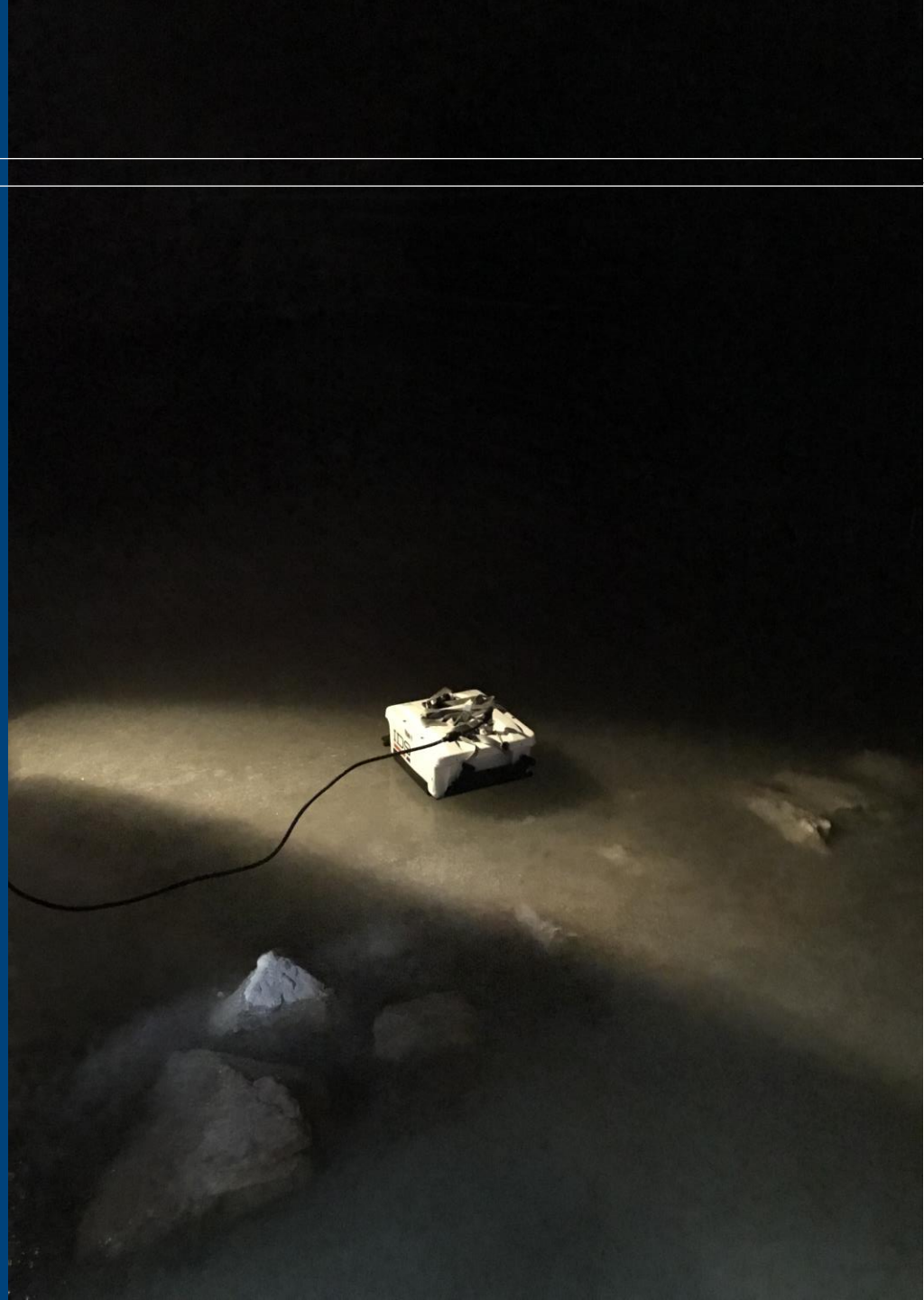
TECHNISCHE UNIVERSITÄT DRESDEN

Ice-Basement Mapping of Eisriesenwelt Cave Using Ground Penetrating Radar



Master Thesis Presentation

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31.01.2018

International Master of Science in Cartography

Contents

Introduction - Motivation

Pioneering

- First areal ice-basement mapping in an ice cave globally. Example of the application of ground penetrating radar (GPR) in Eisriesenwelt, the largest ice cave on Earth.

“Hot” research topic

- Cave-ice volume and its stability is a crucial indicator of climate changes.

Proxy

- Together with the 3D visualization model of Eisriesenwelt, a large-scale ice-thickness map is able to serve as a historical ice volume record.

Introduction - Workflow

Data Collecting

- Collecting raw GPR data of ice thickness

Data Processing

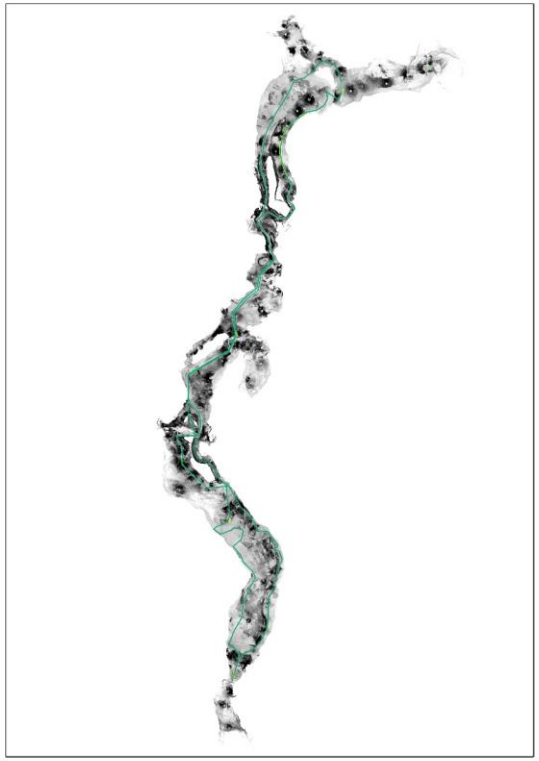
- Data enhancement, time-depth conversion, layer analysis

