Snow cover heterogeneity and its impact on the Climate and Carbon cycle of Arctic regions (SnowC²)

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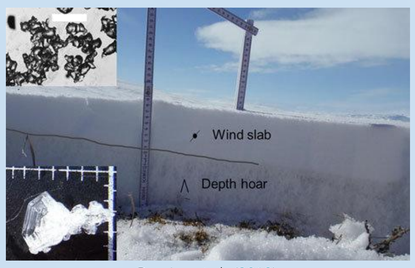
Problematic

- The Arctic has warmed 2 to 3 times faster than the global average (e.g., Cohen et al., 2014) ; nearly four times faster than the globe since 1979 (Rantanen et al., 2022)
- Impacts on ecosystems and human activities such as transportation, resource extraction, water supply, land use and infrastructure among others.
- Current snow models fail to capture essential aspects of Arctic snowpacks (depth hoar + wind slab + spatial heterogeneity).



Domine et al., (2019)

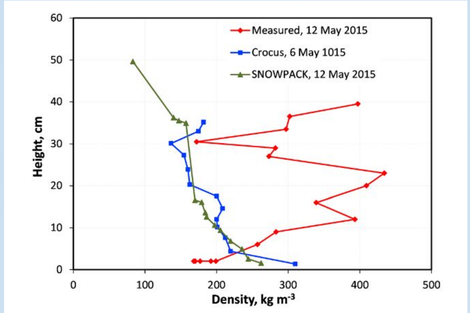


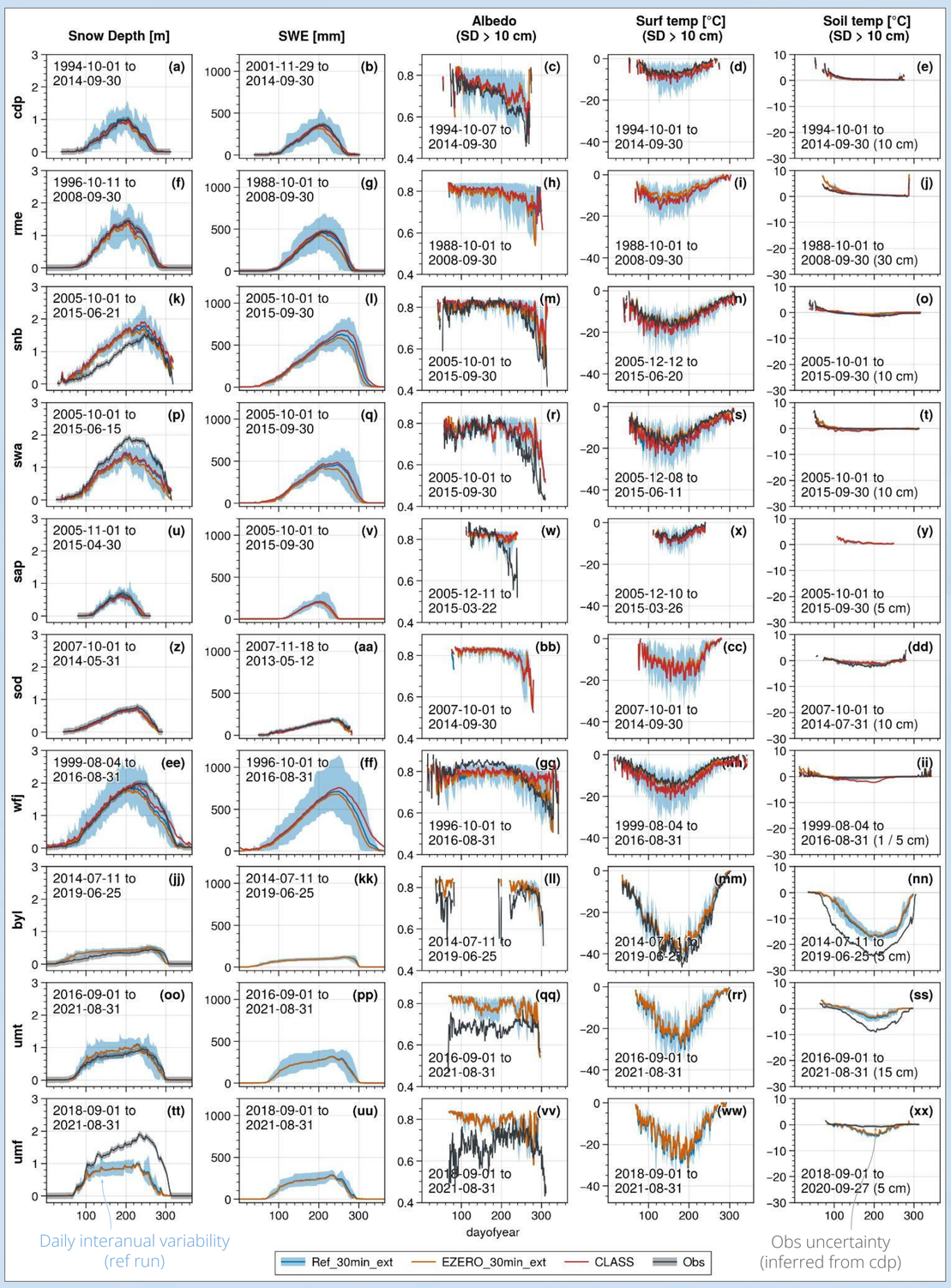
Figure 3. Comparison of measured snow density profiles at Bylot Island in May 2015 with those simulated using the detailed snow models Crocus and SNOWPACK. Crocus runs of 6 May are shown because Crocus simulates melting on 7 May, and this extra process makes comparisons irrelevant on 12 May.

