CDD 2024

Constructing a New Catalogue of Greenland's Iceberg Calving Events through Seismic Data Analysis and Machine Learning

Selina WETTER[1]

Anne MANGENEY[1], Eléonore STUTZMANN[1], Clément HIBERT[2]

[1] Institut de Physique du Globe de Paris (IPGP), Université Paris Cité, France
[2] Institut Terre & Environnement de Strasbourg (ITES), CNRS UMR 7063, Université de Strasbourg, France

IPGP Université Paris Cité EnvSeis Marie Skłodowska-Curie Actions STEP UP ÉCOLE DOCTORALE

Iceberg Calving Events

Alex Zugazagoitia,
“Giant Calving at
Helheim Glacier 2022”

Iceberg Calving Events

Iceberg calving events:
> 1 km^3

Glaciers in the Swiss Alps:
60-70 km^3

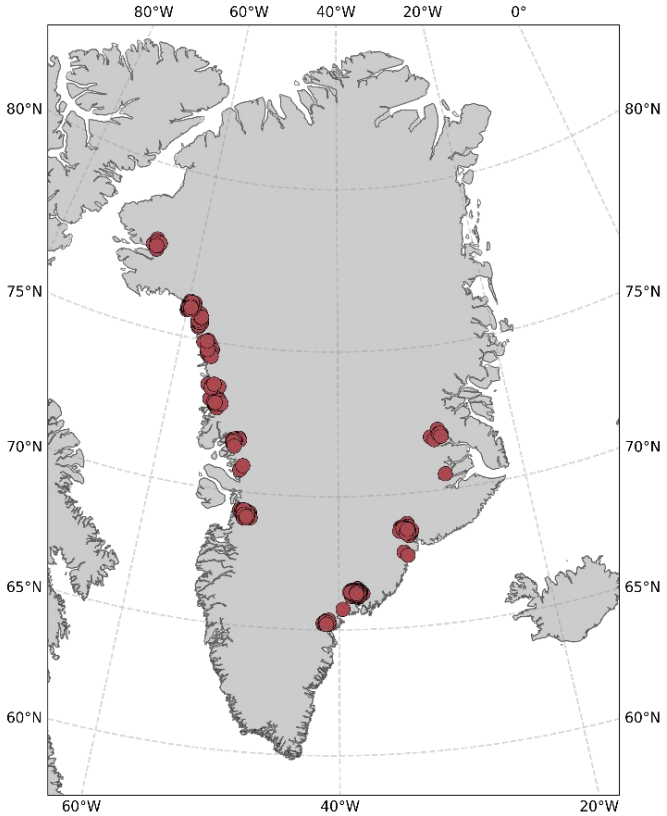
Alex Zugazagoitia, “Giant Calving at Helheim Glacier 2022”

Iceberg Calving Events

Merged catalogue

Tsai and Ekström (2007),
Veitch and Nettles (2012) and Olsen and Nettles (2017)

- 444 calving events
- 1993 - 2013
- Magnitude 4.6 - 5.1

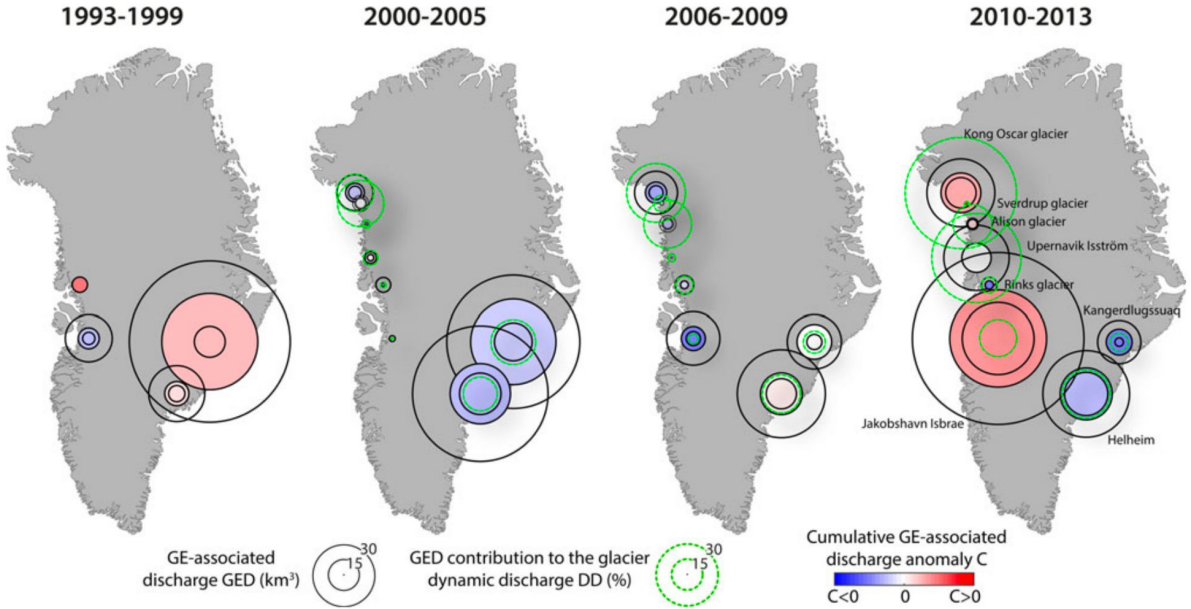


Iceberg Calving Events

Merged catalogue

Tsai and Ekström (2007),
Veitch and Nettles (2012) and Olsen and Nettles (2017)

- 444 calving events
- 1993 - 2013
- Magnitude 4.6 - 5.1



Sergeant et al. (2019)

Iceberg Calving Events

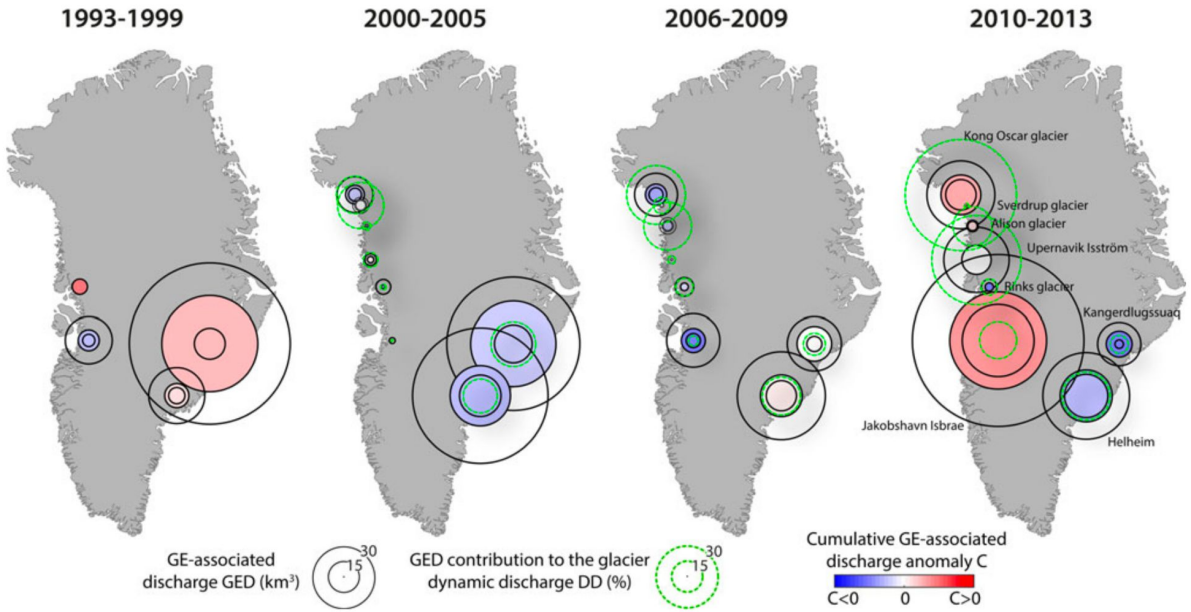
Merged catalogue

Tsai and Ekström (2007),
Veitch and Nettles (2012) and Olsen and Nettles (2017)

- 444 calving events
- 1993 - 2013
- Magnitude 4.6 - 5.1

Sergeant et al. (2019) estimated the total mass loss

- at least 250 Gt over 1993-2013



Sergeant et al. (2019)