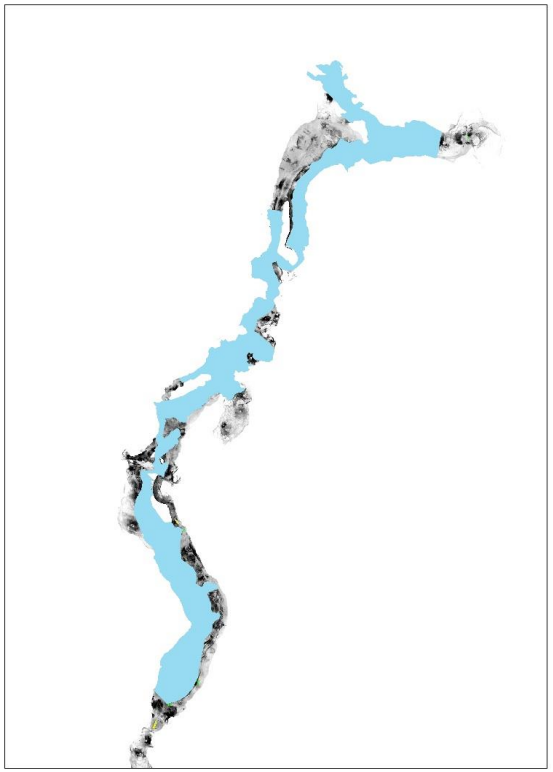
Ice-Basement Mapping

- Feature point extraction, feature point interpolation, map generation

Study Site

- Northern Austrian Alps
- Ice-covered part of cave system
- Approx. 24,400 square metres in 201X





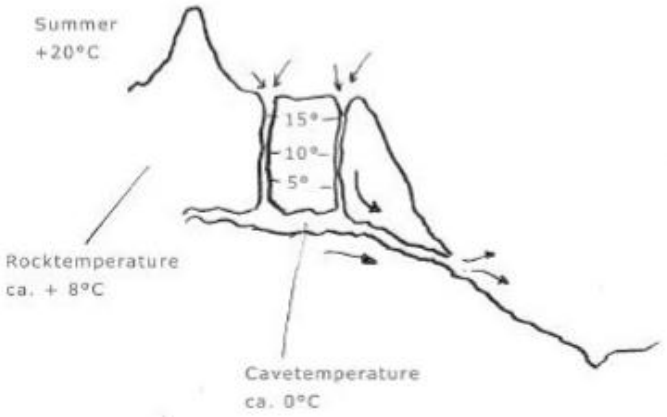
Study Site

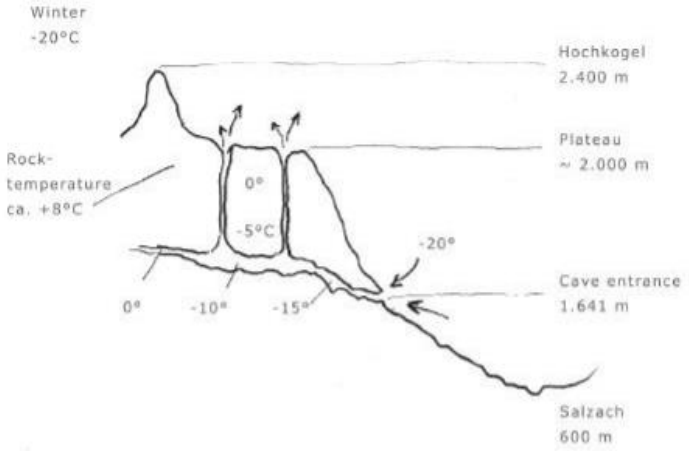
Classification of Eisriesenwelt:

- A dynamic cave with strong Chimney Effect

Origin of the cave ice in Eisriesenwelt:

- Freezing of infiltrating water

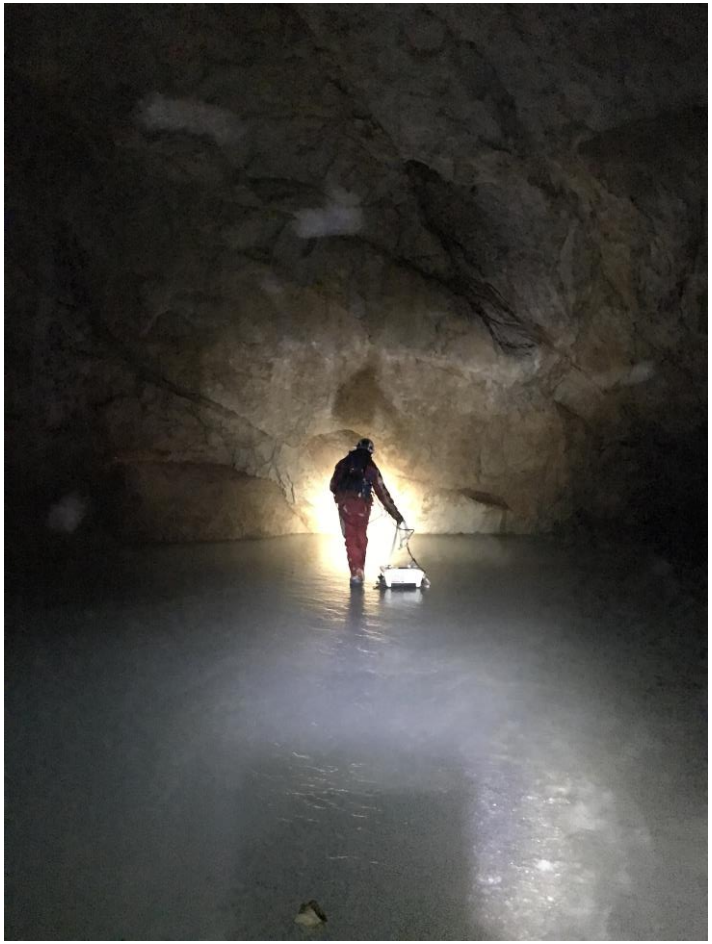




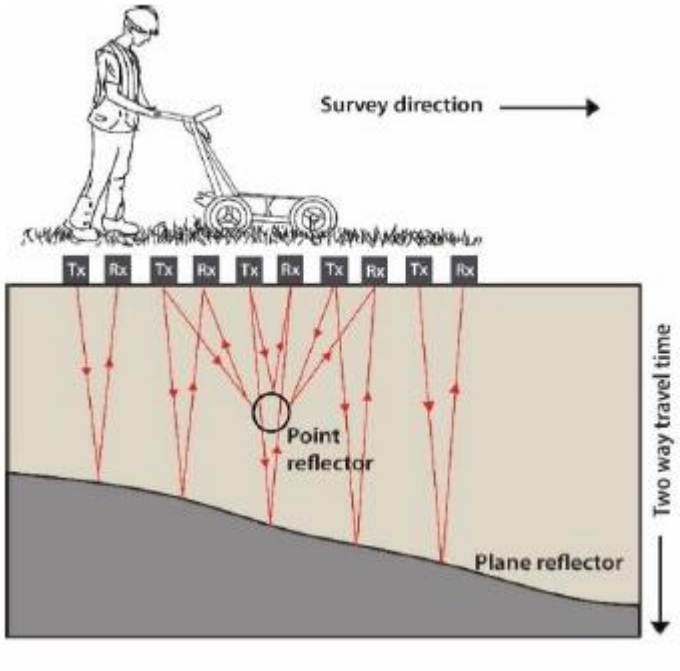
Data Preparation

Data Collection

- 20. 04. 2017 – 23.04.2017
- 143 datasets (survey profiles)
- Type: IDS GPR, RIS MF Hi-Mod (Dual frequency: 200HMz/600HMz)
- Sampling rate: 32 traces per second
- Hand-towing scans: 0.5m/s in average



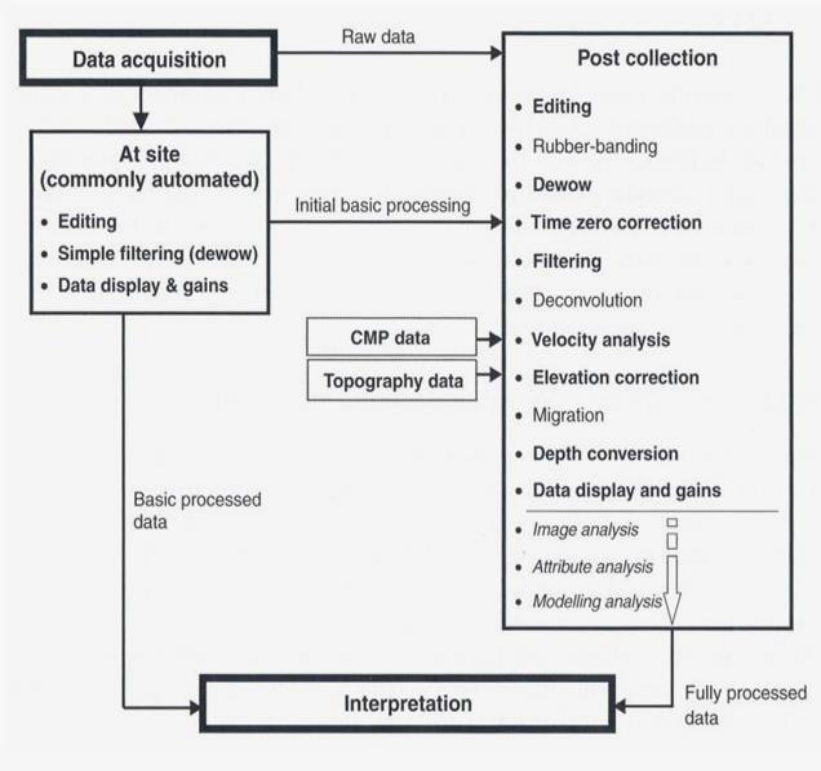
Data Preparation



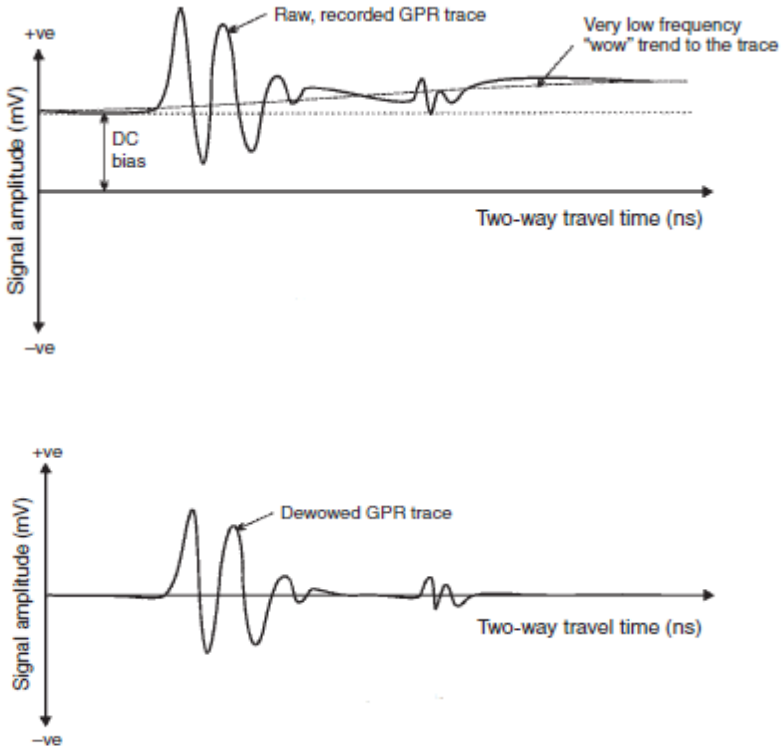
Data Preparation

Data Pre-Processing Steps:

- Dewow Filtering:
  Eliminating low-frequency signal bias caused by Wow Effect
- Time-Zero Correction:
  Removal of the wave echo from the ice surface and radar shell
- User-Defined Gain Function:
  Exponential gain to enhance the traces horizontally
- Trace Editing:
  Removing the traces recorded while the antenna was occasionally stopped incidentally