Domine et al., (2018)

Objectives

1. Implement a multilayer snowpack in the Canadian Land Surface Scheme Including Biogeochemical Cycles (CLASSIC) adapted to the Arctic (in 1D simulations)
2. Include new snow cover fraction parameterizations + multilayer snowpack in spatial Arctic simulations → use of ESA CCI data (snow, land type, etc.) to calibrate and assess these new developments
3. Improved Arctic simulations with new snowpack (snow, energy/carbon fluxes, etc.)

Preliminary in-situ model assessment



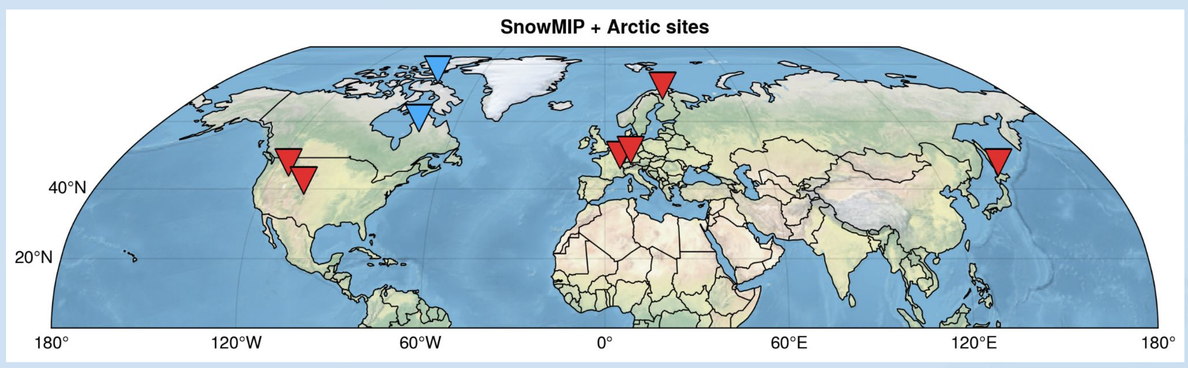
Daily interanual variability (ref run)

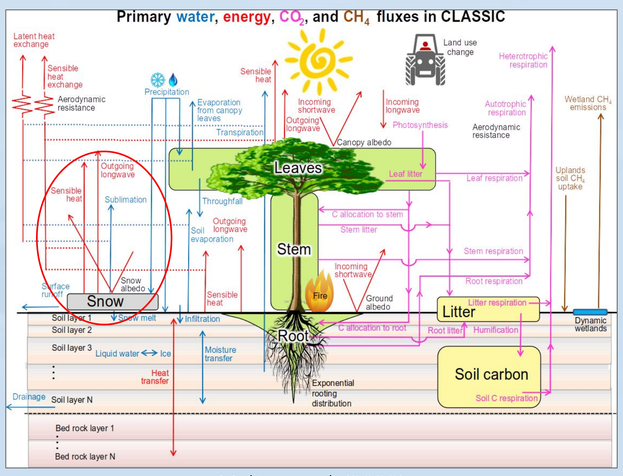
Obs uncertainty (inferred from cdp)

Ref: current CLASSIC version (CLASS + CTEM – 20 soil layers) / **EZERO**: windless exchange coefficient activated (2 W m^{-2} K^{-1}) / **CLASS**: previous model version (CLASS only – 3 soil layers)

*CLASS: Canadian Land Surface Scheme (physics) / CTEM: Canadian Terrestrial Ecosystem Model (biogeochemistry)

