SnT 2025 8 SEPTEMBER ONLINE DAY 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Interactive Event Detection Assessment of the International Monitoring System

Tormod Kværna[1], Mathias Johansen[1], Tina Kaschwich[1], Håkan Bolin[1], Thibault Arnal[2], Alexander Sudakov[2]

[1]NORSAR; [2]Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO)

INTRODUCTION AND MAIN RESULTS

This poster introduces a new interactive web-based tool for analyzing the event detection threshold of the primary seismic network of the International Monitoring System (IMS).

Continuous estimates are calculated by the Threshold Monitoring method and show significant geographical and temporal variability in detection capability.

Objective information on the event detection threshold place confidence in the performance of the CTBT verification system.

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Background

Hourly maps with the average and worst-case event detection capability of the seismic component of the CTBTO's International Monitoring System have for many years been accessible via CTBTO's secure web portal.

The basis for these maps is estimates calculated by the Threshold Monitoring method, which has been part of the CTBTO's processing pipeline since the establishment of the International Data Centre.

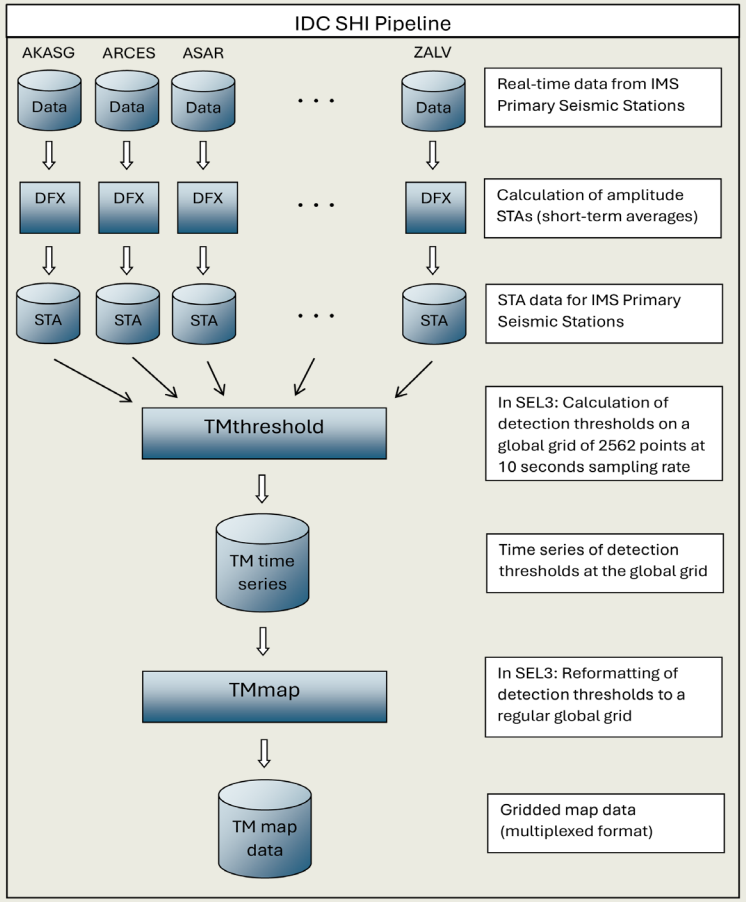
To utilize the full potential of the Threshold Monitoring data accumulated in the processing pipeline, NORSAR has developed software to interactively explore the data in a flexible manner.

With support from the International Data Centre staff, a new web interface is made available to CTBT State Signatories and Authorized Users where the event detection capability can be displayed and analyzed for any user-selected time interval and geographical region.

