

CC1: “Comment on egusphere-2025-5637” – Jeff Welker (28 Nov 2025)

Gabriel, great job on this and thanks so much for continuing to focus on winter emissions so so important.

5 **Response**

We thank Jeff Welker for his positive assessment of the manuscript and for underscoring the importance of winter greenhouse gas fluxes to Arctic carbon fluxes.

10 However, you have missed my program's beginning of this modern day (past ~ 3 decades) field of research which was initially criticized when I presented our initial NSF funded data from Arctic Alaska in CPH at the 1997 ITEX meeting. I showed the flux data, measurable and argued that when winter emissions (~240 days of snow cover in N AK) were added to summer net fluxes, the tundra was a net C source: "Jeff you are crazy". how can all that SOM, permafrost be present if the system is a net C source ?" came the audience challenges. My reply was today is different than the past and we now have real emission data from what makes the Arctic, the Arctic, winter. I have been delighted see Webb, Natalie, and others, including your team, join
15 my winter emission crusade.

Response

We thank Jeff Welker for drawing attention to this important omission. We agree that the pioneering winter flux measurements led by the Welker group in the late 1990s and early 2000s constitute foundational contributions to modern understanding of
20 Arctic winter carbon exchange. We have revised the Introduction to explicitly acknowledge these earlier studies and to situate our work within this established research trajectory.

Revised manuscript text (Introduction)

25 *Simulations urgently require improvement as measurements of cold season GHG fluxes in Arctic ecosystems have been shown to contribute substantially to annual carbon budgets. Field measurements from northern Alaska demonstrated that CO₂ emissions during the snow-covered season can be large enough to offset or exceed growing-season uptake (Fahnestock et al., 1998, 1999; Jones et al., 1999b; Welker et al., 2000), and recent syntheses reinforce these findings at pan-Arctic scales (Natali et al., 2019; Rafat et al., 2021). Relatively small CH₄ emissions during the lengthy cold season have also been shown to contribute >50 % of annual total sources in Alaskan tundra (Zona et al., 2016). Collectively, such studies established winter
30 as a critical period for Arctic carbon cycling and motivated subsequent efforts to quantify cold-season fluxes across a wider range of Arctic and sub-Arctic ecosystems.*

35 *Soil-atmosphere fluxes derived from direct measurements of snowpack CO₂ and CH₄ concentrations and steady-state diffusion models have been used for several decades to estimate winter greenhouse gas fluxes in Arctic ecosystems. Manually extracting air from snowpacks with syringes allows for cost effective and spatially distributed flux measurements. However, large sample sizes (n >10) are difficult to collect within time scales where meteorological conditions are stationary and wind speeds are low, and require several samples to be extracted and analysed per microsite for flux calculations (Jones et al., 1999a;*
40 *Mavrovic et al., 2023; Seok et al., 2009; Zhu et al., 2014). Faster, high accuracy in situ snowpack gradient measurements of CO₂ flux (and later CH₄) were more recently made possible using portable Infrared Gas Analysers (IRGA), quantifying winter soil-atmosphere fluxes across a variety of Arctic land surface covers (Fahnestock et al., 1998; Jones et al., 1999b; Pirk et al., 2016).*

45 These are some of the absolute foundational papers that you should be including in your introduction of the "issue" and in the discussion as to how this data compare to what the Welker program discovered decades ago and continue today. Thank you for all that you and your team are doing but knowing and recognizing the origins of this research theme, is essential to educating the readers on the foundational science and how your new science continues to strengthen our understanding of 2/3 of the Arctic's calendar :)

50 The first 4 are in many ways the "beginning of the modern winter C emission studies initiated by my team/s", W Ochel's group also published a 1997 paper as well.

And, our continued contributions with packages like Natali et al. 2019

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Response

- 85 [We agree and have incorporated the cited literature into the discussion. Several of these studies directly inform interpretation of our winter CO₂ flux magnitudes, snow depth controls, and the role of winter processes in annual carbon budgets.](#)

Revised manuscript text (Discussion)

- 90 *Measured winter CO₂ flux magnitudes at TVC are consistent with early observations from Arctic Alaska showing sustained cold-season emissions under snow cover (Fahnestock et al., 1998, 1999; Jones et al., 1999b; Welker et al., 2000). Subsequent work has demonstrated that snow depth, thermal insulation, and active-layer dynamics exert strong controls on winter respiration and the age of respired carbon (Lupascu et al., 2018; Pedron et al., 2023; Schimel et al., 2006; Sullivan et al., 2008). Measurements at TVC extend these findings by resolving fine-scale spatial variability in winter fluxes and by evaluating how simplified sampling strategies capture this variability under dry snowpack conditions.*

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