Press Release

Belgian researchers involved in a study of a climate-change-triggered landslide causing Earth to vibrate for 9 days

***** Embargoed: Not for Release Until**
14:00 U.S. Eastern Time Thursday, 12 September 2024 (18:00 GMT/20:00 CEST) ***

At this time, the paper will be available via the following link:
http://www.science.org/doi/10.1126/science.adm9247
"A rockslide-generated tsunami in a Greenland fjord rang Earth for 9 days"

A mysterious, globally observed and unprecedented 9-day-long seismic signal that started on 16 September 2023 was caused by a massive landslide in Greenland. 25 million m^3 of rock and ice fell into the remote Dickson Fjord and, in turn, caused a 200 metre-high mega-tsunami that continued sloshing back and forth - a phenomenon called a *seiche* - in the narrow fjord for 9 days. That is the conclusion of research published in the journal *Science.* This movement of a large mass of water generated vibrations through the Earth, shaking the planet and radiating globally observed seismic waves. Never before have scientists, including researchers of the Royal Observatory of Belgium (ROB), the Flanders Marine Institute (VLIZ) and the Université libre de Bruxelles (ULB), observed such an unusual mechanism causing a global seismic signal.

A mysterious seismic signal lasting 9 days, recorded on highly sensitive sensors all over the globe, from the Arctic to Antarctica, puzzled seismologists from ROB and ULB. The signal looked completely different to frequency-rich earthquake recordings - it contained only a single vibration frequency, like a monotonous-sounding hum. At the same time, news of a large tsunami in a remote North East Greenland fjord reached authorities and researchers from VLIZ working in the area. The both teams joined forces with a multidisciplinary international group of 68 scientists from 40 institutions in 15 countries, combining seismometer and infrasound data, unique field measurements, on-the-ground and satellite imagery, and simulations of tsunami waves. The team also used imagery captured by the Danish military who sailed into the fjord just days after the event to capture the collapsed mountain-face and glacier front along with the dramatic scars left by the tsunami. This unique harmony of local field data and remote, global-scale observations allowed the team to solve the puzzle and reconstruct the extraordinary cascading sequence of events in September 2023. The results are now published in *Science*.

The local signal was picked up by a real time monitoring network set up in the Kong Oscar Fjord System by VLIZ and Aarhus University, including cameras and oceanographic moorings, to study climate gradients and freshwater dynamics. Oceanographic sensors in Dickson Fjord and near Ella Ø measured anomalous water levels and peak turbidity. The global seismic signal was picked up by a global network of seismometers; sensitive scientific instruments that record vibrations travelling through the ground - called seismic waves. Traditionally, seismology focuses on measuring seismic vibrations arising from earthquakes in the ground. However, seismic records can also contain information about movements of large masses on Earth's surface, such as landslides and water waves. The study found that the landslide was from the collapse of a mountaintop that previously towered 1.2 km above the fjord. The volume of material that collapsed was massive - more than 25 million cubic metres - or 27 times the volume of all 20 ft containers on world's largest container vessels (circa 24 000 per vessel or 650 000 containers). This collapse was caused by glacial thinning at the base of the mountain over recent decades, ultimately caused by climate change.

The combined signals were so puzzling, that one of the scientific team members tried to recreate the long-lived sloshing effect in their bathtub at home. They failed to simulate the same effect, so it was left to detailed mathematical models to show that the landslide direction, together with the uniquely narrow and bendy fjord channel, was the last missing piece of the puzzle of how climate change rang the Earth for 9 days. The predictions showed that water sloshed back and forth every 90 seconds, the same oscillation period observed in the seismic waves. This perfect match shows how the force of the moving water body, generating a distinct oscillation due to the width and depth of the fjord, creates seismic energy in the crust.