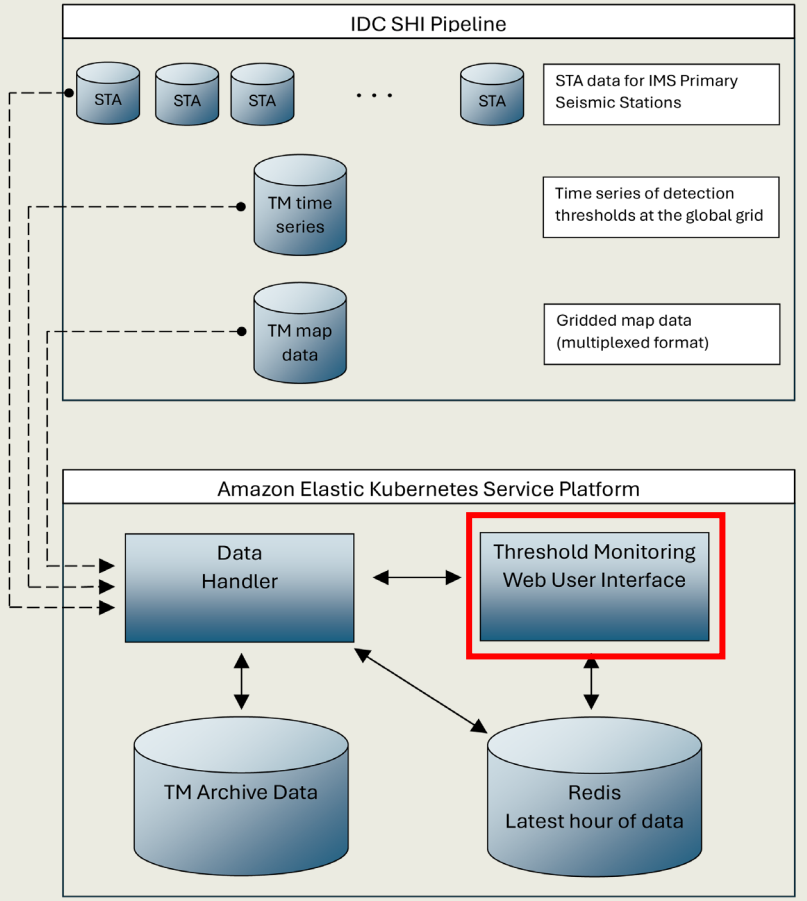
This is particularly useful as the event detection capability can vary significantly with time during periods with high station noise levels, large earthquakes, or outages of key stations.

In this e-poster we illustrate the functionality of the new tool and show results for different real scenarios.

Threshold Monitoring Data are Generated in the Automatic IDC SHI Processing Pipeline



Workflow of the New Threshold Monitoring Web Interface



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Accessing the Web Interface

The new interactive Threshold Monitoring web interface is available to State Signatories and Authorized Users via the CTBTO Secure Web Portal.

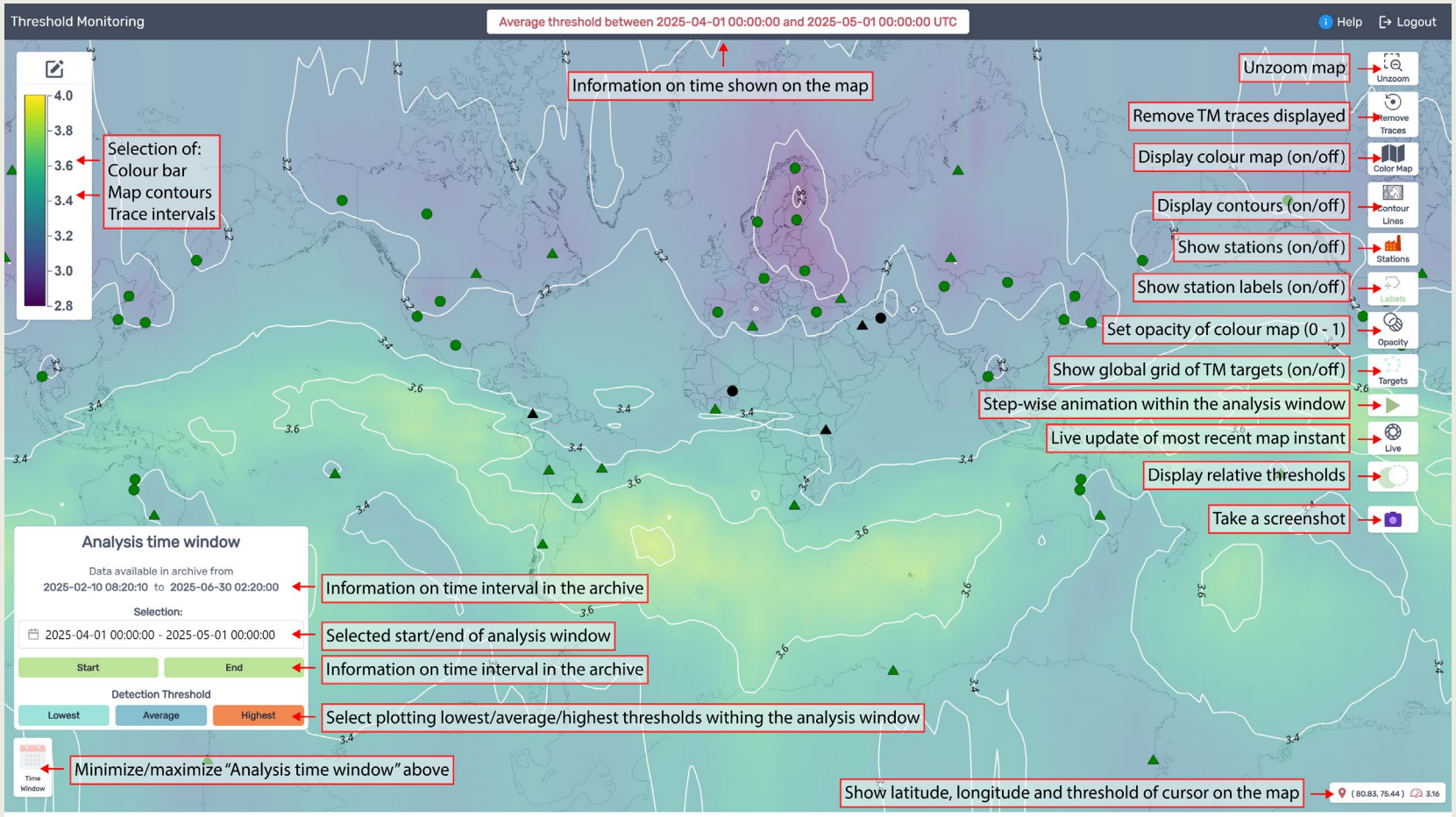
What is calculated by Threshold Monitoring?