Data Preparation – Dewow Filtering



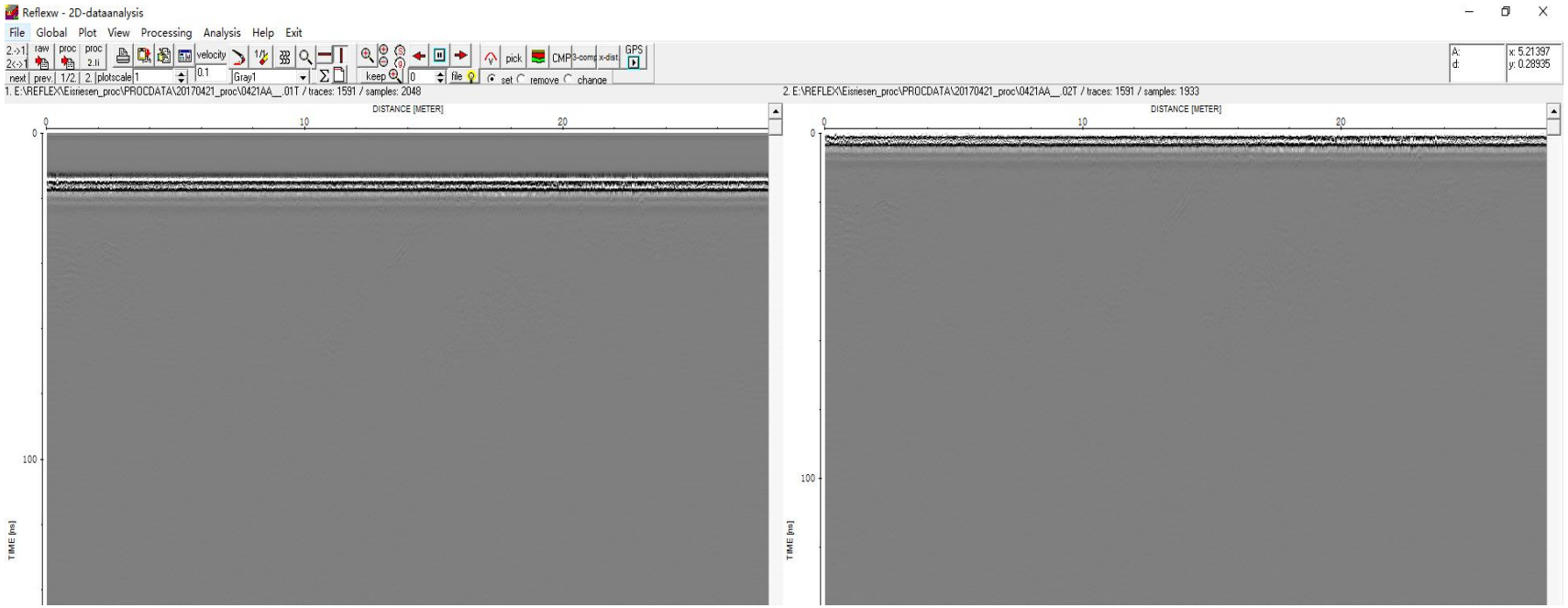
Origin of Wow Effect:

- Caused by swamping or saturation of the recorded signal by early arrival of radar wave echo.

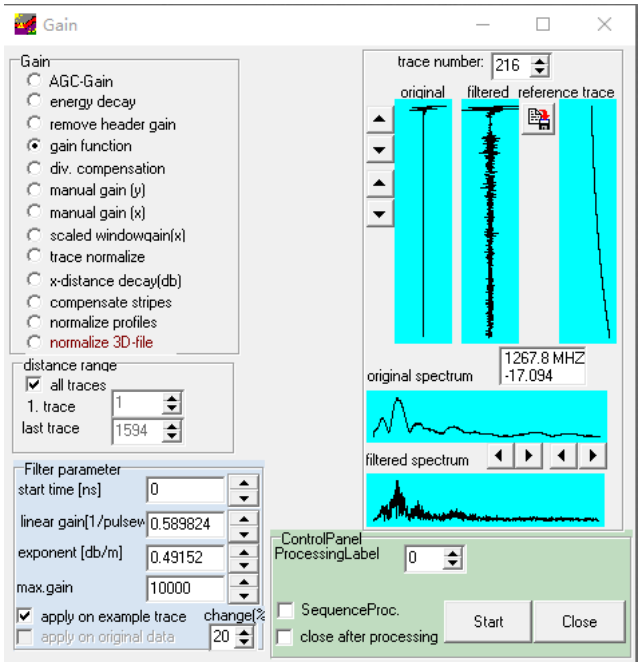
Dewow Filter:

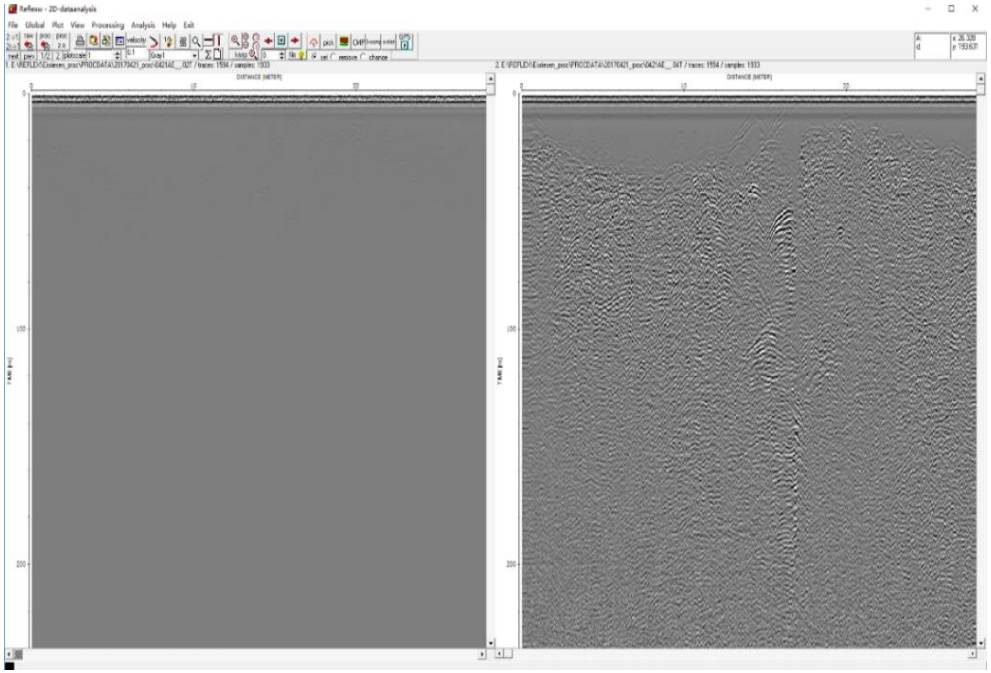
- Quasi Mean Filtering

Data Preparation: Time-Zero Correction



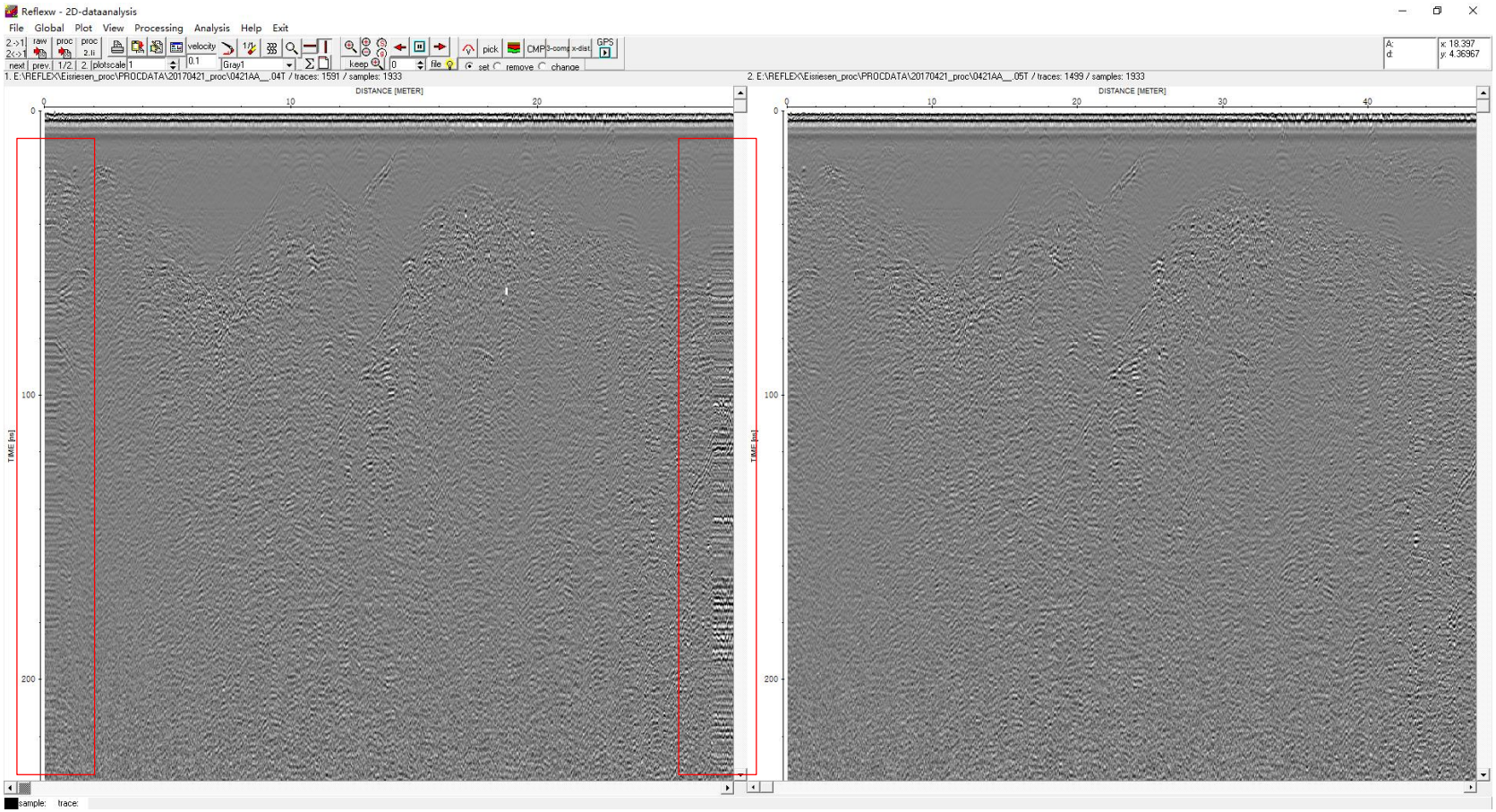
Data Preparation – Gain Function





Amplitude information is enhanced by changing linear gain to exponential

Data Preparation – Trace Editing



Methodology: Time–Depth Conversion

Electromagnetic Wave Propagation Properties

Material	Relative electrical permittivity	Electrical conductivity (mSm^{-1})	Velocity ($m\ ns^{-1}$)	Attenuation ($dB\ m^{-1}$)
Air	1	0	0,30	0
Distilled water	80	0,01	0,033	0,002
Freshwater	80	0,5	0,033	0,1
Saltwater	80	3000	0,01	1000
Dry sand	3 - 5	0,01	0,15	0,01
Saturated water	20 - 30	0,1 – 1,0	0,06	0,03 – 0,3
Silt	5 - 30	1 – 100	0,07	1 – 100
Clay	5 - 40	2 – 1000	0,06	1 – 300
Granite	4 - 6	0,01 – 1	0,13	0,01- 1
Ice	3 - 4	0,01	0,167	0,01

Methodology: Time–Depth Conversion

Data Migration:

- Correction of the trace features for true spatial position in nature
- Enhance section resolution

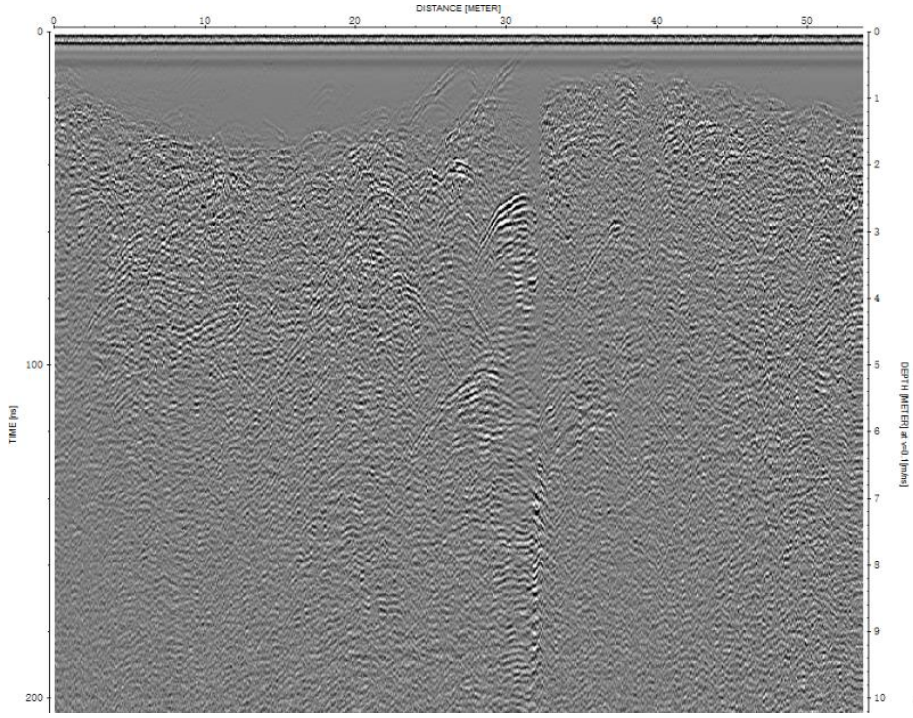
Precondition of Data Migration:

- The velocity structure of the subsurface must be known (or accurately estimated), and the stratigraphy is constructed of laterally invariant, constant velocity layers.
- The source is spatially uniform and propagates spherically.

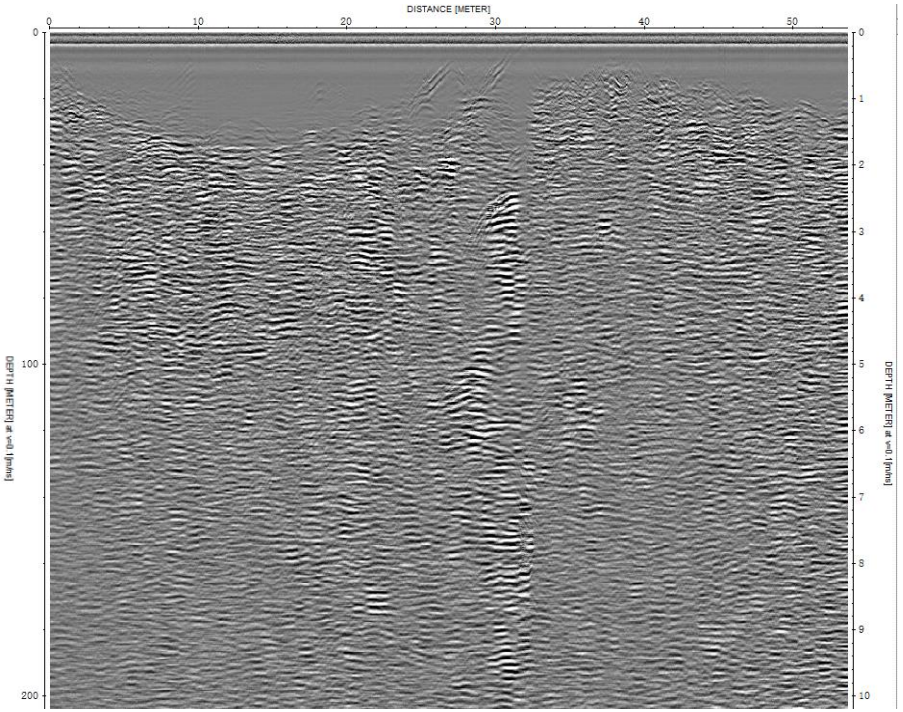
Migration method:

- Kirchhoff Migration (only vertical velocity variation accounted)

Methodology: Time – Depth Conversion



Unmigrated

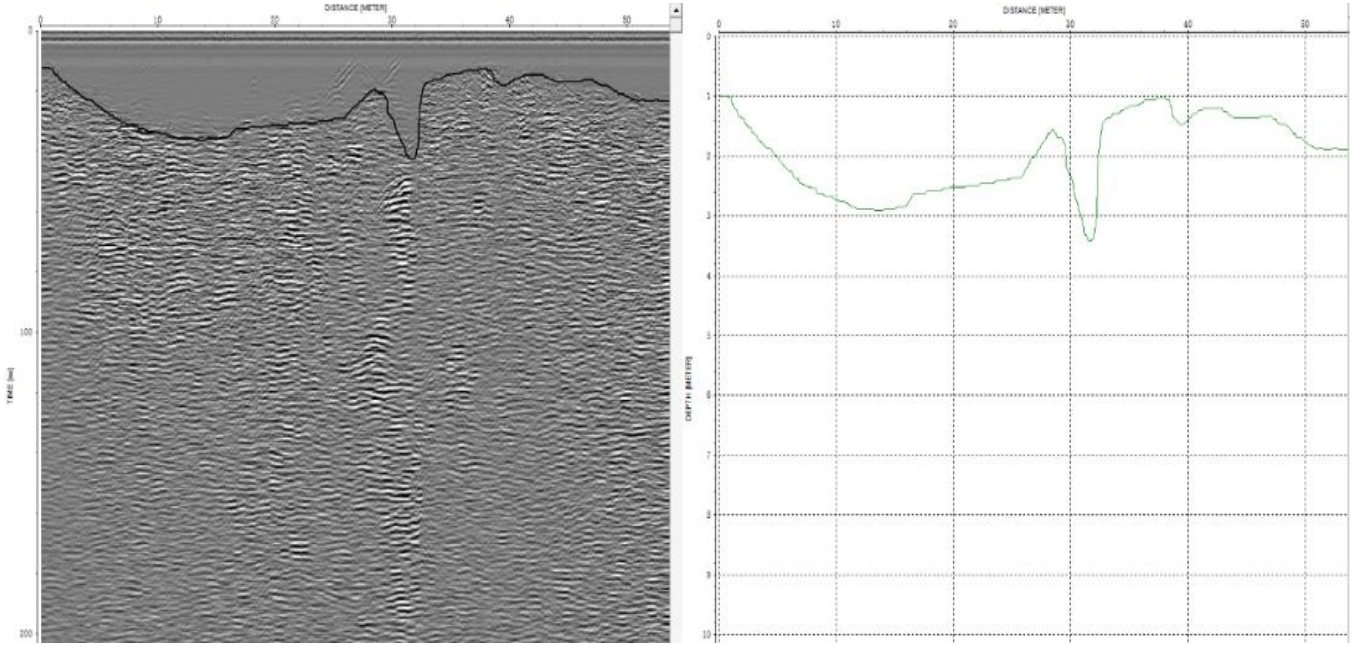


Migrated

Methodology – Layer Analysis

Manual Boundary Drawing:

- Frequently applied in mineral and petroleum prospection
- The most efficient way to extract ice–rock boundaries



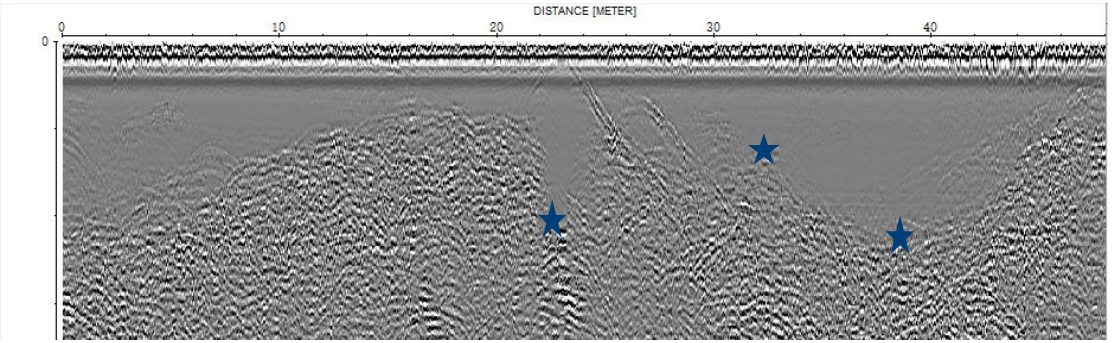
Methodology – Feature Points Sampling

Feature Points:

- Semi–Automated extracted
- Sampling density on the profile direction is less than 2 meters

Feature Points manual picking criteria:

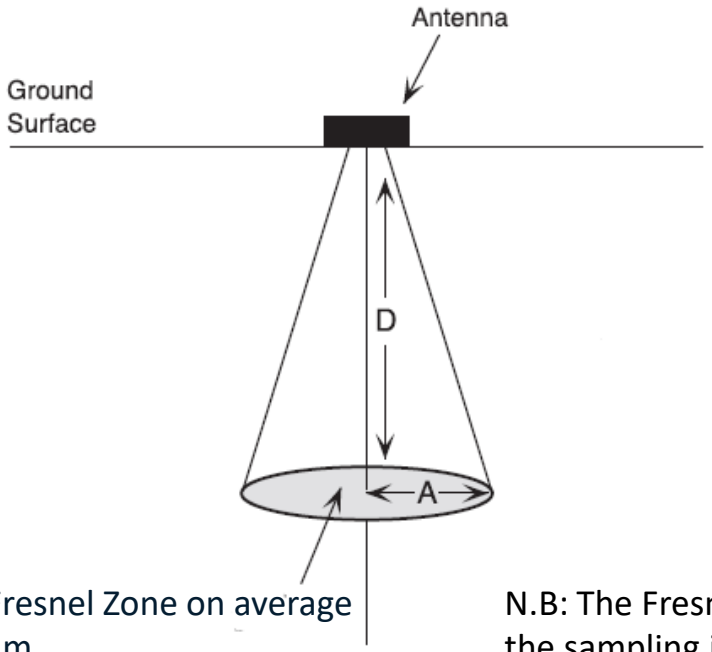
- Discontinuity
- Distinguishable hollow structures
- Local maximum-depth points



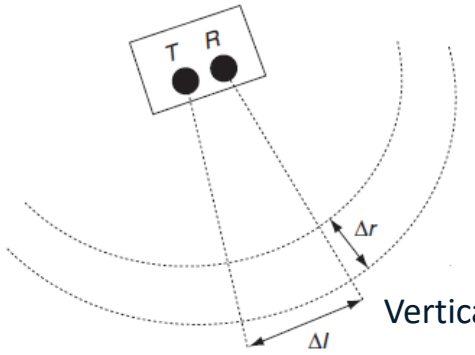
Methodology – Accuracy Assessment

Resolving Power of GPR:

- Horizontal resolution Δl: The width of the radar Fresnel Zone
- Vertical resolution Δr : One-forth of the dominant wavelength



Diameter of Fresnel Zone on average ice depth: 6.1m



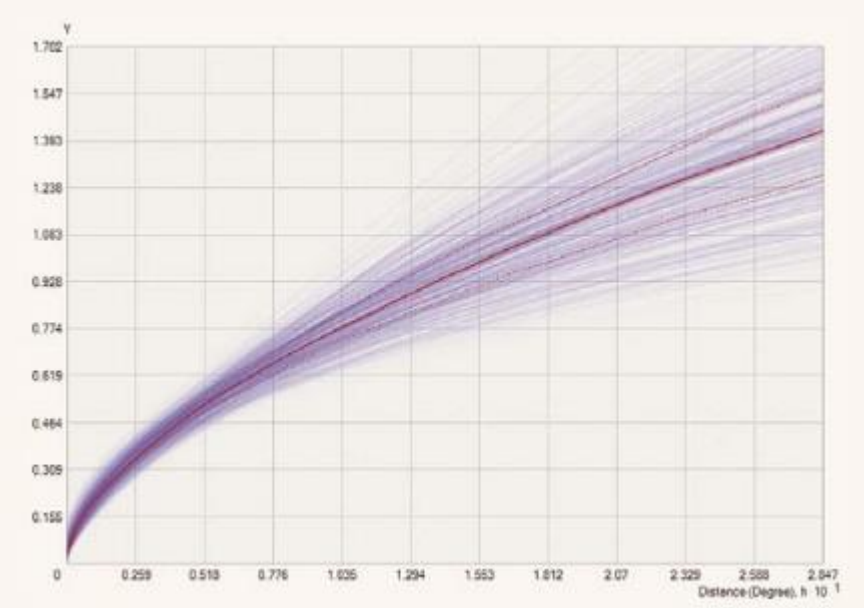
Vertical Resolution: 0.2m

N.B: The Fresnel Zones could cover the sampling intervals effectively

Methodology – Depth Interpolation

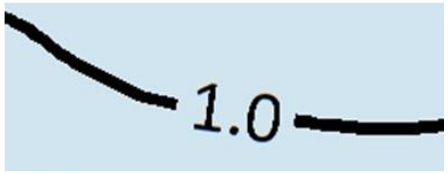
Empirical Bayesian Kriging:

- Multiple semivariogram models involved
- The errors from classical Kriging were taken into account