Iceberg Calving Events

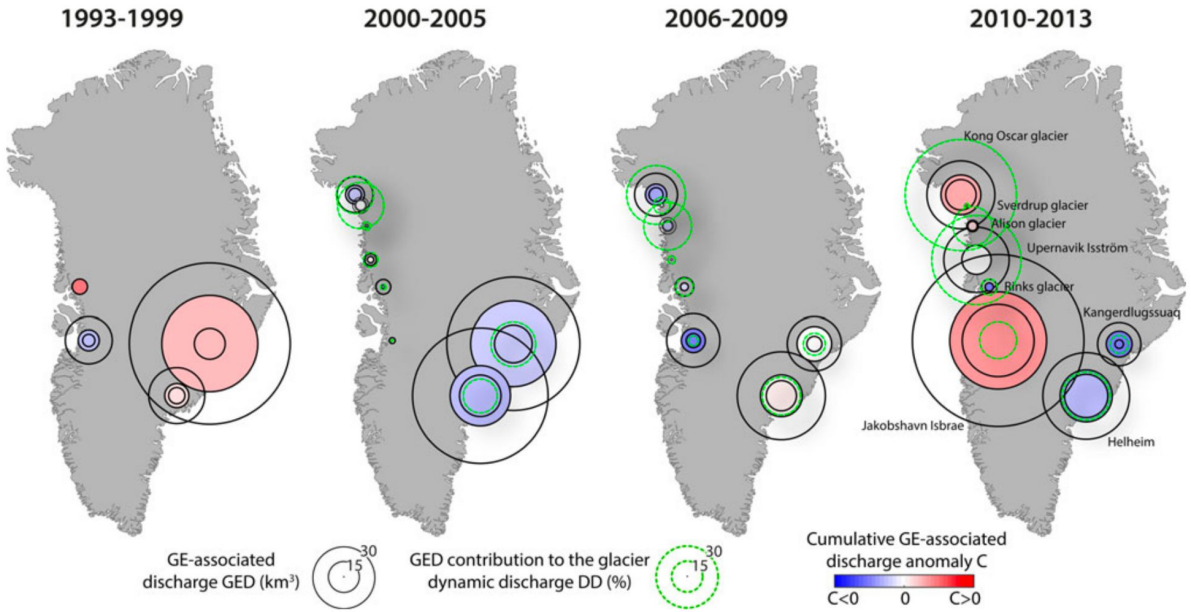
Merged catalogue

Tsai and Ekström (2007),
Veitch and Nettles (2012) and Olsen and Nettles (2017)

- 444 calving events
- 1993 - 2013
- Magnitude 4.6 - 5.1

Sergeant et al. (2019) estimated the total mass loss

- at least 250 Gt over 1993-2013

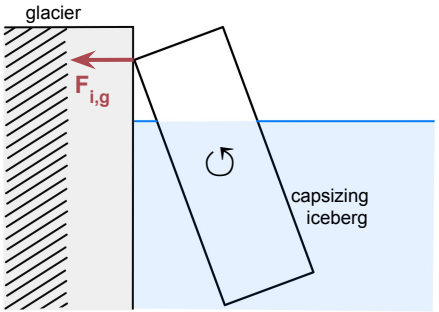


Sergeant et al. (2019)

Constrain a **complete seismic catalogue** with iceberg calving events up to the present day

Seismology and Glacial Earthquake (GEQ)

Force at the glacier front, when a iceberg capsizes

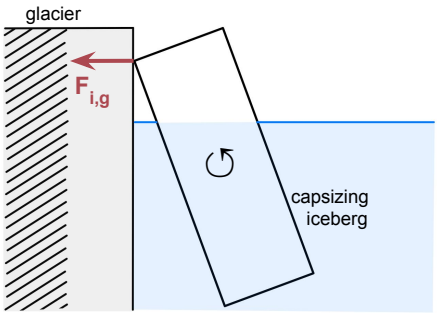


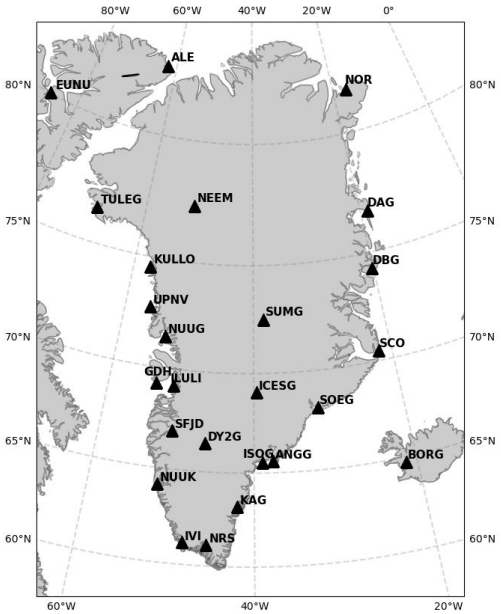
Seismology and Glacial Earthquake (GEQ)

Force at the glacier front, when a iceberg capsizes

+

Seismic stations from the Greenland Ice Sheet Monitoring Network (GLISN)





Seismology and Glacial Earthquake (GEQ)

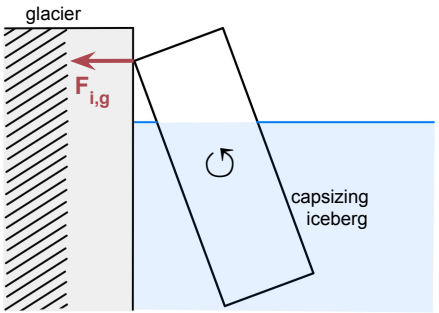
Force at the glacier front, when a iceberg capsizes

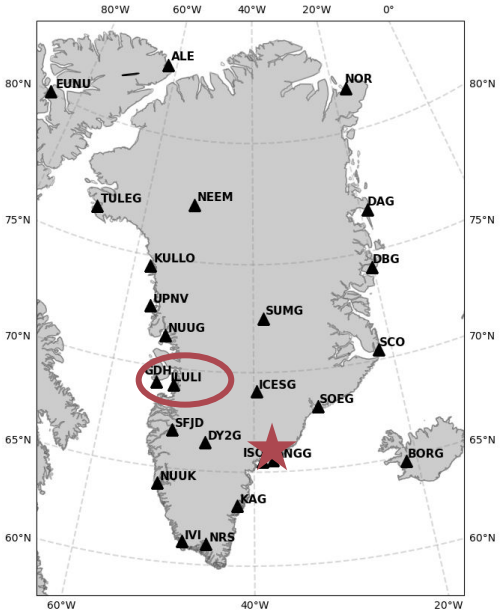
+

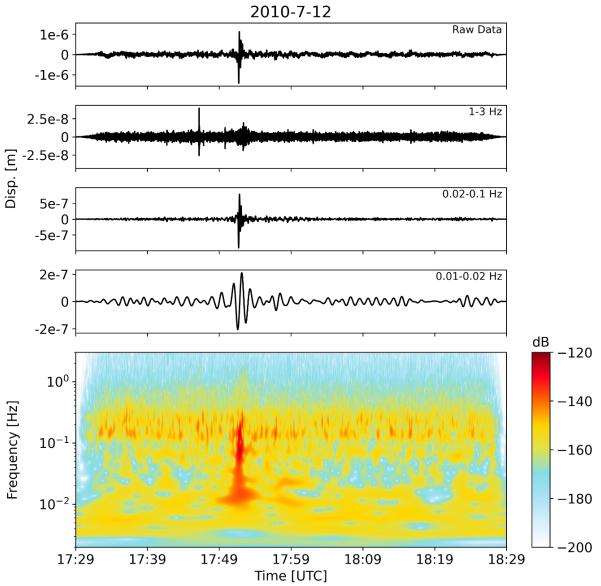
Seismic stations from the Greenland Ice Sheet Monitoring Network (GLISN)