- Estimates of the event detection threshold of the IMS Primary Seismic Network using the following requirements:
  - ✓ Detection by at least 3 stations at the 90% confidence limit

Why using the Threshold Monitoring approach?

- The IMS event detection threshold varies by time because of factors such as station outages, coda from large earthquakes, station noise variability, interfering signals, communication gaps, …
- Threshold Monitoring provides IMS event detection threshold estimates every 10 seconds
- Places confidence in the performance of the performance CTBTO verification system

New Interactive Threshold Monitoring Web Interface



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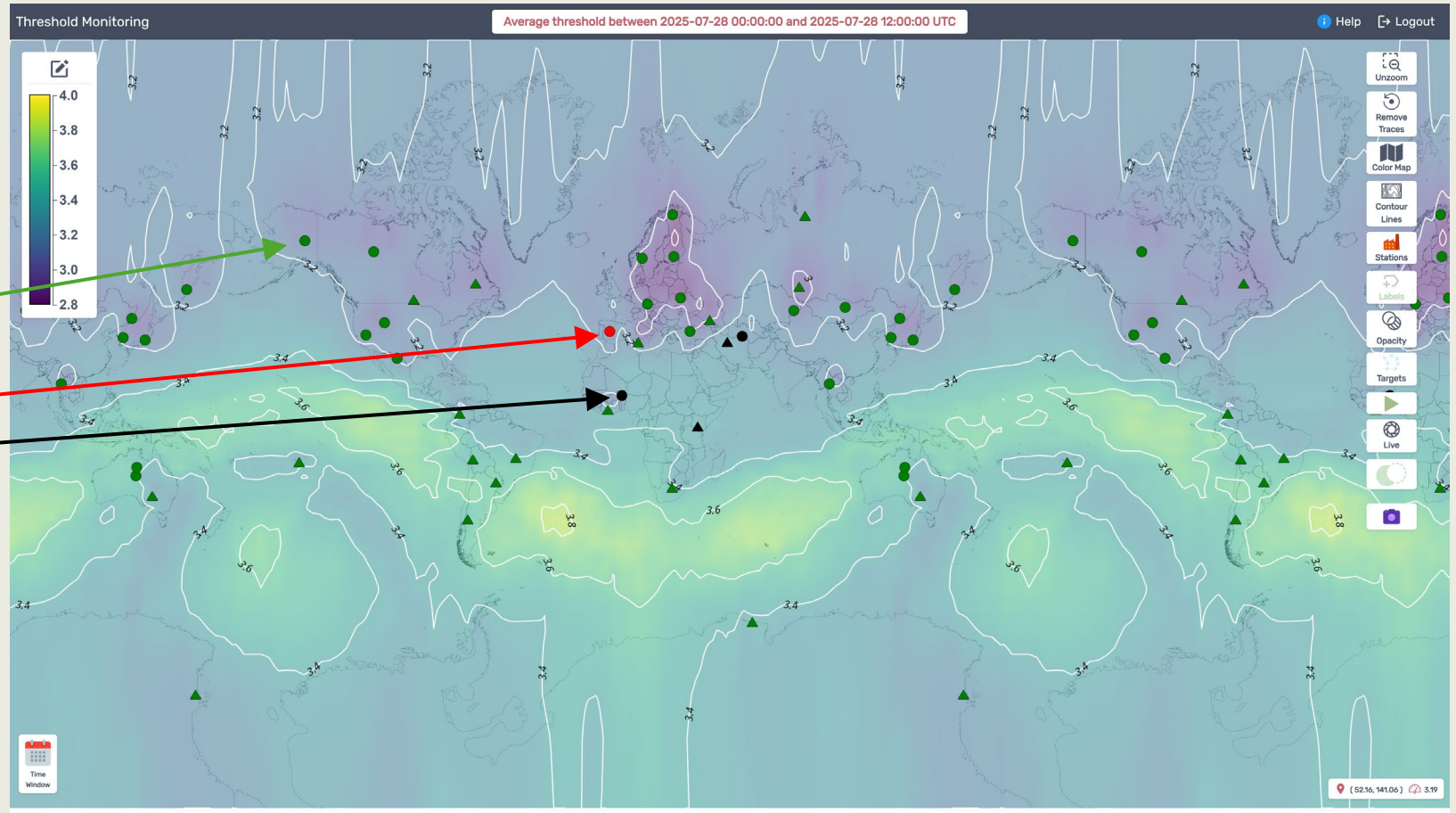
Colour of Station Symbols Represents Data Availability During the Analyzed Time Interval