Co-author Thomas Lecocq (Royal Observatory of Belgium, ROB) says: "*Our initial estimates of its source position centred on East-Greenland. At the same time, Greenlandic and Danish authorities received reports of a large tsunami at the (then unoccupied) Nanok station and research base at Ella Island. As an interdisciplinary and international research team, we have integrated all the information to present a detailed reconstruction of the first documented large, tsunamigenic landslide for East-Greenland and how it generated global very long-period seismic signals. It's amazing that what started as a routine check of a Belgian gravity sensor turned into a global, multi-disciplinary collaboration, with virtual, online exchanges over 24/7, covering many time zones. I'm happy we proved the source of the vibrations was water sloshing, and that this adventure led to new collaborations with colleagues all over the world, including Wieter Boone from VLIZ who is now installing seismic instruments from the ROB in Dickson Fjord to further advance our understanding of this unique area".*

Numerical simulations, data from a local oceanographic sensor network, satellite and on-the-ground imagery confirm that the resulting mega-tsunami is one of the highest seen in recent history. Further out of the fjord, 4 m high tsunami waves damaged a research base at Ella Ø (island) 70 km away and destroyed cultural and archaeological heritage sites across the fjord system. The fjord is on a route commonly used by tourist cruise ships visiting the Greenland fjords. Fortunately, no cruise ships were close to Dickson Fjord on the day of the landslide and tsunami, but if they had been, the consequences of a tsunami wave of that magnitude could have been devastating. With rapidly accelerating climate change, it will become more important than ever to characterise and monitor regions previously considered stable and provide early warning of these massive landslide and tsunami events.

Co-author Wieter Boone (Flanders Marine Institute, VLIZ): *"For our research, we have established a network of real-time oceanographic stations in northeast Greenland. Last year we sailed in through Dickson Fjord to install instruments close to a glacier and almost right in front of the mountain, just weeks before it collapsed. Our instruments survived the tsunami and we were able to monitor events in real time. The observed destruction of an ancient trapper's hut, which had never been hit by tsunamis in its centuries-long history, shows the unexpected magnitude of this event. During the investigation into the cause, an exceptionally dynamic and international collaboration emerged in which the team from KSB played an impressive and central role. This summer we were back in the area. We updated our sensor network, mapped the impact of the tsunami using drones and installed high-frequency seismic and water level sensors in Dickson Fjord."*

Notes

Contact **ROB**: Royal Observatory of Belgium, Brussels, Belgium, Thomas Lecocq (02/3730316; 0471320065, Thomas.Lecocq@seismology.be)
Contact **VLIZ**: Flanders Marine Institute, Ostend, Belgium, Wieter Boone (0485/93.64.07; wieter.boone@vliz.be)
Contact **ULB**: Université libre de Bruxelles, Brussels, Belgium: Corentin Caudron (corentin.caudron@ulb.be)

Belgian contributing institutions

- Royal Observatory of Belgium, ROB, Brussels, Belgium
- Flanders Marine Institute, VLIZ, Ostend, Belgium
- Université libre de Bruxelles, ULB, Brussels, Belgium

Visualisations [files available from a directory that can be accessed using this link]:

Static imagery:

- Before (August 2023) and after (September 2023) photos of the mountain peak and glacier, taken from the fjord:
    - Before: ***glacier_landslide_comparison_before-2023-08-12_SorenRysgaard.jpeg*** (credit: Søren Rysgaard)
    - After: ***glacier_landslide_comparison_after-2023-09-19_DanishMilitary.DNG*** (credit: Danish Army)
    - Annotated version labelling the key features: ***glacier_landslide_comparison_annotated.png*** (credit: Søren Rysgaard, Danish Army).
- After (August 2024) photos of the rockslide gully with the destroyed glacier, boat for scale: **12_Dickson_2024_glacier3_Soren_Rysgaard.jpg** (credit: Søren Ryesgaard)
- Two photos (same as in below GIF) shows Sentinel-2 satellite images of the mountain peak before and after the landslide Image credit (image credit Copernicus, Sentinel-2, EO browser):
    - Before: ***2023-07-14-00_00_2023-07-14-23_59_Sentinel-2_L1C_Highlight_Optimized_Natural_Color_cet.png***
    - After: ***2024-07-14-00_00_2024-07-14-23_59_Sentinel-2_L1C_Highlight_Optimized_Natural_Color_cet.png***
- Record section showing the recorded seismic waves plotted against distance from the landslide (1 degree = 110 km; 180 degrees = antipodal to Greenland), available in two forms:
    - Wiggles plotted as black lines: ***Record_90dists_wiggle.[png|pdf]***
    - The wiggles filled with red (positive amplitude) and blue (negative amplitude colours): ***Record_90dists_waterfall.[png|pdf]***
- Pre- (30 minutes before) and post-landslide (7 minutes after) Planet Labs satellite image: ***PlanetLabsSatelliteBefore-After.png***

