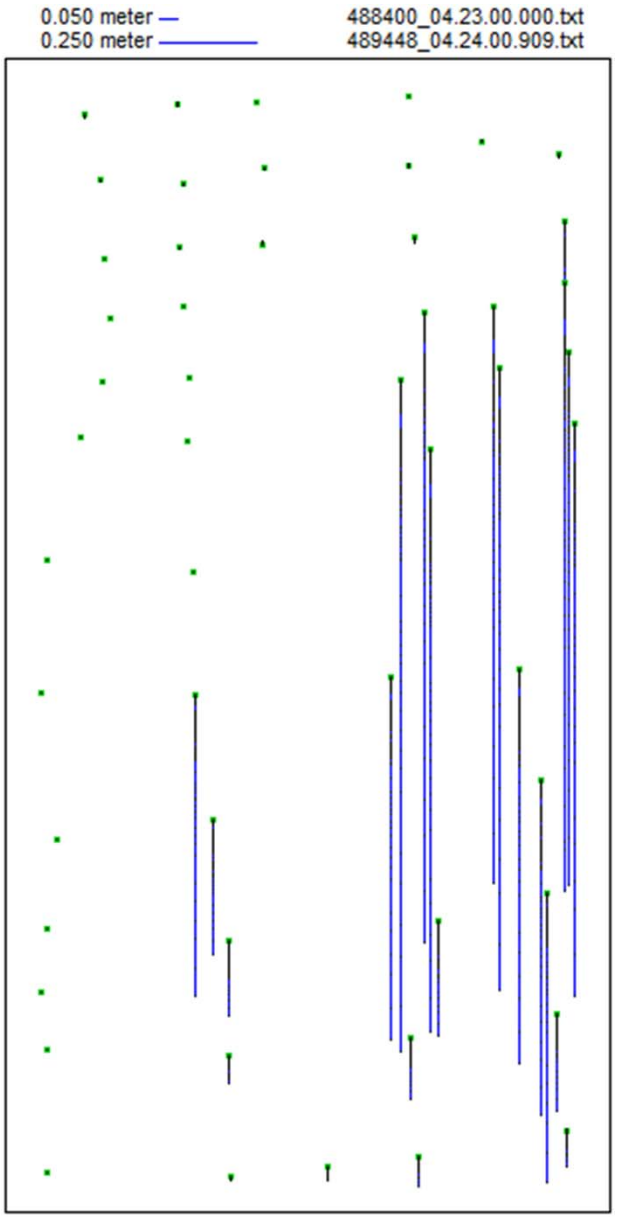
Vertical displacements of the tennis balls



1 fph between
6:00 pm and 3:00 am



1 fpm between
3:01 am and 3:23 am



5 fps between
3:23 am and 3:24 am

The landslide occurred between 3:23 am and 3:24 am.

In this time span,
the upper right quadrant flowed along the slope with
an **average speed of 14.0 cm/seconds**, and
a **maximum speed of 100.4 cm/seconds** was reached at some locations.

CONCLUSIONS

• A photogrammetric network was **designed** and **installed** to monitor an artificially triggered **landslide**.

• Photogrammetry is a **cost-effective** and **accurate** method for such tasks.

• The surface deformation was **quantified** by tracking the small (ping-pong and tennis) balls pegged on the ground.

• The **average 3D point-positioning precision** of
±1.6 cm was achieved in the **first experiment** and
±1.8 cm in the **second experiment**.

• The results of the photogrammetric work provide a better understanding of surface dynamics of landslides.

THANK YOU FOR YOUR ATTENTION.