Data Availability (DA)	Colour
80% < DA ≤ 100%	Green
40% < DA ≤ 80%	Yellow
0% < DA ≤ 10%	Red
DA = 0%	Black

- Arrays

- 3C Stations

IMS Event Detection Threshold Depends on Station Data Availability (Average 2025-07-28 00:00 - 2025-07-28 12:00)



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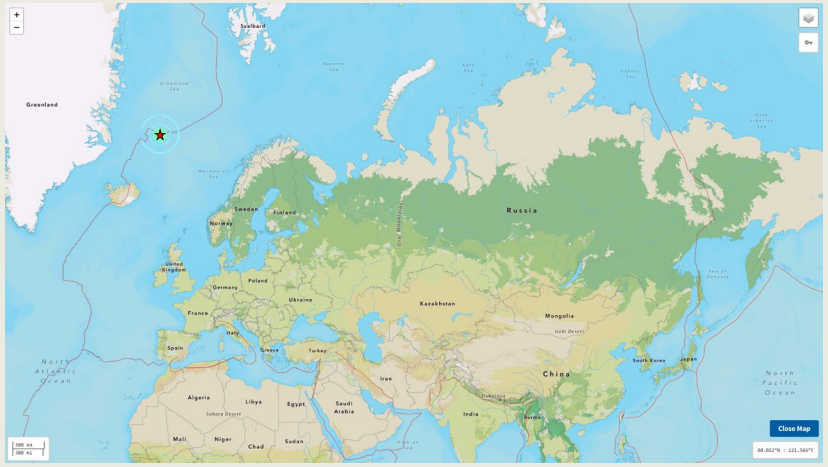
M 6.5 Jan Mayen Earthquake
2025-03-10 02:33:14 UTC