=

Seismic recording of GEQ

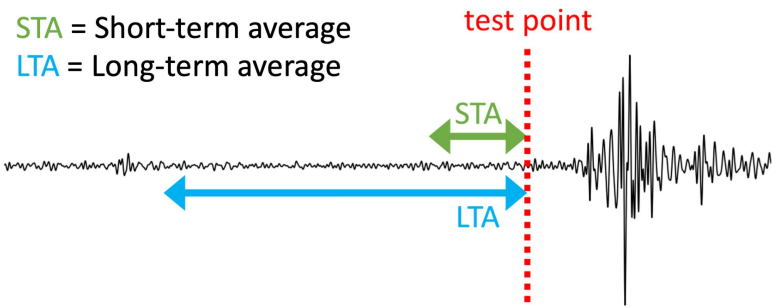


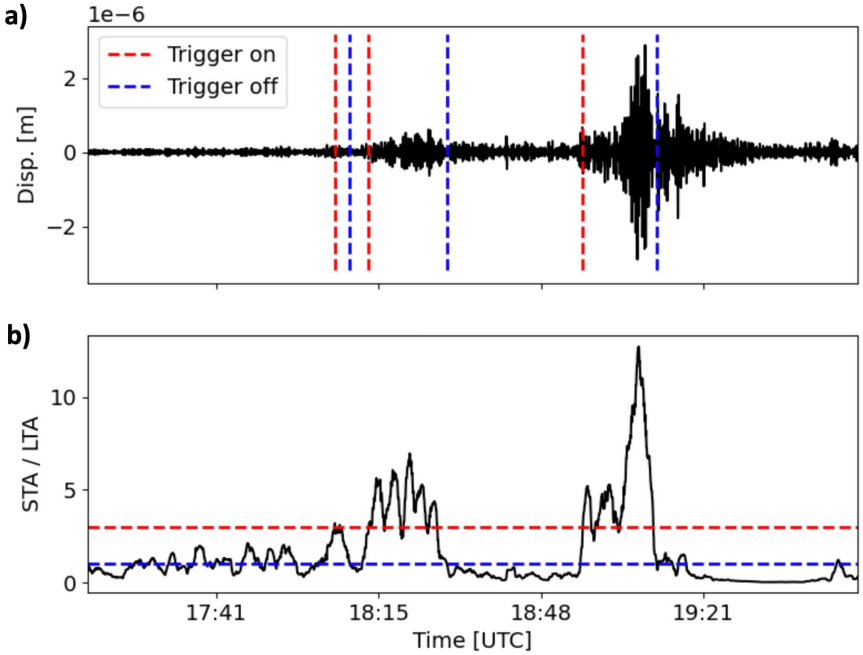




Detection with STA/LTA

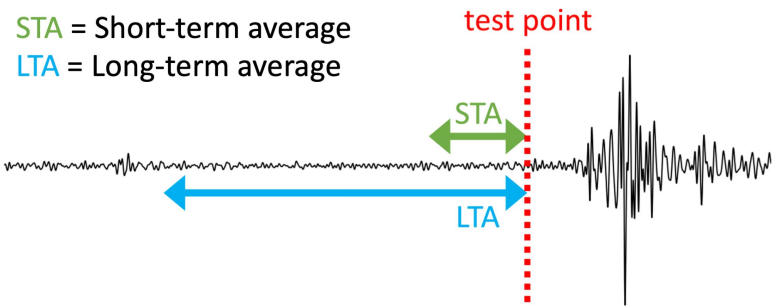
Method



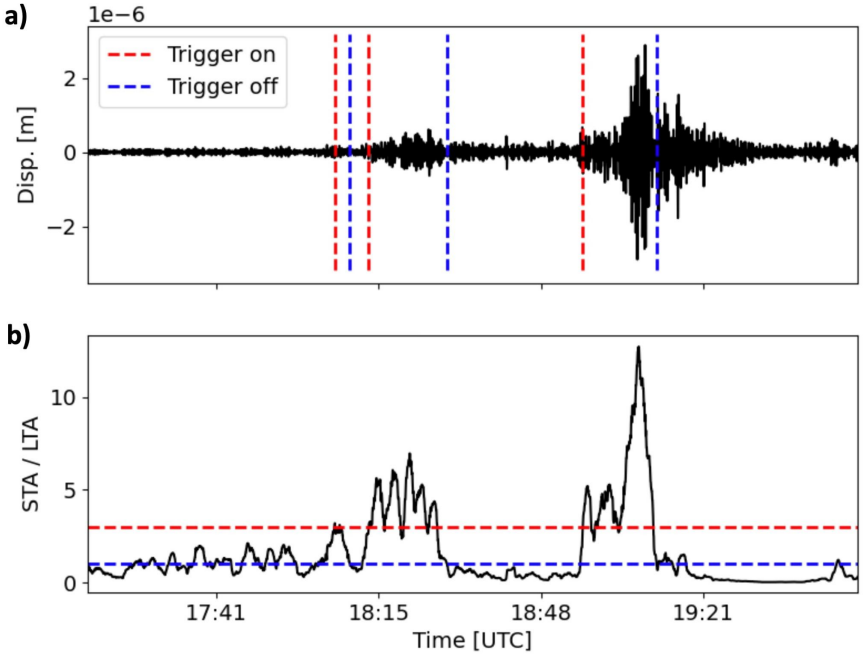


Detection with STA/LTA

Method

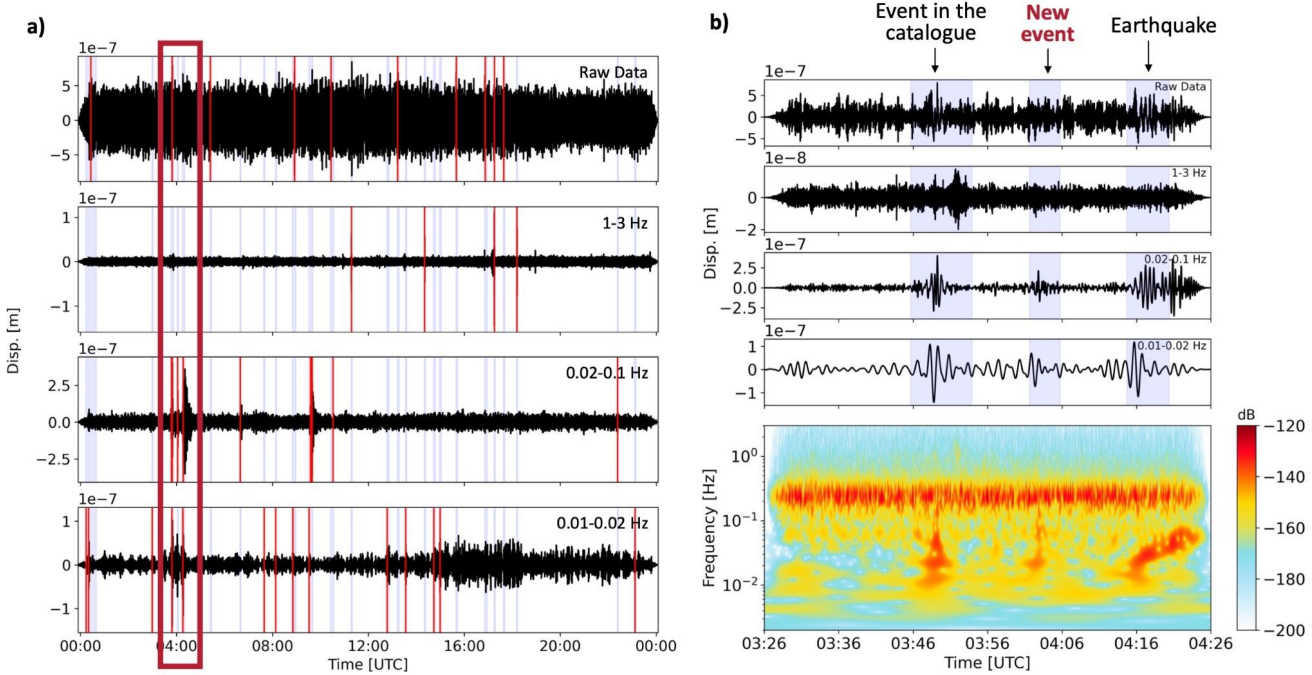


- Detection on 4 different frequency bands
- Individual parameters for every frequency band



