Greenhouse gas (CO_2, CH_4) alteration in shallow ice at Larsen blue-ice area, Northern Victoria Land, East Antarctica

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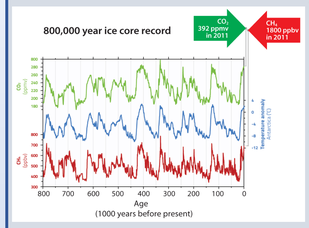
1. Introduction



- To date, CO_2 and CH_4 concentration is reconstructed for the last 800 kyr analyzing air bubbles occluded in Antarctic ice cores.
- CO_2 and CH_4 concentrations can be altered due to high dust contents and/or microbial activity in ice cores (Rohde et al., 2008; Lee et al., 2020).

Figure 1. CO_2 and CH_4 concentration during the last 800 kyr (Source: International Geosphere-Biosphere Programme, modified from Loulergue et al., 2008 and Lüthi et al. (2008)).

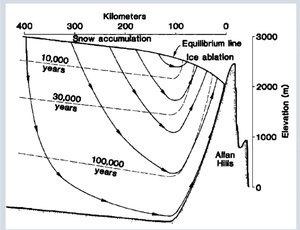


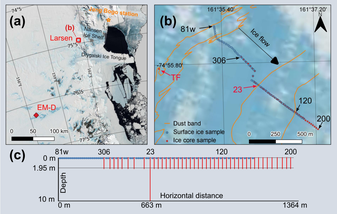
Figure 2. Schematic diagram of Allan Hills blue ice area. Ice flow is stagnated by Allan Hills and the glaciers are outcropped at the surface (Bintanga, 1999).

□ Blue ice area (BIA)
- Ice flow is redirected by topographic obstacles, and so ancient ice is outcropped at the surface.

□ Advantage of blue ice samples
- A shallow coring is available for obtaining very old ice.
- Possible to sample a huge amount of ice in the same age.

□ Disadvantage of blue ice samples
- Ice stratigraphy is complicated due to fold and fault structure.
- Trace gas compositions in shallow depths of ice are usually altered.

2. Study area



- Surface ice sample (●) and 2–10 m long ice cores were collected (◆).
- Dust bands with gentle folding structures in the mid- to downstream part were observed, while severely folded dust bands were observed (e.g. S- and Z-folds) in the upstream part (Fig. 3b).

Figure 3. Location of the Larsen BIA and sample collection. (a) Location of Larsen BIA and Jang Bo Go station. **(b)** Orange lines are dust bands. Blue dots are locations of surface ice samples. Red diamonds are locations of shallow ice cores. **(c)** Schematized cross-section of the transect (Lee et al., 2022).

3. Gas analysis

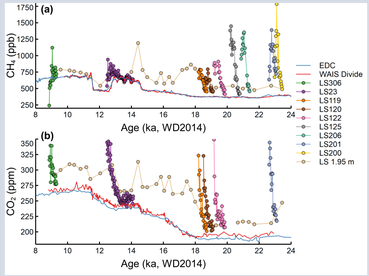


Figure 4. Comparison of CO_2 and CH_4 concentrations from EDC, WAIS Divide, and Larsen BIA. WAIS Divide: Rhodes et al., 2017; Marcott et al., 2014, EDC: Loulergue et al., 2008; Monnin et al., 2001; 2004; Schmitt et al., 2012. LS: Greenhouse gas concentration results from ice cores from Larsen BIA. LS 1.95 m represents ice from 1.95 m depth in each Larsen BIA ice core samples (Lee et al., 2022).

- CH_4 and CO_2 concentrations were measured from Seoul National University by wet and dry extraction methods, respectively.
- CH_4 concentration records from the Larsen BIA generally show an increasing trend from the subsurface to a depth of ~0.35–1.15 m. Then gradually decreases until it reaches to ~4.6 m depth.
- CO_2 concentration in the Larsen BIA shows a gradual decrease from the subsurface until a depth of ~4.6 m where the concentration variation stabilizes.
- CO_2 concentration in Larsen BIA ice samples (depth < 4.6 m) is elevated compared to EDC and WAIS Divide records.
- CH_4 concentration in Larsen BIA ice samples (depth < 4.6 m) is elevated and/or depleted compared to EDC and WAIS Divide records.