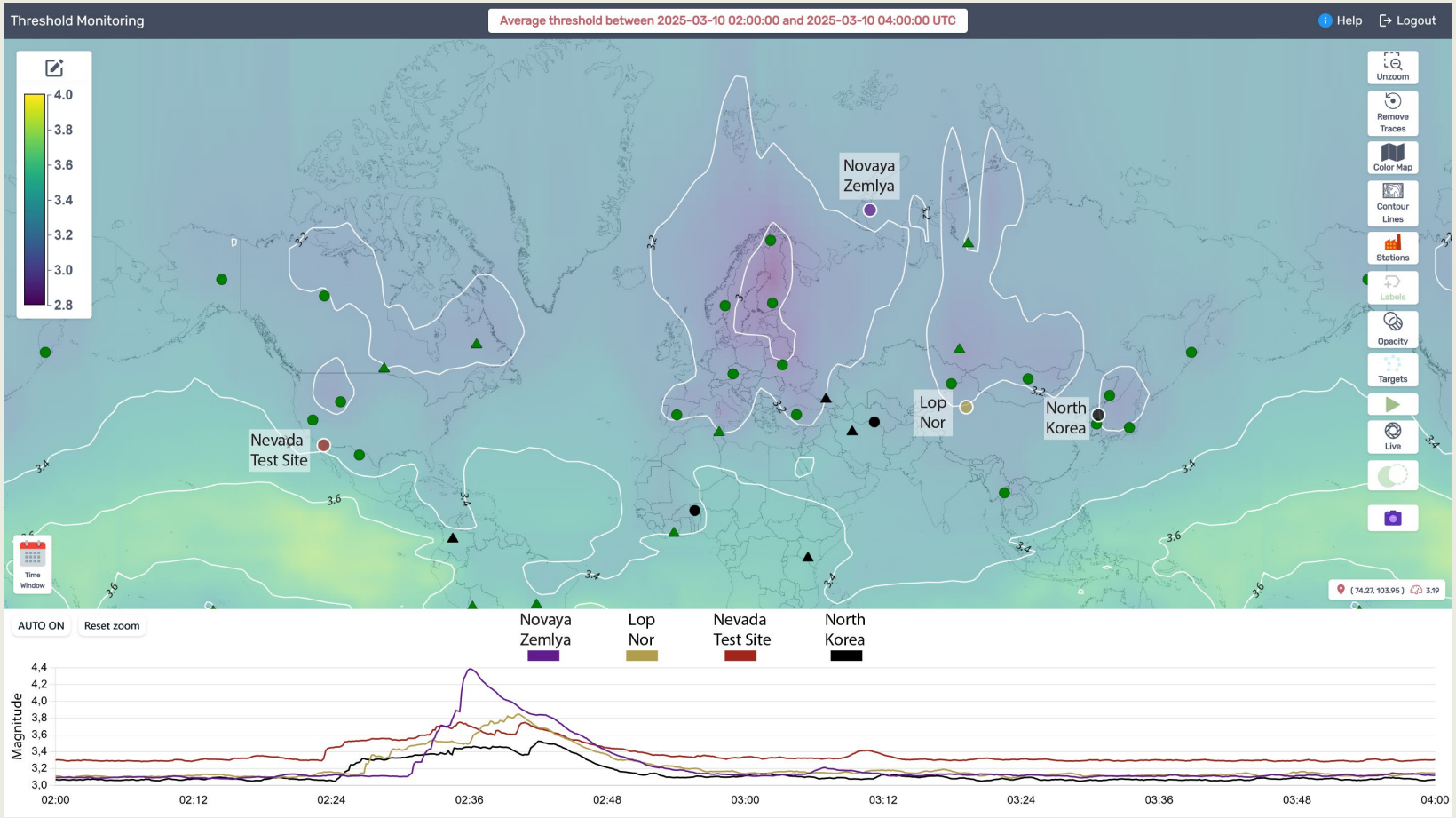
As seismic phases and the associated coda from large earthquakes reach the different IMS stations, the network event detection capability is generally reduced.

In the new interactive tool, the time-dependent detection threshold of selected sites is displayed by just clicking the mouse on a geographical location on the map.

The traces in the lower part of the figure to the right displays the estimated detection thresholds for four sites where underground testing has previously been conducted.

For these four sites the M 6.5 Jan Mayen earthquake caused the IMS event detection threshold to significantly increase for about half an hour after the event origin.

Map: Average IMS Event Detection Threshold (02:00 to 04:00 on 2025-03-10)
Traces: Time-Dependent Detection Threshold of Four Selected Sites