Detection with STA/LTA

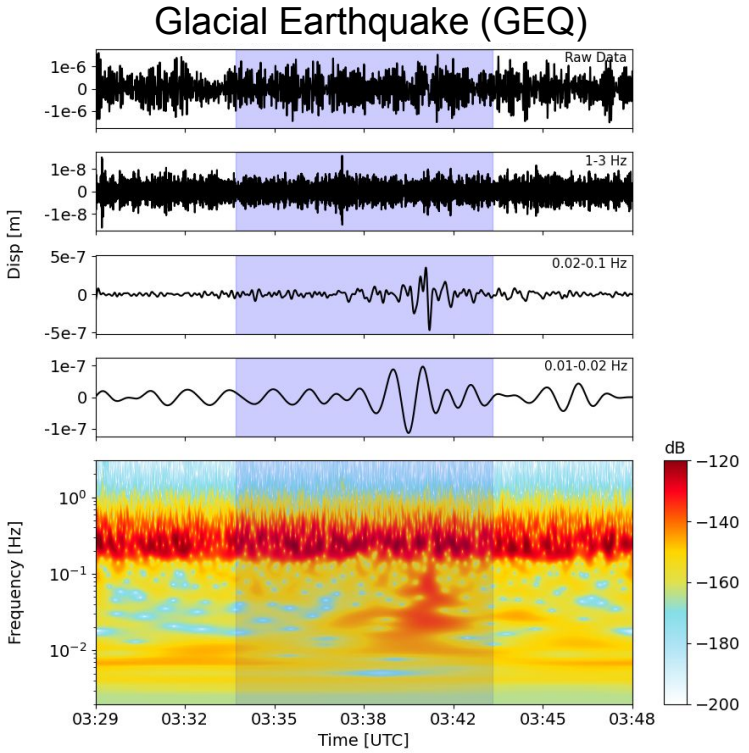
Results



January 2013:
26 stations
> 200 events

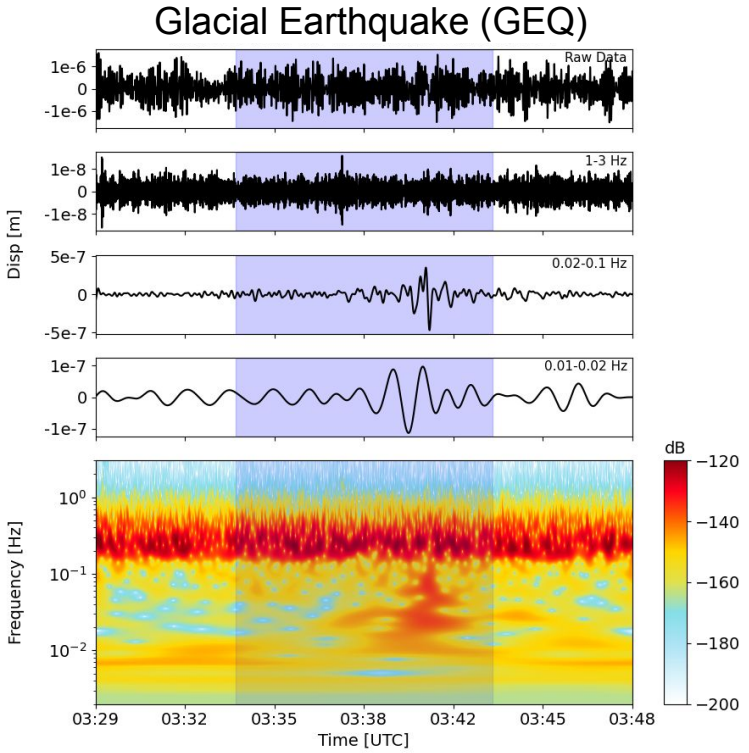
Detection with STA/LTA

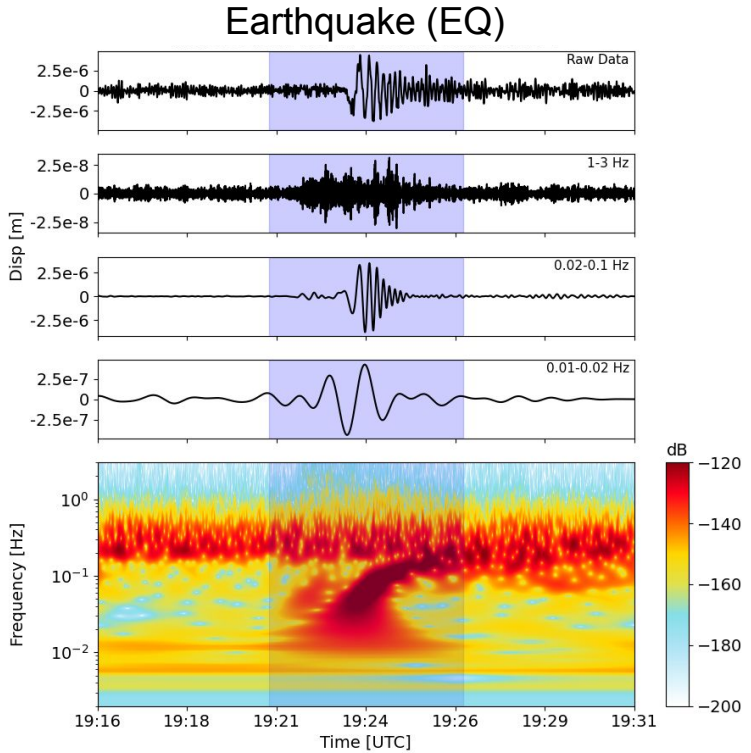
Results



Detection with STA/LTA

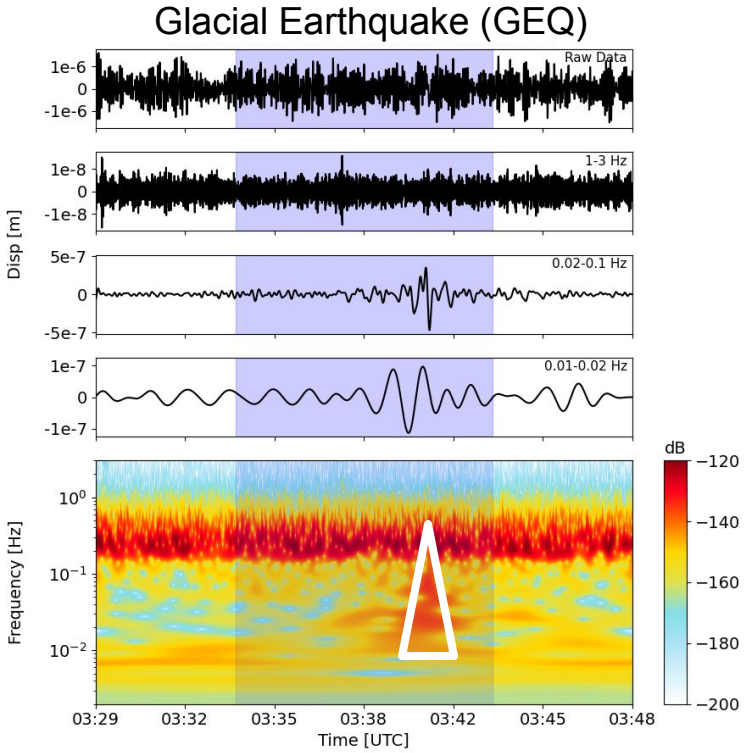
Results

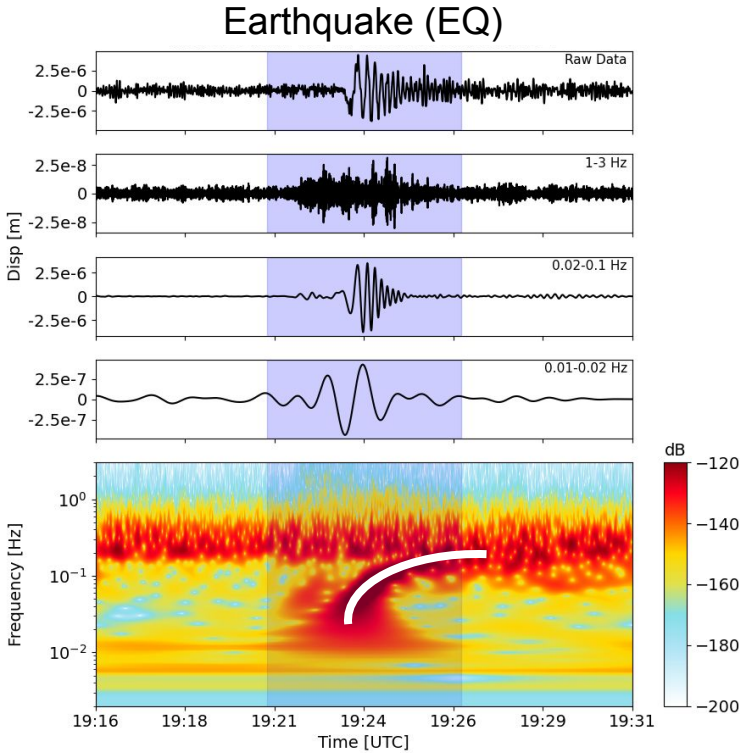




Detection with STA/LTA

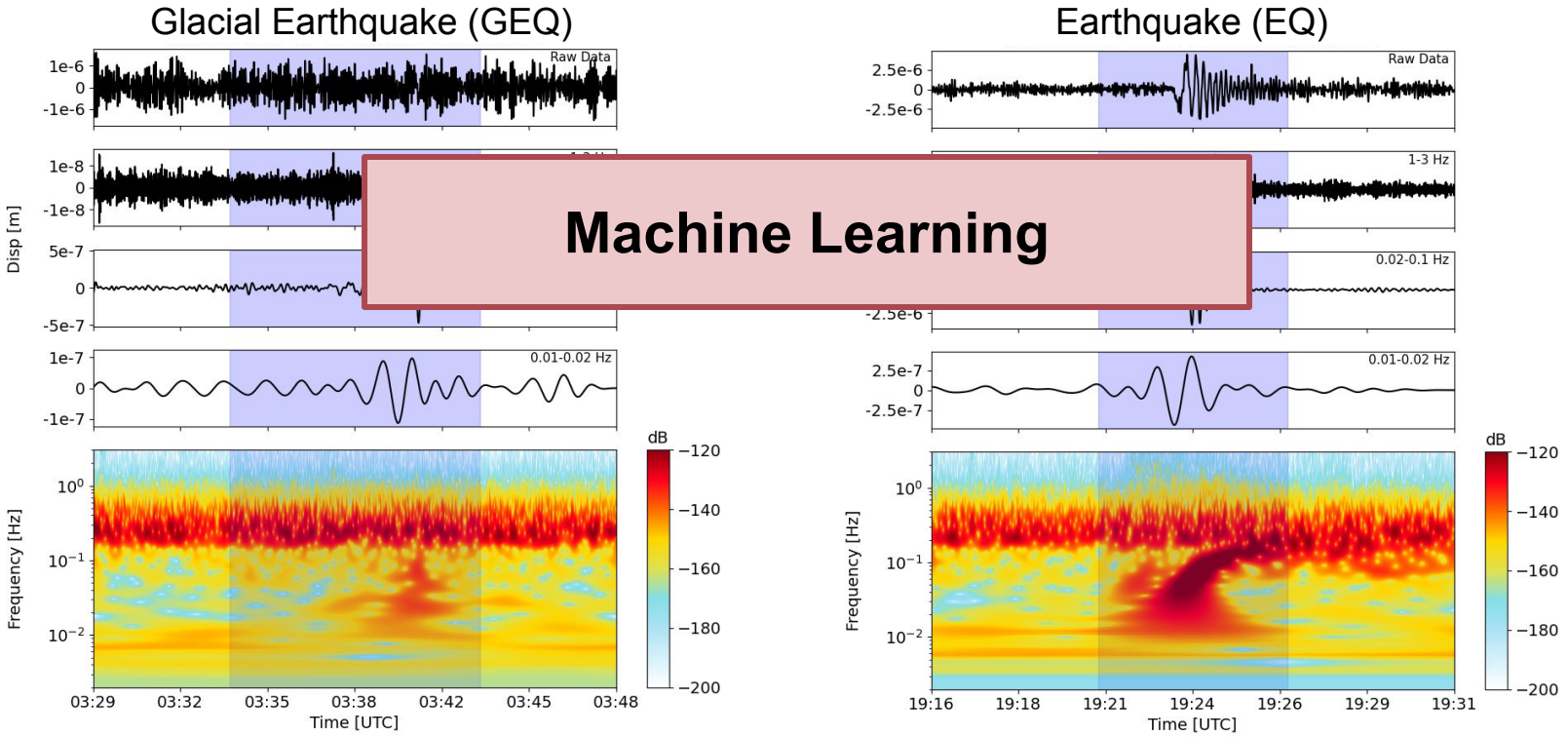
Results





Detection with STA/LTA

Results



Machine Learning

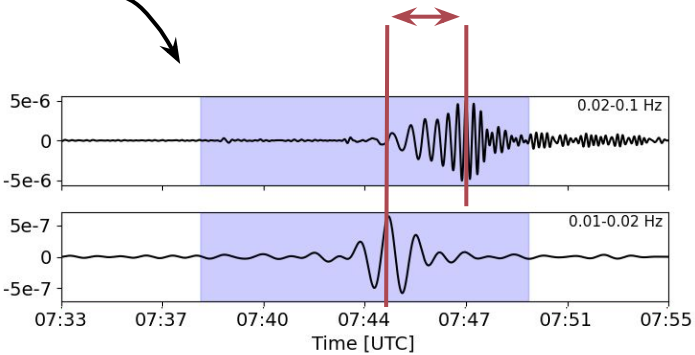
Parameters

- Random Forest
  - Number of trees: 500
- Features
  - 58 features (Provost et al., 2017, Hibert et al., 2017, Maggi et al., 2017)
  - 39 features added by Pirot et al., 2023
  - 6 new features: stacked energy + dispersion effect
- Training Set
  - 444 GEQ corresponding to 3792 signals
  - 476 EQ corresponding to 2986 signals