Methods

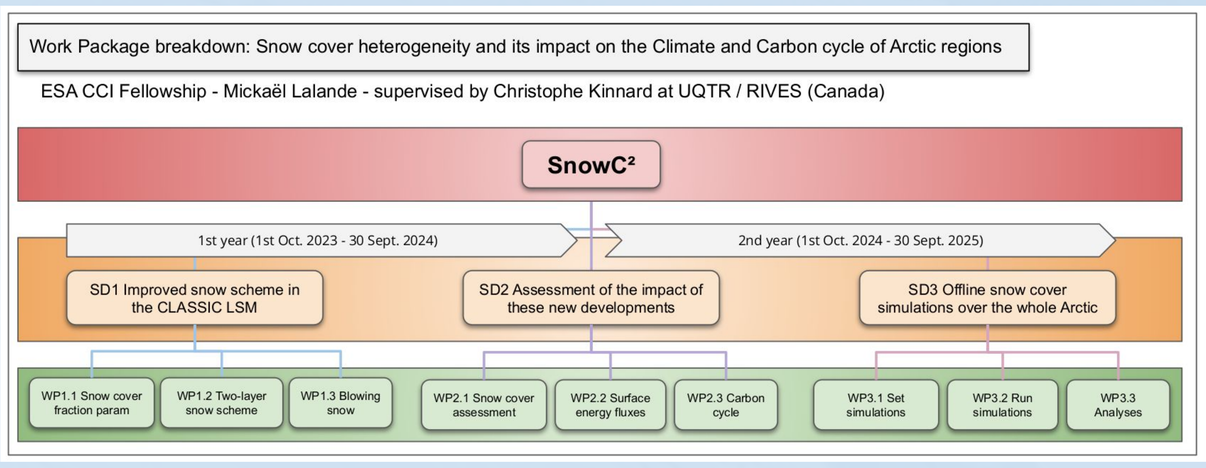




Melton et al. (2020)

1. Use SnowMIP + Arctic sites (Bylot, Umiujaq,...) to assess/develop the multilayer snowpack (e.g., ORCHIDEE, ISBA-ESA, etc.)
2. Arctic adaptation → e.g., Royer et al. (2021): Arctic Crocus (increase the compaction due to the wind + reduce the density of the lower layers)
3. Snow cover fraction param → e.g., Lalande et al. (2023) + ESA CCI data

Project work plan



References

Cohen, J., Screen, J. A., Furtado, J. C., Barlow, M., Whittleston, D., Coumou, D., Francis, J., Dethloff, K., Entekhabi, D., Overland, J., & Jones, J. (2014). Recent Arctic amplification and extreme mid-latitude weather. Nature Geoscience, 7(9), 627-637. https://doi.org/10.1038/ngeo2234

Domine, F., Belke-Brea, M., Sarrazin, D., Arnaud, L., Barrere, M., & Poirier, M. (2018). Soil moisture, wind speed and depth hoar formation in the Arctic snowpack. Journal of Glaciology, 64(248), 990-1002. https://doi.org/10.1017/jog.2018.89

Domine, F., Picard, G., Morin, S., Barrere, M., Madore, J.-B., & Langlois, A. (2019). Major Issues in Simulating Some Arctic Snowpack Properties Using Current Detailed Snow Physics Models : Consequences for the Thermal Regime and Water Budget of Permafrost. Journal of Advances in Modeling Earth Systems, 11(1), 34-44. https://doi.org/10.1029/2018MS001445

Lalande, M., Ménégoz, M., Krinner, G., Ottlé, C., & Cheruy, F. (2023). Improving climate model skill over High Mountain Asia by adapting snow cover parameterization to complex-topography areas. The Cryosphere, 17(12), 5095-5130. https://doi.org/10.5194/tc-17-5095-2023

Melton, J. R., Arora, V. K., Wisernig-Cojoc, E., Seiler, C., Fortier, M., Chan, E., & Teckentrup, L. (2020). CLASSIC v1.0 : The open-source community successor to the Canadian Land Surface Scheme (CLASS) and the Canadian Terrestrial Ecosystem Model (CTEM) – Part 1 : Model framework and site-level performance. Geoscientific Model Development, 13(6), 2825-2850. https://doi.org/10.5194/gmd-13-2825-2020

Rantanen, M., Karpechko, A. Yu., Lipponen, A., Nordling, K., Hyvärinen, O., Ruosteenoja, K., Vihma, T., & Laaksonen, A. (2022). The Arctic has warmed nearly four times faster than the globe since 1979. Communications Earth & Environment, 3(1), 168. https://doi.org/10.1038/s43247-022-00498-3

Royer, A., Picard, G., Vargel, C., Langlois, A., Gouttevin, I., & Dumont, M. (2021). Improved Simulation of Arctic Circumpolar Land Area Snow Properties and Soil Temperatures. Frontiers in Earth Science, 9(June), 1-19. https://doi.org/10.3389/feart.2021.685140

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