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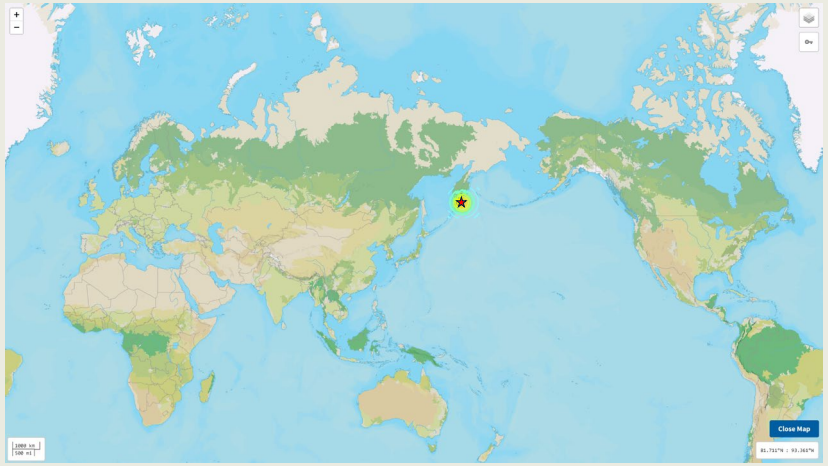
M 8.8 Kamchatka Earthquake
2025-07-29 23:24:52 UTC

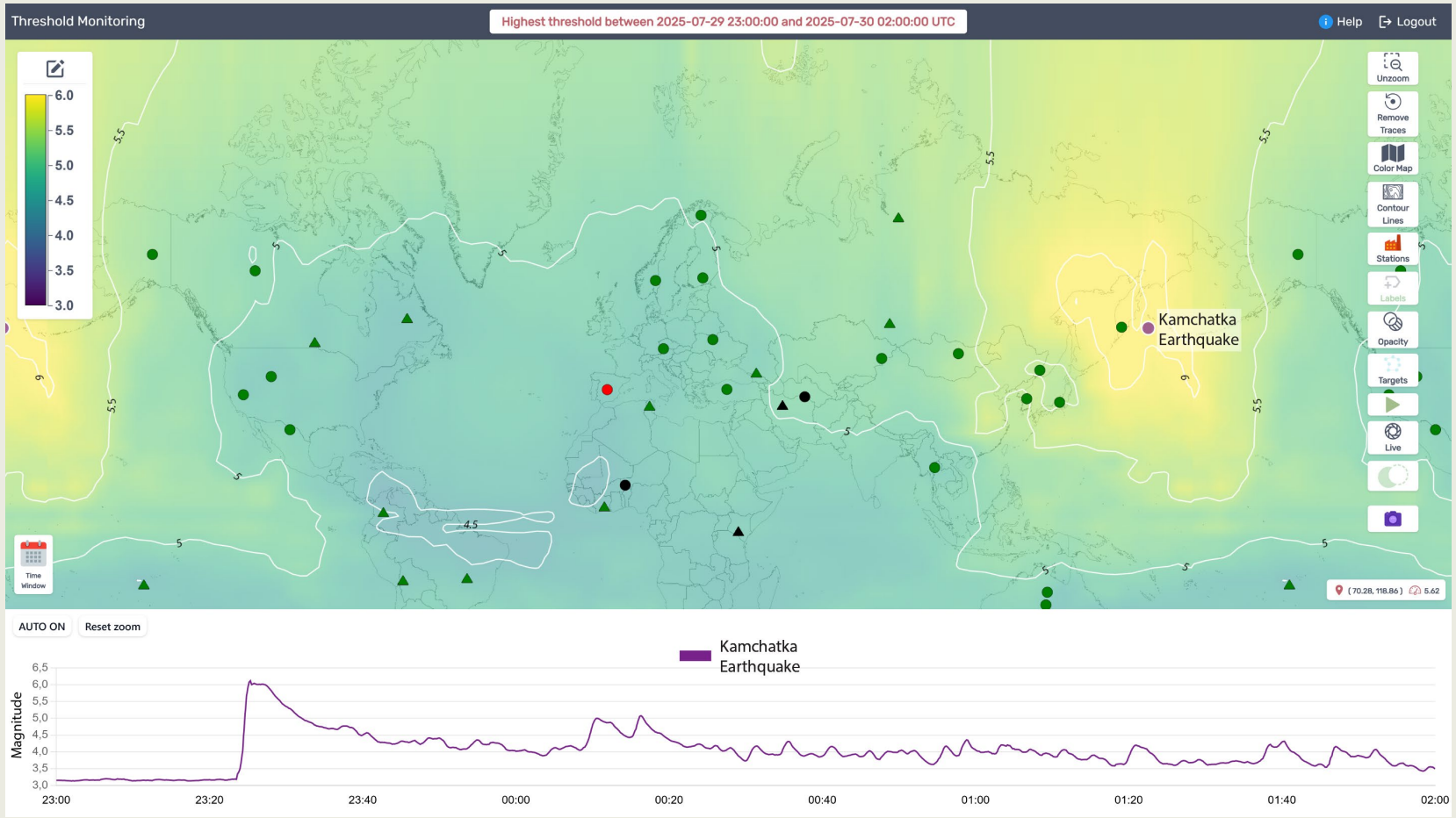


The M 8.8 Kamchatka earthquake on 29 July 2025 was the largest worldwide since the M 9.1 Tohoku earthquake in 2011. The large Kamchatka event was preceded by an earthquake sequence which started 10 days earlier and has been followed by numerous aftershocks with magnitudes up to 6.9.