Machine Learning

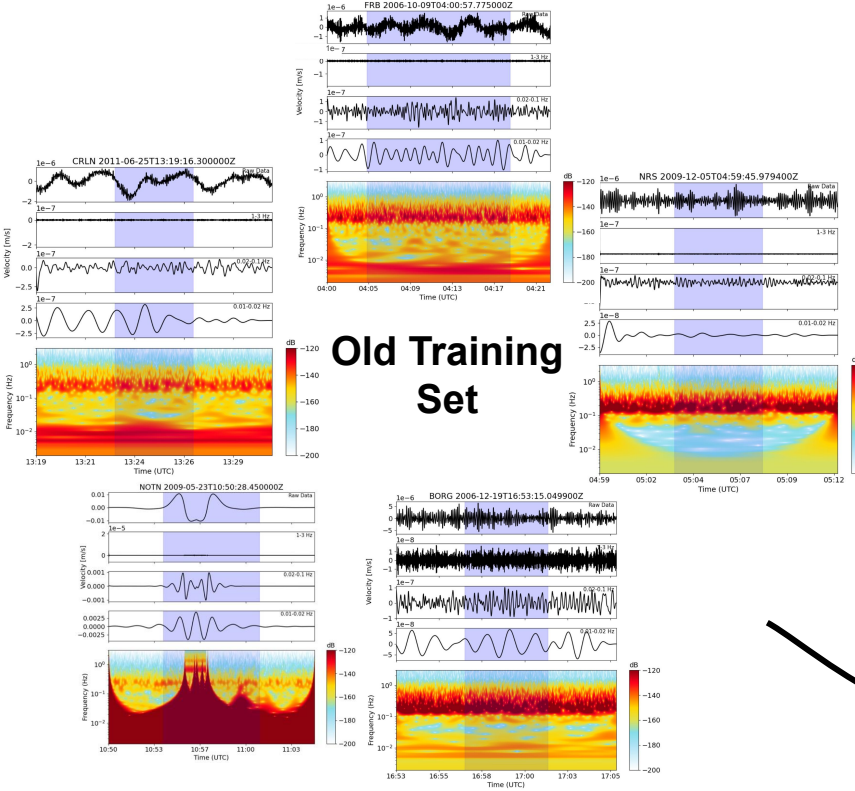
Parameters

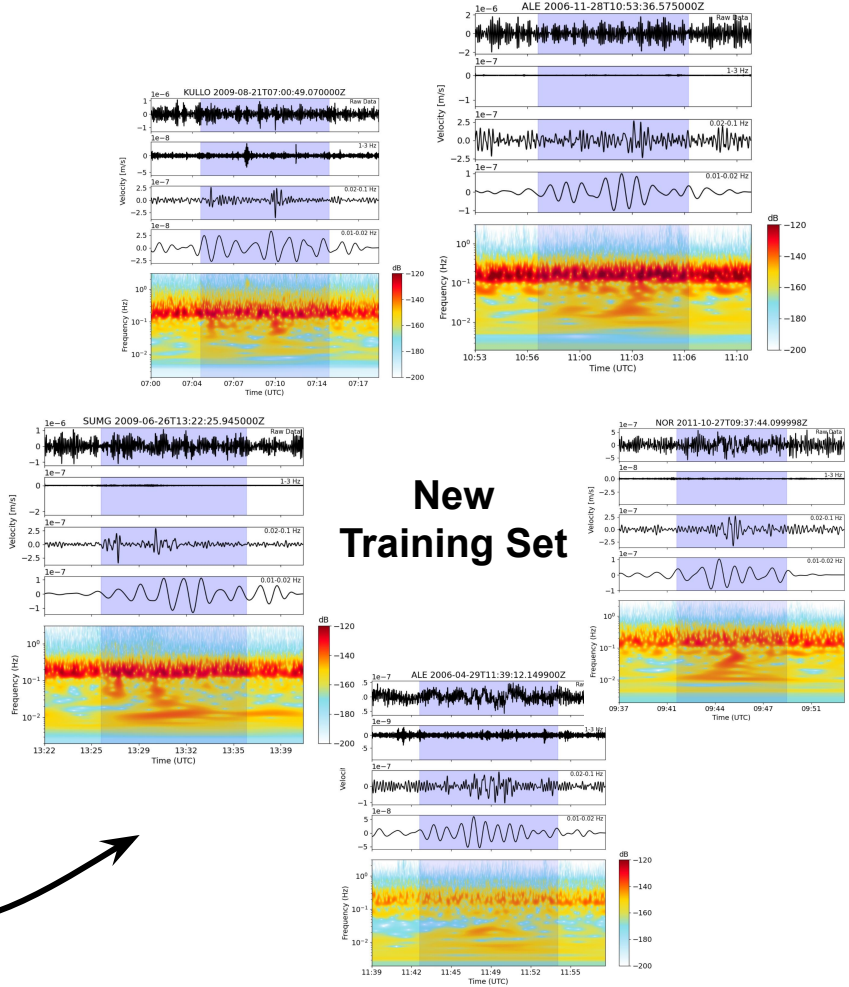
- Random Forest
  - Number of trees: 500
- Features
  - 58 features (Provost et al., 2017, Hibert et al., 2017, Maggi et al., 2017)
  - 39 features added by Pirot et al., 2023
  - 6 new features: stacked energy + dispersion effect
- Training Set
  - 444 GEQ corresponding to 3792 signals
  - 476 EQ corresponding to 2986 signals