Movies / animations:

- GIF animation - available to download here - shows Sentinel-2 satellite images of the mountain peak before and after the landslide: ***S2L1C-392043945839491-timelapse.gif*** (image credit Copernicus, Sentinel-2, EO browser)
- Ground motion visualisation animations showing the very long-period seismic wave propagating around the globe (shown as vertical up-and-down motion):
    - The left panel shows a ground motion visualisation, showing the seismic wave from the Greenland seiche spreading out around the planet. Each circle shows the data from an individual seismic monitoring station. The right panel shows a numerical simulation of the 16 September 2023 tsunami and seiche in Dickson fjord ***GMVRotGlobe.mp4*** (music credit: Isabelle Ryder https://isabellerydermusic.weebly.com/; animation credit: Stephen Hicks; Kristian Svennevig; Alexis Marbeouf)**.**
    - Same as above, but also showing a numerical simulation of the tsunami and seiche process in the fjord ***GMVrotglobe_seichesim.mp4*** (music credit: Isabelle Ryder https://isabellerydermusic.weebly.com/; animation credit: Stephen Hicks)**.**
- Two videos recorded of the landslide area three days after the landslide in the fjord. Image credit Danish Army, Joint Arctic Command:
    - ***droneimagery-1-DanishMilitary.MP4***
    - ***droneimagery-2-DanishMilitary.MP4***
- Animated, sonified seismic signal (seismic waves sped up and converted to audible frequencies) as recorded by a seismic station in Greenland, DK.SCO: ***video_sonification.mp4***
- Animation of the modelled/simulated tsunami waves and seiche in Dickson Fjord: ***MovieS2.mp4***
- Annotated GIF-animation of the pre and post-event images. Source image credits: Søren Rysgaard, Danish Army. GIF-animation: Carsten E. Thuesen: **DicksonFjd4.gif**

Full list of coauthors' institutions

1. Geological Survey of Denmark and Greenland, Denmark
2. University College London, UK
3. Karlsruhe Institute of Technology (KIT), Germany
4. Seismology - Gravimetry, Royal Observatory of Belgium, Brussels, Belgium
5.University of Stuttgart, Germany
6. Institut de Physique du Globe de Paris, France
7. Université de Strasbourg, Strasbourg
8. U.S. Geological Survey, USA
9. Univ. Grenoble Alpes, France
10. Universität Hamburg, Germany
11. Aarhus University, Denmark
12. Flanders Marine Institute, Belgium
13. Norges Geotekniske Institutt, Norway
14. Royal Netherlands Meteorological Institute, Netherlands
15. ALomax Scientific, France
16. University of California Berkeley, USA
17. University of Aberdeen, UK
18. University of Oxford, UK
19. University of California San Diego, USA
20. Università di Catania, Italy
21. Istituto Nazionale di Geofisica e Vulcanologia, Italy
22. Université libre de Bruxelles, Belgium
23. Wel Research Institute, Belgium
24. University of Padova, Italy
25.Uppsala University, Sweden
26. University of Malaga, Spain
27. Volcanological and Seismological Observatory of Costa Rica
28. Data-Terra / Theia, France
29. Delft University of Technology, Netherlands
30. University of Sevilla, Spain
31. University of California, USA
32. University of California San Diego, USA
33. Ludwig-Maximilians-Universität München, Germany
34.Boston College, USA
35. University of Cambridge, Cambridge, UK
36. Technical University of Denmark, Denmark
37. GNS Science, New Zealand
38. University of Washington,, USA
39. Institut Teknologi Bandung, Indonesia
41. Greenland National Museum & Archives