To illustrate the impact of the M 8.8 Kamchatka event on the IMS event detection capability, the map to the right shows the point-wise highest detection threshold within a two-hour window just after the event. Notice that the magnitude scale spans the range between 3 and 6.

The trace in the lower part of the figure displays the time-dependent event detection threshold for the earthquake epicenter. The main event and the aftershock sequence caused a significant reduction in IMS event detection capability for several hours.

Map: Highest IMS Event Detection Threshold (2025-07-29 23:00 to 2025-07-30 02:00)
Traces: Time-Dependent Detection Threshold at the Kamchatka Earthquake Epicenter



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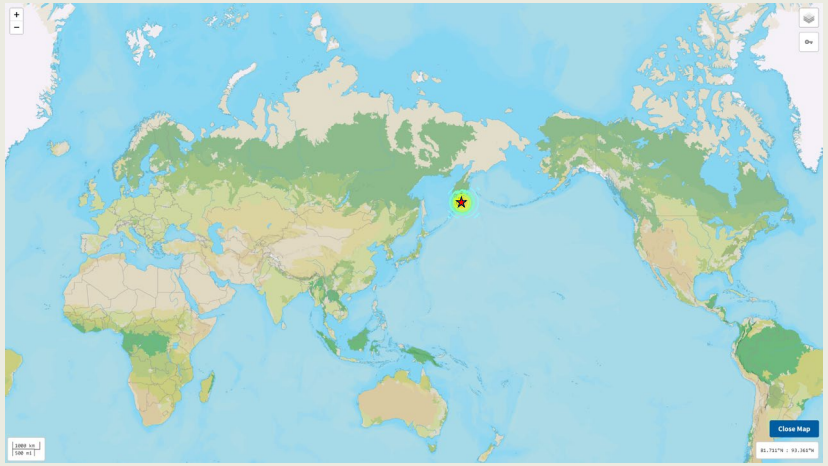


The interactive Threshold Monitoring web interface offers the possibility of displaying the event detection thresholds relative to a baseline time interval selected by the user.