Machine Learning

Training Set



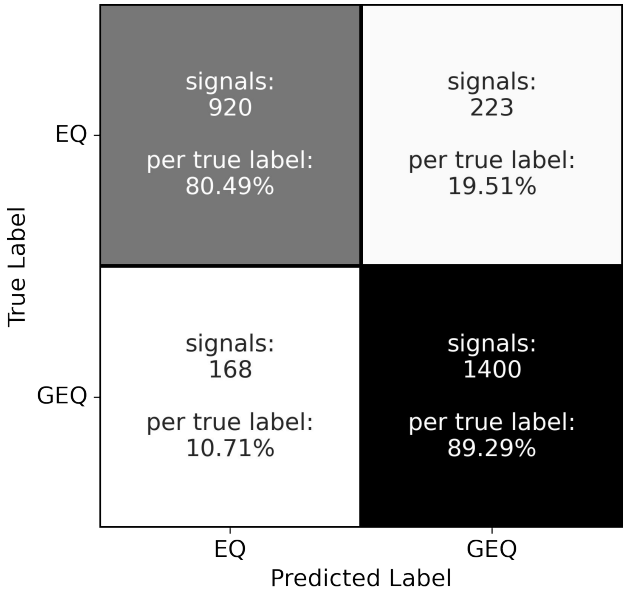


Machine Learning

Results

Old training set

Accuracy: 85.58 %

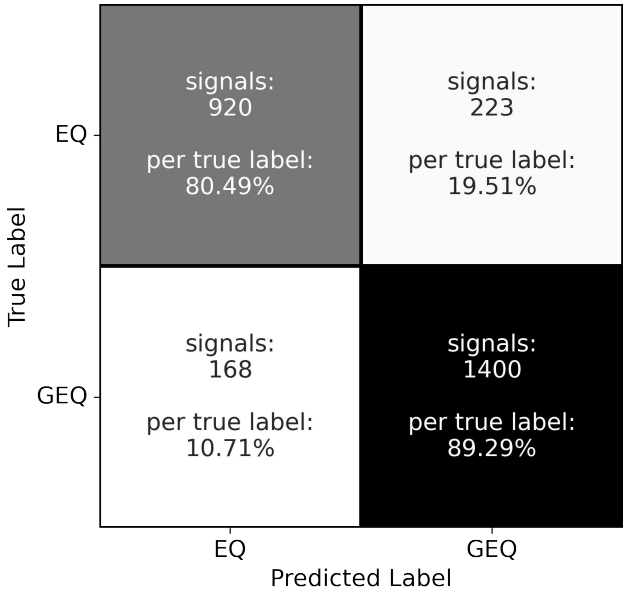


Machine Learning

Results

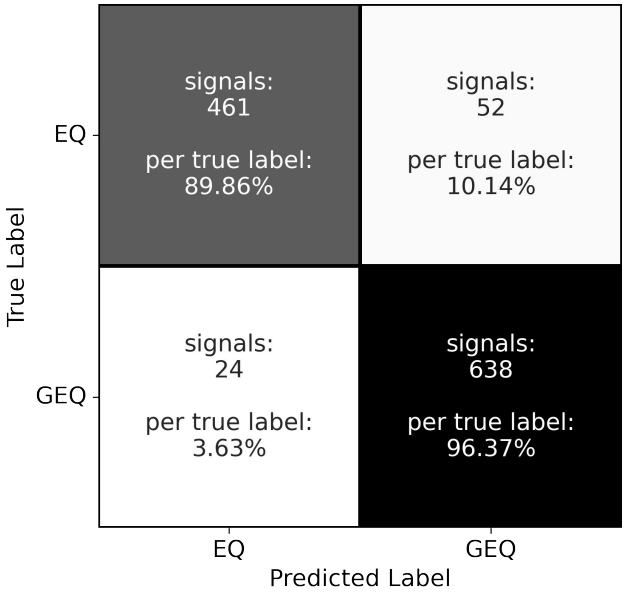
Old training set

Accuracy: 85.58 %



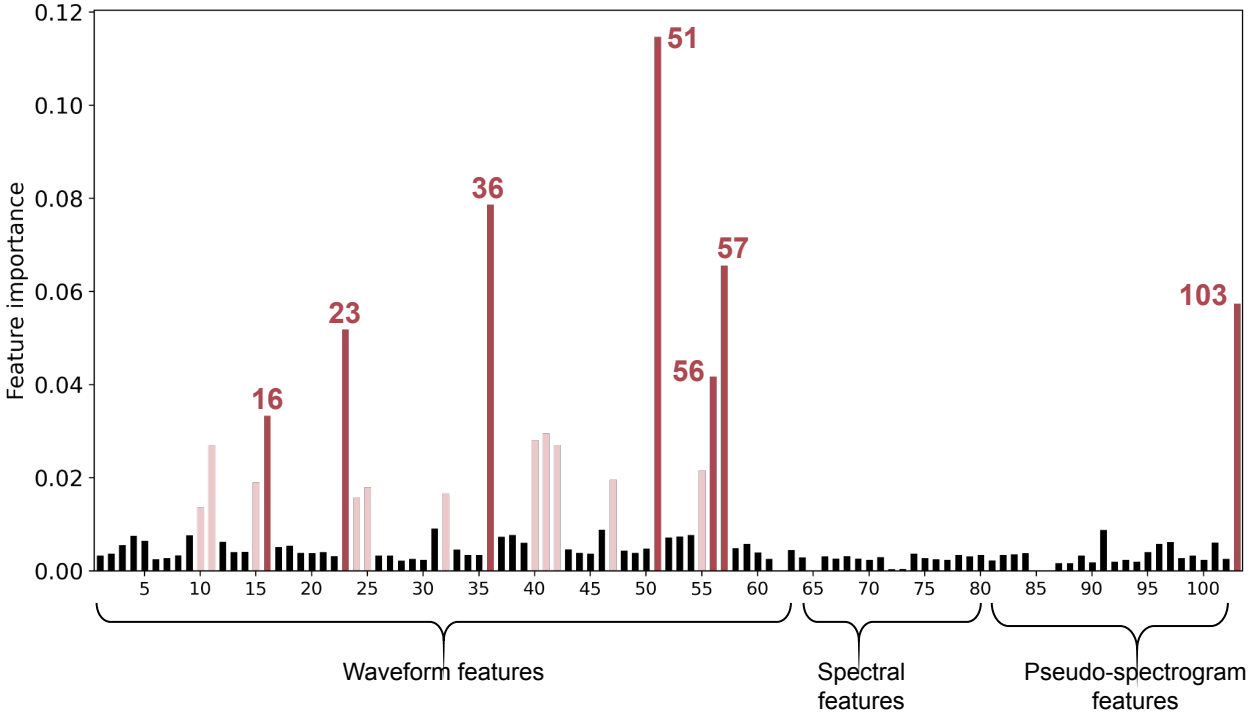
New training set

Accuracy: 93.53 %



Machine Learning

Results



16: Energy 0.02-0.1 Hz

23: Kurtosis 0.01-0.02 Hz

36: Difference of energy 0.01-0.02 Hz & 0.02-0.1 Hz

51: Ratio of energy 0.01-0.02 Hz & 0.02-0.1Hz

56: Ratio of energy 0.02-0.1 Hz & 0.5-1 Hz

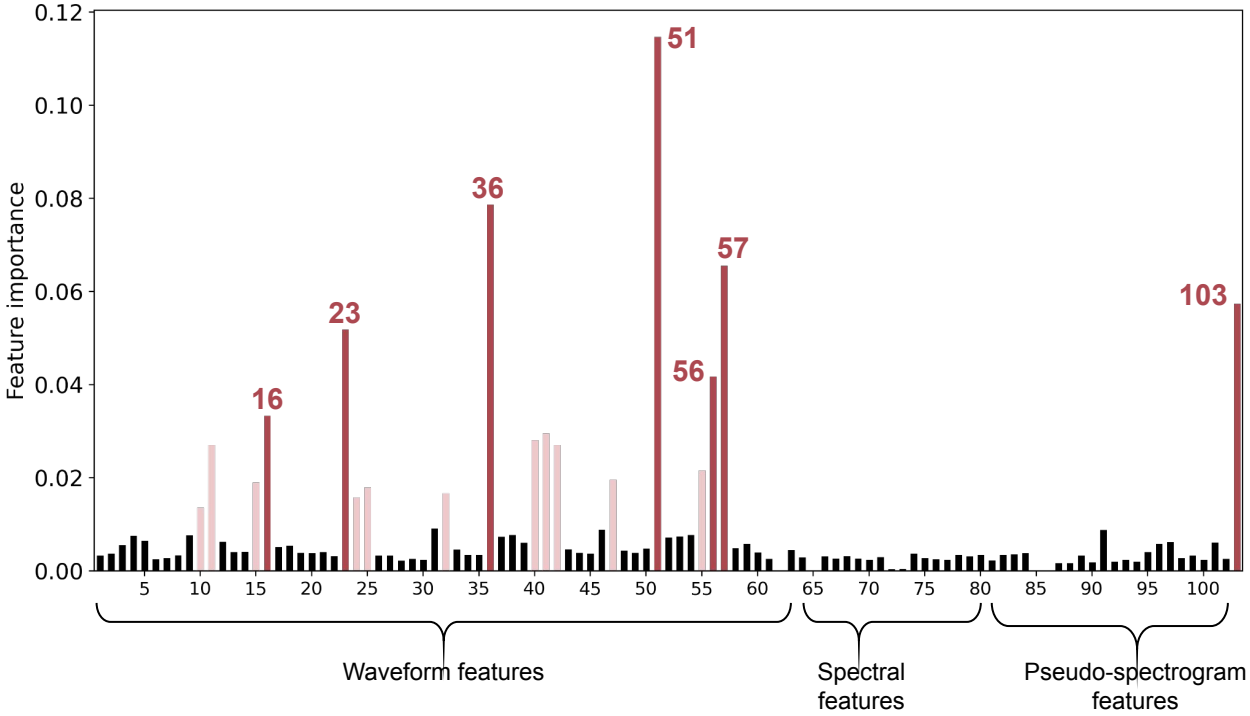
57: Ratio of energy 0.02-0.1 Hz & 1-3 Hz

103: Time difference of highest amplitude in 0.01-0.02 Hz and 0.02-0.1 Hz

Machine Learning

Results

January 2013:
200 events → ~ 30 GEQ



16: Energy 0.02-0.1 Hz

23: Kurtosis 0.01-0.02 Hz

36: Difference of energy 0.01-0.02 Hz & 0.02-0.1 Hz

51: Ratio of energy 0.01-0.02 Hz & 0.02-0.1Hz

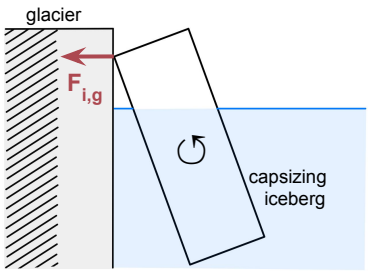
56: Ratio of energy 0.02-0.1 Hz & 0.5-1 Hz