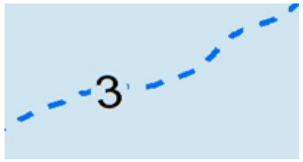
Methodology – Map Symbols

Depth contour with 2-meter interval



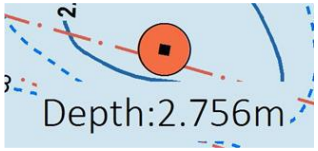
Depth contour with 1-meter interval

Depth contour with 0.5-meter interval

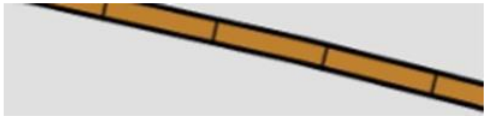


GPR Survey Lines

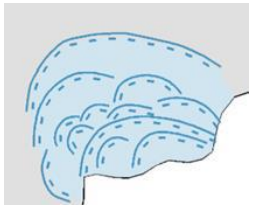
Point of Interest



Walking Path



Icefall



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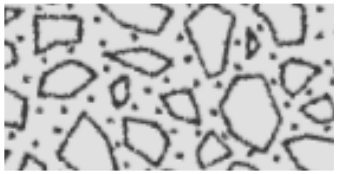
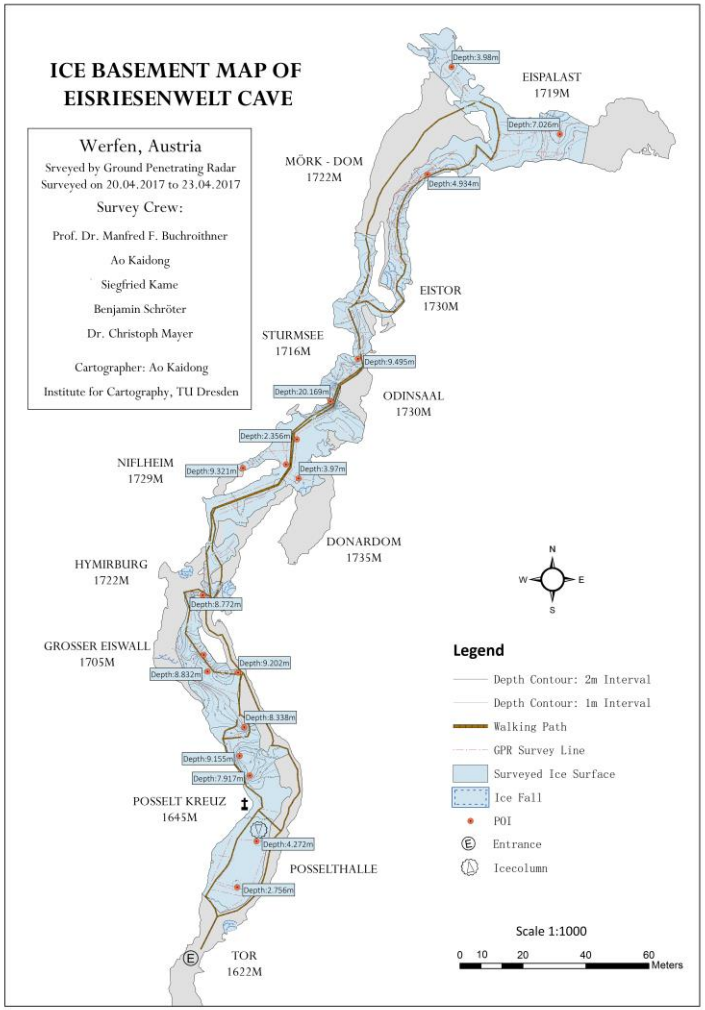
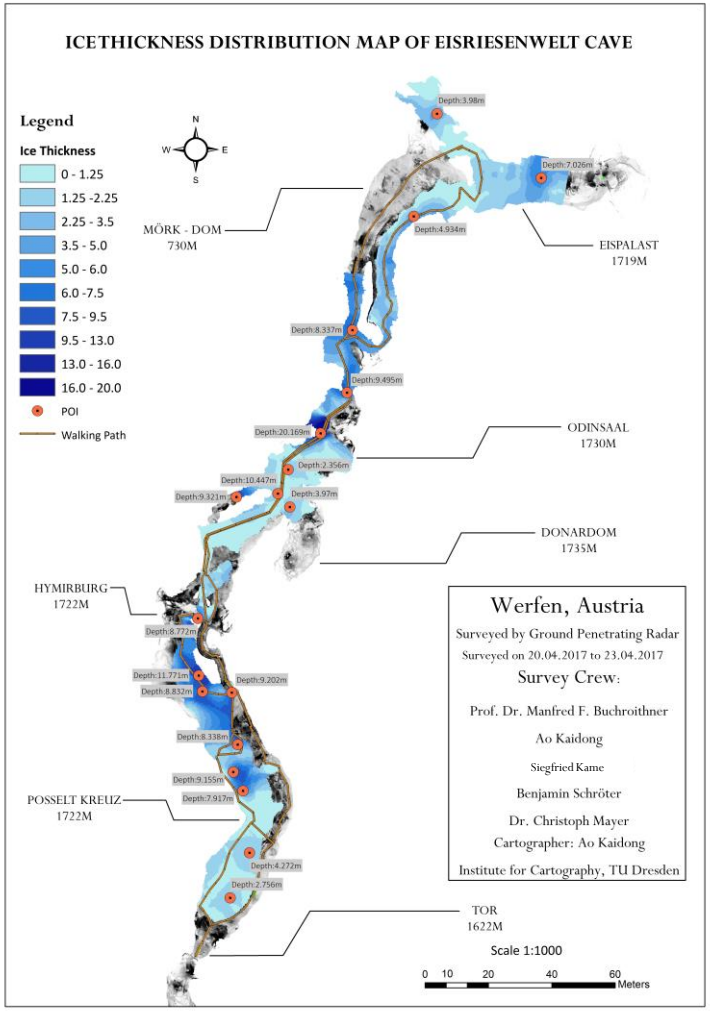


Ice Basement Maps





Outlooks

A 2D map with a profile view with a clear ice-rock boundary can be made in further researches.

Ice volume can be calculated from the ice-thickness data.

Possibilities offered for 3D modelling of ice thickness.

Thank you for your attention