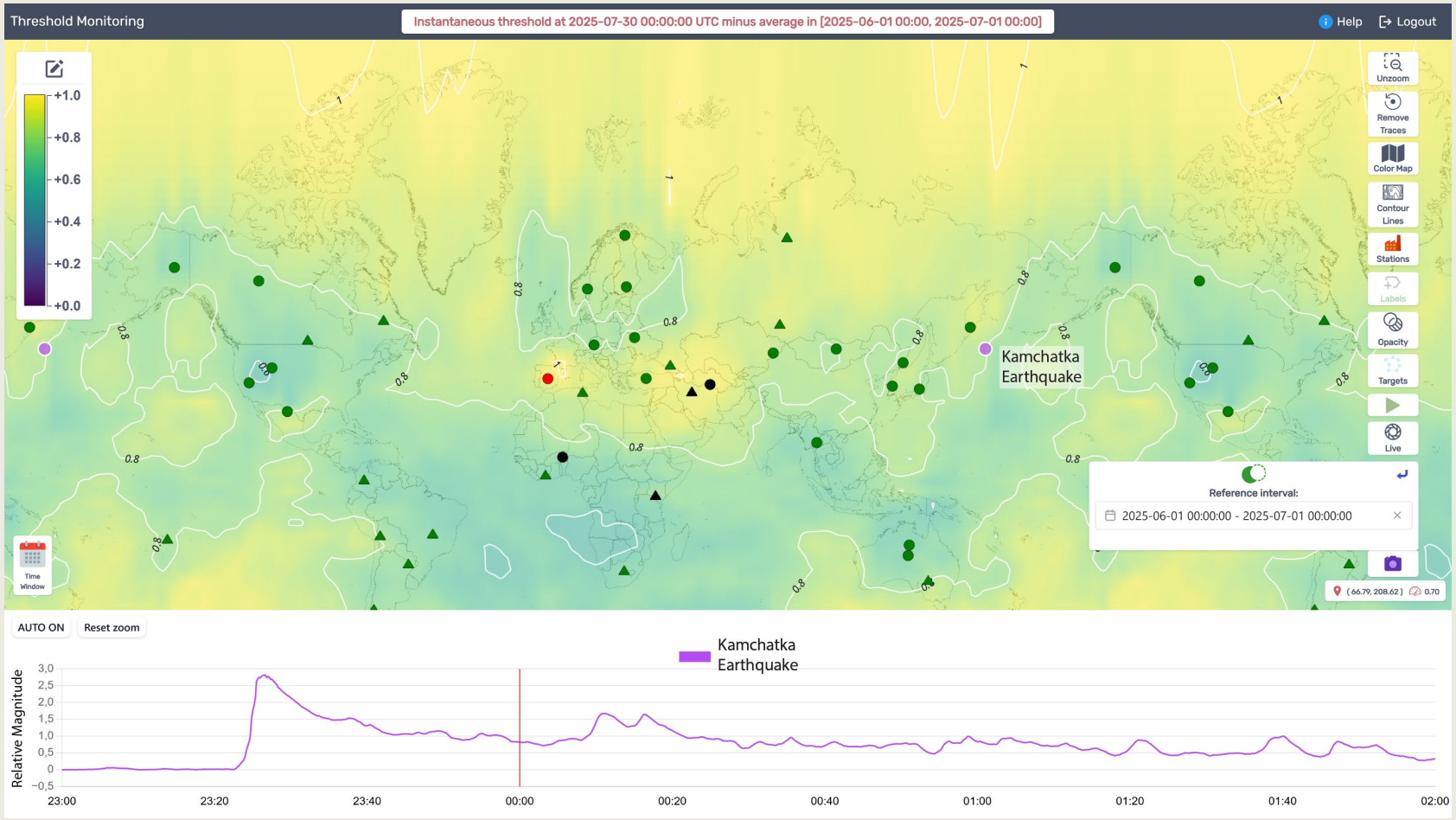
The average detection thresholds for June 2025 is used as the baseline for the map and threshold trace shown in the figure to the right.

The trace in the lower part of the figure displays the time-dependent event detection threshold for the Kamchatka earthquake epicenter relative to the June 2025 baseline.

By clicking the mouse on a time instant on the detection threshold trace, the corresponding map is displayed.

Notice the relative magnitude scaled used:
0.0 to 1.0 for the map
-0.5 to 3.0 for the threshold trace

Map: Instantaneous Detection Threshold at 2025-07-30 00:00 Relative to June 2025
Traces: Time-Dependent Detection Threshold Relative to June 2025



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Applications of the Threshold Monitoring Data in the CTBT Verification System

1. **Building confidence**
   The primary seismic network serves as the backbone of the CTBT International Monitoring System (IMS) for detecting any underground nuclear explosions. For States Signatories of the CTBT it is essential that the performance of this network is continuously documented and assessed.

   The network's ability to detect events—its magnitude detection threshold—can be significantly affected by various factors, including high station noise levels, signals from large earthquakes, station outages, communication failures, and data processing gaps. Threshold Monitoring accounts for all these influences by providing continuous, data-driven estimates of global event detection thresholds.

   Based on Threshold Monitoring data, the new interactive, web-based tool visualize and analyze the actual performance of the primary seismic network across any selected time period and geographical location. Thus, this tool enhances transparency and builds confidence in the CTBT verification system.

2. **Clarifying potential violations of the CTBT**
   In the context of a CTBT, there may arise accusations or suspicions that an underground nuclear explosion has been set off within a given region and time interval.
   The Threshold Monitoring data can provide objective information on the corresponding IMS event detection capability and thus contribute to clarifying the issue.

3. **Provide the upper magnitude limit of non-detected events**
   Given a seismic network, the Threshold Monitoring methodology includes an option for estimating the upper magnitude limit of any event that could possibly have occurred within a given region and time interval.
   Estimates of upper magnitude limits of non-detected events would impose even stronger constraints on the likelihood of a hidden underground nuclear explosion been set off.
   For a future extension, we propose to include this Threshold Monitoring methodology in the IDC processing pipeline. The resulting data will become a valuable supplement to operational monitoring of a CTBT.

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