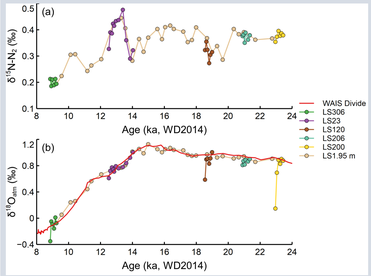


Figure 5. Comparison of $\delta^{15}N\text{-}N_2$ and $\delta^{18}O_{atm}$ records with WAIS Divide records. WAIS Divide: Severinghaus (2015). LS1.95 m and LS23: Lee et al. (2022). LS 1.95 m represents ice from 1.95 m depth in each Larsen BIA ice core samples (Lee et al., 2022).

- $\delta^{15}N\text{-}N_2$ and $\delta^{18}O_{atm}$ were measured from National Institute of Polar Research in Japan simultaneously by a wet extraction method.
- The distribution of $\delta^{15}N\text{-}N_2$ in several Larsen BIA ice cores shows comparable results to each other, which indicates that modern atmospheric air intrusion is not significant at the top ~10 m.
- Depleted $\delta^{18}O_{atm}$ at a depth of < 2 m indicates that microbial activity consuming O_2 gas in Larsen blue ice samples is less likely, because organisms preferentially use ^{16}O, which enriches the residual O_2 in the air bubble (Hu et al., 2022).

4. Pb analysis

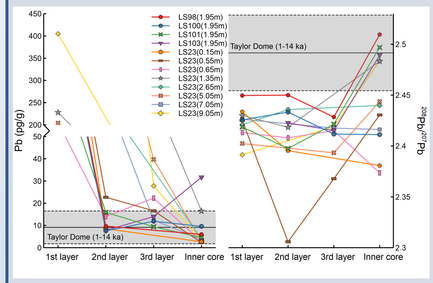


Figure 6. Pb concentration and isotope records from Larsen blue-ice area ices. Numbers in parenthesis are the mid-depth of ice used.

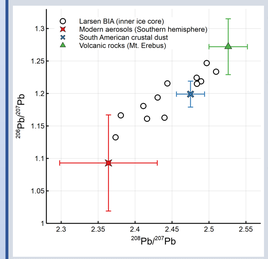


Figure 7. Pb isotope endmembers and isotope records from Larsen blue-ice area ices. Modern aerosols: Bollhöfer and Rosman, 2000. South American crustal dust: Gili et al., 2016. Volcanic rocks: Sun and Hanson, 1975.

- ~3 mm, ~2 mm, ~1 mm of layers from the outermost side of the ice samples were shaved off for decontamination.
- Pb from 1.35 m, 9.05 m depth ice of LS23 and from three 1.95 m depth ices of Larsen BIA ice cores are not significantly altered by modern aerosols.
- ~6 mm shaving of the outermost surface may not be sufficient for decontamination or aerosol records are altered in some Larsen BIA ice samples by modern aerosol intrusion.
- Large amount of excess greenhouse gas concentrations are still present where Pb records are not altered significantly, indicating that greenhouse gas alteration is not related to the modern aerosol intrusion.

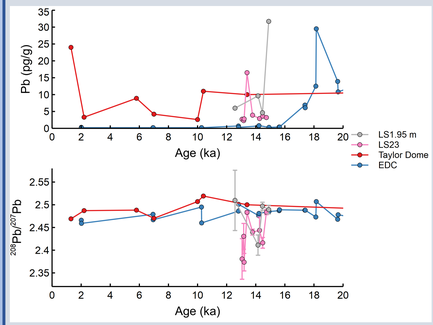


Figure 8. Comparison of Pb concentration and isotope records from Taylor Dome, EDC, and Larsen BIA. Taylor Dome: Matsumoto and Hinkley (2001). EDC: Vallelonga et al., (2010).

5. Conclusion

- Greenhouse gas (CO_2, CH_4) concentrations are altered at shallow depth of < 4.6 m of Larsen BIA.
- CH_4 concentration generally show an increasing trend from the surface to a depth of ~0.35–1.15 m. Then gradually decreases, while CO_2 concentration shows a gradual decrease from the subsurface until a depth of ~4.6 m
- Based on $\delta^{15}N\text{-}N_2$, modern air intrusion has not caused the greenhouse gas alteration.
- Based on $\delta^{18}O_{atm}$, biological activity is less likely for altering the greenhouse gas concentrations in the shallow ice samples.
- Based on the Pb isotope results, greenhouse gas alteration is not related to modern aerosol intrusion.

6. References

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