The Air of the Past

The European Effort to Obtain A 1.5 Myr Greenhouse Gas – Climate Feedback Record from an Ice Core in East Antarctica

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www.beyondepica.eu

The Mid Pleistocene Transition (MPT)

Warmer; less ice

“100k world”

“Mid-Pleistocene Transition (MPT)”

Start of N.H. glaciation

“40k world”

Benthic δ¹³C (per mil)

Age (ka)
European Project for Ice Coring in Antarctica
Five IPICS Grand Challenges

1. **The oldest ice core**: A 1.5 million year record of climate and greenhouse gases from Antarctica

2. **History and Dynamics of the Last Interglacial Period from Ice Cores**: A comprehensive record of environmental change during the last interglacial.

3. **Terminations and seesaws**: An ice core contribution to understanding orbital and millennial scale climate change.

4. **The IPICS 2k Array**: A network of ice core climate and climate forcing records for the last two millennia.

5. **Ice Core Drilling Technical Challenges**: Development of advanced ice core drilling technology to realize the grand challenges

(https://www.pages-igbp.org/workinggroups/endorsed-and-affiliated/ipics/white-papers)

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EU expected impact in research

- To fill knowledge gaps in climate sciences
- To support major international scientific assessments such as the IPCC
- To increase confidence in climate change projections
- To provide added-value to decision and policy makers
- To consolidate Europe’s leadership in climate science
Deep polar ice cores since the 1960s

The scientific question
The scientific question

Lisiecki and Raymo, 2005

Global sea level & deep ocean temperature

CO₂ Concentration

+ 6 meters

–120 meters

100,000-year world

40,000-year world

Global Sea Level

1000 Years Before the Present

0 200 400 600 800 1000 1200

0 40,000-year world

100,000-year world

100,000 years

100,000 years

+ 6 meters

–120 meters

1000 Years Before the Present

0 200 400 600 800 1000 1200
Marine sediment records (bottom, black line) provide the combined sea level and deep sea temperature record over many million years back in time. Existing ice core record of Antarctic temperature (middle, red line) and atmospheric CO$_2$ (top, light blue line) going back only 800 kyr. Selected marine and blue-ice proxy records provide time slices of CO$_2$ at low resolution and precision, but no full continuous record (top left).

1 Myr old ice in Allan Hills (blue ice)

Depth-age relationship of ALHIC1502 (blue) and ALHIC1503 (red) ice cores.
Comparison of blue-ice CO₂ record and boron-based CO₂ reconstructions during and before the MPT

**Underlying Science**

- Unless we understand the transition from 40 kyr cycles to 100 kyr cycles, we don’t really understand today’s climate
- Why did we have the Mid-Pleistocene Transition (MPT) around 900 kyr ago?
- Why do we now live in a 100 kyr world?

**We need a continuous ice core record**
Special insights from a 1.5 Myr ice core

- Greenhouse gases (CO$_2$, CH$_4$, N$_2$O) and their isotopes
- Antarctic temperature and precipitation
- Ice sheet altitude
- Sea ice in the 40k world, proxy Br
- Granite weathering proxy CF$_4$
- Mean ocean temperature using noble gas thermometry
- Magnetic anomalies in cosmogenic isotopes
- Organic tracers in the ice
- ...

Pushing forward analytical chemistry

LA-ICPMS

Bohleber et al. JAAS, 2020
Conclusions

The new method advances the key strength of LA-ICP-MS as a technique to study ice impurity localization, namely its high speed, high spatial resolution and highest image quality. The rapid aerosol transfer allowed by the fast washout technology allows line profiles at speeds comparable to existing melting techniques optimized for acquisition of transient signals in ice cores. This could be also beneficial for high speed impurity profiling by continuous line measurements along the main ice core axis. However, as shown in the present work, the higher resolution also raises questions concerning the spatial representativity of single LA-ICP-MS profiles, hence calling for a dedicated investigation of this issue. In the context of future applications, next steps concern the imaging analysis of ice core samples over various depth ranges and climatic periods, targeting the wider investigation also of potential additional elements with paleoclimatic significance. Of additional interest is to perform an inter-method comparison of impurity localization on the same ice samples to obtain additional validation of the new method. If combined with sophisticated large volume cryo-holders for meter-long rods of ice, the LA-ICP-MS technology may eventually surpass both in speed and spatial resolution existing melting techniques optimized for acquisition of transient signals in ice cores.

Through advancing our understanding of the signal constraints arising from the ice microstructure, results of the present work set a cornerstone to tap the full potential of LA-ICP-MS for investigating past environmental signals archived in the oldest and highly thinned layers of ice cores.

Conflicts of interest

There are no conflicts to declare.

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**Pushing forward analytical chemistry**

- CPI values (CPI), determined as the ratio of compounds with odd to even molecular weight fatty acids (LFA) (see below), which have been used and expanded on in subsequent studies (et al., 1996).

- Lipid compounds from terrestrial sources may be identified. Terrestrial particles may further be distinguished from those of anthropogenic sources using the Carbon Preference Index (CPI).

- Beyond EPICA Adventure

- **Our dreams**
  - 3yrs
  - 5yrs
  - 5yrs

- **The reality, ... as it is today**
  - 3yrs
  - 6 (+) yrs

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Beyond EPICA – Oldest Ice Core

What we promised!

1. **Retrieving a continuous ice core to bedrock** in Antarctica, which covers the climate history of the Mid Pleistocene Transition and beyond
2. Logging, screening and cutting of ice core samples in the field
3. Establishing a first robust age scale for the BE-OI Core
4. Deriving first high-resolution climate records over the time interval older than 700 kyr
5. Recovery of basal ice and bedrock

Where to find such old stratified ice?

- **deep ice cores:**
  - low accumulation
  - Cold
  - cold, flat base
  - not too thick
  - little lateral flow
  - Fischer et al., CP 2013
  - Van Liefferinge & Pattyn, CP 2013
  - Parrenin et al., TC 2017

- **blue ice areas?**
  - Keel et al, GRL 2018
  - Yan et al, Nature 2019
Where to find such old stratified ice?

- Deep ice cores: low accumulation, cold, flat base, not too thick, little lateral flow
- Fischer et al., CP 2013
- Van Liefferinge & Pattyn, CP, 2013
- Parrenin et al., TC 2017
- Kehrl et al., GRL 2018
- Yan et al., Nature 2019
- Allan Hills (US)
- Grove Mountains (CN)
- Little Dome C (EUR, AUS)
- Ridge B (RUS)
- Dome F (UP)
- Dome A (CN)
- Dome C (EUR, AUS)

Where to find such old stratified ice?

Beyond EPICA – Oldest Ice Core

Concordia region

More than 2300km in the 2 seasons of survey
Beyond EPICA – Oldest Ice Core

R. Mulvaney, pers. Comm., 2019

Logistic Plan for BE-OIC

5000 man/day in the field
Air cargo: 22 tons
Fuel: 100 m³
Cargo traverse: 80 tons
Overall budget ≈ 30 M€
Thank you for your attention and see you in LDC

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