57: Ratio of energy 0.02-0.1 Hz & 1-3 Hz

103: Time difference of highest amplitude in 0.01-0.02 Hz and 0.02-0.1 Hz

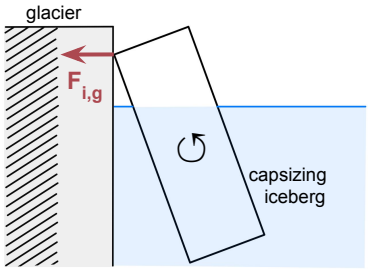
Summary and Outlook

1. Seismology

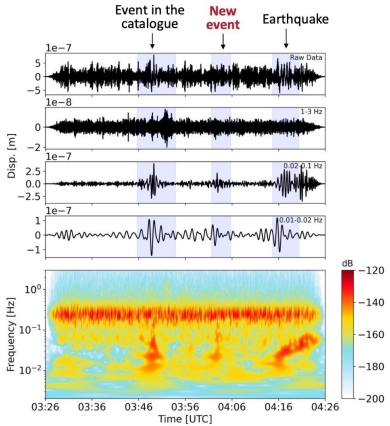


Summary and Outlook

1. Seismology

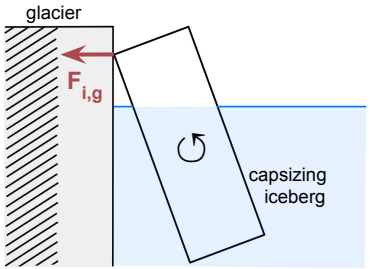


2. STA/LTA

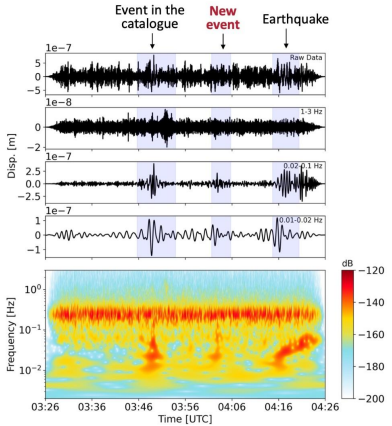


Summary and Outlook

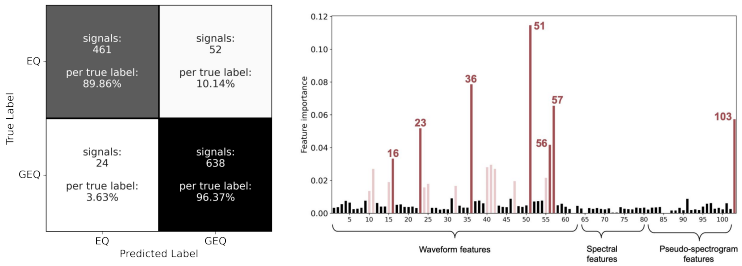
1. Seismology



2. STA/LTA

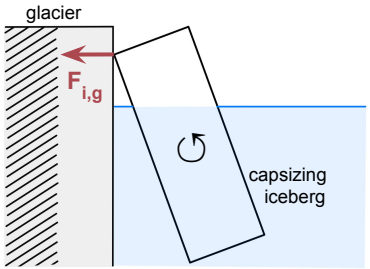


3. Machine Learning

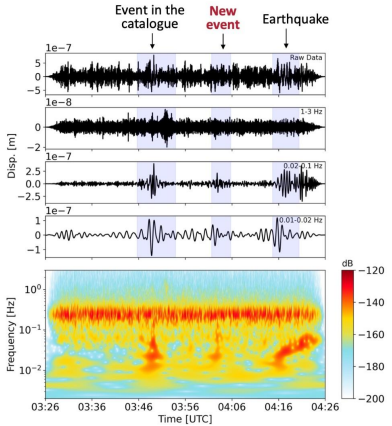


Summary and Outlook

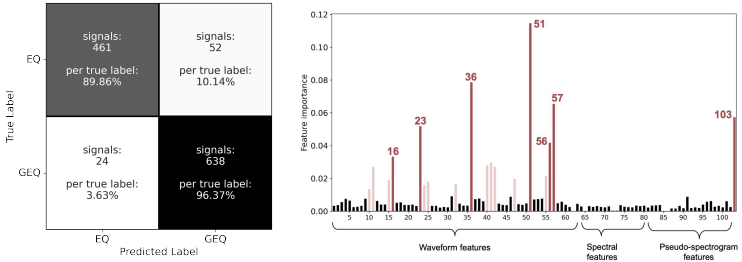
1. Seismology



2. STA/LTA



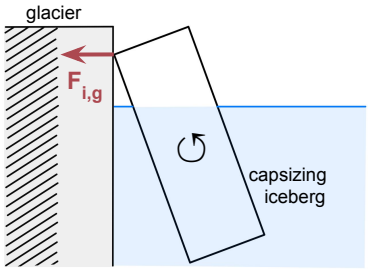
3. Machine Learning



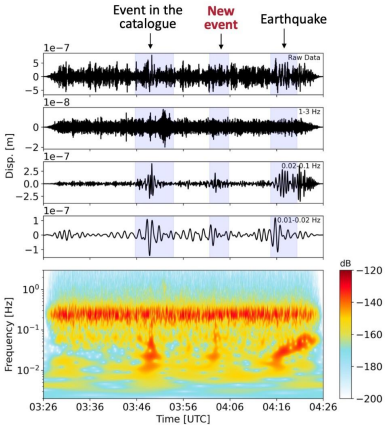
January 2013:
~200 events → ~ 30 GEQ

Summary and Outlook

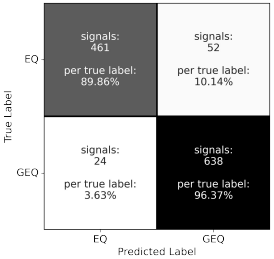
1. Seismology

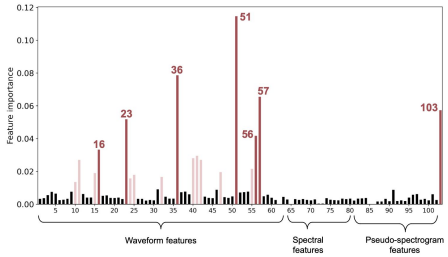


2. STA/LTA



3. Machine Learning





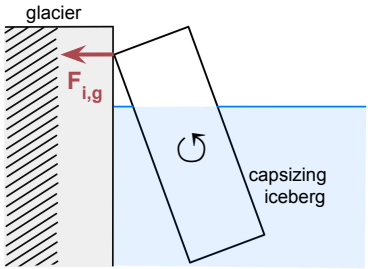
January 2013:
~200 events → ~ 30 GEQ

Outlook:

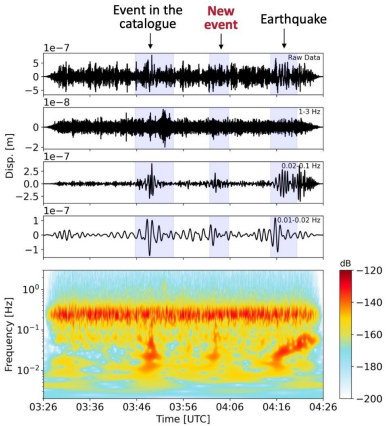
- Extend GCMT catalogue

Summary and Outlook

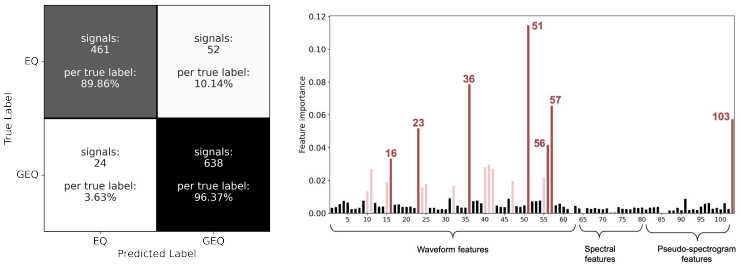
1. Seismology



2. STA/LTA



3. Machine Learning



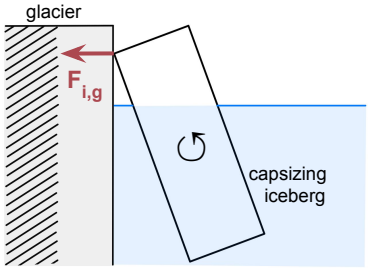
January 2013:
~200 events → ~ 30 GEQ

Outlook:

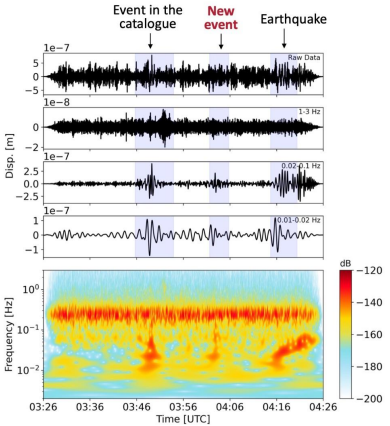
- Extend GCMT catalogue
- Quantify the spatio-temporal change of ice mass loss

Summary and Outlook

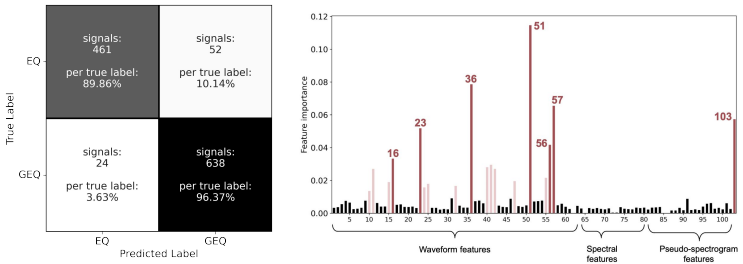
1. Seismology



2. STA/LTA



3. Machine Learning



January 2013:
~200 events → ~ 30 GEQ

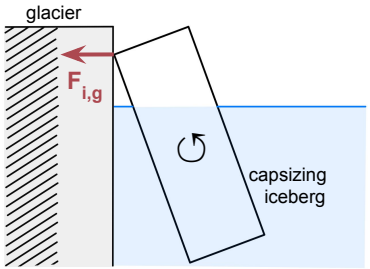
Outlook:

- Extend GCMT catalogue
- Quantify the spatio-temporal change of ice mass loss
- Inversion of the seismic signals to quantify the mass loss

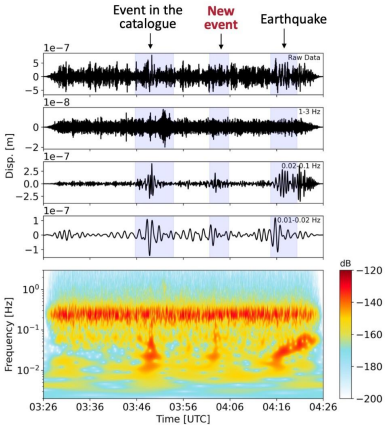
High fidelity modelling of iceberg capsize *Nicolas DE PINHO DIAS*
Amphitheatre, IPGP 11:45 - 12:00

Summary and Outlook

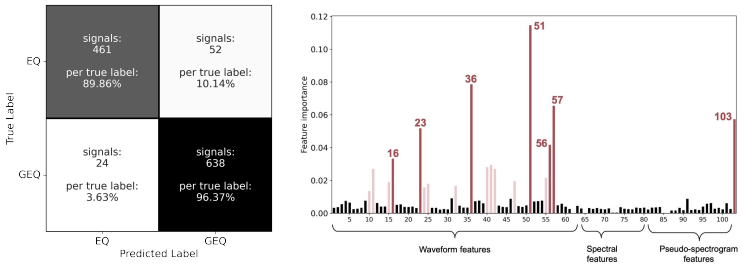
1. Seismology



2. STA/LTA



3. Machine Learning



January 2013:
~200 events → ~ 30 GEQ

Outlook:

- Extend GCMT catalogue
- Quantify the spatio-temporal change of ice mass loss
- Inversion of the seismic signals to quantify the mass loss
- Correlations between events and external factors, such as climatic and meteorological

High fidelity modelling of iceberg capsize *Nicolas DE PINHO DIAS*
Amphitheatre, IPGP 11:45 - 12:00

Thank you!